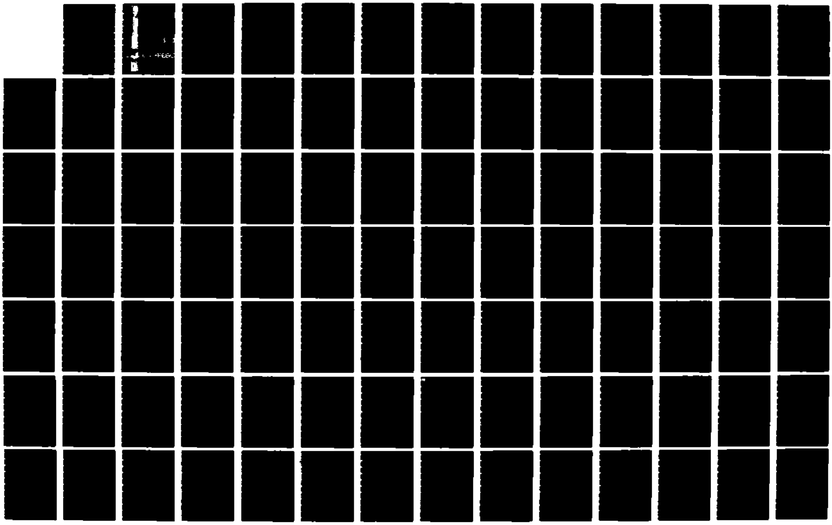
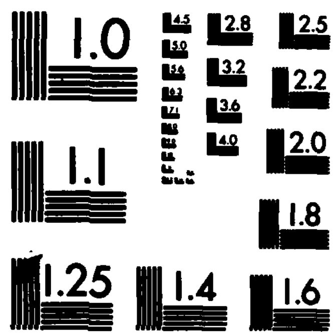
AD-A138 460 AN INVESTIGATION OF TECHNOLOGIES FOR HAZARDOUS SLUDGE REDUCTION AT AFLC (..(U) CENTEC CORP RESTON VA G C CUSHNIE DEC 83 AFESC/ESL-TR-83-42-VOL-3 1/2

UNCLASSIFIED F08635-81-C-0258 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

ESL-TR-83-42

ADA138460

AN INVESTIGATION OF TECHNOLOGIES FOR HAZARDOUS SLUDGE REDUCTION AT AFLC INDUSTRIAL WASTE TREATMENT PLANTS

VOLUME III: Heavy Metal Waste Treatment Research and Development Needs

G.C. CUSHNIE JR.

CENTEC CORPORATION
11260 ROGER BACON DRIVE
RESTON, VA 22090

DECEMBER 1983

FINAL REPORT
SEPTEMBER 1981 - SEPTEMBER 1983

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

AFESC

AIR FORCE ENGINEERING AND SERVICES CENTER

ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFESC/RD (ENGINEERING AND SERVICES LABORATORY). ADDITONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5285 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ESL-TR-83-42
2. GOVT ACCESSION NO.: AD-A138460
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): AN INVESTIGATION OF TECHNOLOGIES FOR HAZARDOUS SLUDGE REDUCTION AT AFLC INDUSTRIAL WASTE TREATMENT PLANTS - VOLUME III: HEAVY METAL WASTE TREATMENT RESEARCH AND DEVELOPMENT NEEDS
5. TYPE OF REPORT & PERIOD COVERED: Final Report, Sep 81 - Sep 83
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): CENTEC Corporation, 11260 Roger Bacon Drive, Reston, Virginia 22090-5281
8. CONTRACT OR GRANT NUMBER(s): F086-35-81-C-0258
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall AFB, Florida 32403
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: PE 62601F, JON 1900-70-16
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Engineering and Services Center, Tyndall AFB, Florida 32403
12. REPORT DATE: December 1983
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES: Availability of this report is specified on the reverse of front cover.
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Electroplating Waste	Sodium Borohydride
Sludge Reduction	Sludge Treatment
Hazardous Sludge	Sludge Washing
Heavy Metal Treatment	Sludge Detoxification

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Hazardous waste disposal costs have risen dramatically in recent years, naking the volume of sludge generated by industrial waste treatment nearly as mportant as the quality of the effluent water. Because of the magnitude of the ir Force's aircraft maintenance mission, over a billion gallons of mixed indus-rial wastewater require treatment each year. The result of this operation is ens of thousands of tons of hazardous sludge requiring disposal. This project as initiated to examine treatment technologies that could reduce this sludge isposal burden. In addition to volume, factors such as operator (continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. **ABSTRACT** (continued).

expertise required, system operating and maintenance costs, and the ability of a given technology to treat a mixed industrial waste stream were considered. Available technologies were first screened from literature and then those deemed most promising were subjected to laboratory scale testing. The results of the literature search, laboratory testing, and a contractor suggested R&D program direction are reported in three volumes, as follows:

VOLUME I: Sodium Borohydride Treatment and Sludge Handling Technologies volume reports on the laboratory scale testing results of all treatment technologies and some innovative sludge treatment methods. Sodium borohydride was the selected technology because not only is this technique capable of reducing the sludge volume by nearly 75 percent, the effluent water quality is better than can be achieved with the standard treatment methods.

VOLUME II: Literature Review of Available Technologies for Treatment Heavy Metal Wastewaters contains a comprehensive review of treatment methods ranging from laboratory scale to commercially available techniques. All technologies are related to a standard wastewater treatment method, namely, acidic reduction of chromium and lime precipitation.

VOLUME III: Heavy Metal Waste Treatment Research and Development Needs was based on a survey of Navy electroplating and waste treatment facilities, but encompasses both ongoing and planned research projects among all three major service branches. By extending the project to other than strictly Air Force facilities, the contractor was able to suggest a coordinated R&D program eliminating redundancy among the three branches.

PREFACE

This document was prepared by CENTEC Corporation, Reston, Virginia, under Contract No. 086-35-81-C-0258 for the Air Force Engineering and Services Laboratory (ESL).

The objectives were to evaluate current Navy practices of electroplating pollution control, evaluate the applicability of available technologies and estimate the future role of research and development in providing timely compliance solutions. The effort was performed between February 1983 and September 1983 and included surveys at nine Navy plating operations. Information and data from additional facilities were acquired through a mailed survey. 1st Lt James Aldrich was the Air Force Project Officer and Nicholas J. Olah was the Navy Project Officer.

This technical report has been reviewed by the Public Affairs Office (PA) and is releasable to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

JAMES R. ALDRICH, 1Lt, USAF
Project Officer

JIMMY N. FULFORD, Lt Col, USAF
Chief, Environics Division

ROBERT F. OLFENBUTTEL, Maj, USAF
Chief, Environment Engr. Branch

ROBERT E. BOYER, Col, USAF
Director, Engineering and Services Laboratory

Accession For
NTIS GRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

(The reverse of this page is blank)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

PROBLEM DEFINITION

A. INTRODUCTION

As a part of its shore support establishment, the U.S. Navy operates metal-finishing shops at more than 70 activities (including GOCOs). These shops contain a variety of metal-finishing operations including: cleaning, degreasing, paint stripping and electroplating. Of the metal-finishing processes, electroplating contributes the highest pollutant loading. The total wastewater effluent from these metal-finishing shops is over 3.6 million gallons per day. These waste discharges are regulated by the U.S. Environmental Protection Agency (EPA) which requires that local control standards be met by June 1984. The disposal of hazardous wastes generated by metal-finishing operations, which include wastewater treatment sludges and spent process solution, is also regulated by EPA. The disposal of these wastes is costly and the lack of permitted disposal sites places a burden on the metal-finishing activities.

The EPA effluent limitations are based on the application of in-plant changes to reduce pollutant generation and water use and the installation of physical/chemical treatment systems. Some efforts have been made in these two areas at Navy metal-finishing activities. For instance, most major activities affected by the regulations now have or are planning for physical/chemical treatment. However, to meet the EPA standards by 1984, some additional effort is required in terms of increasing the efficiency of treatment processes, applying additional in-plant changes and adjusting waste handling practices. Also, since the operation of new treatment facilities will dramatically increase the volume of waste treatment sludges requiring disposal, a concentrated effort must be applied to minimize disposal problems. A summary of identifiable problems follows.

B. EXCESSIVE WATER USE

Excessive water use exists at most Naval metal-finishing activities. High water use increases the operating cost of the plating process, increases the volume of wastewater requiring treatment and often causes poor pollutant removal rates.

C. SPENT-PROCESS SOLUTIONS

Most spent-process solutions generated by Naval metal finishing activities are being drummed and contractor-hauled to private treatment/disposal firms. An excessive amount of handling is involved in drumming and shipping the wastes and this presents safety problems. The cost of treatment/disposal is high as are the administrative costs for shipping hazardous wastes. A need exists to reduce the generation rate of spent solutions and/or develop technologies or procedures for onsite treatment of wastes.

D. TOTAL TOXIC ORGANICS (TTO)

Metal-finishing wastes are regulated for the total toxic organics (TTO) parameter which is the sum of all EPA priority pollutant organics (113 chemical compounds). The metal-finishing processes that generate TTO are primarily paint stripping and degreasing. When combined in the sewer or at the IWTP, these wastes will contaminate other wastewaters. The combined wastewater will then be subject to the regulation. Currently, no data exist to evaluate compliance.

E. LOCAL REGULATION

Most Naval metal-finishing operations will be required to meet the EPA effluent standards. However, some activities may be forced to comply with more stringent standards imposed by local or state authorities. Such standards may not be achievable with the conventional chemical treatment method.

F. SLUDGES

The generation of waste treatment sludges will increase in the near future as more wastewater treatment systems come on-line. In many areas, disposal sites for these hazardous wastes are unavailable and the wastes must be transported long distances. The disposal of these sludges has been cited by both the Army and Air Force as a major problem for metal-finishing activities. A need exists for processes that reduce the volume of hazardous sludge and/or render it nonhazardous.

G. TECHNOLOGY APPLICATIONS

Many technologies and methodologies are commercially available for recovery/treatment of wastewaters and for reducing waste generation. No single source of information is available which provides operational details and cost data on commercial technologies. As a result, many technologies are repeatedly tried by military activities without success. As an example, conductivity probes have been installed in many military shops to reduce rinse water use. Both the Air Force and Army have reported a lack of success with the probes. Many Navy activities have also purchased the probes and found them ineffective, yet new Navy metal-finishing facilities are presently installing the same units. Therefore, a need exists for a technology manual that provides operational and cost details of commercially available equipment.

H. BACKGROUND

1. Water Pollution Regulations

Wastewater discharges from metal-finishing operations are regulated under the Clean Water Act of 1977 (Public Law 95-217). The specific limits vary according to whether an industrial operation discharges directly to a waterway or indirectly through a sewage treatment facility. With only minor exceptions, Navy metal-finishing facilities are indirect dis-charges.* Wastewater treatment before indirect discharge is called pretreatment. The associated regulations are referred to as pretreatment standards.

EPA has divided the metal-finishing industry into two major sectors: integrated and nonintegrated. Integrated facilities are plants that, before treatment, combine electroplating waste streams with significant process waste streams from other metal-finishing operations; nonintegrated facilities are those treating significant wastewater discharges only from operations addressed by the electroplating category.

The Navy operates in both modes. Some treatment systems only serve the plating shop and possibly some small wastestreams (e.g., NAS Alameda) and would be classified as nonintegrated. However, most bases have an IWTP which treats all metal finishing and other industrial type wastes. Such facilities would be classified as integrated.

EPA has further divided the metal industry into two groups: captive and job shops. Captive shops are metal-finishing facilities that own 50 percent or more of the materials they process. Job shops are defined as facilities that own less than 50 percent of the materials they process. This division was developed to protect the small, independent firms from economic burdens resulting from the regulations. In general, the regulations for job shops are less stringent. The Navy plating operations are obviously captive facilities.

By April 27, 1984, nonintegrated facilities are required to meet the pretreatment standards given in Table 1, except for the total toxic organics (TTO) parameter which must be met by July 15, 1986. Note that a less stringent set of standards has been adopted by EPA for nonintegrated facilities that discharge less than 10,000 gpd. Integrated facilities are required to meet these standards by June 30, 1984, and also a more stringent set of standards (Table 2). The compliance date

---

*The "Environmental Protection Manual" OPNAVINST 6240.3E (July 1977) requires the disposal of wastewater to municipal sewer systems when economically feasible.

TABLE 1. EXISTING PRETREATMENT STANDARDS FOR NONINTEGRATED FACILITIES (ELECTROPLATING)

Pollutants	Plants Discharging >10,000 gal/d		Plants Discharging <10,000 gal/d	
	Daily Maximum (mg/L)	4-Day Average (mg/L)	Daily Maximum (mg/L)	4-Day Average (mg/L)
Cadmium	1.2	0.7	1.2	0.7
Chromium, total	7.0	4.0	NR	NR
Copper	4.5	2.7	NR	NR
Nickel	4.1	2.6	NR	NR
Lead	0.6	0.4	0.6	0.4
Silver	1.2	0.7	NR	NR
Zinc	4.2	2.6	NR	NR
Total regulated metals (Cr, Cu, Ni, Zn)	10.5	6.8	NR	NR
Cyanide	1.9[a]	1.0[a]	5.0[b]	2.7[b]
Total Toxic Organics	2.13	2.13	4.57	4.57

[a] Total cyanide.

[b] Cyanide amenable to chlorination.

[c] Total Toxic Organics is measured as sum of 113 specific compounds.

NOTE: NR = not regulated.

TABLE 2. PRETREATMENT STANDARDS, BEST PRACTICAL TECHNOLOGY, AND BEST AVAILABLE TECHNOLOGY FOR INTEGRATED FACILITIES

	Pretreatment and Effluent Guidelines (mg/L)	
Pollutants	Daily Maximum	30-Day Average
Cadmium	0.69 (0.11)[a]	0.26 (0.07)[a]
Chromium, total	2.77	1.71
Copper	3.38	2.07
Nickel	3.98	2.38
Lead	0.69	0.43
Silver	0.43	0.24
Zinc	2.61	1.48
Cyanide, total	1.20	0.65
Total toxic organics	2.13	2.13
Oil and grease[b]	52.0	26.0
Total suspended solids[b]	60.0	31.0

[a]Cadmium limit for new sources.

[b]Applies only to effluent guidelines for direct dischargers. pH limit for direct dischargers is 6.0-9.0.

NOTE: The compliance date for indirect dischargers (to POTW) is February 15, 1986; for direct dischargers the date is July 1, 1984.

for these stricter standards is July 1, 1984 for direct dischargers and February 15, 1986 for indirect dischargers (Reference 1). For indirect discharges, an interim date of June 30, 1984 is set for the TTO parameter. The compliance dates for the metal finishing categories are summarized in Table 3.

TABLE 3. COMPLIANCE DATES FOR METAL FINISHING FACILITIES

Electroplating Standards (Table 1):

Category	Item	Date
Nonintegrated	Metals and CN	4/27/84
Integrated	Metals and CN	6/30/84
All	TTO	7/15/86

Metal-Finishing Standards (Table 2):

Category	Item	Date
Indirect dischargers	TTO (<4.57 mg/l)	6/30/84
	Metals and Cyanide	2/15/86
Direct dischargers	All	7/1/84

The discharge of effluents to the navigable waters is regulated by NPDES permit issued to the industrial plant. NPDES permits are issued case-by-case by the authorized State agency or EPA, and the concentration limits and/or mass-based standards specified in the permit are based on the Federal standards, flow rate and quality of receiving waters.

Pretreatment standards are enforced on a local level. Municipalities must develop a pretreatment program that includes standards at least as stringent as the Federal standards. The programs are approved by the States, if the States have been authorized by EPA, otherwise they are approved by the EPA Regional Office.

2. Hazardous Waste Regulations

Regulations governing hazardous wastes are a result of the Resource Conservation and Recovery Act (RCRA) of 1976 (Public Law 94-580). RCRA hazardous waste regulations are designed to manage and control the country's hazardous wastes, from generation to final disposal.

The RCRA regulations differ from those concerned with water pollution in that water regulations are set to the specific industry (for example, metal finishing), whereas any industries that generate, store, haul, or dispose of hazardous wastes must comply with RCRA.

Under RCRA, the EPA has set strict definitions for hazardous waste. Some, such as electroplating wastewater treatment sludge, are specifically defined as hazardous. For others not specifically listed, EPA has established a set of test criteria to determine if the waste is hazardous. A hazardous waste, by either definition or test, must be stored, transported, and disposed of in accordance with RCRA hazardous waste regulations. The exception is if defined hazardous wastes checked by the test criteria do not possess hazardous characteristics, the generator can petition EPA (or an authorized state) to delist the waste. If delisting is successful, the generator can then dispose of the waste in a less costly manner. Some electroplating operations, including three Army installations, have delisted their wastewater treatment sludges (Reference 2) and one Naval activity (Pensacola NARF) has petitioned EPA but has not received the delisted status.

3. The Navy Plating Operation

Electroplating is one of many operations referred to as metal finishing. Metal finishing is used to improve the surface of a material by various methods, including:

- Cleaning (including pickling)
- Depositing another metal on it by chemical exchange (immersion plating)
- Electroplating another metal or series of metals (electroplating)
- Converting its surface by chemical deposition (phosphating)
- Coating it with organic materials (conversion coating)
- Oxidizing by electrolysis (including anodizing)

The corresponding changes produced by these methods of metal finishing on the waste material serve to enhance the value of the treated item by providing improvements, such as:

- Corrosion resistance
- Durability
- Esthetic appearance
- Electrical conductivity

Metal-finishing processes are used at more than 70 Navy activities. The largest electroplating operations (excluding GOCOs) are found at Naval Air Rework Facilities (NARF), Naval Shipyards (NSY), Naval Air Stations (NAS), the Naval Ordnance Station (Louisville, KY), and the Naval Avionics Center (Indianapolis, IN). Most of these facilities operate a wide variety of metal-finishing operations to repair worn or damaged parts or finish new parts and are capable of plating most common metals. Most other Naval plating operations are an order of magnitude or less in size. Although some smaller facilities can perform a variety of metal-finishing operations, most perform one or two specific tasks such as the production of printed circuit boards.

