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CHEMICAL STOCKPILE DISPOSAL PROGRAM

CHEMICAL AGENT AND MUNITION DISPOSAL

SUMMARY OF THE U.S. ARMY'S EXPERIENCE

21 SEPTEMBER 1987

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The report was prepared in support of the U.S. Army's Chemical Stockpile Disposal Program (CSDP) Programmatic Environmental Impact Statement, and discusses the Army's industrial scale chemical agent and munitions disposal experience. Since 1969, when the National Academy of Science recommended that ocean dumping be discontinued as a method of chemical agent and munition disposal, the Army has destroyed nearly 15 million pounds of chemical agents by either chemical neutralization or incineration. This experience has been incorporated into the design of the Johnston Atoll Chemical Agent Disposal System, which is being constructed on a small island in the Pacific Ocean, and the proposed CSDP disposal plants. (Keywords; —

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GB
VX
GA
H
HD
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L
Sarin
Tabun
Levinstein Mustard
Distilled Mustard
Lewisite
Incineration
Neutralization
Nerve Agents
Blister Agents
Operation CHASE
Project Eagle
Ton Containers
M34 Cluster Bomb
M125 Bomblet
Honest John Rocket
M139 Bomblet
Chemical Agent Identification Sets
CAIS

Chemical Agent Munitions Disposal System
CAMDS
M55 Rocket
Projectiles
Resource Conservation and Recovery Act
RCRA
Toxic Substances Control Act
TSCA
Polychlorinated Biphenyl
PCB

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19 Continued

M34 Cluster Bomb/M125 GB filled bomblet and the Honest John Warhead/M139 GB filled bomblet), and the Chemical Agent Identification Set disposal program, both of which were conducted at Rocky Mountain Arsenal near Denver, Colorado. In addition, the report summarizes the results of tests conducted at the Chemical Agent Munitions Disposal System (CAMDS), which is the Army's pilot plant for testing and evaluating chemical agent and munition disposal equipment, process, and procedures. CAMDS is located at Tooele Army Depot, near Salt Lake City, Utah.

The report provides a concise description of the equipment, process (chemical neutralization or incineration), and procedures used, and environmental requirements, to include ambient air quality and emission standards, and analysis and disposal procedures of waste streams for each program/project.

REPORT SAPEO-CDE-IS-87005

CHEMICAL AGENT AND MUNITION DISPOSAL SUMMARY OF THE U.S. ARMY'S EXPERIENCE

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TABLE OF CONTENTS

TOPIC PAGE

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES PAGE

LIST OF FIGURES (Cont'd) PAGE

LIST OF FIGURES (Cont'd) PAGE

LIST OF TABLES

LIST OF TABLES (Cont'd) PAGE

LIST OF TABLES (Cont'd) PAGE

LIST OF TABLES (Cont'd) PAGE

LIST OF TABLES (Cont'd) PAGE

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1.0.0 Summary

1.1.0 Purpose and Overview.

The purpose of this report is to describe the Army's experience in the disposal of chemical agent/munitions and how this experience led to the choice of incineration for the disposal of the chemical stockpile. This report discusses the historical background of disposal, the scientific reviews that led to the use of chemical neutralization for nerve agent, and the problems encountered with neutralization that led to adoption of the alternative of incineration for nerve agent. This report also discusses the Army's experience with incineration, the incineration and pollution abatement systems to be used in the proposed chemical stockpile disposal program, and the test program being conducted by the Army to verify performance and environmental compliance.

1.2.0 Historical Background.

a. Between World War I and 1969, methods of chemical agent/munitions disposal included open pit, burning, atmospheric dilution, burial, and ocean dumping. Such methods of chemical disposal were also commonly practiced by industry also before public concerns with environmental, health, and safety issues became critically important. The last chemical munition ocean dump occurred with Operation CHASE in August, 1970. In response to such public concerns, the National Academy of Sciences (NAS) was requested by the Department of Defense to perform a scientific review of chemical agent/munitions disposal. The NAS in June, 1969 recommended abandoning ocean dumping as a method of disposal. As alternatives, two different disposal methods were suggested based on the Army's experience at that time: chemical neutralization of nerve agent GB and incineration of blister agents H and HD.

b. In 1972, a Senior Advisory Panel report (also known as the Gross Report) confirmed the original recommendation of the NAS for the dual method approach to disposal and added that the Army should continue to test incineration for disposal of GB and VX. In the early 1970's, incineration of hazardous wastes was a relatively new technology. By 1970, the Army had had experience in incinerating mustard (3,000 tons at Rocky Mountain Arsenal) and in neutralizing GB in limited field operations.

1.3.0 Neutralization.

1.3.1 Introduction.

a. In the next major chemical munitions disposal after Operation CHASE, the Army was charged with getting rid of excess stocks of mustard and GB munitions at Rocky Mountain Arsenal (RMA). In executing its charge, the Army followed the 1969 recommendations of the NAS, by incinerating the mustard and neutralizing the GB. Let us temporarily put incineration aside and focus on why neutralization was generally considered before incineration, what is neutralization, what was the Army's experience with neutralization (GB only on the industrial-scale), how the processes were executed at RMA and Chemical Agent Munitions Disposal System (CAMDS), and what were the problems encountered.

b. Neutralization was attempted before incineration because of the Army's familiarity with neutralization in field disposal and decontamination operations. Neutralization is used in the generic sense of a chemical reaction of the toxic chemical agent with another compound to render a less toxic product. In some cases, the reaction is literally a true chemical neutralization where the chemical agent which acts as an acid undergoes reaction with a base to form an organic salt.

c. Mustard agent can be neutralized by hydrolysis or reacting with an excess of monoethanolamine. However, the homogeneous liquid organic waste that is produced must be disposed of. In addition, the high amounts of impurities in the mustard, particularly the "Levinstein" version rendered neutralization difficult. Because the organic waste was best disposed of by incineration, it was thought best that mustard itself should be incinerated in the first place eliminating the need for neutralization. Thus, no industrial-scale neutralization was carried out for mustard.

d. Chemical agent VX can be neutralized by acid chlorinolysis. However, neutralization of VX was never demonstrated at the industrial-scale.

e. The only chemical agent with which the Army has had industrial-scale neutralization experience is GB. GB was neutralized with caustic sodium hydroxide. The caustic neutralization reaction is sensitive to concentration, pH, and temperature. It is also reversible, albeit marginally, and reformation of GB is possible under fairly restrictive conditions. Approximately 8.4 million lb of GB have been neutralized on an industrial scale at the RMA and CAMDS (see Table 1-1).

1.3.2 Rocky Mountain Arsenal (RMA).

a. The neutralization operations at RMA occurred under two different projects: Project Eagle - Phase II and Project Eagle - Phase II (Expanded). (Project Eagle - Phase I consisted of the incineration of ton containers of mustard between July, 1972 and March 1974 and is covered later in Section 1.4.2). Project Eagle - Phase II consisted of the disposal of 21,114 M34 Cluster Bombs between October 1973 and November, 1976. Project Eagle - Phase II (Expanded) consisted of three disposal sub-operations: (i) GB agent in five underground storage tanks (ii) 2,422 ton containers, and (iii) 106 Honest John M190 warheads (each containing 368 M139 bomblets), 1222 fused M139 Bomblets, and 39,632 unfused M139 bomblets. Project Eagle - Phase II (Expanded) took place between September, 1974 and November, 1976 (refer to Table 1-1 for the dates and amounts of GB neutralized for each sub-operation).

b. The process of disposing the munitions consisted of disassembling or stripping the explosives or fuses and rendering them from functioning, incinerating the explosives or fuses (if present), draining and storing the liquid GB, chemically decontaminating the empty munition or container, shearing the burster (if present), and thermally decontaminating metal parts.

TABLE 1.1.
Summary of Army's Experience in Industrial-Scale Chemical Agent/Munitions Disposal

Operation	Description	Date	Agt	Site(1)	Proc(2)	Quantity (1,000 lbs)
Project Eagle Phase I	Ton Containers	Jul 72-Mar 74	H	R	I	4,428.0
Project Eagle Phase I	Ton Containers	Jul 72-Mar 74	HD	R	I	1,714.0
Project Eagle Phase II	M34 Cluster Bombs	Oct 73-Nov 76	GB	R	N/I	4,129.6
Proj. Eagle Phs II (Expanded)	Underground Storage Tanks	Sep 74-Nov 74	GB	R	N	378.0
Proj. Eagle Phs II (Expanded)	Ton Containers	May 75-Nov 75	GB	R	N/I	3,604.5
Proj. Eagle Phs II (Expanded)	Honest John Warhead (M139)	Apr 76-No 76	GB	R	N/I	76.5
CAIS Disposal	Chemical Agent Identification Sets	May 81-Dec 82	(3)	R	I	36.7
M55 Rocket Disposal		Sep 79-Apr 81	GB	C	N/I	128.0
Agent Injection Incineration Tests		Apr 81-Ja 84	GB	C	I	11.2
Agent Injection Incineration Tests	Ton Containers	Jun 84-Aug 84	VX	C	I	7.9
155mm Projectile Disposal		Jul 81-Jul 82	GB	C	N/I	60.5
105mm Projectile Disposal		Mar 82-Jul 82	GB	C	N/I	
In Situ Agent Incineration		Oct 82-Dec 83	GB	C	I	17.6
M55 Rocket Incineration		Nov 85-Nov 86	GB	C	I	2.3
Liquid Incinerator Test		Aug 85-Aug 86	GB	C	I	37.9
		Grand Total Disposed				14,632.7

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(1) Under Site, R refers to Rocky Mountain Arsenal and C to Chemical Agent Munitions Disposal System.
(2) Under Process, N refers to agent neutralization only; I to incineration of agent and explosive (and/or metal parts thermal decontamination); N/I to agent neutralization and explosive incineration (and/or metal parts thermal decontamination).
(3) Agents include: phosgene, chloropicrin, mustard, lewisite, cyanogen chloride, nitrogen mustard, and GB.

c. No processing was required for disposal of the GB held in underground storage tanks other than that of in-line filtering to remove any solids. The GB was directly pumped from these tanks to neutralization reactors.

d. During all disposal operations at RMA, the same process was used for neutralizing GB. The GB that was drained was pumped to a holding tank. From the latter, it was mixed with caustic. The mixture of GB and caustic flowed to a reactor. The brine resulting from the reaction mixture was continuously agitated and recirculated. Heat generated from the reaction was removed. When the neutralization was determined to be complete by sampling and testing, the brine was reduced to salt by evaporating the water. The water vapor was scrubbed befor atmospheric discharge and the salt packed in drums for disposal. Waste water from the scrubbing process and periodic wash down of the reactors was transferred to an industrial sump or lagoon.

e. The neutralization process at RMA was for the most part successful in achieving its mission. However, there was one environmental concern that would not have been considered as a concern at the time of neutralization: although the waste water contributed to contamination of the underground water, it was then common industrial practice to dispose waste water by allowing it to evaporate from a lagoon. The solid waste included decontaminated metal parts, furnace ash, and the spray dried salt. The decontaminated metal parts were sold as scrap. Furnace ash was not disposed of until 1986, and thus became subject to the Resource Conservation and Recovery Act (RCRA) that required placement in a hazardous waste landfill because of the presence of heavy metals that was not required in the 1970's when the ash was generated. The 21.5 million lb of spray-dried salt that were generated in the 1970's also became subject to RCRA. The salt was placed in an approved industrial hazardous waste landfill in 1986. The only problem that would have been an environmental problem at that time was the reformation of miniscule amounts of GB in the spray dryer gas stream. The problem was solved but it required tedious studies that resulted in a combination of adjusting the pH and brine flow rate, reducing operating temperature, and/or changing the fuel.

1.3.3 Chemical Agent Munitions Disposal System (CAMDS).

a. Following the completion of the RMA neutralization programs, effort was initiated at CAMDS (Table 1-1) to dispose of the M55 rockets and 155mm/105mm projectiles.

b. Between September, 1979 and April, 1981, 13,951 M55 rockets were demilitarized at CAMDS. The process consisted of draining the liquid GB, cutting the rocket into pieces with a Rocket Demil Machine, incinerating the explosive/propellant and thermally decontaminating the metal parts in the Deactivation Furnace System (DFS), and storing the GB for neutralization.

c. Between July, 1981 and July 1982, 12,673 nonburstered 155mm and 105mm projectiles were disposed of. The process consisted of extracting the nose closure, pulling the burster well, and draining the liquid GB with the Projectile Pull and Drain Machine; thermal decontamination of the empty projectiles in the Metal Parts Furnace (MPF); and storage of the GB for neutralization.

d. The GB was neutralized at CAMDS using the Agent Destruction System (ADS). The ADS was modeled after the existing facilities at RMA with certain modified equipment configurations. In the ADS design, the caustic and GB are blended in the reactor rather than in a mixing tee, as done at RMA. Also, the heat of reaction is removed by a reactor recirculation system and cooling jacket in the ADS rather than a heat exchanger downstream of the mixing tee, as done at RMA. These modifications were done to eliminate foaming and line plugging problems experienced at RMA and to improve process operations in general. Also, these changes were necessary to accommodate caustic neutralization of the VX acid brine in the second step of the VX neutralization process.

e. The other significant difference was the changeover from the use of spray dryers at RMA to drum dryers at CAMDS for evaporating the water and reducing the brines from neutralization to salts. The main reason for the changeover was to avoid the conditions present in spray drying that were found to be conducive to GB reformation; these conditions were the high operating temperature and exposure to acidic combustion gases. Furthermore, the drum dryers involved much less air volume because air was used not for heat transfer but only as an effluent to carry away water vapor; thus, a smaller volume of air had to be dealt with in the event of GB emission. The operation of the drum dryers was also more cost-effective than the spray dryers.

f. Significant problems were encountered with the GB neutralization process at CAMDS. The neutralization process did not follow the expected course and presented two major problems: (1) minute quantities of GB were found in the brines and (2) the process took significantly longer than expected. A significant portion of the problems CAMDS was experiencing can be explained by the change in the standard for certifying that the brine was agent-free. At RMA, the standard that was imposed was the mere presence of 5% excess caustic in the brine. However, after RMA faced problems with GB emission in the spray dryer, the Department of Health and Human Services adopted a more stringent standard requiring testing of the brine. This standard was converted into the certification target level of no more than 2ng of GB per ml of brine. Thus, faced with a much stricter standard, CAMDS had more difficulty. The Army spent over $7 million in attempts to determine the cause of the presence of minute quantities of GB in the brine after neutralization. Four predominant theories were proposed but not confirmed: reversal of the reaction under equilibrium conditions, occlusion or encapsulation with solids, introduction as an artifact under the analytical procedures used to detect GB, and false positives resulting from the complex sample matrix. In efforts to achieve the certification target level, the process took much longer than the expected four hours. Some neutralization reactions took as long as forty days while most were 10 to 20 days. Excess caustic was added to accelerate the neutralization reaction and this resulted in significantly high salt production. Other problems had to do with residual water left in the storage tank before filling with GB. Apparently, the water reacted with the GB in a hydrolysis that resulted in a very low pH solution that consumed more caustic than expected and formed a hard to pump sledge that occasionally led to pipe-clogging. On other occasions, although GB was added to the reactor in a controlled manner to reduce heat build-up, the use of a cooling system resulted in too low temperatures that caused precipitation to clog pipes from the reactor vessels.

g. The problems encountered with industrial-scale neutralization of GB led the Army to abandon neutralization for disposal of chemical munitions regardless of the type of chemical agent present. As previously mentioned, the NAS 1969 report had recommended incinerating mustard. VX, which was next to be neutralized, was not neutralized on an industrial-scale because of the problems experienced with GB neutralization. The rationale for abandoning neutralization was based on a number of factors: (1) the sheer complexity of the process (as compared to incineration which was the emerging industrial technology for disposal of organic substances) and the sensitivity of the process to numerous parameters that would slow the reaction or even promote hydrolysis reversal reforming GB, (2) the quantity and nature of the waste that was produced, and (3) the high capital costs (for the complex of equipment required) and operating costs. On March 9, 1982 at a Configuration Policy Board meeting, the Army officially decided to abandon neutralization and adopt incineration for disposal of chemical agent/munitions.

1.4.0 Incineration.

1.4.1 Introduction.

a. As a viable alternative, incineration was seriously considered for a number of compelling reasons. It has always been the Army's preferred method for disposal of mustard agent and it is the only approved method for ensuring that an item that has come in contact with chemical agent is completely decontaminated. Incineration is fairly simple, straightforward, and avoids the problems experiences with GB neutralization. The products of combustion do not allow reformation of the reactants such as GB. Incineration does not produce as much waste as neutralization and furthermore, the waste is generally inorganic. The capital and operating costs of incineration are much less than those of neutralization. Last, but not least important is the fact that one incinerator was required to augment neutralization in disposal of chemical munitions. Because neutralization applies only to the agent, an incinerator had to be used to dispose of explosive/propellant components and thermally decontaminate munition cavities and metal parts. Because incineration would be required anyway, there was little reason to not use it for complete instead of partial destruction and eliminate neutralization. Incineration is the thermal decomposition of organic compounds into simpler inorganic, innocuous compounds, mainly water and carbon dioxide. In addition to these two compounds, acid gases such as hydrogen fluoride (from GB), phosphorus pentoxide (from GA, GB, and VX), nitrogen dioxide (from GA and VX), and hydrogen chloride (from mustard) arise from combustion of chemical agent. These acid gases are easily removed by scrubbing.

b. The National Research Council (NRC) restudied the question of the most safe, effective, and economical means for chemical agent/munitions disposal at the request of the Army in 1982. After reviewing the advances in technology since the 1969 NAS report, the NRC concluded that thermal destruction was the best means for disposal.

c. Incineration is a safe and environmentally sound method of destroying toxic organic compounds, where toxicity is a function of the entire compound (as with chemical agent), and is used commercially for disposal of polychlorinated biphenyls, pesticides, herbicides, and hazardous organic waste products.

d. The Army's experience in incineration of chemical agent includes disposal of over 6.26 million lb of agent (over 60,000 munitions and containers) at RMA and CAMDS together as shown in Table 1-1.

1.4.2 Rocky Mountain Arsenal (RMA).

a. Two major disposal operations using incineration have been accomplished at RMA. The first, designated as Project Eagle - Phase I occurred between August, 1972 and February, 1974 and disposed of 6.14 million lb of mustard agent (H and HD) in ton containers. The second operation involved disposal of over 21,000 Chemical Agent Identification Sets (CAIS) which contained about 36,7000 lb of various chemical agents (see Table 1-1).

b. Project Eagle - Phase I was intended to dispose of excess stocks of mustard agent stored at RMA since the 1940's. They were scheduled for ocean dumping until the NAS recommended incineration. The disposal process consisted of: (1) preheating the ton container, (2) draining of the mustard agent, (3) incineration of the agent, (4) thermal decontamination of the container, and (5) furnace emission control.

(1) The primary incinerator for disposal of the drained mustard agent was the modified hydrazine furnace. A ton container furnace was used to incinerate the agent residue left in the ton containers. The Pollution Abatement System (PAS) for the furnaces included a caustic quench, a scrubber system, an electrostatic precipitator and stack. The four-stage electrostatic precipitator was added to ensure particulate emission and stack opacity limits were met because rust (iron oxide) from inside the ton containers posed potential emissions problems. All waste water and scrubber brines generated by the PAS were dried into salt using a spray dryer.

(2) During incineration, the stack and work area were monitored for mustard. In addition, the perimeter was monitored for nitrogen dioxide, sulfur dioxide, ozone, suspended particulate, and for HCl with sequential samples on a six-hour cycle monitor. Although particulate emission standards were occasionally exceeded, Project Eagle - Phase I had no significant impact on ambient air quality.

(3) A total of 14 million lb of spray dried salt was produced during Project Eagle - Phase I. While the majority of samples of the salt did not show them to be RCRA hazardous waste, minute quantities of arsenic and lead in some samples and sample variability forced a decision to place all of the salt in a RCRA hazardous waste landfill. The decontaminated ton containers were sold as metal scrap. The ash and electrostatic precipitator residue were disposed of by land dilution.

c. The second major incineration operation at was the disposal of CAIS stored at RMA. CAIS were used for identification of various chemical agents during training but were declared obsolete in 1971. There were 18 different set configurations with each set containing from one to five different agents. Although normally only one chemical agent at a time is processed during disposal, the agents could not be easily separated and hence they were incinerated simultaneously. This circumstance made the CAIS disposal operation unique.

(1) The CAIS were first incinerated in the RMA Deactivation Furnace followed by the RMA Decontamination Furnace. The same Deactivation Furnace used in the disposal of the Honest John warheads was used for the CAIS disposal except that it was modified by addition of an afterburner to accommodate glass ampules and bottles. The same Decontamination Furnace used in the disposal of the Honest John warheads was used for CAIS disposal also except that it was modified by installation of a new high-temperature refractory, pedestals to support the CAIS shipping containers, and reconfiguration of the burners to ensure uniform heating. An electrostatic precipitator was added to the PAS to remove arsenic oxide and other particulates in the furnace exhaust. The PAS, in addition, had a quench and dual packed column scrubbers to remove acid gases. All waste water, quench, and PAS scrubber brines were dried into salt with a spray dryer.

(2) The work areas and stack emissions were monitored for the presence of any of nine chemical agents. The spray-dried salt was drummed and disposed of in 1985 in a hazardous waste landfill. The electrostatic precipitator residue, found to contain excessive arsenic, lead and zinc, was drummed and placed into a hazardous waste landfill. The furnace residue, in spite of its acceptability for disposal in a sanitary landfill, was also placed in a hazardous waste landfill. The lead from the gaskets in the CAIS shipping containers was sold as scrap metal while the CAIS shipping containers, themselves, were retained after thermal decontamination for use as overpacks for leaking chemical munitions.

1.4.3 Chemical Agent Munitions Disposal System (CAMDS).

a. The primary purpose of CAMDS is to test and evaluate equipment and processes to be used in chemical agent/munitions disposal plants. While CAMDS is authorized to dispose of some chemical agents/munitions, this disposal usually accompanies the primary purpose of data collection and test and evaluation of process equipment. CAMDS experience with incineration of chemical agent (shown in Table 1-1) consists of disposing 75,000 lb of GB and 8,000 lb of VX (i.e., 38,000 munitions). Three furnaces have been used at CAMDS: Deactivation Furnace System (DFS), MPF, and Liquid Incinerator (LIC). The CAMDS DFS is similar to the RMA DFS (a rotary kiln) used during Project Eagle - Phase II (Expanded) except that the CAMDS DFS also performs thermally decontamination simultaneously eliminating the need for a decontamination furnace. The CAMDS MPF is similar in function to the ton container furnace and decontamination furnace, both used at RMA except that the CAMDS MPF has the additional capability of incinerating bulk liquid agent. The CAMDS LIC was determined to be necessary when it was found to be more efficient to drain chemical agent from a munition or bulk container and then to incinerate or thermally decontaminate each separately in a LIC and MPF, respectively. The CAMDS LIC is analogous to the hydrazine furnace used at RMA for incinerating drained liquid mustard.

b. The purpose of the CAMDS DFS is to incinerate residual chemical agent and deactivate explosives/propellant The DFS has experienced the incineration of 18,300 projectiles.. The DFS consists of a feed chute with double tipping blast valves, rotary kiln furnace protected and isolated by a reinforced concrete enclosure (to shield a potential detonation), heated discharge conveyor, scrap conveyor, cyclone separator, slagging afterburner, and PAS. Segmented rocket pieces, munition bodies and cavities with or without residual agent and all other charge for the DFS are fed from the Explosive Containment Cubicle (ECC).

c. The purpose of the DFS PAS is to remove acid gases and particulate from the furnace exhaust before atmospheric release. The PAS consists of a quench tower, variable throat venturi scrubber, packed bed wet scrubber tower, demister, induced draft fan and exhaust stack. The DFS exhaust is monitored for oxygen, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen dioxide, and the presence of chemical agents. A system of eight perimeter monitoring stations is used to check ambient air quality.

(1) To date, four incineration tests have been completed on the DFS (See Table 1-2): (1) GB Challenge Test, (2) Undrained M55 Rocket Incineration Test, (3) Poly-chlorinated Biphenyl Incineration Test, (4) Drained M55 Rocket Incineration Test, and (5) Ocean Dumping Permit Application Analysis of DFS Scrubber Brines.

d. The primary purpose of the CAMDS MPF is to thermally decontaminate munition bodies, ton containers, projectiles, and other metal parts with residual chemical agent, in the absence of explosive/ propellant. In addition, the CAMDS MPF can be used to incinerate bulk agent (GB and VX). The MPF has experienced incineration of 32,000 lb of GB, 8,000 lb of VX, and 18,897 projectiles. The MPF system consists of a charge car, a roller hearth furnace (containing three chambers: punch, volatilization, and burnout), a primary fume burner, an auxiliary fume burner, and a PAS. Moreover, the MPF system includes scrap handling and cooling equipment. Items are fed from the multipurpose demilitarization machine or bulk drain station to the MPF by the power driven charge car. The MPF PAS is identical to the DFS PAS except that the liquid flow rates (water and caustic) are higher because of the larger MPF exhaust gas flow rate.

(1) Six types of incineration tests have been conducted with the MPF (see Table 1-3): (1) evaluation of the PAS, (2) GB agent injection incineration, (3) thermal decontamination of drained 105mm projectiles, (4) in situ incineration, (5) development of design data for the Johnston Atoll Chemical Agent Disposal System (JACADS) MPF and LIC, and (6) VX agent incineration tests.

e. The purpose of the CAMDS LIC is to burn chemical agent drained from munitions or bulk containers and organic matter in waste liquids such as spent decontamination solution. The CAMDS LIC has experienced operation for over one year and has incinerated 37,930 lb of GB. The LIC has a primary burner and secondary burner and it is designed to take advantage of the high heat of combustion of the chemical agent. The CAMDS LIC is one-third the

TABLE 1-2.

DFS Testing At CAMDS

Testing Description/Purpose	Date	Agent/Munition	Results
GE Challenge Test: determine destruction & removal efficiency (DRE)	Apr 1977	GB (neat)	afterburner (on): DRE=99.9998% after burner (off): DRE=99.9%
Undrained M55 Rocket Incineration Test: determine processing rate	May 1981 - June 1982	GB (neat)	1/2 rkt/hr with DRE = 99.999999% 1/3 rkt/hr with DRE = 99.999994%
Polychlorinated Biphenyl Incineration Test: determine compliance with Toxic Substances Control Act (TSCA)	Mar 1986	drained GB/ M55 rockets with firing & shipping tubes	approved EPA analytical procedures not sufficiently sensitive to demonstrate demonstrate DRE = 99.9999% required by TSCA
Drained M55 Rocket Incineration Test: determine processing rate for baseline performance	May 1986	drained GB/ M55 Rockets	18 rkts/hr with DRE = 99.9999%, combustion efficiency of slagging afterburner > 99.9% particulate emissions < 180 mg/m^3 (RCRA std) PAS brines non-RCRA hazardous composite ash analysis shows Cd > RCRA EP Toxic limit No PICs (i.e., no 40 CFR 261, Appendix VIII compounds)
Ocean Dumping Permit Application Analysis of DFS Scrubber Brine: determine composition and concentration of pollutants	June 1986	drained GB/ M55 rockets with firing & shipping tubes	DFS scrubber brines non-RCRA hazardous Post-burn increase in $SO_4^=$, $PO_4^=$, F^-, and Cl^- Some semi-volatile organic priority pollutants present No volatile organic priority pollutants

TABLE 1-3.

MPF Testing At CAMDS

Testing Description/Purpose	Date	Agent/Munition	Results
GB Challenge Test: determine destruction & removal efficiency (DRE)	Aug 1978	GB (neat)	cold conditions: DRE = 99.99% normal upset conditions (both partial & total failure): DRE > 99.999%
Initial MPF Challenge Test: determine limiting factor for agent incineration	Jul 1981	GB (neat)	limiting factor was stack opacity
Second MPF Challenge Test: determine if incineration is viable alternative to neutralization	Mar 1982	GB (neat)	MPF can incinerate GB at 446 lbs/hr at at DRE ≥ 99.99999%; hence, it is a viable alternative
Thermal Decontamination of Drained 105mm GB Projectiles: determine feasibility of meeting designed processing rate	May 1982	drained GB/ 105mm projectiles	inconclusive
Undrained 155mm GB Projectile Incineration Test: determine feasibility of in situ incineration	Oct 1982 - Dec 1982	undrained GB/ 155mm projectiles	in situ, as opposed to injection, incineration needs much improvement, e.g., furnace draft
Final GB Injection Incineration Test: develop design data for JACADS MPF & LIC	1980 - 1984	GB (neat)	maximum GB incineration rate is 550 lb/hr with DRE = 99.999999%
VX Injection Incineration Test: develop VX incineration design data for JACADS MPF & LIC	June 1984	VX (neat)	maximum VX incineration rate is 400 lb/hr with DRE = 99.9999998%

capacity of the LIC to be used at JACADS and the proposed chemical stockpile disposal plants. The CAMDS LIC also differs in that it does not have its own PAS, but is hooked up to the CAMDS MPF PAS. However, only either the LIC or MPF can be operated at one time.

(1) Between December, 1985 and February, 1986 a series of tests was conducted to obtain emissions data on the LIC and the MPF PAS (with the LIC only operating) and effluent data on the LIC sump brines, PAS scrubber brines, and salts formed from drying the brines. Both the particulate and hydrogen fluoride emissions data were considered inconclusive. No significant emissions or volatile or semi-volatile products of incomplete combustion were identified. The LIC sump brines, PAS scrubber brines, and salts formed from drying the brines were all found to be non-RCRA hazardous.

(2) Tests were conducted in June, 1986 to obtain the composition of and concentration of pollutants in LIC scrubber brines. The LIC scribber brines did not exhibit any metals exceeding the RCRA limit. Large post-burn increases in phosphate and fluoride concentrations were shown (due to GB incineration). No organic priority pollutants, either volatile or semi-volatile were detected in significant amounts.

1.5.0 Disposal Process Description.

1.5.1 Introduction.

a. The method of disposal proposed for the Chemical Stockpile Disposal Program (CSDP) is incineration. The chemical agents that will be disposed of are primarily mustard, GB, and VX with small quantities of lewisite and GA. The incinerators will be based on JACADS design, differing only in fuel used and capacity because of inventory variations from site to site. Four incinerators are addressed in this report: (1) DFS, (2) LIC, (3) MPF, and (4) Dunnage Incinerator (DUN). Each incinerator will have its own PAS and will also be addressed.

1.5.2 Incinerators.

a. The CSDP DFS will consist of four separate sections: (1) rotary retort, (2) blast load attenuation duct, (3) cyclone, and (4) afterburner. In addition to its originally designed purpose of destroying residual agent and deactivating explosives/propellants, the DFS will be used to thermally decontaminate spent filters, such as charcoal filters, high efficiency particulate air filters, and prefilters. At any given time, the DFS will process components from only one munition type and one agent.

b. The rotary retort of the DFS consists of two feed chutes, each with two blast gates in series, a charge end subassembly, a furnace retort drive mechanism, a discharge end subassembly, and a heated discharge conveyor. The feed chutes connect with the Explosive Containment Room. The blast load A attenuation duct conducts the flue gases from the retort to the cyclone which separates solid particulates from the gas stream. The afterburner combusts any organic vapor not combusted in the off gases leaving the cyclone. The gases from the afterburner flow to the quench tower in the DFS PAS.

c. The CSDP LIC is a two-stage refractory lined incinerator designed to combust drained liquid chemical agent and organic matter in waste liquor such as spent decontamination solution. The LIC consists of a primary combustion chamber and afterburner. Drained chemical agent stored in the Toxic Tank is pumped through duplex strainers to the primary combustion chamber where it is air-atomized and burned. The afterburner ensures complete combustion of the chemical agent, if any is still present, in the gases leaving the primary combustion chamber. Spent decontamination solution is atomized to the stream of gases entering the afterburner from the primary combustion chamber and is incinerated in the afterburner. The resultant flue gas from the afterburner flows to the LIC PAS.

d. The CSDP MPF is designed to thermally decontaminate drained, defused and nonburstered projectiles, bulk items such as ton containers and bombs, equipment, and contaminated combustible dunnage. The MPF consists of

(i) a horizontal, three-chamber, roller hearth unit and (ii) an afterburner. The hearth unit's first chamber is an inlet airlock that receives items for feed. The hearth's second chamber is a refractory-lined burnout chamber split into three individually controlled temperature zones. The hearth's third chamber is an egress airlock. Gases from all three chambers are vented to the afterburner, a horizontal refractory-lined cylindrical vessel, to ensure complete combustion. Exhaust from the afterburner flows to the MPF PAS. Handling of molten aluminum in special feed cars is accommodated for processing spray tanks and M116 weteye bombs.

e. The CSDP DUN is designed to incinerate agent-contaminated (as well as uncontaminated) dunnage. Dunnage includes scrap wood, pallets, shipping boxes, laboratory solid wastes, work garments, and miscellaneous waste. Metal mine drums with small amounts of combustible packing will also be disposed of in the DUN. The DUN consists of two separate chambers: the primary combustion chamber and an afterburner. Solid wastes are charged into the primary chamber via an airlock, elevator, and ram feeder. The flue gases from the primary combustion chamber are ducted to an afterburner to ensure complete combustion. Exhaust from the afterburner is vented to the PAS.

1.5.3 Pollution Abatement Systems (PAS).

a. Each CSDP incinerator (DFS, LIC, and MPF) will have its own PAS. The PAS for each incinerator is identical in configuration but differs in equipment size. The PAS consists of the quench tower, venturi scrubber, packed bed scrubber tower, demister vessel, induced-draft fan, and a common stack. The quench tower cools with caustic, in countercurrent flow, the hot gases entering from the afterburner, until the adiabatic saturation temperature is reached. The cooled gases from the quench tower enter the venturi scrubbers which are variable-plug throat scrubbers with a normal operating pressure drop across the throat. Scrub solution is sprayed into the gas stream to remove particulates. The scrubber tower separates the two-phase flow from the venturi scrubbers. The separated gas phase enters the demister vessel in which water is sprayed to capture soluble particulate. The induced-draft fan provides the motive force for the exhaust gases throughout the incinerator and PAS. The common stack provides atmospheric discharge of the scrubbed flue gases from the PAS for all three incinerators. Sampling ports are furnished in the stack for monitoring.

b. The DUN PAS differs from the PAS for the above three incinerators. It consists of a quench tower, baghouse, induced-draft fan, and a stack. All of the DUN PAS components function identically to those discussed previously except for the baghouse. The baghouse is utilized to remove particulates from the gas stream by forcing the stream through a fabric. Dislodged solids are collected in a hopper beneath the bags and packed into drums.

1.6.0 Incineration and Pollution Abatement Systems (PAS) Test Program.

a. A comprehensive test program is underway at CAMDS to verify the performance of the munition disassembly machines, incineration, and PAS which will be used in JACADS and the proposed CSDP. Three types of data will be obtained during incineration system testing and evaluation: (1) performance - including heat and material balances, temperature profiles, furnace stability, etc., (2) environmental compliance - including composition of exhaust gases and solid residues from the incinerators and PAS, and (3) environmental concerns - covering the same items as in (2) but analyzing for constituents not currently required but which might be required in the future, e.g., use of Toxicity Characterisic Leaching Procedure for RCRA characterization of hazardous waste. A comprehensive report on performance and operational characteristics will be prepared at the end of each agent test window. Test reports involving environmental compliance and environmental concerns data will be obtained by conducting special test burns, with the aid of a contractor because of the special sampling and analysis procedures.

b. Environmental compliance data will be obtained with respect to standards established by the Clean Air Act (as administered by all 8 states where chemical agent munitions stockpiles are located). RCRA compliance data will be obtained with respect to incineration emission standards.

Incineration emission standards cover the chemical agent, principal organic hazardous constituent (POHC), HCl, particulate, SO_2, and opacity. RCRA compliance data will be obtained for solid waste residue to determine if it is a characteristic waste; this applies only in states where chemical agents are classified as characteristic waste. In states where the agents are "listed", this data could be used for "delisting" petitions. Environmental compliance data will also be obtained for the Marine Protection, Research, and Sanctuaries Act (ocean dumping).

c. Environmental concerns data will be obtained on (1) products of incomplete combustion, (2) heavy metal emissions from the furnaces, and (3) Toxicity Characteristic Leaching Procedures as applied to solid waste residues.

d. Each test burn in the test program will consist of at least one baseline or background trial plus three trials in which the chemical agents/munitions are processed. With the exception of chemical agent sampling and analysis, and the brine and nitroglycerine analytical procedures, all of which are Army procedures, Environmental Protection Agency (EPA) approved sampling and analysis procedures will be used.

2.0.0. INTRODUCTION.

2.1.0. Purpose.

a. This report has been prepared in support of the U.S. Army's Chemical Stockpile Disposal Program (CSDP) Programmatic Environmental Impact Statement (PEIS). As stated in the CSDP Draft PEIS(1), The Army has selected incineration as the best technology for destroying chemical agents and munitions. The use of incineration for chemical agent and munition disposal was endorsed by the National Research Council in 1984(2), and reflects the wide spread acceptance of incineration as an effective, safe, and environmentally sound method of disposal of hazardous materials. The purpose of this report is to document the Army's chemical agent/munition disposal experience and to explain how this experience has led to the incineration processes which will be used in the proposed CSDP disposal plants. Appendix B contains a complete description of the chemical agents and munitions which will be disposed of in the CSDP.

Four major topics will be covered in this report:

(1) The Army's chemical agent neutralization experience;

(2) The Army's chemical agent and munition incineration experience;

(3) The incineration and pollution abatement systems which will be used in the proposed CSDP disposal plants; and

(4) The test program which the Army is conducting to verify the performance of the proposed incineration and pollution abatement systems and to ensure compliance with current and proposed environmental regulations.

2.2.0. Background.

2.2.1. Field Disposal Methods.

a. Disposal of chemical agents and munitions is not a new problem. Since the first modern use of chemical weapons in 1915, during World War I, the disposal of obsolete, deteriorated, or surplus chemical weapons has been a problem which the United States, and many of the world's countries have had to deal with. Early methods of chemical weapons disposal included open pit burning (Figure 2-1), venting to the atmosphere (applicable only to gaseous compounds such as chlorine) (Figure 2-2), field neutralization (Figure 2-3), ocean dumping (Figures 2-4 and 2-5), and land burial (Figure 2-6).

2.2.2. 1969 National Academy of Science Review(3)

a. The transition from field chemical agent and munition disposal procedures to industrial type procedures, characteristic of those which will be used in the proposed CSDP disposal plants, began in May 1969 when the Department of Defense suspended plans to dispose of approximately 27,000 tons of chemical weapons by ocean dumping in a program known as Operation CHASE ("Cut Holes And Sink Em"). This was done in response to public concerns over the transportation of these items, as well as the potential environmental impact on marine life at the dump site. CHASE involved the rail transport of conventional or chemical weapons to the Navy Ammunition Depot Earle, located near Elizabeth, New Jersey. The munitions or chemical agents were then loaded on excess cargo hulks which were then towed out to the disposal area (centered at 39° 38' N; 71° 0' W) and sunk in approximately 1200 fathoms (7,200 feet) of water. Prior to the suspension of Operation CHASE, 12 disposal operations were accomplished, three of which involved chemical agents or munitions.

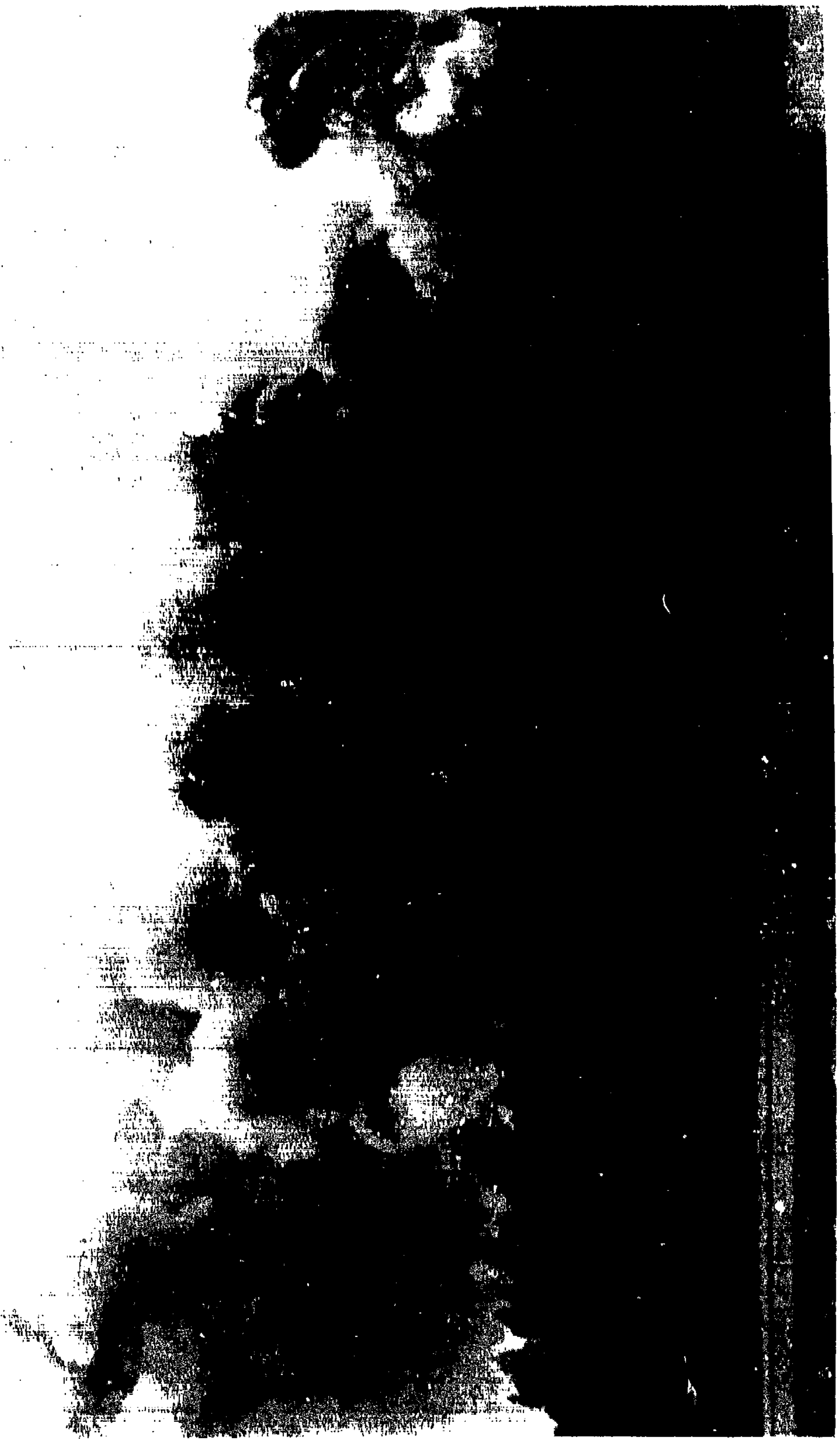

Figure 2-1: Smoke Cloud from a Mustard Agent Open Pit Burn

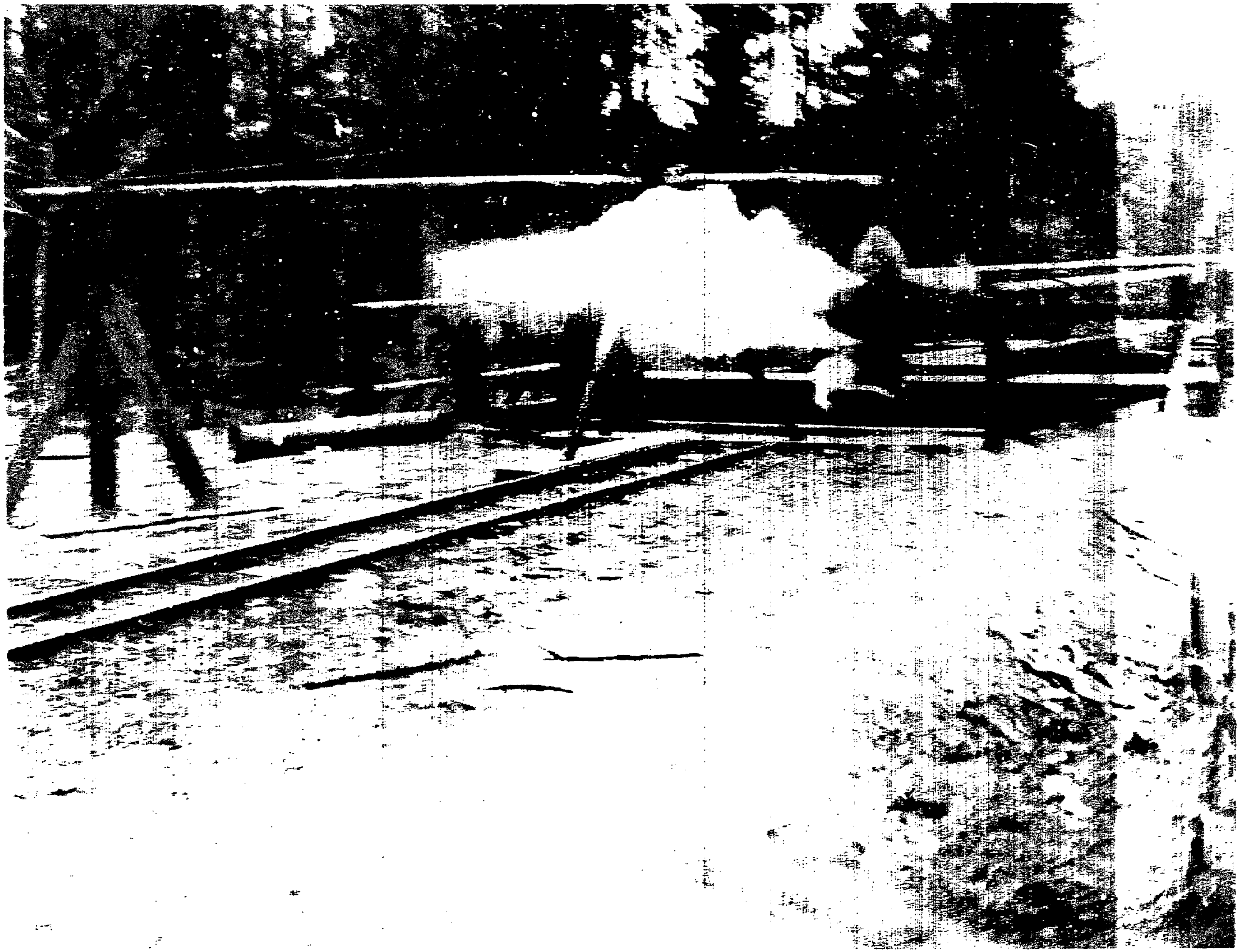

Figure 2-2: Field Venting of 500 Pound Chemical Bomb

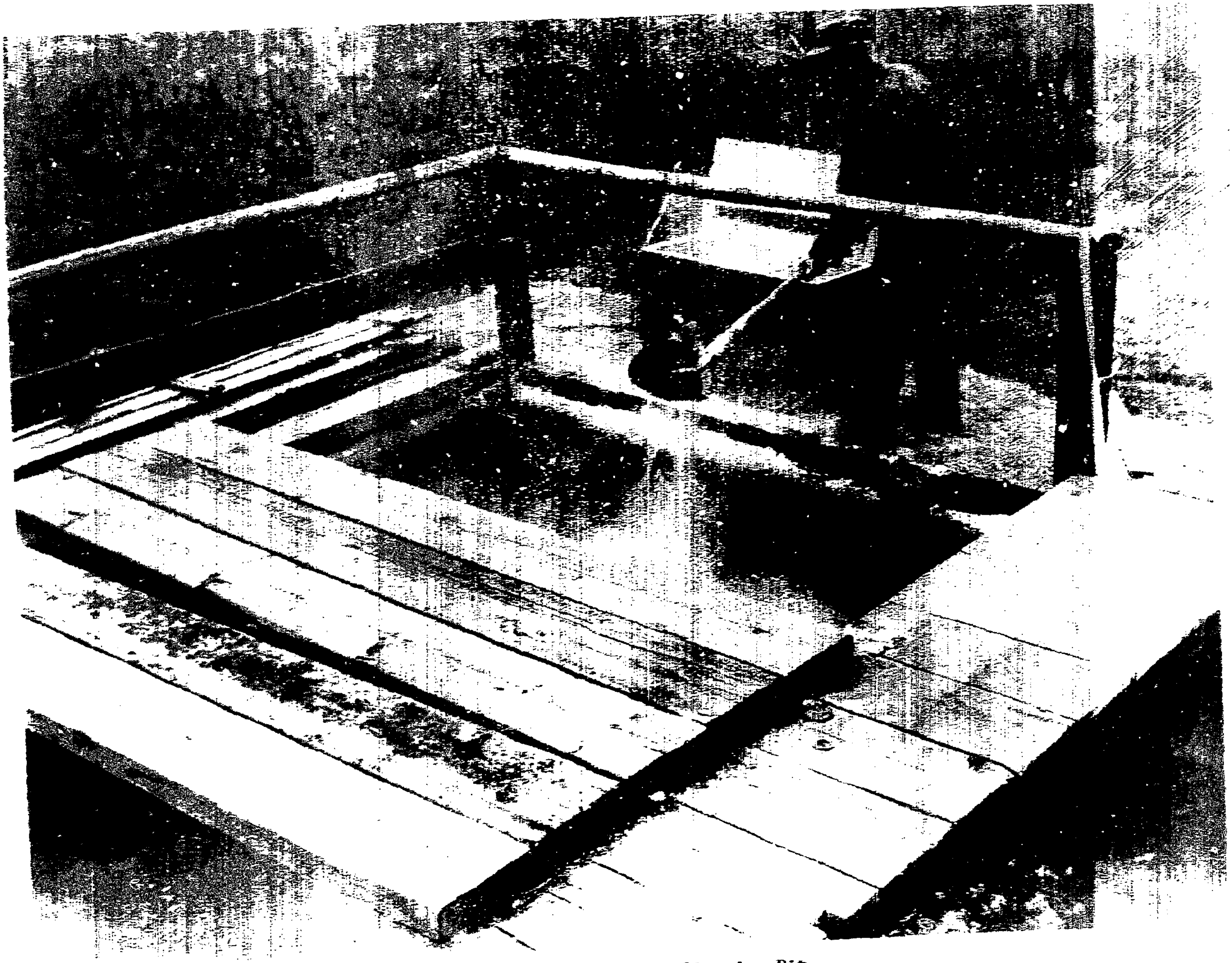

Figure 2-3: Field Neutralization Pit

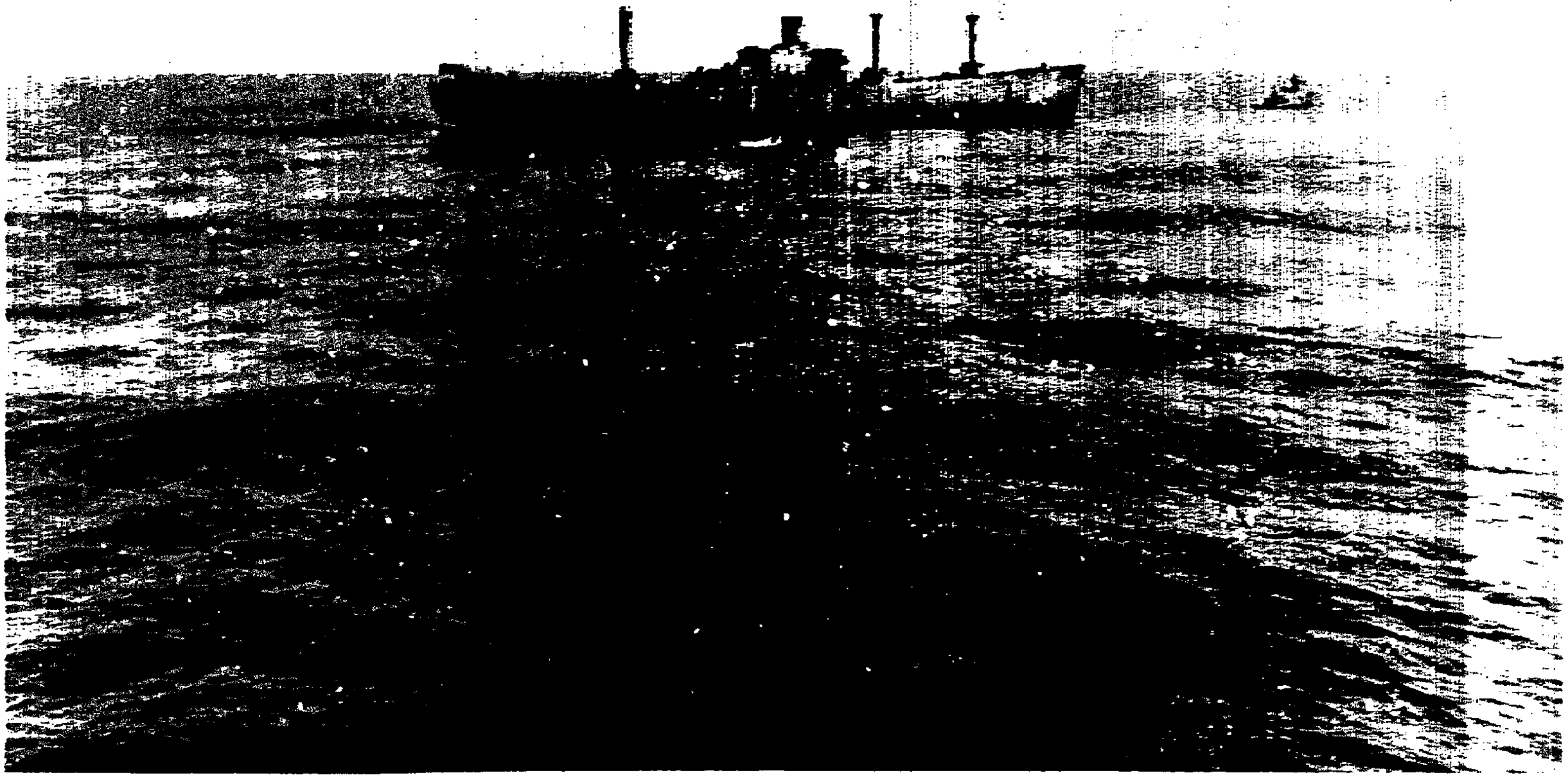

Figure 2-4: Loaded Cargo Hulk Positioned for Sinking

Figure 2-5: Cargo Hulk Sinking During Ocean Disposal

Figure 2-6: Chemical Munitions Being Placed in a Land Burial Pit

b. In response to the public concerns described above, the Department of Defense requested the National Academy of Science (NAS) perform an "assessment of the hazards involved in the execution of Operation CHASE (and alternative plans) for disposal of surplus chemical warfare stocks of the U.S. Army".(3) In response to this request, the NAS convened an Ad Hoc Committee comprised of 12 experts from leading industrial, educational, and research institutions. The Committee was chaired by Dr. G. B. Kistiakowsky, Professor of Chemistry at Harvard University.

c. The Committee report, which was submitted to the Department of Defense in June 1969, made the following recommendations on chemical agent and munition disposal:

(1) Adopt basically the same approach to chemical agents and munitions that the Atomic Energy Commission has adopted toward radioactive waste products from nuclear reactions.

(2) Assume that all chemical agents and munitions will require eventual disposal.

(3) Ocean dumping should be avoided.

(4) Conduct a study of optimal disposal methods at appropriate military installations which involve no hazards to the general population or pollution of the environment.

(5) Large scale disposal facilities should be required as a counterpart to exisiting stocks and planned manufacturing operations.

2.2.3. Agent Destruction - Chemical Neutralization or Incineration?

a. In the NAS Ad Hoc Committee Report, two different methods for chemical agent destruction were recommended - chemical neutralization for nerve agent GB

(Sarin) and incineration for blister agent mustard (H/HD). These recommendations were based on the Army's experience at that time. Approximately 3,000 tons of mustard had been incinerated in a special furnace located at Rocky Mountain Arsenal, however, the Army did not have comparable GB incineration experience. Instead, chemical neutralization of GB had been used successfully during limited field disposal operations.

b. In 1972 a Senior Advisory Panel was established at the direction of the U.S. Army Material Command to review the Army's chemical demilitarization program.(4) The Panel was chaired by Dr. Paul Gross of Duke University and was comprised of eight experts from industry, and educational and research institutions. With respect to agent destruction, the committee concluded that the dual method approach, originally recommended by the NAS, was still the best course to follow because of the limited laboratory data available on nerve agent incineration. However, because of the advantages of having a single disposal process applicable to all chemical agents, the panel recommended that the Army continue to conduct laboratory and pilot incineration tests with nerve agents GB and VX.

2.3.0. Industrial Scale Disposal Experience.

Since the 1969 NAS Ad Hoc Committee Report, Rocky Mountain Arsenal (RMA), Colorado, and the Chemical Agent Munitions Disposal System (CAMDS) located in Tooele Army Depot (TEAD), Utah, have been the "proving grounds" for chemical agent and munition disposal technology for use in "industrial-scale" disposal plants. The data and experience obtained from the disposal programs and tests conducted at these installations (Figure 2-7), in addition to the laboratory data from Edgewood Arsenal (now called Edgewood Area, Aberdeen Proving Ground, Maryland), are the foundation for the disposal methods which will be used in the proposed CSDP disposal facilities. To date, about 15 million pounds of chemical agents have been destroyed either by neutralization or incineration.

CHRONOLOGY OF CHEMICAL AGENT/MUNITION DISPOSAL PROJECTS CONDUCTED AT RMA AND CAMDS

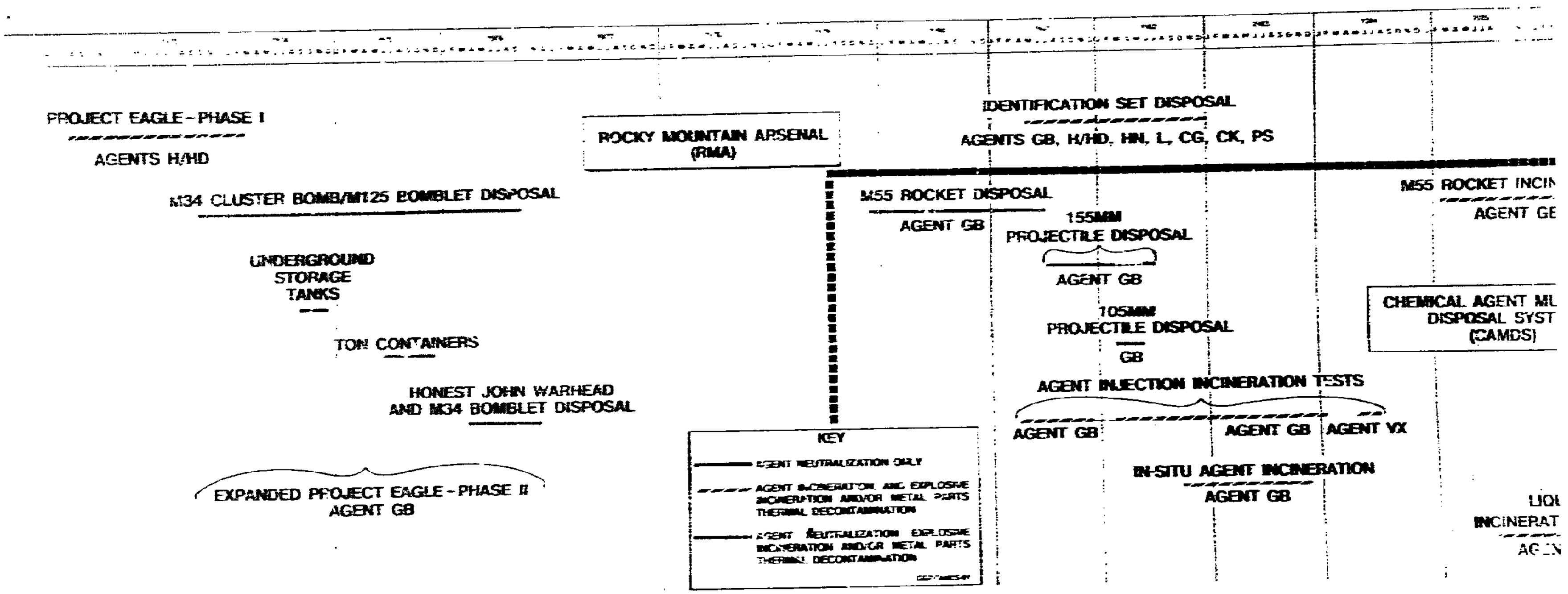

Figure 2-7: Chronology of Chemical Agent/Munition Disposal Projects Conducted at RMA and CAMDS

2.3.1. Rocky Mountain Arsenal.

a. RMA consists of approximately 25 square miles of land located directly northeast of metropolitan Denver, Colorado (Figure 2-8). Land surrounding the Arsenal is diverse and include Stapleton International Airport, a light industrial complex, and residential areas directly to the south; residential areas to the west and northwest; agricultural land to north and east. Two major chemical agent/munition disposal programs have been conducted at RMA: Project Eagle and the Chemical Agent Identification Set (CAIS) Disposal Program. Tables 2-1 and 2-2 list the type, method, and quantity of agents disposed at RMA.

b. Project Eagle. In response to the recommendation of the NAS Ad Hoc Committee, the Department of Defense completely abandoned the proposed ocean dumping of mustard filled ton containers and M34 Cluster Bombs stored at RMA. Instead, Project Eagle was established in August 1969 to dispose of these items in accordance with the recommendations of the NAS Ad Hoc Committee. The project was divided into two phases:

(1) Phase I - Conducted from August 1972 through February 1974 and disposed of the mustard filled ton containers.(5) Disposal operations were conducted in the Mustard Plants Area near the center of the Arsenal (Figure 2-9).

(2) Phase II (Expanded) - Conducted from October 1973 through October 1976. Initially, Phase II dealt only with the M34 Cluster Bombs scheduled for disposal in Operation CHASE; however in October 1973, three additional disposal projects were added: (a) disposal of the bulk GB stored in underground storage tanks; (b) disposal of GB ton containers; and (c) disposal of the Honest John warheads containing M139 GB filled bomblets.(6,7,8,9) All disposal operations were conducted in the GB Complex located in the north central part of the Arsenal (Figure 2-9). Chemical neutralization was used to destroy the

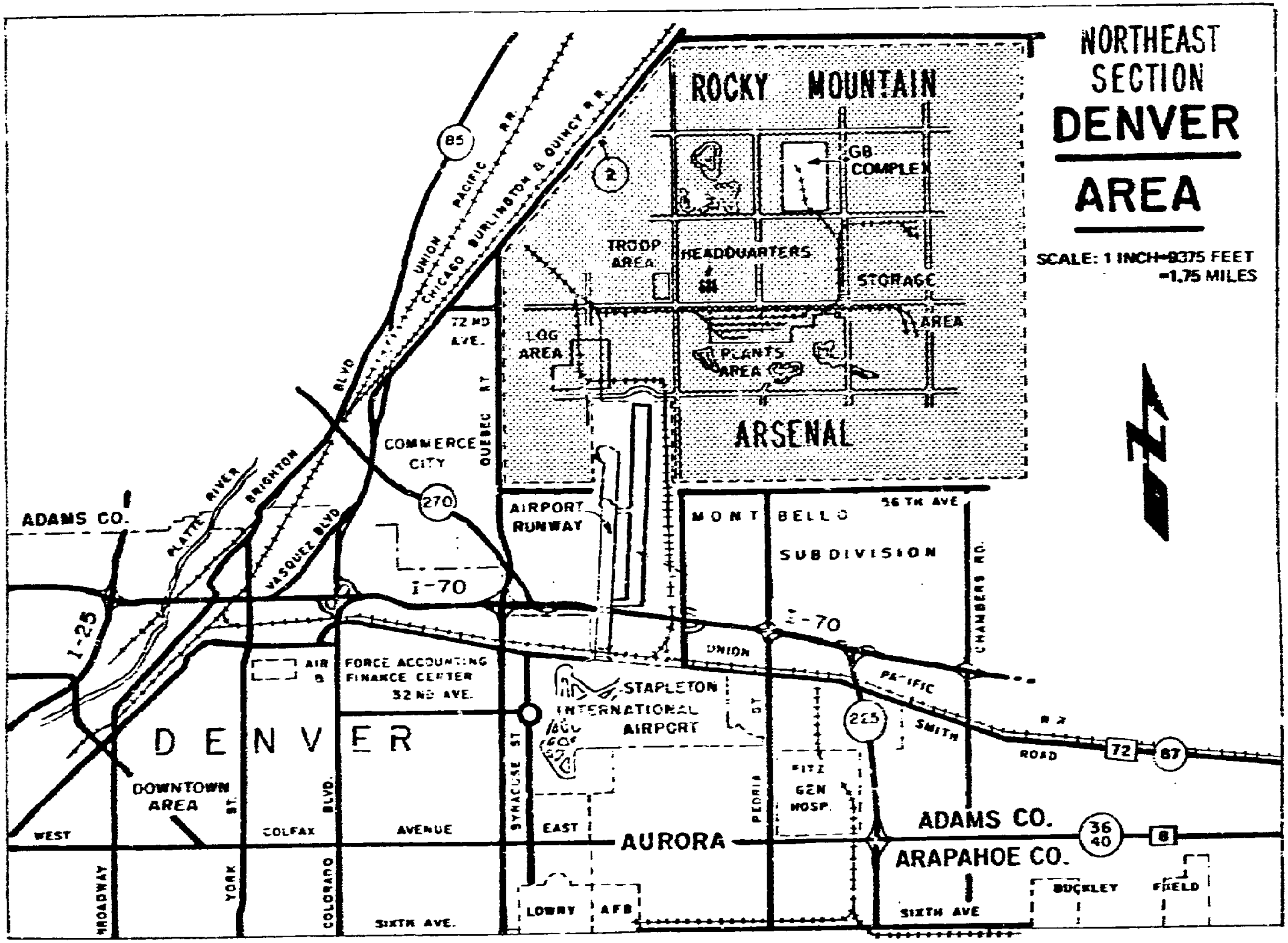

Figure 2-8: Location of Rocky Mountain Arsenal

TABLE 2-1. Chemical Agent Munitions Disposed of in Project Eagle

PHASE	AGENT	MUNITION/CONTAINER	METHOD	QUANTITY (POUNDS)
I	Levinstein Mustard (H)	Ton Containers	Incineration	4,428,000
	Distilled Mustard (HD)			1,714,000
II	GB	M34 Cluster Bombs/ M125 Bomblets	Neutralization*	4,129,600
	GB	Underground Storage Tanks	Neutralization	378,000
	GB	Ton Containers	Neutralization*	3,604,500
	GB	Honest John Warheads/ M139 Bomblets	Neutralization*	76,500

*Incineration Used to Destroy Explosive Components And/Or Decontaminate Metal Parts

TABLE 2-2. Chemical Agents Incinerated in CAIS Disposal Program

AGENT	QUANTITY (POUNDS)
Phosgene (CG)	17,698
Chloropicrin (PS)	10,196
Mustard (H/HD)	6,542
Lewisite (L)	1,385
Cyanogen Chloride (CK)	433
Nitrogen Mustard (HN-1/HN-3)	394
Sarin (GB)	46
TOTAL	36,694

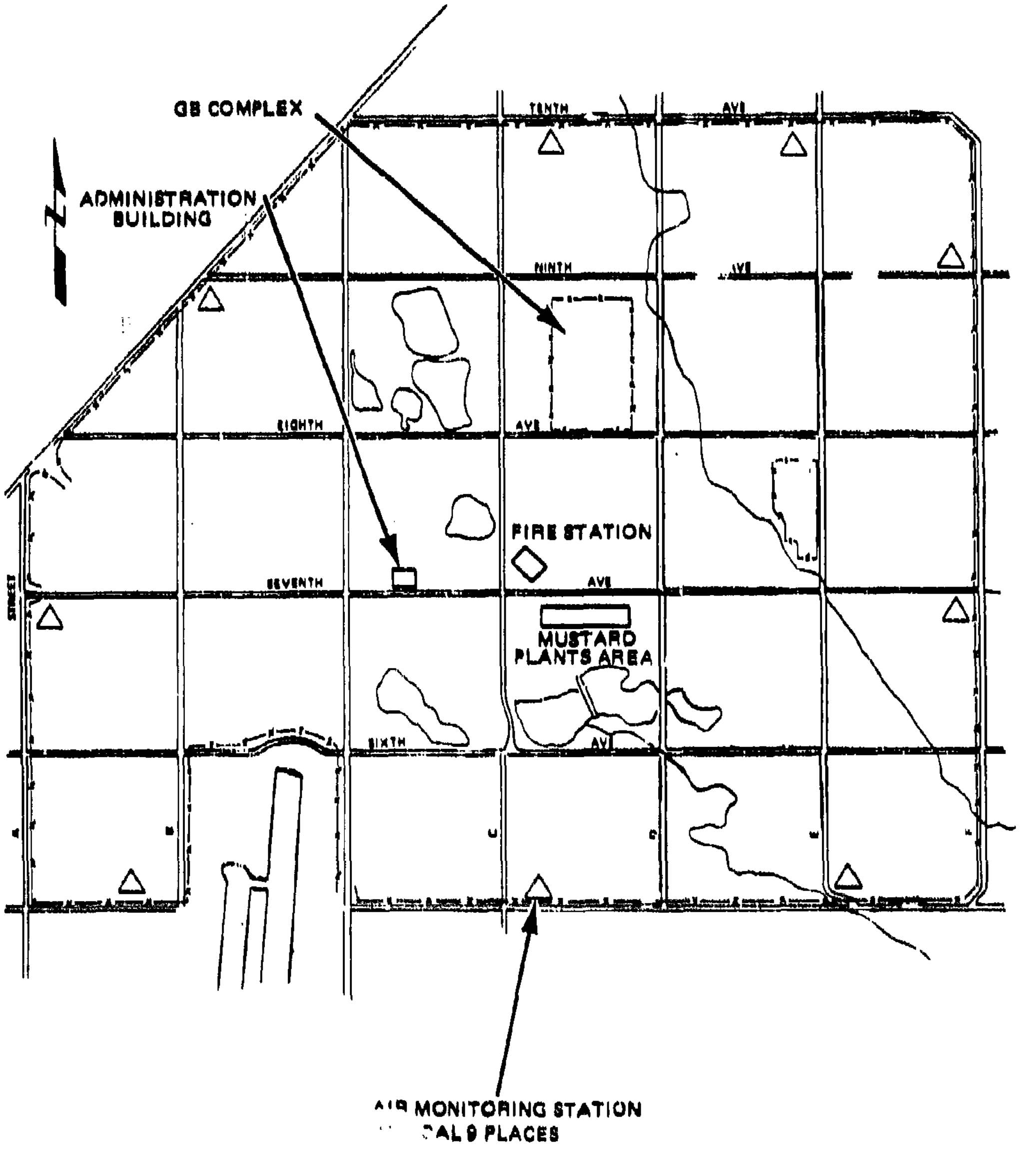

Figure 2-9: Chemical Agent/Munition Disposal Areas of Rocky Mountain Arsenal

GB; incineration was used to thermally decontaminate all metal parts (except the underground storage tanks) and to burn the explosive components of the bomblets.

c. CAIS Disposal - Conducted May 1981 through December 1982.(10) The Honest John disposal facility located in the GB Complex was modified for this project (Figure 2-10). Incineration was used to destroy the agents contained in the sets, and to thermally decontaminate all metal parts.

2.3.2. Chemical Agent Munitions Disposal System.

a. CAMDS is located in the South Area of TEAD, approximately 44 miles south-southwest of Salt Lake City, Utah (Figure 2-11). CAMDS is the Army's test facility for verifying the processes and equipment to be used in the Johnston Atoll Chemical Agent Disposal System (JACADS) and the proposed CSDP disposal facilities. In addition to this mission, CAMDS is authorized to dispose of chemical agents or munitions, located at TEAD, which have been declared unserviceable or obsolete and have been identified for disposal.(11,12,13)

b. Although CAMDS is used to verify the processes and equipment for the JACADS and proposed CSDP disposal facilities, it has a completely different facility layout. This is because initially CAMDS was intended to be a mobile disposal plant which could be transported to different chemical munition storage locations, thus precluding the necessity to move chemical munitions to a central disposal plant or to construct duplicate disposal plants at each storage location.(14) The Transportable Disposal System (TDS) (Figure 2-12), as it was called originally, was to be accomplished by dividing the demilitarization process into subsystems which were further divided into modules capable of being transported by rail. However in October 1972, the primary mission/purpose of the TDS was changed from a mobile disposal plant to

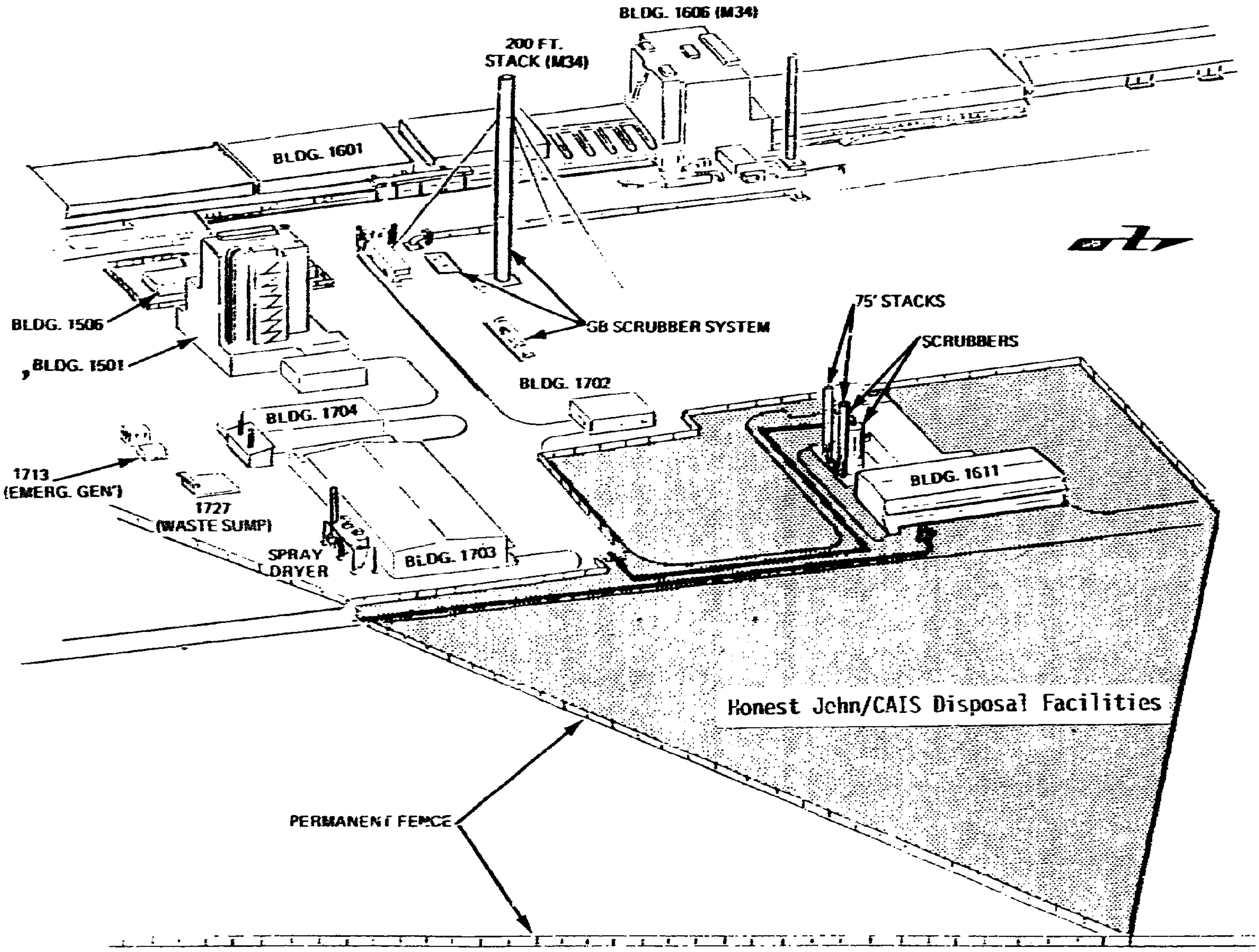

Figure 2-10: Honest John and CAIS Disposal Facilities within the RMA GB Complex

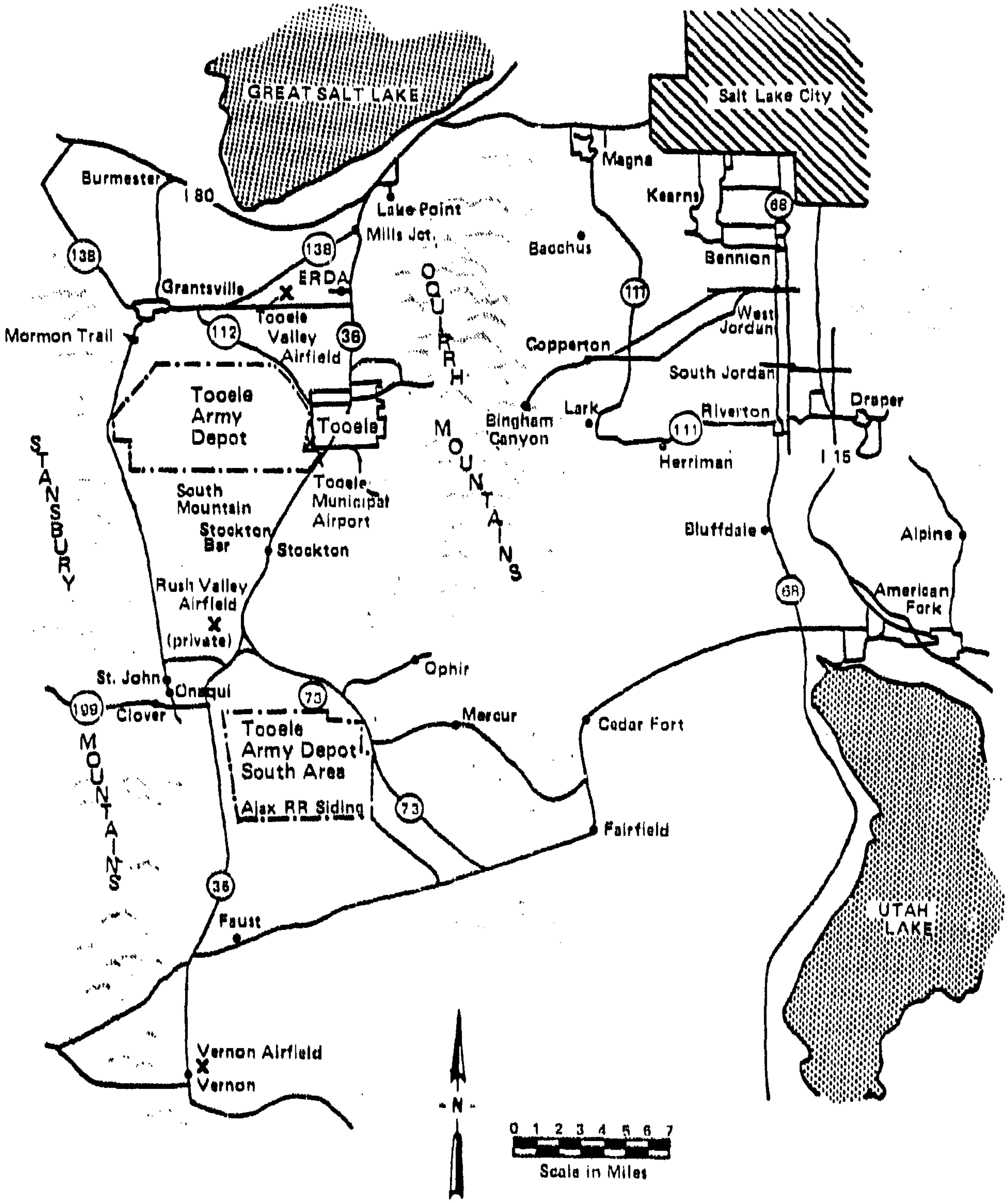

Figure 2-11: Location of Tooele Army Depot South Area

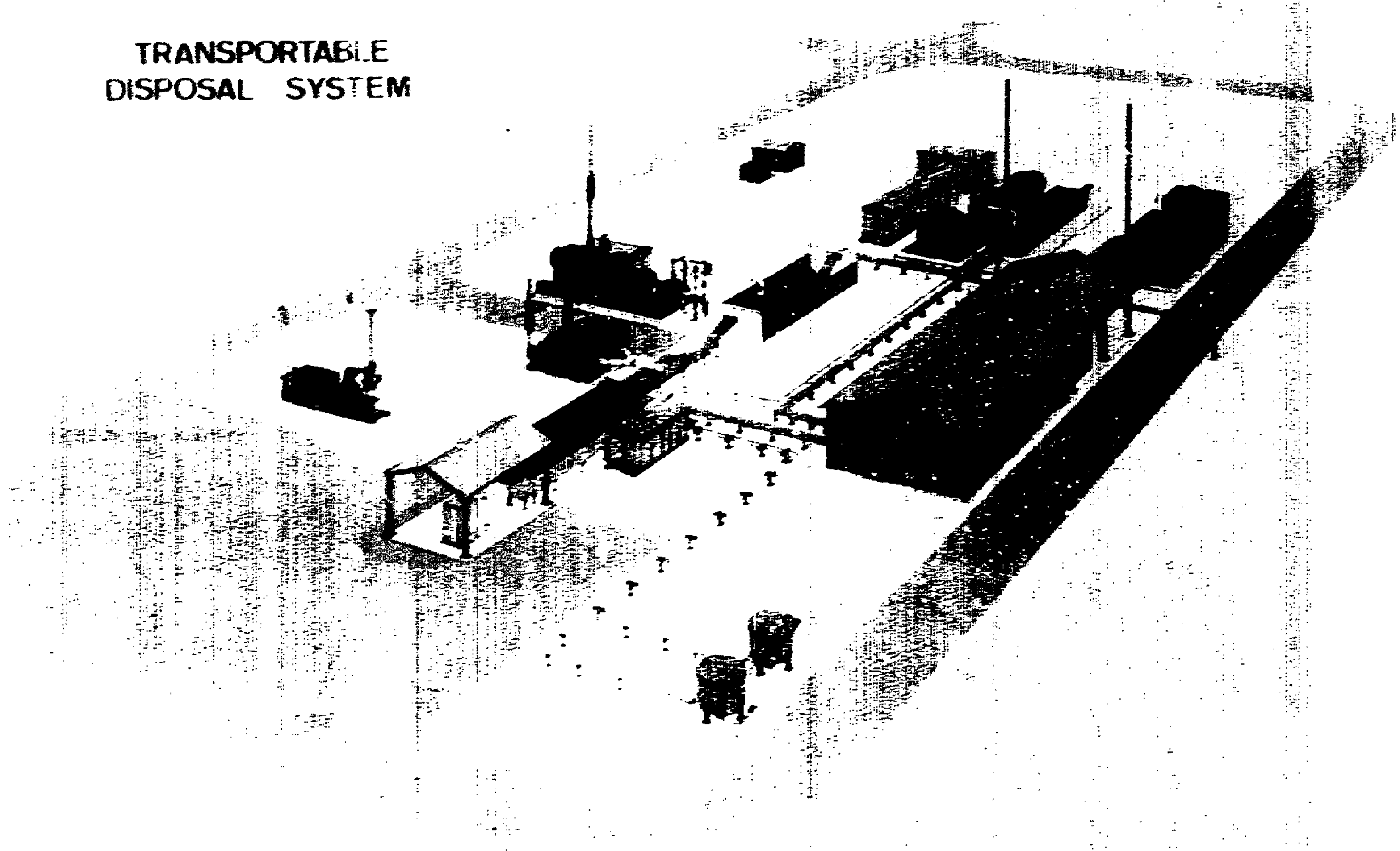

Figure 2-12: Transportable Disposal System

a process evaluation and pilot plant. In addition, the name was changed from TDS to CAMDS to better reflect this change in mission. Elements of the CAMDS design which are a hold over from the TDS and which differ from the JACADS and proposed CSDP plant designs include:

(1) Modular Construction. CAMDS, shown in Figure 2-13, has retained the modular appearance of the TDS and has several different and discrete process areas. This modular layout greatly enhances the Army's ability to test and evaluate several different processes concurrently. Both the JACADS and proposed CSDP disposal plants have consolidated all disposal operations into a single building referred to as the Munitions Demilitarization Building.

(2) Explosive Containment Cubicles (ECCs). CAMDS has two ECCs which are 2 1/2 inch thick steel cylinders with an inside dimension of 10 feet in diameter by 24 1/2 feet long. They are used to house all operations which have the potential to cause an explosive incident. The purpose of the ECCs is to contain the blast and fragments which would result from an accidental detonation. In the new disposal facilities, the ECCs have been replaced with Explosive Containment Rooms (ECRs) of concrete grid steel construction.

(3) Bucket Conveyor. This conveyor is used to transfer the explosive components from the ECC to the deactivation furnace system (DFS) feed chute. This is necessary at CAMDS since the entrance to the DFS feed chute is located about 10 feet above the ECC. The JACADS and CSDP facilities have eliminated the requirement for this conveyor by elevating the ECR above the DFS and using gravity to feed the explosive components to the DFS.

c. As shown in Tables 2-3 and 2-4, CAMDS has destroyed over 265,000 pounds of nerve agents GB and VX as a result of tests and limited disposal projects. Approximately half of the GB destroyed was using neutralization during M55 rocket and 105mm/155mm projectile disposal testing from September 1979 through July 1982. During incineration tests conducted at CAMDS from December 1979 through August 1986 approximately 75,000 pounds of GB and 8,000

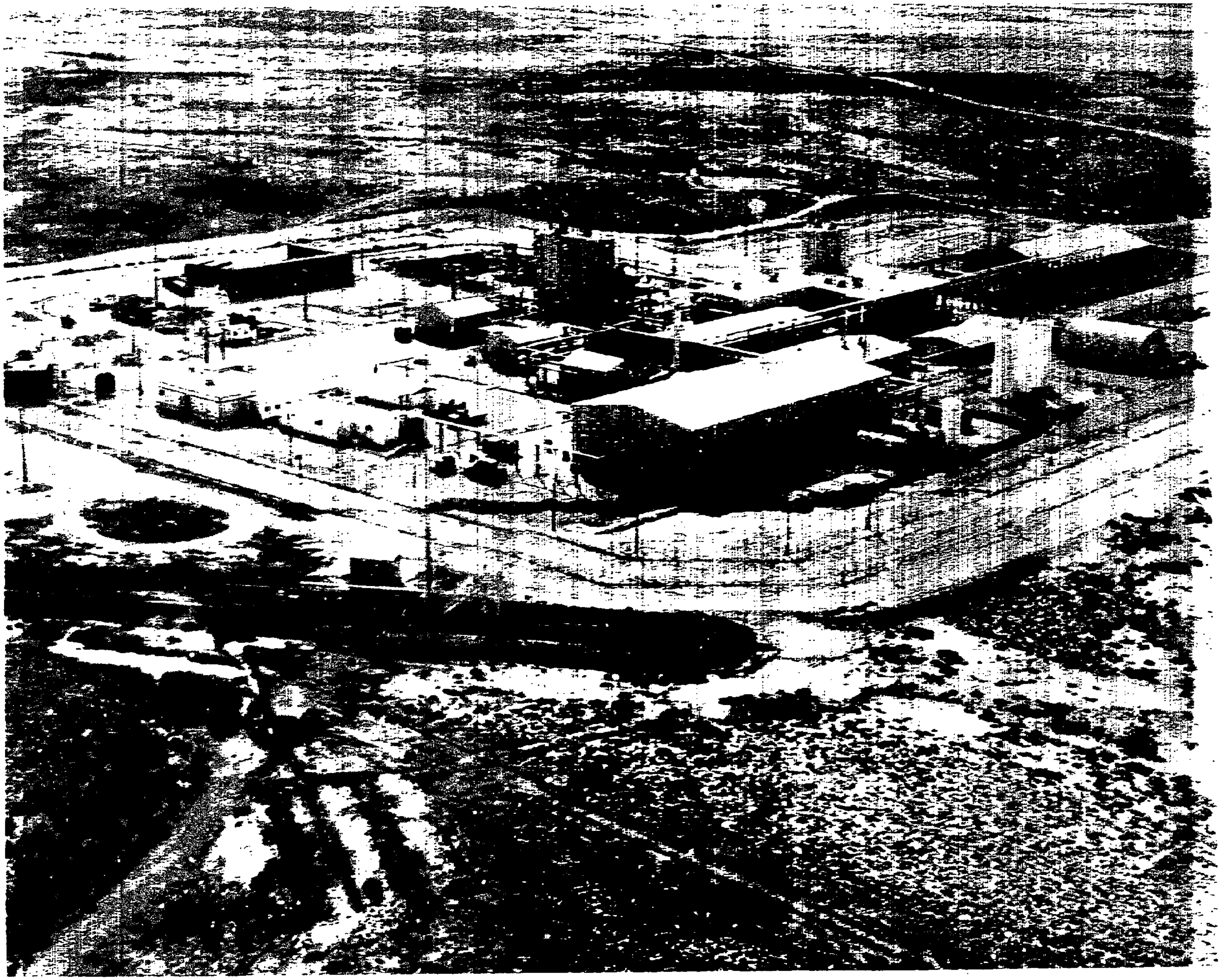

Figure 2-13: Chemical Agent Munitions Disposal System

TABLE 2-3. CAMDS Chemical Agent Neutralization Experience

AGENT	QUANTITY (POUNDS)	SOURCE
GB	127,950	Drained M55 Rockets
GB	54,000	Drained Projectiles

TABLE 2-4. CAMDS Chemical Agent/Munition Incineration Experience

QUANTITY (POUNDS)	MUNITION/CONTAINER	NUMBER
2,331	Drained M55 Rockets	18,308
5,357	Drained 155mm Projectiles	9,157
1,140	Drained 105mm Projectiles	7,771
17,570	Undrained 155mm Projectiles	2,703
37,930	Bulk (From Drained Rockets, Projectiles and Ton Containers)	N/A
7,866	Bulk (Ton Containers)	N/A

pounds of VX have been incinerated. In addition to the agent destroyed, CAMDS has incinerated/thermally decontaminated approximately 38,000 munitions.

CHAPTER TWO BIBLIOGRAPHY

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3.0.0 Neutralization Experience.

3.1.0 Introduction.

a. As discussed in Section 2.0, the Army abandoned ocean dumping in response to public concerns and the recommendations of the National Academy of Sciences (NAS) and instead the Army considered in the 1970's chemical neutralization, in general, as the method for industrial-scale disposal of nerve agent. Neutralization was attempted before incineration because of the Army's familiarity with the use of neutralization in field disposal and decontamination operations. Incineration was adopted for mustard only because of the considerable experience that the Army had at Rocky Mountain Arsenal (RMA).

b. With respect to chemical agent disposal, neutralization is a reaction with one or more other chemicals to form less toxic compounds. In many cases, the reaction is literally a true chemical neutralization where the chemical agent which acts as an acid undergoes reaction with a base, such as calcium hypochlorite, to form an organic salt. Unfortunately, because neutralization is a chemical reaction, it is possible to: (1) form intermediate reaction products that are toxic and (2) reform minute amounts of original toxic chemical agent from the products by reversal of the reaction under the appropriate conditions. The simplest example of a neutralization reaction is a hydrolysis, which is the breakdown of chemical agent by water. As with all chemical reactions, neutralization is sensitive to temperature, concentration, and acidity conditions.

c. The choice of a good neutralizing chemical, the criteria of which were given by Yurow and Davis (1) was based on as follows: (a) maximum ratio of chemical agent to be neutralized to neutralizing chemical consumed, (b) well-defined products of known toxicity, (c) ease of control, (d) acceptable (not too slow) rate of reaction, and (e) safety.

d. After selecting candidate neutralization chemicals, attempts were first made to determine the feasibility of the reactions first on a batch laboratory scale and then on a pilot-plant scale before proceeding to an industrial-scale. Neutralization was studied and determined feasible for the nerve agents, VX and GB. However, neutralization was never demonstrated on an industrial-scale for VX and mustard.

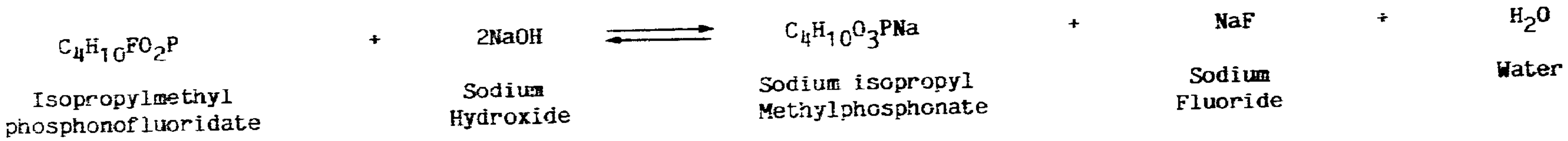
3.1.1 Neutralization Reactions.

a. Neutralization of GB.

(1) The most widely used and well known method for neutralization of GB involves alkaline hydrolysis with sodium hydroxide. The use of sodium hydroxide to neutralize GB, in small or bulk quantities is most effective. The sodium hydroxide chemically reacts with the GB to form a sodium organic salt, sodium fluoride and water, which are nontoxic reaction products, as per Figure 3-1. The reaction rate is fairly quick and the reaction gives off heat (heat of reaction is -44.4 Kcal/mole). The half life for GB in water at different temperatures and pH levels was determined by Epstein(2,3) and is presented in Table 3-1. It can be seen that GB decomposes faster as pH and/or temperature increases. (At pH levels greater than 10, the decomposition of GB is practically instantaneous).

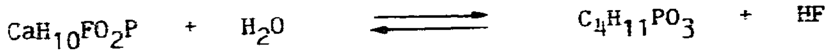
(2) Pilot-scale neutralization studies were also conducted by Thomas(4) to determine the time required for complete destruction of the agent and it was concluded the reaction was very fast and that only very low concentrations of GB remain in solution (<0.037 ug GB/ml solution) after reaction times of only five minutes. For these reasons industrial-scale neutralization by sodium hydroxide was supported and started.

(3) Reagents other than sodium hydroxide, in general, are not sufficiently studied to develop full criteria for their usefulness in bulk neutralization. The most notable reagent other than sodium hydroxide that has received attention is the hypochlorite ion (present in bleach); it possesses a fast reaction rate for reacting with GB at room temperature. Its advantage is lost, however, for bulk neutralization because of the need for large amounts of buffer or neutralizing bases. The chemical agent GB can be neutralized by



$$C_4H_{10}FO_2P + 2NaOH \rightleftharpoons C_4H_{10}O_3PNa + NaF + H_2O$$

Figure 3-1: GB Neutralization Reaction



$$CaH_{10}FO_2P + H_2O \rightleftharpoons C_4H_{11}PO_3 + HF$$

Figure 3-2: GB Hydrolysis Reaction

TABLE 3-1.

Half Life of GB in Hours as a Function of pH and Temperature

Temperature	pH				
°C	6.5	7.0	7.5	8.0	9.0
0	8300	2650	830	265	26.5
10	1870	591	187	59	6.0
20	461	146	46	15	1.5
25	237	75	24	7.5	0.8
30	125	39	12.5	4	0.4

a hydrolysis reaction (Figure 3-2). A series of laboratory-scale studies were used to determine the most effective method for hydrolyzing GB. Primary amines catalyze the hydrolysis of GB. However, the decomposition products are complicated by the presence of amines and therefore primary amine catalysis was not used on a large-scale operation. Metal ions such as copper, manganese, and magnesium have been found to catalytically accelerate the hydrolysis of GB. However, the drawback of this alternative is the disposal of metal ions incorporated in the salt product. Acid hydrolysis of GB is a difficult process to control; continuous generation of acidic products results in the possibility of side reactions and in gaseous by-products. Ion exchange resins, both cationic and anionic exchanges, have been used as hydrolytic catalysts; while this method is efficient, the exchange resins are quite expensive and therefore, were not considered for industrial-scale process.

(4) Unaided hydrolysis, i.e., breakdown of GB by water only, is not the most effective method for neutralizing GB. However, the reader should bear in mind the above equation (Figure 3-2) for unaided hydrolysis because the reverse reaction is important in reformation of GB, a problem with the products of GB neutralization that will be discussed later.

(5) Treatment of the brine resulting from the alkaline hydrolysis of GB is described in a paper by Srinivasan(5) that presents five options: chemfix of the brine, addition of hydrated lime, salt separation, isopropylmethyl phosphonic acid recovery, and photochemical oxidation. The most cost-effective and simplest treatment of the brine turned out to be none of these options; instead it was to evaporate the water and reduce the brine to salt.

b. Neutralization of VX.

(1) The acid chlorinolysis reaction, i.e. chlorination in an aqueous acidic media, provides the best overall VX neutralization reaction, offering destruction efficiencies in the laboratory of 99.99999%. The acid chlorinolysis reaction is a two-step reaction consisting of acid chlorination followed by caustic neutralization. As neat VX may burn on contact with

chlorine gas, the VX is first dissolved in hydrochloric acid. The acid chlorination forms non-toxic reaction products as per Figure 3-3.

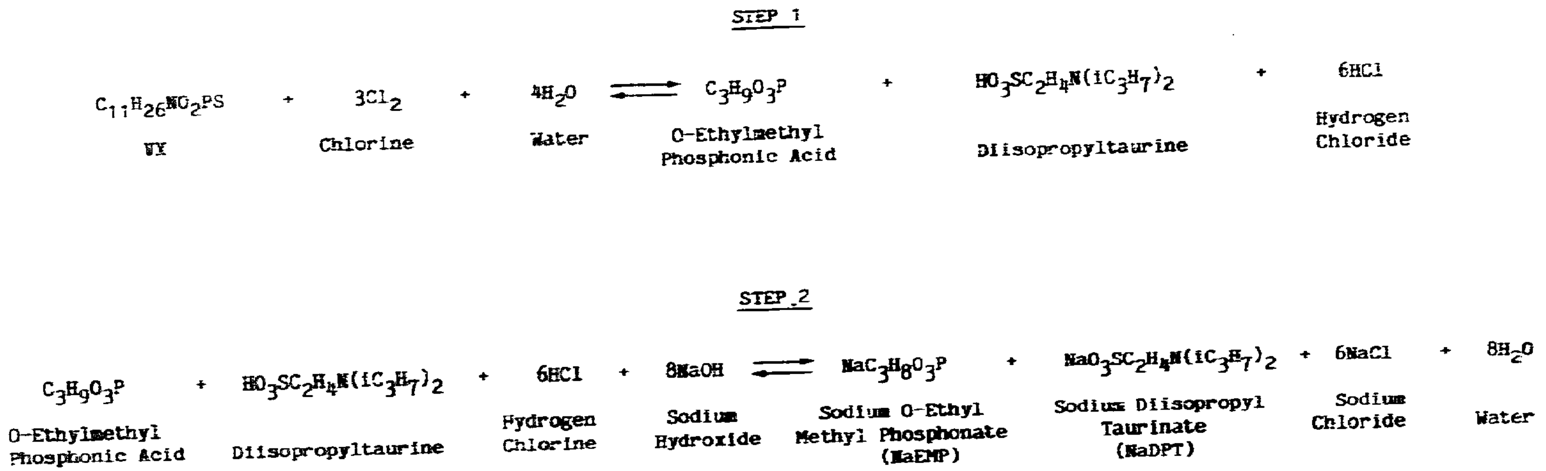
(2) To initiate the neutralization process, the sequence of chemical addition is critically controlled to prevent the hypergolic reaction of VX and chlorine. The reaction is quite exothermic (60 Kilocalories per gram mole of Cl_2) with reaction temperature peaking out at approximately 220°F. A stabilizer must be kept in solution during the course of the reaction to insure complete neutralization. To accomplish this, external heat is applied for a thirty minute period after the reaction temperature has peaked. Approximately three hours of reaction time is required to assure that all VX has been completely reacted. The high corrosiveness of the mixture to metals is a major disadvantage.

