ESTCP Cost and Performance Report

(PP-9501)

Waste Acid Detoxification and Reclamation

April 1999

ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

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LIST OF ACRONYMS

ARDEC	Army's Armaments Research, Development and Engineering Center
CCAC	Close Combat Armaments Center
DoD	Department of Defense
DOE	U.S. Department of Energy
ECAM	Environmental Cost Analysis Methodology
ESTCP	Environmental Security Technology Certification Program
IRR	Internal Rate of Return
IWTP	Industrial Waste Treatment Plan
NPV	Net Present Value
PLC	Programmable Logic Controller
PNNL	Pacific Northwest National Laboratory
PVDF	polyvinyldiene fluoride
WADR	Waste Acid Detoxification and Reclamation
WVA	Watervliet Arsenal

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- MSE Technology Applications - Butte, Montana
- Viatec Recovery Systems, Inc. - Richland, Washington
- U.S. Army Construction Engineering Research Laboratory - Champaign, Illinois
- U.S. Army Environmental Center - Aberdeen Proving Ground, Maryland

1.0 EXECUTIVE SUMMARY

This Environmental Security Technology Certification Program (ESTCP) project demonstrated the Waste Acid Detoxification and Reclamation (WADR) system's ability to recover waste electropolish acid solutions generated during the manufacturing of gun-tubes, and reuse the clean acid. The WADR process uses vacuum distillation technology, an innovative technique in which waste acid is heated to remove water which is subsequently condensed. Additionally, the introduction of new advanced materials makes the WADR distillation process capable of cost-effectively treating high concentrations of waste acid while operating under harsh environments.

Demonstration testing was performed during April and May 1997 (for a total of 16 batch operations) at the Watervliet Arsenal (WVA) in Watervliet, New York. The WADR system, as tested at WVA, was successful at purifying waste acid for reuse during gun-tube manufacturing. Additionally, secondary waste streams generated from the treatment process were accepted for disposal at the WVA's Industrial Wastewater Treatment Plant (IWTP). Testing of the WADR system showed an potential savings of over $80,000 per year when compared to the traditional method of waste acid disposal and acid replacement. The WADR technology is now part of the standard manufacturing operations at the Watervliet Arsenal. Application at other Department of Defense (DoD) facilities may save an estimated $10 million per year, and allow the DoD to comply with new hazardous materials and pollution prevention regulations.

2.0 TECHNOLOGY DESCRIPTION

2.1 DEVELOPMENT HISTORY

The WADR technology was developed at Pacific Northwest National Laboratory (PNNL), a national multi-program laboratory operated for the U.S. Department of Energy (DOE) by Battelle Memorial Institute (Battelle), between 1986 and 1989 as an approach to reclaim acids mixed with radioactive material. Technology development involved a series of research studies to evaluate the feasibility of using commercially available technologies to reclaim waste acids. Based on the success of this research, Battelle PNNL formed a partnership with Viatec, Inc., called Viatec-Recovery Systems, Inc., to develop a acid recycling process using vacuum distillation. In 1993, Viatec-Recovery Systems, Inc. established a joint project between DOE and DoD to design, demonstrate, and install an industrial prototype system at Tinker Air Force Base (AFB) in Oklahoma. This demonstration did not occur because of refurbishment plans at Tinker AFB.

Based on the type and volume of waste acid generated during gun-tube manufacturing at WVA, the WADR system originally developed for demonstration at Tinker AFB was transferred to WVA. Initial testing was planned for recycling waste acid generated from the chrome-plating line, with the potential for a permanent installation of a WADR unit at the vessel-plating line.

2.2 PROCESS DESCRIPTION

The WADR unit, as manufactured by Viatec-Recovery Systems, Inc., is essentially a batch vacuum distillation unit. Major components of the system include a reboiler tank, steam-heated reboiler, vacuum column, water-cooled condenser, condensate tank, and other support equipment (i.e. pumps, instruments and controls, and a vacuum system). The unit also comes equipped with a crystallizer for removing accumulated heavy metal salts, but this was not used during the demonstration. A block-flow diagram is shown in Figure 1 (all components are not shown).

Standard construction materials were used to build the WADR system. All materials in contact with the corrosive process chemicals were constructed of polyvinyldiene fluoride (PVDF). Utility and non-corrosive lines were constructed from galvanized iron, black iron, PVC, or PVDF as required. The use of fluoropolymer liners reinforced with thermosetting plastic makes the WADR system capable of handling the most highly reactive solutions.

Waste acids (also referred as “spent” acid) diluted during the chrome plating process, enter the system from an electropolish holding tank in 300-gallon batches. The feed is transferred to the acid tank and circulated through the steam-heated reboiler. Water contained in the acid solution is vaporized in the reboiler and separated into liquid and vapor streams in the acid tank. The water exits as vapor to be separated in the vacuum column and condensed in the condenser.

The system is then placed under a vacuum to lower the boiling point of waste acid to be recycled. The acid is concentrated by vacuum distillation until the boiling point temperature of the acid solution reaches a temperature consistent with an adequately de-watered acid solution. At that point the batch is removed