Plating processes are relatively uniform with each consisting of several steps during which the parts are immersed in tanks containing process solutions. After each process step the parts are rinsed in tanks containing water to remove the clinging film of plating chemicals, which is known as drag-out. A typical plating room layout, showing process tanks and associated rinse tanks, is presented in Figure 1.

a. Hard Chromium Plating

For NARFs and NSYs the major plating process is usually hard chromium plating. Hard chromium plating is the name adopted by industry for what might be better termed chromium plating for engineering rather than decorative purposes. Hard chrome is applied to shafts, gears, hydraulic hardware and other chromium parts that have been worn from service. The chromium plate is applied to increase the dimensions of the article. This plating process, which is commonly referred to as building-up, usually takes 1 or 2 days, but can require up to a week depending on the thickness of chromium desired. After plating, the parts are machined to the exact desired dimensions and polished.

b. Corrosion Protection Finishes

As a group, the various corrosion protective finishes, namely nickel, cadmium and zinc, are the second most widely used processes at major Navy plating activities. A corrosion protection plate, which is very thin compared with a hard chrome plate, takes only minutes to apply. Nickel is used on new parts for corrosion and wear resistance as well as for salvaging worn or mismachined parts. In the latter case, nickel is applied like hard chromium through the building-up process. Cadmium and zinc are used when the principal aim is protection of the substrate, usually iron or steel. Cadmium is far more expensive than zinc and, therefore, in most industrial applications zinc is preferred. However, cadmium has several distinct advantages over zinc that are important to Navy applications: (1) it is superior to zinc in resistance to salt atmospheres,

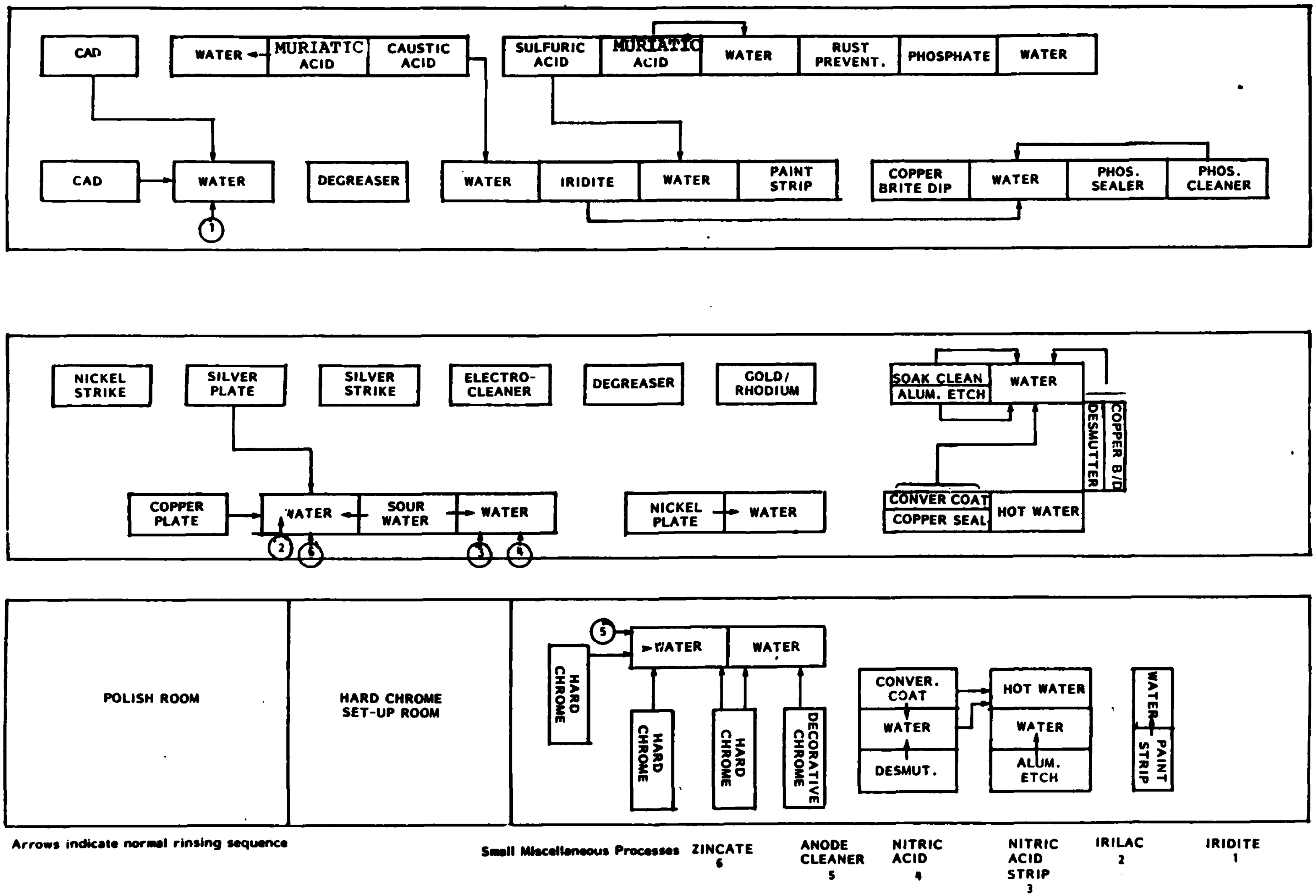


Figure 1. Diagram of Long Beach NSY Plating Shop

(2) its corrosion products are not bulky, hence do not interfere with functional moving parts as do those of zinc, and (3) it is relatively easily soldered compared with zinc.

Many Naval plating operations, including some of the smaller shops, employ the chromic acid anodizing process. This process, which is termed conversion coating rather than plating, is used to develop a protective film on aluminum.

c. Printed Circuit Board Production

An operation found at many Navy activities is the production of printed circuit boards. The boards, which are used in various electronics applications, usually require both electroless plating and electroplating. In electroless plating, the metal is deposited from a solution by means of a chemical reducing agent rather than by an electric current. The primary metals deposited on printed circuit boards include: copper, lead, silver and gold.

d. Other Processes

Many other plating and metal-finishing processes are used at Naval activities. Approximately 30 processes were identified in a recent NCEL survey (Table 4). In addition to those previously mentioned, the other processes most often found are: conversion coating: phosphating (a preparation step for painting) and chromating (similar to anodizing but applied to electrodeposited cadmium or zinc); etching (a conditioning step for parts prior to plating); and bright dip (a nonelectrolytic solution used to produce a bright surface).

One plating process which varies considerably from the usual plating methods is brush plating. This process, which was identified at seven Navy activities during the NCEL survey, generally does not produce a wastewater effluent. Brush plating is performed using a small pad which is saturated with plating solution. The pad is attached to an anode rod and the part being plated acts as a cathode. Most metals can be plated using the brush process which is generally used for repair work when small areas are being plated. It is not practical for large-scale plating operations. A major application of this process for military work is the repair of damaged printed circuit boards.

4. Wastewater Generation

Contaminants in the effluent from electroplating shops originate in several ways. The most obvious source of pollution is the drag-out of various processing baths into subsequent rinses. The amount of pollutants contributed by drag-out is a function of such factors as the design of the racks or barrels carrying the parts to be plated, the shape of the parts, plating procedures, and several interrelated parameters of the process solution, including concentration of toxic chemicals, temperature, viscosity, and surface tension.

TABLE 4. PROCESSES AND RESULTANT WATER USE AT NAVAL PLATING ACTIVITIES

Facility	Parts/Products Plated	Number of Process Tanks	Number of Rinse Tanks	Plating Processes	Water Use (gal/day) CN	Cr	A/A	Total	Water Conservation Measures Counter-current	Flow Regulators	Air Agitation	Recovery Rinse	Conductivity Cells	Other
Printed Circuit Board Lab, Naval Air Test Center Patuxent River, MD	Printed circuit boards	12	4	Cu(1), Sn/Pb(2), Et, EC	0	0	90	90	o	o				
Design and Fabrication Section Naval Air Test Center Patuxent River, MD	Aircraft parts, shafts, fabricated sheet metal parts	10	2	An(1), Cd(2), Ch(3) Zn, Cl, BD	N/S	N/S	N/S	1500						
Naval Ordnance Station Louisville, KY	Gears, shafts, hydraulic valve blocks, pistons, sleeves, ordnance parts (new and overhaul)	52	24	Ni(1), Cr(2), Cd(3), An(4), Ch(5), Cu, Ni, Zn, Sn, Ag, Fe, Et, Ip, EN, EC, EZ, ES, BD	86K	71K	128K	285K			o			
Naval Avionics Center Indianapolis, IN	Printed circuit boards, panels, chasis and cases for electronic, electrical and electro-mechanical assemblies	95	67	Ch(1), Cu(2), An(3), Cd(4), Ni, Sn, Pb, Ag, Au, Et, Ph, Ip, EC, Cl, BD	11K	15K	54K	80K						
Naval Avionics Center Materials Laboratory Plating Facility Indianapolis, IN	N/S	34	5	Cu(1), Ni(2), EN(3), An, Et, Ml, IP, EC, EM, Pl, BO, Sn, Pb	N/S	N/S	N/S	1500	o	o	o			
Naval Ship Repair San Francisco, CA	Boat fittings, shafts, seal and rings	8	5	Cr(1),Ni(2), Cu(3), Zn(4), Sn, Ag, Au, Et, Cl, Pb, BD	N/S	N/S	N/S	9K						
Naval Research Laboratory Washington, DC	R&D prototype	40	16	An(1), Ch(2), Cu(3), Ni(4), Cd(5), Cr, Sn, Pb, Ag, Au, Et, IP	N/S	N/S	N/S	30K		o				
Navy Ship Repair Guam	Gears, shafts, seal rings, nuts, bolts	18	2	Cr(1), Ni(1), Ag(1), Cd(2), Cu(2), Au(2), Et, IP, Cl, BD	2	2	5	10	o					

Plating Process Key

Cu=Copper Plating	Ni=Nickel Plating	Cr=Chromium Plating	Zn=Zinc Plating	Cd=Cadmium Plating
Sn=Tin Plating	Pb=Solder Plating	Ag=Silver Plating	Au=Gold Plating	Fe=Iron Plating
An=Anodizing	Et=Etching	Ch=Chromating	Ph=Phosphating	IP=Immersion Plating
EC=Electroless Copper	Cl=Coloring	BD=Bright Dip	EZ=Electroless Zinc	ES=Electroless Silver
Ml=Milling	Pl=Polishing	Em=Electromachining	Ep=Electro-painting	Rh=Rhodium Plating
EG=Electroless Gold	ER=Electroless Rhodium	BO=Black Oxide	Br=Brass Plating	EN=Electroless Nickel

NOTE: Numbers in parenthesis following plating process codes indicate most highly used processes; e.g., Cr(1) incidates that chromium plating is used more than any other process at that location.

TABLE 4. PROCESSES AND RESULTANT WATER USE AT NAVAL PLATING ACTIVITIES (CONTINUED)

Activity	Parts/Products Plated	Number of Process Tanks	Number of Rinse Tanks	Plating Processes	Water Use (gal/day)				Water Conservation Measures					
					CN	Cr	A/A	Total	Counter-current	Flow Regulators	Air Agitation	Recovery Rinse	Conductivity Cells	Other
[illegible] Systems [illegible]	Printed circuit boards	13	11	Cu(1), Rh(2), Et, Mn, EG, Ed	0	0	470	470						
[illegible]	Hoses, valves, vent pipe, piping, etc.	10	8	Cleaning only	N/S	N/S	N/S	700						
[illegible] Field [illegible]	Aircraft parts	0	0	Brush plating	0	0	0	0						
[illegible] Field [illegible], FL	Printed circuit boards	0	0	Brush plating	0	0	0	0						
[illegible] Propulsion Training Facility Great Lakes, IL	Seal rings, shafts	0	0	Brush plating	0	0	0	0						
Aircraft Intermediate Maintenance Dept. NAS Miramar San Diego, CA	Misc. aircraft components (hydraulic)	0	0	Brush plating	0	5	15	20						
[illegible] Groton, CT	N/S			Brush plating	0	0	0	0						
Naval Weapons Station Concord, CA	Shafts, cylinders, pins (fork lift truck parts)	0	0	Brush plating	0	0	0	0						
NARF Cherry Point, NC	Aircraft parts	31	11	An(1), Cd(2), Cr(3), Ad(4)	0	0	67.3	67.3K			o			
NAS Mayport, FL	Carbon steel, rudders, fan and belts	6	3	Cu(1), Ni(2), Ag(3), Au(4)	0	0	0	0				o		

TABLE 4. PROCESSES AND RESULTANT WATER USE AT NAVAL PLATING ACTIVITIES (CONTINUED)

Facility	Parts/Products Plated	Number of Process Tanks	Number of Rinse Tanks	Plating Processes	Water Use (gal/day)				Water Conservation Measures					
					CN	Cr	A/A	Total	Counter-current	Flow Regulators	Air Agitation	Recovery Rinse	Conductivity Cells	Other
NSWC Dahlgren, VA	Printed circuit boards	24	22	Cu(1), Pb(2), Au(3), Ni(3), ET, BC	0	0	5000	5000	•	•		•		
David Taylor NSY R&D Center Annapolis, MD	Bearings, shafts, electric motor shafts	0	0	Brush plating	0	0	0	0						
Marine Corps, Logistics Base Albany, GA	Ordnance and combat vehicles (tracked and/or wheeled)	26	13	Cn(1), Ph(2), An(3), Cr(4), Cd(5), Et, EN, Cl, BD	N/S	N/S	N/S	150K*						
Navy Weapons Center Ridge Crest, CA	Missile and aircraft parts	29	10	Ni(1), Cd(1), Cn(1) An(1), Cr(2), Cu(2), Cd, Sn, Ag, EN, Pl, Cl, BD	1860	1240	3100	6200						
Mare Island NSY Vallejo, CA	Ship ports, submarine parts, equipment, hardware, circuit boards	65	15	BD(1), Cd(2), Ag(3) Cr(4), Ni(5), Cu(6) Sn, Au, An, Et, Ph, Pb	N/S	N/S	N/S	81K	•	•				
NCSC Plating Shop Panama City, FL	Diver helmets, misc. parts	25	5	Ni(1), Cd(2), Cu(3), Cn(4), Zn, Sn, Pb, Ag, Fe, An, Et, Bm, Pl, Ep, Cl, BD	15	0	100	200	•	•				
NAS Lemoore, CA	Aircraft parts	4	1	Cu(1), Ni(2), Cd(3), An, Et	0	0	1	1						
Yokosuka City Kanagawa Prefecture Japan	Seal rings, switch gears, buss, bars, radar wave guides, motor parts, shaft bearings, etc.	16	8	Cu(1), Ag(2), Ni, Cr, BD	3	0	300	303		•	•			

*Includes all industrial flows

TABLE 4. PROCESSES AND RESULTANT WATER USE AT NAVAL PLATING ACTIVITIES (CONCLUDED)

Activity	Parts/Products Plated	Number of Process Tanks	Number of Rinse Tanks	Plating Processes	Water Use (gal/day) CN	Cr	A/A	Total	Water Conservation Measures Counter-current	Flow Regulators	Air Agitation	Recovery Rinse	Conductivity cells	Other
Naval Weapons Support Center (Bldg. 2521) Crane, IN	Small arms weapons	18	7	Ph(1), BD(2), Ni(3)	N/S	N/S	N/S	300						
Naval Weapons Support Center (Bldg. 2906) Crane, IN	Printed circuit boards	41	18	Cu(1), Sn/Pb(2) Ni/Au(3), BC	15	0	285	300		o		o		
NARF Norfolk, VA	Aircraft parts	60	35	Cr(1), Ni, Cu, Ag, Cd, Sn, BD	30K	30K	40K	100K*						
NAS Jacksonville, FL	Aircraft parts	75	39	Ni(1), Cr(2), Cu(3) Cd(4), As(5), EN, Au, Bt, Ch, Pb, Sn	11K	25K	N/S	36K						Spray rinse
NARF Pensacola, FL	Aircraft parts	124	45	Cd(1), Ni(2), Cr(3) BD, An, Zn, Cu, BD, Ag	N/S	N/S	N/S	360K	o		o			Integrated treatment
NSY Puget Sound, WA	Shafts, gears, misc. parts	60	21	Cr, BD, Cu, Ag, Ni, Cd, Sn, Ph, Zn, An	N/S	N/S	N/S	50K*			o		o	
NAS Alameda, CA	Aircraft parts	67	31	Cr(1), Ni(2), Cu(3), Cd, Ag, An, Sn, Ph, BD, EN	N/S	N/S	N/S	20K					o	
NSY Long Beach, CA	Misc. ship parts	33	18	Cr(1), Cd, Ph, BD, Ag, Ni, Cu	34.2K	46.8K	59.4K	104.4K	o	o	o		o	
Naval Ocean Systems Center San Diego	Misc. ship parts	20	4	An(1), Ni, Cu, BK	250	500	250	1000						
NARF North Island San Diego	Aircraft parts	N/S	N/S	Cr, Cd, Ni, Ag, Ch, Cu	N/S	N/S	N,S	N/S					o	

*Includes all industrial flows
N/S = not specified
N/A = not applicable

With conventional rinsing techniques, drag-out losses from process solutions result in large volumes of rinse water contaminated with relatively dilute concentrations of cyanide and metals. In private industry, rinse waters that follow plating solutions typically contain 10 mg/l to 1000 mg/l of the metal being plated. The higher concentrations are observed with countercurrent rinsing which reduces water use and results in a more concentrated wastewater.

Most industrial plating shops operate several plating lines that contain different types of cleaning and electroplating baths, such as zinc, copper, nickel, cadmium, and chromium. The combined rinse waters dilute the concentrations of individual metals, usually within the range of 1 mg/l to 100 mg/l (see Table 5).

The rinse water from Navy plating appears to be much more dilute, owing to higher water use rates and the lack of countercurrent rinsing. For instance, a survey conducted at the Naval Avionics Center, Indianapolis, IN, showed that metal concentrations averaged less than 1 mg/l for all of the common plating metals. (Reference 3) A contractor's survey of plating wastes from Long Beach NSY indicated that all parameters were less than 2 mg/l (Reference 4). Monitoring data from the Naval Surface Weapons Center, White Oak, Maryland, shows that concentrations for all metals except lead (0.47 mg/l) were below 0.2 mg/l (see Table 5).

Discarded process solutions are another source of wastewater in the plating shop. They are either discharged into the sewer or drummed and hauled to treatment. These solutions are primarily spent alkaline and acid cleaners, used for surface preparation of parts before electroplating and stripping solutions used to remove metal deposits from rejected or damaged parts. These solutions are not formulated with metals; however, a few cleaners and many strippers contain cyanide. The amount of pollutants contained in discarded cleaning and stripping solutions varies considerably among plating shops. However, it is not uncommon to find cyanide and heavy metals in concentrations of several thousand milligrams per liter in cleaner solutions. This contamination is caused by drag-in from previous process cycles and attack of the base metals by the chemicals in the cleaning solutions. The concentration of metals and cyanide in stripping solution usually exceeds 50,000 mg/l.

Plating baths and other process solutions containing high metal concentrations, such as chromates, are rarely discarded in private industry; however, many Navy plating shops discard such solutions on a regular basis. Most Navy facilities put concentrated wastes in drums and have them contractor-hauled to a permitted treatment/disposal site.

The percentage that each pollution source contributes to the pollutant concentration of the final effluent can vary

TABLE 5. EFFLUENT CHARACTERISTICS FROM NAVAL AND PRIVATE INDUSTRY PLATING

Pollutants	Naval Avionics[1] Center, IN	Naval Surface[2] Weapons Center, MD	Plant A[3] (Plumbing Fixtures)	Plant B[3] (Nuts, bolts, etc.)	Plant C[3] (Stampings, etc.)	Plant D[3] (Fasteners, etc.)	Plant E[3] (Machine Parts)
Copper	0.22	0.099	5.16	0.19	11.75	5.03	4.23
Chromium (T)	0.25	0.08	1.14	1.26	4.75	24.00	178
Nickel	0.023	0.014	7.12	8.54	20.50	0.25	0.88
Zinc	0.03	0.070	0.42	24.82	7.00	12.13	0.91
Cadmium	0.025	0.049	0.03	1.72	0.46	0.43	1.30
Lead	0.02	0.470	0.08	0.48	0.36	0.63	0.63
Cyanide (T)	ND	<0.02	4.73	1.68	6.6	6.85	1.4

[1]Data from Northeast Ohio Regional Sewer District, 1980.

[2]Reference 3.

[3]Reference 5.

substantially among electroplating shops. When spent cleaners are the only disposed process solutions, approximately equal amounts of metal are contributed by rinse waters and batch dumps. However, when process solutions such as chromium plating baths are disposed, an overwhelming percentage of metal is contributed by the spent solutions. For example, NCEL measurements indicate that approximately 116 pounds of chromium are lost to the sewer annually through drag-out of hard chromium solutions at NAS Pensacola. At that facility, the chromium baths are dumped occasionally (contractor-hauled), usually once or twice per year. Assuming an average of 1.5 dumps per year per hard chromium tank, the amount of chromium lost at Pensacola is over 20,000 lbs.*--172 times more chromium than the drag-out. Although the dumped solution is not treated at the NAS, the costs of treatment and resultant sludge disposal are reflected in the contractor's hauling price.

The dumping of process solutions is a major difference in waste generation between Navy and private industry plating shops. Many Navy shops dump process solutions (especially chromium) once or twice per year compared to some private industry platers who can operate 10 or 20 years without a dump. The Navy dumps are often performed on a preset schedule for plating quality assurance. Private industry platers place more emphasis on pure economics; the baths are maintained through preventive measures and cost-effective regenerative procedures.

5. Sludge Generation

In addition to rinse waters and spent process solutions, a major source of waste from plating activities is wastewater treatment sludges produced by chemical precipitation of metals in rinse waters at activities with IWTPs. Each activity that generates sludges has them contractor-hauled to a hazardous waste disposal site. The handling, transportation and disposal of these wastes is regulated under RCRA and the sludges must be disposed in permitted landfills. In many parts of the country, such landfills are nonexistent and the sludges must be hauled long distances. The disposal cost is, therefore, relatively expensive. The NARF at Pensacola pays $113.50 per ton of sludge. In 1981, this amounted to an expense of $336,761. On the basis of wastewater volume, this cost is approximately $5.30 per 1,000 gallons treated. Other activities report similar or higher costs. The Puget Sound NSY reports the highest unit cost for disposal at $320 per ton.

