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Final Report

USATHAMA

U.S. Army Toxic and Hazardous Materials Agency

ECONOMIC EVALUATION OF PROPELLANT REUSE/RECOVERY TECHNOLOGY

(TASK ORDER NO. 10)

December 1988
Contract No. DAAK11-85-D-0008

Prepared by:

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140-2390

Prepared for:

U.S. Army Toxic and Hazardous Materials Agency
Process Development Branch
Aberdeen Proving Ground, MD 21010-5401

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Final Report to

United States Army
Toxic and Hazardous
Materials Agency
December 1988

Economic Evaluation of Propellant Reuse/Recovery Technology

(Task Order Number 10)

Final Report

A.A. Balasco
Program Manager

R.F. Machacek — Task Leader
R.C. Bowen
C.A. Jake (RAAP)
L.L. Smith (RAAP)
Principal Investigators

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Arthur D. Little, Inc.
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EXECUTIVE SUMMARY

This report presents an economic evaluation of two reclamation/reuse options for solvent-based obsolete and unserviceable propellants: (1) resolvation/reuse of propellants; and (2) reclamation/reuse of selected propellant ingredients via solvent extraction. Both of these options were recently investigated to determine their technical feasibility under a previous task [Task Order No. 7 under U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) Contract No. DAAK11-85-D-0008] and detailed in a report (USATHAMA Reference No. AMXTH-TE-CR-88026, August 1988) entitled "Propellant Reuse/Recovery Technology" prepared by Arthur D. Little, Inc.

According to the Environmental Conference Proceedings of the "Hazardous Waste Minimization Interactive Workshop" sponsored by the U.S. Army Material Command (AMC) in November 1987, the demilitarization inventory contained 158,000 metric tons of obsolete conventional propellants in 1987 with a projected growth to 249,000 metric tons by 1993. All of the propellants in this demilitarization inventory are potential candidates for reclamation/reuse.

The incentive for considering reuse options center both on the cost savings for: (a) not having to incinerate the obsolete propellants; and (b) avoiding the purchasing of new raw materials for new propellants. The two reclamation/reuse options we considered were:

- resolvation of the obsolete propellants to produce the equivalent single-, double-, or triple-based new propellants; and
- solvent extraction of the obsolete propellants to separate and recover individual ingredients in the propellants.

Of the two options, the resolvation of obsolete propellants provides the greatest savings by reclaiming and, therefore, taking credit for the entire mix of ingredients in the original propellant formulation. In contrast, solvent extraction reclaims only selected ingredients. Consequently, one should probably consider employing solvent extraction only on chemically off-specification propellants, a much smaller category of propellants than those in the demilitarization inventory. As a result, it was decided to concentrate on the larger, demilitarization inventory and focus our economic evaluation on reclaiming/reusing five representative propellants via resolvation:

- M1 propellant (single-based);
- M6 propellant (single-based);
- M7 propellant (double-based stick);
- M30 propellant (triple-based); and
- M31A1 propellant (triple-based).

Another reason for not developing capital and operating cost estimates for the solvent extraction reclamation/reuse processes is that they are in an earlier stage of development than the resolvation process. In addition, the solvent used in the bench-scale solvent extraction tests, methylene chloride, has been classified as both carcinogenic and mutantigenic to human health. Consequently, one should exercise great caution before considering the use of this solvent. As an alternative, one might investigate the use of a safer solvent such as supercritical carbon dioxide.

Capital and annual operating costs were developed for a plant to grind the obsolete propellants under water, then dry the propellant, and finally pack the propellant prior to resolvation. This plant, with a design capacity to process 3 million pounds per year (1,500 tons per year) of obsolete propellant, would have a total installed equipment cost of $5.8 million. The annual net operating savings from this plant range from a low of $3.0 million from processing only single-based M1 propellant to a high of $7.4 million processing only triple-based M31A1 propellant. The payback periods on invested capital range from a high of 1.9 years for M1 propellant to a low of 0.8 year for M31A1.

If one were to estimate the capital investment for the solvent extraction processes, one would have to start (as with the resolvation process) with a $5.8 million capital cost for a plant to grind the unserviceable propellants. One has, in addition, the capital investments for the solvent extraction processes since it can not use any existing facilities. Consequently, the higher investments for the solvent extraction process would appear to limit its applicability to only chemically off-specification propellants.

1.0 INTRODUCTION

1.1 BACKGROUND

The Department of the Army (DA), as the single service manager of the Department of Defense (DOD) ammunition, is responsible for the disposal of obsolete and unserviceable propellants. In recent years, disposal of propellant munitions has become increasingly complicated due to heightened environmental awareness and resulting legislation. Until the early 1970's, munitions were disposed of by open sea dumping. However, the Marine Protection, Research and Sanctuaries Act of 1972 was passed "...to prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare or amenities, or the marine environment, ecological systems, or economic potentialities." (1) In particular, the act restricted ocean disposal of DOD materiel, and as a result, open field burning and detonation became the dominant methods of destroying obsolete or unserviceable propellant munitions. However, even these practices are now subject to increasing restrictions from environmental regulations.

The regulations promulgated under the Resource Conservation and Recovery Act (RCRA), as amended in 1984, prohibit open burning of hazardous waste, "...except for the open burning and detonation of waste explosives. Waste explosives include waste which has the potential to detonate and bulk military propellants which cannot be disposed of through other modes of treatment." (2) While the current Federal regulations exempt military materiel from such controls and allow disposal of these items by open field burning and detonation, the future may bring increased environmental restriction in the form of new Federal regulations.

It must be noted that state and local governments are allowed to impose restriction on hazardous waste disposal that are more stringent than the Federal regulations. Such future restrictions could potentially affect open denotation at many U.S. Army installations. Some states or localities may refrain from issuing environmental permits for open burning and open detonation; this has already been the case at two Army installations: Hawthorne Army Ammunition Plant (Hawthorne, Nevada) and Lexington Blue Grass Army Depot (Lexington, Kentucky). (3) The future method of destruction of propellants will be controlled incineration.