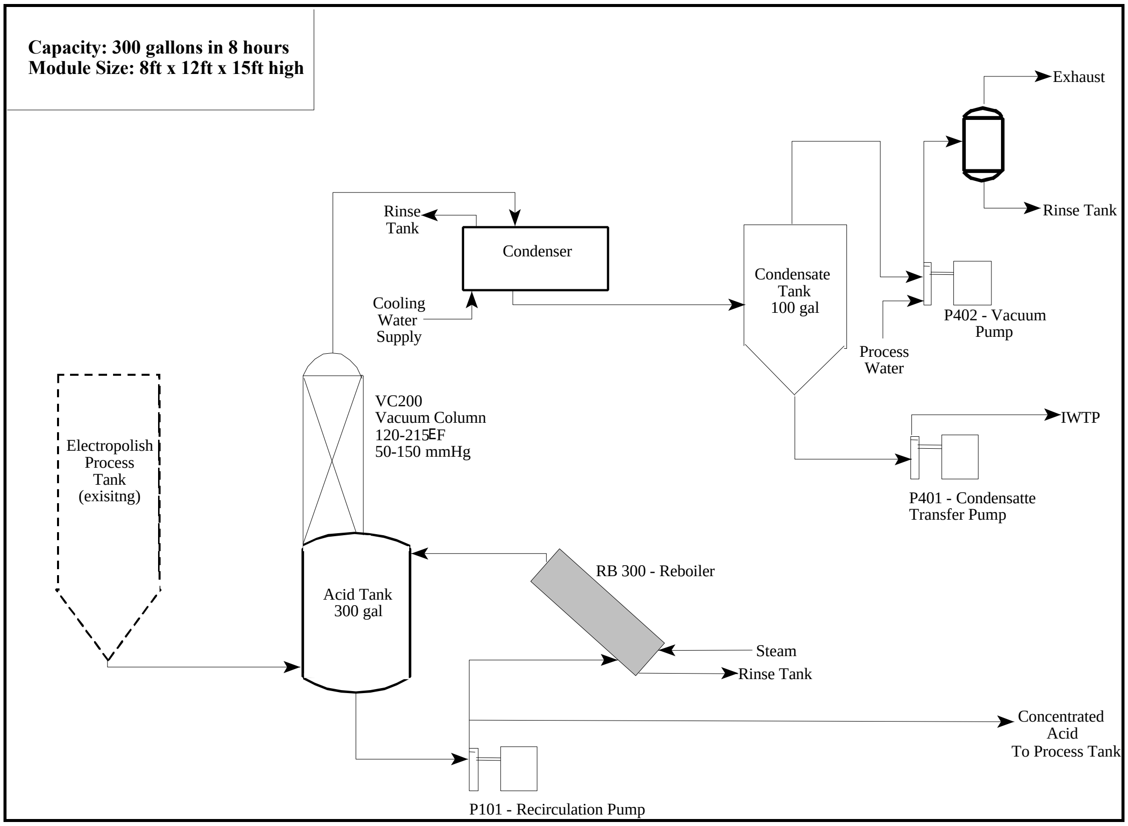

Figure 1. Process Flow Diagram

from the reboiler tank and returned to the holding tank.

The WADR system uses a proprietary materials-manufacturing process developed by Viatec-Recovery, Inc. All other equipment such as valves, controls and piping are off-the-shelf items.
The design of the unit is simple, and the materials used to construct the unit have been proven in the commercial sector. Since the system uses conventional distillation techniques, the equipment reliability is expected to be comparable to conventional distillation equipment. The use of advanced corrosion-resistant materials allows the unit to function in harsh environments. The system is designed to operate at the maximum design flow rate and contaminant concentration. If these values change they will most likely influence the system's efficiency and processing time.

The system is designed to be easy to operate, easy to control, and easy to maintain. Once the system is set up, the only inputs to the system are electricity, steam, cooling water, and waste acid solution. The system is operated through a graphical man-machine interface. A touch screen provides the operator access to the system. A Programmable Logic Controller (PLC) uses data fed to it from the system to control the process. Minimal instruction is needed to operate the system and only occasional monitoring by an operator is required. The system is equipped with safety controls and alarms. These controls and procedures are presented in the *WADR Operations Manual* (Ref. 1).

The WADR system demonstrated at WVA was self-contained, with all products retained in the tanks and all process equipment equipped with secondary containment for spill control. The system was nominally operated at a vacuum of 24 to 28 inches of mercury to allow concentration of the acid to occur at lower temperatures, thus increasing equipment life and allowing the use of corrosion resistant fluoropolymer materials. A liquid ring vacuum pump was used to maintain the system vacuum. The supply water for the vacuum pump was process water that was discharged to the electropolish rinse tank for reuse. No contamination of the vacuum pump water was anticipated since air was the only non-condensable gas that leaks into the system, and acid vapors are not expected in the condensate tank. Nevertheless, the discharge to the building sewer was continuously monitored for pH with alarms set at pH 4 and pH 10. Operational specifications and procedures are presented in the *WADR Operations Manual* (Ref. 1). No hazardous waste was generated from the system. The only products leaving the system were concentrated reusable acid and distilled water, which was conveyed by an industrial sewer network to the IWTP.

2.3 TECHNICAL ADVANTAGES

The WADR system offers many advantages over currently available systems. Most important of these advantages is the ability to effectively purify highly corrosive solutions. Today's standard technologies for solution separation, such as reverse osmosis, cannot be modified to handle the highly reactive and corrosive acid fluids generated during gun-tube manufacturing. The ability to concentrate spent acid solutions will result in significant cost savings associated with hazardous waste disposal. Additionally, by maintaining a purified electropolishing solution, subsequent plating processes should show increased process consistency with potential reduction in solution replenishment and replacement. Important strengths of the WADR system are:

- ***Pollution Prevention*** - By purifying spent acids, the WADR system addresses waste management issues (e.g. reduction in waste storage expenses, transportation fees, administrative and reporting burdens, and liabilities associated with accidental releases). The WADR process does not require additional chemicals or water, thus alleviating secondary waste issues. The process does not require special regulatory permitting.

- ***Advanced Materials of Construction*** - The system is constructed using dual-laminate equipment combining fluoropolymer liners with reinforced thermosetting plastic which is lightweight, corrosion resistant, and custom configured.

- ***Uses Waste Energy for Waste Recovery*** - The technology uses low-temperature waste energy such as low-pressure steam to purify "spent" acids.

- ***Flexible and Simple Operation*** - The process can be designed for batch, semi-batch, or continuous operation for multiple or single waste streams, and can be built as a mobile or fixed system. Distillation is a proven technology that is easily and safely operated and maintained with little impact from misoperation or variation in feed compositions.

The WADR system can process a wide range of acid types (such as nitric, hydrochloric, hydrofluoric, sulfuric and phosphoric) and can treat acid concentrations ranging from 5% weight percent (wt%) to fullstrength. The system can also treat acid waste streams with metal contamination (such as iron, chromium, cadmium, zinc, and other heavy metals) ranging in concentrations from hundreds of parts per million (ppm) to wt%. Current testing has been conducted using normal mineral acids, but the technology can potentially be applied to a wide variety of other concentrated chemical waste streams.

