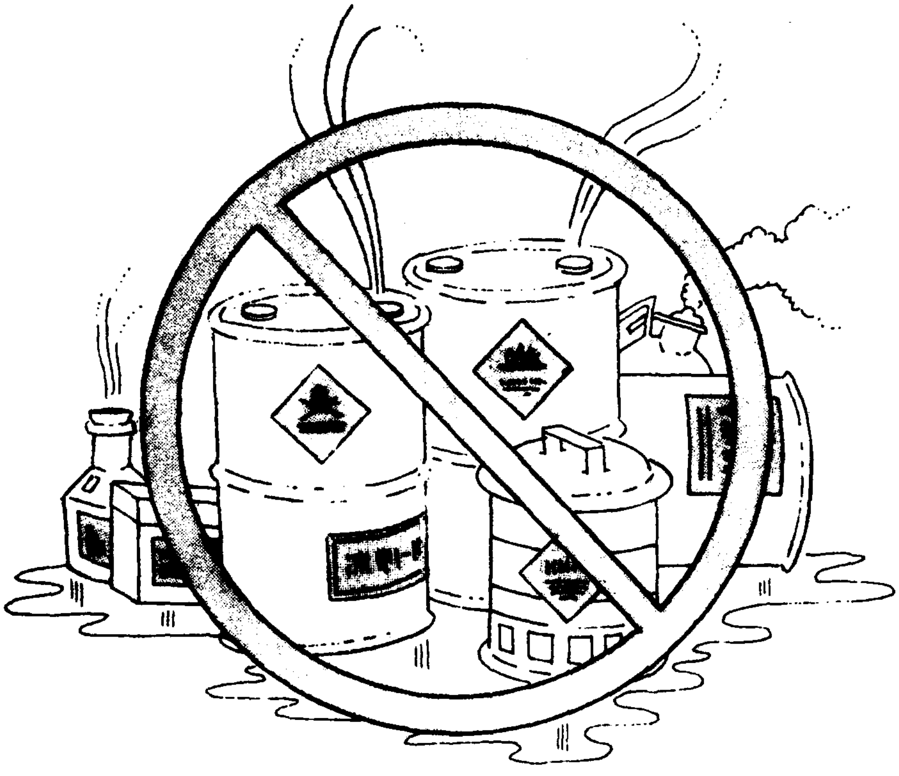
4

TECHNICAL NOTE

TN-1787

VOLUME I



HAZARDOUS WASTE MINIMIZATION INITIATION DECISION REPORT

by

R.M. Roberts, J.L. Koff, and L.A. Karr

June 1988

Sponsor: Naval Facilities Engineering Command
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NAVAL CIVIL ENGINEERING LABORATORY, PORT HUENEME, CA

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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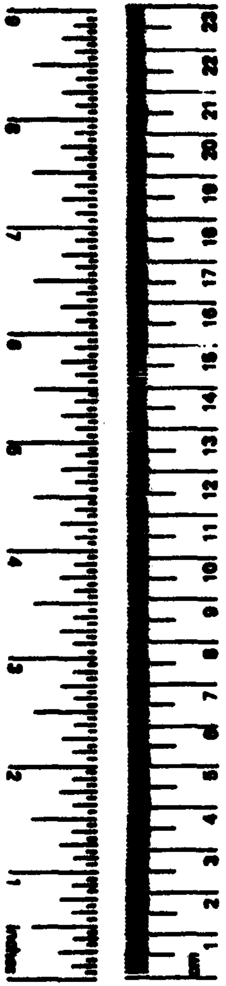
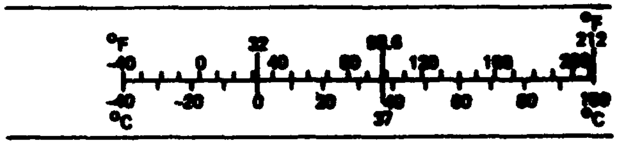
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The IDR study defines the magnitude of process and hazardous wastes and the costs associated with their management. A review of other military applications, civilian practices, as well as new and emerging technologies and practices, are presented for each HW-generating process. Using this information, comparisons are made to identify which areas can be upgraded to more current technologies and techniques. Administrative practices that cause HW to be formed are also considered and suggestions offered as to how such management procedures might be beneficially modified.

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The IDR study defines the magnitude of process and hazardous wastes and the costs associated with their management. A review of other military applications, civilian practices, as well as new and emerging technologies and practices, are presented for each HW-generating process. Using this information, comparisons are made to identify which areas can be upgraded to more current technologies and techniques. Administrative practices that cause HW to be formed are also considered and suggestions offered as to how such management procedures might be beneficially modified.

PREFACE

This report was reviewed and amended in two separate phases. An initial version was transmitted by CNO letter in December 1986. That volume presented the engineering information required for the first three sections of the IDR format as specified in NAVFACINST 3900.7; that is, the Introduction, Problem Definition, and State of Navy Hazardous Waste Management Technology and Alternatives. It was felt that information in these areas should be corroborated by the overall industrial sector of the Navy before finalization of the second portion of the IDR; that is, the Projections for Evolving Technologies, Recommendations, Technology Goals, and Capability Goals. Reviewers included all of the Syscoms, NAVFAC EFD's, and the twenty-four activities responsible for most of the hazardous waste generated in the Navy.

After the reviewers' comments on the initial volume were furnished and incorporated, a draft of the complete report was returned to the same reviewers. Again, their comments were submitted and incorporated. The document was then finalized after a last internal review at NCEL. This IDR is, thus, the product of Navywide inputs from activities already in dynamic change with regard to hazardous waste minimization and management.

ACKNOWLEDGMENTS

This Initiation Decision Report was developed under the auspices of the Naval Facilities Engineering Command on work unit No. 71-021A. The cognizant organization of that command was the Environmental Quality Division (code 112) with Mr. T.J. Zagrobelny ably serving as task manager.

The report was prepared by the Naval Civil Engineering Laboratory with initial assistance from Systems Technology Corporation. Technical editorial management of this rather complex document was the well-acquitted responsibility of Dr. E. Riser of Syscon Corp.

TABLE OF CONTENTS

VOLUME I - IDR TEXT

LIST OF TABLES

LIST OF ILLUSTRATIONS

VOLUME II - APPENDICES

APPENDIX

EXECUTIVE SUMMARY

OVERVIEW

The Navy generates over 4 million tons of process and hazardous wastes (HW) a year. A conservative estimate (most Navy labor excluded) of the cost of handling this waste is set at $18 million. It is projected that that figure will increase by a factor of three over the next seven years due to the tightening of regulatory constraints. In order to fulfill CNO objectives, the Navy must implement a hazardous waste minimization program to reduce by at least half the amount of hazardous wastes it produces.

The Resource Conservation and Recovery Act (RCRA) places strict controls on the storage, treatment, and disposal of HWs. In response to this, and subsequent amendments that establish a regulatory schedule that the Navy must meet over the next ten years, the present study was initiated at NCEL to assess Navy HW management practices. The study resulted in an initiation decision report (IDR) that defines:

- The optimum process technologies that are immediately implementable to minimize HW generation,
- The optimum treatment and disposal technologies that are immediately implementable, and
- The RDT&E required to modify processes to render them less HW productive and to improve HW treatment, and disposal technologies.

The IDR study defines the magnitude of process and hazardous wastes and the costs associated with their management. A review of other military applications, civilian practices, as well as new and emerging technologies and practices, are presented for each HW-generating process. Using this information, comparisons are made to identify which areas can be upgraded to more current technologies and techniques. Administrative practices that cause HW to be formed are also considered and suggestions offered as to how such management procedures might be beneficially modified.

Ordnance processes are considered by reference only and are restricted to "end-of-pipe" HW minimization issues. Installation Restoration topics are being addressed at NCEL in a separate IDR now under preparation and are therefore not included here. This is also true of asbestos and PCBs, which are considered special action items. Cost burdens in HW management are not limited to the Navy only but include the entire Department of Defense, particularly those of the Defense Logistics Agency (DLA).

The top industrial processes accounting for 95% of all HW generated in the Navy in 1984 were:

- Industrial Waste Treatment Plant
- Electroplating/metal finishing
- Ordnance
- Bilge water
- Abrasive blasting
- Nonrecurring
- Painting operations
- Demilitarization
- Pipe flushing/cleaning
- Boiler layup
- Ship boiler cleaning
- Fluids changeout
- Submarine steam generator cleaning
- Cleaning with solvents
- Battery repair/replacement
- Metal prep
- Bilge derusting
- Chemical paint stripping
- Torpedo cleaning

TECHNOLOGY ASSESSMENT

A technological assessment of the various alternatives for each process was performed with the assistance of a computer model, which prioritized the options considered. The Hazardous Waste Management Technology Assessment Model (HAMTAM) considers technology options in terms of RCRA-conformance, cost/benefits, availability, logistical adaptability, and risk in realizing sought-for performance improvements. The figures-of-merit generated thus enabled the objective selection of the most desirable process modifications.

APPLICATION OF IMPROVED KNOW-HOW (READILY IMPLEMENTABLE)

This technology is not in general use in the Navy, but is found to some degree there or in industrial practice. Some of the following examples have already been, or are on the verge of being implemented at selected Naval facilities.

- Plastic Media Blasting
- Used Solvent Elimination Program
- Hard Chrome Plating
- Waste Acid/Alkali as IWTP Reagents
- Dry Paint Booth Conversion
- Used Oil Reclamation and Recycle
- Delisting
- Mechanical IWTP Sludge Dewatering

- Otto II Fuel Recycling
- Reduced Overspray Paint Technology
- Dual Media Spray Technology
- Steam Purity Testing
- Conventional IWTP Process Optimization
- Minimal HW-Producing Electroplating Technology

APPLICATION OF TECHNOLOGY NOT COMMERCIALLY AVAILABLE

This technology is in the R&D sector and may be implemented within the Navy only after a 6.3/6.4 program. This technology is not available through industrial/commercial products and practices.

- Recycling of Hydroblast Wastewater
- Aircraft Paint Stripping Wastewater Treatment
- Nonpersistent Emulsifiers
- Plastic Media Blasting
- Reducing Blasting Grit Hazards and Type
- Recycle of Steam Generator Wastes
- Recycle of Bilge Tank Cleaning Wastes
- Cyanide Oxidation
- Ion Exchange/Metal Recovery
- Waste Acid/Alkali as IWTP Floccing Reagents
- Reuse Technology for Pickling/Electroplating Bath
- Thermal Combustion Technology
- Distillation of Spent Torpedo Solvents
- Torpedo Afterbody Washwater Treatment
- Encapsulation/Fixation
- Peroxidation of Pink Water

ADVANCES IN TECHNOLOGY (EXPLORATORY DEVELOPMENT)

These technologies require exploratory development to advance the state of technology with respect to specific technical parameters and their application to Naval HW minimization problems.

- Supercritical Fluid Technology
- Innovative Encapsulation/Fixation
- New Solvent Selection (to replace chlorofluorocarbons)
- Carbon Dioxide Pellets to Strip Paint
- New High-Energy Battery Types
- HW Thermal Destruction

Based on the results of the technology assessments made, specific recommendations were developed. These included twelve discrete recommendations for modifying Navy administrative practice so as to reduce HWM. Twenty two RDT&E projects were proposed for DERA funding and a number of additional projects were recommended for 6.2 and 6.3 funding. This body of information was then formally organized into technology goals that the Navy should pursue and acquire in order to attain a 50% reduction in the HW it now produces.

GLOSSARY

WORD, ACRONYM, OR ABBREVIATION	MEANING
AAP	Army ammunition plant
ABG	Ammunition burning ground
A/C	Aircraft
AFB	Air Force base
AFFF	Aqueous firefighting foam
AIMD	Air Intermediate Maintenance Department
Al	Aluminum
APC	Air pollution control
APCD	Air pollution control district
API	American Petroleum Institute
As	Arsenic
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASW	Antisubmarine warfare
ATCC	American Type Culture Collection
atm	Atmosphere
BOD	Biological oxygen demand
$CaCl_2$	Calcium chloride
CALTRANS	California Department of Transportation
CBC	Construction Battalion Center
CBS	Carolina Biological Supply [Co.]
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CESD	Chemical Engineering Science Division [NBS]
CFC	Chlorofluorocarbon
CFR	Code of Federal regulations
Cl_2	Chlorine
CN	Cyanide [ion or complex]
CNO	Chief of Naval Operations
CO_2	Carbon dioxide
COD	Chemical oxygen demand
Cr	Chromium
CR	Contractor report
CSTR	Continuously stirred reactor
Cu	Copper
CWA	Clean Water Act
CY	Calendar year
DAF	Dissolved air flotation
DEMIL	Demilitarization
DLA	Defense Logistics Agency
DNT	Dinitrotoluene
DOD	Department of Defense
DOE	Department of Energy

DRE	Destruction and removal efficiency
DRMO	Defense Reutilization and Marketing Office
DSRV	Deep submergence rescue vessel
DTR	Developmental technical report
DTRC	David Taylor Research Center (*formerly* Naval Ship R&D Center)
EDR	Earliest date ready
EDTA	Ethylenediaminetetraacetic acid
EGDN	Ethyleneglycol dinitrate
EP	Extraction procedure [toxicity test]
EPA	Environmental Protection Agency
EUAC	Equivalent uniform annual cost
FB	Fluidized bed
Fe	Iron
$FeCl_2$	Ferrous chloride
FFR	Final feasibility report
F/M	Food-to-microorganism [ratio]
FOR	Fuel oil relaimed
FY	Fiscal year
GAC	Granular activated charcoal
GOCO	Government-owned, contractor-operated
gpd	Gallons per day
HAMTAM	Hazardous Waste Minimization Technology Assessment Model
HAZMAT	Hazardous material
HCl	Hydrochloric acid
HCN	Hydrogen cyanide
H.E.	High energy [fuels]
HF	Hydrofluoric acid
HM/W	Hazardous materials/wastes
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulfuric acid
HSWA	Hazardous and Solid Waste Amendments [1984]
HTH	High test hypochlorite [calcium hypochlorite]
HW	Hazardous waste
HWERL	Hazardous Waste Engineering Research Laboratory [EPA Cincinnati]
HWF	Hazardous waste fuel
HWM	Hazardous waste minimization
IDR	Initiation decision report
IFR	Initial feasibility report
IGT	Institute of Gas Technology
I/O	Input/output
IR	Infrared
IRAD	Independent research and development
IWTP	Industrial wastewater treatment plant
IX	Ion exchange
JP	Jet propulsion [fuels]

KGPD	Kilograms per day
$KMnO_4$	Potassium permanganate
K_2O	Potassium oxide
KO_2	Potassium superoxide
KOH	Potassium hydroxide
KWH	Kilowatt-hour
LAP	Load, assemble, and pack
LAS	Linear alkyl sulfonate
LD_{50}	Lethal dose for 50% of recipient animals
L.E.S.S	Leading Edge Space Shuttle
LET	Load equalization tank
Li	Lithium
$LiBr$	Lithium bromide
LSU	Louisiana State University
MARCORP	Marine Corps
MCAS	Marine Corps air station
MCB	Marine Corps base
MEK	Methylethyl ketone
MFD	Marine fuel diesel
mg/l	Milligrams per liter
Mgpy	Million gallons per year
MILCON	Military construction
MLSS	Mixed liquor suspended solids
N.A.	Not applicable
NAC	Naval Avionics Center
$NaCN$	Sodium cyanide
NADC	Naval Air Development Center
NADEP	Naval aviation depot
NAEC	Naval Aviation Evaluation Center
$NaNO_2$	Sodium nitrite
$NaNO_3$	Sodium nitrate
$NaOH$	Sodium hydroxide
NAPC	Naval Air Propulsion Center
NARF	Discontinued designation; see NADE
NAS	Naval air station
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air [Systems Command]
NAVBASE	Naval Base
NAVFAC	Naval Facility [Engineering Command]
NAVFACHQ	NAVFAC Headquarters
NAVMED	Naval Medical Systems Command
NAVSEA	Naval Sea [Systems Command]
NAVSSES	Naval Ships System Engineering Station
NAVSUP	Naval Supply [Systems Command]
NBS	National Bureau of Standards
NCEL	Naval Civil Engineering Laboratory
NEESA	Naval Energy and Environmental Support Activity
NH_4ClO_4	Ammonium perchlorate
NH_4NO_3	Ammonium nitrate
NH_4OH	Ammonium hydroxide
$NiCl_2$	Nickel chloride

ng	Nitroglycerine [glycerol trinitrate]
NIROP	Naval Industrial Reserve Ordnance Plant
NOS	Naval ordnance station
N.O.S.	Not otherwise specified
NOSC	Naval Ocean Systems Center
NOx	Oxides of nitrogen (NO_2 and/or NO)
NPDES	National Polluted Discharge Elimination System
NR	Not reported
NS	Naval station
NSC	Naval supply center
NSL	Naval supply list
NSN	Naval stock number
NSWC	Naval Surface Warfare Center
NSY	Naval shipyard
NUWES	Naval Undersea Warfare Engineering Station
NWIRP	Naval Weapon Industrial Reserve Plant
NWS	Naval weapons station
NWSC	Naval Weapons Support Center
O&M	Operation and maintenance
OBA	Oxygen breathing apparatus
OB/OD	Open burning/open detonation [of explosives and munitions]
OESO	Ordnance Environmental Support Office
ONR	Office of Naval Research
OSH	Occupational safety and health
OT&E	Operational test and evaluation
OTR	Operational technical report
OWTP	Oil/water treatment plant
Pb	Lead
PCB	Polychlorinated biphenyl(s)
PCP	Pentachlorophenol
PGDN	Propylene glycol dinitrate
PHST	Packaging, handling, storage, transportation
PIC	Products of incomplete combustion
PM	Preventive maintenance
PMB	Plastic media blasting
PMI	Preventive maintenace inspections
PMS	Preventive Maintenance System
PMTC	Pacific Missile Test Center
POC	Point of contact
POHC	Principal organic hazardous constituents
POPS	Paperless Order Procurement System
POTW	Publicly owned treatment works
POTWP	Publicly owned treatment works plant
ppm	Parts per million
PVC	Polyvinyl chloride
PWC	Public works center
PWD	Public works department
PWO	Public works office
QA	Quality assurance

QC	Quality control
R&D	Research and development
RAM	Reliability, availability, maintainability
RAS	Return activated sludge
RBC	Rotating biological contactor
RCP	Request for Contractual Procurement
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, development, test, and evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RO	Reverse osmosis
SCF	Supercritical fluid
SCW	Supercritical water
SECNAV	Secretary of the Navy
SIR	Savings-to-investment ratio
STARCHAPS	Ship and Tank Chemical Cleaning Hardware and Process System
STP	Sewage treatment plant
SWOB	Ships waste off-loading barge
SYSCOM	Systems Command
T0	Technology in routine use in the Navy
T1	Technology in routine use in industry
T2	Technology proven at least at bench scale
T3	Technology and concepts requiring proving
TADS	Technical assessment data sheet
T&E	Test and evaluation
TCE	Trichloroethylene
TCLP	Toxicity characteristic leaching procedure
TEA	Triethanol amine
TIC	Total installed cost
TM	Technical memorandum
TN	Technical note
TNT	Trinitrotoluene
TOC	Total organic carbon
tpy	Tons per year
TSD	Treatment/storage/disposal [facility]
TSP	Trisodium phosphate
TTO	Total toxic organics
tpy	Tons per year
UBSC	Unspecified boiler system component [in nuclear-powered ships and submarines]
UDP	Users' data package
UG	Users' guide
UO&S	Used oils and solvents
USE	Used Solvent Elimination [Program]
UV	Ultraviolet
VOC	Volatile organic compounds
WQEC	Weapons Quality Engineering Center (NWSC Crane)
WR	Work request
WW	Wastewater

Chapter 1

INTRODUCTION

1.1 RATIONALE

The Resource Conservation and Recovery Act (RCRA) places strict controls on the storage, treatment, and disposal of hazardous wastes (HW). Further, significant amendment of the RCRA in 1984 substantially tightened the required controls on the handling and disposal of HWs and on the minimization of the generation of HW. These RCRA amendments establish a regulatory schedule with effective dates over the next 10 years. The overall effect of the amendments will be to significantly increase the cost of managing HW at Naval activities. This burden will be further compounded by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which will place on the Navy perpetual responsibility for environmental damages caused by our buried wastes. These factors provide considerable incentive to develop alternative HW management technologies.

This study assesses Navy HW management practices to define:

- The optimum process technologies that are immediately implementable to minimize HW generation
- The optimum treatment and disposal technologies that are immediately implementable
- The research, development, testing and evaluation (RDT&E) needed to provide improved process control, treatment, and disposal technologies

1.2 INITIATION DECISION REPORT (IDR) APPROACH

The Naval Civil Engineering Laboratory (NCEL) has initiated this IDR to determine the present state of HW management practices within the overall Naval Establishment and to develop means for reducing the generation of HW. This effort serves as an update of similar earlier studies conducted in selected command areas, such as the 1983 Moore-Gardner report on Naval Shipyards. The present NCEL study defines the magnitude of HW generated and the costs associated with their management. A review of other military applications, civilian practices, as well as new and emerging technologies and practices, is presented for each hazardous waste-generating process. Using this information, comparisons are made to identify which areas can be upgraded to more current technologies and techniques.

This IDR focuses on the more critical processes that generate HW, as ranked in Chapter 2.4. Emphasis is placed on the "front-end" of the problem. Our preference for reducing HW generation is to identify potential changes to the processes, the materials, or the operating conditions that would eliminate or minimize the amount of hazardous waste generated.

This IDR includes technologies used by the Navy on a limited basis and other on-going RDT&E. This IDR identifies HW sources, recommends the most cost-effective solutions to satisfy RCRA without compromising productivity, product quality, or our military mission. If several alternative processes, treatment, or disposal alternatives are available, selection is by an objective technology assessment methodology (Hazardous Wastes Management Technology Assessment Model--HAMTAM). This system considers technology in routine use in the Navy (T0) and Industry (T1), as well as in bench or pilot T&E (T2) and R&D level (T3). Risk and availability weighting factors are applied to favor technology that is immediately implementable.

1.3 SCOPE OF STUDY

This IDR includes a comprehensive survey of the hazardous wastes generated by the industrial processes in use by the Navy at the present time. In addition to Naval Shipyards (NSYs), Naval Air Depos (NADEPs), and Public Works Departments/Centers (PWD/C)s, the scope includes Marine Corps activities, Navy-owned/Contractor-operated (GOCOs), and Defense Reutilization and Marketing Offices (DRMOs) of the Defense Logistics Agency (DLA). Ordnance processes are considered by reference only and are restricted to "end-of-pipe" HW minimization issues. Installation restoration topics are being addressed at NCEL in a separate IDR now under preparation and are, therefore, not included here. This is also true of asbestos and polychlorinated biphenyls (PCBs), which are considered special action items. Cost burdens in HW management are not limited to the Navy only but include the entire Department of Defense, particularly the costs of the Defense Logistics Agency (DLA).

1.4 DOCUMENT ORGANIZATION

This document is basically organized in accordance with the format recommended in Naval Facilities Engineering Command (NAVFAC) Instruction 3900.7. Because of the wide range of topics addressed, however, it was necessary to develop an arrangement for the IDR that would furnish the best possible clarity. Several manuscript structures were accordingly conceptualized, outlined, and presented to NAVFAC for consideration and comment before the present one was selected.

The narrative portion of the IDR is presented in Volume I, while Volume II comprises the supporting documentation in the form of appendices. The primary subject areas discussed within the individual chapters of Volume I are as follows:

Chapter Number	Subject Area
1	Introduction
2	Problem Definition
3	State of Navy Hazardous Waste Management--Technology and Alternatives
4	Projections for Emerging Technologies
5	Technology Assessment
6	Recommendations for Future Hazardous Waste Management
7	Technology Goals
8	Capability Goals and Options

Major Navy waste-generating processes are discussed in prioritized order (according to tons generated in 1984), starting in Chapter 3.2, with subsections addressing the nature of the industrial technology, the related treatment and disposal processes, and the alternatives to these operations as found in industry and the R&D community.

Chapter 2

PROBLEM DEFINITION

2.1 HAZARDOUS WASTE REGULATIONS

2.1.1 Background

The RCRA, an amendment to the Solid Waste Disposal Act, was passed in 1976 to address a problem of enormous magnitude--how to safely dispose of the huge volumes of municipal and industrial solid waste generated nationwide. The goals set by RCRA are:

- To protect human health and the environment
- To reduce waste and conserve energy and natural resources
- To reduce or eliminate the generation of HWs as expeditiously as possible

To achieve these goals, three distinct yet interrelated programs were developed under RCRA. The first program deals with management of solid wastes, primarily nonhazardous. The second, outlined under Subtitle C of the Act, is the most well known of the RCRA programs. It establishes a system for controlling HWs from the time they are generated until their ultimate disposal, in effect from "cradle to grave." The last of the three programs deals with underground storage tanks, a matter that will be dealt with in another NCEL IDR concerning Installation Restoration.

It is important to note that although RCRA creates a framework for the proper management of hazardous and nonhazardous wastes, it does not address the problems of HW encountered at inactive or abandoned sites or those resulting from spills that require emergency response. These issues are taken care of by a different act, the CERCLA, better known as Superfund.

The improper management of HW is probably the most serious environmental problem in the US. In 1979, the U.S. Environmental Protection Agency (U.S. EPA) estimated that only 10 percent of all HW was managed in an environmentally sound manner. The remainder was transported, treated, stored, or disposed of in a way that posed, and still poses, a potential threat to human health and the environment. Since that time, the amount of HW has steadily risen, and mismanagement is still prevalent.

The Subtitle C program developed under RCRA (Sections 3001 to 3019 of the Act) is designed to ensure that the mismanagement of HWs does not continue. It does this by creating a Federal "cradle to grave" management system that sets forth statutory and regulatory requirements for:

- Identifying HW
- Regulating generators of HW
- Regulating transporters of HW
- Regulating owners and operators of facilities that treat, store, or dispose of HWs
- Issuing operating permits to owners or operators of treatment, storage, and disposal facilities
- Transferring the responsibilities of the Subtitle C program from the Federal Government to the States
- Requiring public participation in the Subtitle C program

2.1.2 Hazardous Waste Minimization

Under RCRA, Section 3002, all hazardous waste manifests must now contain certification that the generator has a program in place to minimize the volume and toxicity of waste, to the extent practical. Such hazardous waste minimization (HWM) activities can be: 1) improved housekeeping in and around the HW-generating process; 2) improved maintenance and modifications to the process to reduce the HW generated; 3) substitution of nonhazardous materials for hazardous materials in processes, even if somewhat more costly; 4) major process modification, as exemplified by the new hard chrome plating process developed by NCEL personnel; or 5) even the discontinuance of nonessential process steps, such as the painting of an item for purely aesthetic purposes.

2.1.3 Recycling, Recovery, and Reuse of Hazardous Materials

Section 6002 of RCRA requires that all Federal agencies procure items composed of the highest percentage of recovered materials practical, consistent with competitive procurement requirements. It also requires federal agencies to use waste-derived fuels wherever practicable. Requiring use of recycled material is consistent with the rest of the Act. Within industry, the practice of recycling and resource recovery with materials reusage has usually proved to be the most cost-effective manner of waste management. Such recycling within the Navy is typified by the Used Oil and Solvent Recycling Management Program. This Navy program derives from the Department of Defense (DOD) Used Solvent Elimination (USE) program and is often called by the USE acronym. Recycling can also include steps such as reusing otherwise nonrecyclable, high-heat content wastes as fuels in furnaces, boilers, kilns, etc.

The recycling concept can be embodied in a treatment process modification. An example would be the segregation of waste streams containing strategic materials (e.g., copper) in order to send the waste, in the form of sludge, for segregated reuse as "low-grade ore." This is being practiced by the Naval Industrial Reserve Ordnance Plant (NIROP) Pomona.

2.1.4 Treatment

The purpose of HW treatment operations is primarily to render wastes nontoxic or nonhazardous or to reduce the volume of the waste. If no such treatment approach exists that will render a waste fully nontoxic and nonhazardous, then the treatment must be aimed at making the waste less hazardous for ultimate disposal.

2.1.5 Ultimate Disposal

As the name indicates, ultimate disposal is the (preferably avoidable) final step in the hazardous waste management process. Those hazardous wastes that cannot be eliminated at the industrial process, cannot be recycled, and cannot be treated to be made nonhazardous, must be made innocuous before going to ultimate disposal. Incineration is often considered an ultimate disposal method, although in reality it is not. This process produces effluent gases (stack gases) that must be controlled, solid effluent (ash and solids related to stack-gas, air pollution control) that must be made innocuous for land disposal, and, sometimes, liquid effluents (such as ash quench tank wastewaters) that may have to be treated before they are discharged. In fact, true ultimate disposal is the final release of innocuous constituents of the waste to the land, air, and surface waters.

The greatest environmental and health dangers are associated with land disposal. In fact, land disposal of many wastes is prohibited under RCRA, Sections 3004 (d), (e), and (f).

2.2 NAVY HAZARDOUS WASTE DATA BASE

The problem definition survey was conducted through the Naval Energy and Environmental Support Activity (NEESA) HW Inventory System, which is based upon activity HW reports submitted annually to NEESA. Throughout the Navy shore-based establishment, approximately 137,000 tons of HW were generated in CY84, according to reports sent by activities to NEESA.

HW volume data were taken from the NEESA data base containing summaries of 1984 activity reports. These summaries, entitled "Waste Types Generated Summaries," were reviewed to identify Navy activities generating the largest volumes of HWs.

This review identified 24 activities accounting for over 95 percent of the Navy HW produced.

To supplement the NEESA data on the top 24 generators with process-specific information, the NCEL staff conducted 19 site and five telephone surveys of these activities. Data packages for 23 activities were eventually assembled. The information submitted by NSY Portsmouth, NH, was received too late to include in the report.

For each activity surveyed, NCEL personnel completed Technical Assessment Data Sheets (TADS) for all waste types (including wastewater) generated in excess of 5 tpy. Tabular summaries of these TADS, along with an original TADS survey form, are included in Appendix A. Other NCEL IDRs also provided a source of data for this study. In some cases, the 1984 NEESA data were supplemented by 1985 data released by NEESA during the course of the IDR preparation. Based upon the NCEL survey, these 23 activities were found to produce approximately 3,977,922 tpy of process wastes (wastewater and HW) Navywide. This total far exceeds the value of 137,000 tpy that was reported to NEESA. The reason for this is that the various types of waste streams that make up the Industrial Wastewater Treatment Plant (IWTP) influent, a major waste flow, were regularly included in the NCEL survey, while the activity reports to NEESA were not consistent in this respect, although most activities did not list wastewater. However, several activities did include wastewater, either because they had no operating IWTP (e.g., Long Beach NSY); because they had overloads that necessitated export of a portion of the untreated wastewater as manifested HW (e.g., NIROP Pomona); or because they simply felt that it should be reported, even though it was detoxified on-site (e.g., Naval Weapons Support Center (NWSC) Crane).

Whether IWTP influent should be classified as a HW when it is detoxified on site is moot. The Clean Water Act (CWA) and the RCRA are not consistent on this point, and local regulatory agencies have held that such wastewater is indeed HW. In terms of the present IDR, however, such streams are considered part of a given process, and HW reduction (e.g., IWTP sludge) can be effected by modifying or reducing the volumes of IWTP influents. For these various reasons, these waste flows were included in the NCEL HW survey.

There is a considerable degree of uncertainty as to the accuracy of the data reported herein. This uncertainty is due primarily to the combined effects of 1) nonstandardized activity nomenclature in the NEESA summaries; 2) many instances of unspecified, poorly defined, or mixed lots of reported wastes; 3) lack of consistency in reporting wastewaters going into IWTPs; and 4) the NCEL data-screening process that ranks HW categories only for those waste streams produced at a rate of five or more tons per year. One problem with the 5-tpy screening cutoff is that it is conceivable, although not likely, that some waste streams may be produced at a rate of less than 5 tpy but are produced at most activities, so that a significant Navywide hazardous waste stream category could go unreported.

The annual HW mass/volume flow data do provide a very effective basis for establishing priorities for HW corrective actions. Cost figures were not used because they were incomplete. They commonly represent only treatment. They may include disposal costs and sometimes, transportation costs, but they seldom address costs associated with Navy manpower or administrative costs involved in hazardous waste management. An example of the uncertainty attaching to the cost data is the fact that Charleston NSY, which won the Secretary of the Navy (SECNAV) "E" award two out of three years for efforts to reduce HWs (they are seventeenth on the list of 24 activities surveyed), ranked third in HW handling costs. Although contractor HW disposal costs are particularly high in the Charleston area, that fact does not adequately account for the discrepancy just mentioned.

The NCEL survey identified volumes of wastewaters, such as electroplating and chemical paint stripping rinsewaters and other IWTP influents that are <u>not considered HWs by RCRA</u>, if piped directly to the IWTP. Only the sludge from these facilities is considered HW and is so reported by activities to NEESA. For the purposes of the present undertaking, however, <u>process modification</u> is the priority theme (per RCRA) and, therefore, input/output (I/O) data defining any particular process (particularly the costs thereof) must be taken into account, whatever mass of HW happens to be generated. In the tabulations that follow, therefore, clear distinctions will be made as to whether the information is process I/O data or is restricted to HW (NEESA) data alone. Because of the nature of the processes considered, the process flows usually involved are almost exclusively HW and wastewater.

2.3 CLASSIFICATION OF NAVY HAZARDOUS WASTE

Table 2-1 lists the 10 largest HW categories found in the 1985 NEESA summaries. Some of the items are clearly attributable to specific Navy industrial processes while others are not. The NCEL survey was, therefore, conducted to obtain information relating all of the NEESA HW data to source processes, as well as to study the mechanisms of such processes and the associated treatment and disposal methods.

In order to correlate the NEESA HW inventory data with processes that formed them, the 23 Naval activities with the greatest HW output were selected for the survey. This constituted more than 95 percent of HW generated. The list contained eight different types of Naval activities and included four Naval Aviation Depots (NADEPs), seven Naval Shipyards

Table 2-1. Top Ten Categories of Hazardous Waste Generated By Navy Activities *

Type of Hazardous Waste	EPA/DOT ID No.	Quantity (tons/yr)	% of Total **
Corrosive Substance	D002	30,667	22
Pink/red Water from Munitions Operations	K047	26,722	20
Spent Cyanide Bath Solutions from Electroplating	F007	26,429	19
Hazardous Waste, N.O.S.	UN9189	13,795	10
Solid Wastes Exhibiting Reactivity	D003	7,052	5
Ignitable Substances	D001	5,961	4
IWTP Sludges from Electroplating	F006	2,971	2
Solid Wastes Exhibiting lead EP Toxicity	D008	2,613	2
Caustic Solutions	UN1824	2,100	2
Chromium	D007	1,888	1
TOTAL		120,198	88

* In addition to the categories listed above, there was one additional major category for those items that were either listed with unknown ID numbers (e.g., D000), listed by state ID numbers, or listed without any ID number. This catch-all category comprised a total of 16,756 tons for 1984. That quantity is 12 percent of the total amount of hazardous waste generated in CY84 and is three times greater than the blank category amount generated in CY83.

** Navy total generated hazardous waste in CY84 = 137,121.5 tons

(NSYs), two Public Works Centers (PWCs), two Marine Corps Bases (MCBs), two Government-owned, Contractor-operated activities (GOCOs), one Naval Supply Center (NSC), and one Naval Base (NAVBASE). With the exception of three NSYs, each activity was visited by one or more NCEL engineer.

During each visit, a Technology Assessment Data Sheet (TADS) was completed for each process that generated hazardous waste. An example of the TADS is presented in Appendix A. The three NSYs not visited were surveyed by telephone, since they had been visited a short time before on the closely related NCEL shipyard HW IDR (Reference 2-1). Information for these NSYs, thus, required only updating and the inclusion of those types of HW categories that had not been studied by the previous IDR. Table 2-2 lists each activity surveyed by NCEL, along with its total volume of process wastes (HW + wastewater) and estimates of associated costs, as developed by the NCEL surveyors.

Costing was based upon activity or DRMO contract disposal costs, wastewater treatment charges assessed users by the Public Works Offices (PWOs), and any related billed charges that were specifically applied to HW items that were not covered in these other costs. No attempt was made to assign costs for intramural labor associated with administration, drayage, storage, or handling of HW.

2.4 MAJOR NAVY PROCESS SOURCES OF HAZARDOUS WASTES

2.4.1 Overview

From the 23 activities surveyed, 33 different processes were identified as generating greater than 5 tpy of HW. The processes were ranked in order to ensure that those processes having the most significant impact could be addressed herein, while those with less impact could at least be identified and targeted for possible future action.

Ranking can be most objectively accomplished on either a cost or tonnage basis or both in combination. Other factors that should be considered are the nature of the hazard (level of hazard) and the susceptibility and availability of the process to changes (considering impacts, such as military mission). After careful analysis of the available data and consideration of the additional factors, it was determined that the ranking should be based on mass or volume flow.

Cost was eliminated for two reasons. Disposal costs were not available for all the generating processes, and available disposal costs were not always complete or adequately traced to the generating source. For example, the cost of treating chemical paint stripping rinsewaters is formally assigned as part of the cost of the IWTP operation, rather than as a cost of the

Table 2-2. Summary of Process Wastes (Wastewater and HW) Generated by Activity for CY84

Activity	Type	Quantity (tons/yr)	Cost ($)
Camp LeJeune	MCB	1,196	37,300
Norfolk	NAVBASE	629	284,360
Cherry Point	MCAB	306	241,990
Cherry Point	NADEP	361,246	708,548
Norfolk	NADEP	175,985	1,864,065
Alameda	NAS	84,457	1,029,335
Jacksonville	NADEP	27,258	531,355
Pomona	NIROP	371,804	369,860
Pt. Molate	NSC	1,628	162,750
Long Beach	NSY	9,473	806,355
Mare Island	NSY	257,863	565,415
Norfolk	NSY	43,311	1,118,005
Pearl Harbor	NSY	2,630	867,130
Keyport	NUWES	55,417	998,625
Dallas	NWIRP	1,666,119	731,715
Earle	NWS	10,677	629,860
Seal Beach	NWS	3,007	238,500
Pensacola	PWC	767,346	1,227,490
Crane	NWSC	32,561	122,755
Puget Sound	NSY	60,126	1,826,280
Charleston	NSY	2,979	1,795,535
San Diego	PWC	60,602	863,685
Philadelphia	NSY	1,650	446,375
TOTAL		3,996,272	$16,755,003

stripping operation. This accounting system, therefore, makes it difficult to assess the actual cost of treatment and disposal of these wastes. Similarly, toxicity could be considered as a suitable weighting factor but, here again, data defining the toxicity of many Navy HWs are largely unavailable.

2.4.2 Problem Summary

Table 2-3 lists the 33 processes ranked according to total amounts reported. This IDR addresses the top 17 processes, which represent over 99 percent of the total amount involved and over 92 percent of the total HW management cost (based upon reported figures). One of the process categories, listed "Nonrecurring," is not addressed in this IDR. The "Nonrecurring" category includes random occurrences, such as spill clean-ups or the accumulation of out-of-spec fuels, which do not intrinsically involve on-going Navy industrial processes or practices.

It should be noted that two of the processes this IDR will address have alternative technologies already being implemented by NEESA through NAVFAC-sponsored projects. These are the hard chrome process and the plastic media, aircraft paint stripping process. The hard chrome process is ready for application and fulfills RCRA compliance requirements. The plastic media, aircraft paint stripping process also appears to be an effective minimization technology. However, NCEL is still studying certain aspects of the latter process that may well influence the eventual configuration it will assume in Navy applications.

2.5 CURRENT AND EVOLVING HAZARDOUS WASTE REDUCTION AND DISPOSAL PROBLEMS

The Navy has placed high priority on HW management practices that will eliminate or minimize the generation of HW to the greatest extent possible. This philosophy, if systematically applied Navywide, would reduce the economic and administrative burdens associated with subsequent handling, treatment, and disposal of HW by many millions of dollars annually. The upgrading of processes to reduce HW will also afford opportunities for long-term savings through newer, more cost-effective production approaches and techniques. This does not necessarily involve investments in RDT&E, but rather investments in technology transfer to exploit Navy practices already in limited use.

There are significant financial liabilities involved with hazardous materials buried in the ground. What was an approved disposal site 20 years ago is often now a threat to human health and is also an extraordinary financial burden to those whose wastes were buried there. The concept of ultimate disposal must be critically reviewed in light of such long-term RCRA and CERCLA liability. The generator's responsibility for a waste

Table 2-3. Navy Hazardous Waste Generating Processes Ranked by Annual Tonnage of Wastewater and HWs

Process ID	Tons	Cost ($)
IWTP	3,680,533	7,357,545
Electroplating/metal finishing	235,191	978,596
Ordnance	26,738	
Bilge water processing *	12,473	691,260
Abrasive blasting	6,662	899,815
Nonrecurring	6,014	
Painting operations	4,139	1,533,612
Demilitarization	3,649	
Pipe flushing/cleaning	3,432	508,970
Boiler lay-up	3,122	55,560
Ship Boiler cleaning	3,019	287,520
Fluids changeout	2,681	630,332
Submarine Steam generator cleaning	1,555	372,695
Solvent cleaning	1,336	357,915
Battery repair/replacement	1,268	992,355
Metal prep	1,081	178,418
Bilge derusting	1,045	506,975
Chemical paint stripping	904	447,350
Torpedo cleaning	683	134,780
Vehicle wash/repair	440	59,850
Bilge/tank cleaning	350	58,000
Firefighting practice	258	17,568
Container/drum disposal	202	468,900
Breathing apparatus	182	368,995
Chem lab	170	34,000
Tank cleaning- CHT system	170	
Fueling operations	158	126,250
Bilge/tank degreasing	120	3,025
Air conditioner repair	109	46,440
Ships offloaded stores	85	50,150
Boiler testing	54	21,350
L.E.S.S. manufacturing	52	4,175
Fluorescent tube replacement	47	8,977
TOTAL	3,997,922	$17,201,378

* In a previous NCEL survey, 99,960 tpy were recorded; see Section 3.5.

lasts forever, or until the waste is no longer a waste by virtue of its being rendered nonhazardous. The responsibility and liability for the proper treatment or disposal of that waste remains exclusively that of the Navy. Whenever technically feasible alternatives to land disposal are available, they must be given very high priority.

The cost to dispose of waste in landfills can no longer be directly compared with the cost per gallon to reduce, eliminate, or to destroy the waste. The long-term liability factor of landfill disposal must be considered. Similarly, there is evidence that old, established practices (especially maintenance schedules) should be reevaluated in light of their impact on HW generation.

In the interest of including all Government costs, the costing scope observed in this IDR will include expenses incurred through DRMO, as well as direct Navy costs.

2.6 ADMINISTRATIVE PROCEDURES AND SUPPLY POLICIES AFFECTING HW MANAGEMENT

While the scope of this IDR is restricted to the identification of alternatives to present Navy industrial practices that cause, treat, or dispose of hazardous wastes, it is also important that the impacts of administrative procedures on HW generation and disposal be considered. Although such issues are outside the purvue of the present effort, brief comments are nonetheless offered below in the interest of stimulating possible corrective actions. Many of the issues raised below are, fortunately, being addressed by NAVFAC in its development of the Hazardous Materials Management Model, HM3, a system for minimizing the conversion of hazardous materials to hazardous waste.

2.6.1 NEESA HW Inventory System

The NEESA HW Inventory System needs better support from the field. The reporting methods are not standardized, and this makes the data difficult to interpret and evaluate. There are also various positions on what materials should be considered HW. There is a valid concern that materials are being reported as hazardous without verification that they actually are. This practice allows activities to avoid the cost of testing to delist a waste material, while ensuring that the waste is being handled safely (previously, at the expense of others; i.e., DRMO).

2.6.2 HW Segregation

One key administrative requirement impacting HW management is proper waste segregation. The volume of HW is greatly increased when a nonregulated waste is mixed with a listed waste.

Likewise, in many operations where multiple processes are employed (such as fluids changeout and solvent cleaning), waste materials are often mixed. Different solvents may be combined or mixed with oils. Such practices make reclaiming/recycling difficult, if not impossible. <u>Personnel must segregate waste streams</u>. Training programs, such as those used for safety, should be conducted to instruct personnel, both ashore and on ship, on the proper handling of materials. They would stress factors, such as required segregation of HWs, reduction of the amount of material thrown away, and proper use of ship stores. An excellent effort in this direction is the shipboard training program for HM/W storage, segregation, and accountability developed by the Navy Safety Center, Norfolk, VA.

Some commands feel that training alone is not sufficient to ensure compliance and that there must also also be penalties imposed for noncompliance with standing instructions and orders.

2.6.3 Logistic Constraints

Procurement operations should be made more flexible to allow the use of material acquisition techniques that will promote HW minimization. Options to consider include: 1) renting solvents from vendors who will then manifest, rework, and recycle wastes or 2) franchising processes that are fully supported by the proprietor/contractor (an allowable exception to normal procurement per FAR). There should also be a provision allowing the purchase of hazardous materials in smaller quantities. Current practices center on purchasing case/pallet lots, regardless of the actual volume of material needed. One possible way to effect such a system would be to have the Naval Supply Systems Command (NAVSUP) set up Servmart-type facilities where authorized personnel could immediately pick up items that are needed in small quantities (e.g., one quart of paint) and have the ship or shop billed for the items. Currently, outdated material is sold by DRMO for a few cents on the dollar to a buyer who will use it as new. Another procurement option to consider would be consignment of overage material to the original vendor for rework into prime quality goods. This vendor could then furnish considerably better credits to the Navy than are available through DRMO sales.

2.6.4 Purchase Specifications

Specifications are often established to avail the best possible product for Navy use; however, the top grade quality may not always be necessary. This may imply initial use of lower grades, as well as extension of the use of materials by having more realistic and flexible specifications.

2.6.5 Shelf Life Term

Shelf life term is specified by Item Managers who are usually not chemists and, therefore, technically unqualified to make such an assessment. As a result, the suppliers are relied upon to specify a "safe" shelf term. The manufacturers have found that shelf term is inversely proportional to Navy sales and, accordingly, often recommend shelf lives that are unrealistically short. When the expiring goods cannot be resold, more HW is produced. It is possible that some materials may not even require specification of a shelf life. It may, therefore, be very productive to initiate a thorough reevaluation of shelf life and other specifications, in order to determine the maximum shelf term of a product for its intended purpose and the conditions to be met if it is to be recycled or used for other applications.

2.6.6 Recycle of Off-specification Materials in Less Demanding Applications

Reuse and recycling of certain materials are often hampered by the need to meet product specifications that are too stringent. It is be possible that while a recycled material is no longer suitable for its original use, it may be usable for some less critical application. Product specifications should be reviewed, and there should be some coordination between activity shops so that potential users of lower specification materials can be identified. Lists of overage materials could be advertised before or after going to DRMO. Such evaluations are particularly applicable to the USE program.

It should also be pointed out that the selling of off-spec materials to companies purportedly recycling or using such material has been the major cause of Superfund clean-up actions nationwide. Sometimes, the ingenuity of these marketeers in getting rid of unprofitable materials is an environmental crime. In addition, when they can no longer maintain a profitable business, their bankruptcy actions protect them but not the original generator, who then has to reassume responsibility for the wastes.

2.6.7 Electronic Mail Order

Stocks of unused, short shelf life items (such as photographic chemicals) can be reduced through the use of an electronic mail order and inventory system. Such a system bypasses NSC warehouses and sends appropriate quantities of items directly from the manufacturer to the user, thereby, eliminating the time that items age while in the logistics process. Such a system is currently being demonstrated between the Navy and Kodak through the sponsorship of NAVSUP.

2.6.8 Paperless Order Procurement System (POPS)

POPS is another computerized or electronic wire accounting/ordering system. It was developed by DLA primarily for the Defense General Supply Center and involves only carefully selected critical items that typically have short shelf lives and are available only from a limited number of sources. The Navy may access the system directly at the activity level; such purchases are routed through the DLA accountability system and billed to the activity's supply organization.

2.6.9 Proliferation of Hazardous Material Types

Consolidation of hazardous materials used in Navy industrial practice is needed. Typically, when new or different equipment and processes are brought into the system, little consideration is given to what is already in place. This results in proliferation of materials and HW.

2.6.10 Segregation of Off-loaded Ship Stores

As reported by Alig, et al. (Reference 2-2), there are no specific procedures for managing the large quantities of hazardous materials and wastes that are off loaded from ships. As reported by Bogucki and Lardis (1985), three activities are involved: The NSC, the DRMO, and the PWC/PWD. The NSC accepts materials that are in ready-for-use condition, that have greater than six months' shelf life remaining, and are items that are regularly stocked. The DRMO accepts materials that are in good condition but have less than six months' shelf life remaining or are in damaged, but not leaking, containers. PWC/PWD will accept any material that is rejected by either the NSC or the DRMO and, thus, is classified as waste. If the containers are leaking, they must be repackaged. Materials off-loaded from ships are hauled by PWDs or PWCs, both of which usually charge for the drayage, but not usually directly to the ship. Material destined for DRMO is frequently picked up by PWD/C first. In such cases, there is no difference in convenience between sending the material by the PWD/C or by the DRMO. In some cases, in fact, PWC picks up at no charge for DRMO deliveries, while charging for wastes that will come under PWC storage/handling cognizance.

2.6.11 Storage of Off-loaded Ship Stores

Dockside off-loading of sea stores should be better organized to allow for proper care and storage of the materials by the responsible parties. Frequently, goods are off loaded without the proper coordination between the ship's personnel and the shore receiving activities. This results in materials being left at dockside in unprotected areas and being damaged by the weather or through improper management. It is during the time that passes between off-loading and final disposition that materials originally suitable for NSC acceptance degrade to materials that can be accepted only by the PWC/PWD. As recommended by Bogucki and Lardis (Reference 2-3), a sheltered shore-side staging area where ship personnel could take material to prepare it for transfer to receiving activities would be a significant advantage. Hazardous waste management ashore will be greatly benefited through the implementation afloat of the David Taylor Research Center (DTRC) recommendations contained in "Afloat Hazardous Material/Waste Control Strategy," soon to be published.

In addition to the material management methods recommended in the latter publication, HWM afloat is also possible in shipboard laboratory and industrial processes. As developed later in this report, HWM technologies affecting these operations are being investigated and piloted at sea under the aegis of the DTRC.

2.6.12 Preventive Maintenance Scheduling

The Navy's Preventive Maintenance System (PMS) wisely calls for a program of preventive maintenance inspections (PMI) to determine whether operating equipment ashore and afloat is in a proper condition of maintenance or needs tagging for immediate preventive maintenance (PM) attention. Conversely, however, some maintenance procedures are performed on a scheduled basis without verification of the need for the procedure. In some cases, hazardous wastes are created by such operations. Their production might be avoided, if PMI were carried out first. An example of this is the hydroblasting of marine boilers during scheduled overhauls. In the process, considerable amounts of sodium nitrite solution are wasted and must then be treated. If sample sections of boiler tube were first removed and examined for fouling, unnecessary cleanings could be avoided.

2.7 REFERENCES

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2-3 M. M. Bogucki and A. E. Lardis. Ship-to-Shore Transfer of Hazardous Material/Waste from USS John F. Kennedy (CV 67), David Taylor Naval Ship Research and Development Center, DTNSRDC/SME-85/69, September 1985

Chapter 3

STATE OF NAVY HAZARDOUS WASTE MANAGEMENT - TECHNOLOGY AND ALTERNATIVES

3.1 OVERVIEW

Chapter 2 presents the estimated mass flows of the major categories of hazardous wastes being generated by the Naval Establishment afloat and ashore. This section of Chapter 3 describes: 1) the Navy operational and industrial practices that are responsible for the generation of these hazardous waste (HW) streams, 2) the treatment/recycle technologies that are or can be applied to the wastes generated by these industrial processes, and 3) the disposal options that are available for the HW residues resulting from processes and the applied treatments after HWM optimization is realized. The discussions of the various Navy processes can, thus, be outlined as followed:

- INDUSTRIAL PROCESS ASPECTS
  - CURRENT NAVY PRACTICE
  - GENERAL INDUSTRIAL PRACTICE
  - ALTERNATIVE TECHNOLOGIES (From all sources)
- TREATMENT OF HAZARDOUS WASTES PRODUCED BY THE PROCESS
  - CHARACTERISTICS OF THE WASTE
  - CURRENT NAVY TREATMENT PRACTICE
  - GENERAL INDUSTRIAL PRACTICE
  - ALTERNATIVE TECHNOLOGIES
- ULTIMATE DISPOSAL OF RESIDUES FROM TREATED WASTES FROM THE VARIOUS PROCESSES

This discussion is, however, preceded by a brief description of Navy practices in the storage and handling of hazardous materials, a major source of HWs.

3.1.1 Hazardous Materials Storage and Handling

A large quantity of HW that must be handled and disposed of by the Navy is virgin hazardous material that has never been used. Such waste hazardous materials include:

- Items with a shelf life that has expired because of product age or chemical instability; overstocking is a major cause of such wastage

- Excess hazardous material that is obsolete, having been replaced by a preferred alternative material
- Items with deteriorated containers (e.g., labeling no longer fully legible)
- Off-spec material
- Partially used material
- Open purchase material, regardless of condition; generally, only material with assigned Naval Stock Number (NSN) can be returned to Naval Supply Centers

Although expired shelf life items are not recorded as a separate category of HW by DRMO, various activities have estimated that from 13 to 50 percent of their HW consists of such materials (Reference 3-1).

3.1.1.1 Types of Materials Stored and Associated Processes. Table 3-1 lists many of the hazardous materials stocked by the Navy and the processes associated with them. These items may have a specific shelf life. A shelf life may be necessary because the material's characteristics may change over time or because the container may deteriorate. Container deterioration is of special concern for off-loaded ship stores. The problems associated with off-loaded ship stores are discussed in Section 2.6.

Table 3-1. Typical Stored Materials and Associated Process Applications

Material	Process
Paints	Painting operations
Reagents	Boiler testing Water testing Fuel testing
AFFF	Firefighting (and practice)
Oxygen breathing canisters	Firefighting (and practice)
Photographic chemicals	Circuit board manufacturing Photo Labs

3.1.1.2 Stocking and Procurement Procedures. Purchasing of hazardous materials in large quantities also contributes to the problem of HW in the form of unused materials. Since the Navy must maintain a war-ready logistics system, many materials are purchased in quantities too large to use within the shelf term.

To further aggravate this situation, shipments of new stocks of material to supply centers are often determined from historic use rather than current needs. This practice frequently results in significant overstocking.

NADEP Pensacola has developed and implemented an effective and efficient Hazardous Material (HM) Control Program. This program, developed by the NADEP's Hazardous Material Committee, has been recommended by the Naval Chief of Operations for Navywide adoption. The program is based upon the principal that control of incoming hazardous materials is vital and prerequisite to the control of HW. The following are the primary guidelines by which Pensacola manages its HMs:

1. Hazardous materials are procured only when required by an engineering directive and when approved by the Hazardous Materials Control Committee.

2. Adequate technical data, including potential hazards and required precautionary measures for safe usage, are maintained for all hazardous materials purchased.

3. Hazardous materials are stored in the minimum quantities necessary to ensure adequate availability.

4. Hazardous materials are labeled to identify the material to warn unfamiliarized personnel of the potential dangers of the material.

5. Hazardous materials are handled and used only by trained personnel under controlled and approved conditions.

6. Excess hazardous materials and hazardous wastes generated by using these materials are disposed of in the most practical manner, considering personnel safety and environmental implications (NARFPINST 5100.50B, 25 November 1985).

Each hazardous material that is used in each shop is listed on a computerized data base. This list is distributed quarterly to the shops. To add a new material to the list, a determination must be made by the Materials Engineering Division to verify there is not a less hazardous material or process available. The Supply and Safety Departments then determine availability and ensure that a material safety data sheet is received. Next, the Production and Safety Departments set the location. The Environmental Engineer establishes the requirements for storage of the material and predetermines the disposal route for excess HMs and HWs that are generated. Hazard codes and personal protection equipment requirements are established by the NADEP Occupational Safety and Health (OSH) Office and Naval Medical Systems Command (NAVMED) Industrial Hygienist before the material is delivered to the shop. A label containing hazard information is affixed to the container, when the material is delivered to the NADEP HM-storage facility. With this procurement procedure, the shop personnel have access to hazard information from the label and the PLATO computerized hazardous material (HAZMAT) information system, which furnishes data on what protective measures to use, how much material they are allowed to store, and the proper procedure for disposing of the material or wastes from the processes employed.

