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Environmental Technology Verification Report

Evaluation of Lobo Liquids Rinse Water Recovery System

Prepared by

CTC Concurrent Technologies Corporation

Under a Cooperative Agreement with

EPA U.S. Environmental Protection Agency

ETV ETV ETV

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Environmental Technology Verification Report

Evaluation of Lobo Liquids Rinse Water Recovery System

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FOREWORD

The Environmental Technology Verification (ETV) Program has been established by the EPA to evaluate the performance characteristics of innovative environmental technologies for any media and to report this objective information to the states, local governments, buyers, and users of environmental technology. EPA's Office of Research and Development (ORD) established a five-year pilot program to evaluate alternative operating parameters and to determine the overall feasibility of a technology verification program. ETV began in October 1995 and was evaluated through September 2000. EPA is preparing a report to Congress containing results of the pilot program and recommendations for its future operation.

EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), has partnered with *CTC* under the Environmental Technology Verification Program Metal Finishing P2 Technologies (ETV-MF) Center. The ETV-MF Center, in association with EPA's Metal Finishing Strategic Goals Program, was initiated to identify promising and innovative metal finishing pollution prevention technologies through EPA-supported performance verifications. The following report describes the verification of the performance of the Lobo Liquids Rinse Water Recovery System.

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ACRONYM and ABBREVIATION LIST

C	Specific Conductivity
cm	Centimeter
CFR	Code of Federal Regulations
COC	Chain of Custody
CTC	Concurrent Technologies Corporation
DI	De-Ionized
EFF	Effluent
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ETV-MF	Environmental Technology Verification Program for Metal Finishing P2 Technologies
ft^3	Cubic Feet
gal	Gallon(s)
gpd	Gallons per Day
gpm	Gallons per Minute
HP	Horsepower
hr(s)	Hour(s)
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
ID	Identification
IDL	Instrument Detection Limit
IN	Influent
IX	Ion Exchange
kg	Kilogram
kWh	Kilowatt-Hour
L	Liter
lbs.	Pounds
m^3	Cubic Meters
MDL	Method Detection Limit
mg	Milligram
mg/L	Milligram per Liter
min	Minute
mL	Milliliter
MP&M	Metal Products & Machinery
MRL	Method Reporting Limit
µg	Microgram
µS	Micro-siemens
NA	Not Applicable
ND	Not Detected
NRMRL	National Risk Management Research Laboratory
O&G	Oils and Grease
ORD	Office of Research & Development
P	Percent Recovery
P2	Pollution Prevention

ACRONYM and ABBREVIATION LIST (continued)

PLC	Programmable Logic Controller
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
RPD	Relative Percent Difference
SA	The concentration added to the spiked sample
SM	Standard Method
SR	Sample Result
SSR	Spiked Sample Result
Std. Dev.	Standard Deviation
SW	Solid Waste
T	Total
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TSA	Technical System Audit
TSS	Total Suspended Solids
U.S.	United States
VOC	Volatile Organic Carbon

ACKNOWLEDGEMENTS

This is to acknowledge Valerie Whitman of *CTC* for her help in preparing this document. *CTC* also acknowledges the support of all those who helped plan and implement the verification activities and prepare this report. In particular, a special thanks to Alva Daniels, EPA National Risk Management Research Laboratory (NRMRL) Assistant Director, Dr. George Moore, EPA ETV Center Manager, and Lauren Drees, EPA Quality Assurance Manager. *CTC* also expresses sincere gratitude to Lobo Liquids, Inc., the manufacturer of the Lobo Liquids Rinse Water Recovery System, for their participation in and support of this program. In particular, *CTC* thanks Ian Tunnicliffe for his assistance. *CTC* also thanks Kelly Mowry of Gull Industries for his assistance during this verification test.

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

Concurrent Technologies Corporation

ETV VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**WATER REUSE**
APPLICATION:	**METAL FINISHING WASTEWATER**
TECHNOLOGY NAME:	**Lobo Liquids Rinse Water Recovery System**
COMPANY:	**Lobo Liquids, Inc.**
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The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups consisting of buyers, vendor organizations, and states, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

Concurrent Technologies Corporation operates the ETV Metal Finishing Pollution Prevention Technologies (ETV-MF) Program, one of 12 technology focus areas under the ETV Program, in cooperation with EPA's National Risk Management Research Laboratory. The ETV-MF Program has evaluated the performance of a wastewater treatment system for processing of wastewater from metal finishing operations. This verification statement provides a summary of the test results for the Lobo Liquids Rinse Water Recovery System.

VERIFICATION TEST DESCRIPTION

The Lobo Liquids Rinse Water Recovery System (Lobo Liquids system) was tested, under actual production conditions, processing metal finishing wastewater, at Gull Industries in Houston, Texas. The verification test evaluated the ability of the treatment system to remove regulated contaminants from the wastewater and recover the wastewater for reuse.

During the test, the Lobo Liquids system was used as a stand alone treatment/water recycling technology. The test consisted of monitoring the ion exchange (IX) system operation for an entire cycle of the ion exchange process, which lasted 15 production days. During testing, the system was operated during production hours, which consisted of one shift per day. It was used to process and recycle wastewater from the electroplating line. Samples were collected of the raw wastewater, final treated wastewater, and ion exchange regenerant. Chemical usage, electricity usage and labor data were collected to perform the cost analysis.

TECHNOLOGY DESCRIPTION

The Lobo Liquids Rinse Water Recovery System consists of three skid-mounted, ion exchange pressure vessels, with interconnecting piping and control valves. The system is configured with one cation exchange column and two anion exchange columns. It is also equipped with a PC-based control system that automates the recycling process. The Lobo Liquids system is designed to treat and recover for reuse wastewaters generated by metal finishing processes. Most of the wastewater generated from metal finishing comes from rinsing, which is performed after each process step to remove chemicals. Used rinse water contains dissolved metals and other chemicals that are associated with plating baths. To provide good rinsing and prevent contamination of the plating solutions, recycled water must meet a certain level of purity, often based on two related factors, total dissolved solids and specific conductance. In operation, wastewater from the electroplating line is pumped to the Lobo Liquids system and is processed sequentially through the cation and two anion columns. The treated water is returned to the electroplating line and reused for rinsing. The ion exchange system automatically regenerates itself when the ion exchange columns are exhausted.

VERIFICATION OF PERFORMANCE

Verification testing was performed from January 14 – March 1, 2002. The Lobo Liquids system was evaluated with respect to key operating and performance criteria. The results of these analyses are summarized below.

System Operation. The Lobo Liquids system was operated for 15 days for an average duration of 9.2 hours (hrs)/day. The total operating time was 137.5 hrs. The total volume of water processed was 472,476 L (124,828 gal). The average flow rate was 58.19 L/min (15.37 gpm). Throughout the test period, the Lobo Liquids system operated automatically, without any stoppage for maintenance.

Pollutant Removal Efficiency. Average pollutant concentrations and removal percentages measured during the ETV test for the Lobo Liquids system is shown in **Table i**. The parameters listed in this table are regulated under current metal finishing effluent standards (40 CFR 433) and/or are found in the proposed Metal Products and Machinery (MP&M) rule (66 FR 424). The Lobo Liquids system removed 99.9 percent or greater of each pollutant parameter found in the influent above detection limits.

Ability to Meet Metal Finishing and Proposed Target Effluent Levels. The results from each set of analytical data were compared to the applicable Metal Finishing and Proposed MP&M limitations to determine if the Lobo Liquids system achieved these standards. Sampling was performed on four separate operating days. The Metal Finishing limitations and proposed MP&M limitations were met for all parameters for each day sampling was conducted (see **Table i**).

Parameter	Avg. IX Influent mg/L	Avg. IX Effluent mg/L	Average % Removal*	Effluent Meets Metal Finishing and MP&M Standards? (Yes/No)
Sulfide	ND	ND	-	-
O &G (HEM)	ND	ND	-	-
TOC	5.5	ND	100.0%	Yes
Cadmium	ND	ND	-	-
Chromium (T)	3.23	<0.01	99.9%	Yes
Chromium +6	3.92	ND	100.0%	Yes
Copper	0.362	ND	100.0%	Yes
Lead	0.147	ND	100.0%	Yes
Manganese	ND	ND	-	-
Molybdenum	<0.13	ND	100.0%	Yes
Nickel	15.6	0.01	99.9%	Yes
Silver	ND	ND	-	-
Tin	<0.023	ND	100.0%	Yes
Zinc	0.55	ND	100.0%	Yes

ND = not detected
*Percent removals are calculated only for pollutants found above detection limits in the raw or influent wastewater.

Table i. Averaged Pollutant Concentrations and Removal Percentages for Lobo Liquids System

Reusability of Treated Wastewater. The reusability of the treated wastewater as process water was determined by comparing the results of the specific conductance and total dissolved solids (TDS) analytical tests of the Lobo Liquids system effluent to standards used by Gull Industries for water reuse. Treated water meeting these standards was deemed reusable. The Gull Industries standards are:

- Specific conductance: maximum of 500 µS
- TDS: maximum of 250 mg/L

The Lobo Liquids system met the Gull Industries water reuse criteria throughout the entire IX cycle. The specific conductance of system effluent samples was measured at or below 10.5 µS for operating days 1 to 3 (15-day operating cycle), and the highest TDS measured was 56 mg/L. On day 14, the specific conductance of the system effluent increased to 426 µS. The system automatically went into regeneration mode on day 15. It was observed that Gull Industries reused all water produced by the Lobo Liquids system as rinse water on their electroplating line during the test, and that no wastewater except after IX regenerant treatment, was discharged to the city sewer system.

Regeneration. The Lobo Liquids system is regenerated after the ion exchange resin beds are chemically full. Passing dilute hydrochloric acid though the cation exchange column and dilute sodium hydroxide through the anion columns, and subsequently rinsing the columns with water regenerates the IX columns. The liquid from these steps is collected into a storage tank. The quantities of chemicals used during regeneration were 901 L (238 gal) of concentrated hydrochloric acid and 1,154 L (305 gal) of caustic (50 percent). These chemicals were diluted with water prior to being used for regeneration. The total volume of wastewater produced during regeneration, including that from rinsing the columns, was 9,690 L (2,560 gal).

Additional Pollutant Removal. The additional pollutant removal of the Lobo Liquids system installed at Gull Industries was measured by determining the quantity of regulated pollutants removed beyond the level required by the current metal finishing regulations (40 CFR 433). The additional pollutant removal from use of the Lobo Liquids system is a reduction of 3,812.4 g (8.4 lbs) of regulated metals for the test period. On an annual basis (260 days/year), assuming 31,498 L (8,322 gal) of wastewater treated per day, the additional pollutant removal is a reduction of 66,082 g/yr (145.6 lbs/yr) of regulated metals discharged from Gull Industries.

Energy Use. The power consumption of the Lobo Liquids system is 0.43 kWh/1,000 L (1.63 kWh/1,000 gal) of wastewater processed. The power is by operating pumps and electronic instrumentation.

Operation and Maintenance. The following parameters were considered in the cost analysis: chemical reagents, electricity, and labor. The non-labor operating cost for the Lobo Liquids system, excluding labor, was $1.50/1,000 L ($5.69/1,000 gal) and $2.22/1,000 L ($8.42/1,000 gal), including labor. The cost savings from water/sewer cost reduction at Gull Industries is $1.72/1,000 L ($6.50/1,000 gal). Operation of the Lobo Liquids system requires approximately one hour of labor per day, which is for starting and stopping the system and periodically checking on its progress. No maintenance tasks were performed during the verification test.

SUMMARY

The effluent produced by the Lobo Liquids system meets all existing and proposed effluent standards for the metal finishing industry. The removal rate for all regulated parameters found in the Gull Industries influent was 99.9 percent or greater. The effluent from the system had a consistently high quality and it met Gull Industries recycle criteria.

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1.0 INTRODUCTION

The Environmental Technology Verification (ETV) Program has been established by the EPA to evaluate the performance characteristics of innovative environmental technologies for any media and to report this objective information to the states, local governments, buyers, and users of environmental technology. EPA's Office of Research and Development (ORD) established a five-year pilot program to evaluate alternative operating parameters and to determine the overall feasibility of a technology verification program. ETV began in October 1995 and was evaluated through September 2000. EPA is preparing a report to Congress containing results of the pilot program and recommendations for its future operation.