2.4 TECHNICAL LIMITATIONS

The system offers no significant installation limitations for incorporation into the current plating processes. The only items of equipment that require significant space for installation are the processing unit and holding tanks. The WADR system usually requires acid concentrations above 5 wt%. Below this concentration, it becomes more efficient and economical to use currently available technology. The system is not effective in recovering acids from solutions containing high concentrations of metals (greater than 150 grams per liter) or in recovering metals from acid solutions containing low concentrations of metals (less than 1 gram per liter). The system is also not capable of separating acid mixtures into separate process streams.

3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

The primary objective of this project was to demonstrate a prototype WADR system at an active chrome-plating facility using waste acid generated during the electropolishing process. The purpose of the WADR demonstration was to gather data to verify the performance of the system, as applied to concentrated acid waste recovery, and to document the system's operability and acceptability to facilitate regulatory and user acceptance of this technology. The following were the performance objectives for this demonstration:

- Demonstrate the ability to maintain electropolish acid concentrations within specification as stated in the Watervliet Arsenal Process Procedures by recycling the batches of recovered acid back to the electropolish holding tank.

- Demonstrate the ability to regenerate acid to within specification at a rate of 37 gallons per hour (gph). This flow rate meets WVA's anticipated processing requirements.

- Demonstrate that the distillation by-product (i.e. condensate) generated during operations was acceptable for disposal at the WVA IWTP.

- Demonstrate safe and economical operation with minimal operator oversight.

Sampling procedures and discussion of how data was used to evaluate performance objectives are presented in greater detail in the *WADR Technology Demonstration Plan* (Ref. 2). Table 1 summarizes the performance data and criteria for this demonstration.

Table 1. Testing Requirements and Acceptance Criteria

Performance Data	Acceptance Criteria	Method
Acid Concentrations	Specification Range (Sensitive Information - Not Reported Here)	WVA Technical Report
Condensate Analytes	Below discharge limits	EPA SW-846
pH of Condensate	6 to 9 pH units	pH Meter
Process Flow Rate	37 gph	Recorded in Operator's Log

A cost evaluation was performed under the Environmental Cost Analysis Methodology (ECAM) recommended by ESTCP (Ref. 3). Findings from this evaluation are summarized in Section V of this report.

3.2 PHYSICAL SETUP AND OPERATION

The WADR system was operated from April 14 to May 1, 1997 on sixteen separate occasions. The system processed a single type of feed within an 8-hour period. Typical system operations consisted of the following three phases: (1) system startup and operation; (2) sampling and data collection; and (3) system shutdown. Specific operating parameters are listed below:

- Temperature of Reboiler and Acid Tank from 140 to 250EF.
- Temperature of Condenser and Condensate Tank from 75 to 115EF.
- System vacuum from 24 to 29 inches of mercury.
- Cooling water delivered at 5 to 7 gallons per minute (gpm).
- Steam delivered at 40 pounds per square inch (psi) at a rate of 100 pounds per hour.
- Electricity delivered in three phase at 208 volts.

Electropolish solution, when newly made, is composed of two proprietary acid types which were mixed at specified concentration described in the WVA Process Procedures. For purposes of this report, they will be referred to as “acid A” and “acid B”. Spent acid solution was pumped from the electropolish holding tank through the WADR system in 300-gallon batches. For each batch, the following operational and sampling sequence was followed:

- Prior to equipment start-up, all sampling containers were labeled.
- The WADR system was charged with 300 gallons of waste acid solution from the electropolish tank.
- Samples were taken from either the electropolish holding tank or the WADR distillation tank and analyzed for acid A and acid B. These concentrations represented “initial” or “before processing” values.
- The WADR system was operated until the boiling point of the charge had reached a temperature consistent with recycled acid.
- After the batch was initiated, samples of the distilled vapors (condensate) were taken from the condensate tank at 1/3 intervals of the processing cycle. These condensate samples were analyzed for a suite of analytes associated with the specific acid type.
- Upon achieving an adequate boiling point, WADR operation was halted and samples were taken from the distillation tank. These samples were analyzed for acid A and acid B. These concentrations represented “final” or “after processing” values.

- After processing, the treated batch was returned to the electropolish tank.

- After completion of batch runs, samples were taken from the electropolish tank. These samples were analyzed for acid A and acid B to analyze for overall acid concentrations.

Samples collected from Location 1 were taken prior to batch operation. Samples collected from Location 2 were taken after each batch has been processed. Samples collected from Location 3 during batch processing were a composite of the entire batch run. Table 2 lists the samples collected during the WADR demonstration.

Figure 2 shows sampling locations for the test demonstration.

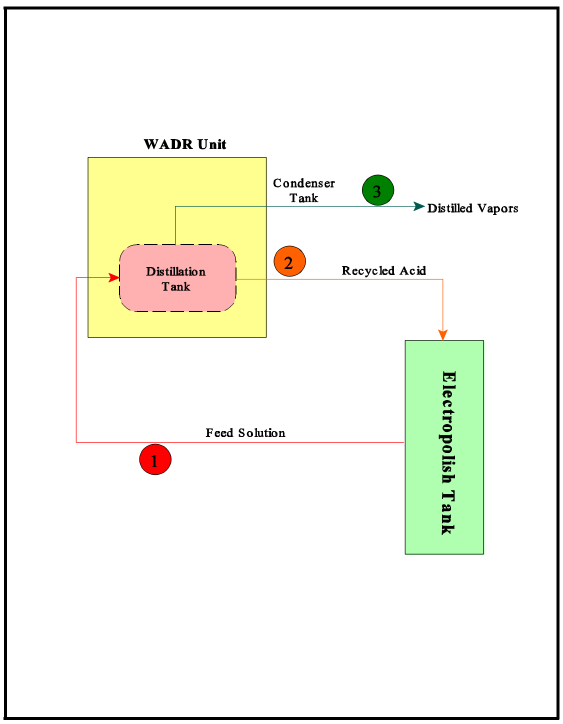

Figure 2. Sampling Points

Benet Laboratories performed all sample analytical testings. Benet Laboratories is a government-owned, government-operated laboratory and is located at WVA. Benet Laboratories is a division of the Close Combat Armaments Center (CCAC), which in turn is part of the Department of Army's Armaments Research, Development and Engineering Center (ARDEC). Benet Laboratories provides support for research and development activities conducted at WVA and other DoD facilities.