(3) The acidic solution from the chlorination step, i.e., first step is neutralized with caustic to make a brine (salt solution) that can be handled by commercial drying equipment. This necessitates adding either 18 percent or 50 percent caustic (NaOH) to raise the pH from 1-2 to 9-11, thereby converting the acid reaction products to the sodium organic salts and sodium chloride which are non-toxic end products as per Figure 3-3. The reaction that takes place between the caustic and acid solution is somewhat exothermic. The composition of the VX neutralization salts (Figure 3-3) is as follows: NaEMP - 18%, NaDPT - 30%, NaCl - 45%, NaOH - 7%, and VX - 2 ppb.

(4) Another method of neutralizing VX is hydrolysis and was studied by Jody et al (6). Because VX is not water soluble, ethanolamine is added to solubilize the VX. The disadvantages of this reaction were the high temperature (150°C) and high pressure (150 psig) required to carry out the reaction.

(5) The neutralization of VX with sodium dichloroisocyanurate ("Fichlor") was studied by Hovanec et al(7). Reaction products varied and definite kinetics could not be established because of the sequential nature of the reactions.

(6) Two independent studies(8,9) confirmed that bulk destruction by reaction with sodium hydroxide is possible but required 6 to 8



STEP 1

$$C_{11}H_{26}NO_2PS + 3Cl_2 + 4H_2O \rightleftharpoons C_3H_9O_3P + HO_3SC_2H_4N(iC_3H_7)_2 + 6HCl$$

STEP 2

$$C_3H_9O_3P + HO_3SC_2H_4N(iC_3H_7)_2 + 6HCl + 8NaOH \rightleftharpoons NaC_3H_8O_3P + NaO_3SC_2H_4N(iC_3H_7)_2 + 6NaCl + 8H_2O$$

Figure 3-3: VX Neutralization Reaction

hours because of the low solubility of VX in water. Additional problems were the unreliability of the method due to the solubilization of VX, critical control of mixing, and the presence of the "bis impurity" which results in a highly toxic waste product.

(7) One approach considered the neutralization of VX by calcium hypochlorite in a basic aqueous media by chlorine in an acidic aqueous media. Neutralization of VX using calcium hypochlorite is theoretically rapid but actually it occurs slowly. Other disadvantages of this reaction were as follows: the possibility of forming an intermediate compound of high toxicity and an extremely high ratio of hypochlorite to VX was required. It was considered for use at Tooele Army Depot (TEAD) (rf Epstein (10)) until the acid chlorinolysis was found to offer more effective neutralization.

c. Neutralization of Mustard Agent.

(1) Only with monoethanolamine (MEA), has mustard agent been neutralized on a pilot-plant scale. The reaction results in a homogenous non-toxic organic liquid waste. The general equation to describe the main reaction is given in Figure 3-4. In carrying out the reaction, sufficient MEA is provided to assure the reaction goes to completion.

(2) Aqueous sodium hydroxide solution for neutralizing mustard has been used but kinetically there is little basis for effectiveness at or near ambient temperatures. The use of calcium hypochlorite slurry or aqueous bleach to neutralize mustard, although they were previously applied to field decontamination, are no longer used because there is uncertainty as to completeness of the reaction. The reactions are heterogeneous in nature and the actual products may contain poorly identified materials whose toxicities have not been assessed.

(3) Mustard in ton containers neutralized by the reaction described above (in Figure 3-4) was planned in 1975 to occur at Fort McClellan(11). The resultant reaction waste product was also planned to be shipped to RMA for incineration. However, these plans were not carried out in

$S\ (CH_2CH_2Cl)_2$	+	$2NH_2CH_2CH_2OH$	$\rightleftharpoons$	$SC_4H_8NHCl(CH_2)_2OH$	+	$HOCH_2CH_2NH_3{}^+Cl^-$
mustard		monoethanolamine		N-(2-hydroxyethyl)-thimorpholine hydrochloride		monoethanolamine hydrochloride

Figure 3-4: Mustard Neutralization Reaction

view of the decision to drop neutralization in favor of incineration (see Section 3.4.0.a.).

3.1.2 Army's Neutralization Experience.

a. As shown in Table 3-2, approximately 8.4 million pounds of GB have been destroyed using the neutralization process at industrial-scale facilities located at RMA and at Chemical Agent Munitions Disposal System (CAMDS). The neutralization operations at RMA occurred under Project Eagle - Phase II (Expanded). (Project Eagle - Phase I consisted of incineration of ton containers of mustard between July, 1972 and March, 1974 and is covered later in section 4.0.). Project Eagle - Phase II (Expanded) consisted of the neutralization of 4.13 million lb of agent GB between October, 1973 and November, 1976 and the neutralization of 4.07 million lb of agent GB between September, 1974 and November, 1976. Thus, a total of 8.2 million lb of GB were neutralized at RMA.

b. The principal neutralization operations at CAMDS occurred under two projects: M55 Rocket Disposal and 155mm/105mm Projectile Disposal. The M55 Rocket Disposal involved the neutralization of 127,950 lb of GB while the 155mm/105mm Projectile Disposal involved the neutralization of 54,000 lbs of GB. Thus, a total of 181,950 lb of GB were neutralized at CAMDS. Each of these neutralization operations will be discussed in more detail in Sections 3.2 and 3.3.

TABLE 3-2. GB Neutralization Experience

Source	Operations Period	Number of Munitions	Approximate Pounds of Agent
For RMA			
Underground Tanks	1974	5 Tanks	378,000
GB Ton Containers	1975	2,422	3,604,500
M139 Bomblets (Honest John Warhead)	1976	59,996	76,500
M34 Cluster Bombs	1973-76	21,114	4,129,600
		SUBTOTAL	8,188,600
For CAMDS			
M55 Rockets	1979-81	13,951	127,950
155mm/105mm Projectiles	1981-82	12,673	54,000
		SUBTOTAL	181,950
TOTAL QUANTITY OF NERVE AGENT GB NEUTRALIZED			8,370,550

3.2.0 Rocky Mountain Arsenal Neutralization Programs.

3.2.1 Introduction.

a. Background.

(1) Between October 1973 and November 1976, four chemical agent disposal projects were conducted at RMA. The major project was the M34 Cluster Bomb Project(12,13) (summarized in Table 3-3) where 4,129,600 pounds of agent GB were neutralized between October 1973 through September 1976.

(2) The purpose of Project Eagle was to dispose of the excess stocks of chemical munitions which had been stored at RMA since the early 1940s. Included originally under Project Eagle - Phase II were 21,114 US Air Force M34 nerve agent GB-filled Cluster Bombs (see Appendix C for description) stored at RMA(14). The NAS had recommended during June 1969 that the M34 clusters be disassembled and the GB be destroyed chemically either with acid or alkaline hydrolysis. In October 1973, the Department of Defense announced that the portion of the national stockpile of bulk GB agent and munitions at RMA would be destroyed at that site (in addition to the M34 Cluster Bomb disposal operation under Project Eagle - Phase II). These additional disposal operations caused Project Eagle - Phase II to be changed to Project Eagle - Phase II (Expanded). Four items were designated for disposal under Project Eagle - Phase II (Expanded): (a) disposal of bulk GB in underground storage tanks; (b) disposal of GB in ton containers (see Appendix B for description); (c) disposal of the Navy's Weteye Bomb(15); and (d) disposal of the Army's Honest John Warhead and M139 bomblets (see Appendix C for description).

(3) The disposal of GB in five underground storage tanks was performed between September and November 1974. The draining of GB from 2,422 ton containers was completed between March and November 1975 and the agent was later neutralized in the GB neutralization facility in conjunction with the M34 Cluster Bomb operation. The Weteye Bomb Project was deferred at the request of the Navy to permit consideration of retaining the Weteye in the

TABLE 3-[illegible]. Chemical Agent Neutralization at RMA

Munition Agent Source	Operations Period	Agent	Quantity (Pounds)
M34 Cluster Bombs	Oct 1973 to Sep 1976	GB	4,[illegible]13,600
Underground Storage Tanks	Sep 1974 to Nov 1974	GB	3[illegible]8,000
Ton Containers	Jun 1975 to Nov 1975	GB	3,60[illegible],500
M139 Bomblets/Honest John	Apr 1976 to Nov 1976	GB	76,500
TOTAL POUNDS OF AGENT GB NEUTRALIZED			8,[illegible]58,600

active inventory. The Honest John Warhead (and M139 bomblet) disposal operation commenced in April 1976 and was completed in November 1976.

b. Facility Layout. Figure 3-5 is a pictorial of the facility layout at RMA.

(1) The M34 Cluster Bomb disposal process consisted of transporting the cluster bombs from the storage area by truck to Building 1606 where they were disassembled in explosion containment cubicles. The 76 bomblets contained in each cluster bomb were removed, fuzes were rendered mechanically nonfunctioning, and bomblets were drained of GB in Building 1606. The draining operation was done in an explosive containment room using robot-like equipment. This equipment rendered the bomblet fuze safe, then punched and drained the bomblet of GB. The GB removed from the bomblets flowed into a storage tank, referred to as the GB day tank, and was periodically pumped to Building 1501 through double-walled piping where the GB was neutralized. After neutralization, the remaining salt solution (brine) was pumped to Building 1703 where the water was vaporized in a spray dryer and the salts removed and drummed. The cluster bomb and remaining bomblet bodies were removed by conveyor through a ventilated corridor to a deactivation furnace where the explosives were incinerated and the metal parts were thermally decontaminated. The metal parts exiting the furnace were sold as scrap metal.

(2) The underground tank storage facility in Building 1506 consisted of ten underground tanks (five of which contained GB and five of which were empty) and the associated piping to fill, empty, and transfer the GB between them. Two of the tanks that contained agent were equipped with submerged pumps and were used to transfer GB through double-walled pipes to the neutralization facility in Building 1501. In the remaining three tanks, the GB was transferred to one of the two pump tanks for pumping to Building 1501.

(3) The ton container unloading operation was accomplished in Building 1601A of the GB Complex. After the ton containers arrived at Building 1601A from the toxic yard, they were drained of agent GB. Draining

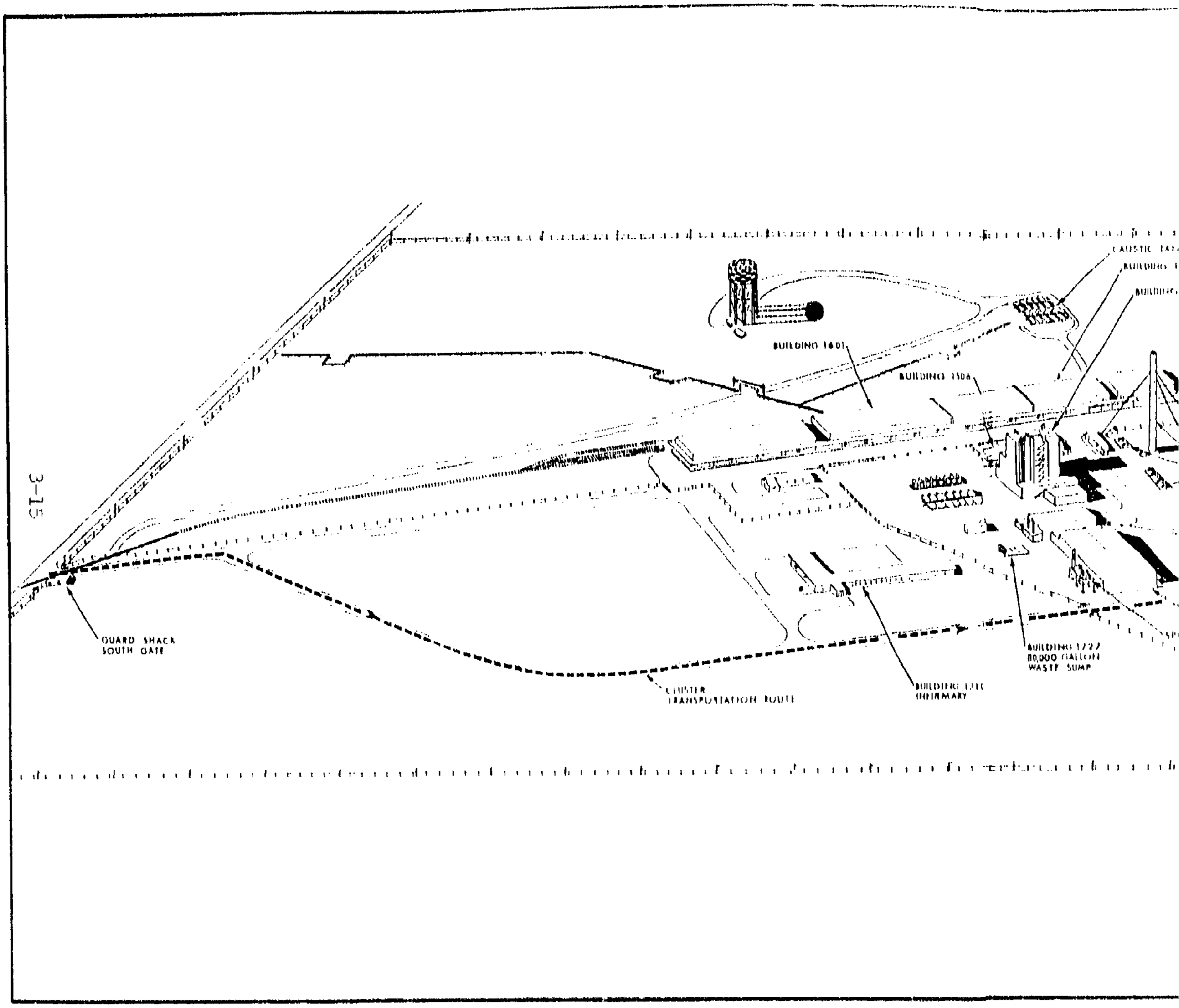
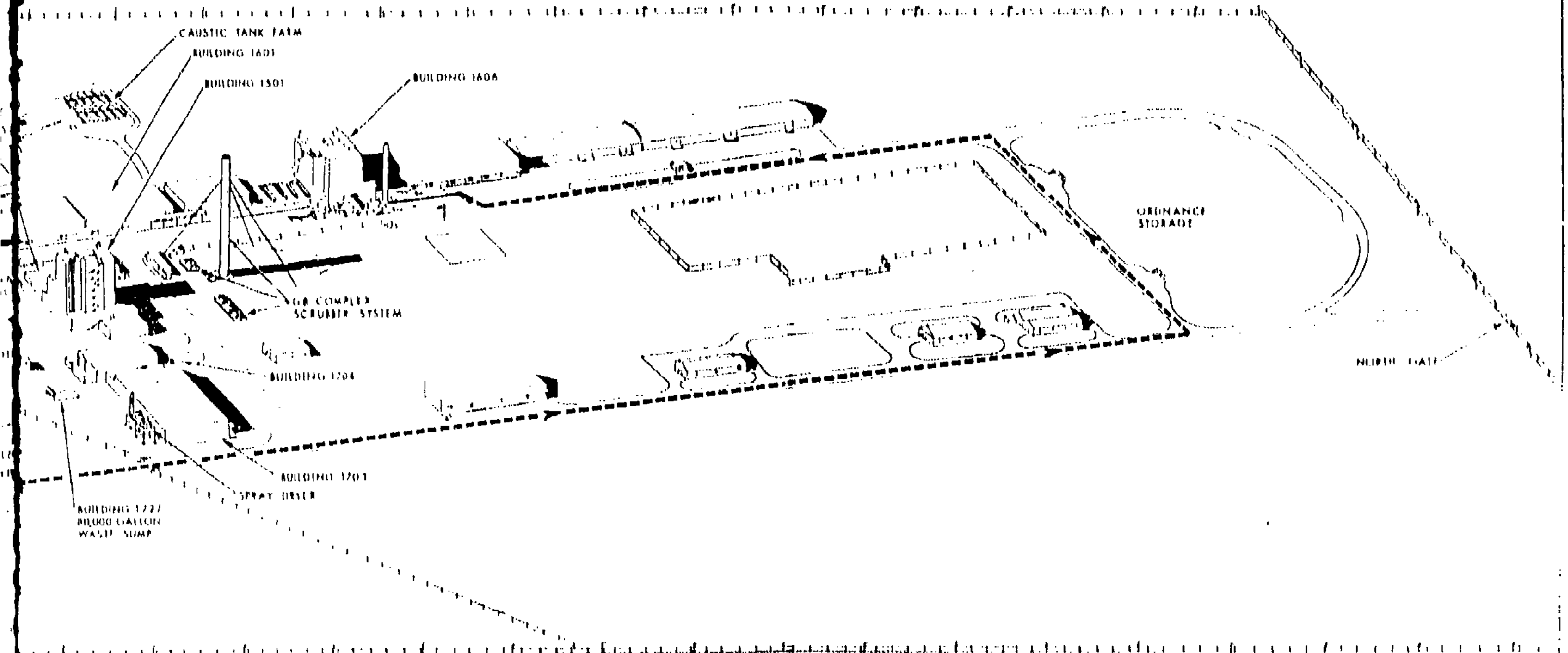


Figure 3-5: Facility La



3-5: Facility Layout at RMA

was accomplished by evacuating an underground storage tank in Building 1506 and allowing the tank to pull a vacuum on the ton container, drawing the GB from the ton container to the underground tank. The GB stored in the underground tank was then pumped through double-walled pipe to the neutralization facility in Building 1501. After the neutralization reaction was complete, the salt solution, as in the M34 Cluster Bomb process, was pumped to Building 1703 for spray drying. The empty ton containers were thermally contaminated in ton container furnaces in Building 538 in the South Plants Area of RMA (see Figure 2-9).

(4) The Honest John M190 Warheads and M139 Bomblets (368 bomblets per warhead) were disposed in Building 1611. The building housed three separate functional areas: processing, control and observation. The processing area included the Warhead and drum holding area, the GB storage and transfer area, the Deactivation Furnace area, and Decontamination Furnace area. The control and observation areas were located adjacent to the processing area on two levels and were equipped with windows so that the main process functions could be observed. The agent GB drained from the bomblets was transferred via doubled-walled pipe from Building 1611 to Building 1506/1501 facilities for ultimate neutralization. Agent neutralization was accomplished utilizing the existing M34 neutralization facility in Building 1501.

e. <u>Neutralization Process Description.</u>(14)

(1) Figure 3-6 illustrates the final Project Eagle - Phase II (Expanded) process configuration for neutralization. Although the exact equipment/process configuration changed and evolved through the life of the four neutralization operations, the basic process remained the same and consisted of the following elements:

(a) Caustic Storage and Delivery

(b) GB Storage and Delivery

(c) Reactor Filling, Neutralization and Emptying

The GB was neutralized in Building 1501 (see Figures 3-7 and 3-8). The process consisted of mixing caustic with GB to form a solution,

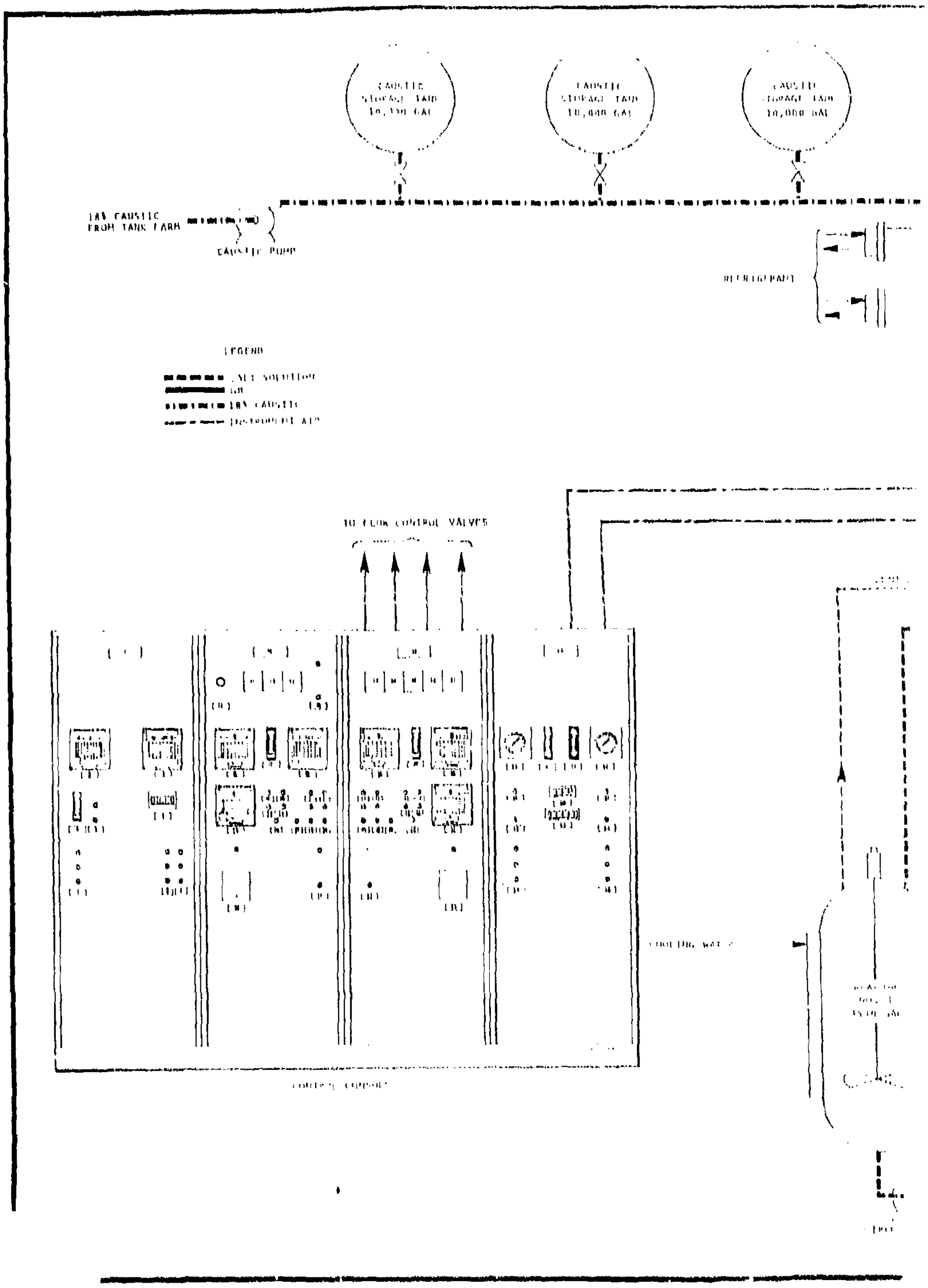
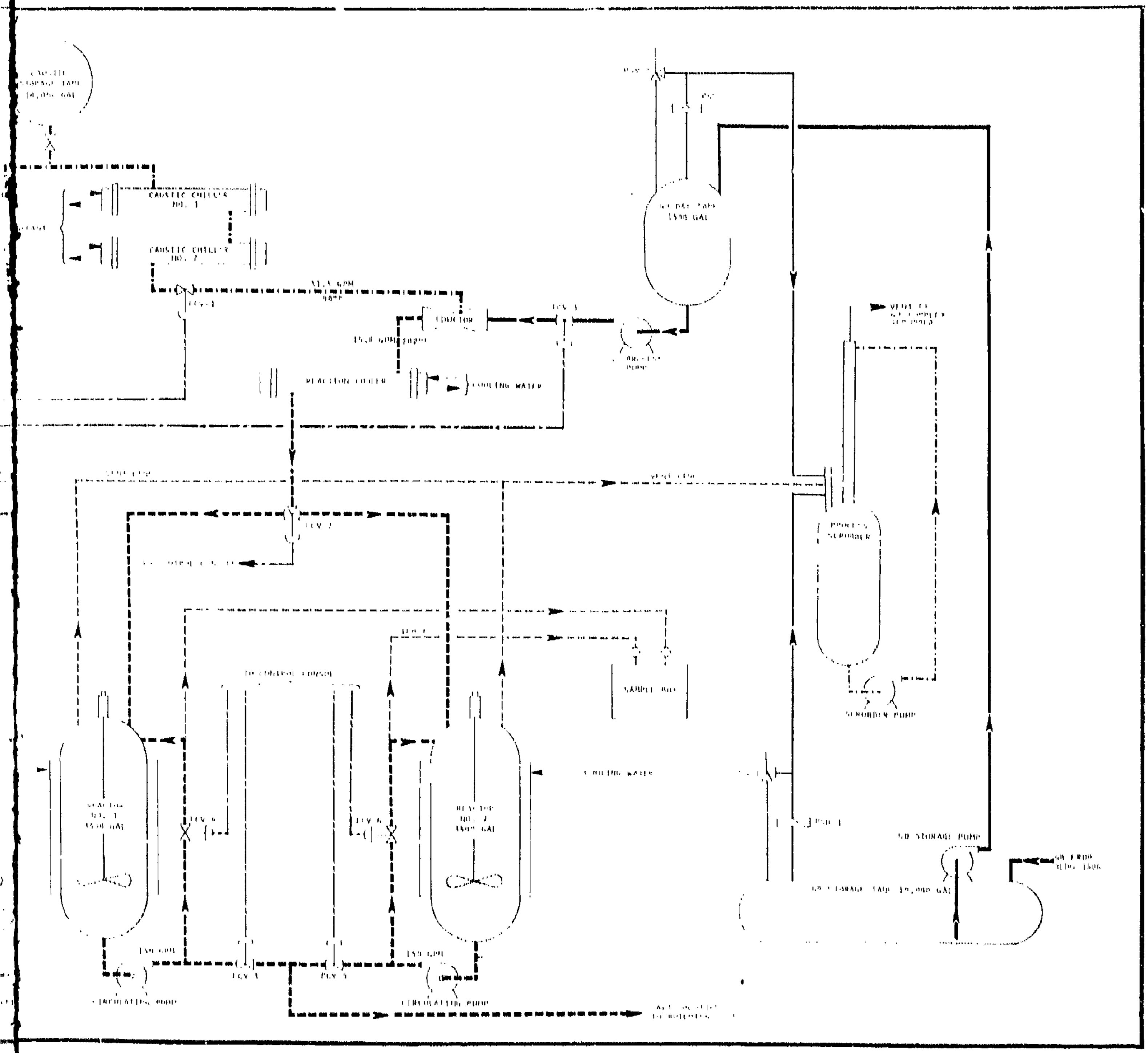


Figure 3-6: Neutral



Neutralization Process Description

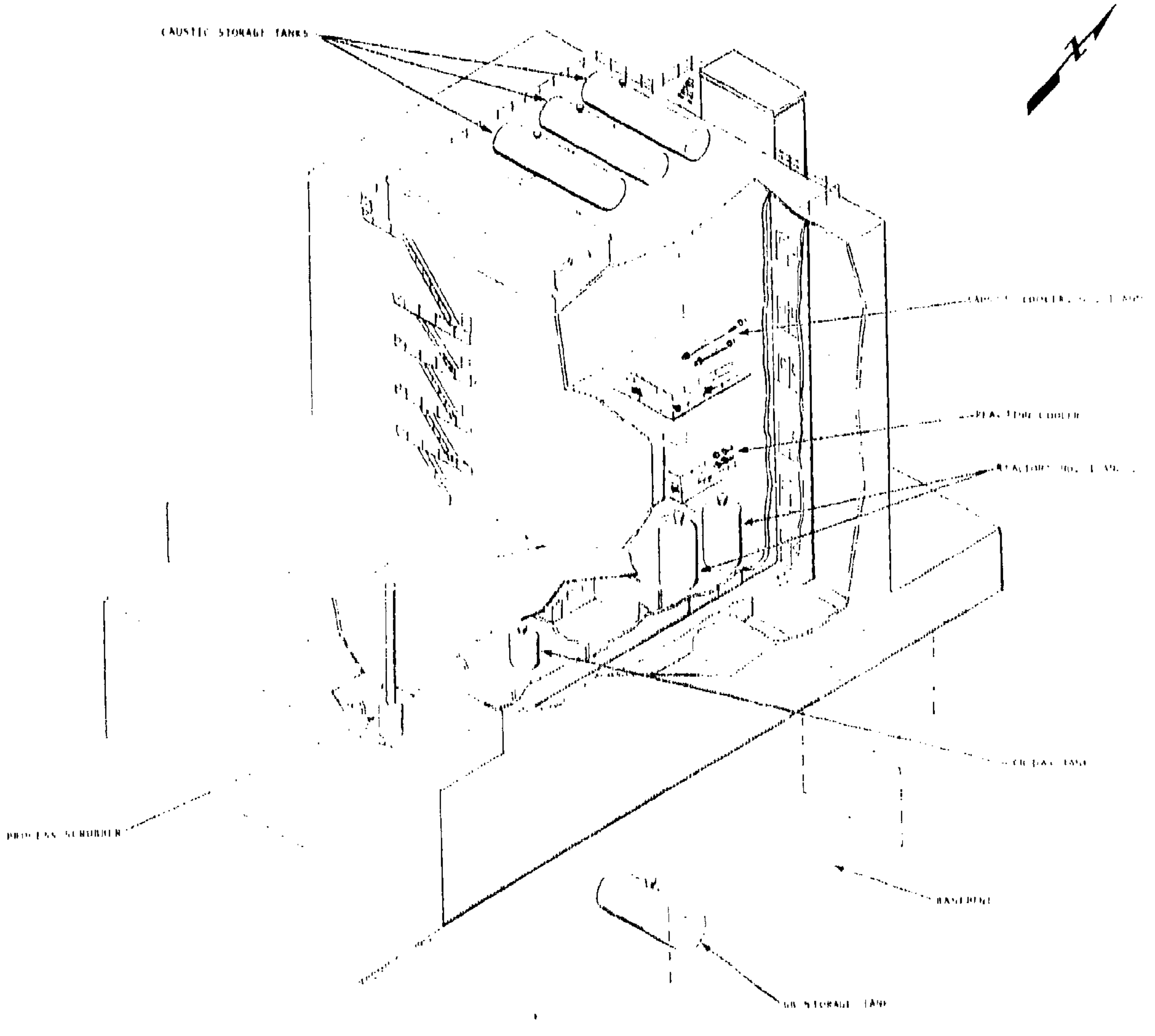
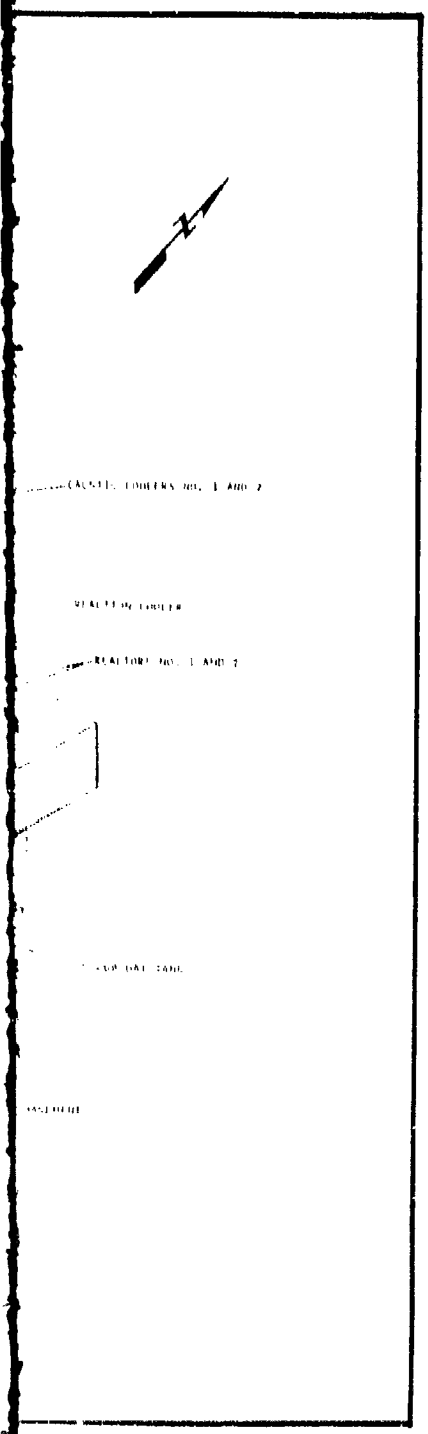
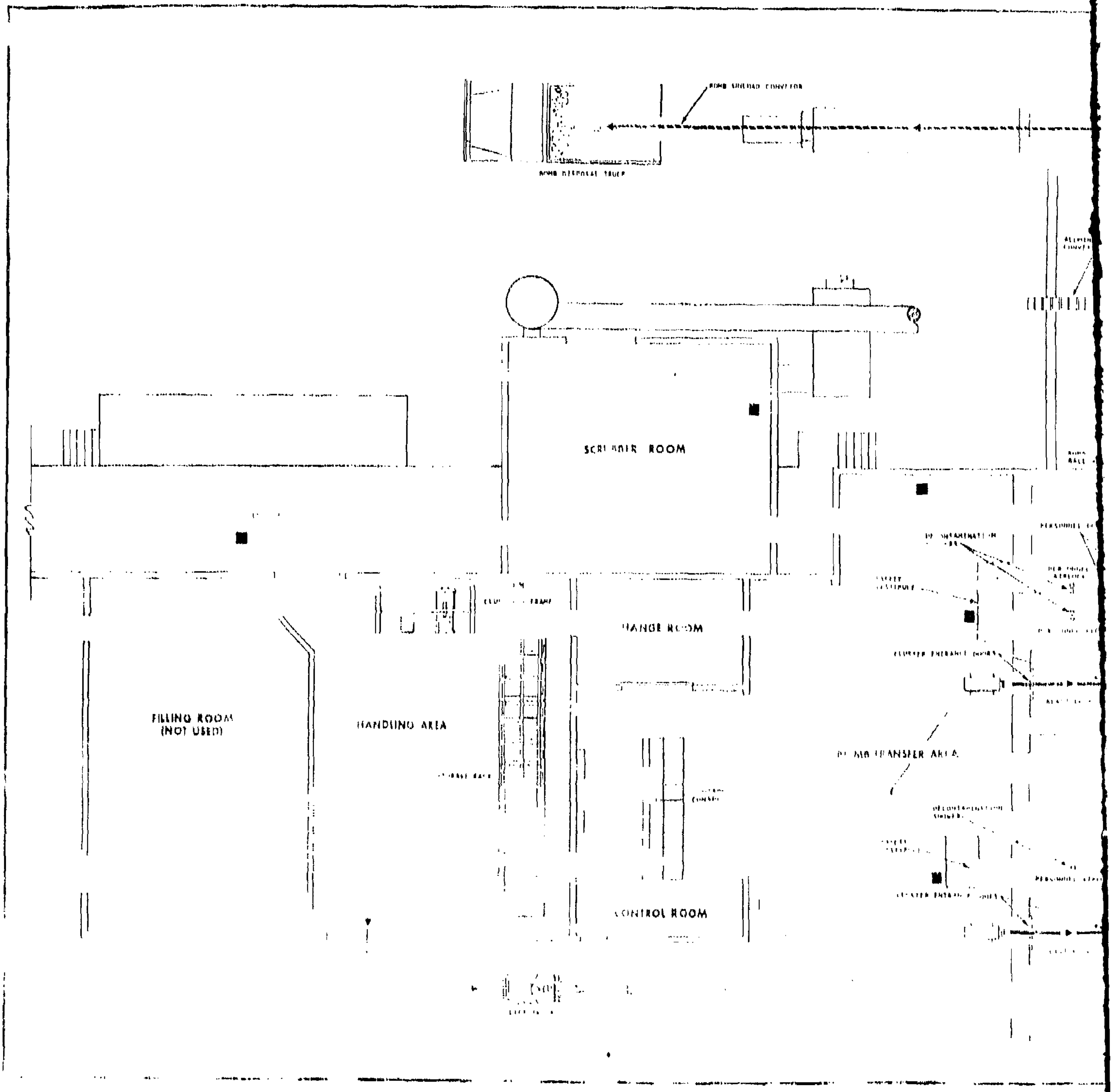
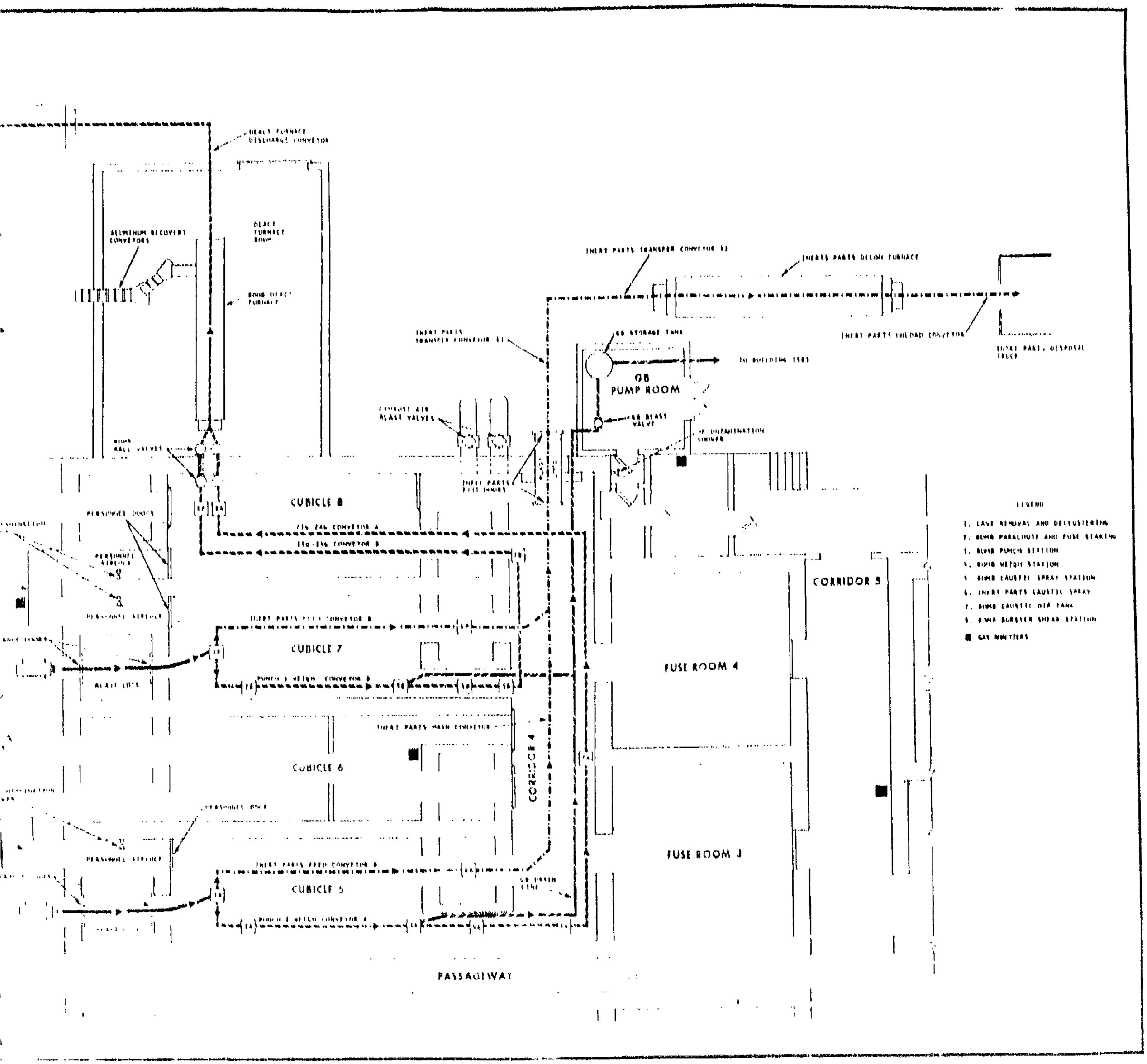


Figure 3-7: Cutaway of Building 1501


CAUSTIC COOLERS NO. 1 AND 2
REACTOR COOLER
REACTORS NO. 1 AND 2
GAS TANK


BOMB UNLOAD CONVEYOR
BOMB DISPOSAL TRUCK
SCRUBBER ROOM
FILLING ROOM
(NOT USED)
HANDLING AREA
GAUGE ROOM
CONTROL ROOM
DECONTAMINATION
SAFETY VESTIBULE
PERSONNEL
BOMB TRANSFER AREA
DECONTAMINATION SHOWER
BOMB BALL

Fig[illegible]


DEACT FURNACE DISCHARGE CONVEYOR
ALUMINUM RECOVERY CONVEYORS
DEACT FURNACE ROOM
BOMB DEACT FURNACE
INERT PARTS TRANSFER CONVEYOR 12
INERTS PARTS DECON FURNACE
INERT PARTS TRANSFER CONVEYOR 11
GB STORAGE TANK
GB
PUMP ROOM
INERT PARTS UNLOAD CONVEYOR
INERT PARTS DISPOSAL TRUCK
EXHAUST AIR BLAST VALVES
GB BLAST VALVE
DECONTAMINATION SHOWER
BOMB BALL VALVES
INERT PARTS EXIT DOORS
CUBICLE 8
PERSONNEL DOORS
PERSONNEL AIRLOCK
TAG CONVEYOR A
TAG CONVEYOR B
INERT PARTS FEED CONVEYOR B
CUBICLE 7
PUNCH & WEIGH CONVEYOR B
INERT PARTS MAIN CONVEYOR
CUBICLE 6
CORRIDOR 4
PERSONNEL DOOR
PERSONNEL AIRLOCK
INERT PARTS FEED CONVEYOR A
GB DRAIN LINE
CUBICLE 5
PUNCH & WEIGH CONVEYOR A
PASSAGEWAY
CORRIDOR 5
FUSE ROOM 4
FUSE ROOM 3
LEGEND
1. CASE REMOVAL AND DECLUSTERING
2. BOMB PARACHUTE AND FUSE STAKING
3. BOMB PUNCH STATION
4. BOMB WEIGH STATION
5. BOMB CAUSTIC SPRAY STATION
6. INERT PARTS CAUSTIC SPRAY
7. BOMB CAUSTIC DIP TANK
8. BURSTER SHEAR STATION
■ GAS MONITORS

ing System

recirculating the solution in reactors until neutralization had been confirmed, then transfering the solution to Building 1703 (Figure 3-5.) for spray drying.

(2) Caustic Storage and Delivery. The caustic used in the neutralization process was an 18 percent solution of sodium hydroxide (NaOH) stored in three 10,000 gallon tanks on the roof of Building 1501. The storage tanks were filled at a rate of 100 gpm from the caustic tank farm by a 15 hp pump. The caustic was supplied by gravity to a venturi-like mixing tee called the eductor where it was mixed with the agent GB.

(3) GB Storage and Delivery. The GB was stored at room temperature in a 10,000 gallon storage tank in the basement of Building 1501. The tank was filled from Building 1606. The GB was pumped from the 10,000 gallon storage tank into a 1500 gallon day tank and from the day tank to the eductor where it was mixed with caustic.

(4) Reactor Filling Neutralization and Emptying. The brine solution formed from mixing the GB with caustic left the eductor at a temperature of approximately 202°F. Heat generated by the chemical reaction between the caustic and GB was partially removed in a heat exchanger known as the Reaction Cooler. The brine solution then flowed to one of two 3500 gallon reactors. The 3500 gallon reactors were first filled with 50 gallons of caustic to ensure a surplus prior to receiving approximately 2800 gallons of brine solution. The brine solution was continuously agitated by mixers while being recirculated through the reactors until the neutralization process was completed. Cooling water was circulated through the reactor water jackets to assist in removing the heat generated during neutralization. Sampling stations were provided for testing and verifying that all GB had been neutralized before it was certified for transfer to the spray dryer in Building 1703. A remote control panel was provided so that operators could monitor and control temperatures, the reaction progress, and handling and transport. Spray drying reduced the brine to dried salts. Reactor emptying time was approximately one-half hour. The reactors were connected to the Process Water System for washdown prior to a prolonged shutdown, and to the

Process Scrubber Vent System for removing, condensing, and neutralizing vapors generated in the process of neutralizing the GB.

(5) Water. Waste water from the process scrubber and from periodic washdown of the reactors was transferred through a sewer to an 80,000 gallon industrial waste sump. This waste was tested and certified agent-free before periodic emptying and processing through brine drying (see below) where it was dried and the residual salt was drummed. The reactor cooling water was maintained at a positive pressure so any leakage that might have occurred at this interface would have resulted in water flow back into the reactor.

(6) Brine Drying. After neutralization of the nerve agent GB, the brine solution was pumped to a spray dryer facility as shown in Figure 3-9. The spray dryer mixed the brine solution with heated air in a high-speed spray head of the drying chamber to reduce the brine solution to salts and evaporate the water. The salts, water vapor and heated air were then distributed to four cyclone separators where the dried salt particles dropped into hoppers. After removal of the dried salts in the cyclone separators, the heated air and water vapor were scrubbed to remove particulates before release of the gases through an 100-foot stack to the atmosphere. From the hoppers, the dried salts passed through compacting rolls and a chip breaker. Finally, the dried salts were packaged, weighed and sealed in corrosion resistant, epoxyphenolic lined 55 gallon drums.

3.2.2 Project Description.

a. M34 Cluster Bomb (M125 Bomblet).

This section addresses the disposal of the 21,113 M34 Cluster Bombs at RMA completed in September, 1976. Although the initial planning for disposal of the M34 Clusters began in late 1969, actual toxic operations did not commence until the fall of 1973. A description of the M34 Cluster bomb is given in Appendix C. A total of 4,129,600 pounds of GB nerve agent and 883,5[illegible] pounds of explosive were destroyed in this particular disposal operation.

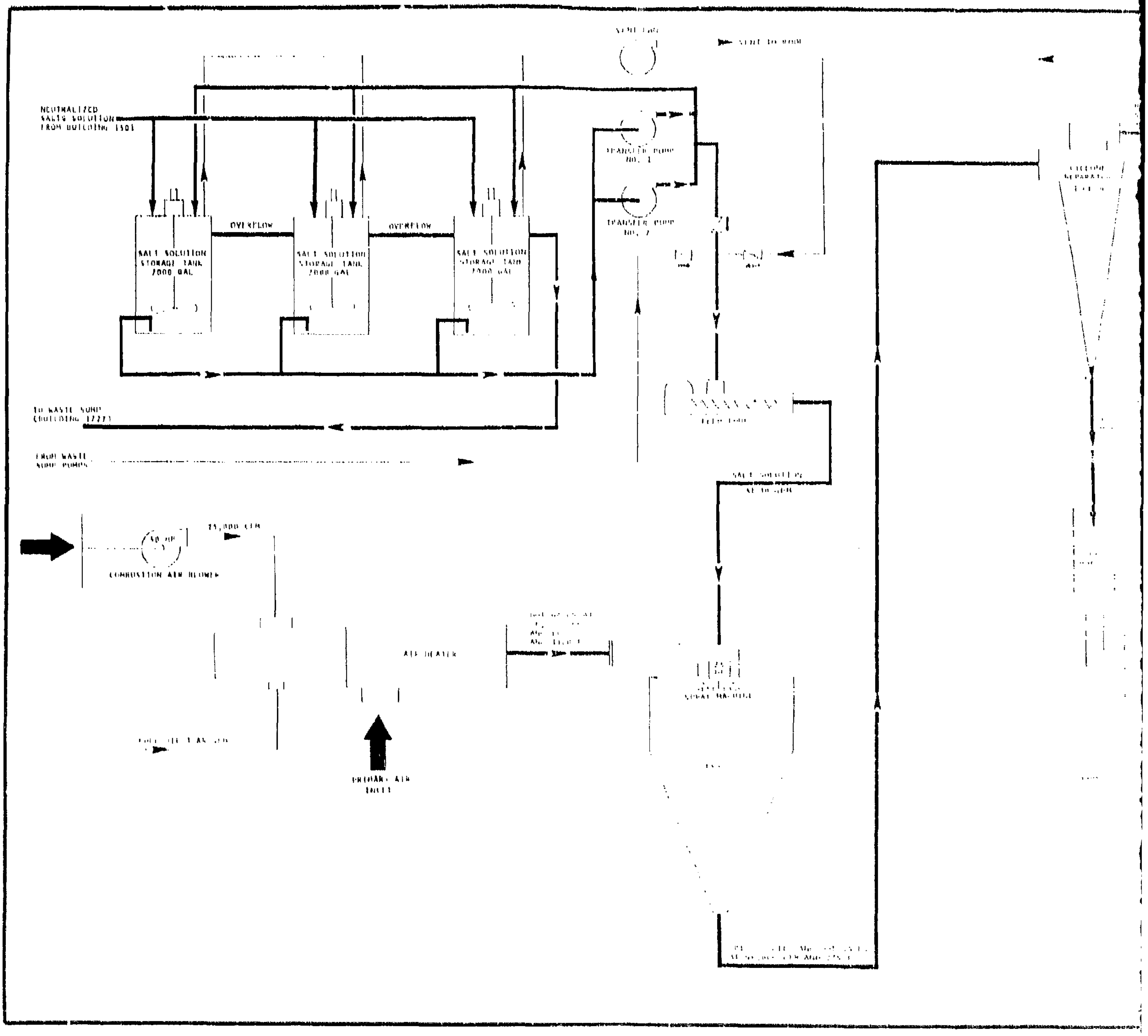
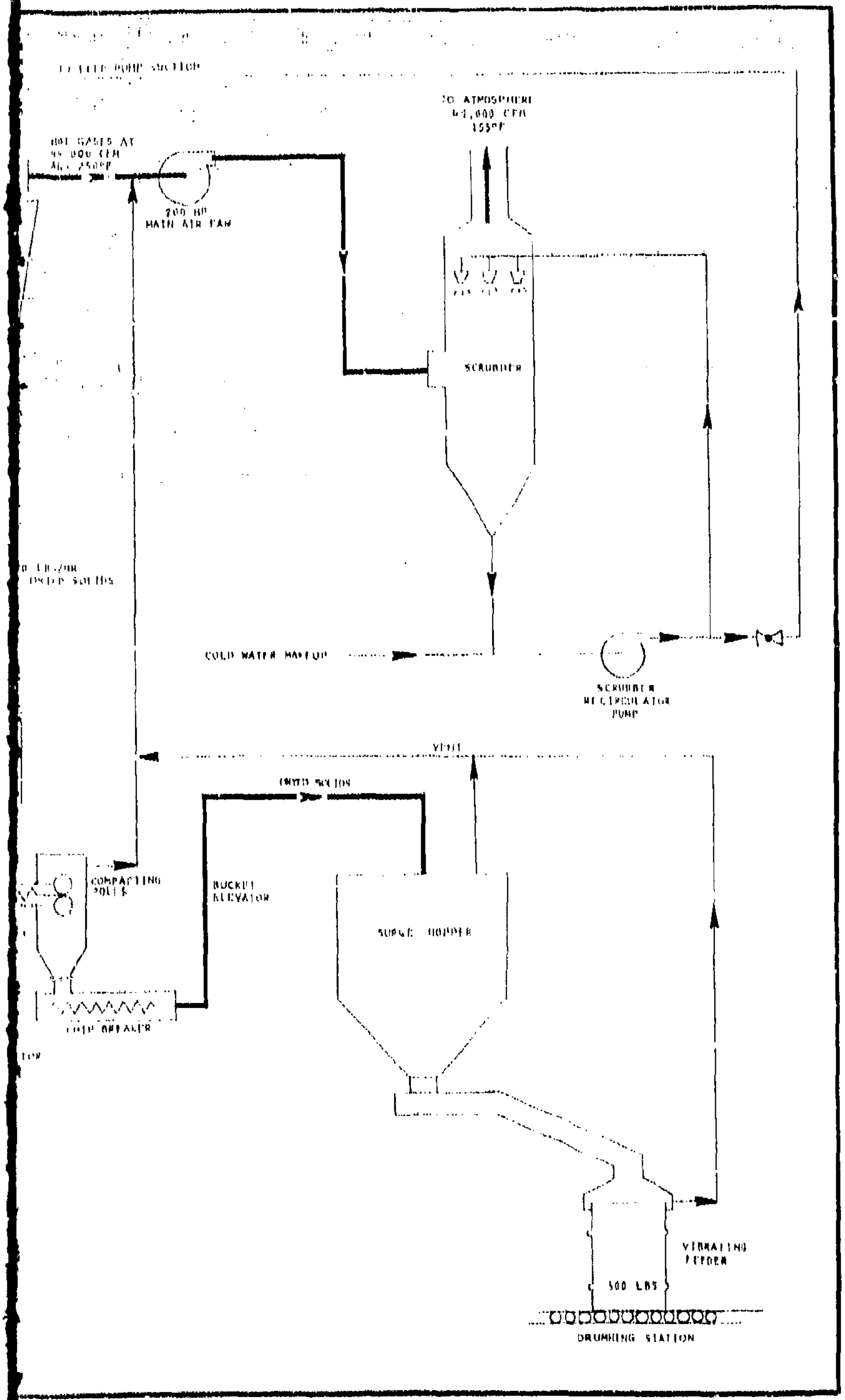


Figure 3-9: Salt Solution Storing and Drumming


TO FEED PUMP SUCTION
TO ATMOSPHERE
61,000 CFM
155°F
HOT GASES AT
95,000 CFM
AT 250°F
200 HP
MAIN AIR FAN
SCRUBBER
O LIQUOR
DRIED SOLIDS
COLD WATER MAKEUP
SCRUBBER
RECIRCULATOR
PUMP
VENT
DRIED SOLIDS
COMPACTING
ROLLS
BUCKET
ELEVATOR
SURGE HOPPER
LUMP BREAKER
TOR
VIBRATING
FEEDER
500 LBS
DRUMMING STATION

(1) Process Description.

(a) Figure 3-10 illustrates the M34 Cluster disposal process at RMA. Major process steps consisted of: removal of the M125 bomblets from the M34 cluster bomb casing, rendering the fuzes safe in the bomblets, draining the liquid GB agent from the bomblets, incinerating a M31 burster charge from the bomblets, thermally decontaminating the cluster casing and inert parts, thermally decontaminating the M125 bomblets, neutralizing the drained liquid GB agent, spray drying of the brine solution from the neutralization, and packing and storing of the dried salts. Controlled ventilation for the entire process and scrubbing of the exhaust were provided to prevent release of agent vapor. Scrubber brines were vaporized in a spray dryer and the salts removed. The water vapor was scrubbed to remove particles before release to the atmosphere.

(b) Punching and Weighing.

1 The M125 bomblets were removed from the M34 Cluster by a programmed manipulator, called a versatron. They were then placed in a staking machine to render the fuze safe. After the staking machine, the bomblets were transported on a punch and weigh conveyor to the punch station (Figure 3-11). The punch station used two hydraulic cylinders to operate punch heads. The punches were spaced so that they pierced both top and bottom of the bomblets and avoided the M31 burster charge located in the burster well at the center of the bomblet. After the punches were retracted, the bomblet remained in the punch station for several seconds until the GB drained from the lower hole into a drain line under the punch station. The punch station was provided with interlocks which prevented further bomb conveyance if the full punch and retract operation was not completed.

2 Bomblets then moved down the punch and weigh conveyor to the weigh station. This system was calibrated so that when an excessive amount of GB remained in the bomblet would stop the conveyor. If such a condition existed, the bomblet remained to allow for further drainage. The weighing operation was then repeated using manual controls

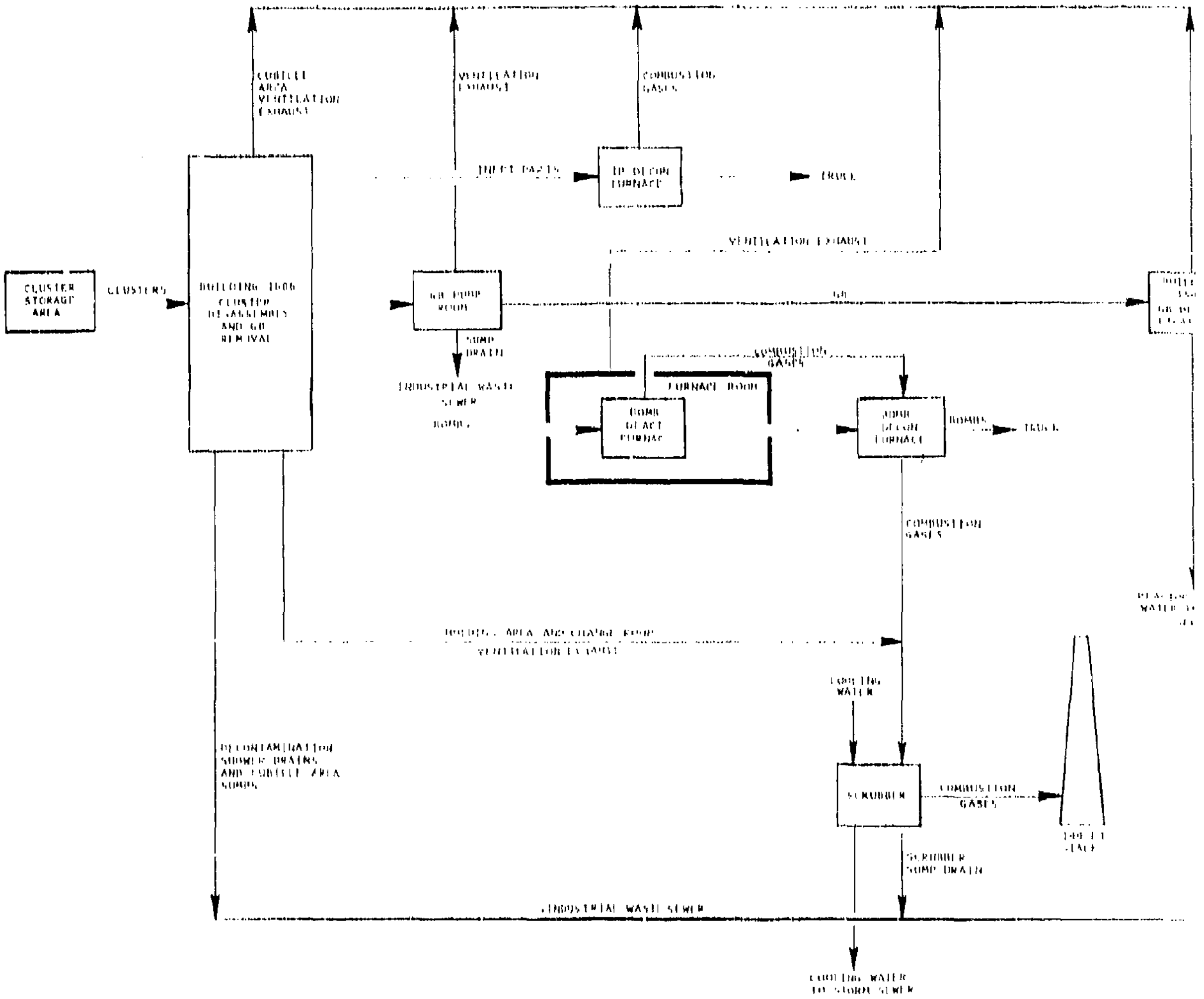
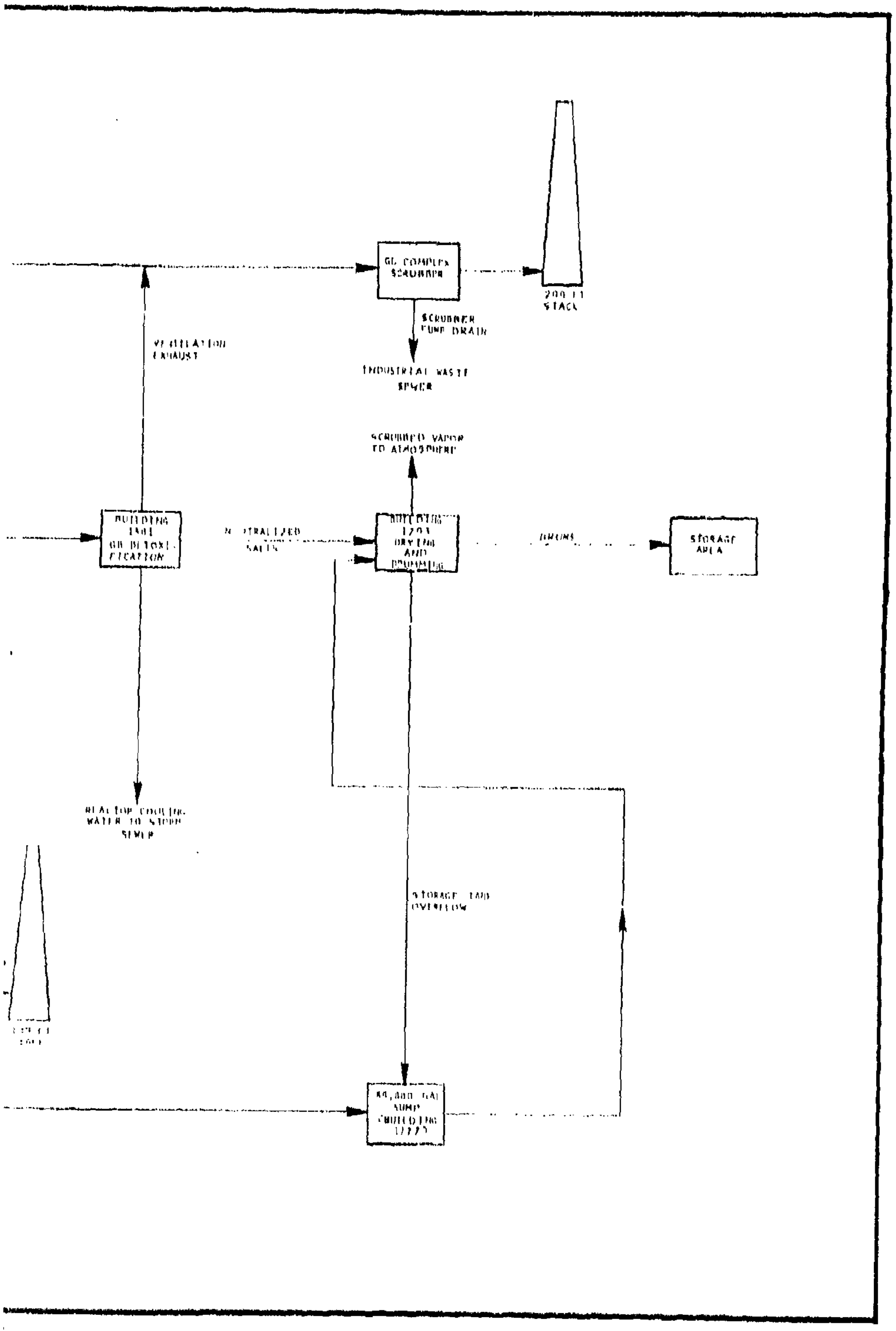


Figure 3-10: M34 Cluster Demilitarization Proces


GB COMPLEX SCRUBBER
200 FT STACK
SCRUBBER FUME DRAIN
VENTILATION EXHAUST
INDUSTRIAL WASTE SEWER
SCRUBBED VAPOR TO ATMOSPHERE
BUILDING 1501 GB DETOXIFICATION
NEUTRALIZED SALTS
BUILDING 1703 DRYING AND DRUMMING
DRUMS
STORAGE AREA
REACTOR COOLING WATER TO STORM SEWER
STORAGE TANK OVERFLOW
44,000 GAL SUMP (BUILDING 1722)

ou PP000333

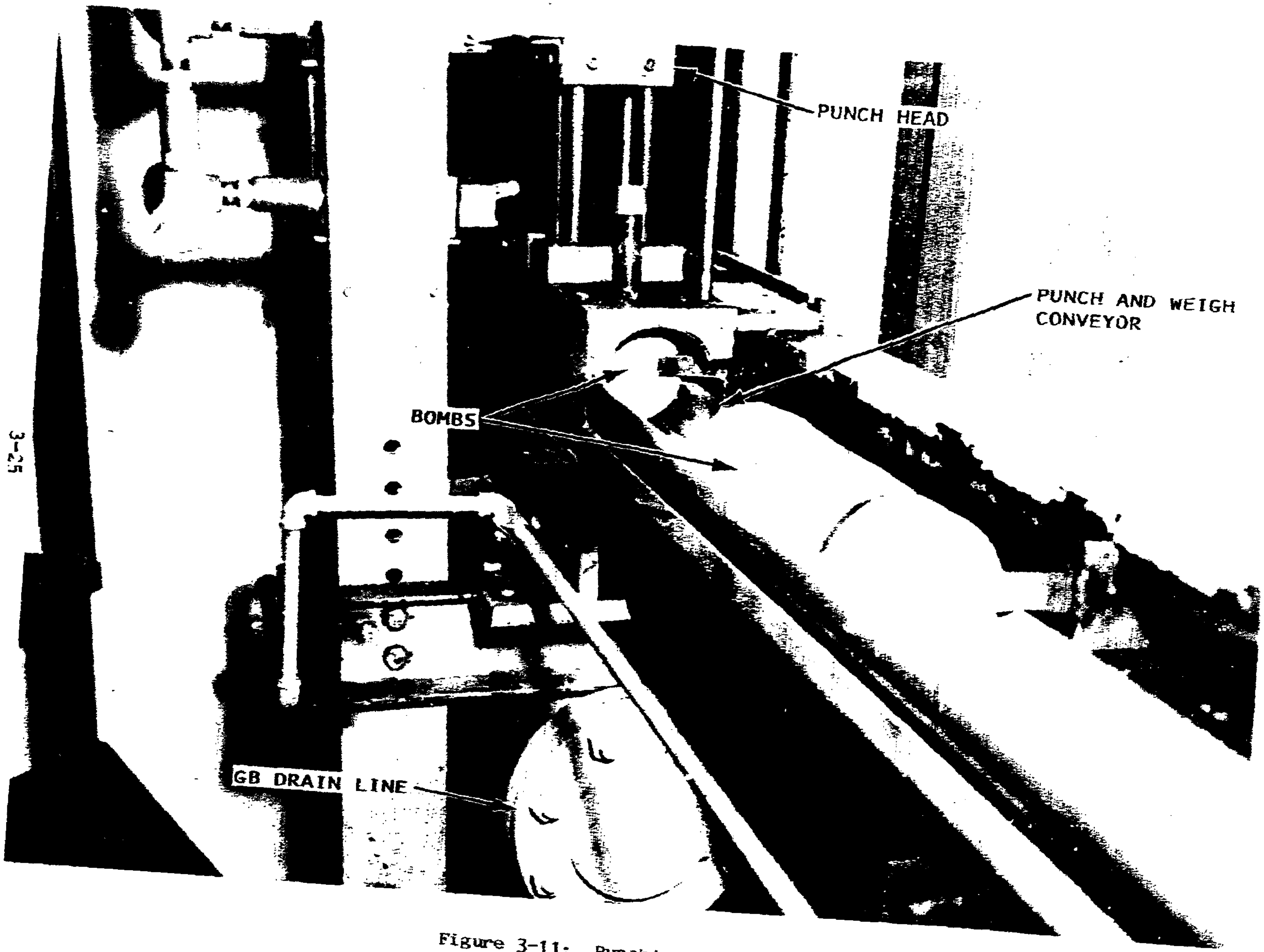


Figure 3-11: Punching and Weighing

which were on the control panel. The punch and weigh conveyor would not operate as long as the bomblet was overweight.

(c) <u>Caustic Dipping and Burster Shearing</u>. After the weigh station the bomblet was transported by conveyor to a dip tank containing a caustic solution where the bomblet was immersed to neutralize any residual GB. The bomblet was conveyed from the dip tank to the burster shear station where the burster of each bomblet was cut. The cut was made prior to feeding the bomblet to the Deactivation Furnace, so that the possibility of the burster exploding in the furnace was greatly reduced.

(d) <u>Deactivation Furnace</u>.

<u>1</u> Figure 3-12 depicts the Deactivation Furnace Room. The furnace was located in a blast-resistant concrete structure, designed to withstand the full blast effect of an unconfined M125 bomblet explosion located in the center of the room.

<u>2</u> The Deactivation Furnace consisted of a rotating retort built to withstand simultaneous detonation of seven bomblets. The drained bomblets were retained in the furnace retort for approximately 10 to 12 minutes to ensure the bursters ignited near the center of the retort and were completely burned. The retort had stationary enclosures at both ends; the feed end of the enclosure contained the metal feed chute and exhaust duct. The discharge end of the enclosure contained the burner assembly and the exit chute. After processing through the retort, the bomblet fell through the discharge chute onto the discharge conveyor which transferred the bomblet to the Decontamination Furnace. The furnace was gas fired and operated at a temperature of 1250°F. The flame propagation and air flow were opposite to the direction of the bomblet movement through the furnace system, so that the bomblets were conveyed into the higher temperature. Combustion gases exited from the feed end of the furnace, flowed into an expansion plenum through four blast-attenuator ducts, and into the feed end of the bomblet Decontamination Furnace. There, the combustion gases from both furnace systems mixed and flowed into the furnace scrubber system (see paragraph (h) below). The melted aluminum from the bomblet fuzes dropped through a separator at the discharge

Figure 3-12: Bomb Deactivation Furnace

end of the retort onto a recovery conveyor which deposited the lumps into containers.

(e) Decontamination Furnace and Inert Parts Furnace.

1 The bomblet Decontamination Furnace was an enclosed steel structure lined with refractory brick as shown in Figure 3-13. An endless woven steel conveyor belt transported the bomblets through the furnace. The furnace operated on natural gas and was thermostatically controlled to supply heat up to 1,500°F. The purpose of this furnace was to ensure complete destruction of any residual GB agent contamination. The residence time in the furnace was approximately 15 minutes. The combustion gases from the bomblet Decontamination Furnace flowed into the furnace scrubber system (see paragraph (h) below).

2 A second Decontamination Furnace (also called Inert Parts Furnace) which was identical in operation and construction to the bomblet Decontamination Furnace as described in the preceding subparagraph was used for inert parts, except the residence time was approximately 25 minutes. The combustion gases from the second furnace were then processed through the GB Complex Scrubber (see below) before release into the atmosphere.

(f) GB Complex Scrubber. The GB Complex Scrubber removed 135,000 cfm of air and gases from the cubicles in Building 1606, the Deactivation Furnace room (not the furnace gases), the GB pump room of Building 1606, combustion gases from the Inert Parts Furnace, and ventilating air from the equipment bays of Buildings 1501, 1506, and 1703. The scrubber system consisted of 5 underground chambers each containing a bank of 92 venturis (see Figure 3-14). Each venturi was preceeded by a high-velocity caustic spray nozzle. The gases were washed with caustic and then drawn through the venturis by the three 200 hp exhaust fans that discharged into a 200 foot stack. The ventilating gases from Building 1606, the Deactivation Furnace room, the GB pump rooms and the Inert Parts Furnace were drawn through a series arrangement of Chamber 1, 2, and 3 (three scrubbing operations) before discharge to the atmosphere. The ventilating air from Building 1501

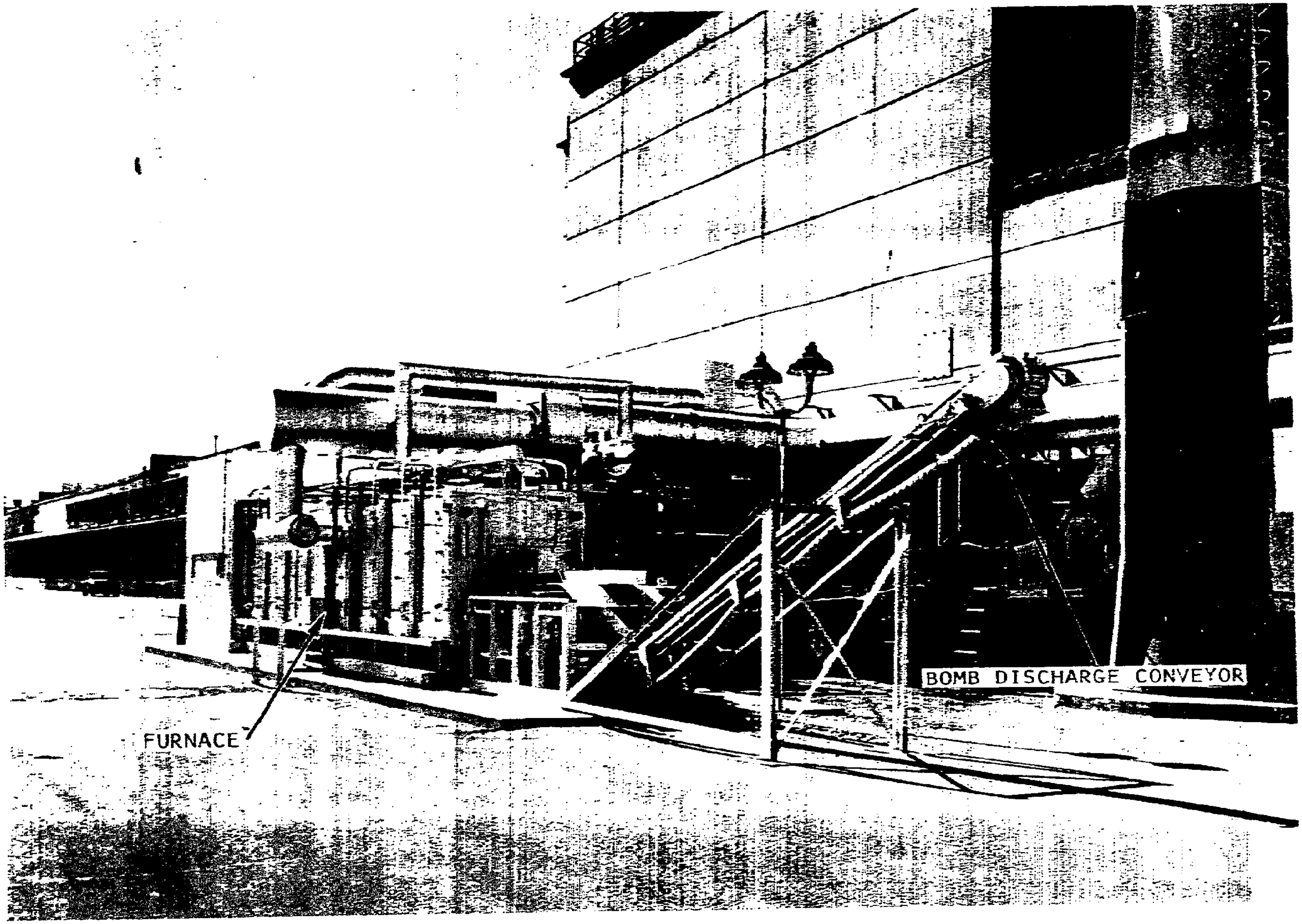


Figure 3-13: Decontamination Furnace

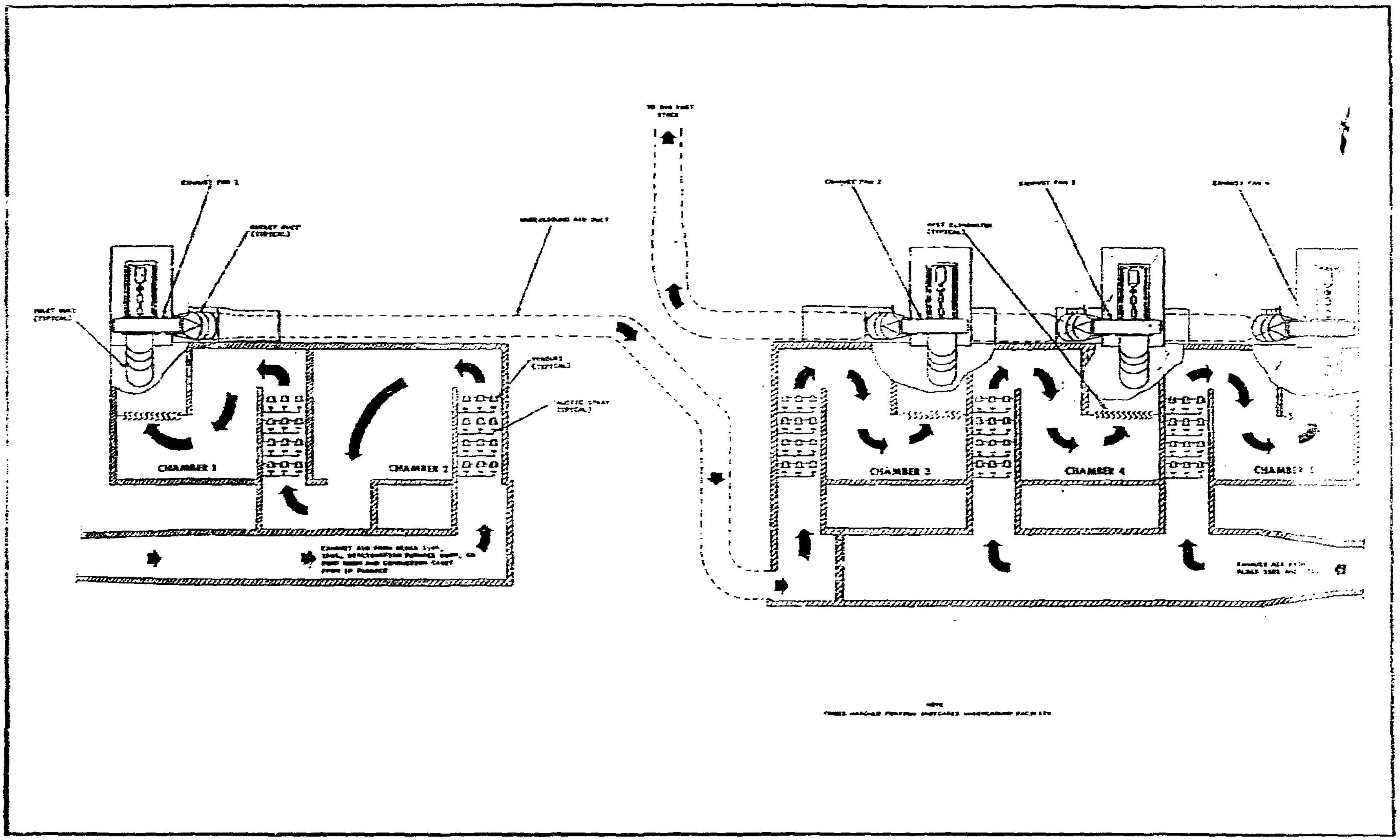


Figure 3-14: GB Complex Scrubber System

and 1703 were drawn through either Chamber 4 or 5 before discharge to the atmosphere.

(g) Ventilation Gases. Ventilation gases from Buildings 1506 and 1601A were passed through a new scrubbing tower located in Building 1602 as shown in Figure 3-15. The scrubber was a vertical column fabricated from 1/2 inch thick carbon steel plates and was packed with 1-1/2 inch diameter polypropylene pall rings. Caustic was sprayed over the packed bed, counter to the airflow. The air passed through a mist eliminator before being released to the atmosphere from the exhaust stack. This new scrubber provided additional capability to the existing GB Complex Scrubber used concurrently for the M34 disposal operations.

(h) Furnace Scrubber System. The combustion gases from both the Deactivation and Decontamination Furnaces were mixed and flowed into a furnace scrubber system as shown in Figure 3-16. In the scrubber system, the gases entered a quench chamber where they were cooled by caustic spray from a series of spray nozzles. The cooled gases were drawn through a venturi in the scrubber chamber where they were washed with high velocity caustic spray. The caustic was then removed from the gases by passing them through a demister and mist eliminator before releasing them to the atmosphere through an 100 foot stack.

b. Underground Tanks.(16)

(1) The procedures and equipment for neutralizing GB contained in the underground tanks was essentially unchanged from those utilized for disposal of GB from M34 Cluster Bombs. The GB was neutralized in Building 1501 using the procedures that were described for the M34 Cluster Bombs. The primary modification was the addition of a dual filter bank within Building 1501 to remove any solids in the GB being pumped from the underground tanks.

(2) The chemical agent GB in the M34 Cluster Bombs was stabilized with tributylamine (TBA). The TBA for the most part remained inert during the neutralization reaction. It was present with the GB neutralization reaction products in the salt dried from the brine with trace amounts of tributyl quaternary ammonium salts. TBA made up 3% of the salts with the

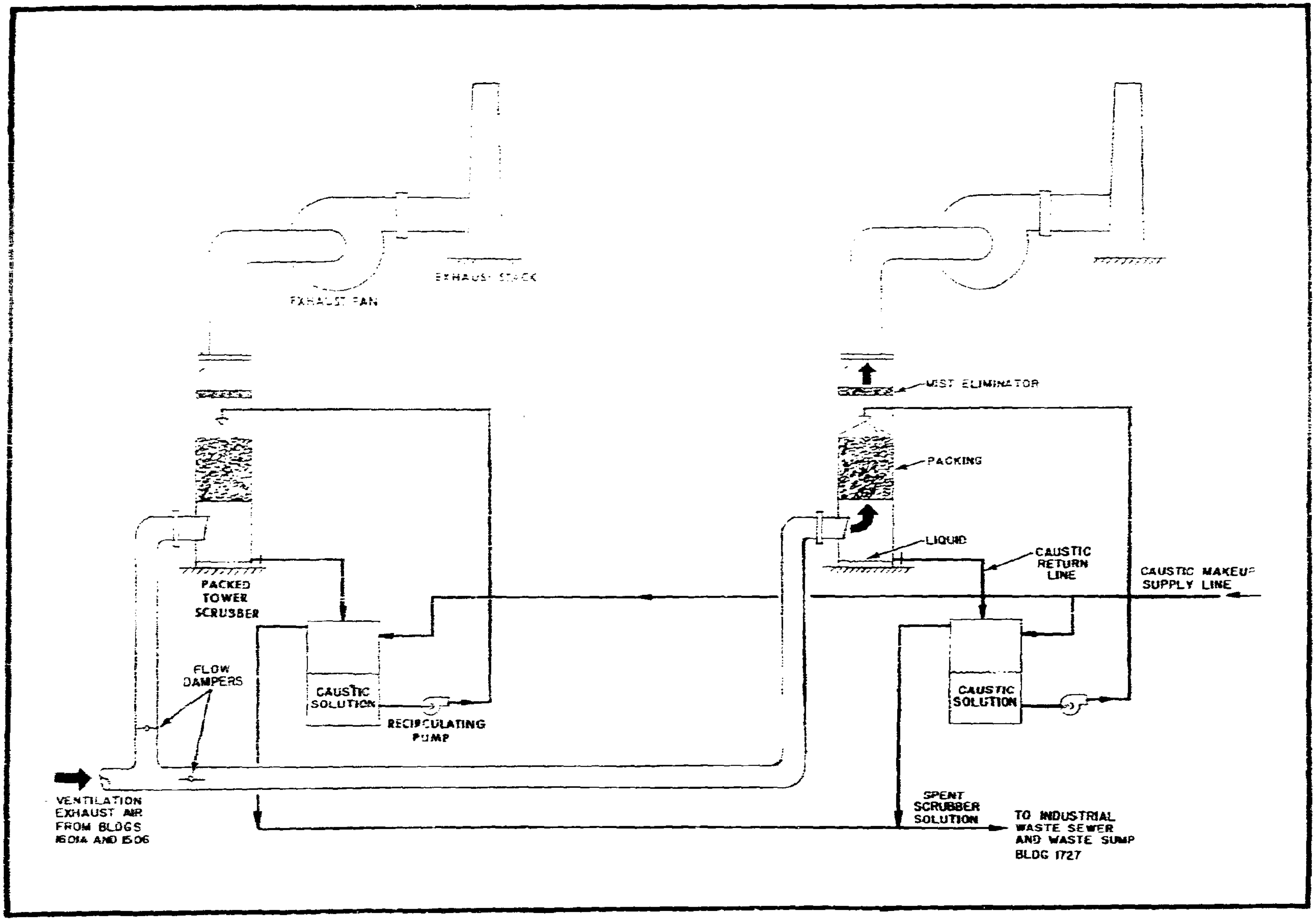


Figure 3-15: Packed Tower Scrubber

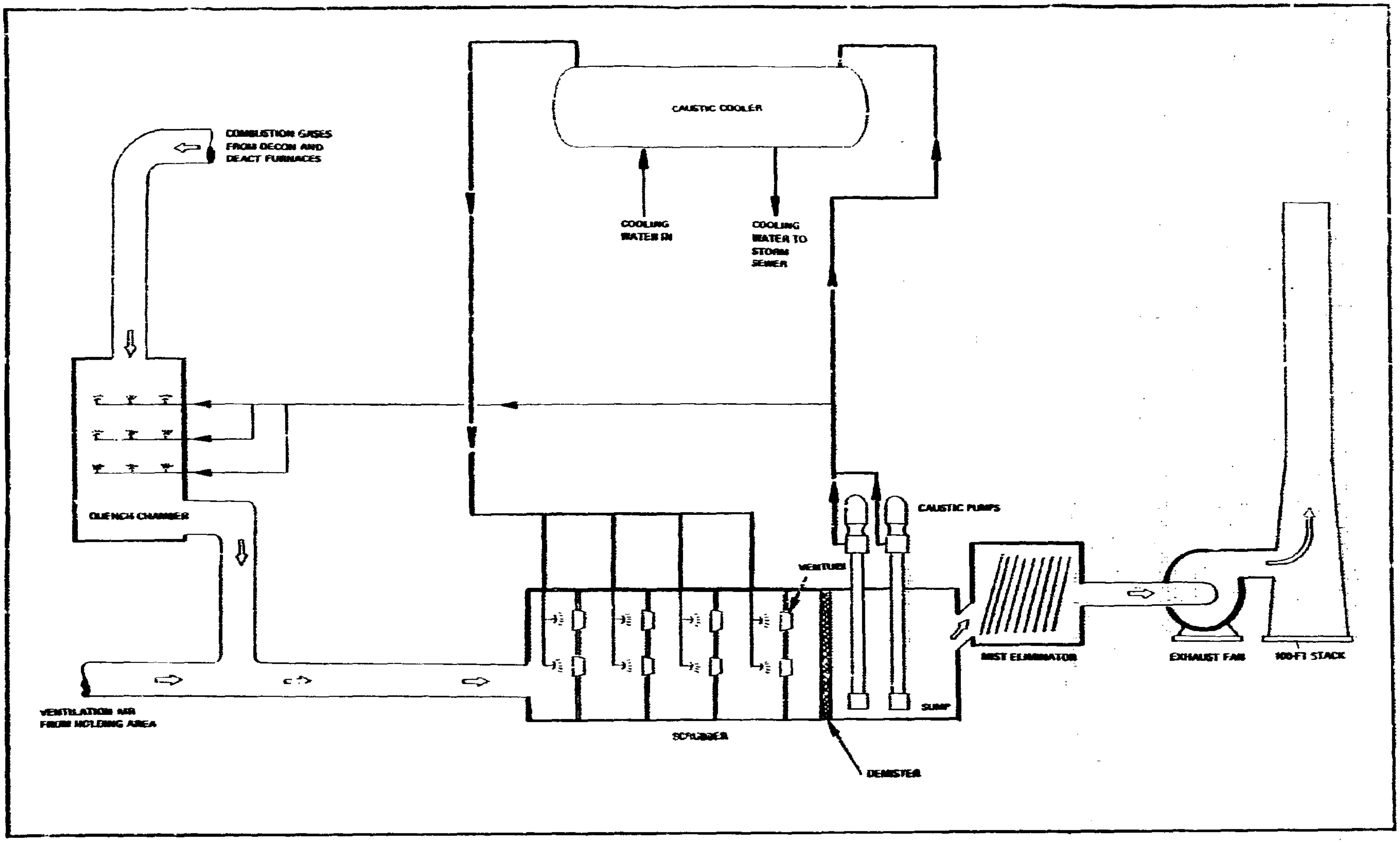


Figure 3-16: Furnace Scrubber System Flow Schematic

exact composition dependent upon the initial quantity added for stabilization. On the other hand, the GB in the underground tanks was stabilized with diisopropylcarbodiimide (DICDI). This resulted in some very minor differences in the reaction mix. The chemical reactions that DICDI undergoes when the agent is neutralized with caustic are shown below:

$$(CH_3)_2CHNCNCH(CH_3)_2 + H_2O \rightleftarrows (CH_3)_2CHNHCONHCH(CH_3)_2$$

Diisopropylcarbodiimide + water   diisopropylurea

$$(CH_3)_2CHNCNCH(CH_3)_2 + HF \rightleftarrows (CH_3)_2CHNHCFNCH(CH_3)_2$$

Diisopropylcarbodiimide + hydrogen fluoride   fluoro(isopropylamino) methylene-isopropylamine

$$(CH_3)_2CHNCNCH(CH_3)_2 + 2CH_3PO_3HC_3H_7 \rightleftarrows (CH_3)_2CHNHCONHCH(CH_3)_2 + C_8H_{20}P_2O_5$$

Diisopropylcarbodiimode + isopropylmethyl phosphonic acid   diisopropylurea + bis(isopropyl-methylphosphonic) anhydride

(3) Waste Treatment.

(a) The treatment of waste was basically the same as for the M34 Cluster Bomb.

(b) Brine Drying. The process was the same as was described for the M34 Cluster Bomb project. However, since the complete chemical characterization of spray-dried salts was necessary prior to their ultimate disposal, DICDI-stabilized GB was segregated from TBA-stabilized GB and processed independently. This was accomplished by filling the GB day tank with only one type of stabilized GB at any given time.

c. Ton Containers.(17,18)

(1) Overview.

(a) The disposal of bulk GB in ton containers (see Appendix C for description) constituted the third task under Project Eagle - Phase II (Expanded). The destruction of the 3,604,500 pounds of GB stored in 2,422 ton containers in the Toxic Yard at RMA was ordered in October 1973. The Final Environmental Impact Statement for the destruction of this material was approved in August 1974.

(b) Both TBA and DICDI were used as stabilizers with the GB in the ton containers.

(2) Process Description.

(a) The disposal of the ton containers consisted of the following steps as shown in Figure 3-17.

1 Transporting the ton containers from the Toxic Yard to the unloading facility in Building 1601A.

2 Draining the GB from the ton containers and transfer of the GB to temporary storage in the underground tanks in Building 1506.

3 Pumping the GB from the storage tanks to the neutralization facility in Building 1501.

4 Neutralizing the GB; spray-drying of the brines and storage of the dried salts in drums.

5 Chemically decontaminating the ton containers in Building 1601A.

6 Thermally decontaminating the ton containers.

(b) After arrival of the ton containers at Building 1601A, they were moved by a monorail to a holding area as shown in Figure 3-18. Upon demand, the containers were moved to an unload booth and transferred to a cart and driven into the booth. The GB was drained from the ton container to the

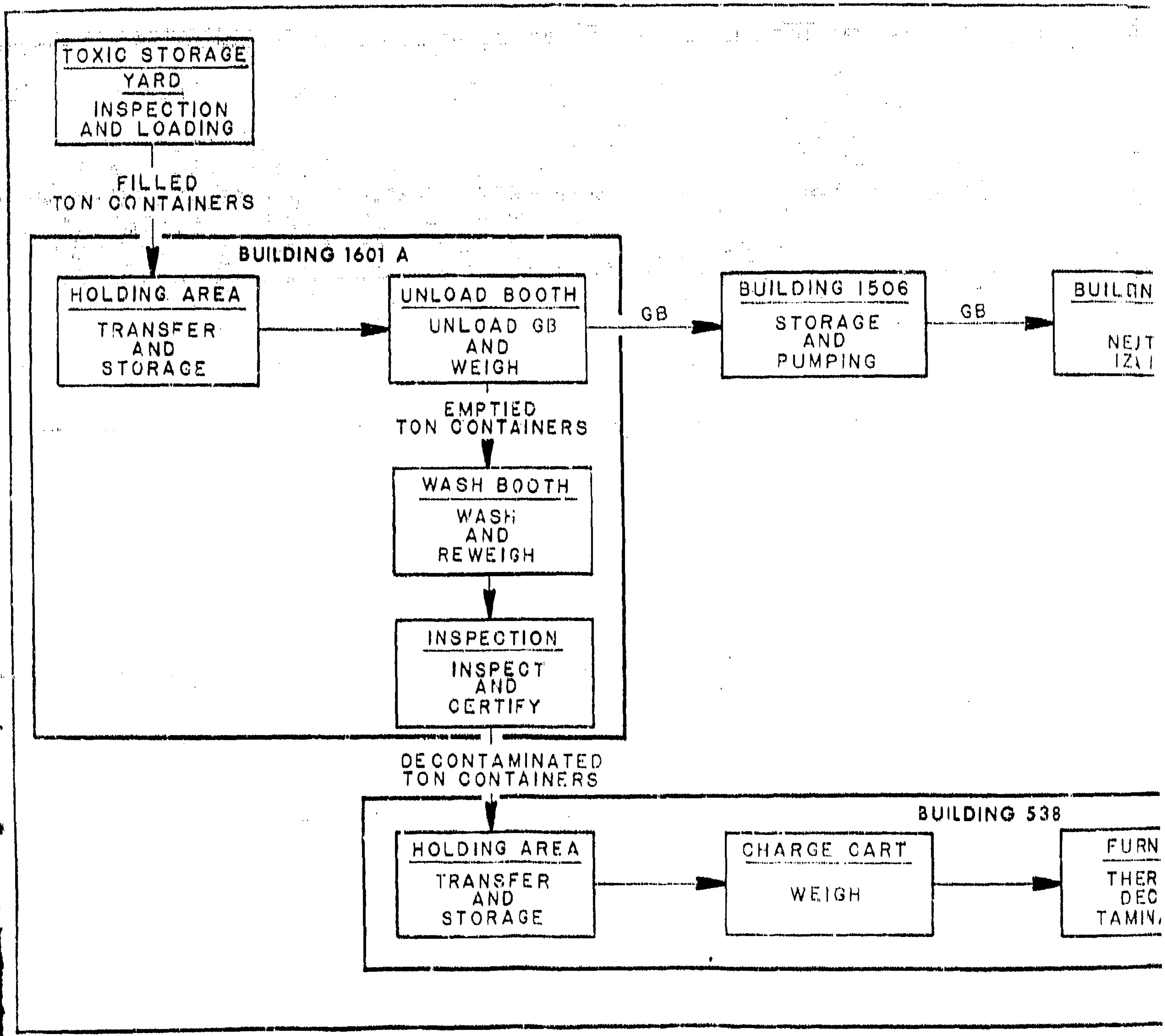
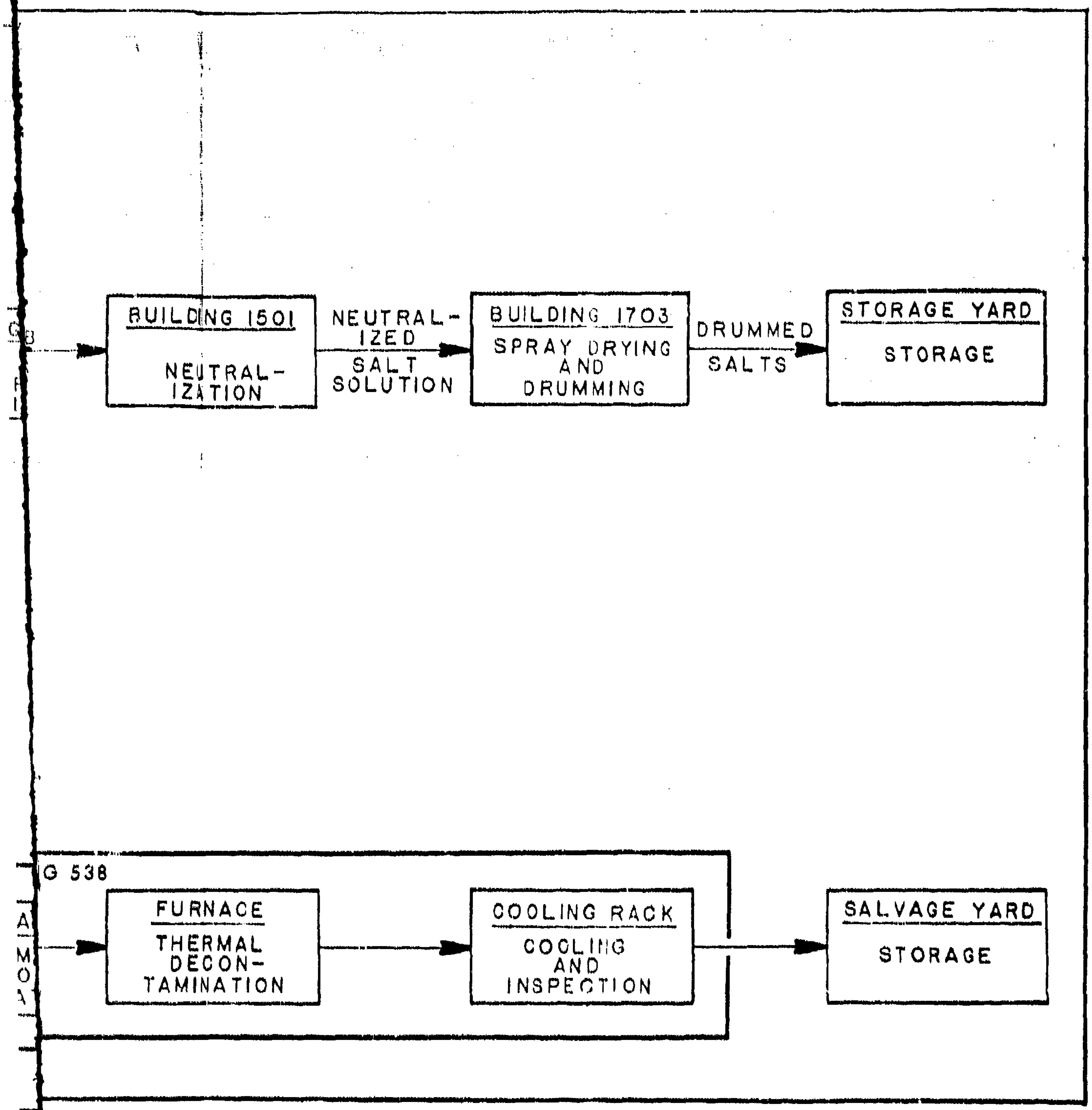


Figure 3-17: Ton Container Process Block Diagr



ean Block Diagram

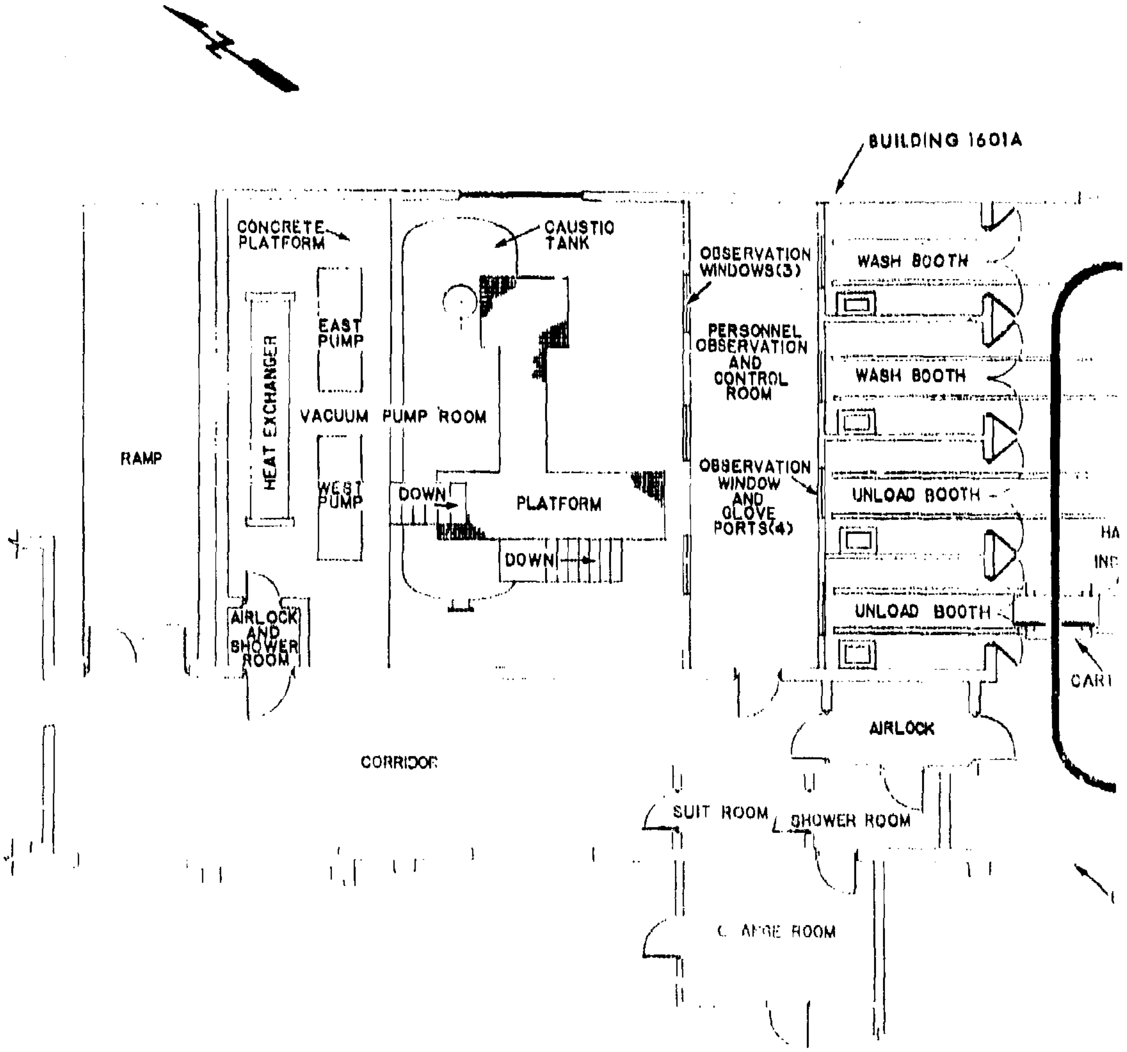
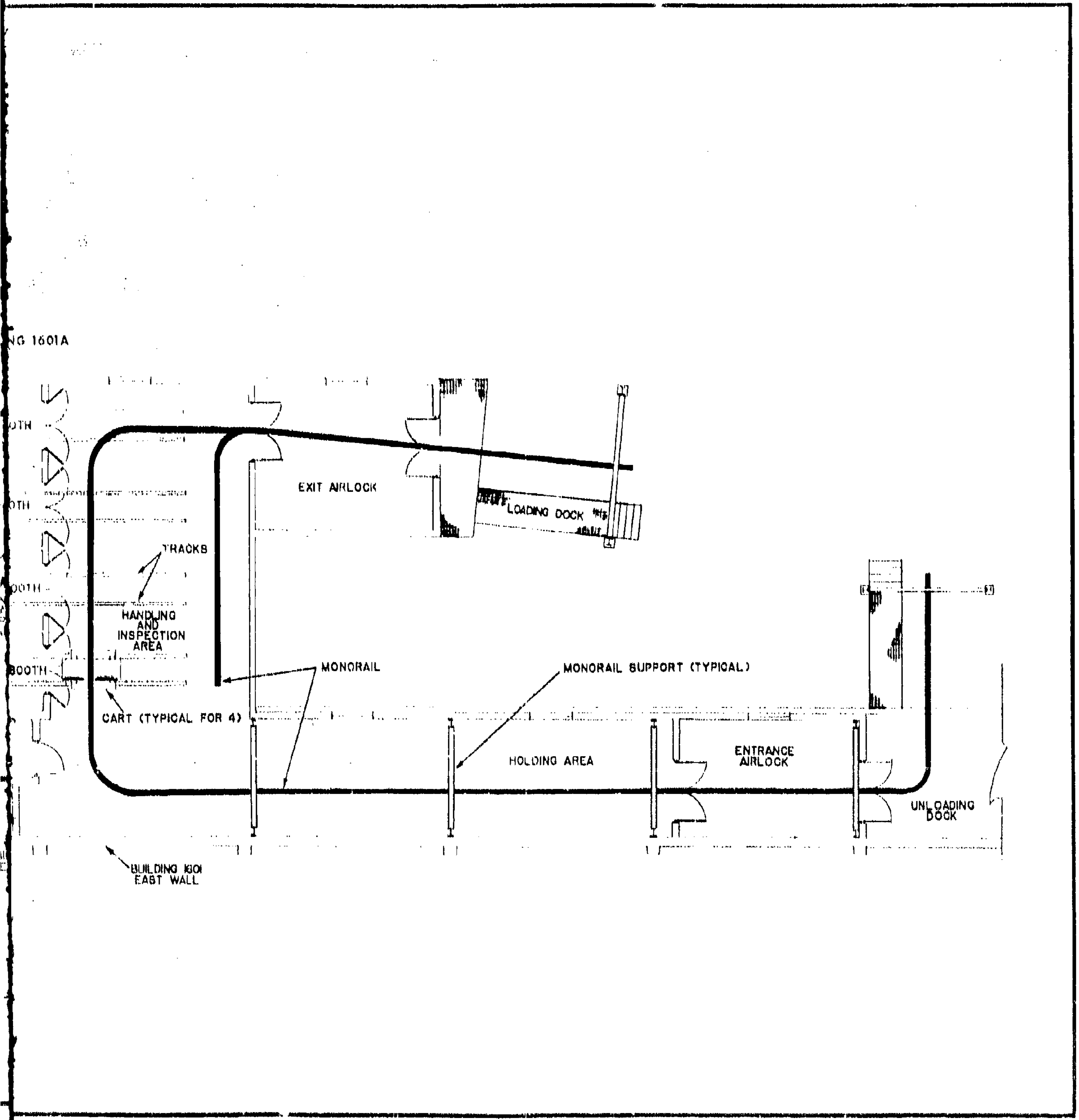


Figure 3-15. Building 16



Building 1601A Floor Plan

underground storage tank in Building 1506 under vacuum which eliminated the need for transferring under pressure. A tilting mechanism on the cart raised the ton container to maximize drainage. The GB was then handled in the manner described for the underground storage tanks.