---

*5,947 gal/yr X 300 g/l X 3.785 l/gal X 1/454 lb/g X 1.5 dumps/yr = 22,311 lb Cr/yr

6. Wastewater Treatment

While many major plating activities have wastewater treatment processes (see Table 6), several exceptions exist, including the Long Beach NSY; Naval Ordnance Station, Louisville, KY; and the Naval Avionics Center, Indianapolis, IN. Plans for waste treatment are currently underway at each of these locations.

The treatment processes used at the major discharge activities are basically the conventional physical/chemical treatment processes consisting of cyanide oxidation, chromium reduction, metals precipitation and sludge dewatering. In general, recovery technologies have not been applied to Navy waste streams except for prototype demonstrations and applications of precious metal recovery.

An in-depth discussion of waste treatment technologies is presented in the Navy Electroplating Pollution Control Technology Assessment (TA) Manual (Reference 5). That report presents design and cost information on established or conventional technologies for end-of-pipe treatment, and substitute treatment technologies and recovery equipment that may offer a cost savings. A technology summary is presented in Section II.

TABLE 6. ELECTROPLATING WASTEWATER TREATMENT AT NAVAL PLATING ACTIVITIES

Facility	Total Water Use (gpd)	Wastestream Segregation Cr	Wastestream Segregation CN	Treatment	Treatment Location Plating Sh.	Treatment Location IWTP	Treatment Processes CN Dest.	Treatment Processes Cr Reduc.	Treatment Processes Precip.	Treatment Processes Dewater.	Treatment Processes Other	Recovery Process	Sludge Disposal Method	Batch Dump Disposal Method Hauled	Batch Dump Disposal Method On-Site	Wastewater Discharge Indirect	Wastewater Discharge Direct
Printed Circuit Board Lab. Naval Air Test Center Pautuxent River, MD	90	N/A	N/A	No	N/A	N/A						None	N/A	●		N/S	N/S
Design and Fabrication Section Naval Air Test Center Pautuxent River, MD	1500	No	No	No	N/A	N/A						None	Contractor hauled	●		●	
Naval Ordnance Station Louisville, KY	285K	No	No	No	N/A	N/A						None	N/A	●		●	
Naval Avionics Center Indianapolis, IN	80K	No	No	No	N/A	N/A						None	N/A	●		N/S	N/S
Naval Avionics Center Materials Laboratory Plating Facility Indianapolis, IN	1500	No	No	No	N/A	N/A						None	N/A	●		N/S	N/S
Naval Ship Repair San Francisco, CA	9,000	No	No	Yes	●		●	●			pH adjust.	None	N/S	●		●	
Naval Research Laboratory Washington, DC	30K	No	No	Yes	●						pH adjust.	None	N/S	●		N/S	N/S
Navy Ship Repair Guam	10	No	No	No	N/A	N/A						None	N/A	●		N/S	N/S

TABLE 6. ELECTROPLATING WASTEWATER TREATMENT AT NAVAL PLATING ACTIVITIES (CONTINUED)

[illegible]	Total Water Use (gal)	Wastestream Segregation Cr	Wastestream Segregation CN	Treatment	Treatment Location Plating Sh.	Treatment Location IWTP	Treatment Processes CN Dest.	Cr Reduc.	Precip.	Dewater.	Other	Recovery Process	Sludge Disposal Method	Batch Dump Disposal Method Hauled	Batch Dump Disposal Method On-Site	Wastewater Discharge Indirect	Wastewater Discharge Direct
[illegible]	11	N/A	N/A											o			
[illegible]	10	Yes	N/A			o					N/S	None	Contractor hauled		o	o	
[illegible] Field, FL	0	N/A	N/A	None								N/A	N/A	N/A	N/A	N/A	N/A
[illegible] Cecil Field, FL	0	N/A	N/A	None								N/A	N/A	N/A	N/A	N/A	N/A
[illegible] Propulsion Training Facility Great Lakes, IL	0	N/A	N/A	None								N/A	N/A	N/A	N/A	N/A	N/A
Aircraft Intermediate Maintenance Dept. NAS Miramar San Diego, CA	0	No	N/A	None								None	N/A	N/A	N/A	o	
[illegible], CT	0	No	N/A	None								None	N/A	N/A	N/A	N/A	N/A
[illegible] Weapons Station [illegible], CA	0	No	N/A	None								None	N/A	N/A	N/A	N/A	N/A
[illegible] Cherry Point, NC	31	No	No	Yes		o					N/S	None	Contractor hauled		o	o	
[illegible]	6	Yes	Yes	Yes	o			o				None	N/S		o	o	

TABLE 6. ELECTROPLATING WASTEWATER TREATMENT AT NAVAL PLATING ACTIVITIES (CONTINUED)

Facility	Total Water Use (gpd)	Wastestream Segregation Cr	Wastestream Segregation CN	Treatment	Treatment Location Plating Sh.	Treatment Location IWTP	Treatment Processes CN Dest.	Treatment Processes Cr Reduc.	Treatment Processes Precip.	Treatment Processes Dewater.	Treatment Processes Other	Recovery Process	Sludge Disposal Method	Batch Dump Disposal Method Hauled	Batch Dump Disposal Method On-site	Wastewater Discharge Indirect	Wastewater Discharge Direct
NSWC Dahlgren, VA	5000	N/A	N/A	Yes		•						None	Composted (fertilizer)	•			•
David Taylor NSY R&D Center Annapolis, MD	0	N/A	N/A	Yes		•						Reverse Osmosis	Lagoon	N/A	N/A	•	•
Marine Corps. Logistics Base Albany, GA	150K*	No	No	Yes	•	•		•	•	•			Contractor hauled		•	•	
Navy Weapons Center Ridge Crest, CA	6200	No	No	[illegible]	N/A	N/A						None	N/A	•			Evaporation
Mare Island NSY Vallejo, CA	81K	Yes	Yes	Yes	•	•	• (plating shop)	• (plating shop)				None	Contractor hauled	•		•	
NCSC Plating Shop Panama City, FL	200	Yes	Yes	Yes	•	•					filt., pH adj (plating shop)		Contractor hauled	•		•	
NAS Lemoore, CA	1	N/A	N/A	Yes		•						None	Lagooning/hauling	•	•		•
Yokosuka City Kanagawa Prefecture Japan	303	Yes	Yes	[illegible]								None	N/A	•		•	

TABLE 6. ELECTROPLATING WASTEWATER TREATMENT AT NAVAL PLATING ACTIVITIES (CONCLUDED)

Activity	Total Water Use (gpd)	Wastestream Segregation Cr	Wastestream Segregation CN	Treatment	Treatment Location Plating Sh.	Treatment Location IWTP	Treatment Processes CN Dest.	Cr Reduc.	Precip.	Dewater.	Other	Recovery Process	Sludge Disposal Method	Batch Dump Disposal Method Hauled	Batch Dump Disposal Method On-Site	Wastewater Discharge Indirect	Wastewater Discharge Direct
[illegible] Support [illegible] Bldg. 2521 [illegible], FL	[illegible]	N/S	N/S	Yes		o						None	Land application	o		o	
[illegible] Support [illegible] Bldg. [illegible] [illegible], FL	300	N/A	Yes	Yes		o						None	Land application	o		o	
NAS [illegible]	100K*	No	Yes	Yes		o	o	o	o	o	Filter Carbon Adsorp	None	Contractor hauled		o	o	
NAS [illegible] Jacksonville, FL	0	Yes	Yes	Yes		o	o	o	o	o		None	Contractor hauled	o		o	
NAS Pensacola, FL	360K	Yes	Yes	Yes		o	o (plating shop)	o	o	o		None	Contractor hauled		o	o	
NSY Puget Sound, WA	50K*	Yes	Yes	Yes		o					Filter Ion Exchange	Chrome Napper	Contractor hauled	o		o	
NAS [illegible], CA	20K	Yes	No	Yes	o			o	o			None	Contractor hauled	o		o	
NSY Long Beach, CA	104.4K	N/S	N/S	No								None		o		o	
Naval Ocean Systems Center San Diego	1000	No	No	No								None				o	
NAS North Island San Diego	N/S	N/S	N/A	Yes		o	o	o	o	o		None	Contractor hauled			o	

*Includes all industrial flows
N/S Not Specified
N/A Not Applicable

SECTION II

ASSESSMENT OF THE STATE OF TECHNOLOGY

A. GENERAL

This section defines current Navy practice and commercially available electroplating pollution control technology. It also differentiates between current Navy practice and the typical practices of private industry. The information presented on commercially available technologies is condensed from the TA (Reference 5). The Navy data are based on an NCEL survey. For each case the discussion is divided into five major problem areas often associated with electroplating operations:

- Water conservation
- End-of-pipe treatment
- Material recovery
- Spent-process solutions
- Sludge handling

To help evaluate available technologies (both commercial and high-R&D technologies) a decision model has been developed that scores the relative appropriateness of each technology by using a common set of criteria. The model, termed application assessment, is described in this section as are the results of the modeling exercise.

B. CURRENT NAVY PRACTICE

An NCEL survey of Navy electroplating activities has provided the major portion of the available data on current Navy practice. This information has been supplemented with a data base provided by NAVFAC.

1. Water Conservation

As indicated by the NCEL data (Tables 4 and 6), flow rates at Navy plating operations vary from less than 500 to 360,000 gpd. The differences in the discharge rates are the result of several factors. First, the NARFs and other major dischargers are processing a large volume of parts, many of which are large. Many of the smaller discharges are processing small parts such as printed circuit boards and have a much lower production volume. As a result of these differences, the sizes of rinse tanks and the flow rates vary. A typical rinse tank at a NARF is 1,000 gal and has a flow rate of 2 to 8 gpm, while rinse tanks for processing printed circuit boards are often less than 25 gal with flow rates less than 0.5 gpm.

Another factor which affects rinse water use is the configuration and use of rinse tanks. Most Navy plating operations use the single overflow rinse which is inefficient in terms of water use. The use of multiple-rinse tanks, as described in the TA, can reduce rinse water use by 90 percent or more. However, the use of multiple-rinse tanks is not always possible because multiple rinses require additional space, and result in additional production time since the plater must rinse at more than one tank.

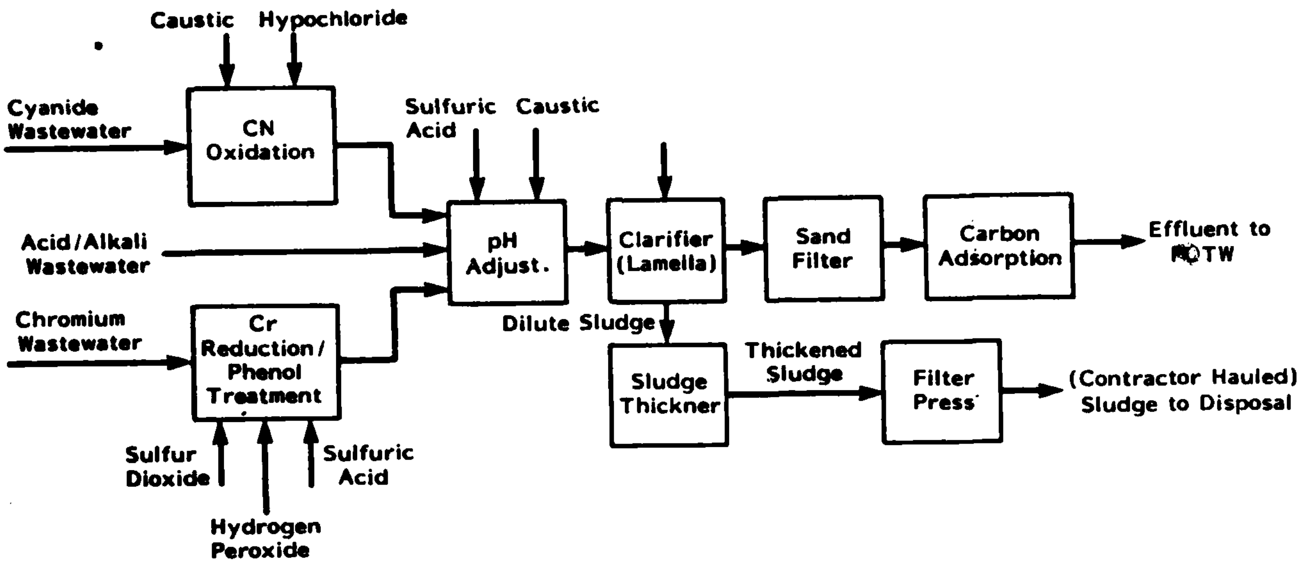
Some water conservation devices such as flow regulators, air agitation, recovery rinses and conductivity cells are in use. The recovery rinses are only used at two activities. Conductivity probes are used at mostly larger-discharge activities. The use of the probes was discussed with plating personnel at several NARFs and NSYs; all reported that the conductivity probes are ineffective in reducing water use. The primary problem with the units is high maintenance. It was also reported that the control devices can be overridden by plating personnel,eliminating any potential benefits.

2. End-of-Pipe Treatment

Treatment systems are currently installed and operated at most major Naval plating activities (see Table 6). These systems are basically conventional treatment processes. Most treatment facilities located at NARFs, NSYs and other large plating activities are industrial waste treatment plants (IWTPs) which treat the combined industrial flows from electroplating and other operations such as machining, painting, paint stripping and dry docks. Some Naval plating shops have their own treatment facilities (e.g., Alameda NAS and Charleston NSY).

Wastewater from the plating shops is generally segregated into three waste streams: chromium, cyanide, and acid/alkali. However, some shops discharge a combined waste stream to treatment. Several other design factors vary among the Naval plating activities. Figure 2 diagrams the various types of systems.

One of the largest IWTPs, located at Norfolk, uses conventional treatment, followed by advanced treatment. The conventional process consists of cyanide oxidation, chromium reduction, metals precipitation and solids dewatering. The advanced portion of the system includes a pressure sand filter for removing fine solid particles and carbon adsorption to remove toxic organics. The batch chromium reduction process can also serve as a phenol waste treatment unit. The chemicals used



NARF NORFOLK

PUGET SOUND NSY

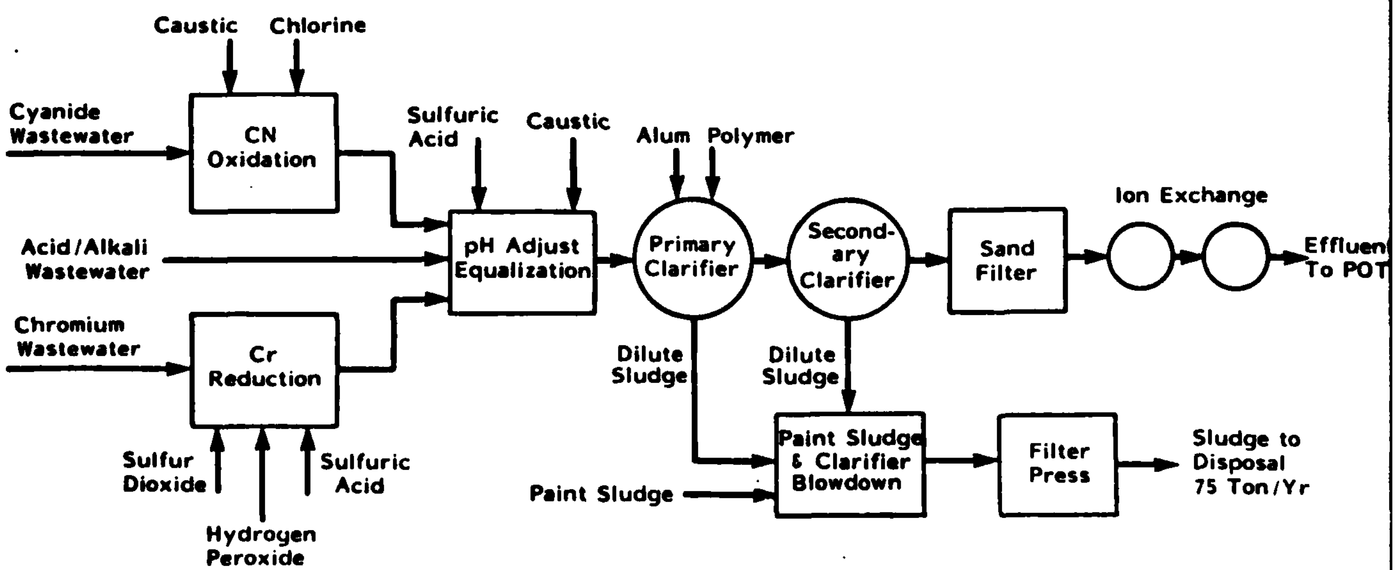
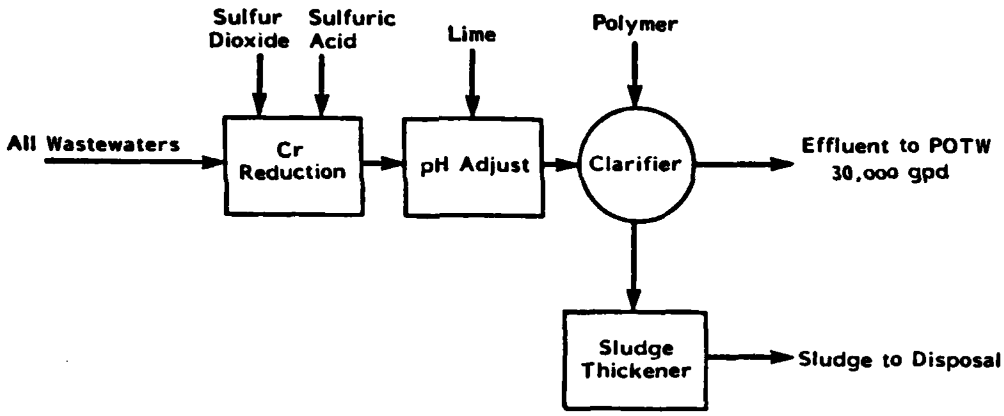


Figure 2. Simplified Diagram of Naval Treatment System

ALAMEDA NAS



NARF SAN DIEGO

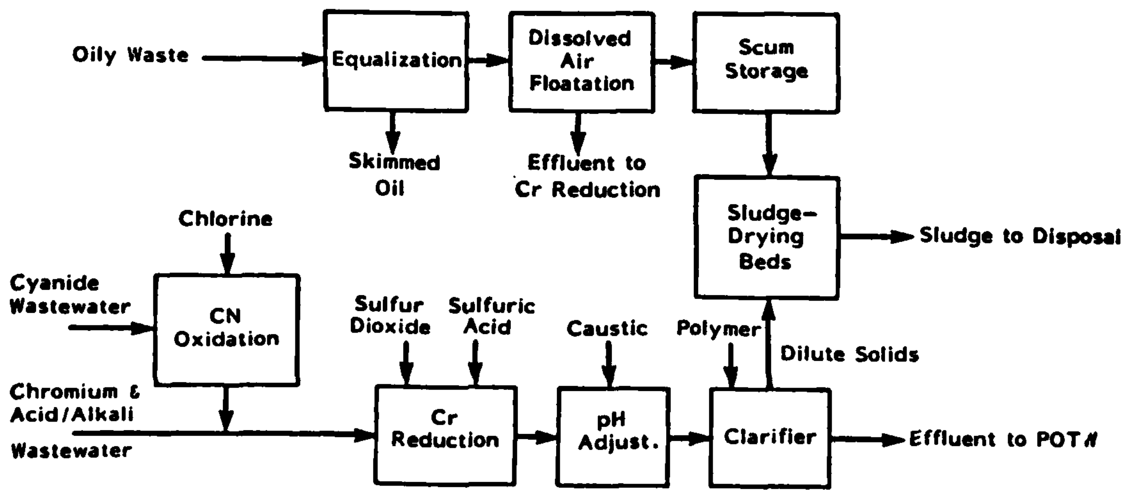


Figure 2. Simplified Diagram of Naval Treatment Systems (Continued)