Table 2. Sampling Schedule

Analyte	Matrix	Location	Frequency	Method
Acid A	Aqueous	1 and 2	Each Batch	WVA Technical Report
Acid B	Aqueous	1 and 2	Each Batch	WVA Technical Report
Condensate Analytes	Aqueous	3	Composite/Each Batch	EPA SW-846
pH	Aqueous	3	Composite/Each Batch	pH Meter

3.3 MEASUREMENT OF PERFORMANCE

Methods for sample analysis are shown in Table 2. These methods are all standard EPA methods (Refs. 5 and 6), with the exception of the acid determinations, which were analyzed via titration. The protocols for acid determinations were developed at Benet Laboratories and these procedures were attached as an appendix to the *WADR Technology Demonstration Plan* (Ref. 2). Steam and cooling water consumption were determined by valving and pipe sizes. Electrical demand on the system was determined by calculation based on loadings marked on supporting equipment. Processing time was recorded by the field operator for each batch run. Details concerning performance measurements were described in *WADR Technology Demonstration Plan* (Ref. 2).

3.4 DEMONSTRATION SITE/FACILITY BACKGROUND AND CHARACTERISTICS

WVA was selected for this demonstration based on the following reasons: (1) type and volume of acid waste stream generated; (2) the capacity limitations of the waste treatment plant; and (3) the emphasis on complying with waste minimization goals mandated by DoD. The New York State Department of Environmental Conservation also encouraged this demonstration as a method of reducing the volume of waste acid solutions generated by WVA.

WVA is located in Watervliet, New York, near the banks of the Hudson River northeast of Albany, New York. The Arsenal began manufacturing operations in 1813 and is the nation's oldest, continuously active arsenal. A variety of products for military use have been manufactured over the years, with the primary products being cannons, howitzers, and battleship guns. During this time, the Arsenal has been a leader in research and development of manufacturing technology for the production of military hardware and commercial applications.

The WADR system was installed adjacent to the electropolish tanks in Building 35 on the Arsenal's Main Process Area. This building houses the primary manufacturing systems for most of the Arsenal's current weapons systems. At the south end of this building lies the manufacturing plating area where waste acid was transferred from holding tanks for treatment through the WADR system. The facility location had sufficient floor space for equipment installation and allowed access to waste acid solution, steam supply, electrical power, and drain connections to the building acid waste lines.

4.0 PERFORMANCE ASSESSMENT

In practice, newly made acid solutions are prepared at the upper end of the specification range and solutions that fall below the lower specification value are classified as "spent" or waste acid. For this demonstration, acid samples were evaluated in terms of the WADR system's ability to purify the "spent" acid solution to above the mid-level specification value. The results obtained during the demonstration are shown in Table 3, expressed as a percentage of specifications. Acid content in the processed 300 gallon batches was raised on an average by 5.8 % for acid A and by 6.1% for acid B. Figures 3 and 4 express these results graphically.

Laboratory reports from Benet Laboratories were designated as "For Official Use Only" and actual concentration values have not been documented in this report. Actual concentration values were included in the *WADR Technology Demonstration Final Report* (Ref. 4) and data from this report was used to calculate concentration factors presented in Table 3.

After examination of these results, some of the data was considered unacceptable for evaluating the performance of the WADR system. The following data were not used:

Batch No. 1: Acid A showed a concentration rise of 10.7%, which was significantly higher than average and therefore considered an outlier value.

Batch No. 6 and No. 7: Samples for initial concentration values for acid A and acid B were collected before agitation of the holding tank. These concentrations were significantly lower than for samples taken after tank agitation, and these values were therefore considered unrealistic indicators of the initial acid concentrations.

Batch No. 8: No samples collected.

Batch No. 9: Batch processed for only 2 hours, producing low acid concentration values.

Batch No. 12: Acid A showed a decrease in acid concentration after processing. The "initial" acid concentration was well above the mid-level specification indicating that the WADR process had minimal effect on further concentrating acid A.

However, the rest of the data obtained from demonstration testing of the WADR system was determined adequate for evaluation of the stated performance objectives, and overall the WADR system met these objectives. Using only the acceptable concentration values, the average concentration factor for acid A was lowered to 3.3% and for acid B was lowered to 3.6%. However, the acid concentrations still exceeded the mid-level specification values necessary for reuse of the solutions for gun-tube manufacturing.

Processing times through the WADR system averaged less than 8 hours for a processing rate of 39.2 gallons per hour (gph), which exceeded the performance requirement of 37 gph. (Batch No. 9 was processed for only 2 hours and was not used in this calculation.) Recorded processing times represented the entire batch run, with no distinction between processing and operational shutdowns.

No condensate samples exceeded the acceptance limits for the IWTP. Condensate sampling showed that most of the impurities were removed during the final 1/3 of the processing cycle.

Table 3. Performance Data (Results Expressed as a Percentage of Specifications)

Batch No.	Gallons Processed	Process Time (hr)	Process Rate (gph)	Initial Acid A Concentration	Final Acid A Concentration	Conc. Factor	Initial Acid B Concentration	Final Acid B Concentration	Conc. Factor
1	300	9:53	31.5	93.3%	104.5%	10.7%	91.4%	94.9%	3.7%
2	300	8:00	37.5	95.4%	99.8%	4.4%	97.3%	100.4%	3.1%
3	300	9:00	33.3	96.8%	99.9%	3.1%	97.5%	100.8%	3.3%
4	300	7:45	40.3	97.6%	101.1%	3.5%	97.4%	103.0%	5.4%
5	300	7:45	40.3	97.3%	101.6%	4.3%	98.2%	102.2%	4.0%
6	300	7:10	42.3	80.9%	103.8%	22.0%	78.0%	104.2%	25.1%
7	300	5:50	54.5	82.0%	102.0%	19.6%	81.2%	101.8%	20.3%
9	300	4:15	72.3	99.2%	100.0%	0.9%	99.4%	99.4%	0.1%
10/11	300	6:30	46.2	98.6%	103.2%	4.4%	99.7%	103.9%	4.0%
12	300	6:00	50.0	103.2%	101.4%	-1.8%	97.4%	102.4%	5.0%
13	300	6:00	50.0	100.3%	103.8%	3.3%	100.8%	103.2%	2.3%
14	300	6:55	45.8	101.0%	104.4%	3.3%	100.6%	103.2%	2.5%
15	300	9:00	33.3	102.3%	104.3%	1.9%	101.1%	105.4%	4.1%
16	300	7:00	42.9	100.8%	102.6%	1.7%	100.4%	102.8%	2.4%