(c) The emptied ton containers were then delivered to a wash booth. There the containers were evacuated and caustic drawn into then to neutralize any residual GB. Connections were again made through the glove port from the control room. After filling with caustic, the containers were rotated to ensure all inner surfaces were decontaminated. The containers were tilted and the caustic removed and returned by pressurization to the caustic recirculation system. The external surfaces were then treated with decontamination solution, the holes plugged and the containers certified by quality assurance personnel. At that point the containers were removed from the booth, lifted by the monorail and transported to the furnace in Building 538.

(d) Two ton container furnaces in Building 538 were used to incinerate the residue heel left in the ton containers after they had been drained. The furnaces had been constructed in 1944 to thermally decontaminate 55-gallon drums of mustard. After weighing, the ton containers were positioned under the punching station at the door of either furnace where two holes were punched into the ton container, one at each end. The ton container was then transferred to the south end of the furnace where an air sparge was inserted in each punch hole to facilitate residue burnout. Each furnace was normally maintained at 920°F and processed an average of seven ton containers per day.

(e) Ventilation gases were treated the same as in M34 Cluster Bomb disposal operation (see Section 3.2.2.a.(1)(g)).

d. Honest John (M190) Warhead/M139 Bomblets.(19,20,21)

(1) Overview.

(a) In October 1973, the Department of the Army ordered the disposal of 106 M190 Honest John Warheads (each containing 368 M139 Bomblets), 1,222 fused, agent-filled M139 Bomblets, and 39,532 unfused, agent filled M139 Bomblet halves stored in 30-gallon drums at RMA. Refer to Appendix C for detailed munitions description of the M190 and M139.

(b) The chemical agent GB present in the M139 Bomblets had been stabilized with DICDI. The reaction that DICDI undergoes when the agent is neutralized with caustic is identical to that given in Section 3.2.2.b.(2) for underground tanks.

(2) Process Description.

(a) The disposal of the Honest John Warheads and M139 Bomblets was accomplished in Building 1611 (see Figure 2-10) which was specifically designed for this particular task. All areas that involved explosively configured materials were designed to at least meet the safety margin for the maximum credible explosive accident of three simultaneous bomblet detonations. Air locks with monitoring and decontaminating equipment were provided for all building entry and exit. New ventilation and scrubbing systems were designed and built specifically for Building 1611. Microprocessor control was utilized wherever possible. The disposal process was carried out according to the following scheme, also shown in Figure 3-19:

1 Move the M190 Warhead/M139 bomblets from the storage area through the holding area into the munitions handling and disassembly area.

2 Remove the M139 Bomblets from the Warhead or the drums.

3 Place the bomblets on the punch and drain machine conveyor.

4 Punch the M139 bomblets and drain the GB via a double-walled pipe to the Building 1501 neutralization facility.

5 Burn the explosives assemblies in the Deactivation Furnace.

6 Decontaminate the inert parts in the Decontamination Furnace.

A	HOLDING AREA MONORAIL HOIST
B	FORK LIFT TRUCK
C	STRIPPING ROOM CONVEYOR
D	HINGED SECTION OF STRIPPING ROOM CONVEYOR
E	DOWNLOADING ROOM CONVEYOR
F	OVERHEAD BRIDGE CRANE
G	INERT PARTS DOWNLOADING ROOM CONVEYOR
H	PUNCH AND DRAIN MACHINE CONVEYORS (2)
J	INERT PARTS AIR LOCK NO. 3 CONVEYOR AND HINGED SECTION
K	INERT PARTS MONORAIL HOIST
L	DEACT FURNACE DISCHARGE CONVEYOR
M	DECON FURNACE FEED CONVEYOR

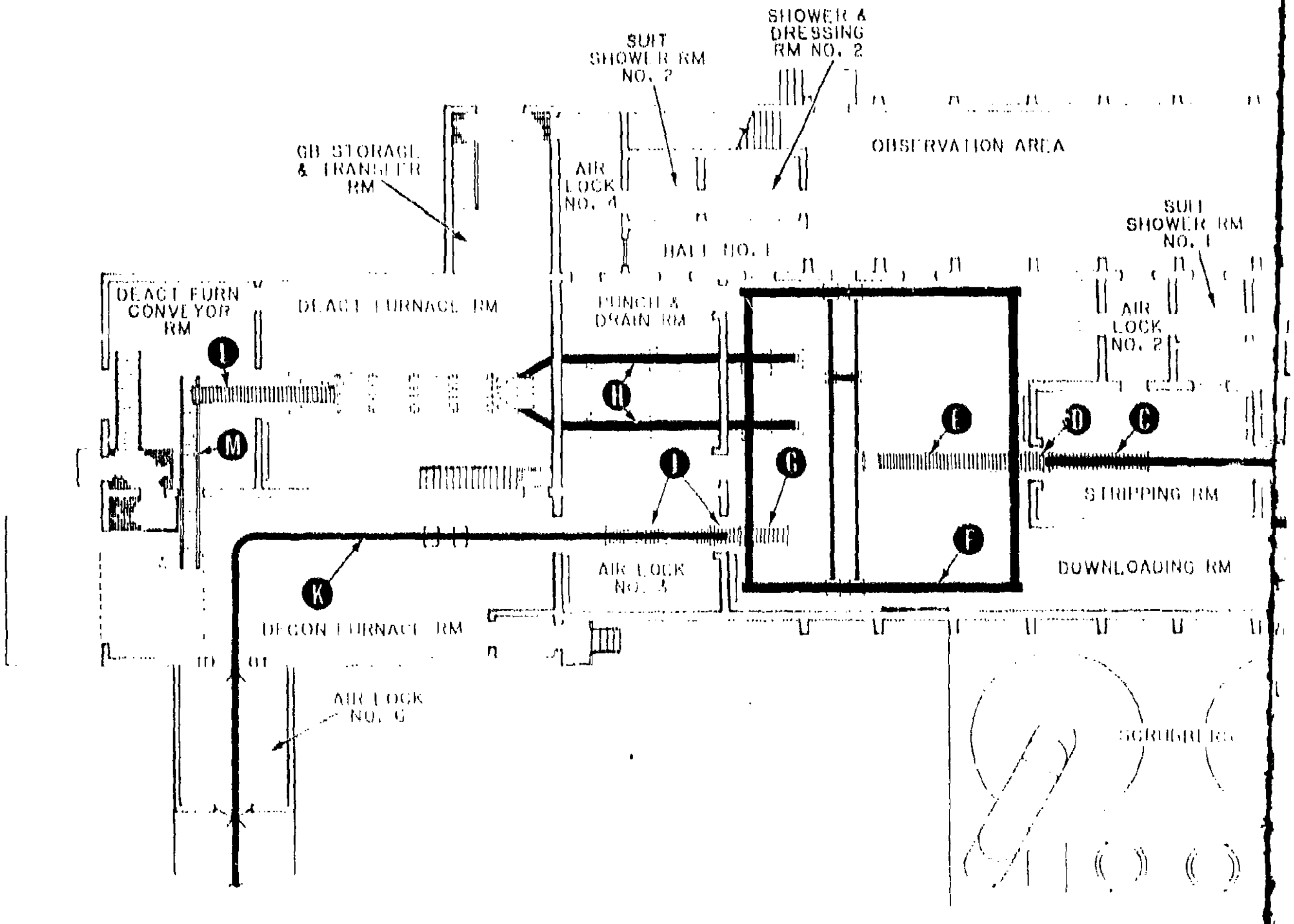
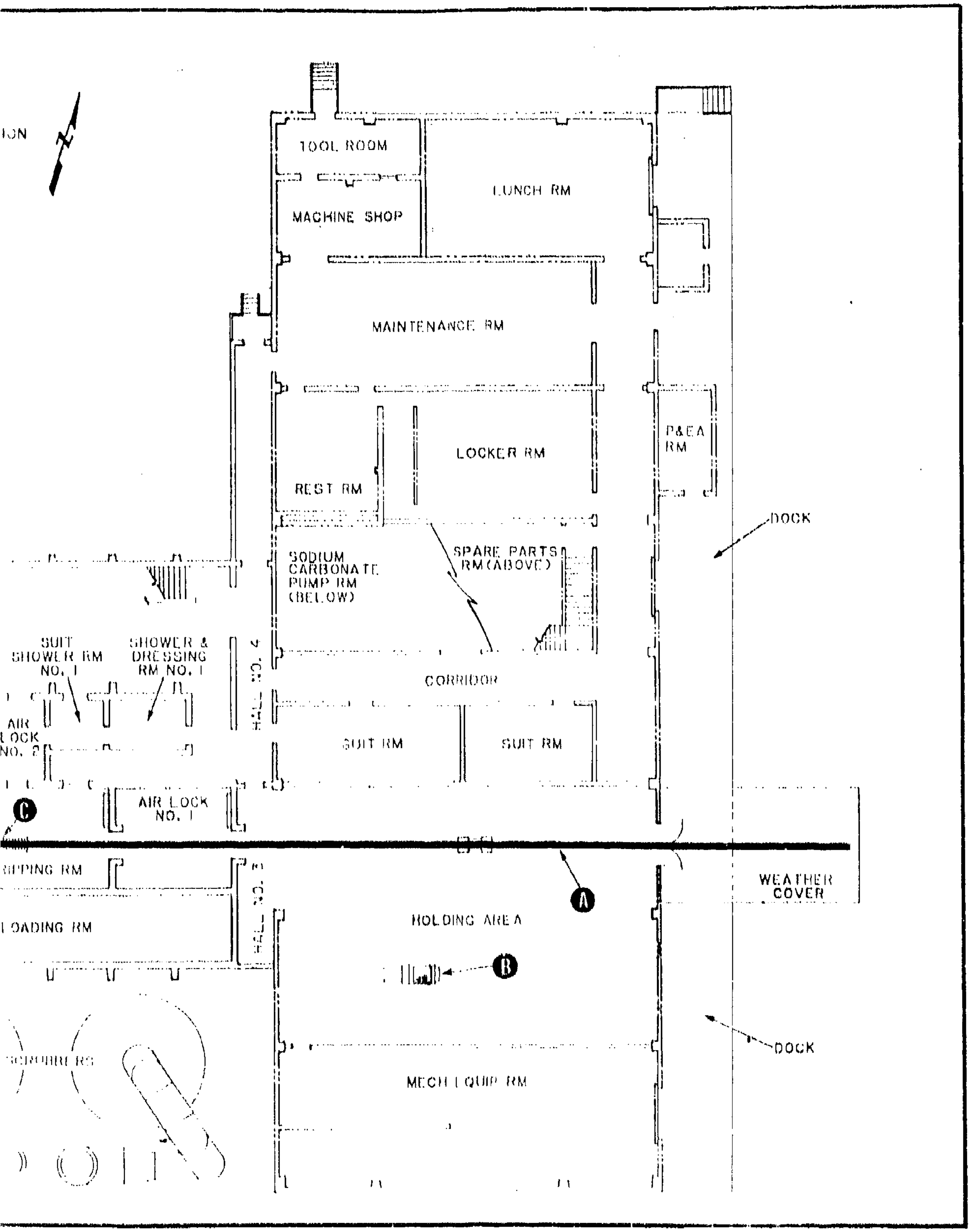


Figure 3-19: Scheme of Materials Handl



ials Handling in Building 1611

7 Neutralize the GB and spray-dry the resulting brine.

(b) Stripping and Downloading. The Warhead in its shipping package was first brought to the stripping room in Building 1611. Here, the vapor-proof bag covering the Warhead, the Warhead nose cone, the M31 burster charges, and the inert parts were removed. The stripped Warhead and removed parts were then sent to the download room where the bomblets were removed from the Warhead by hand and loaded onto the punch and drain machine conveyor. The inert parts were transferred to a conveyor to the Decontamination Furnace.

(c) Punch, Drain and Rinse. The bomblets were punched by one of two parallel punch and drain machines. The GB was drained into a 250 gallon holding tank in Building 1611. When the GB in this tank reached a preset level, it was transferred to one of the underground storage tanks in Building 1506 via a doubled-walled pipe. The GB was eventually pumped from storage to the neutralization facility in Building 1501. The bomblets were rinsed with water to remove any residual agent and sent to the Deactivation Furnace for disposal of the explosives. The deactivated parts were then sent to the Decontamination Furnace.

(d) Deactivation Furnace. This furnace was similar in design to that used for the M34 Cluster Bomb disposal (refer to Section 3.2.2.a.(1)(d)). The Deactivation Furnace was a U.S. Army APE Model 1236 modified for the Honest John Demilitarization.

1 Drained bomblets and explosive components (Composition "B" burster charges) from the Warheads were processed through the Deactivation Furnace.

2 The Deactivation Furnace was a roller-mounted, electric motor driven, rotary kin type unit with internal spiral flights that subjected the drained bomblets and explosive components to a temperature of 500° to 600°F for a period of time (about 30 minutes), sufficient to decompose the explosives and initially decontaminate the bomblet shells.

3 The only material fed to the furnace was at the flue gas discharge and through two blast attenuating pipe chutes which were fed by the

punch and drain machines. The feed chutes also supplied secondary air to the furnace which kept the feed chute system at a positive air pressure relative to the punch and drain area. The positive pressure prevented heat and products of combustion from backfiring onto the punch and drain system. The flue gases were drawn through quench chambers into the furnace scrubber system before discharge through the stacks to the atmosphere.

(e) Decontamination Furnace. All Warhead parts were eventually transferred to a Decontamination Furnace for thermal decontamination. The warhead parts consisted of plastic, aluminum and ferrous alloys, and the drained bomblets from the Deactivation Furnace operations.

1 The Decontamination Furnace was a two-compartment oil-fired forced-draft unit. Normal operating temperature of the melting compartment was 1400° to 1500°F and of the holding compartment was in excess of 1200°F. The melting point of aluminum is 1080° to 1200°F. The plastic and silicone sealant compounds were pyrolyzed and the aluminum parts were melted and recast into ingots.

2 Material from the Deactivation Furnace was delivered via conveyors. Primary combustion air was supplied through separate openings above the burners. The temperature was automatically controlled to a manually preset control point. Exhaust gases were removed by a collector box and stack arrangement from the holding compartment of the furnace through the quench chamber to the furnace scrubber system before discharge to the atmosphere.

3 The holding compartment of the Decontamination Furnace was equipped with a pouring spout. Periodically the spout was opened and the molten aluminum was collected in molds. After cooling, the full molds were replaced by empty molds in preparation for the next pour. When cooling was complete, the ingots were removed and transferred to a salvage yard. Also periodically the pneumatic door on the discharge end of the furnace was opened and the decontaminated ferrous parts were withdrawn. After cooling the ferrous parts were transferred to a salvage yard.

(f) Scrubber System. Two new packed tower scrubbers were installed adjacent to Building 1611 to process the ventilation and exhausts from the Honest John Warhead disposal.

3.2.3 Environmental Concerns.

a. Air Emissions/Standards.

(1) General Standards. During the planning phase of Project Eagle - Phase II (Expanded), GB exposure limits for workers and the general population were established by the U.S. Department of Health and Human Services. These values were as shown in Table 3-4 along with restrictions on industrial pollutant standards that were imposed by the State of Colorado.

(2) Monitoring. Three types of monitoring were conducted to ensure compliance with the above standards: in-plant, stack, and perimeter.

(a) The in-plant monitoring consisted of alarms and bubblers. The M5, E59, and Demilitarization Chemical Agent Concentrator (DCAC) alarms were used as real-time (response time is within a minute) monitors where GB concentrations greater than 0.2 mg/m^3 might occur. (DCAC's lower limit of detection was 0.0001 mg/m^3). Bubblers were used for work areas where long-term, low-level concentrations of GB might occur. Bubblers constitute collection systems that draw air through a sulfuric acid solution (pH 4.5); bubbler samples taken in durations between 30 minutes to 8 hours, had to be taken to a laboratory to be quantitatively analyzed for GB with an colorimetric enzymatic detection method. If significant interferences were observed with the enzymatic method, gas chromatographic analysis was used as an alternative. Personnel were required to mask when an alarm was sounded or a bubbler sample exhibited greater than 0.001 mg/m^3 for one hour or longer. The alarms and bubblers were challenged on a regular schedule to assure proper functioning. The response time for bubblers ranges from 2 hrs. at a lower limit of detection of 0.0001 mg/m^3 to 13 hrs. at that of 0.0000003 mg/m^3.

(b) The furnace exhaust stacks and effluent from the GB Complex Scrubber and spray dryers were monitored with M5 alarms and bubblers as described above. The Army imposed an action limit of 0.0003 mg/m^3. When the action limit was attained, the shift engineer was notified. When the shutdown limit (0.000 mg/m^3) was attained, shutdown was activated.

TABLE 3-4. Process Emission Standards

Substance	Concentration	Duration
GB (unmasked workers)*	0.0001 mg/m^3	8 hr/day
GB (general population)*	0.0001 mg/m^3 0.000003 mg/m^3	1 hour avg. 72 hour avg.
GB**	0.003 mg/m^3	maximum
Suspended particulate matter**	180 ug/m^3 55 ug/m^3	24 hr annual arithmetic mean
NO_2**	100 ug/m^3	annual arithmetic mean
Fluorides**	0.005 ppm	
Opacity**	20%	

*DHHS requirement
**Colorado State requirement

(c) Nine fixed site-sampling stations were established at approximately 40 degree intervals around the RMA perimeter (see Figure 4-21) at the same sites as for Project Eagle - Phase I. Each site-sampling perimeter station was a trailer containing: (1) a Technicon Air Monitor IIA for continuous colorimetric analysis of nitrogen dioxide, (2) a high volume sampler for suspended particulate (greater than 0.3 micrometers), (3) mast ozone meters for measuring total oxidants, (4) anemometer and wind direction transponder/recorder, and (5) GB bubblers. The bubblers were scheduled to take two 12-hour samples every 24-hour period and were analyzed with the detection methods described above.

b. Scrubber and Stack Emissions.

(1) During the preoperational testing in November and December 1972, it was discovered that the GB Complex Scrubber (see Section 3.2.2.a.(1)(f) and Figure 3-14) was not functioning as expected. Examination of the scrubber showed excessive nozzle blockages by solids. The scrubber was modified to eliminate this problem and retested in April 1973. The scrubber was challenged with GB concentrations ranging from 4.83 g/min (normal operational conditions) to 40.20 g/min (maximum amount expected to be released during a major accident). The results of these tests (see Table 3-5) indicated an overall scrubbing efficiency of >99.998%(22). The Army Environmental Hygiene Agency (AEHA) stated in its final report (23) on the impact of the GB neutralization operation on ambient air quality that the scrubbers were effective in preventing GB release to the atmosphere and significantly reducing GB release during upset conditions. At no point in time was there documentation by the perimeter monitors of GB emissions above the general population limit at the ground level.

(2) The exhaust gases from the M34 disposal operation Decontamination and Deactivation Furnaces stack were analyzed for particulate emissions and opacity between 31 August and 22 November 1972. The Colorado emissions standards were met.

(3) In its final report (23), AEHA concluded that the GB neutralization operation that took place over three years at RMA had no

overall detrimental impact on ambient air quality. The AEHA finding on GB emissions has already been discussed above. With respect to suspended particulate matter, AEHA found that there was a decrease in concentration during the period of operation. On the other hand, AEHA determined that there was an increase in ozone concentration but that this increase could not be attributable to the GB neutralization operation. With respect to nitrogen oxides emissions, AEHA found no change in the ambient level over the period of operation.

c. Air Emissions From Spray Dryer.

(1) Initial testing of the spray dryer 6-10 June 1973 indicated that the spray dryer did not meet the Colorado opacity limit of 20%.(24) An intensive effort was undertaken by the manufacturer to fix the problem. The dryer was retrofitted with a venturi scrubber to remove particulate matter from the dryer exhaust. After this retrofit, the system was retested. While operating on natural gas, the spray dryer did meet the opacity requirement. However, the opacity requirement was exceeded(25) when the dryer operated on fuel oil and the brine feed rate exceeded 27 gpm at 17% solids (see Table 3-4). Natural gas burns more cleanly than fuel oil; the latter fuel contains sulfur and sooty burning aromatic hydrocarbons. Since no other fix was possible within budget and time constraints, the Army decided to accept the dryer and operate it on natural gas or at the reduced brine feed rate while on operating fuel oil.

(2) Between 24 January and 7 March 1974, AEHA tested the M34 spray dryer to determine particulate, fluoride, phosphorus and GB emissions. AEHA test data(26) showed relatively high GB emissions (above the 0.0003 mg/m^3 action limit and at times above the 0.003 mg/m^3 shutdown limit). The GB analyses were performed via the enzymatic detection method. Upon initial evaluation of the data, it was not certain if the problem was purely analytical in nature (i.e., interferences from reversible or other irreversible cholinesterase inhibitors) or if GB was actually being emitted from the spray dryer.

TABLE 3-5. Scrubbing Efficiency of GB Complex Scrubber(22)

Test No.	1	2	3	4	5
GB Input					
Rate (g/min)	4.83	5.65	5.33	18.85	40.20
Time (min)	120	120	120	60	60
Efficiency %	99.9975	99.9989	99.9979	99.9988	99.9987
Stack Emissions (mg/m^3)	0.00009	0.00007	0.00010	0.00024	0.00057

TABLE 3-6. Dryer Acceptance Tests(25)

	Gas 25-26 Jan 74	Fuel Oil 26-28 Mar 74
Brine Feed Rate, gpm	30.2 - 30.3	27.6 - 31.1
Scrubber Recycle Rate, gpm	3.0	3.0
Brine spec. gravity	1.10 - 1.13	1.11 - 1.16
Scrubber sp. gravity	1.05 - 1.06	1.04 - 1.05
Brine, % Solids	25.4 - 28.5	17.0 - 27.3
Stack Emissions, lb/hr	6.06 - 9.35	4.53 - 10.8
Stack Opacity	Acceptable	*

*Stack opacity acceptable only when dryer feed rate was reduced to 27 gpm and brine was diluted with water to 17% solids.

(3) During 1974 and 1975, an intensive effort was undertaken to determine the cause of the GB in the spray dryer gas stream. This effort included further investigation into the GB analytical methodology for the bubbler solution, brine and salts; spiking experiments to try to form GB; and distillation experiments to determine if GB was formed during the drying process. The consensus of this work was the following(27,28),

(a) There was no GB in the brine.

(b) GB could be reformed in minisoule quantities when the brine was extracted for analysis under the acidic conditions (pH 4.5) used in the analytical procedures.

(c) GB could be reformed in minute amounts from the brine when the proper pH (less than 6.5) and heat conditions were present.

(d) No GB was formed from the salts when extracted at a pH of 12-13.

(e) Minute amounts of GB were formed from the salts under acidic conditions (pH less than 6.5).

(f) No GB was formed in the bubblers.

Although the above theories about the conditions in the spray dryer under which GB could reform were never positively confirmed, they became the bases from which to undertake equipment modifications to avoid future GB emissions. It should be noted that these conditions are relatively restrictive and the amounts of GB reformed under such conditions are relatively minute.

(5) Spray dryer GB emissions data(29) in the RMA files showed only lists of emission levels. Hence, it is not possible to correlate effects of brine feed rates, temperatures, and scrubber specific gravity although it is known that GB emissions is a complex function of these parameters. Inferences between GB emissions and temperature and brine feed rates can be drawn (see Figure 3-20). Each data point in Figure 3-20 is an average of ten or more analyses. It can be seen that GB emissions increase with temperature

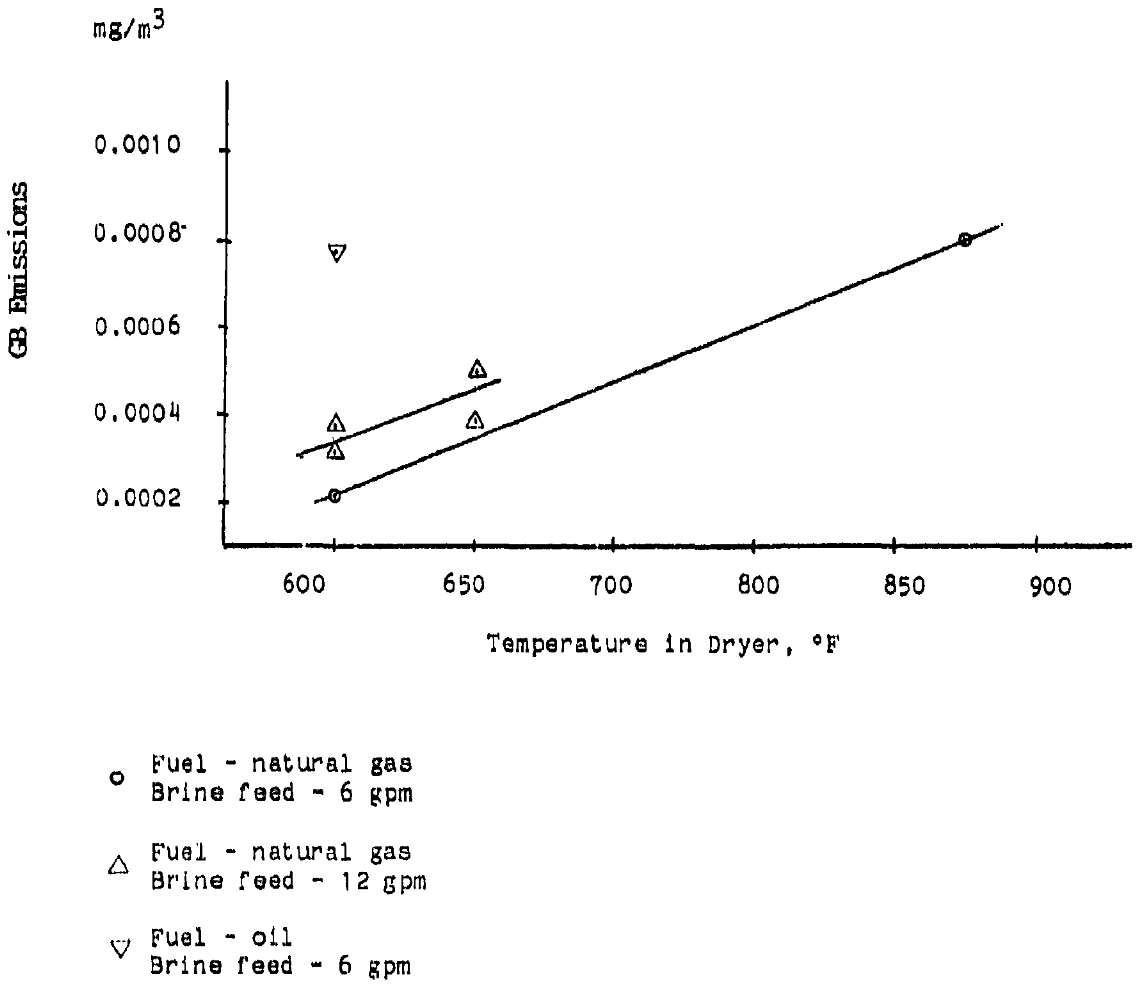


Figure 3-20 GB Emissions From Spray Dryer

(at a constant brine flow rate and for a particular fuel) at a rate of 2.2 $\times 10^{-6}$ mg/m^3/°F. GB emissions also increase with brine feed rate when the temperature is constant and for a particular fuel. When the dryer was operated on fuel oil, GB emissions tripled that of natural gas under the same conditions. This tripling was due to the relatively large quantities of acidic gases formed from fuel combustion due to the presence of sulfur in fuel oil.

(7) Because of possible reformation of GB in the spray dryer (reversal of hydrolysis, see first equation given in Figure 3-20) the action level of 0.0003 mg/m^3 was often exceeded and the shutdown level of 0.003 mg/m^3 was occasionally exceeded. An air sampling study(30) conducted between 20 January and 7 March 1975 showed the limit for general population of 3 $\times 10^{-6}$ mg/m^3 was exceeded in 3 of 30 test samples. In fact, the GB emissions in these three samples exceeded the action limit of 0.0003 mg/m^3. However, the perimeter monitors showed that the emission standard for the general population was not exceeded and thus, there was no threat to the public at large. RMA was able to operate the spray dryer at a brine flow rate of 12 gpm(31) at a temperature of 700°F without GB emissions exceeding the action limit during most of the neutralization.

d. Water Effluents.

(1) The estimate water usage/disposal for the Project Eagle - Phase II disposal as given in the Environmental Impact Statement(19) is shown in Table 3-7.

(2) This water was to be released to the atmosphere through the spray dryer or scrubber exhaust. With changes in process parameters (e.g., the increase in the caustic concentration, disposal of washdown water in Basin F, etc.), these water usage/discharge numbers changed dramatically during operations. The only available data for actual water usage was from the disposal of the Honest John Warhead/M139 Bomblets. This water usage was as follows(21):

TABLE 3-7. Total Waste Stream Flows(19)

Stream Description	Total Flow lb.	Percent of Salt	Total Salt lb.
Miscellaneous Streams	14,933,000	4	597,320
Building 1501 Reactor Discharge:			
M34	18,491,100	34	6,278,880
Underground Tanks	1,617,966	34	549,402
Ton Containers	15,743,000	34	5,345,700
Honest John/M139	337,950	34	114,903
10% Contingency*	5,112,302		
TOTALS	56,235,318		12,886,205

*Applies only to liquid flow.

Process Water	
Scrubber Operations	820,000 gal
Plants Area	180,000 gal
TOTAL	1,000,000 gal

(This water was discharged to Building 1727's sump and eventually to Basin F).

Water Vapor	
Scrubber Exhaust	1,000,000 gal
Spray Dryer	25,000 gal
	1,025,000 gal

(This water was discharged to the atmosphere).

(3) These data differ significantly from the original estimates, i.e., the reactor discharge was only 10% of that predicted while the miscellaneous waste streams were larger than predicted.

e. Solid Wastes.

(1) The solid wastes from the Project Eagle - Phase II disposal process include furnace ash, decontaminated metal parts and the spray dried salts. Furnace ash was drummed and stored until 1986 when it was sent to a hazardous waste landfill for final disposal. This was principally due to the content of heavy metals (cadmium, lead, etc.) in the furnace ash The decontaminated metal parts were sold as scrap. For example, during the Honest John disposal, 36,100 pounds of scrap steel was sold for $5,415.00 ($0.15/lb)(21). Warhead shipping containers were transferred for future use on the Arsenal(21).

(2) Project Eagle - Phase II generated 43,000 drums (55 gallon each weighing 500 lbs.) of salts or about 2.6 lbs of salt for every pound of GB neutralized. The major components of these salts were sodium ispropyl methylphosphonate (SIMP), sodium fluoride, and sodium carbonate. EP Toxicity tests were performed which showed varying concentrations of heavy metals in the salts. However, the levels found were below the Resource Conservation Recovery Act (RCRA) maximum concentration limits for hazardous waste classification. Based on the RCRA Part B Permit for RMA(32), these salts were listed (Army classification X003) and managed as hazardous waste under Army

policy, although sample test results did not qualify them as RCRA hazardous waste. The Army considered the salts hazardous mainly due to their corrosivity (high pH levels ranging from 7.0 to 12.3) which is a characteristic of high sodium fluoride levels. Also, it was believed that a minute amount of GB remained in the salts even though the spray dryer was operated above the boiling point of GB. An exact analysis for measuring GB residue is not possible due to the analytical methods used. Since the Army considered the salts hazardous, they were disposed of by U.S. Pollution Control, Inc. in a RCRA approved landfill (Grassy Mountain Site) near Salt Lake City, Utah in the fall of 1986.

3.3.0 CAMDS Chemical Agent GB Neutralization.(33,34)

3.3.1 Introduction.

a. This section describes two major chemical agent disposal operations at CAMDS using neutralization as the method for chemical agent destruction.

b. The first neutralization operation was initiated in September, 1979 and completed during April 1981. A total of 13,951 M55 rockets were processed through a Rocket Demil Machine (RDM) from which 127,950 lb of agent GB were destroyed by the CAMDS agent neutralization process in the Agent Destruction System (ADS). The second operation was the disposal of 155mm nonburstered projectiles and 105mm cartridges filled with agent GB. A total of 12,673 munitions was drained of agent and a total of 54,000 lb of agent was neutralized in the CAMDS ADS. The latter disposal operation commenced during July 1981 and was completed during July 1982. Table 3-8 lists the amount and type of each chemical agent neutralized at CAMDS during the two programs.

c. In the M55 Rocket disposal project, the M55 rockets were drained of agent and cut using the RDM. The rocket pieces were then conveyed to the CAMDS Deactivation Furnace System (DFS) where the explosive components of the rocket and any residual agent were burned in the DFS. In the nonburstered projectile disposal operation, the projectiles were processed through a Projectile Pull and Drain Machine (PPD) where the agent was removed from the projectile and sent to the ADS for neutralization. The empty projectile and metal parts (burster well and the nose closure) were then sent to a Metal Parts Furnace (MPF) for decontamination.

3.3.2 Neutralization Process Description.(35,36)

a. The chemical neutralization process at CAMDS was contained in the ADS. The ADS was modeled after the existing facilities at RMA with certain modified equipment configurations. In the ADS design, the caustic and GB are blended in the reactor rather than in a mixing tee, as done at RMA.

TABLE 3-8: CAMDS Chemical Agent GB Neutralization Programs

Project	Number of Munitions	Agent	Approximate Lbs of Agent
M55 Rockets	13,951	GB	127,950
155mm Projectiles	7,942	GB	54,000
105mm Projectiles	4,731	GB	
	Total Pounds of Agent Neutralized		181,950

Also, the heat of reaction is removed b a reactor recirculation sysem and cooling jacket in the ADS rather than a heat exchanger downsteam of the mixing tee, as done at RMA. These modifications were done to eliminate foaming and line plugging problems experienced at RMA and to improve process operations in general. Also, these changes were necessary to accommodate caustic neutralization of the VX acid brine in the second step of the VX neutralization process. Although this system was designed to neutralize both GB and VX, the VX neutralization program was never implemented (see Section 3.4.0.b. for rationale).

b. The ADS was divided into five major components of operations: chemical storage and distribution, agent reactors, waste neutralization, evaporator, and brine drying. The location of these components is laid out pictorially in Figure 3-21.

(1) Chemical Storage and Dilution. Sodium hydroxide (NaOH) was received in a 50 percent solution and diluted to 18 percent before use. NaOH to be used in the ADS was piped from a storage site to a Chemical Distribution System (CDS) for use as a decontamination solution.

(2) Agent Reactors. In the neutralization process, NaOH reacted chemically with GB to form sodium isopropyl methylphosphonate, sodium fluoride, and water. The design of the system involved a batch neutralization process, in which GB was collected until a sufficient amount had accumulated to m ke up a full batch. This method was employed throughout all of the M55 rocket and most of the projectile runs.

(a) The addition of GB to the reactor was undertaken in a controlled manner to reduce heat buildup from the exothermic reaction. A cooling water system for the reactors was used as an additional method to control the heat, but was later eliminated when it was found that cooler temperatures caused salts to precipitate out of the brines and to clog pipes.

(b) After sufficient reaction time, the brine was sampled to ensure that 5 percent excess caustic (NaOH) was present and that the residual concentration of GB was 2 nanograms per milliliter or less. The

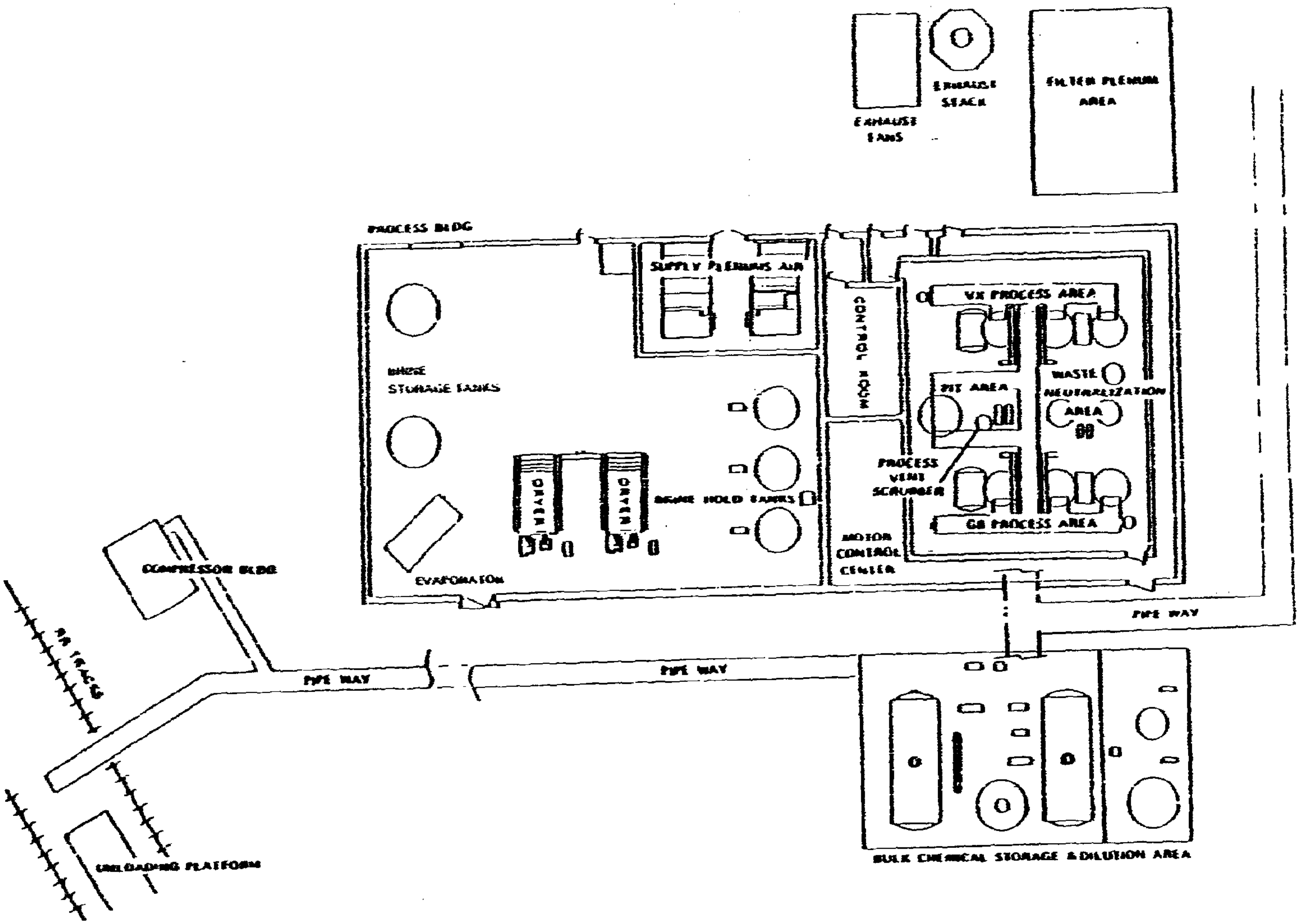


Figure 3-21: General Arrangement of the Agent Destruction System

brine was then transferred to the brine holding tanks before drying. If the criteria were not met, additional NaOH was added, and the brine was retested.

(3) Waste Neutralization. The waste neutralization tanks were designed to treat spent decontamination solutions from all areas of the CAMDS facility that might have contained low levels of agent. All liquid wastes generated in the ADS toxic cubicle from agent spills, Explosive Containment Cubicle #1, Rocket Shear Machine (RSM), PPD, and other areas where agent/munitions were handled, passed through floor drains to a sump. Wastes from this sump were periodically pumped into the waste neutralization tanks for treatment. Spent caustic from the ADS scrubber was also transferred to these tanks. Toxic shower water was also routed to the waste tanks for neutralization.

(4) Evaporator. An evaporator was installed in the brine holding area to heat the diluted waste waters and decrease the volume of water going to the drum dryers. The evaporator had a 4.7 million Btu tube bundle heat exchanger and was rated at a capacity of 250 gallons per hour.

(5) Brine Drying.

(a) Whereas at RMA the neutralization brine was spray-dried to a salt, it was drum-dried at CAMDS. The change was based on a study by Rowan (37) showing the following improvements in obviating conditions that were conducive to GB reformation: (i) Drum dryers operated at a lower temperature than spray dryers. (ii) Drum dryers rely on steam heat instead of fuel oil boilers; do not expose CO_2 and SO_2 to the brine; and thus do not promote acidic conditions, unlike the spray dryers. (iii) Drum dryers involve a much lower volume of air than spray dryers. The air serves only to carry away effluent gases in the drum dryer whereas air is used as the heat transfer medium in the spray dryer. Thus, dusting is minimized and if GB emission occurs, the lower volume of air is easier to deal with. It was also determined that drum dryers were more cost-effective than spray dryers.

(b) The brine drying area consisted of five brine (45,000 gal capacity) holding tanks with transfer pumps, two parallel steam-heated twin-drum dryers with circulating pumps, and a solids handling conveyor system for each twin-drum dryer, salt storage bin and salt compactor. The brines after being certified as agent-free entered the drying area from two sources: (1) the agent reactor or waste neutralization tanks and (2) brines from other areas of the plant, e.g., scrubber liquids from the MPF and DFS. The concentrated brine was pumped from the holding tanks to twin-drum dryers, where moisture was removed by evaporation on the hot surface (approximately 350°F) of the rotary drum.

(c) The solids from the drum dryers are conveyed to a surge bin equipped with a level indicator. The solids compactor has a meter to measure the electrical loading on the motor. The solids from the compactor are fed into plastic-lined fiberboard storage drums. It should be noted that this past practice has been changed to the current one of collecting uncompacted salts in commercially leased dumpsters that are periodically collected. (See Section 3.3.4.c. for disposal).

3.3.3 Project Description.(33)

a. M55 Rockets.

(1) The first GB neutralization project at CAMDS involved disposal of 13,951 M55 rockets during the period of September 1979 to April 1981. See Appendix B for a description of the M55 rocket.

(2) Process Description. Figure 3-22 is the process schematic that was used at CAMDS in disposing of these rockets.

(a) Pallets of M55 rockets were delivered to the CAMDS Munition Holding Area (MHA) by ammunition transport vans with charcoal filters. Each pallet of M55 rockets was placed in a Single Pallet Only Rocket Transport (SPORT) container before it was transported to the MHA. No more than two SPORTS containing rockets were permitted in the Unpack Area (UPA) at any time.

(b) Rockets were then manually fed onto a conveyor which introduced the rocket into an Explosive Containment Cubicle (ECC) where the rocket was drained and cut into seven pieces by the RDM and the rocket pieces

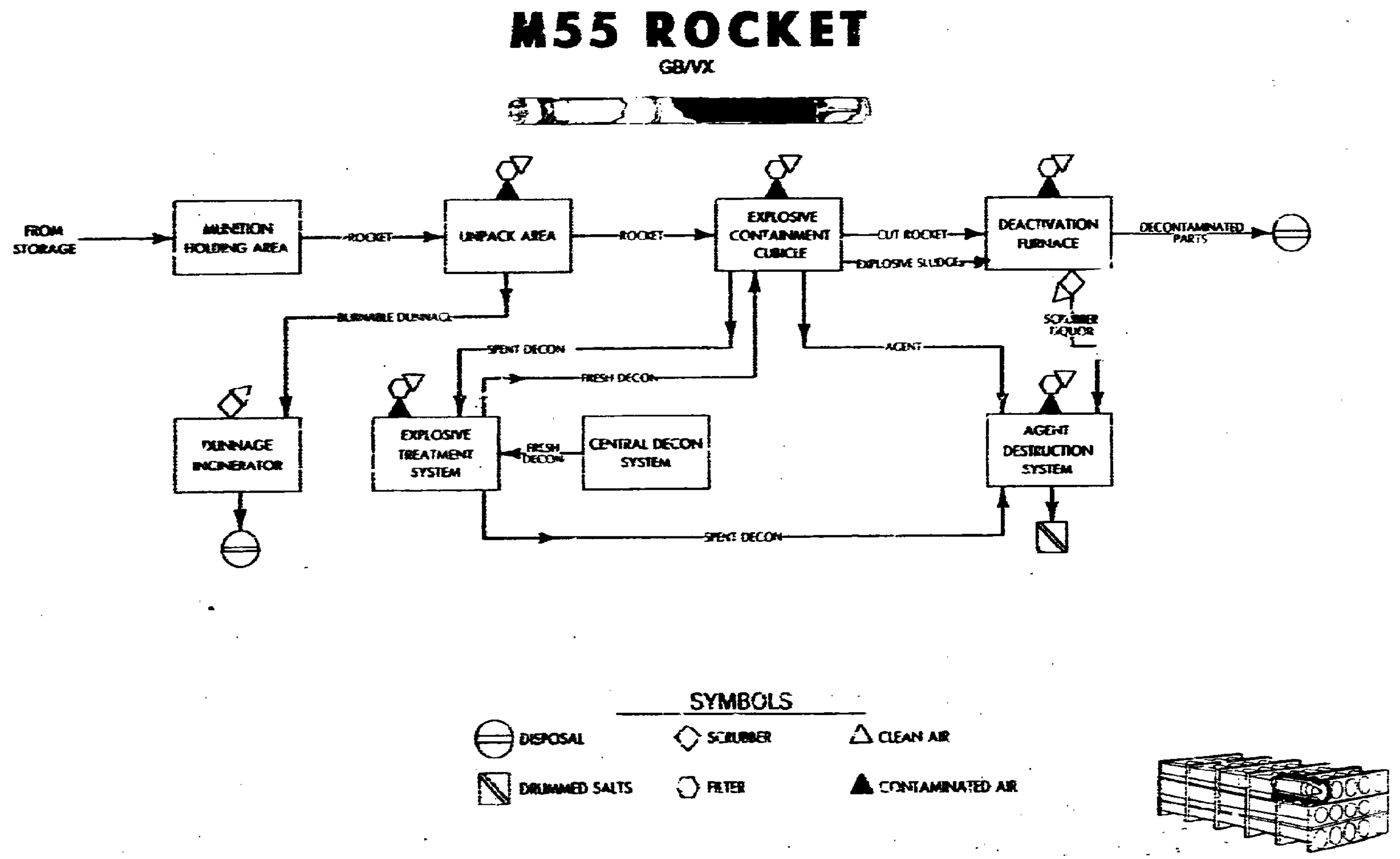


Figure 3-22: Process Schematic for M55 Rockets

conveyed to the CAMDS DFS. The explosive portions of the rocket were burned in the DFS and any residual agent was incinerated. Decontaminated metal parts and fiberglass from the rocket shipping tube were discharged from the DFS at a temperature of 1000°F. The discharged pieces were carried on an electrically heated conveyor which insured retention of the pieces at 1000°F for the 15 minutes required for thermal destruction of residual agent traces.

(c) The drained GB from the M55 rocket was transferred from a measuring tank in the ECC to the ADS through a double-walled pipe. The agent was then collected in a storage tank inside the ADS and neutralized as described in Section 3.3.2.

(3) Key Components.

(a) Rocket Demil Machine (RDM). The RDM was a multistation machine. Figure 3-23 is a cutaway of the RDM which was installed in the ECC and consisted of the following conveyors and stations:

1 ECC input conveyor which was used to move the rocket from the UPA into the ECC.

2 RDM input conveyor which was used to move the rocket into the punch and drain station in the ECC.

3 Punch and drain station in the ECC which punched the rocket and drained the GB agent.

4 Saw station in the ECC which had six motor-driven radial saws that cut the drained rocket into seven pieces.

5 ECC discharge and segregator conveyor which was installed in the ECC housing between the ECC and the Deactivation Furnace input conveyor. Figure 3-24 is a

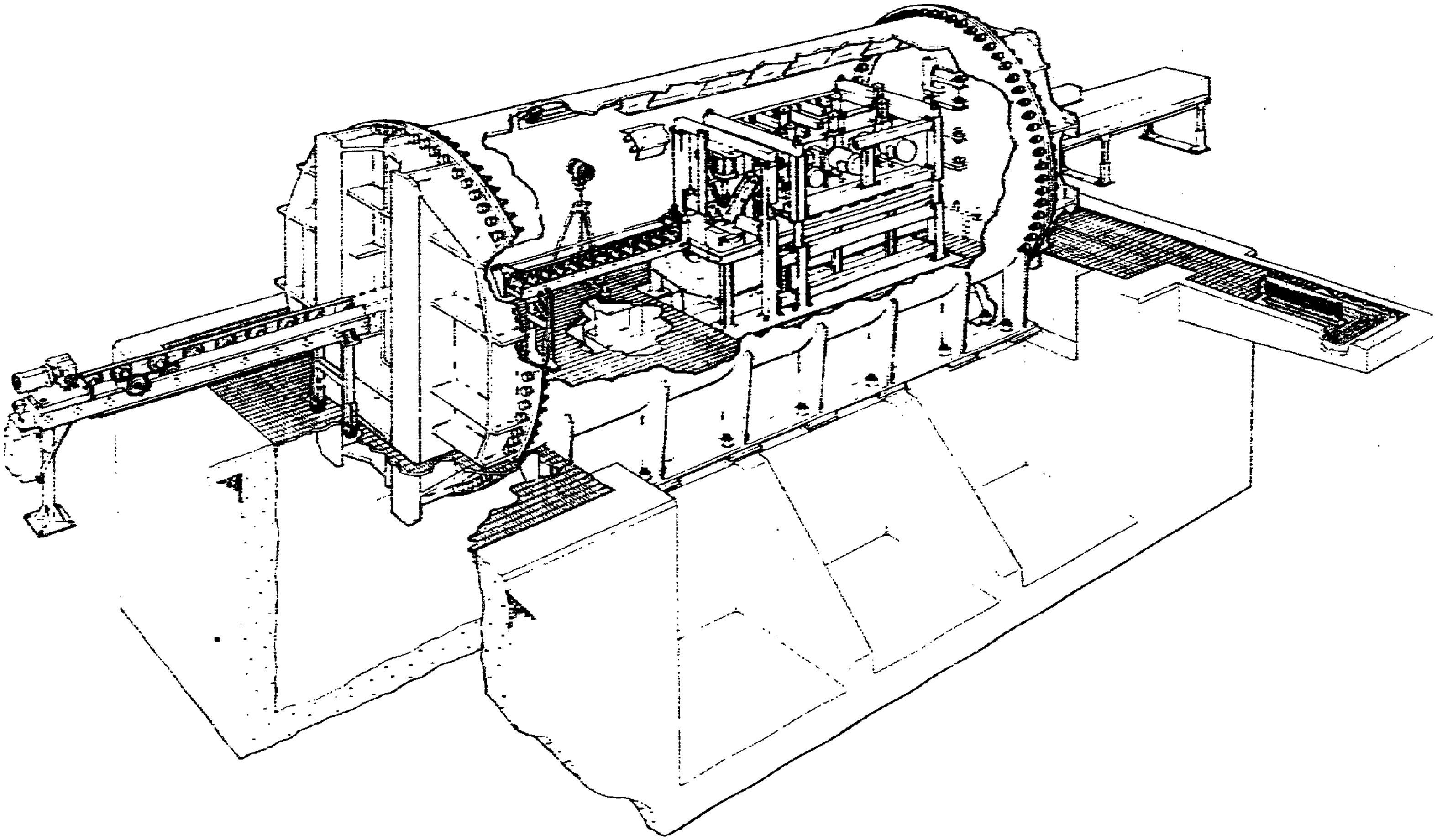
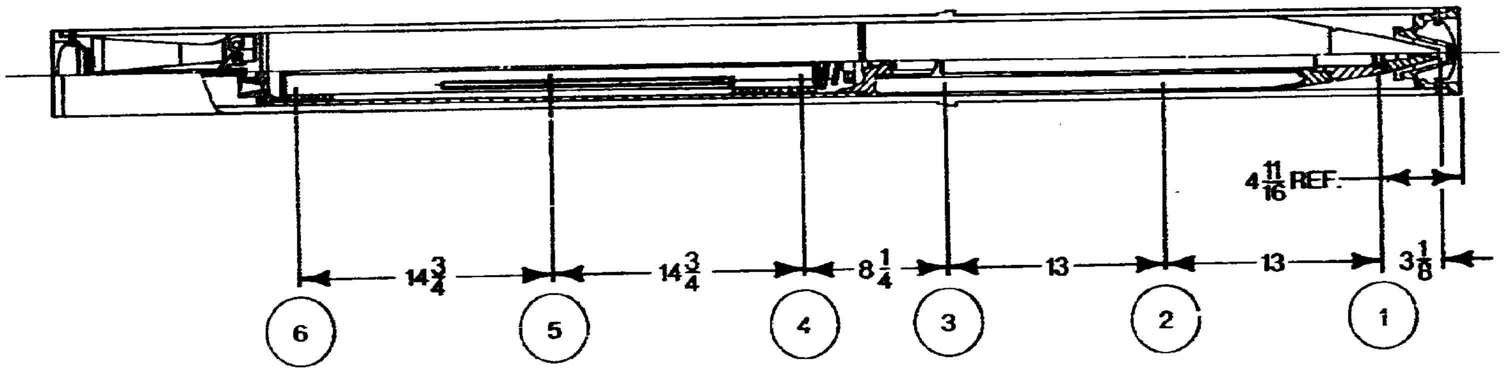


Figure 3-23: Rocket Demil Machine



NOTE:
CUT LOCATIONS ARE SHOWN IN RELATION TO ROCKET.
CUT LOCATION RELATIVE TO CASE MAY VARY SLIGHTLY
DUE TO VARIABLE CASE-TO-ROCKET RELATIONSHIP.

Figure 3-24: Rocket Demil Machine Processing of M55 Rocket schematic of an M55 Rocket after it had been processed through the RDM.

(b) Deactivation Furnace System (DFS). The DFS at CAMDS was similar in design to the one used at RMA but slightly larger; it was used for the thermal deactivation of the propellants and explosives as well as the thermal detoxification of the metal parts containing residual agent from drained M55 GB agent filled rockets. Propellants and explosives from all chemical munitions, and metal parts containing residual agents from drained M55 VX rockets and M23 VX mines were also deactivated and/or decontaminated in the DFS. A detailed description of the DFS appears in Section 4.3.2. of this report. The major components of the DFS were an oil-fired rotary retort, a shrouded electrically heated discharge conveyor and pollution abatement system.

b. 155mm/105mm Projectiles.(33)

(1) The second neutralization project at CAMDS was the disposal of 7,942 GB filled nonburstered 155mm projectiles during the period of July 1981 to February 1982. The third neutralization project at CAMDS was the disposal of the 105mm, nonburstered, GB filled projectiles between March 1982 and July 1982. (See Appendix B for a description of the 155mm projectile and 105mm projectile.) The agent from 4,731 of the total 7,771 rounds of 105mm projectiles was destroyed in the ADS. The agent from the remaining 3,040 projectiles was drained and collected in ton containers.

(2) Process Description. Figure 3-25 is the process schematic that was used at CAMDS in disposing of these projectiles.

(a) The palletized munitions were taken from the storage igloo to the CAMDS MHA by the ammunition van. The palletized rounds were then taken from the MHA to the UPA where the rounds were removed from the pallet and placed on an ECC by-pass conveyor. The conveyor would carry them to the Projectile Disassembly Facility to be processed in the PPD. The pallets were then sent to the Dunnage Incinerator (DUN) for burning and the resulting ash was sent to disposal.

PROJECTILES/CARTRIDGES

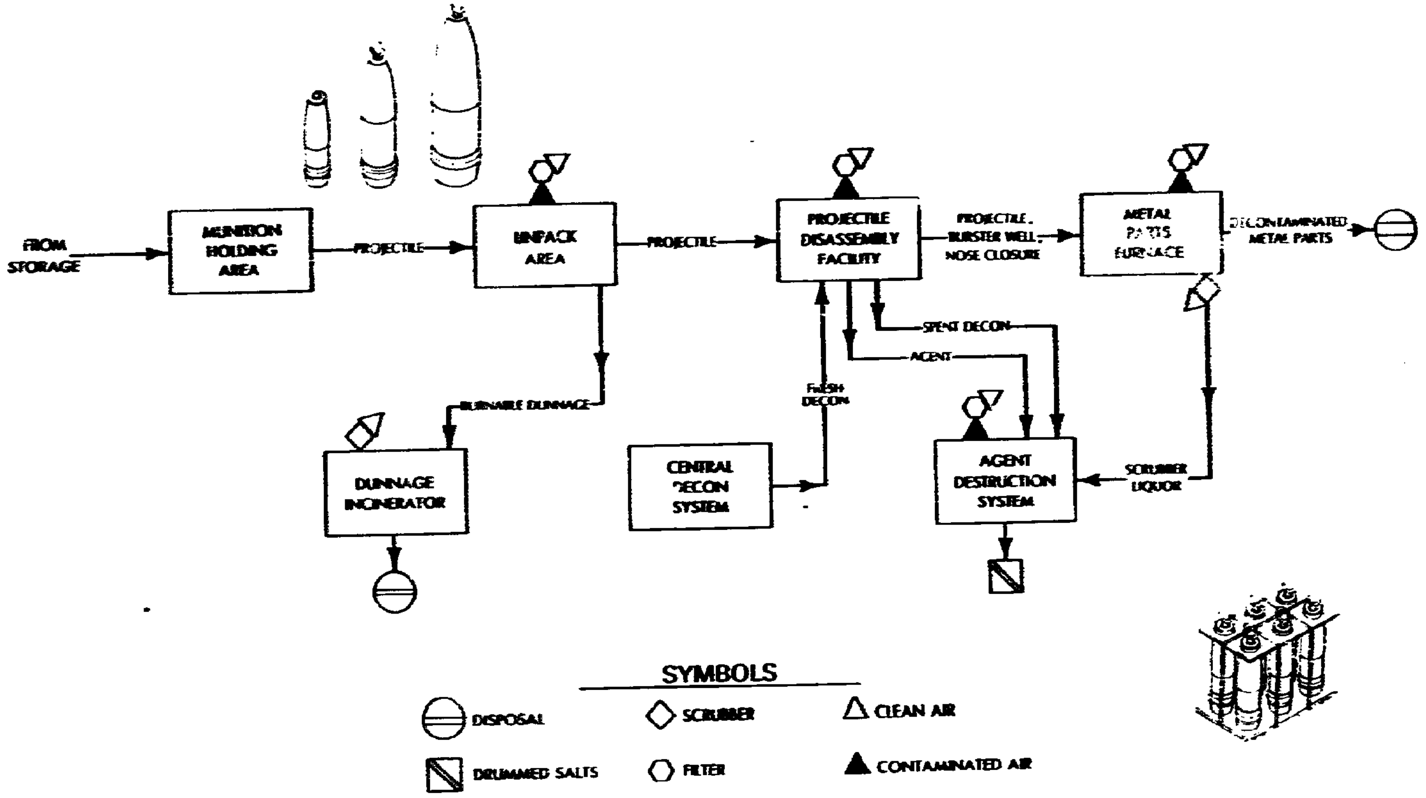


Figure 3-25: Process Flow for 105mm/155mm Non-explosively Configured Projectiles

(b) In the PPD, the nose closure was removed from the projectile and the burster well was extracted. The GB agent was then removed and sent to the ADS for neutralization as described in Section 3.3.2. The burster well was passed through a decontamination bath. The decontamination solution was supplied by a CDS, and the spent decontamination solution was sent to the ADS for neutralization and drying.

(c) The drained projectiles, burster wells and nose closures were sent to the MPF for decontamination. The scrap metal parts from the MPF were disposed of by the Property Disposal Office, TEAD.

(d) The drained GB agent was neutralized in the ADS, and the resulting brine and the brine from the MPF scrubber were also dried in the ADS using the drum dryer system. The salts produced during the drying operations were placed in drums and sent to storage.

(3) Key Components.

(a) Projectile Pull and Drain Machine (PPD).

1 Purpose. The function of the PPD was to open projectile bodies by tapering the burster well so that the projectile could be further processed and to drain the agent from projectiles as shown in Figure 3-26.

2 Description. Because the PPD was located in a toxic area, it was contained within a ventilated interior housing (shroud). An airlock with shower, also ventilated, was attached to the shroud to allow access to the toxic area. Ventilation air exhaust was filtered through activated charcoal beds to remove traces of toxic agent. The PPD consisted of the following stations:

- PPD load station
- Nose closure removal station
- Burster well weld cutting station
- Burster well pull station
- Drain station
- PPD unload station

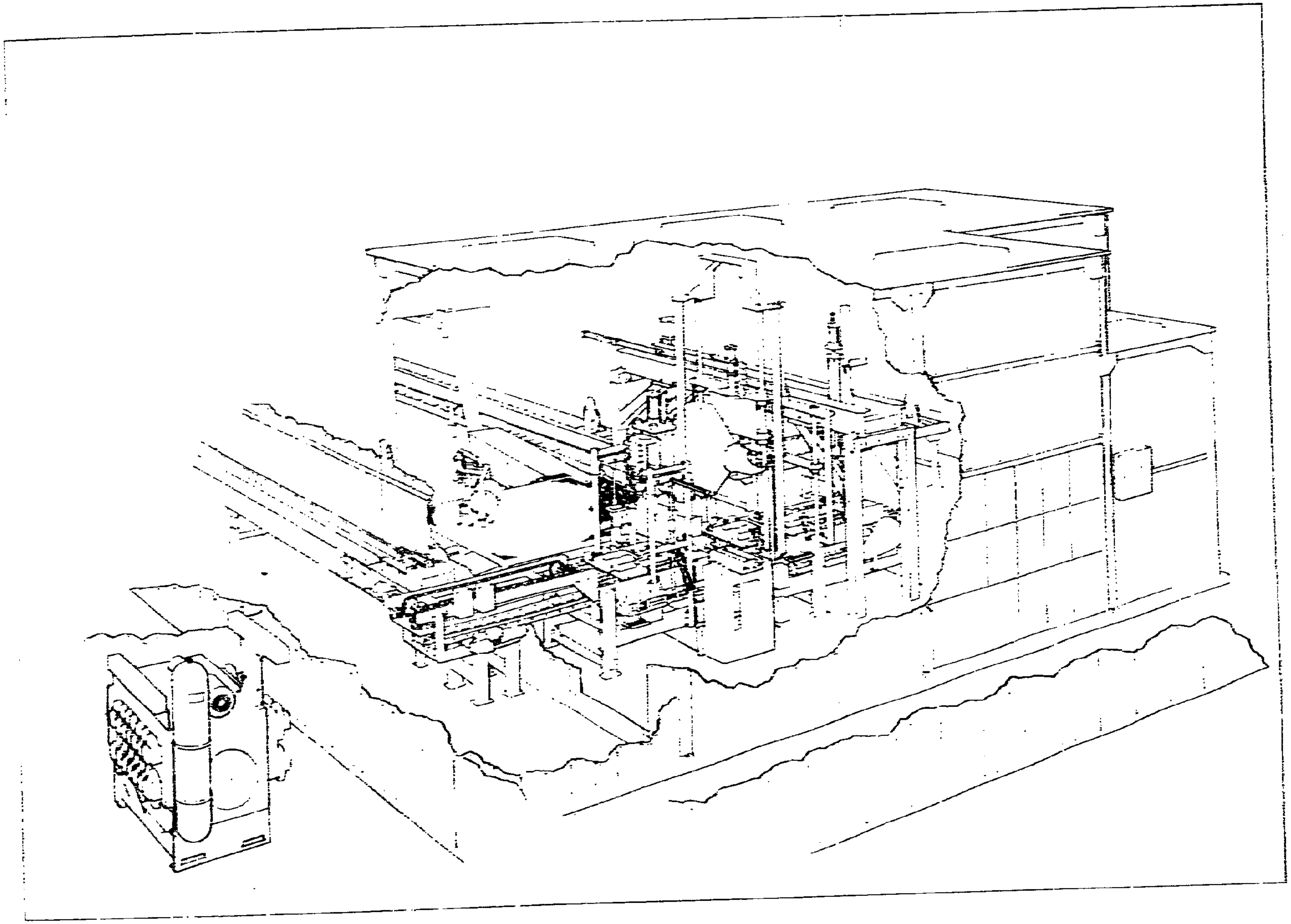


Figure 3-26: Projectile Pull and Drain Machine

3 Operation. Nonburstered projectiles only came directly from the UPA by way of the ECC by-pass conveyor. Burstered projectiles had all explosives removed in the ECC prior to transfer to the PPD. Only one type of projectile was processed through the PPD at any one time. The machine was capable of being adapted to the various munition types. A computer program had been developed to insure the proper sequence for each particular munition. All stations were tied to a control program so that if a station failed to complete its operation, that operation would automatically be repeated before the conveyor could advance the projectile. Had a station failed to complete its function, the process was automatically stopped until the malfunction was corrected.

(a) PPD Load Station. Projectiles were received at the PPD by way of the input conveyor and PPD accumulator. The accumulator provided for inline storage of projectiles. This provided a cushion in the projectile line that would allow minor problems in the PPD to be solved without interrupting operations in the UPA and ECC.

(b) Nose Closure Removal Station. The nose closure removal station used a high torque, pneumatically operated impact wrench. A clamp device consisting of three "arms," 120 degrees apart, gripped and unscrewed the nose closure. After the closure had been removed, the cavity was probed to determine whether a burster was present. The process would not continue if a burster was detected.

(c) Burster Well Weld Cutting Station. This station was used on projectiles that contained welded burster wells. They were not processed with the other munitions. This station used a vertical boring mill with a hydraulically controlled feed rate and a variable speed.

(d) Burster Well Pull Station. This apparatus consisted of a hydraulically operated carriage that was lowered to cause a collar to make contact with the tapered outside surface (ogive) of the projectile. With the collar in contact with the projectile, a rod with an expandable collet attached was lowered into the projectile burster well. The collet was expanded, causing it to press against the inside wall of the burster well. The collet was then raised, removing the burster well from the projectile.

(e) Drain Station. Agent was removed in this station using a vacuum to drain the munition. A vacuum tube and probe were lowered into the projectile. The probe was provided to determine when the agent had been removed.

(f) Unload Station. Transfer of the projectile to the MPF was accomplished by a powered roller, floor level conveyor. To transfer the projectile onto the conveyor, a tapered collet was used. The collet was lowered into the projectile cavity and expanded tightly against the inside projectile wall.

(a) Metal Parts Furnace (MPF).

1 Analogous to the purpose of the Decontamination and Inert Parts Furnaces at RMA, the purpose of the MPF during the neutralization process at CAMDS was to thermally decontaminate the drained 105mm/155mm munitions components, cavities and metal from which explosives had been removed. A detailed description of the MPF appears in Section 4.3.3.

3.3.4 Environmental Concerns.

a. Emission Standards and Monitoring.

(1) The Department of Health and Human Services (DHHS) standards for GB emissions during neutralization at CAMDS remained unchanged from those given in Table 3-4 and Section 3.2.3 for RMA. The standards for industrial pollutants during neutralization at CAMDS were the same as those during incineration at CAMDS. Nonetheless, the emission of industrial pollutants at CAMDS during neutralization was neither a problem nor environmental concern. The reader is referred to Table 4-16 and Section 4.3.2.c. for discussion of standards for industrial pollutants. The rest of this section will focus only on GB emissions.

(2) While the M5, E59 and DCAC alarms and the bubbler were used at RMA; the M5, M8, modified M8 with concentrator, bubbler, and real-time monitor (RTM) were used at CAMDS. The M5, E59, and bubbler were previously described in Section 3.2.3.; the others will be described here. The M8 alarm is a portable real-time (response time of one minute) monitor that detects nerve agent electrochemically with a lower limit of detection of 0.2 mg/m^3 for GB. The modified M8 with concentrator differs from the M8 in that it detects as low as 0.001 mg/m^3 of GB but at a response time of 33 minutes. The RTM detects as low as 0.0001 mg/m^3 of GB at a response time of ten minutes; it uses the colorimetric enzymatic method of detection similar to that described for the bubblers in Section 3.2.3. and represented a considerable improvement over the M8.

(3) The M8 alarm was placed in all neutralization toxic process areas to monitor the presence of agent as well as to indicate process upsets. Bubblers were placed on the stacks from the brine dryers. The modified M8 with concentrator, bubblers, and RTM were placed in all work areas. The exhaust stacks of furnaces were monitored with bubblers at all times and with combinations of M5, M8, or RTM. As with RMA, all CAMDS alarms and bubblers were periodically challenged to check their operation.

(4) The perimeter monitoring network during neutralization at CAMDS consisted of eight identical sampling stations positioned as shown in Figure 4-23. As with RMA, each station was a semi-permanent trailer containing an ozone monitor, sulfur dioxide monitor, nitrogen dioxide monitor, anemometer and wind direction indicator, a high-volume sampler for suspended particulate, and a GB bubbler.

b. The neutralization process did not follow the expected course and presented two environmental problems: (i) minute quantities of GB were found in the brine and (ii) the process took significantly longer time than expected, required excess caustic (NaOH), thus resulted in excessive salt production.

(1) Whereas in the RMA neutralization process the major environmental concern was GB emissions in the spray drying of the brine, the

major one in the CAMDS process was the encounter of minute quantities of GB in the brine. That this was a problem for CAMDS and not for RMA although CAMDS followed RMA and took advantage of RMA's experience can be explained. First, the brines from the neutralization could not and were not analyzed for the presence of GB at RMA.(38) This practice was permitted under a DHHS Standard that only required that there be 5% excess caustic (NaOH) in the brines because it was faithfully believed that this amount of excess caustic would decompose any GB present. However, DHHS intended to tighten the standard after RMA reported problems with GB emissions during spray-drying; in its desire to tighten the standard, DHHS sought a standard that was an actual performance standard rather than one based on faith. In the end, DHHS accepted the Army's proposal that the standard for GB not exceeding 20 parts per billion in drinking water for soldiers be applied to the brine.(39) By this time, the neutralization had been completed at RMA, and CAMDS was required to comply with this stricter standard. Thus, CAMDS had to analyze the brine for GB from each neutralized batch. While DHHS imposed this standard of 20 ppb of GB in water, which corresponds to 20 ng/ml (w/v), the Army adopted a certification (that a brine was agent-free) target level that was 10% of the DHHS standard, i.e., 2 ng/ml or 2 ppb (w/v). CAMDS experienced much difficulty in meeting this target level. Part of this difficulty was reflected in the lengthy reaction times required to reach the certification target level (see paragraph 3 below).

(2) In attempts to solve the difficulty, the Army spent over $7 million to determine the reasons for the presence of minute quantities of GB in the neutralization brine at CAMDS. Numerous studies were performed by Battelle, Southern Research Institute, the Army's Chemical Research, Development and Engineering Center, and a nationally reputed panel of chemists was retained. Nevertheless, the one comprehensive study that best explains the difficulty is by Joel Harris(40). His study explores four reasons for detecting the presence of GB in the brine and why sometimes the certification target level could not be achieved:

(a) The caustic (NaOH) neutralization reaction is still not well understood. However, even at the present level of understanding, incomplete destruction of GB is predictable by equilibrium considerations.

(b) GB that was either encapsulated or occluded (within solids, e.g., rust, scale, arising from slow degradation of the munition over the years or from degradation of the reactor vessel) was released after or continued to be released after addition of and mixing with the caustic (NaOH).

(c) GB could have reformed during the analytical procedures carried out to detect it in the brine. The analytical procedures carried out to detect GB involve acidifying a brine sample to pH 7 from pH 13, extraction with chloroform, and analysis with gas chromatography. The acidification is a condition that favors reversing the hydrolysis reaction reforming GB, as shown in Figure 3-2. The chloroform solvent extraction provides two conditions that are conducive to concentrating GB: a highly polar solvent with which the highly polar GB is compatible and an H-bond donor solvent with which the H-bond acceptor GB matches. The chloroform extraction also provides a condition conducive to reforming GB; namely, a highly polar solvent facilitates proton transfer in reversing both the neutralization (Figure 3-1) and the hydrolysis (Figure 3-2). The analysis with gas chromatography also provided a condition conducive to reforming GB. Gas chromatography requires the extracted brine sample to pass through a heated column. Heat is a condition favoring reversing the neutralization reaction which is exothermic (see Figure 3-1).

(d) The presence of GB could also have been attributable to false positives in the analytical procedures due to the very complex sample matrix. Multiple interferences have been identified in blanks (i.e., solutions known not to contain any GB) and some phosphorus-containing compounds have been identified as the interferences. Contributing to the complexity of the sample matrix is the involvement of solids i.e., rust, scale, etc. mentioned in the occlusion of GB. Wynne(41) mentions that a heel of water was inadvertently left in the storage tank after emptying of the GB and washdown. Apparently, when the storage tank was filled with GB drained from munitions, the GB reacted with the heel of water. This hydrolysis reaction (given in Figure 3-2) formed acidic conditions that corroded the tank and yielded in turn metal complexes and a sludge that was hard-to-pump if it did not actually clog pipes.

3. The neutralization process at CAMDS took significantly longer time that expected. In the laboratory, it was found that GB had a half-life of less than one second in 5% aqueous sodium hydroxide. On the batch scale, the reaction was planned to take no more than three to four hours. However, CAMDS was documenting that it was taking as long as thirteen days for the brines to attain the certification target level. In at least 3 instances, it took more than 30 days. Needless to say, these excessive reaction times were extremely disappointing and frustrating because they held up disposal operations schedules. Furthermore, after an initial drop in GB concentration immediately following the mixing in of caustic (NaOH), the brines would then exhibit a minute rise in GB. Apparently, a correlation was found by Lurk (42) between the time that GB was held in the storage tank and the time that it took to attain the certification target level; this correlation supports the contention that the heel of water was hydrolyzing the stored GB forming acidic products which were consuming the caustic and interfering with the neutralization. The only known way of resolving the difficulty and of accelerating the neutralization reaction time was to add more caustic (NaOH) which was done. The detrimental effect of this additional caustic was the high salt production which is discussed next.

c. <u>Salt from the Neutralization Process</u>.

(1) The M55 rocket, 155mm projectile and 105mm projectile disposal at CAMDS generated 1,093,620 lb of salts or about 6.01 lb of salt for every pound of GB neutralized. Of the 1,093,620 lb of salts generated at CAMDS, 309,325 lb resulted from the GB neutralization and the remaining 784,295 lbs resulted from waste salts (spent decontamination solution, equipment washdown, etc.) generated during GB neutralization.

(2) The waste salts have been disposed of in an approved RCRA landfill while the salts resulting from the GB neutralization are being stored

at TEAD pending award of a contract for disposal at a RCRA landfill.(43) The CAMDS Demilitarization Plan of 1978 called for disposal of the salt at a leachate controlled landfill before RCRA was enacted.

3.4.0 Rationale For Dropping Neutralization.

a. The fact that the product of the mustard neutralization reaction (see Section 3.1.1.c.) was hazardous and had to be disposed of by incineration led to the proposal of incinerating mustard in the first place, thus, eliminating the need for neutralization at all. Moreover, there were three other factors that favored incineration over neutralization for disposal of mustard. The neutralizing reagent, MEA (see Figure 3-4), has a high flashpoint; its use in a laboratory test resulted in an explosion. Second, the neutralization reaction is exothermic and must be temperature-controlled; otherwise, a slowly appearing unrecognized exotherm can result in a violent runaway reaction. Third, when neutralized in 60-gallon batches, residual amounts of mustard, on the order of less than 0.25 mg per liter of waste product were left behind. Adoption of the proposal to incinerate mustard eliminated further consideration of neutralization for mustard as a disposal technology and obviated demonstration of the technology on the pilot- or industrial-scale. The Army had had considerable experience with incinerating mustard by the time the NAS promulgated its finding and recommended incinerating mustard.

b. Laboratory and pilot-scale studies were conducted on the chemical destruction of agent VX; these studies demonstrated that the acid chlorinolysis was feasible as an industrial-scale process for neutralizing agent VX. The positive results of these studies led to the design and construction of the ADS at CAMDS that was capable of neutralizing VX. However, VX was never destroyed by neutralization on an industrial-scale at CAMDS or elsewhere by the Army. There were several reasons for this lack of action. First, there was no reliable low-level detection/monitoring capability for VX in the neutralization brine at that time (detection problems included poor extraction recovery, considerable interferences, and low sensitivities, e.g., 600 ug/l of brine); it was anticipated that lack of such capability would preclude the DHH (whose authority is required under PL 91-121 and PL 91-441) from approval for VX disposal. Second, VX neutralization by acid chlorinolysis posed a possible risk of explosion from the potentially hypergolic chlorination step and posed profound consequences for a mishap because of the corrosiveness of the mixture. For these reasons, VX neutralization was postponed to the last moment. While neutralization (of GB) was performed, experimental studies with incineration, as recommended by the 1969 NAS report, had progressed to the point where the feasibility of a destruction and removal efficiency of 99.9999% or better was demonstrated with GB and VX. Combined with the problems being experienced in neutralization of GB and with the inference that these problems would be aggravated for VX due to its greater reaction complexity, destruction of VX by neutralization was dropped in favor of incineration when it was ready to begin VX munitions disposal.

c. The only experience that the Army has gained in using neutralization for disposal was for disposal of GB agent/munitions. However, the problems encountered during this experience inevitably led to abandoning neutralization in favor of using incineration for four principal compelling reasons: (1) the sheer complexity of the neutralization process and the sensitivity of the process to numerous parameters that would slow the reaction (or promote hydrolysis reversal reforming miniscule amounts of GB). The complexity and sensitivity of the process were disparaged by the straightforwardness of incineration (which was the emerging industrial technology for disposal of hazardous organic substances). (2) The quantity and the nature of waste produced by neutralization were disadvantages as compared to that for incineration. (3) The capital and operating costs of neutralization were high as compared to that for incineration. (4) Last but not least important was the fact that neutralization applied to destruction of the chemical agent only whereas incineration could be applied to destruction of the explosives/propellants in the munitions as well as the agent.

3.4.1 Complexity of the Process.

a. Neutralization is vastly more complex a process than is incineration. Its complexity stems from the nature of the reaction or reactions that take place. Neutralization reactions require, in addition to the chemical agent as a substrate, the presence of reactants such as acid, caustic, chlorine, or other reagent. The reactants need to be stocked, properly prepared (i.e. diluted or blended), and stored. The reactants are invariably hazardous, toxic, and/or corrosive and must be handled safely in bulk quantities (10,000 gal or more). The handling of such hazardous chemicals in bulk adds to the risk of an upset. The neutralization reaction must take place in limited quantities - so called batch operations that must be regulated under specified restrictive conditions (pH, temperature, concentration, etc. which are discussed later.) These conditions in turn necessitate a complex system of batch, day and holding tanks; reactor vessels; heat exchangers; recirculators; agitators; reflux condensers; and evaporators connected by a vast infrastructure of plumbing, valves, tees, pumps, sampling ports, pressure and flow regulators and monitors. Although the GB neutralization is only one-step (see Figure 3-1), the complexity is intensified for multiple step reactions, such as for VX neutralization (see Figure 3-3). On the other hand, whereas incineration involves a straightforward combustion reaction, the only required reactant, besides the chemical agent as a substrate, is oxygen, which is available as air. Since combustion is heat driven, a fuel must be burned. Chemical agents, as a generalization, have high heats of combustion (see Table 6-8) and are fairly easier to incinerate than most commonly incinerated compounds. This property enables them to act as a fuel minimizing consumption of natural gas or fuel oil. The only major piece of equipment that is necessitated is a simple furnace which can be designed to take into account the easy incinerability of chemical agents. The only infrastructure needed to support the furnace is a fuel tank and pollution abatement system. The complexity in the neutralization process versus incineration is directly reflected in the capital and operating costs of equipment which are discussed later in Section 3.4.3.

b. The sensitivity of neutralization as compared to incineration is manifest in the number and kinds of conditions, namely, pH, temperature, and concentration that must be controlled properly for the reactions to proceed. (For neutralization reactions, pH and concentration of the acid or caustic reactant are redundant.) The consequences of poor regulation of reaction conditions were evident in problems with the slowness of the reaction, excessive amount of salt formed, and the reversal of the hydrolysis reaction resulting in reformation of the chemical agent (see Figure 3-2). For example, the sensitivity of the process to temperature was revealed by the CAMDS experience in neutralizing GB in the requirement for quick removal of the exothermic heat of reaction of 30 Kcal per gram mole of GB. In order to preclude reaction temperature in excess of 190°F and consequently, quenching the reaction or terminating the chemical agent flow, a cooling water system was installed. (Potential consequence of failure to control the heat was release of the chemical agent and/or caustic, thus adding to the risk of an upset.) Apparently, the cooling system for the CAMDS neutralization process caused sufficiently low temperatures for salt precipitation to occur resulting in clogged pipes. Low temperatures had to be remedied by adding excessive caustic significantly slowing the reaction. Excess caustic caused another problem discussed below in paragraph d and Section 3.4.2. Incineration is not subject to the same extent of sensitivities that neutralization is.

c. The slowness of the neutralization reaction was a frequently raised complaint in view of the fact that the industrial-scale experience did not match expectations. Based on the laboratory and field measurements of chemical reaction rates, GB has a half-life of less than 1 second in a 5% aqueous solution of sodium hydroxide. Thus, caustic neutralization was expected to progress rapidly. In practice, however, it was difficult to achieve the necessary mixing of components to speed up the process; excess quantities of sodium hydroxide were added to do so. While the expected batch reaction time was 3 to 4 hours, on numerous occasions, the completion of reaction for a batch within 24 hours was only 50%, with the remainder requiring between five and sixteen days. One reaction took as long as 48 days. Suffice it to say that incineration does not suffer from these kinds of problems involving reaction kinetics and that combustion reactions are rapid (on the time scale of milliseconds) compared to neutralization. Furthermore, in the event of an upset with the neutralization process, one would have to contend with a large batch of partially reacted chemical agent while with incineration, the chemical agent flow would be stopped immediately.

d. The use of excess caustic to accelerate the neutralization reaction produced larger quantities of salt wastes than had been anticipated. Laboratory calculations showed that roughly 1.5 lb of salt should be produced for every pound of GB neutralized. The use of excess caustic generated an average of 2.6 lb of salt per pound of GB neutralized at RMA while 3 to 6 lb of salt were generated per pound of GB neutralized at CAMDS. With incineration, the ratio of pounds of salt generated (from the Pollution Abatement System brine) per pound of GB neutralized is fairly constant around 1.4 and is far less than that for neutralization.

e. The neutralization and hydrolysis reactions can be reversed under appropriate conditions to reform the original chemical agent. This is perhaps one of the most serious drawbacks to neutralization because of the environmental ramification. The reformation of miniscule amounts of GB occurred at both RMA and CAMDS. At RMA, it was during the process of drying the brine to salt. Acidic conditions, heat, and removal of water, all of which are conducive to reversing the hydrolysis of GB, were present in the brine drying environment.(28) Reformation of the chemical agent or reversal of the hydrolysis can be arrested by removing and/or separating the reaction products; for GB, these would be sodium fluoride and sodium isopropyl methylphosphonate. However, such removal and/or separation is tedious and costly. On the other hand, combustion and pyrolysis are generally irreversible reactions in which reformation of the original reactants from the combustion products is not plausible. The destruction and removal efficiency of incinerating chemical agent with scrubbing is 99.99995% for GB and 99.999996% for VX.

f. The form and the environment of the chemical agent agent also contributed to the complexity and slowness of the neutralization reaction if not the incomplete destruction of the chemical agent itself. The chemical agent substrate was not always in the desired form - liquid and not always homogeneous. The GB from M55 rockets were often jelled making it difficult to achieve proper mixing with caustic to promote optimum reaction conditions. Solid particles, rust, scale, etc. arising from slow degradation of the munition over the years were frequently mixed with the liquid chemical agent. The solid particles either encapsulated or absorbed the chemical agent and occluded it from neutralization. If occlusion did occur, the solid particles slowly released the chemical agent during and/or even after the caustic was added. The release of chemical agent during or after agitation was a much slower process than the neutralization reaction itself and may have been the rate-determining step and the explanation for the five to sixteen days to complete the reaction. These problems with the form and the environment (heterogeneity) of the substrate chemical agent encountered in neutralization would not be problems for incineration for the reason that in incineration, all chemical agent is converted into the gaseous phase. Thus, the fact that chemical agent is a gel, liquid, a liquid absorbed on metal, or a solid is immaterial; all of it is removed and transferred by volatilization. Furthermore, the destruction, i.e. combustion, takes place in the gaseous phase wherein the presence of solid particles basically do not interfere as they would in neutralization.

g. Certification that the chemical agent destruction was complete within specified limits, i.e., no more than 2 nanograms of GB per milliliter of brine, was often difficult and desultory. In terms of impact on throughput or processing rates, certification imposed a reduction factor of 24.(44) Many times, false positives were obtained due to the complexity of the matrix from which samples were taken for analysis. There were also many interferences with the testing for the presence of agent. Delays, whether they be caused by agitation to break-up a gel, slow release of agent occluded in solids, excessive cooling of the reaction mixture, precipitation from the reaction, or certification of the reaction mixture, magnify the risk of agent release in the event of an upset condition with the neutralization process. The causes of these delays are absent in the incineration process.

3.4.2 Quantity and Nature of Waste Produced.

The quantity of waste produced by neutralization under ideal conditions is supposed to be 1.472 lbs of salt/lb of GB neutralized which is comparable with that of incineration which is 1.471.(45) However, as previously mentioned, the typical quantities being encountered in practice were in the ratios of 2.6 to 6.0 for neutralization because of the sensitivity to caustic consumed. On the other hand, the ratio of 1.471 for incineration is fairly constant because combustion reactions are robust compared with neutralization reactions. The other characteristic of the waste products favoring incineration over neutralization is that products of combustion do not reform the chemical agent whereas it is possible for the products of neutralization to do so. A third characteristic of the waste products favoring incineration over neutralization is the fact that the products of combustion and the salts of the pollution abatement system brine are generally inorganic while those of neutralization are organic. Waste products that are organic in chemical structure are not in the state of ultimate disposal as are those having inorganic chemical structures. The inference is that neutralization is only a stop-gap method while incineration is an ultimate disposal method. Thus, incineration is preferable to neutralization as a disposal method.

3.4.3 Capital and Operating Costs.

A study by A.D. Little(45) showed that there is a net cost reduction in incinerating rather than neutralizing chemical agent. In particular, the study was made for the differential in cost in using incineration instead of neutralization for the Johnston Atoll Chemical Agent Disposal System. The result was that there was a net savings of $16.877 million in capital cost, a net savings of $2.714 million in operating cost, and a total net savings of $19.591 million. Additional cost savings are possible but not included in the total. It was assumed that two Metal Parts Furnace are used to destroy the agent in place of neutralization and that the operating costs are based on destruction of the Johnston Island stockpile of chemical agent/munitions. In analysis of the cost reduction, the authors attributed the predominant savings to capital costs for equipment in using incineration in lieu of neutralization. The predominant savings in operating costs were attributed to reduction/elimination of the consumption of chemical feedstocks (e.g. caustic or chlorine). Second-order savings in operating costs were attributed to reduced production of salts and reduced maintenance.

3.4.4 Neutralization's Limited Role.

a. Last but not least important is the fact that incineration was required to augment neutralization in disposal of chemical munitions. Because neutralization applies only to the agent, incineration had to be used to deactivate explosive/propellant components and to thermally decontaminate munition cavities and metal parts. At RMA, Deactivation, Inert Parts, and Decontamination Furnaces were used to accomplish these functions. At CAMDS, the DFS was used to accomplish both deactivation and decontamination while the MPF was used for both agent incineration and decontamination. Because incineration is required any way for part of the disposal, it was fruitful to explore its use for complete disposal of chemical munitions and thus, eliminate the need for the costly and complex neutralization process. Furthermore, only one instead of two disposal technologies would be needed simplifying operations.

b. In deciding on incineration for the Johnston Atoll Chemical Agent Disposal System (JACADS) on 9 March 1982 in a Configuration Policy Board Meeting, the Army officially adopted incineration and abandoned neutralization as the method for chemical agent/munitions disposal.(46)

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4.0.0 CHEMICAL AGENT AND MUNITION INCINERATION EXPERIENCE.

4.1.0 Introduction.

4.1.1 Purpose/Background.

a. The purpose of this chapter is to document the Army's chemical agent and munition incineration experience. Incineration has always been the preferred method of disposal for chemical agent mustard (see Chapter 2), and is the only approved method to ensure that an item, which has been in contact with a chemical agent, is completely clean (decontaminated).(1,2)

b. Because of the difficulties experienced with chemical neutralization of GB, and the uncertainties associated with "industrial scale" VX neutralization, the Army expanded the test program at CAMDS to include GB and VX incineration. The success of these tests, coupled with the problems experienced with GB neutralization, plus the fact that at least one incinerator would be required at each disposal facility to thermally decontaminate the agent containers, as well as burn any contaminated wood and trash, led to the Army's decision to select incineration as the best technology for chemical agent munition disposal.

4.1.2. 1984 NRC Study On Disposal Of Chemical Munitions and Agents.(3)

a. In 1982 the Department of the Army requested the NRC perform a study "to recommend the most effective, economical, and safest means for disposing of the Army's aging and obsolete stockpile of chemical agents and munitions." In response to the Army's request, the NRCs Commission on Engineering and Technical Systems established a committee on Demilitarizing Chemical Munitions and Agents under the Board of Army Science and Technology in August 1983.

b. The Committee, the first management group to study the whole range of U.S. chemical weapons since the 1969 NAS report(4), consisted of 25 members. In addition to members with expertise in chemistry, environmental science, toxicology, and industrial, mechanical, chemical and human factors engineering, members were also selected who had knowledge of law, public health, systems safety, industrial safety and the storage and handling of explosives.

c. With respect to the best methods for chemical stockpile disposal, the report stated:

> "Considering the above advantages and disadvantages of each disposal technology (neutralization and incineration), thermal destruction is the preferred means for disposing of the current stockpile of chemical agents and munitions. The Army has already selected thermal destruction as the most appropriate method. The Committee supports this decision."

4.1.3. Comparative Industry Experience.

a. Incineration is a safe and environmentally sound method of destroying toxic organic compounds where toxicity is a function of the entire compound (as in the case of chemical agents) rather than a specific toxic element, and is widely recognized as the principal method for organic waste disposal.(5, 6, 7) Incineration, which is the thermal breaking of organic compounds into simpler inorganic, innocuous compounds such as water, carbon dioxide and easily removed acid gases such as hydrogen chloride and sulfur dioxide, has been increasingly used by private industy to destroy polychlorinated biphenyls (PCBs), pesticides, herbicides and other commercial toxic organic compounds.

b. The role of incineration in commercial hazardous waste disposal is anticipated to increase with the enactment of the 1984 Hazardous and Solid Waste Amendments (HSWA) which greatly restricts land disposal of hazardous materials.

4.1.4. Chemical Agent Incineration. As shown in Tables 4-1 and 4-2, the Army has disposed of over six million pounds of chemical agents and over sixty thousand munitions and containers by incineration at CAMDS and the RMA disposal

TABLE 4-1. ROCKY MOUNTAIN ARSENAL CHEMICAL AGENT - MUNITION INCINERATION EXPERIENCE

AGENT	QUANTITY (LBS)	SOURCE	NUMBER	FURNACE	INCLUSIVE TIME PERIOD
H	4,428,000	Ton Containers	2456	Ton Container Furnace	Aug 72 - Feb 74
HD	1,714,000	Ton Containers	951	Hydrazine Furnace	
Multiple Agents	Approx 36,694	ID Sets	21,458	Deactivation Furnace Decontamination Furnace	May 81 - Dec 82

TABLE 4-2. CAMDS CHEMICAL AGENT - MUNITION INCINERATION EXPERIENCE

AGENT	QUANTITY (LBS)	MUNITION/SOURCE	NUMBER	FURNACE(1)	INCLUSIVE TIME PERIOD
GB	0(2)	Drained M55 Rockets	13,951	DFS	Sep 79 - Jun 81
GB	977	Ton Container (Sprayed)	—	MPF	Apr 81 - Nov 81
GB	5,357(3)	Drained 155mm Projectiles	9,157	MPF	Jul 81 - Feb 82; Jul 82
GB	1,140(3)	Drained 105mm Projectiles	7,771	MPF	Mar - Jun 82
GB	10,227	Ton Container (Sprayed)	—	MPF	Mar 82 - Jan 84
GB	17,570	Undrained 155mm Projectiles	2,703	MPF	Oct 82 - Dec 83
VX	7,866	Ton Container (Sprayed)	—	MPF	Jun - Aug 84
GB	2,331(4)	Drained M55 Rockets	4,357	DFS	Nov 85 - May 86; Nov 86
GB	37,930	Ton Container/Drained M55 Rockets	—	LIC	Aug 85 - Aug 86

Notes:
(1) DFS - Deactivation Furnace System
MPF - Metal Parts Furnace
LIC - Liquid Incinerator
(2) Rockets were flushed with decontamination solution while being cut into segments (Chapter 3). It is assumed that no residual agent remained in the rocket when it was incinerated.
(3) Assumed 9% residual remained in projectile after draining. Agent from 105 and 155mm projectiles was mixed before it was neutralized (Chapter 3). Percent residual is based on the difference between total agent fill weight and total agent neutralizated.
(4) Assumed 5% residual remained in the warhead after agent had been drained.

plants. In addition to the industrial-scale experience from RMA and CAMDS, the Army has conducted extensive tests at its laboratories located in the Edgewood Area of Aberdeen Proving Ground, Maryland.(8, 9, 10, 11) Figure 4-1 illustrates the incineration reactions for nerve agents GA, GB and VX, and Figure 4-2 illustrates the incineration reactions for blister agents H/HD, HT and L.

4.2.0. Rocky Mountain Arsenal Chemical Agent Incineration Programs. Two major chemical agent demilitarization programs using incineration as the method for chemical agent destruction have been accomplished at RMA. The first program, designated Project Eagle - Phase I, was conducted from August 1972 through February 1974 and disposed of approximately 6,179,000 pounds of blister agent mustard (H/HD). The second program involved the disposal of over 21,000 chemical agent identification sets (CAISs) which contained eight chemical agents totaling 36,694 pounds. Table 4-3 lists the amount and type of each chemical agent incinerated at RMA during both programs.

4.2.1. Project Eagle - Phase I.(12)

a. Background/Overview.

(1) The purpose of Project Eagle - Phase I was to demilitarize the excess stocks of chemical agent mustard which had been stored at RMA since the early 1940s. As described in Chapter Two, these stocks were scheduled for disposal by ocean dumping in Operation CHASE. However, after receipt of the NAS report, the DOD abandoned the proposed ocean dump and initiated Project Eagle - Phase I to dispose of the mustard filled ton containers by incineration at RMA.

