# LARGE ROCKET MOTOR

# DEMILITARIZATION TECHNOLOGY REVIEW

# AND

# RESEARCH AND DEVELOPMENT FUNDING REQUIREMENT

# FOR

# FISCAL YEAR 1991-1992

TWENTY-FOURTH DOD EXPLOSIVES SAFETY SEMINAR

28-30 AUGUST 1990

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# ABSTRACT

As the result of increasingly stringent environmental regulations and public pressures, alternative disposal technologies for large rocket motor demilitarization must be developed to replace open burning and detonation. The restriction or loss of open burning and detonation disposal options could have a severe effect on the ICBM life cycle, since wastes are generated and must be dealt with at every step, from manufacturing through final disposition of the system. There is a critical need, then, to develop and transition new disposal technologies to the user that includes provisions for dealing with both 1.1 and 1.3 sensitivity category propellants. This need is particularly relevant since missiles containing over 150,000,000 pounds of solid propellant may have to be disposed of over the next few years.

In addition to waste disposal requirements at every stage of the ICBM life cycle, potential arms limitation treaties, if promulgated, will compound an already severe disposal problem. A mechanism must be established to identify maturing as well as emerging technologies and to provide sufficient resources and management emphasis to ensure promising technologies are developed within required time frames.

Nineteen large rocket motor demilitarization technologies and processes were reviewed and evaluated to determine the extent of the technical maturity and feasibility, engineering scale-up capability, and funding required for research and development efforts.

# INDEX

# INDEX OF TABLES, FIGURES, & CHART

# INTRODUCTION

## 1. Background

Millions of pounds of solid propellants are produced annually in the United States to support the Nation's missile and rocket programs. An acute requirement exists today, within the Government, to establish the capability of demilitarization and disposal of the excess inventory generated from the disarmament treaties, the military's on-going upgrading program for the existing missile systems, and the aging stockpiles.

The development of technology for the demilitarization and disposal of Large Rocket Motors (LRM) is fragmented in its cohesiveness as a complete, operational, and production system. It is recognized that there are pockets of well defined and developed technology bases addressing segments of demilitarization and disposal operations for LRMs within the military agencies, private industries, and the academic communities. Often environmentally correct solid propellant disposal technology developments are at their embryonic stages which require monitoring and coordination to bring to full maturity.

Realizing that there was insufficient commitment to research and development (R&D) activities for the demilitarization of solid propellant rocket motors in an environmentally acceptable manner within the military organizations, in July 1989 and again in November 1989, the United States Senate Armed Services Committee assigned the Director of Defense Research and Engineering (DDR&E) to establish a consolidated Solid Rocket Motor Demilitarization Research and Development Program. This precipitated Dr. Joseph V. Osterman, Office of the Under Secretary of Defense (Research and Advanced Technology) Environmental and Life Sciences (OUSDA[R&AT]ELS), to task Mr. John L. Byrd, Jr., Director, U.S. Army Defense Ammunition Center and School (USADACS), to provide an overview of the LRM demilitarization and disposal technology and to make recommendations for the fiscal year (FY) 90-92 funding requirements for the implementation of the LRM demilitarization and disposal program (Appendix A).

Parallel to this effort, in March 1989, the Joint Ordnance Commanders Group (JOCG) tasked the chairman of the JOCG Munition Demilitarization and Disposal Subgroup to develop a charter for the Joint Large Rocket Motor Demilitarization Office (JLRMDO) which will develop a Department of Defense (DOD) corporate solution for the demilitarization of LRMs. The JLRMDO will manage and coordinate the investigation, R&D, documentation, evaluation, maintenance of the technology base, and the resources control to support the LRM demilitarization and disposal program. This draft charter was presented to the JOCG at the Keyport, WA meeting in September 1989 (Appendix B).

The Office of the Scientific Advisor, USADACS, was tasked by the JOCG Munition Demilitarization and Disposal Subgroup, to imperatively conduct a survey of technology development efforts within the government organization, industry, and academic community, specifically for the LRM demilitarization and disposal program.

2. Scope

The purpose and limitation of this report is to selectively screen and review demilitarization technology development as applicable to the LRM demilitarization and identify the funding requirements to support the overall demilitarization efforts for FY 91-92 as requested.

3. Source of Information

A comprehensive assessment of LRM demilitarization and disposal technology would require critical and comparative evaluation of technical feasibility, engineering scale-up capability, process materials compatibility, demilitarization and disposal efficiency, operation safety, environmental impacts, and most importantly, construction and operation costs. Such a comprehensive study requires a long concerted effort by many engineers and scientists, and is beyond the scope of this report.

Notwithstanding, in writing this report, the author relies on the pertinent published reports, "Disposal of Solid Rocket Motor Propellants" by T. D. Wilson and T. Moskios at the Chemical Propulsion Information Agency (CPIA), "Solid Propellant Reclamation Study" by M. P. Coover and L. W. Pulter at Thiokol Corporation, and "Demilitarization Of Conventional Ordnance: Priorities For Database Assessment Of Environmental Contaminates" by D.W. Layton at Lawrence Livermore National Laboratory; literature surveys conducted at the U.S. Army Technical Center for Explosives Safety (USATCES) Technical Library; site visits for the currently available demilitarization technologies at Thiokol Corporation, Hercules Aerospace Inc., Lockheed Missiles and Space Research Center, Lawrence Livermore National Laboratory, Aerojet Strategic Propulsion Company, Environmental Systems Company, Ogden Environmental Services, Inc., Combustion Engineering Inc.; and the USADACS collective knowledge and expertise in dealing with energetic materials, including solid propellant, explosives, and pyrotechnics.

4. Technology Overview

There are two fundamentally contesting approaches, the reclamation or destruction techniques, to the LRM Solid Propellant Demilitarization and Disposal Program. The waterjet washout, the mechanical mining out, the solvation/solvolysis of the solid rocket propellants, and use of the recovered propellant as fuel supplement, obviously are some of the reclamation technologies. Whereas, the controlled incineration in a furnace, the biodegradation, the catalytic oxidations of the propellants belong to the destructive technology.

In many instances, both the reclamation and destruction technologies for the LRMs as they exist today are incomplete, overlapping, repetitive, fragmented and often have slight variations in identical unit operation equipment. Clearly, as stated, a systematic analysis of the LRM demilitarization and disposal technologies, regardless of the status, whether fully developed, emerging, conceptual, or past experimentations, would be exhaustive.

The process flow showing the major demilitarization technology for LRM is provided in Chart 1. The chart identifies the engineering knowledge gaps that exist between some of the major demilitarization process steps. Potential application and limitation of existing and emerging demilitarization technologies to the LRM Disposal Program, for the Army, are shown in Chart 2. Similar information for the Air Force and Navy is shown in Chart 3. Application of these technologies requires some finite R&D efforts to tie them together as a complete demilitarization system. As an example, the incineration is applicable to all propellant but the incineration of propellant must be proceeded by the removal process of the propellant in some form from the motor casing followed by the preparation of the material for the incineration. The engineering characteristics such as pumpability, material compatibility, separation, sedimentation, and safety must be carefully studied and engineered.

5. <u>Organization of the Report</u>

The LRM demilitarization and disposal technologies are discussed in four parts in chapter 3. The existing technology discussing the currently available demilitarization technology including washout, hogout, and incineration is given in the first section. The discussion of the past studies of applicable demilitarization and disposal works, including reclamation of Ammonium Perchlorate (AP) are given in the second section. These past development efforts merit recognition and discussion even though the research has been discontinued.

The third section discusses the emerging technologies, such as the U.S. Army Missile Command (MICOM) Super-Critical Fluid Extraction Method in which liquid-ammonia was used to recover AP. These R&D efforts require coordination, monitoring, and funding to evolve them into useful and applicable technology. The last section briefly discusses technology at conceptual stages which includes exotic approaches such as confined static firing. Funding requirements are discussed in chapter 4. The conclusions and recommendations are given in chapter 5.

## DEMILITARIZATION INVENTORY

1. <u>Military Services.</u>

As of 1986, the military's disposal inventory of all composite,

# MAJOR DEMILITARIZATION TECHNOLOGY FOR LARGE ROCKET MOTORS

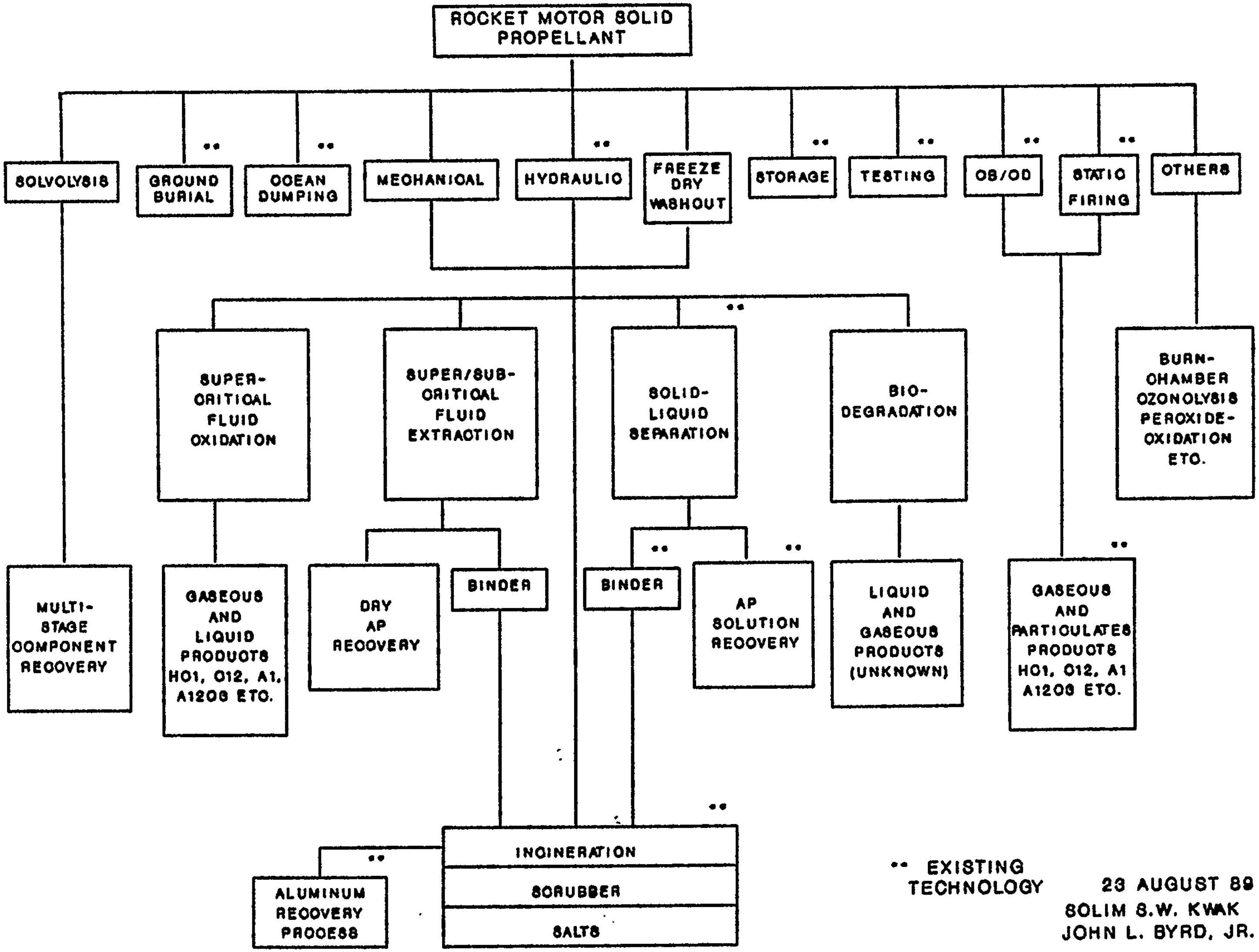



Chart 1.

DEMILITARIZATION TECHNOLOGY PROCESSES APPLICATION (ARMY)



| INVENTORY | PROPELLANT TYPE | WASHOUT* | SOLVATION | CONTROLLED INCINERATION | CRITICAL FLUIDS | BIODEGRADATION | ENERGY RECOVERY | OXIDATION |
|---|---|---|---|---|---|---|---|---|
| ATACMS | AP | Y | Y | Y | Y | NDA | Y | NDA |
| AAWS-M | TBD | NDA | NDA | NDA | NDA | NDA | NDA | NDA |
| CHAPARREL | XLDB | Y | NDA | Y | N | NDA | Y | NDA |
| DRAGON | DB | Y | NDA | Y | N | NDA | Y | NDA |
| FOTL | AP | Y | Y | Y | Y | NDA | Y | NDA |
| HAWK | AP | Y | Y | Y | Y | NDA | Y | NDA |
| HELLFIRE | XLDB | Y | NDA | Y | N | NDA | Y | NDA |
| HONEST JOHN | DB | Y | NDA | Y | N | NDA | Y | NDA |
| HYDRA-70 | DB | Y | NDA | Y | N | NDA | Y | NDA |
| JGLTR | AP | Y | Y | Y | Y | NDA | Y | NDA |
| LANCE | LIQ PROP | n/a | n/a | Y | n/a | N | Y | N |
| LOSAT | XLDB | Y | NDA | Y | N | NDA | Y | NDA |
| LOS-F-H (ADATS) | DB | Y | NDA | Y | N | NDA | Y | NDA |
| M-22 (SS-11) | DB | Y | NDA | Y | N | NDA | Y | NDA |
| MLRS | AP | Y | Y | Y | Y | NDA | Y | NDA |
| MPIM | DB | Y | NDA | Y | N | NDA | Y | NDA |
| MSAM | TBD | NDA | NDA | NDA | NDA | NDA | NDA | NDA |
| NIKE HERCULES, BOOST | DB | Y | NDA | Y | N | NDA | Y | NDA |
| NIKE HERCULES, SUSTAIN | AP | Y | Y | Y | Y | NDA | Y | NDA |
| NLOS (FOG-M) | TBD | NDA | NDA | NDA | NDA | NDA | NDA | NDA |
| PATRIOT | AP | Y | Y | Y | Y | NDA | Y | NDA |
| PERSHING IA | AP | Y | Y | Y | Y | NDA | Y | NDA |
| PERSHING II, BOOST | AP | Y | Y | Y | Y | NDA | Y | NDA |
| PERSHING II, SUSTAIN | AP | Y | Y | Y | Y | NDA | Y | NDA |
| REDEYE | AP | Y | Y | Y | Y | NDA | Y | NDA |
| ROLAND | DB | Y | NDA | Y | N | NDA | Y | NDA |
| SHILLELAGH, BOOST | AP | Y | NDA | Y | Y | NDA | Y | NDA |
| SHILLELAGH, SUSTAIN | DB | Y | NDA | Y | N | NDA | Y | NDA |
| STINGER | AP | Y | Y | Y | Y | NDA | Y | NDA |
| TOW | DB | Y | NDA | Y | N | NDA | Y | NDA |

*Waterjet 'Hogout' process is included in washout technology.

Y = Yes
N = No
n/a = not applicable
NDA = NO DATA AVAILABLE

AP = Ammonium Perchlorate
DB = Double Base
XLDB = Cross-Linked Double Base
LIQ = Liquid
TBD = To Be Determined

Chart 2.

APPLICATION OF

LARGE ROCKET MOTOR DISPOSAL TECHNOLOGY

| ITEM | MOTOR DIMENSIONS (IN)** LENGTH | DIAMETER | CHEMICAL COMPOSITION** | PROPELLANT WEIGHT POUNDS** | BIODEGRADATION | SUPERCRITICAL WATER OXIDATION | PROPELLANT REMOVAL/ REUSE | STATIC FIRING W/SCRUBBER |
|---|---|---|---|---|---|---|---|---|
| ARMY | | | | | | | | |
| NIKE HERCULES M30 SUSTAINER | 93 | 28 | AP/BINDER | 2,396 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| NIKE HERCULES M42 BOOSTER | 136 | 17 | DOUBLEBASE | 3,009 | CONCEPT | CONCEPT | *YES | CONCEPT |
| AIR FORCE | | | | | | | | |
| MM II, 1ST STAGE | 295 | 66 | AP/Al/PBAN | 50,250 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| MM II, 2ND STAGE | 162 | 52 | AP/Al/CTPB | 15,500 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| MM II, 3RD STAGE | 85 | 38 | CMDB | 4,250 | CONCEPT | CONCEPT | *YES | CONCEPT |
| MM III, 1ST STAGE | 295 | 66 | AP/Al/PBAN | 50,250 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| MM III, 2ND STAGE | 162 | 52 | AP/Al/CTPB | 15,500 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| MM III, 3RD STAGE | 91 | 52 | AP/Al/CTPB | 7,305 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| NAVY | | | | | | | | |
| POLARIS A-3, 1ST STAGE | 181 | 54 | AP/Al/BINDER | 20,800 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| POLARIS A-3, 2ND STAGE | 89 | 54 | CMDB | 15,900 | CONCEPT | CONCEPT | *YES | CONCEPT |
| POSEIDON C-3, 1ST STAGE | 188 | 74 | AP/Al/BINDER | 38,800 | BENCH DEMO | CONCEPT | YES | CONCEPT |
| POSEIDON C-3, 2ND STAGE | 97 | 74 | CMDB | 15,900 | CONCEPT | CONCEPT | *YES | CONCEPT |
| TRIDENT C-4, 1ST STAGE | 184 | 74 | HMX/AP/Al/BINDER | 38,900 | CONCEPT | CONCEPT | *YES | CONCEPT |
| TRIDENT C-4, 2ND STAGE | 97 | 74 | HMX/AP/Al/BINDER | 17,500 | CONCEPT | CONCEPT | *YES | CONCEPT |
| TRIDENT C-4, 3RD STAGE | 120 | 31 | HMX/AP/Al/BINDER | 4,800 | CONCEPT | CONCEPT | *YES | CONCEPT |

*SENSITIVITY OF HIGH PRESSURE FLUID JET IMPACT FOR CLASS 1.1 PROPELLANT HAS NOT BEEN ESTABLISHED.