The intent of RCRA, however, is to promote a reduction in hazardous waste through increased recovery of useful resources, while ensuring that any necessary hazardous waste disposal operations are environmentally sound. Thus, the recovery of obsolete and unserviceable propellants is consistent with the intent of RCRA, and may be an attractive alternative to thermal treatment of these items. The Army has adopted this philosophy and has given top priority to recovery and reuse of obsolete and unserviceable propellants. (4,5)

1.2 OBJECTIVE

The objective of this task was to evaluate the economic feasibility of reclaiming and reusing propellants from obsolete and unserviceable munitions. This involved developing both capital and operating costs for the reprocessing (reclamation/reuse) of several types of propellants. The net credit for reprocessing the propellant(s) included the credit for the savings on new raw materials and the savings from avoiding costs of incinerating the obsolete propellant(s) minus the operating costs of grinding the obsolete propellant(s).

1.3 SCOPE OF WORK

Under Contract No. DAAK11-85-D-0008, with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), Process Development Branch, Arthur D. Little, Inc. was issued Task Order No. 10 entitled "Computerization and Application of a Standard Cost Evaluation Method." We based our work on the bench-scale studies carried out at Radford Army Ammunition Plant (RAAP) on grinding, drying and packing obsolete propellants and either resolvating them or recovering the raw materials by solvent extraction. The report entitled "Propellant Reuse/Recovery Technology" (6) presents the results of these tests. We also used the costs of equipment for processing developed by Radford Army Ammunition Plant personnel (7). With this information, we have developed budgetary (± 40%) estimates of the total capital investment for the grinding of the propellants and the operating costs of the processing of the propellants.

2.0 WASTE PROPELLANT RECYCLING OPTIONS

2.1 INTRODUCTION

There are two major approaches to the reclamation/reuse of obsolete and unserviceable propellant munitions:

- resolvation of the obsolete propellants to produce the equivalent single-, double-, or triple-based new propellants; and
- solvent extraction of the obsolete propellants to separate and recover individual ingredients.

The following two sections describe each process and indicates the major processing steps. Section 2.2 describes the resolvation processes for the five propellants investigated and the plant to reprocess these propellants. The resolvation of any of the five propellants evaluated involve grinding it under water, drying it, and packing it into drums. One may produce new propellant by resolvating the ground propellant in an existing propellant production line. Section 2.3 describes both the solvent extraction processes for the same five propellants and the limitations of these processes.

2.2 RESOLVATION PROCESSES

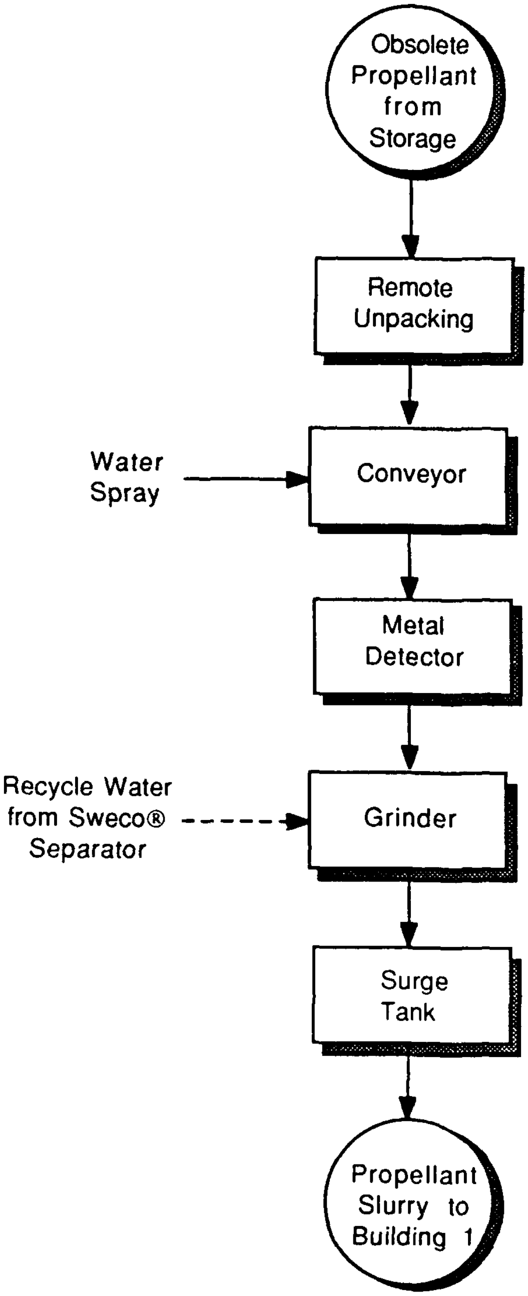
The resolvation process will use existing production lines for the extrusion of the new propellants. The only additional step necessary for this reclamation operation is the grinding of the obsolete propellant. For obvious safety considerations, the propellant must be ground under water, then dried and finally repacked into drums for storage. From storage, the drums of ground propellant would be sent to the production lines.

The grinding operation is the same for all the different types of propellants and can be carried out in the same grinding equipment. The production rate is also the same for all types of propellants, namely 500 pounds per hour. In actual operation, however, one would have to carefully clean the grinding, drying and packing equipment and replace the grinding water before processing a new type of propellant. It might be desirable, therefore, to have dedicated grinding lines for any of the largest quantity propellants.

