THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

Concurrent Technologies Corporation

ETV VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**WASTEWATER TREATMENT**
APPLICATION:	**RINSE WATER RECYCLING**
TECHNOLOGY NAME:	**Hadwaco MVR Evaporator**
COMPANY:	**Hadwaco US, Inc.**
POC:	**David Thomas**
ADDRESS:	**2310 Peachford Road Atlanta, GA 30338** **PHONE: (770) 457-4429 FAX: (770) 457-4420**
E-MAIL:	**david.thomas@hadwaco.com**

The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups consisting of buyers, vendor organizations, 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 treatment system for processing wastewater containing dissolved metals. This verification statement provides a summary of the test results for the Hadwaco Mechanical Vapor Recompression (MVR) Evaporator.

VERIFICATION TEST DESCRIPTION

The Hadwaco MVR Evaporator was tested, under actual production conditions, processing copper pickling wastewater, at a test site in Canada. The verification test evaluated the ability of the Hadwaco MVR Evaporator to recycle wastewater and recover process chemistry.

The test plan was designed for four days of testing, and data were collected on three different streams:

?? Evaporator Feed (process rinse water)
?? Evaporator Distillate or Condensate (rinse water makeup)
?? Evaporator Concentrate (process makeup).

Electricity and water usage data were collected to perform the cost analysis.

TECHNOLOGY DESCRIPTION

The Hadwaco MVR Evaporator tested is a standard unit, which has a capacity of 92,500 gallons per day (gpd). The unit was permanently installed on a full-scale production line. The evaporator tested contains 24 individual heat transfer cartridges: each cartridge is comprised of 46 individual heat transfer elements. The metal-containing wastewater is pumped into the circulating stream. The circulated stream is pumped onto the heat transfer cartridge where the liquid boils, thus separating water (vapor) from the concentrating liquid. A part of the concentrating liquid is pumped off as concentrate and the rest is recirculated with some feed wastewater back to the heat transfer cartridge. MVR Evaporators recycle all vapors as heating steam by adding energy via vapor compression with high-pressure fans.

VERIFICATION OF PERFORMANCE

Grab samples were collected twice daily over a four-day period from the Hadwaco MVR Evaporator feed, condensate, and concentrate. Samples were analyzed to determine the chemical characteristics of the feed, condensate, and concentrate. The data from Hadwaco's MVR Evaporator in-process computer were used to obtain the flow rates of feed, condensate, and concentrate to determine evaporator workload, concentration factor, and recovery efficiency. Both the chemical characteristics and the flow rates were used to determine the mass balances and separation efficiencies.

Average analytical results for the chemical parameters are shown in **Table i.** Chemical parameters of concern are copper, lead, pH, sulfate, acidity (as $CaCO_3$), total suspended solids (TSS), and total dissolved solids (TDS).

