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# Environmental Technology Verification Report

# Evaluation of the MART Corporation's EQ-1 Wastewater Processing System

Prepared by

Concurrent Technologies Corporation

Under a Cooperative Agreement with

**U.S. Environmental Protection Agency**

## NOTICE

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# Evaluation of the MART Corporation's EQ-1 Wastewater Processing System

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# FOREWORD

The Environmental Technology Verification (ETV) Program has been established by the U.S. Environmental Protection Agency (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) has 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 will be 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 P2 Metal Finishing 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 MART Corporation's EQ-1 Wastewater Processing System.

## ACRONYM and ABBREVIATION LIST

| | |
|---|---|
| AF | Air Force |
| AGE | Aircraft Ground Equipment |
| amps | Amperage |
| ANG | Air National Guard |
| AVG. | Average |
| AW | Airlift Wing |
| Ba | Barium |
| Cd | Cadmium |
| COC | Chain of Custody |
| Cr | Chromium |
| *CTC* | Concurrent Technologies Corporation |
| Cu | Copper |
| DCN | Daraclean® |
| DOD | Department of Defense |
| EPA | U.S. Environmental Protection Agency |
| ETV | Environmental Technology Verification |
| ETV-MF | Environmental Technology Verification Program P2 Metal Finishing Technologies |
| FID | Flame Ionization Detector |
| FPS | Final Polishing System |
| $ft^3$ | Cubic Feet |
| g | Gram |
| gal | Gallon |
| GC | Gas Chromatography |
| gph | Gallon per Hour |
| gpm | Gallon per Minute |
| g/L | Gram per Liter |
| HCL | Hydrochloric Acid |
| HDPE | High Density Polyethylene |
| HP | Horsepower |
| HQ | Headquarters |
| hr | Hour |
| Hz | Hertz |
| ICP-AES | Inductively Coupled Plasma – Atomic Emission Spectrometry |
| ID | Identification |
| IDL | Instrument Detection Limit |
| kWh | Kilowatt-hour |
| lb | Pound |
| L | Liter |
| $m^3$ | Cubic Meters |
| MART | The MART Corporation |
| MDL | Method Detection Limit |
| mg | Milligram |
| mg/L | Milligram per Liter |
| mL | Milliliter |

| | |
|---|---|
| NA | Not Applicable |
| ND | Not Detected |
| Ni | Nickel |
| NIOSH | National Institute of Occupational Safety and Health |
| No | Number |
| NRMRL | National Risk Management Research Laboratory |
| O&G | Oil and Grease |
| O&M | Operating and Maintenance |
| OANG | Ohio Air National Guard |
| ORD | Office of Research and Development |
| P | Percent Recovery |
| Pb | Lead |
| PEL | Permissible Exposure Limit |
| POTW | Publicly Owned Treatment Works |
| ppm | Part per Million |
| PVC | Polyvinyl Chloride |
| QA | Quality Assurance |
| QC | Quality Control |
| QMP | Quality Management Plan |
| Ref. | Reference |
| RI | Refractive Index |
| RPD | Relative Percent Difference |
| rpm | Revolutions per Minute |
| S | Siemens |
| SM | Standard Methods for Examination of Water and Wastewater, $20^{th}$ ed. (1998) |
| SR | Spiked Result |
| SSR | Spiked Sample Result |
| STE | Short Term Exposure |
| TCLP | Toxicity Characteristic Leaching Procedure |
| TS | Total Solids |
| TSA | Technical Systems Audit |
| TSS | Total Suspended Solids |
| TWA | Time Weighted Average |
| U.S. | United States of America |
| VAC | Voltage (AC) |
| vs | Versus |
| wk | Week |
| µ | Micro |
| $^{o}$F | Degrees Fahrenheit |

## ACKNOWLEDGEMENTS

This is to acknowledge Percy Peltzer and Valerie Whitman of *CTC* for their 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 ETV Center Manager, and Lauren Drees, EPA Quality Assurance Manager. *CTC* also expresses sincere gratitude to the MART Corporation, the manufacturer of the MART Corporation's EQ-1 Wastewater Processing System, for their participation in and support of this program, and their ongoing commitment to improve metal finishing operations. *CTC* also thanks the 179$^{th}$ Airlift Wing (AW) Unit of Mansfield, Ohio, for the use of their facilities and materials, and the extensive contributions of Captain Troy Cramer and Krista Keplinger for the performance of this verification test.

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

Concurrent Technologies Corporation

# ETV VERIFICATION STATEMENT

| | |
|---|---|
| **TECHNOLOGY TYPE:** | **ENCAPSULATION** |
| **APPLICATION:** | **AQUEOUS CLEANING APPLICATIONS** |
| **TECHNOLOGY NAME:** | **The MART EQ-1 Wastewater Processing System** |
| **COMPANY:** | **The MART Corporation** |
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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, and stakeholder groups consisting of buyers, vendor organizations, states, and others, 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 credible.

The ETV P2 Metal Finishing Technologies (ETV-MF) Program, one of 12 technology focus areas under the ETV Program, is operated by Concurrent Technologies Corporation, in cooperation with EPA's National Risk Management Research Laboratory. The ETV-MF Program has evaluated the performance of a wastewater recycling technology for recycling aqueous alkaline cleaners and/or treating spent cleaning solutions. This verification statement provides a summary of the test results for the MART EQ-1 Wastewater Processing System.

## VERIFICATION TEST DESCRIPTION

The MART EQ-1 System was tested, under actual production conditions, using spent alkaline cleaner solutions, at the 179th Airlift Wing (AW) in Mansfield, Ohio. Alkaline cleaning is performed on their C-130H aircraft engine compressors and various parts on the aircraft (engine panels, tire rims, bolts, heaters, aircraft ground equipment, etc.). The verification test evaluated the ability of the MART EQ-1 System to sufficiently remove oils, suspended solids, and heavy metals, to recover the alkaline cleaning chemistry, or to treat the alkaline cleaner for discharge to the Publicly Owned Treatment Works (POTW).

Testing was designed to treat cleaners from four distinct processes:

- During the first test, the MART EQ-1 System was evaluated on its ability to remove contaminants (primarily oil and cadmium) from spent alkaline cleaner and rinse water used to clean C-130H engine compressors. The alkaline cleaner and water were treated through the EQ-1 and the optional Final Polishing System (FPS).
- During the second test, the MART EQ-1 System was evaluated on its ability to recover the contaminated alkaline cleaning chemistry used in the R&R parts washer. The alkaline cleaner was treated through the EQ-1 only.
- During the third test, the MART EQ-1 System was evaluated on its ability to recover the contaminated alkaline cleaning chemistry used in the Aircraft Ground Equipment (AGE) parts washer.
- During the fourth test, the MART EQ-1 System was evaluated on its ability to recover the contaminated alkaline cleaning chemistry used in the Engine Shop parts washer. Again, the alkaline cleaner was treated through the EQ-1 only.

Historical operating and maintenance labor requirements, chemical usage, and waste generation data were collected to perform the cost analysis.

## TECHNOLOGY DESCRIPTION

The MART EQ-1 System is a process technology that chemically separates and clarifies the alkaline cleaner solution and encapsulates the waste for disposal. The MART process utilizes adsorption and electrostatic forces to encapsulate waste products. The chemical compound used in the MART encapsulating process is a non-hazardous proprietary product called Magic Dust, which is formulated to treat a range of specific contaminants in the waste stream based on the desired disposition of the effluent; e.g., recycling or discharge to a POTW. The MART EQ-1 unit is equipped with two connecting tanks made of sheet steel: a mixing/reaction tank (upper reservoir tank) and a holding tank (lower reservoir tank). The upper tank is of a trapezoidal design; this is where the untreated alkaline cleaner is pumped and the treatment chemical (Magic Dust) is added. Once the solution is thoroughly mixed, the encapsulated material is allowed to settle to the bottom of the upper tank. After encapsulation, the treated alkaline cleaner is allowed to pass through a filtration media (30 micron filter paper) into the lower tank. As the waste is collected on the filter paper, the paper is slowly pulled forward and wrapped around the encapsulated waste. As the encapsulated waste is rolled in the filter paper, the paper is squeezed to remove excess solution. This process is continued until all of the solution passes through the filter paper into the lower tank. The treated alkaline cleaner in the lower tank is transferred either to the FPS for further treatment or directly back into the parts washer. The FPS is a basic ion exchange system that utilizes a granular activated carbon filter along with a polymer resin chamber.

## VERIFICATION OF PERFORMANCE

During each test period, grab samples were taken of the MART influent, effluent, and waste sludge. In addition, samples of standard cleaner make-up solutions were analyzed for comparison purposes, in order to understand the baseline analytical interference from the cleaner.

Analytical results for key parameters are shown in **Table i**. Alkalinity measures the key inorganic and organic ingredients of the alkaline cleaner. Total suspended solids, oil and grease (O&G), and cadmium are the contaminants being removed during the recovery process. **Table i** also contains the field measurements used to measure the key ingredients of the alkaline cleaner (conductivity for Daraclean® (DCN) 282; refractive index for Daraclean® 235). The manufacturer of the Daraclean® alkaline cleaner recommends that conductivity and refractive index measurements be used to obtain the cleaner concentration of Daraclean® 282 and 235, respectively. It was found that the key ingredient of Daraclean® 282 is diethylene glycol monobutyl ether; therefore, it was analyzed during Test #3.

**Table i** shows the analysis results for influent, effluent, and waste sludge samples. The FPS was used for treating the Engine Compressor Wash because it was discharged to Publicly Owned Treatment Works (POTW) and not for the R&R (Tire Shop), Aircraft Ground Equipment (AGE), and Engine Shop parts washer cleaners because they are recycled. The results of sludge samples analyzed for oil and grease and total metals were not used due to lack of reliability in the data. Sample results were drastically different than duplicates and sample re-tests, which indicates that the results were not accurate or reproducible. The problem does not appear to lie with the analytical method, but is attributed to interference caused by the Magic Dust in the waste sludge. It is possible that the interference could be caused by the chemical structure of the Magic Dust being altered as it encapsulates the waste stream contaminants. Moreover, this may illustrate difficulties in obtaining a representative sludge sample. Additional investigation as to the extent of the Magic Dust's impact was not done because identification of the content and characteristic of the Magic Dust was believed to be outside the scope of the ETV-MF Center. Since the sludge analytical results were unusable, the oil and grease and cadmium concentrations were calculated using a simple batch mass balance (influent – effluent = sludge). Also, the conductivity is consistently higher in the effluent indicating an interference by the Magic Dust.

| Sample ID | Total Alkalinity mg/L as CaCO3 (EPA 310.1) | Total Suspended Solids mg/L (EPA 160.2) | O&G mg/L (SM 5520B) | Cadmium mg/L (EPA 200.7) | Conductivity µS | Refractive Index % Brix | Glycol Ether mg/L |
|---|---|---|---|---|---|---|---|
| **Test #1. Engine Compressor Wash** | | | | | | | |
| MART Influent | 280 | 370 | 370 | 6.5 | 1,314 | NA | NA |
| FPS Influent | 260 | 53 | 26 | 0.36 | 1,625[1] | NA | NA |
| FPS Effluent | 22 | 15 | 12.5 | 0.13 | 2.0 | NA | NA |
| Waste Sludge (calculated) | NA | NA | 32,337 µg/g | 2,333 µg/g | NA | NA | NA |
| **Test #2. R&R Parts Washer Alkaline Cleaner** | | | | | | | |
| MART Influent | 700 | 2,900 | 500 | 30.0 | 3,480 | NA | NA |
| MART Effluent | 520 | 62 | 160 | 27.0 | 5,960[1] | NA | NA |
| Waste Sludge (calculated) | NA | NA | 24,892 µg/g | 332 µg/g | NA | NA | NA |
| **Test #3. AGE Parts Washer Alkaline Cleaner** | | | | | | | |
| AGE Influent | 660 | 830 | 390 | 0.4 | NA | NA | 660 |
| AGE Effluent | 180 | 150 | 150 | 0.36 | NA | NA | 660 |
| Waste Sludge (calculated) | NA | NA | 35,000 µg/g | 3 µg/g | NA | NA | NA |
| **Test #4. Engine Shop Parts Washer Alkaline Cleaner** | | | | | | | |
| MART Influent. | 2,000 | 250 | 1,600 | 12.0 | NA | 1.4 | NA |
| MART Effluent | 2,000 | 140 | 1,000 | 11.0 | NA | 1.2 | NA |
| Waste Sludge (calculated) | NA | NA | 69,938 µg/g | 174 µg/g | NA | NA | NA |

MART Influent = Feed to the MART EQ-1 unit    MART Effluent = Recovered alkaline cleaner from MART EQ-1 unit
FPS Influent = Feed to the FPS    FPS Effluent = Effluent from FPS
SM = Standard Methods for the Examination of Water and Wastewater, 18th Ed.
EPA = Methods for Chemical Analysis of Water and Wastes, 1983
NA = Not Applicable    AVG = Average
1 = Magic Dust interference with conductivity measurement

**Table i. Summary of Key Analytical Data**

**Alkaline Cleaner Recovery.** The recovery percentages for the two Daraclean® cleaners were high (**Table ii**), indicating that the MART EQ-1 is efficient in recovering the cleaning chemistry. The recovery in Test # 2, greater than 100 percent, is due to additional ions associated with the Magic Dust when measuring for conductivity. For Test #3 GC/FID analysis for diethylene glycol monobutyl ether was performed instead of conductivity to determine the concentration of DCN 282. The GC/FID analysis is a better method of determining the concentration of the DCN 282. The Magic Dust was not specifically formulated for treating the AGE Parts Washer (Test #3). While recovery of DCN 282 was high, the alkalinity recovery was lower than in Tests #2 and 4.

| Test No. | Total Alkalinity % Recovered | DCN 235 Cleaner % Recovered | DCN 282 Cleaner % Recovered |
|---|---|---|---|
| 2 | 71 | NA | 163[1] |
| 3 | 26 | NA | 94 |
| 4 | 96 | 83 | NA |

NA – Not Applicable 1 = Magic Dust interferes with conductivity measurement

**Table ii. Cleaner Recovery Efficiency**

**Contaminant Removal Efficiency**. Contaminant removal efficiencies are calculated for the primary contaminants of the alkaline cleaning bath (O&G, cadmium, and TSS) and are shown in **Table iii**. For the four test runs, average O&G removal efficiency ranged from 40 to 97 percent, cadmium removal efficiency ranged from 12 to 98 percent, and TSS removal efficiency ranged from 46 to 98 percent. The MART EQ-1 System was more efficient during Test #1 when the FPS was used in the treatment of engine compressor cleaner and wash water for discharge to the POTW, in comparison to Tests #2, #3, and #4, when the FPS was not used to recycle parts washer aqueous alkaline cleaner.

Complete contaminant removal is not required to recycle alkaline cleaners. With Tests #2, #3, and #4 yielding satisfactory removal efficiencies for O&G, and TSS, and low contaminant removal efficiency for cadmium, the alkaline cleaner was effectively recycled.

| Test No. | O&G % Removal | Cd % Removal | TSS % Removal |
|---|---|---|---|
| 1 | 97 | 98 | 96 |
| 2 | 69 | 14 | 98 |
| 3 | 63 | 14 | 83 |
| 4 | 40 | 12 | 46 |

**Table iii. Contaminant Removal Efficiency**

**Worker Exposure Monitoring.** Exposure air monitoring was conducted during operation of the MART EQ-1 System and handling of the encapsulated waste to determine if there was a potential for exposure to cadmium and chromium. Testing consisted of monitoring during the C-130H engine compressor cleaning (Test #1) and R&R parts washer (Test #2) tests. In addition to cadmium and chromium, monitoring of silica was performed during Test #2 to assess the potential exposure to silica when handling the Magic Dust. National Institute of Occupational Safety and Health (NIOSH) protocols were used on all samples.

**Table iv** summarizes the results of the air monitoring. The Time Weighted Average (TWA) results are compared to the Permissible Exposure Limits (PEL).

| Sampling Date | Sampling Location | Compound | TWA (mg/m$^3$) | PEL (mg/m$^3$) |
|---|---|---|---|---|
| 1-25-01 | Handling Waste | Cadmium | <0.0005 | 0.005 |
| 1-25-01 | Handling Waste | Chromium | 0.0002 | 0.5 |
| 1-31-01 | Handling Waste | Cadmium | <0.0005 | 0.005 |
| 1-31-01 | Handling Waste | Chromium | 0.001 | 0.5 |
| 1-31-01 | Magic Dust Weigh-up & Dispensing | Silica (Respirable) | <0.0044 | 0.05 |

**Table iv. Air Monitoring Results**

As noted above in the monitoring results, all samples are well within the recommended standards. The results indicate that there was no overexposure to the specific compounds during the treatment process.