Figures 2.1, 2.2 and 2.3 present schematic flow diagrams of the equipment necessary for the grinding operations. To limit the quantity of propellant in a single building, we have placed the operations into three separate buildings. In the first building, shown schematically in Figure 2.1, remote unpacking of drums of obsolete propellant, checking for any stray metal, and then grinding of the propellant as a water slurry in a knife grinder is carried out. In Figure 2.2 for the second building, screening of the ground propellant slurry on a Sweco screen, drying of it in a Wolverine drier, and placing of the dried

FIGURE 2.1

SCHEMATIC FLOW DIAGRAM FOR PROPELLANT GRINDING
(BUILDING 1)



Source: Hercules Aerospace Co. (RAAP)

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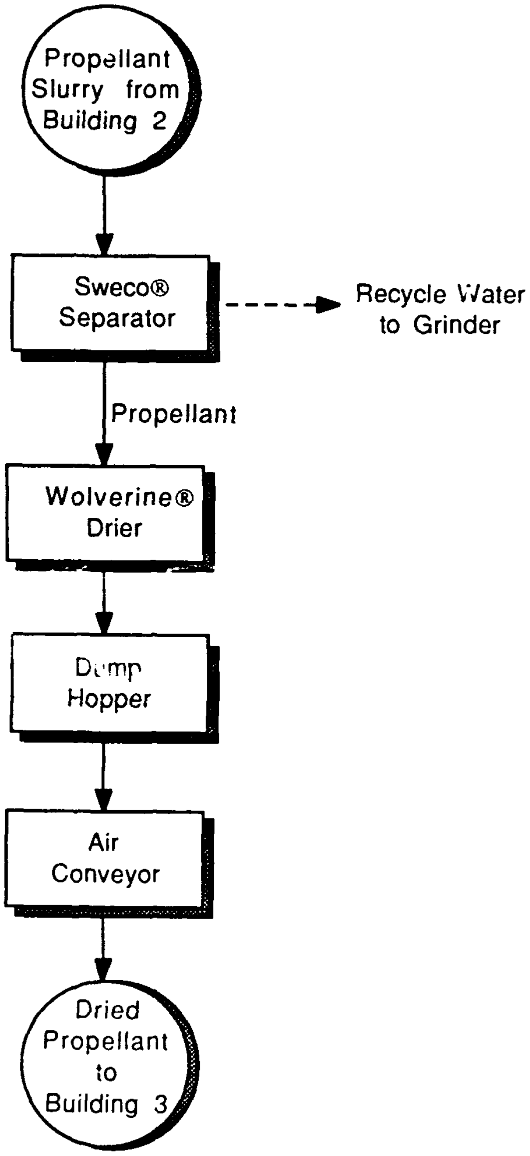
FIGURE 2.2

SCHEMATIC FLOW DIAGRAM FOR PROPELLANT GRINDING
(BUILDING 2)

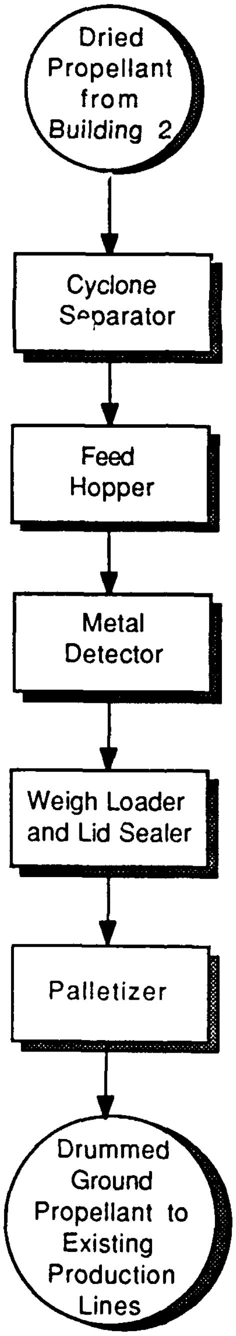


Source: Hercules Aerospace Co. (RAAP)

FIGURE 2.3

SCHEMATIC FLOW DIAGRAM FOR PROPELLANT GRINDING

(BUILDING 3)



Source: Hercules Aerospace Co. (RAAP)

propellant into an air conveyor to be sent to the third building takes place. In Figure 2.3 for the third building, the recovering of the propellant in a cyclone separator, checking for metal again, and weighing and loading of drums of ground propellant is carried out. We have based the estimates of capital costs shown in Section 3.2 on the installed costs of the equipment shown in Figures 2.1, 2.2 and 2.3.

2.3 SOLVENT EXTRACTION PROCESSES

Any of the solvent extraction processes will require grinding of the unserviceable propellant in equipment identical to that used to grind the propellant for resolvation. Thus the equipment shown in the previously cited Figures 2.1, 2.2 and 2.3 will also be required for the solvent extraction processes. In addition, to this grinding equipment, solvent extraction equipment is also required. The type and complexity of the solvent extraction equipment will vary depending on whether one extracts single-, double-, or triple-based propellants. The more complex propellants such as the double- or triple-based types will require more processing steps to separate the individual ingredients before their reuse than the single-based type. A separate extraction plant will have to be built and dedicated to each type of propellant.

Since the bench-scale tests employed a solvent, methylene chloride, that should not be used for worker safety reasons, further bench-scale tests need to be performed. These tests need to be performed before one develops any designs or prepares any associated cost estimates. The only general comments one can make is that any solvent extraction process by its nature will be more complex and costly than resolvation. The more costly nature of any solvent extraction processes will limit their applicability to propellants that can not be processed by resolvation, i.e., chemically off-specification propellants.

3.0 ECONOMIC ANALYSIS

3.1 INTRODUCTION

This economic evaluation of reclamation/reuse options for obsolete and unserviceable propellants addresses two fundamental issues:

- USATHAMA currently has no comprehensive capital and operating cost data base for the reuse/recovery of obsolete and unserviceable propellants; and
- The economic attractiveness of the concept of reusing propellants must be established to support management decisions regarding future expenditures for research and development of these technologies.

To assist in addressing these issues, this report provides budgetary capital and operating costs for the resolvation of five propellants discussed in Section 3.2. In Section 3.3, the report discusses the economics of solvent extraction processes, to the extent practicable, and the need for further research studies to help define these processes before additional costing can be performed.

3.2 RESOLVATION PROCESS COST ESTIMATES

As was discussed in Section 2.2, the only new equipment for the resolvation of propellants would be for the actual grinding of the obsolete propellant. After the grinding, one could use the ground obsolete propellant as feed to an existing production line. The equipment for grinding is the same for all five propellants, and thus one estimate for capital investment is valid for each type of propellant. We have divided the grinding operations into three separate buildings to minimize the total amount of propellant (for safety considerations) in any one building.