	Analysis Method								
Sample	Total Suspended Solids mg/L (EPA 160.2)	Total Dissolved Solids mg/L (EPA 160.1)	pH* (EPA 150.1)	Copper mg/L (EPA 200.7)	Lead mg/L (EPA 200.7)	Acidity (as C_aCO_3) mg/L (EPA 305.1)	Sulfate mg/L (EPA 300.0)	Conductivity	Temp C?
#1 Day 1 Feed	<5.0	680	2.0	97.0	0.099	1100	1400	4.64 ms	51.8
#1 Day 1 Condensate	<5.0	46	1.9	1.9	<0.005	36	13.2	138.0 µs	25.2
#1 Day 1 Concentrate	50.0	23000	1.1	6800	2.700	37000	45000	>19.99 ms	54.8
#2 Day 1 Feed	12.0	2600	1.5	790	0.380	3400	6300	11.99 ms	42.6
#2 Day 1 Condensate	<5.0	28	3.7	1.9	<0.005	46	7.2	108.7 µs	37.8
#2 Day 1 Concentrate	69.0	27000	1.0	6400	2.600	45000	38000	>19.99 ms	53.8
#2 Day 1 Dup. Feed	15.0	3100	1.8	780	0.400	3600	3300	11.99 ms	42.6
#2 Day 1 Dup. Condensate	<5.0	50	3.2	2.0	<0.005	130	13.4	108.7 µs	37.8
#2 Day 1 Dup. Concentrate	78.0	25000	1.2	6700	<2.500	23000	46000	>19.99 ms	53.8
#1 Day 2 Feed	7.2	760	1.4	260	0.110	1300	1400	5.26 ms	42.9
#1 Day 2 Condensate	<5.0	50	1.9	3.0	<0.005	51	13.5	131.9 µs	46.5
#1 Day 2 Concentrate	89.0	34000	<1.0	8800	3.400	56000	50000	>19.9 ms	58.8
#2 Day 2 Feed	8.4	1100	2.3	220	0.098	1500	1500	6.07 ms	45.6
#2 Day 2 Condensate	<5.0	48	2.1	3.3	<0.005	28	15.0	146.4 µs	46.2
#2 Day 2 Concentrate	87.0	37000	<1.0	9300	3.400	50000	60000	>19.9 ms	49.9
#1 Day 3 Feed	<5.0	660	1.6	100	<0.050	870	980	4.01 ms	46.2
#1 Day 3 Condensate	<5.0	22	1.9	1.6	<0.005	17	6.4	103.9 µs	46.9
#1 Day 3 Concentrate	56.0	22000	1.0	4900	<2.500	34000	30000	>19.9 ms	56.9
#2 Day 3 Feed	<5.0	1100	1.8	240	0.078	2100	1900	7.89 ms	47.7
#2 Day 3 Condensate	<5.0	28	2.9	1.8	<0.005	54	9.1	108.7 µs	47.5
#2 Day 3 Concentrate	63.0	24000	1.0	5600	<2.500	36000	44000	>19.9 ms	51.7
#1 Day 4 Feed	5.2	740	1.6	150	<0.005	1100	1200	4.98 ms	48.0
#1 Day 4 Condensate	<5.0	92	1.8	1.8	<0.005	20	12.1	132.2 µs	48.2
#1 Day 4 Concentrate	85.0	33000	<1.0	6700	<2.500	50000	46000	>19.9 ms	55.8
#2 Day 4 Feed	9.2	1200	1.7	260	0.080	1900	1800	7.05 ms	48.3
#2 Day 4 Condensate	<5.0	30	2.2	1.7	<0.005	74	11.7	130.8 ms	50.3
#2 Day 4 Concentrate	91.0	80000	1.0	6800	<2.500	54000	60000	>19.9 ms	54.1

*pH units

Table i. Summary of Analytical Results

Mass Balance. The mass balances were calculated by adding condensate constituent mass and concentrate constituent mass and dividing by feed constituent mass for each day, then multiplying the results by 100 percent and are shown in **Table ii**. The mass balances for the first day were below the mass balance accuracy criterion of 75 percent to 125 percent. These values were low because the MVR Evaporator was operated in recycle mode (the condensate and concentrate streams were returned to the feed tank) due to a transfer pump between the process and the evaporator being out of service. For the other three days, the mass balances ranged from 78.9 percent (acidity – day 3) to 201.4 percent (TDS – day 4). The mass balances for the TDS were a little over 125 percent for day 2 and well over 125 percent for day 4. Over all, the mass balance calculations indicate that all of the mass can be accounted for within a reasonable error and the system was operating without major upset on days 2-4. The mass balance calculation is affected by normal concentration variations in the feed and concentration variations in the concentrate inherent in the operation of the evaporator. The mass balances for lead and TSS were not calculated because the feed concentration for them was below detection limits.

Date	Copper %	Sulfate %	TDS %	Acidity %
09/25/01	48.6	35.2	51.6	60.8
09/26/01	120.6	121.0	125.9	122.7
09/27/01	101.3	84.0	87.6	78.9
09/28/01	111.2	119.2	201.4	119.3

Table ii. Mass Balance

Evaporator Workload. The evaporator workload was determined by the volume of condensate recovered per day. The evaporator workload is shown in **Table iii**.

Date	Evaporator Workload L/day (gpd)
09/25/01	338,000 (89,300)
09/26/01	345,000 (91,100)
09/27/01	337,000 (89,000)
09/28/01	217,000 (57,300)*

*9/27/01 test was for 16 hours

Table iii. Evaporator Workload

Concentration Factor. The concentration factors were calculated on a daily basis as a quantitative measure of system performance. The concentration factors for the evaporator were calculated by dividing the feed volume by concentrate volume. The concentration factors range from 29.8 to 31.6 as shown in **Table iv.**

Date	Concentration Factor
09/25/01	30.9
09/26/01	31.6
09/27/01	30.8
09/28/01	29.8