**SOME OF THE INFORMATION LISTED IS POTENTIALLY SENSITIVE.

Chart 3.

Office of the Scientific Advisor
U.S. Army Defense Ammunition Center
and School
12 April 1990

doublebase, and modified doublebase propellants was 32.3 million pounds as reported in a CPIA study. The JOCG Munitions Demilitarization and Disposal Subgroup reported in 1989, that the current disposal inventory of the LRM propellant was over 3.2 million pounds. It is projected that the total demilitarization inventory will increase to 23.3 million pounds by 1995. During a JOCG conference, 13-14 February 1990, Eglin AFB, FL, the Army, Navy and Air Force reported there will be a total of 83.9 million pounds of solid propellant in the demilitarization inventory by FY 1996. The JOCG estimate did not include the propellants from the foreign military sales (FMS), the propellants which would result from the Strategic Arms Control Treaty (START), and the propellants from storage installations impacted by the military's proposed base closures.

2. Other Government Agencies

The disposal inventory of the LRM propellant among the government agencies such as the National Aeronautics and Space Administration (NASA) is not identified at this time. The NASA is currently pursuing an open-pit burning permit for the production rejects and scraps from its Advanced Solid Rocket Motor for the Space Shuttle Program.

3. Industry

The disposal inventory of the LRM propellant among the propellant production industry has not been identified at this time. Each propellant manufacturer has its own open-pit burning program for the disposal of the production rejects, scraps and excess propellant formulation during the motor casting process. It can be assumed that the disposal inventory will be substantial from the commercial production efforts.

REVIEW OF LRM PROPELLANT DEMILITARIZATION TECHNOLOGY

1. Introduction

The LRM Propellant demilitarization and disposal technology development efforts are fragmented. The segment of LRM demilitarization technology that has been developed is well defined and some has progressed through the development effort into the production stage. The LRM propellant disposal processes reviewed in this report were selected to demonstrate the extent of their maturity, applicability, and the cost to the government. In order to identify and facilitate the amount of fundings required to bring these technologies to a complete and unified process system, and to meet the governments needs, a description of essential process equipment and operation procedures is discussed for each technique, followed by a short narrative of the limitations of the process. An estimate of the development funding required is given in chapter 4.

2. Existing Technology

Twelve fully developed demilitarization technologies have been chosen for discussion. The first five reviewed are the washout methods, followed by one discussion on reclamation, and the rest are the controlled incineration processes.

a. Washout Technologies

(1) Thiokol Process

The Thiokol Corporation, Brigham City, UT, has a contract with the Navy to manufacture both Standard MK 104 missiles and the High Speed Anti-Radar Missile (HARM) motors. When a flawed motor is found, the motors are washed out and the cases are reused. The washout fixture will accept a missile motor from 10 to 60 inches in diameter with a maximum length of 220 inches. A 10,000 psig-120 gallon/minute waterjet is sprayed into the base of the missile through a bank of high pressure spray nozzles. The propellant is removed at a rate of approximately 1,500 pounds/hr. The waterjet cuts the propellant into small pieces which are removed in slurry form. The slurry is channeled to a screen where the solid propellant is collected and removed to be open-burned and the water is recycled.

Limitations: The holding fixtures and the washout nozzle will have to be redesigned to accommodate the LRM.

(2) Aerojet Process

The Aerojet Solid Propulsion Company, Sacramento, CA is operating a "hogout" operation to remove the propellant from the Minuteman Second Stage missile motors. The system is capable of removing about 1,000 pounds of propellant per hour. The missile motor is placed on a horizontal saddle and rotated during the hogout operation. The propellant is washed out and dewatered. The water is reused until it reaches a 10 percent AP concentration and sold to explosives manufacturers. The residue is packed into plastic-lined fiber drums and open burned on sand-lined concrete pads. The aerojet AP recovery process and incinerator are discussed in later sections.

Limitations: This process is a fully developed production scale operation.

(3) Western Area Demilitarization Facility (WADF) Process

The WADF, Hawthorne, NV has a Washout System located in the south tower of the Washout/Steamout Building. This washout system is designed to remove two types of press-loaded explosives, Explosive A3 and Explosive D, from medium and major caliber gun ammunition items. Explosive A3 is removed from projectiles by use of cold water at a pressure up to 15,000 psig, while Explosive D is removed by use of $195^{o}$ F water at 80 psig.

Two different methods are used for holding the projectiles while the explosives are removed; a washout turntable for projectiles ranging in size from 3 inches through 6 inches and a washout chamber for those from 8 inches through 16 inches. When items containing Explosive A3 are being processed, the mixture of water and explosives from the washout turntable are directed to a dewatering screen and separated. The contaminated water is directed to the Water Treatment Facility and the Explosive A3 is dried, weighed, packaged, and reclaimed. The Explosive D slurry from the washout process is directed from the turntable to the slurry collection tank where the materials are kept hot and stirred to prevent settling and caking. The material from the slurry collection tank is processed (grinding) and burned in the rotary kiln incinerators. Figure 1 shows a flow diagram of the Washout System. Figure 2 shows the arrangement of the washout system in the south tower.

Limitations: The washout/steamout building is configured to accommodate various sized projectiles. The building was designed to be modified as new methods and technologies emerged to replace outdated processes.

(4) Naval Weapons Support Center Crane (NWSCC) Process

The NWSCC, Ordnance Engineering Department, has contracted the University of Missouri-Rolla (UMR), since 1982, to investigate the use of high pressure waterjets to remove plastic bonded explosives (PBX) from a variety of ordnance. An automated pilot system, the Waterjet Ordnance and Munitions Blastcleaner with Automated Tellurometry (WOMBAT), for removal of PBX from munitions has been designed, fabricated, installed and tested at UMR. The WOMBAT is a multi-tasking computer monitored and controlled, state-of-the-art, system for maneuvering the waterjet lance through a variety of different geometries to be encountered in the various munitions. The WOMBAT is located in an underground facility at the UMR experimental mine.

Limitations: The WOMBAT device would have to be sized for the LRM demilitarization and disposal program.

(5) Flow International Corporation Process

The Flow International Corporation, Kent, WA manufactures ultrahigh-pressure waterjets and abrasive jets for industrial cutting and milling. The ultrahigh-pressure intensifier pump pressurizes water up to 55,000 psi and forces it through a nozzle, as small as 0.004 inches in diameter, generating a high velocity waterjet at speeds up to 3,000 feet per second. This waterjet can cut a variety of non-metallic materials. To cut metallic or hard materials, a mixing device that entrains abrasives such as garnet or aluminum oxide into the waterjet has been developed to enhance the cutting capability.

The abrasivejet cuts with little heat, causes no metallurgical changes, can operate underwater, and leaves a quality edge that usually requires no

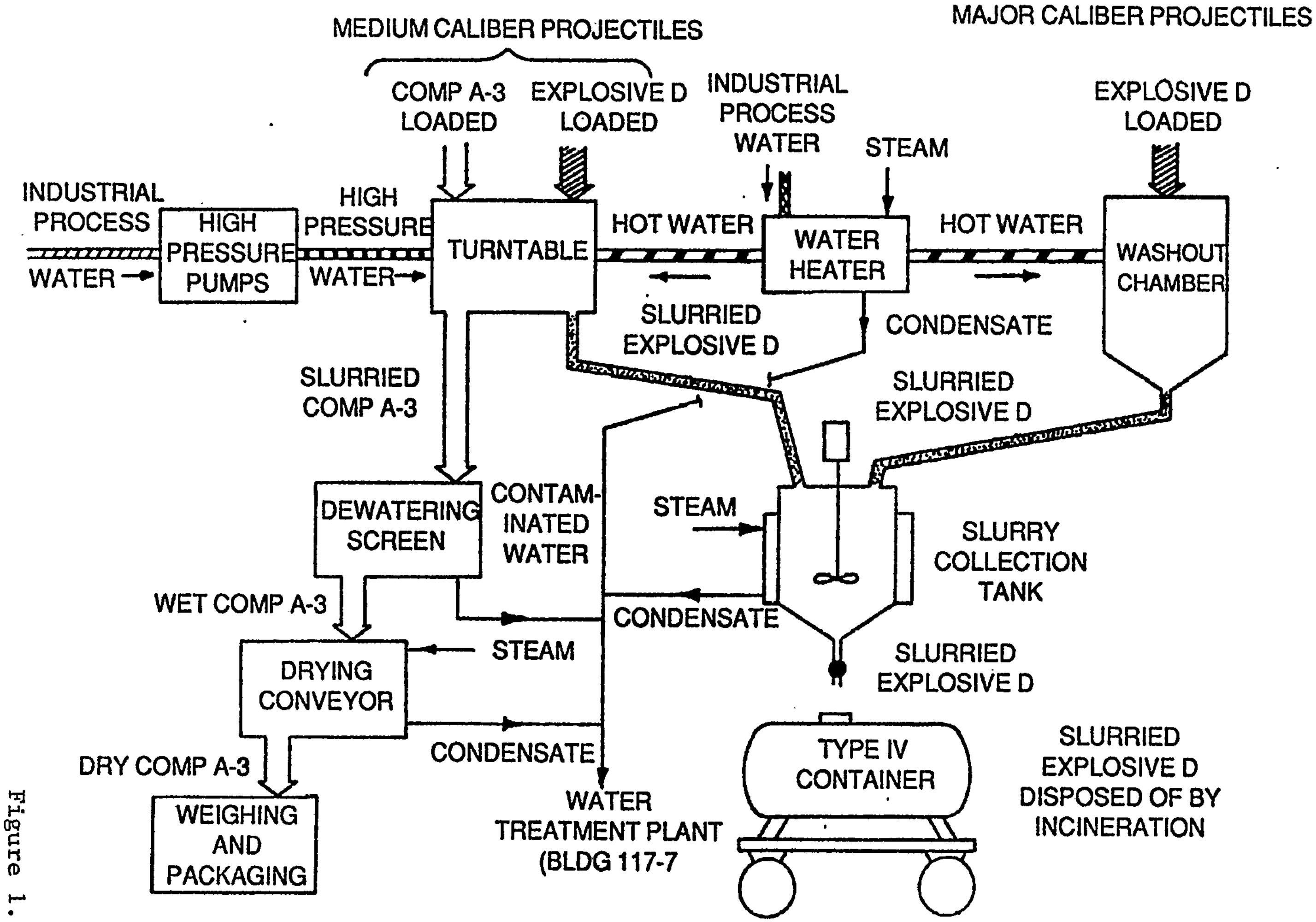



Figure 1.

FLOW DIAGRAM OF THE WASHOUT SYSTEM

665,

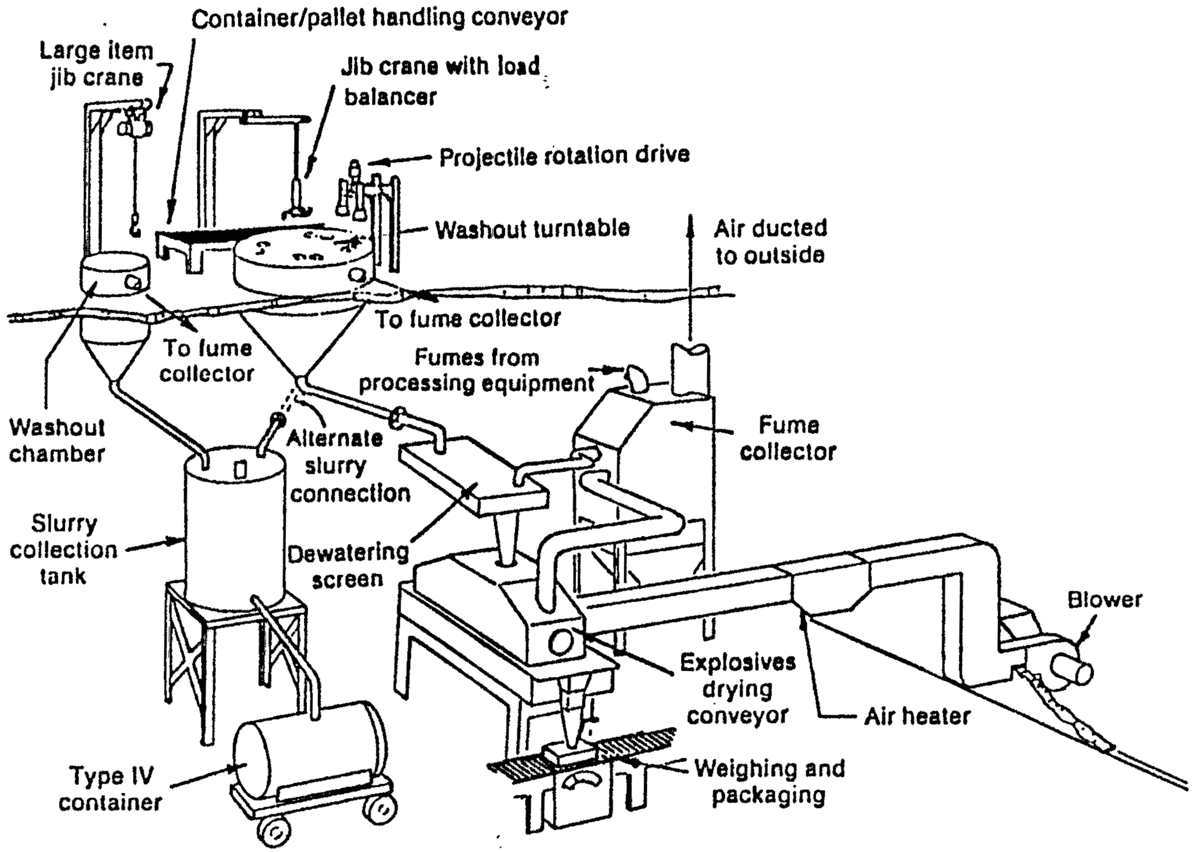



Figure 2.

CONCEPTUAL ARRANGEMENT OF THE SOUTH TOWER additional finishing. The abrasivejet is easily integrated with computer controlled motion systems. The abrasivejet cutting head can be remotely operated. Figure 3 shows a line drawing of the abrasivejet cutting nozzle. Figure 4 shows a schematic of the intensifier system.

Limitations: This technology could be adapted for removal of the solid propellants and energetic materials. Nozzle design will have to be optimized for propellant hogout operation. The high velocity sensitivity of waterjet impacting on the propellant has not been established.

b. Reclamation Technology

(1) Aerojet Process

The Aerojet Solid Propulsion, Central Waste Management, Sacramento, CA has developed a full scale Propellant Thermal Processor (PTP) system equipped with AP recovery capability and binder separation system. This unit will remove approximately 95 percent of the AP contained in class 1.3 propellant.

The reclaimed AP solutions is sold as a raw material to AP manufacturers. The residue that contains binder, aluminum, and 5 percent AP is incinerated in the two-stage PTP incinerator. Aerojet's initial requirement was to design a plant that would process approximately 2 million pounds of class 1.3 propellant per year. The final upgraded system would be able to handle 3 million pounds per year operating at 60 percent duty cycle. Figure 5 shows a line schematic of the proposed recovery process from a hogout operation.

Limitations: The washout and the AP recovery solvation system requires further process refinement.

c. Incineration Technology

(1) Rotary Kiln Process

The WADF, Hawthorne, NV has two refractory lined rotary kiln incinerators that are a part of the Bulk Incineration System (BIS). This BIS was designed to receive, prepare, and incinerate explosive slurry materials transported from the various demilitarization buildings. The explosives slurry feed rate may be varied from 0 to 10 gpm. The incinerators are equipped with a variable speed drive which is capable of rotating the incinerator body at the speed range of 1/2 to 6 rpm. A fuel oil burner is located at the discharge end of the incinerator and provides the heat required to maintain the incinerator body temperature and to burn slurry. The afterburner is located downstream from the rotary kiln body. It is a refractory lined chamber equipped with two burners that insure that all of the combustibles in the effluent gases are destroyed and emissions are reduced to acceptable environmental levels.