The equipment, which would be housed in the first building, includes a trolley conveyor, a barrel dumper, a vibratory conveyor, a metal detector, a slurry knife grinder and a ground propellant slurry tank. The equipment is sized to handle 1,000 pounds per hour of propellant for flexibility while the typical throughput will average 500 pounds per hour. The equipment costs are budgetary in nature and have an uncertainty of plus or minus 40%. As is shown in Table 3.1, the purchased equipment in the first building totals $405 thousand. Adding in as a percentage of the equipment cost; installation labor at 25%, piping at 30%, electrical at 20%, and spare parts at 2%, the total direct cost amounts to $775 thousand. Adding in the engineering and supervision, overhead and fee, and the contingency as indicated in Table 3.1, the total capital investment amounts to $1.0 million.

The equipment for the second building includes a Sweco® separator, a vibratory conveyor, a Wolverine® drier and an air conveyor that total $1.35 million. The costly items of equipment are the Wolverine® drier

Table 3.1

Capital Cost Estimate for
Preparation Facility Before Propellant Resolvation
(Building 1 - Remote Unpacking and Grinding)

Equipment Item	Quantity	Total Cost ($ '000)
Trolley Conveyor System	1	35
Dump Hopper, Stainless Steel	1	5
Vibratory Feeder	1	25
Vibratory Conveyor	1	25
Metal Detector	1	5
Grinder Feed Hopper	1	5
Grinder	1	265
Slurry Tank	1	25
Slurry Pump and Piping	1	15
● SUBTOTAL EQUIPMENT COST		$ 405
Installation Labor		100
Piping		120
Electrical		60
Instrumentation		80
Spare Parts		10
o TOTAL DIRECT COST		$ 775
Engineering and Supervision @ 8%		60
Contractor's Overhead and Fee @ 15%		115
● TOTAL DIRECT AND INDIRECT COST		$ 950
Contingency @ 10%		95
● TOTAL CAPITAL INVESTMENT		$ 1,045

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

and the custom fabricated air conveyor at over $600 thousand each. Adding in all the factored costs as we did in the previous cited Table 3.1, we see in Table 3.2 a total capital investment of $3.5 million for the second building.

The equipment for the third building includes a cyclone separator, a metal detector, a weigh loader and a lid sealer, a roller conveyor, a palletizer and another roller conveyor at a total cost of $475 thousand. Adding the factored installation costs, one sees in Table 3.3 a total capital investment of $1.2 million for the third building. To find the total capital investment for all three buildings, Table 3.4 presents a total capital investment of $5.8 million.

One of the reasons for the large uncertainty in the capital investments is that one needs a total systems hazards analysis to ensure that the proposed facilities provide adequate safety to personnel and property. One must assess the potential hazards and ensure that all equipment and subsequent operations meet acceptable safety criteria provided in DARCOMR-385-3 and Supplement 1, "Hazards Analysis for Facilities, Equipment and Process Development." Since many of the operations proposed in the facilities already exist at Radford AAP, one may use previous system safety study findings where applicable. Where systems design and operation or modifications preclude use of existing hazards assessments, then one must identify potential hazards and assess them quantitatively to eliminate or control potential hazards to an acceptable level.

If one looks at the operating costs for grinding the propellants and at the savings resulting from recycling the obsolete propellants, one can estimate the net operating credit. For the single-based propellant M1, there is a net operating cost (Table 3.5) for grinding of $1.52 million per year. One requires an additional expenditure of $0.6 million for replacement solvents and ingredients for the new propellant. Offsetting these costs are a credit of $3.75 million for avoided new raw materials and a credit of $1.38 million for avoided incineration of the obsolete propellant resulting in a net operating credit of $3.0 million per year.

In Table 3.6, for the single-based propellant M6, a slightly higher net credit for recovery of $3.9 million per year is realized. This slightly higher net credit is caused solely by the larger credit for the avoided raw materials for the M6 propellant compared to the M1 propellant.

For the double-based propellant, M7, one has an even higher net credit for recovery of $7.0 million per year. The larger credit, shown in Table 3.7, is due to a number of factors. The replacement ingredients cost less; there is a credit for avoided labor for nitroglycerin blending; and a larger credit for avoiding more costly raw materials. A trend can be realized that the more complex the propellant, the greater the net credit for its resolvation into a new propellant.

Table 3.2

Capital Cost Estimate for Preparation Facility Before Propellant Resolvation (Building 2 - Dewatering and Drying)

Equipment Item	Quantity		Total Cost ($ '000)
Swecc® Separator	1		15
Feed Hopper	1		5
Vibratory Conveyor	1		20
Wolverine® Drier with Steam Heater	1		660
Dump Hopper	1		5
Air Conveyor	1		645
● SUBTOTAL EQUIPMENT COST		$	1,350
Installation Labor			340
Piping			405
Electrical			200
Instrumentation			270
Spare Parts			30
● TOTAL DIRECT COST		$	2,595
Engineering and Supervision @ 8%			210
Contractor's Overhead and Fee @ 15%			390
● TOTAL DIRECT AND INDIRECT COST		$	3,195
Contingency @ 10%			320
● TOTAL CAPITAL INVESTMENT		$	3,515

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

Table 3.3

Capital Cost Estimate for Preparation Facility Before Propellant Resolvation (Building 3 - Automatic Packout)

Equipment Item	Quantity		Total Cost ($ '000)
Cyclone Separator with Bag Filter	1		10
Feed Hopper	1		5
Metal Detector	1		10
Weigh loader and Lid Sealer	1		260
Powered Roller Conveyor	1		15
Palletizer with Telescoping Roller Conveyor and Pallet Stacker	1		75
Powered Roller Conveyor System	1		100
• SUBTOTAL EQUIPMENT COST		$	475
Installation Labor Costs			120
Piping			145
Electrical			70
Instrumentation			95
Spare Parts			10
• TOTAL DIRECT COST		$	915
Engineering and Supervision @ 8%			75
Contractor's Overhead and Fee @ 15%			140
• TOTAL DIRECT AND INDIRECT COST		$	1,130
Contingency @ 10%			110
• TOTAL CAPITAL INVESTMENT		$	1,240