Table iv. Concentration Factor

Recovery Efficiency. The recovery efficiency was determined by dividing the volume of water recovered as condensate by the volume of water in the feed and multiplying by 100 percent for each day. The recovery efficiencies for the evaporator range from 96.6 percent to 96.8 percent and are shown in **Table v.**

Date	Recovery Efficiency %
09/25/01	96.8
09/26/01	96.6
09/27/01	96.8
09/28/01	96.6

Table v. Recovery Efficiency

Separation Efficiency. The separation efficiencies were calculated on a daily basis. They were calculated by subtracting the condensate constituent mass from the feed constituent mass, dividing the result by the feed constituent mass times, and then multiply by 100 percent. Separation efficiencies for the parameters ranged from 93.9 percent (TDS – day 4) to 99.7 percent (Sulfate – day 1). The separation efficiencies are shown in **Table vi.**

Date	Copper %	Sulfate %	TDS %	Acidity %
09/25/01	99.6	99.7	97.8	98.2
09/26/01	98.7	99.1	94.9	97.3
09/27/01	99.0	99.5	97.3	97.7
09/28/01	99.2	99.2	93.9	97.0

Table vi. Separation Efficiency

Energy and Water Use. The power consumption of the Hadwaco MVR Evaporator unit was 12.0 kWh per 1000 liters of condensate produced. There were 152 liters of noncontact cooling water used per 1000 liters of condensate produced. To produce steam for the system, 1.9 kWh of power were required per 1000 liters of condensate.

Operation and Maintenance Labor Analysis. The labor costs are minimal because of the fully automated design; therefore, the operator was only required to make daily inspections of the unit and check the system operation parameters during the test. These tasks are projected to require a total of approximately three hours of operation and maintenance labor per week.

Cost of Operation. The costs of the operation are figured on the costs of producing a thousand liters of condensate. The energy cost is based on 13.9 kWh electricity per thousand liters of condensate at a cost of $0.015/kWh based on an exchange rate of $1.00 (Canadian) = $0.627 (US Dollars) as of 1/15/02. The energy cost calculated for a thousand liters of condensate is $0.209. The system noncontact cooling water cost is $0.029 per thousand liters of condensate. This is based on using 152 L of noncontact cooling water per thousand liters of condensate with a water cost of $0.194 per thousand liters. There was an expenditure of 1.6 hours of labor at a cost of $31.35/hour. Dividing by the total volume of condensate recovered. This results in labor cost of $0.041 per thousand liters of condensate. Total costs for a thousand liters of condensate during the test run is calculated by summing the individual cost elements: $0.209 + $0.029 +$0.041 = $0.279.

Environmental. The evaporator is operated as a totally automated closed-loop system; both the concentrate and condensate are returned to the process. The energy costs are very low because the system utilizes the latent heat in the condensing distillate and feed (feed temperature is approximately 46°C). The system uses no materials other than steam and noncontact cooling water. The only waste stream produced is noncontact cooling water.

Based on the host facility's seven days/forty-eight weeks of operation, the Hadwaco MVR Evaporator system is projected to eliminate the need to treat 116,600,000 L per year of process wastewater. In addition, 112,900,000 L of water per year is projected to be saved by using the condensate as makeup water for the process. The evaporator system produces a concentrate that allows the host facility to effectively electrowinn metallic copper for reclaiming. Thus, it is projected that the host facility evaporator system in combination with electrowinning could prevent approximately 23,900 kg/year of copper and 170,700 kg/year of sulfate from being treated as waste. The copper is recovered as metallic copper through electrowinning and sold as scrap metal, and a projected 99,700 L of recovered sulfuric acid is reused in the process.

SUMMARY

The test results show that the Hadwaco MVR Evaporator system provides an environmental benefit by evaporating the host facility wastewater for reuse within the process, thereby reducing the amount of fresh makeup water required each day. The Hadwaco MVR Evaporator system achieved a very high recovery of the treated water (96 percent). The major economic benefit associated with this technology is in reduced waste disposal costs and raw water purchase costs associated with the recycling of the wastewater back to the process. As with any technology selection, the end user must select appropriate wastewater treatment equipment and chemistry for a process that can meet their associated environmental restrictions, productivity, and water quality requirements.

Original Signed by:
E.Ttimothy Oppelt

E. Timothy Oppelt
Director
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency

Original Signed by:
Donn W. Brown

Donn W. Brown
Manager
P2 Metal Finishing Technologies Program
Concurrent Technologies Corporation