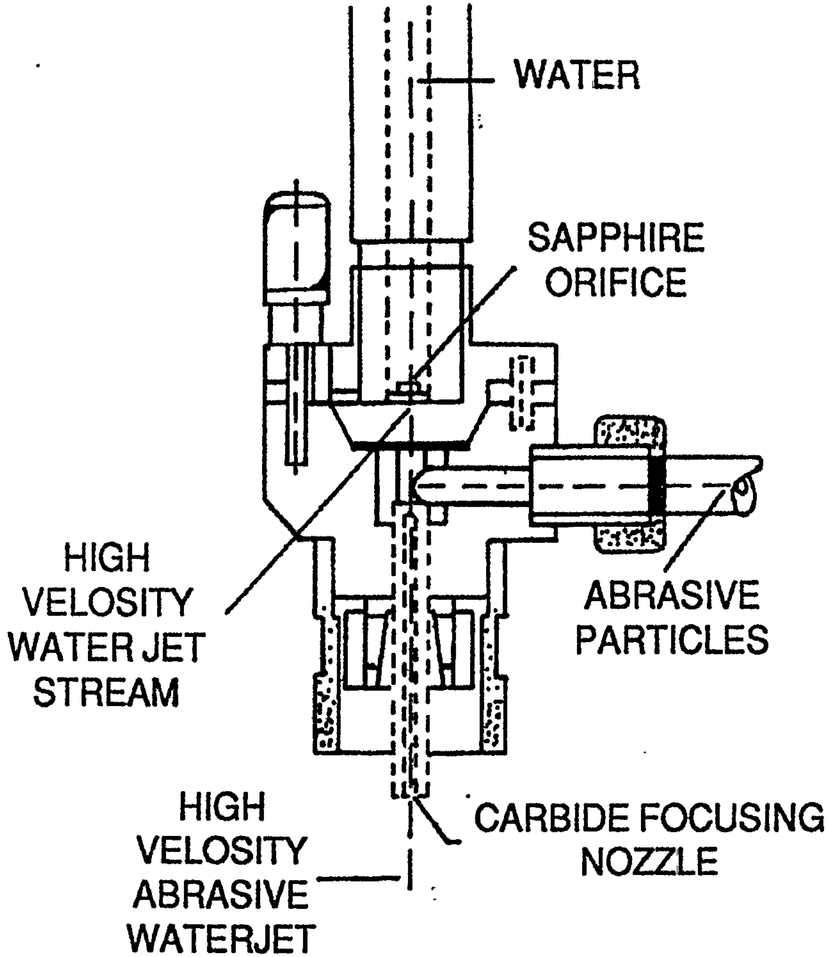
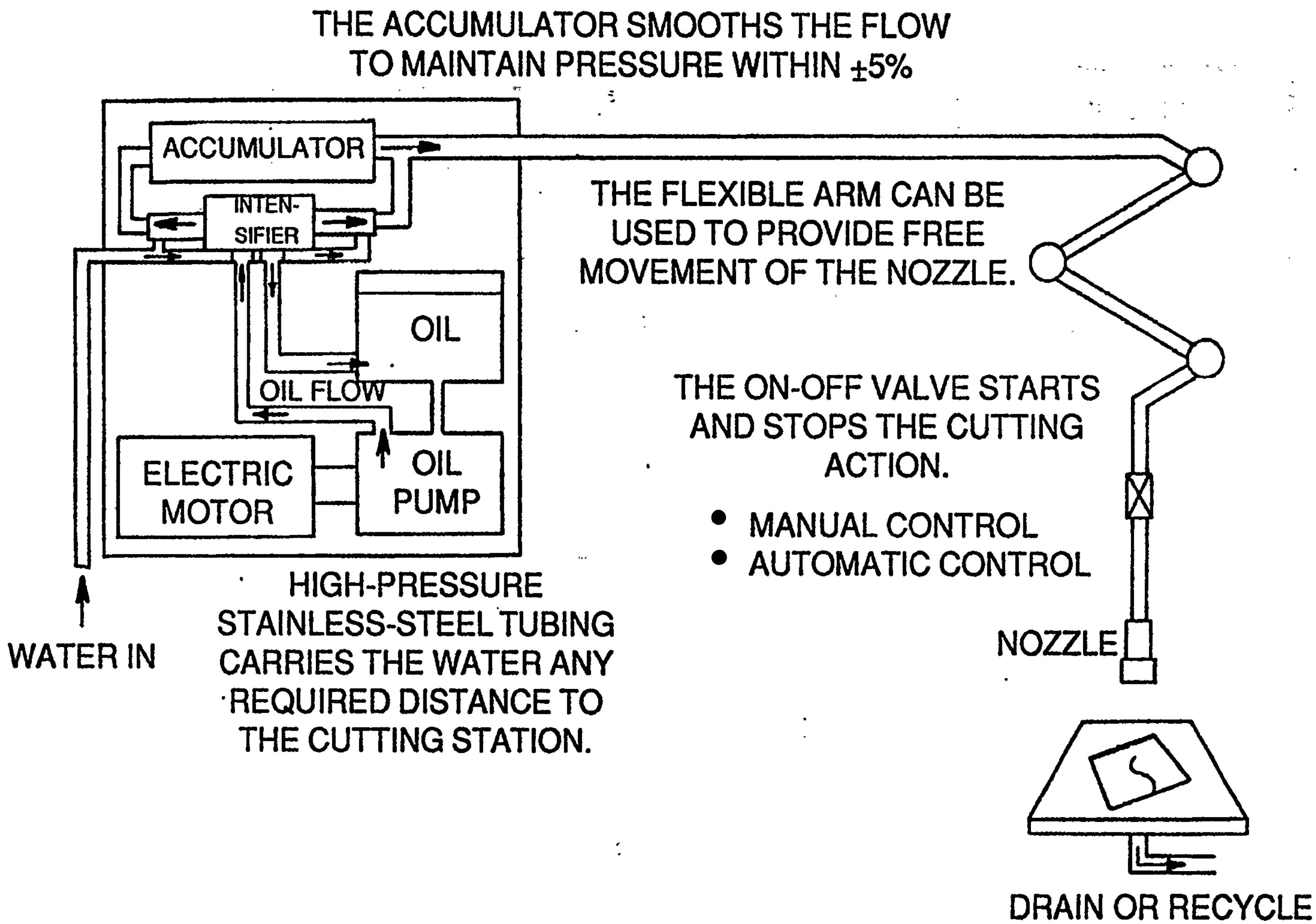



Figure 3.

CROSS-SECTION OF FLOW's ABRASIVEJET CUTTING NOZZLE




SCHEMATIC OF THE INTENSIFIER SYSTEM

Figure 4.

# PTP SYSTEM WITH AP RECOVERY

UNIT BASIS IS 1,000,000 POUNDS 1.3 PROPELLANT

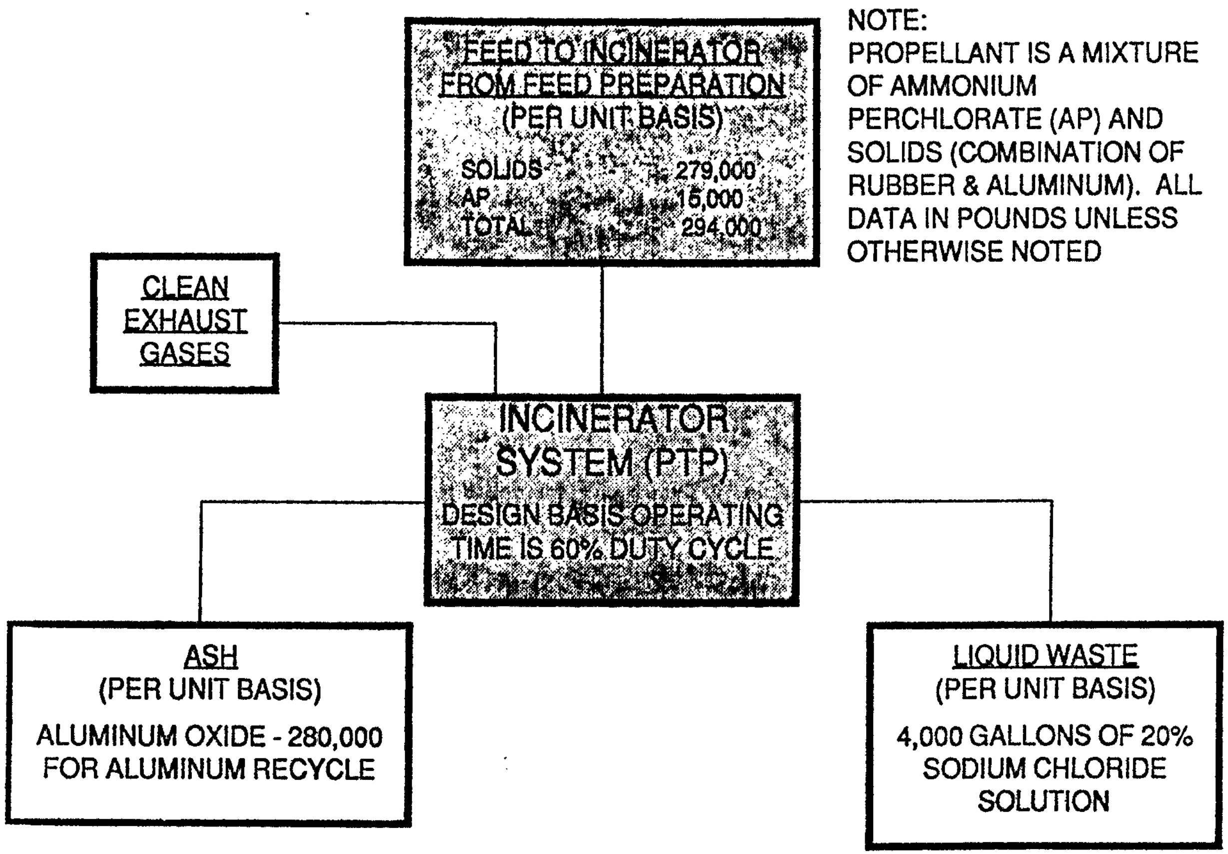



Figure 5.

Pink water has been processed through the incinerator at a rate of 5 gpm with a rotary kiln temperature of 1000 F and an afterburner temperature of 1750 F. Otto fuel incineration tests have been conducted using the rotary kiln temperature of 1600 F with an afterburner temperature of $2200^{o}$ F, showing the versatility of this incineration system. Figure 6 shows the location of the incinerators relative to the Bulk Explosives Disposal Building, which could be used in the preparation of the LRM propellant slurry.

Limitations: The incinerator has been used to burn a variety of hazardous materials including explosives slurries, however, the disposal of LRM propellants slurry has not been demonstrated.

(2) Aerojet Propellant Thermal Processor (PTP) System

Aerojet developed a two chamber incinerator system to burn propellant residue, aluminum, binder, and 5-10 percent ammonium perchlorate, from the hogout/AP recovery operations. The initial reductive incineration is conducted at $1850^{o}$ F and leaves a reclaimable aluminum. The second incineration, the oxidation process, is conducted at $2100^{o}$ F to complete the combustion and destroy any remaining organics in the gaseous effluent from the initial incineration. The hot gases are cooled and scrubbed to remove particulates and hydrogen chloride gas. For every one-million pounds of class 1.3 propellant burned in the system, there will be approximately 4000 gallons of scrubber liquid waste (inorganic salts) that the Aerojet is disposing of by deep-well injection at a cost of $1.00/gallon. Figure 7 and Figure 8 show a line schematic material balance and a system schematic of the incineration process respectively.

Limitations: The existing incinerator system is now operational for the disposal of the propellant residue.

(3) Explosive Waste Incinerator (EWI) Process

The EWI, similar in design and operation to the Ammunition Peculiar Equipment (APE) 1236 Deactivation Furnace System, was developed by the U.S. Army. There are four major components; a Deactivation Furnace, a Positive Feed System, an Air Pollution Control System, and Equipment Control Panels.

The pollution control system is consisted of a low temperature ($1000^{o}$ F to 250 F) heat exchanger, a cyclone dust collector, a baghouse, and a draft fan. There are plans to upgrade the EWI with an afterburner, a high temperature heat exchanger, and a new control system. Also, it will have a shrouded containment system similar to the upgraded APE 1236 Deactivation Furnace System. Figure 9 shows the facility layout.

Limitations: The disposal of LRM propellants has not been demonstrated. A positive propellant slurry feed system has to be developed.

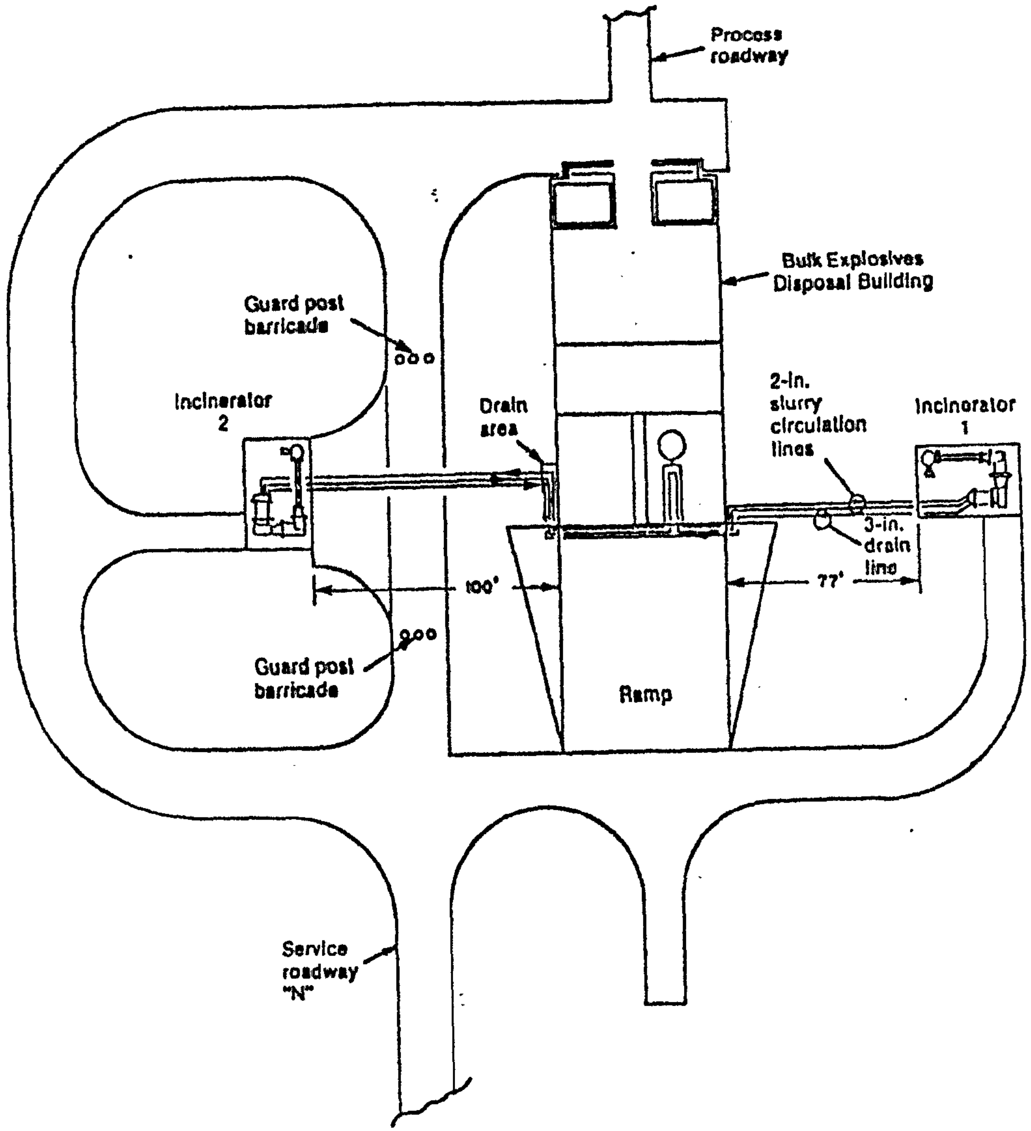
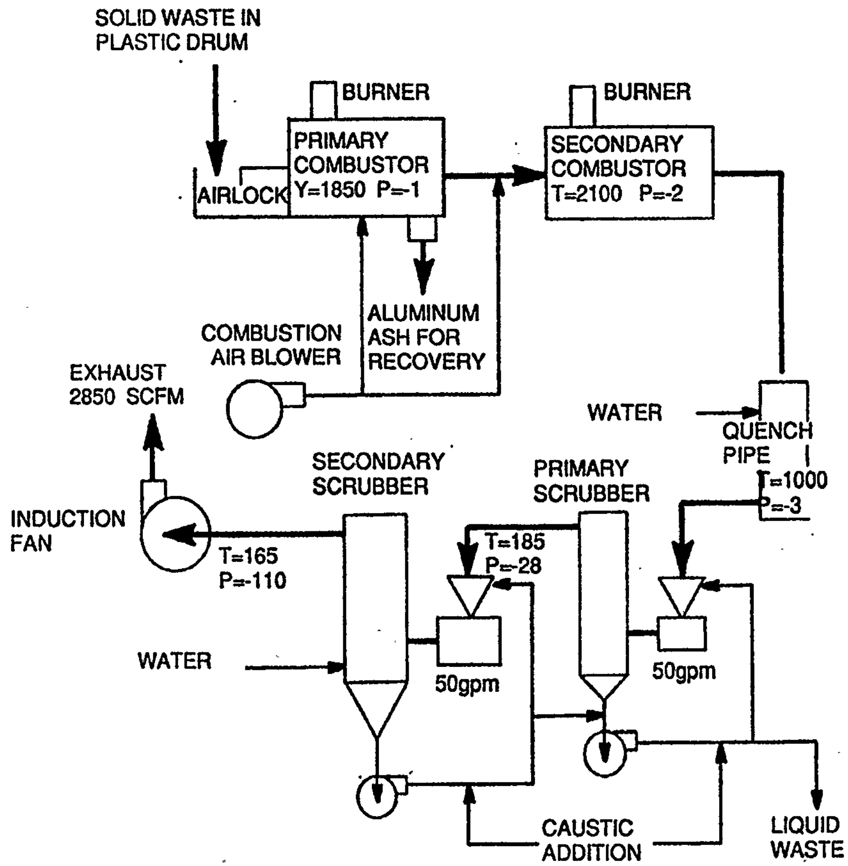



Figure 6.