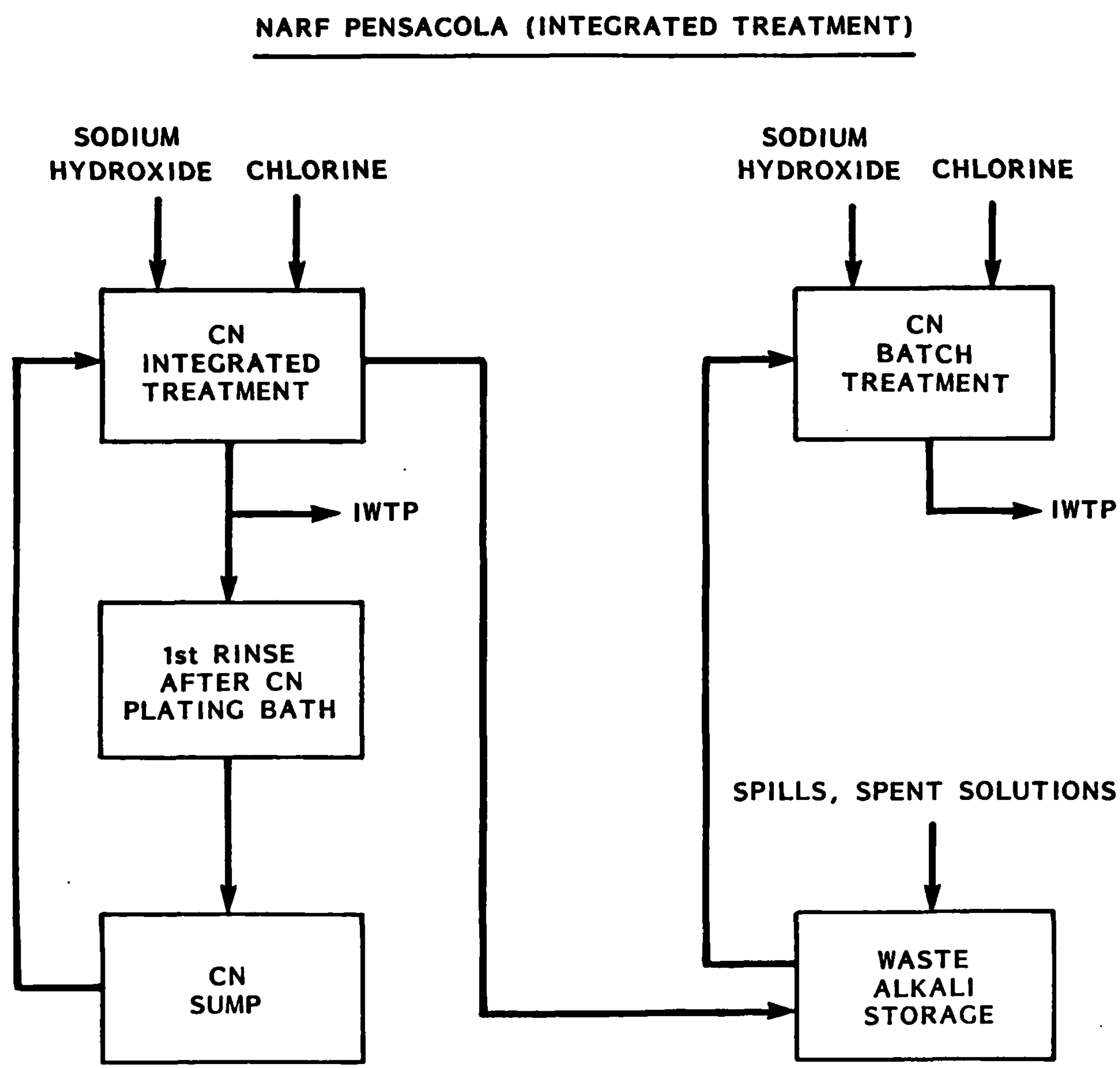


Figure 2. Simplified Diagram of Naval Treatment Systems (Concluded)

for treatment at Norfolk are typical of conventional treatment and Navy practice: hypochlorite for cyanide destruction, sulfur dioxide for chromium reduction, and caustic with polymer for metals precipitation.

While the IWTPs at Puget Sound NSY and Norfolk are similar; several distinct differences exist. Puget Sound uses alum as a coagulant and has ion exchange following the sand filters. The ion exchange was intended to serve as a final polishing step for metals removal; however, the units have never been regenerated and are therefore ineffective. Finally, paint sludges are combined with clarifier underflow and dewatered on the filter press.

The Alameda NSY varies from the systems previously discussed in that wastewaters are not segregated prior to treatment. That facility receives only small, dilute quantities of cyanide and, therefore, does not provide cyanide destruction. All wastewaters are treated for chromium reduction,then for metals precipitation. Alameda does not have a dewatering device; therefore, a larger volume of sludge is produced then normally expected.

The NARF at San Diego receives a large volume of oily wastes and provides for their separate treatment by using oil skimmers in an equalization tank with dissolved air flotation. The effluent from the oil treatment system is combined with other industrial wastes and treated with the conventional process. In this system, the cyanide wastes are segregated, treated, and combined with the remaining waste streams prior to chromium reduction. Sludge is dewatered, using drying beds rather than a filter press or other mechanical device. The climate of the area and the availability of space permit this practice.

A new and innovative treatment system is being constructed at the Charleston NSY (not shown in Figure 2) to serve the new plating facility that goes on-line later this year. That system varies from most Naval treatment systems in that it is dedicated to the plating shop--no other waste streams will be treated there. Another unique feature of the system is the method of cadmium treatment. Cadmium plating at the new shop will be done in an acid solution rather than in the conventional cyanide bath, hence, no cyanide wastes will be generated at the shop and cyanide oxidation is not necessary. Cadmium waste will also be segregated so that the cadmium can be precipitated at its optimum pH (i.e., where the solubility of cadmium is at a minimum point). This approach was used because Charleston is faced with a strict cadmium limit.

The treatment system at the Pensacola NARF also contains an innovative process--integrated treatment. Integrated treatment is a method of treating cyanides in the plating process. The rinse immediately following the cadmium plating bath contains a chemical rinse (hypochlorite) to oxidize the cyanides. The chemical rinse water is then continuously bled to a cyanide sump, located one floor below, then pumped to a treatment tank. The treatment rinse water is then normally recycled to the rinse tank.

Concentrated cyanide solutions are treated on a batch basis in a separate tank, next to the integrated treatment/holding tank. These wastes are spills, drips and spent solutions which are collected and pumped to the batch treatment tank (3,500 gal). The treated cyanide waste streams and other wastewaters are discharged from the plating area to the IWTP (not shown in diagram).

In general, the Naval treatment systems discussed in this section can meet the Federal limitations for metals, however, more stringent local standards may have to be met by Naval dischargers. The USAF, for example, is required to reduce its metals and cyanide concentrations well below the Federal standards at McClellan AFB (Reference 6). Under such circumstances the Navy's treatment techniques for metals removal may not be sufficient.

Another potential compliance problem will be encountered with the total toxic organics (TTO) parameter. While TTO is usually not a problem from the electroplating processes, degreasing and paint stripping can significantly contribute. As discussed in the regulatory section of this report, an initial TTO limitation (4.57 mg/l) must be met by all Navy facilities by 1984 and a more stringent limitation (2.13) by 1986 (direct discharges must meet the more stringent standard in 1984). Of the Navy treatment systems discussed in this section, only the Norfolk NARF has a specific technology for TTO removal. The other systems can expect some incidental removal but no direct and controllable method of TTO removal exists at these locations. At Norfolk NARF, as well as other facilities, there are not enough data to validate compliance with TTO.

3. Material Recovery

Presently only three applications of chemical recovery (other than precious metal recovery) have been installed or are pending installation at Naval plating activities. The three applications include: Li-Con evaporator (NARF Pensacola); Innova Chromenapper (Puget Sound NSY); and Eco-Tec ion exchange (Jacksonville NAS).

The Li-Con unit includes high-vacuum vapor compression and waste heat modules. It was installed on a hard chromium line to recover chromic acid and recycle rinsewater. After a period of operation it was discovered that an insufficient amount of drag-out is generated by hard chromium plating which makes the recovery unit uneconomical. The Li-Con unit was recently removed from operation, as was the Eco-Tec unit.

The Innova Chromenapper (Reference 5, p. 307) was recently purchased by Puget Sound NSY. That unit will be applied to hard chromium rinse waters. No data are yet available on its operation.

4. Spent Process Solutions

All Navy plating activities, except for those using only brush plating, generate spent process solutions. Most spent solutions are alkaline cleaners, acid pickles or strippers. These solutions are dumped regularly, one to four times per month, depending on use and activity procedures. Plating solutions are also discarded at most activities, however, much less often than the cleaners and strippers. Some activities only discard solutions when they develop a quality problem and others dump solutions at scheduled intervals.

Three methods are used by Naval plating activities to dispose of spent solutions. Most activities put these wastes in drums and have them contractor-hauled for treatment/disposal. These outside firms usually apply conventional treatment to the wastes and concentrate the metal pollutants into a sludge. The cost of using private firms is generally high. A second method of disposal is to bleed spent solution into the IWTP. This is practiced, for instance at the Norfolk NARF, where spent solutions are drummed and sent to the IWTP. The third method of disposal involves onsite treatment at the plating shop. This practice was only observed at the Pensacola NARF where concentrated cyanide wastes are treated in a batch reactor.

5. Sludge Handling

Sludge handling practices at Naval IWTPs vary only slightly between activities. Most sludges are generated during chemical precipitation, thickened, dewatered, then contractor-hauled to a disposal site.

As discussed previously the volume and characteristics of Naval wastewater vary considerably between activities. One major factor that effects the volume and characteristics of the waste stream is whether or not the plating wastes are combined with other industrial wastes prior to treatment. Most NARFs and NSYs combine wastewaters from paint stripping, machining, dry docks and other operations. The dissolved and suspended solids from these wastewaters will add to the total hazardous sludge volume. If these wastes had been treated separately, the resultant sludge might not be nonhazardous and would not require disposal at an expensive permitted landfill.

The choice of treatment chemicals varies only slightly between Navy treatment systems. Most systems use sodium hydroxide and a polymer for metals precipitation. At least one treatment system (Norfolk NSY) uses lime. Both lime and sodium hydroxide (caustic) are considered to be standard practice, although a significant difference exists between the two chemicals in terms of sludge volume produced. As indicated in the TA, lime can produce several times more sludge than sodium hydroxide.

Sludge dewatering is important in reducing sludge volume. When sludge is removed from the treatment process, it contains 98 percent or more water. For economical disposal, at least 70 percent of the water should be removed prior to contractor hauling. This would reduce the sludge volume by more than 90 percent.

Sludge dewatering is used at all major IWTPs except Alameda NAS. Most IWTPs use filter presses for dewatering, although two treatment systems have drying beds (NARF San Diego, NARF Pensacola*).

C. COMMERCIALLY AVAILABLE TECHNOLOGY

Technologies available commercially and those receiving a substantial R&D effort were described in detail in the TA manual. That information is summarized here as per the five major problem areas. Table 7 highlights several important aspects of each technology including: cost, state-of-the-art technology, and advantages/disadvantages.

TABLE 7. WORTH ASSESSMENT MODEL DECISION CRITERIA

	Evaluation Criteria	Relative Value
1.	Response Time	.1
2.	Effect on Metal-Finishing Quality	.1
3.	Reliability and Maintainability	.1
4.	Manpower Requirement	.1
5.	Energy Demand	.1
6.	Skill Requirement	.1
7.	Facility Space Requirement	.1
8.	Investment Cost	.1
9.	Operating Cost	.1
10.	Material Requirements	.1

*NARF Pensacola plans to install a filter press because the drying beds produce a wet (2% solids) sludge.

1. Water Reduction

Approximately 90 percent of the water used in a plating shop is rinse water. Consequently, the most effective means of reducing water use is to alter rinsing techniques. The devices and methodologies available for conserving water in a plating shop are discussed in detail in the TA. These techniques can be categorized as follows:

- Multiple-Rinse Tanks
  - parallel
  - countercurrent
  - recovery rinse

- Flow Control
  - flow regulators
  - conductivity probes

- Innovative Rinsing
  - recycle rinsing
  - spray rinses

- Other
  - air knives
  - air spargers

Most private industry plating shops are making some use of the available flow reduction measures. The most prominent techniques are countercurrent rinsing, recovery rinses, and flow regulators. Very few firms make full use of all the techniques; however, those that do have been very successful in reducing or eliminating wastewater treatment needs.

2. Chemical Recovery

Due to the high cost of raw materials and pollution control, plating processes are being equipped with recovery systems to reclaim the chemical content in the rinse water and recycle a concentration of these chemicals to the plating bath. Frequently, the water is also purified and can be reused for rinsing.

A number of technololgies have been used for the chemical recovery; the one best suited for an application depends on the type of plating solution being recovered. Figure 3 summarizes the commercially available recovery techniques and the types of bath they have been applied to.

Justification for the investment in recovery systems, which have minimum installed costs of $30,000, is based on the savings in replacement chemicals, waste treatment cost and waste disposal.

RECOVERY TECHNOLOGY	PLATING BATH									
	DECORATIVE CHROMIUM	HARD CHROMIUM[b]	NICKEL	ELECTROLESS NICKEL[b]	CADMIUM (CN)	ZINC (CN)	ZINC (Cl)	COPPER (CN)	TIN (BF_4)	SILVER
EVAPORATION	●		●		●	●	●	●	●	●
ELECTRODIALYSIS			●		●	●	●	●	●	●
REVERSE OSMOSIS			●			●		●		
ION EXCHANGE	●		●	●						●
ELECTROLYTIC					●	●	●	●	●	●
DONNAN DIALYSIS										
ION TRANSFER MEMBRANES	●	●								
COUPLED TRANSPORT MEMBRANES	●									

[a]Indicates applications that have been commercially demonstrated or proven successful on full-scale pilot system.

[b]Low drag-out rate has limited applications of recovery technologies.

Figure 3. Summary of Recovery Technology Applications[a]

3. End-of-Pipe Treatment

The current state of the art in electroplating wastewater treatment includes:

- Chromium reduction
- Cyanide oxidation
- Neutralization/metal precipitation
- Solids separation
- Sludge dewatering

The most efficient approach is to segregate wastes containing chromium or cyanide and pretreat these wastes before mixing with the balance of the wastewater in a common neutralization/metal precipitation system.

Cyanide oxidation to cyanates and then to CO_2 and N_2 is usually accomplished in a two-stage stirred-tank reactor with a suitable oxidizing agent, such as chlorine gas, sodium hypochlorite or ozone. Other approaches have used a packed tower to achieve the liquid/gas contact with gaseous reagents. Chromate reduction is normally accomplished in a single stirred-tank reactor with sulfur dioxide or sodium metabisulfite. Other approaches have utilized ferrous ions either from a ferrous salt or formed by consumable iron electrodes.

Metal removal from the combined stream is most often accomplished by precipitation as metal hydroxides. By adding an acid or base, the pH is adjusted to the point where the metals exhibit minimum solubility. Other metal precipitation processes use a sulfide compound to precipitate the metal as a metal sulfide. Following precipitation, the precipitants are usually flocculated by addition of a suitable organic polyelectrolyte. The large-particle floc is then separated from the wastewater prior to discharge either by clarification or filtration. The solids are normally dewatered and disposed of in a permitted landfill.

4. Spent-Process Solutions

In most industrial plating operations the only process solutions dumped regularly are spent cleaning and stripping solutions. Typically, these solutions are discarded by metering them to the treatment system. When they are diluted with rinse water, their impact on the treatment process is minimized. Only a small percentage of private industry shops contractor-hauls their spent solutions.

Some solutions, including many strippers, contain high concentrations of cyanide--up to 8 oz/gal. In such cases, conventional treatment of the solution is not economical.* An effective method of reducing treatment costs and further reducing the impact on end-of-pipe (EOP) treatment is to destroy the cyanide on a batch basis before metering the waste to the sewer. This is currently being accomplished by at least one plating shop, using thermal destruction.

---

*1000 gal of stripper solution containing 8 oz/gal CN would consume 3,750 lbs of chemicals during treatment, resulting in a cost of $1,500.

Batch dumping of plating solution is very rare in the private sector, except in printed circuit shops (spent copper plating solutions are returned to the manufacturer where the chemicals are recycled). Instead, two methods of bath purification are widely applied: preventive and curative. The following is a list of commonly used methods:

- Preventive
  - filtration
  - ion transfer membranes
  - ion exchange
  - proper scheduling of work

- Curative
  - filtration
  - chemical treatment
  - electrolytic treatment ("dummying")
  - carbon treatment

To minimize discarding plating baths, private industry platers install the preventive technologies and perform frequent monitoring of bath parameters. In most plating shops, except for very small ones, laboratory equipment is used to test plating solutions. The most widely used test is performed with the Hull cell.

To supplement the monitoring capabilities of in-house chemists or technicians, private plating firms rely on their chemical supply companies for technical advice. Often, these technical representatives can provide the necessary troubleshooting required to avoid a batch dump. Such representatives are backed by experienced laboratory personnel and knowledgeable chemists.

5. Sludge Handling

Practices in private industry are essentially the same as the Navy. Sludges produced by treatment are dewatered, stored and contractor-hauled to secure disposal sites.

Some processes commercially available for detoxification of sludges are basically, solidification processes which stabilize the waste and prevent leaching of toxic metals. By using such a process, a sludge generator can delist his waste and dispose of the material in a common landfill. (Actually, disposal requirements for delisted wastes vary between states.) A number of commercial detoxification processes exist (e.g., Soliroc®, Sealosafe®, Chemfix®). These companies supply the fixation materials and/or perform the process. Also, noncommercial processes using Portland cement, fly ash and similar materials have been employed by sludge generators.

The present use of detoxifying processes in the private sector is very small. The reason this technology is unexploited is that the RCRA hazardous waste regulations have only recently gone into effect. Also, only a fraction of the plating industry currently has installed waste treatment and is generating sludge. As the need progresses, the use of detoxification/solidification technologies will increase.

D. TECHNOLOGY APPLICATION ASSESSMENT

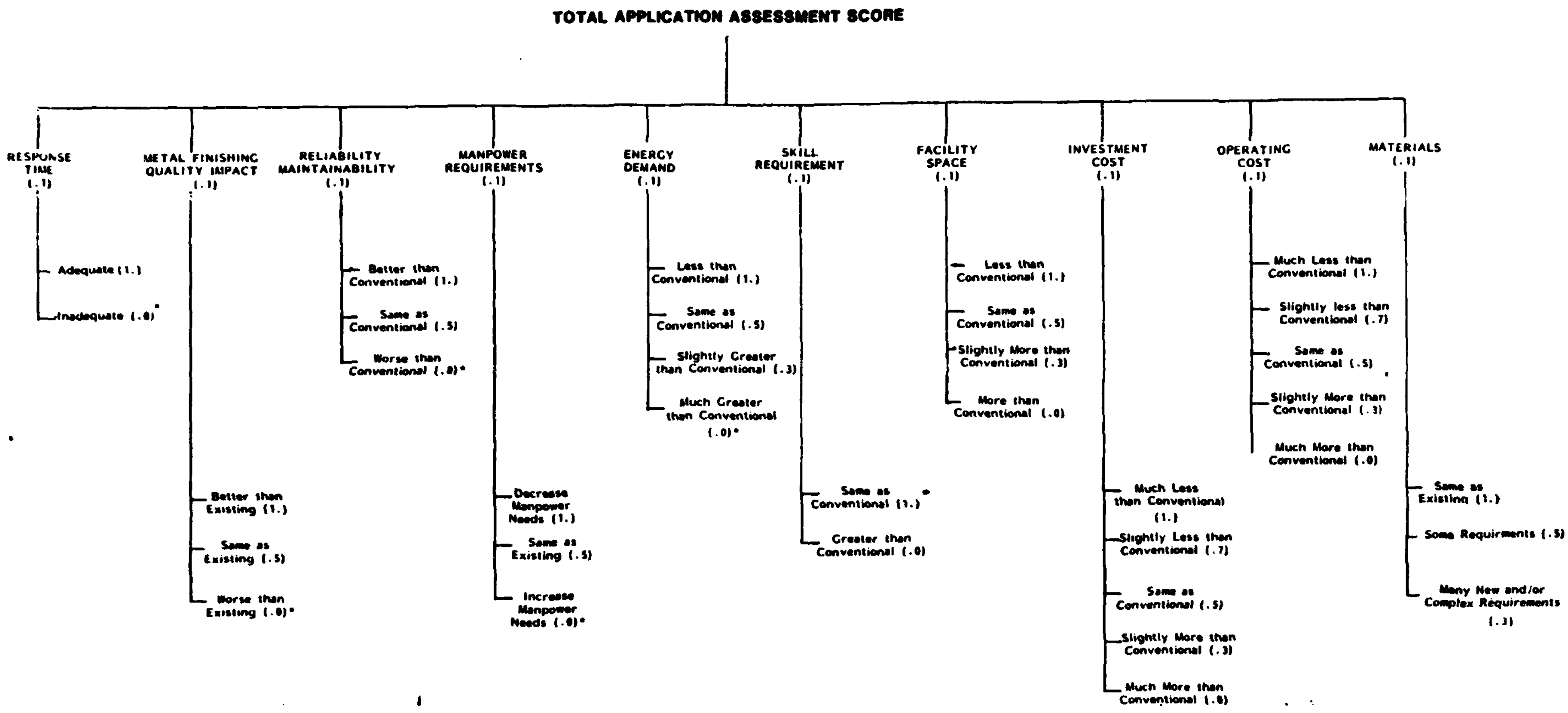
To help evaluate available technologies, an application assessment model has been prepared which scores and ranks technologies based on a common set of decision criteria. The technologies with the highest scores are most applicable to Navy activities.