**Energy Use.**
The electrical service required for the MART EQ-1 System at the 179th AW is 115 VAC and 17 amps.
Energy usage was calculated by converting the system electrical service requirements (17 amps, 115 volts) into kilowatts and multiplying by the number of hours operated.

17 amps X 115 Volts = 1955 watts (1.955 kW)

The MART EQ-1 System operated for 26.33 hours during the first test run which included pumping the effluent through FPS system and for 14.19 hours during test runs 2 – 4, for a total of 40.52 hours. The estimated energy used for all four tests was:

1.955 kW X 40.52 hours = 79.2 kWh

**Waste Generation.** A waste generation analysis was performed using current operational data and historical records from the 179$^{th}$ AW. Implementation of the MART EQ-1 System has eliminated the need to dispose of the parts washer alkaline cleaning solutions and eliminated shipping the engine compressor cleaner and rinse water off-site for disposal. The parts washer alkaline cleaning solutions are recycled and the engine compressor wastewater is sent to the local POTW. Hazardous waste has been decreased from 700 gallons annually[1] of hazardous wastewater to a 50-gallon container of encapsulated waste. The overall volume of hazardous waste generated from alkaline cleaning has been reduced by 93 percent.

| TCLP Metals | Cd (mg/L) | Cr (mg/L) | Pb (mg/L) | Ba (mg/L) | Ni (mg/L) | Cu (mg/L) |
|---|---|---|---|---|---|---|
| ***Test #1*** | ***Engine Compressor Wash*** | | | | | |
| **Sludge Cake** | 8.8 | <0.1 | <0.1 | <1.0 | 5.7 | 0.04 |
| ***Test #2*** | ***R&R Parts Washer Aqueous Alkaline Cleaner*** | | | | | |
| **Sludge Cake** | 3.4 | <0.1 | <0.1 | <1.0 | 0.08 | 0.75 |
| ***Test #3*** | ***AGE Parts Washer Aqueous Alkaline Cleaner*** | | | | | |
| ***Sludge Cake*** | 0.12 | <0.1 | <0.1 | <1.0 | 0.07 | 0.10 |
| ***Test #4*** | ***Engine Shop Parts Washer Alkaline Cleaner*** | | | | | |
| **Sludge Cake** | 1.1 | <0.1 | <0.1 | <1.0 | 0.10 | 0.21 |

**Table v. TCLP Metal Results**

[1] The 700 gallons of waste annually is based on historical records from the 179$^{th}$ AW.

The sludge was analyzed to see if it could be classified as non-hazardous sludge. The results are shown in Table v. The AGE parts washer sludge passed the TCLP. The other parts washer sludge and the engine compressor wash sludge failed TCLP only for cadmium.

**Operating and Maintenance Labor.** Operating and maintenance (O&M) labor requirements for the MART EQ-1 System were monitored during testing. It takes approximately three labor hours to process one batch of alkaline cleaner. Historical and current operational data show that 0.7 hrs/wk of O&M labor is required for the system. O&M tasks include system processing alkaline cleaner, handling encapsulated waste, changing filter cartridges and resin, cleaning the system for winter storage, and performing unexpected maintenance for part replacements.

**Cost Analysis.** A cost analysis of the MART EQ-1 System was performed using current operating costs and historical records from the 179$^{th}$ AW. The installed capital cost (1998) of the unit was $9,100 (includes $6,100 for the basic EQ-1 unit, $2,800 for the optional FPS, and $200 for the feed pump and associated industrial hoses). The annual cost savings associated with the unit is $3,209. The projected payback period is 2.8 years.

## SUMMARY

The test results show that the MART EQ-1 System provides an environmental benefit by reducing off-site hazardous waste disposal by 93 percent. The treated alkaline cleaner was able to be recycled and reused since contaminants were sufficiently removed, yet the cleaner constituents were not significantly removed. The economic benefit associated with this technology is low O&M labor and a payback period of approximately 2.8 years. As with any technology selection, the end user must select appropriate cleaning equipment and chemistry for a process that can meet their associated environmental restrictions, productivity, and cleaning requirement.

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## 1.0 INTRODUCTION

The MART EQ-1 Wastewater Processing System (MART EQ-1 System) is a batch treatment process that removes contaminants from an aqueous alkaline cleaner in one step. The MART EQ-1 System consists of the EQ-1 unit (**Figure 1**) and an optional Final Polishing System (FPS). The EQ-1 unit employs a proprietary chemical called "Magic Dust" to perform the separation of contaminants such as oil and grease (O&G) and metals from aqueous cleaning solutions. The treatment process utilizes adsorption and electrostatic forces to encapsulate waste products such as paint, solid and dissolved metals (e.g., lead, cadmium, chromium), dust, oil, minerals, and asbestos. The encapsulated material (processed waste) cures and sets up like hardened dough or concrete. The treated alkaline cleaner is recycled.


**Figure 1. The MART EQ-1™ Unit**

The verification test evaluated the ability of the MART EQ-1 System to sufficiently remove O&G, metals, and suspended solids to recover the alkaline cleaning chemistry, or to treat the alkaline cleaner for discharge to the Publicly Owned Treat Works (POTW). It was tested by *CTC* under the U.S. Environmental Protection Agency (EPA) Environmental Technology Verification Program for P2 Metal Finishing Technologies (ETV-MF). The purpose of this report is to present the results of the verification test.

The MART EQ-1 System was tested to evaluate and characterize its operation, through measurement of various process parameters. Testing was conducted at the 179$^{th}$ AW Unit located in Mansfield, Ohio. The 179$^{th}$ AW is an Ohio Air National Guard (OANG) unit that has Federal, state, and community roles. The major activities performed at the OANG include aircraft maintenance, aerospace ground equipment maintenance, ground vehicle maintenance, and facilities maintenance.

## 2.0 TECHNOLOGY DESCRIPTION

### 2.1 Theory of Operation

The MART EQ-1 System is an inventive technology that chemically separates and clarifies the aqueous alkaline cleaner solution and encapsulates the waste for disposal. The treatment process utilizes adsorption and electrostatic forces to encapsulate waste products. The chemical compound used in the treatment process is a non-hazardous proprietary product called Magic Dust. Each Magic Dust formula is developed to treat a range of specific contaminants in the waste steam based on the desired disposition of the effluent; e.g., recycling or discharge to a POTW. The quantity of Magic Dust added may vary based on whether the waste stream, at the time of treatment, is below or above this contaminant load range.

The effectiveness of the treatment process is based on the performance of the Magic Dust. The Magic Dust is a blend of clay, polymeric, acidic, and various other additives that allow the compound to integrate several reactions in one. The function of the Magic Dust is as follows: (1) The acidic components cause oily contaminants to coalesce and separate from the alkaline cleaner; (2) the polymeric cationic portion attracts any remaining oils and the larger, more highly charged anions; (3) the third component group precipitates metallic hydroxides and drives the system to a fully flocculated condition where the clay particles attract the cationic polymer molecules (with absorbed oil), metallic ions and positively charged contaminants; and (4) the heavy metal cations still remaining in solution exchange with sodium in the clay and electrostatically bond to the clay platelets. The fully reacted mass is a complex mixture of encapsulated contaminants and waste solids that are held together by van der Waals as well as electrostatic forces. The clay particles agglomerate, completely entrapping and surrounding suspended solids. Pozzolanic reactions also occur, which form cement-like particles that settle to the bottom of the reaction vessel.

The Magic Dust is added to the alkaline cleaner and the agglomerate is mixed to cause the necessary complex reactions and microencapsulation: molecules with adsorbed oil, metallic ions, and charged contaminants are attracted to the Magic Dust to form a mass. The Magic Dust formulation also includes chemistry to demineralize the treated alkaline cleaner. After microencapsulation, the flocculated waste is filtered through a disposable media paper to collect the waste for disposal. The encapsulated waste is collected in the filter paper, and the clarified solution is collected in a holding tank. The filter paper containing the encapsulated waste is rolled up and allowed to harden into a cement-like material. The filter paper and waste material are put into a drum and disposed of off-site as hazardous waste. The clarified solution can be recycled and reused or treated further with an optional FPS and discharged to the sanitary sewer. The FPS is a basic ion exchange system that utilizes a granular activated carbon filter along with a polymer resin chamber, which employs polystyrene beads with sodium ions as the resin media. The carbon filter removes O&G and other contaminants that may hinder the effectiveness of the resin. Next, the solution is sent through the resin chamber, where heavy metals are removed.

## 2.2 Equipment and Flow Diagram

The MART EQ-1 System is equipped with two connecting tanks (**Figure 2**): a mixing/reaction tank (upper reservoir tank) and a holding tank (lower reservoir tank). Each tank is made of sheet steel and has a capacity of 125 gallons. The upper tank is a trapezoidal design where the untreated alkaline cleaner is pumped and the treatment chemical (Magic Dust) is added. Once the solution is thoroughly mixed, the encapsulated material is allowed to settle to the bottom of the mixing/reaction tank. A sight glass is provided on this tank so that the separation/encapsulation process can be observed.

After encapsulation, the treated alkaline cleaner is allowed to drain into the holding tank. The treated alkaline cleaner flow is controlled by two separate ball valves located at the bottom of the upper tank. Both valves are two inches in diameter and are operated manually. The standpipe valve controls the flow of the clarified solution and light flocculation, and the bottom valve controls the flow of heavy precipitation. The standpipe, located on the inside of the upper tank, can be cut to adjust the height of the pipe to the depth of the flocculated material.

All treated alkaline cleaner is allowed to pass through a filtration media (30 micron filter paper) before entering the holding tank. The EQ-1 System contains a grated metal filter pan, directly below the upper tank, to hold the filter media. The filter media is constructed of rayon fiber and collects the treatment chemical with the encapsulated waste. As the waste is collected on the filter paper, the paper is slowly pulled forward and wrapped around the encapsulated waste. When the waste has been sufficiently wrapped, the filter paper is cut. The encapsulated waste is removed and placed in the drying tray, which is located on the right side of the unit. This process is repeated until all of the alkaline cleaner has been processed. As the encapsulated waste is rolled in the filter paper, the paper is squeezed to remove excess solution. The clarified solution in the holding tank is transferred with a submersible pump to the FPS, which is an optional secondary treatment.

The FPS is a basic ion exchange system. The system is cationic, and polystyrene beads with sodium ions are used for the resin media. The FPS includes a granular activated carbon filter along with a polymer resin chamber. The clarified solution enters the prefilter carbon media to remove O&G, and other contaminants. The filtered solution then enters the ion exchange chamber, where the metal ions are removed by being captured on the beads. The prefilter chamber is 3" in diameter, 25" tall, and requires one 20" – 15 micron filter cartridge. The refillable resin chamber has a polyvinyl chloride (PVC) shell with a 250-micron polypropylene strainer. The strainer prevents resin migration with the solution. The resin has a 2 pounds (lbs) per 1.0 cubic feet ($ft^3$) capacity. The specification for the FPS is 72 gallons per hour (gph) or 1–2 gallons per minute (gpm) for maximum removal efficiency.

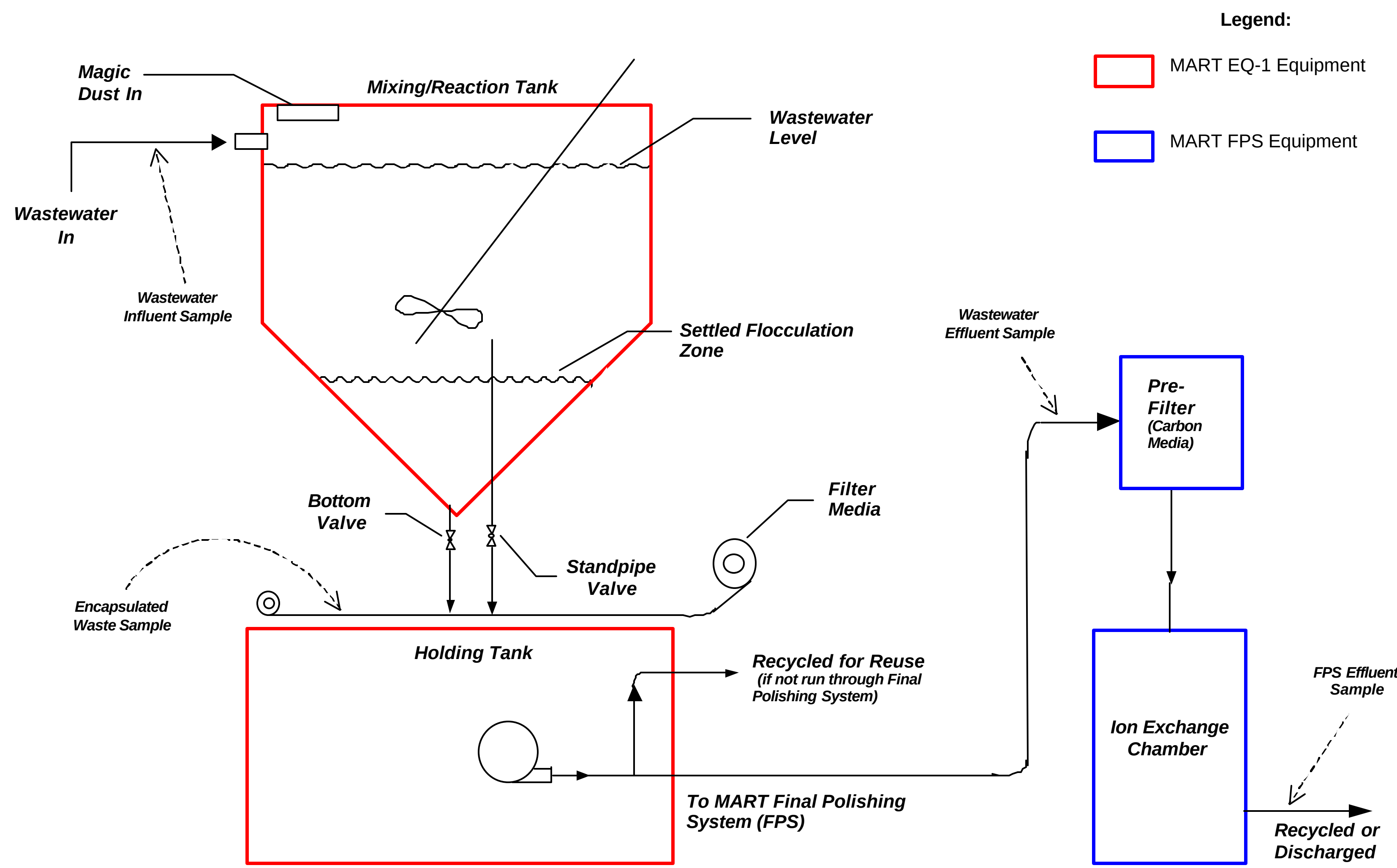


**Figure 2. The MART EQ-1 Schematic**

### 2.3 Test Site Installation

The test site selected for verification of the MART EQ-1 System was the OANG 179th AW Unit in Mansfield, Ohio. The 179th AW has a 52-year history from the early days organizing the unit and flying fighters, to their present day situation as a first string member of the Total Force and flying the C-130 Hercules (C-130H) aircraft. The 179th AW is an Air Force (AF) ANG comprised of 950 personnel, with approximately 250 being full-time. Their primary mission is to provide airlift capabilities for the State of Ohio and the rest of the United States if needed.

The 179th AW utilizes the C-130H transport in their daily airlift capabilities operations. The 179th AW cleans the engines on their eight C-130H aircraft at least once each year as preventative maintenance to ensure maximum performance, as well as aircraft and aircrew safety. In 1993, cadmium was detected in the engine compressor wash wastewater. The cadmium was believed to be coming from the cadmium-plated internal compressor blades in the C-130H aircraft engine. At that time, most of the Department of Defense (DOD) facilities were not collecting their spent wash wastewater. Consequently, in 1994 the ANG Headquarters (HQ) instructed all C-130H bases to stop aircraft engine washing until a collection system could be developed. In 1997, engine compressor washing resumed. The spent engine wash cleaner and rinsate were collected and drummed as hazardous waste, using a wastewater collection container.

The spent wash wastewater collected from the cleaning of the C-130H engines has the potential to generate large quantities of hazardous waste annually at each ANG base. The 179th AW realized this environmental impact and began implementing a program to treat the C-130H engine compressor spent wash wastewater at their site, as well as their spent aqueous parts washer cleaners.