ARRANGEMENTS OF INCINERATORS RELATIVE TO THE BULK EXPLOSIVES DISPOSAL BUILDING

## PROPELLANT THERMAL PROCESSOR SYSTEM SCHMETIC




NOTE:
TEMPERATURE (T) IS IN DEGREES FAHRENHEIT
PRESSURE (P) IS IN INCHES OF WATER COLUMN

Figure 7.

# PTP SYSTEM WITH AP RECOVERY
# FEED PREPARATION FOR PROPELLANT WASTE

UNIT BASIS IS 1,000,000 POUNDS 1.3 PROPELLANT

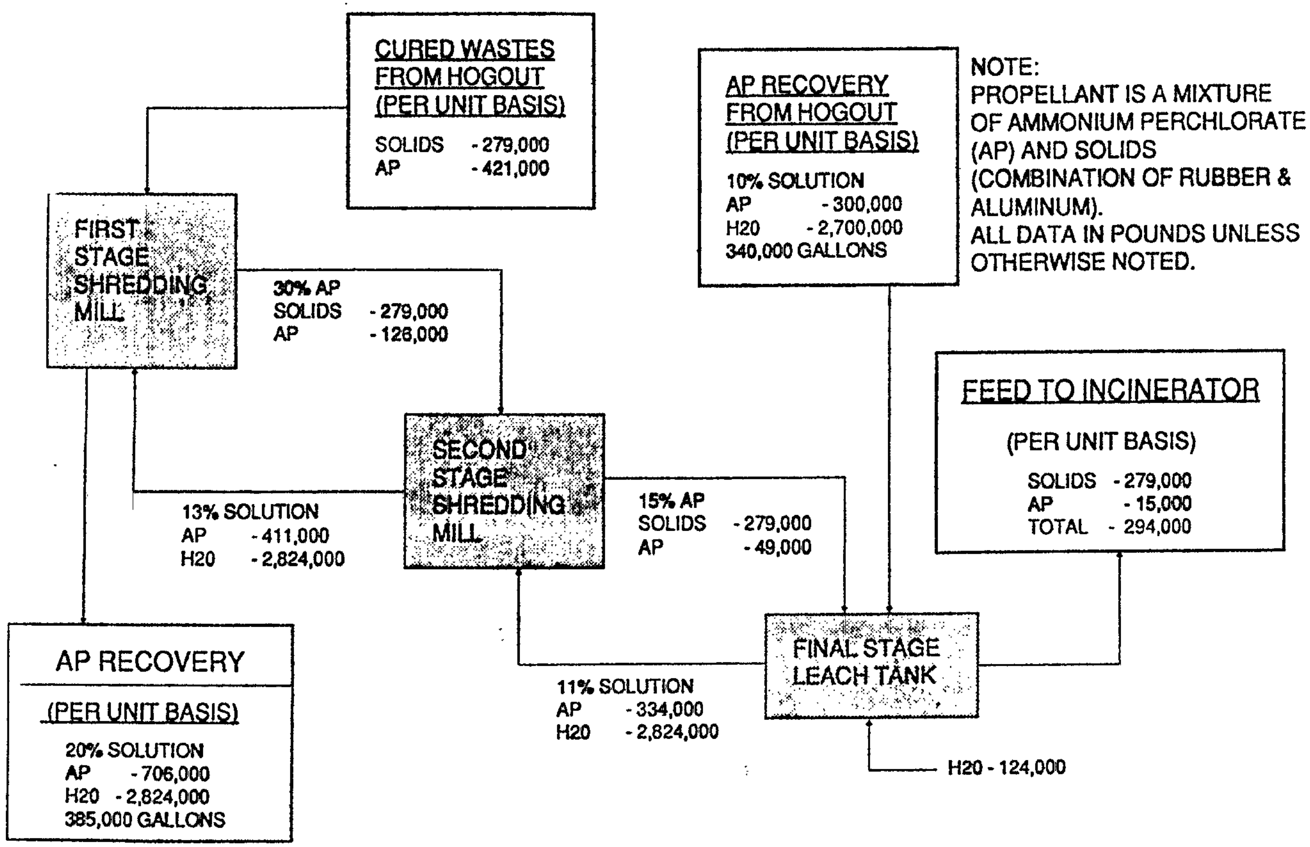



Figure 8.

675

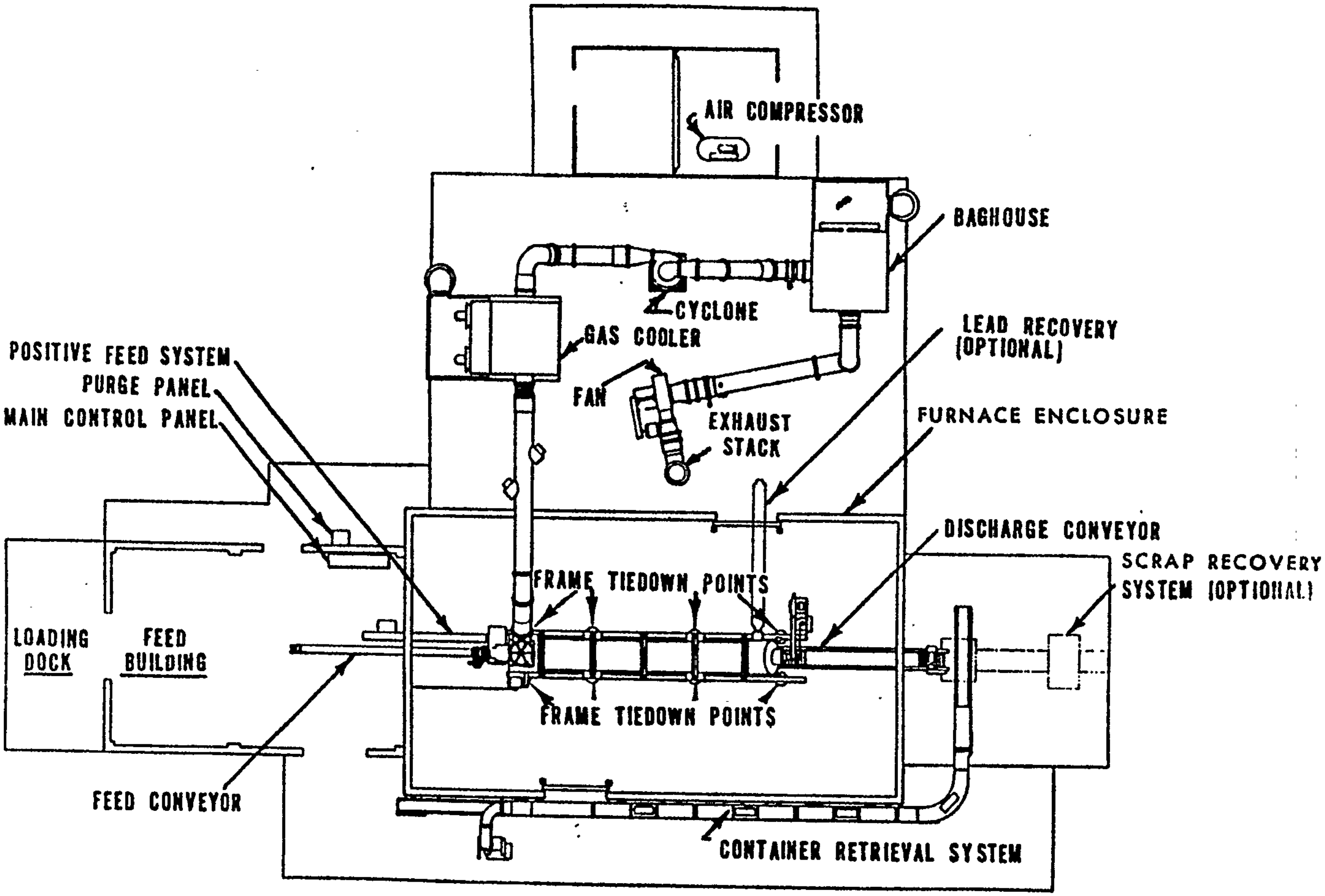



Figure 9.

EQUIPMENT INSTALLATION LAYOUT

(4) Environmental Systems Company (ENSCO) Process

Environmental Systems Company (ENSCO), El Dorado, AR operates a Hazardous Waste Disposal Facility on a commercial basis. Two systems, fixed base and transportable are reviewed.

(a) Fixed Base System

The liquids wastes are pumped directly into the Thermal Oxidation Unit (TOU), a two chamber combuster, while solid wastes are fed into the two rotary kilns through a hopper/shredder/auger feed system. The kiln off-gases are passed through vertical cyclones where ash is removed and the ashless gases from the cyclone travel through a ductway to the first chamber of the TOU. The complete combustion is ensured by burning the effluent gases again in the second chamber of the TOU. In the scrubber, the gas streams are cooled to 200°F and acid gases are neutralized with a lime slurry. The gases exiting the top of the scrubber pass through the Venturi Jet for additional scrubbing to ensure removal of any remaining entrained particulates. Some of the pertinent physical combustion characteristics of the fixed based units are described as follows:

| Fixed Base System | Operating Temperature | Retention Time |
|---|---|---|
| Rotary Kiln #1 | 1750-1900 F | 3/4-1.5 hr (solids) |
| Rotary Kiln #2 | 1750-1900 F | 1/2-2.0 hr (solids) |
| Primary Combustion | 2200-2500 F | 2.5 sec |
| Secondary Combustion | 1800-2400 F | 2.0 sec |
| Waste-Fired Boiler | 1800-2400 F | 2.0 sec |

Figure 10 shows a process schematic for the "fixed base" system.

(b) Transportable System

The Modular Waste Processor (MWP) 2000 consisting of a rotary kiln, an afterburner, a waste heat recovery system, an acid gas neutralization and an air pollution control train, is a stand alone, transportable incineration system. At the ENSCO, the MWP 2000 operates independently except that it utilizes and depends on the waste receiving, the store, and scrubber brine clarifier units of the main fixed base facility. The process is similar to that of the main facility with corresponding pieces of equipment performing similar duties. The MWP 2000 processes 120,000,000 pounds/year of hazardous waste materials at an operating cost of approximately 1.00/lbs. Figure 11 shows the process flow diagram of the MWP 2000 System.

<u>Limitations:</u> The capability of processing energetic materials using these furnaces has not been proven.

(4) Fluidized Bed Incineration (FBI) Process

The FBI at Pine Bluff Arsenal incineration complex has a thermal

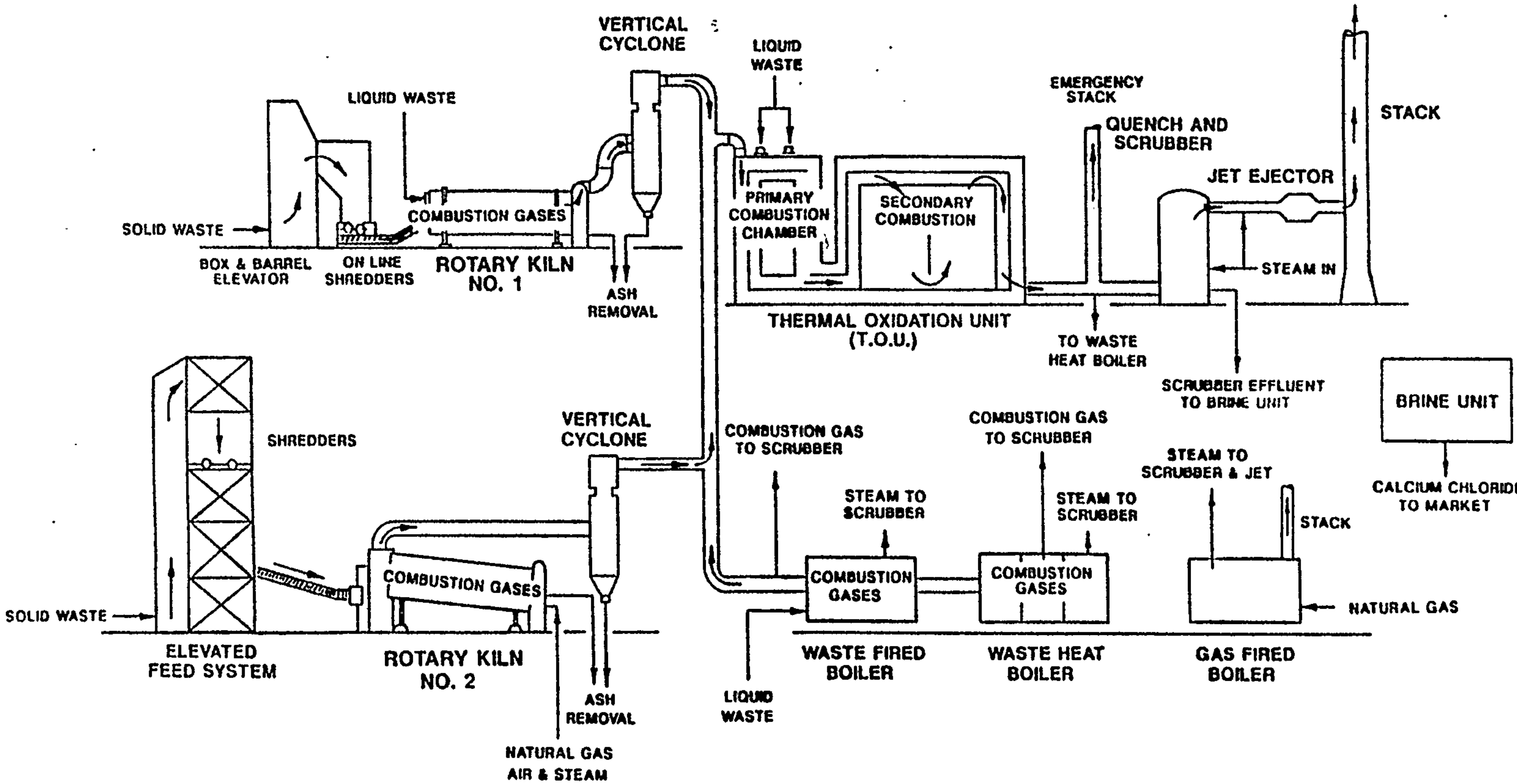



Figure 10.

PROCESS SCHEMATIC INCINERATION SYSTEM

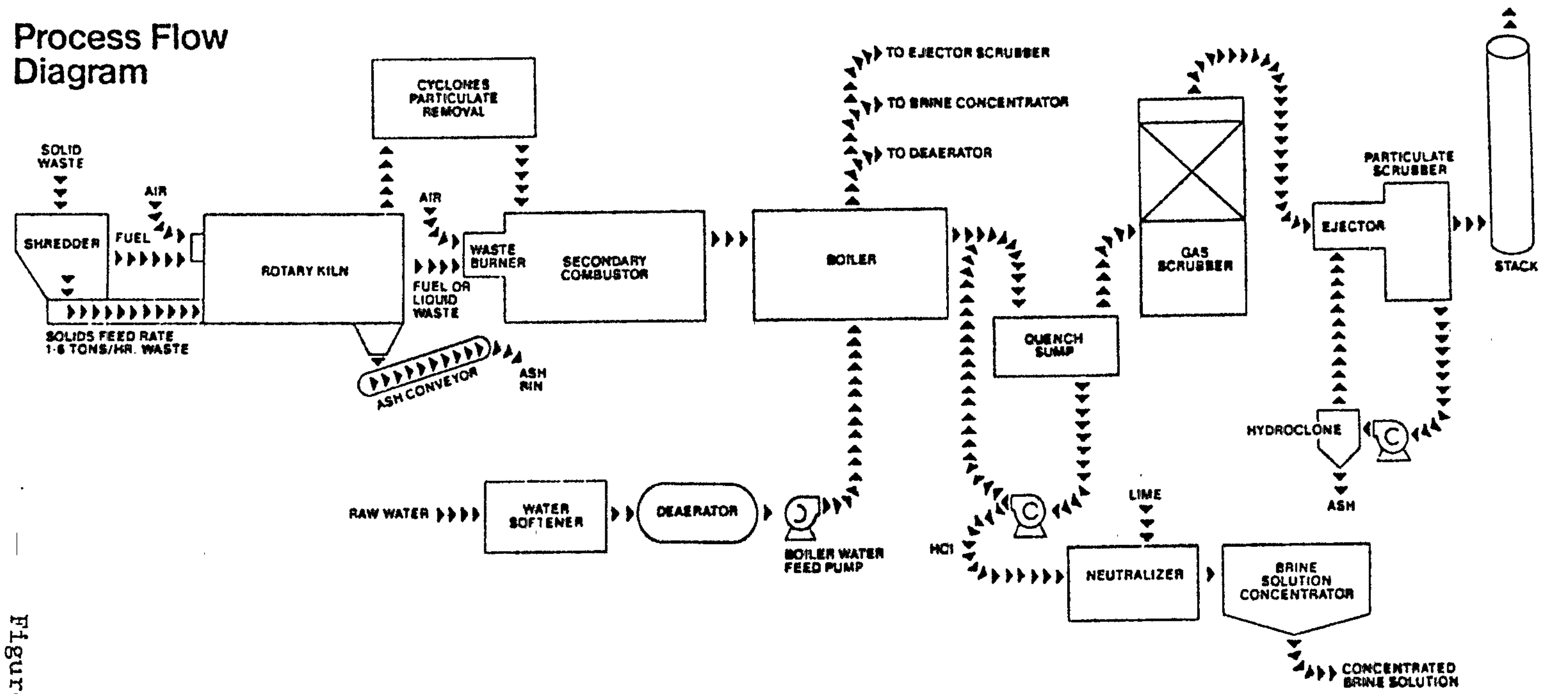

Process Flow Diagram
SOLID WASTE
AIR
SHREDDER
FUEL
ROTARY KILN
SOLIDS FEED RATE 1-6 TONS/HR. WASTE
ASH CONVEYOR
ASH BIN
CYCLONES PARTICULATE REMOVAL
AIR
WASTE BURNER
FUEL OR LIQUID WASTE
SECONDARY COMBUSTOR
BOILER
TO EJECTOR SCRUBBER
TO BRINE CONCENTRATOR
TO DEAERATOR
RAW WATER
WATER SOFTENER
DEAERATOR
BOILER WATER FEED PUMP
QUENCH SUMP
GAS SCRUBBER
HCl
LIME
NEUTRALIZER
BRINE SOLUTION CONCENTRATOR
CONCENTRATED BRINE SOLUTION
PARTICULATE SCRUBBER
EJECTOR
HYDROCLONE
ASH
STACK

Figure 11.

capacity of 26,000,000 BTU/hr. The FBI uses high velocity air to entrain solids in a highly turbulent combustion chamber. The bed media is 8 feet, expanded height, of silica sand. This thermal mass stabilizes the combustion temperature and allows for efficient heat transfer to the material being processed. Materials are fed into the FBI in liquid, slurry, or solid form. The combustion gas stream passes through a Cyclone Separator for removal of large particulates (5 microns), a gas quench tower and a variable throat wet venturi scrubber for removal of acid gases and fine particulates prior to discharge to the stack. Pine Bluff Arsenal is currently procuring a hydro-sonic scrubbing system that will remove particulates down to .02 micron size, which is well below the current environmental standards.