In developing the model, 10 decision criteria were defined and each was given a value based on its relative importance in the decision process. The criteria values were selected such that the total of all values equals one. For each criterion several measures were then defined which describe how well a technology satisfies the criterion. Each factor was then given a value. For example, one criterion selected was the response time of the technology in meeting compliance dates. That criterion was given a value of 0.1, i.e., 10 percent of the decision is based on the ability of the technology to meet the regulations in a timely manner. Two measures were selected and given values to determine how well the technology meets the criteria: adequate response time (1.0) and inadequate response time (0.0).

To determine the worth assessment score for each technology, the appropriate measure is selected for each criterion. Then, the value of the measure is multiplied by the value of the criterion and summed over all criteria. The decision model is further described in Figure 4.

The criteria selected for the modeling exercise are presented in Table 7 along with the criteria values. Criteria 1 through 5 are considered as constraints in the decision process. Failure (a score of 0) in one or more of these criteria makes the technology unacceptable. The level of unacceptability of a particular technology is equal to the number of failures. In the decision model, failure in any of criteria 1 through 5 gives an overall score of 0.0 regardless of the scoring for other criteria.

Failure in criteria 1-5 may be overcome through R&D. For instance, if a technology response time is inadequate to meet regulatory deadlines, then Navy R&D can be applied to speed up the technology development. Similarly, manpower requirements may be increased by the use of a particular technology. However, Navy R&D may be able to automate the technology to the



*Selection of this measure will cause total application score to be 0.

Figure 4. Diagram of Application Assessment Decision Model

point where manpower requirements are the same or less than the use of conventional technologies. For this reason, the technology assessment scores were determined for two cases for each technology. In the first case, the score is determined using the original scoring rules. In the second case, potential R&D improvements are considered. If R&D can eliminate a failure the score is adjusted accordingly. This procedure aids in identifying which technologies will best benefit from R&D. The results of the second exercise are presented and discussed in Section IV.

The results of the technology assessment process are presented in Table 8, where the technologies have been divided into six categories: (1) in-plant changes, (2) recovery technologies, (3) cyanide destruction, (4) chromium reduction, (5) metals removal, and (6) hazardous sludge reduction. The relationship between the five problem areas is discussed at the beginning of Section II, and the technologies selected for the worth assessment exercise are described in Figure 5. Additional details of the worth assessment process are presented in the appendix.

1. Technology Assessment Scoring

Most in-plant changes scored fairly high in the application assessment model, indicating their appropriateness for Navy plating activities. Each should be considered on a case-by-case basis. Often two or more of the in-plant changes can be combined, such as countercurrent rinsing with air agitation and flow regulations, to provide increased water savings. Three in-plant changes received scores of .00 because they cannot be applied in their current state of development to Navy plating activities. As discussed in Section IV, RDT&E could adequately speed up the response time of these technologies.

The recovery technologies all received scores of .00. Failures of these technologies occurred in Criterion 3 (Reliability and Maintainability), Criterion 4 (Manpower Requirement) and Criterion 5 (Energy Demand). (See the Appendix to find the specific failure(s) for each technology.) In addition to these failures, recovery generally did not score well because these technologies have high investment costs and provide only a minimal impact on operating costs (therefore a low ROI). In the private sector where these technologies are successfully applied, drag-out rates are much higher and the impact on operating costs is therefore much greater (therefore providing a high ROI).

For chromium reduction, cyanide oxidation and metals removal the conventional technologies received the highest scores. Therefore, under most circumstances the Navy should apply the conventional technologies. If, however, standards become more stringent, the conventional techniques may not be adequate and other technologies should be considered on a case-by-case basis.

TABLE 8. APPLICATION ASSESSMENT SCORES OF TECHNOLOGIES AVAILABLE FOR NAVY ELECTROPLATING POLLUTION CONTROL

Technology Category/Technology	Application Assessment Scores[a]	Level of Unacceptability
In-Plant Changes:		
Reusing Rinse Water	.69	0
Flow Regulators	.67	0
Air Agitation	.65	0
Spray Rinses	.65	0
Countercurrent Rinsing	.63	0
Recovery Rinsing	.60	0
Innovative Hard Chrome Plating[b]	.00	1
Plating Bath Purification[b]	.00	1
Timer Rinse Control	.00	1
Conductivity Cells	.00	1
Air Knives	.00	1
Recovery Technologies		
Ion Transfer	.0	1
Reverse Osmosis	.0	2
Ion Exchange	.0	2
Electrodialysis	.0	2
Electrolytic	.0	2
Evaporation	.0	3
Coupled Transport Membranes	.0	3
Donnan Dialysis	.0	3
Chromium Reduction:		
Sulfur Compound Reduction	.65	0
Integrated Treatment	.48	0
Sacrificial Iron Anodes	.00	1
Ferrous Sulfate	.00	1
Sodium Borohydride	.00	2
Material Recovery	.00	2
Cyanide Oxidation:		
Alkali Chlorination	.65	0
Integrated Treatment	.61	0
Electrolytic[c]	.56	0
Thermal Oxidation[c]	.00	1
Ozone	.00	1
Material Recovery	.00	2

[a] Based on top score of 1.0. See appendix for scoring criteria.

[b] Not in TA, see description in appendix.

[c] Only applicable to batch treatment of concentrated solutions.

TABLE 8. APPLICATION ASSESSMENT SCORES OF TECHNOLOGIES AVAILABLE FOR NAVY ELECTROPLATING POLLUTION CONTROL (CONCLUDED)

Technology Category/Technology	Application Assessment Scores[a]	Level of Unacceptabilit
Metals Removal:		
Hydroxide Precipitation	.65	0
Sulfide Precipitation	.58	0
Ultrafiltration	.00	1
Electrolytic	.00	2
Ozone	.00	1
Sodium Borohydride	.00	2
Insoluble Starch Xanthate	.00	2
Freeze Crystallization	.00	3
Hazardous Sludge Reduction:		
Sludge Washing	.00	1
Solidification	.00	2
Sludge Aging	.00	2
Sodium Borohydride Precipitation	.00	2
Heat Treatment	.00	4

Technology Category/ Technology \ Technical Problem Areas	Water Conservation	End of Pipe Treatment	Material Recovery	Spent Process Solutions	Sludge Handling
In-Plant Changes:					
Innovative Hard Chrome Plating	X	X			
Timer Rinse Control	X				
Countercurrent Rinsing	X				
Plating Bath Purification				X	
Air Agitation	X				
Flow Regulators	X				
Air Knives	X		X		X
Recovery Rinsing	X		X		X
Reusing Rinse Water	X				
Conductivity Cells	X				
Spray Rinses	X				
Recovery Technologies					
Coupled Transport Membranes	X		X		X
Evaporation			X		X
Electrodialysis	X		X		X
Reverse Osmosis	X		X		X
Ion Exchange	X		X		X
Electrolytic			X		X
Ion Transfer			X		X
Donnan Dialysis			X		X
Chromium Reduction:					
Integrated Treatment	X	X			
Sulfur Compound Reduction		X			
Sacrificial Iron Anodes		X			
Ferrous Sulfate		X			
Sodium Borohydride		X			X
Cyanide Oxidation:					
Electrolytic				X	
Integrated Treatment	X	X			
Alkali Chlorination		X			
Ozone		X			
Thermal Oxidation				X	
Metals Removal:					
Hydroxide Precipitation		X			X
Sodium Borohydride		X			X
Ozone		X			
Ultrafiltration		X			
Insoluble Starch Xanthate		X			X
Sulfide Precipitation		X			X
Electrolytic		X			
Freeze Crystallization		X			X
Hazardous Sludge Reduction:					
Solidification					X
Sodium Borohydride Precipitation		X			X
Sludge Washing					X
Heat Treatment					X
Sludge Aging					X

Figure 5. Relationship Between Technical Problem Areas and Selected Technologies

Integrated treatment, now in at the Pensacola NARF, scored second for chromium reduction and cyanide oxidation. Sulfide precipitation, a technology applied by the Army, scored second under metals removal.

Each of the hazardous sludge reduction technologies received a score of .00. Failures of these technologies were in Criterion 1 (Response Time), Criterion 3 (Reliability and Maintainability), Criterion 4 (Manpower) and Criterion 5 (Energy Demand). As discussed in Section IV, failures in Criteria 1, 3 and 4 can generally be overcome with RDT&E.

SECTION III

TECHNOLOGICAL PROJECTIONS

A. PREVIOUS RESEARCH AND DEVELOPMENT

EPA and the private sector took the lead on electroplating pollution control R&D in the early seventies (Table 9). At that time conventional physical/chemical treatment was already established as the accepted method of wastewater pollutant removal. However, the only treatment systems installed were at locations that directly discharged to waterways.

The impetus for the initial R&D was threefold. First, EPA had cited the electroplating industry as a major contributor of toxic metals and cyanide to the environment. The EPA R&D branch in Cincinnati (Industrial Environmental Research Laboratory), and,to a limited extent, its predecessor in Edison, NJ were charged with developing improved methods of control and treatment of wastewater pollutants for future use in establishing sound regulations and enforcement actions. Their interest was in both end-of-pipe (EOP) treatment and chemical recovery. EPA's ultimate goal, as shown in the Clean Water Act, was to completely eliminate pollutant discharges.

A second force behind early R&D efforts was the potential marketplace. Many pollution equipment firms were working to improve the conventional physical/chemical process and find new methods of end-of-pipe treatment. However, the greatest effort by private industry was placed on control technology through recovery of plating chemicals and recycling of process wastewater. A variety of electroplating chemical recovery devices and processes were developed in the seventies, including: evaporation, ion exchange, electrochemical technology, reverse osmosis and electrodialysis. Another focus of private industry, spurred by environmental concerns and rising treatment costs, was the development of low-polluting plating solutions, such as noncyanide zinc plating (ZnCl) and alternatives to cadmium cyanide plating chemicals.

A third force behind early R&D was the rising costs of water, chemicals and energy. Individual plating facilities adopted conservation measures previously considered uneconomical. Methods and devices, such as countercurrent rinsing, recovery rinsing, flow regulators, and spray rinses, were finding their way into the plating shops. New methods of conservation, such as conductivity probes, were developed to supplement the existing conservation measures. The evolution of conservation measures has, however, been less formal than EOP and recovery technologies. The major reason for this lag is that conservation reduces EOP and recovery needs and, therefore, reduces equipment purchases. These conservation measures are more procedural than equipment-oriented in nature; therefore, there is no product sales incentive. Another key reason for the lag is that many platers felt that these measures were not part of their production processes, and basically ignored implementation for fear of upsetting production.

During the 1980s research and development efforts in plating pollution control have subsided substantially. Several factors have caused the R&D slump. First, the major push in the seventies resulted in a large number of commercially available technologies, reducing the potential market share and making it less attractive for new ideas. Second, since 1977 when the Federal electroplating pollution control standards were first proposed, EPA changed the compliance dates and limitations four times. This indecision by EPA has delayed sales in pollution control equipment, causing many of the early firms to abandon their efforts. Third, the EPA has curtailed their internal R&D work previously performed at EPA-IERL, Cincinnati.

The EPA R&D slump in the eighties has been cushioned somewhat by the R&D efforts of the military. Both the Army and the Air Force have taken active roles in this area. The Army started with a joint EPA project to investigate the applicability of sulfide precipitation as an alternative to hydroxide precipitation. That effort resulted in the construction of a full-scale system at Tobyhanna, PA. The Air Force has funded several projects aimed at alternatives to sulphur-compound chromium reduction and hydroxide precipitation, as well as work with bath purification and sludge volume reduction.

Over the course of the past 12 years, the R&D emphasis has shifted from EOP treatment and chemical recovery to hazardous waste. This change is primarily the result of the implementation of RCRA hazardous waste regulations. A major target in recent years has been wastewater treatment sludge. Early R&D efforts (1978) were jointly conducted by EPA and the American Electroplaters' Society. More recently, the Air Force and Army have taken the lead in finding methods of reducing sludge volumes and rendering the wastes nonhazardous.

B. FUTURE RESEARCH AND DEVELOPMENT

The current mission of EPA is rather clear. No major emphasis will be placed in the near future on electroplating wastewater treatment and control. The final effluent regulations are based on conventional physical/chemical treatment. Therefore, their present position is that no new EOP technologies are needed. However, some additional activity can be expected from EPA on hazardous waste treatment and disposal. For instance, EPA is continuing to fund R&D on the recovery of metals from electroplating treatment sludges.

The USAF is continuing to take an active role in electroplating pollution control R&D (Table 9). They have funded a project to investigate methods of rejuvenating exhausted plating solutions using selective ion exchange. This work may help to minimize batch dumps of plating solutions. The effort is focusing on the common plating solutions, including chromium, nickel, electroless nickel, cadmium and copper. The USAF is also planning to demonstrate methods of improved EOP treatment and continue research on reducing hazardous sludge disposal costs. These demonstrations, scheduled for FY 84-85, will include the construction of a portable pilot system. The sludge work is focusing on methods of reducing the volume of sludge requiring disposal and minimizing its hazardous characteristics. Several techniques have shown promise during the initial work.

As discussed previously, the private sector has reduced R&D efforts. It appears that, for the immediate future, this trend will continue. If EPA decides to increase the stringency of the electroplating standards, a renewed emphasis on R&D may develop. However, this is very doubtful.

TABLE 9. ELECTROPLATING POLLUTION CONTROL RESEARCH AND DEVELOPMENT 1970 to 1986

R&D ENTITY	1970-1977	1977-1980	1980-1983	1983-1986
Environmental Protection Agency - Industrial Environmental Research Laboratory Cincinnati, Ohio Contact: Roger Wilmoth 513/684-7506	o Kastone process o Sulfide precipitation o Ozone oxidation o Reverse osmosis o Electrodialysis o Evaporation o Chrome reduction o Cyanide destruction	o Microprocessor control of wastewater treatment o Centralized waste treatment o Treatment sludge characterization o Applicability of electrolytic treatment o Applicability of sulfide precipitation o Applicability of ion exchange o Soluble sulfide precipitation	o Microprocessor control of wastewater treatment o Centralized waste treatment o Relationship of treatment variables to sludge characteristics o Detoxification of metal-bearing sludges o Fixation of metal-bearing sludges o Optimizing conventional hydroxide precipitation o Donnan dialysis	o Evaluation of emerging technologies o Metal recovery from metal-bearing sludges o Hazardous wastes monofill and treatment
USAF Engineering Services Center Tyndall AFB, FL Contact: Lt. James Aldrich 904/283-2942		o Sludge characterization	o Reduction of sludge volume/hazardousness o Alkaline ferrous sulfate reduction of chromate	o Ion exchange for spent plating baths o Reduction of sludge volume/hazardousness o Alkaline ferrous sulfate reduction of chromate
American Electroplaters' Society Winter Park, FL Contact: Howard Schumacher 305/647-1197	o Reverse osmosis (w/EPA) o Electrodialysis (w/EPA)	o Sludge characterization (w/EPA) o Use of sludge as a concrete additive	o Relationship of treatment variables to sludge characteristics	
National Association of Metal Finishers Chicago, IL Contact: Dallard Carey 312/644-6610		o Electrochemical Reactor for CN (Cd, Cu, Zn) wastewater treatment	o Microprocessor control of wastewater treatment (w/EPA) o Metals recovery from metal-bearing sludge	

TABLE 9. ELECTROPLATING POLLUTION CONTROL RESEARCH AND DEVELOPMENT 1970 to 1986 (CONCLUDED)

R&D ENTITY	1970-1977	1977-1980	1980-1983	1983-1986
U.S. Army Contact: Dave Renard 301/671-2054		o Sulfide precipitation (w/EPA)	o Sludge aging	o Ion exchange
U.S. Navy Contact: Ken Chacey 803/743-5510			o Vapor recompression evaporator o Ion exchange metal recovery	

SECTION IV

RECOMMENDATIONS AND ALTERNATIVES

A. GENERAL

The purpose of this section is to outline the potential courses of action for solving the pollution control problems associated with Navy electroplating activities. As a basis for discussing the alternatives, the pollution problems/needs have been categorized and summarized as follows:

1. Methods To Reduce Water Use

Water use at Naval electroplating activities was estimated at 3.6 million gallons per day. In terms of water costs and municipal sewer charges, this amounts to approximately $3.2 million per year. The industrial wastewater treatment costs (capital and operating) add significantly to this figure. Additionally, high water usage dilutes pollutants and hinders removal mechanisms.

2. Technologies To Meet Federal Guidelines for Metals and Cyanide

To meet the 1984 and 1986 EPA effluent limitations, Navy electroplating activities must use technologies for the removal of cyanide and metals. The EPA regulations are based on the use of conventional chemical treatment. Some innovative alternatives exist which could offer a cost savings in terms of reduced chemical consumption and/or reduced sludge generation.

3. Methods/Technologies To Reduce Frequency/Impact of Batch Dumps

Currently, the Navy discards spent process solutions such as cleaners, strippers and plating baths. At most facilities these solutions are contract-hauled to treatment/disposal sites. The cost of treatment/disposal ranges from $0.25/gal to $3.00/gal. The Navy-wide cost to dispose of these wastes is uncertain but could approach $1.3 million* annually. Treatment of these wastes at IWTPs is not always possible since concentrated wastes can upset the treatment process.

---

*Based on 28 major facilities (Table 3) with an average discharge of 30,000 gpy of concentrated solution and a transportation/treatment cost of $1.50/gal.

Cleaners and strippers have limited life spans and are therefore commonly discarded. However, plating solutions can be economically purified and returned to service. The replacement cost for baths varies considerably, depending on the type and concentration of metal. For most facilities the cost will equal or exceed treatment/disposal costs.

4. Technologies for Low Metals and Cyanide Discharge

The conventional treatment technologies can generally meet EPA's electroplating discharge standards. However, more stringent standards may apply to direct dischargers. In addition, some municipalities may enforce stringent pretreatment standards. Also, some treatment facilities may have difficulty in meeting the basic EPA regulations because of design problems, chemical complexing, or waste variability. Under these circumstances, IWTPs may require some form of additional control.

5. Hazardous Sludge Volume Reduction Technology

Sludge disposal is currently a problem for Naval IWTPs in terms of cost, the availability of disposal sites and the burden of regulations. These problems are expected to intensify as the present disposal areas become filled.

The cost of sludge disposal varies between activities primarily as a result of the availability of disposal sites and associated transportation costs. Based on disposal costs at the Pensacola NARF ($5.30 per 1000 gal of treated wastewater), the maximum Navy-wide cost is approximately $5.7 million, annually.