#### 2.3.1 The 179th AW C-130H Engine Cleaning Process

It is a requirement at the 179th AW to wash the C-130H aircraft engines at least once each year to ensure maximum performance and aircraft and aircrew safety. The cleaning process used at the 179th AW is as follows:

- Soap application (soak for five minutes)
- Soap application again (soak for 20 minutes)
- Two clean water rinses

The aircraft cleaning solution used is Eldorado ED-563. The entire cleaning process generates no more than 10 gallons of alkaline cleaner/rinsate per engine and no more than 40 gallons per plane. This results in the generation of approximately 640 gallons of wastewater per year at the 179th AW base. The cleaner/rinsate mixture is comprised of approximately 94 percent water, five percent alkaline cleaner, and one percent cadmium and O&G. **Table 1** presents background analysis of engine wash wastewater sample taken before treatment. It was collected by the 179th AW on October 20, 1997, and tested by Clayton

Laboratory Services. The spent wash wastewater is hazardous because it contains 11 parts per million (ppm) of cadmium. The cadmium in the wastewater comes from the cadmium-plated internal compressor blades of the engine. The O&G in the wastewater comes from the engine. It is estimated that the concentration of contaminants in this spent wash wastewater remains relatively constant, because the frequency of C-130H engine cleaning is determined based on the number of hours the engine is in service.

| Constituent | Unit | Parameter |
|---|---|---|
| Cadmium (Cd) | ppm | 11 |
| O&G | ppm | 2500 |
| pH | pH units | 7.1 |

**Table 1. Spent Engine Cleaning Wash Wastewater Background Analysis**

After the four C-130H aircraft engines on each plane are cleaned, the cleaning solution and rinsate are collected in a large 500 gallon plastic polystyrene collection container (**Figure 3**) and transported to the MART EQ-1 System. The treated engine wash wastewater is discharged to the POTW, after analysis confirms that the treated water meets permit requirements.


**Figure 3. The 179th AW Wash Wastewater Collection Container**

### 2.3.2 The 179th AW Parts Washer Cleaning Process

There are three part washers at the 179th AW, each of which utilizes an aqueous alkaline cleaner. A description summary of the washers is presented in **Table 2** The alkaline cleaners are treated individually using the MART unit. The spent alkaline cleaners contain contaminants that are primarily cadmium (Cd), chromium (Cr), paint chips, and O&G. Some of the minor contaminants include lead (Pb), barium (Ba), nickel (Ni), and copper (Cu). The spent alkaline cleaner concentration varies depending on the type and quantity of contaminants on the parts and age of the cleaning solution. After treatment in the MART system, the recovered alkaline cleaner is pumped back into the parts washer reservoir for reuse.

| Parts Washer | Size (Liters) | Alkaline Cleaner | Use | Contaminants |
|---|---|---|---|---|
| Engine Shop *(MART Tornado 40)* | 680 | Daraclean® 235 | Aircraft engine panels | Cd, Cr, Cu, Pb, O&G |
| Aircraft Ground Equipment (AGE) *(MART Cyclone 30)* | 490 | Daraclean® 282 | Burner cans from engine heater | Cd, Cr, Pb, Ba, O&G |
| R&R (Tire Shop) *(MART Cyclone 30)* | 490 | Daraclean® 282 | Rims, bolts, & various brake components | Cd, Cr, Cu, Ni, Ba, O&G |

**Table 2. Parts Washers at the 179th AW**

## 3.0 METHODS AND PROCEDURES

### 3.1 Test Objectives

The overall goal of the verification test was to evaluate the ability of the MART EQ-1 System to separate O&G, metals, and suspended solids from the spent cleaning solution. This technology was evaluated under actual production conditions, and the operation of the unit was characterized through the measurement of various process control factors.

The following is a summary of specific project objectives. **Table 3** describes these objectives and how they relate to the test measurements for evaluation of the MART EQ-1 System.

Under normal system operating set-points at the 179th AW and varying contaminant-loading rates:

- Prepare a material balance for waste alkaline cleaner constituents (oils and metals) in order to:

  1) Evaluate the ability of the MART EQ-1 System to remove O&G and metals.
  2) Evaluate the ability of the MART EQ-1 System to recycle alkaline cleaner solution.

- Determine the cost of operating the system for the specific conditions encountered during testing.

  1) Determine labor requirements needed to operate and maintain the MART EQ-1 System.
  2) Determine the quantity of energy consumed by the MART EQ-1 System during operation.

- Quantify the environmental benefit by determining the potential for reduction in alkaline cleaner disposal frequency.

## 3.2 Test Procedure

### 3.2.1 System Set-Up

Prior to startup, the MART EQ-1 System was scrubbed to remove residue and flushed with tap water. The walls of the upper and lower tanks were rinsed, and all associated lines, pumps, and valves were flushed. The discharge of the flushing was allowed to drain on the filter paper and was appropriately disposed of.

### 3.2.2 Testing

The MART EQ-1 System was tested in accordance with the verification test plan [Ref. 1]. Deviations to the verification test plan were documented using a Test Plan Modification Request. Testing was planned on four distinct processes.

During the first test, the MART EQ-1 System was operated using normal operating conditions found at the 179$^{th}$ AW (section 2.3.1). A "typical" level of contamination was found in the spent engine wash alkaline cleaner/rinsate, which was used for this test. This "typical" level was defined as the normal contamination load in the wastewater after being used to clean the C-130H engine.

During the second, third and fourth tests, the MART EQ-1 System was operated using normal operating conditions found at the 179$^{th}$ AW (section 2.3.2). Test #2 evaluated the ability of the MART EQ-1 to remove contaminants in the R&R parts washer alkaline cleaner and recover the cleaner. Test #3 evaluated the ability of the MART EQ-1 to remove contaminants in the Aircraft Ground

Equipment (AGE) parts washer alkaline cleaner and recover the cleaner. Test #4 evaluated the ability of the MART EQ-1 to remove contaminants in the Engine Shop parts washer alkaline cleaner and recover the same. The alkaline cleaner from the parts washers has historically contained a higher concentration of heavy metals, specifically cadmium, than the engine cleaning alkaline cleaner. The AGE Department at the 179th AW unit leaves their parts washer on at all times, and it is used rather infrequently.

| Test | Test Objective | Test Measurement |
|---|---|---|
| 1. Typical contaminant loading rate found in the C-130H engine alkaline cleaner. | Prepare a material balance for aqueous alkaline cleaner constituents (oils and metals). | • Chemical characteristics of feed solution.<br>• Chemical characteristics of recovered product.<br>• Volume and chemical characteristics of wastes removed from alkaline cleaner.<br>• Quantity of fresh cleaning chemicals added during testing. |
| | Evaluate the ability of the MART system to process spent cleaner solution and separate usable cleaner solution chemistry from contaminants. | • Chemical characteristics of feed solution.<br>• Chemical characteristics of recovered product. |
| | Determine the cleaner recovery rate of the system, normalized based on production throughput and contamination loading. | • Volume of product produced.<br>• Production throughput for alkaline cleaner.<br>• Contaminates loading. |
| | Determine labor requirements needed to operate and maintain the MART system. | • O&M labor required during the test. |
| | Determine the quantity of energy consumed by the MART system during operation. | • Quantity of energy used by pumps and mixer. |
| | Determine the cost of operating the alkaline cleaner recycle system for the specific conditions encountered during testing. | • Costs of O&M labor, materials, and energy required during test.<br>• Quantity and price of fresh cleaning chemicals added during testing. |
| | Determine if worker exposure is elevated, as a result of operating the MART system. | • Perform air monitoring at a low and high contaminants load level. |
| | Quantify/identify the environmental benefit. | • Review historical waste disposal records and compare to current practices. |
| 2. High contaminant loading rate using the R&R parts washer alkaline cleaner. | Same as above. | Same as above. |
| 3. High contaminant loading rate using the AGE parts washer alkaline cleaner. | Same as above, except worker exposure analysis not performed. | Same as above, except air monitoring not performed. |
| 4. High contaminant loading rate using the Engine Shop parts washer alkaline cleaner. | Same as above, except worker exposure analysis not performed. | Same as above, except air monitoring not performed. |

**Table 3. Test Objectives and Related Test Measurements for Evaluation of the MART EQ-1System**

Samples and process measurements for the R&R parts washer and the Engine Shop parts washer were taken according to the frequency presented in **Table 4** For the engine compressor wash, three samples for all parameters plus two extra O&G (total of five) were collected. In addition, three samples for all parameters plus two extra O&G (total of five) were collected from the FPS during verification testing of the engine compressor wash.

| Sample Name | Sample Location | Frequency/ Type | Analytical Parameters |
|---|---|---|---|
| Alkaline Cleaner Influent | Alkaline Cleaner In MART EQ-1 Unit | 2 grab samples/batch | O&G, TSS, Alkalinity, Cd, Cr, Pb, Ba, Ni, Cu , Conductivity*, Refractive Index*, Glycol Ether* |
| Alkaline Cleaner Effluent/FPS Influent | Alkaline Cleaner Out MART EQ-1 Unit | 2 grab samples/batch | O&G, TSS, Alkalinity, Cd, Cr, Pb, Ba, Ni, Cu, Conductivity*, Refractive Index*, Glycol Ether* |
| Encapsulated Waste | Filter Pan | 2 grab samples/batch | O&G, Cd, Cr, Pb, Ba, Ni, Cu, TCLP Metal |

* Refractive index was measured when Daraclean® 235 was used. Conductivity or glycol ether was measured when Daraclean® 282 was used.

**Table 4. Sampling Frequency and Analytical Parameters**

#### 3.2.3 Air Monitoring

Worker exposure air monitoring was conducted according to the verification test plan [Ref. 1] during operation of the MART EQ-1 System and handling of the encapsulated waste to determine if there was a potential for exposure to cadmium and chromium. Testing consisted of monitoring during the C-130H engine cleaning and R&R parts washer tests. In addition to cadmium and chromium, monitoring of silica was added during Test #2 – treatment of the R&R parts washer alkaline cleaner. Silica was added, because it was suspected that there was a potential exposure to silica when handling the Magic Dust. One 15 minute Short-Term Exposure (STE) sample for crystalline silica respirable dust was collected in accordance with the National Institute of Occupational Safety and Health (NIOSH) Method 7300.

### 3.3 Quality Assurance/Quality Control (QA/QC)

#### 3.3.1 Data Entry

A Project Team member recorded field sampling events and process measurements on pre-designed forms (**Appendix A**). Sample identification numbers were created for each test and recorded in the field logbook, along with calibration details and all other data collected in the field.

### 3.3.2 Sample Collection and Handling

Prior to the verification test, the need for sampling ports was evaluated, and it was determined that the sampling ports and locations were sufficient without further modification of the MART EQ-1 System. When possible, grab samples were collected directly into their respective sampling containers. When not possible, a 1000-mL high-density polyethylene (HDPE) sampling beaker was used to collect the sample, which was then poured into its respective sample container. During sampling, the sample collection containers were kept cool by placing them in a cooler containing ice packs.

Samples collected during the verification test were stored in a chemical refrigerator until they were packaged for shipment. Samples shipped to the analytical laboratories were packed in coolers containing ice packs and bags of ice. All shipments were secured with strapping tape and security seals and accompanied by chain of custody (COC) forms.

A summary of the sample analysis and handling requirements that were followed during the verification test can be found in **Table 5**.

| Parameter | Test Method | Sample Bottle | Sample Volume Required | Preservation/ Handling | Hold Time |
|---|---|---|---|---|---|
| Oil/Grease Aqueous | SM Method 5520B | Glass jar | 1000 mL | 4ºC Acidify to pH < 2 w/HCl | 28 days |
| Oil/Grease Solids | SM 5520E/ 5520B | Glass jar | 500 g | 4ºC | 28 days |
| Total Alkalinity | EPA Method 310.1 | Glass jar | 500 mL | 4ºC | Analyze as soon as practical |
| Diethylene Glycol Monobutyl Ether | GC/FID (See Appendix E) | Amber glass jar | 250 mL | 4ºC | 28 days |
| TSS | EPA Method 160.2 | Polyethylene | 500 mL | 4ºC | 7 days |
| Metals Aqueous | EPA Method 200.7 | Polyethylene | 500 mL | Acidify to pH < 2 w/$HNO_3$ | 6 months |
| Metals Solids | SW-846 3050B/6010B | Polyethylene | 500 g | 4ºC | 6 months |
| TCLP Metals | SW 846 Method 1311/3010A/ 6010B | Polyethylene | 500 g | 4ºC sample/ Acidify extract to pH < 2 w/$HNO_3$ | 6 months |

GC/FID = Gas Chromatography/Flame Ionization Detector

**Table 5. Summary of Analysis and Handling Requirements**

### 3.3.3 Calculation of Data Quality Indicators

Data reduction, validation, and reporting were conducted according to the verification test plan [Ref. 1] and the ETV-MF Quality Management Plan (QMP) [Ref. 2]. 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 analyses must agree within defined percent deviation limits, expressed as a percentage, calculated as follows:

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

where:

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

The analytical laboratories performed a total of 64 precision evaluations on test samples. All of the aqueous samples were within the precision limits of the verification test plan [Ref. 1]. One TCLP sample (zinc) did not meet the precision limits. 98.5 percent of the precision evaluation met each analyte's precision limits. The results of the precision calculations are summarized in **Appendix B.**

#### 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:

$$P = [(SSR - SR)/SA] \text{ x } 100\,\%$$

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 7** of the verification test plan [Ref. 1]. The analytical laboratories performed 72 accuracy evaluations. There were 68 samples or 94.4 percent that were within the limits. The results of the accuracy calculations are summarized in **Appendix C**.

#### 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 334 total measurements, and 304 of them were valid. This gives 91.0 percent completeness. Therefore, the total completeness objective was satisfied. However, there were 121 total measurements for the solids; 105 of them were valid, which gives 86.8 percent completeness. The sludge samples were analyzed for oil and total metals. The measurements were not used to make conclusions about the efficiency of the MART EQ-1 System.

#### 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 each sample location during Test #1, #3, and #4 and sent to the laboratory for analysis. The results are shown in **Appendix D**.

#### 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% Solids) x Dilution Factor

The MDLs for this verification project are shown in **Table 6**.

| Critical Measurements | Matrix | Method | Reporting Units | Method of Determination | MDL |
|---|---|---|---|---|---|
| O&G | Water | SM 5520B | mg/L | Gravimetric | 1.0 |
| O&G | Solids | SM 5520E/5520B | µg/g | Gravimetric | 1.0 |
| Total Metals | Water | EPA 200.7 | mg/L | ICP-AES | 0.01 – 0.0005* |
| Total Metals | Solids | SW846 3050B/6010B | µg/g | ICP-AES | 1.3 – 0.05* |
| TCLP Metals | Solid | SW846 1311/3010A/6010B | mg/L | ICP-AES | 1.0 – 0.01* |
| TSS | Water | EPA 160.2 | mg/L | Gravimetric | 1.0 |
| Total Alkalinity | Water | EPA 310.1 | mg/L | Titration | 1.0 |
| Glycol Ether | Water | GC/FID (See Appendix E) | mg/L | GC/FID | 20.0 |

*MRL – depends on the individual analyte

**Table 6. Laboratory Methodology Information**

# 4.0 VERIFICATION DATA

## 4.1 Analytical Results

A complete summary of analytical data is presented in **Table 7**. The samples coded "influent" are grab samples of the feed stream to the MART EQ-1 System and/or MART FPS, and those coded "effluent" are grab samples of the recovered permeate.