Limitations: The FBI technology is fully developed. The disposal of LRM propellants has not been demonstrated.

(5) Circulating Bed Combuster (CBC) Process

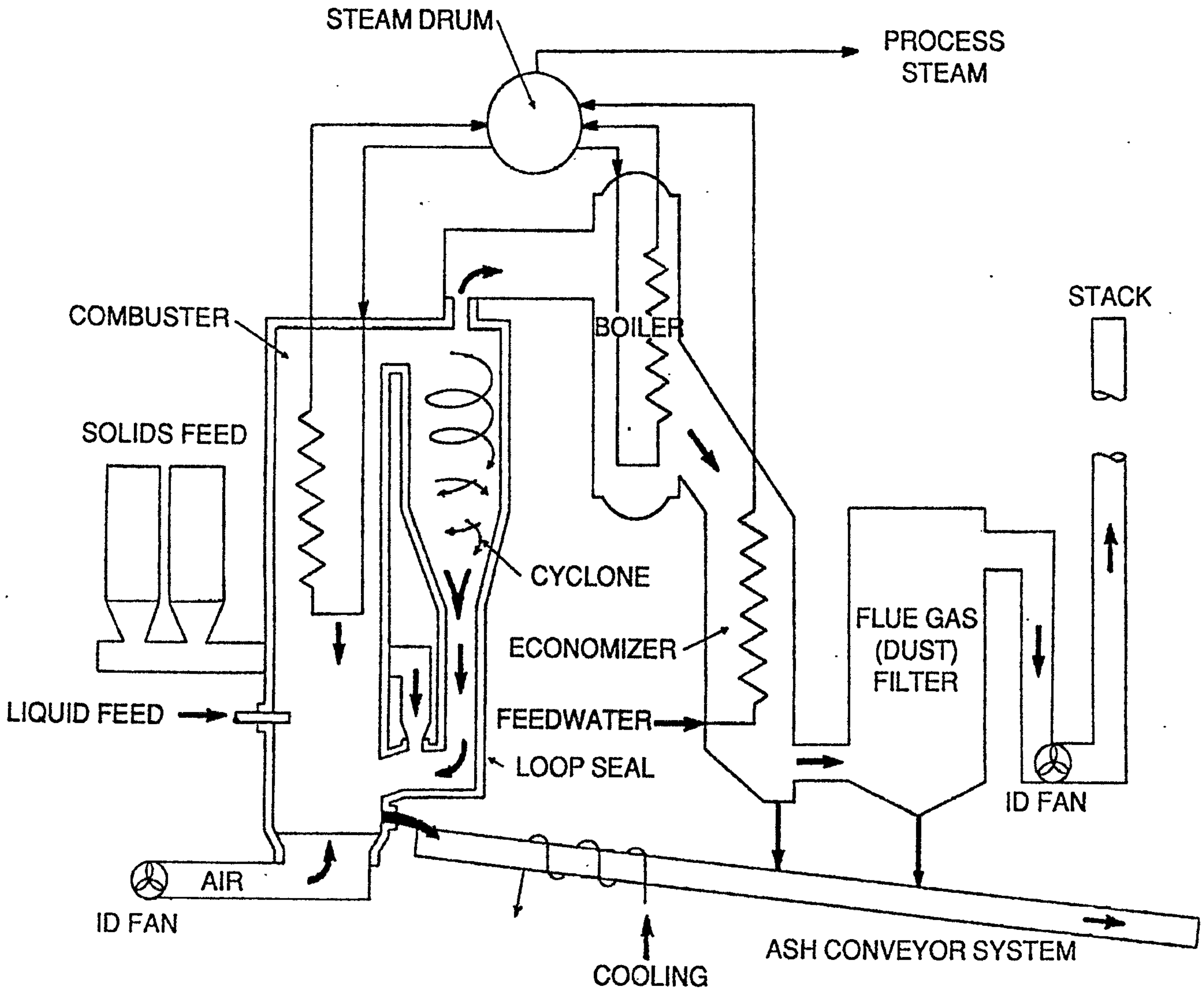
The Ogden Environmental Services Inc., San Diego, CA has developed a CBC which has evolved from the FBI technology. The main differences between the FBI and CBC is that the CBC has a lined cyclone separator in which the additional combustion is sustained, the larger feed materials separated and returned to the combustion chamber. The CBC uses high velocity air (14 to 20 ft/sec) to entrain and circulate solids in a highly turbulent combustion loop. The system design allows combustion along the entire length of the FBI, cyclone, and connecting loop. Due to its high thermal efficiency, the CBC is suited to treat feed with low heat content, such as contaminated soil.

Contaminated wastes are fed into the combuster at the loop seal section where it immediately mixes with hot recirculating material from the cyclone. The retention times in the combustor range from 1.5 to 2 seconds for gases to more than 30 minutes for larger feed materials (more than 1.0 inch in diameter). Hot flue gases and fly ash pass through a convective gas cooler and on to a baghouse where fly ash is removed. The clean solid such as soil in the bottom of the combustor bed is slowly removed by a water cooled ash conveyor system. Temperatures within the entire combustion loop (combustion chamber, hot cyclone, return leg) are maintained at $1800^{o}$ F. Figure 12 shows the process flow schematic.

Limitations: The technology is fully developed and operational. The disposal of LRM propellants has not been demonstrated. A propellant slurry feed system will have to be developed.

3. Past Experiments

Two technologies, reclamation and wet air oxidation, have been reviewed that may be applicable to the LRM demilitarization and disposal program.




**CBC PROCESS FLOW SCHEMATIC**

Figure 12.

a. Reclamation Technique - Hydraulic Macerator Solvation

The Thiokol Corporation, Brigham City, UT conducted a study in 1982 for the Air Force Wright Aeronautical Labs, Materials Laboratory, Wright Patterson Air Force Base (AFB), Ohio on solid propellant reclamation. The process extracts and recovers AP from the scrap propellant. Scrap propellant is charged into a hydraulic macerator where high pressure waterjets cut the propellant into small particles and extracts the AP into solution. The concentrated solution from the macerator is passed through a liquid cyclone and in-line filters to remove suspended solids and then cooled in batch crystallizers to precipitate the AP crystals. The AP crystals are separated from the cooled solution in a basket centrifuge and are recovered in a wet cake. The cooled water is reheated and recycled to the hydraulic macerator. Figure 13 and Figure 14 show a schematic diagram of the process and the hydraulic macerator, respectively.

Limitations: The through put was small. No further development is planned.

b. Wet Air Oxidation (WAO) Technique

The Navel Ordnance Station (NOS), Indian Head, MD, has investigated WAO as an alternative to open burning for the disposal of waste propellants and other energetic materials. The operation of WAO is based on an aqueous phase oxidation of energetic materials using heat and air in a high-pressure reactor. The materials most commonly oxidized in WAO are those which contain a large amount of water that cannot easily sustain combustion under conventional burning conditions. The waste sludge is ground under water to 1/4-inch size before entering the storage tank where it is preheated to $60^{o}C$ to $80^{o}C$. The feed stock is fed into the system by a positive-displacement high-pressure pump and mixed with an appropriate amount of air supplied by a compressor. The pressure of the system is maintained from 150 to 4,000 psig depending upon the fuel concentration. The mixture of air and feed stock passes through a series of heat exchangers to increase its temperature to about $200^{o}C$, the point at which oxidation will proceed spontaneously. Figure 15 shows the process schematic.

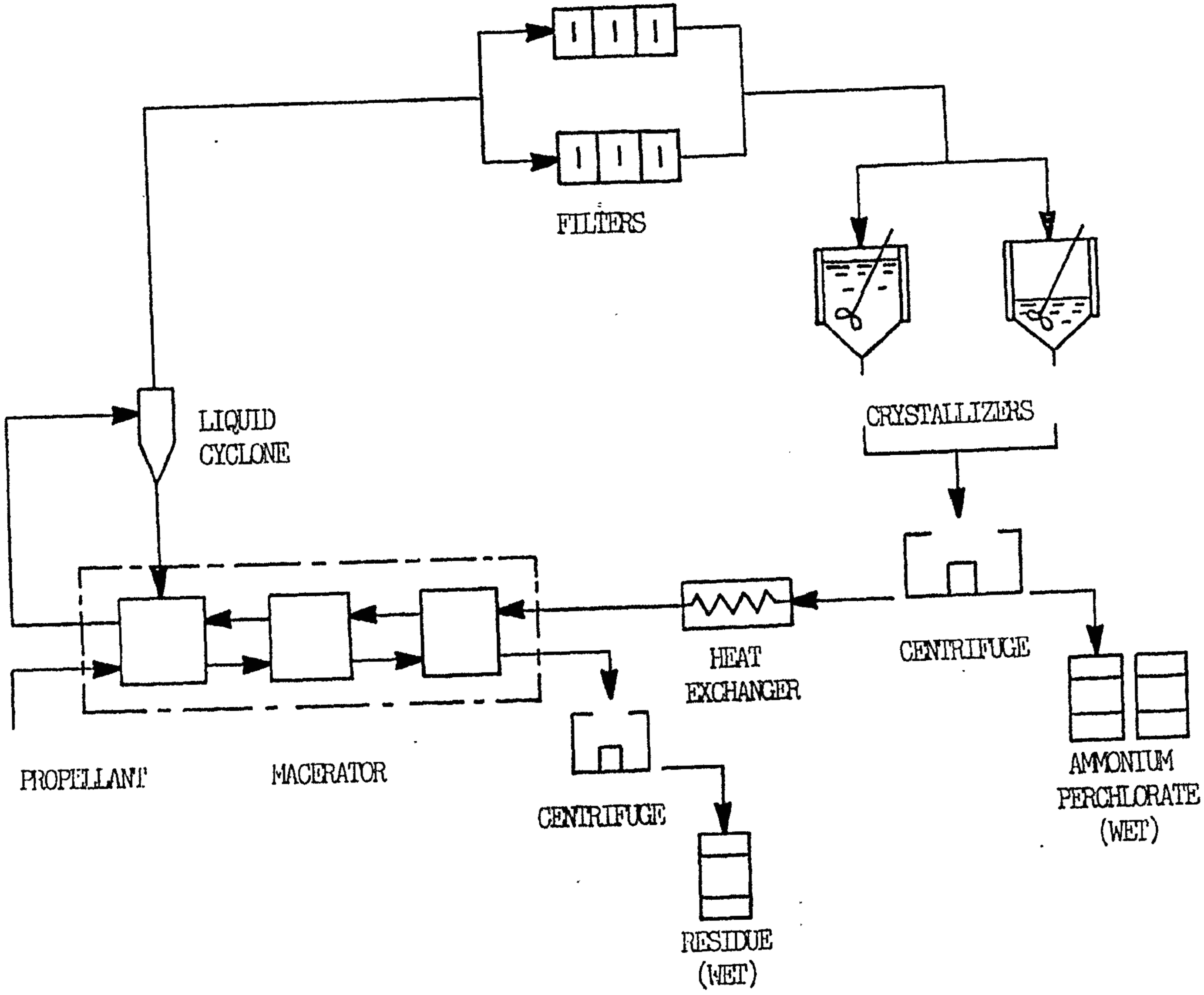
Limitations: The concentration and size of suspended solids has to be controlled for the process to function properly.

4. Emerging Technologies

Four emerging technologies, sub-critical fluids, biodegradation, super critical water oxidation, and energy recovery from controlled incineration, are selected for review as being applicable for the LRM demilitarization and disposal program.

a. Super/Sub-Critical Fluid Extraction Technique

The U.S. Army Missile Command (MICOM) Propulsion Directorate, Research




PROCESS SCHEMATIC

Figure 13.

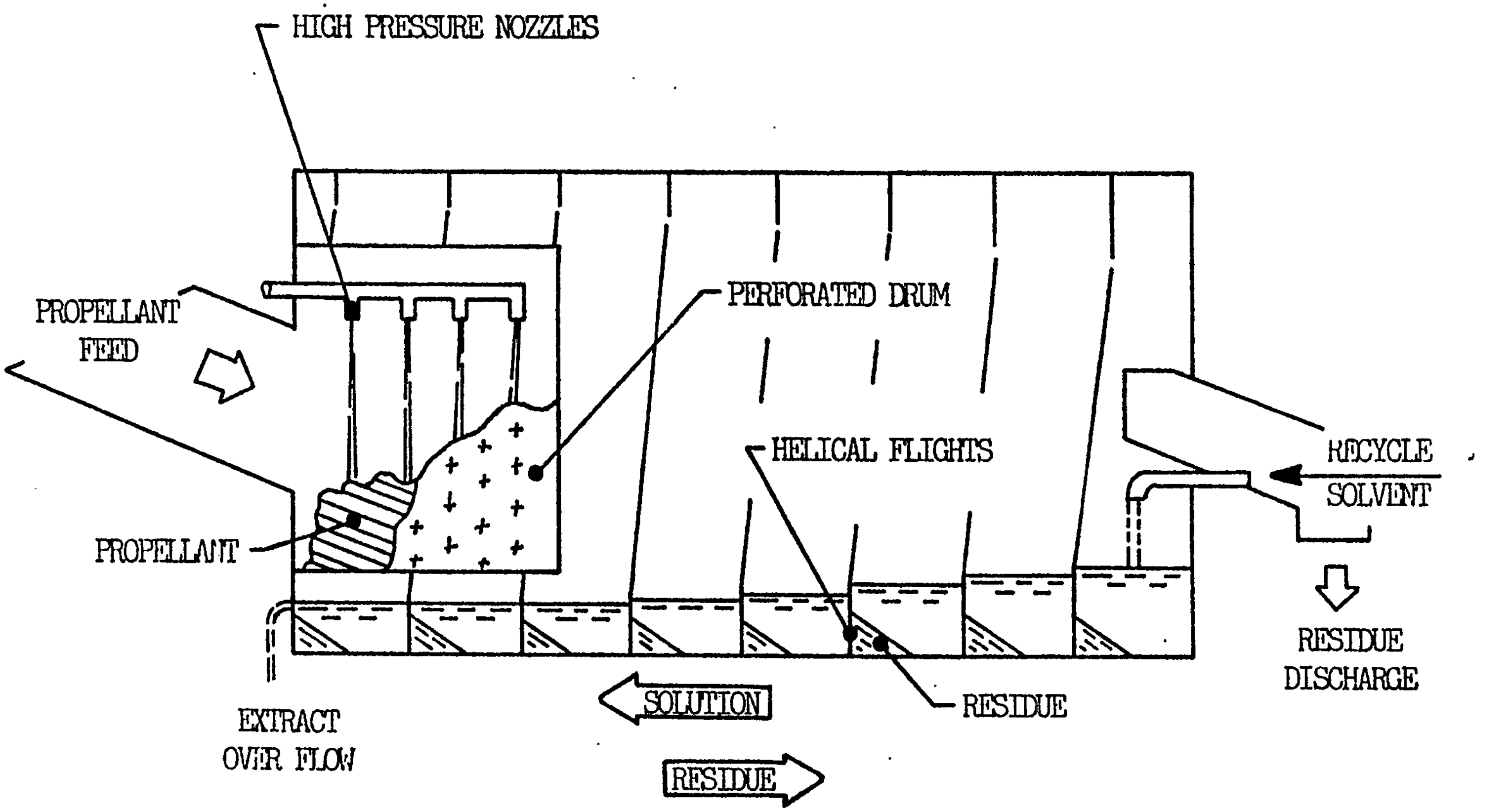



Figure 14.