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2.0 DESCRIPTION TREATMENT SYSTEM

2.1 Ion Exchange System

Ion exchange (IX) is a chemical reaction wherein an ion from solution is exchanged for a similarly charged ion attached to an immobile solid particle (i.e., IX resin). IX reactions are stoichiometric (i.e., predictable based on chemical relationships) and reversible. The strategy employed in using this technology is to exchange somewhat harmless ions (e.g., hydrogen and hydroxyl ions), located on the resin, for ions of interest in the solution (e.g., regulated metals). In the most basic sense, IX materials are classified as either cationic or anionic. Cation resins exchange hydrogen ions for positively charged ions such as nickel, copper and sodium. Anion resins exchange hydroxyl ions for negatively charged ions such as chromates, sulfates and cyanide [Ref. 3].

IX resins are usually contained in vessels referred to as columns. The basic column consists of a resin bed, which is retained, in the column with inlet and outlet screens, and service and regeneration flow distributors. Piping and valves are required to direct flow, and instrumentation is required to monitor water quality and control regeneration timing. The systems are operated in cycles consisting of the following four steps:

1. Service (exhaustion) - Water solution containing ions is passed through the IX column or bed until the exchange sites are exhausted.
2. Backwash - The bed is washed (generally with water) in the reverse direction of the service cycle in order to expand and resettle the resin bed.

3. Regeneration - The exchanger is regenerated by passing a dilute solution of the ion originally associated with it (usually a strong mineral acid or base) through the resin bed.
4. Rinse - Excess regenerant is removed from the exchanger, usually by passing water through it.

The IX system consists of three skid-mounted, IX pressure vessels, with interconnecting piping and control valves. It is also equipped with a PC-based control system. A schematic diagram of the Lobo Liquids system is shown in **Figure 1**. The system operates by receiving influent from a tank, via a three-way valve and the suction side of a pump. The water is then discharged from the pump under pressure, and is monitored for pH, specific conductance, pressure, and flow. The resultant analogue signals are sent to the programmable logic controller (PLC) for subsequent processing and display. Each of the analogue signals has two high-level and two low-level alarms. The alarms cause the valve systems to either open or close, which cause a change of direction or stopping of flow. The water is allowed to enter the top of the first vessel containing a cation resin to remove the initial shock loading of heavy metals, whereupon it exits at the bottom of that vessel.

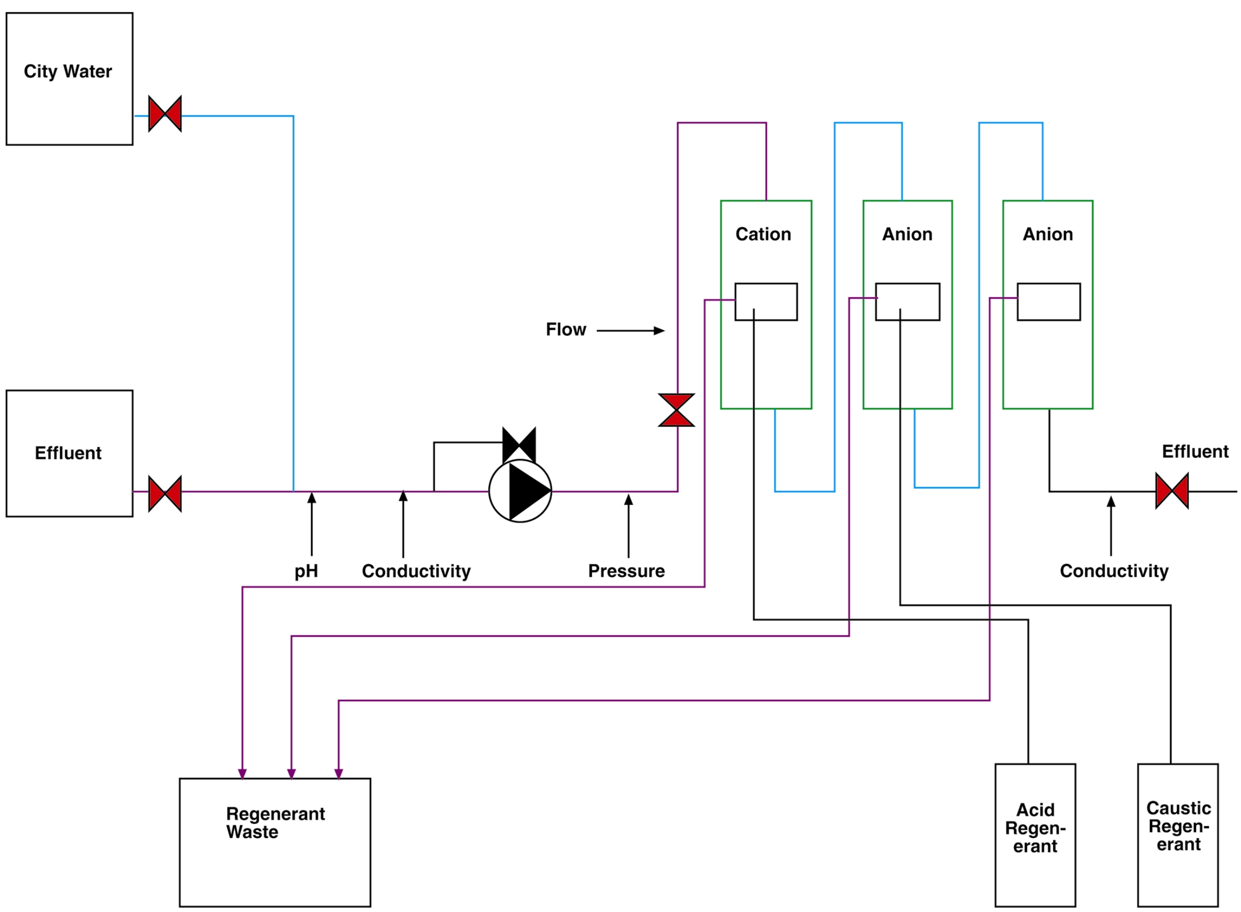

Figure 1. Diagram of Lobo Liquids System

The partially de-ionized (DI) water then enters the second and third vessels (anion columns) in the same manner as the first vessel, and there the remaining ionic loading is removed. The resultant discharge from the third vessel is again monitored for pH and specific conductance and can then be reused in the metal finishing process.

The contaminants from the influent (i.e., cations such as metals and anions such as hexavalent chromium and nonmetals) will remain in each of the three vessels bonded to each of the special purpose resins. The water is allowed to flow continuously through the system until such time that the resin is exhausted (i.e., its ability to remove cations and anions from the water is ended). This is determined by the specific conductance of the water exiting the system at the third vessel. At this point, the system will go off line (usually outside production hours) and regenerate itself *in situ*. Regeneration consists of four stages:

- 1^{st} stage: backwash, DI water at 106 – 114 L/min (28 – 30 gpm)
- 2^{nd} stage: chemical injection, chemicals diluted with DI water at 11 – 15 L/min (3 – 4 gpm)
- 3^{rd} stage: slow rinse, DI water at 11 – 15 L/min (3 – 4 gpm)
- 4^{th} stage: fast rinse, DI water at 106 – 114 L/min (28 – 30 gpm)

The IX regeneration process is carried out automatically. Each vessel will regenerate itself in turn starting with the first vessel. Passing acids and/or bases over the resins, which will remove the captured cations and anions, carries out regeneration of the resin. City water is used as a rinse following regeneration. This regenerant will exit each of the vessels and be captured in the regenerant storage tank for subsequent processing and disposal. At this point, the unit will then be ready to go back on line for the processing of influent.

2.2 Test Site Installation

The Lobo Liquids system was tested at Gull Industries, located in Houston, Texas. Gull Industries is a metal finishing job shop that performs nickel and chromium electroplating, electroless nickel plating, and passivation using nitric acid. The Lobo Liquids system installed at Gull Industries is rated at a maximum flow of 114 L/min (30 gpm). It has one cation column (1.02 m^3 of resin) and two anion columns (total of 1.13 m^3 of resin).

The majority of wastewater generated at Gull Industries is rinse water and to a lesser extent spent cleaning and plating baths. Prior to installation of the closed-loop system, an average of 3,400 L/day (898 gal) of waste rinsewater was discharged to the city sewer. The quantity of regulated metals (mostly nickel and chromium) entering the wastewater is typically 12.5 kg/day (27.6 lbs/day).

A photograph of the Lobo Liquids system is shown in **Figure 2**. A diagram of the Lobo Liquids system at Gull Industries operating as a standalone treatment system is shown in **Figure 3**. During operation, the raw wastewater is pumped from the equalization tank to the Lobo Liquids system, and the effluent is discharged to the final storage tank, from where it is available for reuse on the metal finishing line. In this mode, the Lobo Liquids system is operated continuously during production hrs and is idled during non-production hrs. The system is operated in this manner until the resin columns require regeneration, which occurs approximately every 10 to 20-production days, depending on chemical loading. The system treats wastewater until the resin is exhausted. The point of exhaustion is determined by the specific conductance of the water exiting the system at vessel number 3. Once the resin is exhausted, the system goes off line (usually outside of production hrs) and regenerates itself *in situ*. Regenerant is collected in the regenerant storage tank.

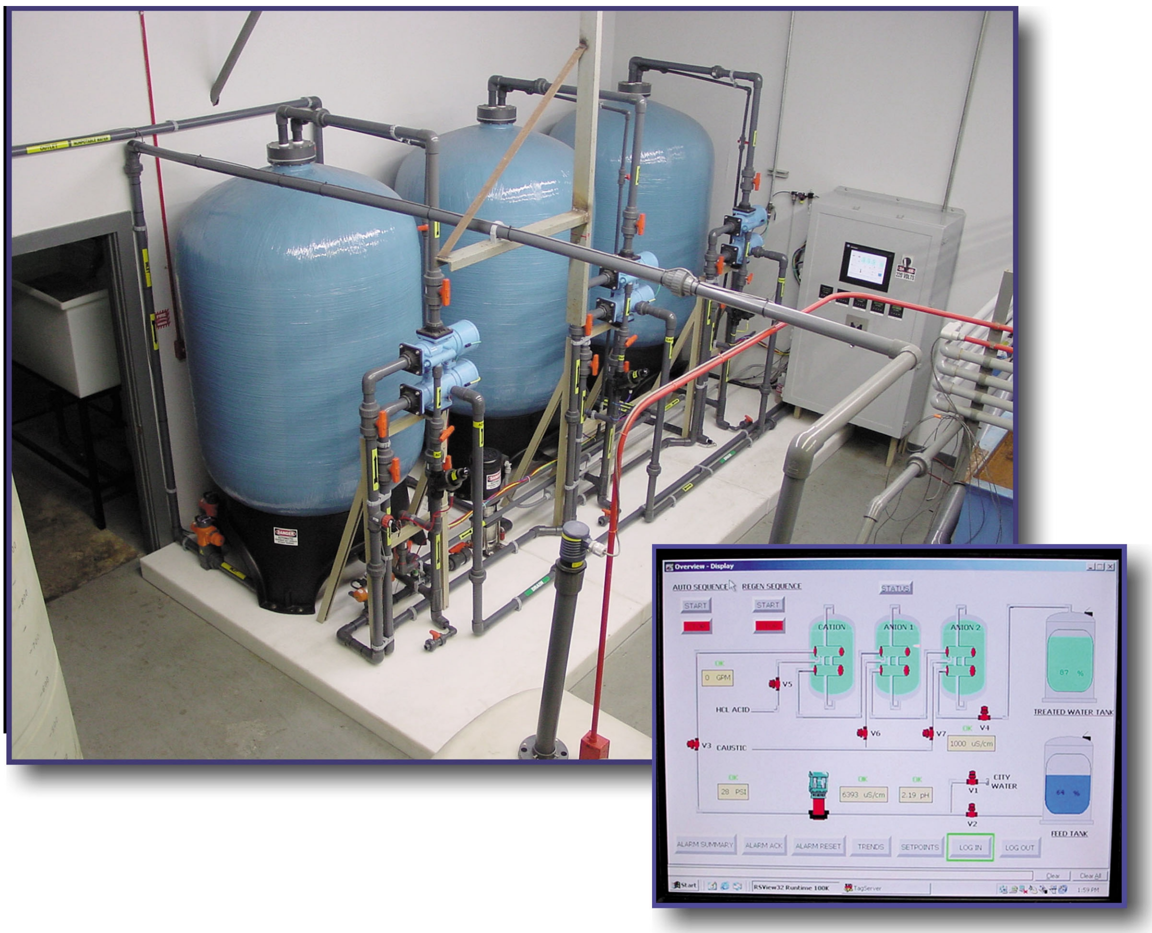

Figure 2. Photograph of the Lobo Liquids System Installed at Gull Industries (also blow-up of CRT display)