QA parameters were evaluated during Test #1, #3, and #4, which included duplicates, matrix spikes, and spike duplicates. The "Standard Solutions" samples are standard cleaner make-up solutions that were made in the field for comparison purposes, in order to understand the baseline analytical interference from the cleaner. These samples represent the concentration of the constituents in a freshly formulated aqueous cleaner bath (the aqueous cleaning solution for the Engine Compressor is formulated with a 5.5 percent solution of ED 563, and the R&R, AGE, and Engine Shop parts washers are formulated with a 13 percent solution of DCN 282, DCN 282, and DCN 235, respectively).

| | Total Alkalinity (mg/L as CaCO3) | TSS (mg/L) | Total O&G (mg/L) | Total Metals Ba (mg/L) | Total Metals Cd (mg/L) | Total Metals Cr (mg/L) | Total Metals Cu (mg/L) | Total Metals Ni (mg/L) | Total Metals Pb (mg/L) | Glycol Ether (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Test #1*** | ***Engine Compressor Wash*** | | | | | | | | | |
| **EQ-1 Influent** | 280 | 370 | 370 | 0.17 | 6.50 | 0.20 | 0.35 | 7.50 | 0.08 | NA |
| **EQ-1 Influent – Duplicate** | 300 | 370 | 490 | 0.12 | 5.50 | 0.17 | 0.31 | 7.60 | 0.08 | NA |
| **FPS Influent** | 260 | 53 | 26.0 | 0.0034 | 0.36 | <0.001 | 0.035 | 0.94 | <0.01 | NA |
| **FPS Influent – Duplicate** | 260 | 54 | 33.0 | 0.0039 | 0.36 | <0.001 | 0.035 | 0.93 | <0.01 | NA |
| **FPS Effluent** | 22 | 15 | 12.5 | 0.0051 | 0.13 | <0.001 | 0.017 | 0.64 | <0.01 | NA |
| **FPS Effluent – Duplicate** | 20 | 26 | 11.5 | 0.0045 | 0.14 | <0.001 | 0.015 | 0.67 | <0.01 | NA |
| ***Test #2*** | ***R&R Parts Washer Alkaline Cleaner*** | | | | | | | | | |
| **EQ-1 Influent** | 700 | 2,900 | 500 | 0.34 | 30.0 | 1.10 | 13.0 | 1.1 | 7.30 | NA |
| **EQ-1 Effluent** | 520 | 62 | 160 | 0.0073 | 27.0 | 0.054 | 6.3 | 1.0 | 2.90 | NA |
| ***Test #3*** | ***AGE Parts Washer Alkaline Cleaner*** | | | | | | | | | |
| **AGE Influent** | 660 | 830 | 390 | 1.4 | 0.40 | 0.72 | 1.5 | 1.0 | 2.3 | 660 |
| **AGE Influent – Duplicate** | 550 | 700 | 390 | 1.4 | 0.42 | 0.73 | 1.5 | 1.0 | 2.4 | 640 |
| **AGE Influent – Duplicate** | NA | NA | 410 | 1.3 | 0.40 | 0.69 | 1.4 | 0.9 | 2.1 | NA |
| **AGE Effluent** | 180 | 150 | 150 | 0.0098 | 0.360 | <0.001 | 0.260 | 0.800 | 1.10 | 660 |
| **AGE Effluent Duplicate** | 200 | 170 | 130 | 0.0089 | 0.354 | <0.001 | 0.258 | 0.772 | 1.12 | 650 |
| **AGE Effluent Duplicate** | NA | NA | 130 | 0.0099 | 0.350 | <0.001 | 0.260 | 0.780 | 1.10 | NA |
| ***Test #4*** | ***Engine Shop Parts Washer Alkaline Cleaner*** | | | | | | | | | |
| **EQ-1 Influent** | 2,000 | 250 | 1,600 | 0.18 | 12.0 | <0.001 | 1.10 | 1.80 | 0.12 | NA |
| **EQ-1 Influent – Duplicate** | 2,000 | 250 | 1,600 | 0.17 | 12.0 | <0.001 | 1.10 | 1.10 | 0.13 | NA |
| **EQ-1 Effluent** | 2,000 | 140 | 1,000 | 0.012 | 11.0 | <0.001 | 1.20 | 1.10 | 0.11 | NA |
| **EQ-1 Effluent – Duplicate** | 2,000 | 180 | 1,100 | 0.035 | 11.0 | <0.001 | 1.00 | 1.10 | 0.12 | NA |
| ***Standard Solutions*** | ***Cleaner Standard Make-up Solutions*** | | | | | | | | | |
| **Engine Compressor –** ***5.5% ED 563 Make-up*** | 800 | 420 | 240 | 0.059 | <0.0005 | <0.001 | 0.18 | <0.005 | <0.01 | NA |
| **R&R Parts Washer –** ***13% DCN 282 Make-up*** | 3,100 | 2 | 680 | 0.039 | 0.0007 | <0.001 | 0.35 | 0.032 | <0.01 | NA |
| **AGE Parts Washer –** ***13% DCN 282 Make-up*** | 3,100 | <1 | 720 | 0.039 | 0.0008 | <0.001 | 0.36 | 0.033 | <0.01 | NA |
| **Engine Shop Parts Washer –** ***13% DCN 235 Make-up*** | 2,500 | 37 | 8,600 | 0.037 | <0.0005 | <0.001 | 0.33 | <0.005 | <0.01 | NA |

NA = Not Applicable

**Table 7. Summary of Analytical Results**

The primary contaminants of the alkaline cleaner streams are total suspended solids, heavy metals, and oil.

The "sludge" samples were grab samples taken from the bottom valve of the EQ-1 upper tank once the permeate solution was removed. Sludge samples analyzed for O&G and total metals were not used due to lack of reliability in the data. The O&G and metals results did not meet the relative percent different limits which indicates that the results were not reproducible as shown below in **Table 8**. Consequently, the concentration of oil and grease and cadmium in the sludge (primary contaminants of the alkaline cleaner baths) were calculated using a simple batch mass balance (influent – effluent = sludge) for the verification statement and not the laboratory data below. Obtaining the concentration of the sludge contaminants in this manner eliminated the ability to calculate the mass balance.

| | O&G (mg/g) | Ba (mg/g) | Cd (mg/g) | Cr (mg/g) | Cu (mg/g) | Ni (mg/g) | Pb (mg/g) |
|---|---|---|---|---|---|---|---|
| ***Test #1 Engine Compressor Wash*** | | | | | | | |
| **Sludge** | 70000 | 230 | 720 | 39 | 39 | 880 | 28 |
| **Sludge - Duplicate** | 35000 | 180 | 840 | 36 | 41 | 950 | 31 |
| ***Test #2 R&R Parts Washer Aqueous Alkaline Cleaner*** | | | | | | | |
| **Sludge** | 17000 | 200 | 520 | 89 | 980 | 20 | 900 |
| ***Test #3 AGE Parts Washer Aqueous Alkaline Cleaner*** | | | | | | | |
| **Sludge Cake** | 9000 | 110 | 3.6 | 24 | 39 | 16 | 41 |
| **Sludge – Duplicate** | 1200 | 100 | 3.6 | 28.7 | 45.1 | 18.9 | 45.5 |
| ***Test #4 Engine Shop Parts Washer Alkaline Cleaner*** | | | | | | | |
| **Sludge** | 620 | 220 | 160 | 4.2 | 140 | 20 | 40 |
| **Sludge – Duplicate** | 410 | 160 | 150 | 11 | 150 | 18 | 35 |

**Table 8. Summary of Sludge Results**

The sludge was checked to see if it could be classified as non-hazardous sludge using SW846 Method 1311/3010A/6010B (TCLP). The AGE parts washer sludge passed TCLP. The other sludge passed the leaching test except for cadmium. The cadmium values were above the 1.0 mg/L, Maximum Allowable Concentration for cadmium. The Magic Dust was unable to encapsulate all of the cadmium particles. Therefore, the sludge from the cleaner at the OANG 179$^{th}$ Unit was classified as hazardous. TCLP results from the waste sludge are summarized in **Table 9**.

| TCLP Metals | Cd (mg/L) | Cr (mg/L) | Pb (mg/L) | Ba (mg/L) | Ni (mg/L) | Cu (mg/L) |
|---|---|---|---|---|---|---|
| ***Test #1*** | ***Engine Compressor Wash*** | | | | | |
| **Sludge Cake** | 8.8 | <0.1 | <0.1 | <1.0 | 5.7 | 0.04 |
| **Sludge Cake – Duplicate** | 9.0 | <0.1 | <0.1 | <1.0 | 6.6 | 0.04 |
| ***Test #2*** | ***R&R Parts Washer Aqueous Alkaline Cleaner*** | | | | | |
| **Sludge Cake** | 3.4 | <0.1 | <0.1 | <1.0 | 0.08 | 0.75 |
| ***Test #3*** | ***AGE Parts Washer Aqueous Alkaline Cleaner*** | | | | | |
| ***Sludge Cake*** | 0.12 | <0.1 | <0.1 | <1.0 | 0.07 | 0.10 |
| ***Sludge Cake – Duplicate*** | 0.11 | <0.1 | <0.1 | <1.0 | 0.07 | 0.10 |
| ***Test #4*** | ***Engine Shop Parts Washer Alkaline Cleaner*** | | | | | |
| **Sludge Cake** | 1.1 | <0.1 | <0.1 | <1.0 | 0.10 | 0.21 |
| **Sludge Cake – Duplicate** | 0.99 | <0.1 | <0.1 | <1.0 | 0.09 | 0.18 |

**Table 9. Summary of TCLP Metal Results**

## 4.2 Air Monitoring Results

Worker exposure air monitoring was conducted during operation of the MART EQ-1 System and handling of the encapsulated waste to determine if there was a potential for exposure to cadmium and chromium. The air monitoring was conducted in accordance with the NIOSH Method 7300. Testing consisted of monitoring during the C-130H engine compressor cleaning (Test #1) and R&R parts washer (Test #2) tests. In addition to cadmium and chromium, monitoring of silica was performed during Test #2 to assess the potential exposure to silica when handling the Magic Dust.

The table below, **Table 10**, summarizes the results of the air monitoring. The TWA results are compared to the PELs.

| Sampling Date | Sampling Location | Compound | TWA ($mg/m^3$) | PEL ($mg/m^3$) |
|---|---|---|---|---|
| 1-25-01 | Handling Waste | Cadmium | <0.0005 | 0.005 |
| 1-25-01 | Handling Waste | Chromium | 0.0002 | 0.5 |
| 1-31-01 | Handling Waste | Cadmium | <0.0005 | 0.005 |
| 1-31-01 | Handling Waste | Chromium | 0.001 | 0.5 |
| 1-31-01 | Magic Dust Weigh-up & Dispensing | Silica (Respirable) | <0.0044 | 0.05 |

**Table 10. Air Monitoring Results**

All samples were below the recommended limits. The results indicate that there was no overexposure to the specific compounds during the treatment process.

## 4.3 Process Measurements

Certain process measurements were taken on field samples during each verification test. These data have been consolidated and are summarized in **Table 11**. Solution temperature measurements were taken using a hand-held digital thermometer, and pH was obtained using pH water test strips. Conductivity (Cond.) measurements were taken using a hand-held digital analyzer, and a refractometer was used to obtain refractive index (RI) measurements.

Feed volumes were obtained using the level indicator on the MART EQ-1 upper tank. The ultrasonic flowmeter was not used because of the configuration of the system's associated piping. Subsequently, we found that the results with the flowmeter yielded inaccurate measurements. The level indicator was checked for accuracy, during Test #1 and #2. Drums of alkaline cleaner were pumped into the MART upper tank and the level indicator was compared to the number of 55-gallon drums that were pumped into the unit. The difference was less than five percent in both cases.

The treated alkaline cleaner (product) was put into drums after being processed by the MART. The product volumes (vol.) were obtained by estimating the volume level in the 55-gallon drums. Waste volumes were obtained by doing a mass balance on the batch system. The extensive sampling events that occurred were also taken into consideration.

| Sample Date | Sample Location | Feed Vol. (L) | Permeate Vol. (L) | Waste Vol. (L) | Temp. (°F) | RI (% Brix) | pH | Cond. (µS) |
|---|---|---|---|---|---|---|---|---|
| ***Test #1 – Engine Compressor Wash*** | | | | | | | | |
| 1-25-01 | MART Influent | 397.0 | NA | NA | 69.0 | NA | 8.0 | 1,314 |
| 1-25-01 | MART Effluent | NA | NA | NA | 69.0 | NA | 9.0 | 1,625 |
| 1-26-01 | FPS Effluent | NA | 364.0 | 12.5 | 69.0 | NA | 7.0 | 2.0 |
| ***Test #2 – R&R Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 2-1-01 | MART Influent | 492.0 | NA | NA | 68.0 | NA | 8.0 | 3,480 |
| 2-1-01 | MART Effluent | NA | 471.0 | 15.0 | 68.0 | NA | 9.5 | 5,960 |
| ***Test #3 – AGE Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 6-13-01 | AGE Influent | 469 | NA | NA | ND | NA | 8.0 | NA |
| 6-13-01 | AGE Effluent | NA | 449.0 | 14.0 | ND | NA | 8.0 | NA |
| ***Test #4 – Engine Shop Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 2-8-01 | MART Influent | 436.0 | NA | NA | 71.0 | 1.4 | 9.0 | NA |
| 2-8-01 | MART Effluent | NA | 417.0 | 13.0 | 71.0 | 1.2 | 9.0 | NA |

NA = Not Applicable    ND = No Data

**Table 11. Summary of Process Measurements**

### 4.4 Other Data

Other data collected during the course of the verification test are summarized in **Table 12**.

| Description | Value |
|---|---|
| Cost of Cleaner – Parts Washers | $31.29/gal |
| Cost of Cleaner – Engine Compressor | $6.43/gal |
| Magic Dust | $7.77/lb |
| Carbon Filters | $27.08/filter |
| Filter Paper | $132.48/roll |
| Resin | $355/ft$^3$ |
| *Total Magic Dust Used for Tests #1, #2, #3 and #4 | 31 lbs |
| Electricity by Cost | $0.0743/kWh |
| Waste Disposal | $4.55/gal |
| *Total Waste Generated for Tests #1, #2, #3 and #4 | 43.4 lbs |
| Labor Cost (loaded rate) | $35.00/hr |
| Cost of MART EQ-1 System | $9,100 |

* Totals are for 474 gal of alkaline cleaner processed.

**Table 12. Other Data Collected During Verification**

## 5.0 EVALUATION OF RESULTS

### 5.1 Conductivity and Refractive Index Correlation to Cleaner Recovery

The manufacturer of the Daraclean® (DCN) Alkaline Cleaner recommends that conductivity and refractive index measurements be used to obtain the cleaner concentration in DCN 282 and 235, respectively. Consequently, both of these measurements were obtained in the field using hand-held measuring equipment. In addition to these measurements, samples were submitted to the analytical laboratory for total alkalinity (mg/L as $CaCO_3$). Alkalinity was used, in addition to the field measurements, in order to evaluate the effectiveness of the MART EQ-1 System in recovering the key components of the concentrated cleaner. Since Test #2 showed that the Magic Dust was interfering with the conductivity measurement, for Test #3 a GC/FID analysis was run for the glycol ether in Daraclean® Cleaner 282. Cleaner recovery efficiency during Test #1, Engine Compressor Wash, was not an objective of this verification test, and subsequently recovery of the ED 563 was not evaluated. The 179$^{th}$ AW does not reuse the treated alkaline cleaner from this waste stream and has no future plans to do so. The Engine Compressor Wash was evaluated to verify the MART's effectiveness in removing contaminants before discharge to a POTW. Primary contaminants include oil and cadmium.

Standard solutions of DCN 282 were made at zero percent, five percent, 10 percent, 12 percent, 17.5 percent, and 22.5 percent in water. Conductivity was measured on each standard sample, and the results were used to plot conductivity versus (vs.) DCN 282 cleaner concentration. The graph is presented in **Figure 4**.

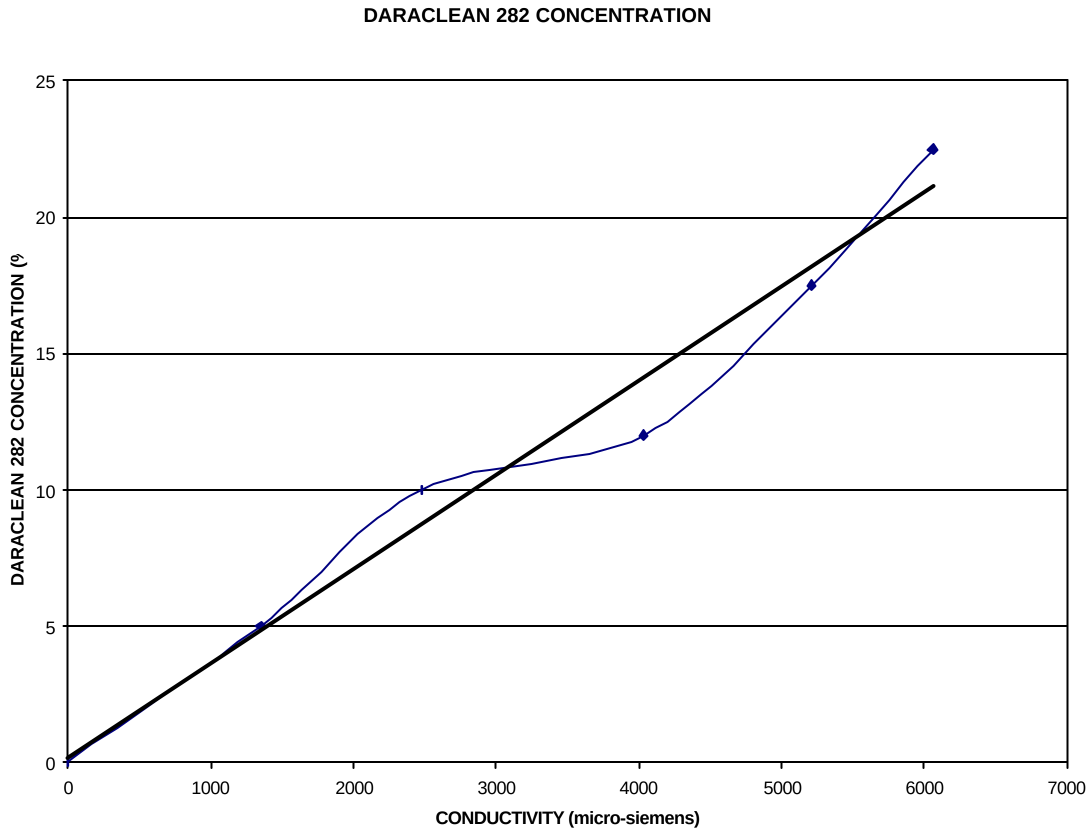


**Figure 4. DaracleanÒ 282 Cleaner Concentration vs. Conductivity**

A similar graph was created for DCN 235, except standard solutions were made and measured for refractive index instead of conductivity. The graph is presented in **Figure 5**. Standard solutions of DCN 235 were made at zero percent, five percent, seven percent, 10 percent, 12.5 percent, 15 percent, and 20 percent in water.