(2) Two types of mustard were disposed of during Project Eagle - Phase I, H and HD. Type H mustard was made by the Levinstein process and contains as much as 30 weight percent impurities which tend to settle out when stored. These impurities are chiefly sulfur, organosulfur chlorides, polysulfides and iron oxide corrosion products. Type HD mustard is type H mustard which has been vacuum distilled to remove the majority of the sulfur impurities; HD

1. **GB (Sarin), CAS No. 107-44-8**

$C_4H_{10}FO_2P$	$+$	$6\ 1/2\ O_2$	$\longrightarrow$	$4CO_2$	$+$	$4\ 1/2\ H_2O$	$+$	HF	$+$	$1/2\ P_2O_5$	
GB		Oxygen		Carbon Dioxide		Water		Hydrogen Fluoride		Phosphorous Pentoxide	

2. **VX, CAS No. 50782-69-9**

$C_{11}H_{26}NO_2PS$	$+$	$19\ 3/4\ O_2$	$\longrightarrow$	$11\ CO_2$	$+$	$13\ H_2O$	$+$	NO_2	$+$	SO_2	$+$	$1/2\ P_2O_5$	
VX		Oxygen		Carbon Dioxide		Water		Nitrogen Dioxide		Sulfur Dioxide		Phosphorous Pentoxide	

3. **GA (Tabun), CAS No. 77-81-6**

$C_5H_{11}N_2O_2P$	$+$	$10\ O_2$	$\longrightarrow$	$5\ CO_2$	$+$	$5\ 1/2\ H_2O$	$+$	$2\ NO_2$	$+$	$1/2\ P_2O_5$
GB		Oxygen		Carbon Dioxide		Water		Nitrogen Dioxide		Phosphorous Pentoxide

Figure 4-1: Nerve Agent Incineration Reactions

1. H/HD (Levinstein/Mustard/Distilled Mustard), CAS No. 505-60-2

$C_4H_8Cl_2S$	+	$6\ 1/2\ O_2$	$\longrightarrow$	$4\ CO_2$	+	$3\ H_2O$	+	$2\ HCl$	+	SO_2
H/HD		Oxygen		Carbon Dioxide		Water		Hydrogen Chloride		Sulfur Dioxide

2. HT (60 wt % HD, 40 wt % T), CAS Nos. 505-60-2 & 63918-89-8

$(C_8H_{16}Cl_2OS_2$	+	$2\ 1/2\ C_4H_8Cl_2S)$	+	$29\ 1/4\ O_2$	$\longrightarrow$	$18\ CO_2$	+	$14\ 1/2\ H_2O$	+	$7\ HCl$	+	$4\ 1/2\ SO_2$
T		HD		Oxygen		Carbon Dioxide		Water		Hydrogen Chloride		Sulfur Dioxide

3. L (Lewisite), CAS No. 541-25-3

$C_2H_2A_sCl_3$	+	SO_2	+	$1/2\ C_3H_8$	$\longrightarrow$	$3\ 1/2\ CO_2$	+	$1\ 1/2\ H_2O$	+	$3\ HCl$	+	$1/2\ As_2O_3$
L		Oxygen		Propane		Carbon Dioxide		Water		Hydrogen Chloride		Arsenic Oxide

Figure 4-2: Blister Agent Incineration Reactions

TABLE 4-3. Chemical Agents Incinerated at RMA

PROJECT	AGENT	QUANTITY (POUNDS)
Project Eagle		
	Levinstein Mustard (H)	4,428,000
	Distilled Mustard (HD)	1,714,000
	TOTAL	6,142,000
Chemical Agent Identification Set Disposal		
	Phosgene (CG)	17,698
	Chloropicrin (PS)	10,196
	Mustard (H/HD)	6,355
	Lewisite (L)	1,385
	Cyanogen Chloride (CK)	433
	Nitrogen Mustard (HN-1)	207
	Mustard Gas (HS)	187
	Nitrogen Mustard (HN-3)	187
	Sarin (GB)	46
	TOTAL	36,694
TOTAL FOR BOTH PROGRAMS		6,178,694

contains about 92 to 95 percent pure 2,2'dichlorodiethyl sulfide. When disposed of in Project Eagle - Phase I, both types of mustard were stored in Type D ton containers similar to the one shown in Figure 4-3, however a large portion of the Levinstein mustard had been drained from obsolete and deteriorating 155mm, 105mm and 75mm projectiles during the 1947 to 1950 time frame when these munitions were demilitarized.

(3) The entire project ran from October 1969 through July 1974, however, full scale disposal operations were only conducted from August 1972 through February 1974; the balance of the time was involved with process development, testing in support of the CAMDS program (which was being designed during this time period), and plant/facility cleanup after all the mustard agent had been incinerated. Disposal operations were conducted on a three shift basis and were broken into three phases;

(a) Phase I: August 1972 - May 1973, work up to bulk mustard incineration at one gallon per minute.

(b) Phase II: June 1973 - September 1973, work up to bulk mustard incineration at two gallons per minute.

(c) Phase III: October 1973 - February 1974, incineration of residue ton containers which had not been incinerated during Phases I and II.

b. Process Description.

(1) Disposal operations were conducted in the plants area of RMA (Figure 2-9). Figure 4-4 illustrates the final Project Eagle - Phase I process configuration. Although the exact equipment/process configuration changed and evolved through the life of the project, the basic concept remained the same and consisted of the following elements:

(a) Ton container preheating and draining.

(b) Agent incineration and ton container thermal decontamination.

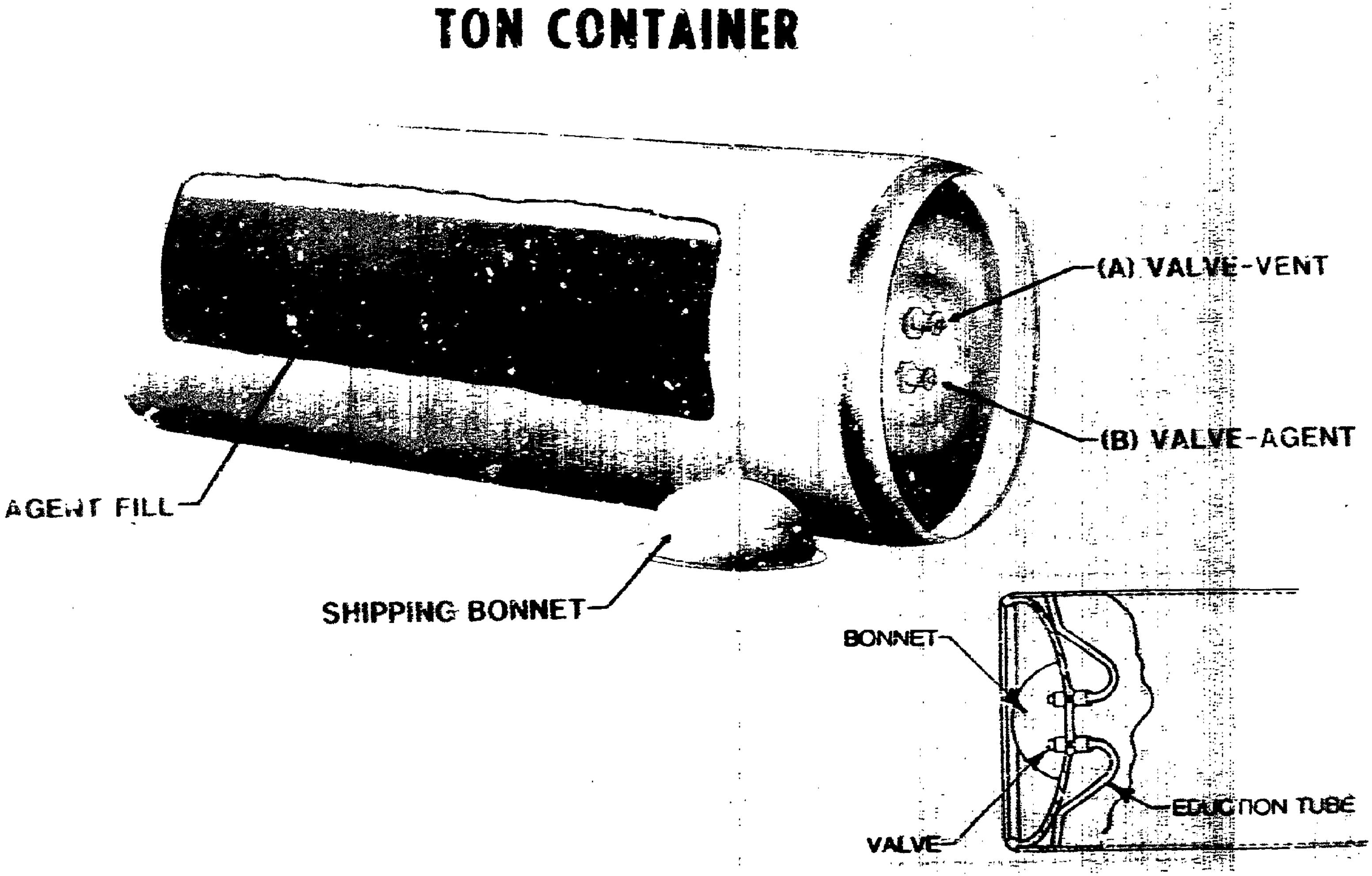


Figure 4-3: Ton Container

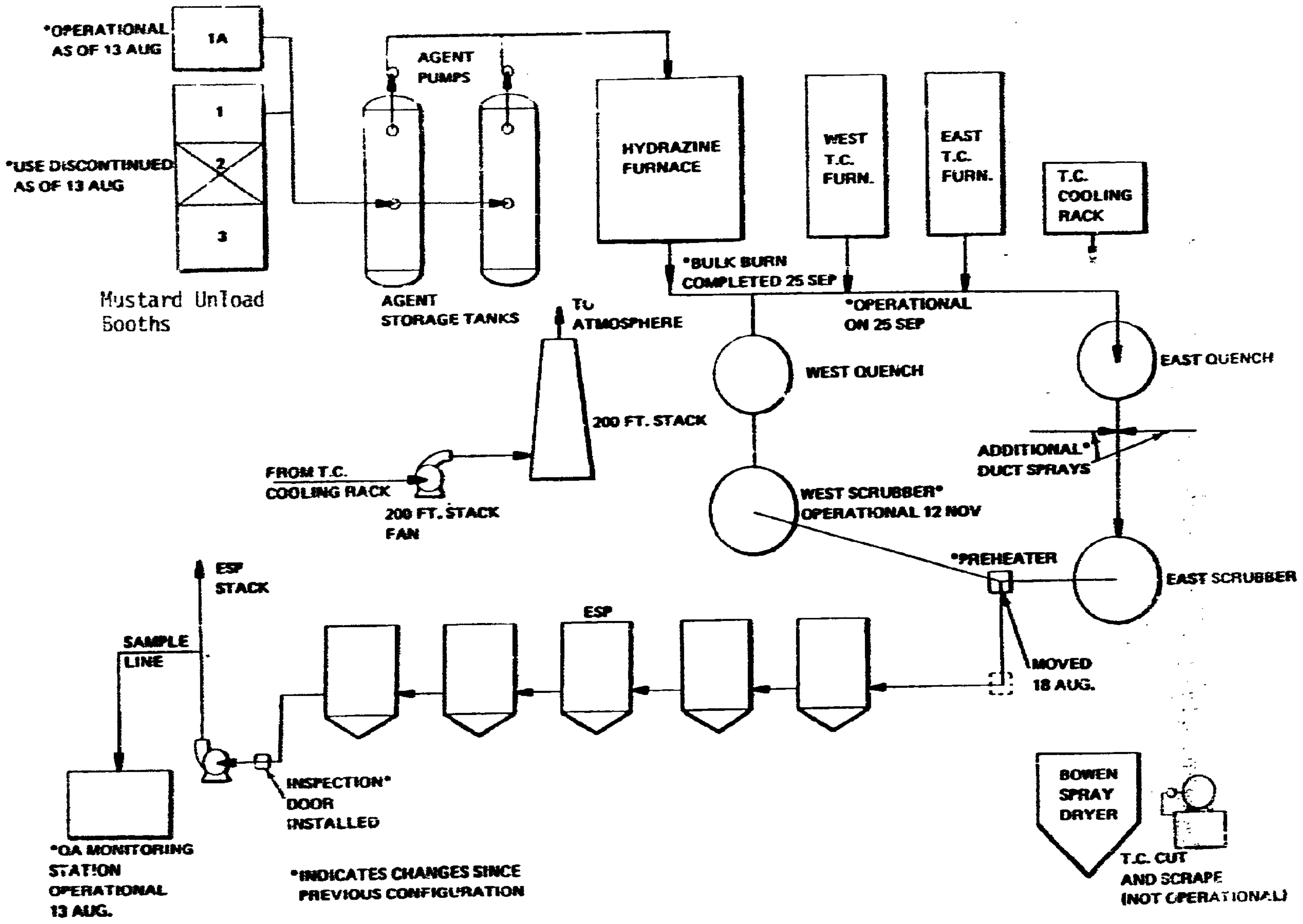


Figure 4-4: Final Project Eagle Process Configuration

(c) Furnace emission control.

(d) Waste treatment and disposal.

(2) Ton Container Preheating and Draining. Because of the high freezing point and viscosity of mustard (mustard freezes at about 58°F and is about as thick as fuel oil), the ton containers were placed in a heated thaw room after they were transferred from the outdoor storage yard. The thaw room was maintained at a room temperature of 90° to 140°F (average 125°F). The warmed ton containers were then placed in one of four mustard unloading booths. The mustard was drained from the ton containers into two 2600 gallon storage tanks located beneath the booths through high pressure, reinforced hoses which were connected to the ton container valves. Negative storage tank pressure was used to draw the mustard from the ton container. After draining, the ton containers which had stored HD had a residue heel which averaged 100 pounds (6%), however the drained H ton containers had an average residue heel of 600 pounds (33%) with some containers containing heels as great as 1400 pounds (78%).

(3) Agent Incineration and Ton Container Thermal Decontamination

(a) Agent Incineration. The primary incinerator for the drained mustard was the modified hydrazine furnace which had previously been used to burn contaminated liquid hydrazine (a common component of liquid fuel rocket motors). Prior to the hydrazine furnace, the west ton container furnace (see Figure 4-4) was used to incinerate the mustard drained from the ton containers. The hydrazine furnace, which is illustrated in Figure 4-5, was a horizontal barrel type incinerator. It did not have a separately fired afterburner but used the large residence time between the combustion chamber (Figure 4-5) and the pollution abatement system to ensure complete destruction of all organics contained in the exhaust gases. Mustard was sprayed into the furnace through an air atomizing nozzle with the agent leaving the nozzle through ten radial 1/8 inch orifices. A ring gas burner surrounding the nozzle was used to heat the furnace up to approximately 2400°F at which time the

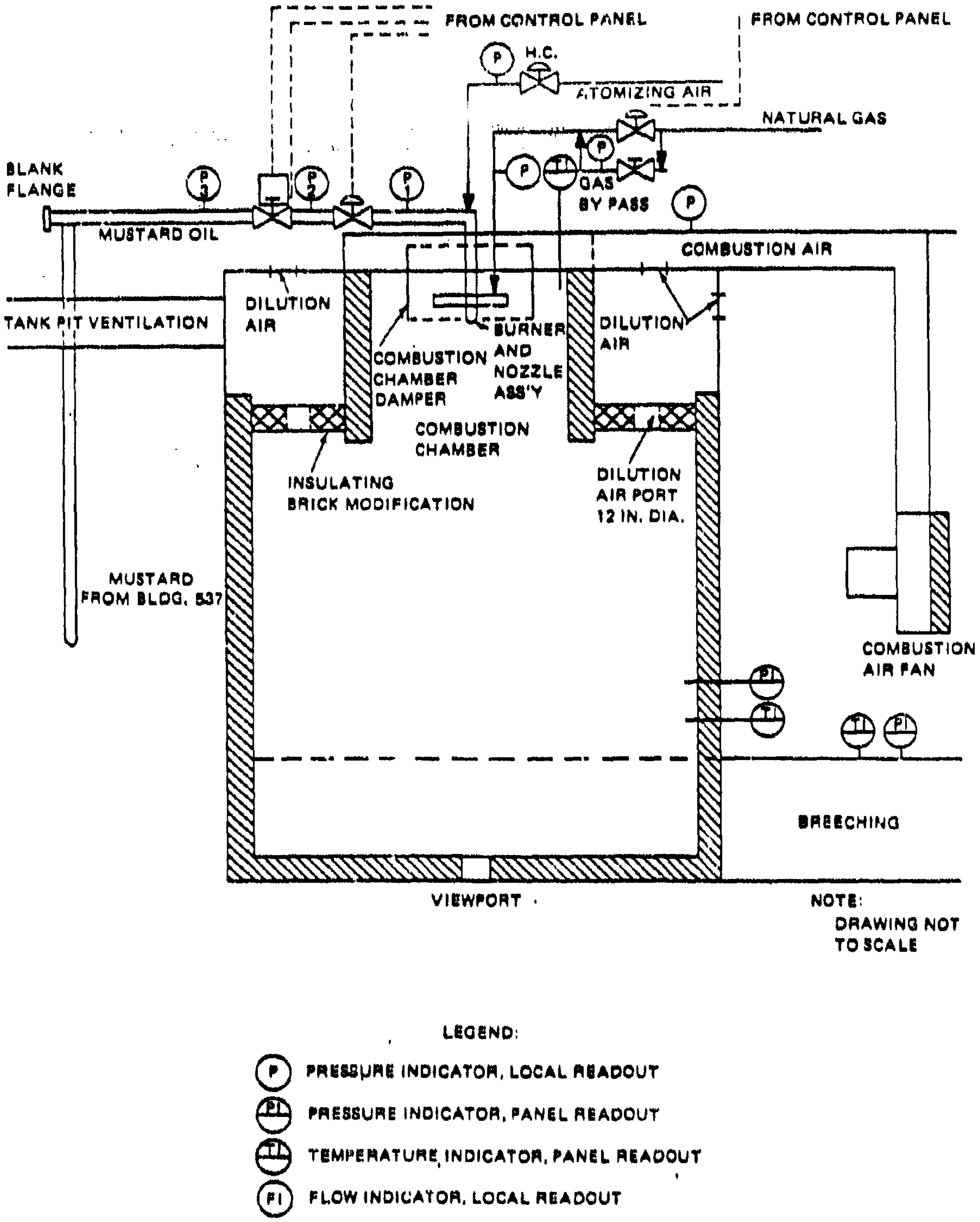


Figure 4-5: Project Eagle Hydrazine Furnace

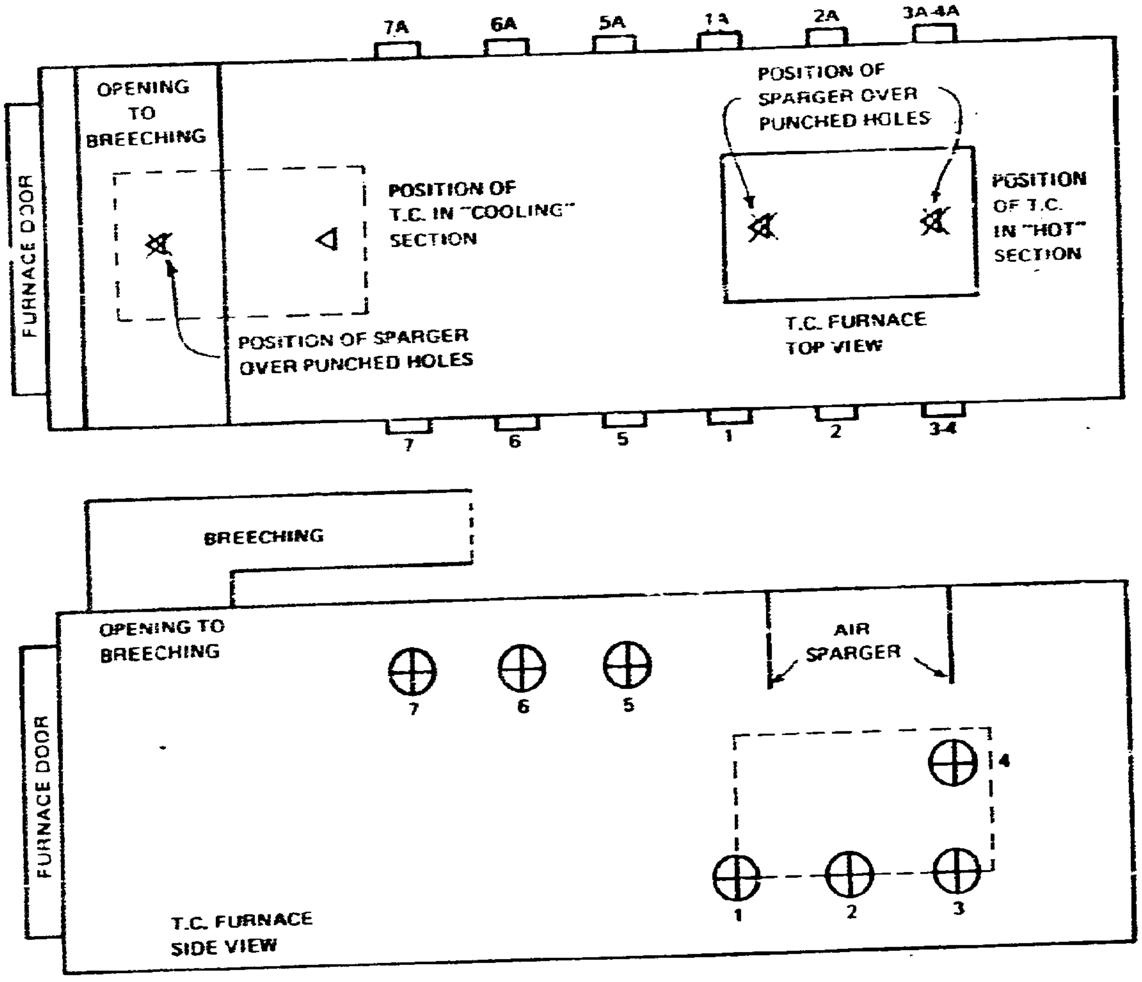
mustard was introduced and the natural gas was slowly cut back to idle. The furnace had a nominal capacity of two gallons mustard per minute.

(b) Ton Container Thermal Decontamination. Adjacent to the hydrazine furnace were two ton container furnaces which were used to incinerate the residue heel left in the ton container after it had been drained. The furnaces had been constructed in 1944 to thermally decontaminate 55 gallon drums of mustard. As shown in Figure 4-6, the west furnace (Figure 4-4) had eight natural gas burners whereas, the east furnace had fourteen of the same type burner. The additional burners in the east furnace were added to facilitate processing ton containers which had large residue heels. Burners 7 and 7a in both furnaces were considered afterburners. After weighing, the ton containers were positioned under the punching station at the door of either furnace where two holes were punched into the ton container, one at each end. The ton container was then transferred to the south end of the furnace where an air sparge was inserted in each punch hole to facilitate residue burnout. Each furnace was normally maintained at 920°F and processed an average of seven ton containers per day.

(c) Pollution Abatement System (PAS). The PAS consisted of two caustic quench and scrubber systems which were connected to a single electrostatic precipitator and stack. The east quench and scrubber system was the original PAS for the ton container decontamination furnaces; the west quench and scrubber system was added in October 1973 to support the increased flowrate during the final phase of the program. The electrostatic precipitator was added in May 1973 to ensure that particulate emission and stack opacity limits were met (Iron oxide (rust) had presented a particulate emissions problem). The east quench/scrubber, west quench/scrubber, and electrostatic precipitator are illustrated in Figures 4-7, 4-8 and 4-9 respectively.

(d) Waste Treatment.

1 All waste water and scrubber brines generated by the disposal of the mustard were dried into a salt using a spray dryer. There were no liquid process effluents discharged from the mustard disposal plant. The brine



NOTE

BURNERS 4, 4A
5, 5A
6, 6A
ARE NOT LOCATED
IN THE WEST
FURNACE
BURNERS 7 AND 7A
ARE REFERRED TO
AS "AFTER BURNERS"
DRAWING TO APPROX.
SCALE ONLY
REFER TO TECHNICAL
DATA PACKAGE FOR
FURNACE SPECIFIC
DIMENSIONS

Figure 4-6: Project Eagle Ton Container Furnaces

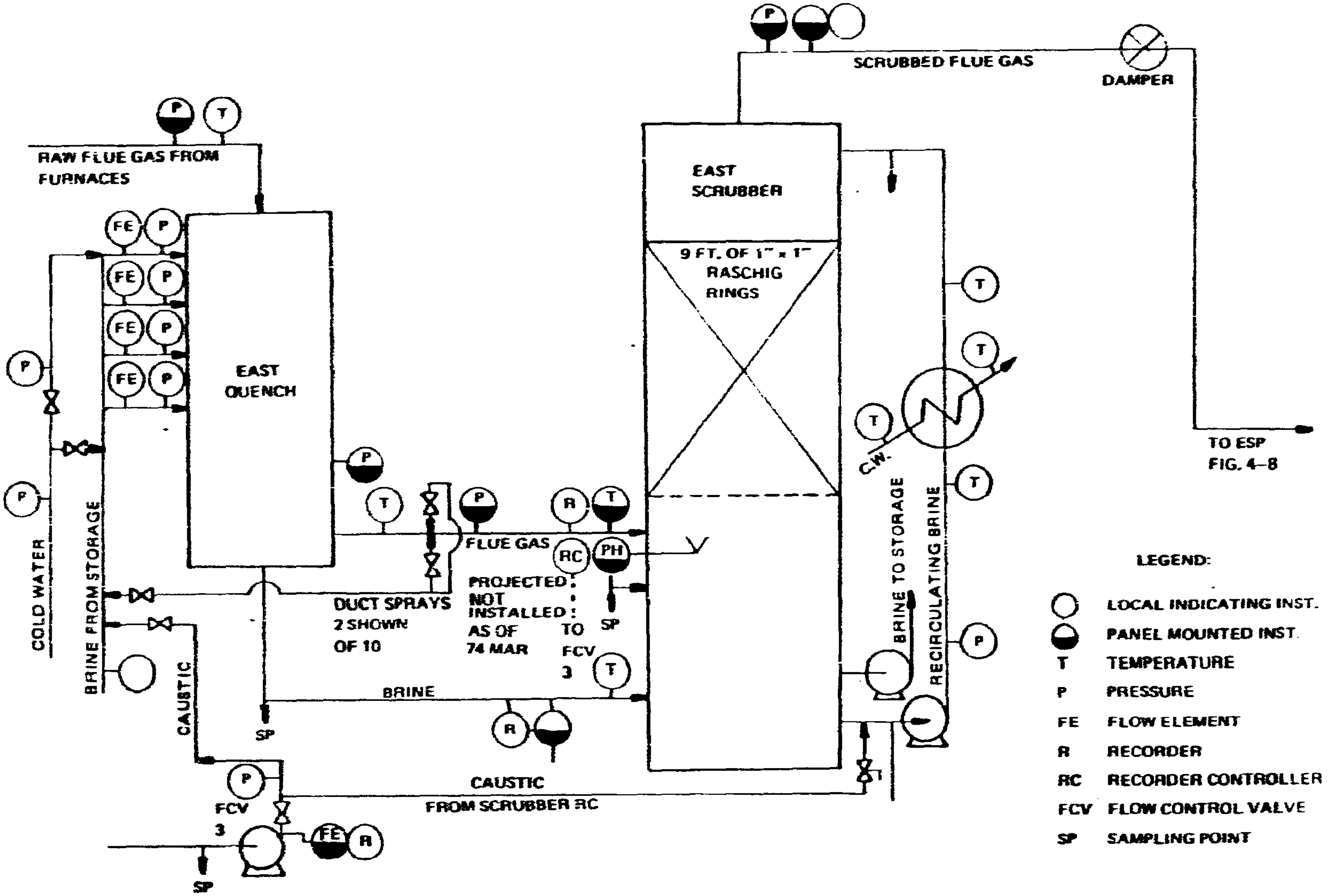


Figure 4-7: Project Eagle East Quench/Scrubber System

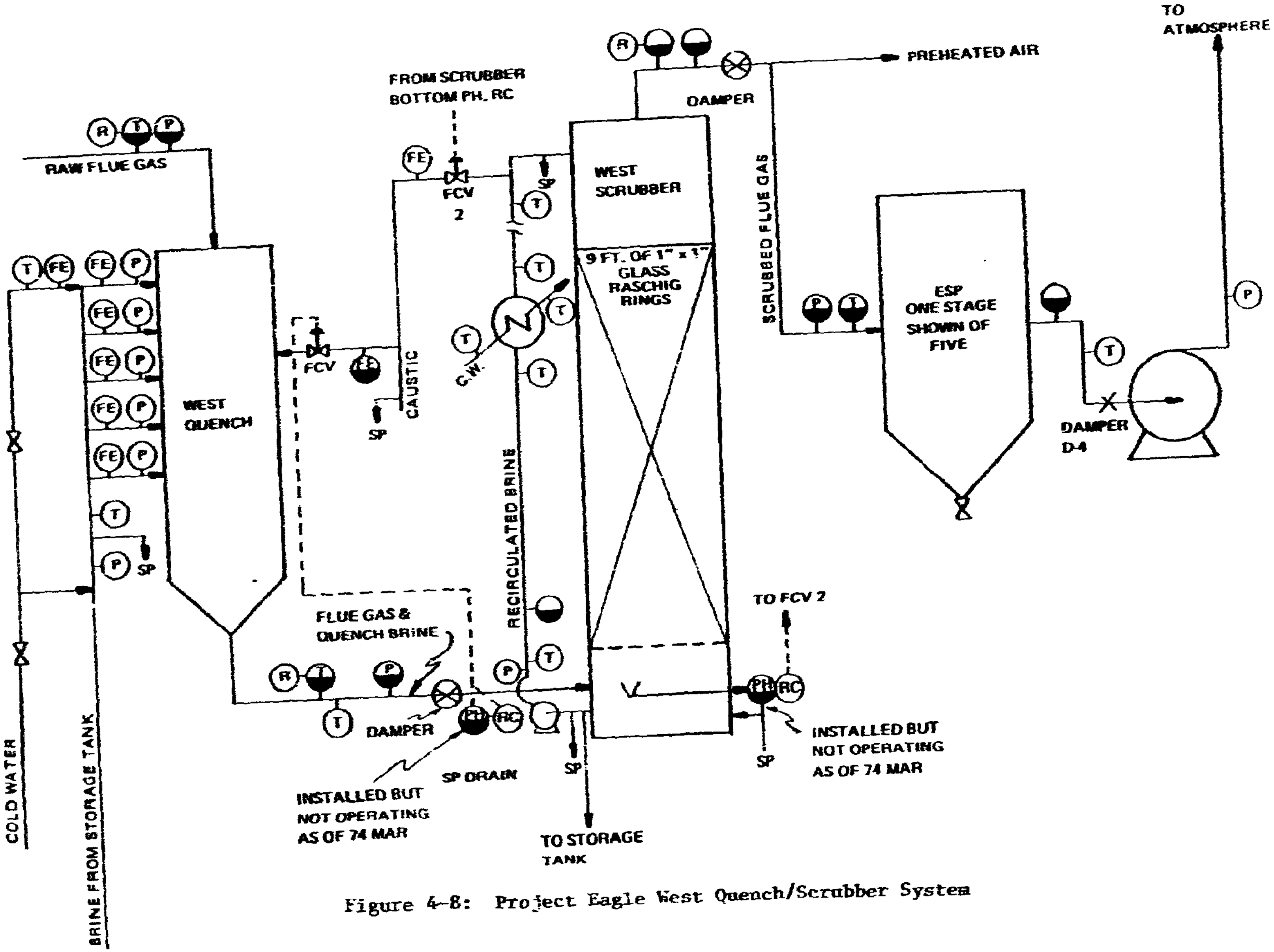


Figure 4-8: Project Eagle West Quench/Scrubber System

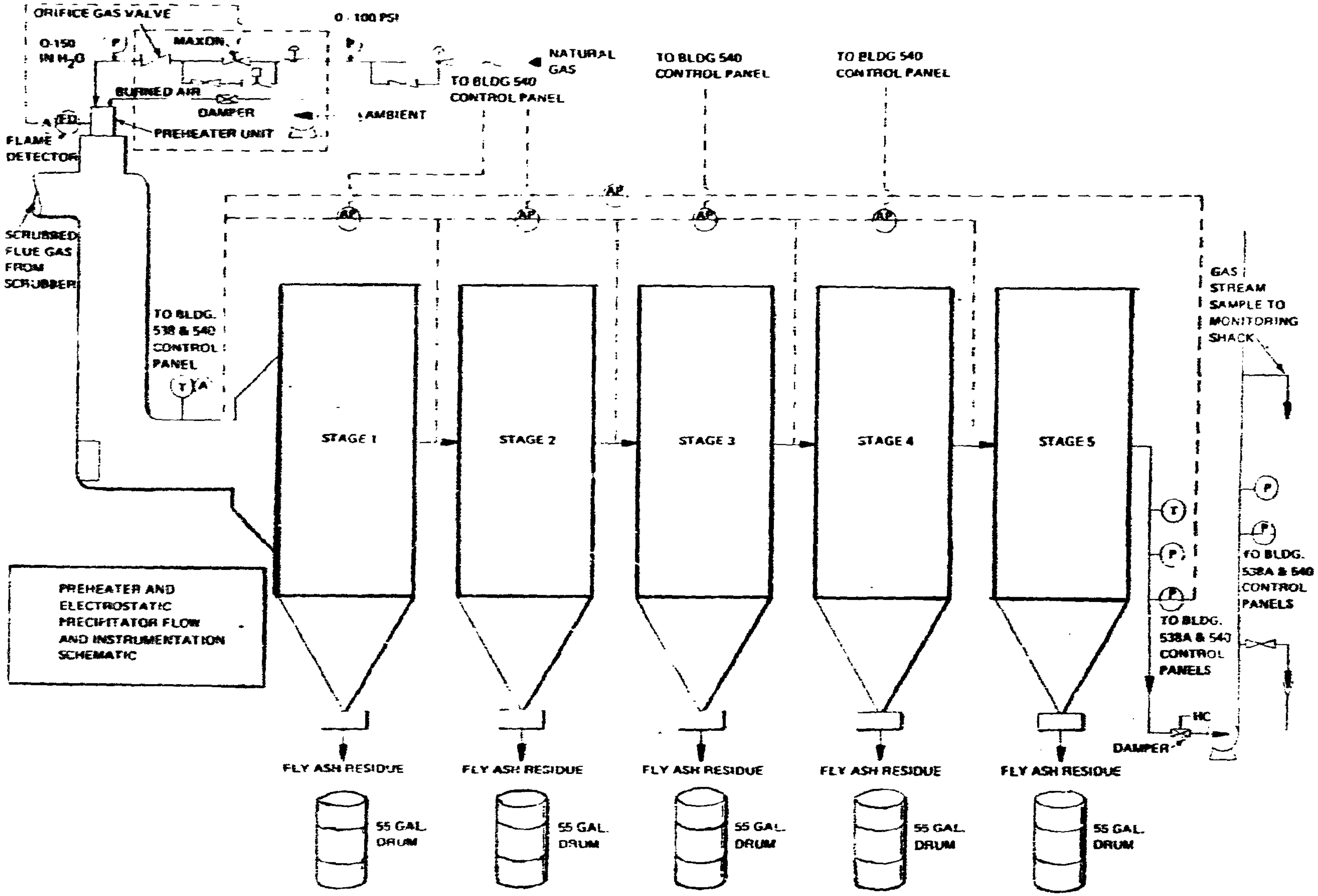


Figure 4-9: Project Eagle Electrostatic Precipitator

was atomized into a drying chamber maintained at 800° to 1150°F. The dried product and hot air were separated in cyclonic separators, fines were removed from the gas stream by a venturi scrubber and a wet cyclonic scrubber. The salt from the cyclone was fed into a compactor and subsequently placed in sealed 55 gallon drums.

2 The agent free ton containers were cut in half. The ash residue (primarily iron oxide and sulfur) remaining after incineration was removed by manual scraping with hoe like tools. The ash was placed in sealed 55 gallon drums. The ton containers were sold as metal scrap.

c. Environmental Concerns.

(1) Air Quality.

(a) Table 4-4 lists the work area and stack standards for Project Eagle - Phase I. Because a fast response stack alarm was beyond the state-of-the-art, two separate detection systems were used: (a) a quick response (4 min) dual column gas chromatograph alarm with a detection limit of 0.5 mg/m^3, and (b) a dibutylphthalate bubbler adsorption system which could detect an average concentration of 0.03 mg/m^3 over a 60 minute cycle. If either system detected mustard emissions, operations were immediately curtailed. The work area was also monitored with a dual system: (a) a Titrilog II instrument provided rapid response (30-60 sec) to mustard concentrations above 0.8 mg/m^3, and (b) a two hour dibutylphthalate bubbler system was used to detect the work area concentration of 0.004 mg/m^3.

(b) In addition to the stack and work area monitoring described above, a network of nine perimeter monitoring stations, shown in Figure 4-10, were operated during Project Eagle - Phase I. The stations were also operated from October through December 1969 to establish the baseline air quality. Each station continuously monitored for NO_2, SO_2, ozone, and suspended particulates, with sequential samples on a six hour cycle monitor for HCl mist. An analysis by the U.S. Army Environmental Hygiene Agency (AEHA) concluded that Project Eagle - Phase I had no significant impact on the ambient

TABLE 4-4. Project Eagle Air Quality Standards

POLLUTANT	STANDARD
Mustard (H or HD)	Emission Standard of 0.03 mg/m^3 (one hour average) Work Area Standard of 0.004 mg/m^3 (eight hour average)
Sulfur Dioxide (SO_2)	Annual Arithmetic Mean - 0.02 ppm 24 hr Max Value - 0.1 ppm(1) 3 hr Max Value - 0.5 ppm(2) 1 hr Max Value - 0.28 ppm(3)
Acid Mist (reported as HCl)	0.015 ppm
Nitrogen Dioxide	Annual Arithmetic Mean - 0.05 ppm
Particulates	Annual Geometric Mean - 60 ug/m^3 24 hr Max Value - 150 ug/m^3 (2)
Oxidants	1 hr Max Value - 0.05 ppm

NOTES:

(1) Not to be exceeded more than once in any twelve month period.
(2) Not to be exceeded more than once per year.
(3) Not to be exceeded more than once per month.

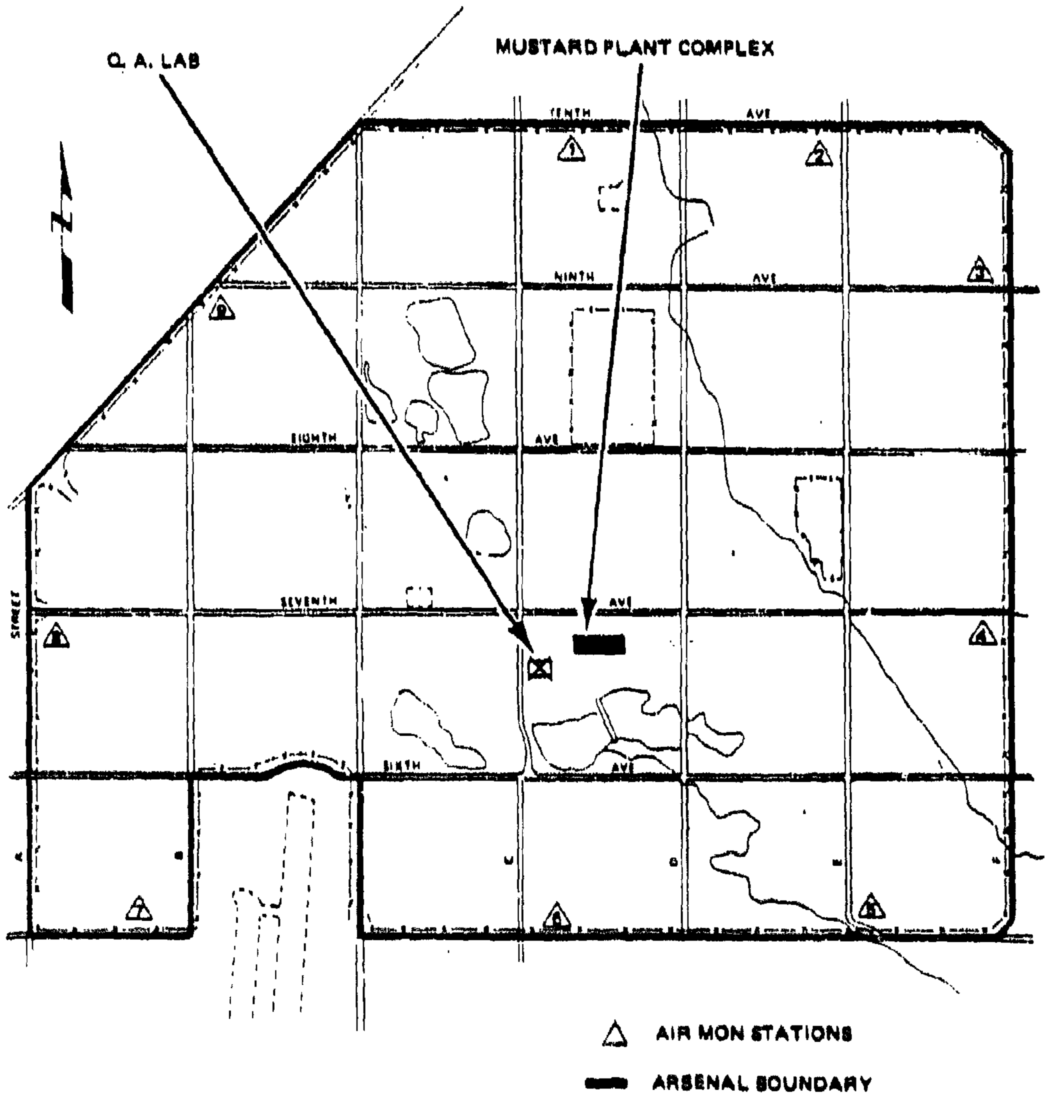


Figure 4-10: Project Eagle - Phase I Perimeter Monitoring System

air quality.(13)

(2) Salt Analysis and Disposal.

(a) A total of 14 million pounds of salt formed by dried brine during Project Eagle - Phase I. This is equal to a salt production rate of 2.3 pounds of salt per pound of mustard incinerated. The salts were placed in sealed steel or fiber board 55 gallon drums and stored in warehouses at RMA until 1985 at which time they were placed in a hazardous waste landfill.

(b) Table 4-5 is a typical chemical analysis of the salts formed by the dried brine. However, the composition of the salts was found to vary widely. Table 4-6 lists the results from the analysis of a composite sample to determine if the mustard incineration salts were a hazardous waste under the Resource Conservation and Recovery Act (RCRA) due to Extraction Procedure (EP) Toxicity.(14) Although the salts were found not to be a characteristic hazardous waste due to EP Toxicity, the salts were treated as hazardous waste due to the potential variability in the salt composition, as well as their origin as a toxic chemical agent. Prior to disposal, several samples were analyzed for the presence of tetrachlorodibenzo-p-dioxins (TCDDs) and tetrachlorodibenzo furans (TCDFs). No TCDDs were detected in any samples; TCDFs were detected in three samples in the parts per trillion range (130-270 ppt).(15)

(3) Ton Container Ash and ESP Residue. The ash and residue generated during Project Eagle - Phase I were disposed of by land dilution. Based on analyses performed by Coors Spectro Chemical Laboratories, Figures 4-11 and 4-12, a dilution criteria requiring that the material be mixed to a depth of six inches and that the concentration of any element in the soil not be increased by more than 0.05 percent was established. A 120 acre tract and a 320 acre tract were designated in the northeast corner of the Arsenal for the disposal of the ton container ash and ESP residue respectively. A total of 222,063 pounds of (wet) ash and 63,158 pounds of (dry) ESP residue were disposed of in this manner. Permanent metal stakes mark the area where both materials were disposed of.

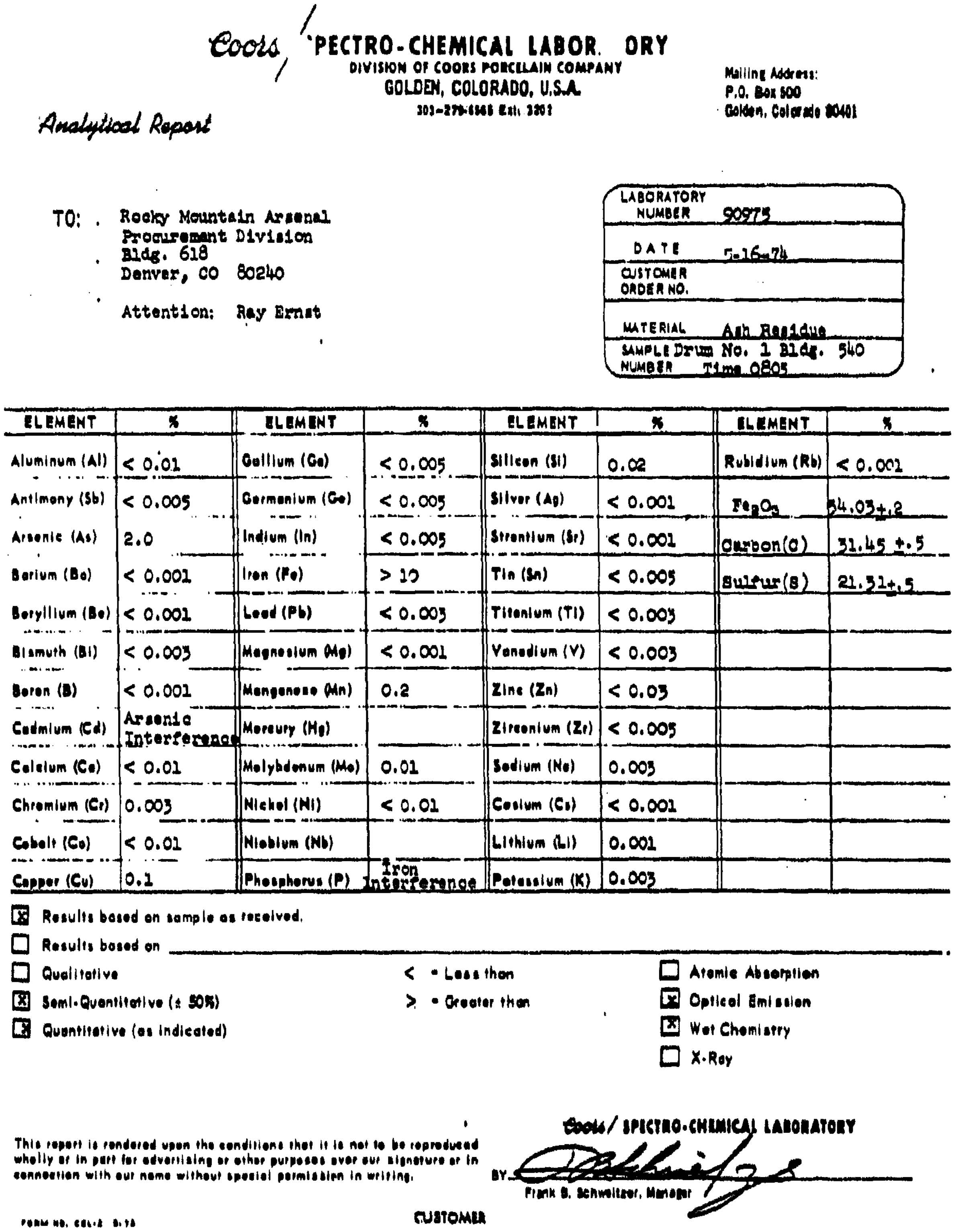
TABLE 4-5. Mustard Salt Chemical Analysis

COMPOUND	AMOUNT
NaCl	44.3%
Na_2SO_3	23.6%
$NaHCO_3$	5.9%
Na_2SO_4	15.7%
Na_2CO_3	11.9%
Fe_2O_3	0.2%
Mercury	1.03 ppm
Cadmium	1.60 ppm
Copper	5.30 ppm
Zinc	3.50 ppm
Lead	5.0 ppm
Manganese	25 ppm
Silver	2.5 ppm
Molybdenum	0.1 ppm
Potassium	0.7 ppm
Sodium	250 ppm
Soluble Iron	147 ppm
Insoluble Iron	2315 ppm

TABLE 4-6: EP Toxicity Analyses of Mustard Incineration Salts

PARAMETER	RCRA Limit (mg/l)	CONCENTRATION, mg/l (1) Sample D1 Split A	Sample D1 Split B	Sample D2 Split A	Sample D2 Split B
Arsenic	5.0	1.75	1.75	1.97	1.91
Barium	100.0	0.015	0.06	<0.01	<0.01
Cadmium	1.0	0.0024	0.017	0.004	0.0094
Chromium	5.0	<0.025	<0.025	<0.025	<0.025
Lead	5.0	0.041	0.054	0.426	0.290
Mercury	0.2	0.0069	0.0073	0.0095	0.009
Selenium	1.0	0.543	0.175	0.043	0.14
Silver	5.0	0.02	0.015	0.01	0.01
Organics	—			Organics Detected (2)	

NOTES:
(1) Mustard salt samples were collected from random drums which were not numbered.
(2) The following organic compounds were detected, however the concentrations were very small and were not quantified: p-chlorophenyl-methyl sulfene, 2-cyclohexen-1-one, and 4-chlorocyclohexanol.



Coors/SPECTRO-CHEMICAL LABORATORY
DIVISION OF COORS PORCELAIN COMPANY
GOLDEN, COLORADO, U.S.A.
303-279-6565 Ext. 3201

Mailing Address:
P.O. Box 500
Golden, Colorado 80401

Analytical Report

TO: Rocky Mountain Arsenal
Procurement Division
Bldg. 618
Denver, CO 80240

Attention: Ray Ernst

LABORATORY NUMBER	90975
DATE	5-16-74
CUSTOMER ORDER NO.	
MATERIAL	Ash Residue
SAMPLE NUMBER	Drum No. 1 Bldg. 540 Time 0805

ELEMENT	%	ELEMENT	%	ELEMENT	%	ELEMENT	%
Aluminum (Al)	< 0.01	Gallium (Ga)	< 0.005	Silicon (Si)	0.02	Rubidium (Rb)	< 0.001
Antimony (Sb)	< 0.005	Germanium (Ge)	< 0.005	Silver (Ag)	< 0.001	Fe_2O_3	54.03±.2
Arsenic (As)	2.0	Indium (In)	< 0.005	Strontium (Sr)	< 0.001	Carbon(C)	31.45 ±.5
Barium (Ba)	< 0.001	Iron (Fe)	> 10	Tin (Sn)	< 0.005	Sulfur(S)	21.31±.5
Beryllium (Be)	< 0.001	Lead (Pb)	< 0.003	Titanium (Ti)	< 0.003		
Bismuth (Bi)	< 0.003	Magnesium (Mg)	< 0.001	Vanadium (V)	< 0.003		
Boron (B)	< 0.001	Manganese (Mn)	0.2	Zinc (Zn)	< 0.03		
Cadmium (Cd)	Arsenic Interference	Mercury (Hg)		Zirconium (Zr)	< 0.005		
Calcium (Ca)	< 0.01	Molybdenum (Mo)	0.01	Sodium (Na)	0.003		
Chromium (Cr)	0.003	Nickel (Ni)	< 0.01	Cesium (Cs)	< 0.001		
Cobalt (Co)	< 0.01	Niobium (Nb)		Lithium (Li)	0.001		
Copper (Cu)	0.1	Phosphorus (P)	Iron Interference	Potassium (K)	0.003		

☒ Results based on sample as received.
☐ Results based on ____________________
☐ Qualitative
☒ Semi-Quantitative (± 50%)
☒ Quantitative (as indicated)

< = Less than
> = Greater than

☐ Atomic Absorption
☒ Optical Emission
☒ Wet Chemistry
☐ X-Ray

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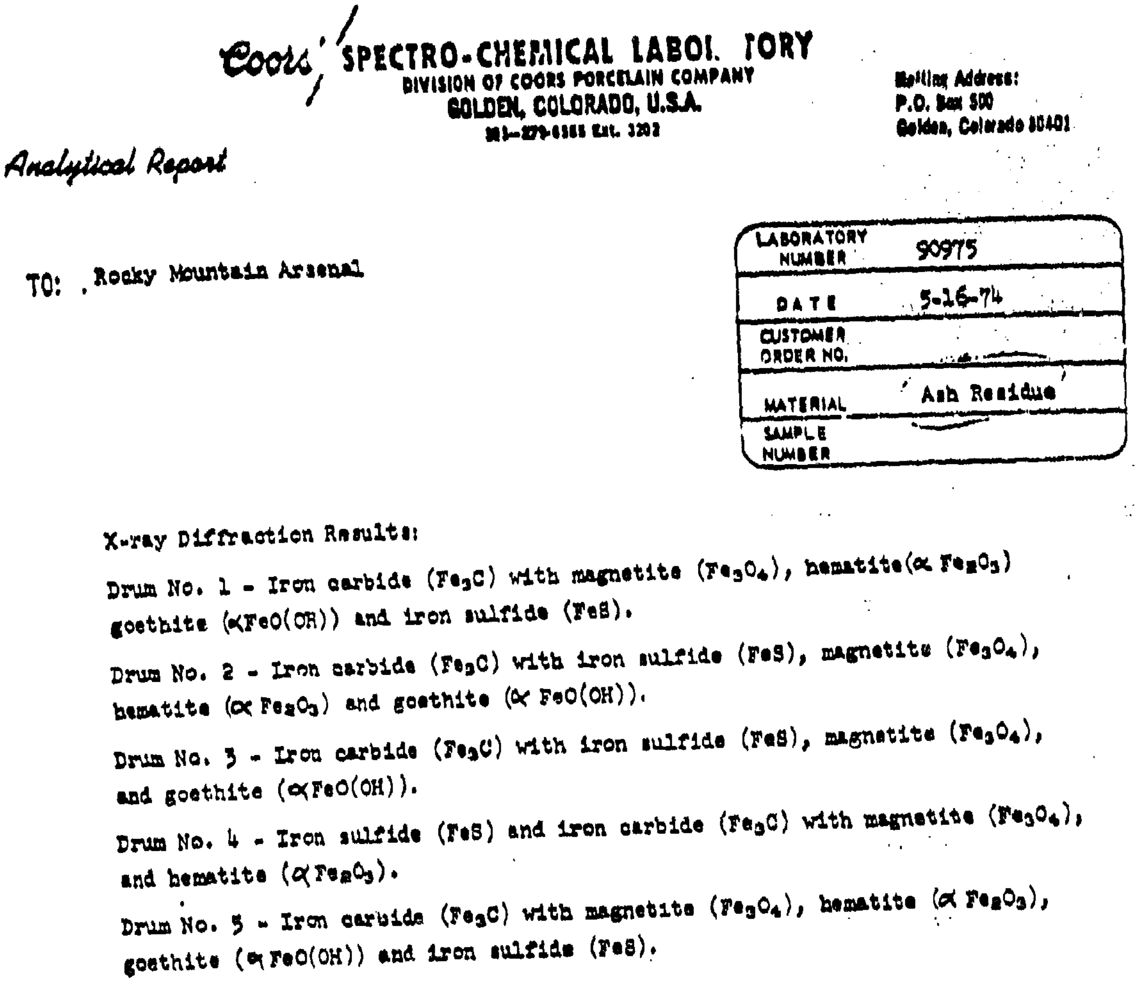
BY
Frank B. Schweitzer, Manager

FORM NO. [illegible]

CUSTOMER

Figure 4-11: Project Eagle Ton Container Ash Analysis



Coors SPECTRO-CHEMICAL LABORATORY
DIVISION OF COORS PORCELAIN COMPANY
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Analytical Report

TO: Rocky Mountain Arsenal

LABORATORY NUMBER 90975
DATE 5-16-74
CUSTOMER ORDER NO.
MATERIAL Ash Residue
SAMPLE NUMBER

X-ray Diffraction Results:

Drum No. 1 - Iron carbide (Fe_3C) with magnetite (Fe_3O_4), hematite(α Fe_2O_3) goethite (αFeO(OH)) and iron sulfide (FeS).

Drum No. 2 - Iron carbide (Fe_3C) with iron sulfide (FeS), magnetite (Fe_3O_4), hematite (α Fe_2O_3) and goethite (α FeO(OH)).

Drum No. 3 - Iron carbide (Fe_3C) with iron sulfide (FeS), magnetite (Fe_3O_4), and goethite (αFeO(OH)).

Drum No. 4 - Iron sulfide (FeS) and iron carbide (Fe_3C) with magnetite (Fe_3O_4), and hematite (α Fe_2O_3).

Drum No. 5 - Iron carbide (Fe_3C) with magnetite (Fe_3O_4), hematite (α Fe_2O_3), goethite (α FeO(OH)) and iron sulfide (FeS).

Figure 4-12: Project Eagle E&P Residue Analysis

4.2.2. Chemical Agent Identification Set (CAIS) Disposal Program.

a. Background/Overview.

(1) The purpose of the CAIS Disposal Program(16,17) was to dispose of the obsolete sets which were stored at RMA. The disposal program, which was conducted in three phases, ran from May 1981 to December 1982 and destroyed 19,697 sets. In addition, a pilot test program which destroyed 1761 sets was conducted from October to December 1979(18). As shown in Table 4-7, a total of 21,458 sets were destroyed.

(2) The sets, some of which are illustrated in Figure 4-13, were developed and manufactured by the Department of the Army from the 1930s through the 1960s. They were distributed to Department of Defense installations for use by all services in training and identification of various agents. In April 1971, the Department of the Army declared the CAISs obsolete; the sets were subsequently consolidated to RMA in two movement operations called Set Consolidation (SETCON) I (1978) and SETCON II (1980).

(3) There were 18 different set configurations grouped into seven types. The sets contained from one to five different chemical agents. In addition, some sets contained chemical agent simulants or non-lethal riot control agents chloroacetopenone (tear agent) and/or Adamsite (vomiting agent). These chemicals were adsorbed on plastic pellets, adsorbed in charcoal, in chloroform solutions or in pure form; all configurations were in glass ampules or bottles. Tables 4-8, 4-9, and 4-10 list the "agent" portion of each CAIS.

(4) Normally only one chemical agent is processed in a disposal facility at a time. However, because the chemical agents in the identification sets could not be easily separated before they were incinerated, the chemical agents, as well as any other chemicals contained in the sets, were incinerated simultaneously. This concept of burning multiple agents (albeit in small quantities) makes the CAIS Disposal Program unique among all the Army's chemical agent munition disposal programs.

TABLE 4-7. Chemical Agent Identification Sets Destroyed

PHASE	SET	TYPE (1,2)	NUMBER
I	K941/K942	PIG	802
5 May 81 - 28 Jan 82	X302	BOX	82
	X547	BOX	1202
	X550	BOX	1302
	X551	BOX	1244
	TOTAL		4634
II			
2 Feb 82 - 19 Apr 82	K945	BOX	1335
	X545	BOX	525
	X546	BOX	333
	X548	BOX	724
	X549	BOX	51
	TOTAL		2968
III	K951	PIG	6995
22 Apr 82 - 22 Dec 82	K952	PIG	3804
	K953	PIG	243
	K954	PIG	254
	K955	PIG	94
	K941	PIG	4
	X552	BOX	701
	TOTAL		12095
Total Number of Sets Destroyed			19697
Number of Sets Destroyed During Pilot Tests			1761
Grand Total of Sets Destroyed			21458

NOTES: Refers to the type of packaging.
(1) PIG- Steel Shipping Container
(2) BOX- Wooden box

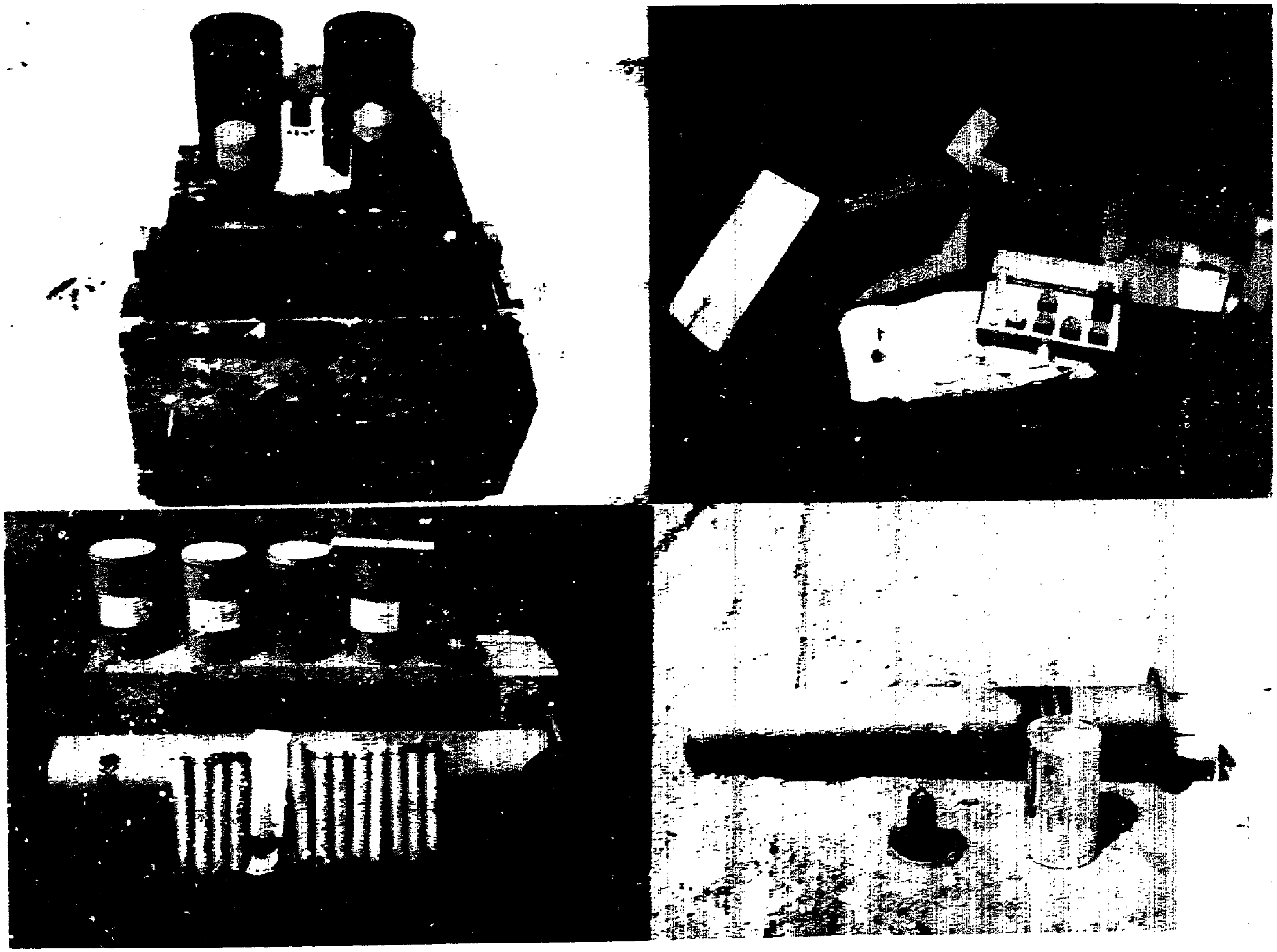


Figure 4-13: Chemical Agent Identification Sets

TABLE 4-8. Agent Composition of Chemical Agent Sets

MATERIAL	K945	K955	K941	K942	K951/2
Mustard (H/HD)	0.003	0.14	7.90	8.82	0.07
Nitrogen Mustard (HN-1)	--	--	--	--	--
Nitrogen Mustard (HN-3)	--	--	--	--	--
Lewisite (L)	0.012	0.10	--	--	0.10
Chloropicrin (PS)	--	0.09	--	--	0.87
Phosgene (CG)	--	--	--	--	1.46
Sarin (GB)	0.029	--	--	--	--
Chloroacetophenone (CN)	--	0.03	--	--	--
Adamsite (DM)	--	0.03	--	--	--
Chloroform	--	--	--	--	3.81
AC Simulant (KCN)	0.013	--	--	--	--
G Simulant (1)	0.041	--	--	--	--
V Simulant (2)	0.051	--	--	--	--
H Simulant (3)	0.046	--	--	--	--
CG Simulant (4)	0.011	0.01	--	--	--
Activated Charcoal	--	0.36	-	--	--
Polystyrene Pellets	0.07	--	--	--	--
TOTAL (lbs)	0.28	0.76	7.90	8.82	6.31

NOTES:

(1) Mixture of hexyleneglycol and methoxyethanol

(2) Mixture of tetrahydrofurfuryl alcohol, m-methylglucamine, and diethylene glycol

(3) Iso-amylsalicylate

(4) Triphosgene

TABLE 4-9. Chemical Agent Composition of K953/K954 Sets

MATERIAL	ALT 1	ALT 2	ALT 3
Mustard (H)	0.09	0.09	0.07
Lewisite (L)	0.07	0.07	0.10
Phosgene (CG)	0.97	0.97	1.46
Cyanogen Chloride (CK)	0.83	0.83	1.25
Nitrogren Mustard (HN-1)	0.08	0.08	--
GA Simulant(1)	0.67	--	--
Chloroform	2.94	4.01	3.01
TOTAL (lbs)	5.65	6.05	5.89

NOTES: (1)Mixture of ethylmalonate, oenanthic ether, and benzonitrile

TABLE 4-10. Chemical Agent Composition of "X" Sets

MATERIAL	X302	X545	X546	X547	X548	X549	X550	X551	X552
Nitrogen Mustard (HN-1)	0.060	—	—	—	—	—	0.120	—	—
Nitrogen Mustard (HN-3)	0.068	—	—	—	—	—	—	0.137	—
CG Simulant(1)	—	0.013	—	—	—	—	—	—	—
Mustard (H)	—	—	—	0.140	—	—	—	—	—
Lewisite (L)	—	—	—	—	0.208	—	—	—	—
Chloropicrin (PS)	—	—	—	—	—	—	—	—	0.182
Chloroacetophenone (CN)	—	—	0.070	—	—	—	—	—	—
Adamsite (DM)	—	—	—	—	—	0.070	—	—	—
Activated Charcoal	0.179	—	—	0.179	0.179	—	0.179	0.179	0.179
TOTAL (lbs)	0.307	0.013	0.070	0.319	0.387	0.070	0.299	0.316	0.361

NOTES: (1)Triphosgene

b. Process Description.

(1) As stated in Chapter Two, the CAIS Disposal Program was conducted in the same facility which was used to dispose of the Honest John Warheads and M139 bomblets (Figure 2-10). However, before CAIS disposal operations were initiated, modifications to the furnace and pollution abatement system were necessary. Modifications which were made included:

(a) Addition of an afterburner to the deactivation furnace. This was necessary since the furnace would be processing glass ampules and bottles filled with chemical agents instead of the drained bomblets processed during the Honest John Disposal Program.

(b) Modifications of the decontamination furnace so it could be used to thermally decontaminate the steel shipping containers commonly referred to as "pigs". Previously the furnace had been used to melt the aluminum from the M139 bomblets into ingots. Modifications to the furnace included installation of a new high temperature refractory, pedestals to support the "pigs", and a slightly different burner configuration to ensure even heating of the containers.

(c) Addition of an electrostatic precipitator to the pollution abatement system to remove the arsenic oxide and other particulates from the furnace exhaust gases.

(2) An overall process flow diagram for the CAIS Disposal Program is shown in Figure 4-14. All X-type sets and the K945 sets were packed in wooden boxes and did not require disassembly before being fed to the deactivation (deac) furnace. The K955 sets were fed directly into the decontamination (decon) furnace; because of their large size they could not be fed to the deactivation furnace. The remaining sets were packaged in "pigs." The "pigs" were opened in a glovebox and their contents were then fed to the deactivation furnace. The contents of the K951/952, K953/954 sets were fed directly to the furnace without additional disassembly; contents of the K941/942 were emptied into cardboard boxes prior to being fed to the

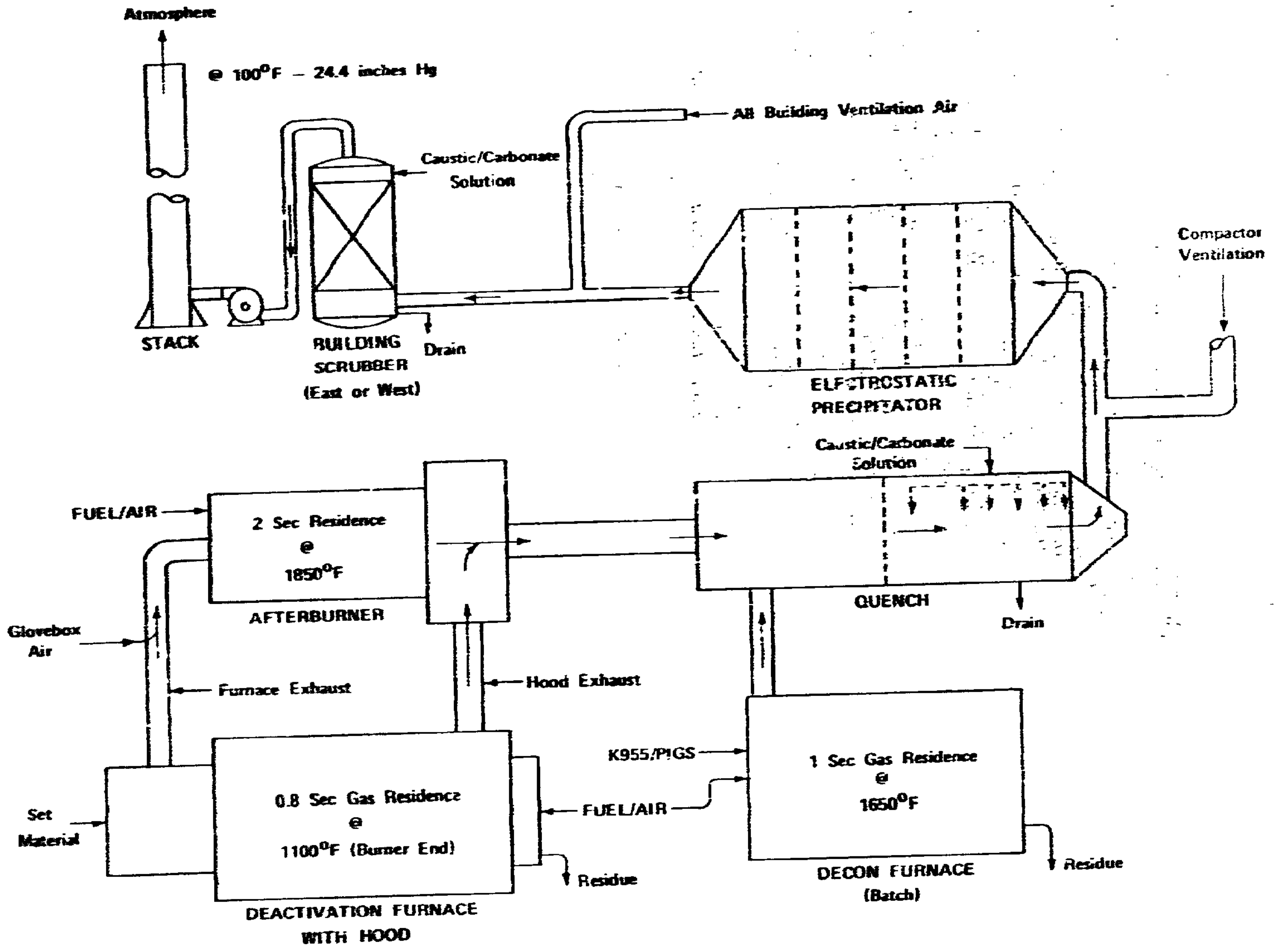


Figure 4-14: Identification Set Flow Diagram

deactivation furnace. All empty pigs were fed to the decontamination furnace. Figures 4-15, 4-16 and 4-17 are the specific process flow diagrams for each set group.

(3) Deactivation Furnace. The deactivation furnace used to destroy all agent set contents, except from the K955 set, was an Ammunition Peculiar Equipment (APE) 1236 furnace. The furnace was a cast alloy rotary retort twenty feet long and three feet in diameter. On its internal surface was an integral cast spiral which caused material to proceed through the furnace at a rate proportional to the rotational speed of the retort. The furnace was fired by a fuel oil burner at the discharge end. Furnace gases were exhausted from the retort input end. Burner end operating temperatures were 1100°F with an exhaust gas temperature of approximately 460°F. Maximum gas residence time under these conditions was 0.8 seconds. The residence time for the set contents was approximately 36 minutes, except for the contents from K941/942 sets which were kept in the furnace for 81 minutes by oscillating the retort.

(4) Deactivation Furnace Afterburner. The exhaust gases from the deactivation furnace passed through a refractory lined oil fired afterburner. The afterburner raised the gases from approximately 460°F to a minimum of 1650°F and held them at that temperature for a minimum of two seconds. The exhaust from the afterburner was mixed with the air from the Deactivation Furnace Room in order to lower its temperature before it entered the air mixing end of the quench system.

(5) Decontamination Furnace. The decontamination furnace was used to incinerate K955 sets and to thermally decontaminate empty "pigs." The furnace was a rectangular structure eleven feet by eleven feet by eight feet high (outside dimensions). Heat was supplied by five oil fired, gas piloted, force draft, proportioning burners. Charge carts were used to place and remove items from the furnace. The items placed in the furnace were positioned on ceramic pedestals and held at a minimum of 1100°F for 30 minutes, except for the large K955 sets which were incinerated at 1650°F for 120 minutes. Exhaust gases from this furnace did not pass through the afterburner but

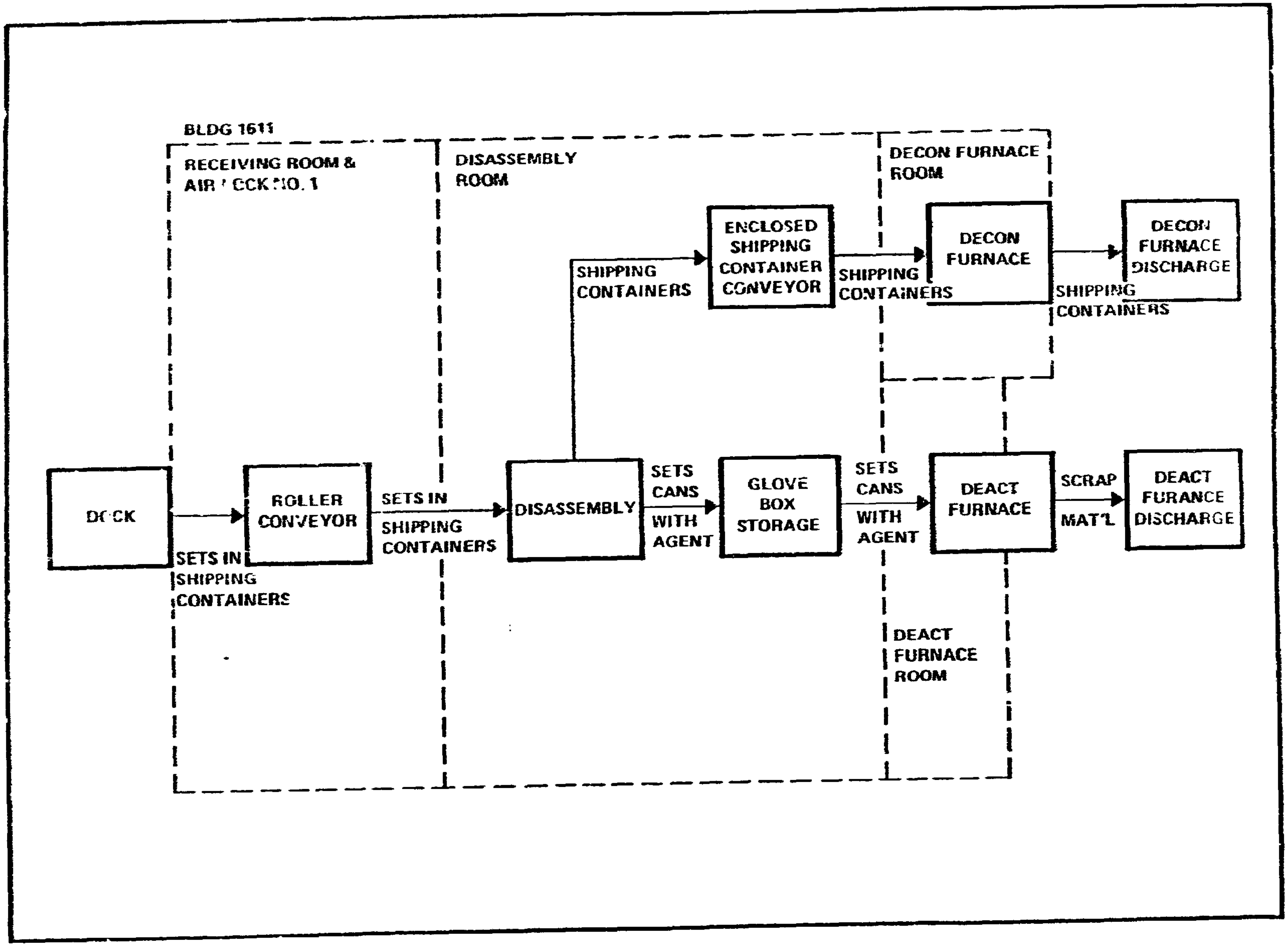


Figure 4-15: 1D Sets Process Flow Diagram (K941/K942, K951/K952, K953/K954)

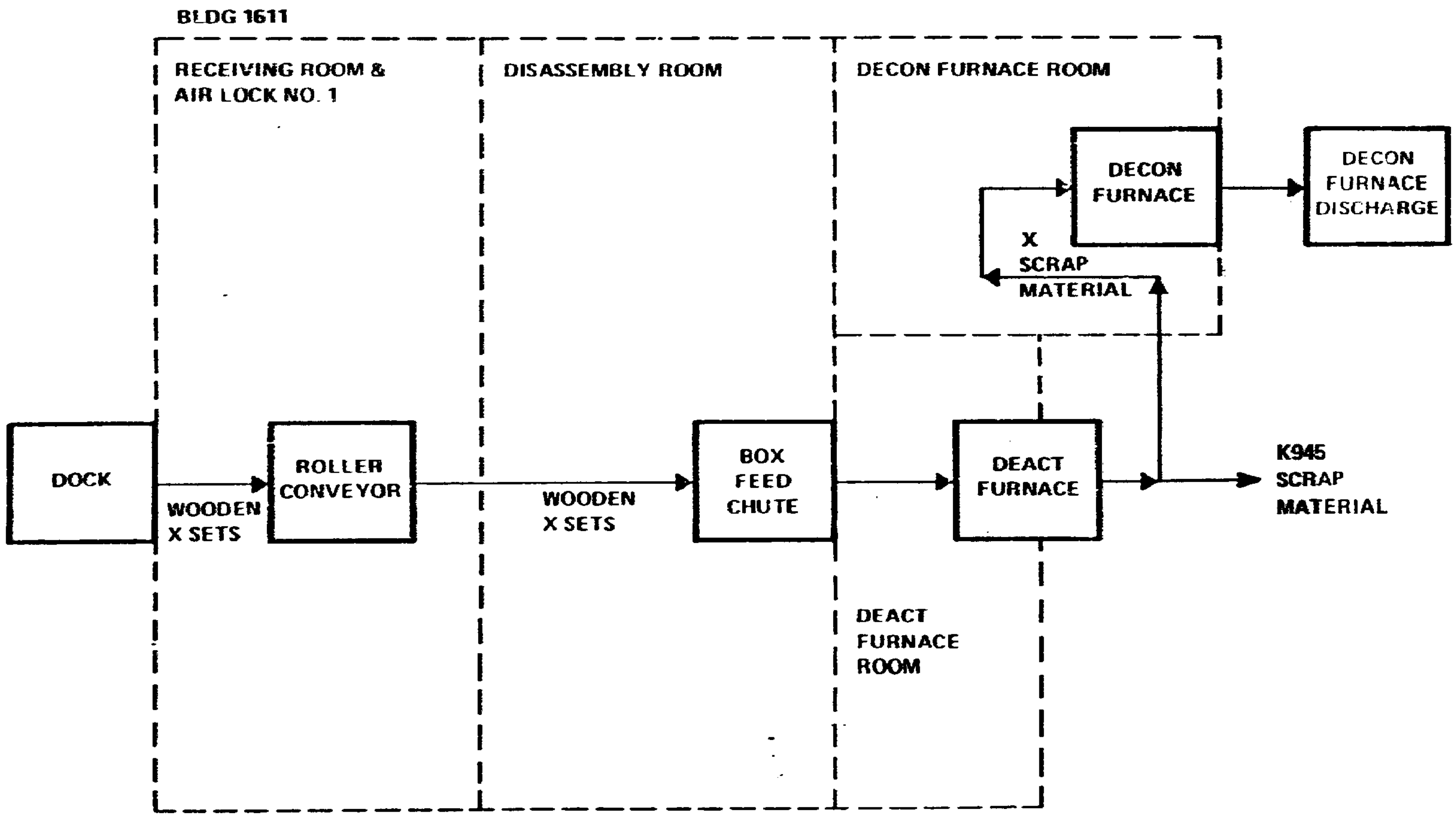


Figure 4-16: X Type and K945 Sets Process Flow Diagram

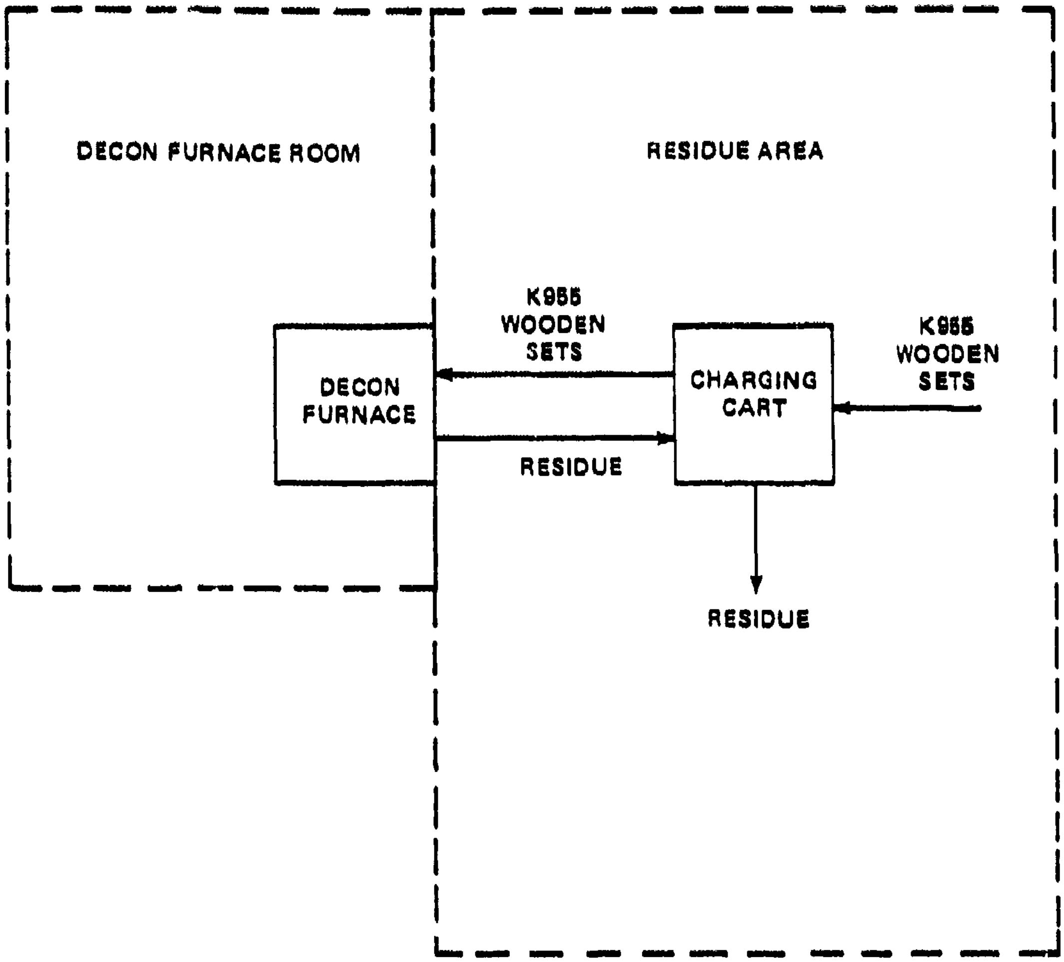


Figure 4-17: K955 Set Process Flow Diagram

proceeded directly to the pollution abatement system.

(6) Pollution Abatement System. The pollution abatement system consisted of a quench, an electrostatic precipitator, dual packed column scrubbers and one exhaust stack.

(a) Quench Chamber. The exhaust gases from the deactivation furnace afterburner and decontamination furnace were first mixed together and then cooled by evaporative cooling with a sodium carbonate spray to approximately 225°F and 100% relative humidity. The quench liquid was kept at a pH above 9 by the addition of sodium hydroxide.

(b) Electrostatic Precipitator. A five stage electrostatic precipitator was used to control emissions of particulates to the environment. The particulate consisted of varying combinations of fly ash, metal oxides, and arsenic oxides depending on which type of set was being incinerated. The particulates removed by the electrostatic precipitator were collected and stored in metal 55 gallon drums.

(c) Scrubber System. A dual column scrubber system was used to remove acid gases from the exhaust gases (Figure 4-18). The exhaust from the electrostatic precipitator was mixed with the remaining building ventilation air before entering one of the scrubber towers. The scrubber towers, which were 65 feet high and 11 1/2 feet in diameter, were divided with two sections, each of which were packed with 1 1/2 inch polypropylene pall rings to a depth of 14 feet. A sodium carbonate/sodium hydroxide solution was used to irrigate the packing.

(7) Waste Treatment.

(a) All waste water and quench and scrubber brines generated by the disposal of the CAISs were dried into a salt using a spray dryer. The brine was pumped to the spray chamber where the hot air from the heater evaporated the water. The dried salt was collected at the bottom of the chamber and packed into drums. The moist exhaust gases were cleaned in a

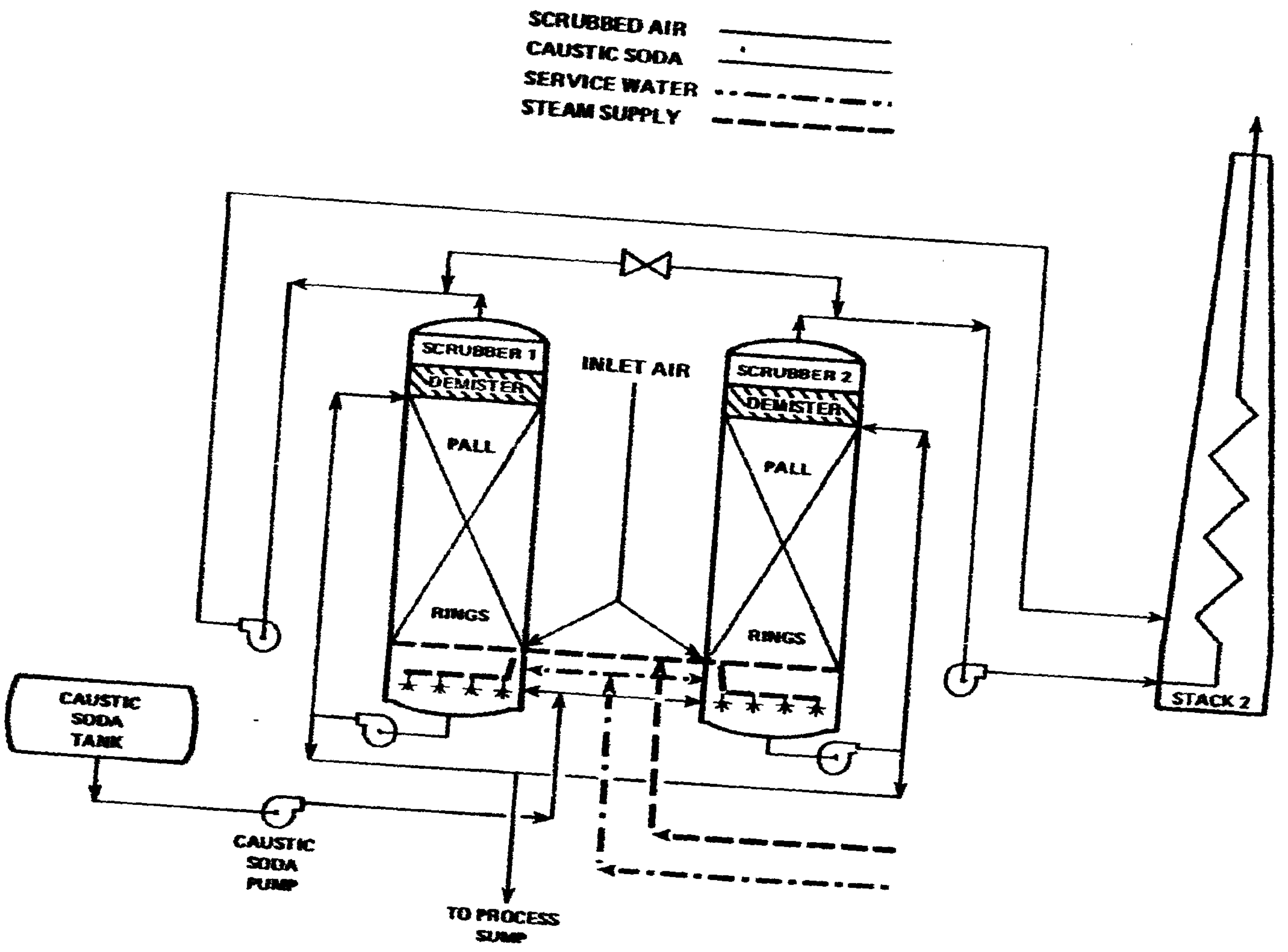


Figure 4-18: CAIS Disposal Program Scrubber Towers

venturi scrubber before release to the atmosphere.

(b) The residue from the furnaces was collected in hoppers and then transferred to a compactor system where the residue was compacted into 55 gallon drums.

c. Environmental Concerns.

(1) Air Quality. Table 4-11 lists the work area and stack standards for the chemicals incinerated during the CAIS Disposal Program. The work area standards were the Time Weighted Average (TWA) levels which are the concentrations a worker may be exposed to during a normal 40 hour work week without suffering adverse effects. Bubbler adsorption systems were used to detect the presence of GB, lewisite, mustard, triphosgene and chloroacetophenone; the lewisite bubbler had an eight hour sampling time, the remaining bubblers had a two hour sampling period. Drager tubes were used to detect the presence of cyanogen chloride and a programmable infrared analyzer, MIRAN 80, was used to monitor for chloroform, chloropicrin and phosgene. In addition a sulfur hexafluoride gas detection system was used to detect leaks outside the glovebox or feed chute.

(2) Salt Analysis and Disposal. Analysis of the salts formed by spray drying the scrubber and quench brines and the spent decontamination solution is shown in Table 4-12. The results were obtained during the pilot incineration test(18). In addition, the salts were a RCRA hazardous waste due to arsenic concentrations above the EP Toxicity limits(14). A total of 2101 55-gallon drums of salt were generated during the CAIS Disposal Program. All the salts generated were stored in RMA warehouses until they were placed in a hazardous waste landfill in 1985. Prior to disposal, the salts were analyzed for the presence of TCDDs and TCDFs; although no TCDDs were detected in any samples, two of three samples contained TCDFs in the part per trillion range (170-200 ppt)(15).

(3). Electrostatic Precipitator Residue. Table 4-13 lists the analysis of two drums of residue analyzed during the pilot incineration test.

TABLE 4-11. CAIS Disposal Program Air Monitoring Standards

COMPOUND	STACK (mg/m^3)	WORK AREA (mg/m^3)
Sarin (GB)	0.0003	0.0001
Lewisite (L)	0.03	0.003
Mustard (H/HD)	0.03	0.003
Triphosgene (as phosgene)	10	0.2
Chloroacetophenone (CN)	2.5	0.2
Cyanogen Chloride (CK)	0.3 ppm	0.3 ppm
Chloroform	105 ppm	1.2 ppm
Chloropicrin	1.06 ppm	0.13 ppm
Phosgene	3.0 ppm	0.06 ppm

TABLE 4-12. Chemical Agent Identification Set Salt Chemical Analysis

COMPOUND	AMOUNT
Carbonate, CO_3	49.2 - 50.5 wt %
Chlorine, Cl	6.38 - 6.79 wt %
Sulfate, SO_4	0.17 - 0.42 wt %
Nitrate, NO_3	3380 - 3650 ppm
Arsenic, As	187 - 440 ppm
Cadmium, Cd,	1 - 18 ppm
Chromium, Cr	6 - 17 ppm
Copper, Ca	8 - 83 ppm
Iron, Fe	0.10 - 1.75 wt %
Lead, Pb	29 - 154 wt %
Manganese, Mn	9 - 95 ppm
Mercury, Hg	0.20 - 1.56 ppm
Potassium, K	580 - 746 ppm
Silver, Ag	3 - 6 ppm
Sodium, Na	37.2 - 39.4 ppm
Zinc, Zn	62 - 230 ppm
Organic Carbon, C	2.6 - 3.2 wt %

TABLE 4-13. Chemical Agent Identification Set Electrostatic Precipitator Residue Chemical Analysis

COMPOUND	AMOUNT
Carbonate, CO_3	18.5 - 19.2 wt %
Chlorine, Cl	18.12 - 22.32 wt %
Sulfate, SO_4	14.37 - 21.1 wt %
Nitrate, NO_3	3330 - 9060 ppm
Arsenic, As	3280 - 7260 ppm
Cadmium, Cd	75 - 160 ppm
Chromium, Cr	25 - 45 ppm
Copper, Ca	67 - 197 ppm
Iron, Fe	1.22 - 3.64 wt %
Lead, Pb	1280 - 2500 ppm
Manganese, Mn	87 - 240 ppm
Mercury, Hg	0.69 - 1.02 ppm
Potassium, K	890 - 1700 ppm
Silver, Ag	3 - 5 ppm
Sodium, Na	32.6 - 37.0 ppm
Zinc, Zn	1530 - 2980 ppm
Organic Carbon, C	0.9 - 3.0 ppm

As expected the residue contained high levels of arsenic, lead and zinc, probably present as metal oxides.(18) The residue was a RCRA hazardous waste due to high arsenic concentrations.(14) When placed in solution the residue had an average pH of 10.2. A total of 173 55-gallon drums of residue were generated during the disposal program. The drums of residue were stored in RMA warehouses until 1985 when they were placed in an approved hazardous waste landfill.

(4) Furnace Residue and Scrap Metal.

(a) Furnace Residue. A total of 985 55-gallon drums of compacted furnace residue were generated by the disposal of the identification stop sets. The residue consisted of cans, ampules, and wooden boxes process through the decontamination furnace into wood ash, broken glass and scrap metal. Samples of the residue generated during pilot testing were analyzed. One sample was from residue typical of a K955 or X-type set; the second sample of residue was typical of a K951/K952 or pig type set. Both samples were divided for use in two extractions, one using deionized water and the second using non-spectro grade N-hexane. The results of the aqueous extractions are shown in Table 4-14. Only traces of sub-ppm organics were present in the hexane extraction. Although acceptable for disposal in a sanitary landfill, the furnace residue was disposed of in the same hazardous landfill as the ESP residue and salts.

(b) Scrap Metal. The lead gaskets, which were placed in the "pigs" before being processed through the decontamination furnace, were removed and sold as scrap metal. The "pigs" were retained for use as overpacks for leaking chemical munitions.

TABLE 4-14. Total Water Solubles from CAIS Decontamination Furnace Residues

	SAMPLE	
	BOX SET RESIDUE	"PIG" RESIDUE
Total Residue	489 g	478 g
Wt Total Solubles	4.27 g	1.90 g
Wt % Solubles	0.88%	0.40%
pH of Extract	8.9	8.5
Sodium wt %	32.3%	16.6%
Arsenic, As, wt %	0.05%	0.05%

4.3.0. CAMDS Chemical Agent and Munition Incineration Experience.

4.3.1. Background/Overview.

a. As stated in Chapter Two, the primary purpose of CAMDS is to test and evaluate the equipment, processes, and procedures which will be used in future chemical agent and munition disposal plants. CAMDS testing does result in the destruction of the chemical agents and munitions, however, the purpose of the tests is not to dispose of chemical agents or munitions but to satisfy specific data requirements.

b. Three separate incineration systems have undergone chemical agent or munition incineration testing at CAMDS: (1) the Deactivation Furnace System (DFS), (2) the Metal Parts Furnace (MPF), and (3) the Liquid Incinerator (LIC). A fourth incinerator, the Toxic Dunnage Incinerator (DUN) has just been modified to burn contaminated materials and will undergo testing beginning in mid-1987. As shown in Table 4-15, approximately 75,000 pounds of GB, 8,000 pounds of VX and 38,000 munitions have been incinerated in the DFS, MPF, and LIC.

c. The CAMDS chemical incineration experience summarized in Table 4-15 can be divided into three categories: (1) furnace/incinerator start up and systemization in preparation for a test, (2) testing and evaluation of the furnace/incinerator or its pollution abatement system, and (3) furnace/incinerator operations in support of other equipment tests where the performance of the furnace/incinerator is not being specifically evaluated. (Example - incineration of drained M55 rockets during evaluation of the RDM and agent chemical neutralization process). Of the three categories, test reports have been prepared only for specific furnace/incinerator or pollution abatement system tests.

TABLE 4-15. CAMDS CHEMICAL AGENT – MUNITION INCINERATION EXPERIENCE

AGENT	QUANTITY (LBS)	MUNITION/SOURCE	NUMBER	FURNACE(1)	INCLUSIVE TIME PERIOD
GB	0(2)	Drained M55 Rockets	13,951	DFS	Sep 79 – Jun 81
GB	977	Ton Container (Sprayed)	—	MPF	Apr 81 – Nov 81
GB	5,357(3)	Drained 155mm Projectiles	9,157	MPF	Jul 81 – Feb 82; Jul 82
GB	1,140(3)	Drained 105mm Projectiles	7,771	MPF	Mar – Jun 82
GB	10,227	Ton Container (Sprayed)	—	MPF	Mar 82 – Jan 84
GB	17,570	Undrained 155mm Projectiles	2,703	MPF	Oct 82 – Dec 83
VX	7,866	Ton Container (Sprayed)	—	MPF	Jun – Aug 84
GB	2,331(4)	Drained M55 Rockets	4,357	DFS	Nov 85 – May 86; Nov 86
GB	37,930	Ton Container/Drained M55 Rockets	—	LIC	Aug 85 – Aug 86

Notes:
(1) DFS – Deactivation Furnace System
MPF – Metal Parts Furnace
LIC – Liquid Incinerator
(2) Rockets were flushed with decontamination solution while being cut into segments (Chapter 3). It is assumed that no residual agent remained in the rocket when it was incinerated.
(3) Assumed 9% residual remained in projectile after draining. Agent from 105 and 155mm projectiles was mixed before it was neutralized (Chapter 3). Percent residual is based on the difference between total agent fill weight and total agent neutralizated.
(4) Assumed 5% residual remained in the warhead after agent had been drained.

4.3.2. Deactivation Furnace System (DFS).(19,20,21,22,23,24)

a. Purpose. The purpose of the DFS is to incinerate residual agent, explosives and propellant from processed land mines and rockets. Fuzes, supplementary charges, bursters, and propellant removed from mortars and artillery projectiles and cartridges are also incinerated in the DFS. In addition, the DFS is also being used to model the proposed rotary kiln which would be used in the cryofracture demilitarization process; tests in support of the cryofracture demilitarization process include incinerating bulk chemical agent which is sprayed into the DFS at ambient temperature and processing cryogenically cooled simulated chemical munition fragments to assess its ability to incinerate cryogenically frozen chemical agents and energetic materials as well as the ability of the DFS to handle the large quantities of metal parts and wood dunnage.

b. Description.

(1) General.

(a) As illustrated in Figure 4-19, the DFS consists of a feed chute with double tipping blast valves, a Deactivation Furnace, heated discharge conveyor, scrap conveyor, cyclone separator, slagging afterburner and a pollution abatement system. The Deactivation Furnace, where incineration of energetic material occurs, is isolated in a reinforced concrete enclosure. The cyclone separator, slagging afterburner and pollution abatement system are located in an adjacent building.