6. TTO Treatment

TTO is not a single compound but rather the combined concentration of 113 organic compounds. As such, the TTO in one waste stream may require a removal technology completely different from that of another. Currently, very few data exist and a determination of TTO compliance is not possible. If TTO concentrations exceed the Federal standard, advanced treatment may be necessary.

B. IDENTIFYING ALTERNATIVES

The application assessment decision model used in Section II has been reapplied as an initial step in identifying alternative courses of action. In the original scoring, many technologies received a total score of 0 since there were failures in one or more of Criteria 1 through 5. The failure of technologies to meet specific criteria may be overcome through an applied RDT&E program. In reapplying the decision model, each technology was reevaluated; if R&D could reasonably be expected to overcome a failure, then the score was appropriately adjusted. For instance, when a technology received a 0 score because of an inadequate response time, the application of RDT&E was considered to speed up development. Similarly, if a technology received a 0 score because it increased manpower needs, RDT&E was considered since it may be possible to automate a given process or technology and eliminate additional manpower needs. R&D could also be expected to overcome reliability and maintainability problems, eliminate quality impact or reduce energy demand. In reevaluating the score, each technology and criterion were considered on a case-by-case basis.

C. RDT&E SCORING

1. In-Plant Changes

The results of the exercise are presented in Table 10. For in-plant changes three new technologies have the highest scores: innovative hard chrome plating, plating bath purification and the timer rinse control. Each of these technologies had previously received a score of 0 because the response time was inadequate.

2. Recovery Technologies

The scores for recovery technologies showed improvement after consideration of RDT&E. The major areas of improvements were in R&M and manpower requirements. Several technologies received nonzero scores (ion transfer, ion exchange and electrolytic); however, these scores were relatively low. The low scores are, in part, a result of the high investment cost of recovery technologies, coupled with the relatively small impact they have on operating costs. In the private sector, where recovery technologies are widely applied, plating production is much higher and as a result considerably more drag-out is generated. With more chemicals to recover in the private sector the recovery technologies can have a significant impact on operating costs and the capital expenditure can therefore be justified. Under current Navy conditions, recovery does not appear to be viable.

3. Chromium Reduction

The top scores for chromium reduction remained unchanged. The conventional method, sulfur compound reduction, appears to be the best choice, even when RDT&E is applied to new and innovative techniques. The ferrous sulfate process scored a relatively high second and may provide some advantages over the conventional method once it is fully developed. The USAF has conducted basic research with the ferrous sulfate processes and is planning an 18-month demonstration project, beginning in FY 84.

TABLE 10. R&D ASSESSMENT SCORES OF TECHNOLOGIES AVAILABLE FOR NAVY ELECTROPLATING POLLUTION CONTROL

Technology Category/Technology	R&D Assessment Scores[a]	Level of Unacceptability
In-Plant Changes:		
Innovative Hard Chrome Plating[b]	1.0	0
Plating Bath Purification[b]	.78	0
Timer Rinse Control	.73	0
Reusing Rinse Water	.69	0
Flow Regulators	.67	0
Air Agitation	.65	0
Spray Rinses	.65	0
Countercurrent Rinsing	.63	0
Recovery Rinsing	.60	0
Conductivity Cells	.00	1
Air Knives	.00	1
Recovery Technologies		
Ion Transfer	.53	0
Ion Exchange	.50	0
Electrolytic	.48	0
Reverse Osmosis	.0	1
Electrodialysis	.0	1
Evaporation	.0	1
Coupled Transport Membranes	.0	2
Donnan Dialysis	.0	2
Chromium Reduction:		
Sulfur Compound Reduction	.65	0
Ferrous Sulfate	.60	0
Integrated Treatment	.48	0
Material Recovery[c]	.48	0
Sacrificial Iron Anodes	.00	1
Sodium Borohydride	.00	1
Cyanide Oxidation:		
Alkali Chlorination	.65	0
Integrated Treatment	.61	0
Electrolytic[d]	.56	0
Thermal Oxidation[d]	.54	0
Ozone	.53	0
Material Recovery	.48	0

[a]Based on top score of 1.0. See appendix for scoring criteria.

[b]Not in TA, see description in appendix.

[c]All recovery technologies received a score of .0 because there is generally insufficient drag-out at Navy plating activities to justify recovery.

[d]Only applicable to batch treatment of concentrated solutions.

TABLE 10. R&D ASSESSMENT SCORES OF TECHNOLOGIES AVAILABLE FOR NAVY ELECTROPLATING POLLUTION CONTROL (CONCLUDED)

Technology Category/Technology	R&D Assessment Scores[a]	Level of Unacceptability
Metals Removal:		
Hydroxide Precipitation	.65	0
Sulfide Precipitation	.58	0
Ozone	.51	0
Ultrafiltration	.00	1
Sodium Borohydride	.00	1
Electrolytic	.00	2
Insoluble Starch Xanthate	.00	2
Freeze Crystallization	.00	3
Hazardous Sludge Reduction:		
Sludge Washing	.60	0
Solidification	.63	0
Sludge Aging	.00	1
Sodium Borohydride Precipitation	.00	1
Heat Treatment	.00	3

4. Cyanide Oxidation

The scores for cyanide oxidation technologies indicate that RDT&E can eliminate some barriers to the implementation of innovative methods. However, the conventional technology, alkali chlorination, again has scored the highest. The electrolytic and thermal oxidation techniques, which are only applicable to batch treatment of concentrated solutions, have scored in the moderate range. The application of these techniques could reduce treatment and disposal costs of concentrated wastes.

5. Metals Removal

Again, the conventional technology, hydroxide precipitation, has received the highest score. Sulfide precipitation, which is currently used on a full-scale basis, was ranked second. RDT&E applied to innovative metals removal processes, such as ozone-enhanced precipitation or sodium borohydride precipitation, can improve the scores of these technologies; however, the technologies do not show a capability improvement above the state of the art.

6. Hazardous Sludge Reduction

Currently, no hazardous sludge reduction technologies are used by the Navy or other branches of the military. Only solidification is applied in the private sector and it is used on a very limited basis. A description of the various hazardous sludge reduction technologies listed in Table 10 is included in the appendix. These technoloiges were investigated in a recent USAF R&D effort.

As indicated by the improved scores, a RDT&E program is expected to make two of these technologies (solidification and sludge washing) viable for Navy application. The moderately high scores indicate that the technologies could provide improvements over current Navy practices. Specifically, these techniques reduce the volume of hazardous material that the Navy must handle, transport and dispose. As a result, the overall operating costs of treatment can be significantly reduced.

D. OTHER PROBLEM AREAS

Three problem areas not specifically covered by the decision model that require consideration are: (1) batch dumps, (2) stringent metal limitations, and (3) total toxic organics. Each of these areas may require RDT&E and they are therefore discussed in this section.

1. Spent-Process Solutions

Spent-process solutions and other concentrated wastes such as spills are discarded by all Navy plating activities. An applied RDT&E program in the area of bath purification can reduce the volume of spent solutions generated each year; however, some solutions will still require treatment/disposal. As discussed in Section 2, these wastes are most often transported to private treatment/disposal firms. In some cases, the wastes are treated onsite at the IWTP. The cost of having the wastes transported and treated by a private firm are extremely high, often exceeding $2/gal. A safety hazard is also associated with the handling and transporting of the wastes. When these wastes are treated onsite, they consume large amounts of treatment reagents and often upset the normal treatment operation. Therefore, less costly and more reliable methods are needed.

Two technologies, thermal oxidation and electrolytic treatment, applicable to the destruction of cyanide in concentrated solutions, were evaluated in the decision model Neither of these technologies are commercially available; however, promising research results have been obtained. Treatment techniques for other concentrated solutions containing pollutants such as chromium are also needed.

2. Stringent Metal Limitations

State governments and local jurisdictions have the authority to establish effluent guidelines. Since the Federal guidelines are based on the application of conventional treatment, this treatment method may be inadequate to meet the more stringent standards. As an example, the Charleston Naval Shipyard has used an innovative design to increase its cadmium removal and meet a strict limitation. Other activities may find and solve similar problems.

RDT&E efforts in this area would only be necessary if specific activities were forced to meet limitations not attainable with conventional technologies. Therefore, an initial recommendation is to survey the affected activities to determine the expected limitations for 1984 and 1986. If a significant problem exists, then RDT&E could be employed. Several potential avenues for better metals removal exist, such as:

- Innovative end-of-pipe techniques
- Polishing techniques added to conventional treatment
- Improved process control using microprocessors

3. Total Toxic Organics (TTO)

The TTO parameter is not directly generated by electroplating operations; however, associated processes, such as degreasing and paint stripping, can contribute significant quantities of TTO. At most Naval activities, all industrial wastewaters are combined before treatment at an IWTP. When these wastes are combined, the entire flow is subject to the TTO limitation.

Currently no data exist to evaluate the extent of TTO contamination at Naval plating activities. The cost of TTO analysis ($700 to $1,000 per sample) makes monitoring expensive; therefore, routine analysis has not been conducted.

TTO may become the most difficult parameter for Navy activities to meet from both a technical and cost standpoint. It is therefore recommended that a substantial RDT&E program be undertaken. Initially, it will be necessary to determine the number of activities with TTO-compliance problems, then determine the sources of TTO. When examining TTO control methods, two approaches should be considered (1) chemical substitution of toxic paint strippers and other chemicals contributing TTO, and (2) TTO treatment.

E. SUMMARY

A problem/alternative matrix which summarizes the recommended approaches is presented in Figure 6. For each problem area, specific technology alternatives have been identified. For each technology a level of Navy involvement has been recommended.

The first level of Navy involvement is "do nothing." Such an alternative is appropriate when the technology is readily available and requires no adaption to Navy operations or when the technology is developing rapidly and is expected to become usable before a Navy RDT&E program would have significant impact.

The second level of involvement is a facility survey. This alternative is recommended when there is not enough data to accurately define the extent of the problem.

The third level of involvement is research and development (R&D). R&D will not be necessary for all technologies. In some instances the technologies have already been developed and only require customizing to Navy needs which is the next level of involvement. The final level is testing and evaluation.

1. Methods To Reduce Water Use

Under a "do nothing" approach, some minor water reduction would take place as a result of individual activities using conventional methods such as flow restrictors. However, in most cases, water use rates would remain unnecessarily high, causing high operating costs and affecting compliance with 1984 and 1986 effluent regulations. Therefore, an active approach is recommended.

Need/Alternative	Do Nothing	Survey Facilities to Est. Magnitude of Problem	Research & Development	Customizing to Navy Operations	Testing & Evaluation
METHODS TO REDUCE WATER USE					
o Timer Rinse Control System				o	o
o Innovative Hard Chromium Plating Process				o	o
o Other Methods (e.g., countercurrent)	o				
TECHNOLOGIES TO MEET FEDERAL REGS. FOR METALS AND CYANIDE					
o Conventional Processes	o				
o Innovative End of Pipe Processes	o				
o Recovery Technologies	o				
REDUCE FREQUENCY AND IMPACT OF BATCH DUMPS					
o Plating Bath Purification		o		o	o
o Batch Treatment		o	o		o
TECHNOLOGY FOR LOW METALS DISCHARGE					
o Innovative End of Pipe		o[1]		o	o
o Polishing		o[1]		o	o
o Microprocessor Control	o				
TECHNOLOGY FOR CONTROL/REMOVAL OF TOTAL TOXIC ORGANICS					
o Chemical Substitution		o[1]	o		o
o TTO Treatment		o[1]	o		o
HAZARDOUS SLUDGE VOLUME REDUCTION TECHNOLOGY					
o Innovative Technology			o		o

[1]If facility survey indicates that problem area is smaller in scope than expected, a "do nothing" alternative is recommended.

Figure 6. Alternatives for Meeting Naval Electroplating Pollution Control Needs

Two methods of reducing water use are suggested: the timer rinse control and the innovative hard chromium plating process. Each technology has previously undergone development in the private sector but requires customizing for Navy application followed by testing and evaluation.

2. Technologies To Meet Federal Regulations for Metals and Cyanide

The conventional technologies for cyanide oxidation, chromium reduction and metals removal are best for meeting the 1984 and 1986 EPA standards. These technologies are currently employed by Navy activities and do not require further RDT&E.

Many innovative technologies, in various stages of development, could be substituted for the conventional methods. Also, recovery technologies exist which can supplement end-of-pipe treatment. However, based on the decision criteria used, it does not appear that these technologies will benefit the Navy. Therefore, a "do nothing" alternative is recommended.

3. Reduction of Frequency/Impact of Batch Dumps

Batch dumps present problems to Navy activities both in terms of treatment system upsets and operating costs. Under a "do nothing" approach the high operating costs will continue and compliance with 1984 and 1986 effluent regulations may be jeopardized. It is, therefore, recommended that the Navy take an active RDT&E approach from two directions: (1) reduce the frequency of batch dumps through bath purification, and (2) treat the dumps onsite with batch treatment (e.g., the use of a combined thermal/electrolytic treatment should be investigated for cyanide oxidation).

Since the available data on the generation rate of spent solutions is rather meager, it is recommended that an initial survey be undertaken to better estimate the magnitude of the problem. Plating bath purification techniques are currently applied by private industry; therefore, R&D is not considered necessary. However, these processes will require customizing to Navy needs, testing and evaluation. The batch treatment technologies, such as thermal/electric oxidation, will require R&D as well as testing and evaluation.

4. Technologies for Low Metals Discharge

The need to investigate new technologies is uncertain since local and state regulations were only recently formulated. A regulatory survey should therefore be conducted as an initial step to determine the number of Navy facilities that will require treatment beyond the conventional process. If additional metals removal is necessary, a "do nothing" approach will result in compliance failures in 1986 when the more stringent regulations would most likely become effective. Two potential

RDT&E approaches include: (1) innovative end-of-pipe technologies and (2) polishing technologies which can be added to existing systems.

Both the innovative end-of-pipe (e.g., sulfide precipitation, ultrafiltration) and polishing technologies (e.g., ion exchange) are commercially available or have been fully developed through recent R&D. However, customizing of these technologies to Navy operations is expected to be necessary, followed by a testing and evaluation effort.

The Navy has previously installed conventional treatment at most major plating activities or plans are underway for installation. It is likely that innovative end-of-pipe technologies will require significantly different equipment than the conventional processes. Therefore, existing equipment would be unusable and a major capital expenditure would be necessary. Also, considering the lag time in major construction projects, it is very unlikely that RDT&E could produce a timely solution for 1986 or even approach that deadline. Therefore, RDT&E is not recommended for innovative end-of-pipe technologies.

Polishing technologies can be retrofit to conventional treatment systems, thereby making full use of existing equipment. The technologies could be tested and evaluated during the next 2 years to allow for implementation by 1986 or shortly after. For these various reasons, a polishing technology approach is recommended.

5. Technology for Control/Removal of Total Toxic Organics

As discussed previously, the extent of the TTO problem is unknown and an analytical survey of Navy facilities is recommended.

The military has a rather unique waste stream with respect to TTO. The high volume of rework, including paint stripping, is generally not found in private industry. Therefore, the military cannot expect solutions to their TTO problem to be developed by the private sector. A "do nothing" approach will most likely result in noncompliance. Therefore, if TTO is found at levels above the 1984 and 1986 EPA limits or local or state standards, a full RDT&E program is recommended.

Research on TTO reduction should focus in two directions. First, after the sources of TTO are identified, alternative process chemicals should be investigated. Second, end-of-pipe methods for TTO should be investigated as a means of ultimate control.

6. Hazardous Sludge Volume Reduction Technology

Sludge will undoubtedly be a major problem for Navy plating activities. If a "do nothing" approach is selected, plating activities will have greater difficulty in disposing of hazardous sludges and will be forced to pay extremely high rates. It is therefore recommended that an RDT&E program be initiated in this area. The program should be coordinated with the USAF and Army, both of which have already begun basic research with sludge.

SECTION V

TECHNOLOGY GOALS

A. GENERAL

The technical goals and required program resources for each RDT&E effort outlined previously are presented in this section.

B. METHODS TO REDUCE WATER USE

Testing and evaluation efforts are recommended to establish the applicability of two methods of reducing water flow: (1) timer rinse control, (2) innovative hard chromium plating process.

1. Timer Rinse Control

The use of a demand rinse-control system (see Appendix B for description) will reduce flow rates at Naval plating activities by 75 percent at most facilities and result in an annual savings of $2.43 million* in water costs and municipal sewer charges. For facilities without installed treatment, the rinse control will decrease capital expenditures by approximately 25 percent.** Facilities that currently have treatment will benefit from additional pollution removal.

The cost of a rinse-control system will vary between plating facilities. The cost is primarily dependent on the number of rinse tanks. The expected cost for an average NARF or NSY having 20 rinse tanks is about $10,000, plus installation (about $8,000). On a Navy-wide basis the total cost will be on the order of $420,000.

The timer rinse-control technology is not fully commercialized; however, a prototype system has been installed at a private plating facility. The goal of this project would be to evaluate the potential water savings in a Navy application

---

* 3600 tgd x .75 x 3.00 $/1000 gal x 300 days/yr = $2.43.

**Based on 28 facilities with rinse tanks (Table 3) with an average number of 16 rinse tanks @ $15,000 per system (installed).

and develop a customized design. The milestones and funding profile to evaluate the technology are as follows:

	$\$ \times 10^3$		
Milestone	FY84	6.2	6.3
1. Select site and survey to establish baseline	15		15
2. Make in-plant changes necessary to optimize use of timer control	10		10
3. Prepare customized design, build and install timer system	15		15
4. Monitor operation and water use	15		15
5. Complete evaluation and disseminate results	10		10
Totals	65		65

The funding profile indicates a total cost of $65,000 to develop and test a prototype timer control customized to a Navy activity. The work could be completed in FY84 which would allow for implementation prior to the 1986 regulations. The related cost benefit to the Navy would be payback within 0.2 years* with a continued annual savings of $2.16 million per year.

2. Innovative Hard Chromium Plating

The use of the Reversible Rack Two Bus Bar System (see Appendix for description) will eliminate rinse water discharges from chromium plating, which is the most common plating process in the Navy. This process will reduce overall water use at Naval plating activities by an average of about 20 percent. In addition, it will reduce chromic acid losses through the ventilation system. The innovative process is expected to increase substantially the rate of production and the quality of plating. When the production rate increases, the number of hard chromium tanks can be reduced by approximately 50 percent. Since these tanks are constantly heated to approximately 130°F a substantial energy savings will be realized. The overall savings expected from use of the innovative process is $914,000 per year. The cost of implementing the changes is approximately $400,000.

*This considers only the operating cost savings. It does not include a 25 percent capital cost savings for facilities that have not yet installed treatment equipment.

The milestones and funding profile to evaluate the Reversible Rack 2 Bus Bar System are as follows:

	$ X 1000		
Milestone	FY84	6.2	6.3
1. Select site for demonstration	5		5
2. Evaluate current method in terms of water use and production rate	10		10
3. Redesign existing system to employ new process	15		15
4. Institute design changes and conduct start-up	15		15
5. Monitor system results	20		20
6. Complete evaluation and disseminate results	15		15
Totals	80		80

The funding profile indicates a total cost of $80,000 to adopt the innovative hard chromium process to a Navy activity. The work could be completed in FY84 which would allow for implementation prior to the 1986 regulations. The related cost benefit to the Navy would be payback within 0.5 years with a continued annual savings of $0.9 million per year.

B. REDUCTION OF FREQUENCY/IMPACT OF BATCH DUMPS

Currently the Navy discards spent process solutions such as cleaners, strippers and plating baths. At most facilities these solutions are contract-hauled to treatment/disposal sites. The cost of treatment/disposal ranges from $0.25/gal to $3.00/gal.

Cleaners and strippers have a limited life span and are therefore commonly discarded. However, plating solutions can be economically purified and returned to service. The replacement cost for baths varies considerably depending on the type and concentration of metal.

Two types of solutions present the highest cost and treatment impact for Naval plating activities: cyanide-bearing solutions and chromium plating baths. Cyanide-bearing solutions include several types of cleaners, strippers, and plating baths.

The high cyanide concentration of these solutions makes treatment expensive since it costs $3 to treat one pound of cyanide. At that rate, a typical 1000-gallon strip solution costs $1,500 to treat. On a Navy-wide basis, the cost is approximately $1 million.