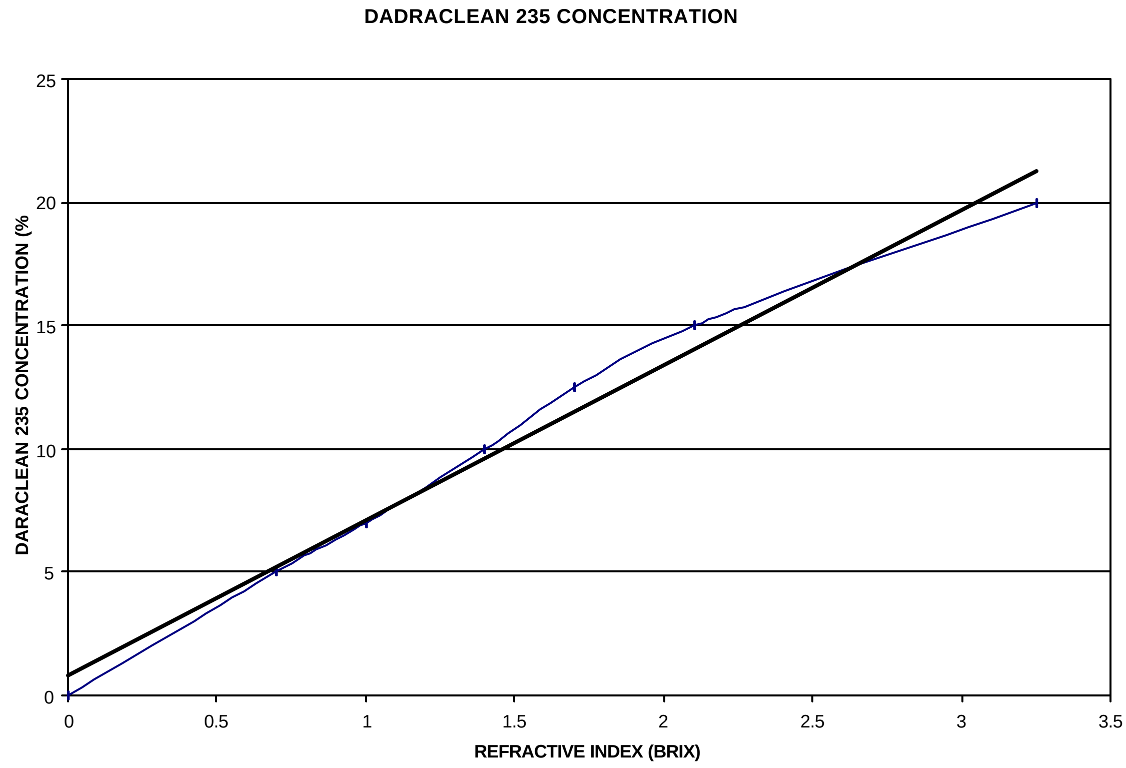


**Figure 5. DaracleanÒ 235 Cleaner Concentration vs. Refractive Index**

The cleaner concentrations obtained when using these graphs are summarized in **Table 13**. **Figure 4** and the field conductivity measurements performed during Test #2 were used to obtain DCN 282 concentrations in the MART influent and effluent streams. **Figure 5** and the field refractive index measurements performed during Test #4 were used to obtain DCN 235 concentrations in the MART influent and effluent streams.

| Sample Date | Sample Location | Conductivity (mS) | DCN 282 Conc. (%) | RI (% BRIX) | DCN 235 Conc. (%) |
|---|---|---|---|---|---|
| ***Test #2 – R&R Parts Washer Alkaline Cleaner*** | | | | | |
| 2-1-01 | MART Influent | 3,480 | 12.5 | NA | NA |
| 2-1-01 | MART Effluent | 5,960[1] | 21.3 | NA | NA |
| ***Test #4 – Engine Shop Parts Washer Alkaline Cleaner*** | | | | | |
| 2-8-01 | MART Influent | NA | NA | 1.4 | 8.6 |
| 2-8-01 | MART Effluent | NA | NA | 1.2 | 7.5 |

NA – Not Applicable 1 = Magic Dust interfered with conductivity measurement

**Table 13. Cleaner Concentration Values**

The DCN 282 concentration increased from the influent to effluent streams. This increase is due to ionic interference associated with the Magic Dust. An increase in ionic interference from the Magic Dust will in turn increase the conductivity. A 0.5 percent solution (the same percentage used at the 179th AW) of Magic Dust in water was made up to evaluate this interference, but because the Magic Dust is not very soluble in water and it flocculates very quickly, the conductivity obtained (1160 µS) is not believed to be representative. Consequently, the conductivity interference associated with the Magic Dust could not be quantified.

## 5.2 Recovery Efficiency of Alkaline Cleaner

To understand the recovery efficiency of the alkaline cleaner, recovery efficiencies were calculated for total alkalinity, conductivity, and refractive index. These calculations were performed for Tests #2, #3, and #4. The equation for the cleaner recovery calculation is shown below and the results are presented in **Table 14**.

$$C_{rec}\ (\%) = [(C_{prod} \times Prod_{vol})/(C_{feed} \times Feed_{vol})] \times 100\%$$

where:

$C_{rec}$ = cleaner recovery efficiency
$C_{prod}$ = product stream cleaner concentration (mg/L)
$Prod_{vol}$ = product volume collected during cycle (L)
$C_{feed}$ = feed solution cleaner concentration (mg/L)
$Feed_{vol}$ = feed solution volume processed during cycle (L)

Example: R&R Parts Washer Alkaline Cleaner – Total Alkalinity % Recovery Efficiency

$$C_{Rec}\ (\%) = \left[\frac{520\ mg/L \times 471\ L}{700\ mg/L \times 492\ L}\right] \times 100\% = 71\%$$

| Sample Date | Total Alkalinity % Recovered | DCN 235 Cleaner % Recovered | DCN 282 Cleaner % Recovered |
|---|---|---|---|
| ***Test #2 – R&R Parts Washer Alkaline Cleaner*** | | | |
| 2-1-01 | 71 | NA | 163[1] |
| ***Test #3 – AGE Parts Washer Alkaline Cleaner*** | | | |
| 6-13-01 | 26 | NA | 94 |
| ***Test #4 – Engine Shop Parts Washer Alkaline Cleaner*** | | | |
| 2-8-01 | 96 | 83 | NA |

NA – Not Applicable    1 = Magic Dust interfered with conductivity measurement

**Table 14. Cleaner Recovery Efficiency**

The recovery percentages for alkalinity were above values typically obtained by 179th AW. The Engine Shop recovery was considerably higher (96 percent), indicating that there was little or no change in the alkalinity concentration from influent to effluent.

The DCN 235 percent recovery was also above values typically obtained by 179th AW. In fact, the percent recovery for DCN 282 in Test #2 was well over 100 percent. This is believed to be due to additional ions contributed by the Magic Dust. For Test #3 GC/FID analysis for diethylene glycol monobutyl ether was perform to determine the concentration of DCN 282. The GC/FID analysis is a better method of determining the concentration of the DCN 282. The DCN 235 percent recovery was still high, 94 percent. The lower alkalinity percent recovery is probably due to the fact that Magic Dust was not specifically formulated to treat the AGE parts washer cleaner.

### 5.3 Contaminant Removal Efficiency

Contaminant removal efficiencies were calculated for the primary contaminants of the alkaline cleaning waste stream: oil, cadmium (Cd), and TSS. The equation for oil removal efficiency is shown below. Cd and TSS removal efficiencies were calculated using a similar equation.

$$O_{eff}\ (\%) = 100\% - [[(O_{out} \times Prod_{vol})/(O_{in} \times Feed_{vol})] \times 100\%]$$

where:

$O_{eff}$ = oil removal efficiency
$O_{out}$ = product stream oil concentration (g/L)
$Prod_{vol}$ = product volume collected during cycle (L)
$O_{in}$ = feed solution oil concentration (g/L)
$Feed_{vol}$ = feed solution volume processed during cycle (L)

The calculated results are shown in **Table 15**.

| Test Run and Sample Date | O&G % | TSS % | Ba % | Cd % | Cr % | Cu % | Ni % | Pb % |
|---|---|---|---|---|---|---|---|---|
| ***Test #1 – Engine Compressor Wash*** | | | | | | | | |
| 1-25-01 | 97 | 96 | 97 | 98 | 100 | 96 | 92 | 100 |
| ***Test #2 – R&R Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 2-01-01 | 69 | 98 | 98 | 14 | 95 | 54 | 13 | 62 |
| ***Test #3 – AGE Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 6-13-01 | 63 | 83 | 99 | 14 | 100 | 83 | 23 | 54 |
| ***Test #4 – Engine Shop Parts Washer Alkaline Cleaner*** | | | | | | | | |
| 2-08-01 | 40 | 46 | 94 | 12 | ND | -4 | 42 | 12 |

**Table 15. Contaminant Removal Efficiency**

As indicated in the data above, during Test #1,the MART EQ-1 System, which included the FPS, removed 97 percent of the oil, 96 percent of the TSS, 97 percent of the barium, 98 percent of the cadmium, 100 percent of the chromium, 96 percent of the copper, 92 percent of the nickel, and 100 percent of the lead from the influent stream. This produced a permeate stream with concentrations of 12 mg/L oil, 20.5 mg/L TSS, 0.005 mg/L barium, 0.135 mg/L of cadmium, no detection of chromium, 0.017 mg/L copper, 0.64 mg/L nickel, and no detection of lead.

During Test #2, the MART EQ-1 System removed 69 percent of the oil, 98 percent of the TSS, 98 percent of the barium, 14 percent of the cadmium, 95 percent of the chromium, 54 percent of the copper, 13 percent of the nickel, and 62 percent of the lead from the influent stream. This produced a permeate stream with concentrations of 160 mg/L oil, 62 mg/L TSS, 0.0073 mg/L barium, 27 mg/L of cadmium, 0.054 mg/L chromium, 6.3 mg/L copper, 1.0 mg/L nickel, and 2.8 mg/L lead.

During Test #3, the MART EQ-1 System removed 63 percent of the oil, 83 percent of the TSS, 99 percent of the barium, 14 percent of the cadmium, 100 percent of the chromium, 83 percent of the copper, 23 percent of the nickel, and 54 percent of the lead from the influent stream. This produced a permeate stream with concentrations of 150 mg/L oil, 150 mg/L TSS, 0.0098 mg/L barium, 0.36 mg/L of cadmium, no detection of chromium, 0.26 mg/L copper, 0.8 mg/L nickel, and 1.1 mg/L lead.

During Test #4, the MART EQ-1 System removed 40 percent of the oil, 46 percent of the TSS, 94 percent of the barium, 12 percent of the cadmium, - 4 percent of the copper, 42 percent of the nickel, and 12 percent of the lead from the influent stream. Chromium was not detected. This produced a permeate stream with concentrations of 1000 mg/L oil, 140 mg/L TSS, 0.012 mg/L barium, 11 mg/L of cadmium, no detection of chromium, 1.2 mg/L copper, 1.1 mg/L nickel, and 0.11 mg/L lead. Low copper concentration and typical analytical variability are the reasons for a negative copper removal efficiency.

The differences in data, between the tests, are attributed to Test #1 utilizing the MART FPS, whereas the other tests did not. However, the contaminant removal efficiencies for Test #1, before the FPS, were relatively high as well (see data in **Table 7**). This can be attributed to the fact that the Magic Dust used was formulated to remove the contaminant levels so that this waste stream would meet the 179th AW local POTW effluent limits.

The same Magic Dust formulation used to treat the engine compressor wash (Test #1) is also used to treat the parts washers evaluated in Tests #2 and #4, because they have similar contaminants. The Magic Dust formulation for the AGE parts washer is formulated differently than for Tests #1, #2 and #4 due to the nature of the waste stream. MART's recommended treatment criteria for the 179th AW's parts washers' streams include only visual clarity, not contaminant removal. The Magic Dust formulations used achieve satisfactory visual clarity. However, there was no research done to understand how the differences in cleaners used for these waste streams would impact the MART EQ-1 System contaminant removal efficiency.

This was justified because complete contaminant removal is not required to recycle alkaline cleaners. With Tests #2, #3, and #4 yielding satisfactory removal efficiencies for O&G, and TSS, and a low-contaminant removal efficiency for cadmium, the alkaline cleaner was considered effectively recycled.

### 5.4 Energy Use

The electrical service required for the MART EQ-1 System at the 179th AW is 115 VAC and 17 amps. Electricity is also used for several very small feed pumps and a mixer; however, the energy requirements for these devices are insignificant and were not evaluated during this project.

Energy usage was calculated by converting the system electrical service requirements (17 amps, 115 volts) into kilowatts and multiplying by the number of hours operated.

17 amps X 115 Volts = 1955 watts (1.955 kW)

The MART EQ-1 System operated for a total of 26.33 hours during the first run which included pumping the effluent through FPS system. The MART EQ-1 System ran for 4.73 hours during each of the three parts washer tests for a total of 14.19 hours. The estimated energy used during all four tests was:

1.955 kW X 40.52 hours = 79.2 kWh

### 5.5 Operating and Maintenance Labor Analysis

O&M labor requirements for the recycling system were observed during testing. The system requires 3.0 hours of labor to operate for each batch, which includes set-up, pumping the waste stream into the upper reservoir, adding the Magic Dust until flocculation occurs, emptying the permeate solution, and wrapping up the encapsulated waste into the filter paper. These tasks require that the system operator not leave the unit unattended. In 2000, the 179th AW had to re-treat a waste stream because it did not meet the effluent limits for cadmium. This task took an additional three hours.

Maintenance requirements for the recycling system are minimal at the 179th AW. Periodic maintenance includes changing the resin in the FPS and cleaning the system for winter storage. These activities amount to approximately four hours per year.

The 179th AW had to replace the FPS pump in the fall of 2000. Maintenance hours associated with this activity amounted to eight hours.

### 5.6 Chemical Use Analysis

#### 5.6.1 Concentrated Cleaner

Prior to the purchase and utilization of the MART aqueous recycling system, the 179th AW was utilizing a solvent cleaning process. The recycling system and the 179th AW's aqueous parts washers were purchased at the same time. The recycling system was obtained to treat the C-130H engine compressor wash that was, at that time, being shipped off-site for disposal. The aqueous parts washers were obtained to replace the solvent cleaning process. The recycling system provided the 179th AW the added bonus of treating the parts washers' alkaline cleaner and recovering the alkaline cleaner for reuse. Since the MART recycling system was instituted with the parts washers already on line, there is no available background data to determine the savings associated solely with the use of the aqueous recycling system at the 179th AW. However, prior to switching from solvent cleaning to aqueous cleaning, the 179th disposed of the spent solvent cleaning waste stream through off-site disposal. Prior to the MART recycling system, the waste stream from the aqueous parts washers was shipped off-site for disposal as hazardous waste.

Prior to utilization of the MART recycling system, concentrated cleaner was replaced in the parts washers once each year. The approximate annual volume of concentrated cleaner that was used to make up fresh solutions for the parts washers was 57 gallons (34 gallons of DCN 282; 23 gallons of DCN 235). In addition, one gallon of concentrated cleaner was added monthly to each of the three parts washers (1 gallon X 3 parts washers X 12 months = 36 gallons). The total annual volume of concentrated cleaner used prior to utilization of the MART EQ-1 System was 93 gallons (57 + 36 = 93).

With the MART EQ-1 recycling system operational, approximately four gallons of concentrated cleaner is added to the treated alkaline cleaner, in each of the three parts washers, in order to get the cleaner concentration back up to a concentration of 12–14 percent (4 gallons X 3 parts washers = 12 gallons). The cleaner concentration is then checked, on a monthly basis. Normally, one gallon of concentrated cleaner is added monthly to each of the parts washers (1 gallon X 3 parts washers X 12 months = 36 gallons). The total annual volume of concentrated cleaner used after installation of the MART EQ-1 System is 48 gallons (12 + 36 = 48).

The standard operating procedure at the 179th AW is to dispose of the engine compressor wash. This waste stream is not recycled. Approximately one to two gallons of concentrated cleaner is used for each aircraft. The annual volume of cleaner (ED563) that was used to clean the C-130H engine compressors in 2000 was five gallons.

### 5.6.2 Magic Dust

The quantity of Magic Dust required to process 100 gallons of alkaline cleaner is about six to eight lbs. for typical contaminant loading. This quantity will vary as the contaminant load in the alkaline cleaner increases or decreases. The quantity of Magic Dust was observed during the verification and is summarized below per 100 gallons of alkaline cleaner:

- Test #1, Engine Compressor Wash (Formulation 29498-73105) – six lbs.
- Test #2, R&R Parts Washer alkaline cleaner (Formulation 29498-73105) – eleven lbs.