Figure 3-1 illustrates the procurement procedure before implementation of NARFPINST 5100.50B. There were no control points or safety/health checks in the process. Figure 3-2 diagrams the improved procurement procedure that has been implemented and provides technical acceptability, safety, and proper disposal checks.

Comments received from some NSYs question the applicability of the Pensacola HM accountability system to their needs. It was pointed out that the specialized industrial operations at a typical NADEP require relatively few HMs and that the HM Control Committee can be correspondingly small. At a NSY, such as Puget Sound, over 6000 HMs are used and about 50 requests per month for HM evaluations are requested. This situation would demand a much larger HM Control Committee. It is, thus, suggested that rather than controlling the use of HMs that could adversely affect production, such manpower could be better utilized in developing process modifications for the elimination, reduction, or recycle of HMs.

3.1.1.3 <u>Handling of Partially Used and Outdated Materials</u>. Outdated materials are currently turned over to DRMO for marketing or disposal. DRMO first attempts to distribute hazardous materials to other DOD branches or other federal departments. If not accepted by anyone in the Federal Government, the materials are offered to state and local governments and charities. If the materials are not accepted by these entities, they are offered for sale to qualified public buyers. If there are no buyers, these materials then become HW, and DRMO must pay a contractor to dispose of them. The DRMO accepts generator liability once the material is turned over to them.

Partially used materials are generally resealed in their original containers and sent out for ultimate disposal. DRMO usually handles disposal of such items in much the same way as it does outdated materials that cannot be resold.

Until FY87, the Defense Logistics Agency (DLA) assumed the cost burden of disposing of HW out of appropriations. To encourage HWM, activities will be billed back for such costs by the DRMOs. The interim arrangement for FY87 was to have the Systems Commands (SYSCOMs) accept such billings and then phase over to direct billing of the activities in FY89. The old DRMO

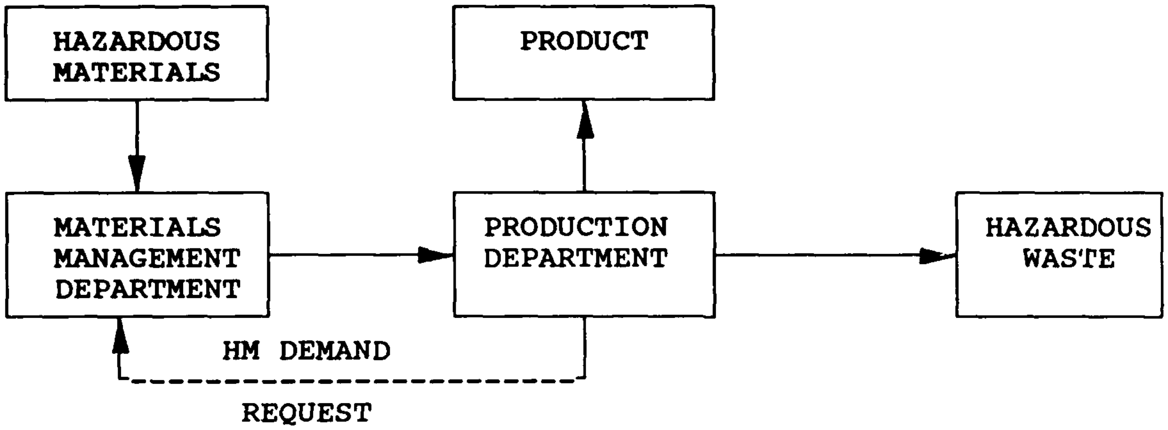


Figure 3-1. Procurement procedure before implementation of NARFPINST 5100.50B

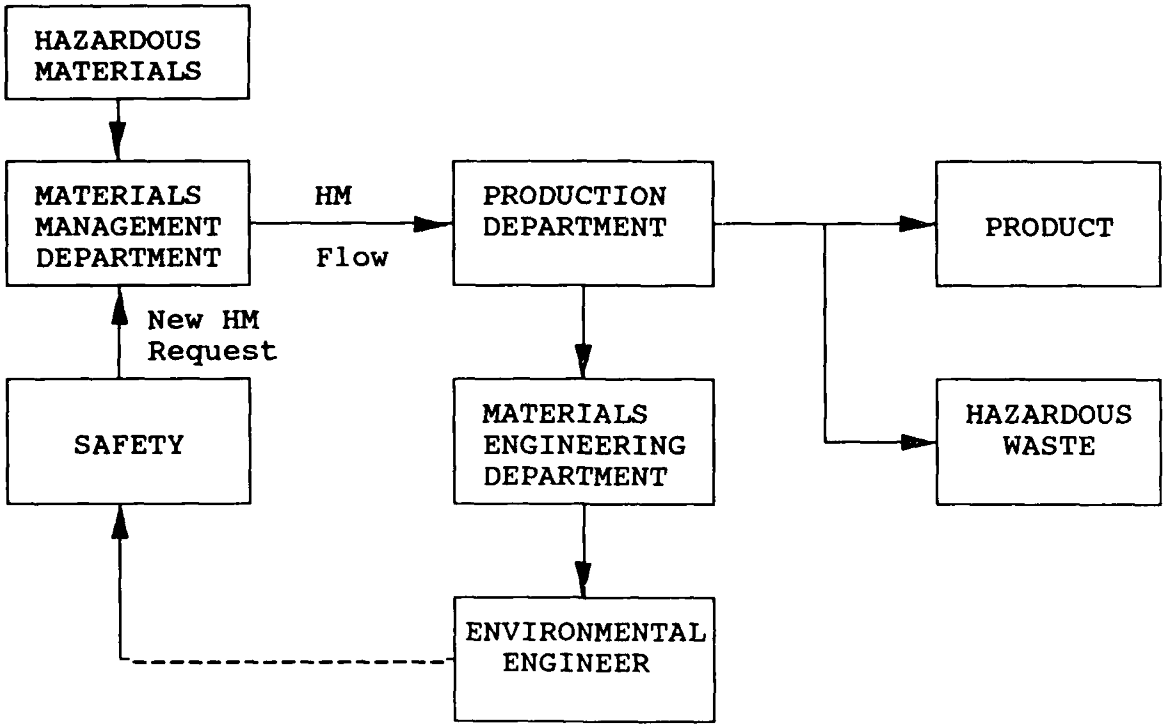


Figure 3-2. Prccurement procedure after implementation of NARFPINST 5100.50B

procedure of issuing credits to activities for hazardous waste or materiel that can be sold off for as-is use or rework (the Resource Recycling Program) remains in effect.

3.1.2 Processes generating Navy Hazardous Wastes

Each HW-generating process is discussed in three discrete levels of technology availability. These levels can be summarized as follows:

- Immediately available technology (T0) - Processes (industrial, treatment, disposal) proven in actual Navy applications at one or more activities
- Readily implementable technology (T1) - Processes in use by industry having a high potential for direct or easily phased application to Navy needs with little or no risk (technology off-the-shelf or nearly so)
- Promising technology (T1 ...Tn) - Processes that have undergone varying degrees of proving ranging from pilot level (T1), through bench demonstration (T2), to conceptualization (T3...Tn). RDT&E definitely required to test applicability to Navy need; significant risk entailed.

In the process discussions that follow, therefore, descriptions of Navy processes (T0) are first presented together with the mechanics by which HWs are formed. Then, where private industry uses process technologies (T1) similar to those of the Navy, these are described for comparison or for possible adoption with appropriate transitional T&E. The final element is the discussion of alternatives to existing Navy practice that can be considered for achieving HW reductions in the Navy. These options not only include techniques and practices already successfully used by the Navy (T0) and Industry (T1) but promising technology (particularly T2 and T3) that may require RDT&E before Navy use that is considered worthy of the investment.

These options may involve any aspect of process change that is regarded cost-effective for achieving HW reduction, whether it is a small part of the process under consideration (e.g., changeout of one detergent for another to achieve faster-breaking kettle wash-out emulsions) or a complete change of the process to something radically different.

In the interest of brevity, discussions of the technical characteristics of candidates for industrial process HW reduction are minimized. Appendices or references furnish needed technical details. In some instances, there may be only a limited amount of information available to support a HW reduction scheme discussed. The philosophy observed, however, has been to point out such weaknesses rather than to ignore the technology.

Information on Navy processes reported in this section is based, in large part, on inputs obtained from the Naval Civil Engineering Laboratory (NCEL) survey and, in part, from the report literature. Distinct disparities in the characteristics of given processes were found between some activities. These were generally caused by the differences in military mission and product characteristics. They were also due to arbitrary variations in the process system designs.

The intent has been to present all the known process technologies available from which candidate concepts for achieving cost-effective, superior HW reduction might ultimately be identified and ranked, based upon merit (see Section 5.3).

3.1.3 Treatment/Recycle Technology Associated with Navy Industrial Processes

Following each discussion of the industrial engineering involved in the various Navy processes outputting HWs, information is presented on the treatment of those HWs and how they might change, if the industrial processes are changed.

The organization of the treatment/recycle material follows the same system observed for the process technology discussions. Current Navy practice (T0) for dealing with the wastes generated by each process is first described; then, relevant treatment procedures used in industry (T1); and, finally, alternative strategies for improving present Navy HW treatment practice (T0 to T3). These alternative candidates are promising technologies that are being practiced to a limited extent within the Navy but that have potential Navywide application (T0); they are technologies available from industry that would require minimal risk and transitional T&E (T1); or they are technologies that may still need further RDT&E before being used (T2 or T3).

These options may involve any aspect of treatment change regarded to be cost-effective, whether applied to minor aspects of the treatment under consideration or to replacement of the treatment with something radically different. All forms of wastes and treatment are considered; wastewaters are included, even if regarded as part of the source industrial processes, since they contribute to the generation of a derivative HW, IWTP sludge. Such associated environmental problems as total toxic organics (TTOs), volatile organic compounds (VOCs) and ground water intrusion (e.g., from IWTP wastewater holding structures) are also considered.

Similarly, it is sometimes difficult to decide whether a particular treatment system should be considered as part of that treatment process or of disposal operations. For example, thermal destruction could be regarded as treatment and not ultimate disposal, since volume reduction, a penultimate effect, is actually involved. The approach used in this report is to refer to thermal destruction as treatment or disposal, depending upon whether energy is recovered from the HW or recyclable solids are produced, respectively. The term "thermal destruction" is, thus, meant to convey ultimate disposal when the HW has little or no fuel value and the residue produced cannot be recycled.

Thermal destruction that involves recovery of energy from the HW or recycle of useful materials from it is, on the other hand, designated as a treatment technology. As can be seen in the fifth decision step in Figure 3-3, those wastes having a calorific value over 8500 Btu/lb can be used as heat fuels. A waste with a heating value below the cutoff point of 2500 Btu/lb would be barely capable of autogenous combustion and, on being fired with an auxiliary or primary fuel, would furnish so little recoverable energy itself that recycle status would not be assignable.

Information on HWs discussed in this section is based, in large part, on inputs obtained from the NCEL survey and, in part, from the report literature. Again, distinct variations in treatment methods were found to exist among some activities. Like the HW-generating industrial processes, these could be partially explained by the differences in military mission and product characteristics. They were also due to differences in the design of the treatment facilities. All of these factors were taken into account to the extent practical while developing these treatment descriptions.

All the known treatment technologies from which candidate concepts for achieving cost-effective, superior treatments might ultimately be identified and ranked (based on comparative figures of merit per Section 5.3) are presented.

3.1.4 Ultimate Disposal Technology

The techniques considered appropriate for ultimate disposal are limited to certain types of thermal destruction and to land disposal with or without fixation/stabilization.

Thermal destruction in the ultimate disposal context (HW heating value $\leq$ 2500 Btu/lb), as defined above in Section 3.1.3, implies simple incineration to reduce volume. Heat recovery, as with a waste-heat boiler, may be practiced, but since the energy derives largely from the conventional fuel, that aspect of the disposal process is considered cogeneration and not recycle.

Ultimate disposal options must be applied only after all other options have been exhausted. As noted in Section 2.2, RCRA regulations (such as those for solid wastes) will have a significant impact on how the Navy ultimately disposes of its

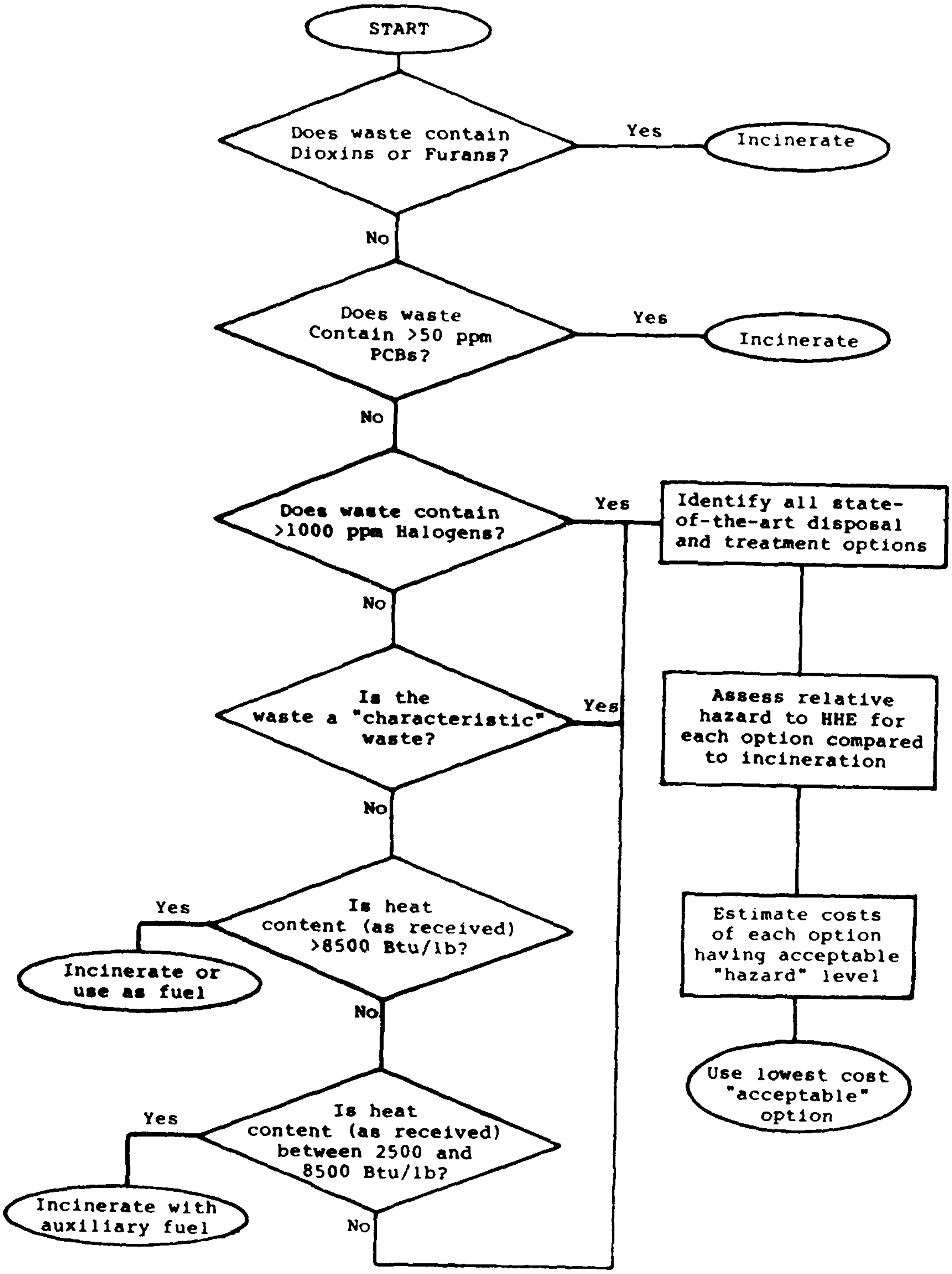


Figure 3.3 Conceptual regulatory strategy for determining waste burnability.

hazardous wastes in the future. For example, landfill requirements for sanitary landfills are currently undergoing regulatory study. According to a policy statement by the administrator of the EPA, changes may place essentially the same design criteria (i.e., double liner with leachate detection, collection, and treatment) on sanitary landfills as are currently required for HW landfills. Therefore, it may become almost irrelevant to prepare and submit a delisting petition for material previously requiring disposal in HW landfills.

Another factor that may impact the Navy's cost and ability to landfill wastes in the future is the decline in the number of HW disposal sites available to receive Navy wastes. Although the Navy may continue off-site disposal of some HWs, liability concerns and poor site availability may dictate centralized, sanitary landfills on Navy or DOD property.

There are, thus, three processes that can be considered for ultimate disposal:

Thermal Destruction by Incineration. Incineration converts wastes in high-temperature reactors to ash and cleaned, innocuous gases. Incineration is often the disposal method of choice for organic waste streams. Strictly speaking, any waste can be incinerated in a high-temperature reactor, wherein the waste stream is physically or chemically altered. Some Navy wastes with greater than 95 percent water content are presently being incinerated, although the cost-effectiveness of this approach is poor.

Although regulatory considerations for incineration have, until now, addressed both the ability of the incinerator to destroy organic materials and to produce acceptable stack emissions, present environmental regulatory concerns deal with controlling particulate emissions and with achieving a destruction and removal efficiency (DRE) of 99.99 percent or better for all of the identified principal organic hazardous constituents (POHCs).

There are two incineration issues that are of great concern to U.S. EPA researchers and will probably impact future regulations. The first is the fate of metals after incineration. The second is the possibility that some wastes banned from landfills might inappropriately be incinerated. Therefore, the EPA is considering the regulatory strategy shown earlier in Figure 3-3. This strategy would require an evaluation of the relative hazard of all disposal options, accounting for all possible effluents. This strategy would address the concerns for potential toxic metal stack emissions and the stability and leachability of incinerator ash when disposed of by landfill.

Some new developing incineration technologies do more than just destroy the organic portion of the waste. For example, the molten salt incinerator is a fluidized bed incinerator with the bed material "treating" and removing chlorine and sulfur from a waste. Similarly, a molten glass incinerator (also under development) not only destroys organic contaminants, but also captures inorganics in an inert glass product that is impervious to leaching and, thus, quite safe for land disposal.

Thermal disposal technologies include wet air oxidation, which is used to destroy low concentrations (typically less than 15 percent) of organic contaminants in aqueous waste streams. Developing technologies based upon wet air oxidation include catalyzed wet air oxidation and supercritical wet air oxidation. Both promise more complete organic destruction than the classical wet air oxidation. NCEL has supported studies by the National Bureau of Standards to evaluate supercritical techniques for specific Navy wastes. These processes, not being combustive in nature, are generically classified as treatment technologies in this report.

A number of industries that generate sufficient quantities of hazardous waste have installed incinerators at their own sites to ensure control over the disposal of their wastes. For example, the Polaroid plant in Waltham, Massachusetts, operates a vertical liquid injection incinerator for disposal of its acrylonitrile waste. As a general rule, on-site incineration should be considered for any facility generating more than 1 tpd of combustible organic wastes. Most industries producing incinerable waste streams ship these wastes to permitted off-site contract incineration operations.

Landfilling. Historically, landfilling has been used as a method for disposing of wastes by burying them in designated, approved areas. It was expected that stable wastes would remain unchanged, while unstable wastes would undergo gradual decomposition to stable and inert residues. This conception degenerated into a disposal practice where "out of sight, out of mind" became the slogan, and environmentally dangerous sites evolved and are now the focus of CERCLA.

Now, landfills must be designed, constructed, and operated so as to prevent any wastes or products of those wastes from migrating from the landfill to the surrounding environment. Under the Hazardous and Solid Waste Amendments of 1984 (HSWA), landfills must have two or more liners with a leachate detection, collection, and removal system between the liners. Each landfill must be designed to detect leachate and collect and remove it for treatment. During operation, landfills must have temporary covers to prevent the infiltration of excess moisture. After closure, the landfill must have a final cover system, conforming with 40 CFR 264.310, that will prevent or minimize any migration of liquids through the closed landfill. EPA has not specified the amount of leakage that can be tolerated from a well-designed and operated landfill. Present EPA standards for existing landfills limit the leak rate to approximately 1 gal/acre/day.

The greatest drawback to landfill disposal today is not technological but the concern for liability. Present regulations do not consider landfilling to be a form of treatment. Rather, they conclude that no matter how well-designed and operated a landfill is, there is always the possibility that it could fail. The consequent liability may rest with the original waste generators. Thus, as a general rule, all other minimization or treatment techniques should be considered before resorting to landfill. If there is no alternative to landfilling, the generator should ensure that the waste is as chemically and biologically stable as possible to prevent leaching.

Land Disposal Following Waste Fixation/Stabilization. Fixation and stabilization technologies are treatment methods. However, they are treatments that are designed specifically to improve disposal of wastes that might otherwise leach. Waste streams with organic contaminants can often be stabilized by polymerization of the organic constituents or by mixing with a monomer that can polymerize to form a stable matrix. This essentially encapsulates the waste. Waste streams with inorganic or low levels of organic contaminants can be stabilized by mixing the waste into a pozzolanic matrix, such as lime or portland cement. Pozzolanic stabilization is used most frequently for wastes containing hazardous metal cations. Sulfates, borates, arsenates, and silicates can often be vitrified and bound into a glass-like substance.

3.2 PROCESS NO. 1 -- INDUSTRIAL WASTEWATER TREATMENT PLANT (IWTP) OPERATIONS

3.2.1 Industrial Process Aspects

The IWTP is considered an industrial process in this discussion, even though it is obviously a treatment facility. Since, however, it outputs a HW (sludge) that must itself be managed, the IWTP is considered as an industrial process or, at least, as a part of the industrial processes it serves. Therefore, the description of the IWTP "process" does necessarily deal with treatment effects, since the characteristics of the product sludge derive from the pretreatment effects incorporated within the IWTP.

3.2.1.1 Current Navy Practice (T0). A majority of the Navy activities surveyed by NCEL have IWTPs that treat discharges from a variety of industrial operations. Although there is a wide range of wastes treated at the IWTPs, the major contributors are the electroplating, metal preparation, painting, paint stripping, bilge cleaning, and machine shop operations. The IWTP unit treatment processes are not identically designed or operated because the chemical compositions of influents treated vary considerably, as do the levels of treatment needed to conform with local wastewater quality regulations. However, all of the treatment systems employ similar physical/chemical unit processes for the treatment of similar wastes.

As discussed in Section 3.2.2., cyanide wastes are segregated and pretreated by alkaline chlorination. Hexavalent chromium wastes are segregated and pretreated with a reducing agent (typically a sulfite) to convert the chromium to the trivalent state. In this form, it is conveniently precipitated. With the exception of the cyanide-containing wastewaters, the pretreated waste streams (including acidic and alkaline streams) are combined. The pH is made alkaline, and the necessary flocculant aids (e.g., lime or polyelectrolytes) are added for clarification, with the accompanying precipitation of the heavy metals. The pH of the effluent is adjusted into the acceptable range, as required. The neutralized effluent is then discharged to a sewage treatment plant (STP), if one is operated on-site, or (in most cases) to a Publicly Owned Treatment Works (POTW).

The IWTP sludges produced are removed from the system and handled in a number of different ways. Usually, sludges are concentrated in a thickener. Then, the sludge is either 1) dewatered via a common dewatering device (e.g., a belt press or a sludge drying bed) before being disposed of in a Class 1 landfill, 2) drummed or bulk delivered to a contractor for dewatering and disposal, or 3) drummed for direct disposal in a

HW landfill. Figure 3-4 depicts the typical configuration of a Navy IWTP.

At several locations, the effluent requires more extensive treatment to meet local discharge requirements. These effluent polishing treatment processes include filtration, activated carbon treatment, and ion exchange. Table 3-2 summarizes the quantity of waters treated and Table 3-3 describes the various unit treatment processes employed at those Navy activities surveyed. Appendix B presents flow diagrams of different types of IWTPs.

Based upon the findings of the NCEL survey, IWTP operations constitute the largest volume of hazardous wastes identified and involve the largest cost for management. This volume includes influent streams and output sludge but not IWTP effluent. The present IDR does not categorize the effluent as hazardous, since the process is assumed to produce an innocuous product. It is recognized, however, that certain solutes covered by EPA regulations may persist in IWTP effluents, and that these must be controlled. This notably includes the classification designated as Total Toxic Organics (TTOs). This problem is separately addressed in Section 3.19.

As can be seen in Table 3-2, the IWTP treatment costs vary widely from activity to activity. These treatment costs range from less than $1/ton to as high as $1264/ton (NSY Pearl Harbor). In addition, treatment costs are reported at some activities and not at others. It is unclear whether the cost of operating the IWTP credits or charges the process generating the waste for the treatment. This confusion is not peculiar to the Navy; industry has the same difficulty with accounting procedures, particularly with end-of-pipe treatment systems. However, theoretically, the IWTP costs should be zero. All costs incurred in the treatment of effluents from the generating process should be passed back to the generator. It should be noted that in industries that have this practice, the generator takes a more active role in reducing the quantity of waste generated by his operation because it impacts his "bottom-line." It also serves to highlight and prioritize those operations that should be addressed in terms of a waste minimization program.

3.2.1.2 <u>General Industrial Practice (T1)</u>. Most of the integrated industrial facilities that generate wastes from electroplating operations and the metal preparation and finishing operations use a similar practice of cotreating the wastes in an industrial waste treatment facility. In general, the same unit processes currently used by the Navy are used by industry. However, industry includes some additional treatment practices and process modifications that permit greater control of the treatment operations. These steps have evolved for several reasons: 1) to expand the capacity of the treatment facility without adding more equipment, 2) to improve treatment of wastes

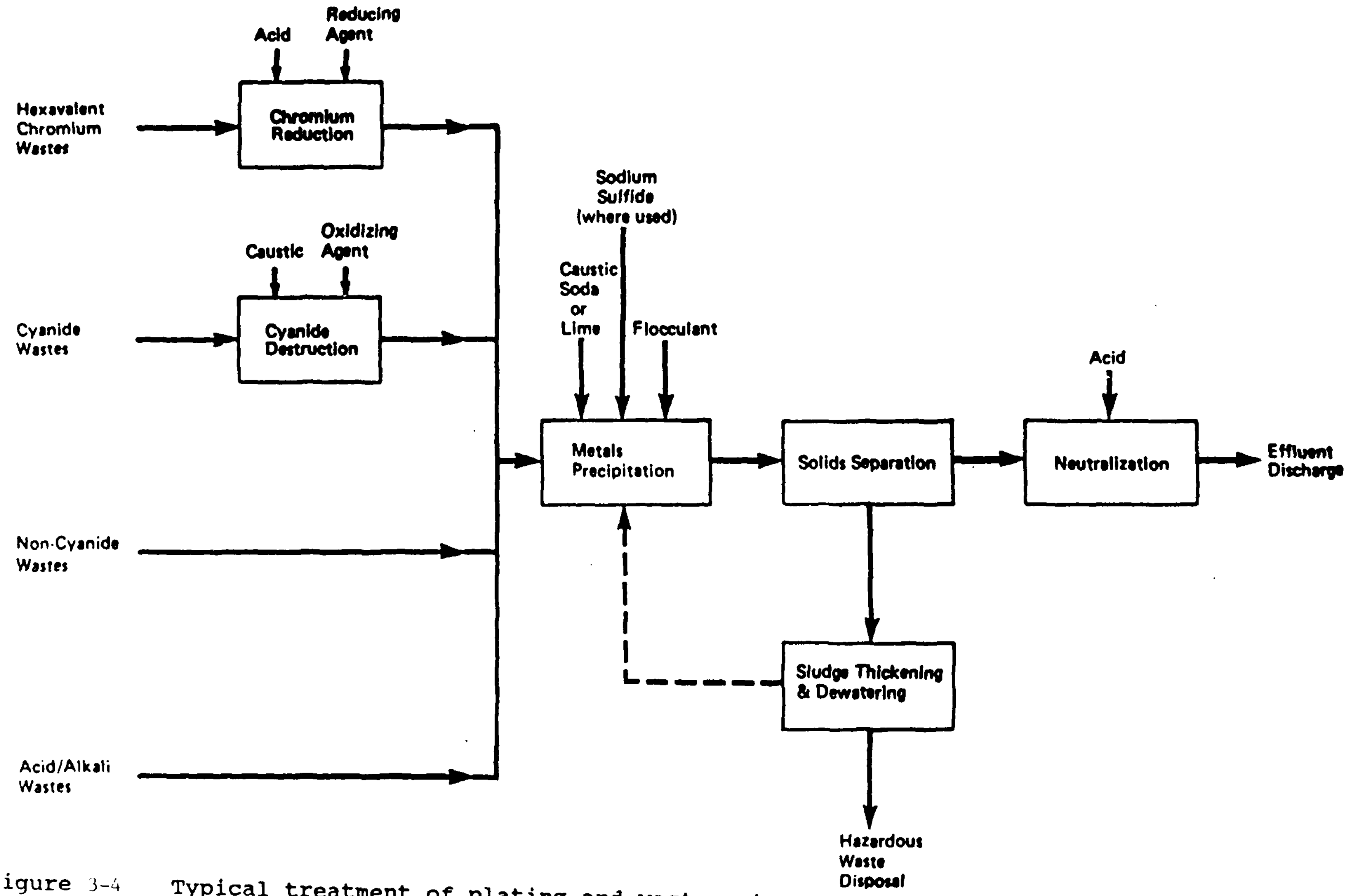


Figure 3-4 Typical treatment of plating and waste waters (Reference 3-1)

Table 3-2. Summary of Wastewaters Treated at IWTPs

Activity	Quantity (tpy)	Wastewater Description	Annual Cost ($)
PWC Pensacola	765,000	From NADEP, NAS, plating bilge, painting	755,820
NADEP Cherry Point	360,000	A/C paint stripping, electroplating	252,000
NSY Pearl Harbor	261	Pretreat unit	330,000
NSY Puget Sound	40,200	Plating, cleaning	327,130
PWC San Diego	2,100	Painting & stripping	NR
NWSC Crane	NR	Plating & metal prep	89,000
NIROP Pomona	364,923	Plating, circuit boards	45,000
NWRIP Dallas	1,480,000	Plating & oily wastes	NR
NUWES Keyport	53,750	Plating	650,000
NSY Charleston	NR	Plating, metal prep	NR
NSY Mare I.	255,000	Plating, metal prep	399,220
NAS Alameda	82,500	Plating, A/C paint stripping	825,000
NADEP Norfolk	175,000	Plating, A/C paint stripping	1,400,000
NSY Norfolk	37,500	plating, metal prep	900,000

NR = Not reported

Table 3-3. Summary of Treatment Processes at Navy IWTPs

	Treatment					
Activity	Chrome Removal	Cyanide Oxidation	Floc Add'n	Filter Pass	Carbon Treatmt	Sludge Dewater
PWC Pensacola	NS	X	X			Belt Press
NSY Charleston	NS	NS	NS			NS
NIROP Pomona	X		X			Filter press
NSWC Crane	X	X	X	X		Pressure filter
NSY Puget Sound	X	X	X	Sand/ Ion Ex.		Filter press
NADEP Cherry Pt	X	X	X			Belt press
NSY Mare Island	X	X	X			Drying beds
NWIRP Dallas	X	X	X			Vacuum filter
NSC Pt Molate			X			NS
NADEP Norfolk	X	X	X	X		Filter press
NSY Norfolk	X		X			NS
NADEP Alameda	X		X			Thickener
NADEP Jax	X	X	X			Drying beds
NADEP Pensacola	X	X	X			Belt press
NADEP North I.	X	X	X			Drying beds
NAS Alameda	X	X	X			Thickener
NAS Jax	X	X	X			NS

NS = Not specified
Jax = Jacksonville

in order to meet more stringent effluent regulations, or 3) to reduce a specific contaminant concentration in the sludge generated to a point that would permit the delisting of the entire treatment plant's sludge as nonhazardous.

IWTP Practices Influencing Sludge Production:

Oil Removal -- Americal Petroleum Institute (API) oil separation devices are used at the influent end of the treatment plant to effect oil removal. If required, the waste stream is acidified to promote oil/water demulsification. The floating oil is skimmed off and directed to a secondary (more efficient) oil/water separation device.

Contaminant Concentration -- Small package treatment plants are used for the pretreatment of highly concentrated waste containing a specific contaminant, such as zinc or nickel. This practice has two purposes. It serves as the first stage of treatment, reducing the contaminant level before the waste receives secondary treatment in the IWTP, in order to meet discharge water quality requirements. It also serves to produce a sludge containing a high concentration of one particular metal, thus, providing the opportunity for reclamation of the metal. These package plants are specifically designed to treat a single metal using conventional metal precipitation or electrochemical techniques. For example, the concentration of zinc from an electrogalvanizing line (levels of 400 to 1000 ppm) can be reduced by lime precipitation to 10 ppm. The effluent can then be treated in the IWTP to reduce the waste stream to meet the required discharge concentration of 0.1 ppm.

Contaminant Reduction -- The same technologies described above for pretreatment to a specific waste stream for effluent quality can be used to reduce the contaminant level of a particular metal in the sludge. This technique is especially useful if only one contaminant causes the sludge to fail the Extraction Procedure (EP) Toxicity test or the new Toxic Characteristic Leachate Procedure (TCLP). By preferentially pretreating and removing that metal, the opportunity for disposal of the material as a nonhazardous waste may become viable. As noted in the preceding discussion, this would also permit reclamation or resale of the sludge. An example of a small package unit, as provided by ANDCO, that could be used for this purpose is described in Section 3.2.2.4 Item 4.

Bleeding Concentrated Wastes -- Tanks and sumps are provided to collect concentrated alkali and acid wastes and floor spillage around electroplating tanks. These collection devices permit, via metering pumps, the controlled discharge of these wastes to the treatment plant, thereby, reducing large fluctuations in influent pH and contaminant loadings. Another way to achieve this same objective is with a large surge tank or a mixing facility upstream of the treatment plant.

Use of Wastes as Treatment Chemicals -- Waste materials from industrial processes are used (to the extent possible) as water treatment chemicals. An example is the use of waste acids to neutralize alkaline solutions, and conversely, the use of waste alkalies to neutralize waste acids not generated by pickling operations. The latter exception is made because waste pickling acid is a listed hazardous waste, unless it is used as a water treatment chemical. This is not a contradiction. Waste pickling liquor (the spent hydrochloric or sulfuric acid) used to clean metal prior to electroplating is a listed hazardous waste. If it receives treatment as a waste from a process, the sludge generated in that treatment becomes a listed hazardous waste. However, if the waste pickling liquor is used as a water treatment chemical in an IWTP, it is considered a beneficial reuse of a hazardous waste and the sludge generated does not automatically become a hazardous waste. (Note: The sludge must still be tested and can be hazardous because of metal content). This provision in the regulations was made because the iron and steel industry has used waste pickling liquor as a water treatment chemical for years, taking advantage of the dissolved iron from the pickling process. The ferrous iron serves as a reducing agent in the chrome treatment process. The free acid content of the waste pickling liquor serves to reduce the pH to facilitate the reaction. When used as a coagulant aid, waste pickling liquor, air, and lime are added to the waste stream. The ferrous ion is oxidized to the ferric ion by the addition of air. When exposed to lime, hydroxide floc is formed enhancing the precipitation of other metal hydroxide floc. This also serves to adsorb any emulsified oils. Note that in order to take advantage of this regulatory provision, waste pickle liquor must be treated as a water treatment chemical. It must remain separate from other waste streams until it is added to perform its intended service.

Sludge Management:

Sludge Dewatering -- This is considered as part of the treatment aspect of the IWTP process and is discussed in Section 3.2.2.1. Most industrial treatment plants routinely employ sludge dewatering practices. This significantly reduces the quantity of material requiring disposal and reduces the transportation costs to the landfill. In addition, the regulations stipulate specific limits of free water content in sludges disposed of in landfills. Although the definitions of free water are often technically flawed, the implications are, nonetheless, clear -- dewatering of sludges must continue.

3.2.1.3 Alternative Technologies (T0 to T3). Consideration of alternatives for present-day practice in the Navy IWTPs should be deferred until after the upstream processes generating the influent wastewaters have been minimized.

The NCEL hard chrome electroplating (zero effluent) process is now being implemented throughout the Navy (see Section 3.3.2). This implementation is necessarily proceeding on a funding-available basis. However, with time, the level of hexavalent chrome at most Navy IWTPs will be dramatically reduced to the amount released during anodizing operations and some chemical paint stripping procedures (assuming the latter survive at all). Similarly, efforts are proceeding at NCEL on innovative cyanide treatment/cadmium removal processes that may profoundly influence the operation of a typical IWTP. Also, plastic media aircraft paint stripping may well reduce phenolic/methylene chloride waterborne wastes to minor proportions. Therefore, the evaluation of alternative IWTP processes must properly take into consideration the impacts of the many upstream process modifications now undergoing implementation or development.

Use of Wastes as Treatment Chemicals (T1). An IWTP process modification that has been implemented in industry is the use of wastes as water treatment chemicals. As described in Section 3.2.2, each of the concentrated waste acids and alkalies should be evaluated to determine whether such materials could be reused in a treatment operation. Any administrative impediments to this approach should be reviewed and necessary modifications sought. Modification of DRMO operating practices and procedures may also be required to facilitate such changes.

Other Process Modifications (T1). Other process modifications that could be implemented depend upon site-specific effluent discharge limitations. It was noted that most IWTPs discharge to POTWs. Based upon the NCEL survey, it is unclear whether or not all POTWs imposed specific effluent limitations on the IWTPs. However, this lax situation is not likely to continue, particularly with respect to TTO management (see Section 3.19). In many cases, pretreatment requirements can be equally as stringent as direct discharge limitations. Thus, additional treatment by the IWTP may be required to achieve compliance. "Polishing" processes, such as activated carbon or filtration may be needed. The costs associated with these additional unit operations should be evaluated against the cost of upstream modifications (either to the process generating the pollutant of concern or for pretreatment of that pollutant).

Electrochemical Heavy Metal Removal System (T1). An electrochemical process, also used by industry, has been installed at NIROP Pomona to remove heavy metals, specifically copper and trace amounts of chrome and nickel. This process uses consumable iron electrodes to generate ferrous ions to coprecipitate heavy metals present in the waste stream. As long as the pH of the entering stream is in the range of 6 to 9, no pH adjustment is required. The precipitated metal hydroxides and ferric hydroxide are settled out in a clarifier, collected, and dewatered in a filter press. The cost of a 200-gpm unit, similar to the one in use at NIROP Pomona, would be on the order of $40 to 50,000. (Note: NIROP Pomona made use of existing clarifying and dewatering equipment.) A complete system including clarifier and filter press would cost approximately $150,000 (Reference 3-2). Operating costs are estimated to be about one dollar per pound of heavy metal removed.

This process, according to equipment manufacturers, reportedly produces 75 percent less sludge than conventional lime precipitation, and the sludge produced is nonhazardous when tested by the EP Toxicity test.

Air Force Sodium Sulfide and Ferrous Sulfate Treatment Technology (T2). A new waste treatment method has been developed through research by the Air Force Engineering and Services Center, Tyndall Air Force Base. This process is currently in use to remove chrome, copper, nickel, cadmium, and other metals from 1 million gal/day of waste stream at the IWTP at Tinker Air Force Base. In the process, sodium sulfide and ferrous sulfate are added directly to the waste stream. Next, a polyelectrolyte is added to enhance the metals precipitation in a clarifier. This new method achieves the same chrome reductions at pHs of 7.5 to 8.5 (rather than 2.5 to 3.0, as in the old process), while reducing sludge volume by two-thirds. The Air Force estimates this process will save $1000/day in chemical and sludge removal costs (Reference 3-3).

Polynucleolyte Treatment (T2). Polynucleolytes are used as a substitute for polyelectrolytes in the coagulation of metal-containing waste streams (Ocean System Engineering, Inc.). Polynucleolytes are silicon-based polymers that chemically react with the metals present in the waste producing an unleachable silicate. This material reacts with metals present either as suspended solids or in dissolved ionic form. Polynucleolytes are much denser than ordinary flocculants, due to their silicon skeletons, and are essentially insoluble. Floc produced is granular in nature and will trap less water. Sludge dewatering by a filter press gives a dense, easy-to-handle filter cake containing approximately 35 percent solids.

3.2.2 Treatment of Hazardous Waste From IWTP Operations

Sludges generated by Navy IWTPs are typically metal hydroxide sludges contaminated with heavy metals. At a number of activities, the sludges are not dewatered and, therefore, contain only 3 to 7 percent solids. At other activities, the sludges are dewatered, and depending upon the type of device used and the wastes treated, the sludge produced is a cake of between 30 and 60 percent solids. Some of the pretreatment process modifications discussed in the next subsection would produce a sludge containing only one specific metal. Treatment of such specific metal sludges is the same as that discussed below.

It should be noted that the U.S. EPA has recently amended its hazardous waste identification regulations to include additional wastes and to propose a new extraction procedure to be used for these and other HWs. The Toxicity Characteristic Leaching Procedure (TCLP) will determine the mobility of both organic and inorganic contaminants present in liquid, solid, and multiphasic wastes (F.R., Vol. 51, No. 114, published on June 13, 1986).

In the preamble to the above proposed rules, the U.S. EPA believes that physical stabilization alone is not enough to ensure that components do not leach in significant quantities. Further, the EPA is investigating the effects of natural weathering, such as wet/dry and freeze/thaw cycles. The TCLP does not permit the use of the Structural Integrity Procedure (a subterranean physical stabilization procedure), thus, ensuring that generators do not rely on such techniques alone.

Another issue is treatment of highly alkaline wastes. The EPA believes that an increase in the leaching of inorganics and some organics may occur as the alkalinity of wastes becomes neutralized due to continuous contact with the acidic leaching medium. Therefore, the EPA is proposing the use of a 200 milliequivalent acetic acid solution for testing of alkaline wastes.

It is unclear what impact the proposed regulations will have regarding the disposal of Navy wastes. However, it makes delisting of IWTP sludges more difficult. It may further affect the Navy's consideration of treatment techniques to dry and stabilize wastes. Although sludge drying techniques may reduce the volume of sludge requiring disposal, it may not stabilize the waste sufficiently to pass the TCLP. A no-action approach may provide time for new technologies to be developed to produce an acceptable stabilized waste.

3.2.2.1 Current Navy Practice (T0). Table 3-4 summarizes the quantities of sludges generated by each of the surveyed IWTPs and identifies the sludge-handling techniques.

Since the sludges generated from the IWTPs are considered hazardous, sludge drying beds (in the classical sanitary engineering sense) require all the design features of a hazardous waste landfill for collection and treatment of the leachate produced. Therefore, a mechanical device for dewatering sludge offers many regulatory, operating, and cost advantages over the drying bed approach.

There are a number of devices available for the dewatering of sludges from IWTPs. Currently, the Navy employs belt presses at several activities. Vacuum filters and plate presses are also being used for this purpose. Each IWTP should have the type of device appropriate to the characteristics of the sludges formed

Table 3-4. Summary of Sludges Produced at Navy IWTPs

Activity	Quantity (ton/yr)	Type of Sludge/Disposal	Annual Disposal Cost ($)
PWC Pensacola	2,335	Lime/alum sludge dewatered sent to off-site TSD	471,670
NAS Alameda	903	Liquid hydroxide sludge & paint skins hauled to TSD	90,300
NADEP Norfolk	216	Hydroxide sludges dewatered sent to off-site TSD	94,000
NSY Charleston	38	Liq. chrome hydroxide drummed for metal reclaimer	34,840
NIROP Pomona	540	Dewatered lime sludge; copper reclaimed by mining co.	297,000
NWSC Crane	36	Hydroxide sludge dewatered/ drummed & sent to TSD	NR
NSY Puget Sound	18	Liq. hydroxide sludge drummed for off-site disposal*	6,690
NADEP Cherry Pt	134	Hydroxide sludge dewatered/ off-site disposal	NR
NSY Mare Island	388	Hydroxide sludge dewatered & hauled off site	45,000
NSY Norfolk	570	78% sludge, 22% liq. sulfides	105,175
NWIRP Dallas	349	Hydroxide sludge dewatered, bulk hauled to HW landfill	78,200
NSC Pt. Molate	1,615	OWTP pond bottoms dredged every 5 years	161,500

NR - Not reported

* In current practice, the sludge is dewatered in a filter press and disposed of as cake

in that treatment plant. This selection would require that vendors of the various types of sludge dewatering equipment test the sludge to determine which device would produce a filter cake suitable for landfill disposal. It should be noted that plate presses typically produce the driest cake, but the equipment and O&M costs are generally higher than those associated with belt presses. On the other hand, the requirement for slurry-conditioning chemical loadings can make a belt press unattractive. Typically, vacuum filters are not used for metal precipitate sludges, since they do not produce as dry a cake as the belt or filter press, and energy costs of vacuum filters can be higher than pressure filters. The key to selecting the right device for each activity's sludge is to submit that sludge for laboratory testing and to establish a general criterion for the dryness of the resultant cake, as a function of allowable capital and operating costs.

Contractor Reclamation. At NIROP Pomona, the copper content of the sludge is sufficiently high to permit reclamation by a copper company. The hauling of one load (20 tons) is $3000. The credit payment for the copper recovered is $1300. Therefore, the net cost is $185 per ton for both transportation and disposal. There are no taxes (currently at $75/ton in California for HW) associated with the haulage and sale of ore, and the final product is specifically exempt from regulation under RCRA. This form of disposal is, therefore, significantly cheaper than disposal at any California landfill.

Drying. At NADEP Cherry Point, driers will be installed to reduce the moisture content of the sludge and to age (stabilize) the sludge so it will pass the EP toxicity test and, thus, be classified as a nonhazardous waste.

This approach has some merit, in terms of volume reduction. However, when the regulations become final and the proposed TLCP is used, the sludge may still be considered hazardous.

3.2.2.2 General Industrial Practice (T1):

Sludge Dewatering. In general, industry practice is to dewater the sludges from IWTPs using filter presses, vacuum filters, and belt presses. There is a general trend away from using sludge drying beds and containerizing the wastes for landfill disposal. There has been some activity in the area of solidification of these wastes, but, to date, there is no widespread use of this technique.

Heavy Metal Segregation. The trend, where possible, is to segregate out those waste streams containing high concentrations of heavy metals. These are treated individually to obtain a sludge containing a high quantity of that heavy metal.

Industries that can use the waste as a feedstock are then located.

3.2.2.3 Alternative Technologies (T1 to T3). Alternative technologies for treatment of IWTP sludges, after they have been dewatered, are limited at this time.

Selective Extraction (T3). The Montana College of Mineral Science and Technology is conducting research on methods for selectively extracting various metal constituents from electroplating hydroxide sludges using resolubilization followed by phosphate precipitation (Reference 3-4).

Sludge Aging (T3). Centec performed studies on sludge aging, which showed that the leachability of aged sludge could be reduced below the current EPA toxicity criteria (Reference 3-5). However, it is unclear whether this approach would meet the new proposed leachability criteria.

Heavy Metal Segregation (T1). For waste streams that contain a high concentration of a given metal (e.g., copper), preferential treatment of that waste stream may be desirable. The waste sludge produced may be more suitable for reclamation, and removal of a large portion of this contaminant may sufficiently change the characteristics of the IWTP sludge to permit delisting. This technique may have limited application to the Navy, since Navy waste streams from the various plating and circuit board shops are too small to justify investment in an off-the-shelf package developed for reclaiming the metals in the waste. For example, small package plants capable of treating 5 gpm are available and would cost approximately $30,000, depending upon the waste characteristics and special design features required. Site-specific conditions would dictate the applicability of such an approach.

Solar Sludge Dewatering (T2). Bench work has been done at the Citadel for Southern Division NAVFAC (References 3-6 and 3-7) to determine the feasibility of drying sludge by using a combination of solar drying and circulated, heated air. Cost analysis of the process, comparing it with costs for a belt filter press, showed the latter to run about $1.50/gal of 2 percent sludge, while the solar process was only $0.17/gal. The volume reduction of the solar process was two and a half times that of the belt press, which represented about half the cost differences between the two processes because of disposal requirements. An obvious disadvantage with the solar process is the reliance on sunshine. The process should, nonetheless, be considered for piloting at a Naval activity in the Sun Belt or overseas.

3.2.3 Disposal of Wastes From IWTP Operations

IWTP sludges are presently landfilled after dewatering. The practice will probably continue, since there are few viable alternatives. It is possible that regulatory changes may require further fixation/stabilization treatment of these sludges prior to their land disposal, although these wastes are already chemically stabilized.

With disposal costs projected to approach $1000/ton, some Navy activities should improve their sludge dewatering. But even more important is the reduction of sludge volume. With the NCEL hard chrome process and more effective sorbents, discussed in Section 3.2.2 (including the electrolytic ferrous hydroxide system at NIROP Pomona), the Navy can reduce sludge production to less than 25 percent of what is now typically generated at Navy IWTPs.

3.3 PROCESS NO. 2 -- ELECTROPLATING AND CIRCUIT BOARD MANUFACTURE

3.3.1 Industrial Process Aspects

Although electroplating and circuit board manufacture consist of differing unit operations and different product requirements, there are certain similarities in the nature of the wastes generated by the two processes. Therefore, they have been combined for the purposes of this report.

Electroplating, a metal finishing operation, is used to improve the surface of a material to provide corrosion resistance, durability, mechanical strength, improved aesthetic appearance, or electrical conductivity of the surface to which it is applied. The methods used for this purpose include:

Immersion Plating. This technique involves deposition of another metal on the base material by chemical exchange.

Electroplating. Another metal or series of metals is electroplated onto the base metal.

Phosphating. The surface of the base metal is converted by chemical deposition.

Conversion Coating. The base metal is coated with organic materials.

Oxidation. The base metal is oxidized by electrolysis (including anodizing).

3.3.1.1 Current Navy Practice. Metal finishing processes are in use at more than 70 Navy activities. In general, the largest electroplating operations are found at NADEPs, NSYs, NASs (Naval Air Stations), and certain GOCOs. These facilities are capable of performing a variety of metal finishing operations to repair worn metal parts or finish new parts, using most of the more common plating metals. Some of the smaller activities that perform metal plating-type operations, do so to perform one or two specific tasks, such as the production of printed circuit boards. To gain a perspective on the magnitude of the hazardous waste problem resulting from the electroplating and circuit board manufacture, the NCEL survey identified activities that generated a total of 235,191 tpy of wastes from these operations. The majority of these wastes results from the electroplating processes surveyed. As estimated by the NCEL survey, 1,115 tpy of wastes were produced in the manufacture of circuit boards.

In general, the electroplating process consists of four main stages: 1) cleaning, 2) pickling, 3) plating, and 4) final rinsing. The first two steps, cleaning and pickling, are common metal cleaning/preparation processes and are discussed in Section 3.2.16. After the surface to be coated has been appropriately cleaned, the part is immersed in tanks containing process solution. The composition of the solution depends upon the type of plating/coating desired. Typical plating solutions used by the Navy include metal electrolytes of copper, chromium, nickel, zinc, cadmium, silver, and gold. When the plating step is completed, the part is then rinsed to remove any residual plating material (dragout) from the surface of the part. A brief description of the more common plating processes used by the Navy follows.

Hard Chromium Plating. Hard chromium plating is the most commonly used plating process at NADEPs and NSYs. The chrome plate is applied to worn shafts, gears, hydraulic hardware, and other chromium-coated parts to increase the dimensions of the article and to increase surface hardness (wear resistance). This process can take up to several days in order to achieve the desired thickness of chromium on the piece. After plating, the parts are machined to the exact dimensions required and polished.

NCEL has developed a greatly improved hard chrome process that reduces plating time to less than 50 percent of that previously required and completely eliminates wastewater production. This is accomplished through the use of conformative electrodes, which furnish isotropic electrical fields for the work pieces. Dragout is removed by sprays rather than baths, and all wash liquid is returned to the electroplating tank to make up for water lost through evaporation. Impurities developed in the plating solution are removed by a chemical purification system, which requires periodic cleaning and generates only residual wastes that are in the form of modest amounts of filter cake. The NCEL hard chrome process is currently in use at Pensacola NAS, Pearl Harbor NSY, Alameda NAS, and Louisville NOS (Naval Ordnance Station).

Corrosion Protection Finishes. The second most widely used plating process at Navy activities is the application of corrosion coatings. Nickel, cadmium, and zinc are used most frequently for this purpose. Unlike hard chromium plating, this process is intended to apply a thin layer of metal over the substrate, a process that takes minutes instead of days. Another corrosion-coating process used at a number of activities is chromic acid anodizing, which forms a protective film on aluminum surfaces.

Many of these electroplating processes involve the use of cyanide as a complexing agent. This results in the production of cyanide-containing wastewater, which is rather expensive to detoxify. Attempts have been made in the past to convert to electroplating procedures that are capable of depositing the same metals but that do not require cyanide in the electrolyte. The

NADEPs that attempted these test and evaluation (T&E) efforts abandoned them as too difficult to practice.

Recently, however, the NIROP Pomona successfully eliminated all use of cyanide while continuing to plate specification-grade coatings of nickel, zinc, cadmium, and other metals. This conversion was undertaken in the interest of hazardous waste minimization. The results should be closely studied for possible application to other Navy electroplating shops. The products output by the NIROP are considerably different from those produced at other Navy activities, such that the cyanide-free plating technology (in the context of outside applications) must be considered as T1, rather than T0.

Printed Circuit Board Production. Printed circuit boards for various electronics applications are produced at many Navy activities. Two processes, electroless plating and electroplating, are typically used in their production. Both processes rely on a plating solution. In electroless plating, however, the metal is deposited from the solution by means of a chemical reducing agent rather than by an electric current. Copper, lead, silver, and gold are the primary metals employed in this process.

In the manufacture of circuit boards, chromic acid is used to preferentially oxidize and dissolve burrs that are formed from the drilling of blank circuit boards. Other corrosive wastes are generated in the metal finishing, assembly, and final manufacture of circuit boards, circuit card assemblies, and printed wiring boards. Also included in these wastes are solder flux acids. Another large quantity of wastes emanates from stripping photoresist from printed wired circuit boards with n-butyl cellosolve or cellosolve acetate.

3.3.1.2 General Industrial Practice (T1):

Conservation Methods. Conservation methods are practiced to prevent unnecessary wasting of the electrolyte. For example, extra tankage is provided if it is necessary to hold an off-spec solution to determine whether it can be brought into specification by chemical adjustment or whether it must be discarded as waste. Stored, off-spec solution can also be mixed in various proportions with future baths to obtain the proper concentrations of the plating salts. Extra tankage also serves to store electrolytes while repairs are made on plating tanks, as in the event of a tank developing a leak during operation.

In industrial practice, air knives (nozzle configurations for directing streams of air onto emerging plated workpieces) are used to control the rate of dragout from the plating tank, as are drip pans to direct the drain-off back into the tank prior to the pieces being rinsed. In some cases, an empty tank serves to collect the drippage from the work piece before it is rinsed.

Control of rinsewaters is practiced using the same procedures as employed at a number of Navy activities. Flow control of discharges from the rinse tanks, use of conductivity cells to determine the frequency and quantity of rinsewater to be discharged, and countercurrent rinsing are common practices in industry.

Plating Metal Recycle. In the industrial sector, there are a number of different approaches to the treatment of electroplating rinsewaters. Some electroplating operations are treating rinsewaters for recovery of the plating metals. These systems take advantage of using normal dragout to control plating solution impurities in the plating bath. The rinsewater is treated to recover the plating metals for return to the plating bath, while the entrained bath contaminants are discarded.