HYDRAULIC MACERATOR

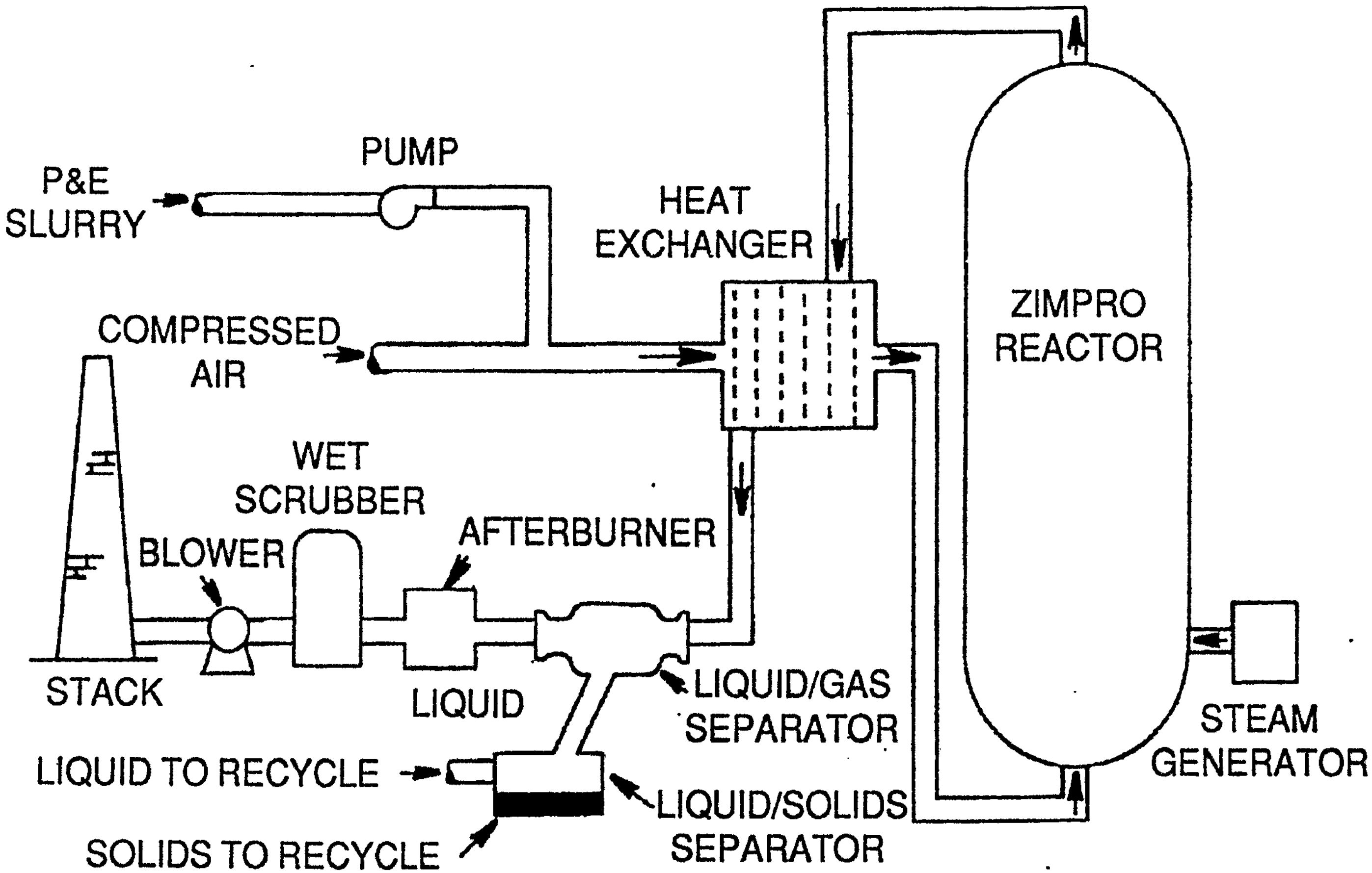



Figure 15.

WET-AIR OXIDATION (ZIMPRO) PROCESS

Development and Engineering Center, Huntsville, AL is conducting R&D to extract AP from the 1.3 solid propellant. This method takes advantage of the enhanced solubility characteristics of the super/sub-critical fluid and the phase transitions which occur during the compression and expansion of gases. Among the three gases, ammonia, carbon dioxide, and nitrous oxide, investigated the sub-critical liquid ammonia was found to be a super-solvent for the extraction of AP from the 1.3 solid propellant.

The rocket motor can serve as its own self-contained high pressure extraction vessel. The working solvent can be nozzle sprayed under sufficient pressure to erode and wash away exposed propellant surfaces.

Soluble propellant ingredients are extracted into the fluidized gas and separated by filtration from all undissolved materials. The dissolved propellant ingredients are recovered in a separation vessel during the liquid-to-gas pressure reduction cycle. The expanded gas, now devoid of all dissolved propellant ingredients, is filtered and re-compressed to the fluid state to complete the solvent regeneration cycle. Figure 16 shows a simple schematic diagram of the system.

Limitations: This process has been demonstrated in laboratory testing. A scaled up pilot study has yet to be proved. Continued R&D is required for final evaluation.

b. Biodegradation Technique

The Lummus Crest Inc., (LC), Bloomfield, NJ has been conducting bench scale laboratory work using White Rot Fungus (WRF) to biodegrade pink water. The process consists of first growing the WRF by bringing the microorganism into contact with a support medium, and letting the culture grow 5-10 days. The growth medium is then nitrogen starved for a period of 3-4 days. By giving the WRF only enough food to subsist, the LC has determined that the WRF culture would last 2-6 months.

The LC studied two compositions, TNT pink water at 150-220 ppm and $80^{o}$ C, and RDX pink water at 20-86 ppm and $80^{o}$ C. Two different mechanical devices, Rotating Biological Contactor and Packed Column Unit were used in their evaluation. The bench scale rotating biological contactor, shown in Figure 17, is a 7 inch by 20 inch horizontal cylinder divided into 4 equal compartments. It has a rotating shaft in the center with 8 cylindrical disks covered with the WRF cultures that are spaced to provide each of the 4 compartments with a pair of disks. The pink water is fed into the RBC until it is about 1/2 full and then the shaft is rotated to allow the 8 disks to alternately be wetted with pink water and then be exposed to the oxygen enriched air. Using a batch method, the LC, has successfully reduced the TNT pink water to 2 ppm in 24 hours and the RDX pink water to less than 10 ppm min 48 hours.

The bench scale packed column, shown in Figure 18, is a 5 inch by 12 inch vertical cylinder packed with plastic balls, approximately 3/8 inch in

# LARGE ROCKET MOTOR DEMILITARIZATION PROGRAM
# PROCESS FLOW DIAGRAM

## CRITICAL FLUID EXTRACTION (CFE) PROCESS FOR AMMONIUM PERCHLORATE MOTORS USING LIQUID AMMONIA

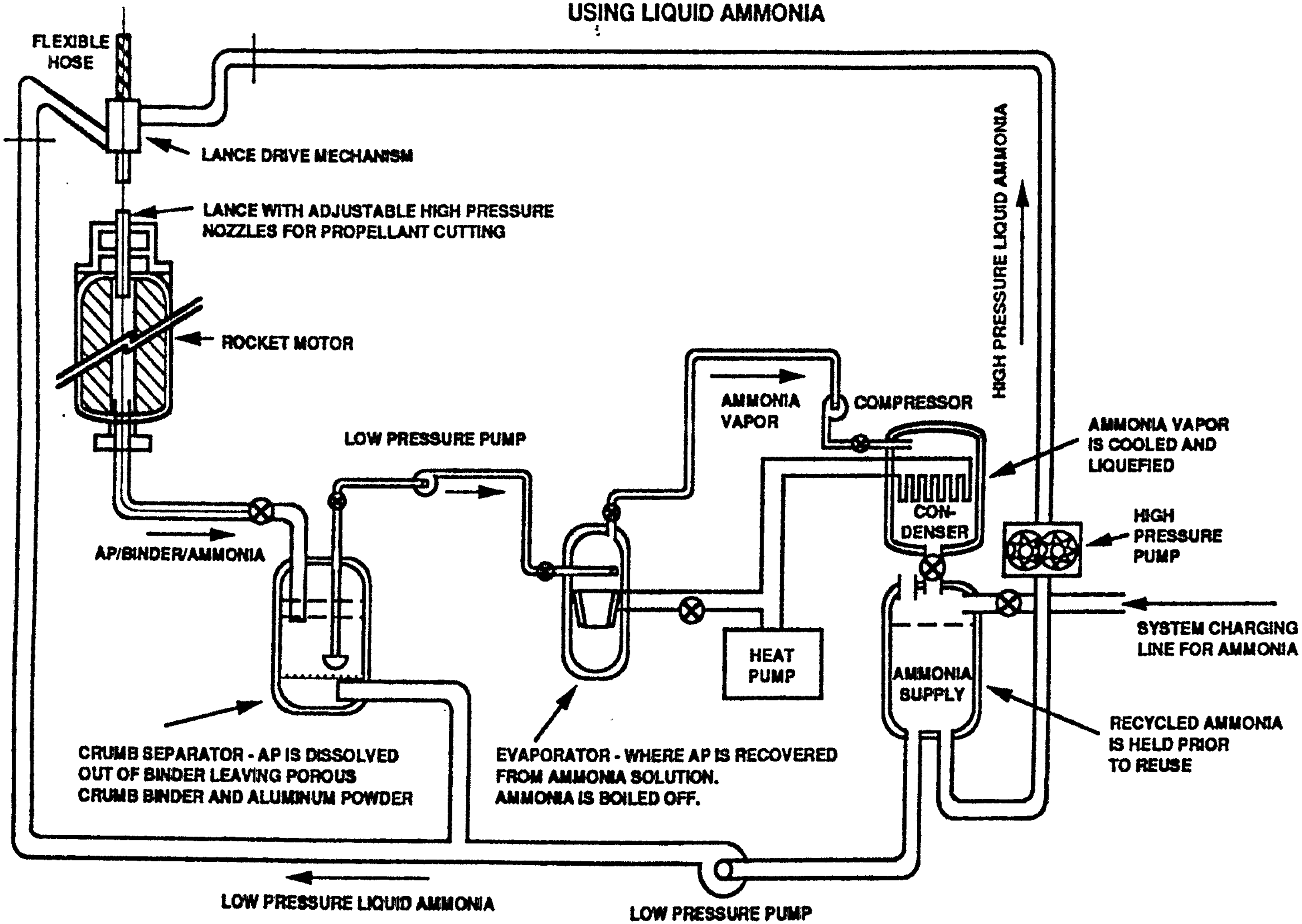
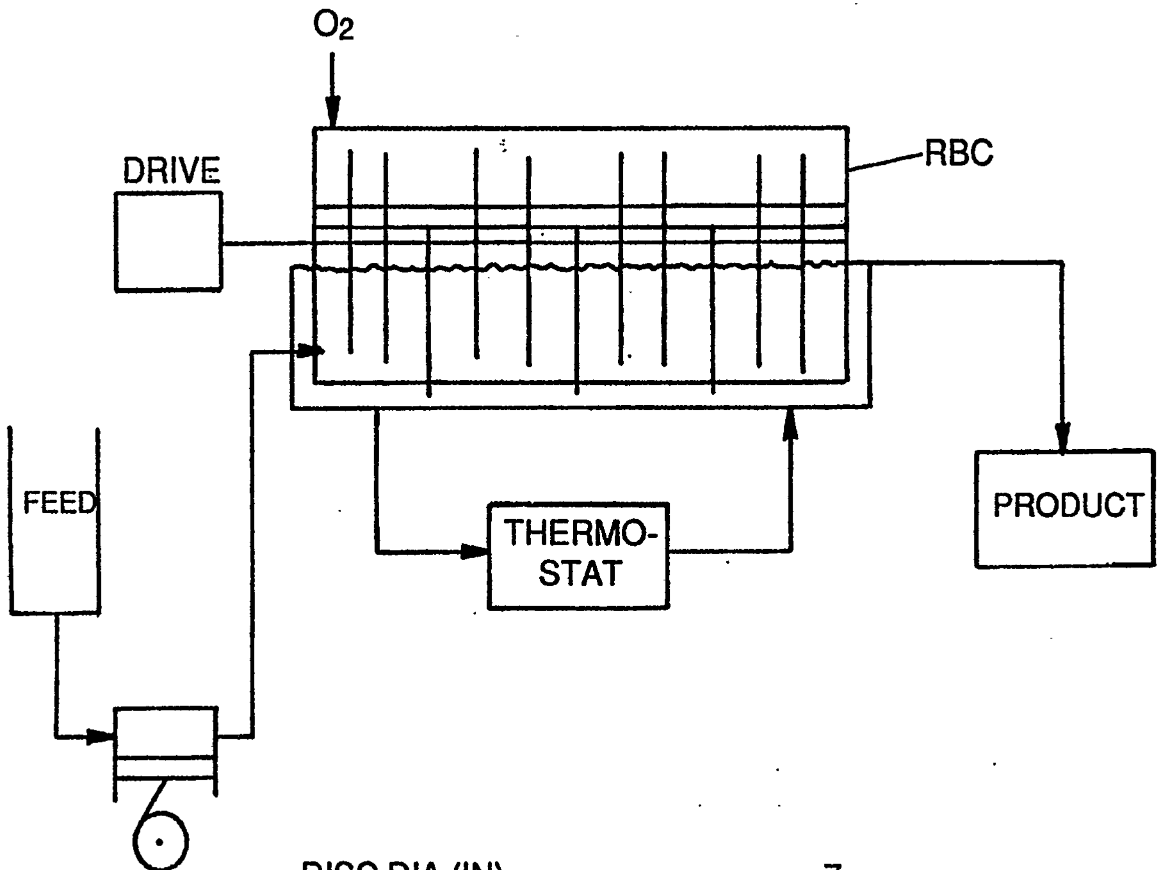



Figure 16.

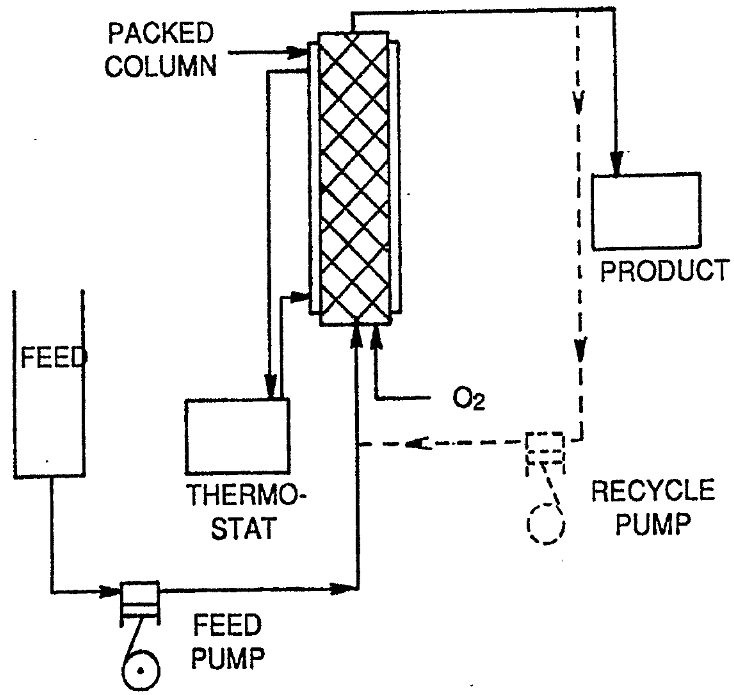
# RBC BENCH UNIT




| | |
|---|---|
| DISC DIA (IN) | 7 |
| NUMBER OF DISCS | 8 |
| NUMBER OF COMPARTMENTS | 4 |
| RPM | 9 |
| TEMPERATURE (°C) | 37 |
| FEED FLOW RATE (cc/Hr) | 40-85 |
| LIQUID INVENTORY (cc) | 2000 |

Figure 17.

# BENCH PACKED COLUMN UNIT




| | |
|---|---|
| COLUMN DIAMETER (cm) | 5.0 X 12.0 IN, L |
| PACKING VOLUME (cc) | 650 |
| PACKING SIZE (cm) | 0.65 X 0.52 |
| TEMPERATURE (c) | 30-39 |
| FEED FLOW RATE (cc/H) | 10-320 |
| LIQUID INVENTORY (cc) | 292 |
| RECYCLE FLOW RATE (cc/H) | 100 |
| O2 FLOW RATE 1 BUBBLE EVER, 10 SEC | |

Figure 18.

diameter, covered with the WRF culture. The method was tested by processing the pink water through the system at a low feed rate, and by recycling the feed material at a higher rate. Using the bench scale packed column, the LC has reduced the concentration of TNT from 100 to 20 ppm in 1 1/2 hours and to 3 ppm in 4 1/2 hours. Further experimentation is needed to confirm, (1) the activity of the WRF over an extended continuous operation with the pink water, (2) the activity of WRF with an outside carbon source and minerals, and (3) the RDX removal efficiency in a continuous operation.

Limitations: Applicability of the Lummus process for LRM demilitarization has not been determined. For explosives contaminated water (pink water), the process shows potential. The process has not been proven in scaled models. Continued R&D is required for final evaluation.