- Test #3, AGE Parts Washer (Formulation 73104-01004) – eight lbs.
- Test #4, Engine Shop Parts Washer alkaline cleaner (Formulation 29498-73105) – six lbs.

#### 5.6.3 FPS Supplies

The FPS contains a carbon filter and resin chamber. The carbon filters are changed at the rate of one for every 100–125 gallons of water processed. The resin chamber contains ½ $ft^3$ of resin, and it is changed out once annually.

### 5.7 Waste Generation Analysis

Prior to the utilization of the MART recycling system, the engine compressor wash was shipped off-site for disposal. The waste had to be shipped as hazardous material primarily due to its heavy metals concentration, specifically cadmium. The labor associated with disposing of the engine compressor wash was 10 hours for the eight C-130H aircraft engines that were cleaned. The labor includes transferring the wash from a collection container into drums for off-site disposal. The cost of off-site disposal for the engine compressor wash, before utilization of the MART system, was $400 to $650 annually (300 gallons @ $400 in 1997; 200 gallons @ $640 in 1998[2]).

The parts washers' waste streams generated 450 gallons of hazardous waste annually. The labor associated with preparing this material for off-site disposal was 12 hours.

With the utilization of the recycling system, the treated engine compressor wash is non-hazardous for cadmium and most often meets the 179th AW's local POTW effluent limits. Wastewater that does not meet effluent limits is re-treated until it does. The parts washers' treated alkaline cleaner is pumped back into the washers' reservoir and reused after concentrated cleaner is added. The encapsulated waste generated as a result of the recycling system, however, is considered hazardous and is disposed of as such. Approximately one 50-gallon drum of hazardous waste is generated annually after treating 750 gallons of wastewater at the 179th AW. The hazardous waste is comprised primarily of encapsulated waste, but it does also contain spent carbon filters and resin.

The sludge wastes generated during each of the tests are summarized below:

- Test #1 – 5,144 g of dry sludge (2,722 g Magic Dust)
- Test #2 – 7,056 g of dry sludge (4,990 g Magic Dust)
- Test #3 – 5,700 g of dry sludge (3,655 g Magic Dust)
- Test #4 – 3,714 g of dry sludge (2,722 g Magic Dust)

The weights above include the Magic Dust, encapsulated waste, and filter paper. The weight of the filter paper, however, is negligible.

[2] The following is historical data provided by the 179th AW. In 1997, the hazardous waste drums were shipped using a government transporter, which provided a good shipping price. In 1998, the drums were shipped via a private company. This is the reason for the drastic difference in cost between the two years.

### 5.8 Cost Analysis

The capital cost of the MART EQ-1 System in 1998 was $9,100 (includes $6,100 for the basic EQ-1 unit, $2,800 for the optional FPS, and $200 for feed pump and associated industrial hoses). There were no installation or start-up costs because the system is self-contained and comes ready for use.

Annual costs and savings associated with the MART EQ-1 System are shown in **Table 16.** The annual operating costs of the MART EQ-1 System are $3,588. The annual operating costs prior to installation of the MART EQ-1 System were $6,897, resulting in a net annual savings of $3,309. The simple payback period is 2.8 years (capital cost/net annual savings).

| Item | Prior to Installation of the MART EQ-1™ System | | | After Installation of MART EQ-1™ System | | |
|---|---|---|---|---|---|---|
| | Units | Unit Cost $/unit | Cost $ | Units | Unit Cost $/unit | Cost $ |
| Electricity for recovery unit (see section 5.4) | 0 | 0 | 0 | 79.2 kWh | .0743 | 5.88 |
| Recycling unit O&M labor (see section 5.5) | 0 | 0 | 0 | 36 hr | 35 | 1,260 |
| Cleaner Use – Parts Washers (see section 5.6) | 93 gal | 31.29 | 2,910 | 48 gal | 31.29 | 1,502 |
| Cleaner Use – Engine Compressor (see section 5.6) | 5 | 6.43 | 32.15 | 5 | 6.43 | 32.15 |
| FPS Supplies – Resin (see section 5.6.3) | 0 | 0 | 0 | ½ $ft^3$ | $355 | $177.50 |
| FPS Supplies – Carbon Filters (see section 5.6.3) | 0 | 0 | 0 | 4 filters | $27.08 | $108.32 |
| Magic Dust Use – (see section 5.6.2) | 0 | 0 | 0 | 31 lbs | $7.77 | $240.87 |
| Filter Paper Use | 0 | 0 | 0 | ¼ roll | $132.48 | $33.12 |
| Waste Generation (associated labor; see section 5.7) | 22 hrs | 35 | 770 | * | * | * |
| Waste Generation (disposal costs; see section 5.7) | 700 gal | 4.55 | 3,185 | 50 gal | 4.55 | 228 |
| **Total Costs** | | | **6,897** | | | **3,588** |

* Waste generation cost after installation is included in the Recycling Unit O&M Labor, because it is a part of the recycling system process.

**Table 16. Annual Costs/Savings**

### 5.9 Project Responsibilities/Audits

Verification testing activities and sample analysis were performed according to section 4.0 of the Verification Test Plan [Ref. 1].

There was one audit conducted during the verification test of this technology. The audit was an internal *CTC* Technical Systems Audit (TSA), conducted by Mr. Clinton Twilley, *CTC* QA Manager, on February 25, 2001. Mr. Twilley identified no findings and five observations (opportunities for improvement). Actions for implementing these opportunities for improvement are being incorporated into future test projects.

## 6.0 REFERENCES

All references are available by accessing the EPA ETV or ETV-MF Program Internet websites at: www.epa.gov/etv or www.etv-mf.org, respectively.


1. Concurrent Technologies Corporation, "*Environmental Technology Verification Program for Metal Finishing Pollution Prevention Technologies Verification Test Plan, Evaluation of MART Corporation's EQ-1 Wastewater Processing System,*" January 5, 2001.

2. Concurrent Technologies Corporation, "*Environmental Technology Verification Program Metal Finishing Technologies Quality Management Plan,*" Revision 1, March 26, 2001.

# APPENDIX A

# PROCESS MEASUREMENTS

Engine Compressor Washwater



## Figure 4. Data Collection Form

Test # : 1 Date: 1/25/01 Batch # : 1
Revision # : 0 Revision Date: Original

Operation: MART EQ-1™ System
Technology Type: Water Recycling

| Date/ Time | Initials | Sample Number | Sample Location | MART EQ-1™ Influent Stream Conductivity/ Refractive Index (% Bx) | MART EQ-1™ Effluent /FPS Influent Stream Conductivity/ Refractive Index (% Bx) | MART FPS Effluent Stream Conductivity/ Refractive Index (% Bx) | Settling Time (minutes) | Flocculation Time (minutes) | Notes and Observations |
|---|---|---|---|---|---|---|---|---|---|
| 1-25 / 1056 | KO | Field | MART Influent | 1314 µS@20.8°C / N/A | | | INSTANT | INSTANT | pH - 8.0; conductivity measurement checked 3 times on same sample yielded same results |
| 1-25 / 1430 | KO | Field | MART Effluent | | 1625µS@20.8°C / N/A | | | | pH - 9.0; " " |
| 1-26 / 1030 | KO | Field | FPS Effluent | | | 2µS@20.8°C / N/A | | | pH - 7.0; " " |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| 1-25 | KO | CAL | 1413µS Soln. | 1199µS @ 43°F(18°C) | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Total Wastewater Flow into MART EQ-1™ (L) 924 (ultrasonic flowmeter)/397 L (EQ-1 upper tank level); # of drums pumped into EQ-1 upper tank = ~2 (55 gal. each)

Total Wastewater Flow out of MART™ FPS (L) ~~not~~ possible (flow too small to get accurate reading when using the ultrasonic flowmeter) ~ 1 3/4 drum (55 gal. each)

Page 1 of 1

CAL - Calibration

N/A - not applicable

R & R Parts Washer Wastewater



**Figure 4. Data Collection Form**

Test # : 2 Date: 1/31/01 Batch # : 1
Revision # : 0 Revision Date: Original

Operation: MART EQ-1™ System
Technology Type: Water Recycling

| Date/ Time | Initials | Sample Number | Sample Location | MART EQ-1™ Influent Stream Conductivity/ Refractive Index (% Bx) | MART EQ-1™ Effluent /FPS Influent Stream Conductivity/ Refractive Index (% Bx) | MART FPS Effluent Stream Conductivity/ Refractive Index (% Bx) | Settling Time (minutes) | Flocculation Time (minutes) | Notes and Observations |
|---|---|---|---|---|---|---|---|---|---|
| 2-1 / 1120 | KQ | CAL | 447 µS Cal. soln. | 402 µS @ 20°C / N/A | | | | | |
| 2-1 / 1120 | KQ | CAL | 1413 µS cal. soln. | 1278 µS @ 20°C / N/A | | | | | |
| 2-1 / 1130 | KQ | CAL | Daracken 282 Neat | 17.97 mS @ 20°C / N/A | | | | | Recheck 2-6-01, 1100 17.92 mS @ 20.4 °C |
| 2-1 / 1131 | KQ | CAL | 5% 282 | 1333 µS @ 20°C / N/A | | | | | Recheck 2-6-01, 1100 1595 µS @ 20.4 °C |
| 2-1 / 1133 | KQ | CAL | 10% 282 | 2.5 mS @ 20°C / N/A | | | | | Recheck 2-6-01, 1100 2.87 mS @ 20.2 °C |
| 2-1 / 1135 | KQ | CAL | 15% 282 | 3.7 mS @ 20°C / N/A | | | | | Recheck 2-6-01, 1100 4.14 mS @ 20.3 °C |
| 2-1 / 1140 | KQ | FIELD | MART INFLUENT | 3.48 mS @ 20°C / N/A | | N/A | INSTANT | INSTANT | pH - 8.0; conductivity measurements checked 3 times on same sample; yielded same result |
| 2-1 / 1145 | KQ | FIELD | MART EFFLUENT | | 5.96 mS @ 20°C / N/A | N/A | | | pH - 9.5; " " " |
| 2-6 / 1045 | KQ | CAL | 20% 282 | 6.13 mS @ 20.2°C / N/A | | | | | |
| 2-6 / 1055 | KQ | CAL | 18% 282 | 4.6 mS @ 20.4°C / N/A | | | | | |
| | | | | | | | | | |

Total Wastewater Flow into MART EQ-1™ (L) ~~492~~ 502 KQ (EQ-1 upper tank level); # of drums dumped into EQ-1 upper tank = ~2 1/2 (55 gal. each)

Total Wastewater Flow out of MART™ FPS (L) N/A ~2 1/4 drums (55 gal each)

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CAL - calibration
N/A - not applicable

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Engine Shop Wastewater

## Figure 4. Data Collection Form

Test # : 4 Date: 2-8-01 Batch # : 1
Revision # : 0 Revision Date: Original

Operation: MART EQ-1™ System
Technology Type: Water Recycling

| Date/ Time | Initials | Sample Number | Sample Location | MART EQ-1™ Influent Stream Conductivity/ Refractive Index (% Bx) | MART EQ-1™ Effluent /FPS Influent Stream Conductivity/ Refractive Index (% Bx) | MART FPS Effluent Stream Conductivity/ Refractive Index (% Bx) | Settling Time (minutes) | Flocculation Time (minutes) | Notes and Observations |
|---|---|---|---|---|---|---|---|---|---|
| 2-8/1345 | KQ | FIELD | MART INFLUENT | N/A / 1.4°@21.6°C (2-9-01, 1250) | | N/A | INSTANT | INSTANT | pH - 9.0; conductivity measurement checked 3 times on same sample; yielded same result. |
| 2-8/1405 | KQ | FIELD | MART EFFLUENT | | N/A / 1.2°@21.5°C (2-9-01, 1300) | N/A | | | pH - 9.0; " " " |
| 2-9/1150 | KQ | CAL | DI H2O | N/A / 0.0°@20°C | | | | | |
| 2-9/1200 | KQ | CAL | 20% DARACLEAN 235 | N/A / 3.25°@27°C | | | | | |
| 2-9/1210 | KQ | CAL | 100% DCN 235 | N/A / no reading (23°C) | | | | | |
| 2-9/1215 | KQ | CAL | 13% DCN 235 | N/A / 2°@28°C | | | | | |
| 2-9/1227 | KQ | CHECK | 5% DCN 235 | N/A / 0.7°@26.6°C | | | | | |
| 2-9/1237 | KQ | CHECK | 10% DCN 235 | N/A / 1.5°@24.7°C | | | | | |
| 2-9/1246 | KQ | CHECK | 15% DCN 235 | N/A / 2.2°@23.1°C | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Total Wastewater Flow into MART EQ-1™ (L) 436 (using level on MART EQ-1 upper tank)

Total Wastewater Flow out of MART™ FPS (L) N/A (~2 drums - 55 gal. each)