Some examples of the types of systems being used for this service are as follows:

Cadmium Recovery. Allied Metal Finishing, Baltimore, uses an electrochemical reactor to recover cadmium. After the workpiece is plated, it receives an initial rinse in a recovery rinse tank where the largest portion of the plating solution is removed from its surface. This rinsewater is drawn out of the rinse tank, filtered, and then sent to the electrochemical reactor. Rinsewater containing cadmium is passed over a carbon fiber cathode, which has a large surface area to volume ratio, plating the cadmium out on the cathode. The metal is removed from the cathode by reversing the current or rinsing the cathode with a stripping solution, which is returned to the plating bath (EPA, 1985). The reactor is also capable of electrolytically oxidizing cyanides at a lower cost than would be incurred with alkaline chlorination.

Nickel Recovery. The Gillete Safety Razor Division uses an automatic dragout recovery system to recover 85 percent of the nickel dragout from three plating tanks. This system has a four-tank countercurrent rinse system that provides for complete rinsing of the workpiece and makeup solution for the plating tanks. The overflow from the first rinse tank, which contains the highest concentration of plating metal, is directed to a sump. As makeup water is needed for the plating tanks, it is furnished by pumps from the concentrated rinsewater sump. This is a closed-loop system, except for evaporative losses. Water, deionized by a reverse osmosis purification unit, is added to the final rinse tank to make up these losses (Reference 3-8). Deionized water minimizes the buildup of impurities in the system. The investment cost for this system in 1979 was $85,000.

Chromium Recovery. The Phillips Plating Company uses a rising film evaporator to concentrate the chromium plating bath dragout in the rinse stream so it can be recycled to the plating bath. This system relies on the use of a countercurrent, multiple-tank rinse system. As with the automatic dragout recovery system, the overflow from the first and most highly bath-contaminated rinse tank is sent to the evaporator. The concentrate is returned to the plating tank, and the distillate to the final rinse tank. The evaporator throughput is high in order to provide sufficient clean water for final rinsing of the workpiece. The cost for this 75 gal/hr system was $60,000 in 1979, had annual operating costs of $30,650, and produced $50,000 in annual savings.

A variation of this system, a smaller evaporator, has also been evaluated. In this case, the overflow rinsewater from the first two of the three countercurrent rinse tanks flows into the evaporator system and the condensate is returned to the second tank. The final or third rinse tank is supplied with fresh water on a once-through basis. The discharge from this tank is directed to the waste treatment plant. This approach achieves a significant dragout recovery and requires less steam for the evaporation effect and, thus, a smaller, less expensive evaporator (Reference 3-8).

Steps to Reduce Plating Solution Dumps. Some bath purification steps are used by industry to remove solids contamination of the plating bath. To do this, plating solution is withdrawn from the system, filtered, refreshed with any needed plating salts, as needed, and returned to the plating tank. This step removes solids, thus reducing the need for periodic emptying of the plating tank for desludging. Dissolved impurities are generally removed by means of dragout and are recovered or treated in the rinsewater phase. It should be noted that although efforts are made to eliminate plating solution tank dumps, there are few operations that can totally escape this problem. Thus, well-designed systems have contingency plans for such events. These contingency plans also are available to handle plating solution that can be lost as a result of leaking pump seals, tank leaks, or piping failures. The quantity of plating solution lost may be relatively small in volume, as a result of these operating failures. However, these wastes also require treatment and serve, in much the same way as the dragout mechanism, to reduce the level of impurities in the plating solution. Operating failures that result in the loss of plating solution are often ignored when referring to "tank dumps." However, if the quantity of plating solution lost over a year from these sources is compared with the volume of liquid held in a plating solution tank, this philosophy could change.

3.3.1.3 Alternative Technologies (T0 to T3). A summary of technologies available for the processing of rinsewaters for recovery of various plating solutions is presented in Table 3-5 (Reference 3-8). These technologies are described in Appendix C. Most of the technologies are in practice commercially, and very little testing and evaluation would be necessary before they could be adopted at various Navy activities.

Table 3-5. Summary of Metal Recovery Technology Applications

	Plating Bath					
Recovery Technology	Chromic Acid	Nickel	Zinc (CN)	Cadmium (CN)	Copper (CN)	Tin (BF_4)
Evaporation		X	X	X	X	X
Electrodialysis		X	X	X	X	X
Reverse Osmosis		X	X		X	
Ion Exchange	X	X				
Electrolysis			X	X	X	X
Permselective membranes	X					

Source: Reference 3-8

Conservation Methods (T1). Rinsewaters for removing the excess plating solution from the plated surface can serve as makeup for the plating bath. Countercurrent rinsing is practiced whenever possible, as it significantly reduces the quantity of wastewater to be treated.

A key aspect to minimizing the quantities of any of the wastes from electroplating operations is maintenance. Collection devices are useful for segregating and correctly directing spillage from each of the various unit processes and are widely employed in industry. In addition, good housekeeping practices and careful attention to preparation and operation of the line can significantly minimize the quantity of wastes generated.

Cyanide Elimination (T2). Cyanide plating solution baths are being phased out for most operations in the iron and steel industry. Although cadmium plating using cyanide complexes tends to be more effective in some specialized cases, noncyanide plating procedures are available for that metal and other metals for which cyanide has been traditionally used (e.g., zinc, copper, and brass).

Periodic review of plating operations that use cyanide plating solutions should be made to determine whether a noncyanide plating solution could be substituted. Furthermore, investigations into the difficulties that have caused Navy activities to abandon noncyanide processes should be conducted to determine if these problems can be overcome.

Bath Purification and Maintenance Procedures (T2). In order to maintain the plating bath quality to permit effective coating of the workpiece, solids that accumulate on the tank bottom must be removed. This can be accomplished through routine filtration of the plating solution. This bath purification setup is particularly applicable to electroplating processes using zinc and nickel and can eliminate the need to dump plating solution to desludge tanks. The process could be applicable to those Navy electroplating processes that experience sludge build-up problems in plating tanks. A pressure filter precoated with diatomaceous earth is frequently used by industry to filter the plating solution. These devices cost on the order of $6,000 for a 30-gph system.

3.3.2 Treatment of Plating Hazardous Wastes

Part I - Hazardous Wastes From Electroplating

3.3.2.1 Plating Solution Characteristics. Typically, two unit operations in the plating process (plating and rinsing) produce a waste stream that is contaminated with heavy metals or cyanide and that will ultimately require treatment. Although such treatment is considered part of the plating process and does not constitute a hazardous waste treatment per se, the plating processes do lead to manifestable HWs in the form of IWTP sludge (discussed in the preceding section) and tank dumps.

The quantity and concentrations of the wastes produced depend upon the process used, the care taken in solution preparation and dragout control, the amount of rinsewater used, the frequency and method of disposal of degraded tank liquids, along with the quality of general housekeeping practices. Table 3-6 presents a list of the activities producing electroplating and circuitboard manufacturing wastes, current disposal practices, and costs, as identified by the NCEL survey.

3.3.2.2 Current Navy Practice (T0). Plating solution wastes are managed differently by the Navy activities surveyed. At some activities, spent electrolyte is drummed and sent to DRMO for land disposal or treatment by an outside contractor. At other activities, electrolyte is treated by conventional methods at the IWTP. Other activities have implemented recycling and recovery practices at the production process site to reduce or eliminate the volume of waste requiring treatment.

One of the most successful efforts (a 1985 DOD Environmental Leadership Project) has been the hard chrome recovery/recycling system developed by NCEL. Because of the process modifications

Table 3-6. Summary of Navy Electroplating/Metal Finishing Wastes

Activity	Waste Type	Tons	ID	Cost, $
NAS Alameda	Cd, Cu, Ni, CN	114	F	11400
NUWES Keyport	Sludge, rinsate	27	T	30
NAS JAX NADEP	Degreaser wax	10	D	2540
NSY Pearl Harbor	Brush plating waste	170	T	34000
NWIRP Dallas	Cr and CN	185000	T	520000
NSY Puget Sound	CN	1502	T	12220
NADEP Cherry Point	Plating bath, sludge	5	D	10000
NSY Puget Sound	Cr waste	15758	T	128230
NIROP Pomona	Photoresist stripper	942	F	9420
NSY Norfolk VA	Chromic acid	46	T	0
NIROP Pomona	Rinsewaters	5157	T	0
NSY Charleston	Chromic acid	51	D	38455
NSY Pearl Harbor	Chrome plating solution	17	T	3300
NADEP Norfolk	NH_4OH-H_2; thiourea	28	D,T	8465
NAS JAX NADEP	Plating sol; spnt CN	25900	T	175000
NADEP Norfolk	$KMnO_4$ w/Pb & EDTA	42	D,T	2740
NADEP Cherry Point	Chromic acid anodize	109	T	76
NADEP Norfolk	Chromic acid w/ Cd	18	D,T	6260
NIROP Pomona	Chromic acid, spent	139	T	0
NADEP Norfolk	HCl, $NiCl_2$, w/Cr, Cd	16	T,D	2985
NWSC Crane	Chromic acid	20	F	2630
NSY Long Beach	Chromic acid	41	T	1020
NIROP Pomona	Acids, solder flux	35	T,F	1820
NADEP Norfolk	NaCN w/Cd	47	D,T	8005
TOTAL		235,191		$978,596

Disposal ID: D: DRMO
T: On-site treatment
F: Final off-site contract
N: Final disposal on-site
R: Recycle

made to the system, dragout no longer can serve as a means of producing wastewater contaminated with chromium. The process is essentially "Zero Effluent," a key EPA environmental objective. Also, bath solution is circulated through a device designed to remove contaminants, so bath dumps can be eliminated or greatly extended in interval.

The purification system consists of a cathode isolated by a permselective surrounded by the bath liquid and the anode. Chromium^{+3} is oxidized at the anode to chromium^{+6}, the principal bath cation for which the membrane is impermeable. Other cations, the bath impurities, are also oxidized at the anode but then permeate the membrane to the cathode where they are reduced and consequently precipitated. The external bath liquid returns to the bath for recycle while the solids accumulated in the cathode chamber are periodically removed as sludge.

In the case of precious heavy metals plating solutions, efforts to recover and reuse silver and gold have been practiced for some time with good success. This is easily understood with the price of gold running at $345 to $350 per ounce and silver costs maintaining at $5 per ounce (Wall Street Journal, 1986).

3.3.2.3 General Industrial Practice (T1). To assist in reducing hazardous wastewaters, collection devices are widely used in industry to segregate and correctly isolate spills from the various unit processes. Typical housekeeping practices observed in industry (Reference 3-5) include the following:

- Repair leaks around processing equipment (e.g., tanks, valves, pump seals, transfer lines, heating coils).
- Install antisiphon devices equipped with self-closing valves on inlet water lines, where needed.
- Check tanks and piping periodically to detect failures.
- Inspect plating tanks frequently for loose insulation that would cause excessive dragout of plating solution.
- Ensure that cyanide solutions do not mix with compounds (e.g., iron or nickel) that would form difficult to treat wastes.
- Use only dry cleanup, when possible, instead of routine flooding with water.
- Install and maintain drip pans and splash guards, where required.

In the metal-finishing industry, electroplating operations conserve materials throughout the process. To reduce electrolyte wastage, several approaches are taken. For example, extra tankage is provided to allow holding an off-spec solution so it can be used at a later time, rather than thrown away. The chemical composition of an off-spec solution is determined and adjusted, or the solution is mixed with future baths to obtain the proper concentrations of the plating salts. The extra tankage can also serve to hold the electrolyte while repairs are made on a plating tank, in the event one should develop a leak during operation.

Purification steps, such as filtration, ion exchange, and electrolytic recovery remove impurities from plating solutions. Many of these systems recover plating solutions taken from the first rinse of the product after plating. This takes advantage of the removal of plating solution impurities through the dragout.

In cases of tank leakage, line failures, or the holding of off-spec or contaminated plating solution, treatment or disposal of plating solution is required. If the treatment plant has the capability of treating these wastes, they are bled to the treatment plant over an extended period of time. If the treatment plant cannot handle the chemical load, or if adequate storage is not available for slow input to the IWTP, the material is removed by vacuum truck for off-site treatment.

3.3.2.4 Alternative Technologies (T0 to T3). Steps can be taken to conserve electrolyte and prevent waste. Good housekeeping practices can be diligently followed at little or no cost to the Navy activity. Extra tankage can be installed at minimal cost (5,000 gallon tank would cost approximately $15,000 installed). This tankage can be used to store plating solutions while repairs are being made to plating tanks.

Direct purification and recycle of plating solutions, such as practiced in the Navy's hard chrome process, is one method for avoiding production of the HWs from electroplating. Alternatively, industry typically elects to use the dragout mechanism for bath purification and uses plating metal recovery techniques on the rinsewater. One reason for this approach may be that the recovery of plating solution does not require modification to existing plating practices and the recovery technology can be installed with little downtime of the production facility.

Part II - Hazardous Waste From Plating Rinsewaters

3.3.2.5 Wastewater Characteristics. Plating rinsewaters are dilute corrosive solutions containing heavy metals. They may be alkaline or acidic in nature, depending upon the type of plating solution used.

3.3.2.6 Current Navy Practice (T0):

Cyanide-containing Wastewaters. Other than dilution with other wastewaters, most cyanide-containing streams generated at a majority of activities are not treated at all. Many of these activities (e.g., Long Beach NSY, Louisville NOS, Indianapolis NAC (Naval Avionics Center)) are, however, in the process of installing or modifying their facilities to provide cyanide destruction.

Alkaline chlorination is the standard method of cyanide treatment in the Navy. It is useful for treating either dilute or concentrated cyanide wastewaters and is capable of destroying amenable cyanide to concentrations below detectability. Destruction of cyanide by alkaline chlorination is achieved by the direct addition of either a hypochlorite (sodium or calcium) or chlorine gas and sodium hydroxide. The decision to use one reagent over the other is generally based upon reasons of availability, economics, or safety. The chemical cost associated with the use of chlorine gas is approximately half that of sodium hypochlorite. However, handling of chlorine gas is more dangerous and requires more expensive equipment.

For dilute rinsewaters, the alkaline chlorination process is usually designed for continuous treatment, although some activities do batch treat. Batch systems are usually used only for small volumes of rinsewater or concentrated cyanide wastes. Continuous treatment can be performed in either a one- or two-stage unit. Because the cyanide destruction reaction is a two-step reaction, the two-stage unit affords better control of the destruction process by allowing each step of the reaction to be performed at its optimum pH. Single-stage units generally require a longer reaction time to ensure complete destruction of the cyanide to carbon dioxide and nitrogen. Most Navy activities operate single-stage effects, Cherry Point NADEP being a notable exception.

The alkaline chlorination process is very reliable, if the equipment is well maintained. The process is not, however, capable of destroying cyanide complexes, such as ferrocyanides. The cost of cyanide wastewater oxidation equipment for an installed two-stage system ranges from $35,000 to 45,000 for a 10-gpm and a 33-gpm unit, respectively. Chemical costs for a 15-ppm cyanide input will range from $0.20 (chlorine) to $0.50 (sodium hypochlorite) per 1000 gal.

Chromate-containing Wastewaters. Wastewaters from chromium plating, chromating, and chromic acid anodizing contain chromium in both the hexavalent and trivalent form. Although most heavy metals are precipitated readily as insoluble hydroxides by pH adjustment in the neutralizer, hexavalent chromium must first be reduced to trivalent chromium. Reduction is usually accomplished by reaction with gaseous sulfur dioxide or a solution of sodium metabisulfite. Because the reaction proceeds rapidly at low pH, acid is added to control the wastewater pH between 2.0 and 3.0. Sulfuric acid is usually used for this purpose, although any strong acid will serve, as will acidic waste materials.

After reduction, the trivalent chromium can be precipitated as the hydroxide by increasing the wastewater pH to above 8.0. Normally, the acidic, reduced chromium wastewater is mixed with the balance of the treated plating wastewater to take advantage of the alkalinity of the latter. In any case, lime is typically used for achieving ultimate pH adjustment.

Many Navy plants do not segregate their chromium waste streams from the rest of the waste streams (cyanide-containing wastewater excepted). Because of this, the entire influent must be treated with acid, reducing agent, and then be neutralized for chromium hydroxide removal. If feasible, wastewater should be segregated so that only unmixed chromium-bearing wastewater is treated.

The typical installed costs for chromium reduction equipment range from about $20,000 for a 10-gpm unit to $28,000 for a 33-gpm unit (Reference 3-5). Chemical treatment costs range from $0.05 to 0.15 per 1000 gal of wastewater, assuming a chromium concentration of 12 ppm. These costs do not include inlet piping and O&M costs, other than chemical costs or equipment annualization. When these costs are included, they could bring treatment costs to as high as $0.30 per 1000 gal.

Additional costs are involved for neutralization, clarification, and sludge removal. The neutralization/precipitation step adds equipment costs between $20,000 and 30,000 and chemical costs between $0.15 and 0.50 per 1000 gal for sodium hydroxide or about half that for lime.

3.3.2.7 <u>General Industrial Practice (T1)</u>. Industrial waste treatment systems specifically designed for wastewaters from electroplating and metal preparation/finishing operations are quite similar to those used by the Navy. Our greatest opportunity to learn electroplating HW reduction techniques from industry is in avoiding dragout. That, however, certainly does not extend to chromium plating, where the learning opportunities are probably reversed.

3.3.2.8 Alternative Technologies (T1 to T3):

Cyanide-containing Wastewaters (T2). Although efforts may be exerted to eliminate the use of cyanide in electroplating, some cyanide-containing wastewaters will continue to be generated. Fortunately, cyanide pretreatment facilities are well segregated, so it is not a problem to add chemical reagents to bulky admixtures (as occurs at some chromium treatment facilities) of cyanide-free water. Thus, the system can be scaled down and be operated in batch mode to handle the reduced flows of cyanide-containing wastewater generated, if cyanide electroplating is reduced.

Electrochemical Processes. At the present time, NCEL is evaluating an electrochemical wastewater process for oxidizing cyanide to innocuous species and reducing and plating out process metals, such as cadmium. With this method, electrolytic oxidation/metal deposition could be a cost-effective alternative applicable to about half the Navy plating shops. Electrolytic treatment differs from conventional chemical treatment techniques in that it uses a DC current to plate out and remove heavy metal contaminants at the cathode and oxidize cyanide to cyanate at the anode.

Developmental testing and evaluation of electrolytic cell systems is being conducted by NCEL at the IWTP at NAS Alameda to determine the effectiveness of the technology and to establish the system requirements. Initial studies have shown the need to reconfigure the cell system to improve process efficiency.

Biological Processes. Fungal enzymes can hydrate cyanide to nontoxic formamide. This process is more cost-effective than alkaline chlorination. Such enzymes are being marketed. Another method of biological cyanide detoxification is via a mutant strain of bacteria called "Mudlock" after the two men who received a patent for it. Included among the cyanide compounds that are degraded by this process are the stable iron-complexed cyanides and thiocyanates.

Several microorganisms are used or have potential for use in recovering metals from wastewaters and other contaminated waste streams, such as painting operations. Some organisms are already being employed to recover metals, such as copper and cadmium.

Chromate-containing Wastewaters (T2). With the implementation of the NCEL Zero Discharge Hard Chrome Plating Process, the loading of chromium into Navy IWTPs should drop dramatically. Despite this HW reduction achievement, chromium ion will still be in some effluents and may have to be removed to meet regulatory limits. The processes that are responsible, i.e., aluminum anodizing, chromating, and a few other minor techniques, will probably not be amenable to the chromium control now available for electroplating. It will likely be necessary to continue present treatment technology, unless the chromium wastes are discharged at acceptable levels.

Assuming that sulfite reduction and Cr^{+3} precipitation are continued, the process must be scaled to the actual demand; that is, the chromium-containing wastewaters must be segregated so treatment is limited to the chromium influent and is not used on other waste streams.

At activities where wastewater piping cannot be cost-effectively modified to segregate chromium-containing streams, pretreatment at the source is the solution. Small packaged treatment units could be installed at, near, or between (shared operation) to effect the reduction and, if appropriate, the precipitation of the formed Cr^{+3}. The latter step may be cost-effective, if it leads to a significant reduction in the amount of flocculating agent added at the IWTP, upstream of the clarifier.

Freeze Crystallization (T3). This technique is considered to be applicable to any type of plating (or other process) wastewater. It is not a treatment process but a concentrating effect. Freeze crystallization separates nearly pure water, as ice, from the contaminated stream. The ice phase is filtered off, washed, then melted to produce a reasonably pure (only about 1 percent of the bulk phase contaminants are occluded in the ice), industrially recyclable water stream. The contaminants are, thus, concentrated into a much smaller (~5 percent) volume that can then be more economically treated (incineration is even suggested). Process costs of from $0.025 to 0.15 per gallon of purified water are suggested. This does not include, however, the cost of treating or disposing of the concentrated waste fraction. The Naval Air Propulsion Center, Trenton, NJ, is currently considering RDT&E studies of this process at NADEP Norfolk using typical electroplating shop wastewaters.

3.4 PROCESS NO. 3 -- ORDNANCE OPERATIONS

3.4.1 Industrial Process Aspects

3.4.1.1 Current Military Practice TO. There are three general types of ordnance operations that generate essentially similar waste streams. These are, 1) the synthesis of ordnance explosives and propellants; 2) washdown of equipment and facilities engaged in load, assemble, and pack operations (LAP), in which individual items of ordnance are loaded; and 3) demilitarization steamout operations, in which individual ordnance casings and parts are cleaned of explosives and propellants (See Section 3.8). Each of these results in, essentially, a similar waste stream.

Explosives manufacturing. All of the processes presently in use within the Defense Department for the synthesis of nitrated explosives result in the formation of some wastewaters containing nitro-organic materials. "Red water" results from washing of solid or molten trinitrotoluene (TNT) with aqueous $NaNO_2$ to remove TNT isomers. "Pink water" is produced in melting/unloading and repacking of munitions. The wastewater or steam condensate containing TNT and its isomers is initially colorless and turns pink, if nonacidic, only when exposed to sunlight. These wastewaters can contain anywhere from 3 to 35 percent dissolved solids.

When the heated wastewaters are released from the manufacturing plant and allowed to cool, large amounts of the nitro-bodies precipitate out. At equilibrium, the resultant liquid waste stream will typically contain 80 to 100 ppm of TNT and similar concentrations of dinitrotoluene and nitrotoluene. When RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) is an ingredient in the explosive being handled, that constituent will also be present in pink water.

Currently, there are no explosives synthesis operations within the Navy, although some double-base nitrate ester explosives containing ethylene glycol dinitrate (EGDN) and glycerol trinitrate (nitroglycerine, so called) are synthesized at NOS Indianhead. Under the Defense Department's single-manager system, explosives manufacture is entirely under Army management, even when performed at Navy facilities. There are some research and development activities involving explosives and propellants manufacture taking place at NOS Indian Head. These operations generate significant amounts of wastewaters that were, however, not of sufficient quantity to be considered in the NCEL survey.

According to the Naval Sea Systems Command (NAVSEA) Ordnance Environmental Support Office (OESO), there appears to be no efficient and practical method for treatment of nitrate esters in wastewaters. Since these particular explosive systems are not under Army management, the OESO recommended that NCEL RDT&E effort be applied to the problem.

Load, Assemble and Pack Operations (LAP). The LAP operation is the final step in the manufacture of munitions. Essentially, it consists of loading the explosive or propellant into the fuel hardware casing. Munitions typically are loaded in the melt-pour, or press-cast, or plastic-bonding procedures. The most common is the melt-pour operation, in which bombs, shells, and other ordnance are filled with TNT or a mixture of TNT and other high explosives. The explosive is poured in molten form from overhead kettles and allowed to solidify. The kettles are large (several thousand gallons), steam-jacketed, stainless steel vessels. Explosive materials are poured into casings on a prescribed basis. When the kettle is nearly empty (typically once a day or once a shift), it is allowed to drain as empty as possible and then is washed out with hot water and dried. Dusts and residues of explosive materials can also accumulate on the general casting areas, floors, and other pieces of equipment, so these are periodically washed down. All of this washwater is collected by gutters in the building and led to catch basins. In the catch basins, the TNT-saturated water cools and, through precipitation, reaches equilibrium concentration of approximately 100 ppm for TNT. As the high concentrations of explosive materials precipitate out and solidify, a sludge of solid TNT and other explosive ingredients collects in the bottom of the catch basin and is periodically removed and burned. The press-cast and plastic-bonding procedures have some similar water cleanup steps, in which the collected residues are allowed to drain into a gutter and collect in a catch basin. Here, again, the cooling, explosive-containing wastewaters reach equilibrium saturation for the constituent chemicals by precipitation.

LAP operations take place at NWSC Crane, NOS Indian Head, and NWS (Naval Weapons Station) Yorktown. The only facility producing sufficient waste to be covered in this survey is NWSC Crane, where 26,722 tons of pink water were generated in 1984.

3.4.1.2 General Industrial Practice (T1). There is no T1 industrial practice anywhere in North America equivalent to the military munitions industry. Thus, there are no process modifications that can be recommended that are in common practice in any equivalent industry.

3.4.1.3 Alternative Technologies (T0 to T3). Evaluation of alternative technologies for ordnance processing was set outside the scope of the present IDR by the sponsor.

3.4.2 Treatment of Hazardous Waste from Ordnance Operations

3.4.2.1 Pink Water Characteristics. All of the ordnance pack/repack operations discussed in Section 3.4.1 result in the production of pink water, an aqueous waste stream contaminated with photosensitive nitro-bodies in the 200 to 400 ppm range. Depending upon the explosives in the process, these contaminants will include the parent, as well as isomers and homologs of TNT (trinitrotoluene), at concentrations of approximately 80 to 100 ppm; RDX at concentrations of 40 to 50 ppm; HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) at concentrations of 10 to 15 ppm; or PETN (pentaerythritol tetranitrate) at concentrations of approximately 20 ppm. The color of pink water is due to the photodegradation of the nitro-bodies into bright red azo derivatives. Although not of particular concern to humans, various of the nitro-bodies present in the pink water have been shown to be toxic to aquatic life and are, thus, considered hazardous due to toxicity. Furthermore, if there is subsequent treatment of pink water resulting in concentration of the explosive nitro-bodies, then that concentrate (e.g., activated charcoal) would be hazardous (flammable or explosive).

3.4.2.2 Current Navy Practice (T0). Historically, pink water was either transferred to oxidation lagoons for gradual, natural decomposition or simply released to the ground or to waterways. All such practices are unacceptable. Now, both the Army and the Navy adsorb the nitro-bodies onto activated carbon. This is an effective means of reducing the levels of TNT in the pink water plant washdowns to less than 1 ppm (Reference 3-9). The U.S. Army's Surgeon General has proposed limits of 0.044 mg/l for TNT and 0.035 mg/l for RDX as interim drinking water limits. The lowest levels of pink water detoxification attained with the NWS Yorktown carbon absorption system was 0.1 mg/l TNT. This suggests that there would be little likelihood of drinking water contamination that would begin to approach the criteria proposed.

The adsorption of the nitro-bodies on the carbon surface, however, has been found to be essentially irreversible, such that the spent activated carbon must be destroyed after a single cycle. Commonly, the spent, activated carbon is dewatered and transported to an open-pit ammunition burning ground (ABG) for burning. The Weapons Quality Engineering Center (WQEC) at Crane, Indiana, estimates the 1980 cost of pink water treatment at $7.10/1000 gal.

3.4.2.3 General Industrial Practice. There is no T1 industrial practice anywhere in North America equivalent to the military munitions industry.

3.4.2.4 Alternative Technologies (T0 to T3):

Carbon Adsorption With Carbon Regeneration (T1). The Army is presently evaluating a commercial facility's ability to regenerate activated carbon containing nitro-bodies. Early indications are that, because of the intense adsorption isotherms, the nitro-bodies decompose in situ rather than elute under best desorptive conditions. This is occasioned by microexplosions, as individual molecules of explosives and monopropellants are elevated in temperature. This event is particularly true when RDX and/or HMX are present. The microexplosions cause fracturing within the carbon granules that subsequently break up into powder as the material is moved about. Evaluation is continuing, but if such thermal processing does reduce the size of the activated carbon, then long shipping distances and subsequent breakage of the carbon granules would make this recovery technique ineffective, if the sorbate phase involved significant amounts of RDX and/or HMX. In the treatment of pink water containing TNT (or nitrated esters - see Section 3.18.2, Part I), the recycling of the spent charcoal is much more successful and is a viable method of waste minimization.

It may also eventually prove feasible to pretreat pink water containing RDX and/or HMX by biological degradation or other forms of intermediate treatment before the waste is subjected to adsorption with activated carbon. This may substantially reduce the challenge to the carbon to the point where the contaminants could be effectively removed to within the recommended limits, while the life of the carbon would be significantly extended.

On-site Regeneration of the Carbon (T2). The U.S. EPA Hazardous Waste Engineering Research Laboratory at Edison, New Jersey, has a mobile carbon regeneration facility that could be used for evaluation of on-site carbon regeneration at any DOD facility. This lab has constructed and equipped a mobile carbon regeneration system suitable for desorbing tightly bound organics and reactivating small quantities of contaminated, granular activated carbon. The system is designed around a rotary kiln, with a secondary combustion chamber and gas scrubber for effluent gas cleanup.

Contaminated, granular activated carbon is heated in the kiln to desorb and pyrolyze all organic substances. Vapors and gases thus produced flow into the secondary combustion chamber and are held under excess oxygen. Temperature and residence time are controlled to assure detoxification of all desorbed hazardous organic substances. Off-gases are water quenched and akaline scrubbed before being vented. When RDX and/or HMX are present, microexplosions still occur within the kiln causing powdering and loss of some of the granular carbon. This approach results in the complete thermal destruction of the toxic hazardous material in the spent activated carbon and allows for recycling and reuse of some of the activated carbon in the treatment of pink water.

Ion Exchange (T2). Ion exchange and ion exchange resins are discussed in more detail in Appendix C of this document. Initial cost of granular activated carbon for the treatment of munitions wastes is less than the cost of common, currently available macroreticular resins. However, recent laboratory studies (Reference 3-10) indicate there are some resins and approaches to their use and desorption that would allow continuous use with normal desorption/reactivation costs. Thus, the life cycle cost would be much lower than the cost of using once-through granular activated carbon.

Wet-Air Oxidation (T2). Wet-air oxidation has been shown to be an effective means of thermal destruction of organics in dilute aqueous waste streams. Because wet-air oxidation takes place at temperatures below the explosive ignition point of most munitions, a gradual nonexplosive oxidation can occur. Catalyzed wet-air oxidation and supercritical wet-air oxidation, both of which are discussed in Appendix D of this document, offer promise as potential thermal destruction treatment processes for aqueous wastes contaminated with low levels of nitrated organic materials.

Photolytically Enhanced Oxidation (T2). Addition of an oxidant material, such as ozone or hydrogen peroxide, to pink water results in the oxidative destruction of some of the organic nitro-bodies. It is common, however, to attempt to enhance the rate and efficiency of oxidative destruction of organic materials with ultraviolet (UV) enhancement. Ultraviolet radiation will raise many of the organic bonds to an energy state at which they are more readily broken so oxidation can take place. Early studies of UV-enhanced oxidation (Reference 3-11) show that the process can be an effective treatment for pink water. An operational difficulty was the formation of a film on the UV lamp. NWSC Crane personnel developed a wiping mechanism that prevents loss of UV intensity. The process is scheduled to be tested on a pilot scale in 1987.

Costs of this process, according to WQEC Crane, range from $3.69 to 4.69/1000 gal (1980 dollars), excluding capital costs annualization. In addition to lowering O&M costs over the carbon process ($7.10/1000 gal, 1980 estimate), the UV process eliminates the burning of activated charcoal with the attendant formation of ash and release of NOx.

Bacterial Denitrification (T2). Biological techniques for general hazardous waste destruction are discussed in Appendix E. Biological processes for denitrification of nitrated organics include standard techniques, as used in the wastewater treatment industry. Such a process was evaluated for the denitrification of explosives by Processes Research, Inc., in 1977. Tests were performed for the individual stages of their proposed process, but the complete process was never tested on a pilot scale. Initial testing indicated slow and relatively ineffective denitrification of the explosive (Reference 3-12).

Other Biological Processes (T3). Studies of two biological processes for the rapid and efficient denitrification of organic materials, including nitrated organics, are presently in the initial stages. These include fungal denitrification and denitrification by Wolfia, a top-growing microscopic water plant. The organisms may not of themselves be able to effect total elimination of the hazardous wastes in pink water. However, they may prove to have significant value as an intermediate process in the standard treatment with activated charcoal, by helping to reduce the contaminant load to which the adsorbent will be subjected.

Fungi -- have been used successfully in tests for denitrification and dechlorination of hazardous materials in studies sponsored by the U.S. EPA (Reference 3-13). Process rates and costs cannot be determined until laboratory studies are performed on samples of specific waste streams with the available fungi. Testing of the white rot fungus, Phanerochaete chrysosporium, on pink water has been initiated to determine estimates of process rates and process costs. This Independent Research and Development (IRAD) work resulted from a response to a general solicitation of industry process information made in connection with this IDR development. Preliminary test results have been highly encouraging. TNT was completely removed from pink water, and RDX, nearly completely, although more slowly. Appendix F presents the limited findings in this preliminary study.

Wolfia -- is a microscopic top-growing plant with a high nitrogen requirement and rapid growth rate. It is particularly suitable for use in denitrification of ponds and has been employed for denitrification of wastewaters in India and Southeast Asia. Recently, species have been discovered that will grow in the North American climate and that show the same rapid growth rate, high nitrogen uptake, and ease of harvesting and removal that has been observed with other Wolfia species.

3.4.3 Disposal of Wastes from Ordnance Operations

Pink water is presently treated by carbon adsorption. The explosive-contaminated activated carbon is incinerated at the open burning/open detonation (OB/OD) site (where explosives and munitions are presently disposed of), and the ash from that incineration is landfilled. This practice may possibly continue indefinitely, provided that applicable Air Pollution Control (APC) regulations are complied with and provided these regulations are not modified. There is a definite possibility, however, that all forms of open burning may be banned, in which case, the charcoal incineration would have to be performed in an appropriately permitted combustor or with containment devices installed over the OB/OD pit to ensure effective collection and treatment of released air pollutants.

3.5 PROCESS NO.4 -- BILGE EMPTYING AND CLEANING WASTES

3.5.1 Industrial Process Aspects

3.5.1.1 Current Navy Practice (T0):

Bilge Water Off-Loading. Primary sources of ship-generated oily wastewater are bilges, oily waste holding tanks for collecting lubricating oils and water-contaminated fuel, and ballast water. Oily ballast water can be discharged from most ships (other than tankers), directly overboard or to DONUTs or SWOBs (waste oil barges), through large-diameter piping. Large Naval bases sometimes utilize a permanently installed collection, storage, and treatment facility for ballast water collected from tankers at fueling piers.

The pier collection system consists of a 6-inch (minimum) pier pressure main with 4-inch (minimum) pressure laterals manifolded to the main. The main is laid in the center or along the sides of the pier. These wastes are transferred ashore, using pumping only when a gravity system cannot serve hydraulically, such as for wastewater collection lines at piers. For these pumping systems, the pumps are located as close as possible to the oily wastewater source. This maximizes detention time between pumping and treatment and minimizes impact of mechanical emulsification. Another possibility is to use an equalization facility. Here, detention times are kept down to prevent odor and gas production. If this is unavoidable, vapor controls are added.

Reciprocating, positive displacement or screw pumps are used to transfer oily wastewater to the equalization facility or treatment unit. Also used are rotary displacement and centrifugal pumps; low speeds are utilized to minimize mechanical emulsification.

Ship bilge daily flow varies with the class of ship, shipboard operations, and condition of the ship's mechanical equipment. In estimating the amount of oily wastes associated with bilge water off-loading, two surveys were used. Using data furnished by the NEESA HW summaries, NCEL personnel located only 12,883.45 tons of oily wastes associated with bilge water offloading. This is due, in part, to the fact that many of the activities operate oily wastewater processing plants (or they send their wastes to a nearby activity that can treat the waste) and, thus, do not report the generated oily wastewater, but only the disposal of oily sludges resulting from treatment. The EPA has not yet listed oily waste as being hazardous, unless it is contaminated with something that would make it so. Because some states already classify such wastes as HW, whether contaminated with other materials or not, it is expected that the EPA will eventually follow their lead.

Another possible reason for the oily wastes not being reported is that the underflow of oil-water separators is often sent to the IWTP. For example, at San Diego Naval Station, the bilgewater collected from ship traffic is processed by the PWC through an air-flotation oil separator, and the oil/emulsion layer is then barged across the harbor to NSC Pt. Loma. The water phase goes into the adjacent PWC IWTP. NSC subjects the oil phase to thermal water knock-out, obtaining a good quality oil, some sludge, and additional brackish water. The oil is sent to Miramar NAS where it is blended with boiler fuel and, thus, fired in the station steam plant with good energy recovery. In this way, the only hazardous waste reported is the small amount of oily sludge that is produced, which typically represents 1 to 2.5 percent of the original volume of oily wastes treated (Reference 3-14). The costs reported for the bilge water practices ($752,285) include land disposal, recycling, and some treatment costs.

On another, earlier survey, conducted as part of an NCEL study on emulsified oily wastewaters in the Navy, over 5 million gal/month of oily wastewater were recorded. Of this amount, 2 million gal/month were from bilges, DONUTs, SWOBs, and shiptank cleaning wastewater (Reference 3-15). This volume represents 99,960 tons of bilgewater wastes generated per year. Of this amount, we can expect a conservative estimate of 1 percent, or 999.6 tons, to be classified as sludge after treatment. The various activities paid anywhere from $0.53 to $26 a barrel for disposal costs. In all, over $100,000 was spent in 1984 for disposal of oily wastes that were classified specifically as emulsified oily wastes.

The volumetric dimensions of the bilgewater problem can be expected to diminish substantially by the year 1992. NAVSEA has entered into a program to equip all Naval forces afloat with shipboard oil/water separators by that time. This will mean that bilgewater processing at shore installations will essentially become a nonexistent requirement. The ships will, instead, be delivering ashore much smaller volumes of oily wastes, most likely only those that are heavily emulsified and require further treatment.

The production of bilgewater in ships was seen to be a somewhat variable phenomenon in terms of the ratio of volumetric production and vessel deadweight. For example, Seal Beach generated 104 tons of oily bilgewater wastes, primarily from operation of an old YT with many engine leaks. Anticipated replacement of the tug is expected to reduce the hazardous oily wastewater generation rate at Seal Beach by more than 50 percent. Similarly, improved engine maintenance and shipboard housekeeping practices (such as eliminating emulsifiers from shipboard cleaning activities), with regard to the handling and use of lubricants and fuels, could contribute to significant reduction of oil contamination in the bilgewaters off-loaded from all Navy ships.

Bilge and Tank Cleaning. As a general cleaning procedure (and specifically prior to bilge paint removal and derusting), degreasers are sprayed into the tanks and bilges to remove oil, grease, and dirt. In 1984, approximately 3120 tons of dilute or partially concentrated wash and rinse waters containing oil, grease, dirt, rust, degreasing solvent, and dissolved and chelated metals were transported to Navy IWTP, OWTP (Oily Waste Treatment Plant), or contractor hazardous waste treatment facilities for oil/water separation and precipitation of wastewater metals.

NSY Long Beach and NWS Earle currently use emulsifying degreasers, such as Gamlen. The use of Gamlen for bilge degreasing creates oil/water/sludge emulsions, the treatment of which is very difficult since the organic phase cannot be readily isolated (Reference 3-16). Also, many degreasing detergents are very alkaline, exhibiting pHs in excess of 12. Waste lines corrode rapidly when sewage pH goes much above 9.0.

3.5.1.2 General Industrial Practice (T1):

Bilge Water Off-loading. Collection of oily leaks and spills in ship bilges is a common occurrence in all commercial hulls. Some merchant ships operate onboard oil/water separation systems and, thus, avoid the expense of off-loading large volumes of oil-contaminated bilge waters. Ocean discharge of the underflow from such devices is generally accomplished without prejudice while under way.

Bilge and Tank Cleaning. Bilge and tank cleaning of privately owned vessels in shipyards is very similar to Navy methods. The trend of commercial practice is toward the use of nonemulsifying degreasers.

3.5.1.3 Alternative Technology (T1 to T3):

Nonemulsifying Degreasers (T1). A number of products are available that may render bilge and tank cleaning less productive of HW. Mirachem All-Purpose Cleaner/Degreaser No. 100 is a nonemulsifying solvent cleaner with some industrial applications. NSY Pearl Harbor has been experimenting with this material on a T2 level and found that it is as effective as Gamlen (an emulsifier) and that it greatly enhances subsequent wall-recoating processes. This material substitution would greatly enhance the effectiveness of on-site oil/water separation and reduce subsequent transportation, treatment, and disposal costs (Reference 3-16). The same command has also investigated Citrakleen, a degreasing agent that also produces fast breaking emulsions with bilge oils. The David Taylor Research Center points out, however, that the active component of Mirachem 100 is a solvent that is currently available through Navy supply and that its use and disposal aboard ship is restricted. They go on to state that advertised "safe solvents" are materials already in common use. Therefore, specifying their use gives their manufacturer an advantage over other similar products using the common chemical name and does not decrease the number or degree of hazard of materials in use.

Puget Sound NSY has recommended the evaluation of terpenes for bilge and tank cleaning. Rochester Midland Corp. has marketed terpene mixtures that hold greases and oils in suspension, as long as the system is agitated. When rested, greases and oils form a distinct layer that can be skimmed off and stored. In this way, the terpene cleaner can be recycled many times.

Bilge Water Off-loading. No alternatives noted.

Bilge and Tank Cleaning (T1). Various systems have been evaluated and involve the use of cleaning devices installed in tanks and sectioned-off bilge areas. These systems pump heated cleaning solutions through articulated spraying assemblies onto the structure walls and collect the draining solutions for recirculation through the heated supply reservoir.

Since this system is designed primarily for the bilge and ship tank derusting process, it will not be considered a technology for implementation here. See Section 3.15 for further information on its use in conjunction with bilge derusting.

3.5.2 Treatment of Oily Bilge Wastes

Part I - Oil Contaminated Bilge and Ballast Waters

3.5.2.1 Characteristics of Bilge and Ballast Waters. Bilge and ballast waters are usually contaminated with about 1 percent mixed lubricating oils, hydraulic fluids, fuels, and bilge and tank cleaning solutions. These wastewaters are not hazardous unless specifically contaminated with other hazardous wastes, which is commonly the case. Before they can be discharged to sewers or streams, they require treatment to lower the oil, grease, and metals content to meet local industrial pretreatment standards or National Polluted Discharge Elimination System (NPDES) permit requirements. During treatment, these dilute wastes are often commingled with other oily hazardous wastes, become concentrated in the form of oily sludges, and exhibit hazardous (per RCRA) characteristics.

3.5.2.2 Current Navy Practice (T0):

Oily Waste Transport Units. Effective pretreatment of oil-contaminated bilge and ballast waters is accomplished at numerous activities using a combination of DONUTs, SWOBs, and/or pier-side oil/water separators. These are conveniently located and are capable of separating the oily waste (with the possible exception of heavily emulsified wastes) into Publically Owned Treatment Works Plant (POTWP)-treatable wastewaters, recovered waste oils, and oily sludges that require further treatment or disposal.

This type of operation is heavily relied upon at activities, such as NAS Alameda, NSY Long Beach, NSY Mare Island, and San Diego NS (Naval Station). One of the most common problems with this form of treatment is insufficient or untimely maintenance, which may lead to reduced separation efficiency, especially in DONUTs. DONUTs are also very useful for oil-spill cleanup activities.

Oil/Water Treatment Plants (OWTP). As in the case of bilge and tank-cleaning operations, the presence of emulsifying agents (e.g., Gamlen) and solids complicates the effective separation of the oily wastes and requires more intensive treatment. The numerous OWTPs in operation throughout the Navy employ a wide variety of different technologies in various combinations to treat oily wastes and waste oils. These include settling tanks, API gravity separators, parallel plate separators, chemical coagulators, diffused-air flotators, ozonation, dissolved-air flotators, multimedia filters, carbon columns, and coalescer filters (Reference 3-17).

The optimum design for utilizing these various technologies in future OWTPs (or renovated OWTPs) is presented in the Civil Engineering Design Manual 5.8, Section 6, Subsection 3. The OWTP design considered adequate to meet industrial pretreatment standards (wastewaters are discharged to POWTPs) is the use of load equalization tanks, followed by inclined-plate separators. When wastewaters are to be discharged directly to bodies of water, additional treatment is generally required to meet NPDES requirements. Dissolved-air flotation, followed by multimedia or coalescing filters, has proved to be effective in meeting more stringent discharge requirements (Reference 3-18).

Load Equalization Tanks (LET). Oily waste may be discharged into a short-term storage/separation tank referred to as a LET. The LET is a batch-operated, gravity oil-water separator. Oily waste is received for a predetermined collection period and then allowed to sit quiescently for about 24 hours to ensure optimum gravity separation and to prevent anaerobic conditions. Free oil floats to the surface and is skimmed off. Settleable solids sink and are scraped to a hopper for withdrawal and disposal. Typical LET effluent contains less than 50 ppm of oil and grease.

Clarified water is passed on for additional treatment or discharge. Multiple LETs are provided for sequential fill and draw operations. Each tank has a capacity equal to the average flow for seven days.

Induced Gravity Separator. An induced gravity separator (such as a parallel plate type) is provided when LET effluent contains more than 50 ppm of oil and grease. The total flow through the separator is distributed through numerous flow paths, formed by inclined plates or tubes at laminar velocity. This increases solids contact and aids solids separation by improving the flotation and settling characteristics of the enlarged particles. The oil droplets coalesce and gradually move upward along the bottom of the plates, eventually collecting at the top of the tank. The effluent produced ranges between 25 and 50 ppm oil.

Dissolved Air-Flotation (DAF) Unit. To meet effluent quality requirements for direct discharge, additional treatment is required after separation in a LET. Secondary treatment in a DAF unit will remove significant amounts of additional free, and some of the emulsified, oil and grease. Emulsified oil is removed through the use of chemical coagulants and rising air bubbles. The coagulants cause the minute oil droplets to agglomerate into larger floc particles. The air bubbles adhere to these particles causing the oil to rise rapidly to the surface.

This scum is mechanically skimmed off and pumped to a storage tank, from which it is periodically decanted off to drying beds, or other dewatering devices. Normally, the effluent from the DAF will contain 10 to 20 ppm of oil and grease.

Tertiary Treatment Units. To provide consistent direct discharge quality effluent, tertiary treatment is required. Either multimedia or coalescing filtration may be used. Multimedia filter systems consist of three multimedia bed-pressure filters designed for plant-specific flow rates. Wastewater enters the top of the filter vessel. It is distributed over the bed area, forced downward through the bed, and discharged through an underdrain lateral collector. The filter vessels are constructed in accordance with the American Society of Mechanical Engineers (ASME) Code for Unfired Pressure Vessels at a design pressure of 100 psig. The filters are backwashed externally.

A coalescing filter consists of mechanical filter-coalescer packs, prefilter elements, and a coalescer. The three components are housed in an enclosed rectangular steel tank, which may also have a recovered oil storage compartment and drywell for the pumps and controls.

When the coalescer is operated, oily waste flows by gravity from the DAF unit into the coalescing separator and through the mechanical filter-coalescer packs. Suspended solids are retained in the packs and the oil floats to the surface and is removed by a floating skimmer and pumped to the oil storage compartment or oil storage tanks. If no oil/water interface is detected, a pump is activated and the oily waste is pumped through the prefilter and coalescer elements. The treated oily waste then passes out of the unit.

3.5.2.3 General Industrial Practice (T1). There are no notable distinctions between general industrial practice in oil/water separation technologies and those currently employed at Navy OWTP operations. OWTP design criteria presented in Civil Engineering Design Manual 5.8, Section 6, Subsection 3, represent technically effective, state-of-the-art, oil/water separation technologies. Optimum implementation of these technologies in industry is often associated with the higher operator skill levels (chemists and engineers) than is the typical case (maintenance personnel) observed throughout the Navy.

3.5.2.4 Alternative Technologies (T1 to T3). Current technology within the Navy is effective in treating oily waste streams when the OWTP receives the type of wastewater for which it was designed. Problems arise only when there is a lack of waste segregation or undesirable pollutants are introduced.

Part II - Recovered Waste Oils

3.5.2.5 Characteristics of Recovered Waste Oils. Prior to November 29, 1985, waste oils were regulated under RCRA only if they exhibited hazardous characteristics or if they were specifically mixed with other hazardous wastes, such as chlorinated solvents, as a result of improper management practices. Until that time, uncontaminated, reclaimed waste and used oils were essentially unregulated and could be sold to reclaimers through DRMO and burned as fuel. These wastes were not reported to NEESA in activity hazardous waste reports. In November 1985, "Phase I" rules regarding the "Burning of Waste Fuel and Used Oil Fuel in Boilers and Industrial Furnaces" (40 CFR Pars 261, 264, 265, 266, and 271) were implemented, providing administrative controls for those persons who market and burn hazardous waste and used oil fuels. These regulations establish specification levels for certain hazardous contaminants and place restrictions on the use of off-specification, used oil fuel. At the same time, future regulations were proposed to place similar administrative controls on all other used oil recycling activities. The preamble proposed regulatory trends to control combustion devices for used oil fuels and to establish the same comprehensive "cradle-to-grave" management requirements for waste and used oils that are currently in place for other listed hazardous wastes. This would have a major impact on the Navy.

3.5.2.6 Current Navy Practice (TO). Waste oils separated from oily wastewaters at OWTPs (and other waste oils) are most commonly 1) recycled, 2) used as fuels by the Navy, or 3) sold to reclaimers by DRMO. These practices will continue to be technically effective management techniques for these wastes. However, as stated above, recent and proposed regulations will add significantly to the administrative and analytical requirements. They will also restrict certain uses of off-specification, used oil fuels (40 CFR pars 260, 261, 266, 270, and 271, "Hazardous Waste Management System; Recycled Used Oil Standards" Federal Register, November 29, 1985). The relative cost-effectiveness of current practices may have to be reviewed, if new regulations are published. Certain technical alternatives could be more appropriate, depending upon the degree of waste segregation and levels of contamination.

Recycling. The USE program identifies the most appropriate types of activities for waste or recovered oils that are relatively free from contamination. Either on-site or contractor recycling options may be the more cost-effective, depending upon volume, plant layout, or local contract options.

Cofiring. The Navy currently burns many of its waste streams for energy recovery. For example, in 1985, NADEP Jacksonville provided over 100,000 gal of oil as a fuel for other Government agencies. NADEP Norfolk blended and burned 97,058 lb of lubricants and hydraulic fluid for miscellaneous shops and blended and burned 238,568 lb of heptane from fuel accessories shops. The Pacific Missile Test Center (PMTC), Point Mugu, fuel farm recovered 17,950 lb of contaminated fuel/oils that were then donated for use in school boilers. The Naval Air Propulsion Center (NAPC), Trenton, fuel farm recovered 500 gal of waste jet fuel for burning with scrap fuels. The fuel farm at Naval Aviation Evaluation Center (NAEC), Lakehurst, recovered 7,900 gal of waste JP-4 and JP-5 fuels for the Department of Energy's (DOE) Brookhaven National Laboratory. NIROP Pomona shipped 3,500 gal of combustible waste to a contract fuel blender for use as fuel in a cement kiln.

Fuel Oil Reclaimed (FOR) is a blend of various reclaimed oils meeting certain fuel specifications (should be less than 2 percent water) and is burned at various Navy locations as fuel for steam plant boilers, process heating, or as engine fuel supplements. In 1980 and 1981, Point Loma shipped over 250,000 gal of FOR to the Marine Corps (MARCORP), Camp Pendleton, and NAS Miramar (Reference 3-19).

Disposal or Sale Through DRMO. Disposal or sale of reclaimed waste oils via DRMO is a common practice when volumes or quality are low or variable. Poor segregation often contaminates these materials and makes them less desirable for recycling or reuse options.

3.5.2.7 General Industrial Practice (T1). The current low market position of virgin oil products, combined with the significant confusion regarding the recent and proposed regulations on burning used oil fuels, has significantly disrupted the reclaimed waste oil industry. What was formerly a valuable resource is now viewed as a potential financial and legal liability. The EPA is concerned about this disruption of the used oil market and recently issued an informative bulletin in an attempt to clarify the issues surrounding the new regulations.

The recycle and fuel-use practices employed by industry and the Navy continue to be technically effective, but there are now certain restrictions on some options, such as burning off-specification, used oil fuels in nonindustrial boilers. Industry is critically reevaluating its practice of burning used oils.

3.5.2.8 Alternative Technologies (T0 to T3). Brinkman (Reference 3-20) offers detailed discussions of the potential presented by re-refining used waste oils into marine fuels and lubricants. This practice of refining converts reclaimed waste oils into original-quality petroleum. Mohawk Oil Company of Canada has developed a hydrodistillation process that is technically effective in separating and refining waste oils into products of quality equal to virgin stock. Increased market acceptance of recycled products will help the economics of recycling and open markets that the Navy can use.

Part III - Oily Sludges

3.5.2.9 Characteristics of Oily Sludges. The volume of oily sludges generated depends upon the source. Sludges contaminated with oils come from on-site reclamation and treatment of waste oils, sump and tank cleanouts, and certain industrial treatment practices. The resulting oil/water emulsions and oily solids require further treatment and/or disposal. These oily sludges can contain significant quantities of toxic organics and inorganics and are normally considered hazardous wastes under existing RCRA regulations (Reference 3-21). Such contaminants can impact the type of ultimate disposal practices suitable for the waste.

Three major types of oily sludges produced at Navy installations account for more than 90 percent of all Navy oily sludges. These three types are 1) gravity separator sludges, 2) oil sump sludges, and 3) dissolved-air flotation sludges. They are distinctly different in chemical, physical, and toxicological properties (Reference 3-14).

Oily sludges from gravity separators contain the largest percentage of oil (20 to 25 percent); the organic and inorganic solid matter compose about 10 percent; and the water content, about 70 percent. The sludges from oil sumps contain about 5 percent oil, 12 percent solids, and around 75 percent water. Sludges from DAF operations contain only about 2 percent oil, 5 percent solid matter, and large amounts of water (between 90 and 98 percent).

These oily sludges contain toxic chemical compounds, including polynuclear aromatic hydrocarbons (PAH), phenols, and heavy metals. The concentration of toxics is greatest in sludges from gravity separators and lowest in DAF sludges. In many cases, the toxicity of gravity separator sludges exceeds, on a wet basis, the toxicity of benzene and phenol.

In spite of the significant quantity of oily wastes being produced, as indicated in the above report, the NEESA HW summary does not highlight hazardous oily waste sludges. There are several possible reasons why these wastes have not been identified: 1) the oily sludges from oil/water separation units went to the IWTP for treatment, 2) the volume of these wastes was so small it did not exceed the 5-ton cutoff observed in the NCEL survey, and 3) the activities failed to report these wastes. Therefore, generated sludges were not included in the NCEL survey and, consequently, have not been identified with their sources.

3.5.2.10 <u>Current Navy Practice (TO)</u>. In 1984, the Navy disposed of over 500 tons of oily sludges in HW landfills, at a cost of over $61,000. This practice is not acceptable under RCRA, if there are cost-effective alternatives to minimize the volume or toxicity of the waste.

<u>Sludge Dewatering</u>. As detailed in Reference 3-19, certain OWTP operations (e.g., NS Mayport) are able to dewater oily sludges and, to some extent, detoxify them with sand drying beds and natural solar/oxidation. The sunny climate at these activities makes this possible. It eliminates the need for further treatment and dramatically reduces the volume of waste for disposal. All activities may not have sufficient sunlight for this option, but they should still consider it. NSC Manchester, WA, has successfully used pressure bags to dewater oily sludges.

<u>Landfarming</u>. Landfarming of oily sludges is ongoing at Craney Island and PWC Pearl Harbor. Life cycle costs for landfarming oily sludges are projected to range from $28,200 to $63,700 per year for the 25-year design life. The projected capital costs are from $120,000 to 150,000; projected annual operating costs range between $15,000 and 46,000. A complete economic breakdown shows a low cost of $0.21/gal at Craney Island to a projected cost of $9.00/gal at Pearl Harbor (Reference 3-14).