Special Note: The U.S. Air Force (USAF) Engineering and Services Center at Tyndall Air Force Base recently reported that the Manville Corporation presented preliminary evidence that development of a biological system is feasible for AP biodegradation.

c. Energy Recovery Technique

The U.S. Army Toxic Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, MD, is developing a means to recover the energy from burning energetic materials in industrial boilers. A pilot scale (1.4 million BTU/hr) commercial boiler is in fabrication for this development. Mixtures of TNT or composition B with number 2 fuel oil and a solvent will be burned to produce steam. The process prove out will be conducted at WADF in the summer of 1990. Investigation of nitrocellulose as a supplemental fuel is also underway. Figure 19 shows a block diagram of a supplemental fuel system.

Limitations: Full scale testing is required to prove the process. The technology has potential in recovery of energy from waste energetic materials. The supplemental fuel method has not been investigated using the LRM propellants and R&D is required.

d. Oxidation Technique

The LC, Bloomfield, NJ conducted oxidation experiments, both high temperature and low temperature oxidation, on red water. The samples used for the experiments had a 14 percent dissolved substance with organic carbon content of 4 to 5 percent. For high temperature oxidation, the operating temperature was $400^{o}C$ with an initial oxygen pressure of 80 psig. The reaction time was less than 10 minutes with 82 percent total organic carbon destruction. For the low temperature experiment, the operation was at moderate temperature and atmospheric pressure. The reaction time was 4 hours with 92 percent total organic carbon removal.

# SUPPLEMENTAL FUEL SYSTEM BLOCK DIAGRAM

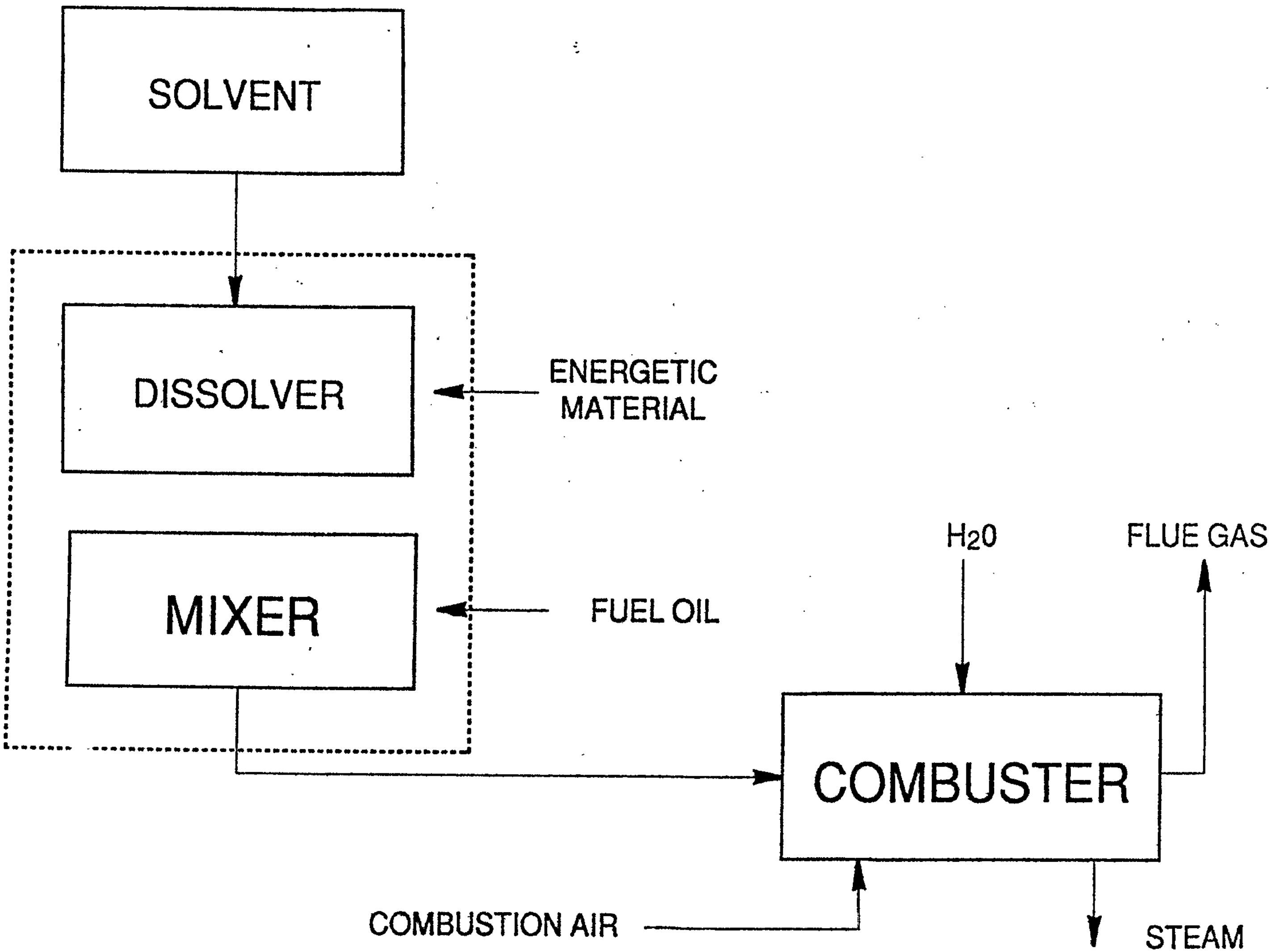



Figure 19.

Limitations: Application of the Lummus oxidation technology for the LRM demilitarization and disposal program has not been demonstrated.

Special Note: The USAF Engineering and Services Laboratory in conjunction with the Los Alamos National Laboratory, NM, and the Modell Corporation is conducting a bench scale supercritical water oxidation research to determine the feasibility of the technology for the destruction of propellants.

5. Conceptual Technology

Two technologies have been reviewed that may have potential for the LRM demilitarization and disposal program.

a. Confined Static Firing with Scrubber

The Lockheed Research Laboratory, Lockheed Missiles and Space Company, Palo Alto, CA conducted a study to determine alternate approaches to the disposal of solid rocket propellants. One concept proposed was the confined burning of the whole motor. The conceptual operation would consist of removing the nozzle from the motor case and burning the motor at ambient pressure. The effluent gas would be conducted through a large, 12 foot diameter pipe sloping downward into a water tank 40 ft deep. The gases would bubble up through the water tank through a series of perforated steel plates into a large, 60 ft high by 170 ft diameter, domed containment chamber. The scrubbed gases from this containment chamber would be conducted through a 6-7 ft diameter duct to the exhaust gas disposal equipment, which is not yet defined. Figure 20 shows a line schematic of the proposed concept.

Limitation: This technology is at conceptual stage. Estimated construction cost is over $100 million.

b. Cryogenic Fluid - Dry Washout Technique

General Atomics Technology and El Dorado Engineering jointly proposed to study the cryogenic fluid-dry washout process to remove propellant from large rocket motors. Liquid nitrogen is used as the washout medium. It is postulated that with cryo-washout there is no waste water stream that requires extensive treatment. The cryogenic fluid would be sprayed onto the surface of the propellant in much the same manner used in high pressure water washout. The cryogenic jet would embrittle the propellant and reduce its sensitivity to ignition or initiation. The embrittled propellant would be susceptible to brittle fracture with relatively small applied forces. For the most brittle propellant materials, the force of the cryogenic jet itself will likely be sufficient to erode the material. A nozzle system will be designed to deliver a high pressure cryogenic gas jet to the material surface. This approach would probably be the most efficient use of the cryogenic fluid, with little loss of liquid. If gas phase erosion is not sufficient, two-phase or liquid phase erosion may prove necessary, with some loss of excess liquid and efficiency.

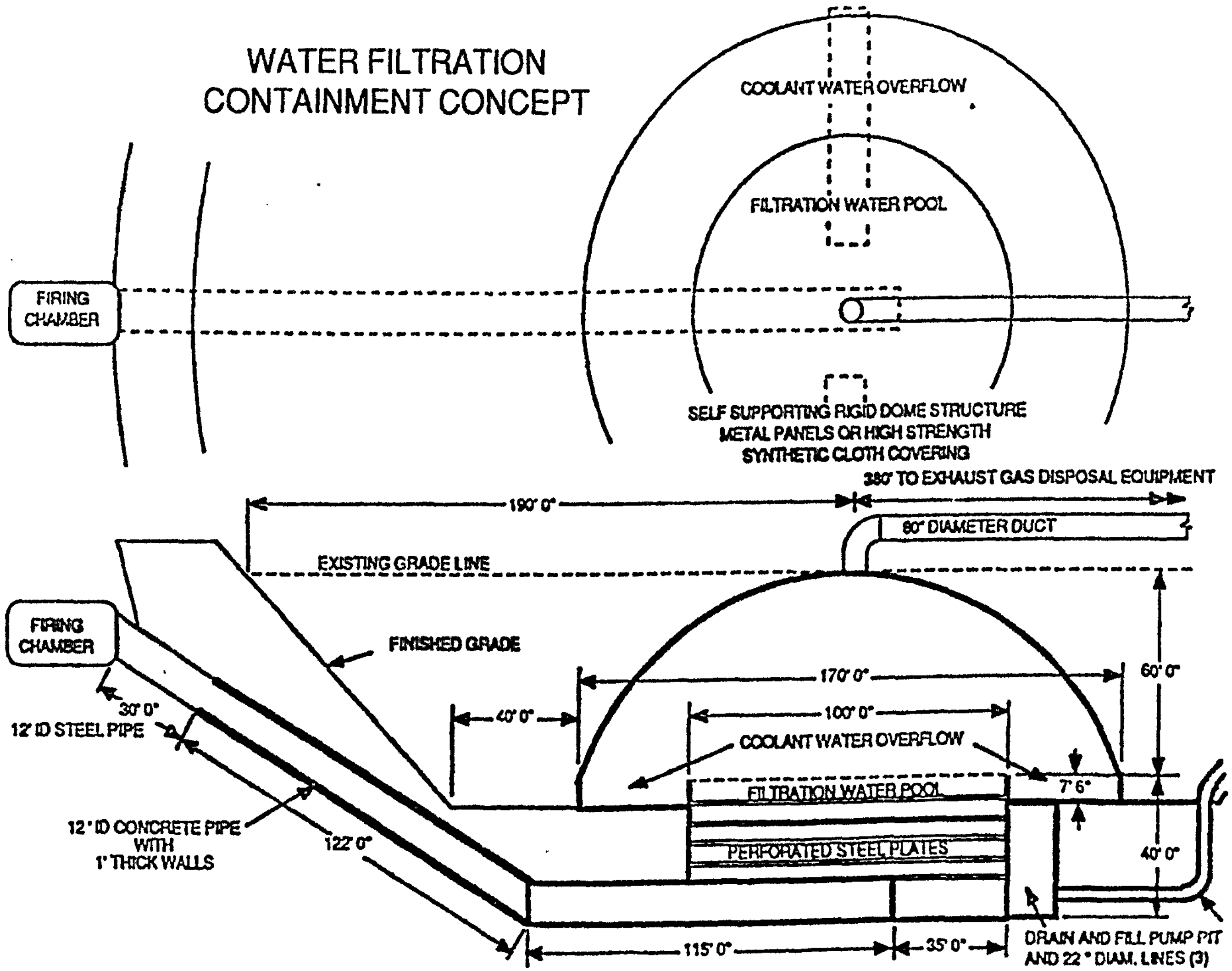

WATER FILTRATION
CONTAINMENT CONCEPT
COOLANT WATER OVERFLOW
FILTRATION WATER POOL
FIRING CHAMBER
SELF SUPPORTING RIGID DOME STRUCTURE
METAL PANELS OR HIGH STRENGTH
SYNTHETIC CLOTH COVERING
380' TO EXHAUST GAS DISPOSAL EQUIPMENT
190' 0"
80' DIAMETER DUCT
EXISTING GRADE LINE
FIRING CHAMBER
FINISHED GRADE
170' 0"
60' 0"
30' 0"
12' ID STEEL PIPE
40' 0"
100' 0"
COOLANT WATER OVERFLOW
7' 6"
FILTRATION WATER POOL
12' ID CONCRETE PIPE
WITH
1' THICK WALLS
122' 0"
PERFORATED STEEL PLATES
40' 0"
115' 0"
35' 0"
DRAIN AND FILL PUMP PIT
AND 22" DIAM. LINES (3)

Figure 20.

Limitations: The optimum flow rate and pressure of the cryogenic fluid/gas, the electrostatic discharge, and the removal efficiency would be investigated. Large quantities of nitrogen may be required for this process.

## FUNDING REQUIREMENT

### 1. Introduction

In June 1989, the JOCG Munition Demilitarization and Disposal Subgroup provided Dr. Osterman's office a Consolidated Funding Requirement for R&D and Pilot Process Efforts for the LRM demilitarization and disposal program. The consolidated funding requirement was based on the R&D funding requests submitted by each service and the nongovernment research groups. Recognizing that some of the proposed R&D programs identified in the original consolidated funding requirement were overlapping, a more critical screening was exercised in evaluating and assessing the funding requirements for the demilitarization technology development efforts in this report. The R&D funding requirement identified in the cost analysis in this report correlates well with the funding requirements previously submitted by the services.

### 2. Limitations.

It is imperative and prudent to set limitations to what can be accomplished with the proposed fundings. The funding will support R&D work for LRM demilitarization and disposal, evaluate and assess to determine viability of R&D efforts, make fundings available to potential projects to further develop and conduct pilot scale operations, evaluate and assess to determine validity of pilot operation, and make recommendations for further action.

### 3. Discussion of Funding Requirement

The LRM demilitarization and disposal funding requirements are identified for the three major technology groups, existing, emerging, and conceptual technologies as shown in Table 1. These three main groups are further broken down into several subgroups which relate to specific processes. The funding requirements for the past experimentations are excluded from this report.

#### a. Existing Technologies

The existing technologies are those that could be assembled in the shortest possible time frame with a high confidence of success. These

TABLE 1 - FUNDING REQUIREMENTS FOR LRM DEMILITARIZATION/DISPOSAL PROGRAM ($MIL)

| PRIORITY | PROGRAM | FY 91 | FY 92 | 2 YEAR TOTAL |
|---|---|---|---|---|
| | EXISTING TECHNOLOGIES | | | |
| 1 | Solvation | 0.600 | 0.650 | 1.250 |
| 2 | Washout | 3.200 | 3.075 | 6.275 |
| 3 | Controlled Incineration | 1.150 | 1.150 | 2.300 |
| | EMERGING TECHNOLOGIES | | | |
| 1 | Reclamation | 0.600 | 1.425 | 2.025 |
| 2 | Controlled Incineration | 0.150 | 0.150 | 0.300 |
| 3 | Biodegradation | 0.100 | 0.125 | 0.225 |
| 4 | Oxidation | 0.100 | 0.125 | 0.225 |
| | CONCEPTUAL TECHNOLOGIES | | | |
| 1 | Confined Static Firing | 0.250 | 0.500 | 0.750 |
| 2 | Cryo-dry Washout | 0.250 | 0.250 | 0.500 |
| | OTHER | 0.600 | 0.600 | 1.200 |
| | TOTALS | 7.000 | 8.050 | 15.050 |

Table 1

technologies have been proven by actual production test runs with full scale systems or test runs with scale model components. Limited system modification may be required of these existing components for the LRM demilitarization and disposal applications. The funding requirements for supporting R&D efforts for each technology group is given, followed by a brief description of the processes.

(1) Solvation Technique: Funding requirement is $1.25 Million. This group of technologies are those that use a liquid to extract major components of the propellant. Mechanical devices for the size reduction of propellants may be required to enhance the solvations process. A macerator and other types of size reduction mechanical devices should be investigated and evaluated for the non-water soluble, nitrocellulose/nitroglycerine propellants (1.1). The funding will also support the investigation of various liquids to establish solubilities and applicabilities in dissolving the 1.1 type propellants.

(2) Washout Technique; Funding requirement is $6.275 Million. This group of technologies are those that use some form of a liquid, usually water, under high pressure 100 to 50,000 psig to hogout the propellant from the LRM cases. Segments of the process equipment have been developed among several different firms, which if assembled in one place, could readily demilitarize the LRMs with AP composite propellant. If the waterjet washout technology (1000 lbs/hr/unit) at Thiokol was interfaced to the AP solvation reclamation and incineration technology that has been successfully demonstrated at Aerojet, it would be possible to demilitarize the LRM at a production rate in excess of 1,000,000 lbs/yr. This process can be scaled up for a greater production rate on demand. The AP and aluminium are the two major components reclaimed for recycling. Western Area Demilitarization Facility (WADF), currently in lay-away status, could accommodate the LRM demilitarization program with minimum modification. Funding will also support the proposed computer controlled waterjet washout systems similar to the one under development by the Naval Weapons Support Center (NWSC) at Crane.

(3) Controlled Incineration Technique: The funding requirement is $2.30 Million. This group of technologies are those that encompass all of the incineration processes. Funding will support development efforts for the advanced incineration techniques which will meet all environmental constraints in a cost effective manner. Currently, controlled incineration is the military's only proven method of disposing the doublebase propellants.

b. Emerging Technologies

The emerging technologies are those that are in the evolutional stages and are not currently matured enough to be used in the short term LRM demilitarization and disposal program. These technologies have shown possibilities in the laboratories and scale model testing and it is recommended that the research and development efforts be pursued at an expeditious pace.

(1) Reclamation Technique: Funding requirement is $2.025 Million. This group of technologies are those that extract valuable components from solid propellant. The Super/Sub Critical Fluid Extraction method has shown potential in the demilitarization of the LRM propellants. The AP is recovered from the solid propellant in the LRM. The residue is the aluminium powder and the binder compound in a sludge form. During the subsequent incineration of the residue sludge, the aluminium powder is recovered.