CAL - calibration
N/A - not applicable

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# APPENDIX B

# PRECISION CALCULATIONS

# PRECISION CALCULATIONS

| Laboratory ID | *CTC* ID | Parameter | Units | Sample Value | Duplicate Value | RPD % | RPD % Limits | RPD Met Y/N |
|---|---|---|---|---|---|---|---|---|
| 01-A001411 | EC01 | Alkalinity | mg/L | 280 | 300 | 8.9 | <10 | Y |
| 01-A001412 | EC02 | Alkalinity | mg/L | 300 | 310 | 3.3 | <10 | Y |
| 01-A001421 | EC16 | Alkalinity | mg/L | 260 | 240 | 8.0 | <10 | Y |
| 01-A001422 | EC18 | TSS | mg/L | 53.0 | 52.0 | 1.9 | <19 | Y |
| 01-A001424 | EC21 | Total Metals – Ba | mg/L | 0.0034 | 0.0034 | 0.0 | <20 | Y |
| 01-A001424 | EC21 | Total Metals – Cd | mg/L | 0.360 | 0.360 | 0.0 | <20 | Y |
| 01-A001424 | EC21 | Total Metals – Cr | mg/L | <0.001 | <0.001 | 0.0 | <15 | Y |
| 01-A001424 | EC21 | Total Metals – Cu | mg/L | 0.035 | 0.036 | 2.8 | <20 | Y |
| 01-A001424 | EC21 | Total Metals – Ni | mg/L | 0.940 | 0.940 | 0.0 | <18 | Y |
| 01-A001424 | EC21 | Total Metals – Pb | mg/L | <0.01 | <0.01 | 0.0 | <20 | Y |
| 01-A001484 | EC25 | Total O&G | mg/L | 28.0 | 33.0 | 16.3 | <22 | Y |
| 01-A001482 | EC28 | Total O&G | mg/L | 39.0 | 34.0 | 13.7 | <22 | Y |
| 01-A001776 | EC29 | Total O&G | µg/g | 120,000.0 | 110,000.0 | 8.7 | <22 | Y |
| 01-A001793 | EC42 | Total O&G | mg/L | 13 | 13 | 0.0 | <22 | Y |
| 01-A002110 | ESM03 | Total O&G | mg/L | 8600.0 | 9400.0 | 8.9 | <22 | Y |
| 01-A001775 | ECM04 | Total Metals – Ba | mg/L | 0.0506 | 0.0570 | 2.8 | <20 | Y |
| 01-A001775 | ECM04 | Total Metals – Cd | mg/L | <0.0005 | <0.0005 | 0.0 | <20 | Y |
| 01-A001775 | ECM04 | Total Metals – Cu | mg/L | 0.175 | 0.173 | 1.1 | <20 | Y |
| 01-A001775 | ECM04 | Total Metals – Ni | mg/L | <0.005 | <0.005 | 0.0 | <18 | Y |
| 01-A001775 | ECM04 | Total Metals – Pb | mg/L | <0.01 | <0.01 | 0.0 | <20 | Y |
| 01-A002110 | ESM03 | Total O&G | mg/L | 8600 | 9400 | 8.9 | <22 | Y |
| 01-A002352 | ES05 | Total O&G | mg/L | 1600.0 | 1700.0 | 6.1 | <22 | Y |
| 01-A002361 | ES08 | Total Metals – Ba | mg/L | 0.017 | 0.016 | 9.7 | <20 | Y |
| 01-A002361 | ES08 | Total Metals – Cd | mg/L | 11.7 | 11.7 | 0.0 | <20 | Y |
| 01-A002361 | ES08 | Total Metals – Cr | mg/L | <0.001 | <0.001 | 0.0 | <25 | Y |
| 01-A002361 | ES08 | Total Metals – Cu | mg/L | 1.13 | 1.13 | 2.7 | <20 | Y |
| 01-A002361 | ES08 | Total Metals – Ni | mg/L | 1.11 | 1.10 | 0.9 | <18 | Y |
| 01-A002361 | ES08 | Total Metals – Pb | mg/L | 0.13 | 0.12 | 8.0 | <20 | Y |
| 01-A002364 | ES18 | TCLP Metals – As | mg/L | <0.03 | <0.03 | 0.0 | <25 | Y |
| 01-A002364 | ES18 | TCLP Metals – Ba | mg/L | <1.0 | <1.0 | 0.0 | <21 | Y |
| 01-A002364 | ES18 | TCLP Metals – Cd | mg/L | 0.99 | 0.96 | 3.1 | <20 | Y |
| 01-A002364 | ES18 | TCLP Metals – Cr | mg/L | <0.1 | <0.1 | 0.0 | <25 | Y |
| 01-A002364 | ES18 | TCLP Metals – Pb | mg/L | <0.1 | <0.1 | 0.0 | <25 | Y |
| 01-A002364 | ES18 | TCLP Metals –- Hg | mg/L | <0.01 | <0.01 | 0.0 | <20 | Y |
| 01-A002364 | ES18 | TCLP Metals –- Se | mg/L | <0.05 | <0.05 | 0.0 | <20 | Y |
| 01-A002364 | ES18 | TCLP Metals –- Ag | mg/L | <0.05 | <0.05 | 0.0 | <20 | Y |
| 01-A002364 | ES18 | TCLP Metals – Cu | mg/L | 0.18 | 0.16 | 12.0 | <25 | Y |
| 01-A002364 | ES18 | TCLP Metals – Ni | mg/L | 0.09 | 0.09 | 0.0 | <25 | Y |
| 01-A002364 | ES18 | TCLP Metals – Zn | mg/L | 0.30 | 0.30 | 0.0 | <22 | Y |
| 01-A009212 | AGE 21 | Glycol Ether | mg/L | 660 | 630 | 3.1 | <10 | Y |
| 01-A009194 | AGE 16 | Total Metals – Ba | mg/L | 0.0086 | 0.0086 | 3.4 | <20 | Y |
| 01-A009194 | AGE 16 | Total Metals – Cd | mg/L | 0.354 | 0.349 | 1.4 | <20 | Y |
| 01-A009194 | AGE 16 | Total Metals – Cr | mg/L | <0.001 | <0.001 | 0.0 | <25 | Y |
| 01-A009194 | AGE 16 | Total Metals – Cu | mg/L | 0.258 | 0.258 | 0.0 | <20 | Y |
| 01-A009194 | AGE 16 | Total Metals – Ni | mg/L | 0.772 | 0.770 | 0.0 | <18 | Y |
| 01-A009194 | AGE 16 | Total Metals – Pb | mg/L | 1.12 | 1.11 | 0.9 | <20 | Y |
| 01-A009203 | AGE 11 | O&G Solid | ug/g | 9000 | 8600 | 4.5 | <22 | Y |
| 01-A009200 | AGE 12 | Total Metals – Ba | ug/g | 100 | 102 | 2.0 | <20 | Y |
| 01-A009200 | AGE 12 | Total Metals – Cd | ug/g | 3.60 | 3.60 | 0.0 | <20 | Y |
| 01-A009200 | AGE 12 | Total Metals – Cr | ug/g | 28.7 | 28.7 | 0.4 | <25 | Y |
| 01-A009200 | AGE 12 | Total Metals – Cu | ug/g | 45.1 | 47.7 | 5.6 | <20 | Y |
| 01-A009200 | AGE 12 | Total Metals – Ni | ug/g | 18.9 | 19.0 | 0.5 | <18 | Y |
| 01-A009200 | AGE 12 | Total Metals – Pb | ug/g | 45.5 | 45.3 | 0.4 | <20 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – As | mg/L | <0.03 | <0.03 | 0.0 | <25 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Ba | mg/L | <1.0 | <1.0 | 0.0 | <21 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Cd | mg/L | 0.11 | 0.11 | 0.0 | <20 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Cr | mg/L | <0.1 | <0.1 | 0.0 | <25 | Y |

| Laboratory ID | *CTC* ID | Parameter | Units | Sample Value | Duplicate Value | RPD % | RPD % Limits | RPD Met Y/N |
|---|---|---|---|---|---|---|---|---|
| 01-A009201 | AGE 14 | TCLP Metals – Pb | mg/L | <0.1 | <0.1 | 0.0 | <25 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Hg | mg/L | <0.01 | <0.01 | 0.0 | <20 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Se | mg/L | <0.05 | <0.05 | 0.0 | <20 | Y |
| 01-A009201 | AGE 14 | TCLP Metals –-Ag | mg/L | <0.05 | <0.05 | 0.0 | <20 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Cu | mg/L | 0.10 | 0.01 | 0.0 | <25 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Ni | mg/L | 0.07 | 0.08 | 13.0 | <25 | Y |
| 01-A009201 | AGE 14 | TCLP Metals – Zn | mg/L | 40.0 | 32.0 | 32 | <22 | N |

# APPENDIX C

# ACCURACY CALCULATIONS

# ACCURACY CALCULATIONS

| *CTC* ID | Parameter | Units | Sample Value | Sample +Spike Value | Spike Value | Recovery % | Target % Recovery | Accuracy Met? Y/N |
|---|---|---|---|---|---|---|---|---|
| EC21 | Total Metals – Ba | mg/L | 0.0034 | 0.910 | 0.900 | 101 | 85-115 | Y |
| EC21 | Total Metals – Cd | mg/L | 0.360 | 1.34 | 0.900 | 109 | 85-115 | Y |
| EC21 | Total Metals – Cr | mg/L | <0.001 | 0.850 | 0.900 | 94.4 | 80-120 | Y |
| EC21 | Total Metals – Cu | mg/L | 0.035 | 1.08 | 1.00 | 104 | 80-120 | Y |
| EC21 | Total Metals – Ni | mg/L | 0.940 | 1.73 | 0.900 | 87.8 | 80-120 | Y |
| EC21 | Total Metals – Pb | mg/L | <0.01 | 0.17 | 0.18 | 94.4 | 85-115 | Y |
| ES16 | Total Metals – Ba | mg/L | 0.0035 | 0.910 | 1.00 | 87.5 | 85-115 | Y |
| ES16 | Total Metals – Cr | mg/L | <0.001 | 0.900 | 1.00 | 90.0 | 80-120 | Y |
| ES16 | Total Metals – Cu | mg/L | 1.04 | 1.99 | 1.00 | 95 | 80-120 | Y |
| ES16 | Total Metals – Ni | mg/L | 1.08 | 1.90 | 1.00 | 82.0 | 80-120 | Y |
| ES16 | Total Metals – Pb | mg/L | 0.12 | 0.30 | 0.20 | 90.0 | 85-115 | Y |
| ES17 | TCLP – As | mg/L | <0.03 | 0.19 | 0.20 | 95.0 | 80-120 | Y |
| ES17 | TCLP – Ba | mg/L | <1.0 | 1.0 | 1.0 | 100.0 | 80-120 | Y |
| ES17 | TCLP – Cd | mg/L | 1.1 | 2.0 | 1.0 | 90.0 | 80-120 | Y |
| ES17 | TCLP – Cr | mg/L | <0.01 | 0.90 | 1.0 | 90.0 | 75-125 | Y |
| ES17 | TCLP – Pb | mg/L | <0.1 | 0.20 | 0.20 | 100.0 | 75-125 | Y |
| ES17 | TCLP – Hg | mg/L | <0.01 | 0.20 | 0.20 | 100.0 | 80-120 | Y |
| ES17 | TCLP – Se | mg/L | <0.05 | 0.21 | 0.20 | 105.0 | 75-125 | Y |
| ES17 | TCLP – Ag | mg/L | <0.05 | 0.20 | 0.20 | 100.0 | 80-120 | Y |
| ES17 | TCLP – Cu | mg/L | 0.21 | 1.2 | 1.0 | 99.0 | 75-125 | Y |
| ES17 | TCLP – Ni | mg/L | 0.10 | 0.98 | 1.0 | 88.0 | 82-118 | Y |
| ES17 | TCLP – Zn | mg/L | 0.33 | 1.20 | 1.0 | 87.0 | 82-118 | Y |
| AGE 07 | O&G Water | mg/L | 410 | 500 | 100 | 90.0 | 75-125 | Y |
| AGE 19 | O&G Water | mg/L | 130 | 210 | 100 | 80.0 | 75-125 | Y |
| AGE 11 | O&G Solid | ug/L | 9000 | 9400 | 500 | 80 | 75-125 | Y |
| AGE 11 | O&G Solid | ug/L | 9000 | 9400 | 500 | 80 | 75-125 | Y |
| AGE 17 | Total Metals – Ba | mg/L | 0.00 | 1.14 | 1.00 | 113 | 85-115 | Y |
| AGE 17 | Total Metals – Ba | mg/L | 0.00 | 1.20 | 1.00 | 119 | 85-115 | N |
| AGE 17 | Total Metals – Cd | mg/L | 0.351 | 0.537 | 0.200 | 93.0 | 85-115 | Y |
| AGE 17 | Total Metals – Cd | mg/L | 0.351 | 0.530 | 0.200 | 89.5 | 85-115 | Y |
| AGE 17 | Total Metals – Cr | mg/L | <0.001 | 1.15 | 1.00 | 115 | 80-120 | Y |
| AGE 17 | Total Metals – Cr | mg/L | <0.001 | 1.10 | 1.00 | 110 | 80-120 | Y |
| AGE 17 | Total Metals – Cu | mg/L | 0.264 | 1.39 | 1.00 | 113 | 80-120 | Y |
| AGE 17 | Total Metals – Cu | mg/L | 0.264 | 1.41 | 1.00 | 115 | 80-120 | Y |
| AGE 17 | Total Metals – Ni | mg/L | 0.779 | 1.84 | 1.00 | 106 | 80-120 | Y |
| AGE 17 | Total Metals – Ni | mg/L | 0.779 | 1.90 | 1.00 | 112 | 80-120 | Y |
| AGE 17 | Total Metals – Pb | mg/L | 1.10 | 1.30 | 0.20 | 100 | 85-115 | Y |
| AGE 17 | Total Metals – Pb | mg/L | 1.10 | 1.34 | 0.20 | 120 | 85-115 | N |
| AGE 12 | Total Metals Solid – Ba | ug/L | 102 | 350 | 250 | 99.2 | 80-120 | Y |
| AGE 12 | Total Metals Solid – Ba | ug/L | 102 | 384 | 300 | 94.0 | 80-120 | Y |
| AGE 12 | Total Metals Solid – Cd | ug/L | 3.60 | 54.0 | 50.0 | 101. | 80-120 | Y |
| AGE 12 | Total Metals Solid – Cd | ug/L | 3.60 | 55.0 | 60.0 | 85.7 | 80-120 | Y |
| AGE 12 | Total Metals Solid – Cr | ug/L | 28.7 | 72.0 | 50.0 | 86.6 | 80-120 | Y |
| AGE 12 | Total Metals Solid – Cr | ug/L | 28.7 | 81.0 | 60.0 | 87.2 | 80-120 | Y |
| AGE 12 | Total Metals Solid – Cu | ug/L | 45.1 | 293. | 250 | 99.2 | 75-125 | Y |
| AGE 12 | Total Metals Solid – Cu | ug/L | 45.1 | 289. | 300 | 81.3 | 75-125 | Y |
| AGE 12 | Total Metals Solid – Ni | ug/L | 18.9 | 345. | 250 | 130. | 82-118 | N |
| AGE 12 | Total Metals Solid – Ni | ug/L | 18.9 | 350. | 300 | 110. | 82-118 | Y |
| AGE 12 | Total Metals Solid – Pb | ug/L | 45.5 | 97.0 | 50.0 | 103. | 80-120 | Y |
| AGE 12 | Total Metals Solid – Pb | ug/L | 45.5 | 95.0 | 60.0 | 82.5 | 80-120 | Y |
| AGE 14 | TCLP – As | mg/L | <0.03 | 0.23 | 0.20 | 115. | 80-120 | Y |
| AGE 14 | TCLP – As | mg/L | <0.03 | 0.26 | 0.25 | 104. | 80-120 | Y |
| AGE 14 | TCLP – Ba | mg/L | <1.0 | 1.2 | 1.0 | 120 | 80-120 | Y |
| AGE 14 | TCLP – Ba | mg/L | <1.0 | 1.6 | 1.5 | 107 | 80-120 | Y |
| AGE 14 | TCLP – Cd | mg/L | 0.12 | 0.32 | 0.20 | 100 | 80-120 | Y |
| AGE 14 | TCLP – Cd | mg/L | 0.12 | 0.35 | 0.25 | 92.0 | 80-120 | Y |
| AGE 14 | TCLP – Cr | mg/L | <0.01 | 1.2 | 1.5 | 120 | 75-125 | Y |

| *CTC* ID | Parameter | Units | Sample Value | Sample +Spike Value | Spike Value | Recovery % | Target % Recovery | Accuracy Met? Y/N |
|---|---|---|---|---|---|---|---|---|
| AGE 14 | TCLP– Cr | mg/L | <0.01 | 1.4 | 1.5 | 93.3 | 75-125 | Y |
| AGE 14 | TCLP– Pb | mg/L | <0.1 | 0.20 | 0.20 | 100. | 75-125 | Y |
| AGE 14 | TCLP– Pb | mg/L | <0.1 | 0.22 | 0.25 | 88.0 | 75-125 | Y |
| AGE 14 | TCLP– Hg | mg/L | 0.01 | 0.48 | 0.50 | 94.0 | 80-120 | Y |
| AGE 14 | TCLP– Hg | mg/L | 0.01 | 0.47 | 0.50 | 92.0 | 80-120 | Y |
| AGE 14 | TCLP– Se | mg/L | <0.05 | 0.24 | 0.20 | 120. | 75-125 | Y |
| AGE 14 | TCLP– Se | mg/L | <0.05 | 0.29 | 0.25 | 116. | 75-125 | Y |
| AGE 14 | TCLP– Ag | mg/L | <0.05 | 0.58 | 0.50 | 116. | 80-120 | Y |
| AGE 14 | TCLP– Ag | mg/L | <0.05 | 0.47 | 0.50 | 94.0 | 80-120 | Y |
| AGE 14 | TCLP– Cu | mg/L | 0.10 | 1.2 | 1.0 | 110. | 75-125 | Y |
| AGE 14 | TCLP– Cu | mg/L | 0.10 | 1.5 | 1.5 | 93.3 | 75-125 | Y |
| AGE 14 | TCLP– Ni | mg/L | 0.07 | 1.2 | 1.0 | 113 | 82-118 | Y |
| AGE 14 | TCLP– Ni | mg/L | 0.07 | 1.3 | 1.5 | 82.0 | 82-118 | Y |
| AGE 14 | TCLP – Zn | mg/L | 1.2 | 2.2 | 1.0 | 100 | 82-118 | Y |
| AGE 14 | TCLP – Zn | mg/L | 1.2 | 2.5 | 1.5 | 86.7 | 82-118 | Y |