These projected costs do not, however, reflect the new regulatory burdens associated with synthetic liners, leachate collection systems, ground water monitoring, RCRA hazardous waste disposal permits, post closure monitoring, and long-term CERCLA liability. Although no data are available at this time, it is predicted that the additional requirements for ground water and post closure monitoring will significantly increase the projected capital and operating expenses. These new regulatory burdens and the long-term liability associated with the land application of hazardous wastes, makes landfarming of oily sludges a less desirable treatment option.

3.5.2.11 General Industrial Practice (T1). Industrial practices for sludge treatment generally parallel Navy practices. Typically, oily sludges from oil/water waste streams are dewatered and disposed of in a landfill. Filter presses dewater the sludge since other dewatering devices, such as vacuum filters and belt presses, generally fail because of the high oil content of the sludge. Filter aids, such as lime, frequently help provide good filtration rates and disposable cakes. Pressurization can also squeeze out additional oil and water from sludge. This approach may become important, if the level of oil in sludge determines whether it is hazardous or nonhazardous.

3.5.2.12 Alternative Technologies (T0 to T3). The NCEL IDR on oily sludge treatment technologies (Reference 3-14) summarizes the waste characteristics, applicable treatment technologies, and associated costs of oily sludge treatment. It identifies four T2 and T3 alternatives to landfill disposal, discussed below. Biological treatment options could also be applicable. In the meantime, incineration is technically effective and is the preferred alternative to land disposal. Since this is a disposal and not a treatment technique, it is discussed in Section 3.5.3.

Pyrolysis (T2). Thermal degradation in the absence of air is a promising technology, especially if it does not require air pollution hardware. However, no off-the-shelf equipment is currently available. In addition, it is estimated that annualized costs for this technology are between $81,000 and 112,000 per year over the 10-year life of the equipment. Preliminary cost estimates were developed at NCEL for two oily sludge-generating activities. The per gallon costs ranged from about $0.52 at Craney Island to about $6.48 at North Island (Reference 3-14).

Supercritical/Subcritical Wet Air Oxidation (T3). This process uses high pressure and moderate temperatures to degrade oxidizable materials. According to Zimpro, Inc., a 2000- to 3000-gpd unit would have capital costs of $600,000 to 800,000. This size unit is much larger than the Navy needs; however, due to the amount and size of ancillary equipment required, this is the smallest feasible size for the system (Reference 3-14). Use of such a system for oily sludge alone is not cost-effective, but it may be practical if other HWs are included.

Detoxification by Oxidation (T2). The technology decision model in the NCEL IDR (Reference 3-14) identifies detoxification by oxidation as the best option. This process can be installed in line with an OWTP, allowing treatment before additional handling/storage. It provides additional free oil recovery and, because, of the oxidation of toxic organics and metals, is capable of meeting extremely strict discharge water quality standards.

Although ozone is demonstrably the most effective oxidizer, there are currently no commercially available, cost-effective ozone generators this small. The projected annualized cost for a 50 lb/day ozonator/detoxifier system would be approximately $28,000 over the 10-year economic life of the system (Reference 3-14). Hydrogen peroxide is a better choice, even though it is less powerful than ozone. Costs associated with the use of oxidative/detoxification are reasonable. R&D plans project the expenditure of $1.5 million over a four-year period for development of an implementable hydrogen peroxide technology.

Biological Treatment:

Activated Sludge Process -- Aqueous waste flows into a basin where it is aerated for several hours. During this time, a suspended active microbial population (maintained by recycling sludge) aerobically degrades organic matter in the stream while producing new cells. The zoogleal sludge is settled out in a clarifier where a portion (Return Activated Sludge, or RAS) is recycled to the aeration basin. The remaining sludge is wasted, while the clarified water is discharged in a manner appropriate to its quality.

Activated sludge processes utilizing oxygen or oxygen-enriched air instead of air produce more rapid breakdown of chemical solutes. Extended aeration involves longer detention times than conventional activated sludge and relies on a higher population of microorganisms to degrade wastes. Contact stabilization involves only short contact of the aqueous wastes and suspended microbial solids, with subsequent settling of sludge and treatment of the sludge to eliminate the sorbed organics.

Fixed Film Systems -- These systems involve contact of the aqueous waste stream with microorganisms attached to some inert medium, such as rock or specially designed plastic material. The original trickling filter consisted of a bed of rocks over which the contaminated water was sprayed. Microbial deposits form slime layers on the rocks, where metabolism of the solute organics occurs. Oxygen is provided with the air, being injected countercurrently to the wastewater flow. Present technology suggests, however, that gas-suspended biomass systems are more applicable to treating oily sludges than are fixed film systems.

Biological Towers -- Biological towers are a modification of the trickling filter. The medium (e.g., of polyvinyl chloride, polyethylene, polystyrene, or redwood) is stacked into towers that typically reach 16 to 20 feet. The wastewater is sprayed across the top, and as it moves downward, air is pulled upward through the tower. A slime layer of microorganisms forms on the medium and removes the organic contaminants, as the water flows over the slime layer.

Rotating Biological Contactor (RBC) -- An RBC consists of a series of rotating discs, connected by a shaft set in a basin or trough. The contaminated water passes through the basin where the microorganisms, attached to the discs, metabolize the organics present in the water. Approximately 40 percent of the disc's surface area is submerged. This allows the slime layer to alternately come into contact with the contaminated water and the air, where the oxygen is provided to the microorganisms. These units are compact, and they can handle large flow variations and high organic shock loads. They do not require the use of aeration equipment. Due to the varied composition of oily sludges and high concentrations of solids, oils, and heavy metals, the applicability of the RBC to this problem material is questionable.

Because the oily sludge generation rates at Naval facilities are fairly low (200 to 2000 gpd), the size of the required systems would be relatively small. EPA projections for an activated sludge treatment system capable of treating 100,000 gal/day indicate a construction cost of $78,500 with annual O&M costs of $4,300 (Reference 3-22). Although this system appears grossly oversized on a volume basis, it is designed for oil and grease concentrations of less than 0.1 percent, rather than the 1 to 10 percent oil present in Navy sludge. An engineering study and some experimentation would be required to determine appropriate sizing, dilution factors, retention times, enzyme enhancement, and the associated cost factors for the optimum system configuration. However, it may be possible to determine preliminary feasibility with existing tanks at OWTPs, on an experimental basis, with very little capital cost. At least one manufacturer (Envirex) is of the opinion that the rheology of oily sludge makes it unsuitable for treatment in the RBC.

3.5.3 Disposal of Wastes From Bilge Water Treatment

Following oil/water separation, recovered oil can be cofired. The sludge, however, cannot be safely blended with fuels and must be treated or disposed of. Chemical treatment is a possibility (see Section 3.5.2). If ultimate disposal becomes necessary, the sludge can be incinerated.

3.6 PROCESS NO. 5 -- ABRASIVE BLASTING

3.6.1 Industrial Process Aspects

Abrasive blasting is a process used to physically remove paint or rust from substrate material. The selection of blasting medium is based upon the type of surface to be cleaned. The blasting material is projected by a high-pressure air or liquid stream onto the surface, where the abrasive action of the blasting grit removes the softer surface coating and leaves the substrate or base material essentially unharmed.

Abrasive blasting operations are typically performed by personnel with hand-held blasting guns. The manual nature of this operation requires that blasting personnel be trained to achieve efficient removal of the surface coating through control of the pressure used to apply the grit, the distance from which the grit is applied, and the length of time that any one portion of the surface is blasted. Most of the removed surface coating and the spent blasting material falls to the ground and is periodically swept up and collected for disposal. A small percentage of the blasting medium and surface-coating material is so small that it remains airborne and must be removed via air-cleaning systems, prior to being exhausted to the atmosphere.

In order to control the airborne emissions and ricocheting debris produced by blasting operations, these processes are typically conducted in an enclosed or limited-access area. Permanent enclosures for blasting include blasting booths, rooms or hangers for cleaning large surfaces, or glove boxes for smaller pieces. Temporary enclosures, such as tarpaulins draped around the blasting area, are erected for the abrasive blasting of ships and massive pieces too large to be moved into an enclosure. Personnel working in such areas are required to wear protective clothing and use breathing apparatuses.

3.6.1.1 Current Navy Practice (T0). Abrasive blasting techniques paralleling those described above are used in a number of applications by the Navy to prepare various surfaces for painting or receiving other surface coatings. In addition to routine sand blasting of storage tanks and ship hulls to uncover the base metal for repainting, abrasive blasting operations are employed as an alternative to solvent paint stripping of aircraft and aircraft components. This approach improves productivity and minimizes the overall cost for aircraft repainting, which is strongly impacted by the increasing costs associated with the disposal of the hazardous wastes generated by chemical paint-stripping practices. Furthermore, aircraft parts that were formerly subjected to chemical stripping are now being stripped by abrasive blasting alone or by presoftening of the paint with chemical preparations, followed by blasting. Currently, the Navy uses eight different blasting media. These media and the applications for which they are used are presented in Table 3-7.

Table 3-7. Types of Blasting Media and Uses

Types	Use
Sand	Cleaning ship hulls
Copper/nickel slags	Cleaning ship hulls
Garnet	Cleaning ship hulls
Glass beads	Various
Aluminum oxides	Booth blasting of aircraft components
Rice hulls	Cleaning of aircraft component parts
Walnut shells	Cleaning of aircraft component parts
Plastic beads	Cleaning of aircraft external skin

Heavy metals present in many coating materials, primer coats, surface treatments, and the coated substrates can contaminate the blasting material. Of particular concern are cadmium, chromium, and lead, which can be leached out of the landfill media, as determined by the EPA extraction procedure (EP) toxicity test. Arsenic has also been identified as a contaminant of some blasting grits. Tributyl tin oxide has been used as the active ingredient in antifouling paint applied to some Navy ships. Its use has been suspended in response to concerns expressed as to its toxicity to marine biota. This agent will be present in residues from the abrasive blasting of ships that were painted with this material. The EPA is still conducting environmental assessments of tributyl tin oxide. There is also a potential for contamination of blasting grits with organic solvents, when these are used to soften the paint prior to blasting.

Based upon the survey conducted by NCEL, it was reported that 7000 tpy of hazardous wastes are generated from abrasive blasting operations. Abrasive blasting processes producing hazardous waste in excess of 5 tpy were reported at seven Navy activities surveyed:

NADEP Cherry Point, NC
NADEP Norfolk, VA
NADEP Alameda, CA
NSY Mare Island, CA
NSY Long Beach, CA
NAS Jacksonville, FL
NWS Crane, IN

The quantities reported (see Table 3-8) represent abrasive blasting media that have been determined to be hazardous. They do not include other processes that use abrasive blasting materials for removal of nonhazardous paints or coatings. On a weight basis, approximately 70 percent of the waste is generated by hard-media blasting and the remaining 30 percent, by soft, dry-media blasting. The survey did not indicate the use of plastic or moderately hard media, although such material is currently being used at the Pensacola NADEP, a site not included in the survey. The quantity of hazardous wastes produced by abrasive blasting represents 4.4 percent of the total wastes generated by the Navy. Such blasting wastes should be subjected to the EP toxicity test to ensure compliance with the Resource Conservation and Recovery Act (RCRA) regulations. This will also indicate that appropriate techniques are being used for disposal of any given substance. Table 3-8 summarizes the abrasive blasting operations at several Navy facilities. At most locations, used abrasive blasting media are collected, placed into drums, and disposed of in a HW landfill. At the NADEP Norfolk, the spent media are solidified at a contractor's hazardous waste treatment, storage, and disposal site prior to being placed in a landfill.

Environmental concerns are increasing as a result of the RCRA regulations, NPDES requirements, and air emissions standards. Some of the environmental problems associated with the use of organic solvents for paint stripping can be minimized through the increased use of abrasive blasting techniques. Although abrasive blasting operations themselves are not without some environmental problems, these problems are solvable. Thus, abrasive blasting may provide cost-effective and environmentally sound alternatives to solvent paint stripping.

A major advantage of modern abrasive blasting techniques is that the grit used can usually be recycled, thereby, reducing the volume of hazardous material requiring disposal. At NAS Jacksonville, a grit-recycling operation is being implemented and should be in the shakedown phase before the end of FY86.

Off-site recycling of aluminum oxide grit through DRMO is being practiced at NSY Long Beach. Although not identified in this survey, Pensacola NADEP has installed a system to separate reusable plastic blasting media from paint residues. This system is in the developmental stages and, according to reports, is being modified by the manufacturer to improve its durability for continuous operation (Reference 3-1). Hill AFB has implemented a plastic media recycling operation similar to that currently being tested at NADEP Pensacola. The process itself, as an alternative to chemical paint stripping, is further discussed in Section 3.2.17.3. NSY Pearl Harbor has attempted to recycle used blasting grit with a grit reclamation system that was built in conjunction with a new sandblast and painting facility in the mid-70s. The system uses an air classifier to separate paint and

Table 3-8. Summary of Navy Abrasive Blasting Operations

Activity	Media Type	Quantity (ton/yr)	Contaminants	Disposal Method	Annual Cost, k$
NADEP Cherry Pt	Glass beads	53	Cd	Store for landfill	NR
NADEP Norfolk	Rice Hulls	53	Cd	Solidify & landfill	
	Glass beads	63	Cd, As		
	Al oxide	32	Cd, As		149
NADEP Alameda	Glass beads	--			
	Garnet	--			
	Rice hulls	298	Cd	Landfill	
	Walnut shells	--			47
	Sand	20		Landfill	
NSY Mare Island	Green Diamond	490	NR	Landfill	41
NSY Long Beach	Al oxide	285	NR	DRMO recycles	365
	Cu/Ni slag	4062	NR	Landfill	
NAS Jacksonville	NR	1176	Cd, Cr	Landfill/ Grit recycle T&E	282
NWS Crane	Sand	150	Cd, Cr, Pb	Landfill	Note 1

NR - Not reported
Note 1: Navy reimbursed for costs of haul/disposal

rust particles from reusable grit. The system is currently shut down because of operational difficulties that were encountered (heavy metal buildup in recycled grit). Nonetheless, the results may provide useful lessons learned in designing future systems.

3.6.1.2 General Industrial Practice (T1). Contacts were made with commercial shipyards to assess common industrial practice. In general, the sources were reluctant to discuss anything related to HW. Based upon limited information, it appears that common industrial practice in commercial shipyards is to use sand or steel shot as blasting grit and to recycle grit (without separation or size regrading) until it is too fine to remove paint.

3.6.1.3 Alternative Technologies (T0 to T3). Certain process changes can be made to abrasive blasting operations to impact the amount and types of wastes generated, the resultant treatment, and the ultimate disposal of residuals. These changes include 1) substitution of nonhazardous grits for hazardous grits; 2) standardization of the types of grit, to promote recycling; 3) segregation of materials to be blasted into hazardous and nonhazardous surface coatings; 4) substitution of abrasive blasting for solvent stripping; 5) substitution of nontoxic for toxic coatings; and 6) limitation of the painting of noncombatant aircraft to identification markings only. The last suggestion, discussed in Section 3.7, would require a change in administrative procedures. All of the other modifications identified can be implemented with little or no testing and evaluation.

Materials Substitution (T1). Based upon information collected in the survey, copper and nickel slags used as abrasive blasting materials at NSY Long Beach are hazardous before use. It is unclear whether the paint to be removed is also a hazardous material. NSY Pearl Harbor currently uses Green Diamond grit. The operation does, at times, generate a spent grit that is considered hazardous, depending upon the composition of the paint being removed. In fact, only two out of eight shipyards surveyed reported hazardous waste being generated by grit blasting. Elimination of any hazardous material as a blasting medium, unless it is the only material capable of performing that function, would provide immediate payback. Even if the substituted blasting grit is initially more expensive, the overall cost would be less.

Reduction of Types of Blasting Grits (T1). At the seven shipyards reporting, eight different media types where identified. These can be grouped into two broad categories of abrasive blasting materials.

1. Hard media, which consist of blast material, such as glass beads, slag or sand, garnet, and Green Diamond

blasting grit. Currently, sand is not used extensively because of the threat of silicosis.

2. Soft, dry media that include organic materials, such as rice hulls and walnut shells.

Other media, such as plastic media, steel shot, and Black Diamond blasting grit, are currently being used at several Navy activities. These materials were not identified on the NCEL survey since the wastes generated were considered nonhazardous, and the amount generated by nonmineral abrasives are too small for consideration here. The identification of these blasting grits is intended to illustrate the number and variety of blasting materials used.

It appears that the Navy uses too many different blasting grits. In at least one case, NSY Pearl Harbor, a hazardous material (copper slag) was selected to perform the same job for which sand is used. Activities should consider reducing the variety (number and types) of media for this purpose. One advantage of such consolidation would be that smaller operations could send used grit to a common location for economical separation and recovery. This would reduce the need for duplicating equipment and manpower at the site of each unit process.

Materials Segregation (T1). At NADEP Norfolk, we found that the abrasive blasting of a small number of aircraft components with a coating containing cadmium was the sole source of the cadmium contamination of a large quantity of grit. These were: 1) Aircraft engine compressor parts that have a diffused nickel-cadmium plate coating; and 2) cadmium-plated parts of high-strength steel, where chemical stripping is prohibited by Naval Air Systems Command (NAVAIR) instructions. It is only this cadmium content that contaminates the grit. By segregating the materials to be blasted by surface coating type and by segregating the used blasting grit, NADEP Norfolk estimated a 90 percent reduction in the volume of waste rice hull requiring disposal as a HW. Each of the Navy activities should review its situation to see whether materials segregation based upon surface coating type would offer a similar opportunity to reduce the volume of hazardous waste generated from abrasive blasting operations.

Blasting as Replacement for Solvent Stripping (T2). One of the major drawbacks to widespread use of abrasive blasting is that proper selection of blasting medium is critical to preventing damage to the substrate material. In addition, the use of abrasive blasting requires experienced, careful operators. A great deal of study has been performed to define which medium works best on which substrate and associated coatings and to establish proper operating practices. Use of abrasive blasting techniques as an alternative to solvent stripping may compromise or damage fiberglass, lightweight aluminum, and carbon composites. Other drawbacks of abrasive blasting include damage to plastic windows and removal of cadmium coatings on screws. It may be possible to overcome these difficulties through careful media selection and improved protection of sensitive parts. See Section 3.17, Chemical Paint Stripping.

Substitution of Nontoxic Coatings (T3). In order to significantly reduce the quantity of hazardous waste generated by abrasive blasting, additional testing and evaluation are required in the area of nontoxic coatings for aircraft and ships.

Several approaches are being explored to find alternative coatings for ships. "Slippery surface" paints are being tested to prevent fouling. The National Aeronautics and Space Administration (NASA) has developed a fiber-like coating, "Refrosil," which is abrasion resistant and to which nothing will adhere. It is being used with limited application in the steel industry to protect equipment around molten metal operations. Duke University has attributed the barnacle-repelling capability of corals to the presence of coral diterpenes. Further characterization of the compounds is necessary before they can be incorporated into a protective coating for evaluation. NCEL is conducting basic research for the Office of Naval Research (ONR) to identify antifouling principals in sponges, gorgonians, starfish, and soft corals. Such substances, if nontoxic, may provide a good substitute for the toxic, short-lived organotins previously used in Navy ship paints.

Recycling (T2). In order to minimize the hazardous wastes generated from certain abrasive blasting operations in the Navy, abrasive materials must be recycled to the extent practical.

Physical Separation (T2) -- An initial step in the recycle of blasting grit is separation of the reusable material from the paint residue and fine particles from the broken grit. This may require implementation of physical separation techniques, such as those used at Pensacola. An extensive report on the techniques used at Hill AFB is presented by Higgings (Reference 3-1) and includes references to detailed design criteria and costs for the installation of plastic media recycling. The system, now under needed improvement, consists of a live floor for collection of the blasted plastic media, ducting, and a separation device using screening and dust collection effects. Many of these features could be applied to the recycling of other media. Other separation techniques, such as screening, heavy media separation, cyclones/centrifugation, or a combination, may be more applicable to different media types. See Section 3.17, Plastic Media Blasting.

Thermal Processing (T2) -- Another recycle technology that may be suitable for hard media, such as sand or copper and nickel slags, is currently under evaluation for possible Navy applications by the Institute of Gas Technology (IGT). This technology uses a fluidized bed calciner to burn paint organics and separate paint particles ash from the used blasting grit. Application of this technology may permit a large percentage (80 to 90 percent has been claimed) of the blasting material to be recovered for reuse (Appendix G). It is unclear whether physical separation would have been equally as efficient. Furthermore, there are indications that the calcining process reduces the useful life of the slag or sand, thereby, lowering the overall recycle rate to approximately 40 to 50 percent. Since the blast material to be calcined contains heavy metals, a scrubber system may be required to control air emissions. There are still some unanswered technical questions about the IGT process, and the operating costs have not been fully defined.

Rotary Dryer/Mechanical Siever (T2) -- One notable exception to the lack of industry efforts is a prototypic recycling system at Bethlehem Steel Sparrows Point Shipyard (Reference 3-23). The Society of Naval Architects and Marine Engineers proposed this system through the National Shipbuilding Research Program. The project was funded by the Advanced Ship Development Office of the Maritime Administration Transportation Department.

The Bethlehem pilot unit consists of a rotary dryer and a mechanical sieving system. The prototype handles 20 tph at 4 percent moisture, the typical water content of drained stockpiles. It outputs 65 percent of the coal slag grit at the particle size distribution specified for hull blasting. An 80 percent recycle of copper slag was estimated. The installed cost of the system was $240,000, while the O&M costs run to $10 per ton of usable product, including depreciation at 7 percent over an effective life span of 15 years. Copper slag grit was calculated to cost $7.51 per ton of recycled product. New material costs out at about $50 per ton at Sparrows Point, while disposal runs to about $40 per ton.

Negotiations are now underway to move the Apache system from Sparrows Point to Norfolk NSY, where it can be evaluated under NAVSEA funding on Navy hulls.

3.6.2 Treatment of Abrasive Blasting Hazardous Wastes

3.6.2.1 Characteristics. Heavy metals present in coating materials, primer coats, surface treatments, and the coated substrates can contaminate the blasting material. Of particular concern are cadmium, chromium, and lead, which can be leached out of the landfill media, as determined by the EPA Toxicity Characteristic Leaching Procedure (TCLP). Arsenic has also been identified as a contaminant in some blasting grits. Tributyl tin oxide had been used as the active ingredient in antifouling paint applied to some Naval vessels. Navy use of this material was suspended by Congress pending resolution of the question of organotin toxicity. This substance will be present in residues from the abrasive blasting of some Navy hulls for a few more years. There is also a potential for media contamination with organic solvents when these are used to soften the paint prior to blasting.

The resultant residuals from recycling abrasive blasting grits will produce wastes with the following characteristics:

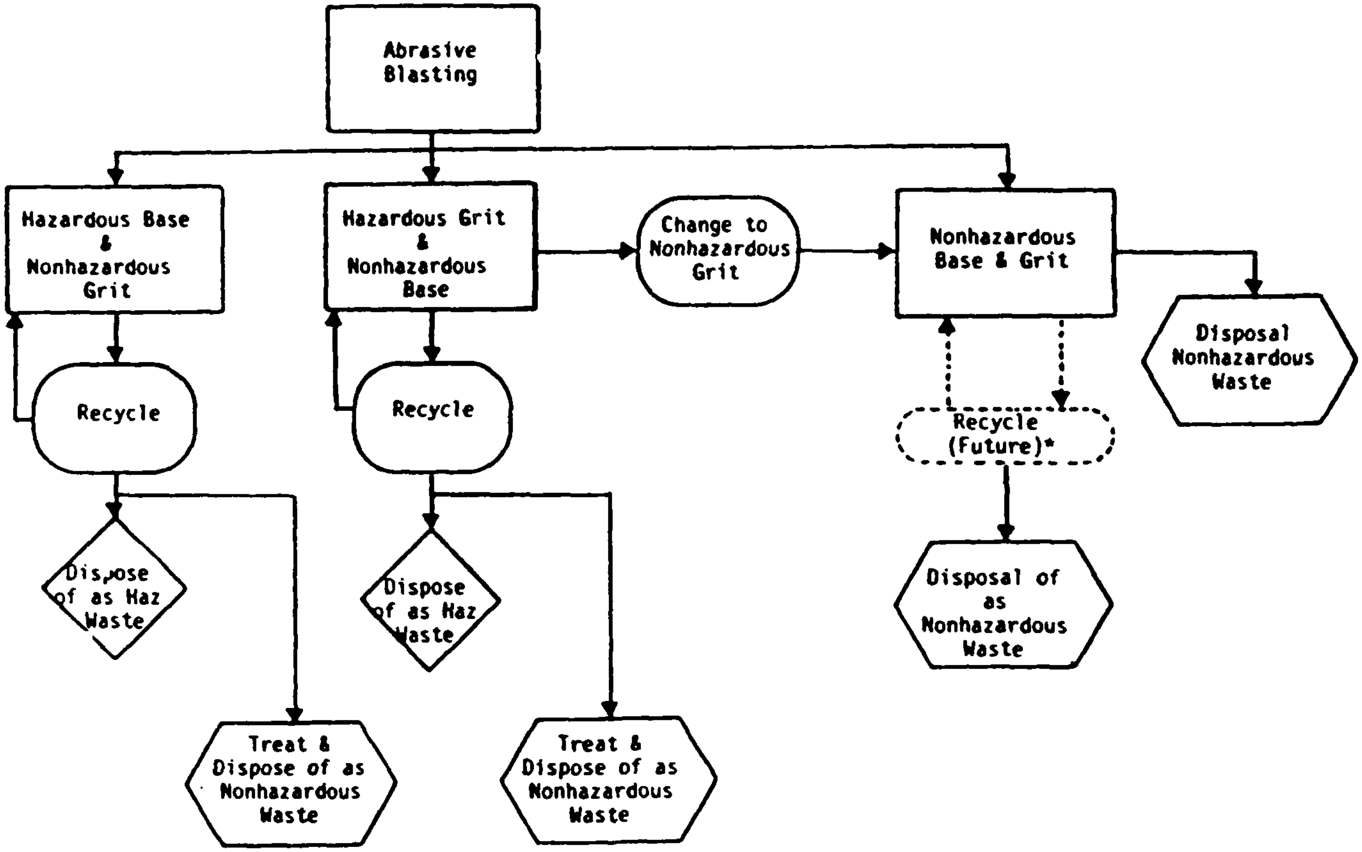
- Glass particles contaminated with heavy metals
- Plastic media particles contaminated with heavy metals
- Sand, slag, and aluminum oxides contaminated with heavy metals
- Rice hulls and walnut shells contaminated with heavy metals

3.6.2.2 Current Navy Practice (T0). As shown in Table 3-8, there is no current treatment of abrasive blasting media at most locations. Usually, this material is drummed and sent directly to a HW landfill.

3.6.2.3 General Industrial Practice (T1). Commercial shipyards were reluctant to discuss abrasive blasting and waste disposal. Therefore, the information presented here is incomplete. As with the Navy, toxic paints are used to protect the hulls of large ships and must be removed about every five years and new paint applied. The abrasive blasting material is typically sand or sand-like grit. It was reported that these materials are fully recycled with no residuals. This implies that no separation efforts are made to remove paint residuals and dusts.

3.6.2.4 Alternative Technologies (T0 to T3). Alternative technologies available for testing and evaluation on Navy abrasive blasting operations that could minimize the quantity of hazardous wastes generated by this process include 1) incorporation of the residual material into products and 2) reclamation of heavy metals. The flow diagram presented in Figure 3-5 illustrates the impact of changes and the resultant waste streams.

Solidification. At Norfolk NADEP, the spent media are solidified by a contractor prior to land disposal. Solidification and other forms of stabilization to prevent leaching are acceptable approaches to treating hazardous, metal-bearing wastes. Technologies for solidification are discussed in Appendix I of this document.



* May be desirable to lower landfill cost in the future

Figure 3-5. Treatment options for abrasive blasting media

Incorporation into Products (T2). A recent change in the California Health and Safety Code waives the hazardous waste regulations for recyclable material used as ingredients to produce commercial or industrial products. Abrasive blasting grit disposal costs the Long Beach NSY about $1,000,000 per year. NSY Long Beach has submitted a plan to Caltrans, the state transportation agency, to use Navy spent copper slag grit as aggregate in asphalt at a concentration of 2 to 10 percent. This would save the Navy about $100 per ton in disposal costs and Long Beach $800,000 per year. The program is awaiting approval. Caltrans has conducted tests with the Long Beach NSY used grit and found the product to be superior to control samples. Due to administrative considerations, however, the scheme was eventually abandoned.

The same shipyard subsequently arranged a special test program with a Portland cement company in nearby Colton, CA. The NSY has acquired a vibratory siever that will reduce the spent grit to a maximum 0.25-in. size. An initial 1000-ton lot has been agreed to by the user, who will evaluate the material as a possible substitute additive. A similar arrangement has been negotiated by the Puget Sound NSY with a nearby cement plant.

Metals Reclamation (T2). Metals reclamation may be a viable option for treatment, especially if grit recycling is implemented. Many of the hazardous metals are strategic materials and should not be indiscriminantly wasted. The mechanism for leaching metals from a residue is well known. Acid extracts the metals present. The acid is then drained from the waste and the metals removed from the acid bath via electrolytic recovery methods, or the acid is regenerated. The regeneration process leaves 1) a product with residual impurities that are frequently acceptable to the paint industry as a source of raw materials and 2) a high-quality acid suitable for reuse in a variety of different operations. If sufficient spent acid is generated by a Navy activity in its electroplating operations to warrant an on-site acid regeneration facility, it may be feasible to leach heavy metals from blasting grit. The waste remaining after acid treatment would have to be rinsed or neutralized, and this waste could be delisted.

3.6.3 Disposal of Wastes From Abrasive Blasting Operations

3.6.3.1 Solidification of Waste for Disposal (T2). The treatment technologies that could be used after recycling options include thermal and nonthermal methods. Thermal solidification of glass and plastic media is possible. These mechanisms would employ variations of the molten glass technology, described in Appendix E. Upon exposure to heat, these media will liquify. On cooling, the metal contaminants in the media will be entrapped and, thus, be fixed and nonleachable. The resultant waste will be suitable for nonhazardous disposal. Drawbacks include the possibility that the metals will volatilize at the temperatures required to melt the media. Toxic air pollutants may be produced at the temperatures required for the liquification of the plastic media by volatilization of metals. In the case of sand or slag blasting media, a nonthermal approach to disposal would be required. More common fixation/solidification processes are described in Appendix H.

3.6.3.2 Incineration (T2). This is another treatment method for the discarded fraction from pneumatic or mechanical grit recycling systems, whether the media are organic or inorganic. There are several different types of incineration processes suitable for use. These include fluidized bed, rotary kiln, plasma arc, and infrared incinerators. A brief description of each of these technologies is presented in Appendix E. Because abrasive blasting materials typically have leachable heavy metals, the residuals from incineration will contain those contaminants. Both the bottom ash and the scrubber systems may contain heavy metals, and treatment or disposal practices must consider this. In the case of organic blasting materials, incineration of the residuals significantly reduces the volume of material ultimately requiring disposal. In addition, the heavy metals present are concentrated and reclamation techniques may become viable.

3.7 PROCESS NO. 6 -- PAINTING OPERATIONS

3.7.1 Industrial Process Aspects

3.7.1.1 Current Navy Practice (TO). Painting operations occur at virtually all Navy activities. The paint coatings used by the Navy include epoxies, enamels, lacquers, dry powders, and, when permitted, paints containing antifouling agents, such as organotins. These coatings are applied to the surfaces of parts, weapons, vehicles, ships, aircraft, and structures for surface and corrosion protection, identification, camouflage, and aesthetic appeal. Wastes generated from painting operations include paint sludge (from overspray), solvents (equipment cleaning), expired "pot life" material (from epoxy applications), and expired shelf life and off-spec paint. The expired and off-spec materials are a significant proportion of wastes from painting operations. Handling of expired material is discussed in Section 3.1.

Approximately 5,770 tons of painting waste were reported by the 23 activities surveyed. The total Navywide volume generated may be much higher. The NCEL survey excluded HW items that were generated in quantities of less than 5 tons per year. Unlike many types of hazardous wastes that tend to be associated with specialized industrial processes conducted at only a limited number and certain types of Navy activities, the use of paint is a general practice throughout the Navy. Thus, paint wastes generated in relatively small quantities by the hundreds of activities excluded from the NCEL survey could well exceed the quantities produced by the 23 activities that were actually surveyed.

Types of Coatings:

Water-based Coatings. Water-based primer coatings for aircraft and other surfaces are currently in use by the Navy at the Pensacola, Jacksonville, and North Island NADEPs. There are plans at Alameda to switch to water-based primers, based upon the results obtained at the other NADEPs. The NIROP Pomona has been using water-reducible primers with good results since 1984. These coatings eliminate the need for solvents for paint thinning or cleanup. In general, water-based coatings are believed to provide a lower level of protection than do solvent-based coatings. In industrial applications, these paints are typically used on surfaces that require only moderate protection or that are decorative.

There are two primary disadvantages to the water-based paints. For proper adhesion, the surface must be completely free of oil films. This presents a significant problem if the paint is applied to components that still contain oil or other lubricating fluids. Water-based primers will work very well in selected applications, especially for components that have been thoroughly stripped. Longer drying times, and hence the potential need for drying ovens, may also be required for the water-based paints. However, drying ovens have not been necessary at either Jacksonville or Pensacola because of the relatively warm Florida climate (Reference 3-1). During the summer months, an object is ready for the top coat one-half hour after application of the water-based primer. During the winter months, drying times of up to two hours may be required.

<u>Conventional Epoxy Coatings</u>. Epoxy paints are prepared by individually premixing the component parts, then combining the ingredients in the appropriate proportions in a separate container. After mixing and waiting the specified time, application may proceed. Once mixed, the components have a limited "pot life" that cannot be exceeded without affecting the characteristics of the paint. If the application procedure is interrupted to the point where the pot life is exceeded, the mixture must be discarded and the application equipment rinsed with a solvent. In one report (Reference 3-24), it was estimated that each Naval shipyard spends approximately $90,000/yr for epoxy waste management. This includes disposal and paint and solvent replacement.

<u>Powder Coatings</u>. Often referred to as "dry powder painting," this method uses a dry powder coating that is applied to an object and fused to its surface at a temperature in excess of the melting point of the powder. Curing is thermoactivated and can take place immediately after application. With the elimination of solvents, curing time is substantially reduced when compared with the time required for conventional liquid coatings. The material to be so treated must be able to withstand typical curing temperatures of 350° F for 30 min. Aluminum alloys cannot be subjected to these conditions without significant loss of strength. Powder coating is especially appropriate when a thick coating is required, as there is no upper limit to the film thickness that can be obtained in a single application. This eliminates the need for the multiple coating applications used in conventional spray painting. Conversely, powder coating is not appropriate for very thin coatings, since it is difficult to obtain uniform thickness with this technique (Reference 3-25). Dry powder coating has been in use for 10 years at Puget Sound NSY.

<u>Technologies to Apply Coatings</u>:

<u>Liquid Spray Technology</u>:

Conventional Air Spray -- Liquid spray technology is the most commonly used procedure for applying paint coatings. The paint is mixed with a carrier, typically an organic solvent, and applied to the surface with an air pressurized sprayer. Conventional spray painting is usually done in a horizontal or downdraft paint booth or in a paint hanger, as in the case of airplane painting. Conventional liquid spray painting is typically very inefficient, with as little as 10 percent of the paint being deposited on the object, while the remaining 90 percent, the overspray, goes into the booth collection system. Waterfall spray booths are used most often to collect the overspray. The booth air is typically exhausted through a wet scrubber system (waterfall) to remove the volatiles and paint solids. This water is recycled, and the solids concentrated in the scrubber sump. This waste material is discussed in Section 3.7.2.

Airless Sprayers -- High pressure airless sprayers have been in use at the Alameda NADEP for the past 10 years for painting large aircraft. Airless sprayers have a 20 to 30 percent higher efficiency than conventional air sprayers, causing less fogging and overspray. However, the airless spray nozzles are more difficult to control. They are also less efficient for smaller applications or on irregularly shaped objects, where the spray flows must be constantly varied. Airless sprayers have also been tested at NADEP Pensacola. Improvements were observed in paint application, but excess paint collected in the convoluted surfaces. Since it was too difficult to control the flow to obtain the correct coverage, the project was abandoned. The difficulties in painting such surfaces discourages painters from using this technique. Airless spray is ideal for outside maintenance on structures such as stucco, or wood. Exact coverage, as required for military hardware, need not be that stringently conformed to.

Air-assisted Airless -- This technology is actually a blend of both airspray and airless principles. A medium pressure pump is used to provide the spray gun with between 200 and 1000 psi material pressure. This is adequate to preatomize the material hydraulically through a specially designed tip. At this point, a small amount of refining air (10 to 20 psi) is introduced to provide the final atomization. This technique allows for a high transfer efficiency, which helps reduce VOC emissions. This may soon become a significant factor in choosing methods of application. Its major drawback, however, is that it takes longer to paint by this method, which is a discouragement to painters. Pensacola and Cherry Point NADEPs use air-assisted airless for inside work on aircraft.

Dual Media Spray Equipment -- This spray equipment can be used in the application of epoxy coatings, and the components do not have to be premixed. This eliminates the potential for expired pot life materials, the associated use of additional solvents to clean the equipment, and the need for treating these materials as hazardous wastes. The dual sprayer equipment pumps the individual components from the original containers in a consistent 1:1 volume ratio. Pressure gauges monitor the flow from both parts to ensure consistency. An in-line heater reduces the viscosity of the individual components. An in-line static mixer is used to thoroughly combine the two components before application to the object. This system is currently in use at the Pearl Harbor Submarine Base (Reference 3-24). Alameda NADEP hopes to be converted over to this technique by late Spring, 1987. Pomona NIROP has been using dual media spray equipment for over two years.

Electrostatic -- Pensacola tried this technique about 10 years ago and found it difficult to spray with the large guns of that period. The polyurethane Navy paint of that time had too much MEK as a solvent carrier, which bled off the charge.

Both Cherry Point and Jacksonville also tried these systems more recently. Problems encountered included lack of flexibility with the guns and a fear of loss of grounding and its attendant safety concerns, since everything needs to be grounded. It must be established what constitutes possible safety hazards. For example, if the plane loses its ground, the slightest spark when using solvent-based paint could set the whole plane surface on fire.

The Pomona NIROP is successfully using electrostatic spray equipment with polyurethane paints and waterbased primers on Standard Missile and Phalanx. Previous reports from NADEP Pensacola had indicated that water-based paint systems handle very poorly in electrostatic fields.

Alameda, based on a recent demonstration by Graco, is converting over to electrostatic by mid-1987. They were quite pleased with the demo and are now putting together procedures for use in their aircraft paint hangers.

Electrostatic coating is subject to the Faraday cage effect, which causes a buildup of paint on part edges. The Alameda assembly will have a manual on-off switch that would enable the painter to turn the charge on or off while painting. Also, electrostatic application is questionable for rework and touchup of surfaces that have already been painted, as there may be insufficient bare metal for grounding. Furthermore, electrostatic painting around systems with electrostatic discharge (ESD)-sensitive devices is not recommended.

Dry Powder Technology:

Electrostatic Dry Powder Painting. In this technique, the aerosolized paint system is passed through an electrostatic gap that imparts a layer of electrons to the individual droplets. The target piece being coated is maintained at a D.C. voltage gradient, which attracts the paint aerosol to the target, thereby, greatly reducing overspray.

This painting technique is in use at Air Force Plant No. 44, operated by Hughes Aircraft Company--Missile Systems Group, for the interior of the fuselage section of the Phoenix missile. It is also being employed at the Puget Sound NSY for various paint shop operations, such as painting bunk bed frames. This technique is an improvement over wet spray applications because it is more effective on hard-to-reach surfaces. Wastes generated from powder coating operations consist of cleanup solvents and waste powder. Powder overspray can be collected in conventional air filter systems for reuse; thus, wastewater and paint sludge is eliminated with this technique. In commercial applications, it is common for 90 to 99 percent of the paint to deposit on the target. At Puget Sound, the powder is not recycled, due to the "job shop" nature of their operation. Higgins (Reference 3-1) reports that powder coatings cost approximately one-third the amount of conventional wet spray applications, primarily because fewer coats are needed. However, the procedure requires a higher level of operator skill.

3.7.1.2 General Industrial Practice (T1):

Technologies to Apply Coatings.

Wet Electrostatic Painting -- This technique is widely used for painting aircraft parts and other small, complex nonaluminum objects. An electrostatic charge attracts the coating (as in the dry powder coating), except that a small amount of solvent is required as a thinner. Both waste carrier and cleanup solvents are generated by this process. However, the volume of solvent used is considerably less than that in liquid spray applications. The major limitation of this technique is the potential hazard of imparting high voltage to an aircraft that may still contain fuel vapors. This technique was employed at the Hughes Aircraft Company, Missile Systems Group in Tucson, Arizona, to paint spools for the TOW missile. However, there were problems associated with the electrically nonconductive materials used in the spools, and the technique was abandoned. Conventional spray painting is now employed at this site (Reference 3-1). Navy applications were described under current practices.

Fluidized Bed Application -- The object is immersed into the powder, which is suspended in the fluidized bed vessel by an air current. The heat of the object causes the powder to "melt" and adhere to the object. The coated item is then transferred to an oven for final curing. This method is most appropriate in production line manufacturing processes and not in situations where a variety of objects are coated, such as in a NADEP facility.

Electrocoating -- This method is very similar to metallic electroplating. The object to be painted is dipped in a solution containing the ionized coating. The paint ions are deposited onto the object through the action of an electric current. This process is widely used by the automotive industry. There are three significant limitations to the application of this process:

- The part must be electrically conductive.
- The requirement for a dip tank limits the size of the object.
- Only a single coating can be applied, since the coating is nonconductive (References 3-1 and 3-24).

Electrocoating probably does not represent a viable technology change. It requires excessive modifications (the dip tank), it has limited applicability (only those items that can fit in the tank), and it does not minimize waste generation.

Conveyor Systems and Robotics -- Both of these application techniques have the potential for minimizing hazardous waste generation through more efficient painting. Both techniques are, however, best suited to mass production of vehicles and components. Most military painting activities involve working with a variety of components of different sizes and shapes, as well as with the need to apply various coatings. However, new developments in the robotics field may provide the option to program robots for multiple tasks, such as painting differently shaped objects.

The "job shop" atmosphere of the shore-based paint shop does not lend itself well to the use of robotic equipment. Other alternatives are available that are more appropriate, less costly, and involve less risk.

Technologies for Air Pollution:

Dry Filter Booths. Dry filter booths eliminate wastewaters, but the filters require treatment or disposal. The frequency of filter changes and, thus, the volume to be disposed of, depends upon the amount of painting and the type of application technology used. Filter change requirements are determined by monitoring the differential air pressure. The filters are contaminated with cured paint and would be considered hazardous only if the paint contained toxic metals. The Naval Industrial Reserve Ordnance Plant (NIROP) at Pomona is switching to dry filter booths. Treatment of the filters generated in the dry filter booths is discussed in Section 3.7.2.

Coating Elimination:

The use of protective coatings on aircraft has been essentially eliminated by two of the major commercial airlines. American and Eastern airlines no longer paint the bodies of their aircraft. While Eastern continues to paint on logos and identification marks, American Airlines has eliminated the need for paint altogether by using decals.

This is not considered an alternative, as protective coatings for military vehicles, as well as camouflage protection is vital to the overall success of the Navy's mission.

3.7.1.3 Alternative Technologies (T0 to T3):

Expired/Off-spec Paint Usage (T1). A large amount of reported waste paint is actually out-of-date material, but, typically, records are not kept for such volumes. While out-of-date or off-spec paint may not be suitable for its specified application, these materials could be used for noncritical applications, avoiding disposal. In addition, out-dated paint could be tested to determine whether specifications are still met, thus extending the life of the material. See Section 2.6 for further information.

Dual-media Sprayers (T0). These devices can be used for the application of conventional epoxy coatings. Dual media (also known as plural component) sprayers eliminate the potential for expired pot life materials, the associated use of additional solvents to clean the equipment, and the need to treat these materials as hazardous waste. Conventional sprayers are used Navywide, with the exception of Pearl Harbor Submarine Base, where plural component sprayers are used. The epoxy waste management costs are estimated at

Disposal	$12,000/yr
Paint replacement	$60,000/yr
Solvent replacement	$18,000/yr
	$90,000/yr

per activity using conventional sprayers (Reference 3-24). A dual media system costs approximately $10,000, and has a very low risk factor, since they are already in use by the Navy.

Powder Coating:

Electrostatic Dry Powder Coating (T2) -- Table 3-9 furnishes estimates of the comparative costs of powder coatings and conventional liquid spray. This estimate is based upon a facility that coats 12,000,000 sq ft of parts with a 1-mil polyester coating.

Puget Sound NSY has used dry powder painting for 10 years. As a result of their experience, NAVSEA is publishing manuals for application instructions, equipment selection, and process applicability for use throughout the Navy shore establishment. Puget Sound personnel have determined that a coating thickness of 2.5 mils can be applied with powder coating at a materials cost of $0.02/sq ft, while conventional coatings cost $0.13/sq ft.

Table 3-9. Cost Comparison of Solvent and Powder Painting

	Cost, $	
Item	Conventional	Dry Powder
Material	333,600	242,400
Labor, cleanup	132,100	75,600
Maintenance	18,000	10,000
Energy	29,100	15,700
Hazardous waste disposal	10,800	1,100
TOTAL ANNUAL COST	$523,600	$344,800
COST PER SQ FT	$0.044	$0.029

This represents an 85 percent materials savings. As a result of eliminating the paint sludge, the Navy can realize significant savings. In FY84, 333,680 gal were reported by the 23 surveyed activities. Disposal costs for this material were estimated at $371,415.

Most shore-based paint shops can implement electrostatic dry powder painting for an estimated $3,000/gun. The experience at Puget Sound provides a low risk factor, along with the availability of adequate documentation, process performance ratings, and training and maintenance requirements. This equipment is described as field serviceable, indicating that subcomponents can be replaced in the field with minimal down time.

An entire power cartridge can be replaced for $750, while the turbine can be replaced for $100 to 250, depending upon whether new or rebuilt components are used. These guns have been documented to exhibit 3,000 hr of use without requiring service (excluding regular cleaning). No auxiliary equipment is required, assuming curing ovens are available, which is typically the case.

Plasma Spraying (T2) -- This powder coating technique is still in the developmental stages. It is currently undergoing test and evaluation at Puget Sound NSY. It employs an extremely high temperature gas stream (5,000 to 15,000°F) to melt and carry the paint particles to the object. Although the gas stream temperature is very high, the temperature of the object does not exceed 185°F, and no additional curing is required. This technique makes powder coating a possible alternative for aluminum alloys, which are common materials in aircraft parts. This process is under evaluation at Puget Sound NSY to determine Navy applicability. Principal concern there focuses on safety considerations. Aluminum powder overspray, for example, reacts with water (in spray booth water walls) to generate hydrogen, which must be continuously vented.

Wet Coatings:

Wet Electrostatic Painting (T2) -- Wet electrostatic painting can be implemented at most shore-based paint shops at an approximate cost of $2,000/spray gun. The only requirement is that the material to be coated must be electrically conductive. Although this application technology was not identified through this survey, it is believed to be in use at some MARCORP installations. It is also in use by the Army Tank Plant in Lima, OH (a GOCO). Some level of T&E would be required to implement this technology, but verification of its actual use in the Navy establishment should significantly enhance the implementation of this option. The risk factor should be fairly low, given the extensive use of this system in industrial applications similar to those in the Navy. This technology can reduce paint sludge generation by 75 percent, due to the increased application efficiency.

Air Pollution Control:

Dry Filter Booths (T1) -- Dry filter booths can be installed in most paint shops for approximately $2,000 per booth. They are in use by the Navy at NIROP Pomona, CA, and are in limited use at other Navy activities. The use of dry filter booths will totally eliminate the generation of paint sludge. Maintenance of the booth involves changing the filters. Filter change out is determined by monitoring the differential pressure, and manometers are provided on the booth for this purpose. The filters are inexpensive, generally less than $1.00 each. The use of a dry filter system is most appropriate when used in conjunction with a wet electrostatic or dry powder application system. The higher efficiency of these application systems results in less frequent filter changes.

3.7.2 Treatment of Hazardous Waste From Painting Operations

Part I - Wastewaters

3.7.2.1 Characteristics of Painting Wastewaters. Water contaminated with solvents and paint solids is generated from the water-walled spray paint booths. Paint overspray is collected by a recirculating water curtain. This wastewater is considered hazardous due to metals and solvents. The paint aerosol coagulates and separates from the water phase so the wastewater contains moderate amounts of solvent, paint solids, and (depending upon the type of paint used) heavy metals. Samples taken at Puget Sound NSY showed levels of 1775 ppm methylene chloride and 160 ppm of Freon 113. Because these VOCs cannot be treated at the Puget Sound Naval Shipyard IWTP, wastewater from the spray booths is outhauled by a contractor for treatment.

3.7.2.2 Current Navy Practice (TO). Wastewaters are typically treated at Navy IWTPs. Paint solids that drop out of the wastewater in sumps and channels within the painting structure (sludge) are generally collected every six months and drummed for removal by a hazardous waste disposal contractor. IWTPs generally provide various forms of chemical treatment that include chrome reduction, cyanide oxidation, neutralization, metals precipitation with flocculants, and wastewater clarification. This will remove (with varying efficiency) heavy metals and residual paint particles. Organics, however, may not be removed. IWTPs may need to be modified to treat for TTOs. This is discussed in Section 3.19.

3.7.2.3 General Industrial Practice (T1). Industrial practice in handling wastewaters from water-wall painting structures is essentially the same as Navy practice.

3.7.2.4 Alternative Technologies (T0 to T3). The present IWTP practices, discussed in Section 3.2, are considered satisfactory, provided that electroplating waste treatment occurs (Section 3.3.2) and TTOs are managed, as discussed in Section 3.19.

Part II - Waste Solvents

3.7.2.5 Characteristics of Waste Solvents. The Navy uses hydrocarbons, halocarbons, and oxycarbons (alcohols, ketones, and esters). Waste solvents or thinners are generated primarily through the cleaning of paint equipment. The type of solvent used varies with the coating (paint) and sometimes with the surface to be painted. The most common solvents are methylethyl ketone (MEK), xylene, toluene, and mineral spirits. These are listed as RCRA hazardous wastes because of their flammability and/or toxicity.

Generally, oxygenated hydrocarbon solvents, such as MEK, are used for epoxy and polyvinylchloride (PVC) coatings; aromatics, such as toluene and xylene, for chlorinated rubber, phenolic, and vinyl alkyd coatings; and mineral spirits, for alkyd and other oil-based coatings. Thinner formulations rarely consist of a single chemical or petroleum distillate cut. They are usually carefully formulated mixtures designed to provide a specific thickness, coverage, and drying time.

Wastes generated from powder-coating operations consist only of cleanup solvents. There is no other waste or expired paint for disposal. Powder overspray is collected in conventional dry air filter systems and can be reused. In commercial application, 90 to 99 percent utilization is common.

Cleanup solvents from the wet electrostatic painting technique are essentially the same as those from conventional painting. However, the volume used is significantly lower than that in conventional liquid spray technology. The waste characteristics depend upon the specific solvent used but, in general, would contain toxic organics and possibly toxic metals.

The NCEL survey identified the disposal of 530 tpy of all types of waste solvents used in the cleaning and degreasing operations. However, certain unaccounted amounts of solvents from routine operations also enter the wastewater stream. These present a total toxic organics (TTO) problem, a subject discussed in Section 3.19.

Some contaminated solvents are recovered in stills with up to 80 percent solvent yield. The remaining 20 percent of the material, the still bottoms, is periodically removed from the still and disposed of without further treatment.

3.7.2.6 Current Navy Practice (TO). Typically, used solvents and paint are mixed and disposed of through DRMO or by contract. Currently, high prices are being paid by DRMO for disposal of waste solvents. For example, DRMO San Diego contracts out to pay $35 per 55-gal drum. Many activities are implementing solvent recovery programs through the Used Solvent Elimination (USE) Program.

The DOD has developed the USE program to reduce the risks and costs associated with disposal of used organic solvents. Activities specifically identify techniques to minimize the quantity of waste solvents generated and disposed.

Since used oil recycling is strongly encouraged by OPNAVINST 5090.1, and the EPA may classify oil as a hazardous waste, many activity USE programs include used oil recycling.

There are four recycling options stressed in the USE program: 1) on-site/off-site reclamation of solvents, 2) closed-loop recycling of high-cost hydraulics and lubricants, 3) burning of appropriately segregated used oil and solvents (UO&S) in Navy boilers, or 4) sale of UO&S through DRMO.

On-site Recycling. This is a process technology, referenced in Section 3.14, but also described here. Often this is the preferred USE program option, as it is usually the most cost-effective. Used solvents are distilled in batch or continuous stills that range in size from 14 gph to over 200 gph. Some stills are explosion proof and have optional features for easy operation and maintenance. NSY Norfolk Paint Shop is successfully recycling its solvents.

Off-site Recycling. If on-site recycling is not cost-effective or is too difficult to implement, off-site recycling by contractors is a viable alternative. Costs for this process vary with costs of virgin materials, volumes, handling and transportation, and ease of recycling. Reclaimed solvents generally cost from 20 to 30 percent less than virgin material.

Some companies lease solvents and replace them when they become too dirty. This operation is attractive to smaller Navy facilities because the supplier assumes all responsibility (although not ultimate liability, should the supplier file for bankruptcy) for the solvent, including ultimate disposal. The Construction Equipment Department at Naval Construction Battalion Center (CBC), Port Hueneme, is using off-site recycling with good results.

Closed-loop Recycling. This is an option to consider when an activity generates large volumes of contaminated high-cost hydraulics and lubricants and is near a reclaimer or manufacturer. The reclaimer or manufacturer contracts with the activity to 1) reclaim the used petroleum products and return them directly to the activity or 2) accept the contaminated petroleum products and give the activity credits on its purchase of virgin materials. This option is not likely to be cost-effective for lubricants that contain complex additives or require costly requalification testing.

Cofiring. Some Navy activities burn appropriately segregated UO&S in Navy boilers. CBC Port Hueneme has burned contaminated oil at 5 percent blend with fuel oil #5 without any boiler modifications. The only Navy-generated waste solvent thus far recommended for blending with fuel oils is PD-690 Type II. Only high-flash point paint thinners should be mixed with oils for cofiring. Halogenated solvents must be kept segregated and not mixed with the intended boiler fuel.

DRMO. UO&S transfer through DRMO may involve disposal, resale, or donation. However, if used oils or solvents are donated to another agency, the activity normally receives no credit. Therefore, the above three options are usually preferred.

3.7.2.7 General Industrial Practice (T1). Industry commonly segregates waste solvents and recycles them on or off site or disposes of them by incineration, such as in a cement kiln, as a fuel supplement. Some industries distill solvents as the Navy does. Often, this is by contract with a commercial solvent reclaimer.

Solvent reclaimers may rent solvents to industry, collect used solvents and replace them with virgin or recovered solvents, as needed by the user. This eliminates the need for on-site distillation and the associated capital costs and manpower requirements. To protect against liabilities, the user should carefully check out the solvent reclaimer. This is necessary because the user's liability does not end with the removal of the material from the user's site.

3.7.2.8 Alternative Technologies. Recycling by distillation for reuse and utilization as hazardous waste fuel are TO technologies now being implemented by the Navy. Other alternatives minimize the amount of waste solvent produced with painting methods that require little or no solvents, as discussed in the preceding portions of this Section 3.7.

Part III - Dry Paint Filters

3.7.2.9 Characteristics of Dry Paint Filters. If the wet spray booths are converted to a dry system, the wastewater and paint sludge will be eliminated, but the filters will require treatment or disposal. The frequency of filter changes and, thus, the waste volume, depend upon the amount of painting. Filter change requirements are determined by monitoring the differential pressure. If these filters are contaminated with dried paint that does not contain toxic metals, they may not be hazardous waste. If the paints do contain toxic metals, the filters could be hazardous. In that case, the filters should be tested for leachability, using the TCLP, the newly introduced method that replaces the older EP test. With the introduction of the TCLP method, 38 compounds were added to the previous list of 14 toxic chemicals.