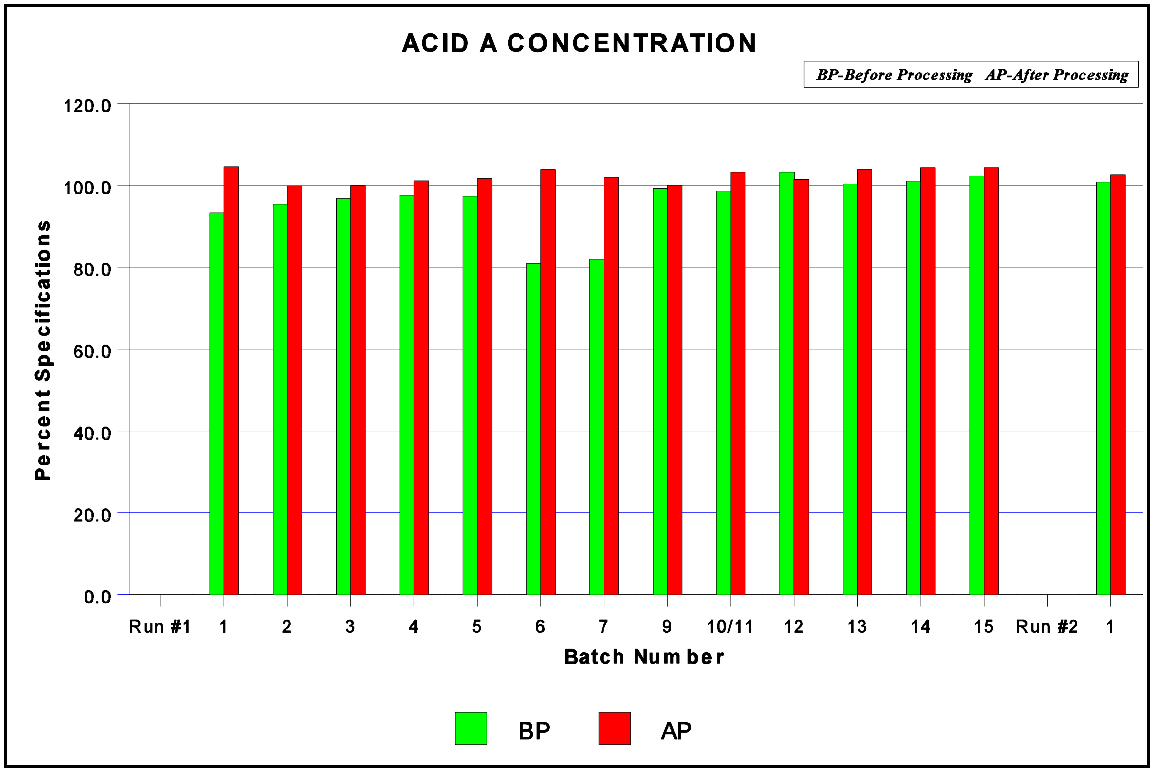

Figure 3. Acid A Concentration

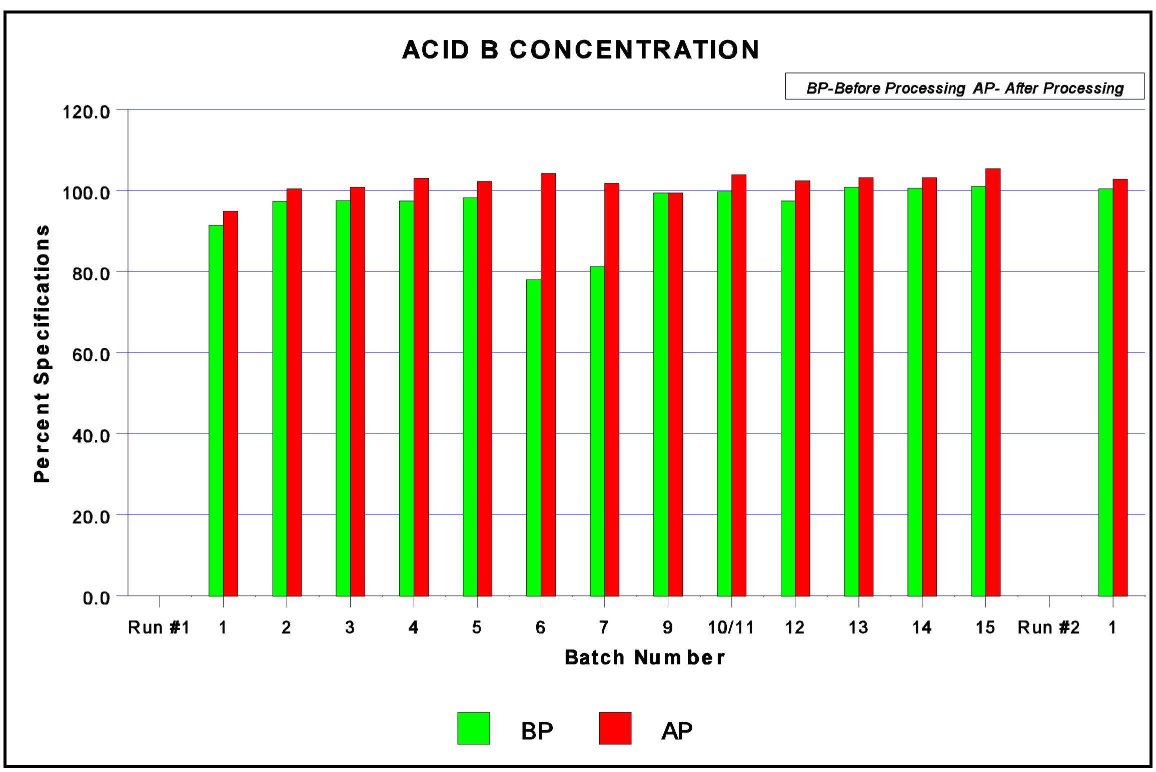

Figure 4. Acid B Concentration

5.0 COST ASSESSMENT

The WADR technology was evaluated using the Environmental Cost Analysis Methodology (ECAM) (Ref. 3). The ECAM methodology proved to be more useful for assessing the merits of an environmental technology than a conventional financial analysis that was previously conducted by WVA. The conventional financial analysis was only able to identify savings due to reduced purchases of new acid and reduced hazardous waste disposal. Through activity-based accounting, ECAM was able to identify additional environmental cost savings that could be attributed to installing the WADR system. These additional environmental cost savings were due to reduced labor requirement for environmental management, testing of waste streams, and manifesting of hazardous waste shipments.

A comparison was made between two alternatives:

(1) Acid-dip process for gun-tubes on the chrome-plating line at WVA, with disposal of spent acid every three months, and replacement with new acid (EXISTING PROCESS).

(2) Same acid-dip process for gun tubes on the chrome-plating line at WVA, but addition of WADR technology for recovery, recycle for re-use of the spent acid every three months (NEW TECHNOLOGY).

Because the WADR demonstration unit was only in operation for a short period of time, several engineering estimates were necessary to provide a cost basis for the ECAM cost analysis. These were derived from the material balance shown in Figure 6:

Electroplating bath volume = 3,400 gallons
Electroplating bath processed by WADR 5-6 times per year
Flow rate to WADR = 37.5 gallons/hr (for 8 hrs) = 300 gallons/day
(maximum 3 day/week operation)
Annual flow rate to WADR = 18,100 gallons/year
Acid Recovery by WADR unit = 90% (by volume)
Spent acid production rate with WADR installed = 1/6 previous = 2,267 gallons/year

Using a conservative estimate, the WADR system should extend the life of an acid bath by approximately six times, or 18 months. Likewise, hazardous waste costs such as disposal and labor are reduced by a factor of six compared to disposal of the waste acid solution.

The costs provided by the ECAM analysis are summarized in Table 4.

Using the WADR system, the direct process costs for the acid bath portion of the overall plating process are $94,041 per year. Disposal of the spent acid as hazardous waste costs $177,162 per year. The total annual costs for recycling through the WADR system are $83,121 less than the disposal costs.