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

Table 3.4

Capital Cost Estimate for Preparation Facility Before Propellant Resolvation (All Three Buildings)

Cost Element	Total Cost ($ '000)
Building 1 - Total Capital Equipment	1,045
Building 2 - Total Capital Equipment	3,515
Building 3 - Total Capital Equipment	1,240
● TOTAL CAPITAL INVESTMENT	$ 5,800

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

Table 3.5

Operating Cost Estimate for M1 Propellant Preparation Facility Before Propellant Resolvation (All Three Buildings)

Basis:

24 Hour Long Stream Day
250 Stream Days Per Year
12,000 Pounds Processed Per Stream Day

Operating Item	Unit	Units Required	Cost per Unit	Total Cost ($'000)
Labor	Manhours	33,900	$10.80	365
Fringe and Holidays	55% of Labor			200
Utilities				150
Maintenance (Labor and Materials)	4% of Total Capital Investment			230
General and Adminstrative Overhead	72% of Labor and Maintenance			575
● NET TOTAL OPERATING COST				$1,520
Replacement Propellent Ingredients				600
Credit for Avoiding New Raw Materials	Million Lbs	3.00	($1,250,000)	(3,750)
Credit for Avoiding Incineration	Million Lbs	3.00	($460,000)	(1,380)
● NET CREDIT FOR RECOVERY OF PROPELLENT				($3,010)

Source: Hercules Aerospace Company (RAAP) and Arthur D. Little, Inc.

Table 3.6

Operating Cost Estimate for M6 Propellant Preparation Facility Before Propellant Resolvation (All Three Buildings)

Basis:

24 Hour Long Stream Day
250 Stream Days Per Year
12,000 Pounds Processed Per Stream Day

Operating Item	Unit	Units Required	Cost per Unit	Total Cost ($'000)
Labor	Manhours	33,900	$10.80	365
Fringe and Holidays	55% of Labor			200
Utilities				150
Maintenance (Labor and Materials)	4% of Total Capital Investment			230
General and Adminstrative Overhead	72% of Labor and Maintenance			575
• NET TOTAL OPERATING COST				$1,520
Replacement Propellent Ingredients				600
Credit for Avoiding New Raw Materials	Million Lbs	3.00	($1,550,000)	(4,650)
Credit for Avoiding Incineration	Million Lbs	3.00	($460,000)	(1,380)
• NET CREDIT FOR RECOVERY OF PROPELLENT				($3,910)

Source: Hercules Aerospace Company (RAAP) and Arthur D. Little, Inc.

Table 3.7

Operating Cost Estimate for M7 Propellant Preparation Facility Before Propellant Resolvation (All Three Buildings)

Basis:
24 Hour Long Stream Day
250 Stream Days Per Year
12,000 Pounds Processed Per Stream Day

Operating Item	Unit	Units Required	Cost per Unit	Total Cost ($'000)
Labor	Manhours	33,900	$10.80	365
Fringe and Holidays	55% of Labor			200
Utilities				150
Maintenance (Labor and Materials)	4% of Total Capital Investment			230
General and Adminstrative Overhead	72% of Labor and Maintenance			575
● NET TOTAL OPERATING COST				$1,520
Replacement Propellent Ingredients				120
Credit for Avoiding Labor in Nitroglycerine Blending				(570)
Credit for Avoiding New Raw Materials	Million Lbs	3.00	($2,220,000)	(6,660)
Credit for Avoiding Incineration	Million Lbs	3.00	($460,000)	(1,380)
● NET CREDIT FOR RECOVERY OF PROPELLENT				($6,970)

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

In Table 3.8, a net credit of $6.4 million per year is realized for resolvation of the triple-based propellant M30. In Table 3.9, it is evident that the largest net savings is for the triple-based propellant M31A1, a savings of $7.4 million per year. The triple-based propellants require less grinding than the other propellants and have lower operating costs for grinding. They also have the largest credits for avoiding very expensive raw materials. Resolvating the more complex propellants offers the greatest cost savings, but all propellants provide an attractive net operating credit.

The payback periods for the capital investment range from the longest of 1.9 years for the single-based M1 propellant to the shortest of 0.8 years for the triple-based M31A1 propellant. All of the payback periods are highly attractive with the shorter paybacks for the more complex double- and triple-based propellants.

3.3 DISCUSSION ABOUT SOLVENT EXTRACTION COSTS

With any solvent extraction process, the unserviceable propellant will have to be ground in the same equipment as for the resolvation process discussed in Section 3.2. Thus, all of the capital costs associated with the grinding equipment would apply to any solvent extraction process. Also, the operating costs for grinding would apply as shown in the net total operating cost line in the previously cited Tables 3.5 to 3.9. However, there would be additional costs for the solvent extraction processes to recover the individual ingredients in the propellants. All these additional capital and operating costs for the solvent extraction processes would decrease the overall attractiveness of solvent extraction as compared to resolvation.

Since we do not have well-defined processes or solvents identified, it is not possible to develop total capital or operating costs for the solvent extraction options at this time. It is obvious, however, that for the more complex propellants, one would require a more complicated process for separation of the ingredients which would result in more expensive equipment. In all cases, solvent extraction options would be less attractive than the corresponding resolvation option. Thus, chemically off-specification propellants would be the primary candidate for solvent extraction since these propellants can not be recovered by the less expensive resolvation option.