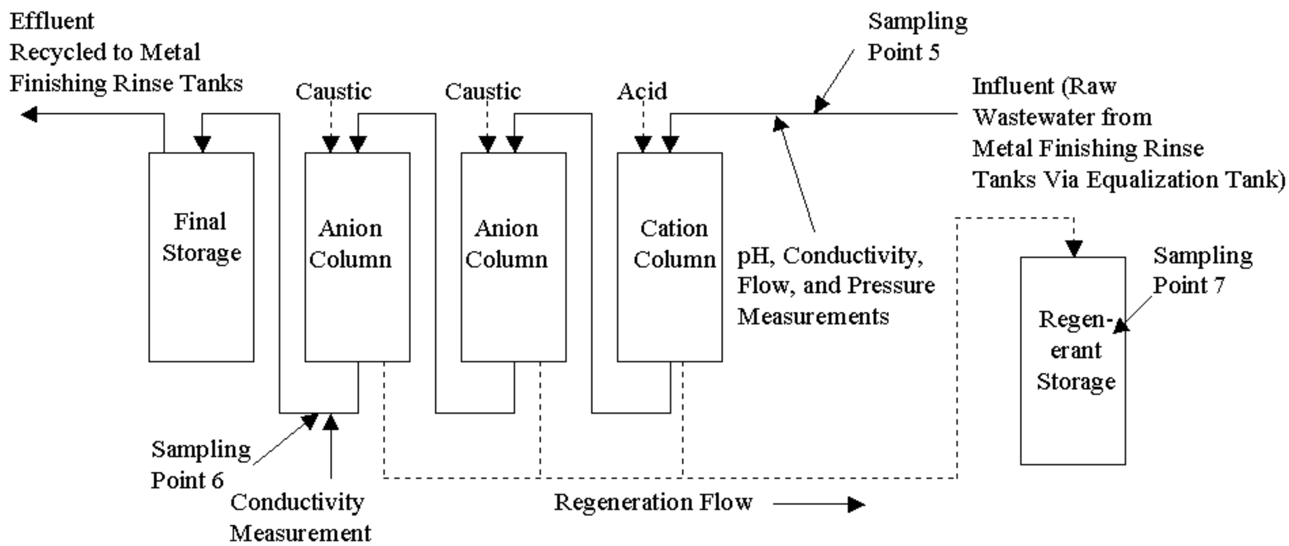

Figure 3. Diagram of Lobo Liquids System Installed at Gull Industries

3.0 METHODS AND PROCEDURES

3.1 Test Objectives

The overall goals of this ETV-MF project are: (1) evaluate the ability of the Lobo Liquids system to remove pollutants from metal finishing job shop wastewaters, with the metal finishing effluent guidelines and proposed MP&M limits used as target effluent concentrations, (2) determine the ability of the system to recover water for reuse in the electroplating process, (3) evaluate the operating characteristics of the system with respect to energy use, regenerant production and operating costs, and (4) evaluate the environmental benefit by determining the reduction in metals discharged to the city sewer system.

The following is a summary of primary project objectives. Under normal system operation for the installation at Gull Industries, and processing actual wastewater:

- Determine the ability of the Lobo Liquids system to remove specific contaminants from metal finishing wastewater and meet target effluent standards and Gull Industries' criteria for water reuse.
- Determine the quantity and chemical characteristics of the regenerant produced by the Lobo Liquids system.
- Determine the cost of operating the Lobo Liquids system for the specific conditions encountered during testing.
- Quantify the environmental benefit by determining the reduction in metals discharged to the sewer system beyond that required by existing metal finishing standards.

3.2 Test Procedure

3.2.1 System Set-Up

The rinse water system was set up in a closed-loop configuration as shown in **Figure 3**. Raw wastewater from the plating line was pumped from the equalization tank to the IX system. The treated water was returned to the electroplating line and used as rinse water. The system was operated in this configuration for one week prior to the verification test.[1]

The IX system was regenerated prior to testing, and the regenerant and effluent storage tanks were drained.

3.2.2 Testing

Testing was performed in accordance with the verification test plan [Ref. 4] from January 14–30, 2002. During verification testing, the systems were operated by Gull Industries personnel using their standard procedures. A representative from Lobo Liquids, Inc., was present to observe testing.

During testing, the IX system was operated during production hrs (i.e., approximately 0600 hrs to 1600 hrs, five days per week) and idled during off hrs. During the test, the system was operated for one full IX cycle, which lasted 15 days (137.5 operating hrs). A total of 472,476 L (124,828 gal) of wastewater was processed during the verification test. Regeneration of the IX columns was automatically initiated when the specific conductivity of the effluent approached 500 µS.

Per the test plan, sampling of the Lobo Liquids system influent and effluent was conducted during four separate days; the first three days of the operating cycle and the 14th day of the cycle. Day 14 sampling was performed in order to evaluate the characteristics of the effluent one-day prior to regeneration.[2]

3.3 Quality Assurance/Quality Control

A technical system audit (TSA) was performed during verification testing by the *CTC* Quality Assurance (QA) Manager on November 29, 2001 to ensure testing and data collection were performed in accordance with the test plan.[3]

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[1] At Gull Industries, a separate verification test was performed one month earlier, where a different treatment system was evaluated. Once that test was completed, the Lobo Liquids system was placed into the closed-loop configuration and operated for one week. This time period was sufficient to permit the closed-loop water system to reach a state of equilibrium.

[2] In order to collect a sample on the next to last day of the cycle, samples were collected during days 8 to 14. Only the day 14 sample was analyzed.

[3] The audit was performed at Gull Industries during verification testing of the Kaselco Electrocoagulation treatment System. Procedures for sampling the Lobo Liquids system were also reviewed at that time.

3.3.1 Data Entry

Sampling events, process measurements, and all other data were recorded by the ETV-MF Project Manager on a pre-designed form [Ref 4].

3.3.2 Sample Collection and Handling

Samples were collected from the three sampling points identified in **Figure 3**. The procedures used at each sampling point are described below.[4]

- **Ion exchange system influent (sample point 5).** Grab samples of influent to the IX polishing system were collected from a discharge line for hexavalent chromium, other metals, pH, TDS, and specific conductance analyses.
- **Ion exchange system effluent (sample point 6).** Grab samples of treated wastewater from the IX polishing system were collected from a sampling port for hexavalent chromium, other metals, pH, TDS, specific conductance, Oils & Grease (O&G), and sulfide analyses.
- **Ion exchange system regenerant (sample point 7).** The IX system is regenerated approximately every 15 to 20 operating days. The regenerant is collected in a storage tank. A Gull Industries employee, who was trained by the ETV-MF Project Manager, took grab samples of the regenerate from the storage tank for metals analyses.

At the time of sampling, each sample container was labeled with the date, time, and sample identification (ID) number. Samples were temporarily stored on-site in coolers containing ice. The ETV-MF Project Manager or a designated Gull Industries employee transported samples to a local laboratory for analysis. A chain of custody (COC) form accompanied the samples. The COC form provided the following information: project name, project address, sampler's name, sample numbers, date/time samples were collected, matrix, required analyses, and appropriate COC signatures.

3.3.3 Calculation of Data Quality Indicators

Data reduction, validation, and reporting were conducted according to the verification test plan [Ref. 4] and the ETV-MF Quality Management Plan (QMP) [Ref. 5]. Calculations of data quality indicators are discussed in this section.

3.3.3.1 Precision

Precision is a measure of the agreement or repeatability of a set of replicate results obtained from duplicate analyses made under identical conditions. Precision is estimated from analytical data and cannot be measured directly. To satisfy the precision objectives, the replicate

[4] Sample points 1 to 4 are associated with verification testing of a separate treatment system and are not discussed in this report.

analyses must agree within defined percent deviation limits, expressed as a percentage, calculated as follows:

$$RPD = \{(|X_1 - X_2|)/(X_1 + X_2)/2\} \text{ x } 100\% = \left\{\frac{|X_1 - X_2|}{\frac{(X_1 + X_2)}{2}}\right\} x100\,\%$$

where:

X_1 = larger of the two observed values
X_2 = smaller of the two observed values

The analytical laboratories performed a total of 102 precision evaluations on test samples. All of the aqueous samples were within the precision limits of the verification test plan [Ref. 4]. 95 percent of the precision evaluation met each analyte's precision limits. The results of the precision calculations are summarized in **Appendix A.**

3.3.3.2 Accuracy

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured. Analyses with spiked samples were performed to determine percent recoveries as a means of checking method accuracy. The percent recovery (P), expressed as a percentage, is calculated as follows:

$$P = [(SSR - SR)/SA] \times 100\,\%$$

where:

SSR = spiked sample result
SR = sample result (native)
SA = the concentration added to the spiked sample

QA objectives are satisfied for accuracy if the average recovery is within the range identified in **Table 9** of the verification test plan [Ref. 4]. The analytical laboratories performed 32 accuracy evaluations. There were 31 samples or 97 percent that were within the limits. The results of the accuracy calculations are summarized in **Appendix B.**

3.3.3.3 Completeness

Completeness is defined as the percentage of measurements judged to be valid (met precision, accuracy, and representativeness) compared to the total number of measurements made for a specific sample matrix and analysis. Completeness, expressed as a percentage, is calculated using the following formula:

$$\text{Completeness} = \frac{\text{Valid Measurements}}{\text{Total Measurements}} \times 100\%$$

QA objectives are satisfied if the percent completeness is 90 percent or greater. There were 164 total quality measurements, and 155 of them were valid. This gives 94.5 percent completeness. Therefore, the total completeness objective was satisfied.

3.3.3.4 Comparability

Comparability is a qualitative measure designed to express the confidence with which one data set may be compared to another. Sample collection and handling techniques, sample matrix type, and analytical method all affect comparability. Comparability was achieved during this verification test by the use of consistent methods during sampling and analysis and traceability of standards to a reliable source.

3.3.3.5 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter. For this verification project, one duplicate sample was collected in the field for sample locations 1, 2, 3, 4, and 6, and sent to the laboratory for analysis. Points 1-4 were sampled to test the electrocoagulation system. The results are shown in **Appendix C**.

3.3.3.6 Sensitivity

Sensitivity is the measure of the concentration at which an analytical method can positively identify and report analytical results. The sensitivity of a given method is commonly referred to as the detection limit. Although there is no single definition of this term, the following terms and definitions of detection were used for this project.

Instrument Detection Limit (IDL) is the minimum concentration that can be differentiated from instrument background noise; that is, the minimum concentration detectable by the measuring instrument.

Method Detection Limit (MDL) is a statistically determined concentration. It is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, as determined in the same or a similar sample matrix. In other words, this is the lowest concentration that can be reported with confidence. The MDL for the metal sludge sample varies for each individual metal analyte and sludge sample. This is due to the percent moisture in the sludge and is calculated as follows:

Sludge MDL = Standard MDL x (100 percent Solids) x Dilution Factor
The MDLs for this verification project are shown in **Table 1**.

Critical Measurements	Matrix	Method	Reporting Units	Method of Determination	MDL
O&G	Water	SM 5520B	mg/L	Gravimetric	1.0
Total Metal	Water	EPA 200.7	mg/L	ICP-AES	0.04 – 0.005
Total Metal	Solids	SW846 3050B/6010B	µg/g	ICP-AES	0.4 – 0.010
TSS	Water	EPA 160.2	mg/L	Gravimetric	1.0

Table 1. Laboratory Methodology Information

4.0 VERIFICATION DATA

4.1 Analytical Results

Table 2 presents the analytical results for wastewater samples collected from sampling points 5 and 6 during testing. **Table 3** contains the analytical results for the IX regenerant (sample point 7).