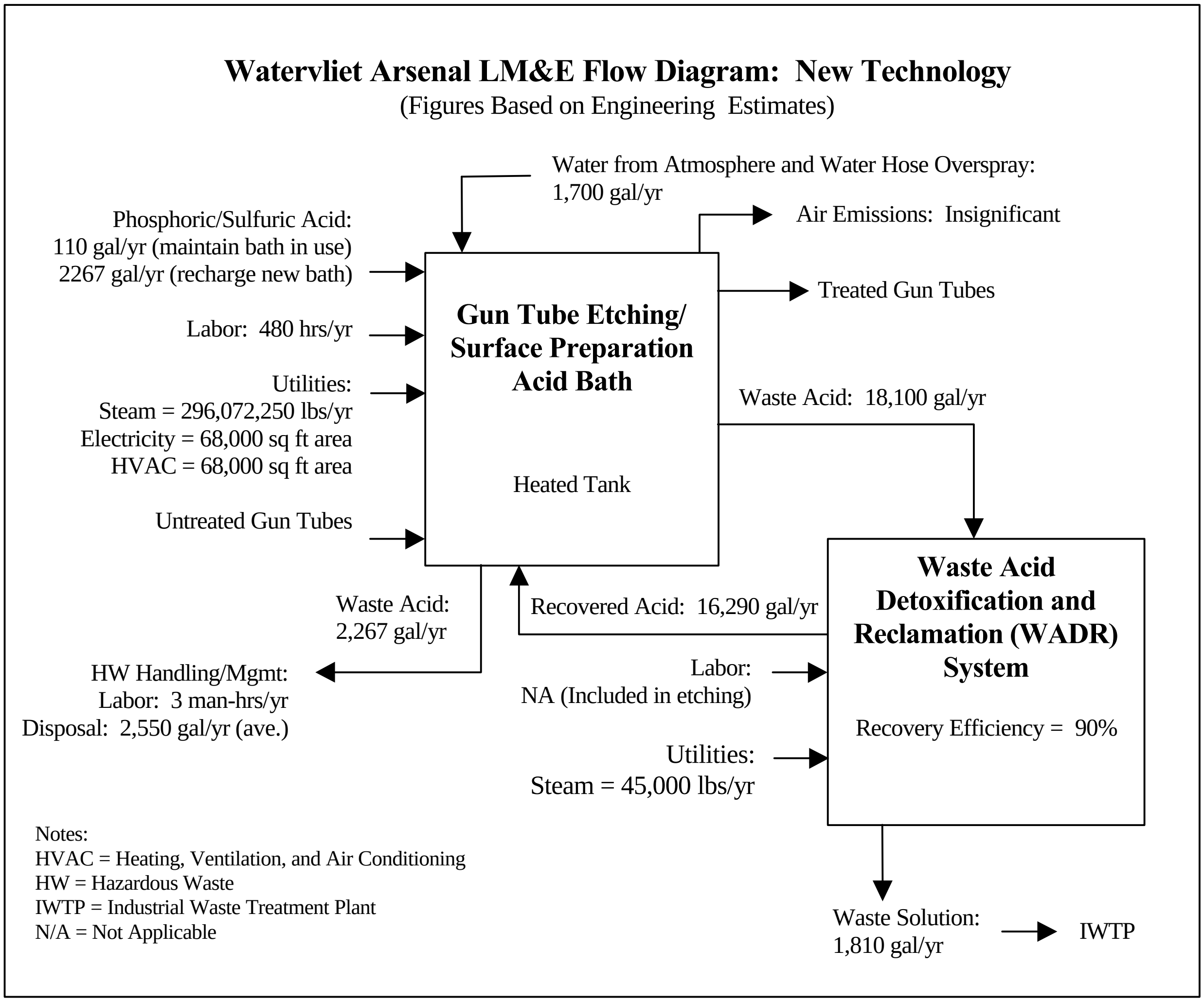

Figure 5. Labor, Material and Energy (LM&E) Balances for WADR Process

Table 4. Summary of Costs for Technology Comparison

Cost Category	ECAM Cost Activity	Existing Process Spent Acid Disposal	New Technology WADR Spent Acid Recycling
Capital Costs	Purchase Equipment		$500,000
	Installation/Site Preparation		$7,553
	Misc. Materials		
	Working Capital		
	Total Capital Costs	$0	$507,553
Annual Operating Costs			
Non-Environmental Costs	Acid Purchase	$69,564	$12,164
	Labor	$12,000	$12,000
	Utilities	$63,240	$63,381
	Sub-total	$144,804	$87,545
Environmental Costs	HW Disposal	$29,988	$4,998
	Labor to handle HW	$400	$75
	IWTP	$0	$362
	Additional Environmental Activities	$1,970	$1,061
	Sub-total	$32,358	$6,496
	Total Annual Operating Costs	$177,162	$94,041

IWTP = Industrial Wastewater Treatment Plant HW = Hazardous Waste

The ECAM includes a life-cycle cost (LCC) analysis and a financial analysis. Both analyses were performed using the Pollution Prevention Financial Analysis and Cost Evaluation System (P2/FINANCE) software program, which is proprietary and copyrighted by Tellus Institute of Boston, Massachusetts. The U.S. EPA provides this software as a service to government organizations for purposes of facilitating financial analysis of pollution prevention projects. P2/FINANCE compares the costs of the current process against those of an alternative process and generates financial indicators that describe the expected performance of a capital investment. In addition to capital costs (e.g. equipment, materials, utility connections, site preparation) and operating costs, P2/FINANCE allows the user to specify the project lifetime and the discount rate. For this analysis, a project lifetime of 15 years and a discount rate of 3.5% were used. This discount rate was based on guidance offered by the Office of Management and Budget (OMB)

Appendix C of Circular A-94[1]. The LCC analysis sums the costs of several items for the current and alternative processes such as: (1) initial/capital investment; (2) capital replacements; (3) operating, maintenance and repair costs; and (4) energy costs associated with the processes, and compares these with the savings afforded by the alternative technology.

The data in Table 4 were used as input data for P2/FINANCE to discount annual cash flows (net annual savings) over the project lifetime to give their present worth. P2/FINANCE subtracted the initial capital investment from the cumulative present worth savings to give the net present value (NPV) of the project. The NPV equated to the life cycle savings afforded by the WADR technology. P2/FINANCE treated the current equipment as a sunk cost with a zero dollar value, with an assumed zero-dollar salvage value.

The economic indicators given by P2/FINANCE from the cost estimates provided by the ECAM analysis (Table 4) are summarized in Table 5.

Table 5. Financial Indicators for WADR Process

Total First Year Costs	Net Present Value (NPV)	Payback Period	Internal Rate of Return (IRR)
$601,594	$752,739	7 years	16.4%