(b) Segmented rocket pieces, mine bodies, and all explosive components of the munitions are transferred from the ECC by a bucket conveyor to the double tipping valve (Figure 4-20). The munition pieces or explosive items are then gravity fed through the double tipping valves to the Deactivation Furnace. After approximately 12 minutes the decontaminated scrap falls from the retort onto an electrically heated discharge conveyor that provides an additional 30 minutes of residence time at a temperature of 1000°F to ensure thermal decontamination of any trace quantities of chemical

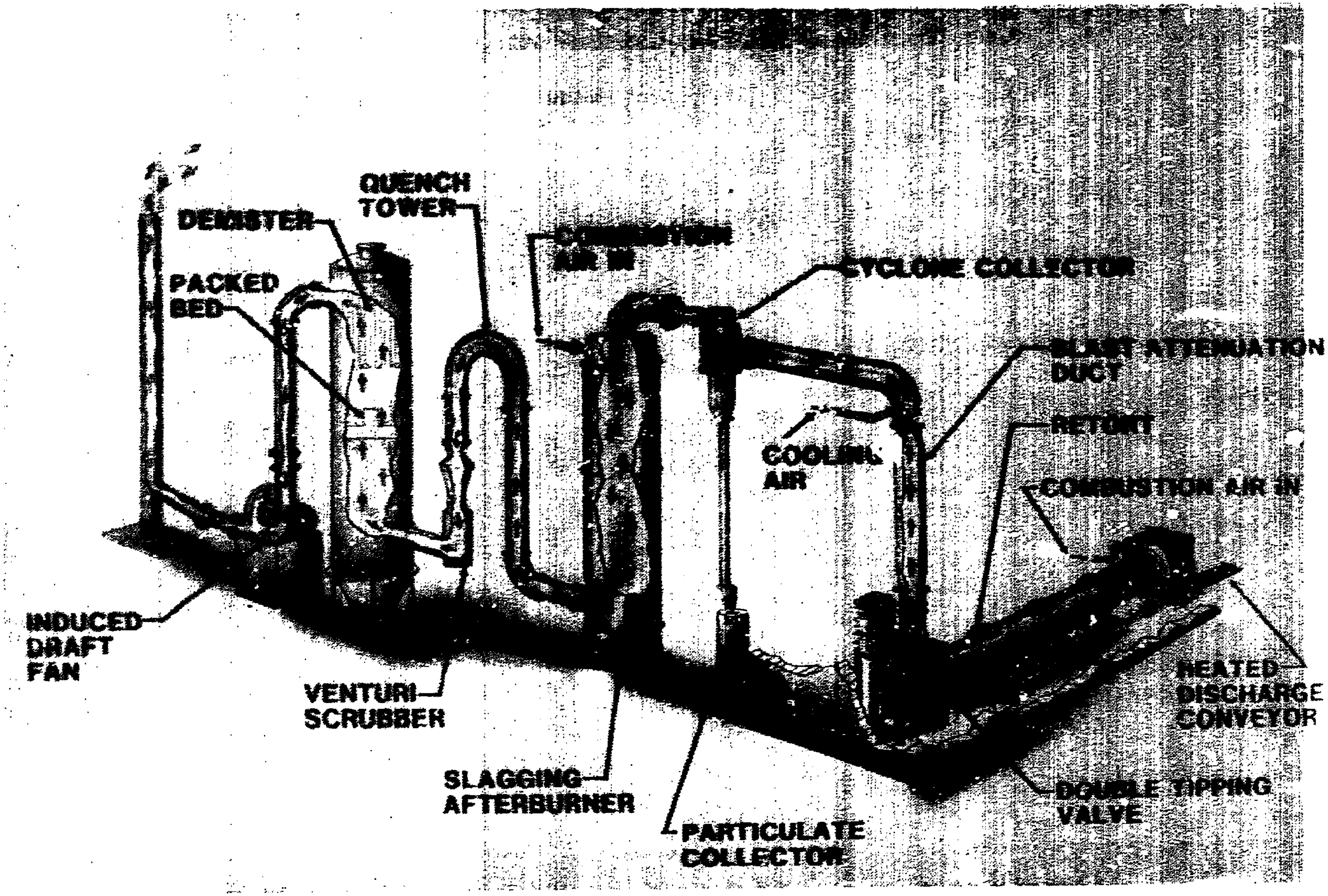


Figure 4-19: CAMDS Deactivation Furnace System

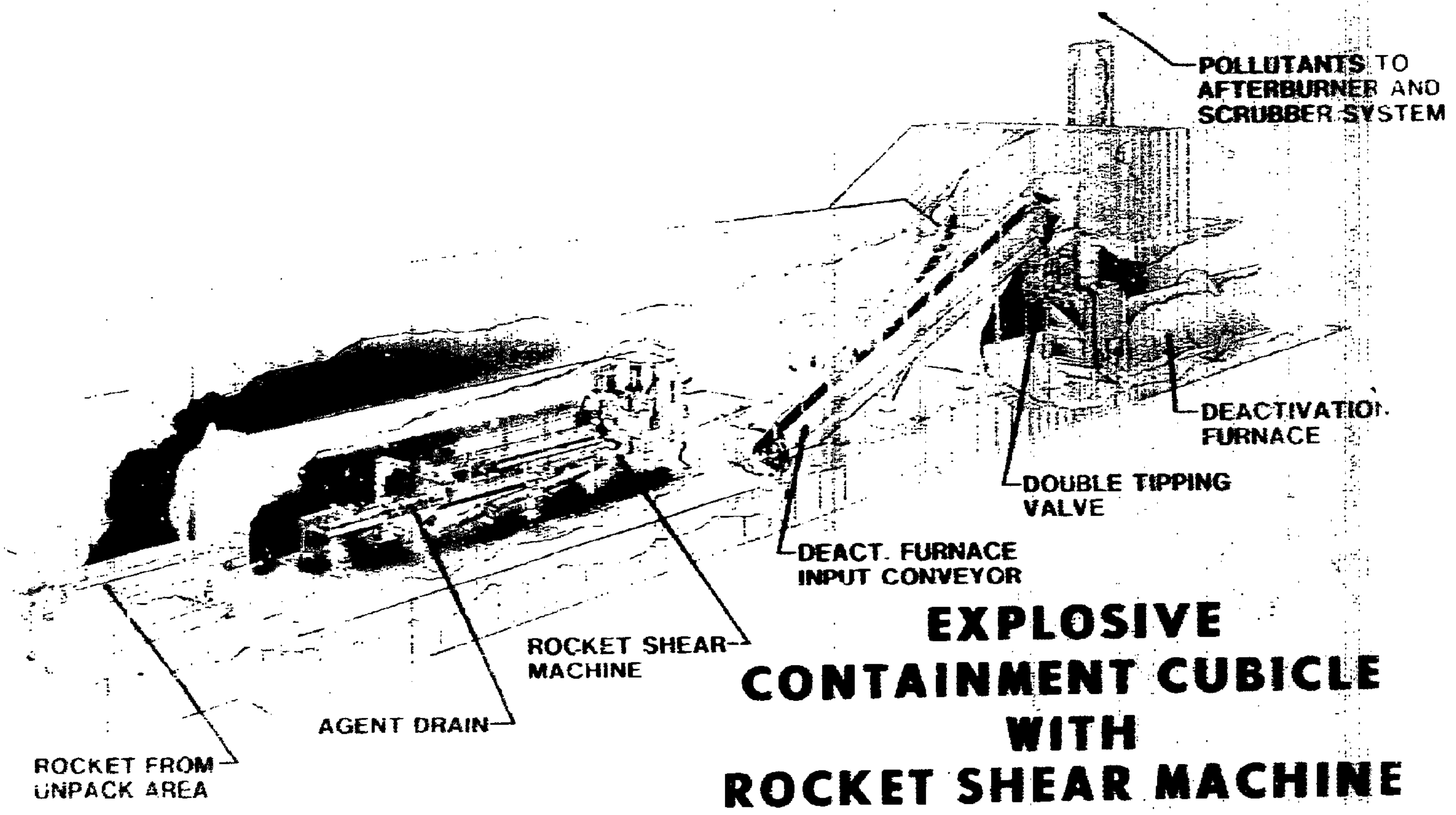


Figure 4-20: CAMDS Deactivation Furnace System Feed System

agent. The flue gases leaving the furnace exit the kiln at the feed end of the retort and are ducted through the cyclone separator which removes large particles, primarily fiberglass. The gases then pass through the slagging afterburner which melts the finer fiberglass particles on the afterburner walls and destroys any toxic vapors or other organic compounds which may be present in the kiln exhaust gases. Finally the gases pass through the pollution abatement system where they are cooled and any acid gases and remaining particulates are removed.

(2) Deactivation Furnace. The deactivation furnace (Figure 4-21) is a 30 foot long, 4 foot diameter rotary kiln. The kiln has a single thread internal cast spiral of 2.5 foot pitch that provides a 12 minute residence time at one revolution per minute. The kiln is fabricated from an alloy to withstand a maximum temperature of 1800°F and is formed by four bolted flanged sections. Two of the bolted flanges rotate on base, mounted trunnion rollers. A dual fuel burner, located on axis at the discharge end of the kiln was recently installed; previously an oil fired burner was used to heat the kiln.

(3) Cyclone Separator. The cyclone separator (Figure 4-19) is a cylindrical vessel with a cone shaped bottom. The purpose of the cyclone is to minimize fiberglass particle overloading of the slagging afterburner. The cyclone is a dry collector with the kiln exhaust gases entering tangentially at the top and large particles falling into the conical section at the bottom. The particles then fall down a long drop tube going to floor level terminating in a valve. The particles are then collected in a sealed 55 gallon drum located below the valve. Material removed by the cyclone is later placed on the heated discharge conveyor to ensure thermal decontamination.

(4) Slagging Afterburner. The slagging afterburner is designed to destroy any agent vapor or other organics in the kiln exhaust gas and to melt and remove any fiberglass particles in the gas. The afterburner is a refractory lined, vertical fume incinerator and is operated at a minimum temperature of 1650°F with a residence time of approximately 0.62 seconds. Two dual fuel (propane and fuel oil) burners were installed replacing the

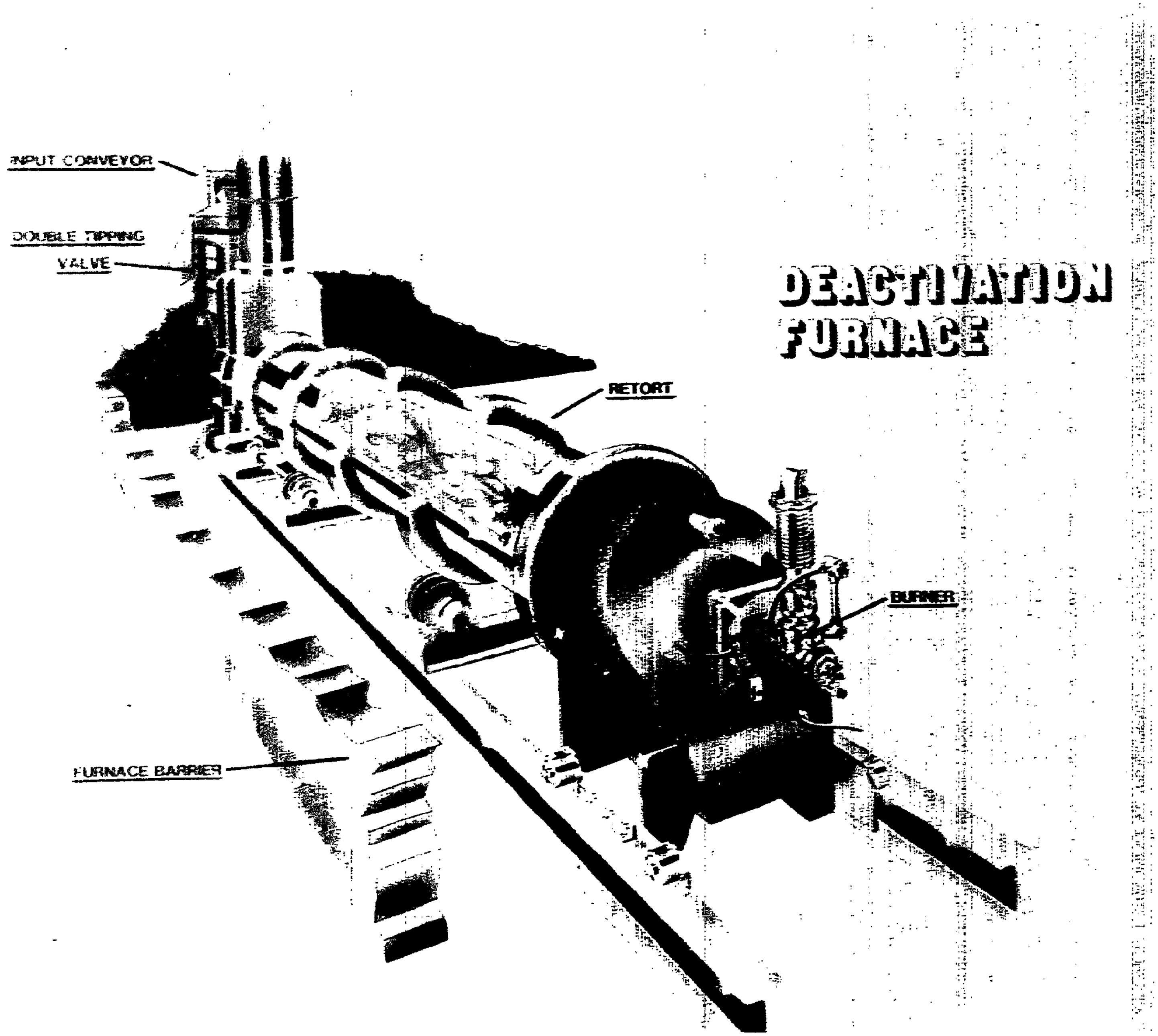


Figure 4-21: CAMDS Deactivation Furnace

original oil fired burners.

(5) Pollution Abatement System (PAS).

(a) The purpose of the PAS is to prevent pollution of the atmosphere with gases produced by the combustion of explosives, fiberglass resin, and chemical agents in the DFS. As shown in Figure 4-19, the PAS consists of a quench tower, a variable throat venturi scrubber, a packed bed wet scrubber tower, a demister, an induced draft fan and an exhaust stack.

1 Quench Tower The quench tower is a 3.5 foot diameter by 12 foot high, partially firebricked vessel constructed of Inconel 625. The quench tower is mounted directly on top the venturi scrubber. Exhaust gases from the slagging afterburner enter the quench tower at approximately 1400-1600° F and are cooled to approximately 200°F. The quench tower is a cocurrent flow design and the exhaust gas cooling is accomplished by evaporation of water from seven air atomized spray nozzles. The water flow rate is generally between 10 and 15 gallons per minute; any excess water falls or is entrained by the gas stream and carried directly into the venturi.

2 Venturi Scrubber The venturi scrubber is a variable throat type equipped with inlet scrubbing liquid ports without nozzles. The primary purpose of the venturi scrubber is to remove particulate matter contained in the exhaust gases; some acid gas removal also is accomplished. The venturi throat has a manually adjusted damper blade which is set to maintain a pressure drop of approximately 20 inches water column. Brine from the packed tower scrubber sump is used as the scrubbing liquid. A liquid to gas ratio of approximately 14:1 is maintained in the venturi.

3 Packed Bed Scrubber Tower The packed bed scubber is used to remove acidic industrial pollutants contained in the exhaust gases. The packed tower is a six foot diameter vessel constructed by Hastelloy- lined carbon steel. The vessel contains a sump which collects the excess liquid from the venturi scrubber as the exhaust gases enter the bottom of the tower. The gases then flow up through a chimney tray which supports a six foot deep bed of

2-inch polypropylene Super Intalox saddles. The packed bed is wetted by recirculating an alkaline scrubber liquid (clear liquor) which is introduced at the top of the bed by means of a weir-trough distributor. The acidic pollutants react with the brine to form salts. Fresh caustic is added to the clear liquor, just before it enters the tower, to maintain a clear liquor pH of approximately 10. A York mist type entrainment separator is located directly above the packed bed to prevent carry over of large liquid droplets to the demisters.

4 Fiber Bed Demisters The fiber demister unit is located two feet above the entrainment separator in the packed tower vessel, and consists of seven elements, two foot in diameter by 12 foot high. The demisters are used to remove small liquid droplets and fine particulate before the gases are discharged to the atmosphere. During M55 rocket incineration, the demisters are not normally used because of the relatively low level of particulate emission. An isolation damper allows the demisters to be bypassed.

5 Induced Draft Fan The induced draft fan pulls the gases through the PAS and maintains a negative pressure in the entire furnace system, thus preventing any release of agent vapors during operation. The fan is capable of 14,500 acfm at 165°F and 45 inches static pressure. A 200 horsepower, two-speed, motor provides the drive for the fan.

(b) Brine from the packed tower is periodically drained and transferred to the Brine Drying Area where the brine is dried to a salt using rotary drum dryers similiar to the one shown in Figure 4-22. The salts are then placed in an approved landfill. As in the RMA disposal programs, no liquid process wastes are discharged from CAMDS.

c. Furnace Emissions.

(1) Standards. Table 4-16 lists the specific emission standards to which the DFS PAS was designed to meet. In addition, since the propellant, explosives and chemical agents are considered RCRA hazardous waste,

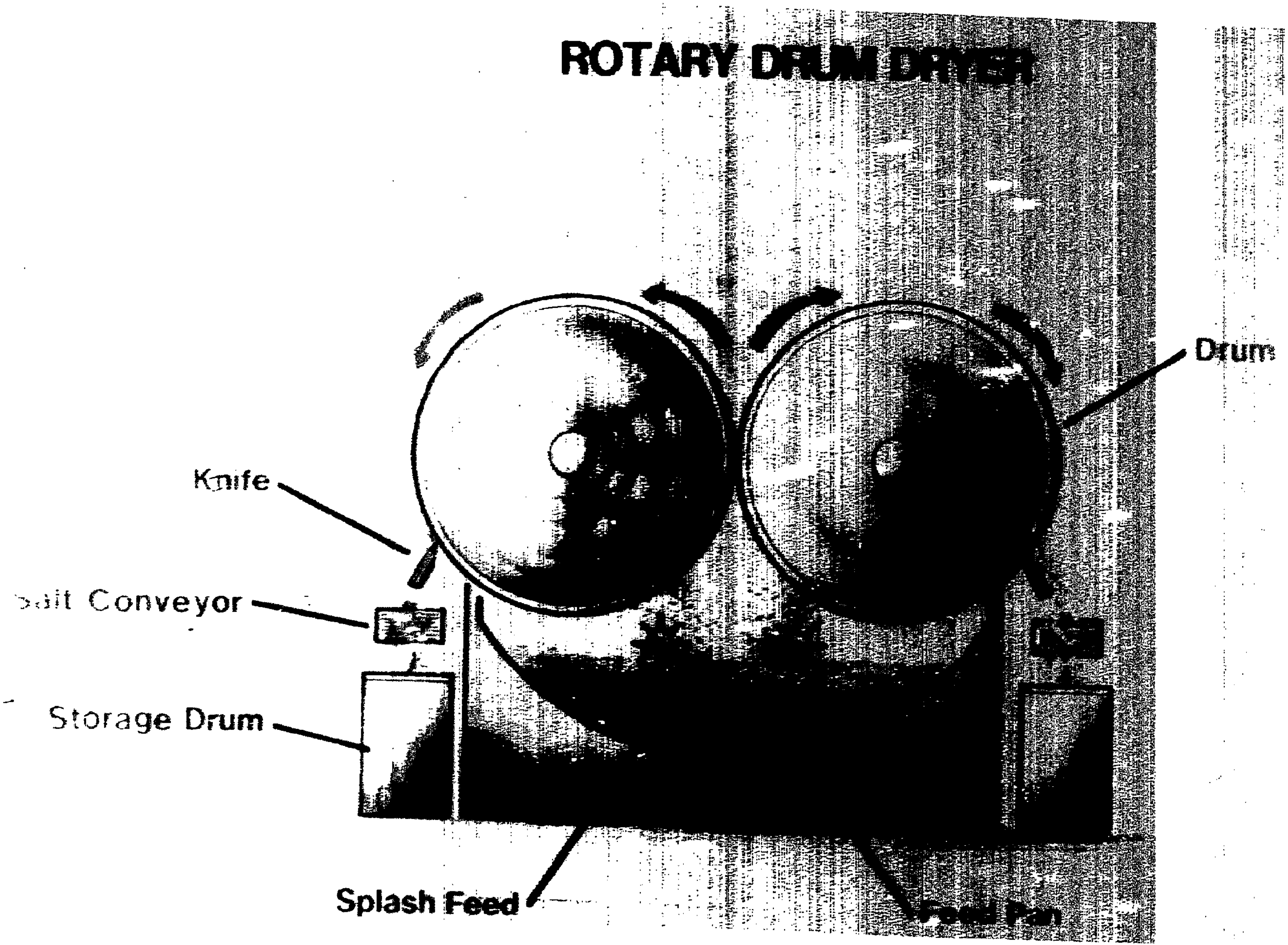


Figure 4-22: CAMDS Drum Dryer (1 of 2)

TABLE 4-16. CAMDS Stack Emission Design Standards

EMISSION	STANDARD
NO_x as NO_2	No source standard.
SO_x as SO_2	500 ppm (by volume).
Visible Opacity	20% or less. This standard is interpreted to mean no air containment will be emitted that is of a shade or density to obscure an observer's vision to a degree in excess of 20%. An air contaminant is defined as any fume, smoke, particulate, vapor, gas, or any combination thereof, but not including water vapor or steam condensate.
Incinerator Particulate	0.2 gram/standard cubic foot corrected to 12% carbon dioxide.
Process Particulate	$E = 3.59\ p^{0.62}$ Where E is the allowable emission rate, lb/hr; p is the weight of material introduced (combustible and non-combustible, excluding gas and liquid fuel), ton/hr.
Agent GB	0.0003 mg/m^3 (1 hour average)
Agent VX	0.00003 mg/m^3 (1 hour average)
Agent Mustard	0.03 mg/m^3 (1 hour average)

the emissions must also meet the RCRA standards listed in Table 4-17 (This is explained in greater detail in Chapter 6). Finally, Table 4-18 lists the ambient air quality standards for CAMDS.

(2) Monitors. In addition to industrial monitors for oxygen, carbon dioxide, carbon monoxide, sulfur dioxide, and nitrogen dioxide, the exhaust gases are monitored continuously for the presence of chemical agents. The rapid response alarms and historical monitors listed in Table 4-19 are used for this purpose. In addition, a system of eight perimeter monitoring stations (Figure 4-23) is used to monitor the ambient air quality. To date the perimeter monitoring system has shown that CAMDS has had no impact on the surrounding air quality.

d. Completed Incineration Tests. As shown in Table 4-15, over 17,000 M55 rockets and approximately 2000 pounds of GB have been incinerated in the DFS. Four types of tests have been completed in the DFS: (1) PAS evaluation; (2) undrained M55 rocket incineration; (3) drained rocket incineration and (4) a special test to determine the ability of the DFS to incinerate polychlorinated biphenyls.

(1) GB Challenge Test of the DFS PAS.(25)

(a) Purpose. Although the PAS was not designed to remove chemical agent vapors it was challenge tested in April 1977 to determine its capability to remove GB from the furnace exhaust in the event of a furnace upset. The objectives of the test were:

1 Determine the GB removal efficiency of the PAS under cold conditions with the kiln and afterburner off.

2 Determine the GB removal efficiency of the PAS and afterburner under normal conditions (kiln and afterburner on).

TABLE 4-17. RCRA Emission Standards

EMISSION	STANDARD
Principle Organic Hazardous Constituent (POHC)	Destruction and Removal Efficiency (DRE) of 99.99%
HCl	The greater of 4 lbs/hr or 1% of the HCl in the gas stream entering the pollution abatement system
Particulate	0.08 grains per dry standard cubic foot corrected to seven percent oxygen.

TABLE 4-18. CAMDS Ambient Air Quality Standards

POLLUTANT	STANDARD
Agent Mustard	Work Place - 0.003 mg/m^3 (8 hour average) Ambient - 0.0001 mg/m^3 (72 hour average)
Agent GB	Work Place - 0.0001 mg/m^3 (8 hour average) Ambient - 0.000003 mg/m^3 (72 hour average)
Agent VX	Work Place - 0.00001 mg/m^3 (8 hour average) Ambient - 0.0000003 mg/m^3 (72 hour average)
Sulfur Dioxide	0.03 ppm Annual Arithmetic Mean 0.14 ppm, 24 hour average(1) 0.50 ppm, 3 hour average(1)
Nitrogen Dioxide	0.05 ppm Annual Arithmetic Mean
Suspended Particulate	75 $grams/m^3$ Annual Arithmetic Mean 260 $grams/m^3$, 24 hour average(1)
Total Oxidants	0.08 ppm, 1 hour average(1)

NOTES: (1) Not to be exceeded more than once per year.

TABLE 4-19: CAMDS Chemical Agent Monitors and Alarms

Instrument	Agent	Sensitivity mg/m	Response Time Minutes	Principle of Operation	Deployment
High-Level Automatic Continuous Air Monitoring System (ACAMS)	GB	0.2	2.0	Gas Chromatography	Work Areas
	VX	0.4	2.0		
	HD	0.4	2.0		
Bubbler	GB	0.0001	120	Enzyme/Colorimetric	Work Area, Stack, * Perimeter
	VX	0.00001	120	Enzyme/Colorimetric	
	HD	0.003	120	DB-3/Colorimetric	
Real Time Monitor	GB	0.0001	12	Enzyme/Colorimetric	Work Area, Stack
	VX	0.00001	12	Enzyme/Colorimetric	
Low-Level Automatic Continuous Air Monitoring System (ACAMS).	GB	0.0001	10	Gas Chromatography	Work Area, Stack
	VX	0.00001	20		
	HD	0.003	10		
Depot Area Air Monitoring System (DAAMS)	GB	0.0001	120	Gas Chromatography	Work Area, Stack, * Perimeter
	VX	0.00001	120		
	HD	0.003	120		

*SENSITIVITY INCREASED BY LONGER SAMPLING TIMES TO MEET 72 HOUR PERIMETER MONITORING REQUIREMENTS.

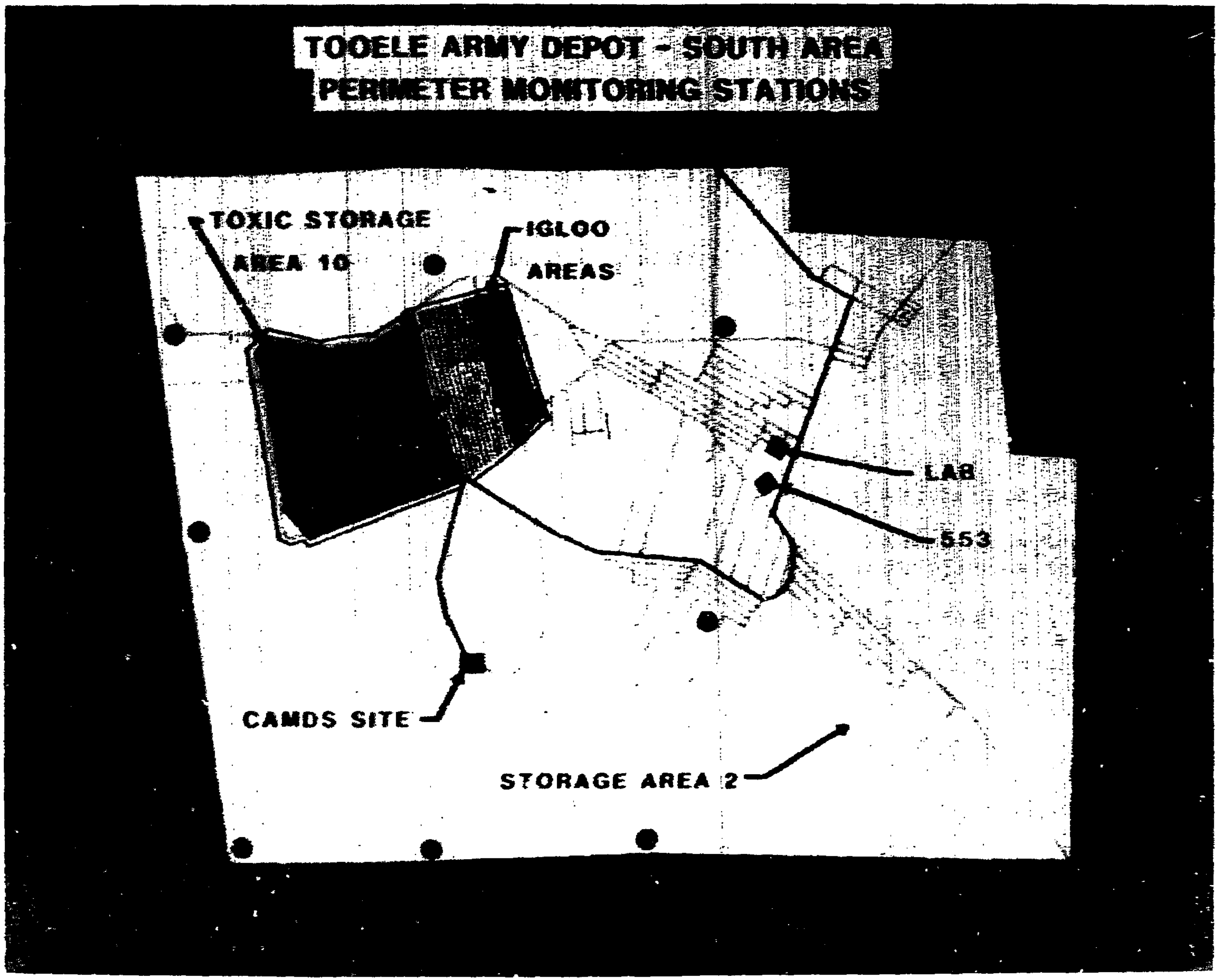


Figure 4-23: CAMDS Perimeter Monitoring System

(b) Method.

1 Dilute acidic solutions of GB were prepared by mixing 86% pure GB with sulfuric acid (pH 4.5). Agent solutions were sprayed into the afterburner exhaust duct (Figure 4-19) at challenge rates of 6.7×10^{-3}, 4.4×10^{-2} and 1.6×10^{-1} gm/min. The air flow through the duct was 5364 acfm. GB monitors (bubblers) were located before the quench, after the venturi scrubber and in the exhaust stack.

2 Neat, 86% pure GB was sprayed into the kiln exhaust duct upstream of the cyclone separator. Agent challenge rates of 2.86, 15.54, 33.20, 48.01, and 82.32 gm/min were used. The exhaust gas flow rate was 11,360 acfm. GB monitors were located before the afterburner, before the quench, after the venturi scrubber and in the exhaust stack.

(c) Results.

1 The GB removal efficiency of the PAS under cold conditions was approximately 99.9% but was limited to a maximum agent challenge of 0.36 mg/m^3.

2 Under normal operating conditions, the PAS and afterburner had a GB DRE of 99.9998% at a GB challenge rate of 82 gm/min. This challenge was equal to the agent from 15 drained M55 rockets per hour.

(2) Undrained M55 Rocket Incineration Tests. In May 1981(26) and July 1982(27) two tests were performed to determine the ability of the DFS to incinerate undrained GB M55 rockets. This was in response to observations that large quantities of jelled agent had been fed to the DFS when some of the M55 rockets processed during evaluation of the GB neutralization process (Chapter 3) were incinerated.

(a) Purpose.

1 May 1981 Test. To determine if the DFS could efficiently destroy GB up to challenge rates of 4.5 liters every two minutes. This was equivalent to the agent from processing one undrained M55 rocket through the DFS every two minutes. No propellant or explosives were incinerated during this test, only agent.

2 June 1982 Test. To determine if the DFS could process undrained M55 rockets at a feed rate of one rocket every three minutes.

(b) Method.

1 Plastic bottles filled with 65% pure GB and wrapped in wet canvas were fed through the double tipping valves and into the rotary kiln. The purpose of the wet canvas was to insulate the bottles so the agent would not be released until the bottle reached the second section. This was a safety precaution to prevent agent from leaking out of the kiln. Agent challenge was increased from 120 ml every two minutes to 4500 ml every two minutes. Six tests lasting 30 minutes each were performed. Maximum DFS temperatures were: retort burner - 950°F, retort exhaust - 850°F and afterburner - 1730°F.

2 Plastic bottles filled with GB (no purity specified) and wrapped in wet canvas were fed with sheared M61 rocket sections. (The M61 rocket is a simulant filled version of the M55 rocket.) A total of 22 "rockets" were processed. The DFS temperatures measured were 1100°F in the blast attentuation duct (Figure 4-19), 900-1000°F in the retort at the burner end, and 1550-1600° in the afterburner.

(c) Results.

1 DFS demonstrated a GB DRE of 99.999999% based on a GB feed rate of 2.25 liters per minute. This was equivalent to the agent from one undrained M55 rocket every two minutes. Limiting factor was the stack opacity which reached 80% since the demisters were not employed during the test.

2 DFS successfully processed simulated M55 rockets at a feed rate of one rocket every three minutes. A DRE was not calculated, however, based on the exhaust flow rates observed during the May 1981 test and an allowable stack concentration of 3×10^{-4} mg/m^3, an estimated DRE of 99.999994% is obtained. The stack opacity reached 100% without the demister installed. It was felt the DFS could handle more than 20 rockets per hour since limiting temperatures were not reached during the test.

(3) March 1986 Polychlorinated Biphenyl (PCB) Incineration Test.

(a) Purpose. To evaluate the ability of the DFS to meet the Toxic Substance Control Act (TSCA) solid PCB incineration criteria when burning M55 rockets with shipping and firing tubes containing regulated concentrations of PCBs.

(b) Background.

1 The M55 rocket is packaged in the fiberglass M441 shipping and firing tube (Figure 4-24). The shipping and firing tube, which weighs approximately 13.7 pounds, is made with one of two types of fiberglass: chopped or matted. The difference between the two types of fiberglass can be distinguished visually, however the exact distribution of chopped versus matted tubes in the M55 rocket stockpile is unknown.

2 An assessment of the M55 rocket stockpile conducted in 1985(28), and a subsequent analysis conducted by the AEHA in 1986(29), showed that some of the shipping and firing tubes contained PCBs. The source of the PCBs is not known, however it may have been added as a fire retardant to the resin used in the fiberglass. The concentration of PCBs was found to vary depending on the type of fiberglass used to make the shipping and firing tube. Ninety-four percent of the chopped fiberglass shipping and firing tubes contain PCBs at concentrations less than 50 ppm (most contained less than 10 ppm) with 95 percent confidence. Shipping and firing tubes made of matted fiberglass exhibit a bi-modal distribution where approximately 40 percent of the tubes contain PCBs at a concentration less than 50 ppm (most contained less than 10

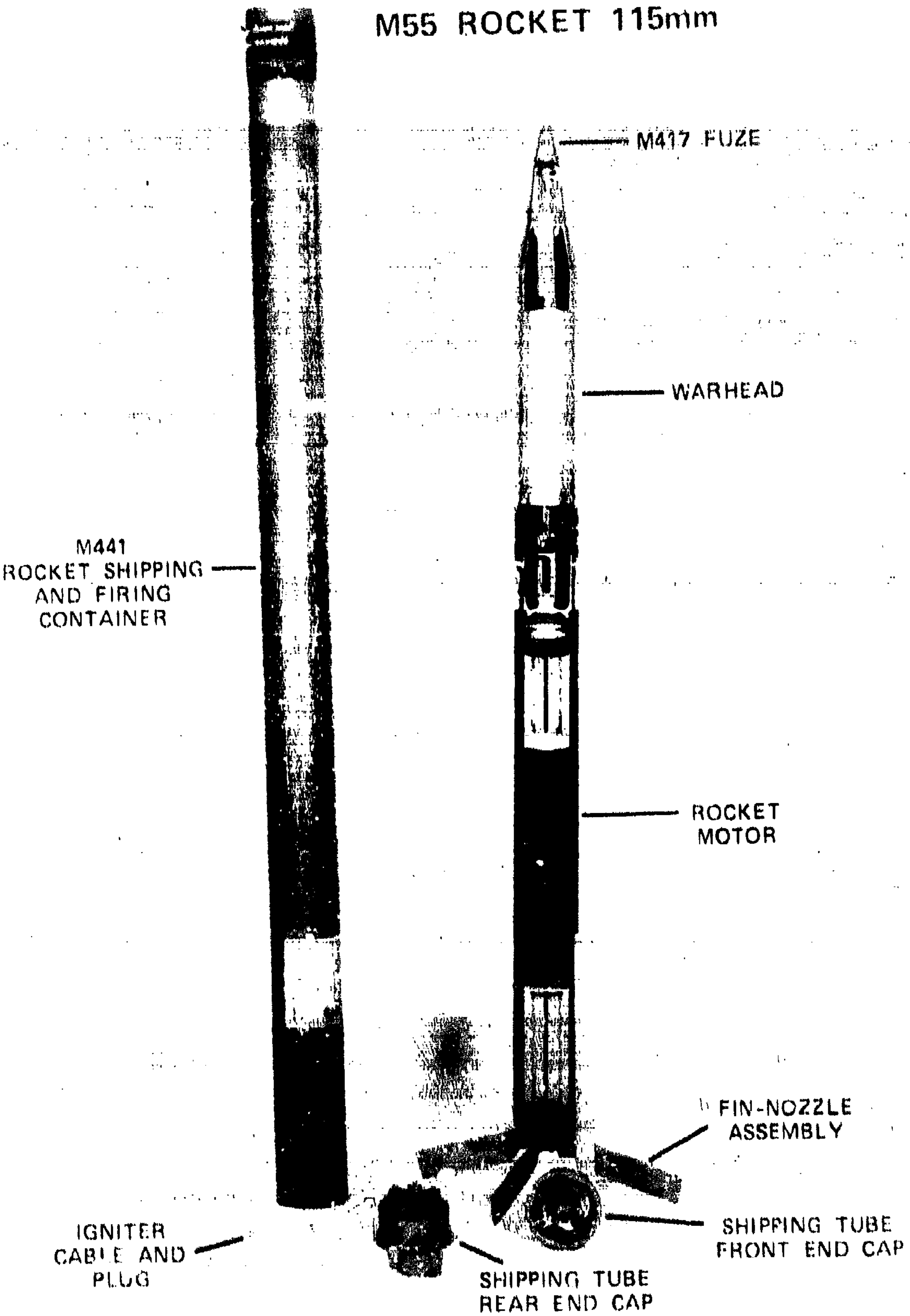


Figure 4-24: M55 Rocket and M441 Shipping and Firing Tube

ppm) and approximately 60 percent contain PCBs at concentrations greater than 2000 ppm. The average concentration of the upper distribution is 3400 ppm.

3 Incineration of PCBs is regulated under TSCA(30). Specific requirements are dependent on whether the PCBs are liquid or solid (as with the shipping and firing tubes), and are based on the concentration of PCBs in the material being incinerated: less than 50 ppm - not regulated; 50 to 500 ppm - PCB contaminated; greater than 500 ppm - PCB item. Therefore, only the matted shipping and firing tubes are regulated under TSCA. Table 4-20 lists the requirements for solid PCB incinerators. Alternatively, an incinerator can be permitted if it is demonstrated it will not present an unreasonable risk of injury to health or the environment from PCBs.

4 Because the performance of the DFS had not been evaluated from the stand point of solid PCB incineration, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) and TEAD applied for and were granted a Research and Demonstration (R&D) Permit under TSCA.(31,32)

(c) Method.(33,34)

1 Figure 4-25 illustrates where solid, liquid and gaseous samples were collected from the DFS during the test burns. All samples were analyzed for PCBs, polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs). In addition the solid and liquid process streams were analyzed for EP Toxicity and pH, and the stack gases were analyzed for particulates, HCl, total chlorinated organics and combustion gases. A summary of analytical methods used for the test burns are contained in Table 4-21.

2 Initially two background test burns were conducted. Run 1 was performed with only the burners and pollution abatement system in operation. This run was used to establish baseline levels of chlorinated organics as well as PCBs from the scrubber system and fuel oil combustion. Run 2 was conducted with M55 rockets in shipping and firing tubes which contained less than 50 ppm of PCBs.

TABLE 4-20: Non Liquid PCB Incineration Criteria (40 CFR 761.70 ( ))

1. Mass emissions from the incinerator limited to 0.001g PCB/kg of PCB feed (99.9999% DRE)

2. Combustion efficiency must equal at least 99.9%

3. PCB feed rate must be monitored and recorded at least every 15 minutes

4. Combustion temperature must be continuously monitored and recorded

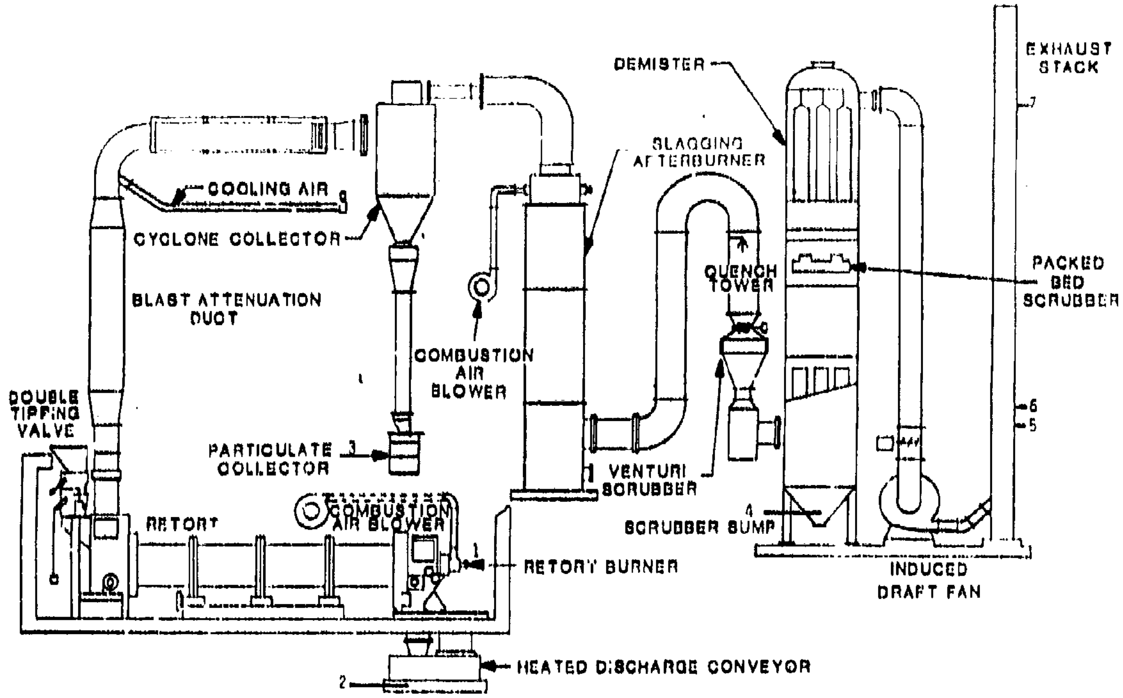
5. Stack Monitoring

    a. Start-up: (when PCBs are first incinerated or after modifications which could effect emissions): O_2, CO, CO_2, NO_x, HCl, PCBs, Total Chorinated Organics, and Total Particulate

    b. Normal Operation: Continuous O_2 and CO; Periodic CO_2

6. Automatic PCB shut off when a failure occurs in 3 or 5b.

7. HCl emissions controlled with water scrubber or accepted alternative method



Sample Site	Process Stream	Sample
1	Auxiliary Fuel	Fuel Oil
2	Furnace Residues	Metal, Glass Fibers, Ash
3	Cyclone Residue	Ash, Glass Fibers
4	Scrubber Sump	Brine
5	Stack Gases	Continuous Emissions Monitor (O_2, CO_2, CO, SO_2, NO_x)
6	Stack Gases	Volatile Organic Sample Train (VOST) (Volatile Organics)
7	Stack Gases	EPA M5 (Particulate, HCl, Orsat) EPA MM5 (Extractable Organics)

Figure 4-25: Location of Process Stream Sampling Points During the March 1986 PCB Test Burns

TABLE 4-21: Summary of Analytical Methods Used During the March PCB Test Burn

Analysis Parameter	Sample Types	Method Description	Method
Particulate	M5 filter; probe rinse	Gravimetric	M5
HCl	M5 impinger solution	Ion Specific Electrode Ion Chromatography	Orion Manual
Volatile RCL	VOST sorbent cartridge VOST condensate	Thermal desorption; GC/MS	SW-846 Method 8270
Extractable RCL	MM5 resin, probe rinse; filter; impinger solution	Extraction; HRGC/LRMS	SW-846 Method 8240
EP Toxicity (metals only)	Fuel oil; furnace, PAS and cyclone residues	Atomic Absorption	SW-846 Method 1310
pH	Furnace, PAS and cyclone residues	Potentiometric	SW-846 Method 9040
PCB	MM5 resin, probe rinse, filter, and impinger solution, furnace, PAS and cyclone residues; fuel oil	Direct injection or extraction; HRGC/LRMS	EPA 560/5-82-006
PCDD/PCDF	MM5 resin, probe rinse, filter, and impinger solution furnace, PAS and cyclone residues; fuel oil	Direct injection or extraction; HRGC/LRMS Method 8280	IT Corp. Methods; SW-846 Revised

3 Three four-hour test burns (Runs 4, 6 and 7) were conducted using only M55 rockets which had matted fiberglass shipping and firing tubes with a PCB concentration greater than or equal to 2700 ppm. Prior to feeding the designated PCB rockets, the DFS was stabilized by processing rockets which had shipping and firing tubes with a PCB concentration of less than 50 ppm. After stabilization, the Test Officer directed operators in the Unpack Area (UPA)to feed the designated rockets to the Rocket Shear Machine (RSM). The rocket numbers and feed time to the RSM were recorded.

(d) Results.(29,34)

1 PCB Incineration. Because the PCB feed rate to the DFS was very low (188 to 335 gm/hr) and because of the complex background matrix of the stack gas, from the incineration of explosives, fiberglass resin, and residual GB, the approved EPA analytical procedures were not sensitive enough to demonstrate the 99.9999 percent DRE required by TSCA (Table 4-20). However, as Table 4-22 shows, the test burns did yield DREs ranging from greater than 99.9966 percent to 99.9996 percent. Based on a comparison of PCB emissions from DFS to emissions from permitted commercial PCB incinerators, DFS emissions were an order of magnitude less. A health assessment of the resulting worst case ambient concentration of PCBs demonstrated that the concentration was much less than the permissible work place exposure limit and that the concentration poses an insignificant health risk to the public. At the request of the Army Surgeon General, the Department of Health and Human Services (DHHS) reviewed the PCB emissions data from the March test burn and concluded that there was no threat to human health from this level of emissions, and cited that even if the DRE was reduced to 99.99 percent, there would be a factor of 10^3 to 10^4 between the DFS contribution and the ambient air concentrations reported in the literature.(35)

2 Particulate and HCl Emissions. Emissions for both items were found to be in compliance with RCRA standards (TSCA does not have standards for particulates or HCl). The maximum and average emissions for

TABLE 4-22: PCB Emissions and DREs From March 1986 Test Burn

Trial	Rocket Feed Rate (rkts/hr)	PCB Feed Rate (gm/hr)	Detected Emissions (mg/hr)	Calculated Emissions (mg/hr)	DRE (%)
4	11.25	188	BDL	2.44×10^{-3}	99.998
5	14.00	234	BDL	7.96×10^{-3}	99.9966
7	19.23	335	1.23×10^{-3}	--	99.9996

BDL - Below Detection Limit

particulates and HCl were 0.080 and 0.071 gr/dscf and 6.9×10^{-3} and 4.0×10^{-3} lb/hr respectively as compared to the RCRA standards of 0.080 gr/dscf for particulates and 4.0 lb/hr for HCl.

3 Furnace Residue, Scrubber Brine, and Cyclone Ash. Where detected, the PCB concentration was below the 50 ppm level which TSCA defines as a PCB contaminated item. The cyclone ash contained tetrachlorodibenzo furans and pentachlorodibenzo furans in the part per billion range (1.4 to 6.5 ppb). As shown in Table 4-23, the majority of the furnace residues, scrubber sump brine, and cyclone ash samples did not exhibit metal concentrations above the EP Toxicity standard. However, the scrubber brine did contain lead above the RCRA limit in four out of five samples, and cadmium above the RCRA standard in the sample collected from run seven. The furnace residue samples from runs six and seven contained cadmium above the RCRA limit.

4 PCDD, PCDF, Chlorinated Organics, and Hydrogen Fluoride Emissions. Tables 4-24 and 4-25 summarize the emissions of volatile chlorinated organics and the octachlorodibenzo-p-dioxin (OCDD) and hydrogen fluoride emissions from the test burns. No semi-volatile chlorinated organics, or PCDFs were detected in the stack gases. The health assessment of the resulting ambient concentrations from the compounds listed in Tables 4-24 and 4-25 demonstrated that the concentrations of these compounds do not pose a significant health risk to the public or to CAMDS workers.

(4) Ocean Dumping Permit Application Analysis of DFS Scrubber Brine(37).

(a) Purpose. To obtain analytical data on the DFS scrubber brine in support of the JACADS Ocean Dumping Permit Application. The Army is evaluating the disposal of the scrubber brines by ocean dumping in lieu of drying the brine to a salt followed by placement in an approved landfill. Specific data to be collected included:

1 Total and EP Toxicity Leachate Metals

TABLE 4-23. EP Toxicity Leachate Metal Analysis from March 1986 PCB Test Burn

Sample Location	Run Number	Metal Concentration (mg/l) Ag	As	Ba	Cd	Cr	Pb	Hg	Se
Scrubber Brine	1	<0.002	<0.300	0.74	<0.001	0.03	0.06	<0.001	<0.200
	2	<0.002	<0.300	0.10	0.030	0.04	12.00	<0.001	<0.200
	4	<0.002	0.790	0.43	0.076	0.06	12.00	<0.001	<0.300
	6	<0.002	0.405	0.20	0.651	0.12	12.00	<0.001	0.360
	7	<0.002	0.350	0.10	1.050	0.12	16.00	<0.001	0.160
Cyclone Residue	2	<0.002	0.013	0.08	0.166	0.02	0.28	<0.001	0.020
	4	<0.002	0.004	1.50	<0.001	1.10	<0.01	<0.001	0.048
	6	<0.002	0.003	1.30	0.006	2.00	<0.01	<0.001	0.034
	7	<0.002	0.007	1.00	0.055	0.10	<0.01	<0.001	0.024
Furnace Residue	2	<0.002	0.083	0.08	0.003	<0.01	<0.01	<0.001	<0.030
	4	<0.002	0.057	0.20	0.058	0.16	<0.01	<0.001	0.024
	6	<0.002	0.024	1.60	1.400	<0.01	<0.01	<0.001	<0.020
	7	<0.002	0.035	1.80	2.900	<0.01	0.24	<0.001	<0.020
RCRA Standard		5.0	5.0	100.0	1.0	5.0	5.0	0.2	1.0

TABLE 4-24: Summary of Emission Rates for Volatile Chlorinated Organic Compounds From March 1986 PCB Incineration Trial Burn

Compounds	Emission Rate (mg/hr) Run 1	Run 2	Run 4	Run 6	Run 7
bromodichloromethane	119.29	6.24	13.80	1.30	8.93
carbon tetrachloride	ND	1.07	ND	ND	0.75
chloroform	80.52	27.97	35.74	28.57	17.60
chloromethane	5.57	ND	14.56	16.48	5.17
dibromochloromethane	ND	6.14	1.15	0.41	4.00
1,1,1-trichloroethane	22.07	23.00	5.94	4.87	6.42
1,1-dibromo-2-chloro-2-fluoro cyclopropane	ND	146.17	ND	ND	ND
trichlorofluoromethane	ND	367.57	105.40	162.51	252.08
methylene chloride	166.51	302.09	147.17	144.08	196.86
vinyl chloride	ND	ND	1.44	ND	ND
methyl ester dichloroacetic acid	ND	ND	ND	20.09	ND
dichlorodifluoromethane	ND	ND	ND	ND	14.17
tetrachloroethane	ND	ND	ND	0.16	ND
TOTALS	393.96	880.25	325.20	378.67	505.98

ND - none detected

TABLE 4-25: Summary of Emission Rates for HF and OCDD From March 1986 PCB Incineration Test

RUN NUMBER	AVG ROCKET FEED RATE (RKTS/HR)	HF EMISSION RATE (LB/HR)	OCDD EMISSION RATE (MG/HR)
1	—	4.8×10^{-3}	RDL
2	—	$<5.2 \times 10^{-3}$	5.6×10^{-2}
4	11.25	$<9.7 \times 10^{-3}$	5.7×10^{-2}
6	14.00	1.1×10^{-3}	3.0×10^{-2}
7	14.23	36.74×10^{-3}	4.0×10^{-2}
Average		$<11.5 \times 10^{-3}$	4.6×10^{-2}

2 Priority Pollutant Organic Compounds

3 Phase Determination (Total Solids/ Total Dissolved Solids)

4 Chemical Oxygen Demand (COD)

5 Total Organic Carbon (TOC)

6 pH

7 Inorganic Anions

(b) Method. Prior to incinerating drained GB M55 rockets, samples were collected from the DFS scrubber sump. Additional samples were collected from the same location after completion of the PCB/M55 rocket incineration test described in section 4.3.2.d (3).

(c) Results.

1 Tables 4-26 and 4-27 list the Total Metals and EP Toxicity Leachate Metal Analyses of the DFS scrubber brine. Of particular interest is the fact scrubber brine did not exceed the EP Toxicity metal limits for either cadmium or lead. This is particularly unexpected for lead since, as shown in Table 4-23, the lead concentration in the scrubber brine samples collected during the PCB incineration test were consistently above the RCRA limit. The difference could be due to differences in sample collection methods, or to settling of the lead compounds if there was a significant delay in collecting the brine sample for the ocean dumping permit analyses. This inconsistency will be resolved during future M55 rocket incineration tests when the resulting scrubber brine will be analyzed to determine the lead content of the EP Toxicity leachate.

2 As shown in Table 4-28, the scrubber brine had a large increase in sulfate (SO_4^{-2}), phosphate (PO_4^{-3}), fluoride (F^-) and chloride (Cl^-) anion concentrations. The sulfate is due to the sulfur

TABLE 4-26. Total Metals Analysis of DFS Scrubber Brine, After GB M55 Rocket Incineration

Metal	Pre-Burn Concentration (mg/1)	Post Burn Concentration (mg/1)
Ag	< 0.02	< 0.02
Al	3.4	152.0
As	0.004	0.021
B	0.12	15.0
Ba	< 0.4	(2)
Be	< 0.02	< 0.02
Ca	61.0	> 500.0
Cd	0.017	15.7
Co	< 0.06	< 0.06
Cr	< 0.09	3.1
Cu	0.03	2.63
Fe	1.6	34.0
Hg	0.002	< 0.0005
K	6.7	748.0
Mn	< 0.03	0.70
Mo	< 0.3	< 0.3
Na	300.0	29,000.0
Ni	< 0.06	1.99
Pb	3.7	62.0
Sb	< 0.25	< 0.25
Se	< 0.002	0.30
Su	< 1.2	< 1.2
U	< 0.7	< 0.2
Zn	0.4	12.2

NOTES: (1) Total drained GB M55 rockets incinerated: 485

(2) Barium content could not be determined due to high sulfate concentration in DFS Scrubber Brine.

TABLE 4-27. EP Toxicity Leachate Metal Analysis of DFS Scrubber Brine After GB M55 Rocket Incineration

Metal	Pre-Burn Concentration (mg/l)	Post Burn Concentration (mg/l)	RCRA Limit (mg/l)
Ag	< 0.04	< 0.05	5.0
As	< 0.002	0.019	5.0
Ba	< 0.08	5.5	100.0
Cd	0.022	0.85	1.0
Cr	< 0.09	0.14	5.0
Fe	< 0.07	< 0.13	—
Hg	0.002	< 0.0005	0.2
Na	290.0	14,000.0	—
Pb	0.9	< 0.22	5.0
Se	< 0.002	0.118	1.0
Zn	0.012	0.62	—

NOTES: (1) Total drained GB M55 rockets incinerated: 483
(2) No EP Toxicity standards for Fe, Na, or Zn

TABLE 4-28. Chemical Analysis of DFS Scrubber Brine, After GB M55 Rocket Incineration Test

Parameter	Pre Burn Concentration (mg/l)	Post Burn Concentration (mg/l)
pH (1)	9.9	9.1
Total Solids	1,872	141,000
Total Dissolved Solids	1,258	107,000
Sp. Gr. (1)	1.000	1.108
NO_3	3.5	824.0
Cl^-	105.0	7630.0
F^-	12.0	1550.0
PO_4^{-3}	7.0	2550.0
Alkalinity as CO_3^{-2}	44.0	413.0
SO_4^{-2}	380.0	34,300.0
COD	10.0	1,400.0
TOC	3.0	310.0

NOTES: (1) Stated Unit.

(2) Total number of drained GB M55 rockets incinerated: 483

contained in the fuel oil used in the afterburner on rotary kiln; the phosphate and fluoride are attributable to the residual GB contained in the M55 rocket warhead. The chloride is probably from the process water used in the PAS.

3 Table 4-29 lists the semi-volatile organic priority pollutant compounds detected in the scrubber brine. Although very small concentrations of volatile organic priority pollutant compounds were detected before the rockets were incinerated, no volatile compounds were detected in the post burn sample.

(5) May 1986 M55 Rocket Incineration Test(38)

(a) Purpose. The purpose of this test was to obtain environmental and process data from the DFS while incinerating drained M55 rockets and to establish baseline performance of the DFS while burning only fuel oil. Specific data requirements included:

1 Characterize DFS waste streams.

2 Determine exhaust gas particulate loading and particulate size distribution.

3 Quantify and qualify products of incomplete combustion (PICs).

(b) Method.

1 Only M55 rockets with shipping and firing tubes which contained PCBs at a concentration of less than 50 ppm were used during this test.

2 A total of five test burns were conducted. Two background tests (Baseline 1 and 2) were conducted to determine the baseline performance when the DFS was only burning fuel oil (no rocket fuel). Three test burns (Trials 1, 2, and 3) were conducted for the purpose of characterizing the waste

TABLE 4-29. Priority Pollutant Compound analysis of DFS Scrubber Brine, After GB M55 Rocket Incineration

Compound	Concentration (ug/l)
Bis(2-ethylhexyl) phthalate	16.0
2-Nitrophenol	20.0
2,4- Dinitrophenol	370.0
2-methyl-4,6-dinitrophenol	350.0

streams when the DFS was incinerating drained GB M55 rockets. Each test was run for approximately four hours to allow for collection of the required data.

(c) Results.

1 The DFS successfully incinerated the drained M55 rockets at a feed rate of up to approximately 18 rkts/hr. Because the exact amount of agent drained from the rocket was unknown, it was estimated based on the amount of hydrogen fluoride in the afterburner exhaust (Figure 4-19). Using this approach, the agent heel contained in the rocket warhead was equal to approximately 0.3 pounds or 2.8 percent of the original agent fill. During the test, no agent was detected in the exhaust gases. Based on the allowable GB stack concentration of 0.0003 mg/m^3, the estimated GB DRE was greater than 99.9999%.

2 The combustion efficiency of the slagging afterburner was greater than 99.9% for all test burns including the baseline tests burns.

3 A summary of the average PAS removal efficiencies during the rocket incineration trials is listed in Table 4-30. All listed efficiencies are based on calculated pollutant mass concentrations. It must be noted that the demisters were bypassed for these tests and that the particulate and phosphorous pentoxide removal efficiencies were lower than expected. However, the particulate emission rate was less than the RCRA standard of 180 mg/m^3 corrected to seven percent oxygen. Table 4-31 illustrates the PAS (less demisters) particulate removal efficiency as a function of particle size. As would be expected the PAS removal efficiency decreases with the decreasing particle size.

4 The chemical analysis of the PAS brines before and after each rocket incineration test is summarized in Table 4-32. Dissolved solids include the sodium salts and other soluble materials. Suspended solids include the insoluble materials such as metal oxides. The source of chloride is not known and may have come from the PAS makeup water which was not analyzed. As shown in Table 4-33, the brines were not RCRA hazardous due to EP Toxicity, or

TABLE 4-30 Average PAS Removal Efficiency From May 1986 M55 Rocket Incineration Tests(1)

PARAMETER	PARTICULATE lb/hr	P_2O_5 lb/hr	HF lb/hr
Inlet	10.75	0.27	0.71
Outlet	2.61	0.06	0.01
Removal (%)	75.72(2)	77.78(2)	98.59

NOTE:

(1) PAS Removal Efficiencies are Average Values Derived from all Three Test Burns.

(2) Demister Bypassed During Test

TABLE 4-31 PAS Particulate Removal Efficiency versus Particle Size Distribution

Cut Point (micron)	Inlet (lb/hr)	Outlet (lb/hr)	% Removal (weight basis)
20	12.11	2.37	80.43
10	6.06	2.33	61.55
5	4.72	2.30	51.27
3	3.81	2.26	40.68
2	3.15	2.23	29.21
1	2.14	2.14	0

TABLE 4-32. Chemical Analysis of PAS Brines From May 1986 M55 Rocket Incineration Test

Parameter	Trial 1		Trial 2		Trial 3	
	Before	After	Before	After	Before	After
Total solids	56,000	58,000	72,000	72,000	95,000	97,000
Total dissolved solids	54,000	57,000	68,000	65,000	92,000	90,000
Total suspended solids	680	940	1,600	3,000	3,800	5,200
Specific gravity[a]	1.049	1.054	1.063	1.061	1.081	1.082
pH[a]	8.72	8.40	9.05	7.07	8.69	8.48
TOC	96	98	100	100	123	110
Na_2CO_3	848	583	173	26	406	576
Na_2SO_4	47,465	33,122	50,274	54,266	74,820	76,298
Na_2SO_3	<3	<3	6	<3	9	<3
Na_2HPO_4	164	550	550	961	4,581	3,572
NaF	287	663	619	3,359	3,514	3,669
NaCl	4,660	4,940	5,615	6,175	7,229	7,377
$NaNO_3$	610	620	777	705	770	1,038
$NaNO_2$	96	103	67	40	93	102
COD	410	420	450	570	720	1,200

[a] Stated unit.

TABLE 4-33. RCRA Analysis of PAS Brines; May 1986 M55 Rocket Incineration Test

Parameter	Maximum Concentration Limit[a]	Trial 1		Trial 2		Trial 3	
		Before	After	Before	After	Before	After
EP Toxicity							
As	5.0	0.010	0.017	0.048	0.059	0.065	0.071
Ba[b]	100	<6	<6	<6	<6	<6	<6
Cd	1.0	0.06	0.14	0.21	0.26	0.22	0.25
Cr[b]	5.0	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Pb	5.0	2.22	4.82	1.10	0.94	0.67	0.47
Hg[b]	0.2	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Se	1.0	0.074	0.083	0.084	0.111	0.122	0.098
Ag[b]	5.0	<0.1	<0.05	<0.05	<0.05	<0.06	<0.06
Corrosivity [b,c]	-	<1	<1	<1	<1	<1	<1
Reactivity							
$S^{=b}$	-	<10	<10	<10	<10	<10	<10
Cn^-	-	1.2	1.3	0.6	0.76	0.28	0.90

[a] 40 CFR 261.24.
[b] Below detection limits.
[c] mm/yr.

to cyanide or sulfide reactivity.

5 Composite ash samples were collected from the heated discharge conveyor and collection bin during each test burn while incinerating M55 rockets. Three grab samples of ash were collected at equal intervals throughout the test period. The samples were mixed to provide a representative sample. As shown in Table 4-34, the residue contained cadmium above the RCRA EP Toxicity limits, and was a reactive characteristic hazardous waste due to cyanide reactivity.

6 Although not regulated by EPA, the exhaust gases, before and after the PAS, the PAS brines, and furnace residue were examined for PICs. The exhaust gases were only sampled with the Modified Method 5 sampling train which is suitable only for semivolatile organics. No PICs, in terms of RCRA Appendix VIII compounds, were detected, however, low levels of long chain hydrocarbons (C_5H_{10} - $C_{30}H_{62}$) in the exhaust gases and PAS brines were detected. Similar PICs were observed in the samples collected during baseline testing which suggests most of the organic compounds detected were associated with fuel oil combustion rather than combustion of agent and rocket feed materials. The concentration of compounds identified in the PAS brine was very low and did not change appreciably as a result of the incineration tests. Table 4-35 presents the results of the PIC analysis completed for the composite furnace residue sample. The lower boiling point compounds are believed to be laboratory contaminated since the residue was maintained at more than 1000°F for 15 minutes (on the heated discharge conveyor) before the samples were collected. Because of problems experienced with sample analyses, primarily in-sufficient sample size and surrogate recoveries below quality control limits, the PIC results cannot be considered definitive. During future incineration tests (see Chapter 6), the DFS exhaust gases will be carefully analyzed for volatile and semi-volatile PICs.

4.3.3. Metal Parts Furnace System (MPF)(19,20,21,22,24,39)

a. Purpose. The primary purpose of the MPF is to thermally destroy residual agent contamination from munition components without explosives and to thermally detoxify mustard (H) filled ton containers and projectiles that have had the fuzes and bursters removed. In addition, the MPF

TABLE 4-34. RCRA Analysis of DFS Residue From
May 1986 Rocket Incineration Test

Parameter	Maximum Concentration Limit[a]	Trial 1	Trial 2	Trial 3
EP Toxicity (mg/L)				
As[b]	5.0	<0.01	<0.01	<0.01
Ba[b]	100.0	<0.2	<0.2	<0.2
Cd	1.0	1.8	0.83	1.5
Cr[b]	5.0	<0.04	<0.04	<0.04
Pb	5.0	0.17	0.11	0.23
Hg[b]	0.2	<0.001	<0.001	<0.001
Se[b]	1.0	<0.01	<0.01	<0.01
Ag[b]	5.0	<0.05	<0.05	<0.05
Reactivity (mg/kg)				
$S^{=}$[b]	500	<250	<250	<250
Cn^{-}	250	150	500	360

[a] Source: 40 CFR 251.24, Table 1.

[b] Below detection limits.

TABLE 4-35. Product of Incomplete Combustion Analysis of DFS Residue From May 1986 Rocket Incineration Test (ug/kg)

Parameter	Trial 1[a]	Trial 2[a]	Trial 3[a]
Unknown	23	<10	<10
1,4-dioxane	92	<10	230
2,2-dimethylhexane	<10	1,400[b]	<10
Chloromethane	<38	160	120
Dichloromethane	<11	210	2,000
Chloroform	<6.2	<6.2	11
4-methyl-2-pentanone	<6.2	<6.2	11
Carbon tetrachloride	<11	<11	15
Benzene	190	350	46

[a] Values reported with a "less than" sign indicate that the results are below detection limits of the analytical method used.

[b] Suspect result due to laboratory contamination. Verified by blank analysis.

has been used to incinerate bulk agent (GB and VX).

b. Description.

(1) General.

(a) As illustrated in Figures 4-26 and 4-27, the MPF system consists of a charge car, a Metal Parts Furnace, a Primary Fume Burner (PFB), an Auxiliary Fume Burner (AFB), and a PAS consisting of a quench tower , a variable throat venturi scrubber, and a packed tower scrubber with demister section. In addition, the MPF system includes a scrap handling and cooling equipment. The MPF, PFB, and charge car are all housed in a ventilated shroud.

(b) Items are transferred from the munition drain machines, either the Multipurpose Demilitarization Machine (MDM) or the Bulk Drain Station (BDS) to the MPF by the p[illegible] driven charge car. The drained projectiles or bulk containers (ton containers, bombs or spray tanks) are then conveyed through the punch chamber of the MPF to the volatilization chamber where the remaining agent is vaporized. The munitions are then transferred to the third and final chamber of the MPF, the burnout chamber, where they are heated to 1000°F for 15 minutes to ensure complete agent destruction, and thermal detoxification of the metal parts. The flue gases from the punch chamber and volatilization chamber enter the PFB where any agent vapors are incinerated. The exhaust from the PFB and the burnout chamber pass through the AFB where any remaining organic compounds in the exhaust gases are incinerated. From the AFB the exhaust gases pass through the PAS where they are cooled and any acid gases and particulate are removed. The metal parts are transferred from the burnout chamber into a hooded area where they are checked for chemical agent contamination; the parts are then transferred to one of two cooling bays where they are allowed to cool to (near) ambient temperatures before being disposed of.

(2) Metal Parts Furnace. The CAMDS MPF is a three chamber

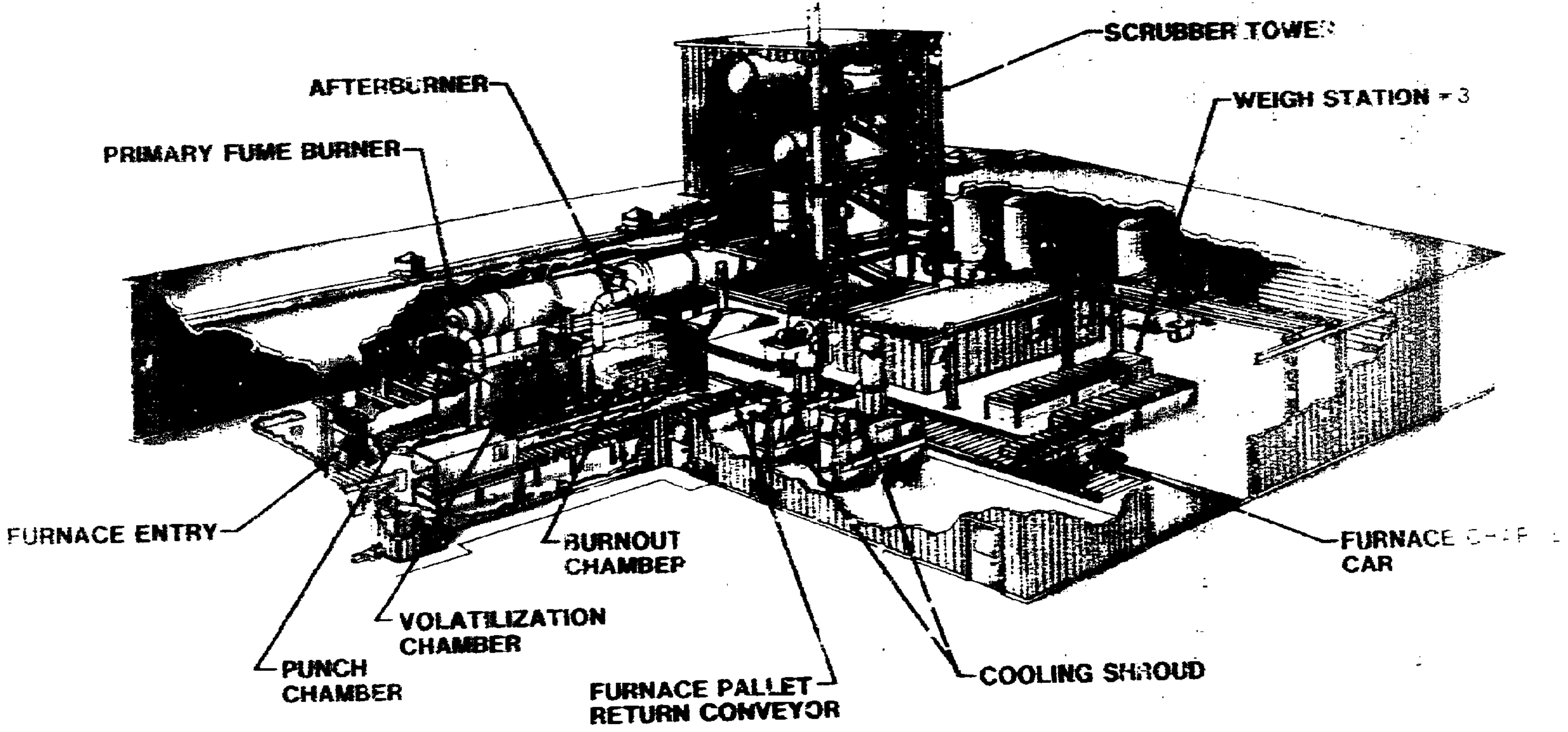


Figure 4-26: CAMDS Metal Parts Furnace System

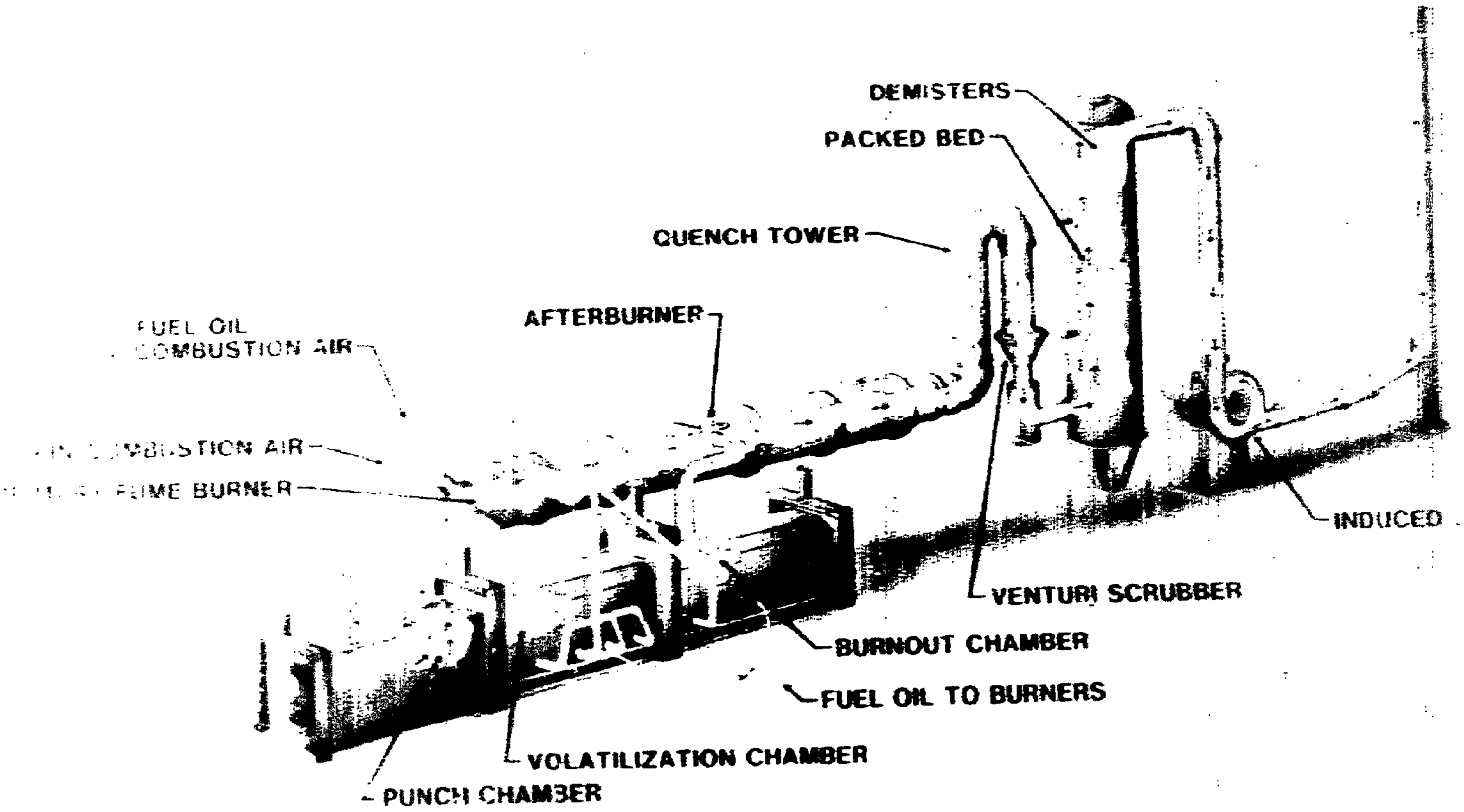


Figure 4-27: Metal Parts Furnace and Pollution Abatement System

roller hearth furnace. The three chambers comprising the MPF are an uninsulated punch chamber, a refractory-lined volatilization chamber and a refractory lined burnout chamber.

(a) Punch Chamber. The punch chamber is an uninsulated ventilated metal housing surrounding the punch station. The punch station is designed to hydraulically punch two holes, one in each end, in undrained ton containers filled with mustard. The punch chamber serves only as a vestibule/air lock for items which have been processed through either the MDM or the BDS.

(b) Volatilization Chamber. The volatilization chamber is a refractory lined chamber containing eight oil fired burners. These burners are planned to be replaced with dual fuel burners (propane (LPG) and fuel oil) in the near future. The volatilization chamber is designed to heat the projectiles or bulk containers quickly to the boiling temperature of the agent and then hold it at that temperature to produce a controlled volatilization in an oxygen deficient atmosphere. Under normal operations, agent vapors are not incinerated in the volatilization chamber.

(c) Burnout Chamber. The final chamber in the MPF is the burnout chamber which is used to burnout any residual heel left in the munition/container in an excess oxygen atmosphere. Like the volatilization chamber, the burnout chamber is a refractory-lined box, but only contains two oil fired burners. The burnout chamber is maintained at a minimum of 1000°F. Items leaving the burnout chamber are completely detoxified.

(3) Primary Fume Burner. Agent fumes from the punch chamber and the volatilization chamber are incinerated in the primary fume burner. The primary fume burner contains two oil fired burners (each rated at 1.05 million BTU per hour) followed by a refractory-lined residence chamber which maintains the exhaust gases at 1650°F for a minimum of 0.5 second.

(4) Auxiliary Fume Burner. The auxiliary fume burner is actually the afterburner for the primary fume burner and the burnout chamber.

The auxiliary fume burner uses a single, 1.4 million BTU per hour, burner which maintains the flue gas temperature at 1600°F for a minimum of 0.5 second.

(5) Pollution Abatement System (PAS) and Exhaust Standards.

(a) The purpose of the PAS is to prevent pollution of the atmosphere with gases produced by the combustion of chemical agents in the MPF. As shown in Figure 4-27, the PAS consists of a quench tower, a variable throat venturi scrubber, a packed bed wet scrubber tower, a demister section, an induced draft fan and an exhaust stack.

1 Quench Tower The quench tower is a 3.5 foot diameter by 7 foot high, partially firebricked vessel constructed of Inconel 625. The quench tower is mounted directly on top the venturi scrubber. Exhaust gases from the AFB enter the quench tower at approximately 1400° F and are cooled to approximately 200°F. The quench tower is a cocurrent flow design and the exhaust gas cooling is accomplished by evaporation of water from four hydraulic atomized type spray nozzles. The water flow rate is generally between 0.8 and 4.2 gallons per minute; any excess water falls or is entrained by the gas stream and carried directly into the venturi.

2 Venturi Scrubber The venturi scrubber is a variable throat type equipped with inlet scrubbing liquid ports without nozzles. The primary purpose of the venturi scrubber is to remove particulate matter contained in the exhaust gases; some acid gas removal also is accomplished. The venturi throat has a manually adjusted damper blade which is set to maintain a pressure drop of 10 to 20 inches water column. Brine from the packed tower scrubber sump is used as the scrubbing liquid. A liquid to gas ratio of approximately 14:1 is maintained in the venturi.

3 Packed Bed Scrubber Tower The packed bed scubber is used to remove acidic industrial pollutants contained in the exhaust gases. The packed tower is a six foot diameter vessel constructed by Hastelloy- lined carbon steel. The vessel contains a sump which collects the excess liquid from the venturi scrubber as the exhaust gases enter the bottom of the tower. The

gases then flow up through a chimney tray which supports a ten foot deep bed of 2-inch polypropylene Super Intalox saddles. The packed bed is wetted by recirculating an alkaline scrubber liquid (clear liquor) which is introduced at the top of the bed by means of a weir-trough distributor. The acidic pollutants react with the brine to form salts. Fresh caustic is added to the clear liquor, just before it enters the tower, to maintain a clear liquor pH of approximately 10. A York mist type entrainment separator is located directly above the packed bed to prevent carry over of large liquid droplets to the demisters.

4 Fiber Bed Demisters The fiber demister unit is located two feet above the entrainment separator in the packed tower vessel, and consists of five elements, two foot in diameter by 12 foot high. The demisters are used to remove small liquid droplets and fine particulate before the gases are discharged to the atmosphere. An isolation damper allows the demisters to be bypassed.

5 Induced Draft Fan The induced draft fan pulls the gases through the PAS and maintains a negative pressure in the entire furnace system, thus preventing any release of agent vapors during operation. The fan is capable of 17,400 acfm at 250°F and 42 inches static pressure. A 200 horse power, two-speed, motor provides the drive for the fan.

(b) The stack emission standards are identical to those described in paragraph 4.3.2.c. (see Tables 4-16 and 4-17).

c. Completed Incineration Tests. As shown in Table 4-15, approximately 32,000 pounds of GB, 8,000 pounds of VX and 18,897 projectiles have been processed through the MPF system. Four different types of tests have been conducted with the MPF system: (1) PAS evaluation; (2) agent injection incineration; (3) thermal decontamination of drained projectiles and (4) in-situ incineration. Each of these four categories will be discussed in detail in the following sections.

(1) GB Challenge of the MPF PAS.(40)

(a) Purpose. As with the DFS PAS, the MPF PAS was not designed to remove agent vapors. This test, which was conducted in August 1978, was designed to determine the ability of the PAS to remove GB vapors from the furnace exhaust in the event of furnace upset. The specific objectives of the test were:

1 Determine GB removal efficiency of the PAS under cold conditions with the hearth, fume burner and afterburner off.

2 Determine the GB DRE under normal operating conditions.

3 Determine the GB DRE in the event of a partial system shutdown (loss of PFB).

4 Determine the GB DRE in the event of total system shutdown (loss of PFB and AFB).

(b) Method.

1 Dilute acidic solutions of GB were prepared by mixing neat GB with sulfuric acid (pH 3.7). Agent solutions were sprayed into the AFB exhaust duct, upstream of the quench, at challenge rates of 0.122 mg/m^3, 1.06 mg/m^3 and 3.17 mg/m^3. The air flow through the PAS was 2206 acfm for the first two trials and 2535 for the third trial. GB monitors (bubblers) were located before the quench, after the venturi scrubber and in the exhaust stack.

2 For the normal operation tests, neat agent was sprayed into the volatilization chamber at challenge rates of 202 and 865 mg/m^3. The exhaust gas flow rate was 3797 acfm for both trials. The GB monitors were located in the same positions as were used during the cold performance test.

3 The partial failure test was conducted in the same manner as the normal operating trial except that after a designated period of time the PFB was shutdown. In the first trial 1236 mg/m^3 was sparyed for four minutes after which the PFB was shutdown; two and one-half minutes later, the GB spray

was stopped. GB monitor sampling continued for 15 additional minutes. The second trial was identical to the first except that the PFB was shutdown after 12 minutes instead of four.

4 Two trials were conducted for the total system failure test. The first trial involved spraying GB at a challenge rate of 161 mg/m^3 for 14 minutes, after which the PFB and AFB were shutdown. Two and one-half minutes later, the GB spray was shut off. The furnace quench, which is automatically activated in the event of an AFB failure, was manually shut off 30 seconds after the GB flow rate was stopped. The bubblers sampled for fifteen additional minutes. The second trial was conducted the same as the first except the challenge rate was 1323 mg/m^3 and the GB was sprayed for 6 minutes before shutdown and three and one-half minutes after shutdown.

(c) Results.

1 The GB removal efficiency of the PAS under cold conditions was a minimum of 99.99% up to GB challenge rates of 3.17 mg/m^3.

2 Under normal operating and upset conditions, both partial and total failure, the observed GB DRE was greater than 99.999%.

(2) Initial MPF Agent Challenge Test.(41)

(a) Purpose. The purpose of this test was to determine the limiting factor for agent incineration in the MPF: destruction efficiency or thermal capacity.

(b) Method. Neat, 69% pure GB was transferred from a ton container via a double-walled pipe to the volatilization chamber by pressuring the ton containers with nitrogen at 6-12 psi pressure (Figure 4-28). An empty, open one-half ton container was placed in the volatilization chamber under the feed pipe to collect any liquid agent which did not immediately volatilize in the furnace. Five agent trials, 30 minutes each were conducted; the agent challenge increased from 0.83 pounds per minute (49.8 pounds per hour) to a

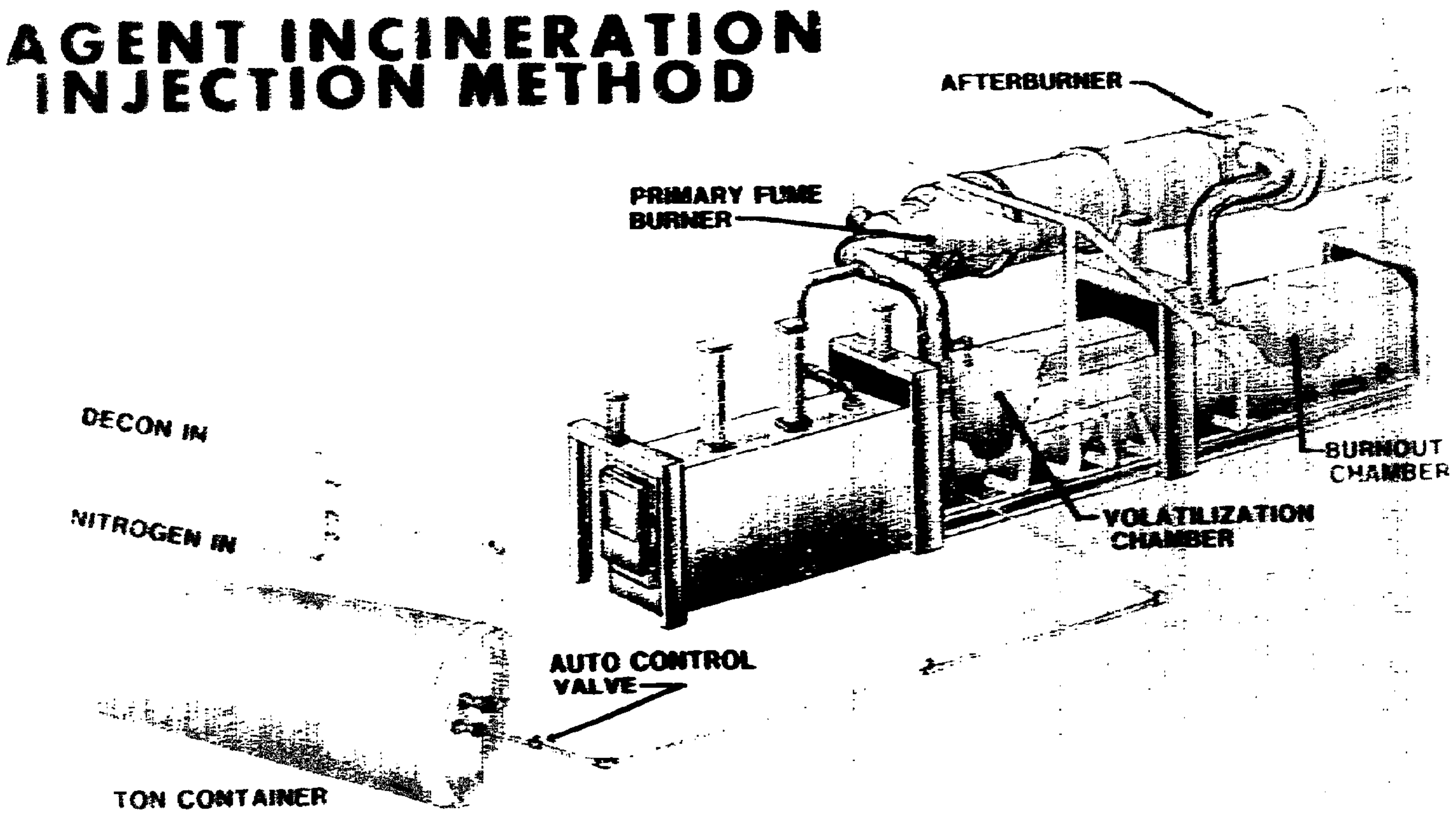


Figure 4-28: Metal Parts Furnace Bulk Agent Feed System

maximum feed rate of 6.63 pounds per minute (397.8 pounds per hour). The test was conducted without the demisters to eliminate the possibility of test interruption due to plugging with phosphorous pentoxide (P_2O_5) particulate (a by-product of GB incineration).

(c) Results. The MPF successfully incinerated GB at a feed rate of 6.63 pounds per minute. No agent was detected in the exhaust stack and the thermal limits of the system were not reached. A GB DRE of greater than 99.99999%, was obtained based on a GB allowable stack concentration of 3×10^{-4} mg/m^3 (Table 4-16) and an exhaust gas flow rate of 8999 acfm. The stack opacity exceeded the Utah limit of 20% when incinerating GB at flow rates of 3.32 pounds per minute or greater due to P_2O_5 particulate.

(3) March 1982 MPF Agent Challenge Test.(42) Because of the success of the previous GB injection incineration test, and the continuing problems which CAMDS was experiencing with GB neutralization, it was decided to conduct additional tests to determine if incineration was a viable alternative to neutralization for GB destruction.

(a) Purpose. To determine the feasibility of incinerating GB at a sustained rate equal to or greater than: (1) the ability of projectile pull and drain machine (PPD) (which was the predecessor to the MDM) to generate agent; or (2) the ability of the neutralization process to destroy it. In addition, the system's PAS, thermal capacity, and air flow handling characteristics were examined.

(b) Method. The same procedure described in paragraph 4.3.3.c.(2)(b) was used for this test. A total of seven trials were conducted. Agent challenge rates of 0.96, 2.40 and 4.8 (for four trials) pounds per minute were conducted. After the successful completion of these trials an additional trial where the agent was incrementally increased from 5.29 pounds per minute to 7.44 pounds per minute was conducted. In addition to the normal operational data collected by CAMDS personnel, the AEHA and Battelle Laboratory representatives collected additional data to evaluate the performance of the PAS.(43,44)

(c) Results.

1 The MPF demonstrated it could efficiently incinerate GB at a rate at least equal to 7.44 pounds per minute (446 pounds per hour). The calculated GB DRE was greater than 99.99999% based on the allowable GB stack concentration (Table 4-16), a stack flow rate of 7015 acfm, and an agent purity of 69%.

2 The stack opacity never exceeded 20% at any time during the test. With the demister in the flow path, the stack opacity did not exceed 5%, even at an agent flow rate of 7.44 pounds per minute. Only when the demister was bypassed at an agent flow rate of 7.44 pounds per minute did the opacity reach the 20% limit. The improvement in the stack opacity, as compared to the previous GB injection incineration test, was attributed to increased liquid flow rate to the quench tower.

3 During the last three 4.8 pounds per minute GB challenge trials Battelle performed an ICAP (Inductively Coupled Argon Plasma) analysis to determine the concentration of heavy metal in the stack gas. As shown in Table 4-36 only trace quantities of metals were detected. The metals could have come from impurities in either the fuel oil or the GB.

(4) Thermal Decontamination (5Xing) of Drained 105mm GB Projectiles (45)

(a) Purpose. To determine if the MPF system was capable of thermally decontaminating drained 105mm projectiles at the designed processing time of one hour and temperature of 1100°F in each chamber (Volatilization and Burnout).

(b) Method. In May 1982, 150 105mm drained GB projectiles (two trays of 75 each) were processed through the MPF. Each projectile contained a residual amount of GB one-quarter inch deep; this equated to a GB challenge of approximately three pounds per 75 projectiles.

TABLE 4-36. ICAP Metals Analysis of MPF Stack Gas During GB Incineration(1)

	CONCENTRATION, mg/Nm^3			
METAL/TRIAL	BLANK	1	2	3
Calcium, Ca	0.42	0.35	0.55	0.74
Magnesium, Mg	0.14	0.18	0.13	1.10
Iron, Fe	6.05	0.08	1.7	2.6
Aluminum, Al	0.12	0.16	0.13	0.09
Boron, B	0.09	0.09	0.07	0.03
Titanium, Ti	0.01	0.015	0.01	0.006
Barium, Ba	0.007	0.006	0.0007	0.004
Tin, Sn	ND(2)	0.23	0.13	0.09

NOTES: ND = Not Detected
GB Flow Rate = 288

(c) Results. When the first tray was removed from the MPF and placed underneath the exhaust hood, the chemical agent monitor went into alarm. The GB bubbler was analyzed by gas chromotography and confirmed low levels (1×10^{-4}) of GB. The second tray did not set off the chemical agent alarm when removed from the furnace.

(5) Undrained 155mm GB Projectile Incineration.(46) From October to December 1982, undrained 155mm GB filled projectiles were processed through the MPF. This was to investigate a method of incinerating the agent directly from the munition or storage container commonly referred to as "in-situ incineration." By this time, the Army had decided to abandon neutralization, in favor of incineration, as a viable method for large scale chemical agent disposal. In-situ incineration was being evaluated as an alternative to "injection" incineration.

(a) Purpose. The purpose of this test was to demonstrate that the MPF could safely volatilize and destroy the GB contained in 48 undrained 155mm GB projectiles, to optimize operating conditions to identify and minimize any disturbances that could result in agent releases and to decrease the time required to process a tray of 48 projectiles through the furnace.

(b) Method. A total of 36 trials were performed to determine if the MPF system was capable of incinerating the agent contained in the projectiles. (The burster wells were removed to access the agent cavity of the projectiles (Figure 4-29)). During the first 17 trials the number of agent filled projectiles was increased from four until a full tray of 48 was achieved. The remaining 19 trials involved processing full trays of 48 GB filled projectiles under varying operating conditions. Several of the latter 19 trials were run under the same conditions to verify the repeatability of the burn process.

(c) Results.

1 The test was successful in that it demonstrated that the

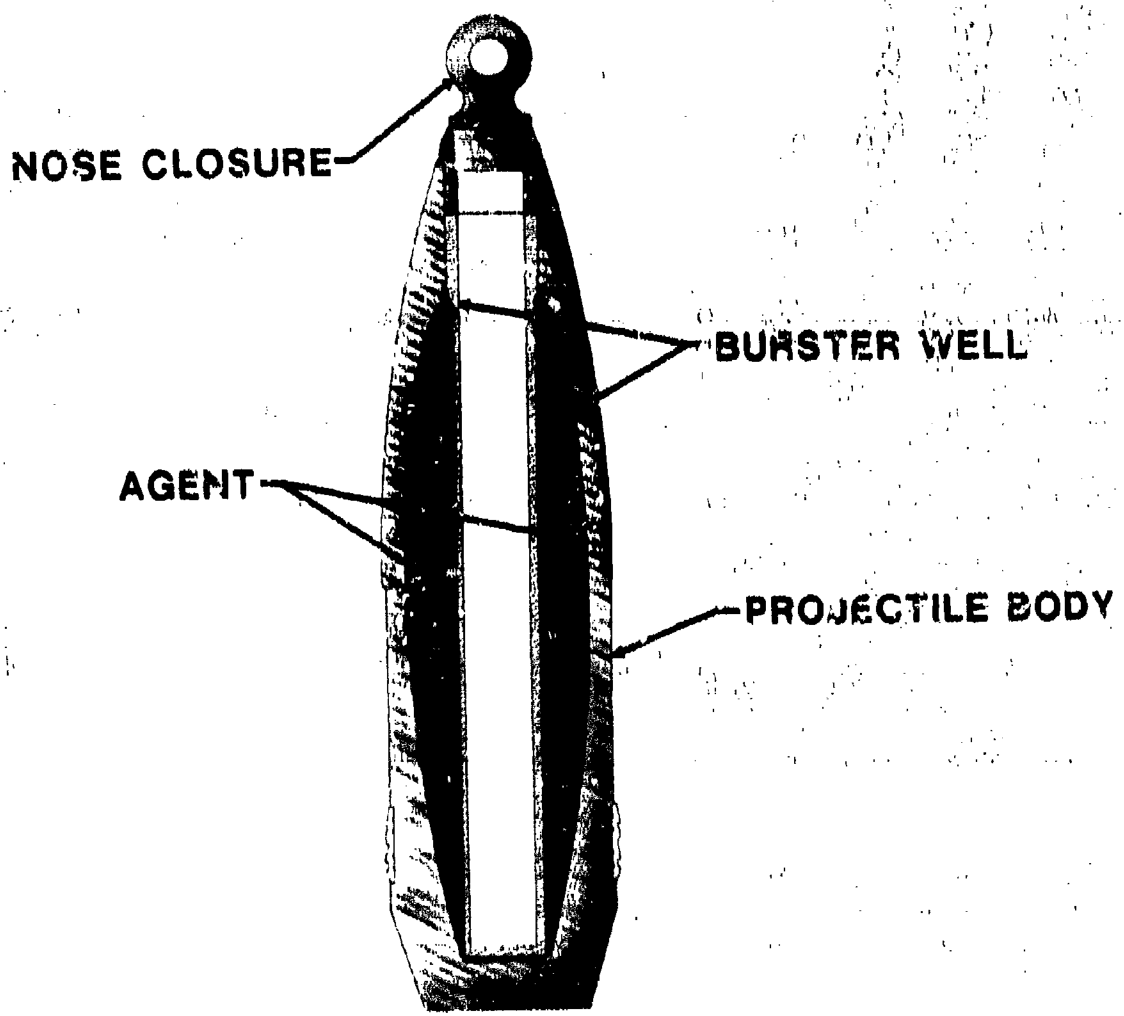


Figure 4-29: 155mm Projectile Illustration

MPF could volatilize and incinerate a tray of 48 GB filled 155mm projectiles, however further testing was determined to be necessary to optimize and improve operating conditions such as furnace draft.

2 Although GB was occasionally detected before the quench tower, no agent was detected in the exhaust stack. The estimated GB DRE was greater than 99.99999% based on the allowable stack concentration.

(6) Final GB Injection Incineration Tests.(47,48)

(a) Purpose. The purpose of this test was to develop design data for the JACADS MPF and Liquid Incinerator (LIC). Because of some instability of furnace drafts during the GB 155mm projectile in-situ incineration, in-situ incineration was dropped from the JACADS design criteria. It was decided that, for JACADS, all chemical agents would be drained from their respective munition or container and burned in a separate Liquid Incinerator. Specific test objectives were:

1 Determine the maximum GB incineration capacity of the MPF.

2 Evaluate the adequacy of the PAS to meet RCRA standards.

3 Characterize PAS and furnace waste streams.

4 Incorporate process and analytical data into comprehensive heat and material balances.

(b) Method. The GB was fed into the MPF in the same manner as the earlier injection incineration tests (Figure 4-28). The agent flow rate was increased from 200 pounds per hour to 550 pounds per hour (referred to as workup tests); above this flow rate, the PFB and AFB temperature and entire furnace draft became unstable. A total of six trials were conducted at 550 pounds GB per hour. Representatives from the Ralph M. Parsons Company of Delaware assisted CAMDS personnel in data collection and evaluation.

(c) Results.

1 The MPF successfully incinerated GB at flow rates of 550 pounds per hour. No confirmed agent stack emissions occurred during the test. Based on the allowable GB stack concentration, the calculated GB DRE was greater than 99.999999%.

2 Table 4-37 is the analysis of the MPF exhaust before and after treatment by the PAS. While the removal efficiencies were in the range of CAMDS PAS design specifications, the particulate emissions exceeded RCRA limits (806 mg/m^3 and 1014 mg/m^3 corrected to 7% oxygen for trials H1-11 and H1-12 respectively). This situation was believed to have been caused by leakage occurring through the demister bypass line; it was estimated that 30% of the furnace exhaust gases bypassed the demisters allowing P_2O_5 particulates to escape to the stack.

3 The analysis of the PAS brines, before and after GB incineration, is shown in Table 4-38. Heavy metal content of the scrubber brine indicated varying quantities of metals. The sources of these metals include the agent, caustic, process water or system materials.

4 After GB incineration, a residue was found in the ton containers located in the volatilization chamber. The ash was gray and very light in density. As shown in Table 4-39 only the ash created during the workup tests was RCRA hazardous due to cadmium concentration above the RCRA standard.