	IX Influent (sample point 5)					IX Effluent (sample point 6)				
Parameter	**Day 1**	**Day 2**	**Day 3**	**Day 14**	**Avg.**	**Day 1**	**Day 2**	**Day 3**	**Day 14**	**Avg.**
Cadmium, mg/L	ND	ND	ND	ND	<0.005	ND	ND	ND	ND	<0.005
Chromium (T), mg/L	3.43	3.37	6.43	0.044	3.32	ND	ND	ND	0.019	<0.01
Chromium +6, mg/L	3.80	3.57	6.89	1.42	3.92	ND	ND	ND	ND	<0.75
Copper, mg/L	0.262	0.456	0.701	0.030	0.362	ND	ND	ND	ND	<0.010
Iron, mg/L -		-	-	1.70-	1.70		-	-	ND	<0.400
Lead, mg/L	0.055	0.201	0.332	ND	0.147	ND	ND	ND	ND	<0.10
Manganese, mg/L	ND	ND	ND	ND	<0.030	ND	ND	ND	ND	<0.030
Molybdenum, mg/L	ND	ND	ND	0.501	<0.13	ND	ND	ND	ND	<0.020
Nickel, mg/L	1.23	1.09	60.0	0.151	15.6	ND	ND	ND	0.045	0.01
Silver, mg/L	ND	ND	ND	ND	<0.010	ND	ND	ND	ND	<0.010
Tin, mg/L	ND	0.037	0.053	ND	<0.023	ND	ND	ND	ND	<0.020
Zinc, mg/L	0.239	0.635	1.09	0.250	0.55	ND	ND	ND	ND	<0.030
Specific Conductance, µS	328	480	1250	1450	877	10.5	10.0	10.5	426	114
Lab pH	3.56	3.35	2.75	2.53	3.05	-	-	-	-	-
Field pH					-			-	-	-
TDS, mg/L	134	151	444	200	232	83	100	55	230	117
TSS, mg/L	ND	ND	ND	ND	<10	ND	ND	ND	ND	<10
Sulfide, mg/L	ND	ND	ND	ND	<5	ND	ND	ND	ND	<5
TOC, mg/L	1.28	1.6	8.27	10.9	5.5	ND	ND	ND	ND	<1
O&G, mg/L	ND	ND	ND	ND	<5.6	ND	ND	ND	ND	<5.6

Table 2. Analytical Results for IX Influent and Effluent

Parameter	Concentration of Parameter in IX Regenerant, mg/L	Mass of Parameter in IX Regenerant, kg (lbs)*
Cadmium	ND	-
Chromium (T)	5,780	56.0 (123.2)
Chromium (+6)	6,040	58.5 (128.7)
Copper	30.7	0.4 (0.9)
Iron	-	-
Lead	ND	-
Manganese	ND	-
Molybdenum	ND	-
Nickel	30,400	294.6 (648.1)
Silver	-	-
Tin	ND	-
Zinc	100	1.0 (2.2)

*Based on 9,690 L (2,560 gal) of regenerant generated.

Table 3. Analytical Results for Ion Exchange Regenerant

4.2 Process Measurements

IX system operating data are shown in **Table 4**. These data were logged by the internal Lobo Liquids data acquisition system. The parameters shown include flow rate, influent pH, influent conductivity and effluent conductivity.

Processing Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Avg. for 15 Processing Days
Processing Time, hrs.	9.6	11.1	10.4	10.2	9.6	9.4	8.6	8.8	7.1	10.8	9.3	9.3	9.1	10.4	3.6	9.2
Volume Processed, L (gal)	28,200 (7,451)	32,302 (8,534)	29,712 (7,850)	29,244 (7,726)	28,593 (7,554)	25,764 (6,807)	24,288 (6,417)	27,205 (7,187)	32,207 (8,509)	42,130 (11,131)	35,629 (9,413)	37,716 (9,965)	37,990 (10,037)	46,015 (12,157)	15,475 (4,089)	31,498 (8,322)
Flow, L/min (gpm)																
Average	48.90 (12.92)	48.30 (12.76)	47.50 (12.55)	47.58 (12.57)	49.58 (13.10)	45.91 (12.13)	46.86 (12.38)	51.25 (13.54)	75.40 (19.92)	64.80 (17.12)	63.97 (16.90)	67.41 (17.81)	69.30 (18.31)	73.96 (19.54)	72.10 (19.05)	58.19 (15.37)
Minimum	37.85 (10.00)	30.28 (8.00)	22.71 (6.00)	30.28 (8.00)	30.28 (8.00)	30.28 (8.00)	37.85 (10.00)	37.85 (10.00)	52.99 (14.00)	52.99 (14.00)	52.99 (14.00)	52.99 (14.00)	56.78 (15.00)	41.64 (11.00)	60.56 (16.00)	41.89 (11.07)
Maximum	113.55 (30.00)	113.55 (30.00)	98.41 (26.00)	113.55 (30.00)	83.27 (22.00)	102.20 (27.00)	83.27 (22.00)	113.55 (30.00)	113.55 (30.00)	113.55 (30.00)	83.27 (22.00)	83.27 (22.00)	83.27 (22.00)	83.27 (22.00)	87.06 (23.00)	97.91 (25.87)
Std. Dev.	8.55 (2.26)	8.06 (2.13)	4.96 (1.31)	5.37 (1.42)	7.65 (2.02)	3.97 (1.05)	0.25 (0.07)	10.33 (2.73)	5.37 (1.42)	4.92 (1.30)	4.05 (1.07)	3.67 (0.97)	3.29 (0.87)	4.28 (1.13)	4.35 (1.05)	5.27 (1.39)
Inlet pH																
Average	4.47	3.68	3.25	4.34	3.99	3.88	3.01	3.40	3.41	3.13	3.25	3.25	2.95	2.80	2.72	3.44
Minimum	3.22	2.78	2.79	3.11	2.97	2.29	2.74	3.14	3.13	2.77	3.06	2.97	2.76	2.70	2.59	2.87
Maximum	9.31	10.34	7.86	11.32	9.54	10.23	4.69	4.94	8.66	6.21	4.50	4.76	4.61	4.30	4.13	7.03
Std. Dev.	1.59	1.77	0.96	2.05	1.78	1.85	0.36	0.26	0.37	0.33	0.20	0.30	0.26	0.21	0.28	0.84
Inlet Conductivity, µS																
Average	240	640	710	580	320	910	770	290	230	480	240	360	930	1,410	2,230	689
Minimum	0	100	100	100	0	0	0	0	0	0	0	0	0	0	0	20
Maximum	1,000	1,200	1,200	7,400	700	5,700	1,200	500	800	1,800	500	500	1,300	1,700	3,400	1927
Std. Dev.	130	260	300	1,090	140	1,240	290	100	90	300	80	120	270	270	610	353
Outlet Conductivity, µS																
Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.120	0.00	0.00	0.08	0.00	0.40	222.28	410.00	42.18
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	405.00	27.00
Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	416.00	438.00	57.20
Std. Dev.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.27	0.05	0.49	203.90	2.06	13.79

Total processing time for 15 days was 137.5 hrs. T otal volume of water processed was 472,476 L (124,828 gal.).

Table 4. Lobo Liquids System Operating Data

Unit cost data for labor, electricity, and IX system regeneration chemicals are shown in Table 5. Gull Industries provided this information.

Parameter	Cost
IX System Labor	$20/hr (loaded rate, includes overhead and fringe benefits)
Electricity	$0.10/kWh
Water/Sewer	$6.50/1,000 gal
Hydrochloric Acid	$0.28/L
Sodium Hydroxide	$0.38/ L

Table 5. Unit Cost Data

Chemical usage during the verification test are shown in **Table 6**.

Item	Usage
Hydrochloric Acid Used*	238 gal
Sodium Hydroxide Used*	305 gal

*For entire IX cycle (124,828 gal treated).

Table 6. Chemical Usage Data

The ETV-MF Project Manager made observations during the course of the verification test. The labor required to operate the IX system was for starting and stopping the system on a daily basis and periodically checking on its progress. The average labor needed per day was 1.0 hrs. At the completion of the IX cycle, the system was regenerated. The regeneration process took seven hrs to complete, although it was mostly performed automatically and unattended. The labor required for regeneration was 1.5 hrs (not including treatment of regenerant) that was needed for initiating the regeneration cycle and periodically checking on the progress of regeneration.

5.0 EVALUATION OF RESULTS

5.1 System Operation

A diagram of the Gull Industries chromium/nickel electroplating line and rinse water recycle system is shown in **Figure 4**. The plating line consists of five process steps, each followed by a rinse system. There is a single overflow rinse after alkaline cleaning, double counterflow rinse systems following electrocleaning and acid dip, and three-stage counterflow rinses following nickel and chromium electroplating. In order for a rinse tank to be effective, the concentration of chemicals in the rinse tank must be sufficiently low. In a counterflow rinse system, such as those used at Gull Industries, it is the final rinse of each rinse system that is of particular concern. If the concentration of chemicals in the final rinse is too high, then chemicals remain on the parts. This can cause unwanted chemical reactions, staining of parts, and contamination of subsequent process tanks [Ref. 3].

Prior to the installation of the Lobo Liquids Rinse Water Recovery System, used rinse water was stored in a large equalization tank (18,925 L), treated using a metals precipitation technology (electrocoagulation), and discharged to the city sewer. The average volume of wastewater discharged was 7,500 L/day (1,982 gpd). According to Gull Industries, production rates and pollutant loading rates were approximately the same before and after the closed-loop rinse system was installed.

During the course of the verification test, the Gull Industries electroplating rinse water system was operated in a closed-loop. Used rinse water from the rinse tanks was processed through the Lobo Liquids system and returned to the rinse tanks. No wastewater was discharged to the city sewer system during the 15 operating day duration of the ETV test. Rinse water was recycled by the Lobo Liquids system at an average rate of 58.19 L/min (15.37 gpm) for an average duration of 9.2 hrs/day. The average daily volume of water recycled was 32,121 L/day (8,484 gpd).

Table 7 compares the concentration of chemicals in the used rinse water, before and after implementation of closed-loop rinsing at Gull Industries.[5] The average concentration of TDS in the used rinse water prior to implementation of closed-loop rinsing was 1,320 mg/L. Following implementation of closed-loop rinsing, the TDS concentration was 232 mg/L, an 82 percent decrease. This comparison indicates that the water in the rinse tanks was significantly cleaner with the new closed-loop system than with the old, non-circulated system. This is due to the higher flow rate of water used in the closed-loop system as compared to the non-circulated system.

The mass of TDS discharged from the rinse systems was similar before and after implementation of closed-loop rinsing (9,900 g/day before compared to 7,308 g/day after closed-loop rinsing was implemented). However, the mass of chromium and nickel discharged from the rinse systems dropped significantly after closed-loop rinsing was implemented. Gull Industries personnel attributed this drop to use of recovery rinsing, which they implemented simultaneously along with closed-loop rinsing.[6] Prior to closed-loop rinsing, Gull Industries was hesitant to use recovery rinsing due to a fear of building up contaminants in process tanks. This can occur when rinse water is insufficiently pure enough to effectively remove chemicals from the parts and the chemicals from one process tank are carried over to a subsequent process tank.

[5] At Gull Industries, the water discharged from each of the various rinse systems following electroplating processes is combined prior to treatment. The concentration of chemicals in the combined rinse water is an indicator of the relative purity of water used in the final rinse tanks. When there is a high concentration of chemicals present, the effectiveness of the rinsing is diminished.

[6] At Gull Industries, recovery rinsing is performed by manually transferring a portion of the first rinse to the process tank to make up for evaporative losses. This practice is sometimes referred to as drag-out recovery rinsing. At Gull Industries this is done with rinses following nickel and chromium electroplating.