The capital cost of the WADR equipment is high and is a major cost driver due to the expensive materials of construction necessary to withstand the highly corrosive processing conditions. However, the design basis for the chrome-plating line did not utilize the WADR all the time, thus a smaller unit may be acceptable. When considering an investment decision, it would be necessary to accurately match WADR equipment size to plating operations to ensure optimum usage, and also to accurately determine its capital cost.

Minor cost drivers are the steam and cooling water supplied to the WADR unit. These increase with greater usage of the WADR, and would offset to some extent the higher level of utilization of capital equipment.

The projected service life of a WADR installation (before renewed investment is required for equipment replacement) is also important for economic feasibility because of the high capital costs. The longer the project lifetime over which a financial evaluation can be made, the more attractive is WADR technology because more cost savings from the out-years can be offset against the capital cost. The result presented in Table 5 is for a 15-year project lifetime. P2/FINANCE also provided economic indicators for a 10-year project lifetime. NPV and IRR are less attractive for a 10-year project lifetime.

The additional, non-quantifiable benefit of significantly reducing hazardous waste impact on the environment

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[1]Circular No. A-94 (Transmittal Memo No. 64), Office of Management and Budget, Washington DC, October 29, 1992, Appendix C (revised February 1997). Internet: http://www.whitehouse.gov/WH/EOP/OMB/html/circulars/a094/a094.html.

may also influence an installation decision.

6.0 IMPLEMENTATION ISSUES

6.1 PERFORMANCE OBSERVATIONS

Mineral acid solutions are widely used in the metal finishing industry to chemically clean, or otherwise prepare a base metal for plating. At WVA, waste acid generated during gun-tube manufacturing has been identified as a hazardous waste of concern and targeted for reduction. The WADR system tested at WVA performed as expected addressing recovery and recycling of generated waste acids, and was successful in purifying spent acid to process specifications for reuse in the electropolishing process under specified operating conditions.

The WADR technology to recycle, recover and reuse waste acid reduces raw material consumption and waste while maintaining consistent bath quality and improving the plating process. Projected cost savings by WVA are over $80,000 per year. Operational experience on the vessel-plating line will also test the feasibility of processing the electroplating bath contents only once every 3 months to give a six-fold extension of bath lifetime. It may be necessary to process the contents more frequently to maintain acid quality within the electroplating bath, which would increase utility costs for the WADR, may increase the size of unit required, and may reduce the extension of bath lifetime. It will also become apparent whether there is a need to crystallize and separate out accumulated metal salts in the WADR (at additional cost), or whether these salts will be purged from the recycle loop during the less frequent disposal of bath contents.