Table 3.8

Operating Cost Estimate for
M30 Propellant Preparation Facility Before Propellant Resolvation
(All Three Buildings)

Basis:

24 Hour Long Stream Day
250 Stream Days Per Year
12,000 Pounds Processed Per Stream Day

Operating Item	Unit	Units Required	Cost per Unit	Total Cost ($'000)
Labor	Manhours	25,200	$10.80	270
Fringe and Holidays	55% of Labor			150
Utilities				150
Maintenance (Labor and Materials)	4% of Total Capital Investment			230
General and Adminstrative Overhead	72% of Labor and Maintenance			470
• NET TOTAL OPERATING COST				$1,270
Replacement Propellent Ingredients				390
Credit for Avoiding New Raw Materials	Million Lbs	3.00	($2,210,000)	(6,630)
Credit for Avoiding Incineration	Million Lbs	3.00	($460,000)	(1,380)
• NET CREDIT FOR RECOVERY OF PROPELLENT				($6,350)

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

Table 3.9

Operating Cost Estimate for M31A1 Propellant Preparation Facility Before Propellant Resolvation (All Three Buildings)

Basis:

24 Hour Long Stream Day
250 Stream Days Per Year
12,000 Pounds Processed Per Stream Day

Operating Item	Unit	Units Required	Cost per Unit	Total Cost ($'000)
Labor	Manhours	18,000	$10.80	195
Fringe and Holidays	55% of Labor			110
Utilities				150
Maintenance (Labor and Materials)	4% of Total Capital Investment			230
General and Adminstrative Overhead	72% of Labor and Maintenance			385
● NET TOTAL OPERATING COST				$1,070
Replacement Propellent Ingredients				300
Credit for Avoiding New Raw Materials	Million Lbs	3.00	($2,450,000)	(7,350)
Credit for Avoiding Incineration	Million Lbs	3.00	($460,000)	(1,380)
● NET CREDIT FOR RECOVERY OF PROPELLENT				($7,360)

Source: Hercules Aerospace Company (RAAP) and
Arthur D. Little, Inc.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The major conclusion of this report on reclamation/reuse of obsolete propellants is that resolvation is a very economically attractive option for reuse of obsolete propellants. The capital investment for the grinding of the obsolete propellant is $5.8 million, and one can use existing production lines for the resolvation without any further capital investment. The capital investment produces a net operating credit ranging form $3.0 million to $7.5 million per year and attractive payback periods ranging from the longest of 1.9 years to shortest of 0.8 year.

We recommend that the U.S. Army proceed with a detailed design and costing study of the grinding process in preparation for the potential construction and operation of a facility at Radford AAP. We suggest Radford as the site of this facility, because it has the only operating production lines that could conveniently resolvate the ground obsolete propellant.

The major conclusion on the solvent extraction processes is that they require further bench-scale testing with a less hazardous solvent such as supercritical carbon dioxide. Without these tests, one can not develop meaningful budgetary capital investment cost estimates. However, it is clear that more capital equipment will be required for solvent extraction than that for resolvation; consequently, the capital costs for solvent extraction will be higher than for resolvation. This will most likely limit the use of any solvent extraction process to recovery of only chemically off-specification propellants.

Consequently, we recommend that the U.S. Army consider funding further bench-scale testing of solvent extraction processes for chemically off-specification propellants, but only after carefully evaluating the need for such, depending on both the actual and anticipated generation of such off-specification propellants.

5.0 REFERENCES

1. "Marine Protection, Research and Sanctuaries Act of 1972," enacted by P.L. 92-532, October 23, 1972, 86 Stat. 1052; 33 U.S.C. 1401 *et. seq.*; Amended by P.L. 93-254, March 22, 1974; P.L. 93-472, October 26, 1974; P.L. 94-62, July 25, 1975; P.L. 94-326, June 30, 1976; P.L. 95-153, November 4, 1977; P.L. 96-332, August 29, 1980; P.L. 96-381, October 6, 1980; P.L. 96-470, October 19, 1980; P.L. 96-572, December 22, 1980; P.L. 97-16, June 23, 1981; P.L. 97-109, December 26, 1981; P.L. 97-375, December 21, 1982; P.L. 97-424, January 6, 1983; P.L. 98-498, October 19, 1984.

2. "Resource Conservation and Recovery Act, Part 265, Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities, Subpart P, Thermal Treatment, Section 265.382, Open Burning, Waste Explosive," 40 CFR 265, 45 FR 33232, May 19, 1980, Effective November 19, 1980; Revised as shown in 40 CFR, July 1, 1982; Amended by 47 FR 30447, July 13, 1982; 47 FR 32349, July 26, 1982, Effective January 26, 1983; 47 FR 44938, October 12, 1982; 48 FR 2511, January 19, 1983; 48 FR 3981, January 28, 1983; 48 FR 14153, April 1, 1983; 48 FR 30115, June 30, 1983; 48 FR 52720, November 22, 1983; 49 FR 46095, November 21, 1984; 50 FR 661, January 4, 1985, Effective July 5, 1985; 50 FR 1999, January 14, 1985, Effective July 15, 1985; 50 FR 4513, January 31, 1985; 50 FR 16048, April 23, 1985, Effective October 23, 1985; 50 FR 18374, April 30, 1985, Effective June 14, 1985; 50 FR 28742, July 15, 1985.

3. Zaugg, M. M., Ammunition Equipment Directorate, Tooele Army Depot, Tooele, Utah, Personal Communication with Arthur D. Little, Inc., Cambridge, Massachusetts, January 15, 1986.

4. "Hazardous Waste Management," Personal Communication, Headquarters, U.S. Army Materiel Development and Readiness Command, DRCIS-S letter, 30 November 1979.

5. "Efficient Use of Resources," Personal Communication, Headquarters, U.S. Army Materiel Development and Readiness Command, DRCCP letter, 4 June 1981.

6. *Propellant Reuse/Recovery Technology (Task Order No. 7)* USATHAMA Report No. AMXTH-TE-CR-88026, prepared by Arthur D. Little, Inc. under Contract No. DAAK11-85-D-0008, August 1988.

7. "Cost Estimating Information on a Conceptual Propellent Resolvation Preparation Facility," Radford Army Ammunition Plant Memorandum by J. F. Cross, September 14, 1988.