3.7.2.10 Current Navy Practice. The waste filters are considered equivalent to painted hardware and may currently go to ultimate disposal untreated.

3.7.2.11 General Industrial Practice. The waste is untreated and is disposed of via landfill or incineration.

3.7.2.12 Alternative Technologies. There are no applicable treatment alternatives.

Part IV - Paint Sludge

3.7.2.13 Characteristics of Paint Sludge. Paint sludge is collected in water wall booths as a soft, gelatinous mass of agglomerated aerosol. As paint settles, a cohesive gel is formed. This gel has sufficient mechanical strength to withstand the supernatant flow of discharging water. With time, the sludge tends to harden.

3.7.2.14 Current Navy Practice (T0). Paint sludge from recirculating waterfall booths collects in sumps and drains. It is removed periodically and is containerized for disposal.

3.7.2.15 General Industrial Practice (T1). Waterfall spray booths are essentially the same in industry as in the Navy; sludge is handled much the same way as is done in the Navy.

3.7.2.16 Alternative Technologies (T0 to T3). Reduction of paint sludge production can be achieved only by minimizing overspray or by using dry-filter techniques for collecting overspray.

3.7.3 Disposal of Wastes From Painting Operations

Wastewaters from painting operations go to the IWTP for treatment. The finely dispersed solid portion becomes bound up in the IWTP sludge. Waste solvents from painting operations are recycled. Still bottoms and solvent sludges should be incinerated and the resulting ash sent for land disposal. Dry paint filters should be incinerated and the ash disposed of by landfill. Paint sludges from drainage channels and sumps should be incinerated and the ash from that incineration disposed of by land.

3.8 PROCESS NO. 7 -- MUNITIONS DEMILITARIZATION OPERATIONS

3.8.1 Industrial Process Aspects

3.8.1.1 Current Navy Practice (T0). After being stored for long periods of time, ordnance explosives and propellants deteriorate. Depending upon the high energy chemical system involved, this aging process can involve polymerization, depolymerization, phase separation, or crystallization of the chemical constituents of the explosives and propellants. Such aging consistently results in a significant loss of stability of the ordnance, which can then become dangerous to store and handle. It is, therefore, a routine procedure to survey expired shelf life munitions by destroying them or, when the munition is worth recycling, to melt out the explosive and repack the carrier (casing) with fresh high energy packing.

The procedures for demilitarization (DEMIL) of ordnance hardware varies somewhat from item to item, as does the configuration range of ordnance items handled by the Navy. DEMIL ordnance material ranges from small arms ammunition up to 16-inch Navy shells.

Incineration. Generally, small arms ammunition and other small ordnance items, such as fuses, blasting caps, and actuators are sent directly to DEMIL furnaces. Here, the items are loosely confined and detonate with low brisance. The Navy operates DEMIL furnaces at Earle, Charleston, Seal Beach, and Subic Bay for this purpose. The DEMIL furnaces at NWSC Crane, however, are under Army management, since the munitions manufacturing operation there is an Army-managed operation.

DEMIL furnaces are currently being tested for processing ordnance items up to about 20 mm caliber. Open burning, however, continues to be the usual method of destroying larger caliber ordnance and explosive wastes too bulky or dangerous to put through DEMIL incinerators. As pointed out in Section 3.4.3, OB/OD pits may come under tighter APC regulation, wherein containment devices may have to be provided to ensure effective collection and control of air pollutants released during such operations.

Larger ordnance items are also disassembled and the casings and other reusable and nonobsolete hardware sent for inspection for possible reuse in the load, assemble, and pack (LAP) operations. If the explosives and propellant can be removed in bulk dry form, the material is offered for resale through DRMO. If it is not sold, but is reblendable, it is introduced into new munitions mixtures. The explosive and propellant charges that are removed from ordnance shapes and cannot be sold or reblended are burned in the OB/OD pits or in existing DEMIL furnaces. Such combustors are presently permitted to burn only materials classified as nonhazardous. Permit applications have been submitted for the incinerators at Charleston to allow their use as hazardous waste incinerators, thereby, permitting combustion of Class I and Class II munition materials.

Steamout. The demilitarization of outdated or otherwise suspect ordnance items involves removal of explosive materials, either through high pressure, hot water washout or steamout. The use of either steam or hot water in these operations generates a wastewater stream high in dissolved organics. However, when these wastewaters are allowed to come to equilibrium at atmospheric temperatures and pressure, the nitrated organic materials precipitate out until the waters are at the saturation point. Explosives and propellant ordnances from DEMIL steamout operations are often sent for reblending. Cleaned casings are either disposed of as nonhazardous waste or, if reusable, can be sent to the LAP operations for reuse. Demilitarization disposal operations take place at NWSC Crane and NWS Yorktown. A new facility is going in at Keyport but is not yet generating such wastes.

Open-pit Burning. In the past, it was common practice to incinerate demilitarization waste by burning in the open at the ammunition burning ground (ABG). This practice will be severely restricted under RCRA, and most wastes will be required to be burned in permitted incincerators. Recently, the Army successfully completed RCRA test burns for their explosive waste incinerator at Picayune Army Ammunition Plant (AAP). Thus, it is apparent that most demil burning can (and, therefore, must) be performed in permitted hazardous waste incinerators. A large amount of ash has been stockpiled from past demilitarization combustion taking place at ABG. Ash pile removal and cleanout at such facilities are underway, and the disposal of such open-burning pit ash will no longer be a standing hazardous waste problem for the Navy. In the future, it is expected that the only items going for disposal by open-pit burning will be those too dangerous to combust in an enclosed incinerator and that cannot be cleaned out for reloading.

3.8.1.2 General Industrial Practice (T1). Discussions with representatives of sporting ammunition manufacturers indicate that aging munitions are not a problem because of the common practice of "clearance sale" stock reduction at wholesale and retail levels well before shelf life limits are approached. Off-spec material is recycled in a manner analogous to the military's.

3.8.1.3 Alternative Technologies (T0 to T3). Evaluation of alternative technologies for ordnance processing was set outside the scope of the present IDR by the sponsor.

3.8.2 Treatment of Wastes from Demilitarization Operations

Part I - Waste Explosives and Propellants

3.8.2.1 Characteristics of Waste Explosives and Propellants. This stream is composed of specific explosive and propellant materials removed from obsolete or other ordnance items, as well as manufacturing and processing wastes. The ingredients of common ordnance formulations are shown in Table 3-10.

3.8.2.2 Current Navy Practice (T0). If the explosive or propellant formulations can be removed in dry, bulk form, the material is sold through DRMO. If the explosive material does not appear to be suitable for sale to DRMO, or if it is not sold in a reasonable length of time, the material (if recoverable) is used as a reblend item in the formulation of new explosive propellants. When the removed materials cannot be recycled or reused in any way, the materials are burned in a permitted incinerator or at the OB/OD pit. The ash from incineration is, by definition, a hazardous waste, unless proved by testing to be nonhazardous. This ash waste is discussed in Part II of this Section.

3.8.2.3 General Industrial Practice (T1). Commercial small-arms ammunition is generally recycled with procedures similar to those used by the military. Incineration is not commonly used.

3.8.2.4 Alternative Technologies (T1 to T3). Chemical decomposition of explosive materials is technically feasible. For example, TNT is decomposed by adding it slowly to a sodium sulfite solution under constant agitation. The reaction products, however, are hazardous and should be burned in an incinerator equipped with an acid gas scrubber. Such chemical decomposition techniques are suitable only for small quantities of ordnance chemicals. Furthermore, plastic bonded materials are resistant to such chemical destruction techniques.

Part II - DEMIL Pit and Incinerator Ash

3.8.2.5 Characteristics of DEMIL Pit and Incinerator Ash. Ash is generated in the controlled incineration demilitarization processes and in open burning of military ordnance items in OB/OD pits. Combustion processes can be controlled so that such ash is relatively free of organic contaminants. Further treatment of these materials prior to disposal is not now commonly practiced. However, should this ash fail the required EPA leaching tests, it may be necessary for it to be treated by fixation or solidification processes prior to ultimate disposal. This ash may contain toxic metals derived from shell casings or

Table 3-10. Principal Ingredients of Explosive and Propellant Formulations

Material	Principal Ingredients
Explosives	
Amatol	TNT, NH_4NO_3
Composition A1-A6	RDX, wax
Composition B	TNT, RDX, wax
HBX	RDX, Al pwdr, $CaCl_2$, wax
Minol	TNT, NH_4NO_3, Al pwdr
Octol	HMX, TNT
PBX	RDX or HMX, polymeric binder
Tritonal	TNT, Al pwdr
Propellants	
Smokeless powder	NG, nitrocellulose
Single base	DNT, nitrocellulose
Double Base	NG and nitrocellulose
Crosslinked/dbl base	Nitrocellulose, NG, HMX, Al pwdr, NH_4ClO_4 and polymeric binder
Triple base	Nitrocellulose, Nitroguanidine, NG
Composite	NH_4ClO_4, Al pwdr, polymeric binder
Base grain casting powder	Nitrocellulose, Al pwdr, HMX, NH_4ClO_4

(Source - Reference 3-26)

from constituents of various ordnance formulations, such as those found in colored smokes. Various types of furnace ash are finding their way into useful products, such as concrete and asphalt paving. Fixation and solidification are discussed in Appendix I of this document. Casings and other large pieces of recoverable metals can be separated and sent to DRMO for recovery as scrap metal.

3.8.2.6 Current Navy Practice (T0). This ash goes directly to ultimate disposal (landfill) with no further treatment.

3.8.2.7 General Industrial Practice (T1). This ash goes directly to ultimate disposal (landfill) with no further treatment.

3.8.2.8 Alternative Technologies (T1 to T3). No superior alternatives are apparent.

3.8.3 Disposal of Wastes From Demilitarization Operations

Explosives and propellants that are not recoverable and reusable should be demilitarized by controlled incineration in a DEMIL furnace or at an OB/OD pit. Ash from such firing operations should be tested to determine whether it is a hazardous waste and be treated and/or disposed of accordingly. Similarly, existing stockpiles of ash from prior open burning of demilitarization wastes should be leach tested to determine if it is hazardous waste and be treated and/or disposed of accordingly.

3.9 PROCESS NO. 8 -- PIPING FLUSHING AND CLEANING

3.9.1 Industrial Process Aspects

The procedures used for cleaning/flushing piping depend upon the materials of which the piping is constructed, the fluid to be carried in the piping, and the ultimate disposition of the fluid. For example, firefighting water systems require a different cleaning procedure and sanitary guidelines than aircraft oxygen lines.

3.9.1.1 Current Navy Practice (T0). In general, a piping cleaning process as practiced at Navy activities has five steps: precleaning, cleaning, rinsing or purging, inspecting, and drying (Reference 3-1). Precleaning can consist of degreasing with a liquid or gaseous solvent, flushing the piping with an acid cleaner, or simply flushing the piping with compressed air. The cleaning step consists of flushing the piping or dip-soaking segments of piping in the appropriate cleaning fluids. These can be solvents (e.g., chlorofluorocarbons (CFCs)), solutions (e.g., trisodium phosphate (TSP)), or chelating acids (e.g., citric or sulfamic). In some cases, cleaning can be augmented by mechanical or ultrasonic scouring.

The rinse step can be performed with tap water, distilled water, or CFCs (for the removal of organic solvents). Depending upon the intended use of the piping, the inspection step can be a simple visual inspection, a check for a water break, or a wipe test, with subsequent testing for nonvolatile residues or condensable hydrocarbons. If the material passes the initial inspection step, it is dried by heating or by blowout using dry, filtered air or nitrogen. In situations demanding extreme cleanliness, the drying step can be performed in a vacuum oven.

Depending upon the service of the fluid to be delivered through the cleaned piping, laboratory testing may be specified for the fluid. Breathing gas for deep sea submergence rescue vessels, for example, must be exhaustively tested and certified before dives are permitted.

3.9.1.2 General Industrial Practice (T1). Industrial practice is essentially the same as the current Navy practice for piping cleaning and flushing.

3.9.1.3 Alternative Technologies (T0 t T3). Piping cleaning and flushing procedures in use in the Navy have been established to deal with the specific purposes for which the pipes are used on board ships and aircraft. Such procedures are generally quite acceptable. One process, however, that can be considered for revision is CFC (or any volatile solvent) piping flushing. After use 10 times, recovery of these expensive materials is inefficient. Even with vapor recovery or distillation, the recovered products will not meet the specification. A possible solution to this is the use of supercritical fluid cleaning of piping amenable to the high pressures discussed below.

Supercritical Piping Cleaning (T2). The solvent properties of many fluids improve dramatically in the supercritical state. Furthermore, separation of solvent and solute is simplified by merely bringing the pressure or temperature below those of the critical point of the solvent, whereupon, the solute comes out of solution. The National Bureau of Standards (NBS), in a study for NCEL, has reported on potential solvents for supercritical pipe cleaning. Such systems all require high pressures (30 to 220 atm) to achieve the supercritical state. This cleaning approach would work only for piping systems containing components that will tolerate the elevated pressures. The NBS report covering the potential of supercritical fluid processes for piping cleaning and for the destruction of (e.g., wet air oxidation) HWs is included here as Appendix H.

3.9.2 Treatment of Hazardous Wastes from the Cleaning of Piping

Part I - Waste Chlorofluorocarbons (CFCs)

3.9.2.1 Characteristics of Waste CFCs. This waste consists of contaminated Freon 113 used in precleaning and cleaning operations for the removal of oils and organic solvents from inside various types of process and shipboard piping.

3.9.2.2 Current Navy Practice (T0). The current Navy practice is to redistill the Freon 113 and recyle it for continued use in pipe cleaning or to use it in other cleaning operations that do not require as high a level of solvent purity. In some cases, however, recovery of the more volatile CFCs in shipboard operations is difficult because of the lack of transfer compressors. There have been instances where the material has been blown off to the atmosphere and reported to the Air Pollution Control District (APCD) as accidental releases.

3.9.2.3 General Industrial Practice (T1). General industrial practice is to recycle the CFCs, as does the Navy.

3.9.2.4 Alternative Technologies (T1 to T3). Investigations (T3) should be conducted to determine the feasibility of using supercritical fluids that are environmentally acceptable (e.g., CO_2) to clean adequately pressure-rated piping. Alternatively, nonhalocarbon substitutes for CFCs should be identified and evaluated. The use of CFCs should also be limited in use to only critical needs.

Part II - Alkaline Wastes from the Cleaning of Piping

3.9.2.5 Characteristics of Alkaline Wastes. Alkaline cleaning solution used in pipe cleaning operations consists of solutions of trisodium phosphate (TSP) and water. When used in the cleaning of piping, TSP accumulates heavy metals, greases and oils, exfoliated coating material, etc.

3.9.2.6 Current Navy Practice (T0). At most Navy activities, this material is collected in tanks and sent to the IWTP where it is neutralized and any dissolved solids allowed to settle. Exceptions in this are the Long Beach, Puget Sound, and Charleston NSYs, all of which send out both alkaline and acid wastes. Charleston NSY disposes of its alkaline waste through DRMO at a cost of $3.80/gal. Long Beach NSY had previously contract hauled this waste but currently has an arrangement with PWC San Diego to treat the material at the latter activity. Haul costs are about equivalent to the treatment costs. Puget Sound NSY contract disposes of its TSP wastes at a cost of about $3.75/gal.

3.9.2.7 General Industrial Practice (T1). Industrial treatment for TSP wastes is identical to treatment methodologies used in the Navy.

3.9.2.8 Alternative Technologies (T1 to T3). No superior alternative treatment approach is recommended. Activities that do not have the IWTP capability of treating alkaline wastes should modify their plants so that they will have this ability.

Part III - Waste Acids from Cleaning Piping

3.9.2.9 Characteristics of Acidic Wastes. Waste acids used in pipe cleaning operations include phosphoric acid, erythorbic acid, citric acid, sulfuric acid, and sulfamic acid.

3.9.2.10 Current Navy Practice (T0). All of these acids are sent to the IWTP for neutralization and metal precipitation. The exceptions are noted above. Also see Sections 3.11 and 3.13 for related information on this topic.

3.9.2.11 General Industrial Practice (T1). Industrial practice is essentially the same as current Navy practice.

3.9.2.12 Alternative Technologies (T0 to T3). No alternative waste management method is recommended at this time. Again, those NSYs that are not using conventional IWTP practice for the treatment of waste acid should do so.

3.9.3 Disposal of Wastes From Pipe Cleaning Operations

No wastes requiring ultimate disposal are directly produced from pipe cleaning operations.

3.10 PROCESS NO. 9 -- BOILER LAY-UP

3.10.1 Industrial Process Aspects

3.10.1.1 Current Navy Practice (T0). For short (one month or less) lay-ups, dockside steam is introduced, usually at the drum, and passed through the ship's boiler to prevent corrosion. A problem with this process is that impurities in the dockside steam can cause boiler damage. However, standards (NAVSEA Naval Ship Technical Manual 0901 LP, Section 220/22.13) have been developed for dockside steam that, if conformed to, should eliminate this problem. In steam lay-ups, the boiler is fed enough dockside steam to maintain an elevated temperature and, thereby, avoid excessive condensation and development of negative pressure (air intake) within the tube circuitry. Elevated boiler temperature also allows for better ship readiness. An average-sized marine boiler would then require a steam input of only about 100,000 Btu/hr to maintain isothermal lay-up. Typical dockside steam costs are about $\$15/10^6$ Btu, which means daily lay-up costs are only about $36.

NSYs use a wet lay-up process for shipboard boilers. A dilute sodium nitrite solution is pumped into the drained, laid up boiler as a short-term lay-up measure to prevent steam-side corrosion. On light-off, the boiler is drained and the steam circuitry rinsed with some feedwater, which is drained and combined with the lay-up water. During 1984, an estimated 2975 tons of wastewater generated from this process were either trucked to IWTPs, discharged to STPs, or contract hauled to special contractor treatment plants for a total cost of $236,800. Chemical costs for the process were an additional $14,000. The shipyards had previously used hydrazine/morpholine solutions but were directed by NAVSEA to switch to sodium nitrite because of the health hazards associated with the amine chemicals (Reference 3-16). Other Naval activities also generate some sodium nitrite. San Diego PWC, for example, received 12,000 gal of the solution in 1984 from Navy ships.

3.10.1.2 General Industrial Practice (T1). ASME Boiler and Pressure Vessel Code (1983) Section VII-- "Recommended Rules for Care of Power Boilers," specifically addresses the laying up of boilers (C7.300). Several boiler lay-up processes are described as best engineering practice.

When a boiler is taken out of service, it is cooled until the feedwater is below 180° F, emptied, and flushed. An inspection determines needed repair work and mechanical and chemical cleaning. A decision is then made whether to use dry or wet lay-up. Since freshly cleaned metal surfaces are much more vulnerable to corrosion during lay-up than surfaces that have operational oxides on them, it is much preferred to delay chemical cleaning until the boiler is ready to be returned to service.

Dry Lay-up. This approach may be preferable for boilers out of service for extended periods of time or in locations where freezing temperatures may be expected during standby. For boilers that will be out of service for very long periods of time, the steam circuitry can be drained and thoroughly dried. Moisture-absorbing material, such as quicklime, is placed on trays and installed inside the drums to absorb moisture from the air. The manholes are then closed and all connections on the boiler tightly closed. Alternatively, for normal lay-up periods, dried air may be circulated through the boiler.

In electrical utility practice, it is commonplace with large boilers to use nitrogen as the inert filler fluid. As discussed in the next section, nitrogen may be used as a "cap," leaving the feedwater in the boiler. Rather than maintain the water in the boiler at the normal operating level with a nitrogen cap, it is sometimes preferred to drain the boiler completely, applying nitrogen continuously during the draining operation and maintaining a pressure of nitrogen greater than atmospheric throughout the draining and subsequent lay-up. The use of nitrogen alone completely eliminates the generation of any hazardous waste from the boiler lay-up process.

Wet Lay-up. A wet procedure may be used for a boiler to be placed in standby condition. Wet lay-up is particularly useful if the standby boiler may be required for service at short notice or if it is impractical to employ a dry lay-up procedure. There are several alternative procedures. The empty boiler is closed, filled to the top with water, and conditioned chemically to minimize corrosion during standby. For a short lay-up period, condensate or feedwater containing approximately 200 ppm of sodium sulfite may be used. It is not clear why the ASME prefers sulfite over nitrite. The latter is cheaper, exhibits about the same toxicity (LD_{50}=175mg/kg vs 180mg/kg for sulfite), and is equally effective as an oxygen scavenger.

As an alternative, the boiler may be laid up with the feedwater at the normal operating level in the drum. The head gas is then purged out with nitrogen, which is then maintained above atmospheric pressure in all vapor spaces.

Rather than maintain the water in the boiler at the normal operating level with a nitrogen cap, it is sometimes preferred to drain the boiler completely, applying nitrogen continuously during the draining operation and maintaining a pressure of nitrogen greater than atmospheric throughout the draining and subsequent lay-up. The use of nitrogen alone completely eliminates the generation of any hazardous waste from the boiler lay-up process.

3.10.1.3 Alternative Technologies (T0 to T3)

Lay-up Solution Reuse. An obvious, although not necessarily practicable, way of reducing boiler lay-up wastes is to store the solution and reuse it. Chemical purity is not critical as long as the ReDox strength of the solution is maintained by sweetening the solution before each recycle. It would be safe to assume that the same liquid could be used over at least 10 times with only minor salt ($NaNO_3$) buildup. Treatment would then be approached as with a single cycle solution, since the only significant compositional change would be in the nitrate content, an environmentally innocuous substance. Waste reduction of at least 90 percent could, thus, be realized.

Long-term Steam Lay-up. The principal reason that steam lay-up is not used for periods of time longer than one month is that impurities in dockside steam (e.g., silica) cause boiler steam wall wastage. Standards have been promulgated that require the use of dockside steam of a purity that will not produce steam side damage. This would suggest that steam lay-up could be used for much longer periods of time without deleterious effects. This possibility has not, as far as is known, been investigated. It would, therefore, be worthwhile to conduct steam lay-ups over extended periods of time to study the effects on internal surfaces.

3.10.2 Treatment of Hazardous Wastes From Boiler Lay-up Operations

Sodium nitrite wastes are discussed in Section 3.11.

3.10.3 Disposal of Wastes From Boiler Lay-up Operations

No wastes requiring ultimate disposal are directly produced from boiler lay-up operations.

3.11 PROCESS NO. 10 -- BOILER CLEANING

3.11.1 Industrial Process Aspects

3.11.1.1 Current Navy Practice (T0). Four major operations for boiler cleaning on Navy ships are practiced at NSYs. These include waste from cleaning nuclear-powered ship and submarine steam generators (NOS), sodium nitrite hydroblasting of boiler tubes, hydrochloric acid cleaning, and trisodium phosphate cleaning. An IDR completed by NCEL on "Volume Reduction of Major Hazardous Wastes at Naval Shipyards" (Reference 3-16) covered the first three boiler-cleaning operations and evaluated alternative volume reduction techniques. The first waste mentioned is designated as NOS because of the classified nature of the system involved. This precludes any characterization of the waste being made herein.

Cleaning of Nuclear-powered Ship and Submarine Steam Generators. The cleaning of steam generators on nuclear-powered ships and submarines results in the generation of NOS hazardous waste. For 1984, 1,555 tons were generated. These wastes are treated on-site at half the activities doing this work, while the others ship these wastes to off-site treatment and disposal facilities. The costs for on- and off-site treatment and disposal totaled $326,000 in 1984. Details of this cleaning operation and specific waste characteristics are classified. The Naval Sea Systems Command Code 08 is cognizant of the cleaning processes and any modification of the existing process to minimize the amount of waste generated. Therefore, NAVFAC established that only end-of-pipe treatment or disposal were to be considered with respect to this waste. The results of these analyses are not presented here so as to avoid the need to classify this document.

Boiler Tube Hydroblasting with Sodium Nitrite. Most of the NSYs perform boiler hydroblasting operations by Shop 41. In the hydroblasting operation, a high-pressure jet of dilute sodium nitrite solution is sprayed into shipboard boiler tubes to remove scale hydraulically. The insides of the water tubes are subjected to a 5,000- to 10,000-psig water stream emitted from a lance nozzle at the rate of 20 gpm. The water jet lance and 1 1/2-inch hose are passed through the length of the tube at a rate of 20 sec per tube. Sodium nitrite ($NaNO_2$) is added to the hydroblasting solution to maintain a passive surface on the boiler tubes and, thus, reduce corrosion. During the hydroblasting process, this dilute $NaNO_2$ solution (carrying scale particles) is allowed to overflow from the boiler into the ship's bilge after one pass. It is combined with the contents of the bilge, which could contain anything from dirt to oily waste to heavy metals, and then transferred to a waste tank on shore. The contaminated NaNO solution is either treated at the IWTP or discharged to the sanitary sewer, depending upon local regulations.

Typical wastewater characteristics include scale solids and, possibly, metals, such as copper. An estimated 1,916 tons of wastewater are generated from this process (Reference 3-16). At three NSYs (Norfolk, Charleston, and Long Beach), these wastewaters must be treated and are reported as hazardous wastes.

Hydrochloric Acid Boiler Cleaning. At the time of the NCEL survey, the seven NSYs reported a total of 2,728 tons of HCl wastes; however, this amount included some HCl generated from dip tank, metal acid-cleaning operations. Since that time, better boiler water techniques have been implemented. As a result, boilers now require less frequent cleaning and can be tested to determine when cleaning is necessary. Hydrochloric acid is no longer the agent of choice and now is seldom, if ever, used.

Boiler Cleaning with Trisodium Phosphate (TSP). Most NSYs employ the boiler boilout process using TSP to remove oil and dirt contaminants. TSP solutions are pumped into the shipboard boilers, heated and recirculated, and then drained to the bilge where they are pumped out. These wastes are typically treated at an IWTP. However, some shipyards, such as Charleston, often neutralize them on a barge and, thus, are not required to report them as hazardous wastes. A volume of 2,290 tons of TSP wastes were reported as hazardous wastes generated by the NSYs, but this volume includes wastewaters from pipe flushing operations that also use TSP solutions for oil and dirt removal.

3.11.1.2 General Industrial Practice (T1). The ASME boiler and pressure vessel code places considerable emphasis on the avoidance of mechanical or chemical cleaning of boilers by rigidly controlling boiler water chemistry. A detailed scheme of water treatment analytical data interpretation and corrective adjustments can result in significant reductions in the rate of boiler deposit accumulations. The addition of chelants can even reverse the deposition process.

ASME C7.205 Chemical Cleaning. This operation uses solvents primarily to remove mill scale and products of corrosion. The solution may be acidic or basic, or successive solutions of differing pH may be used. Considerable chemical control is required to ensure successful cleaning, to avoid damage to both ferrous and nonferrous materials through improper use of the solvent, and to eliminate the potential dangers associated with corrosive solutions (including possible explosive and toxic products of the cleaning process). Qualified personnel with training and experience in this area should supervise this type of work.

ASME C7.207 Internal Chemical Cleaning. Boiler deposits, mill scale, and corrosion products not readily eliminated by simple washing or mechanical cleaning may be removed by internal chemical cleaning. Chemical analysis of the material to be removed is necessary to determine chemical cleaning solutions needed. It may sometimes be necessary to experiment with various cleaning solutions on samples of tubing removed from the boiler to determine the best possible solution to remove the deposit present (ASME, 1983).

3.11.1.3 Alternative Technologies (TO to T3):

Minimization of Acid-cleaning Operations Through Inspection Routines (T1). The present day treatment of boiler feedwater is much more efficient than previous methods. This has resulted in a much slower scale buildup and less need to acid clean the boilers (Reference 3-27). A number of boiler inspection methods currently in use allow a more detailed evaluation of when boiler cleaning is required. For example, a section of boiler tube can be cut out and inspected to determine whether acid cleaning is necessary. Several shipyards already conduct this analysis, which is widely used in utility boilers, and have not had to acid clean a boiler in two to three years.

Chordal thermocouples installed in the highest heat transfer areas of the furnace walls can monitor internal deposit buildup. These thermocouples enter the tube wall from the back wall and pass through the tube wall circumferentially to form a junction on the hot side of the tube. Thus, periodic checks of tube metal temperature can signal the buildup of harmful deposits and permit internal cleaning before overheating damages pressure parts.

Recirculation and Filtration of Hydroblasting Solution (T1). Recycling of boiler hydroblasting solutions can be achieved by straightforward use of a filtration system. Filtering and recirculation permit a smaller volume of sodium nitrite solution to accomplish the same job. The recycling system could occupy the space of the 4,000-gal tank currently used. The large tank is replaced by a 400-gal tank, return pump, and filter unit. The filter unit must be sized to remove 100 percent of the particles greater than one-tenth the diameter of the holes in the spray nozzle, or 0.0025 in. The filter can be used until the pressure gauge indicates clogging. The spent filter is thrown away as a nonhazardous solid. The recycled liquid can be neutralized at an IWTP and treated for removal of metals. The complete system would have a low investment cost ($3000). Return lines would require plumbing from the boiler blowdown to the return pump inlet. The only additional O&M costs to the present operation would be those associated with replacing and changing the filter. This setup could achieve a 90 percent reduction in volume with an 80 percent cost savings (Reference 3-27).

Substitution of Rust Preventive Chemicals (T1). Sodium sulfite is a possible substitute for sodium nitrite in boiler tube hydroblasting operations. This is suggested only on the basis of the fact that the ASME specifies its use. No compelling rationale for this choice is apparent, however, and it would appear that the Navy's choice of chemical (sodium nitrite) may well be the superior one. The matter should be given further study.

3.11.2 Treatment of Hazardous Wastes From Boiler Cleaning Operations

Part I - Waste From Nuclear-powered Ships and Submarines (NOS)

3.11.2.1 Characteristics of Waste. The specific constituents and characteristics of these wastes are classified.

3.11.2.2 Current Navy Practice (T0). At some Navy activities, this waste stream is treated at the IWTPs. Other activities send the material out for treatment by contractors.

3.11.2.3 General Industrial Practice (T1). Wastes similar to those considered here are variously treated in industry.

3.11.2.4 Alternative Technologies (T1 to T3). Alternative technologies are available and were evaluated in technical assessments on the present effort. Work is now being pursued at NCEL on the most promising options.

Part II - Waste Sodium Nitrite

3.11.2.5 Characteristics of Sodium Nitrite Wastes. This chemical is toxic to aquatic life forms. It should be noted that sodium nitrite wastes have metal concentrations that are borderline for disposal to sanitary sewers. The shipyards should analyze these wastes to determine if a metals problem exists (Reference 3-27).

3.11.2.6 Current Navy Practice (T0). Dilute sodium nitrite wastewaters are trucked to an IWTP, an STP, or are contract hauled outside for treatment and disposal at a total cost of $236,800 (Reference 3-27).

3.11.2.7 General Industrial Practice (T1). This waste is not generated in utility or industrial boiler cleaning or lay-ups.

3.11.2.8 Alternative Technologies (T0 to T3). Sodium nitrite is a strong reducing agent that readily reacts with oxygen. It is possible, therefore, to pump air through waste sodium nitrite solutions and convert the chemical to sodium nitrate. The latter salt is innocuous and can be directly discharged. However, since the lay-up solution may contain some heavy metals, it could be necessary to remove heavy metals at the IWTP. Alternatively, an IWTP could treat by contact aeration for COD reduction. In this arrangement, the oxidation of nitrite to nitrate would follow heavy metal precipitation.

Bioaccumulation and subsequent recovery of heavy metals in the boiler lay-up wastewater is also a possibility. Heavy metals are routinely recovered by microorganisms in mining wastewaters. See Appendix E.

Part III - Waste Hydrochloric Acid

3.11.2.9 Characteristics of Waste Hydrochloric Acid. Wastewater containing hydrochloric acid has a low pH and contains dissolved mineral deposits and metals. This waste may be hazardous (corrosive) depending upon the dilution from rinsewaters. This waste does require pretreatment prior to discharge to POTWs or streams due to pH, dissolved solids content, and perhaps certain metals.

3.11.2.10 Current Navy Practice (T0). Hydrochloric acid wastewaters are sent to IWTP for neutralization and metals precipitation. In 1984, approximately 597 tons of waste HCl were treated at an estimated cost of $252,000 (Reference 3-27).

3.11.2.11 General Industrial Practice (T1). See Section 3.16.

3.11.2.12 Alternative Technologies (T0 to T3). See Section 3.16.

Part IV - Waste Trisodium Phosphate

See Section 3.9

3.11.3 Disposal of Wastes From Boiler Cleaning Operations

No wastes requiring ultimate disposal are directly produced from boiler cleaning operations.

3.12 PROCESS NO. 11 -- FLUIDS CHANGE-OUT

3.12.1 Industrial Process Aspects

3.12.1.1 Current Navy Practice (T0). Waste oils are generated by a number of operations, including machine shop operations, vehicle repair operations, vehicle engine change-out, and change-out of aircraft lubricating and hydraulic systems. Machine shop activities include a broad spectrum of operations that generate waste oils contaminated with heavy metals and other particles. In addition, various hydraulic fluids are used in presses and in positioning and braking devices. Eventually, these fluids degrade and must be changed. Such fluids are routinely discharged or spilled. Also, heat transfer fluids are used in electronic components, and these require periodic refreshing or change-out.

The Navy uses more than 50 different types of petroleum-based lubricants, hydraulic fluids, and cutting oils at its various activities (Reference 3-28). For most types of engine operation, detergent-dispersant additives are required in the petroleum lubricants used. These additives consist of metallic salts of sulfuric acid, phenol and phenyl sulfide derivatives, and carboxylic (e.g., naphthenic) acids; of polymers of methacrylic esters and amides; and of polymeric acid imides. The type and amount of additives used depends upon the severity of the application.

Cutting oils usually contain emulsifiers. These oils can be used neat or in aqueous dispersion and can contain a wide variety of chemicals, such as ordinary and sulfurized mineral oils, sulfo-chlorinated mineral oils, various aromatic sulfonates, and naphthenates. Another group of oils frequently used in machine shop operations is synthetic-based oils. These oils are rather expensive, containing special chemical components to make them suitable for severe service. Synthetic-based oils are used for lubrication and for hydraulic and cutting applications, where stable, fire-resistant properties are required.

Another working fluid used in machine shops is machine coolant. These liquids are aqueous systems containing glycolic heat exchange compounds and various bacteria inhibitors to prevent the infection of jacketed sections of machining devices and the sumps. The liquids are typically used in once-through cycle with considerable waste of the expensive ingredients.

Recycling and Good Housekeeping Techniques. Currently, the Navy is in the early phases of resolving this issue. To this end, activities are addressing used oil recycling in conformance with instructions contained in the Navy's Used Oil and Solvent Recycling Management Program. That program is being implemented by NEESA, which, because of popular Navy usage, has had to adopt the narrower (and older) DOD program acronym designation of USE (Used Solvent Elimination). In this IDR, the term USE is accordingly retained but does include used oils as well as solvents. This program recognizes the need for segregation of wastes as a first step in achieving HW reduction. It further insists that good housekeeping practices in Navy machine shops are an essential ingredient. The official Navy guidelines for USE activities are paraphrased in Section 3.14.2.

A good example of such practices being used to segregate and collect waste oils to prevent their discharge to industrial sewer systems has been implemented at NAVBASE Norfolk. There, waste oils are collected in color-coded drums to encourage treatment, reuse, or reclamation. The treatment of oily wastes is discussed in Section 3.5.2.

The NIROP Pomona has installed an exemplary recycle system for minimizing loss of coolant while maintaining reasonable sterility of the cooling circuitry. All lathes, milling devices, and other machines (mostly programmed devices) are interconnected with a common cooling main. This is practical at the NIROP because Phalanx and Standard missiles are produced in a huge, single-roofed, very long structure, with clusters of machining devices conveniently located for coolant recycle.

Coolant circulated to the shop machines is returned to a central processing point where the liquid is centrifuged to remove cutting oil (which is in a fast break emulsion and, on separation, can be reused). The coolant is then filtered, sweetened with makeup bacteriostat, and returned to service cycle.

The NIROP, which had previously experienced frequent infections of machines that required complete change-out of the sour coolant, had gone over 11 with only one machine experiencing sump infection with the modified system. That machine was quarantined with block valves and was completely sterilized. The infection did not spread as coolant recirculation continued.

Although this may not be practical for shop machines in the Navy, due to the considerable separation of the shops, there is no reason why the technique could not be used on a more limited basis within separate shops.

3.12.1.2 <u>General Industrial Practices (T1)</u>. Industry utilizes various methods to minimize the quantity of waste oil discharged to sewers or for later removal, handling, and disposal. The key element is providing easy methods for segregating and disposing of various waste oils. This compares with the program instituted at NAVBASE Norfolk, discussed above, where color-coded drums are placed at convenient locations within shops.

Another common industrial practice is to place warning signs around the workplace reminding workers of the consequences of improper oil management (e.g., discharge of oil to the sewer system is grounds for immediate dismissal). In general, industrial shop policy fosters good housekeeping techniques to control excessive discharges of oils from machine operations. Certain equipment and operations, such as grinding machines, hydraulic equipment, and lubrication of moving parts on various machines, by their very nature, must generate waste oils. Opportunities for recycle and reclamation of these oils is addressed in Section 3.12.2.

3.12.1.3 Alternative Technologies (T1 to T3). In general, the Navy and industry are practicing about the same methods for segregation and disposal of waste oils and good housekeeping practices for minimizing the quantities of waste produced. These technologies, which are being implemented by NEESA through the Navy's USE Program, are covered in detail in the Used Oil and Solvent Recycling Guide, Reference 3-29.

Purification and Recirculation of Coolant (T1). Coolants from machine shop operations have been recirculated by both the Navy and industry. Centrifugation is required where cutting oils become mixed with the coolants. The isolated coolant can then be filtered, sweetened with makeup bacteriostat and returned to the service cycle. The cost for such a system will vary, depending upon the quantity of material flowing in the loop, the location of the shop machinery, and the condition of the fluid.

3.12.2 Treatment of Hazardous Wastes From Fluid Change-out

3.12.2.1 Characteristics of Fluid Change-out Wastes. The fluid change-out operations identified by the NCEL survey indicate the generation of 2,315 tpy of waste hydraulic fluids, oils, cutting oils, and coolants contaminated with water. Moore, Gardner, and Associates, Inc., (Reference 3-24) reported that, for a typical NSY, there are approximately 60 machines (lathes, grinders, etc.) using an average of 13,600 gpy of water-based coolants. The coolant is usually mixed in a 20:1 ratio with water. It is estimated that half the coolant is lost to evaporation, leaving approximately 136,000 gpy of wastewater containing emulsified oil for disposal. Many of the oils appear on the survey because they contain heavy metals; e.g., contaminants resulting from the grinding and machining of electroplated and other prepared parts.

3.12.2.2 Current Navy Practice (T0). A variety of handling and disposal procedures are being practiced at the various Navy locations surveyed. These include collecting waste oils, placing them in drums that usually contain sorbents (clay, saw dust, etc.), and disposing of them in HW landfills; simple oil/water separation techniques, followed by landfill disposal in drums; and oil/water separation, followed by reclamation, sale, or disposal by outside contractors. In one case, the waste oil is used as a fuel off-site. However, oily waste management practices have not yet received the attention that solvent management practices have.

Several activities appear to have or are in the process of implementing programs for recycling or reclamation of used oil. NAVBASE Norfolk is one such activity. Black and Veatch (References 3-30 and 3-31) and Moore, Gardner, and Associates, Inc., (Reference 3-24) identify equipment for the recycle of specific oils.

3.12.2.3 General Industrial Practice (T1). Generally, industries are moving toward extensive recovery and recycle of most oils. The typical first step in a recycling effort is segregation. Oil skimmers are widely used to collect oil. Oil/water separators or decant tanks allow for the oil and water to be further separated. The quality of the waste oil and the required final specifications dictate the combination of the following treatments:

- Chemical treatment
- Heat treatment
- Centrifugation
- Pressed cotton filtration
- Vacuum distillation
- Complete redistillation
- Fuller's Earth filtration
- Enhancement with additives
- Blending

These processes are designed to separate different types of oils, remove dirt and water, obtain a specified viscosity, or otherwise improve the characteristics of the oils.

At some locations, recovered oil is divided into two classes, referred to as "grossly contaminated" and "lubricating." The grossly contaminated oil comes mainly from electroplating or finishing operations. These oils are chemically treated to enhance phase separation (oil, water, and solids), filtered, and thermally dried. The recovered product is then reused as a supplemental fuel. Industry commonly uses reclaimed oil as fuel in industrial boilers to reduce the quantity of virgin fuel purchased. Some clean oils that are relatively free of water can be used as fuel without pretreatment. Other oils must be treated and blended to produce a suitable fuel, depending upon the requirements of the fuel user.

The lubricating oils are recovered and laboratory tested to assure quality before treatment. If suitable, the oil is heated and chemically treated to enhance phase separation, the water and sediment drawn off, and the oil phase filtered. The cleaned oil is retested for quality and reused, where appropriate. Where practical, gear boxes are cleaned on-line by mobile treatment equipment to eliminate the need for the discharge of this oil when a change-out is necessary. Other lubricating systems, such as those used for turbines, can be purified by a vacuum hydration process (Reference 3-28).

PORI, Oil Tech, Inc., Research Oil, and Eko-Tech, Inc., are examples of the companies that perform oil reclamation. This list is not exhaustive nor an endorsement of these companies but rather an illustration of the numerous companies available to supply this service. Ford et al. (Reference 3-28) present a comprehensive listing of companies in oil-reclamation service. In most cases, if the recovered oil can be reused, there is a significant cost savings to the production facility. Some oils sent to reclaimers contain a significant amount of heavy metal contamination. Most emulsion-breaking practices require the acidification of the oily waste stream. This solubilizes the heavy metals in the water phase and removes them from the oil.

If the oil cannot be reused, the reclaimer generally pays a nominal price or charges a nominal price (around $0.10 per gal) for the waste oil. Some reclaimers share profits from sales with generators, but such arrangements are not common within the Navy. The Navy pays a premium price for disposal of its waste oil. A change in the administrative policy for waste oil could be cost-effective.

3.12.2.4 Alternative Technologies (T0 to T3)

Combustion of Fuel Oil Reclaimed (T2). The Naval Surface Weapons Center, Dahlgren, is assessing the impact of recently proposed regulations dealing with cofiring used automotive oil or Fuel Oil Reclaimed (FOR) in Navy steam plants. Current data indicate that the lead levels in FOR are below 100 ppm. Therefore, the regulatory changes should not affect the burning of FOR.

The Used Oil Program (T1 to T3). The Used Oil and Solvent Recycling Management Program is discussed in Section 3.12.1. As described by Ford et al. (Reference 3-28), the Used Oil Program offers an extensive plan for identifying opportunities for recycling various oils and determining the types of devices appropriate for restoring oils to specification quality. It also discusses the extant practices encountered at Navy activities for recovering, upgrading, and recycling various types of used oils.

Petroleum Lubricating Oils (Gasoline- and diesel-engine lubricants) (T2) -- These oils contain high levels of additives. In service, these products become highly contaminated with fuel, dirt, combustion products, and water and, thus, are hard to reclaim. No new alternative technologies appear promising. propulsion systems (UBSC) is considered classified.

Other Petroleum Oils (T2) -- Hydraulic, turbine, transformer, heat transfer, and other oils not subjected to severe service remain relatively clean. These oils, in general, can be recycled after inexpensive treatment, such as coarse filtration. The possible presence of PCBs in certain types of oils should be determined, however.

Synthetic Oils (T3) -- These oils are generally expensive and typically see noncontaminating service. Many synthetic oils can be reclaimed. Unfortunately, since these oils are used for critical applications, reclamation may not produce oils meeting the rigid specifications. However, reclaimed oils can be reused in less critical services, sold for alternative reuse in other industries, or burned as a fuel.

High Flash Point Fuels (T2) -- The amount of contamination determines whether they can be recycled. Oils slightly contaminated with dirt or water can be restored to their original specification conditions by filtration or by combined filtration and coalescence treatment. Highly contaminated waste fuels may require fractional vacuum distillation.

Low Flash Fuels (T2) -- The same general guidelines applied to high flash fuel just noted also apply to these fuels. In some cases, small amounts of contaminated fuels can be blended with other fuels and be used within specification.

Cutting Oils (T2) -- Cutting oil can be recycled after filtration for removal of dirt and fine metal particles. Normally, the waste stream from the machining or grinding operations can be collected from the machine, pumped to a filtering device, and then returned to the machine. Addition of chemicals may be required to prevent biological degradation of the oils. It may also be necessary to add storage tanks for blending virgin oil when refreshing the solution to the required specifications.

Miscellaneous Oils (T1) -- Miscellaneous materials, such as greases and waxes are seldom recycled. They can be thermally destroyed in incinerators that meet RCRA requirements. Most oils can be used as fuels in boilers. However, those waste oils that contain halogenated products, or vanadium and sodium, have detrimental effects on boiler components and cause harmful stack emissions (Reference 3-28). In many cases, used oils may be reclaimed for use as boiler fuel. Treatment technologies include gravity separation, filtration, or coalescence to remove sediment and waters; or thermal processing, such as distillation. Refer to Section 3.5.2 for additional information on this subject.

Oily Sludge From Fluid Change-out -- Refer to Section 3.5.2.

3.12.3 Disposal of Wastes From Fluid Change-out Operations

Waste oils from fluid change-out operations should be recycled and reused whenever possible. These processes come under the Navy's USE Program and are in the process of implementation. Disposal of oily sludges generated from these processes is discussed in Section 3.5.3.

3.13 PROCESS NO. 12 -- BATTERY REPAIR AND REPLACEMENT

3.13.1 Industrial Process Aspects

3.13.1.1 Current Navy Practice (T0). The handling and disposition of old, nonfunctioning batteries removed from service generated sufficient quantities of hazardous wastes at five Navy activities included in the NCEL survey. It is estimated that all Navy activities produce such wastes from similar operations, to some extent.

The Navy uses several types of batteries: lead acid, lithium, magnesium, mercury, nickel, and zinc. Lead acid batteries generate the bulk of battery wastes and are, therefore, the topic of the present discussion. Most, but not all, NSYs have battery shops and deal with large lead batteries used on ships and, thus, are the primary generators of this waste at Navy activities. Casings and internal plate elements are separated, and the lead plates are turned over to DRMO for lead reclamation (recycle). Battery and battery acid wastes from five Navy activities account for the generation of 1268 tpy of hazardous waste. Battery wastes from other activities may not be recognized as a hazardous waste and, thus, may not be reported as such.

It appears that there may be some confusion about the regulatory requirements with respect to wastes generated by this process. From a regulatory compliance standpoint, current Navy reporting and manifesting may require modification at some activities. According to Mr. M. Strauss, Waste Identification Branch of the U.S. EPA, the language in 40 CFR 266.30 (Subpart G, Spent Lead-Acid Batteries Being Reclaimed) applies only to the reclamation of the entire battery (i.e., casing, plates, and acids). He further advised that if the acid is removed from the battery and the plates are separated from the casing, the Navy then becomes a generator of two hazardous wastes: lead plates and a corrosive, EP toxic waste, (i.e., spent electrolyte). These wastes are subject to all aspects of the RCRA regulations. Thus, when these wastes are removed off-site for treatment or reclamation, they would require manifesting. However, at some activities, battery components are not separated on-site, but are recycled by DRMO under contract. In this case, the batteries are not required to be reported as hazardous wastes or manifested. This is appropriate by virtue of 40 CFR 266.30.

Electrolyte and rinse water are collected from dead batteries and, depending upon local policy, different treatment or disposal practices are followed. For example, acids are treated on-site at NPDES-permitted facilities, such as NSY Norfolk. Acid rinses are treated at IWTPs, and concentrated acids are trucked to IWTPs and used as reagents in appropriate IWTP treatment (e.g., Mare Island). In some cases, the entire battery, after being emptied of electrolyte, is sent to a reclaimer by DRMO.

This operation generates and requires the disposition of a waste that, at present, cannot be minimized through process modification or material substitutions. Therefore, the issue of how to treat and dispose of the wastes generated is the key to minimizing the overall costs and liabilities to the Navy. These issues are addressed later in this section. There is ongoing research in new battery materials, which could result in the development of new battery types. These may reduce or eliminate the hazardous wastes presently encountered with battery disposal.

3.13.1.2 General Industrial Practice (T1). The methods' practiced in industry parallel those used by the Navy.

Recycling Lead and Battery Acid. Large battery manufacturing plants usually accept trade-ins from dealers and process these wastes in-plant. Lead plates are cut out of cases and the poles extruded from the lid sections with manually operated rams. Recovered lead is smelted in-plant and used, with virgin lead pigs, in casting new production grids. Battery shells are typically hauled to sanitary landfills by ordinary solid waste disposers. Battery acid is removed and processed in much the same manner as at Navy facilities.

Because of the comparative size of a (lead acid) battery plant, lead smelting is practical. However, it is not indicated for Navy facilities as a cost-effective approach.

3.13.1.3 Alternative Technologies (T0 to T3):

New Battery Types (T3). Research and development sponsored by DOE and NASA on new high-energy/density batteries is currently underway. Such batteries will use different electrolytes and plate elements, thereby, providing a different set of waste-handling problems when these batteries become commercially available. However, the expected battery life will increase, reducing the overall volume of wastes produced. NCEL will monitor this program, and when these new batteries have been adequately tested, the Laboratory will evaluate the impacts of using these batteries. Such an analysis should include disposal costs for these batteries. Widespread replacement of the currently used lead acid battery with new battery systems is more than five years away.

3.13.2 Treatment of Hazardous Wastes From Battery Repair and Replacement

Part I - Lead Battery Plates

3.13.2.1 Characteristics of Waste Lead Battery Plates. Lead plates are hazardous because of the toxicity of the predominant metal.

3.13.2.2 Current Navy Practices (T0). At most Navy activities, lead battery elements or plates are removed after the battery casing is drained and rinsed. Plates are collected and sent to a reclaimer via DRMO. After the lead plates and spent battery acid are removed and the internals rinsed, the battery casings are considered a nonhazardous waste and can go to a sanitary landfill. Navy activities generating only a small number of used batteries can send the entire battery to a reclaimer. This eliminates the need for segregating the plates and neutralizing the spent electrolyte. This practice, which is consistent with industrial practice, is becoming the norm in the Navy.

3.13.2.3 General Industrial Practice (T1). Industrial practice is to contract with reclaimers who collect and remove the batteries from the facility, separate the materials, and melt the lead for reuse. In the process, the reclaimer also treats or disposes of the electrolyte. Reclaimers should be carefully selected to ensure they are reputable and that their hazardous waste management practices meet RCRA regulations. Often, large battery manufacturers accept scrap batteries and recover the lead for use.

3.13.2.4 Alternative Technologies (T0 to T3). There are no alternatives known at this time.

Part II - Spent Battery Electrolyte

3.13.2.5 Characteristics of Spent Battery Electrolyte. This material is concentrated sulfuric acid that has been diluted with rinse water and contaminated with lead. The corrosivness of the fluid renders it hazardous. If the lead content is greater than 5 mg/l, spent electrolyte would be considered hazardous also because of its contamination with a toxic heavy metal.

3.13.2.6 Current Navy Practice (T0). Washed out electrolyte is typically neutralized at the shop or is placed in drums for disposal by DRMO. Long Beach NSY, having no battery shop, sends its battery wastes to PWC San Diego for disposition, an example of regional cooperation.

Neutralization alone is the acceptable treatment for these wastes, if the concentration of lead in the spent electrolyte is less than 5 mg/1. However, neutralization (typically with lime) does not completely remove the lead, which is usually present at greater levels. NPDES discharge limitations would typically require a higher degree of treatment for the direct discharge of the neutralized effluent to a receiving stream. However, most of the effluents from the neutralization go to an IWTP. This can be seen from Table 3-11. In its survey, NCEL found that most of the IWTPs, which could provide such data, met local metal limits.

3.13.2.7 General Industrial Practices (T1). Battery acid is neutralized by some companies and sent to an IWTP for secondary treatment and metals removal. This practice closely parallels that of the Navy. Other industries collect the spent battery acid and haul it to a contractor for treatment and disposal. Still other companies treat these wastes at small package plants. The effluent is discharged to a POTW, when possible, and the sludge is sent to a reclaimer or a HW landfill.

3.13.2.8 Alternative Technologies (T0 to T3). Figure 3-6 presents an overview of treatment and disposal options for spent electrolyte. Removal of lead (if in excess of 5mg/l) prior to mixing neutralized battery shop wastewater with other waste streams at the IWTP is important. Such pretreatment would become critical, if this lead-bearing stream caused the IWTP sludge to fail the EP toxicity test. The options for reducing lead levels include chemical precipitation and electrolyte recovery.

Chemical Precipitation (T0). Lead can be precipitated at elevated pH with lime, sodium hydroxide, sulfides, carbonates, or phosphates. Lead removal probably occurs at many battery shop neutralization pits when lime is used as the alkali. The question is whether sufficiently high pH is being developed and whether the sludge is being properly managed.

The residual, dewatered sludge can be sent to a reclaimer. Additional information on this technology is presented in Appendix C. If reclamation of metals from the sludge is not an option, the sludge should be solidified or encapsulated, prior to disposal in a HW landfill. Solidification and related processes are described in Appendix I.

Electrolytic Recovery (T1). The lead in the liquid would be plated out on the cathode of an electrochemical cell. The remaining acid would then be suitable for reuse as a waste treatment chemical or could be neutralized and ultimately discharged. A more detailed description of this technology is presented in Appendix C.

Part III - Battery Acid Sludges

3.13.2.9 Characteristics of Battery Acid Sludge. Two types of sludges can result from battery repair and replacement operations. A lead sulfide sludge is generated in the battery during its lifetime. A second sludge is generated by the treatment of spent battery acids. Both of these sludges would be handled in the same manner as IWTP sludges (Section 3.2.2.).