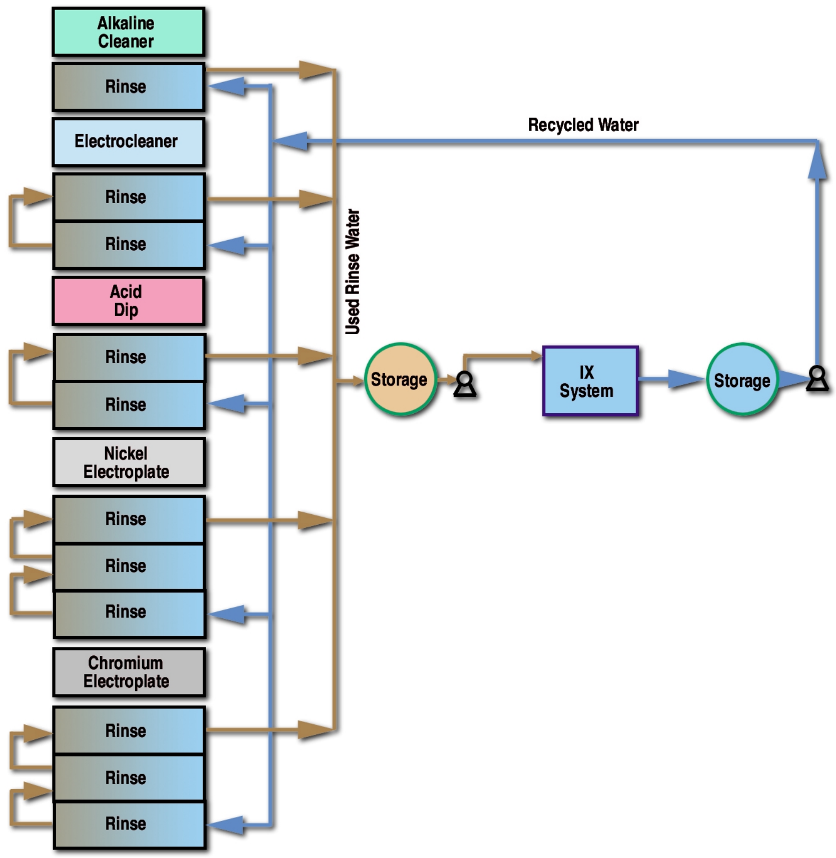

Figure 4. Diagram Showing the Gull Industries Decorative Chromium Plating Line and Lobo Liquids Rinse Water Recovery System

Parameter	Concentration of Parameter in Used Rinse Water Prior to Closed-Loop Installation, Avg.[7]	Mass of Parameter in Used Rinse Water Prior to Closed-Loop Installation, Avg.	Concentration of Parameter in Used Rinse Water After Closed-Loop System Installation, Avg.	Mass of Parameter in Used Rinse Water After Closed-Loop System Installation, Avg.
Cadmium	0.008 mg/L	0.06	<0.005 mg/L	<0.2
Chromium (T)	89.5 mg/L	671	3.32 mg/L	105
Chromium +6	70.5 mg/L	529	3.92 mg/L	123
Copper	1.31 mg/L	9.8	0.362 mg/L	11.4
Lead	0.252 mg/L	1.9	0.147 mg/L	4.6
Manganese	0.171 mg/L	1.3	<0.030 mg/L	<1.0
Nickel	202 mg/L	1,515	15.6 mg/L	491
Tin	0.57 mg/L	4.3	<0.023 mg/L	<1.0
Zinc	3.09 mg/L	23.2	0.55 mg/L	17.3
TDS	1,320 mg/L	9,900	232 mg/L	7,308

Table 7. Impact of Closed-Loop Ion Exchange System Installation

[7] Data collected at Gull Industries during preliminary ETV testing in July 2001 (see **ref. 4**).

A graph showing specific conductivity data, logged by the Lobo Liquids data acquisition system, over the entire course of the test is shown in **Figure 5**. This graph indicates that the Lobo Liquids system produced a consistently pure effluent throughout the entire IX cycle, until resin bed was nearly exhausted (chemically full). The point at which the specific conductivity rapidly rises is termed "breakthrough." This occurred 128.4 hrs into the IX cycle. Just prior to breakthrough, the specific conductivity was 4 µS. Within 10 seconds, the specific conductivity increased to 410 µS. The specific conductivity stayed in the range of 408 µS to 438 µS for the remainder of the IX cycle, a time period of 9.1 operating hrs. Regeneration was automatically initiated at that point in time.

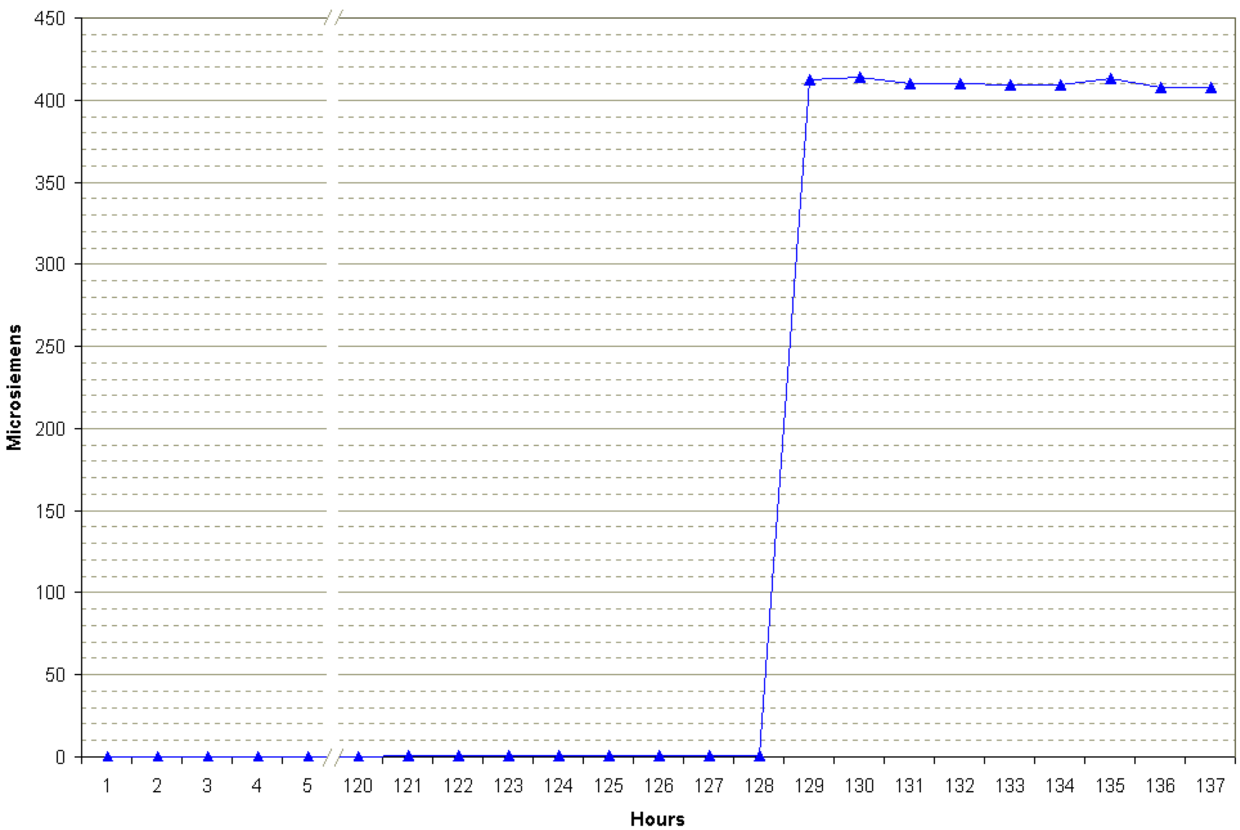

Figure 5. Specific Conductivity of Lobo liquids System Effluent During ETV Test Period

5.2 Pollutant Removal Efficiency

The pollutant removal efficiency was calculated based on a comparison of influent and effluent concentrations for each pollutant parameter. Removal efficiency was only calculated for parameters that were found at concentrations above detection limits in the influent for at least one day. These calculations are performed for paired sets of analytical results (i.e., daily influent and effluent samples). Also, average removal efficiencies were calculated for the entire test. For the purpose of pollutant removal calculations, parameters that were not detected in the treated wastewater by analytical measurements were given a concentration value of zero.

The results of the pollutant removal efficiency analysis for the Lobo Liquids system are shown in **Table 8**. Percent removal could not be calculated for cadmium, manganese, silver, and sulfide because the concentration of these parameters in the influent was below detection limits for all four days batches. Average pollutant percent removals for the remaining parameters ranged from 99.9 percent to 100.0 percent.

	IX Inf. Day 1 mg/L	IX Eff. Day 1 mg/L	% Removal Day 1	IX Inf. Day 2 mg/L	IX Eff. Day 2 mg/L	% Removal Day 2	IX Inf. Day 3 mg/L	IX Eff. Day 3 mg/L	% Removal Day 3	IX Inf. Day 14 mg/L	IX Eff. Day 14 mg/L	% Removal Day 14	Avg. for Four Days, % Removal
Cadmium, mg/L	ND	ND	-	ND	ND	-	ND	ND	-	ND	ND	-	-
Chromium (T), mg/L	3.43	ND	100.0%	3.37	ND	100.0%	6.43	ND	100.0%	0.044	0.019	56.8%	99.9%
Chromium +6, mg/L	3.80	ND	100.0%	3.57	ND	100.0%	6.89	ND	100.0%	1.42	ND	100.0%	100.0%
Copper, mg/L	0.262	ND	100.0%	0.456	ND	100.0%	0.701	ND	100.0%	0.030	ND	100.0%	100.0%
Iron, mg/L	-	-	-	-	-	-	-	-	-	1.70	ND	100.0%	100.0%
Lead, mg/L	0.055	ND	100.0%	0.201	ND	100.0%	0.332	ND	100.0%	ND	ND	100.0%	100.0%
Manganese, mg/L	ND	ND	-	ND	ND	-	ND	ND	-	ND	ND	-	-
Molybdenum, mg/L	ND	ND	-	ND	ND	-	ND	ND	-	0.501	ND	100.0%	100.0%
Nickel, mg/L	1.23	ND	100.0%	1.09	ND	100.0%	60.0	ND	100.0%	0.151	0.045	91.0%	99.9%
Silver, mg/L	ND	ND	-	ND	ND	-	ND	ND	-	ND	ND	-	-
Tin, mg/L	ND	ND	-	0.037	ND	100.0%	0.053	ND	100.0%	ND	ND	-	100.0%
Zinc, mg/L	0.239	ND	100.0%	0.635	ND	100.0%	1.09	ND	100.0%	0.25	ND	100.0%	100.0%
TOC, mg/L	1.28	ND	100.0%	1.6	ND	100.0%	8.27	ND	100.0%	10.9	ND	100.0%	100.0%
Sulfide, mg/L	ND	ND	-	ND	ND	-	ND	ND	-	ND	ND	-	-

Average percent removal for four days calculated using average influent and effluent values for the four days (not shown).

Table 8. Results of Pollutant Removal Efficiency Analysis for Lobo System

5.3 Ability to Meet Metal Finishing and Proposed Target Effluent Levels

The results from each day of sampling were compared to the applicable metal finishing limitations and target level effluent limitations. To meet a metal finishing or target limit, the analytical result must be equal to or below the corresponding daily maximum value. The applicable limitations are the pretreatment standards for existing sources for the metal finishing category (40 CFR 433.15) and proposed pretreatment standards for existing sources for the Metal Products & Machinery (MP&M) Job Shop subcategory (66 FR 543).

The results of the comparison for the Lobo Liquids system are shown in **Table 9**. The metal finishing limitations and proposed MP&M limitations were met for all parameters for each day of sampling.

Parameter	Metal Finishing Category Limits, Daily Max. mg/L	MP&M Job Shop Subcategory Limits, Daily Max. mg/L	Day 1		Day 2		Day 3		Day 14	
			IX Eff. Meets Metal Finishing Limits? Yes/No	IX Eff. Discharge Meets MP&M Limits? Yes/No	IX Eff. Meets Metal Finishing Limits? Yes/No	IX Eff. Discharge Meets MP&M Limits? Yes/No	IX Eff. Meets Metal Finishing Limits? Yes/No	IX Eff. Discharge Meets MP&M Limits? Yes/No	IX Eff. Meets Metal Finishing Limits? Yes/No	IX Eff. Discharge Meets MP&M Limits? Yes/No
Sulfide	NR	31	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
O & G (HEM)	NR	52	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TOC	NR	78	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cadmium	0.69	0.21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chromium	2.77	1.3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Copper	3.38	0.55	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lead	0.69	0.12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Manganese	NR	0.25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Molybdenum	NR	0.79	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nickel	3.98	1.5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Silver	0.43	0.15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tin	NR	1.8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Zinc	2.61	0.35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

NR = not regulated

Table 9. Results of Regulatory Limits Comparison Analysis for Lobo Liquids System

5.4 Reusability of Treated Wastewater

The reusability of the treated wastewater as process water was determined by comparing the results of the specific conductance and TDS analytical tests of the final treated water (Lobo Liquids system effluent, i.e., sample point 6) to standards used by Gull Industries for water reuse. Treated water meeting these standards was deemed reusable. The Gull Industries standards are:

- Specific conductance: maximum of 500 µS
- TDS: maximum of 250 mg/L

The results of this comparison are shown in **Table 10**. For days 1, 2, 3 and 14 the Lobo Liquids system met the Gull Industries water reuse criteria.