APPENDIX A

A description of and the associated costs for the equipment necessary for the grinding operation of a conceptual propellant resolvation facility are presented in this Appendix. This information was provided by Hercules Aerospace Co. (RAAP).

Table I. Potential equipment for conceptual propellant resolvation preparation facility

Building I - Remote Unpacking and Grinding (Building Size ~5092 ft^2; Process flow rate - 1100 lb propellant/h)

Item	Equipment	Current value, $^{a,b}	Description	Manufacturer
A	Trolley Conveyor System	36,560	System contains the following for explosion-proof service: a. Drive unit assembly - 1500 lb capacity for speeds of 2 to 10 ft per min complete with: 1. Worm reducer 2. Link belt 3. Motor - 3 hp 4. Chain drive 5. Drive guard 6. Coupling(s) 7. Drive sprocket b. Screw take-up 90° traction wheels (2) and turns (2) c. Stainless steel track and chain d. Anti-backup and anti-runaway devices e. Trolleys (39) with attachments f. Electric remote speed and indicator controls	Material Handling Systems Inc., Atlanta, GA Now: FMC Corp., Material Handling Systems Div. Colmar, PA
B	Dump Hopper	1,875	Hopper and appendages are 304 stainless steel that meets Hercules Incorporated weld specifications for explosive service. Size is 42-in. dia. inlet and 20-in. dia. exit. Equipment was custom fabricated for process.	American Sheet Metal, Inc. Doraville, GA Now: General Metals, Inc. Electromate Corp. Jacksonville, FL
C	Vibratory Feeder	25,845	Model No. FP-2480S: 1/4 in. 316 stainless steel with 1-hp motor. Feeder is a vibrating type of conveyor designed to regulate the flow of material from a hopper. Trough is constructed in a single section with the drive firmly attached. Entire machine is suspended from or supported by low frequency isolation springs. Size is 12-ft long by 10-in. high to accommodate dump hopper.	Carrier Vibrating Equipment, Inc., Louisville, KY Now: Rexnord, Inc., Conveying Equipment Operation Milwaukee, WI

Table I. (cont)

Building I - Remote Unpacking and Grinding (Building Size ~5092 ft^2; Process flow rate - 1100 lb propellant/h)

Item	Equipment	Current value, \$^{a,b}	Description	Manufacturer
D	Vibratory Conveyor	25,170	Model No. SSD-2480F: 1/4 in. 316 stainless steel - 33 ft 2 in. with 2-hp motor. The complete conveyor is 40-ft long and 2-ft wide having a 1° slope decline capable of producing a dynamic reaction with a horizontal component of ± 2204 lb and a vertical component of ± 1276 lb. Component parts are two gates, drive, belt guard, and fiberglass flat leaf.	Carrier Vibrating Equipment, Inc., Louisville, KY Now: Rexnord, Inc., Conveying Equipment Operation Milwaukee, WI
E	Metal Detector	3,975	Model is a standard series detector for tramp metal with an electromagnetic conveyor-type rectangular coil (8-1/2 in. wide by 6-in. high coil opening) for feed rate of 15 to 600 ft per minute.	ITT Industrial Automation Systems Now: ITT Power Systems Corp. Galion, OH
F	Grinder feed hopper	1,875	Hopper and appendages are 316 stainless steel that meets Hercules Incorporated weld specifications for explosive service. Size is 23-3/4 in. dia. inlet and 21-in. dia. exit. Equipment was custom fabricated for process.	American Sheet Metal, Inc. Doraville, GA Now: General Metals, Inc. Electromate Corp. Jacksonville, FL
G	Grinder	267,410	Knife grinder with cutting chamber having rotating and stationary knives with sized screen in bottom discharge section for particle size reduction. Grinding of propellants is accomplished underwater. Maximum propellant and water feed rates are 1100 lb/h and 3300 lb/h, respectively. All equipment is rated for explosion-proof service. Model No. 14-CSF stainless steel Hog. Motor requirement is 150-hp.	Mitts & Merrill, Inc. Saginaw, MI Now: Mitts & Merrill Products Div., Carthage Machine Co. Carthage, NY
H	Slurry tank	25,200	Tank is 304 stainless steel that meets Hercules Incorporated weld specifications for explosive service. Tank capacity is 1700 gal. Tank is 8-ft high by 6-ft dia. Tank has agitator driven by 15-hp motor to keep propellant and water as a slurry.	American Sheet Metal, Inc. Doraville, GA Now: General Metals, Inc. Electromate Corp. Jacksonville, FL

Table I. (cont)

Building I - Remote Unpacking and Grinding (Building Size ~5092 ft^2 process flow rate - 1100 lb propellant/h)

Item	Equipment	Current value, \$[a,b]	Description	Manufacturer
1	Slurry pump and piping	16,155[c]	Model No. 2-VRG-200: capable of >80 gpm for a total head of 76 ft. 2-in. horizontal pump with 11-in. impeller for various speeds and and 20-hp motor for explosion-proof service. rpm - 1600; frame - 215-T; Type - TEFC; voltage - 230/460/360. Piping requirement is ~250-ft 304 stainless steel schedule 40 3-in. dia. pipe.	The Galigher Co. Jersey City, NJ Now: B G A International Salt Lake City, UT

Table I. (cont)

Building 2 - Dewatering and Drying (Building Size ~2560 ft^2; Process flow rate - 1000 lb propellant/h)