5 Material balances around the MPF closed within ± 10 percent through the use of verification data and engineering data. Heat balances could only be closed within ± 20 percent; this was due to carbon material balance non-closure since the carbon compounds (fuel oil and agent) were the source of heat input.

TABLE 4-37 Analysis of MPF Exhaust: September 1983 GB Injection Incineration Test

PARAMETER	TRIAL H1-11	 H1-12
1. Particulate		
a. AFB Exhaust		
(1) Concentration (gr/DSCF)	4.89	11.89
(2) Emission Rate (lb/hr)	166.93	397.14
(3) % P_2O_5	14.8	10.0
b. PAS Stack		
(1) Concentration (gr/DSCF)	0.25	0.23
(2) Emission Rate (lb/hr)	9.42	8.75
(3) % P_2O_5	39.6	39.7
c. Removal Efficiency	94.6%	97.9%
2. Hydrogen Fluoride (lb/hr)		
a. Emission Rate		
(1) AFB Exhaust	50.63	51.02
(2) PAS Stack	0.57	0.63
b. Removal Efficiency	98.87%	98.77%

TABLE 4-38 MPF PAS Brine Analysis: September 1983 GB Injection Incineration Test

PARAMETER	CONCENTRATION (mg/liter) BEFORE	AFTER(1)
pH	8.7	7.5
Solids	11,000	170,000
Dissolved Solids	110,000	170,000
COD	150	70
TOD	.22	27
$NaHCO_3$	1694	852
Na_2CO_3	42	2
NaF	2.824	25,743
Na_2SO_3	1645	1645
Na_2SO_4	5969	21,718
$NaNO_2$	77	0.3
$NaNO_3$	120	179
Na_2HPO_4	39,507	50,608
Mercury, Hg	0.008	0.010
Silver, Ag	0.016	0.02
Arsenic, As	0.034	0.037
Barium, Ba	4.3	27.1
Cadmium, Cd	1.1	2.8
Cromium, Cr	0.6	1.4
Lead, Pb	0.6	0.2
Selenium, Se	0.036	0.040
Boron, B	50	56
Aluminum, Al	15	22
Beryllium, Be	0.016	0.021
Calcium, Ca	455	269
Cobolt, Co	0.3	0.3
Copper, Cu	14	21
Iron, Fe	155	442
Potassium, K	73	125
Manganese, Mn	2	6
Molybdenum, Mo	0.13	0.51
Sodium, Na	34,227	44,744
Nickel, Ni	33	69
Antimony, Sb	0.2	0.2
Tin, Sn	0.016	0.02
Uranium, U	0.2	0.7
Zinc, Zn	10	21

NOTE: 1013 pounds of GB incinerated.

TABLE 4-39 EP Toxicity Analysis of GB Ash Residue: September 1983 GB Injection Incineration Test

METAL/TRIAL	CONCENTRATION (mg/liter) WORKUP	H1-04	H1-07	RCRA STANDARD
Arsenic, As	0.01	0.02	0.01	5.0
Barium, Ba	0.7	0.8	0.9	100.0
Cadmium, Cd	1.2	0.01	0.77	1.0
Lead, Pb	1.6	0.08	1.1	5.0
Mercury, Hg	0.005	0.0005	0.005	5.0
Selenium, Se	0.01	0.01	0.01	1.0
Silver, Ag	0.01	0.01	0.01	1.0
Chromium, Cr	0.01	0.01	0.01	5.0

(7) VX Injection Incineration Test.(49,50)

(a) Purpose. The purpose of this test was to develop VX incineration design data for the JACADS MPF and LIC. In addition, the feasibility of incinerating spent decontamination solution (five weight percent aqueous sodium hypochlorite) by spraying it into the AFB exhaust duct was to be evaluated.

(b) Method. The VX incineration test was conducted from 30 April 1984 to 19 June 1984. The test was conducted in the same manner as the GB injection test. The agent flow rate was increased from 175 pounds per hour to 550 pounds per hour at which time the furnace draft became unstable. A maximum of 400 pounds per hour were used for the remainder of the test. In addition to the agent incineration trials, a series of trials involving the injection of spent decontamination solutions of sodium hypochlorite in the AFB exhaust duct were conducted. Fresh decontamination solution was injected into the AFB exhaust duct approximately 12 feet downstream from the AFB discharge. Decontamination solution was injected at a rate of 2000 pounds per hour while the MPF was incinerating 400 pounds of VX per hour. Representatives from the Ralph M. Parsons Company of Delaware assisted CAMDS personnel in data collection and evaluation.

(c) Results.

1 The MPF successfully incinerated VX at flow rates of 400 pounds per hour. No agent readings were recorded during the test. The calculated DRE, based on the allowable VX stack concentration (3×10^{-5} mg VX/m^3), was greater than 99.9999998%.

2 Table 4-40 lists the range of particulate emissions observed before and after treatment by the PAS. During trial H3-03 both agent and decontamination solution were processed; only agent was processed in trial H3-02. All particulate emissions were well below the RCRA mandated 180 mg/m^3. All chloride levels (from the spent decontamination solution) were

TABLE 4-40 Particulate Analysis of MPF Exhaust Gas VX Injection Incineration Test

PARAMETER	TRIAL	
	H3-02(1)	H3-03(2)
1. Particulate		
a. AFB Exhaust		
(1) Concentration (gr/DSCF)	2.1568	2.3340
(2) Emission Rate (lb/hr)	67.96	71.28
(3) % P_2O_5	34.91%	--(3)
b. PAS Stack		
(1) Concentration (gr/DSCF)	0.0240	0.0185
(2) Emission Rate (lb/hr)	1.153	0.796
(3) % P_2O_5	39.20%	26.26
c. Removal Efficiency	98.6%	98.6%

NOTES:

(1) Agent Only Trial

(2) Agent and Decon Trial

(3) AFB Exhaust Stream Not Sampled During Decon Spraying Operations

below detectable levels. These results are considerably better than those obtained during the final GB injection incineration test; this is probably the result of modifying the demister bypass for the VX tests thus ensuring all exhaust passed through the demisters.

3 Analysis of the PAS brines before and after the VX injection incineration test (all levels) is listed in Table 4-41. As shown, the brines contained varying quantities of heavy metals. A large portion of the brine heavy metals was the result of the spent decontamination solution processing; Tables 4-42 and 4-43 list the metals analysis for the decontamination solution and its contribution to the brine heavy metal content, respectively.

4 As was observed during the final GB injection incineration test, a large quantity of ash accumulated in the open ton container located in the volatilization chamber. The ash appeared gray and more dense than that found after GB incineration. Approximately 2.7 pounds of ash were produced for every 100 pounds of VX incinerated. As shown in Table 4-44, the furnace residue was not EP Toxic.

4.3.4. Liquid Incinerator (LIC).(22)

a. Purpose. The purpose of the LIC is to burn chemical agents drained from munitions or bulk containers as well as to incinerate organic matter contained in waste liquors such as spent decontamination solutions. The LIC is the primary chemical agent incinerator for CAMDS, JACADS and the proposed disposal plants.

b. Description.

(1) The LIC is a proprietary design of Trane Thermal, Incorporated.

(a) As shown in Figure 4-30, the LIC is a dual-chamber refractory-lined incinerator. The chemical agent drained from the various

TABLE 4-41. MPF PAS Brine Analysis VX Injection Incineration Test

PARAMETER	BEFORE TEST (mg/1)	AFTER TEST(1) (mg/1)
pH	8.8	9.4
Sp Gr	1.004	1.203
Solids	9360	262,000
Dissolved Solids	8070	258,000
COD	100	270
TOC	32	330
Na_2HPO_4	464.7	32,800
NaCl	260	39,183
Na_2SO_4	4556	15,229
Na_2CO_3	6865	69,889
$NaNO_3$	41.8	607
Arsenic, As	0.02	0.416
Barium, Ba	0.2	1.087
Cadmium, Cd	0.077	2.044
Chromium, Cr	0.1	0.805
Lead, Pb	0.02	0.136
Mercury, Hg	0.0008	0.0449
Selenium, Se	0.02	0.02
Silver, Ag	0.02	0.768
Aluminum, Al	0.8	2.62
Copper, Cu	0.172	3.703
Iron, Fe	7.646	194.9
Nickel, Ni	0.405	11.92
Zinc, Zn	6.660	8.586

NOTES: Material Processed
VX: 2641 pounds
Decon: 10,252 pounds

TABLE 4-42 Analysis of VX Spent Decontamination Solution (4.6 wt% Sodium Hypochlorite)

PARAMETER	CONCENTRATION (mg/liter)
Sp. Gr.	1.078
Solids	116,000
Dissolved Solids	115,000
NaOCl	47,827
Arsenic, As	0.02
Barium, Ba	0.1
Cadmium, Cd	2.418
Chromium, Cr	2.376
Lead, Pb	0.056
Mercury, Hg	0.0002
Selenium, Se	0.02
Silver, Ag	0.258
Aluminum, Al	1.437
Copper, Cu	0.264
Iron, Fe	52.19
Nickel, Ni	4.861
Zinc, Zn	0.406

TABLE 4-43 Spent VX Decontamination Solution Contribution to Heavy Metals in MPF PAS Brines

	BRINES(1)			DECON(2)		CHANGE(3)	
	mg/1	1	mg	mg/1	1	mg	%
As	0.396	4126	1634	0.02	4321	86	5.3
Ba	0.007	4126	3660	0.1	4321	432	11.8
Cd	1.967	4126	8116	2.418	4321	10449	128.8
Cr	0.705	4126	2909	2.376	4321	10267	353.9
Pb	0.116	4126	479	0.056	4321	242	50.5
Hg	0.0441	4126	182	0.0002	4321	0.86	0.5
Se	0	4126	0	0.02	4321	--	--
Ag	0.748	4126	3086	0.258	4321	1115	36.1
Al	1.820	4126	7509	1.432	4321	6108	82.4
Cu	3.531	4126	14569	0.266	4321	1149	7.9
Fe	187.25	4126	772610	52.19	4321	225527	29.2
Ni	11.515	4126	47511	4.86	4321	21006	44.2
Zn	7.926	4126	32703	0.406	4321	1754	5.4

NOTES:

(1) Concentrations are Net Values Based on Data from Table 3-12

(2) Based on 10252 Total Decon Feed to System During H1-03, H1-04

(3) % Metal from Decon Injection {(mg/brine metal)/(mg decon metal)} x 100

TABLE 4-44 EP Toxicity Analysis of VX Ash Residue

METAL/TRIAL	CONCENTRATION, mg/liter H3-01	H3-02	H3-03	H3-04	RCRA STANDARD
Arsenic, As	0.01	0.01	0.01	0.01	5.0
Barium, Ba	0.1	0.3	0.5	0.6	100.0
Cadmium, Cd	0.01	0.06	0.15	0.16	1.0
Chromium, Cr	0.05	0.05	0.49	0.49	5.0
Lead, Pb	0.01	0.032	0.212	0.165	5.0
Mercury, Hg	0.0002	0.0002	0.0002	0.0002	0.2
Selenium, Se	0.01	0.01	0.01	0.01	1.0
Silver, Ag	0.01	0.01	0.05	0.05	5.0

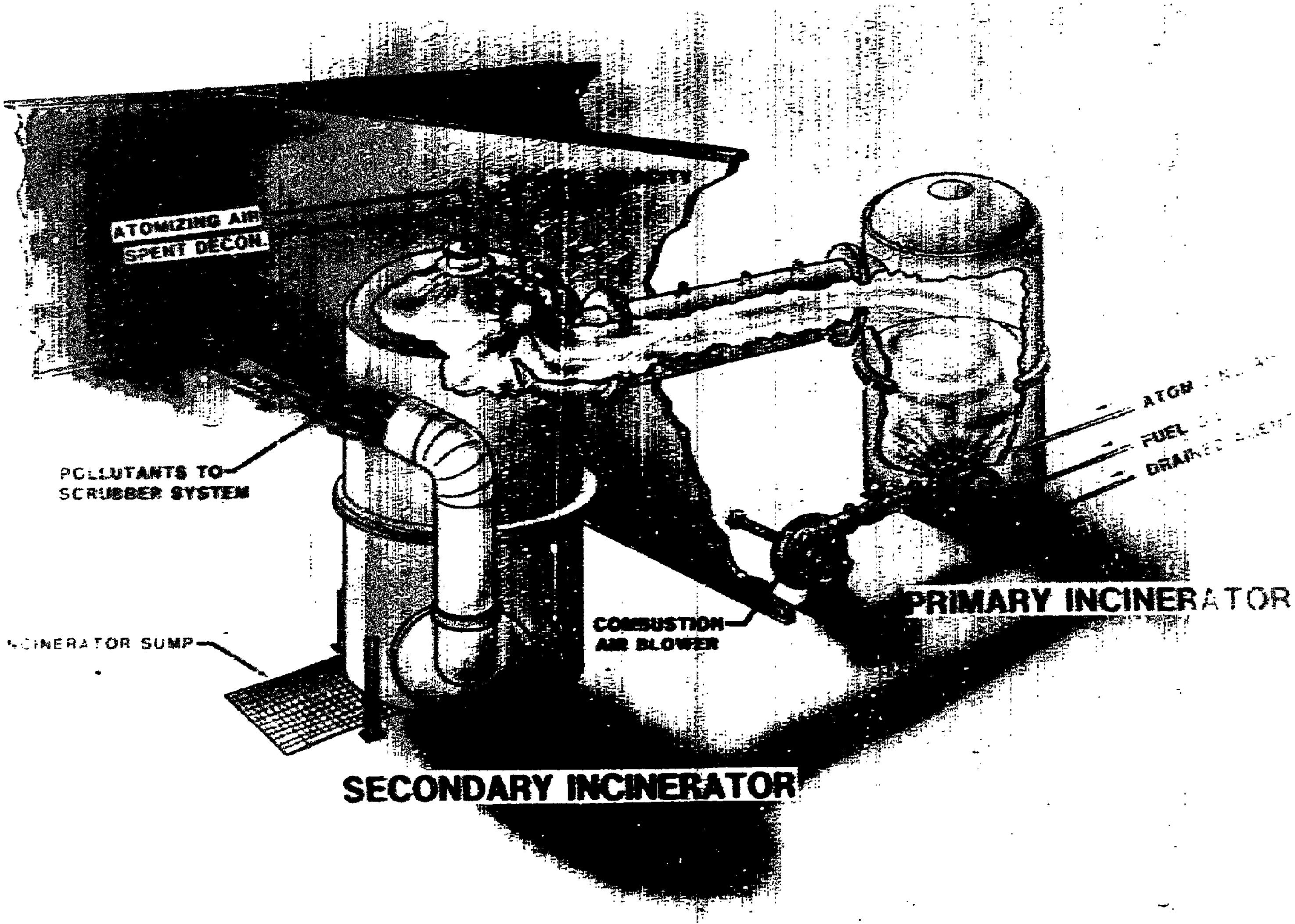


Figure 4-30: CAMDS Liquid Incinerator

munitions or containers is incinerated in the first chamber or primary incinerator. At CAMDS either fuel oil or LPG is used to raise the primary incinerator to approximately 2500°F at which time agent is gradually introduced as the fuel oil or propane is reduced. Under normal operations, the chemical agent provides sufficient heat to maintain temperature and combustion after warmup; the fuel oil or propane is used only to ensure a stable flame pattern.

(b) The secondary incinerator is actually an afterburner and provides additional time at temperature for the gases leaving the primary incinerator. The temperature in the secondary incinerator is maintained at 2000°F by burning fuel oil or propane. The secondary incinerator is also used to thermally destroy any organic compounds contained in the spent decontamination solutions generated in the disposal facility.

(c) The CAMDS LIC has approximately one-third the capacity of the LIC which will be used in JACADS or the proposed CSDP disposal facilities. In addition, instead of having an independent PAS, the CAMDS LIC uses the MPF PAS, as shown in Figure 4-31, to remove acid gases and particulates from the LIC exhaust gases. Note that the afterburner shown in Figure 4-31 belongs to the MPF; the exhaust from the LIC does not pass through the MPF afterburner but is ducted directly to the MPF PAS. Because the LIC and MPF share the same PAS both incinerators cannot be operated concurrently.

c. Completed Tests As of 19 August 1987, 37,930 pounds of GB have been successfully incinerated in the LIC. The GB incinerated was agent drained from M55 rockets as well as bulk GB from ton containers.

(1) Ocean Dumping Permit Application Analyses of LIC Scrubber Brines(37)

(a) Purpose. To obtain analytical data on the LIC scrubber brine in support of the JACADS Ocean Dumping Permit application. The purpose

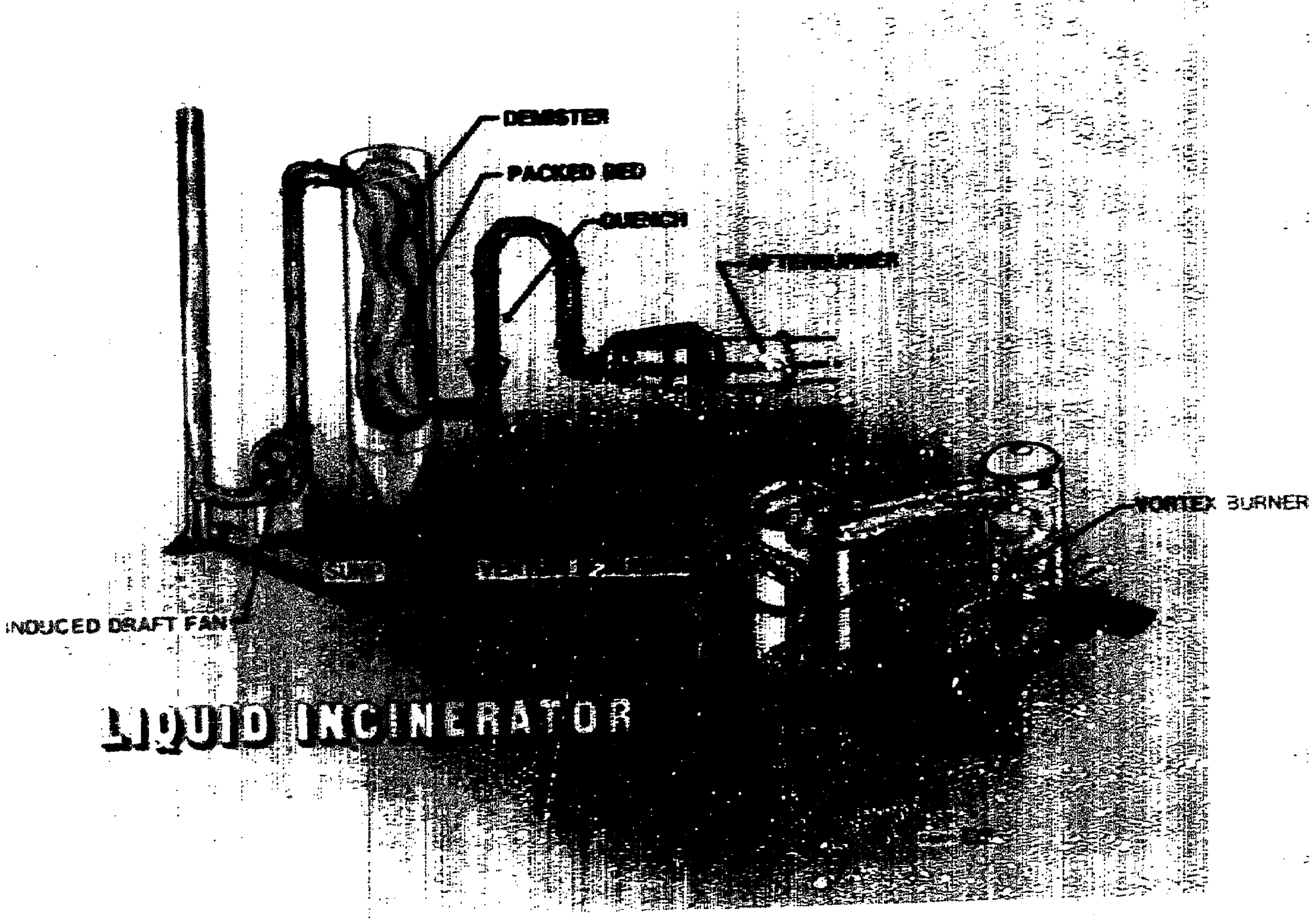


Figure 4-31: CAMDS LIC-MPF PAS Interface

and data requirements of this test were identidcal to those described in section 4.3.2.d (4) for the DFS Scrubber brine. This data will be used in lieu of the data obtained from the Final GB Injection Incineration Test, described in section 4.3.3.c (6) because:

1 Brine generated by incinerating GB in the CAMDS LIC/MPF PAS system will be more representative of the brine generated by the JACADS LIC.

2 Improved analytical procedures have corrected many of the problems experienced when analyzing the brine generated during the Final GB Incineration test.

(b) Prior to incinerating GB in the LIC, samples were collected from the scrubber sump of the PAS. GB was incinerated in the LIC over a two-day period until the specific gravity of the brine exceeded 1.08. Above this value, CAMDS operations are required to add water to prevent a build-up of solids which would require purging of the scrubber system pipes. Upon completion, additional samples were collected from the same location used to collect the pre-burn samples. The total amount of GB incinerated in the LIC over the two-day period was approximately 1726 pounds.

(c) Results

1 Tables 4-45 and 4-46 list the total metals and EP toxicity leachate metals analyses of the scrubber brine. The brine did not contain any metals above the RCRA limit.

2 As would be expected for GB incineration, Table 4-47 shows that the scrubber brine had a large increase in phosphate and fluoride anion concentrations. Chloride and sulfate anions also increased but to a lesser extent. COD and TOC levels did not change significantly during the test. This is to be expected given the high temperature in the LIC. The total solids content of the scrubber brines was approximately 14% w/v.

3 No organic priority pollutant compounds, either volatile

TABLE 4-45 Total Metal Analysis of LIC Scurbber Brine, February 1986 GB Incineration Test

Metal	Pre Burn Concentration (mg/1)	Post Burn Concentration (mg/1)
Ag	<0.02	<0.02
Al	9.2	6.0
As	0.014	0.048
B	7.1	11.0
Ba	<0.4	<0.4
Be	<0.02	<0.02
Ca	148.0	48.0
Cd	0.082	0.162
Co	<0.06	<0.06
Cr	0.10	<0.09
Cu	0.27	0.12
Fe	67.0	50.0
Hg	0.002	0.004
K	15.3	18.6
Mn	0.70	0.83
Mo	<0.3	<0.3
Na	1200.0	38000.0
Ni	0.64	0.37
Pb	0.19	0.39
Sb	<0.25	<0.25
Se	<0.002	<0.002
Sn	<1.2	1.43
V	<0.7	<0.7
Zn	1.2	1.3

NOTES: (1) Total GB Incinerated: 1726 Pounds.

TABLE 4-46. EP Toxicity Leachate Metal Analysis of LIC Scrubber Brine
February 1986 GB Incineration Test

Metal	Pre-Burn Concentration (mg/l)	Post Burn Concentration (mg/l)	RCRA Limit (mg/l)
Ag	<0.04	<0.04	5.0
As	<0.009	0.047	5.0
Ba	<0.08	<0.08	100.0
Cd	0.019	0.145	1.0
Cr	<0.09	0.09	5.0
Fe	<0.07	7.6	—
Hg	<0.0005	0.0005	0.2
Na	2000.0	23,000.0	—
Pb	<0.18	0.43	5.0
Se	<0.002	<0.002	1.0
Zn	0.036	1.8	—

NOTES: Total GB incinerated: 1726 pounds

TABLE 4-47. Chemical Analysis of LIC Scrubber Brine, February 1986 GB Incineration Test

Parameter	Pre-Burn Concentration (mg/l)	Post Burn Concentration (mg/l)
pH (1)	8.5	7.8
Total Solids	7850.0	145,294
Total Dissolved Solids	5556.0	112,421
Spc. Gr (1)	1.006	1.109
NO_3	2.5	25.0
Cl	358.0	2,180.0
F	480.0	22,150.0
PO_4	1410.0	64,450.0
Alkalinity as CO_3	520.0	110.0
SO_4	240.0	5,100.0
COD	300.0	290.0
TOC	73.0	58.0

NOTES: (1) Stated limit.

(2) Total GB incinerated: 1726 pounds.

or semivolatile, were detected in the scrubber brine in significant concentrations. Two semivolatile compounds were detected, 2-Nitrophenol and Phenol. However the concentrations were just above the detection limit.

(2) GB Incineration Test (51)

(a) Purpose. The purpose of this test was to obtain emissions and process data that could be used to evaluate the performance of PAS when GB was incinerated in the LIC both with and without injection of decontamination solution into the afterburner. The exhaust gases were sampled before and after treatment by the PAS to determine the concentration and removal efficiency of particulate and acid gases. The scrubber sump brines, LIC sump brines and the dried salt formed by drying the brines were analyzed to determine if they were RCRA characteristic hazardous wastes due to EP Toxicity.

(b) Method. From December 1985 through February 1986 a series of seventeen test burns (runs) were conducted. The GB mass flow rate averaged 226 pounds per hour and the duration of the test runs ranged from 55 minutes to 360 minutes. IT Corporation was contracted to perform the analyses (LIC exhaust and MPF stack gas sampling were performed by York Services Corporation which was subcontracted by IT).

(c) Results.

1 Agent DRE. No GB was detected during any of the test runs. The observed agent DRE for the LIC/MPF PAS system was greater than 99.99999%. This is based on an allowable stack concentration of 3×10^{-4} mg GB/m^3, a stack gas flow rate of 5638 dscfm and a GB purity of 69%. This is believed to be a conservative assessment since stack alarms are set at one-third the allowable stack concentration (ASC). The method detection limit necessary to demonstrate the RCRA mandated 99.99% DRE is 1.1 mg/m^3, which is 3666 times higher than the ASC and 11,000 times higher than the alarm set point.

2 Particulate Emissions .

a. The particulate concentration in the stack gases from each test run exceeded the RCRA limit of 0.08 gr/dscf,corrected to 7% O_2. This is believed to have been caused by insufficient liquid to the quench tower. The quench exit gas temperatures were estimated to be about 250-300°F for most runs. This would have resulted in a gas residence time of about 0.3 second which is too short to achieve any significant particle growth and agglomeration. The hot quench gases in turn would have dried the venturi scrubber brine into a fine particulate. These fine particles and additional condensed P_2O_5 particles would have had a better chance of passing through the venturi and packed bed resulting in a higher loading on the demisters. In addition. Closer control by CAMDS operators could have reduced the particulate emissions.

b. Table 4-48 lists representative particulate emissions and removal data from the test runs. IT experienced considerable difficulty in recovering particulate filters from the sampling train at the inlet to the PAS. Runs GB-3 and GB-7 were felt to be representative of particulate inlet emissions for the GB incineration tests and runs GB/DC-11 and GB/DC-15 were felt to be representative of the particulate inlet data for the combined GB and decontamination solution runs. The corresponding even-number trials were the companion runs when the particulate size was determined. The average particulate concentration in the stack gases was 18 gr/dscf (corrected to 7% O_2) which was equivalent to a removal efficiency of only 97%.

3 Hydrogen Fluoride As shown in Table 4-49 HF emissions ranged from 0.25 to 1.16 pounds per hour. This corresponded to an average removal efficiency of 98%. This was slightly lower than expected and was attributed to insufficient liquid to gas contact in the PAS, as previously discussed.

TABLE 4-48. Particulate Emissions Data from LIC GB Incineration Test

Run Number	GB Flow Rate (lb/hr)	Particulate Size (1) (um)		Particulate Concentration gr/dscf		Emission Rate (lb/hr)		Removal %
		In	Out	In	Out	In	Out	
GB-3,4 (4)	226.4	0.62	0.58	2.69	0.13	37.80	1.43	96.2
GB-7,8 (4,5)	226.0	0.50	<0.30	2.65	0.29	30.61	3.32	89.2 (7)
GB/DC-11,12 (4)	226.0	0.64	0.50	6.72	0.14	89.12	1.62	98.1
GB/DC-14,15	181.6	0.78	0.35	8.54	0.13	66.87	1.55	97.7

NOTES:
(1) Mass Mean Diameter
(2) Corrected to 7% O_2
(3) Sample lost due to filter erosion.
(4) Tests performed conservatively on same day.
(5) GB supply replenished between Runs 7 and 8.
(6) Data questionable due to filter erosion.
(7) Mist Eliminator media problems discovered after test.

TABLE 4-49. Hydrogen Fluoride Emission from LIC GB Incineration Test

Run Number	HF Concentration ppm (Value) In	HF Concentration ppm (Value) Out	HF Emissions (lb/hr) In	HF Emissions (lb/hr) Out	Removal %
GB-1	2515	3716	39.28	0.59	98.5
GB-2	1451	23.9 (1)	21.64	0.39 (1)	98.2
GB-3	2247	14.5	39.57	0.25	99.4
GB-5	564	70.7	9.26	0.36	96.1
GB-7	3595	30.8	42.44	0.38	99.1
GB/DC-9	2100	66.1	30.34	1.10	96.4
GB/DC-11	(2)	85.3	(2)	1.11	—
GB/DC-15	(2)	9.7	(2)	0.16	—
GB/DC-16	4190	76.7	44.34	1.14	97.4

NOTES: (1) Does not include HF from probe wash and filter; § 1 percent of total HF in other GB only tests.
(2) Impinger sampler destroyed during shipment.

<u>4</u> <u>Products of Incomplete Combustion</u> An attempt to sample for PICs in the afterburner exhaust gases was made during the last test run. Although no PICs were detected, the high hydrogen fluoride concentrations encountered may have interfered with sample collection and analysis.

<u>5</u> <u>Brine and Salt Analyses</u> As shown in Table 4-50, the LIC sump brines, PAS scrubber brines and dried brine salts were all found to be non RCRA hazardous due to EP Toxicity. Table 4-51 lists representative PAS scrubber brine chemical analyses. Data from the GB only runs were questionable because of the dilution which occurred when CAMDS operators added water to keep the specific gravity of the brine below 1.08.

TABLE 4-50. EP Toxicity Leachate Metals Analysis from LIC GB Incineration Test

Metal	Maximum Concentration (1) (mg/l) Scrubber Brine (2)	Maximum Concentration (1) (mg/l) LIC Brine (2)	Maximum Concentration (1) (mg/l) Salt (3)	Average Concentration (1) (mg/l) Scrubber Brine	Average Concentration (1) (mg/l) LIC Brine	Average Concentration (1) (mg/l) Salt	RCRA Standard (mg/l)
Ag	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	5.0
As	<0.900	<0.100	<0.600	<0.012	<0.395	<0.6	5.0
Ba	0.830	1.020	0.630	0.338	0.161	0.530	100.0
Cd	0.560	0.005	0.263	0.110	0.001	0.234	1.0
Cr	1.100	0.120	0.510	0.372	0.019	0.477	5.0
Hg	0.005	0.004	0.001	0.001	0.001	0.001	0.2
Pb	0.680	0.480	3.200	0.194	0.044	2.530	5.0
Se	<0.600	<0.070	<0.300	<0.245	<0.008	<0.300	1.0

NOTES: (1) Less than (<) indicates all values reported below detection limit.

(2) 16 samples

(3) 3 samples

TABLE 4-51. Representative LIC Scrubber Brine Analysis

Parmeter	Run GB/DC-15		Run GB/DC-16	
	Pre Run	Post Run	Pre Run	Post Run
Duration, min	80		75	
GB Incinerated, lbs	242		282	
TOC, ppm	23	15	42	39
COD, ppm	63.2	100	200	273
Phosphate, ppm	39.841	58.229	77020	92706
Flouride, ppm	7.400	11500	16000	21500
Sulfate, ppm	345	250	415	480
Carobonate, ppm	1200	37	380	63
Nitrare, ppm	0.38	0.37	0.36	1.14
Chloride, ppm	1040	1300	1800	2200
pH, Stated units	9.3	8.3	8.1	7.8

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5.0.0 Disposal Process Description(1,2)

5.1.0 Introduction.

5.1.1 Purpose/Background.

a. The purpose of this chapter is to describe the disposal processes for the Chemical Stockpile Disposal Program (CSDP) disposal plants. The process design efforts for the CSDP have been minimized by utilizing the existing Johnston Atoll Chemical Agent Disposal System (JACADS) design and site adapting separate or multiple facilities to provide the plant throughput required. Site adaptation of the JACADS facility to the continental United States (CONUS) sites requires modifications for site climatic and altitude differences, and for differences in the munition inventory at each site. Signficant design revisions for site adaptation consist of the following:

(1) Equipment weather enclosures will be added for all process equipment located outdoors, (i.e., the Pollution Abatement System (PAS), the Brine Reduction Area (BRA), and the Bulk Chemical Storage (BCS)).

(2) Building heating systems.

(3) The JACADS seawater cooling system will be changed to a freshwater system utilizing cooling towers.

(4) All fuel burning equipment, ducts and fans will be resized for higher altitude and different fuel where applicable. Natural gas will be used at all CSDP sites, with the possible exception of Tooele Army Depot (TEAD) which currently uses liquified petroleum gas (LPG) at Chemical Agent Munitions Disposal System (CAMDS).

(5) Rooms will be resized to provide additional space to accommodate the above changes.

(6) The structural design for the building and equipment supports will be evaluated and revised, if required, to meet higher seismic loads.

(7) On-site production equipment for sodium hypochlorite decontamination solution will be deleted from the JACADS design, as the solution is readily available at CONUS sites.

(8) Projectile/Mortar Disassembly Machine (PMD) and Multipurpose Demilitarization Machine (MDM) hardware and software will be added as necessary for M122 GB 155mm and M104 HD 155mm Projectiles. Bulk Drain Station (BDS) hardware and software will be added as necessary for MK116 GB bombs and TMU-28/B VX spray tanks.

(9) Building heating, ventilating, and air conditioning systems will be modified to meet ambient conditions.

(10) Refrigerated plant air dryers will be changed to desiccant type to prevent water condensation in outdoor piping during winter operation.

(11) JACADS site security provisions may require revision to conform to CONUS site requirements.

(12) JACADS foundation designs will be revised to conform to CONUS soil conditions.

b. The chemical munition disposal process is based on the "reverse assembly" concept which involves separating the chemical munition into its major components. As shown in Figure 5-1, the chemical munition is separated into agent, explosive components (if any), metal parts, and dunnage with the aid of specialized, fully automated and remotely controlled mechanical equipment. A separate two-stage incinerator or furnace will be used for each component stream. Each incinerator has its own pollution abatement system which cools the exhaust gases and removes acid gases and particulates generated by the incineration of these components. Table 5-1 lists the furnaces used in the CAMDS, JACADS, and proposed CONUS disposal facilities and the material incinerated in each. Besides the exhaust gases, the other waste streams are decontaminated scrap metal, ash, solid particles, and dried salts.

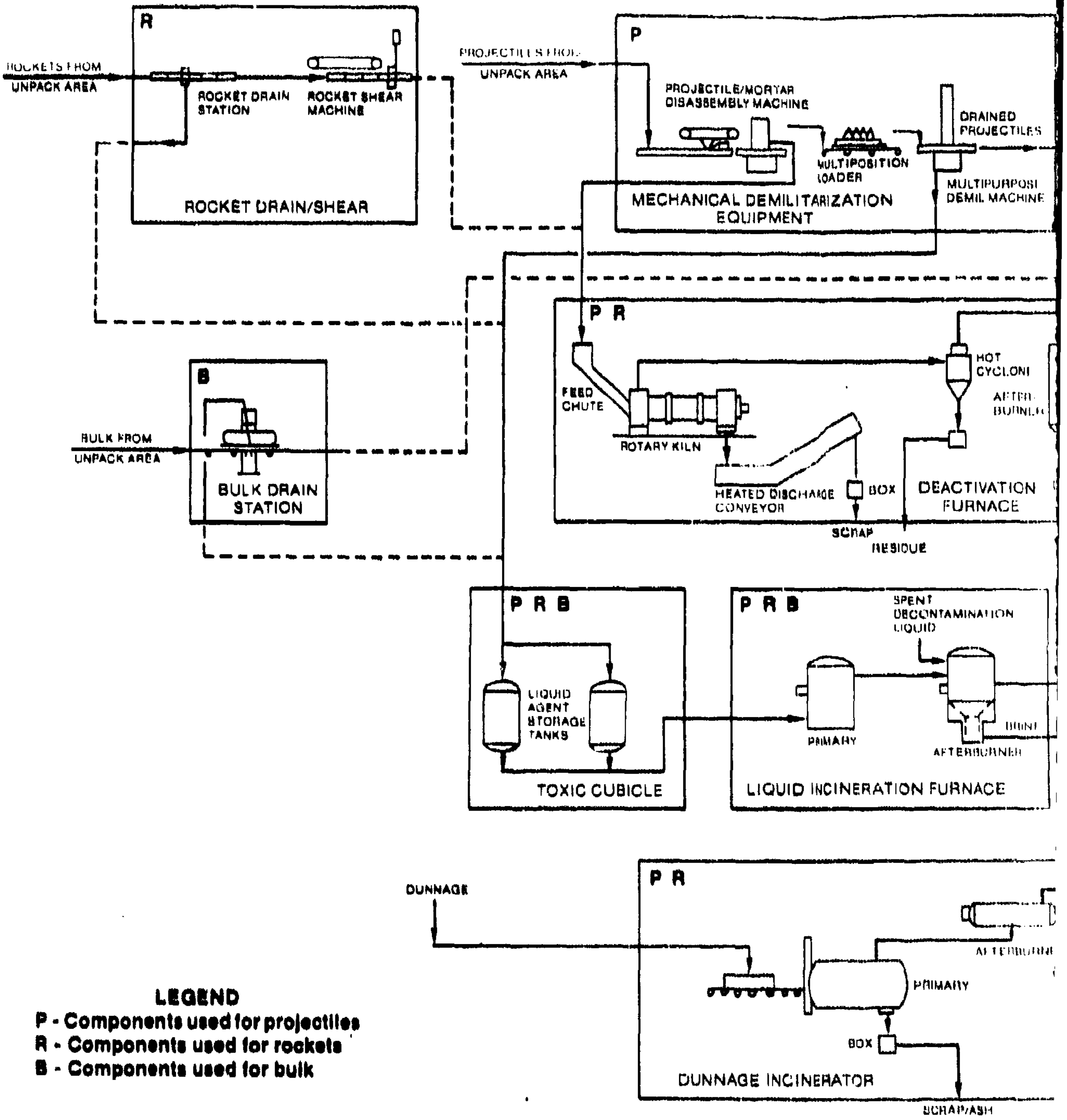
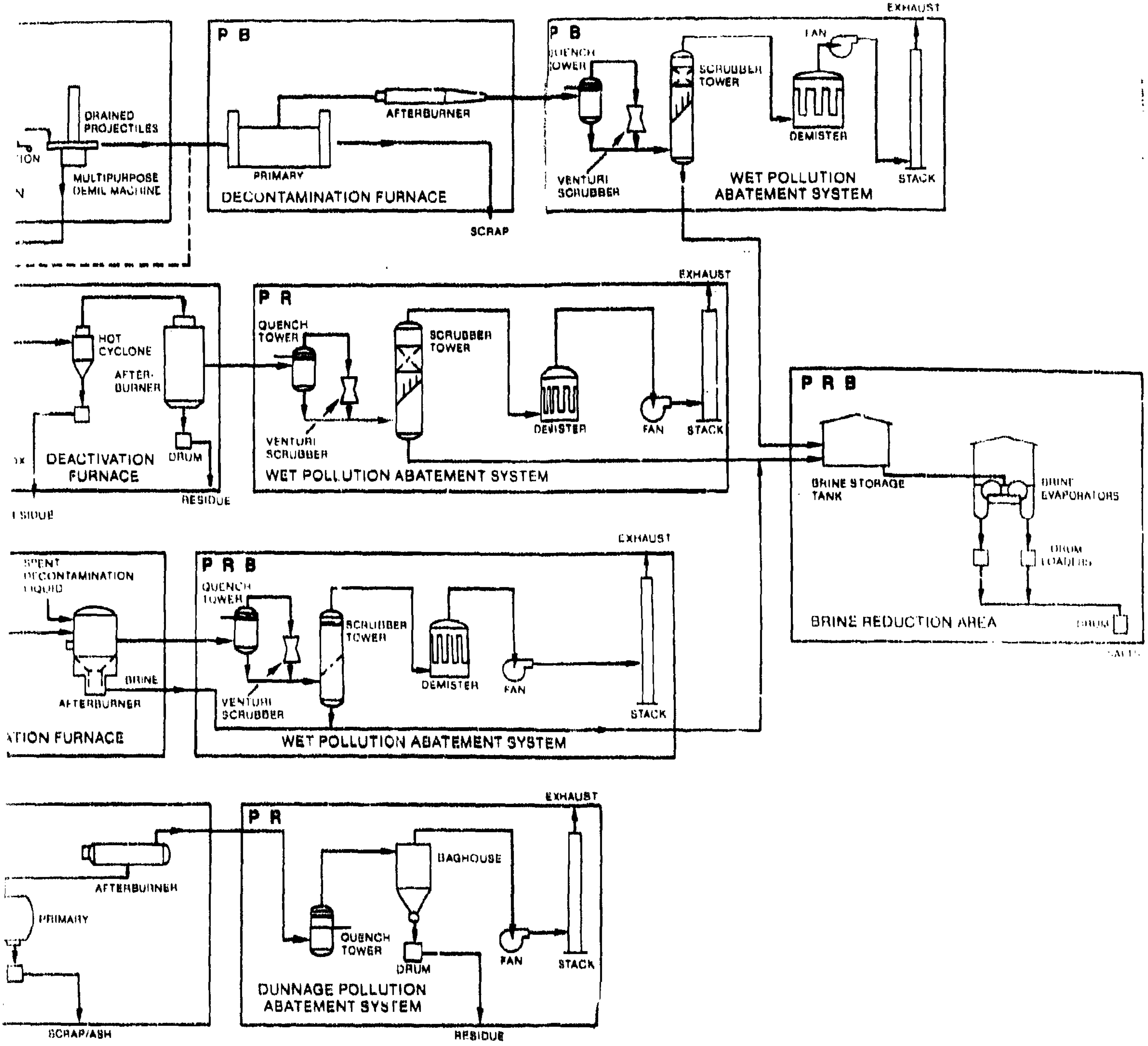


Figure 5-1: Schematic



-1: Schematic Flow Sheet of Process Components

TABLE 5-1. Chemical Agent and Munition Disposal Furnaces and Their Associated Feed Streams

Incinerator/Furnace	Feed Stream
Liquid Incinerator	o Chemical Agent o Spent Decontamination Fluids
Deactivation Furnace	o Drained and Sheared M55 Rockets o Punched and Drained M23 Landmines o Fuzes and Bursters o Propellant
Metal Parts Furnace	o Drained Projectiles and Bulk Containers
Dunnage Incinerator	o Wood Dunnage o Demilitarization Protective Ensembles o Packing Materials o M23 Landmine Drums o Other Combustibles

5.1.2 Munition Process Description.

The following section presents an overview of the CSDP disposal procedure. The descriptions are keyed to Figure 5-1. During the disposal process, only one type of munition and only type of agent will be processed at one time. This practice is imposed not just for safety, the primary reason, but also for reasons involving dedication of equipment. The equipment operated in the Explosive Containment Room (ECR) including the Rocket Shear Machine (RSM), Mine Machine (MIN) and the combination of the PMD and Burster Size Reduction (BSR) Machine are mutually exclusive. Each piece of equipment or combination will be exchanged depending on the munition being processed. The ECR is a reinforced concrete enclosure that is designed to contain the effects of an accidental explosion, including agent release.

a. Initial Processing. Munitions on pallets are moved by truck from the storage igloo to an unpack area within the destruction facility where they are checked off a list and verified, monitored for agent leakage, and stored in a buffer area to maintain the designed processing rate of the system. Nonleaking munitions are unpacked and are fed to process operations conveyors. Pallets and packing materials remaining in the unpack area are sent to the Dunnage Incinerator (DUN) for incineration. Munitions found to be leaking are conveyed into an agent containment area where they are unpacked by personnel in protective clothing and fed onto the process operations conveyors.

(1) M55 Rockets, in their individual fiberglass shipping tubes, are unloaded and unbanded from their pallets, placed on a metering input device, and conveyed into an ECR. Once in the ECR, the rockets are punched and drained of liquid agent, cut into five segments by a RSM as shown in Figure 5-2, and fed by gravity through a chute into a Deactivation Furnace System (DFS) for incineration.

(2) M23 Land Mines arrive at the demilitarization facility packed three to a drum. The mines, fuzes, and actuators are manually removed from the drums by an operator working through a glovebox and are passed into

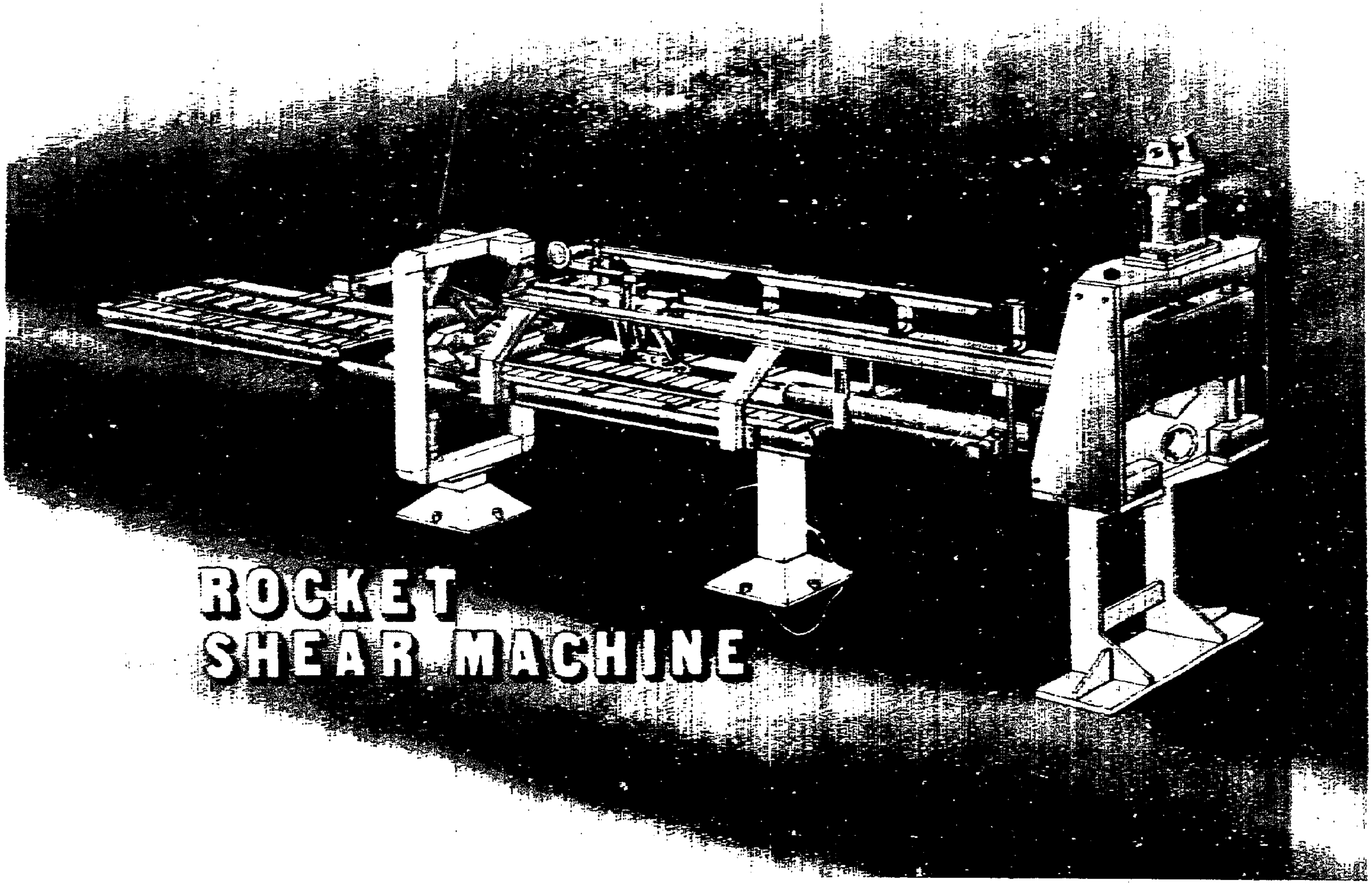
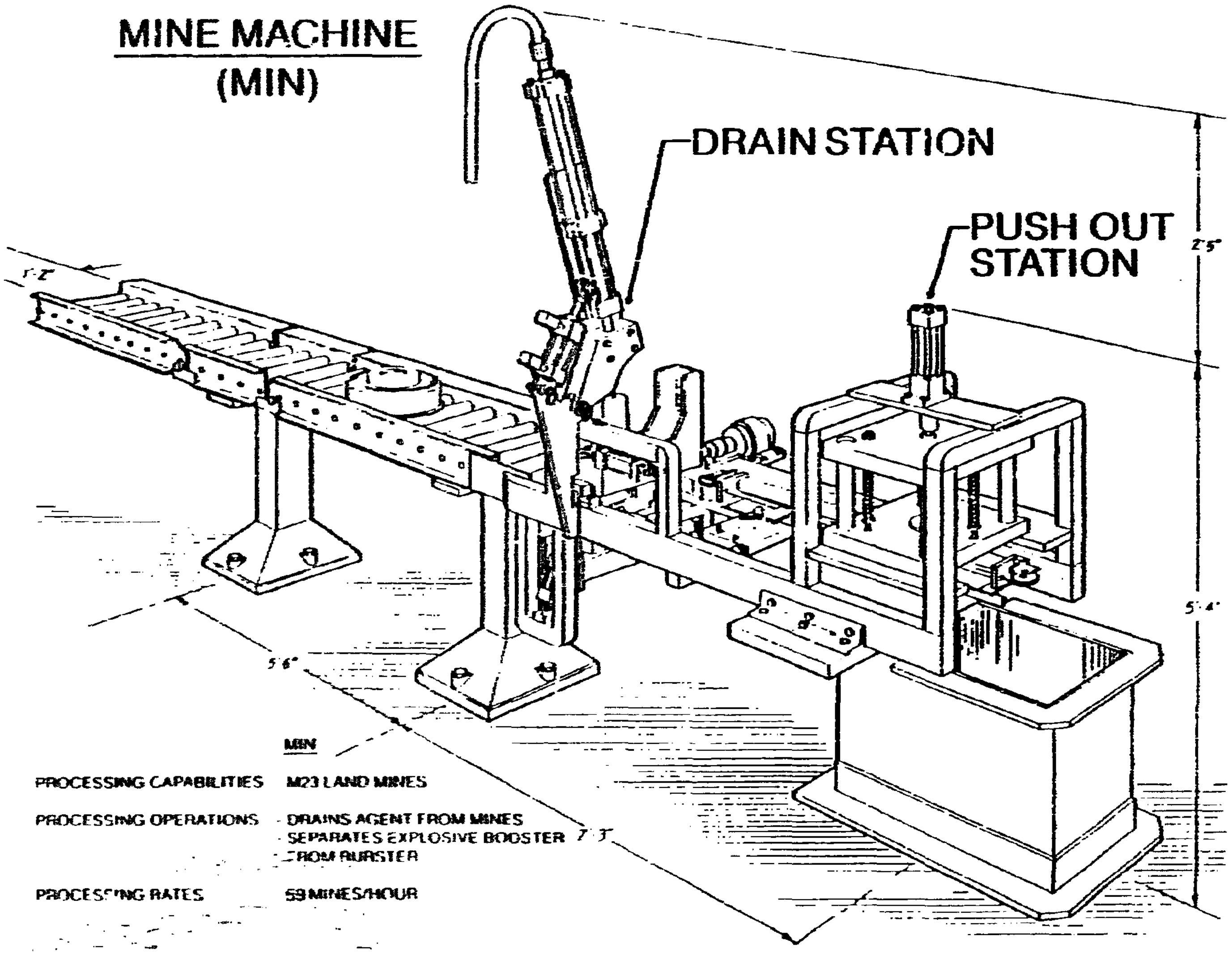


Figure 5-2: Rocket Shear Machine/Rocket Drain Station

the ECR. (The fuzes and actuators are stored or assembled in the drum during production.) The packing materials and drums are fed to the DUN. The mine's explosive booster charge is punched out and the agent is drained using a MIN inside the ECR as shown in Figure 5-3. The explosive components and drained mine body are then gravity-fed to the DFS.

(3) Projectiles and mortars containing explosives and propellants are fed into the ECR where they are processed by PMD as shown in Figure 5-4. A rotating table incorporated into the PMD advances the munition through several separate work stations where the following operations are performed: (1) nose closure/fuze removal, (2) supplemental charge removal, and (3) burster removal. If the munition is an 155mm or 8-inch projectile, the bursters are automatically sheared by a BSR to the appropriate size. All parts and pieces are then gravity-fed to the DFS. After burster removal is verified, the nonexplosive projectile and mortar bodies are then mechanically placed into pallet assemblies on a conveyor for transport from the ECR to a Munitions Processing Bay (MPB), where there is a MDM as shown in Figure 5-5. The MDM has a pick-and-place mechanism that lifts a munition out of the pallet assembly, places it on an operating turntable, and returns the processed munition to the pallet assembly. The operations on the turntable consist of removal of a portion of metal from the top of welded or stuck bursters well by a milling head, removal of the burster well, draining of chemical agent, crimping of the burster well and replacing the burster well part way into the munition. The drained and nonexplosive projectile and mortar bodies are conveyed in pallet assemblies to a buffer storage area. From the buffer storage area, the bodies move directly to charge cars which unload the bodies into the Metal Parts Furnace (MPF), for thermal decontamination of the munition bodies.

(4) Bulk items including bombs and ton containers, and spray tanks are loaded onto unit pallet assemblies in the Unpack Area and are conveyed directly to the MPB. The BDS in the MPB punches the bulk item and drains the agent. The drained bulk item is then conveyed on its pallet assembly to the buffer storage area. From the buffer storage area, the bulk item moves directly to charge cars which unload the item at the MPF for thermal decontamination.



	MIN
PROCESSING CAPABILITIES	M23 LAND MINES
PROCESSING OPERATIONS	- DRAINS AGENT FROM MINES - SEPARATES EXPLOSIVE BOOSTER FROM BURSTER
PROCESSING RATES	59 MINES/HOUR

Figure 5-3: Mine Machine

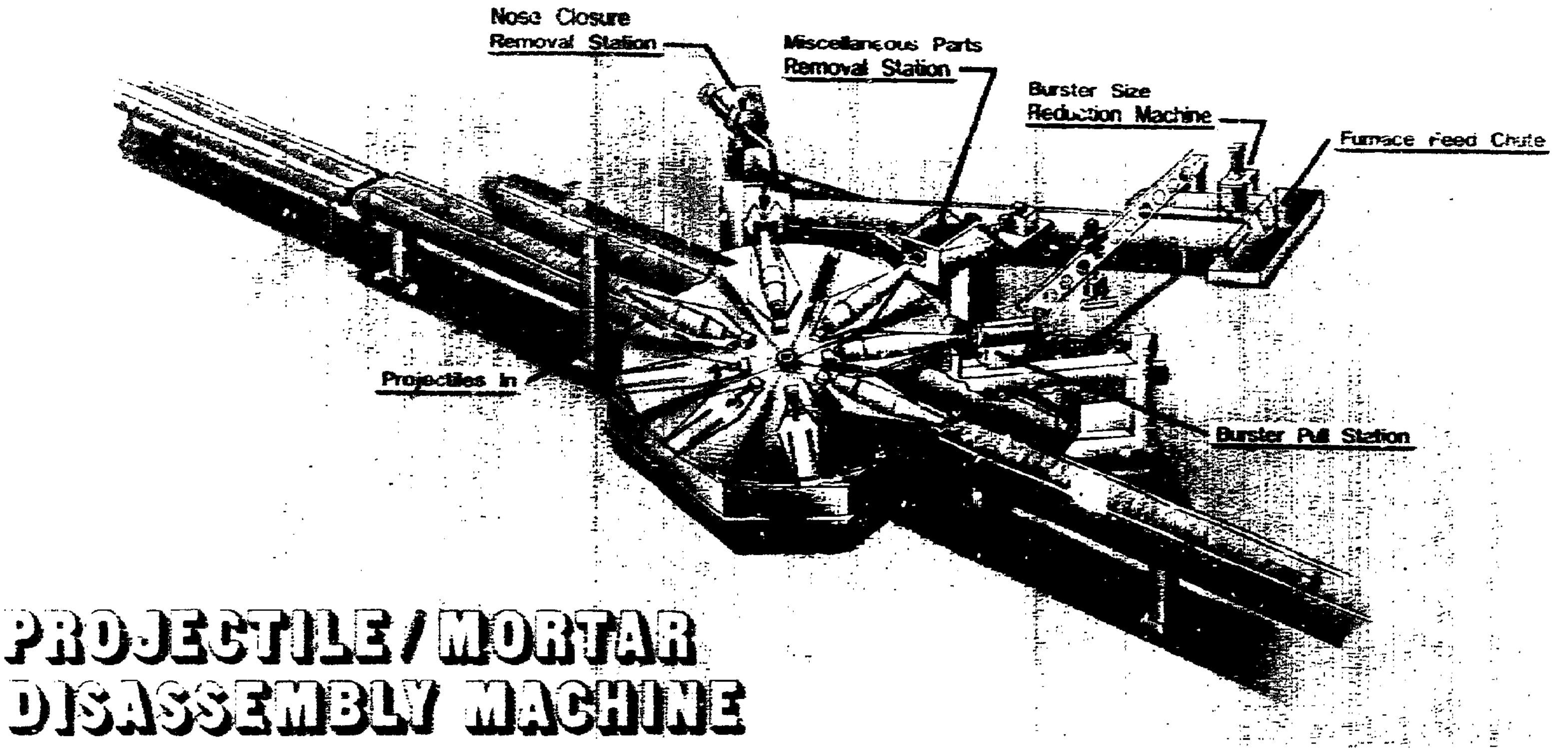


Figure 5-4: Projectile/Mortar Disassembly Machine

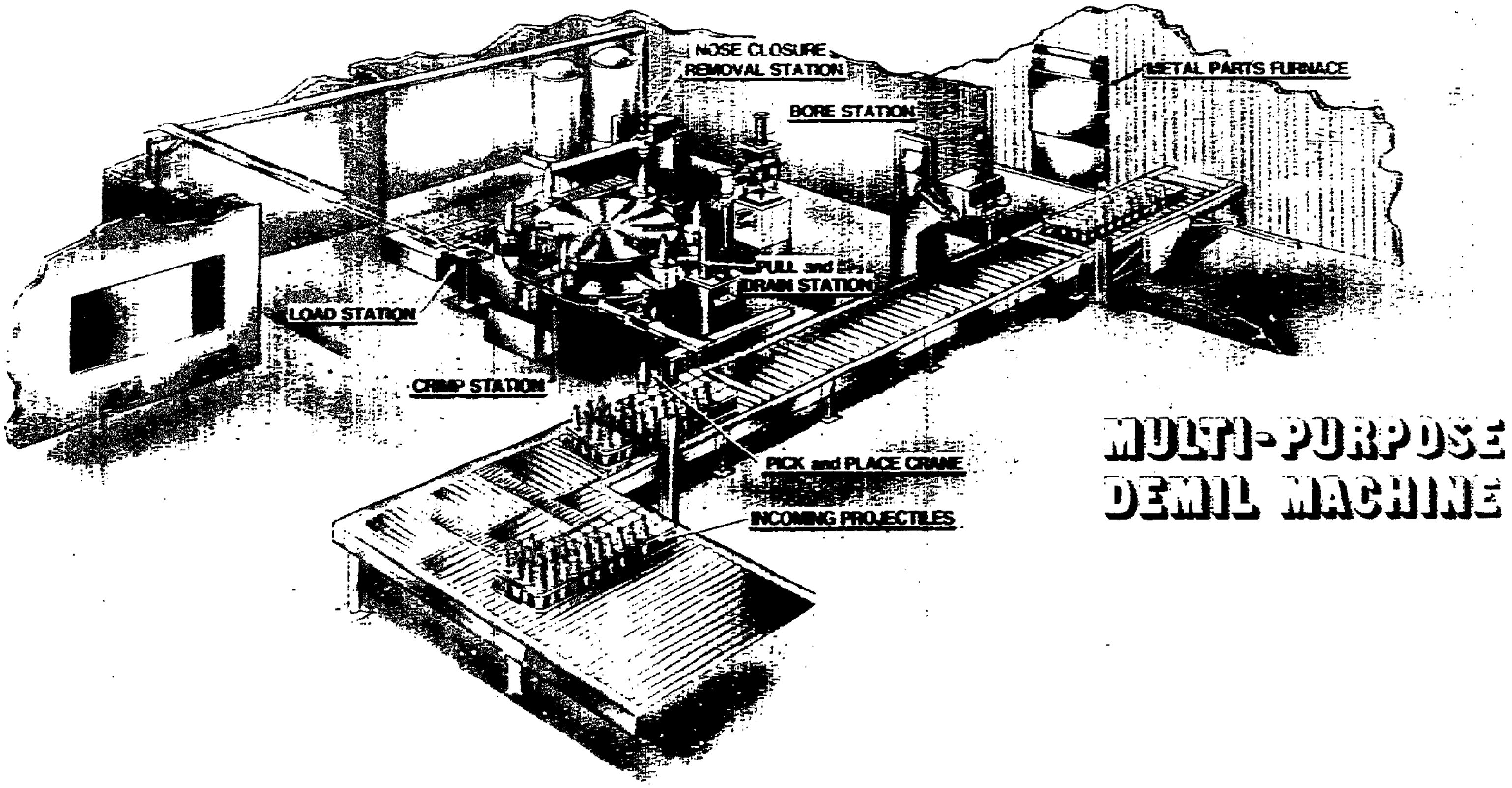


Figure 5-5: Multipurpose Demil Machine

(5) The drained liquid agent from all the munitions is collected in a short-term agent storage tank in the toxic cubicle to await incineration in the Liquid Incinerator (LIC). Spent decontamination solutions are collected in separate liquid storage tanks to await eventual incineration in the LIC.

b. Incineration and Thermal Decontamination.

As was mentioned previously agent destruction, explosive disposal, and decontamination are accomplished by incineration. The four furnace systems are the DFS, LIC, MPF and DUN as shown in Figures 5-6 through 5-9, respectively, and discussed in Section 5.2.c.

c. Pollution Abatement and Final Disposal.

(1) The pollution abatement systems cool, scrub, and chemically neutralize the exhaust gases from the four furnace systems so that the exhaust gases can be safely released into the atmosphere. Each furnace system has itsown pollution abatement system. The pollution abatement systems are discussed in Section 5.3.

(2) The BRA as shown in Figure 5-10, incorporates rotary double-drum dryers that treat the brine from all scrubber towers. The concentrated brine is pumped to the BRA, where the brine is heated to evaporate the water, leaving dried salts and solid particles. The drum dryers use steam heating and produce dried salts that are loaded into containers for transport and disposal.

5.2.0 Incineration Systems.

The development of the design of the incineration systems for the DFS, LIC, MPF, and DUN was based on the previous experience with incineration at RMA and CAMDS. This experience started with use of the incinerators for thermal decontamination and destroying explosive materials during neutralization at RMA to which incineration of chemical agent at both RMA and CAMDS was added, and with which further testing, research and development is continuing at CAMDS.

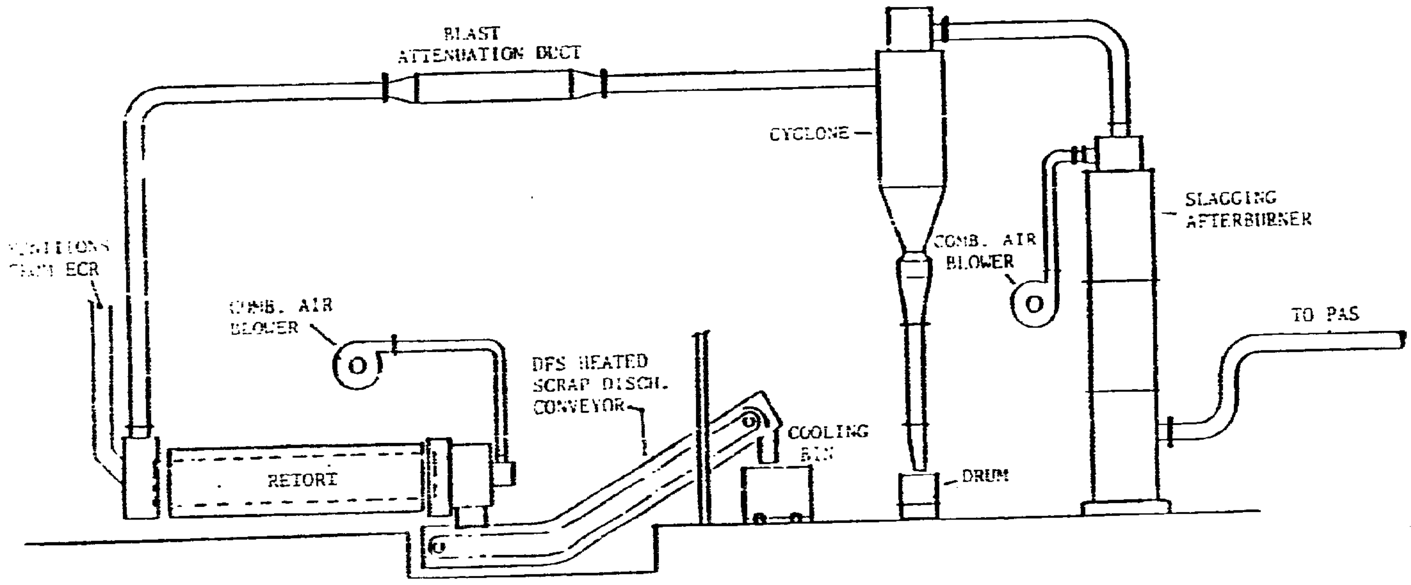


Figure 5-6: Schematic Diagram of DFS

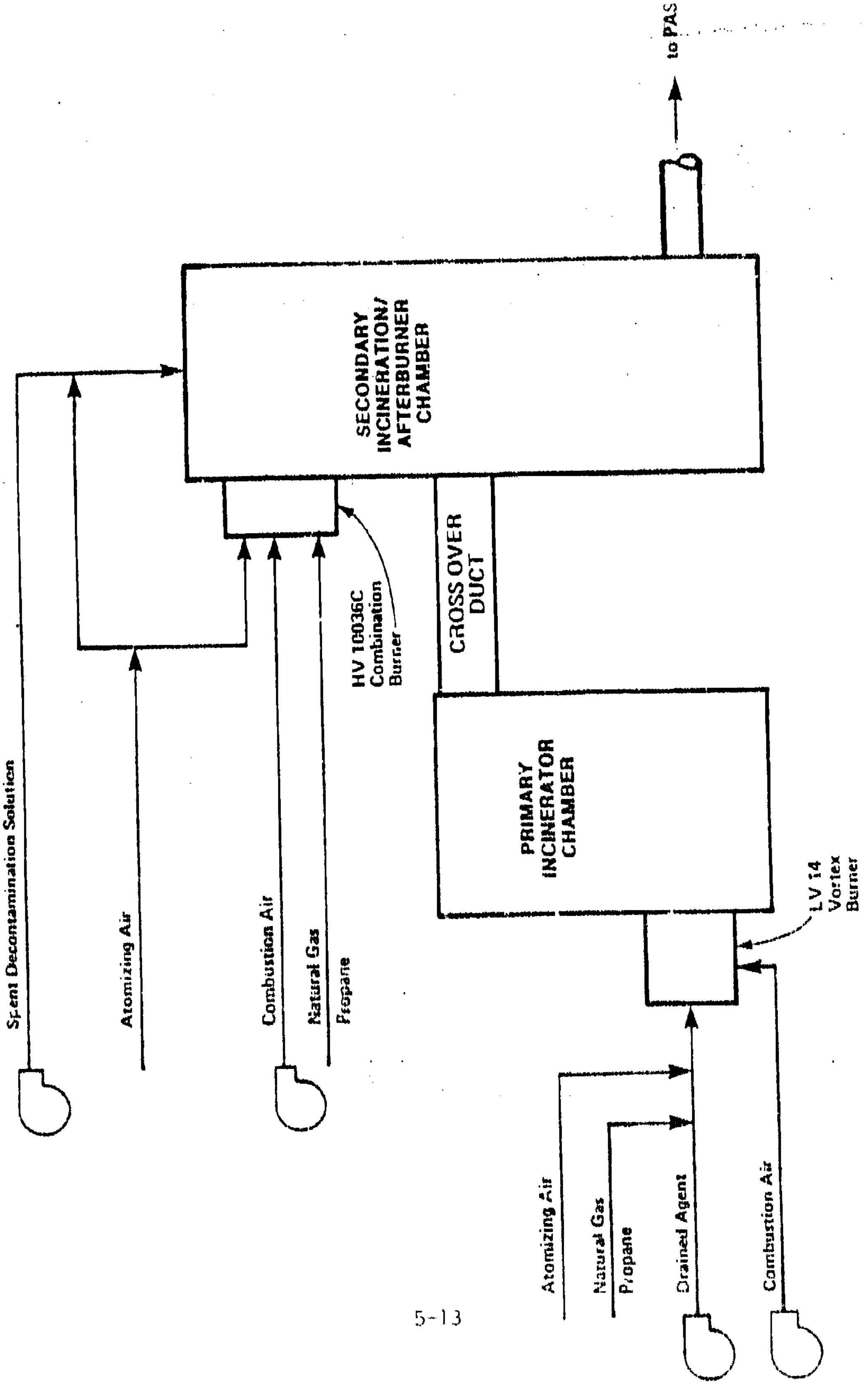


Figure 5-7: Schematic Diagram of LIC

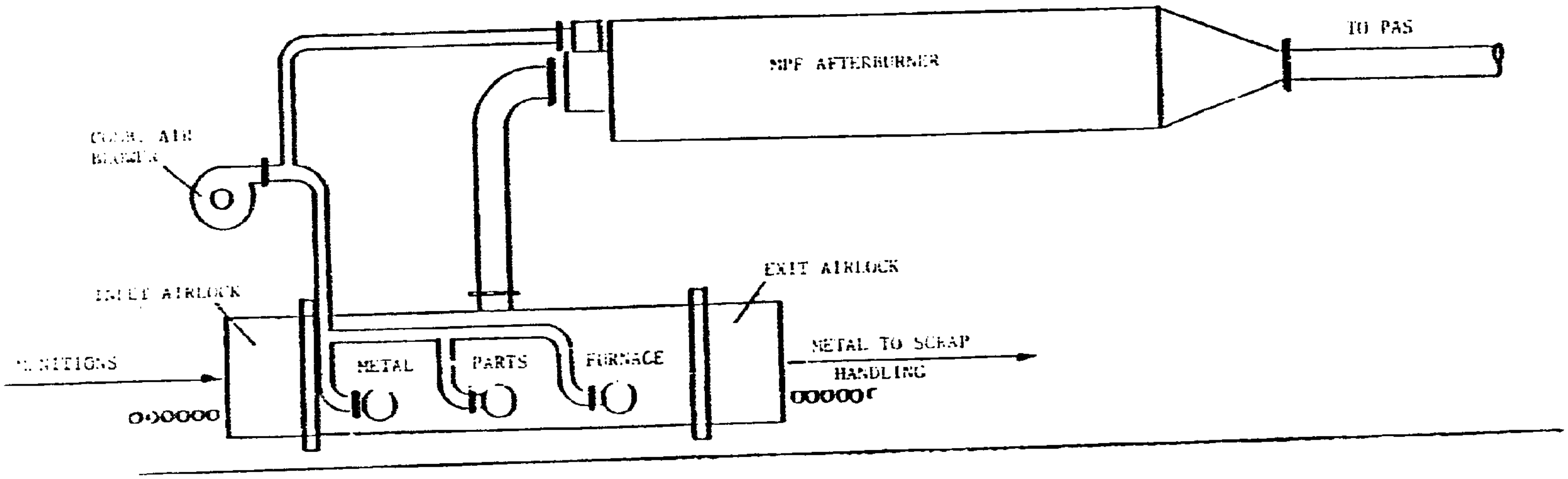


Figure 5-8: Schematic Diagram of MPF

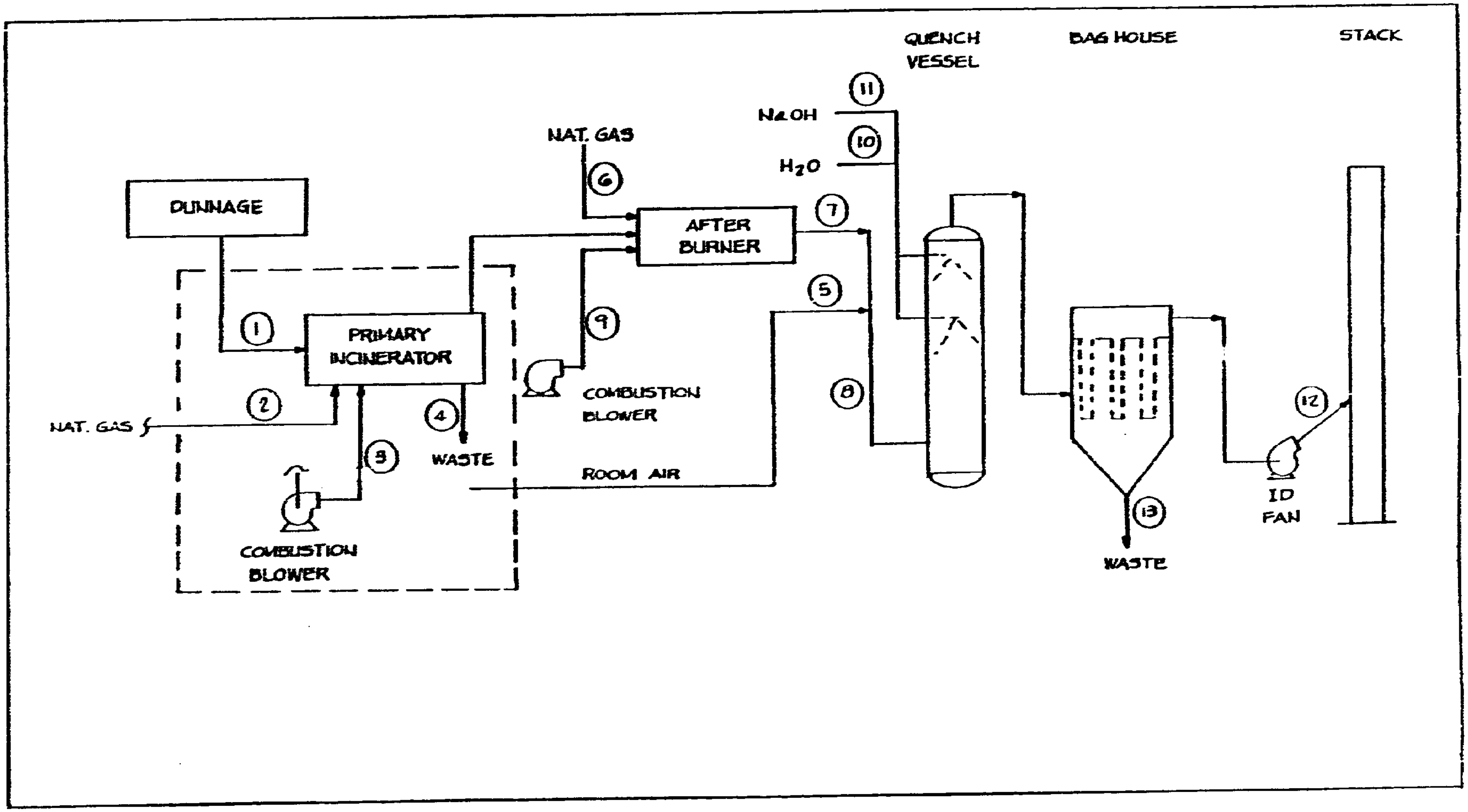


Figure 5-9: DUN Process Flow Diagram

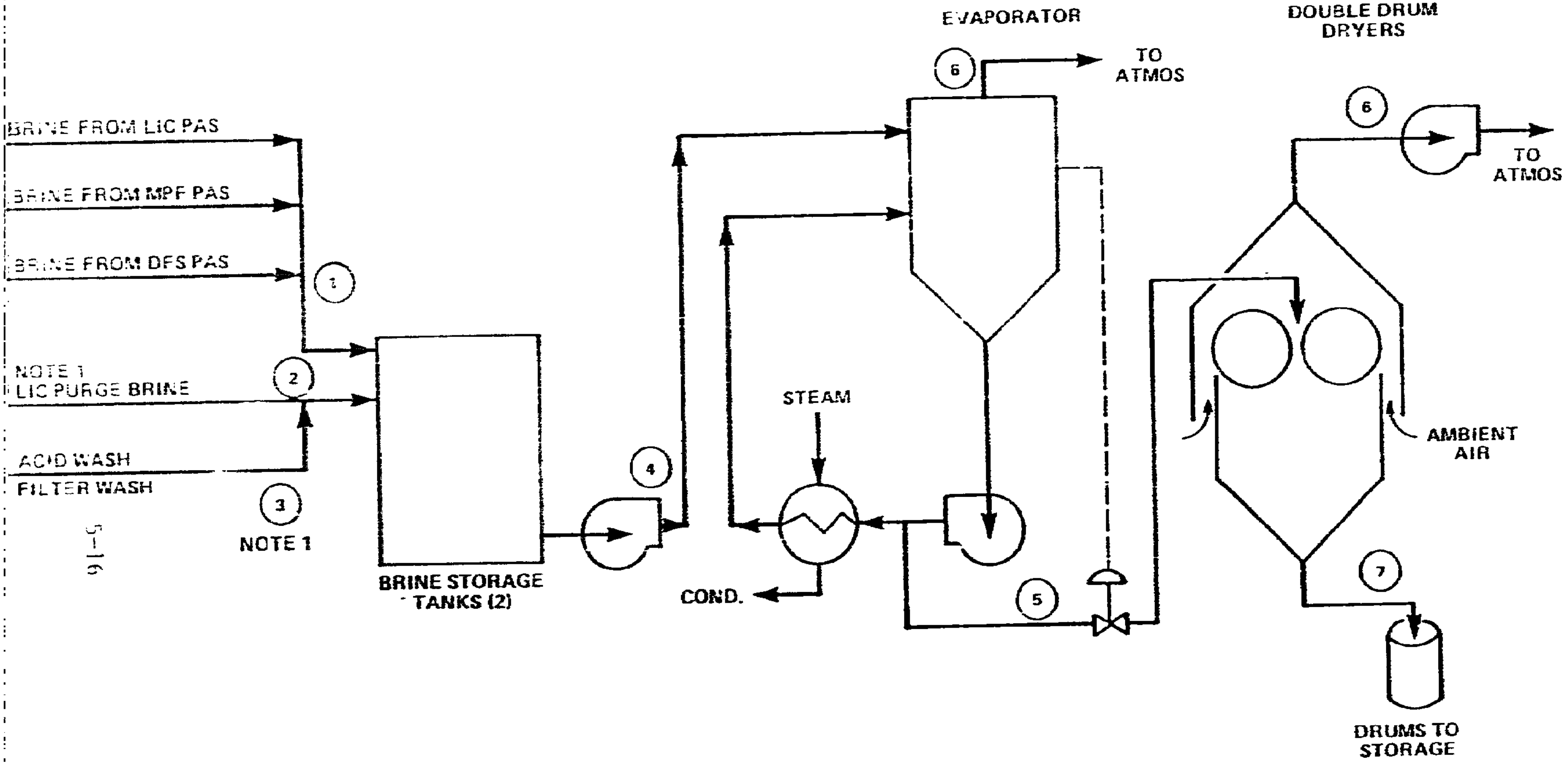


Figure 5-10: BRA Flow Diagram

5.2.1 Deactivation Furnace System (DFS).

a. The DFS consists of four separate sections. These are: (1) rotary retort, (2) blast load attenuation duct, (3) cyclone, and (4) afterburner. As addressed earlier the DFS is designed to process drained M55 Rocket and M23 Landmine munition components. In addition, it will process fuzes, explosives, and propellants from other explosively configured munitions as found at each of the eight stockpile locations. However, at any given time, the DFS will only process components from a single munition type and a single agent such as the M55 Rockets containing GB or VX, and M23 Landmines containing VX.

b. The process flow for the DFS is given in Figure 5-11.

(1) Rotary retort. This section of the DFS consists of two feed chutes, each with two blast gates in series, a charge end subassembly, a furnace retort drive mechanism, a discharge end subassembly, and a heated discharge conveyor. Feed to the retort is by way of the blast gates, which isolate the retort from the ECR.

(a) The charge end subassembly accepts munition components from the blast gates, and feeds the furnace retort. The munition components enter from the blast gates and slide down a chute into the DFS retort. The DFS retort then thermally deactivates and incinerates the explosive and propellant components, and destroys any residual agent on the munitions hardware after the munitions draining operations. The munitions move in the retort from the charge chute to the discharge chute as thermal processing occurs. The retort is fabricated from an iron-chromium alloy to withstand a maximum external metal temperature of 1,600°F and is to be supported by a pair of riding rings mounted on the outer circumference of the shell. The rings rotate on, and are supported by, floor-mounted trunnion rolls. The retort has an internal spiral to convey the material through the length of the retort. The retort is completely shrouded to control the temperature in the room housing the DFS. The DFS duct between the retort and the hot cyclone is externally insulated to minimize heat losses. The combustion gas temperature

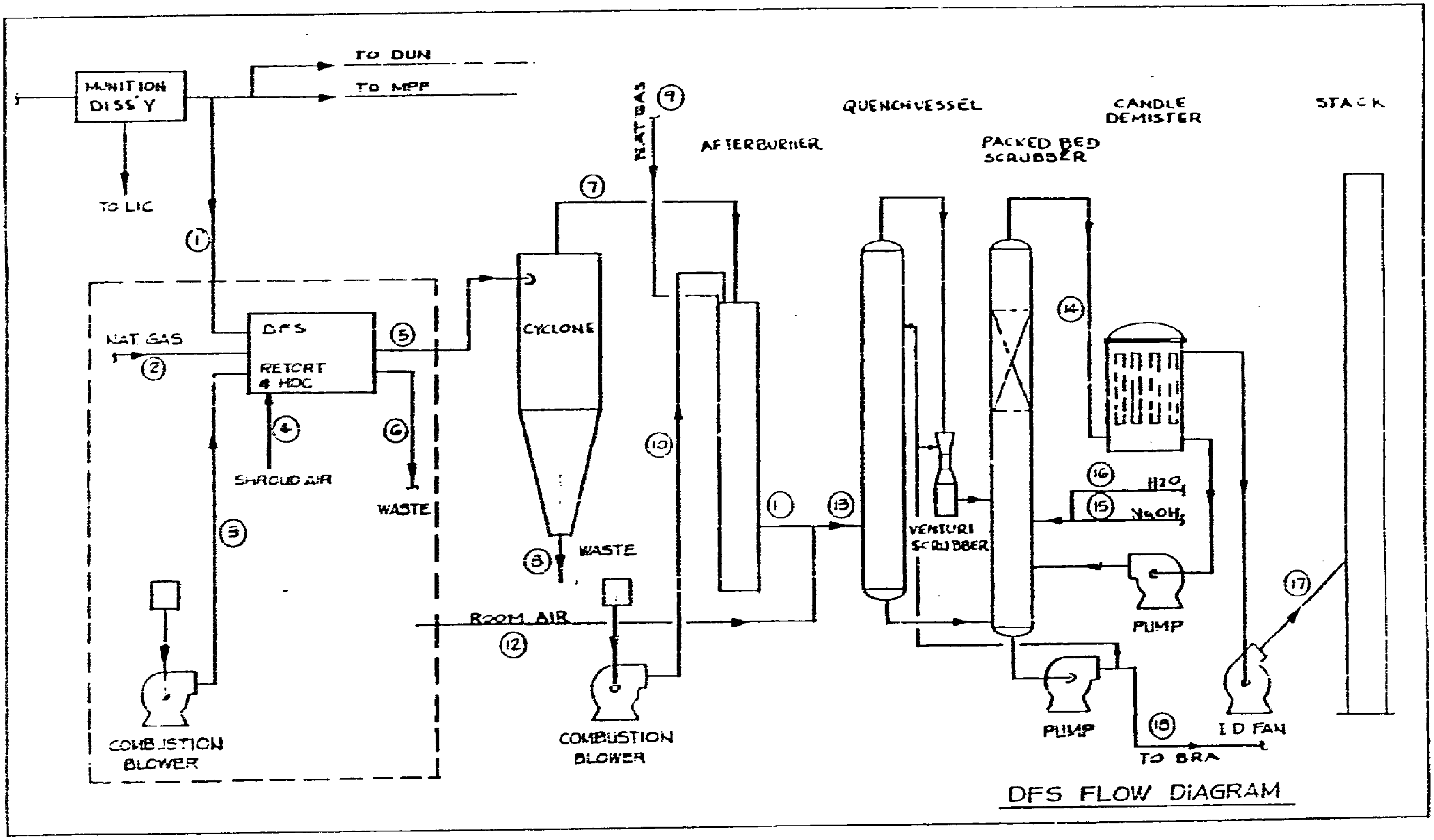


Figure 5-11: DFS Process Flow Diagram

in this section of the DFS is limited to 1,600°F maximum by a water quench spray in the duct. The temperature inside the retort is controlled by burning natural gas in addition to the propellants, explosives, and residual agent. Approximately 90% of the shroud cooling air enters the retort at the firing end and serves as combustion air for the feed stock. The remaining 10% of the shroud air bypasses the retort and joins the combustion gases at the feed end of the retort.

(b) Scrap metal and combusted fiberglass from the furnace retort are transferred to the electrically heated discharge conveyor. The discharge conveyor accepts material from the furnace retort, conveys the material on a conveyor belt, and provides a minimum of 15 minutes holding time at a minimum solids temperature of 1,000°F to ensure destruction of residual agent to the appropriate level of decontamination. The heated conveyor discharges the ash and scrap metal through a chute with dual blast gates to a residue bin.

(2) Blast Attenuation Duct. Flue gases flow from the retort through an alloy duct with a blast attenuation duct to the cyclone, which separates particulates from the gas stream. The metal duct, which is exterior to the DFS enclosure, and the blast attenuation duct are designed to contain the explosive overpressure from 28.2 lb of TNT equivalent.

(3) Cyclone. The cyclone is a refractory-lined cylindrical vessel with a cone-shaped bottom. The inlet is on the side near the top of the unit and the outlet directly on top of the cyclone. A drop line from the cone bottom is provided to discharge collected solids into a sealed container at floor level.

(4) Afterburner. ...e offgases leaving the cyclone flow downward through a vertical, cylindrical afterburner. The afterburner has two fired burners located at the top. A combustion air blower using outside air provides air for the two burners. The design of the afterburner provides a minimum gas residence time of 0.5 second at 1,800°F. The gases leaving the afterburner flow through an internal refractory-lined duct to the quench tower in the DFS PAS.

5.2.2 Liquid Incinerator (LIC).

a. The LIC is a two-stage refractory-lined incinerator designed to incinerate chemical agents drained from munitions and bulk items, and to dispose of spent decontamination solution. The agent is drained from the munitions using the various demilitarization machines as addressed earlier and pumped to an agent holding tank. Spent decon is pumped to the LIC from two spent decon holding tanks by either of two feed pumps. Automatically operated duplex strainers are provided in the pump suction lines from the holding tanks to protect the pumps and prevent plugging of the burner/atomization feed lines.

b. The process flow for the LIC is shown in Figure 5-12.

(1) The drained agent collected in the agent tank is pumped at a uniform, continuous rate to the primary chamber (first stage incinerator) of the LIC. The agent is dispersed into the chamber with air-atomizing nozzles and mixed with combustion air. Combustion is controlled at or above 2,800°F by the controlled addition of agent, fuel, and air. The flue gases are ducted to the afterburner with a minimum temperature of 2,000°F being maintained in the afterburner by natural gas burner. Excess air is maintained in both the primary chamber and the afterburner to ensure destruction of the agent and the spent decontamination solution.

(2) The primary combustion chamber is a refractory-lined chamber that uses the combustion of natural gas to initiate agent combustion and raise the temperature to approximately 2,800°F. Natural gas, agent, agent-atomizing air, and combustion air are primary feeds to the chamber. The atomizer provides a mean droplet size less than 50 microns and a maximum droplet size not exceeding 100 microns. During normal operation, waste agent supplies sufficient heat to maintain temperature and adequate combustion. The natural gas is used to ensure a stable flame pattern within the primary chamber.

(3) The afterburner is a refractory-lined cylindrical chamber that provides additional time at temperature for the gases leaving the primary

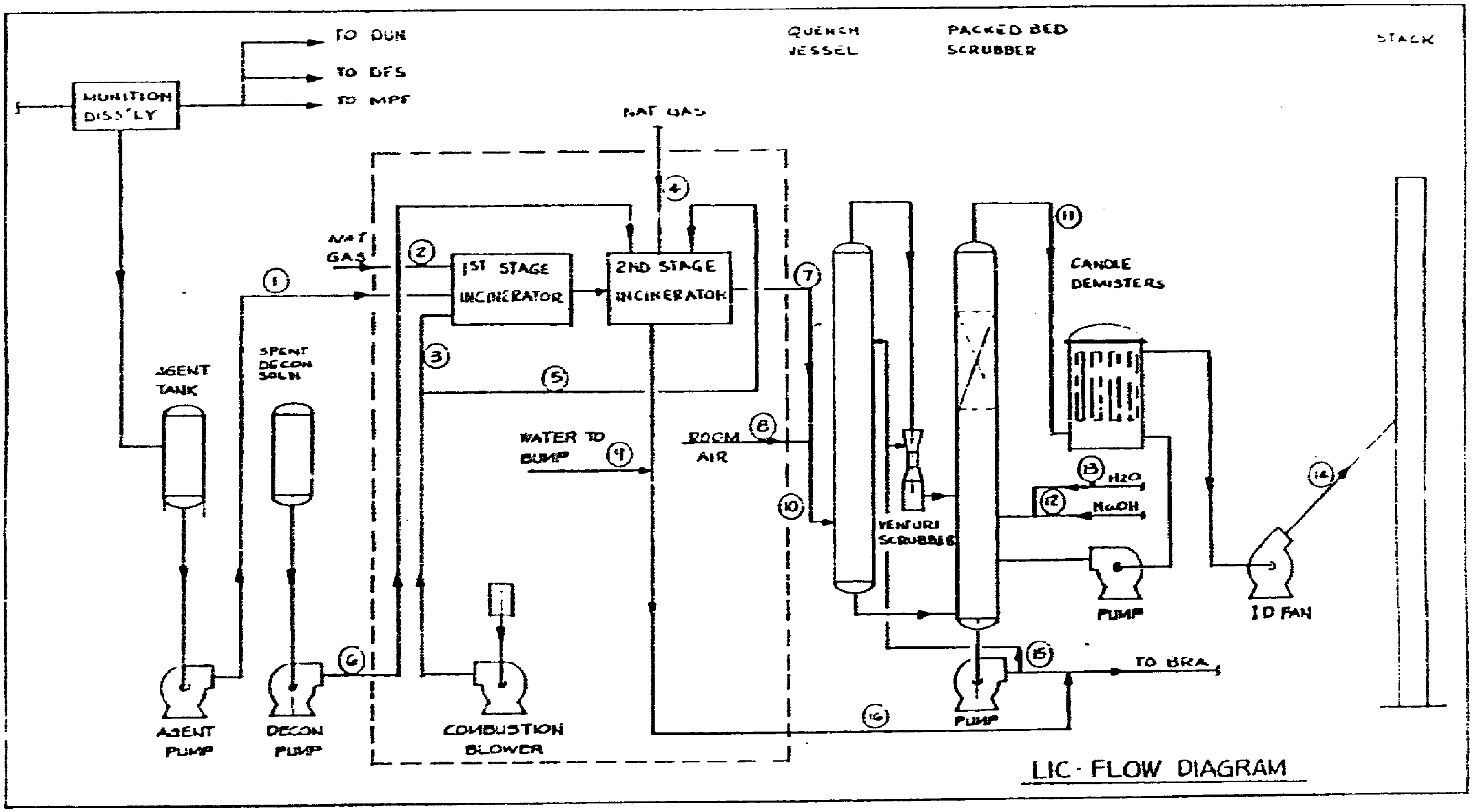


Figure 5-12: LIC Process Flow Diagram

combustion chamber to ensure complete combustion. The afterburner also serves to incinerate organic salts in the spent decontamination solution generated onsite, including liquid wastes from the laboratory. The afterburner is sized to complete the combustion of agent, vaporize up to 2,000 lb/hr spent decon, and incinerate any organic salts. A natural gas fired burner is provided to ensure that the 2,000°F operating temperature is maintained. The resultant combustion flue gas flows to the LIC PAS for cleaning the exhaust gases.

(4) The spent decontamination solution is sprayed through an atomizing nozzle into the top of the afterburner chamber. The atomized water stream mixes with the flue gases from the primary chamber where the water is evaporated and the organic residual from the spent decontamination solution is combusted. The temperature inside the afterburner is maintained by burning natural gas in a separate burner block in the afterburner chamber. Salts in the spent decontamination fluid collect on the walls, melt, and run down to the salt removal chamber. The melted salt falls through an opening in the bottom of the afterburner into a sump where it is quenched with water and dissolved. The dissolved salts are circulated with the brine through the PAS. If the brine exceeds a threshold density, a line is opened to the brine dryer. Nonsoluble salts settle out and are removed via a screw-type conveyor to a barrel.

5.2.3 Metal Parts Furnace (MPF).

a. The MPF is designed to thermally treat drained projectiles and bulk items such as ton containers and bombs. This treatment is accomplished by the incineration of all residual agent and the heating of all metal components to a minimum of 1,000°F and holding at 1,000°F for 15 minutes to attain the appropriate level of decontamination. The design of the MPF also provides for the incineration of contaminated combustable dunnage and decontamination of components and equipment as may be required. The operating temperature of the MPF is approximately 1,600°F.

b. The process flow for the MPF is shown in Figure 5-13. The MPF consists of two primary components: the roller hearth unit and an afterburner.

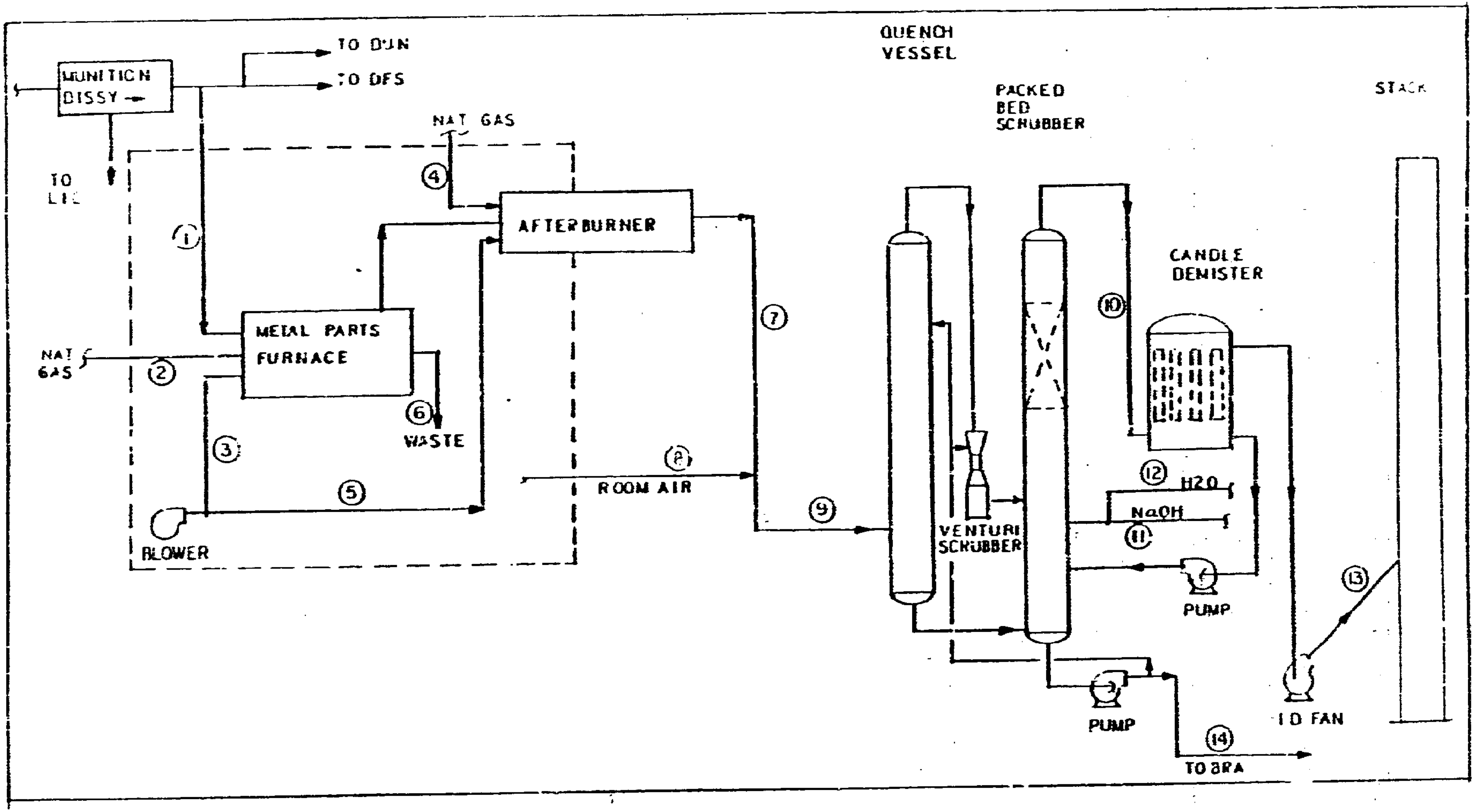


Figure 5-13: MPF Process Flow Diagram

(1) The MPF is a horizontal, three-chamber, roller hearth unit.

(a) The first chamber is an inlet airlock which receives projectiles or bulk items in trays for feed to the second chamber. It is sealed by vertical doors at both ends. Powered rollers are provided to transport the tray assemblies into and through the airlock. The airlock is of sufficient length to accommodate one tray assembly of the longest bulk item which is the spray tank to be thermally treated. The airlock operates at a slight negative pressure when both doors are closed. Any vapors generated in the first chamber are vented to the afterburner.

(b) The second chamber is the burnout chamber which has internal refractory insulation and natural gas burners. This chamber has the capacity for three tray assemblies of projectiles or bulk items. The chamber is divided into three firing zones with each zone being individually temperature controlled. The normal temperature within the burnout chamber is 1,600°F. Metal parts are heated to a minimum of 1,000°F and maintained at this temperature for 15 minutes to ensure decontamination. The tray assemblies are transported into and from the chamber by the powered rollers. The tray assemblies are then oscillated in each of the three firing zones to ensure uniform heat distribution to the tray assemblies. Handling of molten aluminum in special feed cars is required in the MPF cooling area for processing of spray tanks and MK-116 Weteye Bombs. Flue gases from the second chamber flow through an internal refractory-lined duct to the afterburner.

(c) The third chamber of the MPF is the exit airlock. It is designed to have the capacity for one tray assembly of decontaminated metal parts. All gases from the third chamber are likewise vented to the afterburner. After the tray assembly has cooled, the metal parts are removed and placed in scrap metal bins by means of an electromagnet.

(2) Afterburner. The afterburner is a horizontal, refractory-lined cylindrical vessel which is equipped with natural gas burners and pilots with spark ignitors. The afterburner receives the flue gases from the furnace airlocks and burnout chamber and maintains the flue gas at approximately 1,800°F for a minimum residence time of 0.5 second to ensure complete combustion. The flue gas leaving the afterburner flows to the MPF Pollution Abatement System through an internal refractory-insulated duct.

