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**		
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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 179th 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 179th 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 179th 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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