Item	Equipment	Current value, $[a,b]	Description	Manufacturer
J	Sweco® separator[d]	13,615	Sweco® Vibro-Energy separator Model No. A-10-8 containing 48-in. screen (150 mesh, 0.0041-in. wire dia., 0.0026-in. wire opening), leveling separator, and motor, ground, and spout connections, uses 2-1/2 hp explosion-proof motor.	Sweco, Inc. Los Angeles, CA Now: Emerson Electric Co./ Sweco Inc. Los Angeles, CA
K	Feed hopper	4,440[c]	Custom-fabricated isometric design of aluminum; 3 ft 6 in. by ~6 in. opening, horizontal retraction 234°, vertical retraction 90°; welded according to Hercules Incorporated specifications.	Wolverine Corporation Merrimac, MA
L	Vibratory conveyor	21,260	Custom-fabricated of aluminum; 2 ft 6 in. by 4 ft 9 in. welded according to Hercules Incorporated specifications.	Wolverine Corporation Merrimac, MA
M	Wolverine® dryer with steam heater	659,595[e]	165 ft^2 jet zone dryer consisting of 4 modules: first module is 2 x 15 ft for removing unbound moisture from propellant that could be present; last 3 modules are 1-1/2 x 30 ft for drying; propellant bed depth is 1 to 2 in. Each module contains 2 fans (2400 cfm max), supply air unit is balanced with the fans. Seven cyclone participators are present throughout 165 ft^2 train. Construction is 304 stainless steel meeting Hercules Incorporated explosive service and die checked welds. Temperature requirement is 140°F for drying nitroglycerin (NG) containing propellants (40% NG). Heat is serviced by steam.	Wolverine Corporation Merrimac, MA
N	Dump hopper	3,700[c]	Custom-fabricated of standard design having 30 in. opening of aluminum welded according to Hercules Incorporated specifications.	Wolverine Corporation Merrimac, MA

Table I. (cont)

Building 2 - Dewatering and Drying (Building Size ~2560 ft^2; Process flow rate - 1000 lb propellant/h)

Item	Equipment	Current value, \$[a,b]	Description	Manufacturer
O	Air conveyor	644,740[c]	Custom-fabricated of 4-in. dia. schedule 10 aluminum alloy pipe of 180 ft min. meeting Hercules Incorporated welding specifications.	Buell Engineering Co., Inc. King of Prussia, PA Now: General Electric Co. Fairfield, CT

Table I. (cont)

Building 3 - Automatic Packout (Building Size -3710 ft^2; Process flow rate - 887 lb propellant/h)

Item	Equipment	Current value, $[a,b]	Description	Manufacturer
P	Cyclone separator with bag filter	11,070[c]	Tank cyclone receiver custom fabricated for process out of 304 stainless steel. 4-ft high by 2-ft dia. with 8 in. throat containing a double peristaltic valve for discharge. Bag filter for particulates should be adapted to cyclone followed by air scrubbing prior to exhausting air.	Buell Engineering Co., Inc. King of Prussia, PA Now: General Electric Co. Fairfield, CT
Q	Feed hopper	5,180[c]	Custom-fabricated of aluminum; 60 in. dia. opening with 8-in. dia. discharge. Split skirt is of conductive rubber. Welded according to Hercules Incorporated specifications.	Alloy Fab, Inc. South Plainfield, NJ
R	Metal detector	7,455	Model Metlokate metal detector consisting of: a. Search head containing inspection coils and through which the product is passed for monitoring. b. Control unit containing power supply amplifiers, timers, control relay, and monitoring meter.	Goring Kerr Inc. Tonawanda, NY
S	Weigh loader and lid sealer[f]	262,275	1. Weigh loader: A batch-type automatic Thayer scale containing a weigh bucket which collects the desired quantity required to fill one drum. The bucket is filled with drum filling hopper model N18V, rotary type scale weigh hopper with dribble feed control.	Thayer Scale, Hyer Industries Inc. Pembroke, MA
			2. Lid sealer: custom fabricated to automatically assemble lid and lock ring on a 30-gal. drum at a rate of 32 per hour.	Honeywell Hopkins, MN

Table I. (cont)

Building 3 - Automatic Packout (Building Size ~3710 ft^2; Process flow rate - 887 lb propellant/h)

Item	Equipment	Current value, $[a,b]	Description	Manufacturer
T	Powered roller conveyor	15,195	Conveyor for fiber drums consisting of: a. One 4-ft straight section b. One 45° spur c. Two 90° curves d. one 26-ft straight section e. one 4-ft 8 in. straight section with counter	American Industrial Corporation Virginia Beach, VA Now: America Laubscher Corporation Farmingdale, NY
U	Palletizer with telescoping roller conveyor and pallet stacker[f]	76,325	1. Automatic drum palletizer model B200. Automatically stacks six loaded fiber drums, approximately 16 in. dia. on a 32 in. by 48 in. four-way double faced wooden pallet. Fabricated of 304 stainless steel of custom design.	Beacon Machinery, Inc. St. Louis, MO
			2. A telescoping roller conveyor is utilized to move three drums at a time off the powered roller conveyor via a push wiper to load six drums total onto a 32 by 48-in. wooden pallet.	Acco-Olson Acco Babcock Inc. Warren, MI
			3. A custom-fabricated pallet stacker is located next to the palletizer to deliver pallets.	Alvery, Inc. St. Louis, MO
V	Powered roller conveyor system	99,995	Custom fabricated 40-in. powered roller conveyor system consisting of: a. Staging or air chain conveyor b. Powered chain trailer conveyor c. Transfer car for intra-plant use d. Ancillary equipment, e.g., motors, etc	Alvery, Inc. St. Louis, MO

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[a] Calculated using CE plant cost indexes, "Economic Indicators," Chemical Engineering, Vol. 95, No. 10, p. 9, July 18, 1988.

[b] If project material is purchased at RAAP, an additional 20.83% overhead cost is required per the 88 Change I Proposal.

[c] Calculated using CE plant cost indexes, "Economic Indicators," Chemical Engireering, Vol. 95, No. 10, p. 9, July 18, 1988 and Peters, Max S. and Timmerhaus, Klaus D., Plant Design and Economics for Chemical Engineers, 3rd Ed., McGraw-Hill Book Company, New York, NY © 1980.

[d] Another Hercules Incorporated facility uses a Baker-Perkins pusher-type centrifuge for dewatering.

[e] Based on drying double-base flake propellant in a Wolverine® dryer at another Hercules Incorporated facility.

[f] Lid sealer is not in continuous operation during packout; current method is manual operation.

[g] Palletizer has a pallet magazine which is loaded manually with a capacity for about 4 h of operation.