Typically, a chromium solution, the most common solution used by the Navy, costs $3.00/gal. Disposing of baths once or twice per year at a NARF such as Pensacola results in the loss of 6,000 gallons of chromium plating soution which contains 22,311 pounds chromium. The cost of this solution is approximately $18,000. On a Navy-wide basis, the loss is approximately $1 million.

To reduce the frequency and impact of batch dumps two areas of investigation are proposed: (1) purification of chromium plating solutions, and (2) onsite batch treatment of cyanide plating solutions.

1. Purification of Chromium Plating Solutions

One of the main sources of pollutants in Naval plating facilities is spent chromium plating solutions. These solutions are discarded because of fouling by bath impurities or are replaced according to a bath replacement schedule. This practice should be eliminated because chromium is both expensive and scarce (a strategic metal) and because of the high cost of treatment and disposal of the resulting hazardous waste.

Technology exists to purify and rejuvenate fouled chromium solutions, as substantiated by the fact that chromium solutions are rarely, if ever, discarded in private industry. Purification techniques exist for removal of cation impurities, trivalent chromium, oil and grease, sulfates and particulate matter. The Navy needs to assess why chromium plating solutions are discarded at their various facilities and determine the required purification method to remedy the situation.

Potential remedies include

- Cation exchange treatment to remove cation buildup (e.g., Fe, Cr^{3+}, Al, Cu) from the plating solution.
- Cation transfer membrane modules which are placed in the bath and extract cation impurities.
- Sulfate removal by barium addition.
- Oil and grease and particulate removal by diatomaceous earth filtration.
- Oxidation of trivalent chromium by electrolysis.

The technical goals of this project are to clearly identify the reasons for the Navy's high chromium plating solution discard rate and to define the best purification technology to remedy the problem. Since commercial remedies do exist, identification of the specific technological problem or problems is imperative to ensure that the correct remedy will result in long chromium plating solution life. The milestones and funding profile to achieve the goal of longer-lasting chromium plating solutions follow:

	$ X 10^3		
Milestones	FY84	6.2	6.3
1. Identify technological reasons for excessive chromium plating solution discard rate	30	30	
2. Identify remedy technologies available	15	15	
3. Design test program for transition to 6.3	15	15	
4. Initiate test program of remedy technologies on chromium plating solutions	30		30
5. Complete test/evaluation; disseminate results	10	—	10
Totals	100	60	40

The funding profile indicates a total cost of $100,000 to develop and test a prototype unit. The work could be completed in FY 84 which would allow for implementation prior to the 1986 regulations. The related cost benefit to the Navy would be payback within 1.2 years (assumes technology unit cost of $40,000) with a continued annual savings of $1.22 million per year.

2. Electrolytic/Thermal Oxidation of Concentrated Cyanide Solutions

A combined treatment approach for oxidation of cyanides in concentrated solutions is a feasible method of reducing treatment costs and minimizing the burden of batch dumps on the end of pipe treatment processes. Electrolytic oxidation of cyanides is a currently applied technology. Its widest use is with recovery equipment such as the HSA electrolytic recovery cell (Reference 5). Thermal oxidation of concentrated cyanide solutions has been investigated as an alternative to conventional alkali chlorination treatment. The American Electroplaters' Society (AES) demonstrated the process using a reactor which treats 55-gallon drums of cyanide solution in approximately 3 hours.

Electrolytic/thermal oxidation has a significant cost advantage compared to alkali chlorination for treatment of concentrated wastes. Treatment of 1000 gallons of waste at 50,000 mg/l of cyanide would cost approximately $1500, using sodium hypochlorite. The energy required to accomplish the same treatment is estimated to be 4.5 million Btu, or $50 at current electrical power costs. A further advantage is that thermal oxidation requires no treatment chemicals and the associated handling and storage equipment.

The advantage of the electrolytic/thermal oxidation process compared to electrolytic oxidation alone is that it can oxidize the cyanides to levels suitable for disposal within a reasonable time period. Electrolytic oxidation is an effective treatment to a residual concentration of 500 mg/l of CN. Further treatment is exceedingly slow using conventional anode/cathode process equipment. As shown in Table 11, the thermal process reaches low cyanide levels in 2 hours.

TABLE 11. CYANIDE REMOVAL FROM ALKALINE DESCALER AT 477°F AND 600 LB/IN^2 GAUGE

Item	Total Cyanide Concentrations (mg/L)
	Batch Process
Feed	50,000
Reactor residence time (min):	
0	12,000
15	2,300
30	450
60	15
90	0.6
120	0.02

At this time, no predesigned process equipment is commercially available to provide this treatment. Research efforts should concentrate on development of the equipment to suit the Navy's needs in terms of disposal of spent cyanide solutions and other concentrated wastes.

The milestones and funding profile to achieve the stated goals are as follows:

Milestones	FY84	FY85	6.2	6.3
	$ X 10^3			
1. Determine sources, volumes and characteristics discarded CN solutions	20		20	
2. Compare Navy wastes to previous R&D situation and develop design criteria	30		30	
3. Design and construct prototype unit	80			80
4. Initiate test program		40		40
5. Complete test/evaluation and disseminate results		60		60
Totals	130	100	50	180

The funding profile indicates a total cost of $230,000 to develop and test a prototype unit. The work could be completed in FY 85 which would allow for implementation prior to the 1986 regulations. The related cost benefit to the Navy would be paid back within 0.8 years with a continued annual savings of $0.97 million per year.

C. TECHNOLOGIES FOR LOW METALS AND CYANIDE DISCHARGE

The conventional treatment technologies are generally capable of meeting EPA's electroplating discharge standards. However, some activities may be required to meet more stringent standards. This will most likely occur at activities that direct discharge, although some municipalities may enforce stringent pretreatment standards. Also, some treatment facilities may have difficulty in meeting the basic EPA regulations as a result of design problems, chemical complexing, or waste variability. Under these various circumstances, IWTPs may require some form of additional control.

Three potential alternatives have been identified to provide additional metals and cyanide removals: (1) innovative end-of-pipe technologies, (2) polishing, and (3) microprocessor control.

Before initiating any R&D in this area, it is recommended that a regulatory survey of Navy plating activities be conducted to determine the magnitude of the problem. If a very small percentage of the activities have regulations more stringent than Federal standards, then these may be more economically handled on a case-by-case basis.

1. Innovative End-of-Pipe Technologies

A variety of technologies have been developed during the last 10 years that can replace conventional treatment and provide better pollutant removal. Generally, these technologies are more expensive to install and operate than conventional treatment and, therefore, have not been widely applied. Two technologies commercially available include sulfide precipitation and ultrafiltration. Another technology that has shown good promise is sodium borohydride precipitation. The latter technology is being developed by the USAF.

A "do nothing" alternative is recommended since commercially available technologies and other methods are rapidly developing and are expected to become usable before a Navy RDT&E program would have significant impact.

2. Effluent Polishing

Conventional treatment systems can be retrofitted to supply additional pollutant removal. The two primary technologies utilized for this purpose are sand filters, which are used at the Norfolk NARF and ion exchange, which is installed (but not operating) at Puget Sound NSY.

Depending on the outcome of the regulatory survey, it is recommended that a testing and evaluation program be undertaken to determine the effectiveness of sand filters and ion exchange in reducing the metal concentrations of effluents. Testing could be done at the existing Navy installations. The milestone and funding profile to achieve this goal follows:

	$ X 10^3			
Milestones	FY84	FY85	6.2	6.3
1. Regulatory survey to determine extent of compliance problem	15		15	
2. Identify potential regulatory compliance problem pollutants	5		5	
3. Estimate effectiveness of existing technologies & design test program for transition to 6.3	15		15	

	$\$ \times 10^3$			
Milestones	FY84	FY85	6.2	6.3
4. Make necessary hardware changes and initiate monitoring at 2 sites	20	30		50
5. Complete test and evaluation and disseminate results		80		80
Totals	55	110	35	130

The funding profile indicates a total cost of $165,000 to test and evaluate the two technologies. The work could be completed in FY 85 which would allow for implementation in 1986.

3. Microprocessor Control

Conventional chemical treatment processes are generally operated below their optimal pollutant removal levels. This situation exists because the instrumentation associated with conventional systems cannot respond accurately to waste stream variability.

To improve the response of treatment systems and increase pollutant removal, microprocessors can be used to sense problems and respond appropriately. A computer-assisted treatment system is currently operated at the Norfolk NARF. A more sophisticated and less expensive microprocessor has been developed on a joint EPA-NAMF project. The new system, which contains less than $20,000 in hardware, will be demonstrated in Summer/Fall of 1983.

The microprocessor technology has been well developed; however, it is not yet commercially available. Because EPA has eliminated further R&D efforts in wastewater, the final testing and evaluation of the system will not be fully completed.

An extension of the EPA work by the Navy could produce a highly usable system that would aid in treatment system control. In addition to improving compliance, the system would reduce treatment chemical use by minimizing overdosage. However, a "do nothing" alternative is recommended because the microprocessor technology should receive rapid development in the private sector.

D. TECHNOLOGY FOR CONTROL/REMOVAL OF TOTAL TOXIC ORGANICS

A total toxic organics (TTO) limitation (the sum of 113 toxic organic compounds) has been set by EPA and must be met by 1986. The Navy discharges TTO from paint stripping and degreasing operations. When these wastes are combined with electroplating rinse waters, the entire flow must be treated for TTO removal.

Currently, no data exist to evaluate the extent of TTO contamination at Naval plating activities. The cost of TTO analysis ($700 to $1,000 per sample) makes monitoring expensive. However, it is known that paint strippers and degreasing solvents used by the Navy contain the toxic organic compounds.

Two alternative solutions for meeting the TTO limitation should be considered: (1) chemical substitution, and (2) TTO treatment.

1. Chemical Substitution

The largest contributing source of TTO is most likely paint strippers since degreasing units do not directly discharge to the wastewater sewer. Several years ago, many Naval paint stripping operations were using phenolic-based strip solutions. At the time, the trend was to avoid the use of phenol, and alternative paint strippers containing solvents, such as methyl chloride were substituted. Although both phenol and methyl chloride contribute to TTO, phenol is more easily and cheaply removed. At least two Naval IWTPs are capable of phenol removal (Norfolk NARF and Puget Sound NSY).

Therefore, chemical substitution may provide at least a portion of the solution. At some activities, chemical substitution may be sufficient to meet TTO standards. The milestone and funding profile to achieve the goal of TTO compliance through chemical substitution follows:

	$\$ \times 10^3$			
Milestones	FY84	FY85	6.2	6.3
1. Evaluate extent of TTO compliance problem and identify TTO pollutant sources	100		100	
2. Identify substitute process chemicals	80		80	
3. Design test program for transition to 6.3	15		15	
4. Select substitute chemicals and initiate test program	20	60		80
5. Complete test and evaluation of substitute chemicals and disseminate results		80		80
Totals	215	140	195	160

The funding profile indicates a total cost of $355,000 to identify and test substitute process chemicals. The work could be completed in FY 85 which would allow for implementation prior to the 1986 regulations.

If TTO treatment is avoided through chemical substitution, the savings will be extremely high. For an average size NARF, TTO treatment would cost approximately $150,000. If 50 percent of the 28 major facilities could avoid TTO treatment, the savings would be $2.1 million.

2. TTO Treatment

TTO is not a single compound but rather the combined concentration of 113 organic compounds. As such, the TTO in one waste stream may require a completely different removal technology than another. At Naval activities the primary contributing factors are paint strippers and degreasing compounds which contain phenol and solvents. The treatment processes which can be used for treatment of these compounds include: hydrogen peroxide treatment, steam stripping, and carbon adsorption.

Each of these technologies has been used on a full scale for many years. Both hydrogen peroxide treatment and carbon adsorption are currently used at the Norfolk NARF. Although these technologies are commercially available and installed at Naval activities, their actual performance and ability to meet the EPA TTO standard are unproven. It is therefore recommended that monitoring of the existing systems be conducted and the designs be refined to meet all future needs.

The milestone and funding profile to achieve TTO compliance follows:

	$ X 10^3			
Milestones	FY84	FY85	6.2	6.3
1. Characterize wastes at existing Naval systems locations	40		40	
2. Monitor the performance of existing systems	60		60	
3. Develop redesign of existing technologies, if required	20	80		100
4. Retrofit existing units with new design		200		200
5. Monitor the performance of new system		80		80
6. Complete evaluation and disseminate results		80		80
Totals	120	440	100	460

The funding profile indicates a total cost of $560,000 to redesign and test a TTO removal technology. The work could be completed in FY 85 which would allow for implementation prior to the 1986 regulations.

E. HAZARDOUS SLUDGE VOLUME REDUCTION TECHNOLOGY

Sludge disposal is currently a problem for Naval IWTPs in terms of cost, the availability of disposal sites and the burden of regulations. These problems are expected to intensify in the future as the present disposal areas become filled.

The cost of sludge disposal varies between activities primarily as a result of the availability of disposal sites and associated transportation costs. Based on disposal costs at the Pensacola NARF ($5.30 per 1000 gal of treated wastewater), the maximum annual Navy-wide cost is approximately $5.7 million.

The Air Force and Army are currently engaged in R&D to find methods that will reduce the volume and/or hazardousness of electroplating wastewater treatment sludges. Each of these efforts are currently in the 6.2 research stage. The USAF expects to perform pilot testing in FY 84 for promising technologies. EPA is continuing its efforts to develop a technology to recover metals from treatment sludges. The volume of waste generated by the Navy does not appear to make recovery economical.

The Air Force and Army efforts appear to be on track and will benefit the Navy. Therefore, a "do nothing" alternative may be acceptable. However, to assume that these efforts are directly applicable and that the technology is easily transferred, a joint 6.2 and 6.3 effort is recommended.

The milestones and Navy funding profile for the proposed joint effort follows:

	$\$ \times 10^3$					
Milestones	FY84	FY85	FY86	6.1	6.2	6.3
1. Characterize Navy treatment sludges and perform laboratory testing of USAF and Army technologies	60			60		
2. Provide assistance in the design of pilot facilities[1]	50				50	
3. Monitor pilot facility and evaluate effectiveness of technologies[1]	50				50	

Milestones	FY84	FY85	FY86	6.1	6.2	6.3
			$ X 10^3			
4. Select optimal technology and initiate design for Navy demonstration		200	100			300
5. Complete test and evaluation of prototype hardware and disseminate results			200			200
Totals	160	200	300	60	100	500

[1]Assumes joint funding by Navy, Air Force, and Army.

The funding profile indicates a total cost of $660,000 to develop and test new technologies. The work could be completed in FY 86. The sludge treatment design could then be added to any existing wastewater treatment system.

SECTION VI

CAPABILITY GOALS

A. GENERAL

The capability goals of the alternatives recommended for RDT&E are summarized in Figure 7. The overall goals are to comply with effluent and hazardous waste regulations in a timely manner and, if possible, to provide significant improvement over the current practice.

B. METHODS TO REDUCE WATER USE

1. Timer Rinse Control

The capability goals for this effort include a rinse-water-control system capable of reducing current water use in Naval plating activities by 75 percent. This system is intended to provide this savings without using plating room space which is often severely limited.

2. Innovative Hard Chromium Process

The capability goals for this effort include a hard chromium plating process which reduces water use and pollution, associated with the current plating method while improving plating quality and speed. By increasing the speed of the plating process, the number of hard chromium plating tanks operated by the Navy can be significantly decreased to: (1) decrease energy requirements, and (2) increase available plating room space.

C. REDUCE FREQUENCY AND IMPACT OF BATCH DUMPS

1. Plating Bath Purification

The capability goals for this effort include a plating bath purification technique for chromium plating baths which will reduce or eliminate the need to occasionally dispose of these solutions. This effort will require an initial 6.2 phase to identify appropriate technologies and 6.3 phase to customize the prototype process to Navy needs.

2. Batch Treatment

The capability goals for this effort include a prototype treatment unit capable of oxidizing cyanide in concentrated solutions. The process should show improvement over the current

	Major Goals		Projected Improvements					
Need/Alternative	Aids Compliance w/Effluent Regulations	Aids Compliance w/Haz.Waste Regulations	Improves Plating Quality	Reduces Manpower Requirements	Reduces Energy Demand	Reduces Facility Space Require.	Reduces Capital Expendature	Reduces Operating Costs
METHODS TO REDUCE WATER USE								
o Timer Rinse Control System	o					o	o	o
o Innovative Hard Chromium Plating Process	o		o		o	o		o
REDUCE FREQUENCY AND IMPACT OF BATCH DUMPS								
o Plating Bath Purification	o	o	o					o
o Batch Treatment	o	o						o
TECHNOLOGY FOR LOW METALS DISCHARGE								
o Innovative End of Pipe	o							
o Polishing	o							
TECHNOLOGY FOR CONTROL/REMOVAL OF TOTAL TOXIC ORGANICS								
o Chemical Substitution	o						o	o
o TTO Treatment	o							
HAZARDOUS SLUDGE VOLUME REDUCTION TECHNOLOGY								
o Innovative Technology		o						o

Figure 7. Capability Goals Matrix

practice of transporting the wastes to private treatment/disposal firms both in cost and safety. This effort will require an initial 6.2 phase to characterize the wastes and develop design criteria and 6.3 phase to design and construct the prototype unit.

D. TECHNOLOGY FOR LOW METALS DISCHARGE

1. Polishing

The capability goals for this effort include an evaluation and redesign of sand filters and ion exchange technologies. This effort will require an initial 6.2 phase to identify activities requiring low metals discharge and problem pollutants, as well as estimate the effectiveness of existing technologies. Under a 6.3 phase, an equipment redesign will be accomplished, along with testing and evaluation.

E. TECHNOLOGIES FOR CONTROL/REMOVAL OF TTO

1. Chemical Substitution

The capability goals for this effort include the selection of substitute process chemicals for paint stripping which are low in TTO. By using low-TTO process chemicals, the Navy may be able to eliminate the need for removing TTO from wastewaters. This effort will require an initial 6.2 phase to evaluate the extent of the TTO problem and identify substitute process chemicals, as well as a 6.3 phase to test promising chemicals.

2. TTO Treatment

The capability goals to be obtained in this effort include a treatment process capable of achieving compliance with the 1986 TTO requirement. This effort will require a 6.2 phase to monitor the performance of existing system and a 6.3 phase to redesign existing technologies, retrofit end-of-pipe treatment systems, and monitor their performance.

F. HAZARDOUS SLUDGE VOLUME REDUCTION

1. Innovative Technology

The capability goals to be obtained in this effort include sludge treatment processes that can reduce or eliminate the volume of hazardous sludge produced by IWTPs. This effort will be coordinated with ongoing USAF and Army RDT&E. It will require a 6.2 phase to characterize Navy treatment sludges and conduct tests of promising technologies, and a 6.3 phase to design , construct, and test prototype hardware.

REFERENCES

1. Federal Register, Volume 48, Number 137.

2. Chester, Gail P., Plating Wastes Survey, Report 2374, U.S. Army Mobility Equipment Research and Development Command, Fort Belvoir, VA, November 1982.

3. Electroplating Waste Pretreatment Study, Naval Avionics Center, Indianapolis, IN, Naval Facilities Engineering Command, October 1981.

4. CDM, Industrial Waste Collection and Treatment Facilities, Long Beach Naval Shipyard, Department of the Navy, Naval Facilities Engineering Command, August 1978.

5. Navy Electroplating Pollution Control Technology Assessment Manual, NCEL, June 1983.

6. An Investigation of Technologies for Hazardous Sludge Reduction at AFLC Industrial Waste Treatment Plants, Air Force Engineering and Services Center/Engineering and Services Laboratory, ESL-TR-83-42, August 1983.