Table 3-11. Summary of Navy Battery Shop Wastes

Activity	Waste ID	Disposal Tons	Disposal ID	Disposal Cost, $
NSY Mare Island	Lead cmpd (80%)	37	D	29920
NSY Charleston	Lead scrap	888	D	799470
MCAS Cherry Point	Acid	5	T,D	140
Camp LeJeune MCB	Battery acid/cases	24	T	9700
MCAS Cherry Point	Batteries; Li	9	D	45000
NSY Charleston	KOH (70% water)	27	D	20975
PWC San Diego	Batteries	10	D	7760
NSY Norfolk VA	H_2SO_4	84	T	29920
NSY Charleston	"	15	D	11430
NSY Pearl Harbor	Battery acid	160	T	32000
NSY Puget Sound	H_2SO_4	8	F	6040
TOTAL		1,268		$992,355

Disposal ID: D: DRMO
T: On-site treatment
F: Final off-site contract
N: Final disposal on-site
R: Recycle

pa

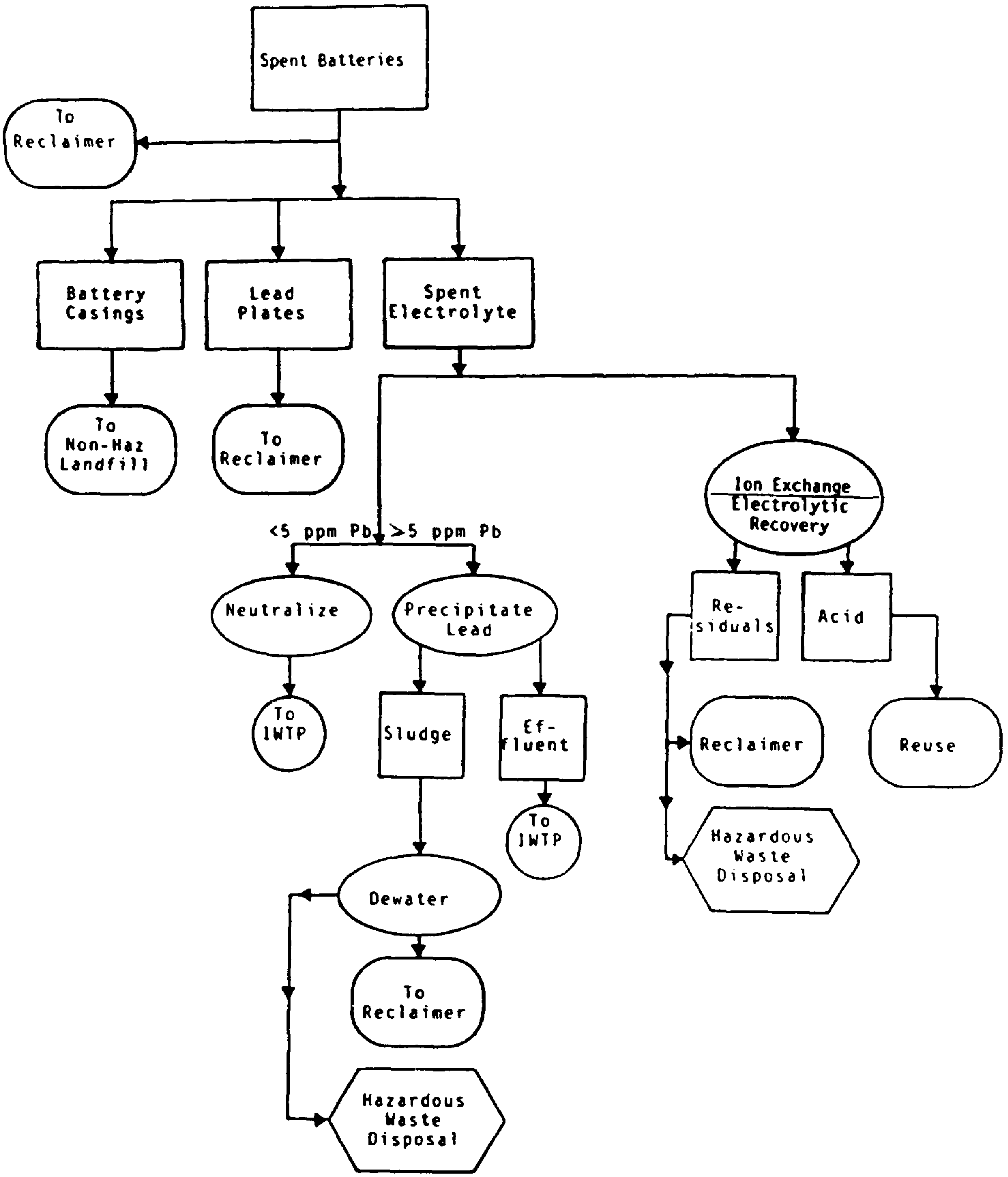


Figure 3-6. Treatment options for battery wastes

3.13.3 Disposal of Wastes From Battery Repair and Replacement Operations

Battery plates should continue to go to a reclaimer, but for credits. Disposal of other battery types, such as lithium, mercury and Ni/Cd, and variants thereof, was not considered in the present study since the quantities of these HWs were below the cut-off point observed in limiting the study field. It can, nonetheless, be noted that NAVSEAINST 9310.1 specifies that lithium batteries (the largest waste item of the nonlead types) should be thrown overboard and not stored for shore disposal. Where that is not done, the batteries may be burned in an approved lithium battery incinerator or buried in a HW landfill.

3.14 PROCESS NO. 13 -- CLEANING WITH SOLVENTS

3.14.1 Industrial Process Aspects

3.14.1.1 Current Navy Practice (TO). Solvents are employed to clean machine parts and metal surfaces, to thin various paints and coatings, and to calibrate equipment. The solvents used by the Navy can be categorized into four types: hydrocarbons, halogenated hydrocarbons, oxygenated hydrocarbons, and mixtures thereof. Hydrocarbon solvents are typically light petroleum distillates (kerosenes) and are used as cleaners, paint thinners, and vapor degreasers. Halogenated hydrocarbons are usually low molecular weight chloroalkanes and are used for cleaning and vapor degreasing. Oxygenated hydrocarbons are mostly low molecular weight ketones and alcohols and are used for cleaning and paint thinning. Table 3-12 lists the solvents commonly used for the various Navy applications. Table 3-13 summarizes the solvent wastes identified by the NCEL survey.

This section of the report deals with those solvents used for cleaning, degreasing, and miscellaneous purposes. Use of solvents as paint thinners is discussed in Section 3.7.1. There are three types of solvent cleaning and degreasing operations common in the Navy. These can be classified as 1) cold cleaning, 2) vapor degreasing, and 3) metal preparation and precision cleaning.

Cold Cleaning. This is the most common type of solvent cleaning. The solvent is applied either by brush or by dipping the item to be cleaned in a solvent dip tank. The most common solvent for this purpose is PD-680 (Mil-Spec), a naphtha or Stoddard solvent. It is also known under various proprietary, commercial names, such as Varsol (Reference 3-1).

Vapor Degreasing. This method uses high flash point, chlorinated hydrocarbons in the vapor phase to clean metallic and other tolerant material surfaces (Reference 3-1). The solvent is situated in the lower portion ("pot") of a special tank where it is heated to boiling to fill the upper portions of the tank with solvent vapor. The item to be cleaned is inserted into the vapor region of the tank (either manually or by conveyor). The hot solvent vapor condenses onto the surface of the item and drips back (refluxes) into the liquid bath, carrying with it any dissolved dirt or grease. The solvent vapor is prevented from escaping into the atmosphere by use of a refrigerated condenser section arranged in the vent path constituting the upper part of the tank. The condensed solvent returns to the liquid sump or "pot" for reboil in the continuous reflux process. The most common solvents used in vapor degreasing are trichloroethylene, perchloroethylene, 1,1,1-trichloroethane, and methylene chloride (Reference 3-1). The most widely used of these solvents is trichloroethylene. The low boiling point of this solvent (189°F)

Table 3-12. Solvents Used by the Navy

Solvent Type/Name	Navy Applications	Where Used
<u>Hydrocarbon</u>		
Heptane	Calibration fluid	NADEP
Naphtha, coal tar	Pitch and tar diluent	NSY
Stoddard solvent	General cleaner/paints	All
Naphtha, aliphatic	Coating thinner	NADEP,NAS,NWS
Naphtha, aromatic		NAS
Paint thinner		NAS,NWS
Toluene		NADEP,NAS,NSY
Xylene	Cleaner/coating thinner/ rubber cement thinner	NADEP,NAS,NSY, Amphib base
<u>Halocarbons</u>		
Methylene chloride	Degreaser/paint stripper/ general cleaner	NADEP,NAS,NSY, NWS
Trichloroethane	Degreaser/gen. cleaner	NADEP,NSY,NWS
Freon 113	Precision cleaning/degreaser	NADEP,NAS,NSY, NWS
<u>Oxycarbons</u>		
Acetone	Cleaner/thinner for various applications	NADEP,NSY
Ethyl acetate		NADEP,NAS,NWS
Ethanol (denatured)	A/C cleaner/shellac thinner	NADEP,NSY,NWS
Ethylene glycol	Antifreeze/coolant	NADEP,NAS,PWD
Isopropanol		NADEP,NAS
Methanol	Antifreeze/shellac thinner	NADEP,NAS,NWS, PWD
Methylethyl ketone	Cleaner/coating thinner	NADEP,NAS,NSY
Methylisobutyl ketone		NSY
<u>Mixed solvents</u>		
Carbon removing compound	Engine cleaner	NADEP,NAS,NSY, PWD, Amphib base
Paint remover/ stripper	As indicated	NADEP, NSY
Thinners & related products	As indicated	NADEP,NAS,NSY

Source: Reference 3-28

Table 3-13. Solvent Wastes Generated by Navy Activities

Activity	Waste Description	Tons	ID	Cost
NADEP Cherry Point	Solvents, chlorinated	19	D	13910
NADEP Cherry Point	Trichloroethane	24	D	19200
NADEP Norfolk	Solvents, chlorinated	64	D	0
Camp LeJeune MCB	Solvents, petroleum	92	D	27600
NADEP Cherry Point	Solvents, petroleum	141	D	112520
NADEP Norfolk	Solvents, chlorinated	41	D	8315
NSY Puget Sound*	Trichloroethylene	116	F	42680
COMNAVBASE Norfolk	Solvents, chlorinated	66	D	9700
PWC San Diego	Solvents/thinners	185	D	0
NSY Charleston	Naptha	I3	D	9730
COMNAVBASE Norfolk	Solvents, petroleum	65	D	14190
PWC San Diego	Paint waste	215	D	70950
NSY Mare Island	Solvents, petroleum	12	D	3720
NAS JAX NADEP	Carbon removal cmpd	100	D	25400
NSY Philadelphia	Chlorinated solvents	185	D	-
TOTAL		1,336		$357,915

Disposal ID: D: DRMO
T: On-site treatment
F: Final off-site contract
N: Final disposal on-site
R: Recycle

* Usage of trichloroethylene (TCE) here has since been reduced to ~2 percent, while use of other solvent types, mostly chlorinated, has correspondingly increased.

allows the use of low pressure steam for heating and permits handling of the cleaned parts almost immediately after cleaning (Reference 3-1). The next most popular solvent for vapor degreasing is 1,1,1-trichloroethane. Its boiling point (165° F) is even lower than that of trichloroethylene. However, 1,1,1-trichloroethane is reactive with zinc and aluminum and cannot be used to clean those materials.

Metal Preparation and Precision Cleaning. For metal preparation operations, the surfaces of a workpiece are cleaned prior to application of final surface coatings. Solvents, such as alcohols, ketones, aliphatic esters, or cresylic acid are frequently used. The solvent employed in this application is usually lost to the air or absorbed in wipe cloths or, if collected, is contaminated beyond specification allowances in the process (Reference 3-1). Solvents having high purity, high solvency, and rapid evaporation rates (such as CFC compounds) are used for the cleaning of precision instruments and electronic components. Cold or hot carbon removers are mixtures of solvents, which may or may not include halogenated materials that are used to remove soot deposits from aircraft and engine parts.

The Navy currently disposes of most of its solvent wastes by placing them in drums and sending them to DRMO. At Mare Island NSY, that portion of the solvent wastes considered reasonably biodegradable is sent to the IWTP.

Calibration Fluids. Solvents, such as heptane, are also used as calibration fluids for fuel flowmeters. Calibration with a fluid other than the actual fuel metered is necessary since jet aircraft fuel, a petroleum-based mixture, varies somewhat in chemical composition and physical properties.

Used Solvent Elimination (USE) Program. The Navy has developed the USE program to minimize the quantity of waste solvents generated. Three of the USE options for handling these wastes are categorized as treatments, while one, in-house recycling, is considered a process technology. In-house recycling is discussed in this section as one of the Navy process technologies but is described in Section 3.7.2, along with the treatment processes and other aspects of the USE program.

3.14.1.2 General Industrial Practice (T1):

Segregated Collection. In the industrial community, solvents have applications similar to those of the military. The major thrust of industrial practices for the control of wastes resulting from solvent use focuses on segregation and collection of spent solvents. One of the reasons for segregated collection TTO limitations placed on the effluents of the wastewater treatment facilities serving the operations producing solvent wastes. Segregation further simplifies any recycle/recovery practices that may be required.

Substitution. Material substitutions can be used to reduce the number of different types of solvents employed and to allow the selection of less toxic substances, where possible. A particularly pressing issue is the use of CFCs. These materials are associated with damage to the stratospheric ozone layer that protects the earth from UV radiation. A recent international concord, to which the US was a signatory, agreed to reduce the production of CFCs by 50 percent. It is possibly a matter of time before these liquids are completely eliminated from commercial production, such that substitutes will be critically needed by the Navy. Based upon National Academy of Science guidelines, it appears to be against public policy for the Navy to continue using CFCs as a solvent or otherwise. In this issue, present research points to the chlorine substituents on CFC molecules as being the active principals in the ozone-damage problem. This tends to suggest that fluorocarbons containing no chlorine might be acceptable substitutes for the CFCs.

Stills on Vapor Degreasing Tanks. Several companies, including Burrows and Aerojet General, are using a process modification on vapor degreasing tanks. Typically, the vapor comes into contact with the metal part, condenses, and cleans the metal, while the grease goes into the solvent. In the modification, a separate still is connected to the tank to distill the used solvent and return the purified solvent directly back into to the degreasing tank.

Cooling Coils in Vapor Degreasing Tanks. Cooling coils located in the open tanks above the solvent level condense the vapor before it can escape and return it to the degreasing tank. This is not a purification process, but rather a means of reducing solvent loss. This is in use at several locations, including Burroughs and Aerojet General.

3.14.1.3 Alternative Technologies (T1 to T3):

Stills on Vapor Degreasing Tanks (T1). As described above, industry uses stills close-coupled with vapor degreaser tanks. This method of solvent recovery meets the goals of the USE Program.

Cooling Coils in Vapor Degreasing Tanks (T1). Use of cooling coils in vapor degreasing consists of placing cooling coils in the upper portion of the tank to enhance condensation. This practice is comparable to the use of refrigerated condenser arrays in the vent path, a commonly seen arrangement in Navy degreasers.

3.14.2 Treatment of Hazardous Wastes From Cleaning with Solvents

3.14.2.1 Waste Cleaning Solvent. The solvents used by the Navy are hydrocarbons, both halogenated and nonhalogenated types. By virtue of their ignitability and/or toxicity, these solvents are commonly listed RCRA hazardous wastes. The NCEL survey identified the disposal of 530 tpy of all types of waste solvents used in the cleaning and degreasing operations. The solvents are collected and do not normally enter the sewer systems. However, a certain amount of solvents from washdowns may get into the wastewater stream. These present a TTO problem and are discussed in Section 3.19. Refer to Section 3.7.2 for additional information on the treatment of these wastes.

3.14.2.2 Solvent Still Bottoms. The residue remaining in a solvent still after the bulk of the solvent has distilled off typically contains about 50 percent solvent. This is sought after in order to keep the material fluid for ease of pumping and handling. Other stills produce a dry bottom, the residues of which contain less than 10 percent solvent. Still bottoms are either removed by scraping or, if reasonably flowable, by discharge through the low-point drain. The material is then usually stored in drums lined with neoprene bagging. The material is identified by proper labeling, manifested (DD Form 1348-1), and sent to DRMO for disposal. Disposal is usually by incineration, landfilling, or use as a fuel without further treatment. Refer to Section 3.7.2 for relevant comments on the handling of such wastes.

3.14.2.3 USE Program. Chief of Naval Operations (CNO) directives require Navy activities that generate 400 or more gal/yr of a single solvent to discontinue disposal of the waste liquid and to initiate USE-supported recycle operations. The CNO has directed that the following options be evaluated in the development of an activity's particular USE program:

1. Changing the process to reduce or eliminate the generation of used organic solvents
2. Substitution of materials to minimize adverse health/environmental effects of used organic solvents
3. In-house recycling with return of usable product for use at Navy or other DOD activity
4. Outside recycling by commercial or other recycler (Navy or DOD) and return of usable product to process
5. Use as fuel waste solvents having less than 4000 ppm of chlorine
6. Selling through DRMO

Each of the above options must include segregation of used solvents and wastes, as a first consideration. The primary thrust of the USE program is to recycle used solvents, wherever possible.

The "Used Oil and Solvent Recycling Guide," prepared by Robert H. Salvesen Associates (Reference 3-29) for NEESA contains detailed data on the scope of the USE Program. This includes Use Program options, on-site recycling, off-site reclamation, combustive disposal, sales opportunities, and USE Program development and implementation.

3.14.3 Disposal of Wastes From Solvent Cleaning Operations

When energy recovery of the solvent in still bottoms is not feasible, these wastes should be incinerated, and the ash from that incineration should be land disposed.

3.15 PROCESS NO. 14 -- BILGE AND SHIP TANK DERUSTING

3.15.1 Industrial Process Aspects

3.15.1.1 Current Navy Practice (T0). The Navy reported generating 1045 tons of citric acid-containing wastewaters in 1984 from bilge derusting operations. The derusting process was used by Shops 56 and 71 at NSYs Puget Sound, Long Beach, Norfolk, and Pearl Harbor. Aqueous citric acid solution (5 to 10 percent) is sprayed onto bilge or tank walls that have been manually cleaned of paint. The citric acid preferentially chelates the oxidized iron form, although some base metal is also lost in the process. As a result, difficult rust deposits are dissolved, as is the thin film of rust that covers the entire bare surface.

The citric acid, contaminated with iron and traces of other chelatable heavy metals present in the carbon steel walls, is flushed out of the structure being derusted with water and is collected for disposal. To avoid flash rusting of the now white metal, the walls are immediately sprayed with an inhibitor solution containing triethanolamine. This oxygen-getter adheres to the surface, protecting it until a primer can be applied. This is accomplished without removing the amine film.

The chemical costs to the Navy for employing the citric acid process were approximately $400,000 in 1985 and the disposal costs were $194,000 (Reference 3-16).

3.15.1.2 General Industrial Practice (T1). Current industrial practice for derusting ship bilges with citric acid is essentially the same as current Navy practices. Stronger acids are not used because of safety problems.

3.15.1.3 Alternative Technologies (T0 to T3). The use of citric acid, recycled by the treatment processes described in this section below, is the only alternative to consider at this time. Other chelating agents have been carefully considered by the Navy in the past, with the conclusion that citric acid is the chemical of choice.

In addition to rinsing off the degreasing solutions applied, the same equipment can also be used for paint stripping, derusting (with citric acid and other chelating agents), and passivation prior to recoating. The work chamber is unoccupied during the active operation.

An example of such systems is the NCEL Ship's Tank and Bilge Cleaning Hardware and Process System (STABCHAPS), which has seen T&E service at several NSYs. Because the process operates on the minimum volume of fluid necessary to prime recirculation, reduction in wastewater volume by as much as 75 percent is possible. At present, a system similar to the STABCHAPS is commercially available and used at several shipyards. The primary difference between commercially available equipment and the system developed by NCEL involves the use of a vacuum return (as opposed to a mechanical pumping arrangement) that allows for recirculation up to 75 gpm.

3.15.2 Treatment of Hazardous Wastes from Bilge Derusting

3.15.2.1 Characteristics of Bilge Derusting Wastes. The principal material of concern is citric acid, a chelating agent that selectively dissolves, through complexation, iron oxides with minimal effect on the base metal. The wastewater has a moderately low pH, contains dissolved metals (predominantly iron) and dirt, and may be contaminated by bilge oils and greases. This waste stream probably is not corrosive enough to be classified as a RCRA hazardous waste, regardless of the extent of its dilution with rinsewaters. It may, however, contain concentrations of nonferrous toxic metals or organics, depending upon the conditions in the bilge. This waste requires neutralization and metals precipitation prior to its discharge.

3.15.2.2 Current Navy Practice (T0). Citric acid wastewaters were trucked to an IWTP or contract hauled. Citric acid wastewater at NSY Norfolk cost $2.25 per gallon to treat and was normally contract hauled (Reference 3-27). Total cost reported for the treatment or disposal of these wastes in 1984 was over $500,000. This does not reflect, of course, the substantially greater savings that would be available, if the citric acid were recovered for recycle.

3.15.2.3 General Industrial Practice (T1). Organic acid wastes of this type are normally neutralized and the metals precipitated on-site or by contract off-site.

3.15.2.4 Alternative Technologies (T0 to T3). Depending upon the contaminants in the citric acid wastewater, filtration combined with reverse osmosis or ion exchange may be used to recycle the citric acid. NCEL is presently designing laboratory reverse osmosis and ion exchange arrangements to determine whether these units can reduce the volume of these wastes and potentially recover citric acid for reuse. The projected savings-to-investment ratio (SIR) for a working system based upon ion exchange would be 2.6.

3.15.3 Disposal of Wastes From Bilge Cleaning Operations

No wastes requiring ultimate disposal are directly produced from bilge cleaning operations.

3.16 PROCESS NO. 15 -- METAL PREPARATION

3.16.1 Industrial Process Aspects

3.16.1.1 Current Navy Practice (T0):

General. In order to clean a work piece for subsequent coating, all dirt, oil, grease, and undesirable surface oxides must be removed. This process is normally associated with electroplating operations and usually consists of alkaline cleaning followed by acid pickling. If the work piece has an oil film, a precleaning step may precede the alkaline cleaning step. Table 3-14 summarizes the types of metal preparation materials used by the various activities surveyed, the quantities generated, the current disposal practices, and associated costs.

Degreasing. As noted above, if a work piece is quite oily, it may be necessary to preclean the part before subjecting it to alkaline cleaning. By isolating the oily contaminants elsewhere, the precleaning step extends the life of the alkaline cleaning bath. Solvent degreasing or detergent washes are frequently used. Solvent degreasers are discussed in Section 3.14.1. At NADEP Cherry Point, detergent washes with silica soaps were identified as a hazardous waste by the NCEL survey. However, the survey reports indicate that the siliceous materials have been replaced with nonhazardous phosphate- or borate-based cleaners. No other activity reports the use of silica soap or any other type of detergent for precleaning purposes, either because such materials are not being used or they are being used in insufficient quantities to be included by the NCEL survey.

Alkaline Cleaning. The Navy uses alkaline cleaners to remove dirt and light oil films. According to the NCEL survey, sodium hydroxide is the caustic of choice for this application, although some activities use the more expensive potassium hydroxide for the same applications. Most activities dip the work piece in a tank containing the alkaline cleaning solution. Wetting agents are sometimes added to the bath to improve cleaning. After the soil is loosened from the surface, the piece is then rinsed. Sodium hydroxide is also used at Cherry Point in the paint stripping of nonaluminum alloys.

Acid Treatment. Before the piece can be coated, surface defects, such as scale and metal oxides, must be removed. This is accomplished by acid cleaning, a process also known as pickling. Typically, hydrochloric acid is used, although mixed acids, consisting of hydrofluoric and nitric acids, are employed for etching operations, as is phosphoric acid. Following the pickling operation, the piece must be rinsed prior to coating. Other materials, such as alkaline chelates, are used to descale surfaces.

Table 3-14. Navy Hazardous Wastes From Metal Preparation

Activity	Waste ID	Tons	ID	Annual Cost ($)
NSY Charleston	NaOH (40% water)	10	D	7600
NSY Pearl Harbor	Caustics	129	T	25700
NADEP Norfolk	H_2SO_4	31	T	200
COMNAVBASE Norfolk	NaOH	17	D	3715
NADEP Cherry point	KOH, chelates	26	T	18
NSY Mare Island	Acids/alkalis	400	T	625
NSY Charleston	Corrosives, NOS	7	D	5550
NSY Puget Sound	HCl, acid mixture	13	F,T	4700
NADEP Cherry Point	$KMnO_4$	14	T	10
NSY Puget Sound	Corrosive liquid	44	F	16000
NWSC Crane	Cr bath soln	43	F	6300
NSY Puget Sound	Acid sludge	8	F	2925
NADEP Norfolk	NaOH	101	D,T	35015
NSY Long Beach	Alk soln	20	D	4000
NADEP Cherry Point	NaOH	10	T	7
NADEP Cherry Point	Silica soap	10	T	7
NADEP Norfolk	Acids	21	T	390
PWC San Diego	Acid wastes	13	T	0
NSY Philadelphia	Acids	68		26851
NSY Philadelphia	NaOH	99		99
TOTAL		1081		$178,418

Disposal ID: D: DRMO
T: On-site treatment
F: Final off-site contract
N: Final disposal on-site
R: Recycle

3.16.1.2 General Industrial Practices (T1). Industry uses essentially the same methods and chemicals for metal preparation as the Navy. In large descale operations, industries try to minimize the discharge of wastes from these metal preparations. Such steps consist primarily of topping up the alkaline cleaning bath with the used alkaline cleaning rinsewaters and the pickling tank with the used pickling rinsewater. Pickling operations typically use countercurrent rinsing to minimize the volume of rinsewater. Furthermore, since fume scrubbers are required on pickling, alkaline cleaning tanks, and electroplating baths, excess rinsewater is used as makeup for those wet scrubber systems. In this case, alkaline rinsewaters are employed for acid fume scrubbers, while acid rinsewaters are used for alkaline cleaner fume scrubbers.

3.16.1.3 Alternative Technologies (T1 to T3). Acid rinsewaters can serve as makeup to the alkaline rinse tank or to the alkaline fume scrubber system. These modifications would require minor piping and control changes to the existing system. The following equipment would be required: a small tank to store acid rinsewater and pumping, piping, and controls to convey the water to the intended service. Naturally, a tank overflow connecting to an industrial sewer would be required. Such modifications should be inexpensive to provide (less than $1000, depending upon lay-up requirements, pump size, and length of piping runs).

Alkaline rinsewaters can serve as makeup to the acid fume scrubbing system, using a system similar to that described above. It should be noted that alkaline rinsewater is not typically suitable to serve as makeup to the acid rinsewater system, since it contains contaminants that would be detrimental to the subsequent plating step.

3.16.2 Treatment of Hazardous Wastes From Metal Preparation

Part I - Waste Alkaline Solutions

3.16.2.1 Characteristics of Waste Alkaline Solutions. Caustic solutions that have become contaminated with dirt, oils, and greases must be periodically dumped and replaced with new materials. These materials can be contaminated with heavy metals. Alkaline wastes represent approximately one-half of the wastes generated in metal preparation operations.

3.16.2.2 Current Navy Practice (T0). The Navy currently uses a number of different treatment and disposal practices for spent caustic materials. In some cases, the material is placed in drums and sent to DRMO for disposal or to a contractor for treatment and disposal. Other activities neutralize this material with spent acids and bleed the neutral effluent to the IWTP. Still other activities bleed the concentrated caustic to the IWTP for treatment. Refer to Table 3-14 above for the practices at the various activities surveyed.

3.16.2.3 General Industrial Practices (T1). Industries that use caustics in electroplating or practice acid metal cleaning typically have on-site waste treatment facilities. Collection and storage facilities for caustic bath dumps and for bleeding such wastes into the treatment systems are often available. As at some Navy facilities, waste caustic may be neutralized with spent acid at the process line with the effluent sent to the IWTP. This protects the sewer system from corrosion.

3.16.2.4 Alternative Technologies (T0 to T3). Other than the treatment procedures discussed above, there are no known practical treatment technologies applicable for this waste.

Part II - Waste Acid From Metal Preparation

3.16.2.5 Characteristics of Waste Acids. Waste acids, including waste pickling liquors, are listed as hazardous waste because of corrosiveness and the typical presence of dissolved heavy metals. At the activities surveyed, waste acid represented slightly less than half the waste generated from the metal preparation operations.

3.16.2.6 Current Navy Practice (T0). At the Navy activities surveyed, waste acid is handled in a number of different ways. Some acids are drummed and disposed of by DRMO. At other activities, contractors treat the waste acid and dispose of the residuals. Contract disposal costs, either through DRMO or the Navy, are high, and contractors often limit the pH range they will accept.

At many activities, the waste acid is either neutralized with waste caustics and the effluent treated at the IWTP or the waste acid is sent directly to the IWTP. Activities treating waste acids typically have batch treatment capabilities at the IWTP or can bleed concentrated acids into IWTP influent.

3.16.2.7 General Industrial Practices (T1). Industry uses several different practices for handling waste acid.

Use as a Water Treatment Chemical. Where possible, waste acid is used as a water treatment chemical; therefore, it is not a hazardous waste. Most waste acids are strong enough to adjust the pH during sulfite reduction of chromium^{+6} to chromium $^{+3}$. Acid can also be neutralized with the lime flocculant for air-stirred metals precipitation at IWTPs. Depending upon local municipal treatment plant needs, waste acid can be used as a flocculant aid (e.g., sulfuric acid conversion of lime to the more absorbent gypsum). There is also an industrial demand for spent hydrochloric acid containing iron for feedstock in ferric chloride production. Typically, however, the supply of waste acid exceeds the demand for water treatment chemicals, so it must be disposed of or treated.

The treatment of waste pickling liquor in a centralized treatment plant, like an IWTP, automatically causes the sludges generated to become a hazardous waste. If the sludge can be delisted, based upon metals content, an alternate disposal method for the waste acid is generally sought.

Regeneration. Possible alternatives are acid regeneration or recovery. Acid regeneration is practical only for hydrochloric acid recovery. Distillation produces an azeotrope that is 20 percent HCl. In most cases, this concentration of reclaimed acid can be returned to the process. Sometimes, an additional amount of more concentrated acid must be added to bring the reclaimed acid to the proper pickling strength. The principal nonacid residue from the acid regeneration process is iron oxide, although many other heavy metals can be present that will render the material hazardous.

In the case of sulfuric acids and mixed hydrofluoric and nitric acids, industry is just beginning to use a new ion exchange process. The ion exchange waste contains heavy metals that must receive further treatment.

3.16.2.8 Alternative Technologies (T0 to T3):

Neutralization (T1). Certain Navy activities (e.g., NSY Mare Island and NSY Charleston), which currently drum and dispose of waste acids without treatment, should consider providing on-site neutralization. This is particularly suitable when there are also waste alkalies that are disposed of without treatment.

There are several approaches ranging from the very sophisticated to the simple. Tanks can hold and bleed small quantities of acid and alkalies into the IWTP. A static in-line mixer (e.g., helical type) can provide mixing, if needed. Downstream pH-control feed-back instrumentation can adjust the rate of discharge from servovalves on each of the tanks.

Facilities of this type for a typical NSY would cost out at about $175k installed, including tankage, piping, instrumentation and start-up. Relatively little maintenance is required, although periodic calibration of the pH-controller is critical.

Regeneration (T1). As discussed under industrial practices, hydrochloric acid can be recovered by distillation. Based upon standard equipment commercially available, the smallest acid stills are rated at 5-gpm waste acid processed. This fact makes this alternative impractical for individual activities, since even the largest NSY does not handle that quantity of acid. If regional Navy HWM activities were instituted, the concept might prove viable. A 5-gpm acid distillation facility would cost on the order of $1 million and have energy and utility requirements of the following:

- Fuel - 12,000 Btu per gallon of waste acid
- Electrical - 0.1 KWH per gallon of waste acid
- Water - 1 gallon per gallon of waste acid

According to PERCOR, it is feasible to haul waste acid up to 150 miles for treatment. Therefore, a centralized treatment facility for servicing a number of military activities may be feasible. Also, generators could determine whether any acid regeneration facilities located in the area would accept Navy waste acid. Acid regeneration facilities have been in operation since the early 1970s.

Use as a Water Treatment Chemical (T1). Waste hydrochloric and sulfuric acid containing 20 to 25 percent iron as $FeCl_2$, is used in industry to convert hexavalent chromium to the trivalent form prior to precipitation. Where the ferrous ion content of the acid is too low, iron filings or scrap iron has been added to the acid storage tank to beneficiate the solution.

With the introduction of the NCEL Innovative Hard Chrome Electroplating Process throughout the Navy, chrome reduction requirements will be greatly diminished. The same iron-augmented solutions, however, can also serve as a coagulant aid in the treatment of IWTP wastewaters. Iron hydroxide will form as a precipitate, as the waste acid contacts lime and/or sodium hydroxide is added to the IWTP. The formed flocculent is an excellent medium for bringing down heavy metals (including those dissolved in the waste acid) and organics.

The facility would consist of a storage tank equipped with an air sparger and a feed system. Because this process arrangement would be regarded as a beneficial recycle of a hazardous material, the sludge generated by the IWTP would not automatically be classified as hazardous waste. The cost for implementing such a system at Navy activities, provided waste acid with a suitable iron content is available, would be about $250k for a large NSY. Acid waste disposal could be completely eliminated by this approach.

3.16.3 Disposal of Wastes From Metal Preparation Operations

No wastes requiring ultimate disposal are directly produced from metal preparation operations.

3.17 PROCESS NO. 16 -- CHEMICAL PAINT STRIPPING

3.17.1 Industrial Process Aspects

Chemical paint stripping is used primarily in aircraft paint stripping operations at commercial airline overhaul facilities and at NADEPs in preparation for repainting. Solvents or solvent-containing chemical mixtures are applied to the surface, thereby, chemically destroying the paint or the ability of the paint to adhere to the surface. When the process is complete, the paint and solvent mixture is scraped or washed off with water.

Solvent paint stripping is also used, but to a much lesser extent, in the rework of various mechanical components and ordnance items, such as antisubmarine warfare (ASW) torpedoes. In these operations, the components are usually immersed in tanks of stripping solvent. When the stripping process is complete, the components are washed off with water.

3.17.1.1 Current Navy Practice (T0). Solvent paint stripping generates solvent/paint residue and high volumes of waste washwater. It is estimated that 208 million gal of wastewater are produced annually at the six NADEPs (Reference 3-32). Approximately 3,000 tons of solvent/paint residue are generated, representing approximately 3 percent of the Navy's total organic waste stream.

As discussed in Reference 3-33, each NADEP uses a different procedure for aircraft paint stripping. In addition, the type of paint stripper employed varies according to the type of paint system on the aircraft. Most new aircraft are painted with a polyurethane topcoat over an epoxy primer. It is anticipated that older aircraft will change over to this system, as they are repainted. These coatings have a superior adhesion and must be removed by a strong paint stripper. To be effective, the strippers usually contain dichloromethane (methylene chloride), phenols, and, for some coatings, an acid-activated stripper. Stripper formulations utilized in the Navy are shown in Table 3-15. As discussed in Reference 3-33, there are, generally, six steps in stripping aircraft.

1. The areas where the paint stripper could cause damage or be trapped are masked. This includes acrylic windows, other plastic parts, and rubber hoses.

2. The stripper material is applied by airless spray or brush.

3. There is a dwell time of up to 40 min, followed by manual scrubbing to enhance the action of the stripper.

Table 3-15. Chemical Paint Stripper Formulations

Stripper	Mil Spec	Component
Epoxy system	Mil-R-81294	Chlorinated solvents, phenols
Paint and lacquer	TT-R-248	Organic solvents
Amine-cured epoxy	Mil-R-81903A	Hydroxyacetic or formic acid
CeeBee A238		Similar to Mil-R-81294 but with more active ingredients
McGean A238M		--
Organic coating/ hot tank type	Mil-R-81835	Trichlorethylene, ortho-dichlorobenzene, cresols, and all oil soaps
Carbon remover	Mil-C-19853	Chlorinated solvents, phenols, chromates
Turco 5122 thin, B&B 5075 thin, for aluminum only		Similar to 81903
Clarkson NA-4		--
Turco 3823, or B&B 7219T, or Omega SN (322-12)		Ortho-dichlorobenzene, amine, cresols
	Mil-D-26549	KOH
Eldorado SR-46 or EZE 500-81		--

Table 3-15 continued on next page

Table 3-15. (Continued)

Stripper	Mil Spec	Component
EZE 508 or Gat Ener. 5-24 or magnaflux stripper		--
Turco 4951 X		Chlorinated solvents, ammonia
Caustic paint remover		NaOH
Turco T-5351		--
	Mil-T-6096A or TT-T-266	--
	T-6045	--

Source: Reference 3-33

4. A pressurized water rinse is applied and flushed into the sewer, or the stripper is scraped off by hand, collected on brown paper, and drummed for disposal.

5. Touch-up stripping is followed by additional rinsing.

6. Demasking is performed and followed by application of a corrosion-prevention compound.

The general procedure used for component stripping includes:

1. Hand stripping--The stripper material is applied manually, scrubbed, and water and/or steam rinsed.

2. Vat stripping--The component is placed in a tank of stripper solution, left to soak, then spray or tank rinsed.

One aircraft can use anywhere from 13 to 25 thousand gal of wash water through the entire stripping procedure. Most stripping processes use two main rinses, one following each of the two general stripper applications. These rinses remove the bulk of the paint and spent stripper. These two rinses combined will consume approximately 10 to 15 thousand gal per aircraft. At Norfolk, this initial rinsing is minimized by removing the loose paint and spent stripper with a squeegee.

After the demasking and hand-stripping processes have been completed, a third rinsing operation follows. From 3 to 10 thousand gal of water per aircraft can be used during this rinsing stage. Norfolk and Jacksonville NADEPs minimize water usage during this rinsing step by flushing only those areas that were hand stripped and by applying the water with a sponge or cloth rather than a hose. This procedure reduces water consumption during the final washing to approximately 3000 gal per aircraft.

3.17.1.2 General Industrial Practice (T1):

Scraping and Containerizing. The industrial sector paint stripping operations vary from current Navy practice in the manner in which the spent solvents and rinse waters are handled. In all instances, the stripper is scraped off the aircraft and containerized, thereby, significantly reducing the volume of contaminated wastewater produced. The following information on industrial paint stripping operations was reported in Reference 3-33:

Pan American Airlines -- Aircraft paint stripping is done in three sections from the tail to the crown. Aluminum troughs are taped to the side, and the concentrated stripper and loosened paint flow to the troughs and are collected in 55-gal drums. Rinse water is also collected in drums.

Republic Airlines -- The final rinsewater is pretreated and discharged to the city sewer system. More detailed discussion of this treatment process can be found in Section 3.2.3.

Trans World Airlines -- The concentrated spent stripper and paint are collected in 55-gal drums. Waste rinse water is collected in a tank truck for disposal.

United Airlines -- The concentrated stripper and paint are collected in plastic troughs placed under the aircraft to direct the waste to 55-gal drums. The final rinsewater is treated at the company's treatment facility.

Painting Elimination:

American Airlines -- The aircraft are not painted, and decals are used for logos and identification. There are no paint-stripping operations.

Eastern Airlines -- Only logos and identifications are painted on, limiting stripping to those small areas. The aircraft are not otherwise painted. All wastes are containerized.

3.17.1.3 Alternative Technologies (TO to T3):

Plastic Media Blasting (T2). An extensive evaluation of plastic media stripping (Reference 3-1) suggests that this technique has several advantages over solvent paint stripping for F-4 fighters. Some of the most attractive costs savings have been identified in the areas of labor, wastewater treatment costs, energy, materials, hazardous waste generation, and flow (process on-stream) days. These savings are summarized in Table 3-16.

Work is now on-going at NCEL to eliminate some of the problems associated with plastic media blasting, particularly concerning health impacts, explosion risks, and optimized recycle capabilities (Reference 3-34). In comparison with chemical stripping, it is estimated there are manpower savings of about 25 percent available. Use of chemical stripper can be reduced only 75 percent, since certain components cannot be abrasively cleaned. Waste disposal and treatment costs can be reduced by about 65 percent; media replacement is estimated at a loss rate of 5 percent per cycle. The economic analysis indicated a savings-to-investment ratio of 6.6, with total savings of $1.8 million per year. The estimated payback period for purchasing a $1.8 million plant that would equip an entire NADEP would be one year. The costs are based upon chemical stripping wastewater treatment costs of $100 per 1000 gal.

Table 3-16. Savings Comparison - Plastic Media versus Chemical Paint Stripping

Item	Savings	Annual Cost Savings ($)
Hazardous waste	Generates 1/100 the waste sludge, which requires hazardous waste disposal	218,000
Wastewater disposal	Eliminates generation of 210,000 gal/day of wastewater, which must be treated in on-base waste treatment plant before discharge to the city municipal treatment plant	526,375
Materials	Eliminates the use of chemical solvents and requires minimal use of plastic media to make up for worn-out media	1,091,340
Labor	Requires 1/10 the labor	2,179,060
Energy	Requires 1/10 the energy	233,929
Flow days	Provides increased flow day utilization of aircraft	1,353,210
TOTAL Annual Savings For 215 F-4 Aircraft		$5,591,914

Laser Paint Removal (T3). Based upon the use of a robot-operated, pulsed CO_2 laser, this option is in the experimental stage and requires significant amounts of additional research before it could be applied. The initial capital outlay for a facility for handling fighter aircraft is estimated at over $10 million.

Flashlamp Paint Removal (T3). This process is based upon the use of electromagnetic pulses to remove the paint. The process is under investigation by the Air Force, which estimates that it will be several years, if then, before the system can be considered practical for any kind of (specialized) implementation.

Dry Ice Blasting (T3). Dry ice is used as a blasting medium, leaving only the dry paint chips as a waste. The future of the process for A/C paint stripping is questionable, since the blast force has been frequently seen to damage the A/C skin. The process may have application to ship hulls, although NAVSEA's past experience using the process on painted steel has not been favorable. The removal rate is rather slow and management of the released CO_2 gas is highly problematic.

3.17.2 Treatment of Hazardous Wastes From Chemical Paint Stripping

Part I - Paint Sludges

3.17.2.1 Characteristics of Paint Sludges. Chemical paint stripping generates paint/solvent sludges. These waste solvent/paint mixtures, which consist of undissolved paint coats stripped from the aircraft, accumulate on the floors and are shoveled into drums or flushed into the industrial sewer. This sludge is a RCRA hazardous waste and, although analytical data are not available, it probably contains chromium, other toxic metals, and toxic organics from the stripping solvents (Reference 3-32).

3.17.2.2 Current Navy Practice (T0). At NADEP Cherry Point, paint stripping sludges are collected from the floor, containerized in 55-gal drums, and disposed of by land with no further treatment. At Jacksonville and North Island NADEPs, the sludges are washed down the sewer with the rinsewaters. Both NADEPs have equipment to separate the paint sludge from the wastewater, but neither system is operational. It is suspected that these sludges are fouling inlet piping and, thus, interfering with the efficient operations of the treatment plants. The sludge has high concentrations of hazardous contaminants, increasing the overall concentration of hazardous materials in the wastewater stream and significantly increasing the total load on the treatment plant.

3.17.2.3 General Industrial Practice (T1). A detailed discussion of the treatment practices used in the industrial sector, as well as at other military activities, is presented in Reference 3-32. In general, complete containerization and contract disposal is used by the commercial airlines.

3.17.2.4 Alternative Technologies (T0 to T3). The sludges produced by aircraft paint stripping are chemically resistant to any type of treatment. Present practices of both the Navy and industry may have to continue; that is, the material should be collected, containerized, and then sent for ultimate disposal.

Chemical aircraft paint stripping sludges and wastewaters should diminish as plastic blasting media technology is implemented. Although some chemical paint stripping will still be performed, it is likely that the waste volumes will drop over 90 percent.

Part II - Paint Stripping Washwaters

3.17.2.5 Characteristics of Paint Stripping Washwaters. The washwaters flowing from aircraft when stripping chemicals are flushed off, are contaminated with toxic metals and organics. Table 3-15, presented earlier in this section, lists the strippers used and their formulations. Table 3-17 lists the range of wastewater concentrations obtained from grab samples taken at the Jacksonville, Norfolk, Pensacola, and Cherry Point NADEPs.

3.17.2.6 Current Navy Practice (T0). The Navy has no effective process technology in place for treating chemical paint stripping wastewaters. Paint stripping wastewater is discharged into the industrial sewer and combined with the other industrial wastewaters generated at the activity. The combined wastewaters are flowed through the IWTP and then discharged to either a Navy or a municipal sanitary waste treatment plant. At Jacksonville and North Island NADEPs, paint sludge is included with the wastewater, although it is not known how much of this material drops out in the piping or on pond walls.

In general, the Navy's IWTPs are not designed for the removal of the toxic organics associated with the chemical paint stripping wastewaters, as shown by the IWTP flow diagrams in Appendix B. Pensacola has an aeration pond for phenol removal, but this is not an effective treatment method (Reference 3-33).

3.17.2.7 General Industrial Practice (T1). Industrial practice is largely confined to stripping wastes from commercial aircraft. Private aircraft are seldom repainted and then, usually, without removal of the old paint. NCEL canvassed seven of the largest air carriers. Their findings (Reference 3-32) were as follows:

Table 3-17. Paint Stripping Wastewater Contaminants

Parameter	Concentration, mg/l
Total suspended solids	50 to 300
Total dissolved solids	300 to 1000
BOD, 5 day	300 to 3600
COD	1800 to 8800
Nitrate	0.05 to 9.0
Sulfate	10 to 1500
Cyanide	<0.003 to 0.130
Phosphorous	0.8 to 4.5
Oil and grease	50 to 1300
Phenols	1 to 1300
Total toxic organics	124 to 2765
Chromium, hexavalent	<0.002 to 8
Total chromium	1.5 to 80
Copper	0.03 to 0.4
Cadmium	0.05 to 0.50
Lead	0.04 to 0.6
Zinc	0.25 to 1.25
Nickel	<0.03 to 0.8
Aluminum	0.1 to 1.6
Selenium	<0.005
Silver	0.005 to 0.01
Arsenic	<0.003 to 0.008

Source: Reference 3-32
Note: pH range = 5.0 to 9.5

American Airlines. Aircraft are not painted; decoration is provided with decals.

Eastern Airlines. Stripping is limited to logos. Wastes are containerized and turned over to contract haulers.

Pan American Airlines. All wastes, including rinsewater, are drummed for contract outhaul at $2.72 per gallon.

Pacific Southwest Airlines. An anonymous contractor strips and repaints; wastes are sewered without pretreatment.

Republic Airlines. Concentrated wastes (sludge and initial stripper liquids) are hauled at $0.71 per gallon to HW landfill

Trans World Airlines (TWA). Sludge (paint skins) and initial stripper liquid are drummed and landfilled by a contractor at $4.50 per gallon.

United Airlines. This airline's practice is essentially the same as TWA's, except that drummed wastes are removed by vacuum trucks at $0.36 per gallon.

It can be seen from the above survey data, that industrial practice (like that of the Navy) will have to be modified to meet RCRA. The Navy can learn little from the commercial airlines, other than to cut back on the frequency of aircraft painting, which would result in a reduction of wastes that require treatment.

3.17.2.8 Alternative Treatment Technologies (T0 to T3). NCEL has identified twenty-one different treatment technology alternatives (Reference 3-32). Six of the alternatives are chemical oxidation/destruction methods. Five of the alternatives use aerobic or anaerobic biological digestion processes to break down the organics in the wastewater. Seven alternatives are physical adsorption or separation techniques that may recover valuable organics, such as phenol. The remaining three are physiochemical alternatives. Three of the technology alternatives identified are used by the Navy in various wastewater applications; these include the hydrogen peroxide oxidation, aerated pond, and carbon adsorption treatment. Four of the alternatives are used extensively by industries (petroleum refining, wood and coal processing, and chemical manufacturing) and can be purchased off-the-shelf. Several of the alternatives require further test and evaluation to determine their applicability for Navy use. Finally, several of the alternatives are still in the research and development stage.

The alternatives are presented in Table 3-18. Table 3-19 summarizes the treatment technology capability and efficiency of the alternatives. Table 3-19 serves as a guide for choosing alternatives for handling concentrated and diluted waste streams.

Table 3-18. Phenolic Wastewater Treatment Alternatives

Technology	Implementation Level			
	T0	T1	T2	T3
Chemical Oxidation				
Hydrogen Peroxide	X	X		
Ozone		X	X	
Chlorine Dioxide			X	
Potassium Permanganate			X	
Iron VI Ferrate				X
Catalytic Oxidation			X	
Biological				
Activated Sludge	X	X		
Rotating Biological Contactor		X		
Trickling Filter		X		
GAC Anaerobic Filter				X
Aerated Pond	X			
Physical				
GAC Absorption	X (Note 1)			
Polyurethane Foam Sorption				X
Synthetic Polymer Resin Sorption				X
Pressure Filtration			X	
Foam Fractionation				X
Reverse Osmosis				X
Solvent Extraction		X	X	
Physiochemical				
Incineration				X
Electrolytic Oxidation				X
Ultrasonic Oxidation				X

Note 1: Used as effluent polishing at NAS Jacksonville

Table 3-19. Efficiency of Phenolic Wastewater Treatment Processes

Technology	I/O Phenol (mg/l)	% Phenol Removal	Additional Treatment
Chemical Oxidation			
Hydrogen Peroxide	650/0	100	Yes (COD,TOC)
Ozone	2,000/20	99	Yes (Note 1)
Chlorine Dioxide	6,000/0	100	No
Potassium Permanganate	2,800/97	95	Yes (Note 1)
Iron VI Ferrate	--/--	100	Yes (COD)
Catalytic Oxidation	4,000/40	99	Yes (Note 1)
Biological			
Activated Sludge	3,000/<1	100	No
Rotating Biocontactor	--/--	--	--
Trickling Filter	3,000/1-45	(Note 2)	--
GAC Anaerobic Filter	500/90	80	Yes (Note 1)
Aerated Pond	--/--	--	--
Physical			
GAC Absorption	200/5	97	--
Polyfoam Sorption	100/1	99	Note 2
Synthetic Resin Exchange	100/1	99	Note 2
Pressure Filtration	N.A.	--	--
Foam Fractionation	50/7	80	Yes (Note 1)
Reverse Osmosis	--/--	--	Note 2
Solvent Extraction	2,000/20	99	Yes (Note 1)
Physiochemical			
Incineration	N.A.	100	No
Electrolytic Oxidation	--/--	--	--
Ultrasonic Oxidation	--/--	--	--

Note 1: Additional phenol removal is required
Note 2: Phenol removal must be validated

Of all the candidates considered (Reference 3-32), one was selected and recommended for study from each of the categories of chemical and biological treatment technologies.

Chemical Treatment. This approach involves use of either chlorine dioxide or hydrogen peroxide. The latter may or may not be used with photocatalytic (UV) irradiation of the medium.

Hydrogen Peroxide -- Phenols can be removed by hydrogen peroxide oxidation in the presence of an iron catalyst. Together, these agents are called Fenton's Reagent. Hydrogen peroxide can generally be applied to effluent polishing after biological treatment, batch treatment of concentrated wastes, and as an emergency backup to other treatment systems. However, this treatment does not completely remove all toxic organics in a given wastewater. There has been limited full-scale application to phenolic wastewater treatment to date. Because the TTO issue is now incorporated into the Clean Water Act, it will be important to approach any wastewater treatment requirement on a comprehensive, integrated basis.

The chemical dosage is determined by monitoring the wastewater phenolic concentration. Because of the TTO management requirement, the levels of phenol and other stripper chemicals will have to be determined together with 112 other chemicals. Monitoring can be minimized with batch treatment; otherwise, operation and maintenance requirements for this system are similar to those of conventional chemical treatment systems.

Peroxide treatment can be enhanced through the irradiation of the reaction system with UV light. Energetic photons photocatalytically drive the phenol decomposition reaction rates to the millisecond range. This ensures efficient utilization of the labile oxygen in the desired reaction with minimal loss in nonreactive dissociation. The use of UV light does, however, significantly increase process costs. This particular approach is also being considered for pink water treatment and oily wastes (see Sections 3.4.2 and 3.5.2).

Chlorine Dioxide -- This oxidizing agent has more than twice the oxidizing power of chlorine but has not been widely used in the treatment of wastewater or water, possibly because of its instability, which requires that it be generated on-site from chlorine gas or hypochlorite. The method has not been applied to paint stripping waste treatment, but has been used successfully on concentrated industrial effluent containing 6000 to 16,000 mg/l phenol and 4700 mg/l ammonia. No chlorophenols (dioxin precursors) are formed, as with chlorine oxidation; instead, chlorine dioxide will oxidize any chlorophenols to harmless compounds.

Biological Treatment. The NCEL-recommended biological process approach involves an evaluation of both the conventional activated sludge system and the rotating biological contactor.

Contact-aeration Sludge Process -- The activated sludge system is commonly used for treating wastewaters containing phenol. When properly controlled and operated (pH, nutrients, temperature, oxygen levels, other organics), it can reduce phenol concentrations to an acceptable level ($\leq$ 1 mg/l). The microorganisms will not degrade phenols until they have exhausted the other organics present. This, however, is entirely complimentary to TTO management requirements, where constituents even more refractory than phenol must be destroyed. Selectively developed bacterial strains can improve system performance. Pollutant removal is promoted by aeration of the wastewater to invigorate the biomass. These systems are fairly tolerant of shock loads, but equalization basins should be added to help deal with fluctuations. When a dedicated activated sludge system for dephenolization is installed next to an existing IWTP, O&M needs can be shared.

Rotating Biological Contactor (RBC) -- Another means of providing aeration to a biological system is with a rotating biological contactor. Bacteria grown on rotating disks are alternately exposed to air and nutrients (wastewater) with minimal operator attention. The high density of organisms can absorb organic shock loads. This process must be situated indoors to protect the medium and biomass. Limited pilot studies to date indicate that 7500 mg/l phenol in aircraft maintenance wastewater can be treated successfully by this method. A rotating drum plant is the best for very high concentrations of phenol. The Air Force is currently studying RBC systems at the pilot plant level for phenolic waste treatment.

These alternative chemical and biological technologies have been endorsed by NCEL, where current studies are being conducted to determine which of the candidates will eventually be selected for final use. The recommendation will be included, however, that the scope of the process study effort be expanded to consider all TTOs. Also, very recently, the following new biological process has been successfully demonstrated and should be considered:

Manville/LSU Immobilized Biocatalytic Process -- Selected microorganisms are supported on inert carrier shapes that are installed in a wastewater contactor. Phenols at levels as high as 1500 mg/l can be degraded to less than 1 mg/l at a rate of 1.5 mg/g of carrier per hour. Aliphatic halocarbons, such as methylene chloride, are also eliminated. Manville estimates treatment costs, based upon a 100,00 gpd unit having an economic life of 20 years, to be $23.35 to 25.43 per thousand gallons. The low end of the range is based upon the optimistically low capital investment of $200,000, the high end for a plant costing

$1,000,000. Costs otherwise include biocatalyst makeup, nutrient and pH adjustment, all labor costs and utilities (sparging air, power, cooling water, and steam). A more detailed discussion of the immobilized biocatalytic HW-destruction process is presented in Appendix J.

3.17.3 Disposal of Wastes From Chemical Paint Stripping Operations

The solids (e.g., paint skins) removed during chemical paint stripping operations may be incinerated and the resulting ash disposed of by land. The ash, however, should first be tested for leachability to determine any need for fixation/stabilization or encapsulation prior to burial.

Disposal of paint stripping sludges by incineration would not warrant an on-site erection of a HW incinerator. HW-disposal contractors can access privately owned facilities in the vicinity of most, although not all, Navy activities. However, if other types of HWs can be incinerated at a destruction and removal efficiency (DRE) of 99.99 percent, an activity might consider installment of an on-site HW incinerator.

3.18 PROCESS NO. 17 -- TORPEDO CLEANING

3.18.1 Industrial Process Aspects

3.18.1.1 Current Navy Practice (T0). Significant quantities of HWs are generated in cleaning Mk 46 and 48 torpedoes recovered after practice shots. The wastes are largely generated at NUWES Keyport (150 tpy), although additional wastes (16 tpy) are received there from or are treated at some fifteen other sites. NWS Charleston is the major East Coast torpedo refurbishment center. The 15 activities include designated Intermediate Maintenance Activities (IMAs) such as NWS Charleston, as well as other Navy activities and contractors who test or upgrade torpedoes. The 1984 tonnage figures have increased significantly in later report years, particularly for the wastes sent for treatment at Keyport from these other activities. In the interest of clarity, these operations will be discussed in reverse order of Mk number.

Mk 48 Torpedo Wastes

There are three hazardous waste streams generated from the cleaning and refurbishment of practice Mk 48 torpedoes. All of these waste streams contain some amount of OTTO fuel II and/or its products of combustion. OTTO fuel II is a liquid monopropellant composed of 76 percent propylene glycol dinitrate (PGDN, the energetic component), 22.5 percent dibutyl sebacate, and 1.5 percent 2-nitrodiphenylamine. OTTO fuel II-associated wastes are classified under RCRA as reactive waste D003.

These waste streams include 1) immiscible mixtures of seawater and OTTO fuel, each phase containing a trace of the other; 2) torpedo afterbody washwaters, containing a proprietary detergent (Wesmar AC-24L2), cyanides, preservative oil, mineral spirits, and traces of OTTO fuel; and 3) used mineral spirit cleaner (containing Tectyl, a preservative oil) contaminated with significant amounts of cyanide and OTTO II fuel. Waste management procedures in use at Keyport for the Otto fuel tank drainings and used mineral spirits have proved to be technically efficient, cost-effective, easily implemented, and, until recently, consistent with the requirements of RCRA and all known state and Federal regulations. Revision of the technique for recycling the mineral spirit wastes may prove expedient.