# APPENDIX D

# REPRESENTATIVENESS CALCULATIONS

| *CTC* ID | Parameter | Units | Sample Value | Duplicate *CTC* ID | Duplicate Value | % Difference | RPD % Limits | RPD Met Y/N |
|---|---|---|---|---|---|---|---|---|
| **Engine Cleaner** | | | | | | | | |
| EC 01 | Alkalinity | mg/L | 280 | EC 02 | 300 | 6.7 | 10 | Y |
| EC 04 | TSS | mg/L | 370 | EC 05 | 370 | 0.0 | 20 | Y |
| EC 07 | Barium | mg/L | 0.17 | EC 09 | 0.17 | 0.0 | 20 | Y |
| EC 07 | Cadmium | mg/L | 6.5 | EC 09 | 6.5 | 0.0 | 20 | Y |
| EC 07 | Chromium | mg/L | 0.2 | EC 09 | 0.2 | 0.0 | 15 | Y |
| EC 07 | Copper | mg/L | 0.35 | EC 09 | 0.35 | 0.0 | 20 | Y |
| EC 07 | Nickel | mg/L | 7.5 | EC 09 | 7.5 | 0.0 | 18 | Y |
| EC 07 | Lead | mg/L | 0.08 | EC 09 | 0.08 | 0.0 | 20 | Y |
| EC 10-11 | Liq. O&G | mg/L | 370 | EC 12-13 | 695 | 69.5 | 22 | N |
| EC 15 | Alkalinity | mg/L | 260 | EC 16 | 260 | 0.0 | 10 | Y |
| EC 18 | TSS | mg/L | 53 | EC 19 | 54 | 1.9 | 20 | Y |
| EC 21 | Barium | mg/L | 0.0034 | EC 22 | 0.0039 | 13.7 | 20 | Y |
| EC 21 | Cadmium | mg/L | 0.36 | EC 22 | 0.36 | 0.0 | 20 | Y |
| EC 21 | Chromium | mg/L | <0.001 | EC 22 | <0.001 | 0.0 | 15 | Y |
| EC 21 | Copper | mg/L | 0.035 | EC 22 | 0.035 | 0.0 | 20 | Y |
| EC 21 | Nickel | mg/L | 0.94 | EC 22 | 0.93 | 1.1 | 18 | Y |
| EC 21 | Lead | mg/L | <0.01 | EC 22 | <0.01 | 0.0 | 20 | Y |
| EC 25-26 | Liq. O&G | mg/L | 26 | EC 27-28 | 33.5 | 25.2 | 22 | N |
| EC 30 | Solid Barium | µg/g | 230 | EC 31 | 180 | 24.4 | 21 | N |
| EC 30 | Solid Cadmium | µg/g | 720 | EC 31 | 840 | 15.4 | 20 | Y |
| EC 30 | Solid Chromium | µg/g | 39 | EC 31 | 36 | 8 | 25 | Y |
| EC 30 | Solid Copper | µg/g | 39 | EC 31 | 41 | 5 | 25 | Y |
| EC 30 | Solid Nickel | µg/g | 880 | EC 31 | 950 | 7.7 | 25 | Y |
| EC 30 | Solid Lead | µg/g | 28 | EC 31 | 31 | 10.2 | 25 | Y |
| EC 30 | Solid O&G | µg/g | 70000 | EC 31 | 35000 | 66.6 | 22 | N |
| EC 29 | TCIP Arsenic | mg/L | <0.03 | EC 30 | <0.03 | 0.0 | 35 | Y |
| EC 29 | TCLP Barium | mg/L | <1.0 | EC 30 | <1.0 | 0.0 | 35 | Y |
| EC 29 | TCLP Cadmium | mg/L | 8.8 | EC 30 | 9.0 | 15.4 | 35 | Y |
| EC 29 | TCLP Chromium | mg/L | <0.1 | EC 30 | <0.1 | 0.0 | 35 | Y |
| EC 29 | TCLP Copper | mg/L | 0.04 | EC 30 | 0.04 | 0.0 | 35 | Y |
| EC 29 | TCLP Lead | mg/L | <0.1 | EC 30 | <0.1 | 0.0 | 35 | Y |
| EC 29 | TCLP Mercury | mg/L | <0.01 | EC 30 | <0.01 | 0.0 | 35 | Y |
| EC 29 | TCLP Nickel | mg/L | 5.7 | EC 30 | 6.6 | 14.6 | 35 | Y |
| EC 29 | TCLP Selenium | mg/L | <0.05 | EC 30 | <0.05 | 0.0 | 35 | Y |
| EC 29 | TCLP Silver | mg/L | <0.05 | EC 30 | <0.05 | 0.0 | 35 | Y |
| EC 29 | TCLP Zinc | mg/L | 1.2 | EC 30 | 1.6 | 28.6 | 35 | Y |
| EC 32 | Barium | mg/L | 0.0051 | EC 33 | 0.0045 | 12.5 | 20 | Y |
| EC 32 | Cadmium | mg/L | 0.13 | EC 33 | 0.14 | 7.4 | 20 | Y |
| EC 32 | Chromium | mg/L | <0.001 | EC 33 | <0.001 | 0.0 | 15 | Y |
| EC 32 | Copper | mg/L | 0.017 | EC 33 | 0.015 | 12.5 | 20 | Y |
| EC 32 | Nickel | mg/L | 0.64 | EC 33 | 0.67 | 4.6 | 18 | Y |
| EC 32 | Lead | mg/L | <0.01 | EC 33 | <0.01 | 0.0 | 20 | Y |
| EC 35 | Alkalinity | mg/L | 22 | EC 36 | 20 | 9.5 | 10 | Y |
| EC 38 | TSS | mg/L | 15 | EC 39 | 26 | 53.7 | 20 | N |
| EC 41-42 | O&G | mg/L | 12.5 | EC 43-44 | 11.5 | 9 | 22 | Y |

**REPRESENTATIVENESS CALCULATIONS**

| *CTC* ID | Parameter | Units | Sample Value | Duplicate *CTC* ID | Duplicate Value | % Difference | RPD % Limits | RPD Met Y/N |
|---|---|---|---|---|---|---|---|---|
| **Engine Shop Part Cleaner** | | | | | | | | |
| ES 01 | Alkalinity | mg/L | 2000 | ES 02 | 2000 | 0.0 | 10 | Y |
| ES 03 | TSS | mg/L | 250 | EC 04 | 250 | 0.0 | 20 | Y |
| ES 05 | O&G | mg/L | 1600 | ES 06 | 1600 | 0.0 | 22 | Y |
| ES 07 | Barium | mg/L | 0.18 | ES 08 | 0.17 | 9.7 | 20 | Y |
| ES 07 | Cadmium | mg/L | 12 | ES 08 | 11.7 | 2.5 | 20 | Y |
| ES 07 | Chromium | mg/L | <0.001 | ES 08 | <0.001 | 0.0 | 15 | Y |
| ES 07 | Copper | mg/L | 1.1 | ES 08 | 1.13 | 2.7 | 20 | Y |
| ES 07 | Nickel | mg/L | 1.8 | ES 08 | 1.11 | 47.5 | 18 | N |
| ES 07 | Lead | mg/L | 0.12 | ES 08 | 0.13 | 8 | 20 | Y |
| ES 09 | Alkalinity | mg/L | 2000 | ES 10 | 2000 | 0.0 | 10 | Y |
| ES 11 | TSS | mg/L | 140 | ES12 | 180 | 25 | 20 | N |
| ES 13 | O&G | mg/L | 1000 | ES 14 | 1100 | 9.5 | 22 | Y |
| ES 15 | Barium | mg/L | 0.012 | ES 16 | 0.035 | 97.8 | 20 | N |
| ES 15 | Cadmium | mg/L | 11 | ES 16 | 11 | 0.0 | 20 | Y |
| ES 15 | Chromium | mg/L | <0.001 | ES 16 | <0.001 | 0.0 | 15 | Y |
| ES 15 | Copper | mg/L | 1.2 | ES 16 | 1.0 | 9.5 | 20 | Y |
| ES 15 | Nickel | mg/L | 1.1 | ES 16 | 1.1 | 0.0 | 18 | Y |
| ES 15 | Lead | mg/L | 0.11 | ES 16 | 0.12 | 8.7 | 20 | Y |
| ES 17 | Solid Barium | µg/g | 220 | ES 18 | 160 | 40.9 | 21 | N |
| ES 17 | Solid Cadmium | µg/g | 160 | ES 18 | 150 | 6.5 | 20 | Y |
| ES 17 | Solid Chromium | µg/g | 4.2 | ES 18 | 11 | 89.5 | 25 | N |
| ES 17 | Solid Copper | µg/g | 140 | ES 18 | 160 | 6.9 | 25 | Y |
| ES 17 | Solid Nickel | µg/g | 20 | ES 18 | 18 | 10.5 | 25 | Y |
| ES 17 | Solid Lead | µg/g | 40 | ES 18 | 35 | 13.3 | 25 | Y |
| ES 17 | Solid O&G | µg/g | 620 | ES 18 | 410 | 40.8 | 22 | N |
| ES 17 | TCIP Arsenic | mg/L | <0.03 | ES 18 | <0.03 | 0.0 | 35 | Y |
| ES 17 | TCLP Barium | mg/L | <1.0 | ES 18 | <1.0 | 0.0 | 35 | Y |
| ES 17 | TCLP Cadmium | mg/L | 1.1 | ES 18 | 0.99 | 10.5 | 35 | Y |
| ES 17 | TCLP Chromium | mg/L | <0.1 | ES 18 | <0.1 | 0.0 | 35 | Y |
| ES 17 | TCLP Copper | mg/L | 0.21 | ES 18 | 0.18 | 15.4 | 35 | Y |
| ES 17 | TCLP Lead | mg/L | <0.1 | ES 18 | <0.1 | 0.0 | 35 | Y |
| ES 17 | TCLP Mercury | mg/L | <0.01 | ES 18 | <0.01 | 0.0 | 35 | Y |
| ES 17 | TCLP Nickel | mg/L | 0.10 | ES 18 | 0.09 | 10.5 | 35 | Y |
| ES 17 | TCLP Selenium | mg/L | <0.05 | ES 18 | <0.05 | 0.0 | 35 | Y |
| ES 17 | TCLP Silver | mg/L | <0.05 | ES 18 | <0.05 | 0.0 | 35 | Y |
| ES 17 | TCLP Zinc | mg/L | 0.33 | ES 18 | 0.3 | 9.5 | 35 | Y |
| **AGE Part Cleaner** | | | | | | | | |
| AGE 01 | Alkalinity | mg/L | 660 | AGE 02 | 550 | 19.1 | 10 | N |
| AGE 01 | TSS | mg/L | 830 | AGE 02 | 700 | 17.0 | 20 | Y |
| AGE 03 | Glycol Ether | mg/L | 660 | AGE 04 | 640 | 3.1 | 10 | Y |
| AGE 05 | Liq. O&G | mg/L | 390 | AGE 06 | 390 | 0.0 | 22 | Y |
| AGE 05 | Liq. O&G | mg/L | 390 | AGE 07 | 410 | 5.0 | 22 | Y |
| AGE 08 | Barium | mg/L | 1.4 | AGE 09 | 1.4 | 0.0 | 20 | Y |
| AGE 08 | Cadmium | mg/L | 0.40 | AGE 09 | 0.42 | 4.9 | 20 | Y |
| AGE 08 | Chromium | mg/L | 0.72 | AGE 09 | 0.73 | 1.4 | 15 | Y |
| AGE 08 | Copper | mg/L | 1.5 | AGE 09 | 1.4 | 0.0 | 20 | Y |
| AGE 08 | Nickel | mg/L | 1.0 | AGE 09 | 1.0 | 0.0 | 18 | Y |

## REPRESENTATIVENESS CALCULATIONS

| *CTC* ID | Parameter | Units | Sample Value | Duplicate *CTC* ID | Duplicate Value | % Difference | RPD % Limits | RPD Met Y/N |
|---|---|---|---|---|---|---|---|---|
| AGE 08 | Lead | mg/L | 2.3 | AGE 09 | 2.1 | 9.1 | 20 | Y |
| AGE 08 | Barium | mg/L | 1.4 | AGE 10 | 1.3 | 7.4 | 20 | Y |
| AGE 08 | Cadmium | mg/L | 0.40 | AGE 10 | 0.4 | 0.0 | 20 | Y |
| AGE 08 | Chromium | mg/L | 0.72 | AGE 09 | 0.69 | 4.3 | 15 | Y |
| AGE 08 | Copper | mg/L | 1.5 | AGE 10 | 1.4 | 6.9 | 20 | Y |
| AGE 08 | Nickel | mg/L | 1.0 | AGE 10 | 0.94 | 6.2 | 18 | Y |
| AGE 08 | Lead | mg/L | 2.3 | AGE 10 | 2.1 | 9.1 | 20 | Y |
| AGE 23 | Alkalinity | mg/L | 160 | AGE 24 | 200 | 10. | 10 | Y |
| AGE 23 | TSS | mg/L | 150 | AGE 24 | 170 | 12.5 | 20 | Y |
| AGE 21 | Glycol Ether | mg/L | 660 | AGE 22 | 650 | 1.5 | 10 | Y |
| AGE 18 | Liq. O&G | mg/L | 150 | AGE 19 | 130 | 14.2 | 22 | Y |
| AGE 18 | Liq. O&G | mg/L | 150 | AGE 20 | 130 | 14.2 | 22 | Y |
| AGE 15 | Barium | mg/L | 0.0098 | AGE 16 | 0.0089 | 13.0 | 20 | Y |
| AGE 15 | Cadmium | mg/L | 0.36 | AGE 16 | 0.354 | 2.8 | 20 | Y |
| AGE 15 | Chromium | mg/L | <0.001 | AGE 16 | <0.001 | 0.0 | 15 | Y |
| AGE 15 | Copper | mg/L | 0.26 | AGE 16 | 0.258 | 0.1 | 20 | Y |
| AGE 15 | Nickel | mg/L | 0.8 | AGE 16 | 0.772 | 3.8 | 18 | Y |
| AGE 15 | Lead | mg/L | 1.12 | AGE 16 | 1.12 | 0.0 | 20 | Y |
| AGE 15 | Barium | mg/L | 0.0098 | AGE 17 | 0.0099 | 1.0 | 20 | Y |
| AGE 15 | Cadmium | mg/L | 0.36 | AGE 17 | 0.35 | 2.8 | 20 | Y |
| AGE 15 | Chromium | mg/L | <0.001 | AGE 17 | <0.001 | 0.0 | 15 | Y |
| AGE 15 | Copper | mg/L | 0.26 | AGE 17 | 0.26 | 0.0 | 20 | Y |
| AGE 15 | Nickel | mg/L | 0.8 | AGE 17 | 0.76 | 2.5 | 18 | Y |
| AGE 15 | Lead | mg/L | 1.12 | AGE 17 | 1.1 | 0.0 | 20 | Y |
| AGE 11 | Solid O&G | µg/g | 9000 | AGE 12 | 12000 | 28.6 | 22 | N |
| AGE 11 | Solid Barium | µg/g | 110 | AGE 12 | 100 | 9.5 | 21 | Y |
| AGE 11 | Solid Cadmium | µg/g | 3.6 | AGE 12 | 3.6 | 0.0 | 20 | Y |
| AGE 11 | Solid Chromium | µg/g | 24. | AGE 12 | 28.7 | 18.9 | 25 | Y |
| AGE 11 | Solid Copper | µg/g | 39. | AGE 12 | 45.1 | 14.3 | 25 | Y |
| AGE 11 | Solid Nickel | µg/g | 16.0 | AGE 12 | 18.9 | 17.1 | 25 | Y |
| AGE 11 | Solid Lead | µg/g | 41. | AGE 12 | 45.5 | 11.5 | 25 | Y |
| AGE 13 | TCIP Arsenic | mg/L | <0.03 | AGE 14 | <0.03 | 0.0 | 35 | Y |
| AGE 13 | TCLP Barium | mg/L | <1.0 | AGE 14 | <1.0 | 0.0 | 35 | Y |
| AGE 13 | TCLP Cadmium | mg/L | 0.12 | AGE 14 | 0.11 | 8.7 | 35 | Y |
| AGE 13 | TCLP Chromium | mg/L | <0.1 | AGE 14 | <0.1 | 0.0 | 35 | Y |
| AGE 13 | TCLP Copper | mg/L | 0.1 | AGE 14 | 0.1 | 0.0 | 35 | Y |
| AGE 13 | TCLP Lead | mg/L | <0.1 | AGE 14 | <0.1 | 0.0 | 35 | Y |
| AGE 13 | TCLP Mercury | mg/L | <0.01 | AGE 14 | <0.01 | 0.0 | 35 | Y |
| AGE 13 | TCLP Nickel | mg/L | 0.07 | AGE 14 | 0.09 | 0.08 | 35 | Y |
| AGE 13 | TCLP Selenium | mg/L | <0.05 | AGE 14 | <0.05 | 0.0 | 35 | Y |
| AGE 13 | TCLP Silver | mg/L | <0.05 | AGE 14 | <0.05 | 0.0 | 35 | Y |
| AGE 13 | TCLP Zinc | mg/L | 1.2 | AGE 14 | 1.8 | 40.0 | 35 | N |

# APPENDIX E

# DIETHYLENE GLYCOL MONOBUTYL ETHER ANALYSIS

AM**TEST**
**LABORATORIES**

December 15, 2000

Concurrent Technology Corporation
Marion Rideout

Re: Glycol Analysis

At AMTest, we analyze glycol by GC/FIU. The method is one provided by Texaco 10 years ago, which they developed. We have been routinely using this method since then. The method uses a GC with FID detector and a DB wax column. Each sample was diluted with reagent alcohol (0.50 mL sample to 4.50 mL alcohol) and injected directly onto the column. The standard was provided by your client.

**ANALYSIS OF GLYCOLS FOR *CTC***

**I) Sample preparation**

1). Dilute 0.5 mL of sample to 5 mLs final volume with reagent alcohol.
2). Filter sample if needed to remove solid material through a 0.45 um Teflon filter.
3). Transfer approximately 2mLs to a GC vial for analysis.

**II) GC/Analysis**

1). GC Parameters

DB Wax Column 30 m O.53 um I.D. 1 um Film thickness

| | |
|---|---|
| Detector Temperature | 250 C |
| Injector Temperature | 200 C |
| Initial Temperature | 30 C |
| Initial Time | 5.00 min. |
| Rate | 5 C/min. |
| Final Temperature | 200 |
| Final Time | 0 min. |

2). Prepare 5 point standard curve covering the range of 5 ppm to 100 ppm.
3). Inject 2 ul of standards and samples.
4). Quantitate results based on the linear curve established
5). Sample exceeding the standard curve must be diluted and re-analyzed.