APPENDIX A

DECISION MODEL RESULTS

TECHNOLOGY ASSESSMENT SCORES

In-Plant Changes

8	REUSEING RINSE WATER	.69
6	FLOW REGULATORS	.67
5	AIR AGITATION	.65
11	SPRAY RINSES	.65
3	COUNTERCURRENT RINSES	.63
9	RECOVERY RINSING	.6
1	INNOVATIVE HARD CHROME PLATING	0
2	TIMER RINSE CONTROL	0
4	PLATING BATH PURIFICATION	0
7	AIR KNIVES	0
10	CONDUCTIVITY CELLS	0

(1) INNOVATIVE HARD CHROME PLATING

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	1.0	BETTER THAN EXISTING	0.100	YES	0.10000
3 R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4 MANPOWER REQUIREMENT	1.0	DECREASES MANPOWER NEEDS	0.100	YES	0.10000
5 ENERGY DEMAND	1.0	LESS THAN CONV	0.100	YES	0.10000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8 INVESTMENT COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(2) TIMER RINSE CONTROL

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(3) COUNTERCURRENT RINSES

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.63000

(4) PLATING BATH PURIFICATION

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	1.0	BETTER THAN EXISTING	0.100	YES	0.10000
3 R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(5) AIR AGITATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.65000

(6) FLOW REGULATORS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.67000

(7) AIR KNIVES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(8) REUSEING RINSE WATER

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.69000

(9) RECOVERY RINSING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.60000

(10) CONDUCTIVITY CELLS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0. [illegible]

(11) SPRAY RINSES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.65000

TECHNOLOGY ASSESSMENT SCORES

Recovery Technologies

1	COUPLED TRANSPORT MEMBRANES	0
2	EVAPORATION	0
3	ELECTRODIALYSIS	0
4	REVERSE OSMOSIS	0
5	ION EXCHANGE	0
6	ELECTROLYTIC	0
7	ION TRANSFER	0
8	DONNAN DIALYSIS	0

(1) COUPLED TRANSPORT MEMBRANES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(2) EVAPORATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(3) ELECTRODIALYSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(4) REVERSE OSMOSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

(5) ION EXCHANGE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(6) ELECTROLYTIC

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(7) ION TRANSFER

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(8) DONNAN DIALYSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

TECHNOLOGY ASSESSMENT SCORES

Chromium Reduction

2	SULFUR COMPOUND REDUCTION	.65
1	INTEGRATED TREATMENT	.48
3	SACRFICIAL IRON ANODES	0
4	FERROUS SULFATE	0
5	SODIUM BOROHYDRIDE	0
6	MATERIAL RECOVERY	0

(1) INTEGRATED TREATMENT

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10 MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL					0.48000

(2) SULFUR COMPOUND REDUCTION

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.65000

(3) SACRFICIAL IRON ANODES

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(4) FERROUS SULFATE

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL					0.

(5) SODIUM BOROHYDRIDE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.

(6) MATERIAL RECOVERY

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

TECHNOLOGY ASSESSMENT SCORES

Cyanide Oxidation

3	ALKALI CHLORINATION	.65
2	INTEGRATED TREATMENT	.61
1	ELECTROLYIC	.56
4	OZONE	0
5	THERMAL OXIDATION	0
6	MATERIAL RECOVERY	0

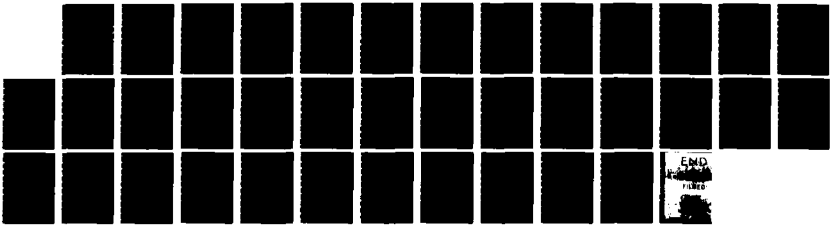
(1) ELECTROLYIC

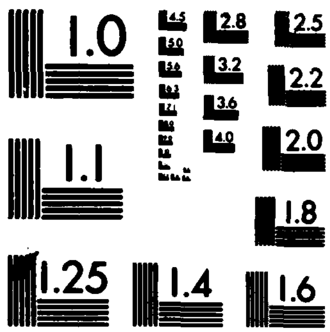
# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(2) INTEGRATED TREATMENT

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.61200

AD-A138 460 AN INVESTIGATION OF TECHNOLOGIES FOR HAZARDOUS SLUDGE 2/2
REDUCTION AT AFLC (..(U) CENTEC CORP RESTON VA
G C CUSHNIE DEC 83 AFESC/ESL-TR-83-42-VOL-3
UNCLASSIFIED F08635-81-C-0258 F/G 13/2 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

(3) SUPERCHLORINATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL 0.65000

(4) OZONE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000

TOTAL 0.

(5) THERMAL OXIDATION

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	= VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.120	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.120	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.120	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.120	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL 0.

(6) MATERIAL RECOVERY

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	= VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.120	YES	0.05000
3 R & M	0.0	WORSE THAN CONV	0.120	YES	0.00000
4 MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5 ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	2.0	MUCH MORE THAN CONV	0.120	YES	0.00000
9 OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL 0.

TECHNOLOGY ASSESSMENT SCORES

Metals Removal

1	HYDROXIDE PRECIP	.65
5	SULFIDE PRECIP	.58
2	SODIUM BOROHYDRIDE	0
3	OZONE	0
4	ULTRAFITRATION	0
6	INSOLUBLE STARCH	0
7	ELECTROLYTIC	0
8	FREEZE CRYSTAL	0

(1) HYDROXIDE PRECIP

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.65000

(2) SODIUM BOROHYDRIDE

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10 MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL					0.

(3) OZONE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.

(4) ULTRAFITRATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(7) ELECTROLYTIC

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(8) FREEZE CRYSTAL

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(5) SULFIDE PRECIP

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.58000

(6) INSOLUBLE STARCH

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.

TECHNOLOGY ASSESSMENT SCORES

Hazardous Sludge Reduction

1	SOLIDIFICATION	0
2	SODIUM BOROHYDRIDE	0
3	SLUDGE WASHING	0
4	HEAT TRREATMENT	0
5	SLUDGE AGING	0

(1) SOLIDIFICATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(2) SODIUM BOROHYDRIDE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.

(3) SLUDGE WASHING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.

(4) HEAT TRREATMENT

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(5) SLUDGE AGING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL 0.

RDT&E ASSESSMENT SCORES

In-Plant Changes

1	INNOVATIVE HARD CHROME PLATING	1
4	PLATING BATH PURIFICATION	.78
2	TIMER RINSE CONTROL	.73
8	REUSEING RINSE WATER	.69
6	FLOW REGULATORS	.67
5	AIR AGITATION	.65
11	SPRAY RINSES	.65
3	COUNTERCURRENT RINSES	.63
9	RECOVERY RINSING	.6
7	AIR KNIVES	0
10	CONDUCTIVITY CELLS	0

(1) INNOVATIVE HARD CHROME PLATING

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	1.0	BETTER THAN EXISTING	0.100	YES	0.10000
3 R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4 MANPOWER REQUIREMENT	1.0	DECREASES MANPOWER NEEDS	0.100	YES	0.10000
5 ENERGY DEMAND	1.0	LESS THAN CONV	0.100	YES	0.10000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8 INVESTMENT COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					1.00000

(2) TIMER RINSE CONTROL

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.[illegible]	SAM[illegible] AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.3	[illegible]HTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	[illegible]0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.73000

(3) COUNTERCURRENT RINSES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.63000

(4) PLATING BATH PURIFICATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	1.0	BETTER THAN EXISTING	0.100	YES	0.10000
3	R & M	1.0	BETTER THAN CONV	0.100	YES	0.10000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.78000

(5) AIR AGITATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.65000

(6) FLOW REGULATORS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.67000

(7) AIR KNIVES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(8) REUSEING RINSE WATER

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.69000

(9) RECOVERY RINSING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.60000

(10) CONDUCTIVITY CELLS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(11) SPRAY RINSES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL . 0.65000

RDT&E ASSESSMENT SCORES

Recovery Technologies

7	ION TRANSFER	.53
5	ION EXCHANGE	.5
3	ELECTRODIALYSIS	.48
6	ELECTROLYTIC	.48
1	COUPLED TRANSPORT MEMBRANES	0
2	EVAPORATION	0
4	REVERSE OSMOSIS	0
8	DONNAN DIALYSIS	0

(1) COUPLED TRANSPORT MEMBRANES

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(2) EVAPORATION

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.

(3) ELECTRODIALYSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(4) REVERSE OSMOSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(5) ION EXCHANGE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.50000

(6) ELECTROLYTIC

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.48000

(7) ION TRANSFER

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.53000

(8) DONNAN DIALYSIS

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

RDT&E ASSESSMENT SCORES

Chromium Reduction

2	SULFUR COMPOUND REDUCTION	.65
4	FERROUS SULFATE	.6
1	INTEGRATED TREATMENT	.48
6	MATERIAL RECOVERY	.48
3	SACRFICIAL IRON ANODES	0
5	SODIUM BOROHYDRIDE	0

(1) INTEGRATED TREATMENT

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
	TOTAL					0.48000

(2) SULFUR COMPOUND REDUCTION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.65000

(3) SACRFICIAL IRON ANODES

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(4) FERROUS SULFATE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
	TOTAL					0.60000

(5) SODIUM BOROHYDRIDE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
	TOTAL					0.

(6) MATERIAL RECOVERY

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.48000

RDT&E ASSESSMENT SCORES

Cyanide Oxidation

3	ALKALI CHLORINATION	.65
2	INTEGRATED TREATMENT	.61
1	ELECTROLYIC	.56
5	THERMAL OXIDATION	.54
4	OZONE	.53
6	MATERIAL RECOVERY	.48

(1) ELECTROLYIC

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.56000

(2) INTEGRATED TREATMENT

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.61000

(3) ALKALI CHLORINATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.65000

(4) OZONE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.53000

(5) THERMAL OXIDATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.54000

(6) MATERIAL RECOVERY

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.48000

RDT&E ASSESSMENT SCORES

Metals Removal

1	HYDROXIDE PRECIP	.65
5	SULFIDE PRECIP	.58
3	OZONE	.51
2	SODIUM BOROHYDRIDE	0
4	ULTRAFITRATION	0
6	INSOLUBLE STARCH	0
7	ELECTROLYTIC	0
8	FREEZE CRYSTAL	0

(1) HYDROXIDE PRECIP

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.5	SAME AS CONV	0.100	YES	0.05000
9 OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.65000

(2) SODIUM BOROHYDRIDE

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10 MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL					0.

(3) OZONE

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.5	SAME AS CONV	0.100	YES	0.05000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
	TOTAL					0.51000

(4) ULTRAFITRATION

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(6) INSOLUBLE STARCH

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
	TOTAL					0.

(7) ELECTROLYTIC

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.3	SLIGHTLY GREATER THAN CONV	0.100	YES	0.03000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	1.0	LESS THAN CONV	0.100	YES	0.10000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	0.7	SLIGHTLY LESS THAN CONV	0.100	YES	0.07000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

(8) FREEZE CRYSTAL

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.0	WORSE THAN CONV	0.100	YES	0.00000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
9	OPERATING COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000

TOTAL 0.

RDT&E ASSESSMENT SCORES

Hazardous Sludge Reduction

1	SOLIDIFICATION	.63
3	SLUDGE WASHING	.6
2	SODIUM BOROHYDRIDE	0
4	HEAT TRREATMENT	0
5	SLUDGE AGING	0

(1) SOLIDIFICATION

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10 MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL					0.63000

(2) SODIUM BOROHYDRIDE

# FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1 RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2 QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3 R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4 MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5 ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6 SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7 FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8 INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9 OPERATING COST	0.3	SLIGHTLY MORE THAN CONV	0.100	YES	0.03000
10 MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL					0.

(3) SLUDGE WASHING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.5	SAME AS EXISTING	0.100	YES	0.05000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.5	SAME AS CONV	0.100	YES	0.05000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	0.5	SOME NEW REQUIREMENTS	0.100	YES	0.05000
TOTAL						0.60000

(4) HEAT TRREATMENT

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	0.0	INADEQUATE	0.100	YES	0.00000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.0	MUCH GREATER THAN CONV	0.100	YES	0.00000
6	SKILL REQUIREMENT	0.0	GREATER THAN CONV	0.100	YES	0.00000
7	FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
TOTAL						0.

(5) SLUDGE AGING

#	FACTOR NAME	VALUE	SELECTION DESCRIPTION	WEIGHT	Y/N	# VALUE
1	RESPONSE TIME	1.0	ADEQUATE	0.100	YES	0.10000
2	QUALITY IMPACT	0.5	SAME AS EXISTING	0.100	YES	0.05000
3	R & M	0.5	SAME AS CONV	0.100	YES	0.05000
4	MANPOWER REQUIREMENT	0.0	INCREASES MANPOWER NEEDS	0.100	YES	0.00000
5	ENERGY DEMAND	0.5	SAME AS CONV	0.100	YES	0.05000
6	SKILL REQUIREMENT	1.0	SAME AS CONV	0.100	YES	0.10000
7	FACILITY SPACE	0.3	SLIGHTLY MORRE THAN CONV	0.100	YES	0.03000
8	INVESTMENT COST	0.0	MUCH MORE THAN CONV	0.100	YES	0.00000
9	OPERATING COST	1.0	MUCH LESS THAN CONV	0.100	YES	0.10000
10	MATERIALS	1.0	SAME AS EXISTING	0.100	YES	0.10000
	TOTAL					0.

APPENDIX B

TIMER RINSE CONTROL SYSTEM

The Naval plating shops are similar to private industry job shops in that they have variations and fluctuations in production. Most lines are more heavily used at certain times than others. Water flow rates must be set to meet these peak production demands, otherwise plating quality would diminish. Therefore, in periods of average or low production, water use will remain at the high rate (usually governed by flow restrictors) which results in wasted water. In most operations this waste is 50 percent or more.

The alternative to high rate continuous rinse water use on plating lines is to implement a demand system. When the rack or barrel is placed into the rinse tank, enough water is then delivered to provide adequate rinsing. The water flow stops when rinsing is complete. This can be accomplished manually by simply turning the water on and off after each barrel is rinsed. However, for most Naval operations this is impractical. Also, since this practice places full control on the operator, it is subject to problems. For example, if a valve is left open and water is continuously fed, the treatment system could be overloaded. Another demand system, which is automated rather than manual, makes use of conductivity probes which are placed in the rinse tank. When the probes sense a high concentration of salts, they send a signal to a controller which opens a solenoid valve. The valve is automatically closed after the salt concentration is reduced to a set point. Such systems were popular several years ago. However, nearly every installation was plagued with maintenance problems and most units have been removed from operation.

An alternative system is a timer-controlled rinse system. This system consists of: a pushbutton which is mounted on the side of each rinse tank (only one pushbutton on a countercurrent rinse); a solenoid valve and a flow restrictor, both installed on the incoming water line; and a control box which houses the timers. When a rack or barrel is placed into a rinse tank the operator pushes the button. On automatic lines, a momentary contact switch starts the timer when a rack or barrel is lowered into the rinse tank. In either case this action opens the solenoid valve for a preset time period, usually less than 5 minutes. By selecting the proper size flow restrictor and timer setting, the volume of water used for rinsing each rack or barrel can be controlled with great accuracy. The timer system places some responsibility on the operator, but the automatic shutoff removes any potential for overusing water and overloading the treatment system.

APPENDIX C

REVERSIBLE RACK TWO-BUS BAR HARD CHROMIUM PLATING SYSTEM

The most widely practiced plating operation in the Navy is hard chromium plating. This process has progressed much differently then other plating technologies. Hard chromium plating was developed in the Cleveland area approximately 35 years ago. Most of the hard chrome plating is still performed in that area. Information on the hard chromium process is very scarce, unlike decorative chrome, nickel, copper, zinc, cadmium, and other common plating processes. Hard chromium plating has developed more as an art and trade rather than a science.

The hard chromium procedures used in the Cleveland area were improved rapidly after its development. The dissemination of these technical improvements has been very slow and as a result is only practiced in the Cleveland area.

The Cleveland process is termed Reversible Rack Two-Bus Bar System. This method of plating meets all military specifications. The two major differences between the Cleveland method and Navy practice are (1) the new method is operated at 140°F to 143°F, the Navy practice at 130°F; and (2) two bus bars (the copper bar which carries current to the cathode and anode bars) are used instead of the usual three.

These differences provide several major advantages. First, the higher temperature causes additional evaporation in the plating tank. This allows the plater to rinse parts directly over the plating bath. The rinse water merely replenishes evaporative losses. This results in zero rinse water discharge. The increased evaporation also nearly eliminates pollutants in the air ventilation scrubber system. The increased mist in the ventilation system keeps the chromic acid from drying on the walls of the ducts. By installing a mist eliminator, nearly all of the chromic acid removed by the ventilation is returned.

The high temperatures also increase production. Plating rates for the Navy process are typically .002 mils per hour on an outside diameter. The Cleveland process plating rates are .002 mils to .006 mils.

The rack design and overall system operation also dramatically increase production. With the Navy process, only one or two parts can be plated at a single time. With the Cleveland process, many parts can be plated at once--increasing production several times over.

The conversion from the Navy plating process to the Reversible Rack Two-Bus Bar System is not difficult or expensive. Changes to the racks, bus bars, exhaust system, and rectifiers are required. Typically, this will cost about $5,000 to $8,000 per plating tank. Since the process increases production, less tanks are necessary than currently used.

The benefits from the conversion include: (1) reduced treatment requirements, (2) reduced chromic acid losses, and (3) faster, higher and better production. The payback is difficult to determine but is most likely less than 6 months.

APPENDIX D

HAZARDOUS WASTE TREATMENT TECHNOLOGIES

A. GENERAL

The disposal of waste treatment residuals (sludge) is a major cost item in electroplating pollution control. These sludges are listed by EPA as hazardous wastes. They must be disposed in secure landfills. In many parts of the country secure sites are unavailable and the wastes must be transported long distances.

There are two approaches to reducing the costs and associated burdens of sludge disposal. First, the sludge volume can be reduced which will proportionally reduce disposal cost. Second, the waste can be converted to a nonhazardous material (measured by the EPA Extraction Procedure) which allows the generator to petition to EPA for delisted status. If successful the generator may be able to dispose of the waste in less costly local landfills.

The Air Force and Army have funded basic research to find ways of reducing sludge volume and the hazardousness of the wastes. Four promising technologies were identified. These are briefly explained in this appendix.

B. SLUDGE AGING

Several years ago it was discovered that sludges which are allowed to air dry for extended periods perform better under the EPA Extraction Procedure (EP), i.e., they do not leach hazardous amounts of toxic metals. The aging process dries the sludge and breaks down its gelatinous characteristics. Sludge aging has been tested on simulated USAF sludges and proved to be an effective method of detoxifying these wastes.

C. HEAT TREATMENT

Sludge aging takes approximately 30 to 90 days to reach a nonhazardous state. For large generators, a substantial storage area would be required to conduct the aging process. As an alternate method, heat treatment can be used to speed the drying process. Tests on USAF wastes indicate that during a 4-hour leaching period at 80°C to 100°C, their wastes can be rendered nonhazardous.

D. SLUDGE WASHING

An effective method of reducing the volume of sludge generated was discovered on an USAF R&D project. The method, termed sludge washing, involves the addition of a dilute ammonium chloride solution (5 to 10 percent) to a dewatered sludge and a second dewatering step. The process appears to be most applicable to sodium hydroxide sludges; the process was able to increase the solids content by 22 percent. The sludge remains hazardous but has a much reduced volume.

E. SODIUM BOROHYDRIDE PRECIPITATION

The conventional lime precipitation process is used at most USAF electroplating wastewater treatment facilities. Sodium hydroxide is also used to some extent, but has demonstrated poor floc-settling characteristics. Under a USAF R&D project, a relatively new method was investigated, sodium borohydride precipitation, which removes metals better than the conventional method and produces only about one-third the amount of sludge as lime treatment.

The sodium borohydride process can be used in existing precipitation systems with some modifications. The cost of the chemical ($14 per pound) is one negative aspect of the process.

F. SOLIDIFICATION

The use of solidification for rendering wastes nonhazardous has been widely investigated. For the treatment of inorganic sludges the most effective systems involve the use of Portland cements, lime-based mortars, and lime-pozzolan cements such as lime.

The use of a cement-fly ash-sludge mixture was investigated by the USAF to determine the applicability of the process to their electroplating wastewater treatment sludges. The results of the work indicated that a mixture of 25 percent cement, 25 percent fly ash and 50 percent sludge produced a hard material that tested nonhazardous, using the EP.

FILMED