Parameter	Recycle Criterion	IX Effluent				IX Effluent Meets Criterion Yes/No
		Day 1	Day 2	Day 3	Day 14	
Specific conductance, µS	500	10.5	10.0	10.5	426	Yes (Days 1, 2, 3, 14)
TDS, mg/L	250	83	100	55	230	Yes (Days 1, 2, 3, 14)

Table 10. Comparison of Analytical Results and Gull Industries Water Recycling Criteria

It should be noted that during the period of testing, it was observed that Gull Industries reused the water produced by the Lobo Liquids system as rinse water on their decorative chromium electroplating line. No wastewater was discharged to the city sewer system during the 15-day verification test.

5.5 Energy Use

The energy requirements were calculated separately for the Lobo Liquids system. The results of the energy use analysis are presented in **Table 11**. Electricity use for the Lobo Liquids system during the ETV test was 205 kWh, which is equivalent to 0.43 kWh/1,000 L. For pumps, energy use was calculated by summing the total quantity of horsepower (hp) hrs for each system and dividing by 1.341 hp-hr/kWh to arrive at electricity needs.

Item	Hp-Hr.	Electricity Use kWh	Electricity Use kWh/1,000 L (KWh/1,000 gal)
Total Lobo Liquids System	275	205	0.43 (1.63)

Table 11. Results of Energy Use Analysis

5.6 Cost Analysis

This analysis determines the operating cost of the Lobo Liquids system considering the following cost parameters: chemical reagents, electricity, and labor. Costs are expressed in dollars per thousand liters processed ($/1000 L) by dividing the cost by the total volume of wastewater processed during the verification test. Total costs are calculated by summing the individual cost elements. The calculation of treatment cost for either system is shown below.

The results of the operating cost analysis are shown in **Table 12**. Operating costs are displayed both with and without labor costs.

Cost Parameter	Unit Cost	Units Used During ETV Test	Cost During ETV Test Batches 1 to 3	Normalized Cost, $/1,000 L ($/1,000 gal.)
Sodium Hydroxide	$0.38/L ($1.44/gal.)	1,154 L (305 gal.)	$438.52	$0.93 ($3.51)
Hydrochloric Acid	$0.28/L ($1.06/gal.)	901 L (238 gal.)	$252.28	$0.53 ($2.02)
Electricity	$0.10/kWh	205 kWh	$20.50	$0.04 ($0.16)
Total Lobo Liquids System, except labor			**$711.30**	**$1.50 ($5.69)**
Labor	$20/hr.	17 hrs.	$340.00	$0.72 ($2.73)
Total Lobo Liquids System, including labor			**$1,051.30**	**$2.22 ($8.42)**

Table 12. Results of Cost Analysis

Use of the Lobo Liquids Rinse Water Recovery System eliminates the discharge of wastewater at Gull Industries, with the exception of processed regenerant. The cost of water/sewer at this facility is $1.72/1,000 L ($6.50/1,000 gal). The water/sewer savings achieved by recovering and recycling water during the ETV test was $794.74, which is greater than the non-labor operating cost. Although not quantified during this test, the savings would actually be higher since Gull Industries previously used deionized water for rinsing. The cost savings from eliminating the old deionizing system are not included.

5.7 Regenerant Analysis

The volume of regenerant produced by the Lobo Liquids system was measured at the end of the verification test. The volume was 9,690 L (2,560 gal). The laboratory analyzed a representative sample of the regenerant. Results from measurements and analytical tests are summarized earlier (see **Table 3**).

At Gull industries, the regenerant is processed by a metals precipitation technology that is not part of the Lobo Liquids system evaluated during this ETV test. The treated regenerant is discharged to the city sewer and the precipitated solids are sent off-site for disposal.

5.8 Environmental Benefit

This analysis quantifies the environmental benefit of the Lobo Liquids system installed at Gull Industries by determining the quantity of regulated pollutants removed beyond the level required by the metal finishing regulations (40 CFR 433). The results of the analysis are shown in **Table 13**. Cadmium and silver were not found in the influent and therefore were not included in this analysis. The raw wastewater concentration for copper, lead and zinc were below the values for metal finishing limitations and therefore the raw wastewater concentration was used in calculating environmental benefit for these three parameters.

Parameter	Metal Finishing Limitations		Lobo Liquids Influent (Days 1, 2, 3, 14)		Lobo Liquids Effluent (Days 1, 2, 3, 14)		Environmental Benefit, g*
	Avg. Daily Max., mg/L	Allowable Mass Discharge, g*	Avg. Conc., mg/L	Avg. Mass Discharge, g*	Avg. Conc., mg/L	Avg. Mass Discharge, g*	
Cadmium	0.69	326.0	0.0	0.0	0.0	0.0	-
Chromium	2.77	1,308.8	4.410	2,083.6	0.0	0.004	1,308.8
Copper	3.38	1,597.0	0.473	223.5	0.0	0.0	223.5
Lead	0.69	326.0	0.196	92.6	0.0	0.0	92.6
Nickel	3.98	1,880.4	20.8	9,827.5	0.0	0.01	1,880.4
Silver	0.43	203.2	0.0	0.0	0.0	0.0	-
Zinc	2.61	1,233.2	0.650	307.1	0.0	0.0	307.1
Total							3,812.42

* Based on 472,476L (124,828 gal) treated.

Table 13. Results of Environmental Benefit Analysis

The environmental benefit from use of the Lobo Liquids system is a reduction of 3,812.4 g (8.4 lbs) of regulated metals for the 15-day test period. On an annual basis (260 operating days per year), the environmental benefit would be a reduction of 66,082 g (145.6 lbs) of metal discharged.

6.0 REFERENCES

1) EPA, Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards for the Metal Finishing Point Source Category (40 CFR 433).

2) EPA, Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards for the Metal Products and Machinery Point Source Category; Proposed Rule (66 FR 424, January 3, 2001).

3) Cushnie, George C., *Pollution Prevention and Control for Plating Operations*, National Center for Manufacturing Sciences, Ann Arbor, Michigan, 1994.

4) Concurrent Technologies Corporation, "*Environmental Technology Verification Program for Metal Finishing Pollution Prevention Technologies (ETV-MF) Verification Test Plan for the Evaluation of Lobo Liquids Rinse Water Recovery System,*" January 8, 2002.

5) Concurrent Technologies Corporation, "Environmental Technology Verification Program Metal Finishing Technologies (ETV-MF) Quality Management Plan," Rev. 1, March 26, 2001.

APPENDIX A

Precision Calculations

PRECISION CALCULATIONS

Laboratory ID	*CTC* ID	Parameter	Units	Sample Value	Duplicate Value	RPD %	RPD % Limits	RPD Met? Y/N
229693-4	D1S5-C	TSS	mg/L	<10	< 10	0.0	<30	Y
229693-4	D1S5-C	pH	NA	3.56	3.56	0.0	<30	Y
229693-7	D1S5-T	TOC	mg/L	<1.0	<1.0	0.0	<30	Y
229776-13	D3S6-TA	TOC	mg/L	<1.0	<1.0	0.0	<30	Y
229776-4	D3S6-SA	Sulfide	mg/L	<5.0	<5.0	0.0	<30	Y
229693-9	D1S6-C	Specific Conductive.	NA	10.46	10.48	0.2	<30	Y
229693-9	D1S6-C	Hexavalent Chromium	mg/L	<0.015	<0.015	0.0	<30	Y
229776-7	D3S6-CA	Hexavalent Chromium	mg/L	<0.015	<0.015	0.0	<30	Y
230445-19	EFF6-C	TSS	mg/L	<10	<10	0.0	<30	Y
229693-20	D2S6-C	TDS	mg/L	100	106	5.8	<30	Y
229693-21	D2S6-M	Cadmium	mg/L	<0.005	<0.005	0.0	<30	Y
229693-21	D2S6-M	Cadmium	mg/L	<0.005	<0.005	0.0	<30	Y
229693-21	D2S6-M	Chromium	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Chromium	mg/L	<0.010	<0.010	0.0	<30	Y
229776-11	D3S6-MB	Chromium	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Copper	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Copper	mg/L	<0.010	<0.010	0.0	<30	Y
229776-11	D3S6-MB	Copper	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Lead	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Lead	mg/L	<0.010	<0.010	0.0	<30	Y
229776-11	D3S6-MB	Lead	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Manganese	mg/L	<0.030	<0.030	0.0	<30	Y
229693-21	D2S6-M	Manganese	mg/L	<0.030	<0.030	0.0	<30	Y
229776-11	D3S6-MB	Manganese	mg/L	<0.030	<0.030	0.0	<30	Y
229693-21	D2S6-M	Molybdenum	mg/L	<0.020	<0.020	0.0	<30	Y
229693-21	D2S6-M	Molybdenum	mg/L	<0.020	<0.020	0.0	<30	Y
229776-11	D3S6-MB	Molybdenum	mg/L	<0.020	<0.020	0.0	<30	Y
229693-21	D2S6-M	Nickel	mg/L	<0.020	<0.020	0.0	<30	Y
229693-21	D2S6-M	Nickel	mg/L	<0.020	<0.020	0.0	<30	Y
229776-11	D3S6-MB	Nickel	mg/L	<0.020	<0.020	0.0	<30	Y
229693-21	D2S6-M	Silver	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Silver	mg/L	<0.010	<0.010	0.0	<30	Y
229776-11	D3S6-MB	Silver	mg/L	<0.010	<0.010	0.0	<30	Y
229693-21	D2S6-M	Tin	mg/L	<0.020	<0.020	0.0	<30	Y
229776-11	D3S6-MB	Tin	mg/L	<0.020	<0.020	0.0	<30	Y
229693-21	D2S6-M	Zinc	mg/L	<0.030	<0.030	0.0	<30	Y
229693-21	D2S6-M	Zinc	mg/L	<0.030	<0.030	0.0	<30	Y

NA = Not Applicable

Precision Calculations

Laboratory ID	*CTC* ID	Parameter	Units	Sample + Spike Value	Duplicate + Spike Value	RPD %	RPD % Limits	RPD Met? Y/N
229693-21	D2S6-M	Cadmium	mg/L	0.4808	0.4767	0.8	<30	Y
229693-21	D2S6-M	Cadmium	mg/L	0.4808	0.4993	5.8	<30	Y
229693-21	D2S6-M	Cadmium	mg/L	0.4767	0.4993	4.6	<30	Y
229776-11	D3S6-MB	Cadmium	mg/L	0.5309	0.5258	1.0	<30	Y
229693-21	D2S6-M	Chromium	mg/L	0.9467	0.9547	0.8	<30	Y
229693-21	D2S6-M	Chromium	mg/L	0.9467	0.9865	4.1	<30	Y
229693-21	D2S6-M	Chromium	mg/L	0.9547	0.9865	3.3	<30	Y
229776-11	D3S6-MB	Chromium	mg/L	1.0099	1.0296	1.8	<30	Y
229693-21	D2S6-M	Copper	mg/L	1.0648	1.0630	0.2	<30	Y
229693-21	D2S6-M	Copper	mg/L	1.0648	0.9842	7.6	<30	Y
229693-21	D2S6-M	Copper	mg/L	1.0630	0.9842	7.9	<30	Y
229776-11	D3S6-MB	Copper	mg/L	0.9801	0.9801	0.0	<30	Y
229693-21	D2S6-M	Lead	mg/L	0.9539	0.9406	1.4	<30	Y
229693-21	D2S6-M	Lead	mg/L	0.9539	0.9817	4.3	<30	Y
229693-21	D2S6-M	Lead	mg/L	0.9406	0.9817	4.3	<30	Y
229776-11	D3S6-MB	Lead	mg/L	0.9914	0.9848	0.7	<30	Y
229693-21	D2S6-M	Manganese	mg/L	0.9532	0.9452	0.8	<30	Y
229693-21	D2S6-M	Manganese	mg/L	0.9532	0.9882	3.6	<30	Y
229693-21	D2S6-M	Manganese	mg/L	0.9452	0.9882	3.6	<30	Y
229776-11	D3S6-MB	Manganese	mg/L	0.9809	0.9711	0.9	<30	Y
229693-21	D2S6-M	Molybdenum	mg/L	0.9292	0.9261	5.3	<30	Y
229693-21	D2S6-M	Molybdenum	mg/L	0.9292	0.9793	5.3	<30	Y
229693-21	D2S6-M	Molybdenum	mg/L	0.9261	0.9793	5.3	<30	Y
229776-11	D3S6-MB	Molybdenum	mg/L	0.9785	0.9761	0.2	<30	Y
229693-21	D2S6-M	Nickel	mg/L	0.9619	0.9536	0.9	<30	Y
229693-21	D2S6-M	Nickel	mg/L	0.9619	0.9981	3.7	<30	Y
229693-21	D2S6-M	Nickel	mg/L	0.9536	0.9981	4.6	<30	Y
229776-11	D3S6-MB	Nickel	mg/L	1.0570	1.0475	0.9	<30	Y
229693-21	D2S6-M	Silver	mg/L	0.4933	0.4917	0.3	<30	Y
229693-21	D2S6-M	Silver	mg/L	0.4933	0.4909	0.5	<30	Y
229693-21	D2S6-M	Silver	mg/L	0.4917	0.4909	0.2	<30	Y
229776-11	D3S6-MB	Silver	mg/L	0.4988	0.4987	0.0	<30	Y
229776-11	D3S6-MB	Tin	mg/L	1.0034	0.9976	0.6	<30	Y
229693-21	D2S6-M	Zinc	mg/L	0.9464	0.9377	0.9	<30	Y
229693-21	D2S6-M	Zinc	mg/L	0.9464	1.0012	5.6	<30	Y
229693-21	D2S6-M	Zinc	mg/L	0.9377	1.0012	7.5	<30	Y
229776-11	D3S6-MB	Zinc	mg/L	1.0260	1.0185	0.7	<30	Y