No hazardous gaseous emissions were detected during operations on the chrome-plating line. Toxic or hazardous materials above regulatory limits are prevented from entering the environment through administrative control, containment barriers, and continuous monitoring of the effluent pH. Process water effluent is returned to the electropolish rinse tank and then discharged to the IWTP. The process water is not expected to become contaminated during operations.

6.2 COST OBSERVATIONS

The ECAM evaluation was demonstrated as a useful decision-making tool for justifying a decision to purchase and install the WADR system. ECAM uses more detailed cost information, which suggests a greater level of confidence in the estimates provided by the ECAM compared to those provided by conventional financial analysis.

The ECAM report indicated a significant cost savings produced by the WADR system from reduced acid purchase for solution replenishment and reduced volume of generated waste requiring disposal, as well as additional indirect environmental cost savings. WVA subsequently installed a WADR unit on its vessel-plating line at a cost of $260,000 for equipment and installation, which is substantially lower compared to the capital costs required for an installation on the chrome-plating line. This lower up-front commitment of capital is attractive but the potential cost savings may be lower than on the chrome-plating line. Operating experience will reveal how quickly the capital cost will be offset by lower cost savings to show the economic feasibility of installing WADR technology on this line.

Private sector plating operations may not find the WADR technology as attractive as government-owned facilities because of the higher discount rate assigned by the private sector to reflect its valuation of investment capital. Private sector concerns would likely assign a discount factor nearer 6% rather than the 3.5% used by government facilities. A 6% discount factor would reduce NPV and lengthen payback period, and the private sector may also view an IRR 16.4% less favorably than a government facility.

The permanent installation of the WADR system enables WVA to operate a "greener" process with respect to its acid disposal issues. The environmental importance of reduced resource (acid) usage and reduced hazardous waste disposal in today's manufacturing arena is difficult to quantify in dollar terms. However, the WADR installation contributes to WVA's goal of achieving 50% reduction in toxic emissions by December 1999 as required by DoD Executive Order 12856 of August 1993 (Ref. 4).

Diffusion Dialysis (DD) technology is another innovative technology that has been evaluated by ESTCP (Ref. 7*)* for waste acid recovery. The ECAM financial analysis conducted for DD may also justify its implementation, and DD also provides the significant environmental benefit (non-quantifiable) resulting from recycle and reuse of the spent acids. For continuous DD treatment of spent acids (8,000 gallons per year) from a chrome-stripping operation, the cost analysis showed an 8-9 year payback period for a $32,000 capital investment. For batch DD treatment (1,400 gallons per year) of copper and magnesium bright dip solutions, the payback period was reduced to 4-5 years for a $22,000 capital investment. It is apparent that for both the WADR and DD technologies, the capital costs of the equipment required are not easily offset by the cost savings realized, although the capital costs for DD treatment, and thus the initial investment required, appear to be lower than for WADR.

6.3 OTHER SIGNIFICANT OBSERVATIONS

The WADR system was a full scale unit capable of processing waste electropolish solution at a rate of 37 gallons per hour. Further scale-up can be accomplished easily by running additional units in parallel.

Reverse osmosis is another candidate acid recovery process but the membranes are not able to withstand the corrosive, high-strength waste acids generated by gun-tube manufacturing operations at WVA.

6.4 LESSONS LEARNED

Lessons learned from this demonstration are listed below:

- Obtaining representative samples for “before processing” values became an issue during the early stages of the demonstration testing. Agitation of the holding tanks alleviated this problem and provided representative samples for determining the WADR’s ability to concentrate the acid solution.
- New technologies procedures associated with the WADR system were difficult to incorporate into the older plating processes. It was determined essential to gain the support of system operators prior to the start of the project.

- The WADR process has been incorporated into special process procedures for electropolish bath maintenance and now an ISO 9000 requirement. The WADR technology is now part of the plating process.

6.5 END-USER/OEM ISSUES

Large quantities of waste acids are produced by electroplating, surface finishing, and chemical milling/dissolution operations common to DoD, as well as DOE and private industry. DoD has a critical need to prevent future pollution by its industrial processes. WADR's results are very promising, and the DoD has shown considerable interest in this technology. Further technology deployment would continue acceptance in the regulatory, governmental, and industrial sectors. DoD-wide application of WADR could reap an estimated cost avoidance of $10 million per year.

At WVA, waste acid represents one of most significant environmental problems. During 1993, WVA produced and disposed of 150 tons of waste acid solutions at a cost of $158,000. With future escalation of hazardous waste disposal cost, waste acid recycling represents an attractive alternative and tremendous cost savings opportunity to WVA, as well as an approach for complying with mandated pollution prevention goals. Due to the success of this demonstration, WVA has implemented the WADR technology in the vessel plating process, which should provide further proof of the operational and cost saving advantages associated with the WADR technology at America's Cannon Factory.

7.0 REFERENCES

1. Viatec-Recovery Systems, Inc., *Waste Acid Detoxification and Recovery Operations and Maintenance Manual*, June 1996.

2. Watervliet Arsenal, *ESTCP Technology Demonstration Plan: Waste Acid Detoxification and Recovery, Watervliet Arsenal*, June 1996.

3. National Defense Center for Environmental Excellence, *Environmental Cost Analysis Methodology Implementation, Site Visit Report for Watervliet Arsenal, Preliminary Draft,* Environmental Security Technology Certification Program, Contract No. DAAA21-93-C-0046, Task No. N.098, September 12, 1997. (http://www.estcp.org or http://www.ndcee.ctc.com)

4. Watervliet Arsenal, *ESTCP Technology Demonstration Final Report: Waste Acid Detoxification and Reclamation System*, July 1998.

5. U.S. Environmental Protection Agency, *Test Methods for Evaluating Solid Waste — Physical/Chemical Methods*, SW-846, U.S. EPA, Washington D.C., 1986.

6. U.S. Environmental Protection Agency, *Methods for Chemical Analysis of Water and Wastes, EPA/600-4-79-020,* U.S. EPA, Washington D.C., 1983.

7. Naval Facilities Engineering Services Center, *ESTCP Technology Demonstration Final Report: Spent Acid Recovery Using Diffusion Dialysis,* January 31, 1999

APPENDIX A

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