5.2.4. Dunnage Incinerator (DUN).

a. The DUN is designed to incinerate both contaminated and uncontaminated dunnage. The dunnage consists of such combustible items as wooden pallets, shipping boxes, laboratory solid wastes, DPEs, and contaminated operational and maintenance solid wastes. Metal mine drums with small amounts of combustible packing are also to be processed through the DUN. This fourth incinerator is designed to thermally detoxify either 1,000 lb/hr of wood dunnage or up to 24 mine drums/hr. The furnace length is sufficient to accommodate two lengths of rocket pallets, and height to hold rocket pallets stacked four high.

b. The process flow for the DUN is shown in Figure 5-14. The DUN consists of two separate chambers: the primary combustion chamber and an afterburner.

(1) The primary combustion chamber is a horizontal refractory-lined chamber operating at approximately 1,600°F. The combustion chamber is equipped with natural gas fired burners that are controlled by the furnace temperature. The solid wastes are charged into the combustion chamber by means of an airlock, an elevator, and a ram feeder. This ram feeder pushes the previously charged wastes ahead of the fresh charge until the totally incinerated dunnage (ash or metal) falls into an ash collection/removal hopper. The flue gases, in varying degrees of completeness of combustion, flow through a refractory-lined duct to the afterburner where combustion is completed.

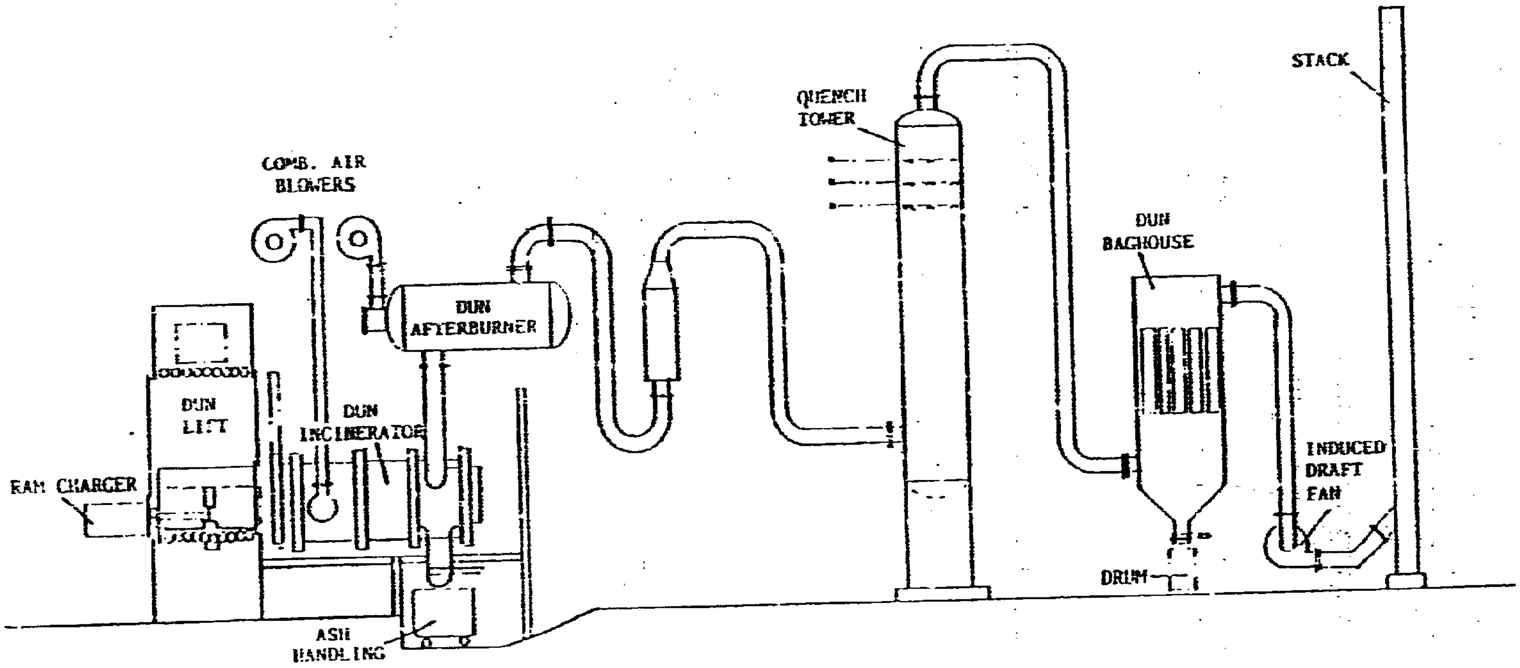


Figure 5-14: Schematic Diagram for DUN Incinerator and PAS

(2) The afterburner is a cylindrical, refractory-lined unit and is equipped with natural gas burners. Combustion air is supplied from a combustion air blower located outside the demilitarization building. The afterburner is designed to completely combust all flue gases from the primary combustion chamber, and is rated for a 2-second gas residence time at 2,000°F. The flue gases from the afterburner flow through a refractory-lined duct to the quench tower of the DUN PAS.

5.3.0 Effluent Characterization.

5.3.1 LIC, DFS, and MPF Pollution Abatement System (PAS).

The control of gaseous emissions from three of the four incineration systems (LIC, MPF and DFS) to meet the environmental regulations/requirements are to be accomplished by a PAS. There will be a separate PAS for each incineration system. Three systems, for the LIC, MPF, and DFS, will be identical in configuration but not equipment size. The major equipment items for these PAS' are: quench tower, venturi scrubber, packed bed scrubber tower, demister vessel, induced-draft (ID) fan, and a common stack. Figures 5-11 through 5-13 show the DFS PAS, LIC PAS and MPF PAS, respectively.

a. Quench Tower. The purpose of the quench tower is to cool the hot furnace exhaust gases to their dew point. The quench tower is countercurrent in operation. The hot gases enter at the bottom and are cooled to about adiabatic saturation temperature by direct brine spray contact with the hot gases. Two sets of spray distributors are provided in the tower. The number and size of the spray nozzles are such that, with one-third of the nozzles plugged, the minimum quench brine flow of three times the quantity required to reach adiabatic saturation of the gas stream is provided. The gas velocity is in the range of 8 to 11 ft/sec.

b. Venturi Scrubber. The purpose of the venturi scrubber is to remove large size particulate from the furnace exhaust gases. The venturi scrubbers are variable-plug throat venturi scrubbers with a normal operating pressure drop across the throat of 40-in. water column. The scrub solution is brine from the associated scrubber tower. The scrub solution is injected into the gas stream in the same direction as the gas flow. A liquid to gas by weight ratio of about 12 to 15:1 is used for the most efficient particulate removal. The venturi scrubber is designed to remove 95% of all particles larger than 0.5 microns.

c. Scrubber Tower. The purpose of the scrubber tower is to remove acidic pollutant gases from the furnace exhaust. The scrubber tower receives the two-phase flow from the venturi scrubbers. The effluent stream enters the tower near the bottom and the two phases are separated, with the gas flowing up the tower through the chimney tray and the liquid collected in a sump. The sump provides a brine residence time of 15 minutes at the maximum quench flow rate. The brine is maintained at a pH of 8.0 in the scrubber sump and at the scrubber liquid feed to the packed bed, as well as a density of 1.08 for GB or 1.15 for VX and HD. The packing consists of 2-inch stainless steel pall rings and occupies a depth and diameter of 10 feet and 6 feet, respectively, in the MPF and LIC PAS scrubbers and of 6 feet and 8 feet, respectively, in the DFS PAS scrubber. The diameter of the scrubber tower and the height of the packing was based on the following:

(1) Packing is such that the head loss across the bed is about 1/2 in. of water pressure drop per foot of packing.

(2) The residence time for scrub solution in the scrubber tower reservoir is one minute. Wire mesh demister pads are provided at the top of the scrubber tower to remove entrained water droplets.

d. Demister Vessel. The purpose of the demister vessel is to remove the fine H_3PO_4 mist when P_2O_5 laden gas is cooled with water. The gases from the scrubber tower enter the lower section of the demister vessel and flow through the candle demisters. Each candle demister is 2 inches in diameter and 20 feet long and fabricated with polyester webbing. There are five such demisters in the MPF PAS vessel, eight in that for the DFS, and sixteen for the LIC. The vessel diameter is eleven feet for the MPF and LIC PASs and thirteen feet for the DFS PAS. The vessel size and number of candle demisters were based on a face velocity of 8 to 30 ft/min. depending on the gas flow rate of the furnace. Water sprays are provided at the candle demister to wash the H_3PO_4 from the demister packing. The demister vessels are provided with the capability of being filled to the top of the demisters in one hour with a dilute hydrochloric acid solution to dissolve any entrained solids. A dedicated demister is provided for the DFS. The LIC and MPF have dedicated demisters as well as sharing a common spare. Bypasses are provided around the DFS demister.

e. Demister Wash System. The demister wash system is used when the high differential pressure monitor detects plugging at a critical level in the demister vessel. The demister wash system consists of an acid storage and transfer system, acid wash storage tank, filter, surge tank, and associated pumps. The acid storage tank is sized to hold one tank truckload of acid (3,500 gal). Acid use is based on washing the LIC demister once per week. The acid wash storage tank is sufficiently sized to hold a minimum of 1-1/2 demister vessel washes. The acid wash liquid is neutralized with caustic soda (NaOH). The vessel has a conical bottom for solids removal and an air sparge to provide mixing of the neutralizing caustic. The filter has a capacity of 30 gal/min. The solids containing residual liquid are pumped from the acid wash storage tank through the filter with the filtrate returning to the PAS for reuse. When the solids have been withdrawn from the acid wash storge tank, the clear supernatant is used to backwash the filters to the brine storage tanks. After backwashing, any remaining supernatant is returned to the PAS.

f. ID Fan. The ID fan (exhaust blower) provides motive force for the gases throughout the incineration system and the PAS.

g. Common Stack. A common stack is provided to handle the flue gases from the PASs for the MPF, DFS, and LIC. The stack will be sized to provide the flue gas dispersion required by environmental regulations. Sampling ports are provided in the stack to permit determination of CO, O_2, and agent. The stack is constructed of carbon steel and has an internal chemical-resistant lining. The structural design will include provisions for seismic forces, wind forces, and other natural phenomena that are site related.

5.3.2 DUN Pollution Abatement System (PAS).

The process flow for the DUN PAS is shown in Figure 5-14. The PAS for the DUN consists of the following components:

a. A quench tower is provided to cool the 2,000°F gases from the DUN to approximately 350°F to 400°F. The tower is equipped to accept 18 wt % caustic solution into the quench water flow to neutralize HCl gases when the DPE suits are being incinerated. The DUN quench tower spray provides sufficient water to quench the maximum gas stream to 350°F with one-third of the nozzles plugged. The quench liquid flow is controlled to ensure that the gas temperature is a minimum of 100°F above the gas dew point.

b. A baghouse is utilized to remove particulates from the gas stream. The baghouse is designed for a maximum velocity through the fabric of 5 ft/min, and to remove particulates to a level below 180 mg/m^3 at 7% O_2 content. The dislodged solids are collected in a hopper beneath the bags and the bag house particulates are deposited in 55 gal drums.

c. An exhaust blower (ID fan) is provided as a motive force for the gases throughout the entire DUN and PAS.

d. An exhaust stack for dispersion of the clean gas to the atmosphere is likewise provided and is sized to meet the environmental requirements.

5.3.3 Air Emissions For Incineration.

a. Noncriteria and criteria air pollutant emission estimates(3) (obtained from the Air Pollution Permit Application for TEAD) for the four incineration systems (LIC, MPF, DFS and DUN) are shown on Tables 5-2 through 5-7. Criteria air pollutants are those pollutants which must meet certain emission standards, such as those defined in 40 CFR 50; these air pollutants generally include sulfur oxides (as sulfur dioxide), nitrogen oxides, particulate matter, carbon monoxide, oxidants (as ozone), and lead. Noncriteria air pollutants are all other air pollutants. Tables 5-2 through

5-5 show the emission estimates for major noncriteria air pollutants for each incineration system. As noted on these tables, the PAS Removal Efficiency is expected to be greater than 99.8% for all noncriteria air pollutants. This efficiency would meet and/or exceed all environmental regulations/requirements which are established by the EPA. Tables 5-6 and 5-7 are summaries of the estimated maximum potential emissions for some criteria air pollutants, nonmethane hydrocarbons (NMHC), and chemical agent. Table 5-6 is hourly-based while Table 5-7 is yearly-based. The values in Table 5-7 assume continuous operations for an one-year period; at some installations, the disposal of a particular agent and munition may not last a year.

b. It is important to note that all of these data are only estimates and actual results may vary with operations and any number of other factors which can occur (i.e., feed rates, temperatures, etc.).

5.3.4 EP Toxicity Analysis of the Salts and Brines.

a. Before disposing of any solid waste generated by the destruction of the chemical munitions, it is necessary to provide an EP Toxicity test in order to determine whether or not the solid wastes should be considered RCRA hazardous. Tables 5-8 through 5-15 provide data for the waste salts, ash and brines from the incineration of the GB and VX filled M55 Rockets. Tables 5-8 and 5-9 cover EP toxicity analyses of the brine and brine salt, respectively, from the PAS of the DFS and LIC. The data for the LIC in Table 5-8 are from a different source than the data for the LIC in Table 5-9 although both were collected during incineration of GB in M55 rockets. Table 5-10 gives EP toxicity analyis for the brine salts from the PAS of the modified hydrazine furnace used to incinerate mustard drained from ton containers at RMA (see Section 4.2.1.b.(3)(a)). Table 5-11 presents the EP toxicity analysis of DFS Furnace and cyclone residue (ash) from incineration of GB in M55 rockets.

b. Tables 5-12 through 5-15 pertain to chemical analyses of the brines. Table 5-12 covers the DFS and LIC PAS brines from incineration of GB in M55 rockets. Table 5-13 covers the MPF PAS brine from incineration of VX in M55 rockets. Table 5-14 is a theoretical calculation of expected

TABLE 5-2
NONCRITERIA AIR POLLUTANT EMISSION ESTIMATE(3)

METAL PARTS FURNACE

Condition	Agent Feed Rate (lb/hr)	Pollutant Parameter	Potential Emissions (Uncontrolled) (lb/hr)	PAS Removal Efficiency (%)	Potential Emissions (Controlled) (lb/hr)	Annual Emissions (ton/yr)
GB Ton Container (drained)	129	HF	17.9	99.98	0.0036	0.006
		P_2O_5	60.8	99.8		
		H_3PO_4		99.8	0.7	0.40
		HCl	0.13	99.94	0.000077	0.00019
		Ni	0.0032	99.8	0.000010	0.00031
VX Ton Container (drained)	138	P_2O_5	34.0	99.8		
		H_3PO_4		99.8	0.094	0.23
		Ni	0.0034	99.8	0.0000069	0.000017
		Cr	0.00058	99.8	0.0000011	0.0000026
		Al	0.014	99.8	0.000028	
		Fe	0.069	99.8	0.00014	0.00033
HD Ton Container (drained)	146	HCl	62.3	99.94	0.037	0.090
		Ni	0.0034	99.8	0.0000073	0.000018
		Cu	0.00058	99.8	0.0000012	0.0000028
		Al	0.0015	99.8	0.0000029	0.0000070
		Fe	0.32	99.8	0.00065	0.0016
L Ton Container (drained)	146[a]	HCl	77.2	99.94	0.046	0.11
		As	52.8	99.8	0.11	0.25

[a] Assumed pure Lewisite for same feed rate as HD.

TABLE 5-3
NONCRITERIA AIR POLLUTANT EMISSION ESTIMATES(3)

LIQUID INCINERATOR

Condition	Agent Feed Rate (lb/hr)	Pollutant Parameter	Potential Emissions (Uncontrolled) (lb/hr)	PAS Removal Efficiency (%)	Potential Emissions (Controlled) (lb/hr)	Annual Emissions (ton/yr)
GB (or GA)	1,050	HF	145.6	99.98	0.0296	0.070
		P_2O_5	495.2	99.8		
		H_3PO_4		99.8	1.2	3.1
		HCl	1.1	99.94	0.00063	0.0015
		Ni	0.026	99.8	0.000052	0.00013
		Cu	0.0042	99.8	0.0000084	0.000020
		Al	2.1	99.8	0.0042	0.01
		Fe	0.53	99.8	0.0011	0.0025
VX	700	P_2O_5	173.1	99.8		
		H_3PO_4		99.8	0.48	1.15
		Ni	0.017	99.8	0.000035	0.000084
		Cu	0.0028	99.8	0.0000056	0.000013
		Al	0.067	99.8	0.00014	0.0004
		Fe	0.35	99.8	0.00070	0.0017
HD	1,330	HCl	567.1	99.94	0.34	0.82
		Ni	0.033	99.8	0.000067	0.00016
		Cu	0.0053	99.8	0.00011	0.000025
		Al	0.013	99.8	0.000027	0.000064
		Fe	2.9	99.8	0.0059	0.014
L[a]	1,330	HCl	701.9	99.94	0.42	1.0
		As	480.7	99.8	0.96	2.3

[a] Assumed pure Lewisite for same feed rate as HD.

TABLE 5-4
NONCRITERIA AIR POLLUTANT EMISSION ESTIMATES(3)

DEACTIVATION FURNACE

Condition	Feed Rate (rockets/hr)	Pollutant Parameter	Potential Emissions (Uncontrolled) (lb/hr)	PAS Removal Efficiency (%)	Potential Emissions (Controlled) (lb/hr)	Annual Emissions (ton/yr)
M55-GB	50	HCl	0.47	99.94	0.00028	0.00068
		HF	3.7	99.98	0.00074	0.0018
		P_2O_5	12.6	99.8		
		H_3PO_4		99.8	0.035	0.084
		Pb	5.2	99.8	0.010	0.025
		Ba	0.00023	99.8	0.00000047	0.0000011
		Al	0.054	99.8	0.00011	0.00026
		Fe	0.013	99.8	0.000027	0.000064
		Cu	0.00011	99.8	0.00000021	0.00000051
		Ni	0.00067	99.8	0.0000013	0.0000032
		Sb	0.00024	99.8	0.00000048	0.0000011
M55-VX	50	HCl	0.44	99.94	0.00027	0.00064
		P_2O_5	53.3	99.8		
		H_3PO_4		99.8	0.15	0.35
		Pb	0.014	99.8	0.000028	0.000067
		Ba	0.00023	99.8	0.00000047	0.00000112
		Al	0.025	99.8	0.000005	0.000012
		Fe	0.03	99.8	0.000025	0.00006
		Cu	0.0001	99.8	0.0000002	0.00000048
		Ni	0.00063	99.8	0.0000013	0.000003
		Sb	0.00024	99.8	0.00000048	0.0000011

TABLE 5-5
NONCRITERIA AIR POLLUTANT EMISSION ESTIMATES(3)

DUNNAGE INCINERATOR

Condition	Agent Feed Rate (lb/hr)	Pollutant Parameter	Potential Emissions (Uncontrolled) (lb/hr)	PAS Removal Efficiency (%)	Potential Emissions (Controlled) (lb/hr)	Annual Emissions (ton/yr)
Normal Operation	2.5 suits/hr	HCl	10.5	95	0.53	1.3

TABLE 5-6
SUMMARY OF FACILITY'S ESTIMATED MAXIMUM POTENTIAL(3) HOURLY EMISSIONS
(lb/hr)

Source	Particulate	SO_2	NO_x	CO	NMHC	GB	VX	Mustard
Process Steam	0.58	12.3	5.8	1.4	0.058	N/A	N/A	N/A
Building Heat	0.29	6.2	2.9	0.72	0.049	N/A	N/A	N/A
LIC	5.5	10.3	10.9	1.5	0.0051	1.5×10^{-5}	1.5×10^{-6}	0.0015
LIC (CAMDS Bulk)	5.6	10.3	10.8	1.6	0.0047	1.5×10^{-5}	1.5×10^{-6}	0.0015
MPF	2.1	1.1	2.4	0.59	0.0084	5.1×10^{-6}	5.1×10^{-7}	0.00051
MPF (CAMDS Bulk)	5.7	1.1	2.8	1.60	0.043	2.0×10^{-5}	2.0×10^{-6}	0.0020
DFS	8.9	0.090	48.0	2.5	0.011	2.1×10^{-5}	2.1×10^{-6}	0.0021
DUN	3.3	0.00011	0.18	0.9	0.00053	1.2×10^{-5}	1.2×10^{-6}	0.0012
Ventilation System	N/A	N/A	N/A	N/A	N/A	1.2×10^{-4}	1.2×10^{-5}	0.012
Facility Total	32.0	41.4	83.8	10.8	0.18	2.0×10^{-4}	2.0×10^{-5}	0.020

TABLE 5-7
SUMMARY OF FACILITY'S ESTIMATED MAXIMUM POTENTIAL[3] ANNUAL EMISSIONS
(ton/yr)

Source	Particulate	SO_2	NO_x	CO	NMHC	GB	VX	Mustard
Process Steam	1.3	26.9	12.6	3.2	0.13	N/A	N/A	N/A
Building Heat	0.47	10.1	4.8	1.2	0.081	N/A	N/A	N/A
LIC	13.2	24.8	4.9	3.7	0.012	6.5×10^{-5}	6.5×10^{-6}	0.0065
LIC (CAMDS Bulk)	13.4	24.8	4.9	3.7	0.011	6.6×10^{-5}	6.6×10^{-6}	0.0066
MPF	5.1	2.7	1.1	1.4	0.020	2.2×10^{-5}	5.1×10^{-6}	0.0022
MPF (CAMDS Bulk)	13.8	2.7	1.3	3.8	0.010	8.6×10^{-5}	8.6×10^{-6}	0.0086
DFS	21.4	0.22	21.6	6.0	0.027	9.1×10^{-5}	9.1×10^{-6}	0.0091
DUN	7.8	0.00029	0.081	2.2	0.0013	5.3×10^{-5}	5.3×10^{-6}	0.0053
Ventilation System	N/A	N/A	N/A	N/A	N/A	5.3×10^{-4}	5.3×10^{-5}	0.053
Facility Total	76.5	92.2	51.3	25.2	0.29	9.1×10^{-4}	9.1×10^{-5}	0.091

TABLE 5-8

RCRA ANALYSES OF DFS AND LIC PAS BRINES DURING INCINERATION OF GB M55 ROCKETS AT CAMDS(4)

EP Toxicity Parameter	DFS PAS Brines[a]	LIC PAS Brines[b]	RCRA Criteria
As	<.3-.79	<.9/<.395	5.0
Ba	.1-.74	.83/.338	100.0
Cd	<.001-1.05	.56/.11	1.0
Cr	.03-.12	1.1/.372	5.0
Pb	.06-16	.68/.194	5.0
Hg	<.001	.005/.001	0.2
Se	.16-.36	.6/.245	1.0
Ag	<.002	<.002/<.002	5.0

NOTES:

[a] Five trials were analyzed during this test. Results provide the minimum to maximum range during these trials. Concentration is in mg/l.

[b] Sixteen trials were analyzed during this test. Results are provided as maximum concentration/average concentration. Concentration is in mg/l.

TABLE 5-9

RCRA ANALYSES OF LIC PAS BRINE SALTS FROM THE INCINERATION OF GB M55 ROCKETS AT CAMDS[(5)]

EP Toxicity Parameter	LIC PAS Brine Salts[a]	RCRA Criteria
As	<.6/<.6	5.0
Ba	.63/.53	100.0
Cd	.263/.234	1.0
Cr	.51/.477	5.0
Pb	3.2/2.53	5.0
Hg	.001/.001	0.2
Se	<.3/<.3	1.0
Ag	<.002/<.002	5.0

NOTES:

[a] Three trials were analyzed during this test. Results are provided as maximum concentration/average concentration. Concentration is in mg/l.

TABLE 5-10

RCRA ANALYSES OF PAS BRINE SALTS DURING THE INCINERATION OF MUSTARD AT RMA (6)

EP Toxicity Parameter	Mustard Salts[a]	RCRA Criteria
As	1.75-1.97	5.0
Ba	<.01-.06	100.0
Cd	.004-.017	1.0
Cr	<.025	5.0
Pb	.041-.426	5.0
Hg	.0069-.0095	0.2
Se	.043-.543	1.0
Ag	.01-.02	5.0

NOTES:

[a] Results provide the minimum to maximum range during the analysis of four trials. Concentration is in mg/l.

TABLE 5-11

RCRA ANALYSES OF DFS RESIDUE FROM INCINERATION OF GB M55 ROCKETS AT CAMDS(4)

EP Toxicity Parameter	Furnance Residue[a]	Cyclone Residue[a]	RCRA Criteria
As	.024-.083	.003-.013	5.0
Ba	.08-1.8	.08-1.5	100.0
Cd	.003-2.9	<.001-.166	1.0
Cr	<.01-.16	.02-2.0	5.0
Pb	<.01-.24	<.01-.28	5.0
Hg	<.001	<.001	
Se	<.02-.03	.02-.048	1.0
Ag	<.002	<.002	5.0

NOTES:

[a] Four trials were analyzed during this test. Results provide the minimum to maximum range during these trials. Concentration is in mg/l.

concentrations in the PAS brines resulting from the salts of incinerating mustard drained from ton containers in the hydrazine furnace at RMA during Project Eagle - Phase I. Table 5-15 shows the concentrations in the brines combined from the DFS, MPF, and LIC. The data are based on pilot tests conducted at CAMDS for JACADS. Table 5-15 compares the concentrations before and after discharge into the ocean and with the EPA-mandated Marine Water Quality criteria.

c. Tables 5-16 and 5-17 exhibit the weight and volume, respectively, of the ash, metal and salt waste expected from the chemical agent/munitions disposal combined for all furnaces per CSDP site.

TABLE 5-12

CHEMICAL ANALYSES OF DFS AND LIC PAS BRINES DURING INCINERATION OF GB M55 ROCKETS AT CAMDS[7]

(Concentration in Milligrams/Liter)

Paramater	DFS PAS Brines	LIC PAS Brines
pH	9.1	7.8
Specific Gravity	1.108	1.109
Solids	141,000	145,294
Disolved Solids	107,000	112,421
Chemical Oxygen Demand	1,400	290
Total Organic Carbon	310	58
Nitrophenols	0.74	0.005
Phenol	0.00	0.004
Phthalate Esters	0.016	0.004
Na_2CO_3	731	195
NaF	3,426	48,952
Na_2SO_4	50,764	7,548
$NaNO_3$	1,129	34
Na_2PO_4	4,412	111,499
NaCl	12,590	3,597
Hg	0.0005	0.004
Ag	0.02	0.02
As	0.021	0.048
Ba	Note a	0.4
Cd	15.7	0.162
Cr	3.1	0.09
B	15.0	308
Pb	62	0.39
Se	0.3	0.002
Ca	990	216
Co	0.06	0.11
Cu	2.63	2.24
Fe	34	50
K	748	130
Mn	0.70	4.23
Mo	0.3	0.3
Ni	1.99	7.02
Sb	0.25	1.03
Sn	1.2	1.96
V	0.7	0.7
Zn	12.2	1.3
Al	179.0	1.0
Be	.02	.02

NOTES:

[a] Could not be analyzed for due to excessive sulfate (Na_2SO_4).

TABLE 5-13

CHEMICAL ANALYSES OF MPF PAS BRINES FROM INCINERATION OF VX FILLED M55 ROCKETS AT CAMDS(8)

Paramater	Conc mg/l	Paramater	Conc mg/l
pH	9.4	Ba	1.087
Specific Gravity	1.203	Cd	2.044
Total Organic Carbon (TOC)	330	Ni	11.92
Chemical Oxygen Demand (COD)	270	Cr	0.805
Total Solids (TS)	262,000	Pb	0.136
Total Dis. Solids (TDS)	258,000	Hg	0.0449
Na_2HPO_4	32,800	Se	<0.02
NaCl	39,183	Ag	0.768
Na_2SO_4	15,229	Al	2.62
Na_2CO_3	69,889	Cu	3.703
$NaNO_3$	607	Fe	194.9
As	0.416	Zn	8.586

TABLE 5-14

EXPECTED CONCENTRATIONS OF PAS BRINES FROM THE INCINERATION OF MUSTARD FILLED TON CONTAINERS[a]

Paramater	Conc mg/l	Paramater	Conc mg/l
Specific Gravity	1.202	Cd	<4
Na_2CO_3	29,800	Hg	0.25
Na_2SO_3	59,000	Cu	13
NaCl	108,300	Zn	8.8
Na_2SO_4	39,300	Cr	<6.3
Pb	13	Fe	500

NOTES:

[a] This is a theoretical brine composition based on analysis of actual salt from previous incineration operations and theoretically projecting the concentration to a brine with a specific gravity of 1.202. These theoretical values are not published and were prepared by G. Mohrman, Environmental and Monitoring Division, Program Executive Officer - Program Manager for Chemical Demilitarization, Aberdeen Proving Ground, MD.

TABLE 5-15

COMPARISON OF FAS BRINE CONCENTRATION WITH REVISED SALTWATER CRITERIA
(Based on Discharge of 100,000 gallons in 1 hour at 4 knots)

PARAMETER	WORST-CASE BRINE CONCENTRATION* (mg/l)	INSTANTANEOUS DILUTION (mg/l) ($E\text{-}X = 10^{x}$)	1-HOUR AVERAGE CONCENTRATION (mg/l)	AGENT TYPE	EPA-MANDATED LIMIT FOR CONCENTRATION LEVEL (mg/l)
$NaHCO_3$	852	0.195	4.7 E-4	GB	-----
NaCl	108,300	24.8	5.9 E-2	HD	-----
NaF	48,952	11.2	2.7 E-2	GB	-----
Na_2SO_3	59,000	13.5	3.2 E-2	HD	-----
Na_2SO_4	50,764	11.6	2.8 E-2	GB	-----
$NaNO_2$	0.3	6.88 E-5	1.7 E-7	GB	-----
Na_3PO_4	111,499	25.6	6.1 E-2	GB	-----
Na_2HPO_4	50,608	11.6	2.8 E-2	GB	-----
Na_2CO_3	69,889	16	3.8 E-2	VX	-----
$NaNO_3$	1,129	0.26	6.2 E-4	GB	-----
Ag	0.768	1.76 E-4	4.2 E-7	VX	0.0023**
As	0.416	9.53 E-5	2.3 E-7	VX	0.069**
Al	179	4.10 E-2	9.9 E-5	GB	-----
B	308	7.06 E-2	1.7 E-4	GB	-----
Ba	1.09	2.50 E-4	6.0 E-7	VX	-----
Be	0.02	4.58 E-6	1.1 E-8	GB	-----
Ca	990	0.23	5.5 E-4	GB	-----
Cd	15.7	3.60 E-3	8.6 E-6	GB	0.043**
Co	0.11	2.52 E-5	6.1 E-8	GB	-----
Cr^{+6}	6.3	1.44 E-3	3.5 E-6	HD	1.1**
Cu	13	2.98 E-3	7.2 E-6	HD	0.0029**
Fe	500	0.115	2.8 E-4	HD	-----
Hg	0.25	5.73 E-5	1.4 E-7	HD	0.0021**
K	748	0.17	4.1 E-4	GB	-----
Mn	4.23	9.70 E-4	2.3 E-6	GB	-----
Mo	0.3	6.88 E-5	1.7 E-7	GB	-----
Ni	11.92	2.73 E-3	6.6 E-6	VX	0.14**
Pb	62	1.42 E-2	3.4 E-5	GB	0.14**
Sb	1.03	2.36 E-4	5.7 E-7	GB	-----
Se	0.3	6.88 E-5	1.7 E-7	GB	0.41**
Sn	1.96	4.49 E-4	1.1 E-6	GB	-----
V	0.7	1.6 E-4	3.9 E-7	GB	-----
Zn	12.2	2.80 E-3	6.7 E-6	GB	0.17**
Nitrophenols	0.74	1.70 E-4	4.1 E-7	GB	4.85***
Phenol	0.004	9.17 E-7	2.2 E-9	GB	5.8***
Phthalate Esters	0.016	3.67 E-6	8.8 E-9	GB	2.94***

NOTES: *These values taken from Tables 5-12 through 5-14.
**Limits are from EPA(9) for acute effects
***These figures represent values known to cause acute toxicity.

FORMULAS: Instantaneous Dilution = Concentration in Brine/4363
(from Csanady(10))
1-Hour Avg. Conc. = Concentration in Brine x 5.5 E-7

TABLE 5-16

TOTAL WEIGHT (TONS) OF ASH, METAL AND SALT WASTE PER SITE*(11)

Material	ANAD	LBAD	PBA	PUDA	TEAD	UMDA
Ash	235	187	295	43	174	288
Aluminum**	964	852	1,348	--	483	1,301
Ferrous	15,053	1,626	2,750	21,657	36,921	7,975
Total Metal	16,017	2,478	4,098	21,657	37,404	9,276
Salt (no Decon)	3,691	836	7,127	4,832	22,987	6,534
Total Salt***	4,335	1,480	7,771	5,476	23,631	7,178

*Amounts for APG and NAAP, where only one kind of material is stored, are classified. TEAD includes CAMDS Bulk.

**From M55 rockets only.

***A constant amount of 644 tons of salt from decontamination per site is included. All salt contains 15% water.

TABLE 5-17

TOTAL VOLUME (yd^3) OF ASH, METAL AND SALT WASTE PER SITE*(11)

Material	ANAD	LBAD	PBA	PUDA	TEAD	UMDA
Ash	317	252	398	57	235	388
Aluminum**	3,901	3,451	5,458	--	1,954	5,263
Ferrous	8,606	625	5,113	10,146	34,637	6,649
Total Metal	12,507	4,076	10,571	10,146	36,591	11,912
Salt (no Decon)	3,906	884	7,542	5,113	24,324	6,915
Total Salt***	4,587	1,565	8,223	5,794	25,005	7,596

*Amounts for APG and NAAP, where only one kind of material is stored, are classified. TEAD includes CAMDS Bulk.

**From M55 rockets only.

***A constant amount of 681 yd^3 of salt from decon per site is included. All salt contains 15% water.

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6.0.0. INCINERATION AND POLLUTION ABATEMENT SYSTEM TEST PROGRAM.

6.1.0. Introduction.

6.1.1. Purpose/Background.

a. A comprehensive test program is underway at CAMDS to verify the performance of the munition disassembly machines (RSM, MIN, MDM, PMD, and BDS), and incineration and pollution abatement systems that will be used in JACADS and the proposed CSDP disposal plants. Some of the tests involving the RSM, DFS, MPF and LIC have already been completed and are described in Chapter Four. The purpose or objective of the CAMDS test program is to verify the performance of these items/systems with stockpile chemical agents and munitions. With respect to the disassembly machines, each has undergone extensive testing with simulant (explosive and agent) filled munitions. The tests at CAMDS will allow the Army to determine what effect, if any, actual chemical munitions will have on the processing rate of each machine.

b. As described in Chapter Four, the Army has demonstrated that incineration is a safe and effective method for chemical agent and munition disposal. The purpose of the majority of the tests which have been completed at CAMDS, was to demonstrate the feasibility of incinerating nerve agents in industrial scale incineration systems. This was accomplished. The feasibility of incinerating mustard agent has already been demonstrated in Project Eagle - Phase I at RMA (see Section 4.2.1.). The purpose of the current test program is to verify the processing rates of the JACADS and CSDP incineration systems and to characterize the effluents and solid residues generated against current and proposed regulatory standards.

6.1.2. Agent Test Window.

a. For safety reasons, only one agent type is processed at CAMDS at any given time. In other words, the LIC cannot incinerate mustard or VX when the DFS is incinerating drained GB M55 rockets. However, in an agent window, several different types of munitions can be processed; the LIC can incinerate

VX from ton containers or drained projectiles, while the DFS is incinerating drained VX M55 rockets. The LIC and MPF are the only two incineration systems that cannot be operated concurrently in an agent window. This is because the LIC and MPF share the same pollution abatement system (Section 4.3.4.c).

b. Table 6-1 outlines the current chemical agent and munition test program through 1988. The time between the test windows is required to clean/decontaminate CAMDS, and to change/adjust the chemical agent monitors so they can detect the next agent. Although not specifically identified in Table 6-1, the dunnage incinerator will also be tested. Table 6-2 lists the chemical stockpile by munition type and agent and Table 6-3 identifies the type of incineration system proposed for each storage location; by comparing Table 6-1 to Tables 6-2 and 6-3, the reader can identify which tests at CAMDS are directly applicable to a specific storage installation.

c. In addition to the tests summarized in Table 6-1, incineration tests involving chemical agent surrogates will be conducted with each incineration system. The purpose of these tests is more fully explained in Section 6.3.2.b.(2). The DFS will also be used to model the proposed rotary kiln that may be used in the cryofracture demilitarization process(1). Tests in support of the cryofracture demilitarization process include incinerating bulk chemical agent which is sprayed into the DFS at ambient temperatures and processing cryogenically cooled simulated chemical munition fragments to assure its ability to incinerate cryogenically frozen chemical agents, and energetic materials, as well as the ability of the DFS to handle large quantities of metal parts and wood dunnage.

d. Three types of data will be obtained during incineration system testing and evaluation: (1) performance and operating characteristics - this includes heat and material balances, temperature profiles, furnace draft stability and other data related to the operation of the incinerator/furnace and its pollution abatement system; (2) environmental compliance - incineration of chemical agents and munitions is subject to many environmental regulations including RCRA(2), TSCA, and air quality regulations. It is necessary, therefore, to determine the composition of exhaust gases and

TABLE 6-I: Chemical Agent and Munition Disposal Test Program Through 1988

Agent	Test Window	Items Processed	Processes Tested	
			Disassembly Machines	Incineration Systems
GB	Through Oct 87	-105 mm Projectiles	MDM	MPF, LIC
		-115 mm Rockets	RSM	DFS, LIC
		-750 lb Bombs	BDS	MPF, LIC
		-Ton Containers	BDS	MPF, LIC
		-105 mm Simulant Mustard Projectiles (1,2)	MDM	--
		-500 lb Simulant GB Bombs (2)	BDS	--
VX	Jan - Jun 88	-155 mm Projectiles	MDM	MPF, LIC
		-115 mm Rockets	RSM	DFS, LIC
		-Spray Tanks	BDS	MPF, LIC
		-Ton Containers	BDS	MPF, LIC
Mustard H/HD/HT	Aug - Dec 88	-4.2 in Mortars	PMD, MDM	MPF, LIC
		-155 mm Projectiles	PMD, MDM	MPF, LIC
		- Ton Containers	BDS	MPF, LIC

NOTES: (1) Simulant filled munitions are not affected by agent windows
(2) No mustard filled 105 mm projectiles/cartridges or GB filled 500 lb bombs are stored at TEAD

TABLE 6-2: CONUS Unitary Chemical Stockpile Distribution

MUNITION TYPE			STOCKPILE LOCATIONS							
			APG	ANAD	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
CARTRIDGE:	105MM	GB		X					X	
	105MM	HD		X				X		
	4.2-IN	HD		X			X	X	X	
	4.2-IN	HT		X				X	X	
PROJECTILE:	105MM	GB		X					X	
	155MM	GB		X					X	X
	155MM	H			X				X	
	155MM	HD		X				X		
	155MM	VX		X	X				X	X
	8-IN	GB		X	X				X	X
	8-IN	VX							X	X
ROCKET:	115MM	GB		X	X		X		X	X
	115MM	VX		X	X		X		X	X
LAND MINE:	2-GAL	VX		X			X		X	X
BOMB:	500-LB	GB								X
	525-LB	GB							X	
	750-LB	GB							X	X
SPRAY TANK:		VX							X	X
TON CONTAINER:		GA							X	
		GB		X	X		X		X	X
		H			X				X	
		HD	X	X			X		X	X
		HT		X			X			
		L							X	
		VX		X	X	X			X	

Notes: Does not include research and development quantities.
Does not include recovered munitions.

TABLE 6-3: CHEMICAL AGENT AND MUNITIONS STORAGE LOCATIONS AND PROPOSED FURNACES AND INCINERATORS

	Agents/Munitions	Furnaces/Pollution Abatement System			
		LIC-WSS	MPF-WSS	DFS-WSS	DUN-BSS
Aberdeen Proving Ground (APG)	HD-TC	X	X		
Lexington Blue-Grass Army Depot (LBAD)	H-P GB-P,R,TC VX-P,R	X	X	X	X
Anniston Army Depot (ANAD)	HD-C,P,TC HT-C GB-C,P,R VX-P,R,M	X	X	X	X
Newport Army Ammunition Plant (NAAP)	VX-TC	X	X		
Pine Bluff Arsenal (PBA)	HD-C,TC HT-TC GB-R VX-R,M	X	X	X	X
Pueblo Army Depot Activity (PUDA)	HD-C,P HT-C	X	X	X	X
Tooele Army Depot (TEAD)	H-P HD-C,P,TC HT-C,P GB-C,P,R,B,TC VX-P,R,M,ST,TC (GA-TC) (L-TC)	X	X	X	X
Umatilla Army Depot Activity (UMDA)	HD-TC GB-P,R,B VX-P,R,M,ST	X	X	X	X

*Key*

TC - Ton Containers
P - Projectiles
C - Cartridges
R - Rockets
M - Mines
B - Bombs
ST - Spray Tanks
BSS-Baghouse Scrubber System
WWS- Wet Scrubber System

incinerator/furnace and pollution abatement system residues to ensure compliance with these regulations; (3) environmental concerns - this includes information on the exhaust gases and solid residues, which is not required by current environmental regulations but may be required to support permitting actions or may be covered by proposed or future regulations. This includes emissions of heavy metals, PICs, and analysis of furnace/incinerator and pollution abatement system residues using the Toxicity Characteristic Leaching Procedure (TCLP) which EPA has proposed to use instead of the EP Toxicity Leaching procedure currently required under RCRA.(3)

6.2.0. Comparison of CAMDS and JACADS Incineration and Pollution Abatement Systems.

a. The incineration and pollution abatement systems that will be used in the JACADS and proposed CSDP disposal plants are based on the designs of the systems installed at CAMDS. That is not to say however, that the systems are identical. Although conceptually the same, the JACADS and proposed CSDP systems differ from the CAMDS systems in several areas. Before discussing the current test program it is advisable to compare the systems, identify the differences, and discuss the impact that the differences have on the test data.

b. There are two main reasons for the changes made to the CAMDS incineration and pollution abatement systems before they were incorporated into the JACADS and CSDP designs.

(1) Purpose and Schedule. The JACADS and CSDP disposal plants are designed specifically to dispose of the chemical stockpile at a given installation within a finite time period. The incineration and pollution abatement systems are designed specifically to handle the required chemical agent and munition disposal rates. CAMDS on the other hand, was constructed to test and evaluate equipment, processes, and procedures which will be used in future disposal plants as well as dispose of a limited number of leaking munitions. The incineration and pollution abatement systems did not have to be as large as those required for the JACADS and proposed CSDP disposal plants. It is accepted engineering practice to design full scale processes based on

smaller pilot scale systems.

(2) Process Improvements. The knowledge gained from the completed disposal tests (Section 4.3.0.) has been incorporated into the JACADS and proposed CSDP designs, and has resulted in several improvements over the current CAMDS design. This "fine tuning" of the designs is the primary reason why the tests at CAMDS are being performed. An example of such an improvement is increasing the pressure drop across the venturi scrubber from 20 to 40 inches of water. During GB incineration tests in the MPF, it was discovered that the pollution abatement system was having difficulty in removing the P_2O_5 particulate. The design of the JACADS venturi was then modified to reflect the higher pressure drop thus improving its particulate removal efficiency.

c. Appendix D contains a detailed comparison of the CAMDS and JACADS incineration and pollution abatement systems. The proposed CSDP designs are identical to the JACADS designs except for site-specific modifications such as altitude, geological conditions and ambient temperature conditions. The results of the comparison are summarized below.

6.2.1. Liquid Incinerator. The CAMDS LIC is an one-third scale version of the JACADS LIC. The configuration and interfaces with agent, auxiliary fuel, spent decontamination solutions, and other utility lines are identical. The design agent incineration rates are 300 lb GB/hr, 200 lb VX/hr and 380 lb HD/hr for the CAMDS LIC as compared to 1050 lb GB/hr, 700 lb VX/hr, and 1330 lb HD/hr for the JACADS LIC. The data obtained from the LIC tests will be directly applicable to the JACADS/CSDP LIC.

6.2.2. Deactivation Furnace System. The CAMDS DFS is similar to the JACADS DFS configuration. The JACADS rotary kiln (retort) is a foot larger in diameter to handle an increased average rocket feed rate (32 rockets per hour versus 15 rockets per hour at CAMDS). The primary difference between the two systems is the method used to feed the rockets and other items to the DFS. As described in Chapter 2, CAMDS uses a bucket conveyor to transfer the munition components to the DFS feed chute. The material then passes through a single double tipping valve (DTV) into the rotary kiln. In the JACADS design the munition components are gravity fed directly from the ECR eliminating the bucket conveyor and considerably increasing the reliability of the system. The dual feed chutes are required because JACADS has dual munition processing lines. The CAMDS DTV design was replaced with sliding blast gates to help eliminate problems with jamming which were occasionally experienced at CAMDS when processing M55 Rockets.

6.2.3. Metal Parts Furnace. The MPF has undergone the greatest evolution/change of the three furnaces. This is because the CAMDS MPF was originally designed to process mustard filled projectiles and ton containers by in-situ incineration. In-situ incineration involves the evaporation (volatilization) of the agent from the projectile or ton container in an oxygen deficient atmosphere. The gases from the volatilization chamber (Figure 4-27) are then incinerated in a fume burner. An afterburner is located downstream of the fume burner to ensure complete destruction of any remaining organic vapors. However, CAMDS tests with GB showed that in-situ agent incineration was slower and harder to control than draining the agent from the projectile or ton container and burning it separately . Therefore, the JACADS MPF was designed strictly to thermally decontaminate projectiles and bulk containers (bombs, spray tanks, and ton containers). The JACADS MPF does not require a fume burner or separate burnout chamber, instead, a single large chamber is used to incinerate the residual agent (the amount that remains after draining) and thermally decontaminate the munition or container. The JACADS MPF is equipped with an afterburner. Although mechanically dissimilar, the current role of the CAMDS and JACADS MPFs is the same. From an environmental standpoint, the emissions of the CAMDS MPF (downstream of the afterburner) and ash contained in the munitions or containers (after processing through the burnout chamber) should be representative of the JACADS MPF.

6.2.4. Dunnage Incineration. Both the CAMDS and JACADS DUNs are commercially available units and include separately fired afterburners to ensure complete combustion of any organic compounds in the incinerator exhaust gases. Although mechanically dissimilar, the purpose of the CAMDS and JACADS DUNs is the same. The primary reason for the differences in incinerator design is to handle the increased dunnage load at JACADS as compared to CAMDS. The emissions and solid residues from the CAMDS DUN should be representative of the JACADS DUN.

6.2.5. Pollution Abatement Systems.

a. LIC, MPF, and DFS Wet Scrubber Systems (WSS). The CAMDS and JACADS PASs are conceptually identical, however, several improvements have been made in the JACADS designs to enhance particulate removal efficiency:

(1) The CAMDS concurrent quench vessel has been replaced by a counter current vessel equipped with a liquid separator. This will provide for better gas cooling and saturation. Any particulate matter absorbed by the water will be removed from the exhaust gases by the liquid separator, thus decreasing the particulate loading on the venturi and demisters;

(2) The pressure drop across the venturi has been increased from 20 to 40 inches of water providing for greater gas/liquid mixing and particle agglomeration and removal; and

(3) The face velocity and pressure drop across the demisters have been lowered to improve submicron size particulate removal.

(Note: The above modifications are planned for the CAMDS LIC/MPF PAS since it is during LIC agent incineration that the PAS sees the greatest particulate challenge. Until these modifications are completed, the particulate emissions from the CAMDS LIC are expected to be significantly greater than the particulate emissions from the JACADS/CSDP LICs.)

b. DUN Baghouse Scrubber System (BSS). A JACADS type BSS is being designed and fabricated for the CAMDS DUN. It will be scaled to the smaller capacity of the CAMDS DUN, but will be identical in configuration.

6.3.0. Planned Test Burns.

6.3.1. Overview.

a. During the agent test windows, each furnace and/or pollution abatement system will be thoroughly evaluated. The evaluation can be broken into three broad categories: (1) performance and operational characteristics; (2) environmental compliance; and (3) environmental concerns. Performance and operational characteristics data will be collected by CAMDS engineers and operators whenever the furnace/incinerator is operated. A comprehensive report will be prepared at the end of each agent test window and will include the following information: agent/munition feed rates both peak and average; temperature profiles; exhaust gas analyses consisting of agent, CO, CO_2, O_2, SO_2, and NO_x; problems encountered and solutions implemented; assessment of the materials of construction, and the amount of scrubber brine, salt, and solid residue generated.

b. Unlike performance and operational characteristics data, environmental compliance and environmental concerns data will be obtained by conducting special test burns with the assistance of a qualified commercial contractor. This is necessary because of the special sampling and analysis procedures required to obtain the data. A test report will be prepared by the contractor after each test. A test burn will take approximately one to two weeks to complete, however, as shown in Table 6-4, a great deal of effort is required to prepare for and analyze the results from a test burn.

6.3.2. Environmental Compliance Data Requirements.

a. Overview.

(1) Regulated releases from the proposed CSDP disposal plants include furnace/incinerator exhaust gases and the furnace/incinerator residues (including the cyclone ash from the DFS), and the salts formed by the dried scrubber brine. No liquid discharges will occur from the proposed plants

TABLE 6-4: TYPICAL TEST BURN SCHEDULE

Activity	Completion Date, Days
1. Prepare Test Burn Plan	D - 60
2. Equipment and Instrument Checkout and Calibration	D - 7
3. Set-up Sampling Equipment	D - 7
4. Start Test Burn	D
5. Complete Test Burn	D + 14
6. Sample Analysis	D + 44
7. Calculate Results and Prepare Draft Test Report	D + 88
8. Technical Review	D + 102
9. Publish Final Report	D + 132

except rainwater and, sanitary sewerage, none of which are regulated. Air emissions from the proposed disposal plants are regulated under the Clean Air Act (CAA), RCRA, TSCA, and the Department of Health and Human Services (DHHS);disposal of the solid wastes is regulated only under RCRA. In addition, each State has specific air quality and hazardous materials regulations which may be more restrictive than the above Federal laws.

(2) Clean Air Act. A review conducted by CH2M Hill(4) showed that all eight States where chemical agents or munitions are stored (Maryland, Alabama, Kentucky, Indiana, Arkansas, Colorado, Utah, and Oregon) have been authorized to administer the requirements of the CAA through their individual air pollution control programs, including New Source Review (NSR) and Prevention of Significant Deterioration (PSD) for attainment area requirements. An attainment area is a geographical location where the National Ambient Air Quality Standards (NAAQS) are being met for each criteria pollutant listed in Table 6-5. A nonattainment area is a location where one or more NAAQSs are not being met. All of the chemical agent and munition storage installations are located in attainment areas except Aberdeen Proving Ground, Maryland which is located in a nonattainment area for photochemical oxidant (O_3).

(3) Resource Conservation and Recovery Act.

(a) Chemical agent and munition disposal is regulated under RCRA, and the corresponding state hazardous waste management regulations, because the munitions and agents have been classified as hazardous wastes. It is important to note that the hazardous waste classification does not apply to the chemical stockpile, except M55 rockets, until the agents or munitions are brought on to the disposal facility site. The M55 rockets have already been classified by the Department of the Army in 1984 as a hazardous waste because they have no further military strategic significance, they have been declared obsolete, because none of the components have any resale value and because they are currently being stored for disposal (5). The remaining chemical agents and munitions, although targeted for disposal in Public Law 99-145 6), are still part of the U.S. defensive stockpile and therefore are not classified "wastes".

TABLE 6-5: NATIONAL AMBIENT AIR QUALITY STANDARDS CRITERIA POLLUTANTS

- Sulfur Dioxide
- Carbon Monoxide
- Total Suspended Particulates
- Nitrogen Dioxide
- Ozone
- Lead

1 Chemical agents and munitions are classified as reactive characteristic hazardous wastes by EPA. Chemical munitions which contain explosive bursters are classified as reactive characteristic hazardous wastes because the munitions are classified as Class A Explosives in the Department of Transportation Hazardous Materials Transportation Regulations (7,8). Chemical munitions and containers which do not contain explosive components are also considered reactive characteristic hazardous wastes because when mixed with water, chemical agents generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment. In addition to being classified as reactive characteristic hazardous wastes, the states of Utah, Maryland, and Oregon have "listed" chemical agents as hazardous wastes due to their toxicity. Table 6-6 lists the basis for classifying chemical agents and munitions as hazardous wastes for each state where they are stored.

2 The distinction between a "characteristic" hazardous waste and a "listed" hazardous waste is important when evaluating methods of disposal for the solid waste generated by chemical agent and munition disposal. A solid waste generated from the disposal of a listed waste is itself a listed hazardous waste unless "delisted" by the appropriate State. The solid residue generated from a characteristic hazardous waste is a hazardous waste until the residue fails to exhibit any of the four characteristics defined in Subpart C of 40 CFR 261 - Ignitability, Corrosivity, Reactivity, or EP Toxicity.

(b) To be permitted under RCRA, an incinerator and its pollution abatement system must complete a special trial burn supervised by representatives from EPA or the State. The purpose of the trial burn is to ensure compliance with the standards for POHC, HCl, and particulate emissions described below. The operating permit issued to the facility will be based on the results of the trial burn.

b. Incineration Emission Standards. Table 6-7 lists the applicable emission standards which will be used to assess the performance of the furnace/incinerator and pollution abatement system during the test burns.

TABLE 6-6: HAZARDOUS WASTE CLASSIFICATION OF CHEMICAL AGENTS

Agency	Classification (As of 2/13/87)
Federal - EPA	Characteristic Waste - Reactive
Alabama	Same as Federal - No Proposed Changes
Arkansas	Same as Federal - No Proposed Changes
Colorado	Same as Federal - No Proposed Changes
Indiana	Same as Federal - No Proposed Changes
Kentucky	Same as Federal - No Proposed Changes
Maryland	Nerve Agent and Mustard - Listed Hazardous Waste as of January 13, 1987: Other Possible Changes but No Public Information
Oregon	Nerve Agent - Listed Hazardous Waste
Utah	Nerve Agent, Mustard and Demilitarization Residues Listed Hazardous Waste as of November 15, 1986

TABLE 6-7: CSDP INCINERATOR EMISSION STANDARDS

EMISSION	STANDARD	REGULATION/REQUIREMENT(1)
Agent (2)	0.003 mg HD/m^3	DOD 6055.9-STD
	0.0001 mg L/m^3	DOD 6055.9-STD
	0.0003 mg GB/m^3	DOD 6055.9-STD
	0.0003 mg GA/m^3	(3)
	0.00003 mg VX/m^3	DOD 6055.9-STD
POHC (4)	99.99% DRE	40 CFR 264.343(a)(1)
HCl (4)	The larger of 4 lb/hr or 99% removal efficiency	40 CFR 264.343(b)
Particulates (4,5)	0.08 gr/dscf at 7% O_2	40 CFR 264.343(c)
	0.03 gr/dscf at 12% CO_2	COMAR 10.18.08
SO_2	500 ppm (volume)	CAMDS FEIS
Opacity	See Table 6-9	See Table 6-9

NOTES:
(1) State regulation citations obtained from reference 4.
(2) One hour average
(3) No current standard, assumes same standard as GB.
(4) States have adopted RCRA standards for POHC, HCl and particulate emissions from hazardous waste incinerators.
(5) RCRA particulate standard is more stringent than state air quality particulate standards except in Maryland.

Table 6-7 is based on a review of the air pollution discharge permit applications for each of the proposed CSDP disposal plants (9-16), and comparing the requirements identified in the applications against those required under RCRA, the CAMDS FEIS, and by DHHS.

(1) Agent Emissions. The emission standards listed in Table 6-7 meet or exceed the limits currently or previously approved by DHHS in accordance with their oversite authority established by Public Law 91-121 as amended by Public Law 91-141(17,18). During the test burns each incineration system will have to meet these standards.

(2) POHC Emissions. Under RCRA, an incinerator must demonstrate a 99.99% destruction (incinerator) and removal (pollution abatement system) efficiency (DRE) for each POHC designated in the feed. DRE is determined by the following equation:

$$\mathrm{DRE} = \frac{W_{in} - W_{out}}{W_{in}} \times 100\%$$

Where W_{in} = mass feed rate of the POHC to the incinerator

W_{out} = mass emission rate of the POHC in the exhaust stack

(a) POHCs for the trial burn are usually selected by EPA or the State from the list of RCRA Appendix VIII compounds (40 CFR 261, Appendix VIII) based on the concentration and degree of difficulty of incineration of the hazardous organic constituents in the waste feed. The method currently adopted by EPA to determine the degree of incinerability is based on the heat of combustion of the constituent. Constituents having low heats of combustion are assumed to be less able to support combustion and therefore more difficult to burn. The Guidance Manual for Hazardous Waste Incineration Permits, contains a list of Appendix VIII compounds and their heats of combustion(21). Table 6-8 lists the heat of combustion for the chemical agents, nitroglycerin and several industrial Appendix VIII compounds which are commonly incinerated in commercial hazardous waste incinerators.

TABLE 6-8: CHEMICAL AGENT INCINERABILITY

Compound	Heat of Combustion (kilocalorie/gm)
Chemical Agents(1)	
GA	5.41
GB	5.60
VX	8.33
H	4.50 (2)
HD	4.75 (2)
HT	5.29
L	2.50 (3)
Appendix VIII Compounds	
Carbon Tetrachloride (CCl_4)	0.24
Chloroform ($CHCl_3$)	0.75
1,1,1 Trichloroethane ($C_2H_3Cl_3$)	1.99
1,1,2,2 Tetrachloroethane ($C_2H_2Cl_4$)	1.19
Pentachlorophenol (PCP) (C_6HCl_5O)	2.09
Nitroglycerin ($C_3H_5N_3O_9$)	3.79
Methyl Ethyl Ketone (MEK) (C_4H_8O)	8.07
Benzene (C_6H_6)	10.03

Notes: (1) Source: Edgewood Arsenal Special Report EO-SR-74001 Chemical Agent Data Sheets; Vol I, Dec 1974.
(2) RCRA Appendix VIII Compound
(3) Calculated heat of combustion based on one mole of Lewisite and 1/2 mole of propane(22)

(b) The state and federal hazardous waste regulators have indicated that each chemical agent and nitroglycerin (an energetic compound contained in the M55 rocket motor) should be selected as POHCs for the CSDP disposal plant trial burns. In addition, the regulators have requested that surrogates be used to demonstrate incinerator performance prior to the chemical agent/munition trial burns. The proposed surrogates for the CSDP trial burns are listed in Table 6-9. The POHCs for the blister and nerve agent surrogates are carbon tetrachloride and 1,1,1-trichloroethane, both of which have lower heats of combustion than any of the chemical agents. In addition to being more difficult to incinerate, the surrogates will simulate the agents particulate matter and HCl emission characteristics.

(c) In addition to demonstrating agent DRE during the CAMDS test burns, special test burns will be conducted with the chemical agent surrogate selected for the CSDP trial burns. This will allow the Army to become familiar with surrogates and to evaluate the performance of the furnaces and incinerators from this perspective before the CSDP disposal plants are constructed.

(3) HCl Emissions. During the trial burn, HCl emissions cannot exceed the greater of four pounds per hour or a mass emission rate of one percent of the HCl entering the pollution abatement system. During the test burns, both with agents and surrogates, the ability of the pollution abatement system to meet this requirement will be verified.

(4) Particulate Emissions. Particulate emissions are regulated under both RCRA and the State air pollution control programs. By comparison, the RCRA standard 0.08 gr/dscf corrected to seven percent oxygen is more stringent than most of the State air pollution control regulations. The exception was Maryland where APG is located. Only HD filled ton containers are stored at APG. During the mustard test window, the Maryland particulate standard will be used to evaluate the performance of the MPF/LIC pollution abatement system.

(5) SO_2 Emissions. This is currently a site specific requirement

TABLE 6-9: CSDF RCRA PERMIT APPLICATION
Chemical Agent/Munition Surrogates

Blister Agent Surrogates

A. Composition

1) 1,1,1-trichloroethane	25 wt%
2) Carbon tetrachloride	38 wt%
3) No.2 fuel oil	37 wt%

B. Properties

1) Heat of Combustion	8,000 BTU/lb
2) Specific Gravity	1.06
3) Viscosity	1.3 cP

Nerve Agent Surrrogate

A. Composition

1) 1,1,1-trichloroethane	18 wt%
2) Carbon tetrachloride	17 wt%
3) DMMP	30 wt%
4) No. 2 fuel oil	35 wt%

B. Properties

1) Heat of combustion	10,000 BTU/lb
2) Specific gravity	1.1
3) Weight Percent Phosphorus	7.5
4) Viscosity	1.4 cP

M55 Rocket Surrogate

1) 33 wt% of propellant containing nitroglycerin similar to the M28 propellant contained in the M55 rocket.
2) 1 wt% of nerve agent surrogate.
3) 45 wt% of metal
4) 21 wt% of fiberglass pipe to simulate the shipping and firing tube (A portion of the fiberglass will be mixed with the nerve agent surrogate.)

DUN Surrogate Feed

Charcoal	80 wt%
Agent Surrogate (both nerve agent and blister agent)	20 wt%

stipulated in the CAMDS FEIS(20).

(6) Opacity. State opacity standards are listed in Table 6-10. Opacity is a visual measure of particulate emissions. The greater the particulate loading, the darker (or more opaque) the exhaust. The steam plume which is normally present in furnace/incinerator exhaust gases is not included in the opacity measurement. Although several States have separate particulate and opacity standards, opacity will normally be less than 20% if the RCRA particulate emission criteria is met.

(d) Solid Residue Disposal. The data requirements for solid residue disposal are to determine if the residues meet the definition of a characteristic waste. If the solid residues generated by the furnaces/incinerators and their pollution abatement systems do not exhibit any of the four characteristics then they do not have to be placed in a RCRA approved landfill. This applies only to the States where the chemical agents are classified as characteristic wastes. In those states where agent is a listed waste, these data could serve as the basis for a delisting petition. In addition to the data requirements described below, all solid waste must prove to be agent free before being released for disposal. The brine is checked before it is dried into a salt.

(1) Reactivity Characteristic. Because both the agents and the energetics are considered reactive, it is necessary to determine if the solid residues exhibit this characteristic. A solid residue is classified as a reactive hazardous waste if a representative sample exhibits any of the characteristics listed in Table 6-11. With respect to the solid residues generated from the incineration of chemical agent or munitions, only characteristics five and six are of concern. During the test burns, all solid residues will be tested to see if they have this characteristic.

(2) EP Toxicity Characteristic. The EP Toxicity characteristic is intended to identify solid wastes which pose a hazard due to their potential to leach significant concentrations of any of the eight metals, four pesticides or two herbicides listed in Table 6-12. The purpose of this test is to determine

TABLE 6-10: STATE INCINERATOR OPACITY STANDARDS(1)

LIMIT	STATE	REGULATION/REQUIREMENT(2)
0%	Maryland	COMAR 10.18.08
20%	Utah Colorado	CAMDS FEIS CAQCC Reg 1: III.A.1
o 20% over 6 minutes o 40% over one 6 minute period during any 60 minute period.	Alabama	AAPCRR 4.1.1
o 40% over 6 minutes o 60% over 60 cumulative readings in a 6 hour period.	Indiana	325 IAC 5-2(a)(1)

NOTES:

(1) Does not include water vapor or steam.
(2) State regulation citations obtained from reference 4.

TABLE 6-11: CHARACTERISTICS OF A REACTIVE HAZARDOUS WASTE

1. It is normally unstable and readily undergoes violent change without detonation.

2. It reacts violently with water.

3. It forms potentially explosive mixtures with water.

4. When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or to the environment.

5. It is a cyanide- or sulfide-bearing waste that, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or to the environment. This is defined as 250 mg of hydrogen cyanide or 500 mg of sulfide per kilogram of waste.

6. It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.

7. It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

8. It is a forbidden explosive, as defined in 49 CFR 173.51, or a Class A explosive, as defined in 49 CFR 173.53, or a Class B explosive, as defined in 49 CFR 173.88.

9. A solid waste that exhibits the characteristic of reactivity, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number of D003.

TABLE 6-12: EP TOXICITY CHARACTERISTIC CONTAMINANTS AND REGULATORY LEVELS

EPA Hazardous Waste Number		Contaminant	Maximum Concentration (mg/l)
D004		Arsenic	5.0
D005		Barium	100.0
D006		Cadmium	1.0
D007		Chromium	5.0
D008		Lead	5.0
D009		Mercury	0.2
D0010		Selenium	1.0
D0011		Silver	5.0
D0012	(1)	Endrin	0.02
D0013	(1)	Lindane	0.4
D0014	(1)	Methoxychlor	10.0
D0015	(1)	Toxaphene	0.5
D0016	(2)	2,4-D	10.0
D0017	(2)	2,4,5-TP(Silvex)	1.0

Notes: (1) Pesticide
(2) Herbicide

if an unacceptably high level of ground water contamination might result from improper waste management. The EP Toxicity limits are the National Interim Primary Drinking Water Standards multiplied by a generic dilution/alternative factor of 100. During the test burns the solid residues will be analyzed to determine if they are EP Toxic due to the presence of one of the eight metals listed in Table 6-11. During the previous CAMDS incineration tests, some of the DFS residues and/or pollution abatement system brines were found to contain cadmium and/or lead above the EP Toxicity limits.

c. JACADS Ocean Dumping Permit Data Requirements. At the present time, the Army is evaluating the disposal of the JACADS furnace residues and pollution abatement system brines by ocean dumping in lieu of drying the brine to a salt and shipping the residues and salts to the U.S. for placement in an approved landfill. A draft Supplemental Environmental Impact Statement on this procedure is due out in the near future. In addition to the data requirements identified in Section 6.3.2.b., the data listed in Table 6-13 will be collected on the brines and residues in accordance with the Marine Protection, Research and Sanctuaries Act(23).

6.3.3. Environmental Concerns Data Requirements.

a. Products of Incomplete Combustion.

(1) Although hazardous waste incinerators must achieve a 99.99% DRE for the POHC, there is a potential that low levels of PICs might still be emitted. This was a concern raised in several of the public scoping meetings held in support of the CSDP PEIS. In this context, PICs are compounds which are present in the exhaust gases which would be considered POHCs if present in the feed (e.g., RCRA Appendix VIII compounds with a feed concentration greater than or equal to 100 mg/liter). PIC emissions are not currently regulated, however, in 1981, EPA proposed to restrict the mass emission of "hazardous combustion by-products" (Appendix VIII compounds) to not more than 0.01% of the total mass feed rate of POHCs fed to the incinerator(24). In other words, the mass emission of PICs could not exceed the mass emission rate of the POHCs at a 99.99% DRE.

TABLE 6-13: JACADS OCEAN DUMPING PERMIT DATA REQUIREMENTS (BRINE AND FURNACE RESIDUE ANALYSIS)

Data Requirement	Brine	Residues
o Phase Determination (Total Solids/Total Dissovled solids)	X	NA
o Bioassay, acute and chronic effects	X	X
o pH	X	NA
o Chemical Oxygen Demand	X	X
o Biological Oxygen Demand	X	X
o Carcinogens Mutagens and Teratogens	X	X
o Organohalogens	X	NA
o Mercury and Cadmuim, Total Metal	X	X
o Other Criteria Pollutants	X	X

(2) To date the proposed regulation has not gone beyond the proposal state. This is primarily due to the fact that the mechanism for PIC formation is not understood very well. EPA has conducted several studies in an attempt to quantify PIC emissions and to determine the mechanism for PIC formation(25-29). In general PICs were found to be influenced by the POHC incinerated. Instead of a single formation mechanism, researchers have identified six contributing mechanisms which can result in "PICs" in the exhaust gases:

(a) Failure of the combustion process to completely incinerate the POHCs to CO_2 and water.

(b) Complex recombination or substitution reactions in the exhaust gases.

(c) Auxiliary fuel (fuel oil, natural gases, etc), combustion by-products.

(d) Incomplete combustion of low concentration Appendix VIII compounds contained in the waste feed or auxiliary fuel.

(e) Stripping of volatile compounds from the PAS scrubber water/brine (quench tower, venturi or packed bed scrubber).

(f) Compounds contained in the infiltration air.

(3) Of the four incineration systems used at CAMDS and the proposed CSDP disposal facilities, M55 rocket incineration in the DFS is the most likely candidate to experience PIC emissions from agent/munition incineration. This is because of the complex matrix of propellant, explosives, residual agent, and fiberglass resin which is fed to the rotary kiln. The completed DFS and LIC tests appear to support this assessment. Very low levels of chlorinated PICs (two to three orders of magnitude lower than the EPA proposed limit) were detected during the March 1986 DFS test burn (Section 4.3.2.d.(4)), but no PICs were detected during the August 1986 GB incineration test in the LIC (Section

4.3.4.c(4)).

(4) During the future test burns the stack gases from each incineration/pollution abatement system will continue to be analyzed for the presence of PICs. The precise method by which the data will be used to evaluate or modify the incinerator or furnace performance is not known at this time since, as stated earlier, the relationship between PIC formation and incinerator operating parameters is not understood very well. However, at the conclusion of the CAMDS tests, a firm data base addressing this issue will be available.

b. Metal Emissions.

(1) Another source of public concerns about hazardous waste incineration is the emission of heavy metals such as arsenic, chromium or lead from the incinerator. Incineration will change the form of the heavy metals (from organometallic compounds to metal oxides) but does not reduce the content of metals in the hazardous waste. Therefore the primary method of controlling metal emissions is the pollution abatement systems.

(2) Metal emissions from the CAMDS or CSDP incineration systems are not anticipated to be a problem. As shown in Appendix B, the only agent which contains heavy metals above trace contamination levels is Lewisite; the explosives and propellant do contain lead compounds but in very small concentrations. In any event, the venturi and demister elements in the pollution abatement systems should be sufficient to remove most metal oxides formed during chemical agent/munition incineration.

(3) During a meeting between Army officials and state and federal RCRA permit writers in September 1986, the Army agreed to expand the proposed CAMDS test burns to include analysis of the exhaust gases for metals (Table 6-14).

c. Toxicity Characteristic Leaching Procedure.(3)

(1) In June 1986, EPA proposed to amend the RCRA Extraction Procedure

TABLE 6-14: RCRA APPENDIX VIII METALS

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Thallium

Toxicity Characteristic (40 CFR 261.24) by:

(a) Expanding the characteristic to include 38 additional compounds (Table 6-15).

(b) Applying compound specific dilution attenuation factors generated from a ground water transport model.

(c) Replacing the EP Toxicity Leaching procedure with the TCLP, which has been developed to address the mobility of both organic and inorganic compound and to solve the operational problems of the EP protocol.

(2) EPA proposes to use the TCLP for its Land Disposal Restrictions Program. Under this program, wastes to be placed in a landfill must be treated unless and until the concentrations of the hazardous constituent in the waste extract of the TCLP does not exceed regulatory limits . Included in the list of land-disposal constituents are TCDF and PeCDF, both of which were detected in the cyclone residue from the March 1986 Test Burn (Section 4.3.2.d.(3)). However, TCLP was not used in the March test, therefore, it is uncertain if the residue would require further treatment.

(3) Although the proposed amendments to the EP Toxicity Characteristic have not gone beyond the proposal state, the TCLP in conjunction with the Land Disposal Restrictions Program could have a significant impact on disposal of the furnace/incineration residues and salts formed by drying the scrubber brines. If additional treatment of these incinerator residues is required before placement in an approved landfill, the cost for the chemical stockpile disposal could increase significantly. For these reasons, the residues from the test burns will be analyzed by both leaching procedures.

6.4.0. Test Burn Procedures.

a. Table 6-16 summarizes the CSDP environmental data requirements for the CAMDS test burns. Although not listed, the data required to support the JACADS Ocean Dumping Permit study will also be obtained during the test burns.

TABLE 6-15: Proposed Toxicity Characteristic Contaminants and Regulatory Levels

HWNO and Contaminant	CASNO	Regulatory level (mg/l)
D018 - Acrylonitrile	107-13-1	5.00
D004 - Arsenic	7440-38-2	5.00
D005 - Barium	7440-39-3	100.00
D019 - Benzene	71-43-2	0.07
D020 - Bis(2-chloroethyl) ether	111-44-4	0.05
D006 - Cadmium	7440-43-9	1.00
D021 - Carbon Disulfide	75-15-0	14.40
D022 - Carbon Tetrachloride	56-23-5	0.07
D023 - Chlordane	57-74-9	0.03
D024 - Chlorobenzene	108-90-7	1.40
D025 - Chloroform	67-66-3	0.07
D007 - Chromium	1333-62-0	5.00
D026 - o-Cresol+	95-48-7	10.00
D027 - m-Cresol+	108-39-4	10.00
D028 - p-Cresol+	106-44-5	10.00
D016 - 2,4-D	94-75-7	1.40
D029 - 1,2-Dichlorobenzene	95-50-1	4.30
D030 - 1,4-Dichlorobenzene	106-46-7	10.80
D031 - 1,2-Dichloroethane	107-06-2	0.40
D032 - 1,1-Dichloroethylene	75-35-4	0.10
D033 - 2,4-Dinitrotoluene	121-14-2	0.13
D012 - Endrin	72-20-8	0.003
D034 - Heptachlor (and its hydroxide)	76-44-8	0.001
D035 - Hexachlorobenzene	118-74-1	0.13
D036 - Hexachlorobutadiene	87-68-3	0.72
D037 - Hexachloroethane	67-72-1	4.30
D038 - Isobutanol	78-83-1	36.00
D008 - Lead	7439-92-1	5.00
D013 - Lindane	58-89-9	0.06
D009 - Mercury	7439-97-5	0.20
D014 - Methoxychlor	72-43-5	1.40
D039 - Methylene Chloride	75-09-2	8.60
D040 - Methyl Ethyl Ketone	78-93-3	7.20
D041 - Nitrobenzene	98-95-3	0.13
D042 - Pentachlorophenol	87-86-5	3.60
D043 - Phenol	108-95-2	14.40
D044 - Pyridine	110-86-1	5.00
D010 - Selenium	7782-49-2	1.00
D011 - Silver	7440-22-4	5.00
D045 - 1,1,1,2-Tetrachloroethane	630-20-6	10.00
D046 - 1,1,2,2-Tetrachloroethane	79-34-5	1.30
D047 - Tetrachloroethylene	127-18-4	0.10
D048 - 2,3,4,6-Tetrachlorophenol	58-90-2	1.50
D049 - Toluene	108-88-3	14.40
D015 - Toxaphene	8001-35-2	0.07
D050 - 1,1,1-Trichloroethane	71-55-6	30.00
D051 - 1,1,2-Trichloroethane	79-00-5	1.20
D052 - Trichloroethylene	79-01-6	0.07
D053 - 2,4,5-Trichlorophenol	95-95-4	5.80
D054 - 2,4,6-Trichlorophenol	88-06-2	0.30
D017 - 2,4,5-TP (Silvex)	93-76-5	0.14
D055 - Vinyl Chloride	75-01-4	0.05

+ o-, m-, and p-Cresol concentrations are added together and compared to a threshold of 10.00 mg/l.

TABLE 6-16: SUMMARY OF CSDP ENVIRONMENTAL DATA REQUIREMENTS

Furnace Exhaust Gases

- Agent concentration/DRE
- Nitroglycerin concentration/DRE (1)
- Particulate Concentration
- HCl
- Opacity
- RCRA Appendix VIII Metals
- PIC
- PCDD and PCDF

Furnace Residues and PAS Brines (2) and Salts

- Agent
- Nitroglycerin (1)
- EP Toxic Metals
- Reactivity
- TCLP Toxicity
- PCDD and PCDF

Notes (1) Only during M55 rocket incineration in the DFS.

(2) PAS brines will be analyzed in addition to the dried salts to determine what effect, if any, the drying operation has on the composition of the salt.

Process data related to temperature, processes, auxiliary fuel, combustion air, and pollution abatement system liquid flow rate, and problems encountered will also be recorded. In addition, material balances around the furnace/incinerator and pollution abatement system will be performed to verify the accuracy of the data measurements and to determine the amount of infiltration air that entered the system.

b. Because of the amount of data to be collected, a complex array of sampling and analysis procedures is required. To help the reader understand the scope and complexity of the test burns, Figures 6-1 through 6-4 and Tables 6-17 through 6-20 have been prepared for the LIC, DFS, MPF, and DUN. The Figures illustrate the location of the sampling points which will be used during the test burns; the Tables are keyed to the Figures and list the sampling points, the parameters sampled/measured, the data to be collected, and the sampling and analysis procedures to be used. The Tables and Figures are for illustrative purposes only, as the data requirements, as well as the sampling and analysis procedures are subject to change based on the requirements of the CSDP. For example, during the test burns involving chemical agent surrogates, only the data to demonstrate RCRA compliance (surrogate DRE, and HCl and particulate emissions), will be collected.

c. With the exception of agent sampling and analysis, and the brine and nitroglycerin analytical procedures, EPA approved sampling and analysis procedures will be used during the test burns. EPA sampling methods are described in references 30-32. Sampling and analysis procedures listed as "EPA Method X" are contained in reference 32. Analysis methods which are preceded by "SW 846" are contained in reference 30, and analytical procedures listed as "Standard Method XXXX" are contained in reference 33. Methods developed by the Army for agent sampling and analysis, and brine and nitroglycerin analyses are contained in references 34-36 respectively.

d. Each test burn will consist of at least one baseline or background trial and three trials where the chemical agents and/or munitions are processed at the desired feed rate. The purpose of the baseline trial is twofold - (1)

to verify that the furnace/incinerator and pollution abatement system, as well as all sampling equipment are operating properly, and (2) to determine the contribution of the auxiliary fuel, infiltration air, and process liquids on the environmental data. Three trials at the desired agent/munition feed rate are required to ensure reproducibility of the data, i.e., that the data collected is an accurate representation of the furnace/incinerator and pollution abatement system performance. Each trial will last approximately four hours to provide for sufficient time for data and sample collection. EPA approved QA/QC procedures for sampling, handling, and analyses will be used during the test burn to ensure the validity of the data. After completion of the test burns, the samples collected will be sent to the contractors laboratory for analysis. The preliminary test results should be available approximately ten weeks after receipt of the samples.

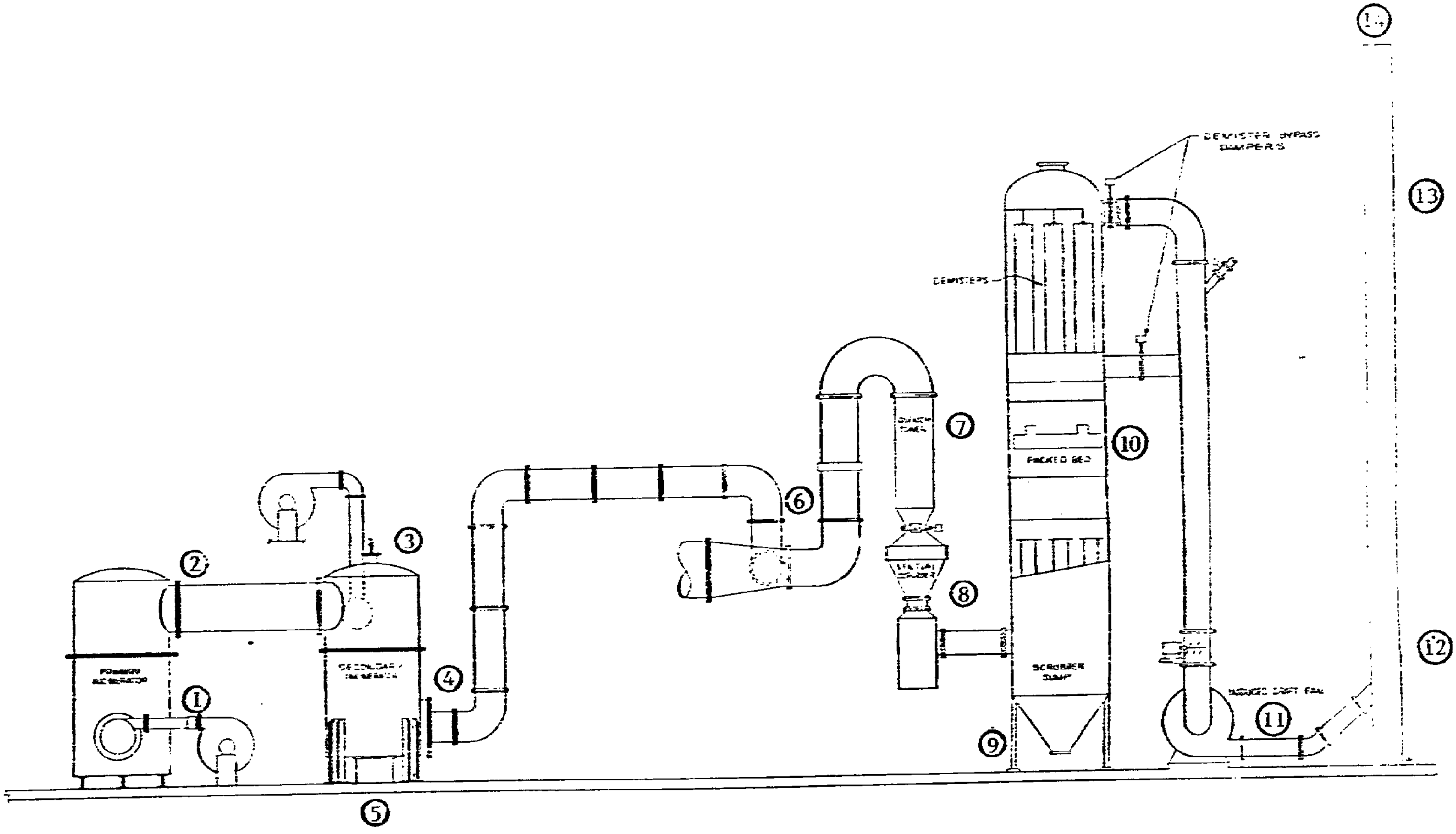

Figure 6-1: LIC Test Burn Sampling Points

TABLE 6-17. LIC TEST BURN SAMPLING AND ANALYSIS PROCEDURES

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
1	Primary Incinerator Burner	Chemical Agent	Flow Rate	Flowmeter	
			Purity	Tap and Line	(2)
			Metals	Tap and Line	Table 6-21
		Propane (1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
2	Primary Incinerator	Exhaust Gases	Temperature	Type K Thermocouple	
3	Secondary Incinerator Burner	Propane (1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
		Spent Decontamination Solution	Flow Rate	Flowmeter	
			pH	Tap and Line	SW 846 Method 9040
			Metals	" " "	Table 6-21
			Agent	" " "	(2)
			Organics	" " "	SW 846 Methods 8740, 8270
		or	TSS	" " "	Standard Method 208D
			TDS	" " "	Standard Method 208C
		Quench Water (1)	Flow Rate	Flowmeter	
			Metals	Tap and Line	Table 6-21
			Organics	Tap and Line	SW 846 Methods 8240, 8270
4	Secondary Incinerator	Exhaust Gases	Temperature	Type K Thermocouple	

TABLE 6-17. LIC TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
5	Salt Discharge	Propane	Temperature	Type K Thermocouple	
			Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
		Makeup Water	Flow Rate	Flowmeter	
			Metals	Tap and Line	Table 6-21
			Organics	Tap and Line	SW 846 Methods 8240, 8270
		Salt (3)	Quantity	Thief or Auger	Weigh Scale
			EP Toxicity	" " "	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jan 86
			Agent	" " "	(2)
			Composition		
		Brine (3)	Quantity	Level Gauge	
			pH	Weighted Bottle	SW 846 Method 9040
			EP Toxicity	" "	SW 846 Method 1310
			TCLP	" "	51 FR 21646, 13 Jun 86
			Reactivity (HCN,H_2S)	" "	SW 846 Para 7.3.3 & 7.3.4
			Agent	" "	(2)
			TSS	" "	Standard Method 208D
			TDS	" "	Standard Method 208C
			TOC	" "	Standard Method 5060
			Salts	" "	(2)

TABLE 6-17. LIC TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
6	Secondary Incinerator	Exhaust Gases	Temperature	Type K Thermocouple	
			Flow Rate	EPA Method 2	
			Pressure	Type S Pitot Tube/ Manometer	
			Moisture	EPA Method 4	
			CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Phosphorus	EPA Method 5	Standard Method 365.3
			Chloride	EPA Method 5	Standard Method 300.0
			Fluoride	EPA Method 13	Standard Method 300.0
7	Quench	Exhaust Gases	Temperature	Type K Thermocouple	
		Quench Water (1)	Flow Rate	Flowmeter	
			Organics	Tap & Line	SW 846 Methods 8240, 8270
			Metals	Tap & Line	Table 6-21
8	Venturi	Throat	Pressure	Differential Pressure Cell	
		Scrubber Liquor	Flow Rate	Flowmeter	
			pH	Tap & Line	SW 846 Method 9040
			Organics	Tap & Line	SW 846 Methods 8240, 8270
9	Scrubber Sump	Brine (3)	Quantity	Level Gauge	
			pH	Tap & Line	SW 846 Method 9040
			EP Toxicity	" " "	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity (HCN,H_2S)	" " "	SW 846 Para 7.3.3 & 7.3.4
			Agent	" " "	(2)
			TSS	" " "	Standard Method 208D
			TDS	" " "	Standard Method 208C
			TOC	" " "	SW 846 Method 9060
			Sodium Salts	" " "	(2)

TABLE 6-17. LIC TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
10	Scrubber Tower	Packed Bed	Pressure Drop	Magnahelic	
		Clear Liquor and Makeup Water (1)	Flow Rate	Rotometer	
			pH	Tap & Line	SW 846 Method 9040
			VOC	" " "	SW 846 Method 8240
		Demisters	Pressure Drop	Magnahelic	
11	ID Fan		Draft	Amperage	Calibration Curve
12	Stack	Exhaust Gases	CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Agent	(2)	(2)
			Volatile PICs	EPA VOST	SW 846 Method 8240
13	Stack	Exhaust Gases	Flow Rate	EPA Method 2	
			Temperature	Type K Thermocouple	
			Static Pressure	Magnehelic	
			Velocity Pressure	Type S Pitot Tube/ Manometer	
			Particulate	EPA Method 5	
			- Mass		EPA Method 5
			- Metals		Table 6-21
			- % Phosphorus		Standard Method 365.3
			- Size Distribution	Cascade Impacter	Gravimetric
			HF (GB Only)	EPA Method 5	Standard Method 300.0
			HCl	EPA Method 5	Standard Method 300.0
			Semivolatile PICs	EPA Modified Method 5	SW 846 Method 8270
			CO_2, O_2	EPA Method 3	
			CO	EPA Method 10	
			Moisture	EPA Method 4	

TABLE 6-17. LIC TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
14	Stack	Exhaust Gases	Opacity	EPA Method 9	

NOTES:
(1) Process water and Propane will be sampled at source.
(2) Method developed by the Army; see references 34, 35 and 36.
(3) Does not include JACADS Ocean Dumping Permit Data Requirements (Table 6-13).

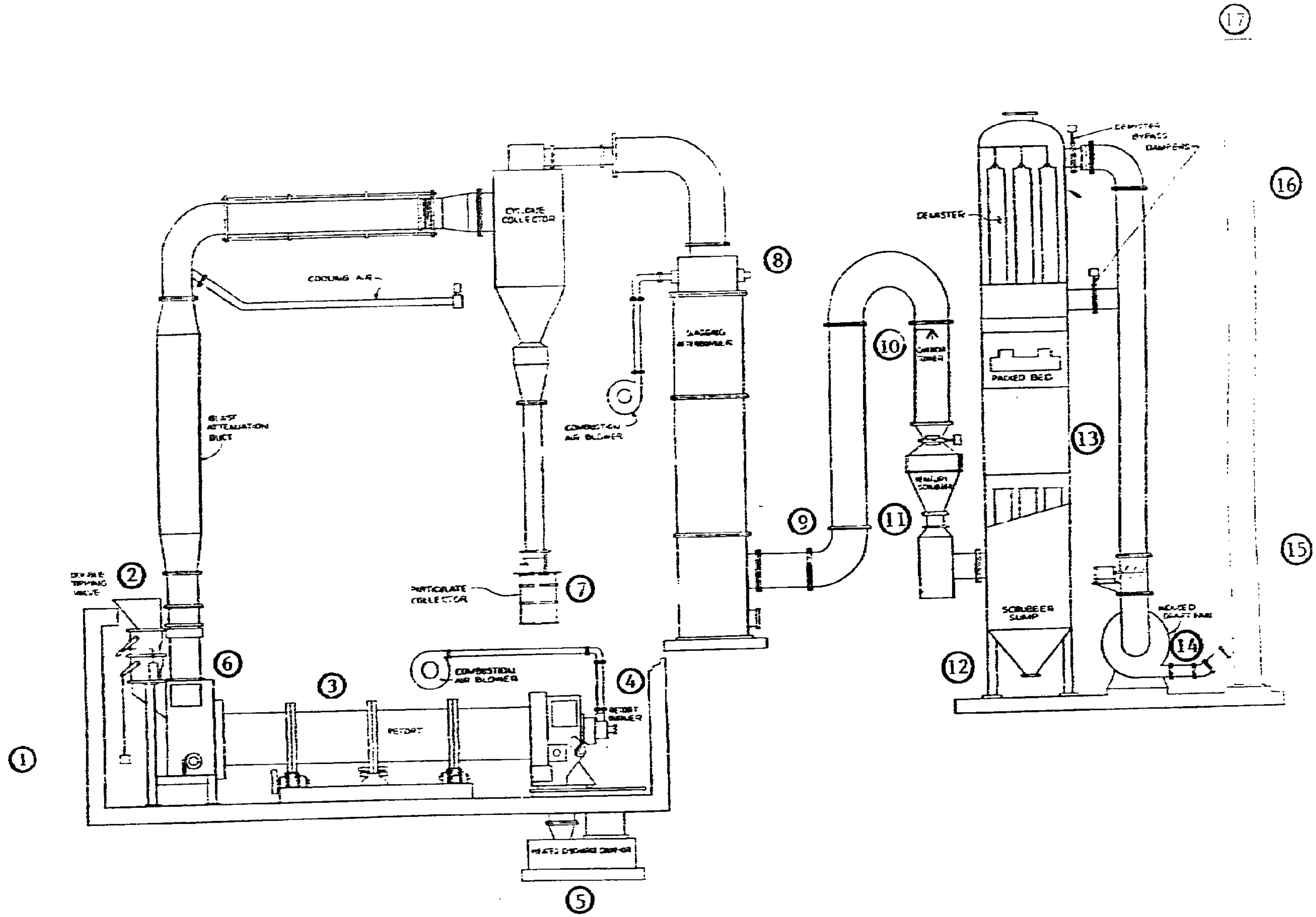

Figure 6-2: DFS Test Burn Sampling Points

TABLE 6-18. DFS TEST BURN SAMPLING AND ANALYSIS PROCEDURES

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
1	Unpack Area	Munitions	Feed Rate	Visual Observation	
2	DTV	Munitions	Feed Rate	CCTV, Visual Observation	
		Quench Water (1)	Flow Rate	Flowmeter	
			Metals	Tap & Line	Table 6-21
			Organics	Tap & Line	SW 846 Methods 8240, 8270
3	Retort		Skin Temperature	Type K Thermocouple	
			Static Pressure	Magnahelic	
4	Retort Burner	Propane(1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
5	HDC	Ash/Residue (3)	Total Mass	Weigh Scale	
			EP Toxicity (Metals)	Thief or Auger	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity	" " "	
			- (HCN, H_2S)	" " "	SW 846, Para 7.3.3 & 7.3.4
			- Shock Sensitivity	" " "	Bureau of Mines Impact Test
			Agent	" " "	(2)
			Nitroglycerin (M55 Rocket Incineration Only)	" " "	(2)
			PICs	" " "	SW 846, Method 8270
			PCDD, PCDF (M55 Rockets Only)	" " "	SW 846, Method 8280
			Temperature	Type K Thermocouple	

TABLE 6-18. DFS TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
6	Feed Housing	Exhaust Gases	Temperature	Type K Thermocouple	
			Flow Rate	EPA Method 2	
			Pressure	Type S Pitot Tube/ Manometer	
		Quench Water (1)	Flow Rate	Flowmeter	
			Metals	Tap & Line	Table 6-21
			Organics	Tap & Line	SW 846 Methods 8240, 8270
7	Cyclone Discharge	Residue (3)	Total Mass	Weigh Scale	—
			EP Toxicity (Metals Only)	Thief or Auger	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity	" " "	
			– (HCN, H_2S)	" " "	SW 846, Para 7.3.3 & 7.3.4
			– Shock Sensitivity	" " "	Bureau of Mines Impact Test
			Agent	" " "	(2)
			Nitroglycerin (M55 Rockets Only)	" " "	(2)
			PCDD, PCDF (M55 Rockets Only)	" " "	SW 846, Method 8280
8	Afterburner	Propane(1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Place	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
9	Afterburner Exhaust	Exhaust Gases	Temperature	Type K Thermocouple	
			Flow Rate	EPA Method 2	
			Pressure	Type S Pitot Tube/ Manometer	
			Moisture	EPA Method 4	
			CO, CO_2, O_2, SO_x, NO_x	CEMS	

TABLE 6-18. DFS TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
			Phosphorus	EPA Method 5	Standard Method 365.3
			Chloride	EPA Method 5	Standard Method 300.0
			Fluoride	EPA Method 13	Standard Method 300.0
10	Quench	Exhaust Gases	Temperature	Type K Thermocouple	
		Quench Water (1)	Flow Rate	Rotometer	
			Organics	Tap & Line	SW 846 Methods 8240, 8270
11	Venturi	Throat	Pressure	Differential Pressure Cell	
		Scrubber Liquor	Flow Rate	Rotometer	
			pH	Tap & Line	SW 846 Method 9040
			VOC	Tap & Line	SW 846 Method 8240
12	Scrubber Sump	Brine (3)	Quantity	Level Gauge	
			pH	Tap & Line	SW 846 Method 9040
			EP Toxicity	" " "	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity	" " "	
			- (HCN, H_2S)	" " "	SW 846, Para 7.3.3 & 7.3.4
			- Shock Sensitivity	" " "	Bureau of Mines Impact Test
			Agent	" " "	(2)
			Nitroglycerine (M55 Rockets Only)	" " "	(2)
			PCDD, PCDF (M55 (M55 Rockets Only)	" " "	SW 846 Methods 8280
			TSS	" " "	Standard Method 208D
			TDS	" " "	Standard Method 208C
			TOC	" " "	SW 846 Method 9060
			Sodium Salts		(2)
13	Scrubber Tower	Packed Bed	Pressure Drop	Magnahelic	
		Clear Liquor and Makeup Water (1)	Flow Rate	Rotometer	
			pH	Tap & Line	SW 846 Method 9040
			Organics	" " "	SW 846 Method 8240, 8270

TABLE 6-18. DFS TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
		Demisters	Pressure Drop	Magnahelic	
14	ID Fan		Draft	Amperage	Calibration Curve
15	Stack	Exhaust Gases	CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Agent	(2)	(2)
			Volatile PICs	EPA VOST	SW 846 Method 8240
16	Stack	Exhaust Gases	Flow Rate	EPA Method 2	
			Temperature	Type K Thermocouple	
			Static Pressure	Magnehelic	
			Velocity Pressure	Type S Pitot Tube/ Manometer	
			Particulate	EPA Method 5	
			- Mass		EPA Method 5
			- Metals		Table 6-17
			- % Phosphorus		Standard Method 365.3
			- Size Distribution	Cascade Impacter	Gravimetric
			HF (GB Only)	EPA Method 13	Standard Method 300.0
			HCl	EPA Method 5	Standard Method 300.0
			Semivolatile PICs	EPA Modified Method 5	SW 846 Method 8270
			CO_2, O_2	EPA Method 3	
			CO	EPA Method 10	
			Moisture	EPA Method 4	
17	Stack	Exhaust Gases	Opacity	EPA Method 9	

NOTES:
(1) Process water and Propane will be sampled at source.
(2) Methods developed by the Army see reference 34, 35 and 36.
(3) Does not include JACADS Ocean Dumping Permit Data Requirements (Table 6-13).