Mk 48 Fuel Tank Drainings -- These practice torpedoes have fuel tanks that hold approximately 35 gal of OTTO II fuel. As the OTTO fuel is consumed, seawater is allowed to enter the fuel tanks to aid in maintaining the buoyancy and trim of the torpedoes. The amount of OTTO fuel remaining in the tank at the end of the practice run is determined by the length of the torpedo run. After recovery, the torpedo engine chambers are loaded with a 50/50 mixture of mineral spirits and Tectyl to prevent corrosion. They are then returned to base for maintenance. This is initiated by draining the fuel tanks of sea water and OTTO II fuel. The latter liquids are relatively immiscible and can be separated by gravity.

Torpedo Afterbody Washwaters -- After fuel tanks are drained, torpedo afterbodies are washed with a detergent/water mixture. The wastewater collected contains approximately 500 ppm cyanide and about 50 ppm OTTO II fuel.

Used Mineral Spirits Cleaner -- The engine compartment is drained and engine components removed for cleaning in Type III mineral spirits containing about 7.5 percent Tectyl preservative oil. This solvent can be used to clean eight or nine torpedoes before it is considered inadequate for further use. The mineral spirits/Tectyl waste contains oil, grease and dirt contaminants, and trace amounts of OTTO II fuel and cyanide.

Mk 46 Torpedo Wastes

Mk 46 torpedoes are considerably smaller than the Mk 48s. Their fuel tanks hold only 6 gal of OTTO II fuel. Unlike the Mk 48, sea water is not intentionally allowed into the Mk 46 torpedo. Fuel transfer from the tank to the combustor is accomplished using CO_2 pressurizing gas. Thus, the unused fuel is reasonably clean, although possibly out of specification because of moisture content. Like the Mk 48, the engine compartment of this torpedo is loaded after a practice shot with an undiluted metal preservative called Steelgard.

The only real waste generated in the Mk 46 cleaning operation is the hydrocarbon cleaner used to clean engine components. For this purpose, Agitene (a light naphtha) is used, once the Steelgard has been removed. The impurities in Agitene include Steelgard, cyanide, OTTO II fuel, and carbonaceous residues.

3.18.1.2 General Industrial Practice (T1). There is no equivalent nonmilitary industry.

3.18.1.3 Alternative Technologies (T0 to T3). Barring the development and adoption by the Navy of a new and different monopropellant for use as a torpedo fuel, there are no process changes identifiable that would effectively reduce or modify the nature of the three waste streams generated in the torpedo refurbishment operation. Adequate and effective means of managing the fuel tank drainings are presently implemented on a regular basis at Keyport. These procedures, along with recommendations for treatment of the stream, are discussed later in this section.

3.18.2 Treatment of Hazardous Waste from Torpedo Cleaning Operations

Part I - Torpedo Fuel Tank Drainings

3.18.2.1 Characteristics of Torpedo fuel tank drainings. The largest volume of hazardous waste generated in torpedo refurbishment operations is unused OTTO fuel II and seawater drained from torpedo fuel tanks.

3.18.2.2 Current Navy Practice (T0). Since the ingredients of OTTO fuel II are not miscible with water and the fuel is heavier than water and not very surface active, it can be readily separated by gravity. NUWES Keyport operates a resource recovery system that exploits this characteristic. The fuel tank drainings are placed in a separation tank, in which the material forms two layers: a bottom layer of OTTO fuel II and a top layer of seawater. The bottom layer is drawn off into a holding tank, where fuel from both Mk 46 and 48 torpedoes is collected. The resultant OTTO fuel II, contaminated with only trace amounts of seawater, is dehydrated with air. The fuel is then passed through a 5-micron filter to remove crystallized salts and other particulate contaminants. The cleaned product is then reused as practice torpedo fuel. Tests have shown that this material, although outside war shot torpedo specifications, is a perfectly suitable fuel for driving torpedoes used in training exercises.

The seawater separated by this process is drained and passed through an activated carbon adsorption system to remove any traces of organic contaminants. The effluent can be discharged directly to a POTW or to an IWTP. Tests should be performed on this water to determine whether it is suitable for direct discharge. Activated carbon is regenerated by a contractor and returned to the Navy for reuse. In 1983, it was estimated (Reference 3-35) that the cost of such carbon treatment (without any reuse of the carbon) was $0.32/gal. This suggests a rather long cycle time for the charcoal beds and, thus, a correspondingly light contamination of the seawater with Otto Fuel ingredients.

3.18.2.3 General Industrial Practice (T1). There is no equivalent nonmilitary industry.

3.18.2.4 Alternative Technologies (T0 to T3). There are none at this time that offer better results and cost benefits over what has been developed for NUWES Keyport.

Part II - Torpedo Afterbody Washwater

3.18.2.5 Characteristics of Torpedo Afterbody Washwater. This wastewater is contaminated with about 500 ppm of HCN and about 50 ppm of OTTO II fuel ingredients. The wastewater also contains considerable amounts of carbonaceous solids that deposited during the combustion process.

3.18.2.6 Current Navy Practice (T0). This washwater was being shipped, in bulk, to North Carolina for incineration without dewatering, at a typical cost of $2.32 per gal. Current practice, adopted while this IDR was in preparation, consists of treating the water with a combination of Cl_2 and H_2O_2 followed by residual organic removal, using a proprietary flocculating polymer. Other wastewaters generated at Keyport are mixed with this influent. The resulting outflow is then passed through the same activated charcoal towers described earlier in this subsection. Sludge obtained from the clarifier is dewatered in a plate press. Process costs are uncertain at this time.

3.18.2.7 General Industrial Practice (T1). There is no equivalent nonmilitary industry.

3.18.2.8 Alternative Technologies (T0 to T3). Candidate approaches for treating aqueous waste streams contaminated with carbonaceous solids and moderate levels of organics and cyanide would include initial solids removal followed by 1) cyanide oxidation and activated carbon treatment of organic residuals, 2) wet air oxidation of both cyanides and dispersed phase organics, and 3) biological treatment with cultures capable of simultaneously or sequentially utilizing both cyanides and organics. Prior R&D (References 3-35 and 3-36) evaluated both carbon adsorption and wet air oxidation as treatment methods for wastewaters containing OTTO fuel II and detergent. The wastes treated in those studies were mixtures of the three separate torpedo cleaning (OTTO fuel II) wastes and contained higher concentrations (approximately 10 percent) of OTTO fuel II than the waste now under discussion. However, the results of those studies are applicable to the treatment of this detergent washwater.

Wet Air Oxidation (T2). Alternatively, clarified afterbody washings can be treated for both cyanide and nitro-bodies removal using wet air oxidation. Studies (Reference 3-36) indicate that wet air oxidation is technically feasible for the destruction of OTTO fuel-contaminated wastes. Although those tests used higher concentrations of OTTO fuel II in the feedwaters, a destruction and removal efficiency (DRE) of four 9s (99.99 percent pure) was nonetheless achieved. However, catalyzed wet air oxidation and supercritical wet air oxidation both show tremendous increases in DREs for aqueous/organic waste streams over unaugmented wet air oxidation. These technologies are discussed in Appendix D of this document.

Catalyzed wet oxidation systems are in common use. Many of the commercially operated wet-air oxidation systems are augmented with copper sulfate or other catalysts. Costs estimated in

Reference 3-36, adjusted to 1986 prices, are $0.55/gal plus transportation charges. This approach would require no Navy investment, training, nor any operation or maintenance concerns. Supercritical wet oxidation, as presently conceived, probably could not be downsized to make it economically feasible as a "captive" treatment process for this waste alone.

Biological Treatment (T2). Biological treatment processes for rapid removal and destruction of hazardous organic constituents at low percentages in aqueous waste streams have been demonstrated for linear alkyl sulfonate (LAS) detergents, PGDN, and cyanide-bearing wastes. Aerobic treatment using a rotating biological contactor (See Section 3.17.2) would probably be the most time- and cost-effective approach. In any biological approach, however, the influent feed would first have to be clarified, since the carbonaceous nature of the suspended phase would likely make it a poor candidate for any form of treatment, other than removal.

A fixed-bed, packed-tower anaerobic digestor would be the most promising technology of choice for anaerobic cultures. Several firms market tailored bacterial cultures for the treatment of specific waste streams. Cultures could be developed with bacteria that treat related wastes on actual samples of the Navy's waste. These technologies are discussed in Appendix G of this document. Because many of the cost factors, such as retention (e.g., vessel size), nutritive requirement, additives, and throughput rate, can only be roughly estimated, testing should be performed before costing is attempted. However, biological process often are very cost-effective. Suppliers will often test cultures at no cost, providing sufficient data for estimating costs. Fungal treatment processes based upon the white-rot (Phanerochaete chrysosporium) fungus are especially exciting in the speed and efficiencies shown in laboratory tests (See Appendix F). ICI markets fungal enzymes that hydrate cyanide to nontoxic formamide.

Photolytically Enhanced Oxidation. This wastewater, once clarified, would doubtless be amenable to treatment by a UV ozone or UV peroxide treatment approach identical to that discussed in Section 3.4.2 for pink water. Cost, risk, and availability should be about the same as for pink water.

Part III - Mineral Spirits Cleaning Wastes

3.18.2.9 Characteristics of Mineral Spirits Cleaning Wastes. The third waste stream resulting from the refurbishment of practice torpedoes is the waste from the mineral spirits and Agitene used to clean torpedo engine components. Both systems contain carbonaceous matter, preservative oil, and trace quantities of OTTO fuel II and cyanides.

3.18.2.10 Current Navy Practice (T0). At Keyport, the petroleum torpedo cleaning wastes are pooled together with other waste hydrocarbon solvents. Until recently, this material cofired in a package boiler. Although the presence of cyanides and OTTO fuel II was known and was not considered deleterious, cofiring of the waste fuel was discontinued because unacceptable levels of cadmium were detected. The material is now accepted by Gibralter Chemical Resources who cofire it as waste-derived fuel in a cement kiln located in Texas.

In February of 1986, NWSC Dahlgren developed a Scope of Work (Reference 3-37) to evaluate cofiring of this spent solvent in Navy shore boilers. The results (Reference 3-38) of this test program should indicate whether this material can be used as a fuel in appropriate Navy boilers. In the meantime, however, NCEL has taken the lead from NWSC Dahlgren and is investigating the use of distillation techniques for recycling the waste mineral spirit used for cleaning the Mk 48 torpedoes (see below).

3.18.2.11 General Industrial Practice (T1). This waste is not generated in industry.

3.18.2.12 Alternative Technologies (T0 to T3). NWSC Dahlgren has coordinated studies of two methods for recycling mineral spirits contaminated with Otto II fuel. One approach involves the cofiring of the waste fuel in existing boilers. The other is distillation for reuse of the solvent. The study of the cofiring option, Reference 3-37, concluded that cofiring was a viable option and recommended that pilot scale and field testing be pursued to verify impact on boilers and air emissions. A report on solvent recovery by distillation, Reference 3-38, found that distillation/detoxification could be accomplished at costs competitive with the cofiring approach. The still is operated under reflux, wherein HCN escapes from the condensing organic phase. The HCN is stripped off the reflux tower head with air and is removed on actived charcoal. During the cyanide removal period, it was noted that under reflux conditions (170 to 190° F), essentially all of the PGDN was destroyed. The still is then slowly evacuated to permit vacuum distillation of the mineral spirits, which are reclaimed with about 90 percent recovery.

NAVFAC Headquarters (NAVFACHQ) decided to pursue distillation as the preferred option with an NCEL RDT&E project that will include field testing, using full-scale distillation equipment. The project began in FY87 and will terminate with delivery of a Users Data Package (UDP) by NCEL in FY89.

3.18.3 Disposal of Wastes From Torpedo Cleaning Operations

No wastes requiring ultimate disposal are directly produced from torpedo cleaning operations. The activated charcoal used in cleaning the sea water separated from the OTTO fuel is regenerated and reused. The only possible residue would occur if the reflux/distillation technique were employed, in which case, still bottoms and cyanide-loaded activated charcoal would be produced. These HWs could probably be incinerated. The cost of this additional step should, of course, be considered when comparing the reflux/distillation technique with other candidate processes, such as cofiring.

3.19 PROCESS NO. 18 -- MANAGEMENT OF TOTAL TOXIC ORGANICS (TTO)

3.19.1 Characteristics of Total Toxic Organics

This topic falls outside the organization of this report, wherein treatment and industrial processes have been associated by using the same numbering system. This category can be associated with many, if not all of the industrial processes used by the Navy. Thus, while handled organizationally as an add-on item, it is by no means a minor subject.

The EPA is adding TTO limitations to wastewater effluent discharge requirements. The TTO concentration is expressed as the total of all the specified 114 toxic organics having concentrations larger than 0.01 mg/l. In most cases, the limit of the summed TTO compounds allowed by NPDES discharge permits is 2.13 mg/l. The compliance date was July 15, 1986. It is not certain whether any Navy activity is aware of how it stands with respect to this requirement.

The Navy is beginning a program to assess the extent of the TTO problem at Navy activities. The planned work includes the development by NCEL of an IDR addressing this issue, with an expected completion date of December 1987.

3.19.2 Current Navy Practice (TO)

Several programs instituted by the Navy will help in management of toxic organics. The most significant program is the USE program for solvents. This program not only addresses the recovery of solvents but directs the attention of operating personnel toward solvent segregation to assist with treatment and recovery, toward substituting the more toxic solvents with safer ones, and toward improving housekeeping practices at all operations using solvents. The direct benefit of this program is a reduction in the volume of solvent waste that is mixed with wastewaters, decreasing the chance of problems at the end-of-the-pipe. An example of this is the Navy's practice of collecting and saving the water from rinsing pesticide application and mixing containers and using this water as a solvent in the preparation of new batches of diluted pesticide.

The problem in TTO control is the IWTP's effluent and sludges. The treatment at most Naval IWTPs will not significantly reduce TTOs. Tertiary treatment is required for this, and that is in very limited use.

At the NADEP Norfolk IWTP, activated carbon treatment of the plant's effluent removes toxic organics. However, the TTO question is so new there is no Navy treatment guideline and, thus, no meaningful cost data within the Navy to allow comparisons of cost-effectiveness between processes. The NCEL

IDR will play a key role in outlining the steps NAVFAC should take to achieve regulatory compliance.

A key aspect of the present RDT&E situation is that the on-going development of solutions for wastewater problems in the Navy, which are often piecemeal and fragmented, should be brought into a comprehensive perspective. Once the Navy has done all it can to minimize or eliminate hazardous wastewater production (e.g., the hard chrome process), it must then systematically review the remaining waste streams to find an integrated answer for acceptable TTO management. A scheme of pretreatment/IWTP-combined treatment, which will be mutually complementary, cost-effective, and lead to an effluent TTO that satisfies regulatory constraints, must be adopted.

3.19.3 General Industrial Practices (T1)

In industry, the TTO problem began receiving attention around 1980 with the renegotiation of NPDES permits. Permit applications required extensive data on the chemical composition of substances involved in each process and in the discharge of various types of wastewaters, such as industrial wastewater, sanitary sewage, storm drainage, and cooling water. As contaminants were identified, industries were required to further investigate why these contaminants were present.

For example, special permit conditions were required by a number of Iron and Steel Industry NPDES permits, requiring studies of the treatment facilities receiving wastes from electroplating operations. These studies were made to determine the influent and effluent concentrations of TTOs at the treatment plant. The results showed that there was some removal of TTOs by the treatment plant and that the plant's effluent could comply with the TTO limitations. In part, compliance was assured because sources of TTOs were identified and efforts were made to prevent the toxic materials from entering the waste stream. It was found that toxic organic levels in the IWTP could be reduced through materials substitution and improved housekeeping practices. The need for incentives for such TTO-reduction activities is apparent, since these treatment plants handle 10 to 22 million gal of water per day, and the end-of-the-pipe tertiary treatment would be extremely expensive.

3.19.4 Alternative Technologies (T0 to T3)

A study was performed at Hill Air Force Base to characterize the organic waste streams and treatment plant effluents and to suggest methods for removing TTOs (Reference 3-39). This study can provide guidance to Navy activities having TTO effluent concentrations in excess of the allowable 2.13 mg/l. The Air Force (AF) study indicated that sources of TTOs were widespread and that most shop discharges were both intermittent in nature and had significant variations in concentration over time. This makes treatment of the individual waste streams difficult, unless sufficient surge capacity can be provided to smooth out both the flow and concentration variations.

The Hill Air Force Base study suggested several ultimate treatment technologies that could have applicability to Navy waste streams. These include the following:

Adsorption (T1). Two adsorption technologies were investigated: carbon adsorption (granular and powdered forms) and polymeric resin adsorption techniques

Chemical Oxidation (T1). The chemical oxidation techniques investigated included wet air oxidation, oxidation with hydrogen peroxide in the presence of a catalyst, oxidation with potassium permanganate, and ozonation.

Liquid Extraction (T1). This technique was investigated as a method for recovering phenols from the waste stream.

Biological Treatment (T1). A number of different biological treatment systems were reviewed for phenolic waste streams. These included stirred-tank, packed- and fluidized-bed (upflow) bioreactors, trickling filters, activated sludge, and rotating biological contactors.

Membrane Systems (T1). Ultrafiltration/reverse osmosis are also being studied for the isolation of phenols from waste streams. The point of application of this technology is also under review. Membrane systems can be used at the source of the contamination to prevent the phenols from entering the waste stream and to permit possible reclamation. Other possible points of application would be after the clarification or biodegradation steps.

To illustrate the relative costs for these alternatives, estimated costs for a 1.5 million gpd unit, assuming 50 ppm phenol, were developed (Reference 3-39). These estimates are presented in Table 3-20.

Other technologies that may be effectively applied to treat Navy wastewaters are:

Photolytically Catalyzed Ozonation (T1). The combined UV/ozone technology is more effective than UV or ozone used alone. The UV/ozone can be applied on-site and operated batchwise or continuously to destroy toxic organics. Hydrogen peroxide may be substituted for ozone with some cost savings but with some loss in efficiency.

Air Stripping (T1). Using a tower that is packed with plastic saddles, traces of VOCs in wastewaters can be stripped effectively with countercurrent air flow. This tower can also be

Table 3-20. Estimated Costs for a 1.5×10^6-gpd Ultimate Treatment Plant

Method	Cost
Biological	$\$1.5 \times 10^6$ (capital/equipment)
Ion exchange	$\$1.2 \times 10^6$ (capital/equipment)
Oxidation (IWTP Add-on):	
(a) $KMnO_4$	$852/day
(b) Fe/H_2O_2	$624/day
(c) Ozone	$\$3 \times 10^5$ (capital/equipment plus $120/day)
Carbon	
(a) Total Flow	$120,000 (capital equipment plus $160,000/yr for regeneration)
(b) Polishing	$120,000 (capital equipment plus $51,000/yr for regeneration)

Source: Reference 3-39

used in conjunction with industrial processes in which the removal of volatiles from process fluids is sought. This technique may not be permitted in the future, however, unless it provides air-cleaning equipment to prevent the escape of VOCs to the atmosphere.

Coagulation and Sedimentation (T1). Various coagulants, such as cationic polymers and aluminum sulfate, can be added to wastewater at a suitable dosage to remove organics. The coagulated sludges containing toxic organics are separated from the treated wastewater in essentially the same manner as is now practiced at Navy IWTPs.

Sludge Treatment (T1). Although it is better to prevent organics from entering sludge by eliminating them from upstream industrial processes, the sludge will still contain some toxic organics. If these levels exceed TTO limits, which is highly likely, the sludge must be detoxified and dewatered and then disposed of by landfill.

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CHAPTER 4

PROJECTIONS FOR EMERGING TECHNOLOGIES

4.1 OVERVIEW

This section defines ongoing and planned RDT&E activities within the Navy and other technological communities that could be directly applied to identified Navy HW problems. Because of the complexity of the problem matrix, however, the information presented is necessarily somewhat limited in detail. The discussion, nonetheless, attempts to point out the particular suitability for Navy application of schemes under study in other institutions and the modification requirements envisioned for making such RDT&E better fit Navy needs. Furthermore, the gaps in ongoing and planned RDT&E activities that should be of concern to the Navy in developing its own unique HWM capabilities are identified. The information presented here in Section 4.2 is organized in essentially the same manner as was observed in Chapter 3. The exception is ultimate disposal technology, which is discussed separately in Section 4.3 under the topics of disposal by incineration and landfilling.

4.2 RDT&E BEING PERFORMED IN THE VARIOUS NAVY HWM PROBLEM AREAS

4.2.1 RDT&E Supporting New Policy Directions

RDT&E leading to Navy-operating policy modification that will promote HWM is rather limited. This is due to the issues themselves not being usually resolvable through the application of RDT&E but rather through the judicious use of systems management and planning expertise. However that may be, NAVSUP is currently involved in the development of procedures that will enable the development of shelf life specifications that are more realistic than many of those that are now in use. This will doubtless include the use of more scientific procedures for both assigning and verifying the shelf life of Naval supply list (NSL) items. For the present, however, such a body of test methodology does not exist and, thus, constitutes a major RDT&E gap.

The NEESA HW Inventory program is continuously being upgraded with the introduction of new data processing methodology. A requirement still outstanding, however, is the development of a standard HW nomenclature and of criteria that can be consistently observed in determining what should or should not be reported to the HW Inventory.

The Preventive Maintenance System is based upon highly conservative schedules for routinely servicing facilities and equipment since, in many cases, technology has not been provided to determine when needed maintenance actually exists. This, of course, leads to the production of excessive HW. In many cases, it is either impractical or highly cost-ineffective to do otherwise. In some cases, however, routine inspection should be substituted for routine service. Examples are the repainting of aircraft, cleaning of marine boilers, change-out of hydraulic fluids, etc. There is, however, an RDT&E gap associated with this in both determining where the inspection-before-servicing policy can be applied and what methodology should be applied to determine if servicing should be delayed.

Due to funding constraints, the Used Oil and Solvent Recycling Program has placed its first emphasis on solvent reclamation (through the Used Solvent Elimination program). The recycle of oil will be a much more challenging issue. Acquisition of technology to support this element of the program is clearly needed.

Work is still going forward on the NAVSEA Ship-to-shore Hazardous Material/Waste Demonstration Program. This highly efficient process for segregating, inventorying, and immediately consigning for further transfer HM/W offloaded from Navy ships is beset with scaling problems. Further T&E should resolve the questions of how the enormous quantities of HM/W stored aboard ships the size of aircraft carriers should be handled.

4.2.2 IWTP Operations RDT&E

There is a great deal of research currently in progress on IWTP-treated wastewater streams. The results of these studies will influence not only the production of sludge but the ability of the Navy to fulfill its TTO and VOC control requirements. This includes the development at NCEL of 1) improved (electrochemical) techniques for managing wastewater from cyanide plating baths; 2) biological processes for treating aircraft paint stripping wastes; 3) management schemes for assessing, through statistically designed sampling protocols, TTO occurrence profiles within specific Navy activity-types; and 4) strategies and systems for controlling VOC emissions from IWTP I/O streams. Reference 4-1 reviews the then-ongoing T&E activities within both the Air Force and the Army for reducing the volume and hazard of IWTP. Of particular interest, is the Air Force process of heavy metals removal using a combination of sulfide precipitation and agglomeration with organic polymer floccing agents. The process greatly reduces the volume of sludge produced during treatment, although no significant detoxification results.

The U.S. EPA has completed the initial phase of a study (performed by the University of Minnesota) on a reversible gel absorption technology that could conceivably be developed into an alternative treatment technique for hydroxide fixation, the final step in the present IWTP process.

Initial studies in support of this IDR have been initiated at NCEL to evaluate the implementability of cyanide-free electroplating at Navy shops and to evaluate advanced techniques for paint application that will also help reduce IWTP sludge volume.

In general, the thrust of efforts for HWM at IWTPs appears to be comprehensive in coverage, and the existence of RDT&E gaps are not obvious. A possible exception to this generalization is the matter of sludge dewatering. At present, the Navy is using the best available technology (although not at all activities). HWM would, of course, be served if more efficient dewatering techniques could be invented. However, such technology, which is hardly uniquely needed by the Navy, should come from the EPA and other sanitary engineering laboratories.

4.2.3 Electroplating and Circuit Board Manufacturing Waste Abatement RDT&E

A substantial amount of RDT&E effort is concentrating on process modifications for plating, as well as on more efficient means of pretreating wastewaters from these processes for release to NPDES-permitted receiving plants. In Reference 4-2, 13 case studies are described for process modifications for metal plating that are in early implementation or T&E within DOD. These include the NCEL innovative hard chrome process, which is now in implementation; the LICON chrome recovery system, previously under evaluation with marginal results at Pensacola NADEP and Charleston NSY; conversion to counter-current and conductivity-controlled rinsing at Alameda NADEP; segregation of chromium and cyanide rinsewaters at Alameda NADEP; modified rinse and bath change procedures at Mare Island NSY; and ion vapor deposition of aluminum as a substitute for cadmium plating at Pensacola and North Island NADEPs. Additionally, the NCEL work mentioned in the preceding section, dealing with enhanced cyanide/cadmium control and the feasibility of substituting noncyanide processes for the electroplating techniques now in use, is in progress.

The Montana School of Minerals Science and Technology is conducting EPA-sponsored research into the recovery of metals from metal hydroxide sludges (Reference 4-3). A pilot unit that successfully separates copper, nickel, zinc, and cadmium has been demonstrated. A recent EPA paper (Reference 4-4) presents a review of several alternative treatment processes for recovering metals from wastewaters.

The present level of activity in this field appears to be adequate to support the Navy's interest. There are no major technology gaps extant at the present time.

4.2.4 RDT&E Activities Applicable to Ordnance Processes

It should be remembered that on the present IDR preparation, ordnance manufacture was set outside the scope of HWM; only HW treatment and disposal were addressed. In that particular context, only red/pink water emerged as problem themes.

NWSC Crane is currently aiming at the full scale T&E of a residue-free, photolytically promoted H_2O_2 oxidation process for detoxifying pink/red wastewaters. The T&E facility, if approved, will be installed on Indian Island, WA. The Army, which does not favor the NWSC UV process because of its alleged high O&M costs, is investigating ways of regenerating the spent activated charcoal that is collected and must be disposed of at both Army and Navy munitions plants. Although the sorption of nitro-bodies on the red/pink water treatment charcoal appears to be irreversible, a novel thermal regenerative technique that decomposes the adsorbed phase in situ is being investigated. This work is being performed at the Lonestar Army Ammunition Plant, TX.

Combustion Engineering Corp. has conducted rather extensive and successful tests on the bioremoval of TNT and RDX from pink water produced at the Louisiana Army Ammunition Plant. A proprietary fungal system was employed for the purpose; selected bacterial strains were not found to be adequate performers. This is discussed more fully in Appendix H. Test work at the National Bureau of Standards (NBS), Boulder, CO, using surrogates (polynitrophenols, including picric acid), has demonstrated 100 percent removal efficiencies, employing stoichiometric levels of H_2O_2 under supercritical conditions. The EPA has evaluated thermal processes for the destruction of aqueous waste streams containing low levels of organic contaminants such as are found in red/pink water.

The problem of pink water management does not appear to be a major HWM issue. Many solutions exist for eliminating spent charcoal (the actual HW problem here) and delivering a wastewater acceptable to an NPDES treatment plant. Even though there are no obvious HWM technology gaps, the question of what is the most cost-effective way to manage the nitro-body wastewaters has not been resolved.

4.2.5 RDT&E Related to Bilge Cleaning Operations

In its program to equip all Navy vessels with oil/water separators, NAVSEA has found that the devices appropriate for larger vessels are not suitable for smaller craft. DTRC is accordingly studying hollow-membrane systems for such applications. The Naval Ships System Engineering Station (NAVSSES, Philadelphia NSY) is also operating a test facility to evaluate several types of separators.

In this same vein, DTRC is trying to improve the performance of parallel-plate separators that are used in the larger vessels. These devices slowly foul with oil sludge that must be manually removed to restore separation efficiency. DTRC is assessing various surfactants that can be used to facilitate the cleaning process, while significantly reducing the cleaning wastes produced by the process.

The principal problem associated with oil/water separation is the presence of surfactants. Since the segregation of such materials (in cleaning compounds) from oily wastes collecting in bilges is difficult, particularly in submarines, faster breaking materials should be identified and substituted. This is a technology gap that must be attacked; specific RDT&E work has accordingly been recommended in Chapter 6.

4.2.6 Abrasive Blasting RDT&E

There are a number of promising developments in blasting grits that should considerably reduce the Navy's need to invest its own money in relevant R&D. A state-of-the-art review has been initiated at NCEL to expand the information base on the innovative abrasive blasting grit recycle systems discussed in this report. Soft media technology, which was perhaps optimistically regarded as implementable, does need and is also receiving further RDT&E attention at NCEL. This includes investigation of the dust hazards associated with occupational health and explosion potential, as well as the inefficiencies of existing equipment in classifying spent material into recycle and rejectate fractions and other related problems. Full scale operational testing of the plastic media blasting (PMB) is now underway at the Pensacola NADEP.

Copper Slag Grit Recycle in Portland Cement. A standard additive to Portland cement is pulverized copper slag. The usage rate by the industry far exceeds the Navy's production of spent grit; thus, market conditions are right. Use of spent grit is being investigated by potential customers (kiln operators) of both Bremerton and Long Beach NSYs. The important question is the effect any paint residues might have on the product. LBNSY has initiated a T&E arrangement with a Colton, CA entrepreneur, who has agreed to accept a trial lot of 1000 tons of processed grit. The shipyard has purchased the necessary delivery equipment, as well as a sieving device. The latter will be used to mechanically reject the larger paint particles.

While this recycle opportunity may develop into a viable option, logistics may restrict its usefulness to those activities that are within economic reach of cement plants.

Improved Blasting Grit and Recycle System. A synthetic blasting grit offered by the Ontario General Research Corp., is being evaluated by the DTRC. In addition to furnishing superior stripping characteristics, this system incorporates a proprietary recycle effect that feeds back specification-grade grit and a rejectate stream rich in paint. The recycle feature and better paint removal efficiency help offset the high unit cost of the grit.

The American Society for Testing and Materials (ASTM) has established Committee D33.05 to look into the selection of optimum abrasive blasting materials to perform specific tasks. The group will also address worker protection and develop standards to better control abrasive blasting.

Apache Abrasives Inc., which has developed a grit recycle system (see Chapter 3), seeks to improve it through the addition of a front-end thermal drying effect to decake the feed and, thus, promote greater sieving efficiency. It has been noted that when organotin-doped paint is being removed from hulls that approximately 20 percent of the tin returns in the recyclate.

IGT has also performed small-scale IRAD testing of Long Beach NSY-spent copper slag grit to demonstrate feasibility of combustive processing to achieve recycle. TRW Corp. has also proposed the use of a slagging furnace to achieve the same results by quenching and refracturing the melted grit.

Grit Recovering Blasting Guns. Paint blasting nozzle hardware from two firms, Vacublast Corp. and Blast & Vacuum Corporation, offers the capability of catching rebounding grit in the same gun that discharges it. These devices, which are being evaluated at DTRC, have shown efficiencies approaching 95 percent. Spent material, drawn back through annular suction configurations at the end of the guns, can be processed through recycle equipment to furnish reusable grit and paint fines for disposal.

Water-jet Paint Stripping. Related to abrasive blasting are techniques utilizing high-velocity water streams to remove paint from tolerant structures. The Office of Naval Research evaluated the potential of self-resonating, pulsed water jets for stripping paint. A Navy-licensed device under evaluation at DTRC applies a high-pressure, cavitating water stream onto the surfaces of painted hulls of ships with little or no damage to the base metal. The system promises only limited utility since the stripping rate is rather slow. A single gun will work only about 30 sq ft/hr of painted surface. A vacuum attachment is provided that permits about 95 percent recovery of the water and carried-off paint. Cleanup of the recovered water, where removal of dissolved organotin is indicated, can be effected by using an activated charcoal system. An appraisal is also being made of a device that will permit the use of cavitating water jets (or wet grit systems) in ganged arrangement under robotic control. An example is the Sandroid, a robotic device offered by CFE Equipment Co. System scale-up is scheduled by DTRC for FY88, with plans for optimizing the vacuum water recovery system for both hydroblasting and wet grit applications.

4.2.7 Paint Application RDT&E

Powder coating and plasma coating technology have been under evaluation by NAVSSES Puget Sound NSY for the past 10 years. Documents have been released by NAVSSES describing application techniques, hardware, and appropriate uses of such systems.

There is an on-going research program within the EPA to establish a method for determining the application efficiency of spray painting systems. A standard method will aid in the evaluation of test results of equipment offered by various manufacturers. Currently, manufacturers use methods developed in-house; the test results and efficiency data obtained are, therefore, often not comparable from one manufacturer to another.

NCEL has recently initiated a state-of-the-art survey to improve the information base on paint application technology prepared for this IDR. This includes the study of powder systems, wet and dry electrostatic techniques, and several other systems of potential interest to the Navy.

4.2.8 RDT&E Activities Related to Munitions Demilitarization

Test burns have been conducted by the Army Environmental Hygiene Agency to provide supporting data for a RCRA permit of the explosive waste incinerator at Picayune Army Ammunition Plant, MI. Successful results will provide the needed precedent for permitting other such explosives destruction incinerators operated within DOD.

Disposal of ash from demil operations may require fixation/stabilization prior to burial. This is an RDT&E requirement that should be addressed by the services operating systems for the destruction of explosives wastes, including activated charcoal used to treat red/pink water.

4.2.9 Piping Flushing and Cleaning RDT&E

NCEL is sponsoring RDT&E by the National Bureau of Standards, Boulder, CO, into the feasibility of supercritical vapor extraction of organic films and deposits from high-pressure piping. The EPA-sponsored supercritical vapor extraction RDT&E is also being conducted by Critical Fluid Systems Corp., Cambridge, MA. These studies have included work with carbon dioxide and low molecular weight hydrocarbons that reach supercritical conditions at lower temperatures than water.

The principal RDT&E gap that has been identified in this particular area is the replacement of fluorochlorocarbons with more environmentally acceptable solvents. The use of supercritical processes for piping, <u>if cost-effective</u>, will unfortunately be limited to piping that can withstand required supercritical conditions or that can be disassembled and be placed in a supercritical cleaning vessel. Thus, alternative solvent processes (preferably ambient condition ones) need to be developed so as to be available when and if fluorochlorocarbons are banned as stratospheric pollutants.

4.2.10 RDT&E Activities Related to Boiler Lay-up

With the NAVSEA specification of tighter criteria for dockside steam quality for use in ships, Navy shore activities have for a number of years been upgrading, or even installing for the first time, feedwater treatment systems for boilers serving berthed Navy vessels. This has involved the application of various types of systems ranging in cost-effectiveness and suitability for meeting NAVSEA's increasingly challenging requirements. NCEL has proposed RDT&E that will lead to the identification or development of improved feedwater and steam treatment technology. This is needed in order to satisfy, in the most cost-effective manner, projected NAVSEA steam quality requirements that are intended to support the wider use of steam lay-up. Unfortunately, this work is not scheduled for initiation until FY90, which will significantly prolong the required continued use of chemical solution lay-up. Rescheduling the work for an earlier start should seriously be considered, given the HWM implications involved.

4.2.11 Boiler Cleaning Wastes RDT&E

The principal RDT&E activity aimed at improved HWM during boiler cleaning is being performed at NCEL. For nuclear-powered ship and submarine steam generator cleanings, this RDT&E effort is directed only to the management of the final wastes produced. Technology gaps identified herein, to which specific RDT&E proposals have been prepared, include the circulated use of nitrate solutions in tube hydroblasting and reevaluation of cleaning operations that should be called for only after verification of need, rather than in accordance with arbitrary schedules.

4.2.12 Fluids Change-out RDT&E Activities

EPA is sponsoring RDT&E at Auburn University for the demetalization of waste oils. This is particularly aimed at waste lubricating oils that can be used as cofired fuels in boilers without causing fireside fouling or corrosion. This is a pilot-scale demonstration, wherein a dehydration/demetalization process previously developed at Auburn U. is being evaluated.

The technology gaps that exist for the Navy include similar wastes that cannot or should not be burned. These include waste oils that are too valuable to destroy, if recycle is achievable, and those that are not environmentally safe to fire. Where outside processors are not available to furnish recycle of such material, RDT&E will be necessary. This will include the development of purification techniques for removing wear-metals (if any), removing other foreign matter, and otherwise restoring the product's chemical integrity to the extent needed to meet specifications for reuse in the original or less demanding applications.

4.2.13 RDT&E Related to Battery Repair and Replacement

There is currently RDT&E at both NASA and the DOE for the development of new high-energy, density battery systems. This could lead to somewhat reduced usage of lead-acid and lithium batteries. Other RDT&E aimed at developing or improving treatment techniques for battery shop wastewater are analogous to those discussed for IWTP and metal plating operations.

4.2.14 Solvent Cleaning Operations RDT&E Activities

Most of the RDT&E related to treating wastes resulting from solvent-cleaning operations focuses on the disposal of solvent recovery still bottoms as feeds in various industrial process furnaces. This area of work is being supported by the EPA.

NEESA, which executes the USE program, has not indicated that any RDT&E gaps involving the distillation technology exist that require attention. There is, however, an obvious need to review the large selection of solvents that are now in use in the Navy and, by reducing the multiplicity, make the USE program more effective and faster in implementation. Some solvents now in use, such as methylene chloride, may be banned by EPA as being carcinogenic. Replacements should be identified for such materials.

4.2.15 Bilge and Tank Cleaning Operations RDT&E

NCEL is currently conducting research on the reclamation of citric acid and triethanolamine used in derusting and passivating, respectively, of bared-steel surfaces. Recovery of these expensive chemicals for recycle, together with concentration of the heavy metal contaminants, constitutes an important HWM project.

The EPA is sponsoring interesting work on metal-bearing waste streams. This includes research by the University of Kentucky to concentrate and purify dilute HWs by the use of low-pressure composite membranes. This involves membrane construction based upon noncellulosic polymers capable of operating over a wide pH range. Reverse osmosis systems that incorporate these membranes can operate at lower pressures than cellulosic membranes and, thereby, effect separation of organic and metal salts at high water fluxes.

A Navy technology need is the identification of efficient cleaning agents for removing grease and oil from ship bulkheads and other structures that do not form persistent emulsions with water. The use of surfactant products that usually become dispersed in various oily wastes to produce salt water emulsions that cannot be separated for cofiring in boilers because of high chloride content, must be discontinued.

4.2.16 RDT&E Activities Related to Metal Preparation

There is relatively little research at this time in the area of acid or alkali metal cleaning. Some studies are being performed by the Navy in regard to using alkaline cleaning as a method for replacing solvent degreasers in some applications.

A number of devices are offered that can be used to process and return on-line contents of both pickling and plating baths for the removal of contaminants so as to extend time between dumps. These devices are based upon various membrane and electrochemical effects and are of uncertain merit. A need exists, therefore, to explore this technology and determine whether opportunities are available that can be exploited.

4.2.17 Chemical Paint Stripping RDT&E

Historically, the Navy has focused its RDT&E efforts on finding more effective paint stripping formulations rather than alternative methods of managing the wastes produced from using such formulations. This has eventuated in the changeover to plastic media blasting (PMB) for paint removal. This technique will lead to the elimination of most of the chemical paint stripping that is now done.

NCEL is, nonetheless, still pursuing the problem of treating chemical paint stripping wastewater. This has largely focused on the need to destroy phenolic constituents. Biological processes have been emphasized for this application. NCEL is also studying the VOC control aspects of paint stripping wastewaters, since methylene chloride is often used in A/C paint strippers.

The Air Force has been funding A/C paint stripping wastewater RDT&E at Hill AFB. This work includes pilot biofiltration systems used in connection with production line A/C paint stripping operations. Researchers in the commercial field claim to have developed biological systems capable of detoxifying phenolic wastewaters. These include the Mannville immobilized bacterial contactor and the Combustion Engineering Corp.'s fungal process.

Because of the attenuation of the problem through change-out with dry process PMB and the success that appears to have been achieved with biological systems (chemical treatment systems are also known to be successful), this problem area appears to be well under control at the present time.

4.2.18 Torpedo Cleaning Wastes RDT&E

Two wastes of particular interest in torpedo cleaning are the afterbody detergent wastewater and mineral spirits used to clean motor and other torpedo parts. The latter have been successfully disposed of by cofiring in conventional boilers, but some doubt exists as to the DRE achieved in this form of recycle. NCEL is, accordingly, initiating work proposed by NWSC Dahlgren into the use of a reflux/distillation technique. The NWSC has already demonstrated that both cyanide and ethyleneglycol dinitrate (EGDN) solutes are destroyed by brief atmospheric refluxing, which clearly predicts that destruction would be almost instantaneous in a boiler flame. The work, thus, suggests that either approach will be viable and that economics rather than technical considerations will determine the outcome.

NUWES Keyport has also taken steps to abandon the combustive approach in destroying aqueous wastes produced in torpedo cleaning. This will involve the use of standard IWTP technology (Cl_2 oxidation of cyanide), followed by final detoxification in the same activated charcoal towers that are currently being used for the cleanup of sea water separated from recovered Otto Fuel. While it is obvious that this change will be beneficial, other RDT&E paths are available in the event of need. For example, the EPA is currently sponsoring work at the Georgia Tech Research Corp. for the development and testing of low-cost sorbents made from lignin. These materials would not only be suitable for torpedo-cleaning wastewater but for pink and red water treatment, as well. Conversely, several of the biological treatment processes for pink/red water discussed in Section 4.2.4 would probably also be applicable to the wastewater discussed here. These include both the Mannville and Combustion Engineering processes.

4.3 ULTIMATE DISPOSAL

4.3.1 Thermal Disposal

The EPA is currently evaluating 10 processes for the detoxification of hazardous wastes, including both process wastes and dump site materials. One system under evaluation is the Ogden Environmental Services combustor. An intense agitation is produced by the combination of a cyclone, air turbulence, and continuous recirculation back to the cyclone. Auxiliary fuel use is limited when burning low energy wastes ($\geq$ 2900 Btu/lb), and successful destruction is possible with flame temperatures as low as 1400° F.

EPA is also evaluating a device designed by Shirco Infrared Systems. IR temperatures of around 1850° F are achieved with secondary combustion proceeding in the 2300° F region. Westinghouse Electric has shown EPA an electric pyrolyzer that operates at temperatures approaching 3000° F. Molten metal and slag are tapped off separately. Pyrolysis Systems has developed a system, useful only for liquid HWs, based upon a plasma torch that operates at temperatures near 27,000° F.

4.3.2 Encapsulation for Landfilling

Two candidate systems for the encapsulation technology are being evaluated by the EPA. Again, the methodology has application to either dump site wastes or to HWs generated by industrial processes. Hazcon has developed a proprietary encapsulant system that renders most HW components compatible with Portland cement. As much as three parts of HW can be blended with one part cement to yield high compressive strength, nonleachable blocks suitable for disposal in Class 2 landfills.

International Waste Technologies offers a similar, proprietary product that will encapsulate as much as 6 lbs of HW per lb of additive. The material, however, has thus far been limited in testing to contaminated soil specimens.

4.4 REFERENCES

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Chapter 5

TECHNOLOGY ASSESSMENT

5.1 OVERVIEW

In order to objectively identify the management options that most effectively minimize the magnitude of hazardous waste produced by Navy processes, a computer-based assessment model was developed and implemented for this IDR. This model, the Hazardous Waste Technology Assessment Model (HAMTAM), is a computerized decision support program. It was designed specifically to support the present effort. Its function has been to systematically prioritize the hazardous waste minimization options identified in Chapter 3. The results of this modelling were used to arrive at the recommendations presented in Chapter 6.

5.2 TECHNOLOGY ASSESSMENT MODEL (HAMTAM)

HAMTAM was designed to prioritize hazardous waste minimization alternatives in an automated manner, utilizing a structured and systematic approach that is as free as possible of subjective error and bias. A set of parameters was chosen to characterize the significant attributes of HWM alternatives. Those parameters are:

- Compliance - Conformity of HWM alternative to RCRA and other Federal, state, and local regulations
- Logistics - Impact of HWM alternative on existing maintenance, documentation, training, facilities, support, transportation, supply requirements of process/treatment/disposal operation being modified
- EUAC - Equivalent Uniform Annual Cost of Alternative
- HW Volume Reduction - Percent HW effluent reduction from the status quo
- Earliest Date Ready - The operational date of a HWM alternative
- Risk level - The probability of successful technical performance of the minimization option and its acceptability in future regulatory climates

A more detailed explanation of the parameters, inputs, and calculations can be found in Appendix K.

5.3 HAMTAM IMPLEMENTATION

To prioritize each HWM alternative, the parametric data are first input and the parametric weights assigned. It was intended that the weighting factors that would vary the significance of each parameter relative to the others were to be based on a Delphi consensus involving nine qualified NCEL technologists. The results of the parametric weightings exhibited such little differentiation, however, that equal weights were assigned to each of the above criteria as a matter of modelling convenience. The exception to this process was the (RCRA) compliance criterion. This parameter has no assigned influence in the scoring process. The inclusion of this parameter was done to avoid the routine rejection of otherwise desirable alternatives that might be considered noncompliant by modellers but that might actually be rendered acceptable through process of appeals, etc.

Initial use of the model exhibited excessive variability in the results, due predominantly to the subjectivity of the risk and logistic parameters. Both involved arbitrary assignment of scorings that fluctuated significantly between independent evaluators. These particular two parameters carry the same weight as the other three parameters, the latter normally being quantified with data inputs that are supported by appropriate source information. In contrast, however, considerable engineering judgment must be applied in assigning scope to the risk and logistics parameters, particularly for T2 and T3 technology. It was, therefore, decided to confine the scoring effect of these two parameters by tightening the scale through the elimination of extreme values. Thus, the numerical values assigned to logistics data were reduced from the suggested scale of 1 to 10 to 1 to 3. The risk value was reduced from 1 to 10 to 1 to 5. It was also decided that guidelines would be established that would indicate, but only as a first approximation, how the individual scoring levels should be used. The protocol for roughly center-pointing scores for these two parameters was accordingly set as shown in the following tables.

RISK

SCORE	APPLICATION
1	Existing and readily implementable alternative for which little or no risk is evident
2	Same category of alternatives for which some elements of risk can be identified
3	Prototypic, pilot, T&E projects that have given good results and suggest minor performance risk
4	The same categories that have recognized risk elements; most R&D projects
5	R&D projects having limited proving and/or for which significant performance and/or economic risk has been projected

LOGISTICS

SCORE	APPLICATION
1	Operating processes for which logistic accommodations are already in place and proposed alternatives that can function within the same logistic battery
2	Proposed alternatives that can operate within the existing logistic battery with only minor or easily effected changes
3	Proposed options requiring significant logistical changes that impact activity operations

For each alternative within a discrete topical area, the program calculates the parametric values, normalizes them, weights and scores them, and finally sorts them based upon their scores, a perfect score being zero. This prioritization can be approached with or without consideration of the risk criterion. A complete discussion of this process is given Appendix K.

5.4 OUTPUT OF THE HAMTAM EVALUATIONS

The results of all the technology assessments performed on this IDR are found in Appendix L. Each HAMTAM package furnishes the following information:

5.4.1 Problem Abstract

A brief description of the hazardous waste problem is provided, together with references to the informational bases that were used in developing cost data and other inputs for the various alternatives selected for technological assessment.

5.4.2 Management Option Inventory

A listing of the viable HWM alternatives is considered in the technical assessment.

5.4.3 Final Results of the Technical Assessment

This is a prioritized listing of all the HWM alternatives for the problem under consideration. The options are listed in order of rank, with the lowest score being most desirable. The listing also summarizes data input for volume reduction, earliest date ready (EDR), logistics, EUAC, and risk.

5.4.4 Management Options Abstract

A brief description of each of the HWM options being assessed for the topical HW problem is provided, together with references to both the economic and technical aspects of the option and any special circumstances that need to be addressed.

5.4.5 Candidate Data Inputs

All management option prioritization data are presented here. These data are used in the calculation of the various parameters. These data sets include logistics input, EUAC input, disposal/treatment cost input, and hazardous waste volume change. A set of data representing four different screens of the model is provided for each HWM alternative considered for the topical problem.

CHAPTER 6

RECOMMENDATIONS FOR FUTURE HAZARDOUS WASTE MANAGEMENT

6.1 OVERVIEW

Based upon the results of the technology assessment discussed in the preceding section, specific recommendations for HWM actions were developed. These are presented below, following Section 6.2.1, which is a compilation of suggestions dealing with operational policies that could be modified to avail HWM. The numbering system observed in Section 6.2.2 follows the serialization of topics used in Chapter 3.

6.2 SPECIFIC RECOMMENDATIONS

6.2.1 Policy Matters

As pointed out in Section 2.6, the scope of the present IDR centers on HWM technology and does not extend to Navy administrative and supply policies that happen to cause HWs to be produced. Consideration of some of the more problematic policy issues is, nonetheless, so highly relevant to HWM objectives that the following recommendations, although necessarily only summary in content, are accordingly offered.

- Hazardous Material Programs. These are vital to the Navy in achieving HWM ashore and afloat. The Navy must aggressively explore and implement improvements in its hazardous material programs, particularly as discussed in the following recommendations.

- NEESA HW Inventory Program. This very important and useful system should be expanded through increased funding to become more interactive with the reporting activities. This would permit periodic on-site audit of reporting procedures to ensure that 1) information standardization (particularly nomenclature) is observed, 2) all HW materials that should be reported are reported, and 3) reported materials that are not HWs be deleted or submitted for delisting.

- Hazardous Waste Segregation. Programs must be instituted throughout the Navy to achieve the proper segregation of HWs at sea or on shore. This would entail a mix of actions, including personnel training, use of well-marked containers, and meting out of appropriate punishments to violators.

- Preventive Maintenance. Standardized PM procedures that generate HWs and are practiced on an arbitrarily scheduled basis should be reviewed to determine if the work is really necessary at the frequency specified. Also, preliminary inspection routines, if not already available, should be developed and employed before undertaking expensive and HW-generating maintenance operations.

- Used Oil and Solvent Recycling Management Program. This effort (also known as the USE Program) should include a search for opportunities whereby specific activities may "rent" solvents from vendors who would then clean up the used material to specification and recycle it. In many cases, particularly for low-volume specialty items, this approach is more cost-effective than attempting to achieve an in-house recycle capability.

- Manufacturer Recycle of Expired Materials. Consideration should be given the concept of having original manufacturers rework expired shelf-life material purchased by the Navy. This would permit parties most knowledgeable in and best equipped for reconditioning assumedly deteriorated materials to recycle such items at specification grade with least cost to the Navy. This approach would be appropriate only after it has been determined by adequate inspection by Navy personnel that the material should be reworked and that the shelf life for the material is realistically set.

- Overpurchase Elimination. The supply system should incorporate a Servmart-type of distribution arrangement for hazardous and potentially hazardous materials. Navy users could then purchase small quantities of needed items and not be constrained by the current, excessively high minimum limits that can induce the wasteful practices ("store the balance and forget") that are sometimes encountered.

- Specification Reevaluation. Navy (and DOD) material specifications should be methodically reviewed to identify performance and property call outs that are unnecessarily and excessively restrictive. The tendency to seek the best quality possible is commendable but leads to short usage life and the increased production of change-out wastes that can be hazardous. If a wider range of material characteristics can be tolerated without compromising the function it promotes, then a relaxation of the specification should be considered. This would lead not only to HW reduction but also to the obvious economies of operation that longer material service lives will avail.

- Technically Sound Validation of Shelf Life Terms. Similarly, shelf life terms specified for Navy materials should be reviewed to verify the technical validity of such (often putative or arbitrary) assignments. A centralized laboratory equipped to perform materials analyses and use-tests could be established for this purpose. Material candidates could be evaluated systematically, beginning with the more questionable and larger volume items and continuing until the mission is fulfilled.

- Reuse of Expired Materials in Less Demanding Applications. A program should be initiated to establish the most cost-effective utilization of materials that have been reworked for recycle but that are no longer able to meet the specification in place for the process whence they originated. Less demanding applications should be identified, regardless of activity locations or process type. Alternatively, reclaimed materials that cannot be utilized by the Navy in some form of recycle should be designated for DRMO marketing opportunities.

- Computerized Procurement Systems. The Navy's electronic mail order system and the Defense Logistics Agency's (DLA) Paperless Order Procurement System, which is now in effect for procuring short shelf life items and bypassing the NSC warehouse system, should be expanded to the maximum extent. Those additional materials that would be appropriate for such procurement should be identified, and cost/benefit analyses that include due consideration of HW issues should be conducted.

- Elimination of Redundant Hazardous Materials. Consolidation of hazardous materials used in Navy industrial practices should be undertaken. Whatever decisions are made on the HWM effort to comply with RCRA, many hazardous materials will still have to be used. However, hazardous (and nonhazardous) materials are often selected without considering items that are already on the Navy stock list and that might serve just as well. Such proliferation complicates the segregation and treatment of wastes issuing from the involved processes. Studies should be conducted to identify opportunities to eliminate hazardous materials, particularly those that are proprietary, and replace them with equally effective but less expensive materials or with hazardous materials that are already in extensive use in other, not necessarily related, applications.

- NAVSEA Ship-to-shore Hazardous Material/Waste Transfer Demonstration Program. This powerfully effective program should be brought to full Navywide implementation stage at the earliest possible date. The concept of methodically off-loading ship stores into specific categories marked for immediate receiving action by the responsible activity will significantly reduce the HW now generated by inadequately organized off-loading procedures. Warehouse space should also be provided so that materiel removed from ships entering overhaul can be properly stored until removed by the responsible activities (DRMO, PWD or NSC).

6.2.2 Hazardous Wastes from IWTP Operations

Part I - Alternative Treatment Technologies

RECOMMENDATION: There is a significant disparity at Navy IWTPs in the reported quantities of sludge generated, with respect to the quantity that should be produced. It is, therefore, recommended that a program be initiated to investigate Navy IWTP operations with the objective of improving operating efficiency. This study would review chemical dosages, alternative flocculating agents, such as polynucleolytes, process control instrumentation used for monitoring chemical additions, and sludge generation rates at Navy IWTPs. Methods should then be identified for optimizing operations and, thereby, reduce costs.

DISCUSSION: The conventional treatment technology ranked higher than any alternatives considered. Thus, it is recommended that Navy IWTPs continue with conventional treatment methods. However, in performing the technology assessment, it became apparent that Navy IWTPs may be operating inefficiently. Taking the sludge generation factors reported by the EPA (Reference 6-1), a 200 kgal per day plant using 20 percent excess of lime for precipitation should generate about 60.7 tons/year of hydroxide sludge (1.2 tpy/Mgpy), assuming influent concentrations typical of Navy operations (Reference 6-2). However, reported quantities of IWTP sludge collected in the survey data were far above the estimated sludge generation figures calculated for conventional treatment methods. The large amount of sludge generation found at Navy IWTPs could result from the excessive use of treatment chemicals.

In the data provided to NCEL, Tinker AFB reported an average dosage of 7.8 lb of sulfuric acid/kgal treated for conventional chromium reduction. This was comparable to the figure of 0.2 lb sulfuric acid/kgal treated that was used by EPA for cost estimates. These wastewaters must then be neutralized with large quantities of lime for heavy metal precipitation, which generates excessive amounts of gypsum along with metal hydroxides in the sludge. The sodium sulfide/ferrous sulfate process being tested by the Air Force does not require chromium reduction under acid conditions and, thus, eliminates the need for subsequent neutralization. A 40 to 60 percent reduction in sludge generation has been reported using this alternative method; however, this results from the elimination of the gypsum sludge produced from the neutralization of the acid wastewaters. This alternative method may not reduce sludge generation at an IWTP that is being operated under efficient conditions wherein the generation of gypsum is minimized.

Similarly, inefficient utilization of conventional IWTP methods prior to installation of the electrochemical metal removal system at NIROP Pomona may have been the reason that a 75 percent sludge reduction was reported (by the vendor) with the new system. Theoretically, the NIROP electrochemical metal removal system (based upon iron hydroxide floc) will generate more sludge than the conventional lime treatment method. Lime precipitation, however, does not significantly affect complexed and organically bound heavy metals in the intermediate alkaline pH range. Excessive use of lime comes about from trying to raise the pH to the higher levels where such species become hydrolyzed and then precipitate.