APPENDIX B

Accuracy Calculations

ACCURACY CALCULATIONS

CTC Sample ID	Parameter	Units	Sample Value	Sample + Spike Value	Spike Value	Recovery %	Target % Recovery	Accuracy Met? Y/N
D1S5-C	TSS	mg/L	< 1.0	8.80	10.00	88	70 – 130	Y
D1S5-C	pH	mg/L	< 1.0	9.20	10.00	92	70 - 130	Y
D1S5-T	TOC	mg/L	< 1.0	9.80	10.00	98	70 - 130	Y
R2-D2-T-G1	O & G (Freon)	mg/L	< 1.0	10.0	10.00	100	70 - 130	Y
R2-D3-T-G1	O & G (HEM)	mg/L	< 1.0	8.40	10.00	84	70 – 130	Y
R2-D3-T-G1	O & G (HEM)	mg/L	< 1.0	8.20	10.00	82	70 – 130	Y
R2-D3-T-G1	O & G (Freon)	mg/L	< 1.0	9.80	10.00	98	70 - 130	Y
R2-D3-T-G1	O & G (Freon)	mg/L	< 1.0	9.90	10.00	99	70 - 130	Y
R3-D3-R-G2	O & G (HEM)	mg/L	< 1.0	9.60	10.00	96	70 – 130	Y
R3-D3-R-G2	O & G (HEM)	mg/L	< 1.0	9.50	10.00	95	70 – 130	Y
R3-D3-R-G2	O & G (Freon)	mg/L	< 1.0	9.80	10.00	98	70 - 130	Y
R3-D3-R-G2	O & G (Freon)	mg/L	< 1.0	9.00	10.00	90	70 - 130	Y
R3-D3-T-G1	O & G (HEM)	mg/L	< 1.0	9.60	10.00	96	70 – 130	Y
R3-D3-T-G1	O & G (HEM)	mg/L	< 1.0	9.50	10.00	95	70 – 130	Y
R3-D3-T-G1	O & G (Freon)	mg/L	< 1.0	9.00	10.00	90	70 - 130	Y
R3-D3-T-G1	O & G (Freon)	mg/L	< 1.0	8.80	10.00	88	70 - 130	Y
R3-D3-T-G1	Total Sulfide	mg/L	< 1.0	18.9	20.0	94	90 - 110	Y
R3-D3-T-G1	Total Sulfide	mg/L	< 1.0	18.9	20.0	94	90 - 110	Y
R3-D3-R-G2	Total Sulfide	mg/L	< 1.0	19.2	20.0	96	90 - 110	Y
R3-D3-R-G2	Total Sulfide	mg/L	< 1.0	19.1	20.0	96	90 - 110	Y
R3-D3-T-G2	Total Sulfide	mg/L	< 1.0	19.2	20.0	96	90 - 110	Y
R3-D3-T-G2	Total Sulfide	mg/L	< 1.0	19.2	20.0	96	90 - 110	Y
R2-D2-T-C	Metal Cadmium	mg/L	0.012	0.568	0.500	111	85 -115	Y
R2-D2-T-C	Metal Cadmium	mg/L	0.012	0.588	0.500	115	85 -115	Y
R2-D2-T-C	Metal Chromium	mg/L	0.014	0.538	0.500	105	85 -115	Y
R2-D2-T-C	Metal Chromium	mg/L	0.014	0.538	0.500	105	85 -115	Y
R2-D2-T-C	Metal Copper	mg/L	7.9	MSB	0.500	NC	85 -115	NC
R2-D2-T-C	Metal Copper	mg/L	7.9	MSB	0.500	NC	85 -115	NC
R2-D2-T-C	Metal Lead	mg/L	0.13	0.677	0.500	109	85 -115	Y
R2-D2-T-C	Metal Lead	mg/L	0.13	0.701	0.500	114	85 -115	Y
R2-D2-T-C	Metal Manganese	mg/L	0.32	0.839	0.500	104	85 -115	Y
R2-D2-T-C	Metal Manganese	mg/L	0.32	0.873	0.500	111	85 -115	Y
R2-D2-T-C	Metal Molybdenum	mg/L	< 0.1	0.533	0.500	107	85 -115	Y
R2-D2-T-C	Metal Molybdenum	mg/L	< 0.1	0.560	0.500	112	85 -115	Y
R2-D2-T-C	Metal Nickel	mg/L	0.45	0.576	0.500	106	85 -115	Y
R2-D2-T-C	Metal Nickel	mg/L	0.45	0.596	0.500	110	85 -115	Y
R2-D2-T-C	Metal Tin	mg/L	0.20	0.728	0.500	105	85 -115	Y
R2-D2-T-C	Metal Tin	mg/L	0.20	0.749	0.500	109	85 -115	Y
R2-D2-T-C	Metal Zinc	mg/L	24.1	MSB	0.500	NC	85 -115	NC
R2-D2-T-C	Metal Zinc	mg/L	24.1	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Cadmium	mg/L	0.053	0.557	0.500	110	85 -115	Y
R2-D3-R-C	Metal Cadmium	mg/L	0.053	0.553	0.500	110	85 -115	Y
R2-D3-R-C	Metal Chromium	mg/L	0.066	0.603	0.500	107	85 -115	Y
R2-D3-R-C	Metal Chromium	mg/L	0.066	0.603	0.500	108	85 -115	Y
R2-D3-R-C	Metal Copper	mg/L	28.6	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Copper	mg/L	28.6	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Lead	mg/L	10.6	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Lead	mg/L	10.6	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Manganese	mg/L	0.089	0.624	0.500	107	85 -115	Y
R2-D3-R-C	Metal Manganese	mg/L	0.089	0.624	0.500	107	85 -115	Y
R2-D3-R-C	Metal Molybdenum	mg/L	< 0.1	0.545	0.500	109	85 -115	Y
R2-D3-R-C	Metal Molybdenum	mg/L	< 0.1	0.543	0.500	109	85 -115	Y

CTC Sample ID	Parameter	Units	Sample Value	Sample + Spike Value	Spike Value	Recovery %	Target % Recovery	Accuracy Met? Y/N
R2-D3-R-C	Metal Nickel	mg/L	0.067	0.593	0.500	105	85 -115	Y
R2-D3-R-C	Metal Nickel	mg/L	0.067	0.591	0.500	105	85 -115	Y
R2-D3-R-C	Metal Tin	mg/L	14.5	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Tin	mg/L	14.5	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Zinc	mg/L	84.4	MSB	0.500	NC	85 -115	NC
R2-D3-R-C	Metal Zinc	mg/L	84.4	MSB	0.500	NC	85 -115	NC
R3-D2-T-C	Metal Aluminum	mg/L	1.4	6.85	5.0	108	85 –115	Y
R3-D2-T-C	Metal Aluminum	mg/L	1.4	6.79	5.0	107	85 –115	Y
R3-D2-T-C	Metal Cadmium	mg/L	<0.005	0.547	0.500	109	85 -115	Y
R3-D2-T-C	Metal Cadmium	mg/L	<0.005	0.561	0.500	112	85 -115	Y
R3-D2-T-C	Metal Chromium	mg/L	0.022	0.536	0.500	103	85 -115	Y
R3-D2-T-C	Metal Chromium	mg/L	0.022	0.548	0.500	105	85 -115	Y
R3-D2-T-C	Metal Copper	mg/L	1.1	1.63	0.500	112	85 –115	Y
R3-D2-T-C	Metal Copper	mg/L	1.1	1.60	0.500	105	85 –115	Y
R3-D2-T-C	Metal Lead	mg/L	0.067	0.605	0.500	108	85 -115	Y
R3-D2-T-C	Metal Lead	mg/L	0.067	0.621	0.500	111	85 -115	Y
R3-D2-T-C	Metal Manganese	mg/L	0.13	0.659	0.500	105	85 -115	Y
R3-D2-T-C	Metal Manganese	mg/L	0.13	0.670	0.500	107	85 -115	Y
R3-D2-T-C	Metal Molybdenum	mg/L	< 0.1	0.557	0.500	111	85 -115	Y
R3-D2-T-C	Metal Molybdenum	mg/L	< 0.1	0.563	0.500	113	85 -115	Y
R3-D2-T-C	Metal Nickel	mg/L	0.038	0.576	0.500	107	85 -115	Y
R3-D2-T-C	Metal Nickel	mg/L	0.038	0.587	0.500	110	85 -115	Y
R3-D2-T-C	Metal Tin	mg/L	0.036	0.564	0.500	106	85 -115	Y
R3-D2-T-C	Metal Tin	mg/L	0.036	0.556	0.500	104	85 -115	Y
R3-D2-T-C	Metal Zinc	mg/L	9.0	MSB	0.500	NC	85 -115	NC
R3-D2-T-C	Metal Zinc	mg/L	9.0	MSB	0.500	NC	85 -115	NC
R3-D2-T-C	Metal Aluminum	mg/L	0.16	5.47	5.0	106	85 –115	Y
R3-D4-T-C	Metal Aluminum	mg/L	0.16	5.45	5.0	106	85 –115	Y
R3-D4-T-C	Metal Cadmium	mg/L	<0.005	0.545	0.500	109	85 -115	Y
R3-D4-T-C	Metal Cadmium	mg/L	<0.005	0.545	0.500	109	85 -115	Y
R3-D4-T-C	Metal Chromium	mg/L	<0.01	0.527	0.500	105	85 -115	Y
R3-D4-T-C	Metal Chromium	mg/L	<0.01	0.526	0.500	105	85 -115	Y
R3-D4-T-C	Metal Copper	mg/L	0.98	1.53	0.500	110	85 –115	Y
R3-D4-T-C	Metal Copper	mg/L	0.98	1.53	0.500	109	85 –115	Y
R3-D4-T-C	Metal Lead	mg/L	0.026	0.578	0.500	110	85 -115	Y
R3-D4-T-C	Metal Lead	mg/L	0.026	0.577	0.500	110	85 -115	Y
R3-D4-T-C	Metal Manganese	mg/L	0.32	0.857	0.500	107	85 -115	Y
R3-D4-T-C	Metal Manganese	mg/L	0.32	0.855	0.500	107	85 -115	Y
R3-D4-T-C	Metal Molybdenum	mg/L	< 0.1	0.568	0.500	114	85 -115	Y
R3-D4-T-C	Metal Molybdenum	mg/L	< 0.1	0.563	0.500	113	85 -115	Y
R3-D4-T-C	Metal Nickel	mg/L	0.032	0.564	0.500	106	85 -115	Y
R3-D4-T-C	Metal Nickel	mg/L	0.032	0.564	0.500	106	85 -115	Y
R3-D4-T-C	Metal Tin	mg/L	0.030	0.560	0.500	106	85 -115	Y
R3-D4-T-C	Metal Tin	mg/L	0.030	0.560	0.500	106	85 -115	Y
R3-D4-T-C	Metal Zinc	mg/L	13.7	MSB	0.500	NC	85 -115	NC
R3-D4-T-C	Metal Zinc	mg/L	13.7	MSB	0.500	NC	85 -115	NC
R2-SLUDGE	Metal Cadmium	mg/L	16.6	464	449	100	85 -115	Y
R2-SLUDGE	Metal Cadmium	mg/L	16.6	476	449	102	85 -115	Y
R2-SLUDGE	Metal Chromium	mg/L	141	574	449	97	85 -115	Y
R2-SLUDGE	Metal Chromium	mg/L	141	563	449	94	85 -115	Y
R2-SLUDGE	Metal Copper	mg/L	111000	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Copper	mg/L	111000	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Lead	mg/L	42200	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Lead	mg/L	42200	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Manganese	mg/L	593	1070	449	107	85 -115	Y
R2-SLUDGE	Metal Manganese	mg/L	593	936	449	76	85 -115	N