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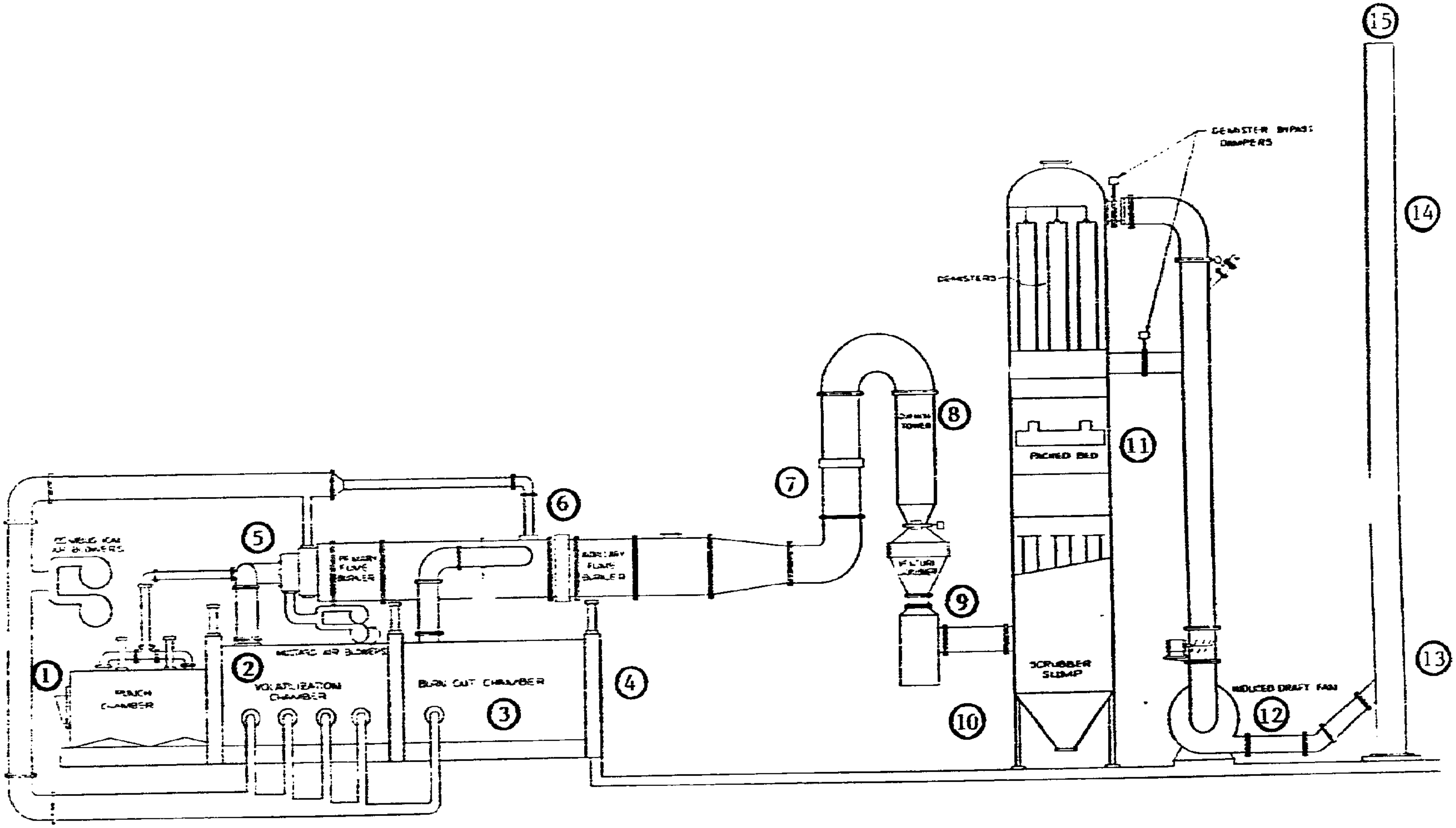

Figure 6-3: MPF Test Burn Sampling Points

TABLE 6-19. MPF TEST BURN SAMPLING AND ANALYSIS PROCEDURES

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
1	Charge Car	Munitions	Feed Rate	CCTV, Visual Observation	
2	Volatilization Chamber	Munitions	Temperature	Type K Thermocouple	
		Chamber	Temperature	Type K Thermocouple	
		Propane (1)	Flow Rate VOC	Flowmeter Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate Temperature Pressure	Orifice Plate Type K Thermocouple Photohelic	
3	Burnout Chamber	Munitions	Temperature	Type K Thermocouple	
		Chamber	Temperature	Type K Thermocouple	
		Propane (1)	Flow Rate VOC	Flowmeter Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate Temperature Pressure	Orifice Plate Type K Thermocouple Photohelic	
4	Discharge/ Unload Area	Ash/Residue (3)	Total Mass EP Toxicity (Metals) TCLP Reactivity (HCN,H_2S) Agent	Weigh Scale Scoop or Shovel " " " " " " " " "	SW 846 Method 1310 51 FR 21648, 13 Jun 86 SW 846, Para 7.3.3 & 7.3.4 (2)

TABLE 6-19. MPF TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
5	Primary Fume Burner	Exhaust Gases	Temperature	Type K Thermocouple	
		Propane (1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
6	Auxiliary Fume Burner	Exhaust Gases	Temperature	Type K Thermocouple	
		Propane (1)	Flow Rate	Flowmeter	
			Organics	Gas Bulb/Bag	GC/MS (Direct Injection)
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
7	Afterburner Exhaust	Exhaust Gases	Temperature	Type K Thermocouple	
			Flow Rate	EPA Method 2	
			Pressure	Type S Pitot Tube/ Manometer	
			Moisture	EPA Method 4	
			CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Phosphorous	EPA Method 5	Standard Method 365.3
			HCl	EPA Method 5	Standard Method 300.0
			HF (GB Only)	EPA Method 13	Standard Method 300.0
8	Quench	Exhaust Gases	Temperature	Type K Thermocouple	
		Quench Water (1)	Flow Rate	Flowmeter	
			Organics	Tap & Line	SW 846 Methods 8240,8270
			Metals	Tap & Line	Table 6-21

TABLE 6-19. MPF TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
9	Venturi	Throat	Pressure	Differential Pressure Cell	
		Scrubber Liquor	Flow Rate	Flowmeter	
			pH	Tap & Line	SW 846 Method 9040
			VOC	Tap & Line	SW 846 Method 8240
10	Scrubber Sump	Brine (3)	Quantity	Level Gauge	
			pH	Tap & Line	SW 846 Method 9040
			EP Toxicity	" " "	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity (HCN, H_2S)	" " "	SW 846, Para 7.3.3 & 7.3.4
			Agent	" " "	(2)
			TSS	" " "	Standard Method 208D
			TDS	" " "	Standard Method 208C
			TOC	" " "	SW 846 Method 9060
			Sodium Salts	" " "	(2)
11	Scrubber Tower	Packed Bed	Pressure Drop	Magnahelic	
		Clear Liquor and Makeup Water (1)	Flow Rate	Flowmeter	
			pH	Tap & Line	SW 846 Method 9040
			Organics	" " "	SW 846 Methods 8240, 8270
		Demisters	Pressure Drop	Magnahelic	
12	ID Fan		Draft	Amperage	Calibration Curve

TABLE 6-19. MFF TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
13	Stack	Exhaust Gases	CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Agent	(2)	(2)
			Volatile PICs	EPA VOST	SW 846 Method 8240
14	Stack	Exhaust Gases	Flow Rate	EPA Method 2	
			Temperature	Type K Thermocouple	
			Static Pressure	Magnehelic	
			Velocity Pressure	Type S Pitot Tube/ Manometer	
			Particulate	EPA Method 5	
			- Mass		EPA Method 5
			- Metals		Table 6-21
			- % Phosphorus		Standard Method 365.3
			- Size Distribution	Cascade Impacter	Gravimetric
			HF (GB Only)	EPA Method 13	Standard Method 300.0
			HCl	EPA Method 5	Standard Method 300.0
			Semivolatile PICs	EPA Modified Method 5	SW 846 Method 8270
			CO_2, O_2	EPA Method 3	
			CO	EPA Method 10	
			Moisture	EPA Method 4	
15	Stack	Exhaust Gases	Opacity	EPA Method 9	

NOTES:
(1) Process water and Propane will be sampled at source.
(2) Methods developed by the Army; see references 33, 34 and 35.
(3) Does not include JACADS Ocean Dumping Permit Data Requirements (Table 6-13).

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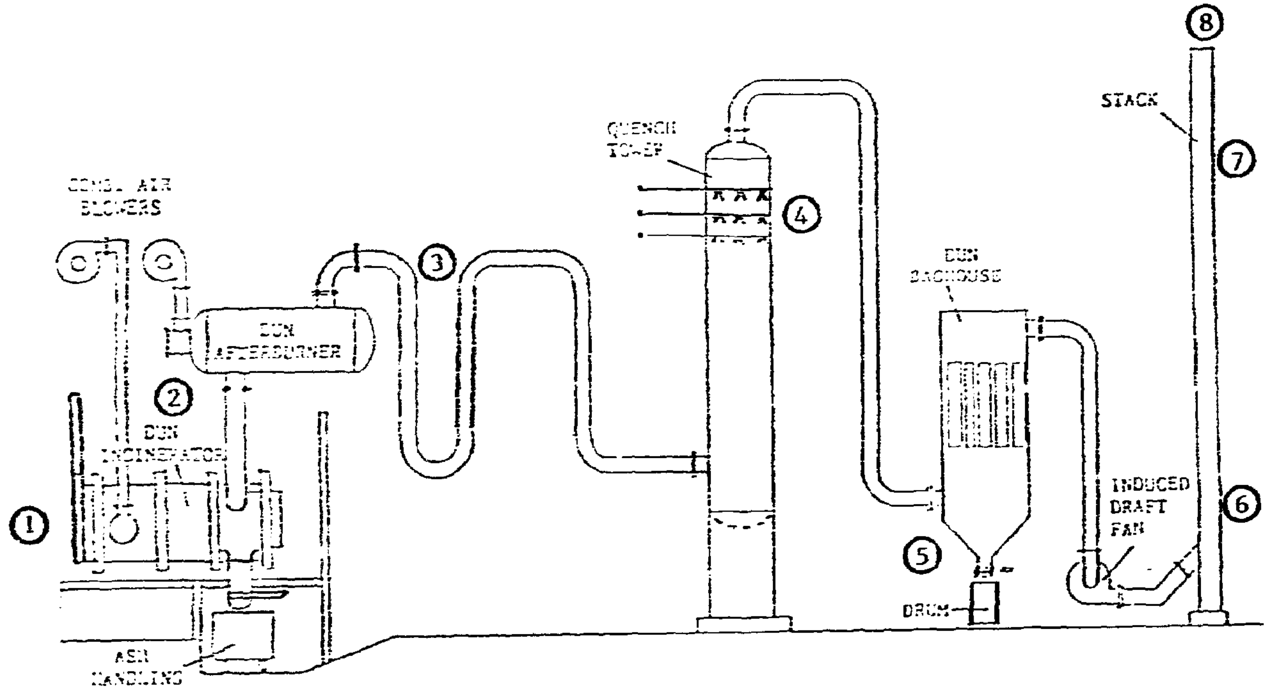

Figure 6-4: DUN Test Burn Sampling Points

TABLE 6-20. DUN TEST BURN SAMPLING AND ANALYSIS PROCEDURES

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
1	Charge End	Waste Feed	Composition	Visual Observation	
			Charge Weight	Weight Scale	
2	Incinerator	Exhaust Gases	Temperature	Type K Thermocouple	
		Propane (1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Inject
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
	Afterburner	Propane (1)	Flow Rate	Flowmeter	
			VOC	Gas Bulb/Bag	GC/MS (Direct Inject
		Combustion Air	Flow Rate	Orifice Plate	
			Temperature	Type K Thermocouple	
			Pressure	Photohelic	
3	Afterburner Exhaust	Exhaust Gases	Temperature	Type K Thermocouple	
			Flow Rate	EPA Method 2	
			Pressure	Type S Pitot Tube/ Manometer	
			Moisture	EPA Method 4	
			CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Phosphorous	EPA Method 5	Standard Method 365.3
			HCl	EPA Method 5	Standard Method 300.0
			HF (GB Only)	EPA Method 13	Standard Method 300.0
4	Quench	Exhaust Gases	Temperature	Type K Thermocouple	
		Clear Liquor	Flow Rate	Flowmeter	
			pH	Tap & Line	SW 846 Method 9090
			Metals	" " "	Table 6-21
			Organics	Tap & Line	SW 846 Methods 8240,

TABLE 6-20. DUN TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
5	Baghouse	Exhaust Gases	Temperature	Type K Thermocouple	
			Moisture	EPA Method 4	
			Press Drop	Mognahelic	
		Residue (3)	Total Mass	Weigh Scale	
			EP Toxicity (Metals)	Thief or Auger	SW 846 Method 1310
			TCLP	" " "	51 FR 21648, 13 Jun 86
			Reactivity (HCN, H_2S)	" " "	SW 846, Para 7.3.3 & 7.3
			Agent	" " "	(2)
6	Stack	Exhaust Gases	CO, CO_2, O_2, SO_x, NO_x	CEMS	
			Agent	(2)	(2)
			Volatile PICs	EPA VOST	SW 846 Method 8240
7	Stack	Exhaust Gases	Flow Rate	EPA Method 2	
			Temperature	Type K Thermocouple	
			Static Pressure	Magnehelic	
			Velocity Pressure	Type S Pitot Tube/ Manometer	
			Particulate	EPA Method 5	
			- Mass		EPA Method 5
			- Metals		Table 6-20
			- % Phosphorus		Standard Method 365.3
			- Size Distribution	Cascade impacter	Gravimetric
			HF (GB Only)	EPA Method 13	Standard Method 300.0
			HCl	EPA Method 5	Standard Method 300.0
			Semivolatile PICs	EPA Modified Method 5	SW 846 Method 8270
			CO_2, O_2	EPA Method 3	
			CO	EPA Method 10	
			Moisture	EPA Method 4	

TABLE 6-20. DUN TEST BURN SAMPLING AND ANALYSIS PROCEDURES (Cont'd)

SAMPLE SITE #	SAMPLE LOCATION	PARAMETER	DATA COLLECTED	SAMPLE METHOD/EQUIPMENT	ANALYTICAL METHOD/EQUIPMENT
8	Stack	Exhaust Gases	Opacity	EPA Method 9	

NOTES:
(1) Process water and Propane will be sampled at source.
(2) Methods developed by the Army; see references 34, 35 and 36.
(3) Does not include JACADS Ocean Dumping Permit Data Requirements (Table 6-13).

TABLE 6-21. Analytical Procedures for Metals

Antimony	SW 846 Methods 6010 or 7040
Arsenic	SW 846 Methods 6010 or 7061
Baruim	SW 846 Methods 6010 or 7080
Beryllium	SW 846 Methods 6010 or 7090
Cadmium	SW 846 Methods 6010 or 7130
Chromium	SW 846 Methods 6010 or 7190
Copper	SW 846 Methods 6010 or 7210
Lead	SW 846 Methods 6010 or 7420
Mercury	SW 846 Method 7470 (liquid) Method 7471 (solid)
Nickel	SW 846 Methods 6010 or 7520
Selenium	SW 846 Methods 6010 or 7741
Silver	SW 846 Methods 6010 or 7760
Thallium	SW 846 Methods 6010 or 7840

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APPENDIX A

ABBREVIATIONS, ACRONYMS AND SYMBOLS

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AAPCRR	Alabama Air Pollution Control Rules and Regulations
AC	Hydrogen Cyanide; Blood Agent
ACAMS	Automatic Continuous Air Monitoring System
acfm	Actual Cubic Feet Per Minute
ADS	Agent Destruction System
AEHA	U.S. Army Environmental Hygiene Agency
AFB	Auxiliary Fume Burner
Ag	Silver
Al	Aluminum
AMC	U.S. Army Materiel Command
ANAD	Anniston Army Depot
APE	Ammunition Peculiar Equipment
APG	Aberdeen Proving Ground
As	Arsenic
ASC	Allowable Stack Concentration
As_2O_3	Arsenic Oxide
B	Bombs, Boron
Ba	Barium
BDL	Below Detection Limit
BDS	Bulk Drain Station
Be	Beryllium
BSR	Burster Size Reduction Machine
BSS	Baghouse Scrubber System
BTU	British Thermal Unit
C	Cartridges
^{o}C	Degree Centigrade
$C_2H_2AsCl_3$	L; Dichloro-2-chlorovinylarsine
$C_2H_2Cl_4$	1,1,2,2 Tetrachloroethane
$C_2H_3Cl_3$	1,1,1 Trichloroethane
$C_3H_5N_3O_9$	Nitroglycerine
$C_3H_9O_3P$	O-Ethylmethyl Phosphonic Acid
$C_4H_8Cl_2S$	H/HD; Bis(2-chloroethyl) sulfide
C_4H_8O	Methyl Ethyl Ketone

$C_4H_{10}FO_2P$	GB; Isopropyl Methylphosphonofluoridate
$C_5H_{11}N_2O_2P$	GA; Ethyl N, N-dimethylphosphoramidocyanidate
C_6H_6	Benzene
C_6HCl_5O	Pentachlorophenol
$C_8H_{16}Cl_2OS_2$	T; Bis(2(2 chloroethylthio)ethyl) ether
$C_{11}H_{26}NO_2PS$	VX; O-ethyl S-(2-diisopropylaminoethyl) methylphosophonothiolate
Ca	Calcium
CAA	Clean Air Act
CCTV	Closed Circuit Television
CAIS	Chemical Agent Identification Set
CAMDS	Chemcial Agent Munitions Disposal System
CAQCC	Colorado Air Quality Control Commission Regulations for Emission Controls
CAS No.; CASNO	Chemical Abstracts Service Number
CCl_4	Carbon Tetrachloride
Cd	Cadmium
CDS	Central Decon System
CEMS	Continous Emissions Monitoring System
CG	Phosgene; Choking Agent
CHASE	"Cut Holes and Sink Em"
$CHCl_3$	Chloroform
CK	Cyanogen Chloride; Blood Agent
Cl_2	Chlorine
CN	Cyanide
Co	Cobalt
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COMAR	Code of Maryland Regulations
CONUS	Continental United States
Cr	Chromium
CSDP	Chemical Stockpile Disposal Program
Cu	Copper
D	D-Day, the Start
DAAMS	Depot Area Air Monitoring System

DARCOM	U.S. Army Material Development and Readiness Command
DE	Destruction Efficiency
DFS	Deactivation Furnace System
DHHS	Department of Health and Human Services
DICDI	Diisopropylcarbodiimide
DOD	Department of Defense
DRE	Destruction and Removal Efficiency
dscf	Dry Standard Cubic Foot
DTV	Double Tipping Valve
DUN	Dunnage Incinerator
EATR	Edgewood Arsenal Technical Report
ECC	Explosive Containment Cubicle
ECR	Explosive Containment Room
EP	Extraction Procedure
EPA	U.S. Environmental Protection Agency
ESP	Electrostatic Precipitator
^{0}F	Degree Fahrenheit
Fe	Iron
FEIS	Final Environmental Impact Statement
ft	Foot, Feet
ft/sec	Foot Per Second, Feet Per Second
FR	Federal Register
GA	Tabun; Nerve Agent
GB	Sarin; Nerve Agent
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectrometry
g; gm	Gram
gpm	Gallon Per Minute
gr	Grain
gr/dscf	Grain Per Dry Standard Cubic Foot
H	Levinstein Mustard; Blister Agent
H_2O	Water
H_2S	Hydrogen Sulfide
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HD	Distilled Mustard; Blister Agent
HF	Hydrogen Flouride

Hg	Mercury
HN-1	Nitrogen Mustard
HN-3	Nitrogen Mustard
$HO_3SC_2H_4N(iC_4H_7)_2$	Diisopropyltaurine
HT	Mixture of 60% HD and 40% T, Blister Agent
HWNO	Hazardous Waste Number
HRGC/LRMS	High Resolution Gas Chromatography/Low Resolution Mass Spectometry
IAC	Indiana Air Pollution Control Regulation
ICAP	Inductively Coupled Argon Plasma
in	Inch
IT	International Technology Corporation
JACADS	Johnston Atoll Chemical Agent Disposal System
K	Potassium
l	Liter
L	Lewisite, Blister Agent
LBAD	Lexington Blue-Grass Army Depot
lb	Pound
lb/hr	Pound Per Hour
LIC	Liquid Incinerator
LPG	Liquified Petroleum Gas; Propane
M	Mines
MDM	Multipurpose Demilitarization Machine
MEA	Monoethanolamine
MEK	Methyl Ethyl Ketone
Mg	Magnesium
mg	Milligram
mg/l	Milligram Per Liter
mg/m^3	Milligram Per Cubic Meter
mg/Nm^3	Milligram Per Newton Meter Cubed
MHA	Munitions Holding Area
MIN	Mine Machine
ml	Milliliter
MM5	Modified Method 5
mm	Millimeter
Mn	Manganese
Mo	Molybdenum

MPF	Metal Parts Furnace System
NAAP	Newport Army Ammunition Plant
NAAQS	National Ambient Air Quality Standards
N_2	Nitrogen
Na	Sodium
Na_2CO_3	Sodium Carbonate
$NaHPO_4$	Sodium Phosphate
$NaNO_3$	Sodium Nitrate
$NaO_3SC_2H_4N(iC_3H_7)_2$	Sodium Diisopropyl Taurinate
Na_2SO_3	Sodium Sulfite
Na_2SO_4	Sodium Sulfate
$NaHCO_3$	Sodium Bicarbonate
$NaC_3H_8O_3P$	Sodium O-Ethyl Methyl Phosphanate
NaCl	Sodium Chloride
NaDPT	Sodium Diisopropyl Taurinate
NaEMP	Sodium O-Ethyl Methyl Phosphanate
NaF	Sodium Floride
NaIMPA	Sodium Isopropyl Methylphosphonate
NaOH	Sodium Hydroxide
NAS	National Academy of Science
ND	Not Detected
ng	nanogram
Ni	Nickel
NMHC	Nonmethane Hydrocarbons
NO	Nitrogen Oxide
NO_x	Nitrogen Oxides
NO_2	Nitrogen Dioxide
NO_3	Nitrate
NRC	National Research Council
NSR	New Source Review
O_2	Oxygen
O_3	Photochemical Oxidant; Ozone
OCDD	Octachlorodibenzo-p-dioxin

P	Projectiles
P_2O_5	Phosphorous Pentoxide
PAS	Pollution Abatement System
Pb	Lead
PBA	Pine Bluff Arsenal
PCB	Polychlorinated Biphenyl
PCDD	Polychlorodibenzo-p-dioxin
PCDF	Polychlorodibenzofuran
PCP	Pentachlorophenol
PeCDF	Pentachlorodibenzofuran
PEIS	Programmatic Environmental Impact Statement
PFB	Primary Fume Burner
PIC	Product of Incomplete Combustion
PL	Public Law
POHC	Principal Organic Hazardous Constituent
PO_4	Phosphate
PMD	Projectile Mortar Disassembly Machine
ppb	Parts Per Billion
PPD	Projectile Pull and Drain Machine
ppm	Parts Per Million
ppt	Parts Per Trillion
PS	Chloropicrin
PSD	Prevention of Significant Deterioration
PUDA	Pueblo Depot Activity
QA	Quality Assurance
QC	Quality Control
R	Rockets
RCl	Chlorinated Organics

RCRA	Resource Conservation and Recovery Act
RMA	Rocky Mountain Arsenal
RDM	Rocket Demil Machine
RSM	Rocket Shear Machine
RMP	Ralph M. Parson's Company
S	Sulfide
Sb	Antimony
Se	Selenium
SETCON	Set Consolidation
Sn	Tin
SO_x	Sulfur Oxides
SO_2	Sulfur Dioxide
SO_4	Sulfate
ST	Spray Tanks
Sp Gr	Specific Gravity
T	Bis(2(2-chloroethylthio)ethyl) ether
TBA	Tributylamine
TC	Ton Container
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
TCLP	Toxicity Characteristic Leaching Procedure
TDI	Toxic Dunnage Incinerator
TDS	Transportable Disposal System; Total Disolved Solids
TEAD	Tooele Army Depot
TOC	Total Organic Carbon
TOD	Total Oxygen Demand
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
TWA	Time Weighted Average
U	Uranium
um	Micrometer
UMDA	Umatilla Depot Activity
UPA	Unpack Area
V	Vanadium

VOC	Volatile Organic Carbon
VOST	Volatile Organic Sampling Train
VX	Nerve Agent
WSS	Wet Scrubber System
wt%	Weight Percent
Zn	Zinc

APPENDIX B

CHEMICAL AGENTS AND MUNITIONS

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SECTION B-1

CHEMICAL MUNITION AND CONTAINER FACT SHEETS

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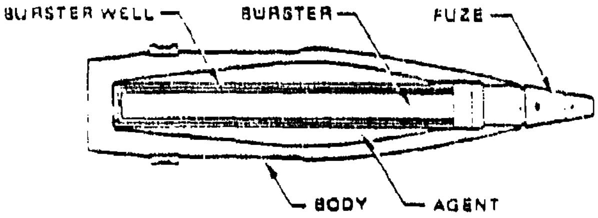
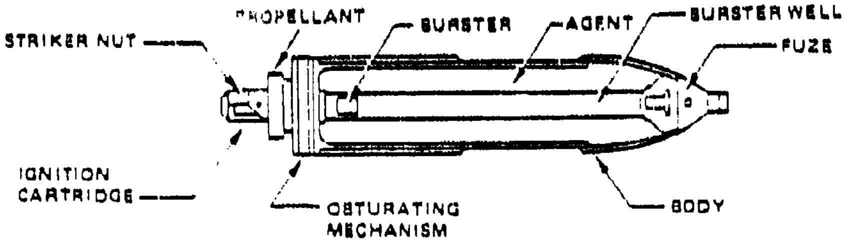


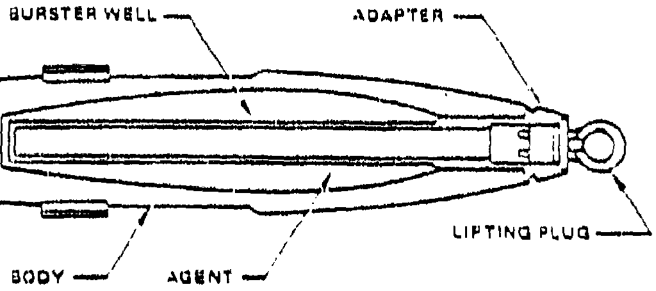
	Cartridge		Projectile
	M360/GB	M60/HD	M360/GB
LENGTH	31.1 in	31.1 in	31.1 in
DIAMETER	105 mm	105 mm	105 mm
TOTAL WT	43.86 lb	42.92 lb	N/A
AGENT	GB	HD	GB
AGENT WT	1.63 lb	2.97 lb	1.63 lb
FUZE	M508,M557	M51A5	--
BURSTER	M40, M40A	M5	--
EXPLOSIVE	Tetrytol, Comp B	Tetrytol	--
EXPLOSIVE WT	1.12 lb	0.3 lb	--
PROPELLANT	M67	M67	--
PROPELLANT WT	2.83 lb	2.83 lb	--
PRIMER	M28B2	M28B2, M28A2	--
PACKAGING	1 round/fiber container, 2 container/ wooden box	1 round/fiber container, 2 container/ wooden box	1 round/fiber container, 2 container/ wooden box

CARTRIDGE, 105 mm HOWITZER, M360, GB
CARTRIDGE, 105 mm HOWITZER, M60, HD
PROJECTILE, 105 mm HOWITZER, M360, GB



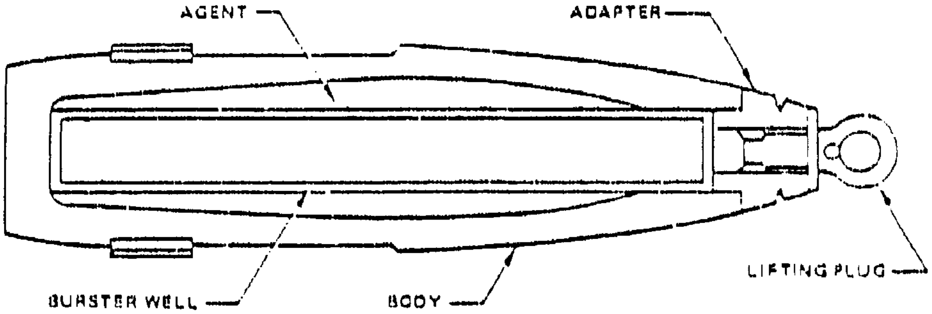
LENGTH	21.0 in	21.0 in
DIAMETER	4.2 in	4.2 in
TOTAL WT	24.67 lb	24.57 in
AGENT	HD	HT
AGENT WT	6.0	5.8
FUZE	M8, M51A5	M8
BURSTER	M14	M14
EXPLOSIVE	Tetryl	Tetryl
EXPLOSIVE WT	.14 lb	.14 lb
PROPELLANT	M6	M6
PROPELLANT WT	.6 lb	.4 lb
PRIMER	M28A2	M2
PACKAGING	1 round fiber/ container, 2 containers/ wooden box	1 round fiber/ container, 2 containers/ wooden box

CARTRIDGE, 4.2 INCH MORTAR, M2/M2A1, HT/HD



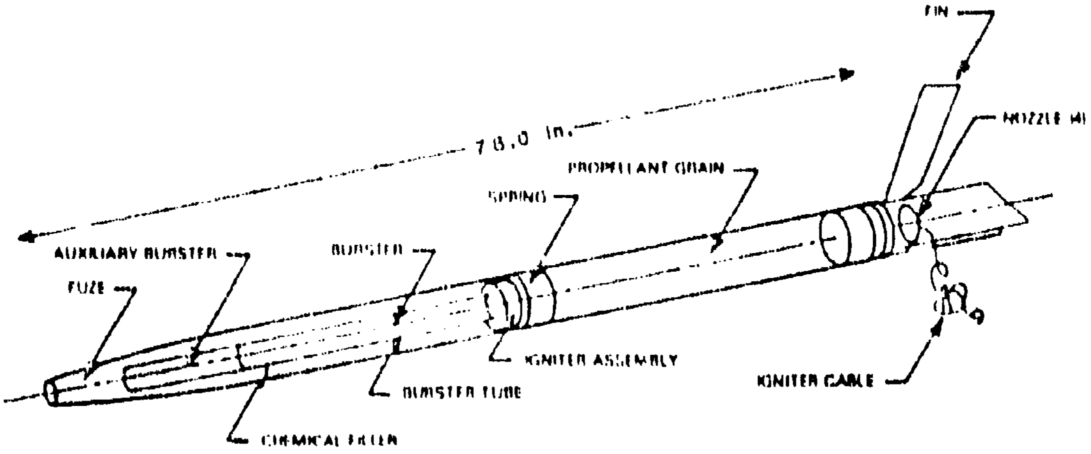
	M121	M121A1	M104	M110	M122
LENGTH	26.9 in	26.9 in	26.9 in	26.9 in	26.9 in
DIAMETER	155 mm	155 mm	155 mm	155 mm	155 mm
TOTAL WT	98.9 lb	98.9 lb	98.9 lb	98.9 lb	98.9 lb
AGENT	GB	VX, GB	H	H	GB
AGENT WT	6.0 lb	6.0 lb	11.7 lb	11.7 lb	6.5 lb
FUZE	None	None	None	None	None
BURSTER	M71	M71	M6	M6	M37
EXPLOSIVE	Comp B	Comp B	Tetrytol	Tetrytol	Tetrytol
EXPLOSIVE WT	2.45 lb	2.45 lb	.41 lb	.41 lb	2.45 lb
SUPPL CHG EXP	TNT	TNT	--	--	--
EXPLOSIVE WT	0.3 lb	0.3 lb	--	--	--
PROPELLANT	None	None	None	None	None
PROPELLANT WT	None	None	None	None	None
PRIMER	None	None	None	None	None
PACKAGING	8 Rounds/ wooden pallet	8 Rounds/ wooden pallet	8 Rounds wooden pallet.	8 Rounds wooden pallet	8 Rounds wooden pallet

PROJECTILE, 155 mm HOWITZER, M121A1, GB OR VX
PROJECTILE, 155 mm HOWITZER, M121, GB or VX
PROJECTILE, 155 mm HOWITZER, M104, H
PROJECTILE, 155 mm HOWITZER, M110, H
PROJECTILE, 155 mm HOWITZER, M122, GB



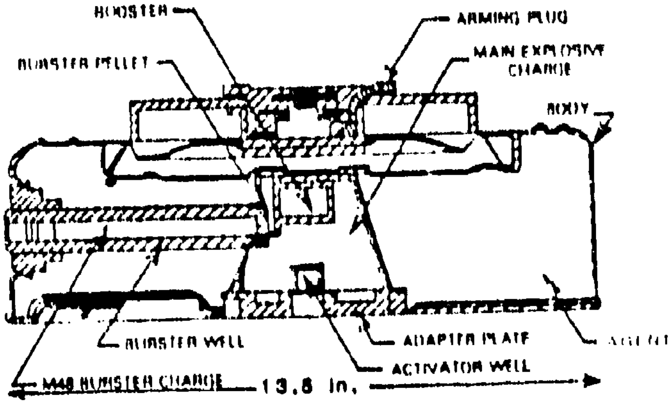
LENGTH	35.1 in
DIAMETER	8 in
TOTAL WT	203 lb
AGENT	GB, VX
AGENT WT	14.5 lb
FUZE	None
BURSTER	M83
EXPLOSIVE	Comp B4
EXPLOSIVE WT	7 lb
SUPPL CHG EXP	TNT
EXPLOSIVE WT	0.3 lb
PROPELLANT	None
PROPELLANT WT	N/A
PRIMER	None
PACKAGING	6 Rounds/ wooden pallet

PROJECTILE, 8-INCH HOWITZER, M426, GB
PROJECTILE, 8-INCH HOWITZER, M426, VX



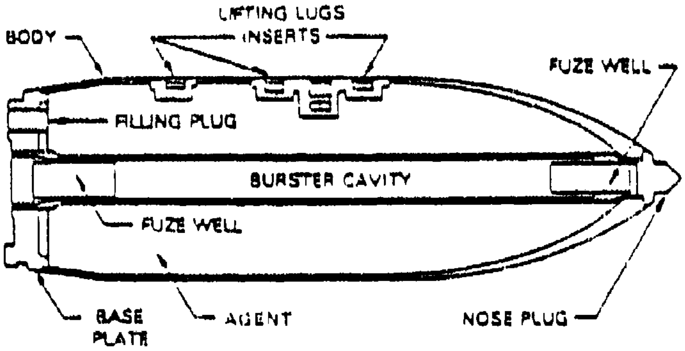
LENGTH	78.0 in	
DIAMETER	115 mm	
TOTAL WT	57 lb	56 lb
AGENT	GB	VX
AGENT WT	10.7 lb	10.2 lb
FUZE	M417	
BURSTER	M34, M36	
EXPLOSIVE	Comp B	
EXPLOSIVE WT	3.2 lb	
PROPELLANT	M28	
PROPELLANT WT	19.3	
PRIMER	M62	
PACKAGING	15 Rounds/ wooden pallet	

<u>ROCKET, 115 mm, M55, GB</u>
<u>ROCKET, 115 mm, M55, VX</u>



HEIGHT	5 in
DIAMETER	13.5 in
TOTAL WT	23 lb
AGENT	VX
AGENT WT	10.5 lb
FUZE	M603
BURSTER	M38
EXPLOSIVE	Comp B4
EXPLOSIVE WT	.8 lb
PROPELLANT	None
PROPELLANT WT	N/A
PRIMER	N/A
PACKAGING	3 Mines/ steel drum

MINE, VX, M23

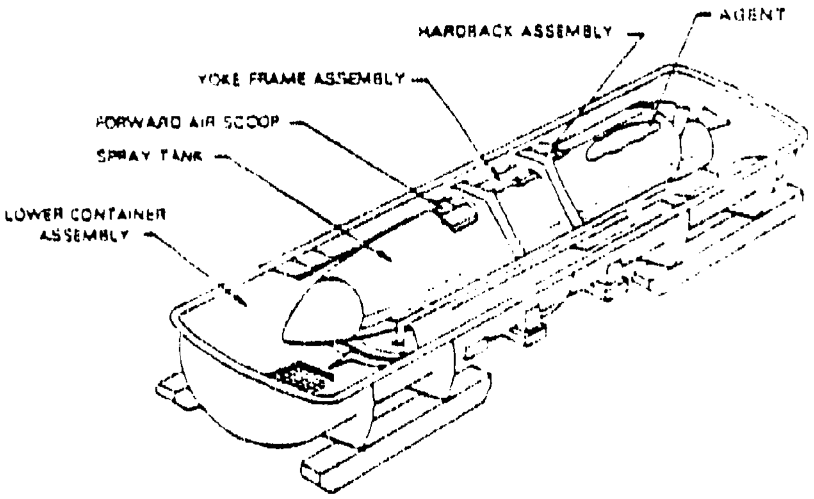


	MC-1	MK-116-0	MK-94
LENGTH	50 in	86 in	60 in
DIAMETER	16 in	14 in	10.8 in
TOTAL WT	725 lb (approx)	525 lb	441 lb (approx)
AGENT	GB	GB	GB
AGENT WT	220 lb	347 lb	108 lb
FUZE	None	None	None
BURSTER	None	None	None
EXPLOSIVE	None	None	None
EXPLOSIVE WT	N/A	N/A	N/A
PROPELLANT	None	None	None
PROPELLANT WT	N/A	N/A	N/A
PRIMER	None	None	None
PACKAGING	2 Bombs/wooden pallet	1 Bomb/metal container	1 Bomb/metal container

BOMB, 750 lb, MC-1, GB

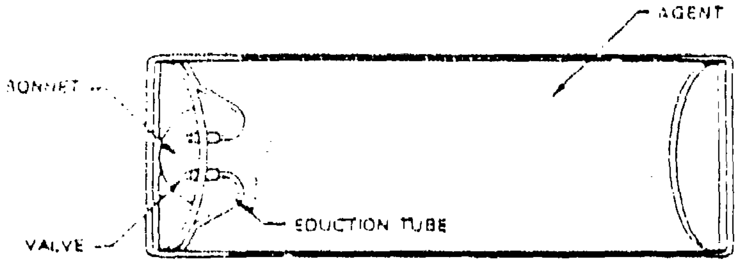
BOMB, 525 lb, MK-116-0, GB

BOMB, 500 lb, MK-94, GB



LENGTH	185 in
DIAMETER	22.5 in
TOTAL WT	1,935 lb
AGENT	VX
AGENT WT	1,356 lb
FUZE	None
BURSTER	None
EXPLOSIVE	None
EXPLOSIVE WT	N/A
PROPELLANT	None
PROPELLANT WT	N/A
PRIMER	None
PACKAGING	1 tank/steel container

TANK, SPRAY, TMU-28/B, VX



	HT	H	HD	GA	GB	L	VX
LENGTH	81.5 in	81.5 in	81.5 in	81.5 in	81.5 in	81.5 in	81.5 in
DIAMETER	31.1 in	31.1 in	31.1 in	31.1 in	31.1 in	31.1 in	31.1 in
TOTAL WT	3,100 lb	3,100 lb	3,100 lb	N/A	2,900 lb	3,100 lb	3,000 lb
AGENT	HT	H	HD	GA	GB	L	VX
AGENT WT	1,700 lb	1,700 lb	1,700 lb	N/A	1,500 lb	1,700 lb	1,600 lb
FUZE	None	None	None	None	None	None	None
BURSTER	None	None	None	None	None	None	None
EXPLOSIVE	None	None	None	None	None	None	None
EXPLOSIVE WT	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROPELLANT	None	None	None	None	None	None	None
PROPELLANT WT	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRIMER	None	None	None	None	None	None	None
PACKAGING	None	None	None	None	None	None	None

TON CONTAINER, HT, H, HD, GA, GB, L, VX

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SECTION B-2

CHEMICAL MUNITION ENERGETIC MATERIAL (PROPELLANT AND EXPLOSIVES) FACT SHEETS

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TABLE B-1. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS

Munition	Component	Weight, gr	Composition
M55 Rocket	1. Fuze, M417		
	a. Booster Lead Charge	1.12	RDX
	b. Pellet Booster	183.5	RDX
	c. Rotor, Lead	2.77	RDX
	a. Detonator, M63		
	(1) Upper Charge Primer Mix	0.31	<u>Overall Mixture:</u> 40% Lead Styphnate 20% Lead Azide 20% Barium Nitrate 15% Antimony Sulfide 5% Tetracene
	(2) Intermediate Charge	2.0	Lead Azide
	(3) Lower Charge	0.99	RDX
	2. Squib, M2		
	a. Flash Charge	1.0 ea (2 required)	<u>Overall Mixture:</u> 32% Lead Thiocyanate 40% Potassium Chlorate 18% Charcoal 10% Egyptian Lacquer

TABLE B-1. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS (Cont'd)

Munition	Component	Weight, gr	Composition
M55 Rocket (con't)	b. Booster Igniter	46.2 ea (2 required)	Overall Mixture: 49% Magnesium 49% Potassium Perchlorate 2% Cellulose Nitrate-Camphor
	3. Igniter, Rocket Motor, M62	385.0	Overall Mixture: 49% Magnesium 49% Potassium Perchlorate 2% Cellulose Nitrate-Camphor
	4. Propellant Grain, M28	134,750	See Table B-2
	5. Burster, M34	22,400 (Total for M34 and M36)	Comp B (See Table B-2)
	6. Burster, M36	—	Comp B
	7. Pellet, Rocket Motor	3.1	Overall Mixture: 49% Mangesium 49% Potassium Perchlorate 2% Cellulose Nitrate-Camphor

TABLE B-i. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS (Cont'd)

Munition	Component	Weight,gr	Composition
M23 Land Mine	1. M603 Fuze		
	a. M45 Detonator		
	(1)	1.9	Overall Mixture: 53% Potassium Chlorate 25% Lead Sulfocyanate 17% Antimony Sulfide 5% Lead Azide
	(2)	4.2	Lead Azide
	(3)	1.9	RDX
	b. M120 Booster	172.5	RDX
	2. M38 Burster	5709.8	Comp B
	3. M48 Initiator	848.8	Comp B
	4. Booster	308.6	Tetryl
M360 Cartridge	1. Fuze, M508A1		
	a. Booster Lead Charge		
	(1)	3.55	Lead Azide
	(2)	3.77	Tetryl Lead
	b. Booster Charge	339.50	Tetryl

TABLE B-1. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS (Cont'd)

Munition	Component	Weight, gr	Composition
M360 Cartrige (con't)	c. Detonator, M18		
	(1) Upper Charge	1.00	Overall Mixture 33.5% Potassium Chlorate 32.2% Antimony 28.3% Lead Azide 5.0% Carborundum
	(2) Intermediate Charge	2.95	Lead Azide
	(3) Lower Charge	1.24	Tetryl
	2. Burster, M40	7840.00	Tetrytol
	M40A	7840.00	Comp B
	3. Primer, M28B2	293.21	Black Powder
	4. Propellant, M67	19810.00	See Table B-2
M60 Cartridge	1. Fuze, M51A5		
	a. Booster, M121A4		
	(1) Booster Lead Charge		
	(a)	3.55	Lead Azide
	(b)	3.77	Tetryl Lead
	(2) Booster Charge	339.50	Tetryl

TABLE B-1. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS (Cont'd)

Munition	Component	Weight, gr	Composition
	b. Detonator, M24		
	(1) Upper Charge	1.05	Overall Mixture 33.4% Potassium Chlorate 33.3% Antimony Sulfide 17% Lead Azide 5.0% Carborundum
	(2) Lower Charge	2.86	Tetryl
	c. Delay Plunger Assembly, M1		
	(1) M54 Primer	0.17	Overall Mixture 53% Potassium Chloride 25% Lead Sulfocynate 17% Antimony Sulfide 5% TNT
	(2) Delay Pallet	0.29	Black Powder
	(3) Relay, M7	1.54	Lead Azide
	3. Burster, M5	2100.00	Tetrytol
	4. Primer M28B2	293.21	Black Powder
	5. Propellant, M67	19810.00	See Table B-2

TABLE B-1. ENERGETIC COMPONENTS OF CHEMICAL MUNITIONS (Cont'd)

Munition	Component	Weight, gr	Composition
M2/M2A1 (4.2" Mortar)	1. Fuze, M8		
	(a) Detonator, M18		
	(1) Upper Charge	0.77	Overall Mixture: 33.4% Potassium Chlorate 33.3% Antimony Sulfide 28.3% Lead Azide 5.0% Carborundum
	(2) Intermediate Charge	2.42	Lead Azide
	(3) Lower Charge	1.08	Tetryl
	(b) Lead Charge	2.03	Tetryl
	2. Burster, M14	980.00	Tetryl
	3. Ignition Cartridge, M2	7.5	M9 Propellant (See Table B-2)
	4. Propelling Charge, M6	4200.00	M8 Propellant (See Table B-2)
M104/110	Burster, M6	2870.00	Tetrytol
M121/M121 Projectile	Burster, M71	17150.00	Comp B
M122 Projectile	Burster, M37	17150.00	Tetrytol
M426 Projectile	Burster, M83	44000.00	Comp B

TABLE B-2. PHYSICAL AND CHEMICAL CHARACTERISTICS OF EXPLOSIVES AND PROPELLANTS

Energetic	Composition	Molecular Weight	Density	Explosion Temperature Test Value (°C)	Heat of Combustion (cal/g) at Constant Pressure
Explosives					
Tetrytol	70% tetryl 30% TNT	266	1.66	275	3136
Tetryl	2,4,6-Trinitrophenylmethylnitramine	267.15	1.73 (crystal) 1.62 (cast)	257	2914
Composition B	60% RDX 39% TNT 1% presensitizer (wax)	224	1.65 (cast)	278	2790
TNT	2,4,6-trinitrotoluene	227.134	1.654 (crystal) 1.56 (cast) 1.465 (liquid)	475	3589.5
RDX	Cyclotrimethylenetrinitramine	222.126	1.816 (crystal)	260	2307

TABLE B-2. PHYSICAL AND CHEMICAL CHARACTERISTICS OF EXPLOSIVES AND PROPELLANTS (Cont'd)

Energetic	Composition	Molecular Weight	Density	Explosion Temperature Test Value (°C)	Heat of Combustion (cal/g) at Constant Pressure
Propellant Types					
M8	52.15% Nitrocellulose (13.15% N) 43.00% Nitroglycerin 3.0% Diethylphthalate 1.25% Potassium Nitrate 6.60% Ethyl Centralite	254.9	--	--	2914
M9	57.75% Nitrocellalose (13.15%N) 40.00% Nitroglycerine 1.50% Potassium Nitrate 0.75% Diphenylamine	258.9	--	--	
M28	60.0% Nitrocellulose 23.8% Nitroglycerine 9.9% Triacetin 2.6% Di-ethylphthalate 2.0% Lead Stearate 1.7% 2-Nitrodiphenylamine	253.4	--	--	2496
M67	86.1% Nitrocellulose (13.15% N) 9.9% Dinitrotoluene 3.0% Dibutylphthalate 1.0% Diphenylamine	259.4	--	--	2780

SECTION B-3

CHEMICAL AGENT FACT SHEETS

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TABLE B-3. CHEMICAL AGENT TABUN (GA) CHARACTERISTICS

GENERAL:

GA is an anticholinesterase agent similar in action to GB (q.v.). Although only about half as toxic as GB by inhalation, GA in low concentrations is more harassing to the eyes than GB. Individuals poisoned by GA display approximately the same sequence or symptoms regardless of the route by which the poison enters the body (whether by inhalation, adsorption, or ingestion). These symptoms, in normal order of appearance, are: runny nose; tightness of chest; dimness of vision and pinpointing of the eye pupils; difficulty in breathing; drooling and excessive sweating; nausea; vomiting; cramps; and involuntary defecation and urination; twitching; jerking; and staggering; and headache; confusion; drowsiness; coma; and convulsion. These symptoms are followed by cessation of breathing and death.

PHYSICAL PROPERTIES:

a. Chemical Name: Ethyl N, N-dimethylphosphoramido-cyanidate
b. Chemical Formula: Empirical. $C_5H_{11}N_2O_2P$
c. Molecular Weight: 162.1
d. Vapor Density, Relative to Air: 5.6
e. Liquid Density: 1.08 g/ml @ 25°C
f. Normal Freezing Point or Melting Point: -50°C
g. Boiling Point: 245°C
h. Vapor Pressure: 0.07 mm Hg @ 25°C
i. Flash Point: 78°C
j. Viscosity (centistokes @ 25°C): 2.18
k. Color: Colorless to brown
l. Odor: Faintly fruity; none when pure
m. Special Properties: None
n. Solubility Properties: Readily soluble in most organic solvents
o. H Combustion: 9,751 BTU/lb
p. Physical State: Viscous Liquid

TABLE B-3. CHEMICAL AGENT TABUN (GA) CHARACTERISTICS (Cont'd)

TOXICITY:

ihl-rat	LC_t50:	450 mg min/m^3 (t=10)
ihl-rbt	LC_t50:	960 mg min/m^3 (t=10)
ihl-dog	LC_t50:	320 mg min/m^3 (t=10)
ihl-mky	LC_t50:	187 mg min/m^3 (t=10)
ivn-rat	LD50:	0.07 mg/kg
ivn-rbt	LD50:	0.063 mg/kg
ivn-dog	LD50:	0.084 mg/kg
ivn-mky	LD50:	0.05 mg/kg

TABLE B-4. CHEMICAL AGENT SARIN (GB) CHARACTERISTICS

GENERAL:

GB is a rapid-acting lethal nerve agent. The action within the body is the inactivation of cholinesterase. The hazard from GB is that of vapor adsorption through the respiratory tract, although it can be absorbed through any part of the skin, through the eyes, and through the gastrointestinal tract by ingestion. The agent absorption rate is accelerated through cuts and abrasions in the skin. When dispersed as large droplets, GB is moderately persistent; it is nonpersistent when disseminated as a cloud of very fine particles.

PHYSICAL PROPERTIES:

a. Chemical Name: Isopropylmethylphosphonofluoridate. Sarin.
b. Chemical Formula: $C_4H_{10}FO_2P$
c. Molecular Weight: 140.10
d. Vapor Density (Air = 1.00): 4.86
e. Liquid Density at 25°C: 1.0887 gm/cc
f. Freezing Point: -56°C
g. Boiling Point: 158°C
h. Vapor Pressure: 2.9 mm Hg @ 25°C
i. Flash Point: Does not flash
j. Viscosity (centistokes @ 25°C): 1.28
k. Color: Clear to straw to amber
l. Odor: None
m. Special Properties: None
n. Solubility Properties: Miscible with water and readily soluble in all organic solvents
o. H Combustion: 10,000 Btu/lb
p. Physical State: Viscous Liquid

TABLE B-4. CHEMICAL AGENT SARIN (GB) CHARACTERISTICS (Cont'd)

COMPOSITION:	Percent[a]
Isopropyl methyl phosphonofluoridate (GB)	93.00
N,N'-Diisopropylcarbodiimide (DICDI)[b]	4.00
Tributylamine (TBA)[b]	1.95
Methyl Difluoride	0.50
HF	0.20
Aluminum	0.20
HCl	0.10
Iron	0.05
Nickel	0.0025
Copper	0.0004

TOXICITY:

TRDS:	eye-hmn:	1 ug/kg	
TXDS:	orl-hmn TDLo:	2 ug/kg	TFX:BLD
	skn-hmn LD50:	28 mg/kg	
	ihl-hmn TDLo:	103 ug/kg	TFX:CNS
	ihl-hmn LC50:	70 mg/m^3	
	orl-rat LD50:	550 ug/kg	
	scu-rat LD50:	113 ug/kg	
	ivn-rat LD50:	45 ug/kg	
	ims-rat LD50:	500 ug/kg	
	skn-mus LD50:	1080 ug/kg	
	ipr-mus LD50:	450 ug/kg	
	scu-mus LD50:	100 ug/kg	
	ims-mus LD50:	222 ug/kg	
	ivn-dog LD50:	19 ug/kg	
	ivn-cat LD50:	22 ug/kg	
	skn-rbt LD50:	925 ug/kg	
	scu-rbt LD50:	30 ug/kg	

TABLE B-4. CHEMICAL AGENT SARIN (GB) CHARACTERISTICS (Cont'd)

ivn-rbt LD50: 28 ug/kg
ihl-gpg LDLo: 128 mg/m^3/2m
scu-gpg LD50: 38 ug/kg

---

[a] These numbers are given as a guide only and do not represent product specifications or the exact constituency of the agent.

[b] DICIDI and TBA are not both in all GB.

TABLE B-5. CHEMICAL AGENT VX CHARACTERISTICS

GENERAL:

VX is a rapid-acting lethal nerve agent. The action within the body is the inactivation of cholinesterase. The hazard from VX is primarily that of liquid absorption through the skin, although it can be adsorbed through the respiratory tract as a vapor or aerosol, and through the gastrointestinal tract by ingestion. VX is slow to evaporate and may persist as a liquid for several days.

PHYSICAL PROPERTIES:

a. Chemical Name: O-ethyl S-(2-diisopropylaminoethyl)
Methylphosphonothiolate
b. Chemical Formula: $C_{11}H_{26}NO_2PS$
c. Molecular Weight: 267.37
d. Vapor Density (Air = 1.0): 9.2
e. Liquid Density at 25°C: 1.008 gm/cc
f. Freezing Point: Below -39°C
g. Boiling Point: 300°C
h. Vapor Pressure @ 20°C: 0.0006 mm Hg
i. Flash Point: 159°C
j. Viscosity (centistokes @ 25°C): 9.96
k. Color: Clear to straw
l. Odor: None
m. Special Properties: None
n. Solubility Properties: Best solvents are dilute mineral acids
o. H Combustion: 15,000 Btu/lb
p. Physical State: Viscous Liquid

TABLE B-5. CHEMICAL AGENT VX CHARACTERISTICS (Cont'd)

COMPOSITION:	**Percent**[a]
O-ethyl, S-(2-diisopropylaminoethyl) methylphosphonothiolate (VX)	93.00
Pyrodiester	3.00
N,N'Diisopropylcarbodiamide (DICDI)[b]	2.50
Free mercaptan	1.00
H_2SO_4	0.30
Free sulphur	0.14
Iron	0.05
Aluminum	0.01
Nickel	0.0025
Copper	0.0004

TOXICITY:

TXDS:	orl-man TDLo:	4 ug/kg	RFX:RBC
	skn-hmn LDLo:	86 ug/kg	
	ivn-man TDLo:	1500 ng/kg	RFX:CNS
	ipr-mus LD50:	50 ug/kg	
	scu-rbt LD50:	15 ug/kg	
	scu-gpg LD50:	8400 ng/kg	

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[a] These numbers are given as a guide only and do not represent product specifications or the exact constituency of the agent.

[b] Dicyclohexylcarbodiamide is an alternate stabilizer.

TABLE B-6. CHEMICAL AGENT MUSTARD (H/HD/HT) CHARACTERISTICS

GENERAL:

Mustard is a persistent and powerful blistering agent. It acts principally by poisoning the cells in the surfaces contacted. Both liquid and vapor cause intense inflammation and may cause severe blistering of both the skin and mucous membranes. Mustard is only moderately volatile.

Mustard is designated H, HD, and HT. H is mustard made by the Levinstein process. It containes up to 25 percent by weight of impurities, chiefly sulfur, organosulfur chlorides and polysulfides. HD (distilled mustard) is mustard purified by washing and vacuum distillation, which reduces impurities to about 5 percent. HT is a 60:40 mixture by weight of HD and T. T is an abbreviation for [2(2-chloroethylthio)ethyl] ether.

PHYSICAL PROPERTIES:

a. Chemical Name: Bis (2-chloroethyl) sulfide
2,2'- dichlorodiethyl sulfide- sulfur mustard

b. Chemical Formula: $(ClCH_2CH_2)_2S$

	H	HD	HT
c. Molecular Weight:	175.00	159.08	189.40
d. Vapor Density, (air= 1.0):	5.40	5.40	6.92
e. Liquid Density gm/cc at 20°:	1.27	1.27	1.27
f. Normal Freezing Point, °C	5.14	14.00	1.00
g. Boiling Point, °C:	225.40	227.80	228.00
h. Vapor Pressure, mm Hg @ 20°C:	0.059	0.072	0.104
i. Flash Point, °C:	100.00	105.00	100.00
j. Viscosity, centistokes @ 20°C:	3.95	3.95	6.05

k. Color: Amber--dark brown liquid (all)

l. Odor: Garlic (all)

m. Special Properties: Permeates ordinary rubber (all)

TABLE B-6. CHEMICAL AGENT MUSTARD (H/HD/HT) CHARACTERISTICS (cont'd)

n. Solubility Properties: Water (distilled)--0.092 at 22°C; completely soluble in acetone, CCl_4, CH_3CL, tetrachloroethane, ethyl benzoate, ether (all)

	H	HD	HT
o. H Combustion: (Btu/lb):	8,100	8,500	9,400

p. Physical State: Viscous Liquid (all)

COMPOSITION OF HD:	Percent[a]
Bis (2-chloroethyl) sulfide (HD-mustard)	92.00
Free sulphur	7.38
$FeCl_2$	0.50
HCl	0.11
Aluminum	0.01
Nickel	0.0025
Copper	0.0004

COMPOSISTION OF H:	Percent[a]
Bis (2-chloroethyl) sulfide (mustard)	67.7
Ferris chloride	0.3
Hydrochloric Acid	0.3
Iron Carbide	2.5
Iron Sulfide	1.5
Chlorinated Hydrocarbons	14.4
Elemental Sulphur	11.3
Carbon Disulfide	2.0

TOXICITY:

MTDS:	mrc-esc 5 ug/well
	dlt-mus-ihl 630 ug/kg
IRDS:	skn-man 200 mg/m^3 1H SEV
	eye-man 100 mg/m^3/6H MOD
	eye-rbt 200 mg/m^3/2M

TABLE B-6. CHEMICAL AGENT MUSTARD (H/HD/HT) CHARACTERISTICS (cont'd)

TXDS:
ihl-hmn LD50: 1500 mg/m^3/M
ihl-hmn LCLo: 23 ppm/10M
skn-hmn LDLo: 64 mg/kg
ihl-rat LD50: 420 mg/m^3/2M
ihl-rat TCLo: 100 ug/,^{3}/1Y-I TFX:CAR
skn-rat LD50: 9 mg/kg
scu-rat LD50: 1500 ug/kg
ivn-rat LD50: 700 ug/kg
ihl-mus LCLo: 189 mg/m^3/10M
skn-mus LD50: 92 mg/kg
ihl-mus TCLo: 170 ppm/15M-C TFX/CAR
skn-mus LDLo: 4 mg/kg
scu-mus TDLo: 6 mg/kg/6W-I TFX:CAR
ivn-mus LD50: 8600 ug/kg
ivn-mus TDLo: 60 ug/kg/6D-I TFX:CAR
skn-dog LD50: 20 mg/kg
skn-rbt LD50: 100 mg/kg
ivn-rbt LD50: 1100 mg/kg
skn-gpg LD50: 20 mg/kg
skn-dom LD50: 50 mg/kg

[a] These numbers are given as a guide only and do not represent product specifications or the exact constituency of the agent.

TABLE B-7. CHEMICAL AGENT LEWISITE (L) CHARACTERISTICS

GENERAL:

L is a vesicant. It produces effects similar to HD but, in addition, acts as a systemic poison, causing pulmonary edema, diarrhea, restlessness, weakness, subnormal temperature, and low blood pressure. In order of severity and appearance of symptoms, it is: a blister agent, a toxic lung irritant, and when absorbed in the tissues, a systemic poison. Liquid L causes an immediate searing sensation in the eye and permanent loss of sight if not decontaminated within 1 minute. L produces an immediate and strong stinging sensation to the skin; reddening of the skin starts within 30 minutes. Blistering does not appear until after about 13 hours. Like HD, it is a cell poison. Skin burns are much deeper than with HD. When inhaled in high concentrations it may be fatal in as short a time as 10 minutes. The body does not detoxify L.

PHYSICAL PROPERTIES:

a. Chemical Name: Dichloro-2-chlorovinylarsine, lewisite
b. Chemical Formula: $C_2H_2AsCl_3$
c. Molecular Weight: 207.32
d. Vapor Density: 1.88 g/ml @ 25°C
e. Solid Density:
    1) Bulk Density: Not applicable
    2) Crystal Density: Not applicable
f. Normal Freezing Point or Melting Point: -18°C +/- 0.1°C, depending on (purity and isomers present)
g. Boiling Point: 190°C
h. Vapor Pressure: 0.58 mm Hg @ 25°C
i. Flash Point: Does not flash
j. Viscosity: 1.09 centistokes @ 25°C
k. Color: Amber to dark brown
l. Odor: Usually geranium like, very little odor when pure
m. Special Properties: None

TABLE B-7. CHEMICAL AGENT LEWISITE (L) CHARACTERISTICS (Con't)

n. Solubility Properties: Soluble in all common organic solvents and slightly soluble in water

o. H Combustion: High heating value 4,676 BTU/lb; low heating value 4,583 BTU/lb

p. Physical State: Viscous Liquid

Toxicity:

skn-mus	LC_t50	900-1400 mg-min/m^3 (t=10min)
skn-rat	LC_t50:	1500 mg min/m^3 (t=9-25 min)
skn-gpg	LC_t50:	1000 mg-min/m^3 (t=9-14 min)
skn-rbt	LC_t50:	1500 mg-min/m^3 (t=60-180 min)
skn-got	LC_t50:	1250 mg-min/m^3 (t=100-255 min)
ihl-mus	LC_t50:	1600 mg-min/m^3 (t=10 min)
ivn-rbt	LD50:	2 mg/kg
pvn-dog	LD50:	2 mg/kg
scu-rbt	LD50:	1 mg/kg
scu-gpg	LD50:	1 mg/kg

APPENDIX C

M34 CLUSTER BOMB AND HONEST JOHN WARHEAD DESCRIPTIONS

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APPENDIX C

MUNITION DESCRIPTION

C.1 Purpose. The purpose of this appendix is to provide a brief description of the M34 Cluster Bombs and Honest John (M190) Warhead/M139 Bomblets. A description of the other munitions that were either demilitarized by neutralization or incineration as described throughout this report are found in Appendix B.

C.2 Technical data regarding these munitions at RMA is as follows:

a. M34 Cluster Bombs. The M34 Cluster Bomb was an air-deliverable munition containing 76 M125 Bomblets as shown in Figure C-1. Each M34 Cluster was approximately 57 inches long, 19 inches in diameter and weighed 1,100 pounds. The M125 Bombs were arranged in four groups of 19 bomblets. Each M125 Bomblet was 12 inches long, 3 5/8 inches in diameter and weighed 8.5 pounds. The M125 Bomblet, as shown in Figure C-2, consisted of a body filled with 2.5 ounces of GB, parachute, M1 parachute opening delay, M196 fuze and M31 burster containing 8.8 ounces (250 grams) of tetryl. The tail assembly of the M34 (shaded portion in Figure C-1) was not attached to the M34 Clusters stored at RMA

b. Honest John (M190) Warhead/M139 Bomblets. The Honest John M190 Warhead was a 762 millimeter rocket that weighed 1,[illegible] pounds when loaded. The M421 fuze as shown in Figure C-3 had already been removed from the warhead. Each M190 Warhead contained 368 M139 Bomblets. The bomblets were spherical as shown in Figure C-4, contained 1.3 pounds of nerve agent GB, and 0.16 pounds of Composition "B". The M197 mechanical fuze in the M139 Bomblet was a spin-to-arm type and required a spinning rate of [illegible] to 1800 RPM for arming. As a result, this fuze was considered insensitive under normal handling operations and was not safed before the munitions were downloaded.

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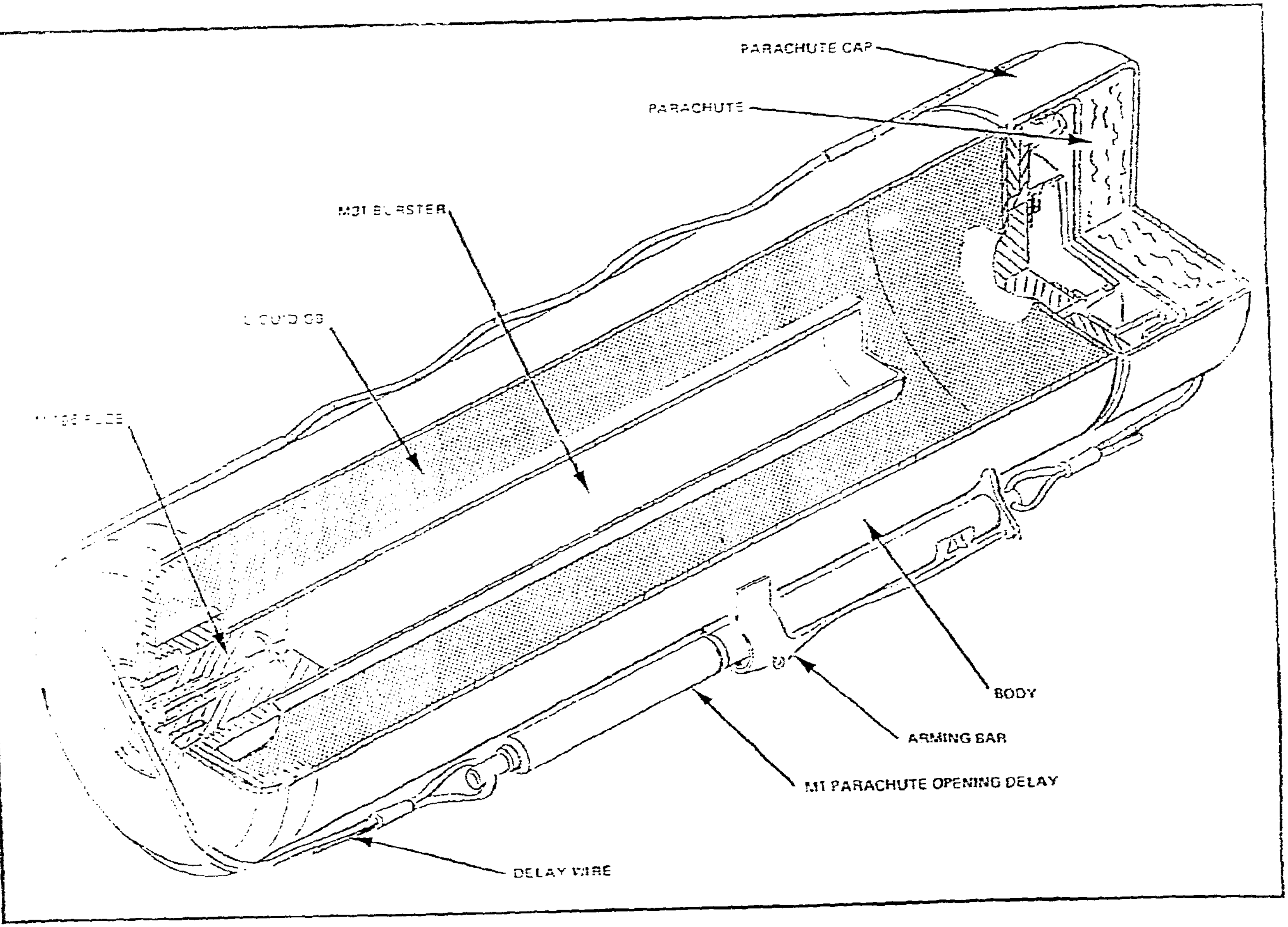


Figure C-2: M125 Bomb Cutaway

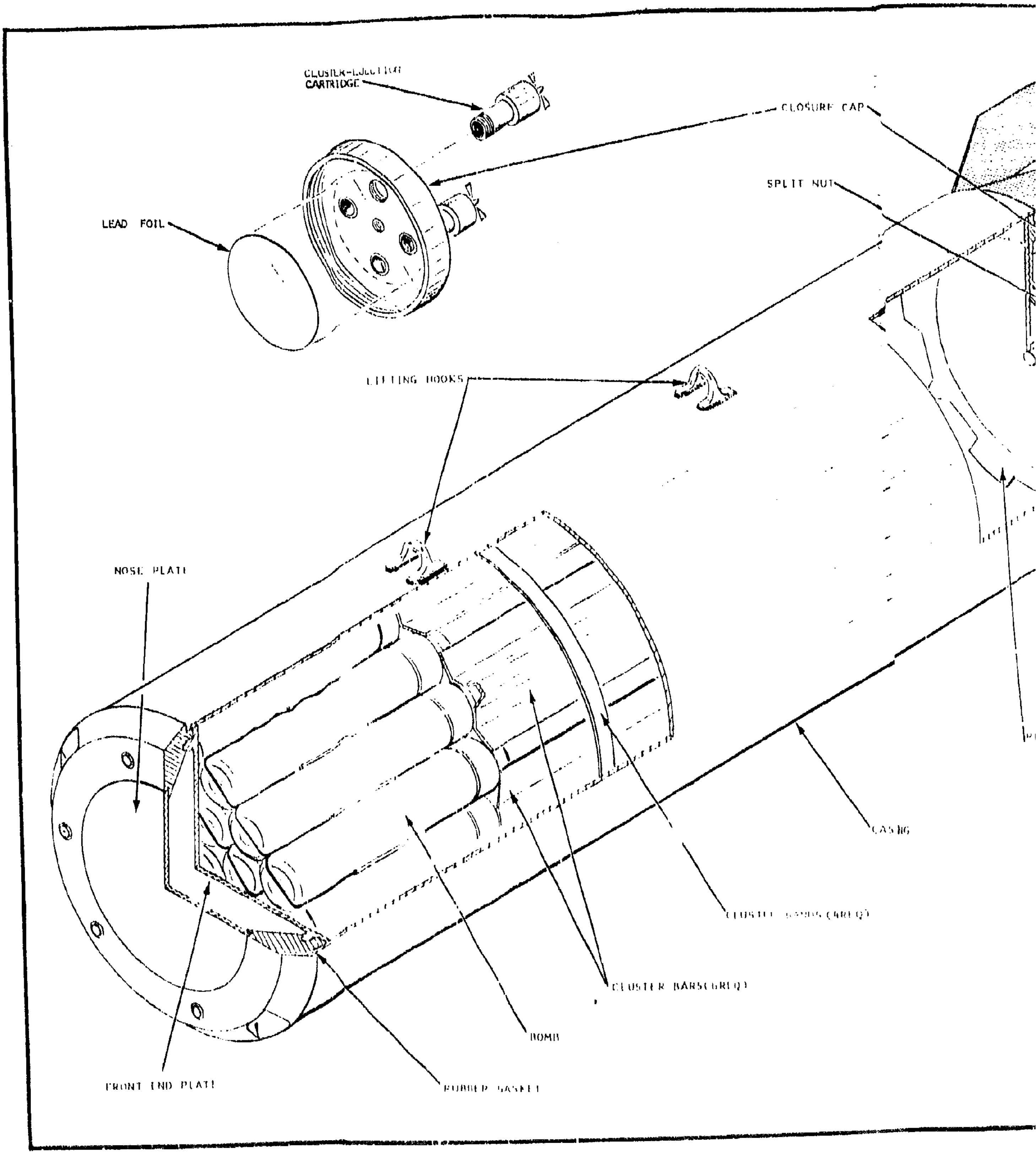
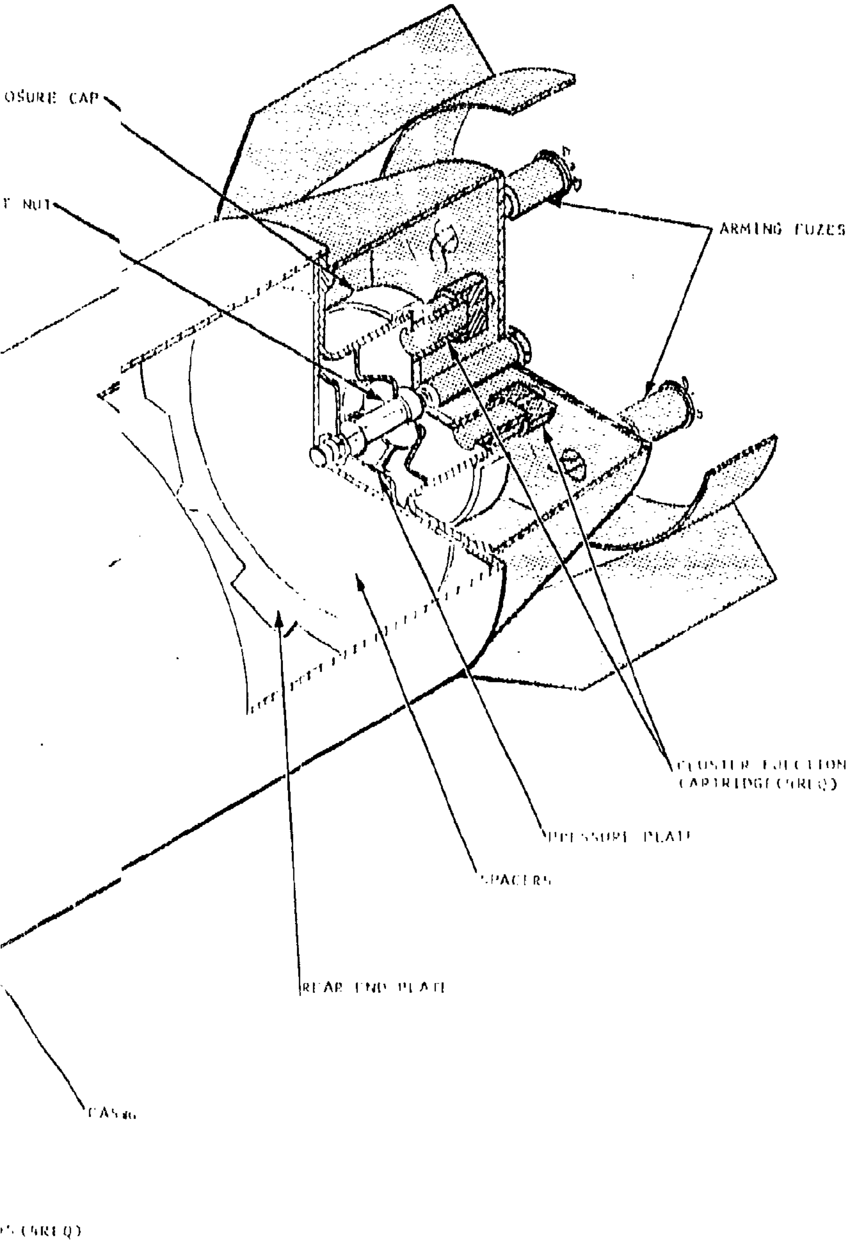


Figure C-1: M34 Cluster Bomb


OSURE CAP
T NUT
ARMING FUZES
CLUSTER EJECTION
CARTRIDGE (9REQ)
PRESSURE PLATE
SPACERS
REAR END PLATE
CASING
S (9REQ)

[illegible] Bomb

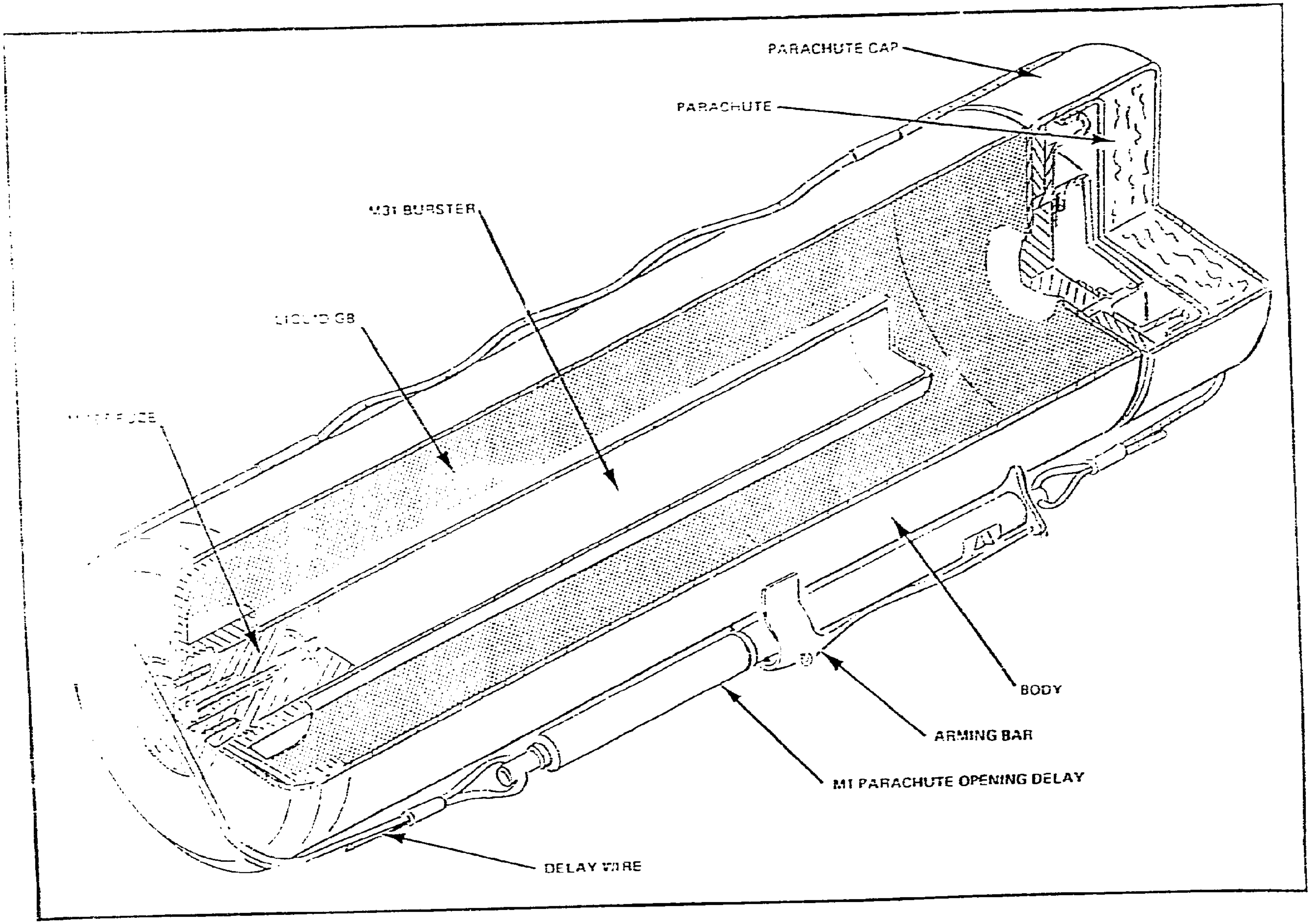


Figure C-2: M125 Bomb Cutaway

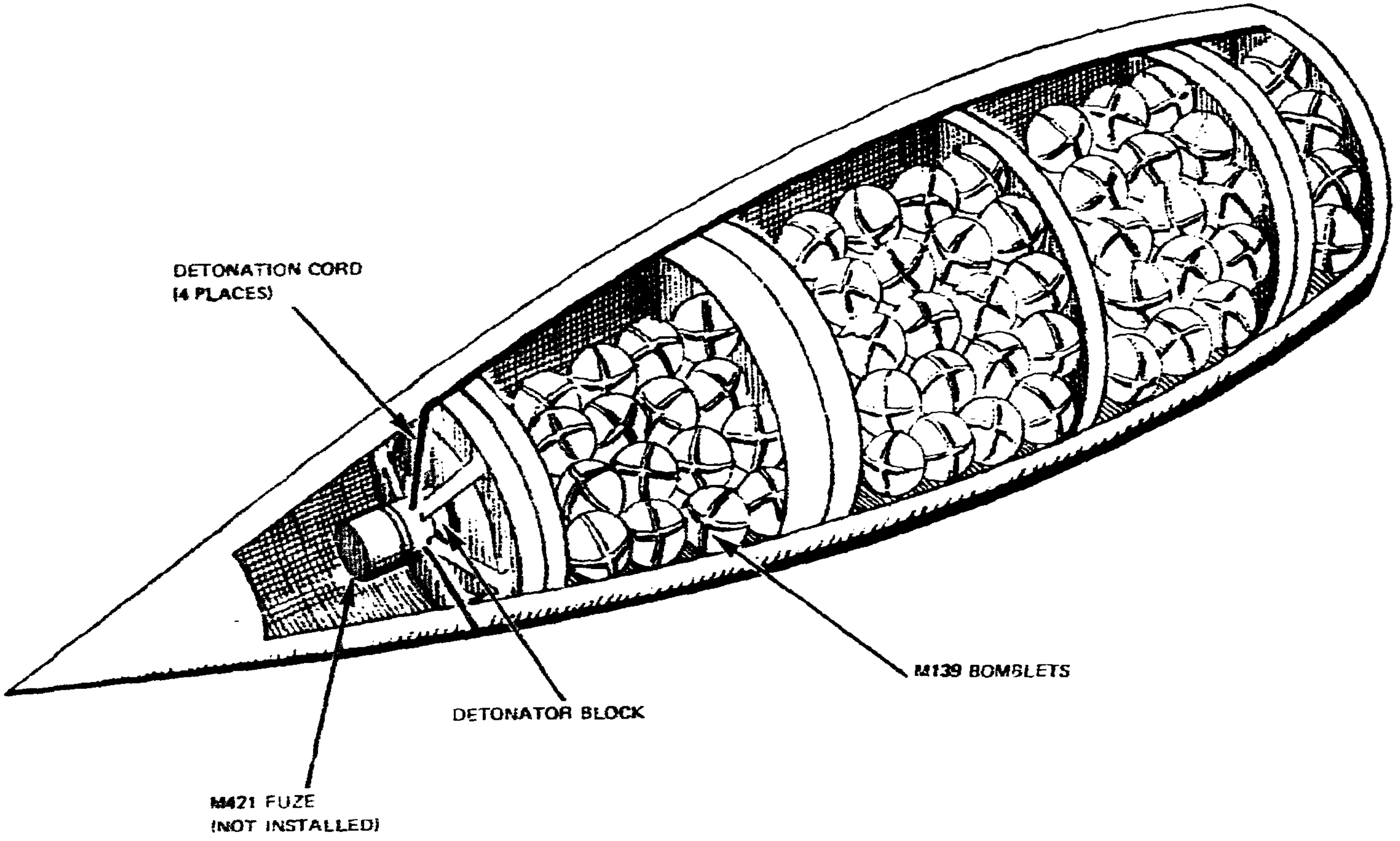


Figure C-3: Honest John M190 Warhead

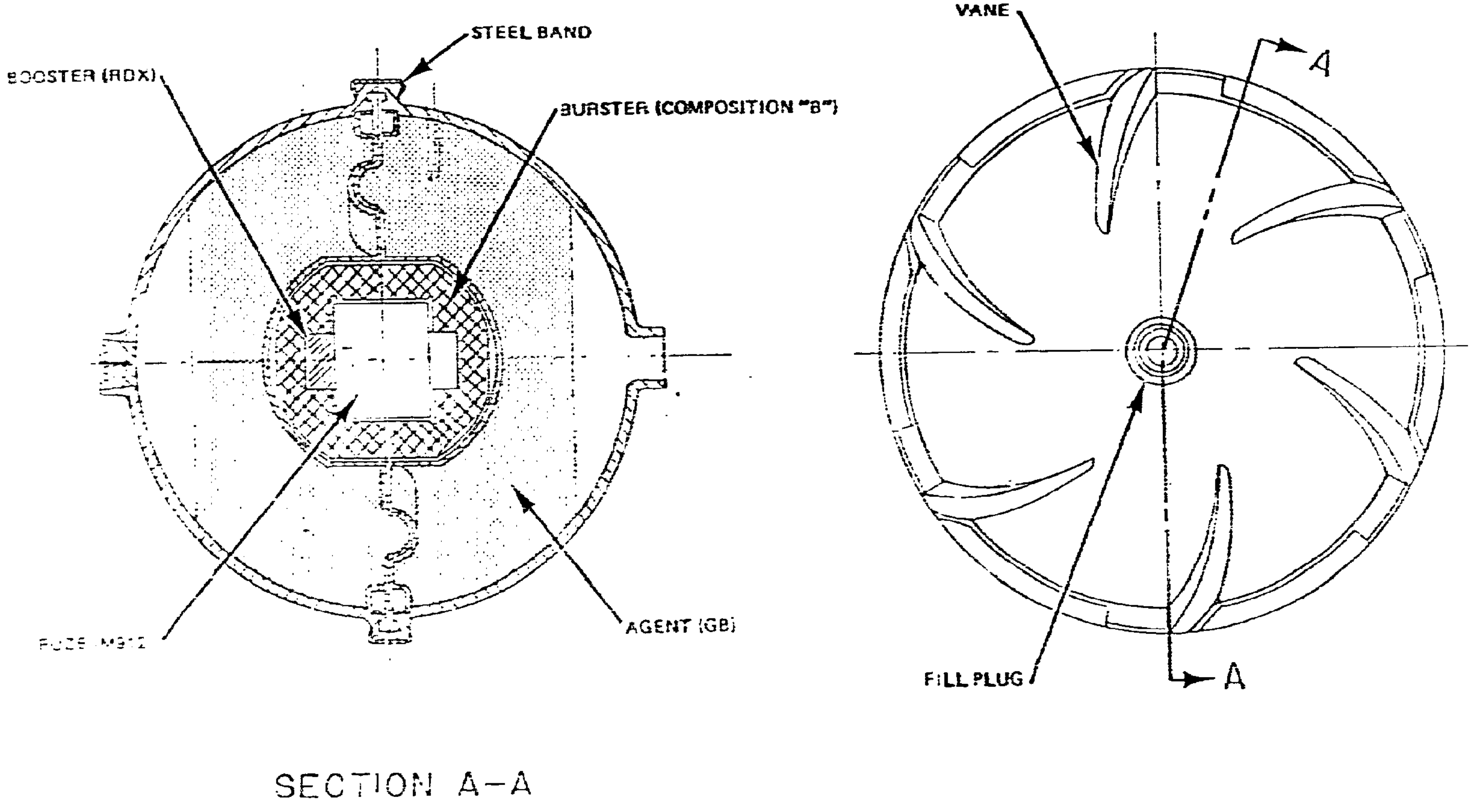


Figure C-4: M139 Bomblet

APPENDIX D

COMPARISON OF CAMDS AND JACADS INCINERATION SYSTEMS

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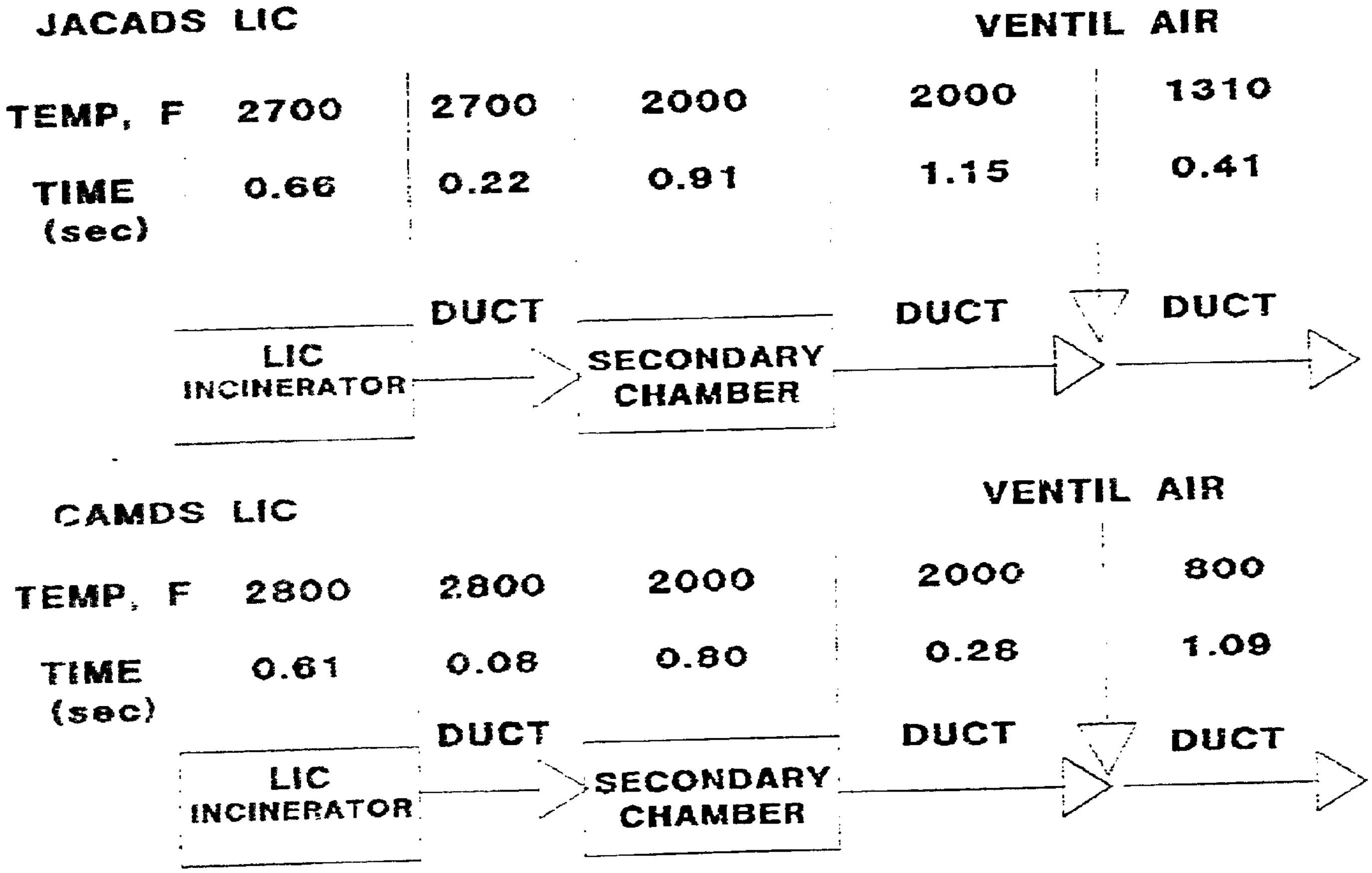
SECTION D-1

LIQUID INCINERATOR COMPARISON

LIC TIME TEMPERATURE PROFILE

(8/13/87)



JACADS LIC

TEMP, F	2700	2700	2000	2000	1310
TIME (sec)	0.66	0.22	0.91	1.15	0.41

CAMDS LIC

TEMP, F	2800	2800	2000	2000	800
TIME (sec)	0.61	0.08	0.80	0.28	1.09

LIQUID INCINERATOR (LIC) Comparison

Parameter	JACADS	CAMDS
1. PRIMARY CHAMBER		
a. Operating Temp (^{o}F)	2700	2800
b. Operating Pressure, in. w.c.	-0.5	-2.0
c. Burner Capacity, MBTU/hr	13.0	4.0
d. GB Incineration Rate, lb/hr	1050	300
e. VX Incineration Rate, lb/hr	700	200
f. Mustard Incineration Rate lb/hr	1330	380
g. Effective Height, ft	8.26	8.83
h. Internal Diameter, ft	4.33	2.76
i. Wall Thickness, in.	17.5	13.5
j. Max Gas Flow, SCFM	2400	800
2. SECONDARY CHAMBER		
a. Operating Temp (^{o}F)	2000	2000
b. Operating Pressure, in w.c.	-2.5	-6.0
c. Burner Capacity, MBTU/hr	10.0	4.0
d. Decon Processing Rate, gpm	4.0	1.2
e. Salt Production, lb/hr	100	68
f. Effective Height, ft	6.67	7.83
g. Internal Diameter, ft	5.83	3.89
h. Wall Thickness, in.	14.0	7.5
i. Max Gas Flow, SCFM	4100	1200

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SECTION D-2

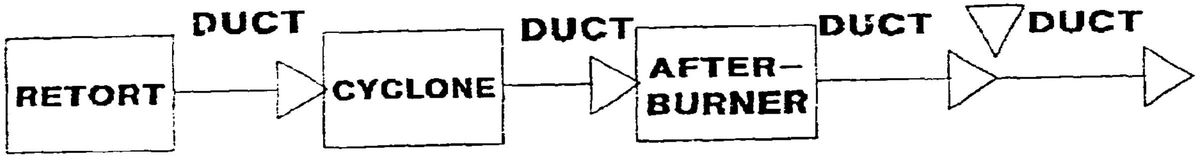
DEACTIVATION FURNACE SYSTEM COMPARISON

DFS TIME–TEMPERATURE PROFILE

(4/8/87)

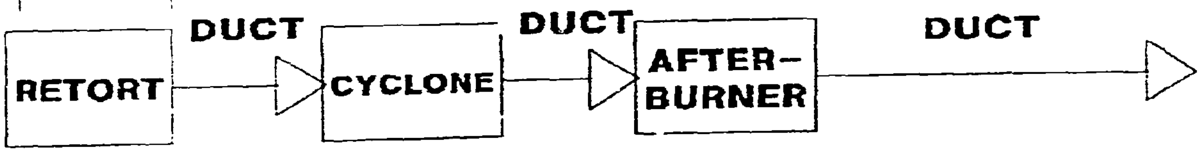
JACADS DFS

TEMP, F	1800	1600	1600	1600	2000	2000	2000
TIME (sec)	0.17	3.03	2.26	0.58	0.64	0.14	0.19



CAMDS DFS

TEMP, F	1200	1200	1200	1200	1525	1400–1650
TIME (sec)	0.34	1.47	0.48	0.16	0.45	0.75



DEACTIVATION FURNACE SYSTEM (DFS) COMPARISON

	JACADS	CAMDS
1. RETORT		
a. Diameter, ft	5	4
b. Length, ft	30	30
c. Number of Sections	4	4
d. Operating Temp ($^{\circ}$F)	1000	1000
e. Operating Pressure, in. w.c.	-0.5	-0.5
f. Retort Speed, RPM	0.78	1
g. Burner Capacity, MBTU/hr	8.6	4.0
h. Fuel Type	JP-5 Jet Fuel	No. 2 Fuel Oil
i. Max Skin Temp ($^{\circ}$F)	1600	1400
j. Material	Rolled 310 SS	Cast HK40
k. Max Exhaust Temp ($^{\circ}$F)	1800	1300
l. Max Throughput, kkts/hr	47	20
m. Exhaust Gas Flow, SCFM	8300	2800
2. AFTERBURNER		
a. Operating Temp ($^{\circ}$F)	2000	1650
b. No. of Burners	2	2
c. Burner Capacity, MBTU/hr	13.5	8.0
d. Exhaust Gas Flow, SCFM	10,100	5400
e. Diameter, ft	5.0	3.25
f. Length, ft	27.7	24.0
3. HEATED DISCHARGE CONVEYOR		
a. Residence Time, min	15	15
b. Operating Temp ($^{\circ}$F)	1000	1000

4. CYCLONE		
a. Pressure Drop, in. w.c.	1.5	4

POLLUTION ABATEMENT SYSTEM (PAS) COMPARISONS

	JACADS	CAMDS
1. QUENCH TOWER		
a. Diameter, ft	8.5	3.5
b. Height, ft	34	12
c. Quench Liquid Rate, gpm	175	10.5
d. Nozzle Type(s)	Hydraulic	Atomized Air
e. Nozzle Location(s)	2 Banks	Top of Tower
f. Number of Nozzles	7 per bank	7
g. Emergency Nozzle Cap., gpm	90	35
h. Nominal Residence Time, sec	2.6	0.5
i. Water Droplet Size, microns	300	60-120
j. Quench Flow	Countercurrent	Cocurrent
k. Inlet Gas Flow, ACFM	44,100	15,000
l. Gas Inlet Temp (°F)	1800	1400
m. Outlet Gas Conditions	Saturated	Saturated
2. VENTURI SCRUBBER (Variable Throat)		
a. Type of Throat Control	Plug	Damper
b. Inlet Conditions	Saturated	Saturated
c. Pressure Drop, in w.c.	40	20
d. L/G Ratio, gal/1000 ACF	15	14
e. Theoretical Collection Efficiency (%) vs Particle Size (microns)		
0.2	61.6	44.7
0.4	85.2	69.4
0.6	94.3	83.1
1.0	99.2	94.8

3. PACKED BED SCRUBBER

a. Tower Diameter, ft	8.0	6.0
b. Packing Height, ft	6.0	6.0
c. L/G (gal/1000 ACF)	75	30
d. Packing Type	2-inch Pall Rings	2-inch Super Intalox Saddles
e. Liquid Distributor Type	Weir	Weir
f. Packing Material	SS	Polypropylene
g. Entrainment Sep Type	Wire Mesh	Wire Mesh
h. Entrainment Sep Wash	Yes	None
i. Scrubber Sump pH	8.0	8.5
j. Gas Velocity, lb/hr-sq ft	1300	900
k. Liquid Velocity, lb/hr-sq ft	19500	5700

4. DEMISTERS

a. Number of Elements	8	7
b. Total Surface Area (sq ft)	838	334
c. Face Velocity (ft/min)	29.7	20-40
d. Collection Efficiency, %	96	99
e. Mist Wash Rate, gpm	1	0.4-0.5
f. Element Material	Polyester	Polyester
g. Pressure Drop, in w.c.	6.5	25-30
h. Vessel Diameter, ft	13	6

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SECTION D-3

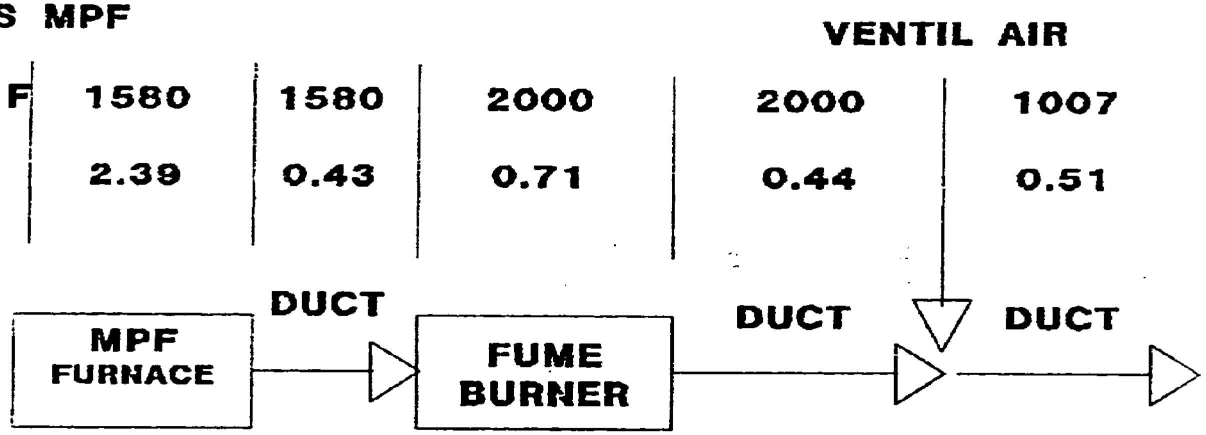
METAL PARTS FURNACE SYSTEM

MPF TIME–TEMPERATURE PROFILE

(8/14/87)

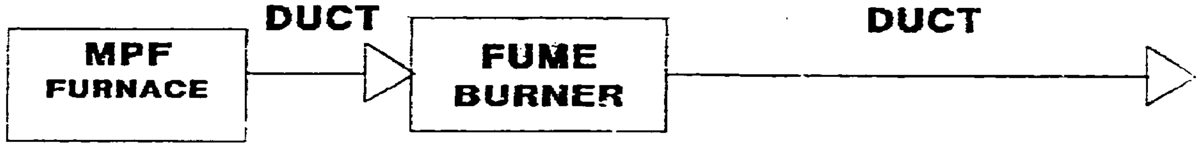
JACADS MPF

TEMP, F	1580	1580	2000	2000	1007
TIME (sec)	2.39	0.43	0.71	0.44	0.51



CAMDS MPF

TEMP, F	1000	1000	1400–1650	1400–1650
TIME (sec)	12.1	1.5	1.99	0.60



METAL PARTS FURNACE COMPARISON

1. FURNACE

a. No. of Chambers	1	1*
b. No. of Airlocks	2	0
c. Type of Atmospheres	Oxidizing	Reducing
d. Tray Capacity	3	1
e. Operating Temperature (°F)	1600	1000
f. Exhaust Air Flow, SCFM	1950	270
g. Operating Pressure, in. w.c.	-3	-5
h. Processing Rate (trays/hr)	3.8	0.83

* CAMDS MPF consists of 1 punch chamber, 1 volatilization chamber and 1 burnout chamber

2. AFTERBURNER

a. Operating Temperature (°F)	2000	1650
b. No. of Burners	2	4
c. Burner Capacity, MBTU/hr	2.5	1.5
d. Operating Pressure, in. w.c.	-4	-6
e. Max Gas Flow, SCFM	3600	4100
f. Diameter, ft	3.5	4.0
g. Length, ft	27	42

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SECTION D-4

MPF AND LLC POLLUTION ABATEMENT SYSTEMS COMPARISONS

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POLLUTION ABATEMENT SYSTEM (PAS) COMPONENT COMPARISONS

1. QUENCH TOWER	JACADS MPF	JACADS LIC	CAMDS LIC (MPF)
a. Diameter, ft	6.0	6.0	3.5
b. Height, ft	35	35	7
c. Quench Liquid Rate, gpm	58	68	4
d. Nozzle Type(s)	Hydraulic	Hydraulic	Atomized Air
e. Nozzle Location(s)	2 Banks	2 Banks	Top of Towers
f. Number of Nozzles	7 per bank	7 per bank	4
g. Emergency Nozzle Cap., gpm	30	35	35
h. Nominal Residence Time, sec	3.1	2.8	0.3
i. Water Droplet Size, microns	300	300	60-120
j. Quench Flow	Countercurrent	Countercurrent	Cocurrent
k. Inlet Gas Flow, ACFM	19,300	21,300	14,000
l. Gas Inlet Temp (°F)	1200	1150	1400
m. Outlet Gas Conditions	Saturated	Saturated	Saturated

2. VENTURI SCRUBBER (Variable Throat)	JACADS MPF	JACADS LIC	CAMDS LIC (MPF)
a. Type of Throat Control	Plug	Plug	Damper
b. Inlet Conditions	Saturated	Saturated	Saturated
c. Pressure Drop, in. w.c.	40	40	20
d. L/G Ratio, gal/1000 ACF	15	15	6-10
e. Theoretical Collection Efficiency (%) vs Particle Size			
0.2	61.6	61.6	44.7
0.4	85.2	85.2	69.4
0.6	94.3	94.3	83.1
1.0	99.2	99.2	94.8

3. PACKED BED SCRUBBER	JACADS		CAMDS
	MPF	LIC	LIC (MPF)
a. Tower Diameter	6.0	6.0	6.0
b. Packing Height, ft	10.0	10.0	10.0
c. L/G (gal/1000 ACF)	75	75	30
d. Packing Type	2-inch Pall Rings	2-inch Pall Rings	2-inch Super Intalox Saddles
e. Liquid Distributor Type	Dist Weir	Dist Weir	Dist Weir
f. Packing Material	SS	SS	Polypropylene
g. Entrainment Sep Type	Wire Mesh	Wire Mesh	Wire Mesh
h. Entrainment Sep Wash	Yes	Yes	None
i. Scrubber Sump pH	8.0	8.0	8.5
j. Gas Velocity, lb/hr-sq ft	1200	1300	900
k. Liquid Velocity, lb/hr- sp ft	18000	19500	5700
4. DEMISTERS			
a. Number of Elements	5	16	5
b. Total Surface Area (sq ft)	524	1676	283
c. Face Velocity (ft/min)	21.1	7.9	20-40
d. Collection Efficieny %	95	99	99
e. Mist Wash Rate, gpm	1	2	0.5
f. Element Material	Polyester	Polyester	Polyester
g. Pressure Drop, in. w.c.	5	5	25-30
h. Vessel Diameter, ft	11	11	6

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