(2) Energy Recovery From Controlled Incineration Technique: The funding requirement is $0.3 Million. Incineration is mainly a destruction process. However, there is at least one known experiment conducted which recovers energy by supplementing the fuel oil with energetic materials such as waste explosives and propellants. This process has potential for extracting energy, in the form of heat, from the washed out propellants. Research effort should be pursued to develop an appropriate feed system for feeding the propellant slurry into incinerators.

(3) Biodegradation Technique: Funding requirement is $0.225 Million. This group of technologies are those that use microorganisms to decompose waste energetic material found in pink water. One technology that has shown potential is the use of White Rot Fungus to reduce the concentrations of TNT and RDX material in pink water. The biodegradation technology R&D should be supported for propellant disposal.

(4) Oxidation Technique: Funding requirement is $0.225 Million. This technology uses the induction of oxygen to speed the decomposition of energetic materials to inert chemical compounds such as carbon dioxide, carbon monoxide, nitrogen, and hydrogen. There are now three types of techniques under study, high temperature oxidation, low temperature oxidation, and wet air oxidation which show potential.

c. Conceptual Technology

(1) Confined Static Firing Technique: Funding requirement is $0.750 Million. This technique proposes the burning of LRMs into a confined chamber. Operation would consist of removing the nozzle from the LRM motor case and burning the motor at ambient pressure. The combustion gases are scrubbed by bubbling the gases through a water tank placed in a large concrete dome.

(2) Cryo-dry washout technique: Funding requirement is $.500 Million. This technology is a dry washout process in that it uses a liquid nitrogen spray to flake off the propellant directly in the LRM. The fragmented pieces of propellant will have to be further processed.

d. Other Techniques

The funding requirement is $1.2 Million. This funding is required to support development of new, innovative technology for the LRM demilitarization and disposal program.

## CONCLUSIONS AND RECOMMENDATIONS

### 1. Conclusions

The Large Rocket Motor and Solid Propellant disposal inventory in the United States is steadily increasing. The rate of increases will continue, and in some instances, will be accelerating for some time. There is no single complete environmentally acceptable demilitarization technology and disposal system for the large rocket motors and propellants within the military organizations or in the industrial communities.

In March 1989, the Joint Ordnance Commanders Group (JOCG) tasked the chairman of the JOCG Munitions Demilitarization and Disposal Subgroup to develop a charter for the Joint Large Rocket Motor Demilitarization Office (JLRMDO) which will develop and implement a Department of Defense corporate Large Rocket Motor Demilitarization policy. The draft charter was presented to the JOCG at the Keyport, WA meeting in September 1989.

Nineteen large rocket motor demilitarization technologies and processes were reviewed and evaluated to determine the extent of the technical maturity and feasibility, engineering scale-up capability and process efficiency and funding required for research and development efforts.

The funding requirement to support Large Rocket Motor demilitarization technology development for FY 91-92 is $15.05 million. A two year research and development funding assignment for supporting the development efforts to investigate consolidation and expansion by the existing technology group is $9.825 Million. Funding for supporting the research and development and scale-up efforts by the emerging technology group is $2.775 Million. The funding of $2.45 million is assigned to the conceptual and other technology development efforts.

### 2. Recommendations

A funding of $15.05 Million for the first 2 years, FY 91 and FY 92 is recommended. This level of commitment is required to initiate a programmatic effort to support Large Rocket Motor Demilitarization Technology research and development work, support pilot scale study efforts, and conduct systematic evaluations of the validity of the research and development and the pilot study project.

It is recommended that the Large Rocket Motor Demilitarization Technology Development efforts be monitored carefully and coordinated judiciously in order to realize an expedient return for the capital investment.

It is recommended that a continued funding commitment be provided beyond the first two years to sustain the current research and development efforts and to achieve cost effective demilitarization and disposal of the Large Rocket Motors and Propellants.

REFERENCE

1. John L. Byrd, Jr. and Solim S. W. Kwak, LARGE ROCKET MOTOR DISPOSAL PROGRAM, Joint Ordnance Commanders Group (JOCG) Munitions Demilitarization and Disposal Subgroup, January 1990.

2. William Melvin, ARMY INVESTMENT PLAN FOR LRM DISPOSAL R&D PROJECT, U.S. Army Missile Command, Huntsville, AL, January 1990.

3. Mark Smith, AIR FORCE INVESTMENT PLAN FOR LRM DISPOSAL R&D PROJECTS, U.S. Air Force Engineering and Services Laboratory, Tyndall Air Force Base, FL, January 1990.

4. Dan Burch, NAVY INVESTMENT PLAN FOR LRM DISPOSAL R&D PROJECTS, Naval Weapons Support Center, Crane, IN, January 1990.

5. William Melvin, REVISED MILESTONE AND FUNDING REQUIREMENT FOR CRITICAL FLUID WASHOUT/EXTRACTION TECHNOLOGY, U.S. Army Missile Command, April 1990.

6. Dan Burch, REVISED MILESTONE AND FUNDING REQUIREMENT FOR THE NAVY LRM DISPOSAL R&D PROJECTS, Naval Weapons Support Center, Crane, IN, April 1990.

7. Leroy Throckmorton, REVISED MILESTONE AND FUNDING REQUIREMENT FOR STATIC FIRING WITH SCRUBBING, U.S. Navy, April 1990.

8. Mark Smith, REVISED MILESTONE AND FUNDING REQUIREMENTS FOR THE AIR FORCE LRM DISPOSAL R&D PROJECTS, Tyndall Air Force Base, FL, April 1990.

# APPENDIX A

## Consolidated Funding Requirement For Research and Development and Pilot Study for Large Rocket Motor Demilitarization

DEPARTMENT OF THE ARMY
US ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
SAVANNA, ILLINOIS 61074-9639

REPLY TO
ATTENTION OF:

SMCAC-DO

19 JUN 1989

MEMORANDUM FOR Dr. Joseph V. Osterman, Director, Mission Enhancement Technologies, Office of the Director of Defense Research and Engineering, Washington, DC 20301

SUBJECT: Consolidated Funding Requirement for Research and Development (R & D) and Pilot Study for Large Rocket Motor Demilitarization

1. Reference:

a. Memorandum for Record, SMCAC-ESS, 12 June 1989, subject: Large Rocket Motor Demilitarization Program (enclosure 1).

b. Memorandum for Record, SMCAC-ESS, 13 June 1989, subject: Large Rocket Motor Demilitarization Program (enclosure 2).

c. Memorandum for Record, SMCAC-ESS, 13 June 1989, subject: Large Rocket Motor Demilitarization Program (enclosure 3).

2. The consolidated funding requirement has been identified as follows:

| | Army | Navy | Air Force | Others* | Subtotal |
|---|---|---|---|---|---|
| FY 90 | 1.5 M | 1.5 M | 0.66 M | 1.5 M | 5.66 M |
| FY 91 | 2.0 M | 2.0 M | 0.95 M | 2.0 M | 6.95 M |
| FY 92 | 2.0 M | 3.5 M | 0.55 M | 2.0 M | 8.05 M |
| | | | | Total | 20.16 M |

* Industry and academic research and development groups

3. Expenditure of this funding will deliver the following:

a. Make fundings available to large rocket motor demilitarization technology research and development work.

b. Evaluate and assess to determine viability of research and development work.

SMCAC-DO
SUBJECT: Consolidated Funding Requirement for Research and Development (R & D) and Pilot Study for Large Rocket Motor Demilitarization

c. Make fundings available to selected groups to further develop and conduct pilot scale study.

d. Evaluate and assess to determine validity of pilot study.

e. Make recommendation for further action.

3. Points of contact (POCs) are the undersigned, SMCAC-DO, and Dr. Solim S.W. Kwak, SMCAC-ESS, at AUTOVON 585-8901 and 585-8618, respectively.

William J. Ernst

3 Encls
as

for JOHN L. BYRD, JR.
Director
Defense Ammunition Center and School

# APPENDIX B

## Large Rocket Motor

## Demilitarization Office

## Charter

# JOINT LARGE ROCKET MOTOR DEMILITARIZATION OFFICE

## CHARTER

27 JULY 1989

JOINT ORDNANCE COMMANDERS GROUP

MUNITIONS DEMILITARIZATION

AND DISPOSAL SUBGROUP

# TABLE OF CONTENTS

# CHARTER

I. DESIGNATION OF JOINT LARGE ROCKET MOTOR DEMILITARIZATION OFFICE (JLRMDO).

Pursuant to Joint Ordnance Commanders Group (JOCG) Task Directive 89-0301, Munitions Demilitarization and Disposal Subgroup, 10 March 1989, the Chairperson of the Subgroup is designated as proponent of the Charter for the JLRMDO. The JLRMDO will have the responsibility and authority to execute this Charter.

II. MISSION.

A. General: The JLRMDO will develop a Department of Defense (DOD) corporate solution for the demilitarization of large rocket motors. Large rocket motors are defined as service peculiar missile motors that are not included in the SMCA Charter. The JLRMDO will manage and coordinate the investigation, research and development (R&D), documentation, evaluation, and maintenance of the technology base to support the Large Rocket Motor Demilitarization Program. The JLRMDO mission is to develop solutions, recommendations, programs, and plans for large rocket motor demilitarization to ensure safe, economical, and environmentally acceptable demilitarization methodologies. The JLRMDO will represent and serve all Military Services, interfacing with other government agencies, academia, and industry. It will provide technology support to the Services and other participating organizations, act as a clearing house and focal point for large rocket motor demilitarization technology, and provide information for DOD program oversight to prevent duplication of effort. The JLRMDO will make recommendations for policy changes regarding the Large Rocket Motor

Demilitarization Program and support budgetary requirements of the Military Services to the Office of the Secretary of Defense (OSD). The JLRMDO will recommend policies that implement the standards and objectives of all Federal, State, and local environmental statutes impacting on the Large Rocket Motor Demilitarization Program.

B. Functions:

The JLRMDO will obtain forecast demilitarization/disposal assets, identify demilitarization capabilities, perform studies, tests, and prototype evaluations as requested. In addition, the JLRMDO will establish a focal point for coordination on interservice demilitarization efforts and support budget activities for technology development and execution of the JLRMDO program. The JLRMDO will obtain resources to support and maintain JLRMDO establishment. Typical functions include, but are not limited to:

1. Identify:

a. Short-term goals:

(1) Subpart "x" requirements of the Resource Conservation and Recovery Act (RCRA).

(2) Disarmament treaty requirements.

b. Short-term solutions: Funding sources and alternatives.

c. Long-term solutions: Institutional solutions.

2. Evaluation/Analysis/Assessment:

a. Analysis of technology (shortfalls).

b. Analysis of asset inventory.

c. Assess compatibility of long-term goals versus short-term goals.

d. Evaluate unsolicited proposals.

e. Consider, assess, and compare alternative operational approaches.

(1) Government-owned, Government-operated [GOGO].

(2) Government-owned, contractor-operated [GOCO].

(3) Contractor-owned, contractor operated [COCO]).

f. Evaluate requests for proposals (RFPs) and proposals contracts for supporting technology development.

g. Assess future demilitarization plans for new or modified rocket motors.

3. Maintain:

a. Environmental standards (including federal, state, local, and international codes and information sources).

b. Treaty agreements impacting large rocket motor demilitarization.

c. A demilitarization technology base.

4. Report/Publish:

a. Quarterly In-process Reviews (IPRs) to JOCG.

b. In-process Reviews to Joint Logistics Commanders, as required.

c. Requests for proposals.

d. JLRMDO Newsletter (technological breakthroughs, progress reports, points of contact (POCs), etc.).

e. Information/recommendations to treaty negotiators.

5. Interfaces:

a. Joint Army-Navy-NASA-Air Force (JANNAF)/Chemical Propoulsion Information Agency (CPIA).

b. Joint Ordnance Commanders Group Subgroups.

c. Environmental Agencies; all levels - federal, state, local, and international.

d. Other demilitarization groups.

e. Acedemia.

f. Industry.

g. Other governmental agencies.

6. Promote the interchange of demilitarization technology data on a national and international basis.

7. Plan for the transition or termination of the JLRMDO.

III. AUTHORITY AND RESPONSIBILITIES.

Delegation of authority to the JLRMDO is from the JOCG. The JOCG delegates the authority for monitorship of the JLRMDO to the JOCG Executive Committee. The JLRMDO is delegated the authority to work directly with OSD and Military Services in the execution of its mission. The responsibility of the JLRMDO is to develop a DOD corporate solution for the disposal of large rocket motors through the analysis of the projected workload and technologies that are applicable to the commodity.

IV. RESOURCE CONTROL.

The JLRMDO will ensure that dollar and manpower requirements to accomplish all assignments are developed and submitted IAW established DOD/JOCG manpower/funding channels and procedures. Internal operations budget of the JLRMDO is based on a fair-share approach. Resource requirements will be developed for inclusion in the Program Analysis Resources Review (PARR) for applicable target program years. Large Rocket Motor Demilitarization

Program requirements and funds are to be separately identified in budget submission by each Military Service and will be supported by the JOCG. The JLRMDO will support the defense of the budget at DOD level. Each Service retains technology development and budget execution. The Large Rocket Motor Demilitarization Program will be designated as a DOD Line Item to be developed and justified by each Service.

V. SUPPORT AND LOCATION.

The JLRMDO will be supported by a jointly staffed group of military and civilian personnel with technical and administrative expertise assigned and/or recruited from each Service to accomplish the JLRMDO mission. The organizational support structure is as follows:

A. General. The JLRMDO will be headed by a Director/GM-15/Colonel (minimum grade level) with an ammunition background. The JLRMDO will be a single element organization with no suborganizational elements.

B. Staffing Support. The U.S. Army (USA), U.S. Navy (USN), and U.S. Air Force (USAF) will each provide funding for their man-years of effort to support the JLRMDO. The JLRMDO will not be space/billet constrained. It will operate on a "manage to payroll" principle. The U.S. Marine Corps (USMC) will provide technical support as required. Clerical support will be accomplished using temporary personnel. Service contracts will be used to procure specialized requirements.

C. Staffing Structure. The staffing will initially be 9 manyears of effort as identified below:

(1) Office Chief (GM-15 Program Manager 340-series/Military Officer 06-Rank, Ammunition Officer (not explosive ordnance disposal [EOD]).

(2) Clerical Personnel (Temporary).

(3) One USA Ammunition Missile Item Expert.

(4) One USN Ammunition Missile Item Expert.

(5) One USAF Ammunition Missile Item Expert.

(6) One Senior Research Chemist.

(7) One Chemical/Environmental Engineer.

(8) One Mechanical Engineer.

(9) One Program/Budget Analyst.

(10) One Logistics Management Specialist.

NOTE: Skills such as legal, safety, procurement, computer systems analyst, etc., will be procured on an as-required-basis.

D. Location. To be determined.

VI. ORGANIZATIONAL RELATIONSHIPS.

All DOD agencies which deal with large rocket motors and other government agencies with related interests will be participants in the JLRMDO. The JLRMDO will maintain communications with JOCG on Services' issues and programs, and will have direct access to the DOD for policy and funding. The JLRMDO will provide quarterly reports to the JOCG and progress reports to the Joint Logistics Commanders as the JOCG requires. The JLRMDO will have open access to all classified and unclassified data related to large rocket motors and will observe security/owner proprietary rights to such data. Unresolved major issues will be elevated to the JOCG Executive Committee. An executive OSD office will be assigned as the focal point for all JLRMDO actions and interfaces and is designated as Office Under the Secretary of Defense, Deputy Director Defense Research and Engineering

(Research and Advanced Technology) Environmental and Life Sciences (OUSD [R&AT] ELS). The JLRMDO has the authority to respond to OSD information needs and will inform Military Service POCs of information provided or requested. The JLRMDO interfaces and coordinates for reasons of policy, budget, technology, and operations with all related agencies. These include the Services, industry, allied nations, academia, Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), JANNAF Interagency Propulsion Committee, CPIA, Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), the States, State Department, OSD, Department of Defense Explosives Safety Board (DDESB), and special Project Managers (PMs).

VII. TIMEFRAME.

The timeframe for a concept discussed is shown below.

| Charter Draft | Charter Staff | Authorization to Proceed | |
|---|---|---|---|
| May 89 | Aug 89 | Nov 89<br>Brief JLC | Feb 90 |

| Budgets - Travel<br>Issue - Computers<br>Housing - Moves<br>Job Descriptions<br>Recruit - Hire | Learning Curve Period | Execute | Termination |
|---|---|---|---|
| Feb 90 | Jun 90 | Jun 91 | Jun 93 |

VIII. TRANSITION AND TERMINATION.

The JLRMDO is programmed to operate 2 1/2 years after establishment. Its existence will be reviewed by the JOCG after its goals are met; i.e., establishing a corporate solution for long-range rocket motor demilitarization. When this goal is met, the JLRMDO will be terminated or will transpire into a permanent office. Termination/transition plan is required and will be developed as a task of the JLRMDO.

IX. FUNDING REQUIREMENTS.

An initial internal operations budget funding requirement is $1,000,000. This funding requirement is to be shared equally on a reimbursable basis by the USA, USN, and USAF. Each Service identified will transfer $333,000 to the JLRMDO initially for office establishment. This cost is based on location at a military installation that can provide base operations support. Base operation cost is dependent on location. The preponderance of costs are in support of research, development, test, and evaluation (RDTE) operations.