Part II - Sludge Dewatering

RECOMMENDATION: It is recommended that dewatering of IWTP sludge at all Navy activities operating such systems be performed with the belt press. Peculiarities of the sludge characteristics input to a few dewatering facilities may justify exceptions being made.

DISCUSSION: Sludges from the IWTPs must be dewatered. The Navy currently uses three different dewatering devices: vacuum filters, belt presses, and plate and frame filter presses. Although testing and evaluation should be required to determine the most cost-effective device for a specific IWTP sludge, these devices were evaluated in the present discussion based upon what were considered average conditions. The HAMTAM model indicated that a belt press would be the dewatering device of choice. It is accordingly recommended that this dewatering configuration be employed whenever the design choice does arise.

It should be noted that, in some cases, an IWTP may produce too little sludge to make an on-site dewatering system cost-effective. In such cases, the material should be sent to an off-site contractor who will dewater the sludge prior to disposal. The EPA suggests that 17 gal/hr is the practical minimum of sludge produced to warrant on-site dewatering. However, as the cost of contract disposal increases, the cost benefit of on-site dewatering of sludges generated at lower rates will become more cost-effective.

6.2.3 Hazardous Wastes From Electroplating and Circuit Board Manufacture

RECOMMENDATION: An integrated program should be established to bring together all phases of the Navy electroplating/circuit board manufacturing industries to develop process improvements at all levels of these operations, in order to provide HWM without sacrificing productivity or output quality.

DISCUSSION: The alternatives available for electroplating HWM, taken in combinations or singly, include conservation methods, cyanide elimination, bath purification/maintenance procedures, wastewater concentration through freeze crystallization, electrolytic oxidation/metal recovery, and the innovative hard chrome process. Rinsewater conservation techniques are practiced at many Navy plating shops. These practices should continue and be further incorporated in new Navy plating shops as they are constructed. NCEL is currently investigating noncyanide process baths for electroplating and metal stripping operations. Substitution of cyanide process baths by noncyanide solutions would eliminate the need for cyanide treatment operations and improve worker safety conditions associated with cyanide plating. The cost/benefit and the Navy applicability of cyanide elimination technologies will be determined. Continuation of this program is recommended for test and evaluation of cost-effective noncyanide solutions identified in the initial feasibility study.

A program to develop bath purification and improve maintenance procedures is, therefore, clearly indicated. Extending the life of process baths will proportionately reduce waste generated from the dumping and disposal of these solutions. NCEL is developing electrolytic technology to provide oxidation of cyanides and metal recovery. This technology can minimize cyanide wastewater generation and toxic discharges by up to 99 percent. The test and evaluation program proposed for this system is recommended. The innovative hard chrome process developed at NCEL is currently in use at four Naval activities. Further implementation of this alternative is now being conducted by NEESA. A technology assessment of these minimization techniques was not performed since all methods may have simultaneous cost/beneficial use for Navy development and implementation.

Of considerable interest in this area is the plan in place at the NIROP Pomona. This activity will be converting all its plating and metal finishing operations into zero-sludge-generating processes over the next sixteen months. Metals and metal salts will be recovered directly from tank dumps and rinses on copper, cadmium, and nickel (no cyanide used); anodize and chemical conversion processes; passivation and descaling processes; and etch and photoengraving processes.

Technology assessment of wastewater treatment following freeze crystallization did not reveal any cost advantage over the status quo practice, even under the most favorable circumstances of implementation. It is possible that the technology has been inappropriately matched with the electroplating requirement and would be more viable in other applications. One possible application would be pink water processing, wherein recovery, purification, and recycle of TNT would be considerably enhanced by the concentration effect.

6.2.4 Hazardous Waste from Ordnance Operations

RECOMMENDATION: The Military Construction (MILCON)-proposed approach to improved pink water treatment should be reviewed for cost validity. Alternative approaches should be developed, if the process proves cost-ineffective.

DISCUSSION: Photolytically enhanced peroxidation of pink water with H_2O_2 (T2) showed the best prospect for implementation in the T/A and is, accordingly, recommended. This result underwrites the present MILCON request submitted by NWSC Crane for the construction of such a plant at Indian I., WA.

The treatment process has been well studied (References 3-20 and 6-3) and apparently poses only one serious question--the matter of cost. In Reference 6-3, it was shown that the costs of UV-photolyzed ozonation of wastewaters containing trihalomethane precursors soared drastically as plant scale was reduced below 0.1 mgd. This clearly involves the throughput range at which Navy plants would be operating. The chemistry involved (ozone vs H_2O_2; halocarbons vs nitro-bodies) is not different enough to invalidate such comparisons.

6.2.5 Bilge Emptying and Cleaning Operations

Part I - Oil-contaminated Bilge and Ballast Waters

RECOMMENDATION: Studies should be initiated to identify materials that can be used for the effective cleaning of contaminated ship spaces, without the resultant production of intractably emulsified wastewaters.

DISCUSSION: The amount of oily wastewater to be treated onshore will be significantly reduced with the installation on board oil-water separators. Current practice of oily wastewater treatment is state of the art and provides satisfactory results. Treatment can be made easier and more efficient through the use of nonemulsifying detergents and degreasers, both for on board use and subsequent bilge and tank cleaning operations. It is clear that the use of nonemulsifying degreasers should be immediately implemented throughout the Navy. This can be done with minimal test and evaluation, since several activities are now using materials that are quite acceptable in the present context.

Part II - Recovered Waste Oils

RECOMMENDATION: It is recommended that studies be conducted to select the best of the various alternatives available for specific types of recovered waste oils based up on appropriate economic and engineering criteria. It is also recommended that further investigations of the safety of burning used oils in existing boilers be funded and that appropriate procedures and precautions for RCRA-acceptable operation be developed. Methods to increase boiler efficiency utilizing these fuels also need to be evaluated.

DISCUSSION: Used oil recycling is covered under the USE program. Waste oils can be recycled by 1) cofiring to recover energy values, 2) on-site reclamation, 3) off-site reclamation, or 4) sold via DRMO. The preferred recycling method depends upon the oil in question. There has been no coordinated effort, as of yet, however, to identify the proper approaches that should be used with specific waste oils. In some cases, disposal costs are incurred for materials that clearly have a potential recycle value.

In short, there should be no instances where a Naval facility has to pay for hazardous waste disposal of used oils, since there are several viable recycling alternatives from which to choose.

Part III - Oily Sludges

RECOMMENDATION: Present practice of contractor outhaul and disposal should be continued, except where quantities generated are sufficient enough to warrant consideration of on-site thermal destruction.

DISCUSSION: Oily sludges will continue to be produced as long as petroleum products are used to power the Navy's fleet and perform other mission-related functions. Oily sludges are reduced in volume by various dewatering techniques, many of which are already employed by major generators/treatment facilities. This volume may also be reduced through the implementation of on board oil/water separators and the use of nonemulsifying degreasers/detergents.

The HAMTAM assessment supports the recommendation of continuing with the current practice of contract haul for sludge treatment/disposal. The next best choice is that of landfarming. Under current regulations and the present rate of oily sludge generation, this would seem to be a good option. However, for even those activities that have the required acreage available, a definite risk exists that the practice will, in the short-term, be prohibited by the EPA. The process must, therefore, be considered an interim solution only.

Where logistically feasible, for those facilities that produce large quantities of sludge and can combine this with other suitable hazardous waste streams, supercritical wet air oxidation may be an effective solution. However, the HAMTAM assessment does not favor this option for small-scale use.

6.2.6 Abrasive Blasting Grit Recycle

RECOMMENDATION: Sub- to full-scale testing of thermal, sieve-classification, or combinations thereof for blasting grit recycle should be evaluated under appropriately parameterized conditions.

DISCUSSION: Recycle of abrasive blasting grit, either by the dryer/sieve or combustive process, represents a clear-cut HWM step that is obviously quite cost-effective. It is, therefore, clearly apparent that demonstration(s) should be initiated in this technology. The Apache process demonstrated a distinct edge over the straight thermal process in the technology assessment. However, it is recommended that both approaches be evaluated, since neither process was credited for cogeneration benefits, a situation that, if reversed, would definitely favor the combustive process.

The Apache system has already been demonstrated at shipyard scale and can be so evaluated by the Navy. The combustive technique has not, and several configurations are available that can be considered. TRW has a system that relies on a slagging effect and refracture of the crystalline material by fast quenching. The IGT process is quite different and probably involves a cost profile that varies considerably from the TRW and other systems. It is appropriate, therefore, that combustive techniques be evaluated at a more basic level. This can be followed by a suitable test approach and scale defined for a T&E phase to be subsequently pursued.

An alternative recycle process is to sell or give spent blasting grit to Portland cement manufacturers or asphalt plants. Copper slag grit is the only known material suitable for use in Portland cement. It is also usable in paving asphalt; however, the acceptability of other slag grits in that particular product is not known. Recycle of used copper slag grit through such consumers is currently under evaluation by the Long Beach NSY and will be followed with interest by NCEL. It should be borne in mind, however, that such recycle opportunities, if indeed real, may not exist within reasonable shipping distance of all Navy activities that produce spent blasting grit.

6.2.7 Painting Operations

The largest contributing factor to the generation of painting wastes comes from off-spec material, expired shelf-life material, or too large volume cans for small jobs. This waste may be eliminated through improved management practices, as recommended in Section 6. .1.

Part I - Wastewaters

RECOMMENDATION: Reduction of wastewater volume and solids loading can best be achieved through conversion of wet spray booths to dry air pollution control devices and the acquisition of paint application equipment that will reduce overspray. Development of both of these capabilities is, therefore, recommended.

DISCUSSION: The wastewaters are being handled through the IWTP. Since current treatment is satisfactory, no recommendations are forthcoming. The only alternative to reduce the amount of wastewater generated is to reduce overspray and convert to dry filter booths. It is, therefore, appropriate to conduct research on the applicability of commercially available dry filter booths for the various Navy painting operations. This technology will dramatically reduce the volume of wastewater and subsequent paint sludge generated. Since dry filter booths are successful in selected applications within the Navy, immediate implementation is suggested for activities operating under similar circumstances.

Overspray and waste paint may be minimized by the following techniques:

1. Utilization of plural media spray technology for epoxy paint mixing and application is a proven technology and may be implemented immediately.

2. Where wet spraying is required, airless or air-assisted, airless sprayers can be used for increased transfer efficiency. By increasing transfer efficiency, less paint is required, which is an effective means of decreasing overall VOC emissions. All wet spray techniques, including water-based systems, can be used in conjunction with electrostatic spraying to further increase transfer efficiency.

3. The use of wet spray technology is largely based upon tradition and subjective views of the painter. It is recommended to conduct a study on the current effectiveness of liquid spray technology for various painting requirements and remove personal bias in the selection of the technology best suited for Navy applications. There is an on-going research program within the EPA to establish a methodology for determining spray painting transfer efficiency. The establishment of a standard method will aid in the evaluation of the test results from various equipment manufacturers. Currently, manufacturers use methods developed in-house, making it impossible to compare the test results and efficiency claims from one manufacturer to another.

4. RDT&E should be initiated to evaluate the benefits of electrostatic and powder paint application.

Part II - Waste Solvents

RECOMMENDATION: The feasibility of using powdered coatings for a variety of Navy applications should be studied. RDT&E projects should then be planned, wherein the validity of these results is established in practical coating evaluations.

DISCUSSION: Waste solvents can be reduced by converting to dry powder coating, where appropriate, and converting to water-based/reducible coatings, where the mission is not compromised. This is already being implemented at some Navy activities, such as NIROP Pomona. It is appropriate that R&D necessary to determine suitable powdered coatings, without compromising coating function, should be conducted. The Naval Avionics Development Center (NADC) and DTRC have initiated programs in this area.

Treatment modifications are already underway at many activities through the implementation of the CNO-mandated USE program. This program will actively enforce the recycling and reclamation of waste solvents. Used solvents may also be sold or donated through DRMO. No activity should have to pay for disposal of a hazardous waste with the above options available. The only wastes that may require disposal or further treatment are sludges produced from solvent recovery stills.

Part III - Dry Paint Filters

RECOMMENDATION: None

DISCUSSION: Upon conversion to dry filter booths, a new waste stream will be generated. Currently, this waste is not considered hazardous and may be disposed of in Class II landfills.

Part IV - Paint Sludge

RECOMMENDATION: None

DISCUSSION: Although paint sludge will be reduced upon implementation of dry filter booths and through improved coating efficiencies, a small amount will still be generated. This must be disposed of in a designated hazardous waste landfill. There are no further recommendations for reducing paint sludge, other than through the use of dry filter booths.

6.2.8 Hazardous Waste from Munitions Demilitarization

RECOMMENDATION: None

DISCUSSION: It is considered appropriate that the current direction be maintained in managing: (1) overage/ defective munitions: and (2) waste propellant and explosives that cannot be marketed by DRMO. The combustive approach used in disposing of both types of wastes is considered proper and cost-effective. It is far less hazardous than the only possible alternative that could be suggested - chemical digestion - an approach omitted from the technical assessment specifically because of the danger factor.

The new generation of demil munitions destructors is well designed and should continue to be used for lesser caliber ammunition, pyrotechnics and moderate energy explosive devices.

Planning aimed at the phasing out of most ABG operations in favor of RCRA-permittable hazardous waste incinerators for burning uncased, high energy (H.E) wastes should also be expedited. Such planning should include particular attention to schedule pressures of pending regulatory constraints as well as the furnace design features required to handle H.E. feed material deflagrations and to minimize NOx emissions. An important aspect in both types of incinerators is the ash disposal. Studies should be conducted to determine the leachability of furnace ash (metals separated) and to establish the technical approaches that might be exploited in disposing of such wastes. Some ultimate disposal will doubtless still be necessary for various waste streams regardless of the Navy's best efforts to minimize HW production. Because use of landfilling technique will be increasingly denied to HW disposers, combustion processes will become more popular and ash disposal more critical a problem. In the interest of economy, a small program should be instituted within the Navy to consider all aspects and types of hazardous ash, possibly including coal ash. The purview of activity could cover the leachability issue and regulatory conflict areas, as well as technology for the detoxification of the HW material by digestion, fixation, encapsulation, incorporation within building/paving materials etc.

6.2.9 Hazardous Wastes From Piping Flushing Operations

RECOMMENDATION: Substitutes for CFC cleaners should be identified, evaluated for their funtional suitability and environmental acceptability, and be put into pilot usage at appropriate sites.

DISCUSSION: The technology assessment clearly showed that the current practice of CFC flushing combined with solvent recycling should be continued. Activities should make full use of CFC recycling operations and provide this service to any shops that use CFC for other cleaning operations. However, freon is an expensive solvent and, being highly volatile, poses air pollution problems. It is regarded as destructive to the UV-shielding ozone layer in the stratosphere. The U.S. has recently begun an initiative aimed at the worldwide ban or use-restriction of fluorochlorocarbons (freon 113 is trifluorotrichloroethane). An investigation of alternative solvents that would improve the cost-effectiveness of the process and reduce environmental hazards is warranted, even though no waste minimization benefits would be derived from solvent substitution.

Wastes generated from trisodium phosphate (TSP) and acid flushing of piping systems are primarily treated in-house at IWTPs. One activity, Charleston NSY, neutralizes TSP wastes on barges, prior to discharge in sanitary sewers. Two activities, Puget Sound NSY and Long Beach NSY, do not treat these wastes on-site. Off-site treatment by contractors is cost-prohibitive and should be discontinued. Alternative treatment techniques for acid/alkali wastes is discussed in detail under Sections 3.16 and 6.2.16.

6.2.10 Boiler Lay-up Procedures

RECOMMENDATION: For the near term, therefore, it is recommended that the steam lay-up procedure be utilized for servicing fleet ships in any activity with a lay-up facility that has a demonstrated capability of delivering dockside steam fulfilling current NAVSEA standards. Those activities not so equipped should continue using the wet (chemical) lay-up, until such time as their boilers are brought into conformity. It is also recommended that the capability of continuous monitoring of steam purity be developed to ensure that ship boilers are not being fouled by substandard steam being delivered under transient circumstances, of which plant personnel may not always be aware.

DISCUSSION: Of the techniques evaluated, steam lay-up was found to be the preferred approach. This and dry lay-up (with nitrogen gas) result in complete elimination of HW and, thus, the need for treatment or disposal. Steam lay-up scored considerably better than either dry lay-up or the usual practice of protecting steam circuitry with a solution of a reducing agent (nitrite). The wet lay-up option, wherein the solution is saved and reused, proved less attractive than the existing practice of treating and discarding the wastewater.

The main problem with the favored process of steam lay-up, particularly for extended periods of time, is that the purity of steam produced by many Navy shore activity plants is not adequate for use in marine boilers, even under low flow conditions for relatively short berthing periods. Dockside steam requirements promulgated by NAVSEA (See Section 3.10) are intended to correct this situation through the use of more effective feedwater processing procedures. It will, however, be some time before all activity steam plants can be brought into conformity.

6.2.11 Boiler Cleaning Operations

In terms of NSY marine boiler maintenance practices, a significant change can be effected to reduce wastes from boiler cleaning. This would involve cleaning boilers only when they need it, rather than when cleaning happens to be scheduled. There is no evidence of a Naval policy, such as routine ASME boiler inspections, that would promote the objective of realizing a reduced frequency of boiler cleaning.

Part I: Waste from Nuclear-powered Ships and Submarines (NOS)

RECOMMENDATION: NCEL is currently engaged in RDT&E aimed at the on-site treatment of these wastes. It is recommended that ongoing research in this area be continued.

DISCUSSION: The technical evaluation conducted on the present effort supports this recommendation and identifies an appropriate (nearly equivalent in merit) fall-back technology. The nature of these processes are classified and are not discussed here.

Part II: Waste Sodium Nitrite

RECOMMENDATION: Since the sodium nitrite solution used in hydroblasting is used once-through, producing excessive volumes of wastewater, it is recommended that procedures be developed wherein minimal quantities of the solution are utilized through a circulation technique.

DISCUSSION: As called for in Reference 3-29, the $NaNO_2$ hydroblast solution would not be allowed to drain to the bilges, but would be pumped from the boiler drum back to a holding tank to be recirculated through the system, until hydroblasting has been completed. The solution would be filtered in order to remove scale particles. There is a potential for 90 percent volume reduction with only minor expense or impact on operations. According to Reference 3-10, the resultant wastewater may be directly sewered. A research program, as outlined by NCEL (Reference 3-29), is, therefore, recommended. This would consist of the design and piloting of a recirculating hydroblast system for evaluation on Navy vessels that are berthed at an appropriate NSY and require boiler cleaning.

Part III: Waste Hydrochloric Acid

RECOMMENDATION: Hydrochloric acid use in boiler cleaning should be limited to the greatest degree possible.

DISCUSSION: Because of the problem of tube thinning caused by HCl, this acid is no longer the cleaning agent of choice in the Navy. In the interest of standardization and HWM, it is recommended that HCl be discontinued altogether for boiler cleaning operations. When and where HCl must be used, it is strongly recommended that routine inspection methods, such as those described in Section 3.11, first be applied.

6.2.12 Fluids Change-out

RECOMMENDATION: Continue the ongoing implementation of the Used Oil and Solvent program.

DISCUSSION: Currently, the Navy is addressing this issue through the Used Oil and Solvent (UO&S) recycling management program. This is the best practicable management option at this time and is being implemented Navywide. A Used Oil and Recycling Guide has been prepared and provides information on the types of UO&Ss generated and specific recommendations on handling, treatment, recycling, and disposal of these materials. Implementation of the UO&S program, which is endorsed by this IDR, consists of an inventory and quantification of UO&S sources, their segregation, and development of recycling alternatives. The cognizant activity for implementation of USE is NEESA. Further details are available by contacting Mr. Wallace Eakes, AV 360-3351.

6.2.13 Battery Repair and Replacement

RECOMMENDATION: Develop strategies for utilizing Navy industrial waste acids (and alkalies) as reagents to supplement IWTP chemistries.

DISCUSSION: The technical assessment of waste sulfuric acid management at battery shops results in a strong recommendation of the current practice at many shops. This consists of neutralizing the acid in the shop area and sending the product for release at the IWTP. The concept of using the acidic battery waste as a neutralizing chemical was not attractive, partly because of the volumetrics. The waste acid has been too diluted to be economical as an IWTP reagent. The continued use of outside contractors to process such wastes scored poorly. It is, therefore, recommended that activities operating shops that do not have neutralization capability, install such equipment.

6.2.14 Solvent Operations

RECOMMENDATION: See Item 6.2.12.

DISCUSSION: Essentially, all of the HWM opportunities associated with this problem area are addressed by the USE Program, which is strongly endorsed by this IDR. This program is being implemented at NEESA, where further information may be obtained by contacting Mr. Wallace Eakes (A/V 360-3351).

6.2.15 Bilge and Ship Tank Derusting

RECOMMENDATION: Continue the support for the ongoing NCEL projects in this area.

DISCUSSION: The analysis of the citric acid ion exchange recycle R&D concept versus the existing practice of outhaul for contractor treatment produced a technical assessment in which the figures of merit were very close but that still favored the recycle approach. The economics, however, strongly favored the ion exchange scheme, largely because of the cost savings with citric acid. The parameters that weighed against the R&D approach were risk and logistics. All R&D projects were routinely penalized through both the risk factor (in this case, on the heavy side) and the logistics element dealing with the availability of the alternative technology. However, since the use of an ion exchange for the chemistry considered here suggests a rather challenging process in practical application, other logistics scores were also weighted against the R&D approach. The scheme, nonetheless, proved viable and is, accordingly, recommended.

Work is now in progress at NCEL to develop an ion exchange process that will recover citric acid from derusting waste solutions. The R&D plan adopted is well designed and is fully consistent with the objectives described in this IDR. This project is, accordingly, endorsed as fulfilling the intent of the present recommendations.

6.2.16 Hazardous Wastes From Metal Preparation

RECOMMENDATION: See Item 6.2.13

DISCUSSION: Technology assessment clearly showed that off-site treatment by contractors of the contents of shop metal treatment baths should be avoided in favor of on-site utilization of such wastes as IWTP chemicals. Of the alternatives assessed (regeneration was not, but see below), the procedure of using bath liquids as part of the flocculation and heavy metal precipitation stage at the IWTP proved quite attractive. Since the technique is not currently employed by the Navy, and its industrial utilization is otherwise somewhat limited, it is recommended that a pilot demonstration be undertaken at one of the smaller IWTPs, where such bath liquids are used. Waste alkali and acid bath liquids compatible with the process (hydrofluoric acid (HF) is questionable) would be stored at the IWTP. Iron would be dissolved in the acid or comixed with ferric chloride, as it is withdrawn. The mixture would then be neutralized with waste alkali to produce a ferric hydroxide floc. This would be supplemented with lime (in much smaller quantities than usual) to precipitate heavy metals from both the waste bath liquids and the other streams being treated at the IWTP. The process would, thus, dispose of the waste chemicals, significantly reduce the IWTP need for reagent chemicals, and lower the amount of sludge that would require disposal.

A technological aspect of this particular HW area is the purification of metal preparation bath liquids by adsorptive techniques. Commercial systems are available that claimed to facilitate circulation of working bath acids through resin columns and return clean acid that is free of heavy metals and other undesirable waste to the bath. This process would greatly extend the life expectancy of a bath, possibly eliminating the need for periodic dumps. There is, however, a HW stream generated (containing the rejected heavy metals) that requires treatment and disposal. In any case, a technical assessment was not attempted on systems of this type, since the technical information available was limited, and a number of questions arose from the field concerning their effectiveness and reliability. However, since the principal of operation is attractive and technically conceivable, it is recommended that RDT&E studies be initiated in this area leading, if warranted, to actual hardware assessments.

6.2.17 Hazardous Wastes from Chemical Paint Stripping

Part I - Paint Sludge

RECOMMENDATION: This material can and should be disposed of in the same manner as recommended for paint sludge generated during paint application. See Section 6.2.7 (Part IV).

Part II - Wastewater

RECOMMENDATION: Eliminate chemical paint stripping to the extent possible, and continue present NCEL RDT&E to develop a biological process for treating any wastewaters that cannot be eliminated, by the introduction of plastic media blast depainting.

DISCUSSION: At the present time, wastewater generated by chemical paint stripping is, generally, not being specifically treated. Even though the implementation of plastic media blasting techniques will reduce the use of chemical paint stripping by as much as 90 percent, some wastewater will continue to be produced. Since it is unlikely that environmentally safe paint stripping gels will ever be developed, a capability for treating such reduced flows of paint stripping wastewater should be developed.

The technology assessment indicated that chemical treatment using H_2O_2 is the preferred approach. The scoring, however, was very close to that for the use of the rotating biological contactor (0.18 vs 0.19, respectively) and even to that for the other biological system considered, the Mansville immobilized biocatalytic process (0.23). At the present time, NCEL is evaluating a treatment technology for the paint stripping wastewaters, per Reference 3-14. This has been limited to only biological processes, although chemical process technology was also recommended. In view of the results obtained in the present, independent evaluation, it is recommended that the current approach should, by all means, be continued but that the H_2O_2 treatment approach also be included in the studies. It is also recommended that the immobilized biocatalytic process be considered, in addition to the other biological processes now under investigation.

A NAVSEA-proposed pretreatment effect is to concentrate the paint stripping wastewaters, using freeze crystallization before treating the HW fraction. Technology assessment failed to demonstrate that this approach could be cost-effective, even under the most optimistic analytical conditions. The process could be useful, however, in other applications,where recycle of chemical values from wastewaters (such as pink water) is contemplated.

6.2.18 Hazardous Waste from Torpedo Cleaning Operations

Part I - Torpedo Fuel Tank Drainings

RECOMMENDATION: The present process used at NUWES Keyport for recycling Otto II fuel and cleaning the admixed sea water (See Sec. 3.18) is considered excellent technology that probably cannot be improved upon. It is recommended that this process be installed at the other four Navy activities servicing torpedoes.

Part II - Torpedo Afterbody Washwater

RECOMMENDATION: Support the ongoing NUWES treatment development, involving cyanide chloroxidation and wastewater tertiary treatment with the existing activated charcoal system.

DISCUSSION: The present practice of disposing of this aqueous waste by combustion is not considered cost-effective and will, doubtless, become much less acceptable, as RCRA constraints come into play. The pilot system that NUWES Keyport plans to evaluate (See Sec. 3.18) should prove cost-effective and is recommended for Navywide implementation, following successful T&E.

The HAMTAM assessment of the three processes considered practical for the application showed only a modest edge of the NUWES pilot system over the contracted combustive disposal currently being practiced. A more convincing superiority would have been obtained, if the R&D penalty had not been applied to the NUWES pilot process. In this instance, however, the treatment approach is well thought out, and the process elements all appear reliable and effective. The concept of sending the effluent from the clarification/CN-oxidation steps to the existing charcoal sorption installation is particularly attractive and praiseworthy. Another consideration is that the package unit for particulate/cyanide removal, which has already been acquired, will, doubtless, be capable of handling the entire wastewater load, merely through increasing batch processing frequency.

Part III - Mineral Spirits Cleaning Wastes

RECOMMENDATION: Continue support of the NCEL project for recovery of these wastes for recycle, using the reflux/distillation technique.

DISCUSSION: It is conditionally recommended that the previous practice of cofiring this material with design fuels, a combustive process used in existing steam plants (see Section 3.18), should be discontinued until it is shown to be RCRA-conformative and unless the present preferred process under investigation (reflux/distillation) does not prove cost-effective. It is highly recommended that the feasibility of recycling the petroleum solvent by distillation continue to be investigated at NCEL. Filtration might also be considered, although the resultant product purity would be of questionable adequacy for recycle to the original process. DTRC is currently funded to evaluate for shipboard use a small filtration unit designed to recover mineral spirits, such as PD 680 II. Larger units are available that may be suitable ashore for reclaiming torpedo mineral spirits cleaning wastes.

6.3 REFERENCES

6-1 Economics of Wastewater Treatment Alternatives for the Electroplating Industry, Environmental Protection Agency Report No. EPA625/5-79-016, June 1979

6-2 Navy Electroplating Pollution Control Technology Assessment Manual, Naval Civil Engineering Laboratory Report No. TM 54-83-11CR, Centec Corp., June 1983

6-3 W.H. Glaze et al., Pilot Scale Evaluation of Photolytic Ozonation for Trihalomethane Precursor Removal, EPA Report No. 600/2-84-136, August 1984

CHAPTER 7

TECHNOLOGY GOALS

7.1 OVERVIEW

In order to reduce hazardous waste streams, the Navy must fill numerous technological deltas. These deltas are summarized below and range from technologies that are readily implementable to those requiring exploratory research. Table 7-1 focuses on a highly integrated R&D HWM plan aimed at fulfilling/closing these technology deltas. Supporting data are given in Chapter 8 and Appendix M.

This R&D HWM plan was developed as part of the IDR preparation effort and was reviewed together with the other elements of the IDR as described in the Preface. As a result of this review process, which involved an active interface between NAVFAC and NCEL, the latter formulated and recommends a HWM Program that would be budgeted as shown in Table 7-2. The differences between Table 7-1 and 7-2 reflect the influence introduced by funding availability, scheduling pressures, and the pace of related work ongoing at other Government agencies.

7.2 APPLICATION OF IMPROVED KNOW-HOW (READILY IMPLEMENTABLE)

The following technology concepts are not yet in general or optimal use in the Navy but are found to varying degrees of scale and development in successful application in either or both domestic and foreign industrial sectors. Many of these HWM technological opportunities have, however, been already, or are on the verge of being, implemented at selected Naval facilities.

- Plastic Media Blasting
- Used Solvent Elimination Program
- Hard Chrome Plating
- Waste Acid/Alkali as IWTP Reagents
- Dry Paint Booth Conversion
- Used Oil Reclamation and Recycle
- Delisting
- Mechanical IWTP Sludge Dewatering
- Otto II Fuel Recycling
- Reduced Overspray Paint Technology
- Dual Media Spray Technology
- Steam Purity Testing
- Optimal Use of the Conventional IWTP Process
- Minimal HW-producing Electroplating Technologies

7.3 APPLICATION OF TECHNOLOGIES NOT COMMERCIALLY AVAILABLE

These technologies are in the R&D sector and may be implemented within the Navy but only after being evaluated and developed for Navy needs in appropriate 6.3/6.4 project work. At the present time, these systems are not available as marketed industrial/commercial products and/or services.

- Recycling of Hydroblast Wastewater
- Aircraft Paint Stripping Wastewater Treatment
- Nonpersistent Emulsifiers
- Plastic Media Blasting
- Reducing Blasting Grit Hazards and Type
- Recycle of Steam Generator Wastes
- Recycle of Bilge Tank Cleaning Wastes
- Cyanide Oxidation/Elimination
- Ion Exchange/Metal Recovery
- Waste Acid/Alkali as IWTP Floccing Reagents
- Reuse Technology for Pickling/Electroplating Bath
- Thermal Combustion Technology
- Distillation of Spent Torpedo Solvents
- Torpedo Afterbody Washwater Treatment
- Encapsulation/Fixation
- Peroxidation of Pink Water

7.4 ADVANCES IN TECHNOLOGY (EXPLORATORY DEVELOPMENT)

These technologies require exploratory development to advance the state of technology, with respect to specific technical parameters and their application to Naval HWM problems.

- Supercritical Fluid Technology
- Innovative Encapsulation/Fixation
- New Solvent Selection (Freon elimination)
- Carbon Dioxide Pellets to Strip Paint
- New High-energy Battery Types
- HW Thermal Destruction
- TNT Recovery by Freeze Crystallization of Pink Water

Table 7-1. INTEGRATED R&D HWM PLAN ($K)

Number	Short Title	FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RC	WR	RCP
1	Development of Beneficial Use of Acid and Alkali Waste Techniques at IWTP	75		100	100	125	400						
2	Recycling of Hydroblasting Wastewater			70	70	80	120	40	80	50	50		
3	Encapsulation of Hazardous Waste at Landfills Using Innovative Methods/Materials	170		425		465							
4	Wet to Dry Conversion of Paint Spray Booth Air Filtering Systems	15	35	170	80	225	150						
5	Development of Purification and Reuse Tech for Pickling/Electroplating Bath			100		100	100	100	200				
6	Aircraft Paint Stripping			275	200	400	250						
7	Combusted Hazardous Waste Ash Hazards and Disposal Study	2	25	125	25	250	25						
8	Hazardous Wastes Thermal Destructive Sys.			260	390	180	570	125	125				
9	Nonpersistent Emulsifying Degreasers for Bilge Cleaning					180		80					
10	New Solvent Selection for Pipe Cleaning							30		80	15	65	80
11	Hazardous Waste Minimization Through Used Oil Reclamation and Recycle							50	25	50	150	75	25
12	Identification of Hazardous Wastes for Potential Delisting							140		50			
13	Third Phase Monitoring Study of Plastic Media Blasting Facilities	40	75										
14	Five Tasks for Improving the Implementation/Operation of PMB in the Navy			330	515	320	715	260	440				
15	Reducing Blasting Grit Hazards and Type	10	25	70	105	65	95						
16	Exploring the Use of Frozen Carbon Dioxide to Strip Paint from Hulls and Bilges									75	130	75	85
17	Furnace Requirements for Burning Hazardous Wastes	40		170	40	200		120	150	100	150		
18	Reduction of Naval Shipyard Hazardous Waste									225	275	125	150

Table 7- 1 is continued on next page

Table 7-1. INTEGRATED R&D HWM PLAN (Continued)

Number	Short Title	FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RC	WR	RCP
19	Developmental Evaluation of Distilling Spent Torpedo Solvents	35	35	60	75	100	75						
20	Operational Testing of Cyanide Oxidation System			50	200								
21	Ion Exchange/Metal Recovery System	60		150	300								
22	Supercritical Fluids			50	65								
23	Non-cyanide Electroplating				300		300		400				
	TOTAL FUNDING	447	195	2,405	2,465	2,690	2,800	945	1,420	630	770	340	340
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RCP
		FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	

Legend: WR = Work Request; RCP = Request for Contractual Procurement

Table 7-2. INTEGRATED R&D HWM PROGRAM ($K)

Number	Short Title	FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RC	WR	RCP
1	Development of Beneficial Us of Acid and Alkali Waste Techniques at IWTP			75		100	100	125	400				
2	Recycling of Hydroblasting Wastewater			70	70	100	140	100	110				
3	Encapsulation of Hazardous Waste at Landfills Using Innovative Methods/Materials					170	150	225	200	265	200		
4	Wet to Dry Conversion of Paint Spray Booth Air Filtering Systems			15	55	75	200	225	175				
5	Development of Purification and Reuse Tech for Pickling/Electroplating Bath			100		100	100	100	200				
6	Aircraft Paint Stripping			230		200		400		250			
7	Combusted Hazardous Waste Ash Hazards and Disposal Study	2	25	175		250		25					
8	Hazardous Wastes Thermal Destructive Sys.							260	390	180	570	125	125
9	Nonpersistent Emulsifying Degreasers for Bilge Cleaning			80		180		80					
10	New Solvent Selection for Pipe Cleaning			30		250	100	130	100				
11	Hazardous Waste Minimization Through Used Oil Reclamation and Recycle					50	25	50	155	75	25		
12	Identification of Hazardous Wastes for Potential Delisting					240		150					
13	Third Phase Monitoring Study of Plastic Media Blasting Facilities			40	75								
14	Five Tasks for Improving the Implementation/Operation of PMB in the Navy			35	147	85	100						
15	Reducing Blasting Grit Hazards and Type					10	25	70	105	65	95		
16	Exploring the Use of Frozen Carbon Dioxide to Strip Paint from Hulls and Bilges					75	130	75	85	75	350		
17	Furnace Requirements for Burning Hazardous Wastes							120		120			
18	Reduction of Naval Shipyard Hazardous Waste					225	275	125	150	150	500		

Table 7-2 is continued on next page

Table 7-2. INTEGRATED R&D HWM PROGRAM (continued)

Number	Short Title	FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RC	WR	RCP
19	Developmental Evaluation of Distilling Spent Torpedo Solvents	35	35	60	75	100	75						
20	Operational Testing of Cyanide Oxidation System			50	200	150							
21	Ion Exchange/Metal Recovery System	60		150	300								
22	Supercritical Fluids					250		250		75			
23	Non-cyanide Electroplating					300		300		400			
	TOTAL FUNDING	97	60	1,110	922	2,910	1,420	2,810	2,065	1,655	1,740	125	125
		WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RCP	WR	RCP
		FY 87		FY 88		FY 89		FY 90		FY 91		FY 92	

Legend: WR = Work Request; RCP = Request for Contractual Procurement

CHAPTER 8

CAPABILITY GOALS AND OPTIONS

8.1 OVERVIEW

This section specifies the operational technical capability goals to be attained in order to achieve RCRA compliance and hazardous waste minimization. These goals entail significant improvements over current Navy practices and include both technology improvements and system/component development. The goals have been organized into four major categories: process, treatment, management, and ultimate disposal. A summary of the full spectrum of RDT&E options that can be supported by NCEL are presented herein. The detailed, integrated plan is presented as Appendix M. Detailed RDT&E plans and specific options are not given for those goals that require the expertise of other Naval laboratories.

8.2 PROCESS CAPABILITY GOALS

PART I - CHEMICAL SUBSTITUTION

8.2.1 Substitution of Bilge Cleaning Chemicals

The capability goal of this category is to replace the emulsifying cleaners being used in bilge cleaning with cleaners (fast-breaking, nonpersistent, nonemulsifying) that produce a waste that is easier and less expensive to treat. This will minimize oily sludge generation and reagent usage. Minimal test and evaluation are indicated in Option 9.

8.2.2 Substitution of Boiler Lay-up Solution

The capability goal of this category is to improve dockside steam requirements to enable conversion to steam lay-up. A proposed NCEL program will be initiated but not until FY90. Additional support is required to develop a quick test that will evaluate the steam quality and ensure its purity.

8.2.3 Substitution of Pipe Cleaning Solvents

The capability goal of this category is to identify a non-halogenated solvent to replace Freon 113 used in piping cleaning operations. Option 10 outlines a limited effort for an IFR and laboratory evaluation.

8.2.4 Substitution of Blasting Grit

The capability goal is to reduce the volume of hazardous blasting grit by substituting a nonhazardous grit or recycling the grit to remove the contamination. Option 15 encompasses both approaches.

8.2.5 Substitution of Lead-acid/Lithium Batteries

High energy-density battery systems will reduce the usage of traditional battery systems that produce hazardous waste streams.

PART II - RECYCLE/REUSE

8.2.6 Recirculation Of Hydroblast Solution

The capability goal of this category is to recycle the boiler hydroblasting solutions, thereby, using a smaller volume of solution to do the same job with a lower volume of resultant wastewater. This will require a T2 level program to test and evaluate the best system for hydroblast fluid recycling. Option 2 describes the proposed effort.

8.2.7 Bilge, Tank, and Boiler Cleaning and Derusting

The capability goals for this category are to reduce the volume of shipyard wastewaters (e.g., citric acid, sodium nitrite) produced from the cleaning and derusting of ship bilges, tanks, and conventional marine boilers. This can, at least partially, be accomplished through the recyling of cleaning solutions and reuse of reagents. This effort has already been funded at NCEL. The current level of effort is described in Option 18.

8.2.8 Waste Acid/Alkali as IWTP Reagent

The capability goal for this category is to reduce hazardous waste by utilizing potential waste acid and alkali solutions as reagents in IWTP operations. This would require a T3 level of effort to identify operational parameters, and this effort is described in Option 1. This will cover areas, such as metal plating and battery shop wastewater.

8.2.9 Metal Prep Bath Purification Systems

The capability goal for this category is to reduce hazardous wastes by purification of the waste stream for continued use. A T3 level of effort would be required to identify operational parameters and a T2 program, to evaluate the best system to treat the metal preparation bath liquids. The level of funding is described in Option 5.

8.2.10 Distilling Spent Torpedo Solvents

The capability goal is to recover spent torpedo solvents using distillation. A comprehensive RDT&E scheme is presented in Option 19.

8.2.11 TNT Recovery by Freeze Crystallization

The capability goal is to concentrate pink water, in order to recover and recycle TNT values. A comprehensive scheme has not yet been developed, since the NAVFAC-defined purview of the present IDR specifically excluded consideration of the LAP and related ordnance processes for HWM. The study was, accordingly, restricted to treatment effects (end-of-pipe).

PART III - PROCESS MODIFICATIONS

8.2.12 Dry Paint Booth Conversion

The capability goal of this category is to eliminate wastewater and subsequent sludge from painting operations through conversion to dry booths. This modest effort is described in Option 4.

8.2.13 Painting Technologies

The capability goal for paint application is to acquire equipment that can operate with reduced amounts of overspray. Research is already underway at NCEL and EPA to achieve improved transfer efficiencies. Test and evaluation will be required to determine whether new application methods meet Navy criteria.

8.2.14 Paint Stripping Utilizing Solid Carbon Dioxide

The capability goal is to strip paint from selected hardware configurations using solid carbon dioxide pellets. Option 16 details the required resources and timeframe.

8.2.15 Plastic Media Blasting

There are six specific tasks related to the overall goal of using plastic media blasting as an alternative to chemical paint stripping of aircraft and components. This integrated program is detailed in Options 13 and 14.

8.2.16 Electroplating Bath Purification

The capability goal is to purify pickling/electroplating baths for extended use, preferably while on-line. Option 5 details the 3-step approach program.

8.2.17 Cyanide Oxidation or Elimination

The immediate goal is to provide an electrolytic system that allows for metal recovery and cyanide oxidation. This goal has been partially funded, as indicated in Option 20.

The ultimate goal is to totally eliminate the use of cyanide in Navy electroplating. A good start has been made in this direction, and the funding requirements for achieving this goal are shown in Option 23.

8.3 TREATMENT CAPABILITY GOALS

8.3.1 Photolytically Enhanced Peroxidation of Pink Water

The capability goal for ordnance hazardous waste is to treat the waste with hydrogen peroxide. A T&E program is underway at NWSC Crane, to be carried out in conjunction with a MILCON request for construction of such a plant at Indian Island.

8.3.2 Aircraft Paint Stripping

The capability goal for managing wastewater from chemical paint stripping is greater destruction of phenolics and control of VOCs. This area is currently being funded, as shown in Option 6.

8.3.3 Ion Exchange/Metal Recovery

The goal is to develop a system that will treat cadmium and other metal cyanide plating wastewaters using ion exchange and electrolytic metal recovery technologies. Option 21 outlines the current plan underway at NCEL.

8.3.4 Supercritical Fluids

The capability goal is to investigate supercritical fluid technolgy for the treatment of numerous hazardous waste streams. RDT&E is suggested in Option 22. Previous research in this field was sponsored by NCEL.

8.4 MANAGEMENT CAPABILITY GOALS

8.4.1 Shelf Life Specifications

RDT&E required to develop scientific procedures for assigning and verifying the shelf life of NSL items is already underway at NAVSUP.

8.4.2 HW Inventory Program

Development of a standardized HW nomenclature to be used in the Navy's inventory program. For consistency in reporting, a set of criteria that will be used in determining what should or should not be reported to the HW inventory need to be established.

8.4.3 Preventive Maintenance Procedures

There is an RDT&E gap associated with this in both determining where the inspection-before-servicing policy can be applied and what methodology should be applied to determine whether servicing should be delayed.

8.4.4 Used Solvent Elimination Program

Technology requirements in the used oil recycle features of this program are needed. Option 11 investigates these aspects.

8.4.5 Ship-to-shore HM/W Demonstration Program

Further T&E is required for large-scale operations (aboard capital ships).

8.4.6 Hazardous Waste Delisting

The capability goal is to provide a methodology to identify hazardous wastes that can be delisted. Option 12 provides a short-term effort is this area.

8.5 ULTIMATE DISPOSAL CAPABILITY GOALS

8.5.1 Encapsulation

RDT&E is required to determine adequate materials for encapsulation of Navy hazardous wastes. Option 3 suggests a detailed six-phase program.

8.5.2 Hazardous Waste Combustion

The goals of this area are to provide the capability of thermal destruction for Navy hazardous wastes. Options 7, 8, and 17 cover the various aspects of this program. Included are determining furnace requirements, combusted ash hazards, and appropriate thermal systems. Demil operations are covered in this area.

8.6 RDT&E OPTIONS

The following 23 RDT&E options are a summary of the hazardous waste minimization proposals presented in Appendix M. These options give a synopsis of the resources, time, and milestones necessary to complete the aforementioned goals for hazardous waste minimization in the Navy. The options are not presented in any order of prioritization, and all may, therefore, be considered with equal emphasis. Additional options will also be defined in the near future as the RDT&E efforts now on-going within the laboratory system of the Navy and other Government and non-Government systems produce results that encourage application studies with respect to HWM.

OPTION 1

DEVELOPMENT OF BENEFICIAL USE OF ACID AND ALKALI WASTE TECHNIQUES AT IWTP

	Cost ($K)					
	FY87		FY88		FY89	
	WR	RCP	WR	RCP	WR	RCP
IFR	75					
FFR			100	100		
Field Test/UDP					125	400
TOTAL	75		100	100	125	400

OPTION 2

RECYCLING OF HYDROBLASTING WASTEWATER

	Cost ($K)							
	FY88		FY89		FY90		FY91	
	RCP	WR	RCP	WR	RCP	WR	RCP	WR
Initial Feasibility	30	30						
Laboratory Tests	40	40	60	40				
Final Feasibility			60	40	80	40		
User Data Package							50	50
TOTAL	70	70	120	80	80	40	50	50

OPTION 3

ENCAPSULATION OF HAZARDOUS WASTES AT LANDFILLS USING INNOVATIVE MATERIALS AND METHODS

	Cost ($K)					
	FY87		FY88		FY89	
	RCP	WR	RCP	WR	RCP	WR
a. Perform Literature Review		30				
b. Obtain Hazardous Wastes and Chemically Define		140				
c. Perform Leaching Tests With Nonencapsulated Wastes				140		60
d. Perform Leaching Tests With Encapsulated Wastes				150		75
e. Evaluate Different Techniques and Forms of Encapsulation				135		180
f. Conduct Pilot Scale Studies						150
TOTAL	0	170	0	425	0	465

OPTION 4

WET-TO-DRY CONVERSION OF PAINT SPRAY BOOTH AIR FILTERING SYSTEMS

	Cost ($K)					
	FY87		FY88		FY89	
	RCP	WR	RCP	WR	RCP	WR
Concept Feasibility	35	15		20		
Full Scale Process Evaluation			80	150		
Operational Evaluation					150	225
TOTAL	35	15	80	170	150	225

OPTION 5

DEVELOPMENT OF PURIFICATION AND REUSE TECHNOLOGY FOR PICKLING BATH/ELECTROPLATING BATH

	COST ($K)					
	FY88		FY89		FY90	
	WR	RCP	WR	RCP	WR	RCP
IFR	100					
FFR			100	100		
UDP					100	200
TOTAL	100	0	100	100	100	200

OPTION 6

AIRCRAFT PAINT STRIPPING

	Cost ($K)			
	FY88		FY89	
	RCP	WR	RCP	WR
Field Test of RBC Unit	150	125		
Operational Testing	50	125	250	250
Documentation		25		150
TOTAL	200	275	250	400

OPTION 7

COMBUSTED HAZARDOUS WASTE ASH HAZARDS AND DISPOSAL STUDY

	Cost ($K)					
	FY87		FY88		FY89	
	WR	RCP	WR	RCP	WR	RCP
Initial Feasibility						
Literature Search and Technical Assessment	2	25				
Benchscale Studies			125			
Submit Initial Feasibility Report				25		
Evaluations Environmental Impacts					100	
Containment Procedures					100	
Incineration and Disposal Guidance					50	25
TOTAL	2	25	125	25	250	25

OPTION 8

HAZARDOUS WASTE THERMAL DESTRUCTION SYSTEMS

	COST ($K)					
	FY88		FY89		FY90	
	RCP	WR	RCP	WR	RCP	WR
Feasibility Study		50				
Site/Technology Selection	50	50				
Plans and Permits	20	125		50		
Pilot Studies	320	35	70	70		
Demonstration Study			500	50	125	50
Documentation				10		75
TOTAL	390	260	570	180	125	125

OPTION 9

NONPERSISTENT EMULSIFYING DEGREASERS FOR BILGE CLEANING

	Cost ($K)	
	FY89 WR	FY90 WR
Feasibility Study/Survey	80	
Operational Evaluation	100	80
TOTAL	180	80

OPTION 10

NEW SOLVENT SELECTION FOR PIPING CLEANING

	Cost ($K)							
	FY90		FY91		FY92		FY93	
	RCP	WR	RCP	WR	RCP	WR	RCP	WR
Initial Feasibility Study		30	15	80				
Laboratory Evaluation					80	65		20
TOTAL	0	30	15	80	80	65	0	20

OPTION 11

HAZARDOUS WASTE MINIMIZATION THROUGH USED OIL RECLAMATION AND RECYCLE

	Cost ($K)					
	FY90		FY91		FY92	
	RCP	WR	RCP	WR	RCP	WR
Initial Feasibility	25	50				
Final Feasibility/Field Program Design			150	50	25	75
TOTAL	25	50	150	50	25	75

OPTION 12

IDENTIFICATION OF HAZARDOUS WASTES FOR POTENTIAL DELISTING

	Cost ($K)			
	FY90		FY91	
	RCP	WR	RCP	WR
Inventory		60		
Methodology		80		
Recommendations				50
TOTAL	0	140	0	50

OPTION 13

THIRD PHASE MONITORING STUDY OF PLASTIC MEDIA BLASTING FACILITIES

	Cost ($K)	
	FY87	
	RCP	WR
1. Prepare Test Plan	20	20
2. Evaluate Large Facility	55	20
TOTAL	75	40

OPTION 14

FIVE SPECIFIC TASKS FOR IMPROVING THE IMPLEMENTATION AND OPERATION OF PLASTIC MEDIA BLASTING IN THE NAVY

	Cost ($K)					
	FY88		FY89		FY90	
	RCP	WR	RCP	WR	RCP	WR
PMB Use on Missiles						
Complete Initial Data Survey	35	15				
Prepare Test Plan	25	15				
Complete Material Research			175	50		
Developmental Test					150	20
Prepare Implementation UDP						60
TOTAL	60	30	175	50	150	80
Large Facility Automation						
Evaluate Feasibility	40	25				
Develop Automated Procedures	250	125	100	50		
Test the Procedures			140	85		
Conduct Operational Test					140	120
TOTAL	290	150	240	135	140	120
Effect of PMB on Composites						
Complete Initial Data Survey	35	15				
Prepare Test Plan	30	15				
Complete Material Research			200	50		
Developmental Test					150	60
TOTAL	65	30	200	50	150	60

Option 14 continued on next page

OPTION 14 (CONTINUED)

	Cost ($K)					
	FY88		FY89		FY90	
	RCP	WR	RCP	WR	RCP	WR
Ventilation Design						
Proposed Requirements	20	20				
System Analysis	55	40				
Convert to Handbook				50		
TOTAL	75	60		50		
Equipment Evaluation						
Complete Initial Survey		35				
Prepare Test Plan		25				
Evaluate Equipment		25	100	35		
TOTAL	25	60	100	35		
PROJECT TOTAL	515	330	715	320	440	260

OPTION 15

REDUCING BLASTING GRIT HAZARDS AND TYPES

	Cost ($K)					
	FY87		FY88		FY89	
	RCP	WR	RCP	WR	RCP	WR
Initial Data Survey	25	10				
Prepare Test Plan			30	25		
Developmental Evaluation			75	45	65	25
Prepare Implementation Plan (UDP) (TN)						70
TOTAL	25	10	105	70	65	95

OPTION 16

EXPLORING THE USE OF FROZEN CARBON DIOXIDE TO STRIP PAINT FROM SHIP HULLS AND BILGES

	Cost ($K)			
	FY91		FY92	
	RCP	WR	RCP	WR
Initial Data Survey	30	35		
Prepare Test Plan	25	15		
Developmental Evaluation	75	25	85	75
TOTAL	130	75	85	75

OPTION 17

FURNACE REQUIREMENTS FOR BURNING HAZARDOUS WASTES

	Cost ($K)			
	FY87		FY88	
	RCP	WR	RCP	WR
System Development -- Operational Evaluation		60	300	150
TOTAL		60*	300	150

*Existing Funds

OPTION 18

REDUCTION OF NAVAL SHIPYARD HAZARDOUS WASTES

	COST ($K)					
	FY91		FY92		FY93	
	RCP	WR	RCP	WR	RCP	WR
Final Feasibility	275	225				
Optimum Operation			100	75		
User Data Package			50	50	140	135
TOTAL	275	225	150	125	140	135

OPTION 19

DEVELOPMENTAL EVALUATION OF DISTILLING SPENT TORPEDO SOLVENTS

	Cost ($K)					
	FY87		FY88		FY89	
	RCP	WR	RCP	WR	RCP	WR
Initial Feasibility	35	35				
Full Scale Laboratory Evaluation			75	60		
Operational Evaluation					75	30
Prepare Implementation UDP						70
TOTAL	35	35	75	60	75	100

OPTION 20

OPERATIONAL TESTING OF CYANIDE OXIDATION SYSTEM

	COST ($K)			
	FY87		FY88	
	RCP	WR	RCP	WR
Operational Test and evaluation (OT&E)			200	50
TOTAL FAC 112 Funding			200	50
Under FAC 03 funding				
DTE II		270		
UDP (and OTR at present)				150

OPTION 21

ION EXCHANGE/METAL RECOVERY SYSTEM

	Cost ($K)			
	FY87		FY88	
	RCP	WR	RCP	WR
System Development Operational Evaluation		60	300	150
TOTAL		60*	300	150

*Existing Funds

OPTION 22

SUPERCRITICAL FLUIDS

	Cost($K)	
	FY88	
	RCP	WR
Manpower: $100K (1 man-year) Equipment and materials: $10K Support Services: $5K	65	50
TOTAL: $115K		

OPTION 23

NON-CYANIDE ELECTROPLATING PROCESSES

	COST (K$)							
	FY87		FY88		FY89		FY90	
	RCP	WR	RCP	WR	RCP	WR	RCP	WR
Feasibility Study		185*						
Lab Development				300				
Alternative Techniques						300		
Shop Tests & Reports								400
Total $1,185k								

*Existing funds

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7 Fire prevention and control
8 Antenna technology
9 Structural analysis and design (including numerical and computer techniques)
10 Protective construction (including hardened shelters, shock and vibration studies)
11 Soil/rock mechanics
14 Airfields and pavements

15 **ADVANCED BASE AND AMPHIBIOUS FACILITIES**
16 Base facilities (including shelters, power generation, water supplies)
17 Expedient roads/airfields/bridges
18 Amphibious operations (including breakwaters, wave forces)
19 Over-the-Beach operations (including containerization, materiel transfer, lighterage and cranes)
20 POL storage, transfer and distribution

28 **ENERGY/POWER GENERATION**
29 Thermal conservation (thermal engineering of buildings, HVAC systems, energy loss measurement, power generation)
30 Controls and electrical conservation (electrical systems, energy monitoring and control systems)
31 Fuel flexibility (liquid fuels, coal utilization, energy from solid waste)
32 Alternate energy source (geothermal power, photovoltaic power systems, solar systems, wind systems, energy storage systems)
33 Site data and systems integration (energy resource data, energy consumption data, integrating energy systems)
34 **ENVIRONMENTAL PROTECTION**
35 Solid waste management
36 Hazardous/toxic materials management
37 Wastewater management and sanitary engineering
38 Oil pollution removal and recovery
39 Air pollution
44 **OCEAN ENGINEERING**
45 Seafloor soils and foundations
46 Seafloor construction systems and operations (including diver and manipulator tools)
47 Undersea structures and materials
48 Anchors and moorings
49 Undersea power systems, electromechanical cables, and connectors
50 Pressure vessel facilities
51 Physical environment (including site surveying)
52 Ocean-based concrete structures
54 Undersea cable dynamics

TYPES OF DOCUMENTS

85 Techdata Sheets
86 Technical Reports and Technical Notes
82 NCEL Guides & Abstracts
☐ None—remove my name
83 Table of Contents & Index to TDS
91 Physical Security