CTC Sample ID	Parameter	Units	Sample Value	Sample + Spike Value	Spike Value	Recovery %	Target % Recovery	Accuracy Met? Y/N
R2-SLUDGE	Metal Molybdenum	mg/L	<89.8	415	449	92	85 -115	Y
R2-SLUDGE	Metal Molybdenum	mg/L	< 89.8	428	449	95	85 -115	Y
R2-SLUDGE	Metal Nickel	mg/L	369	809	449	98	85 -115	Y
R2-SLUDGE	Metal Nickel	mg/L	369	727	449	80	85 -115	N
R2-SLUDGE	Metal Tin	mg/L	49400	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Tin	mg/L	49400	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Zinc	mg/L	251000	MSB	449	NC	85 -115	NC
R2-SLUDGE	Metal Zinc	mg/L	251000	MSB	449	NC	85 -115	NC
R3-SLUDGE	Metal Aluminum	mg/L	833	1370	641	84	85 –115	N
R3-SLUDGE	Metal Aluminum	mg/L	833	1420	641	91	85 -115	Y
R3-SLUDGE	Metal Cadmium	mg/L	<6.4	63.9	64.1	100	85 -115	Y
R3-SLUDGE	Metal Cadmium	mg/L	<6.4	64.8	64.1	101	85 -115	Y
R3-SLUDGE	Metal Chromium	mg/L	70.4	125	64.1	85	85 -115	Y
R3-SLUDGE	Metal Chromium	mg/L	70.4	133	64.1	98	85 -115	Y
R3-SLUDGE	Metal Copper	mg/L	34300	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Copper	mg/L	34300	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Lead	mg/L	4550	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Lead	mg/L	4550	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Manganese	mg/L	55.0	114	64.1	92	85 -115	Y
R3-SLUDGE	Metal Manganese	mg/L	55.0	120	64.1	101	85 -115	Y
R3-SLUDGE	Metal Molybdenum	mg/L	<64.1	61.1	64.1	95	85 -115	Y
R3-SLUDGE	Metal Molybdenum	mg/L	< 64.1	62.0	64.1	97	85 -115	Y
R3-SLUDGE	Metal Nickel	mg/L	19.5	81.3	64.1	96	85 -115	Y
R3-SLUDGE	Metal Nickel	mg/L	19.5	83.5	64.1	100	85 -115	Y
R3-SLUDGE	Metal Tin	mg/L	4390	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Tin	mg/L	4390	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Zinc	mg/L	1380	MSB	64.1	NC	85 -115	NC
R3-SLUDGE	Metal Zinc	mg/L	1380	MSB	64.1	NC	85 -115	NC

APPENDIX C

Representativeness

RESPRESENTATIVENESS CALCULATIONS

CTC ID	Parameter	Units	Sample Value	Duplicate *CTC* ID	Duplicate Value	% Difference	RPD % Limits	RPD Met Y/N
R2-D2-T-G1	O&G (HEM)		<1.0	R2-D2-T-G1-D	<1.0	0.0	30	Y
R2-D2-T-G1	O&G (Freon)		<1.0	R2-D2-T-G1-D	<1.0	0.0	30	Y
R2-D2-T-G2	O&G (HEM)		<1.0	R2-D2-T-G2-D	<1.0	0.0	30	Y
R3-D3-R-G2	O&G (Freon)		<1.0	R2-D2-T-G2-D	<1.0	0.0	30	Y
R3-D3-R-G2	O&G (HEM)		16.7	R3-D3-R-G2-D	19.2	13.9	30	Y
R2-D2-T-G2	O&G (Freon)		16.0	R3-D3-R-G2-D	39.4	88.1	30	N
R3-D3-T-G1	O&G (HEM)		<1.0	R3-D3-T-G1-D	<1.0	0.0	30	Y
R3-D3-T-G1	O&G (Freon)		<1.0	R3-D3-T-G1-D	<1.0	0.0	30	Y
R2-D2-T-C	pH		6.6	R2-D2-T-C-D	6.4	3.1	20	Y
R3-D3-R-C	pH		6.4	R3-D3-R-C-D	6.4	0.0	20	Y
R3-D3-T-C	pH		6.8	R3-D3-T-C-D	6.9	4.4	20	Y
R2-D2-T-C	TDS		2840	R2-D2-T-C-D	2820	0.7	10	Y
R3-D3-R-C	TDS		2060	R3-D3-R-C-D	2040	2.5	10	Y
R3-D3-T-C	TDS		2690	R3-D3-T-C-D	2670	0.7	10	Y
R2-D2-T-C	TSS		14.0	R2-D2-T-C-D	15.0	6.9	15	Y
R3-D3-R-C	TSS		56.0	R3-D3-R-C-D	54.0	3.6	10	Y
R2-D2-T-C	TOC		4.5	R2-D2-T-C-D	4.5	2.2	10	Y
R3-D3-R-C	TOC		10.7	R3-D3-R-C-D	10.8	0.1	10	Y
R3-D3-T-C	TOC		8.7	R3-D3-T-C-D	8.1	7.1	10	Y
R2-D2-T-C	Cadmium	mg/L	0.012	R2-D2-T-C-D	0.012	0.0	10	Y
R2-D2-T-C	Chromium	mg/L	0.014	R2-D2-T-C-D	0.012	6.9	11	Y
R2-D2-T-C	Copper	mg/L	7.9	R2-D2-T-C-D	7.9	0.0	12	Y
R2-D2-T-C	Manganese	mg/L	0.32	R2-D2-T-C-D	0.32	0.0	10	Y
R2-D2-T-C	Molybdenum	mg/L	<0.1	R2-D2-T-C-D	<0.1	0.0	10	Y
R2-D2-T-C	Nickel	mg/L	0.045	R2-D2-T-C-D	0.044	2.2	10	Y
R2-D2-T-C	Lead	mg/L	0.13	R2-D2-T-C-D	0.13	0.0	10	Y
R2-D2-T-C	Tin	mg/L	0.20	R2-D2-T-C-D	0.21	4.6	10	Y
R2-D2-T-C	Zinc	mg/L	24.1	R2-D2-T-C-D	23.8	1.3	10	Y
R3-D3-R-C	Aluminum	mg/L	1.6	R3-D3-R-C-D	1.6	0.0	15	Y
R3-D3-R-C	Cadmium	mg/L	<0.005	R3-D3-R-C-D	<0.005	0.0	10	Y
R3-D3-R-C	Chromium	mg/L	0.042	R3-D3-R-C-D	0.043	2.4	11	Y
R3-D3-R-C	Copper	mg/L	25.5	R3-D3-R-C-D	25.1	1.6	12	Y
R3-D3-R-C	Manganese	mg/L	0.071	R3-D3-R-C-D	0.70	1.4	10	Y
R3-D3-R-C	Molybdenum	mg/L	<0.1	R3-D3-R-C-D	<0.1	0.0	10	Y
R3-D3-R-C	Nickel	mg/L	<0.04	R3-D3-R-C-D	<0.04	0.0	10	Y
R3-D3-R-C	Lead	mg/L	2.9	R3-D3-R-C-D	2.9	0.0	10	Y
R3-D3-R-C	Tin	mg/L	3.0	R3-D3-R-C-D	3.1	3.3	10	Y
R3-D3-R-C	Zinc	mg/L	36.2	R3-D3-R-C-D	35.6	1.8	10	Y
R3-D3-T-C	Aluminum	mg/L	0.39	R3-D3-T-C-D	0.35	10.8	15	Y
R3-D3-T-C	Cadmium	mg/L	<0.005	R3-D3-T-C-D	<0.005	0.0	10	Y
R3-D3-T-C	Chromium	mg/L	0.013	R3-D3-T-C-D	0.012	8.0	11	Y
R3-D3-T-C	Copper	mg/L	1.3	R3-D3-T-C-D	1.3	0.0	12	Y
R3-D3-T-C	Manganese	mg/L	0.20	R3-D3-T-C-D	0.20	0.0	10	Y
R3-D3-T-C	Molybdenum	mg/L	<0.1	R3-D3-T-C-D	<0.1	0.0	10	Y

CTC ID	Parameter	Units	Sample Value	Duplicate *CTC* ID	Duplicate Value	% Difference	RPD % Limits	RPD Met Y/N
R3-D3-T-C	Nickel	mg/L	<0.04	R3-D3-T-C-D	<0.04	0.0	10	Y
R3-D3-T-C	Lead	mg/L	<0.05	R3-D3-T-C-D	<0.05	0.0	10	Y
R3-D3-T-C	Tin	mg/L	<0.1	R3-D3-T-C-D	<0.1	3.3	10	Y
R3-D3-T-C	Zinc	mg/L	8.6	R3-D3-T-C-D	7.9	8.5	10	Y
R2-Sludge	Cadmium	mg/kg	<44.9	R2-Sludge-D	<46.5	0.0	10	Y
R2-Sludge	Chromium	mg/kg	141	R2-Sludge-D	120	16.1	10	N
R2-Sludge	Copper	mg/kg	11000	R2-Sludge-D	10600	4.6	15	Y
R2-Sludge	Manganese	mg/kg	593	R2-Sludge-D	552	0.1	14	Y
R2-Sludge	Molybdenum	mg/kg	<89.8	R2-Sludge-D	<92.9	0.0	10	Y
R2-Sludge	Nickel	mg/kg	369	R2-Sludge-D	334	10.0	10	Y
R2-Sludge	Lead	mg/kg	42200	R2-Sludge-D	38800	1.6	25	Y
R2-Sludge	Tin	mg/kg	49400	R2-Sludge-D	43900	11.8	10	N
R2-Sludge	Zinc	mg/kg	51000	R2-Sludge-D	37000	31.8	36	Y
R2-Sludge	Sulfide	mg/L	<1.0	R2-Sludge-D	<1.0	0.0	10	Y
R2-Sludge	Sp. Gravity	NA	1.1	R2-Sludge-D	1.1	0.0	20	Y
R2-Sludge	% Solid	%	5.6	R2-Sludge-D	5.4	3.6	20	Y
R2-Sludge	% Water	%	77	R2-Sludge-D	91.5	16.0	20	Y
M1-Sludge	Cadmium	mg/kg	<70.8	M1-Sludge-D	<46.5	0.0	10	Y
M1-Sludge	Chromium	mg/kg	198	M1-Sludge-D	323	47.9	10	N
M1-Sludge	Copper	mg/kg	53000	M1-Sludge-D	44700	19.0	15	N
M1-Sludge	Manganese	mg/kg	870	M1-Sludge-D	1410	47.4	14	N
M1-Sludge	Molybdenum	mg/kg	<142	M1-Sludge-D	<123	0.0	10	Y
M1-Sludge	Nickel	mg/kg	518	M1-Sludge-D	231	76.6	10	N
M1-Sludge	Lead	mg/kg	64000	M1-Sludge-D	20900	101.5	25	N
M1-Sludge	Tin	mg/kg	72300	M1-Sludge-D	26800	91.4	10	N
M1-Sludge	Zinc	mg/kg	370000	M1-Sludge-D	105000	111.9	36	N
M1-Sludge	Sulfide	mg/L	<7080	M1-Sludge-D	<6130	0.0	10	Y
M1-Sludge	Sp. Gravity	NA	1.1	M1-Sludge-D	1.0	0.0	20	Y
M1-Sludge	% Solid	%	3.5	M1-Sludge-D	1.2	3.6	20	Y

NA = Not Applicable