U.S. Environmental Protection Agency
Environmental Technology Verification Program
For Metal Finishing Pollution Prevention Technologies
Verification Test Plan

for the

Evaluation of Hydrometrics, Inc. High Efficiency Reverse Osmosis (HERO™) Industrial Wastewater Treatment System

Revision 0

June 15, 2001

Concurrent Technologies Corporation is the Verification Partner for the EPA ETV Metal Finishing Pollution Prevention Technologies Center under EPA Cooperative Agreement No. CR826492-01-0.

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Environmental Technology Verification for Metal Finishing Technologies Program (ETV-MF) Verification Test Plan for the Evaluation of Hydrometrics, Inc. High Efficiency Reverse Osmosis (HERO™) Industrial Wastewater Treatment System.

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ACRONYMS & ABBREVIATIONS

amp	Ampere(s)
ATC	Automated Temperature Compensated
C	Specific Conductivity
^oC	Degrees Celsius
cm	Centimeter
COC	Chain of Custody
CSR	Code of State Regulations
CTC	Concurrent Technologies Corporation
CWA	Clean Water Act
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ETV-MF	Environmental Technology Verification for Metal Finishing
FM&T	Federal Manufacturing & Technology
ft^2	Square Feet
ft^3	Cubic Feet
gal	Gallon
gfd	Gallons of Permeate Produced per Square Foot of Membrane per Day
gpd	Gallons per Day
gpm	Gallons per Minute
HDPE	High Density Polyethylene
HEM	Hexane Extractable Material
HERO™	High Efficiency Reverse Osmosis System
hp	Horsepower
hr)	Hour
Hz	hertz
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
ID	Identification
IDL	Instrument Detection Limit
KCP	Kansas City Plant
kWh	Kilowatt-Hour
JTA	Job Training Analysis
L	Liter
LM	Laboratory Manager
MBS	Metabisulfite
MDL	Method Detection Limit
mg	Milligram
mg/L	Milligrams per Liter
mL	Milliliter
MMTC	Michigan Manufacturing Technology Center
MP&M	Metal Products & Machinery
MRL	Method Reporting Limit
MS	Matrix Spike

ACRONYMS & ABBREVIATIONS (continued)

MSD	Matrix Spike Duplicate
MSDS	Material Safety Data Sheet
µg	Microgram
µS	Micro-siemens
NA	Not Applicable
O&G	Oils and Grease
O&M	Operating & Maintenance
ODP	Open Drip-Proof
P	Percent Recovery
PARCCS	Precision, Accuracy, Representability, Comparability, Completeness and Sensitivity
PM	Program Manager
POC	Point of Contact
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
ppm	Parts per Million
psi	Pounds per Square Inch
PVD	Physical Vapor Deposition
QA/QC	Quality Assurance/Quality Control
QMP	Quarterly Management Plan
R&D	Research & Development
RO	Reverse Osmosis
RPD	Relative Percent Difference
SAC	Strong Acid Cation
SP-	Sampling Point
SR	Sample Result
SSR	Spiked Sample Result
TDS	Total Dissolved Solids
TEFC	Totally Enclosed Fan-Cooled
TOC	Total Organic Carbon
TSA	Technical System Audit
TSS	Total Suspended Solids
U.S.	United States
VOC	Volatile Organic Carbon
WAC	Weak Acid Cation

1.0 INTRODUCTION

The purpose of this test plan is to document the objectives, procedures, equipment, and other aspects of testing that will be utilized at Honeywell Federal Manufacturing & Technology's (FM&T's) Kansas City Plant (KCP), in Kansas City, Missouri, during verification testing of a three-stage reverse osmosis wastewater treatment system manufactured by Hydrometrics, Inc. (Hydrometrics). Hydrometrics' High Efficiency Reverse Osmosis (HERO™) wastewater treatment system is a pollution prevention technology applicable to metal finishing operations that generate wastewater from chemical rinses and spent baths, as well as collected storm water and spill residues. This test plan has been prepared to evaluate the performance of the technology in conjunction with the U.S. Environmental Protection Agency's (EPA's) Environmental Technology Verification for Metal Finishing (ETV-MF) Program. The objective of the ETV-MF Program is to identify promising and innovative pollution prevention treatment technologies through EPA-supported performance verifications and to provide objective performance data to providers, purchasers, and permitters of environmental technologies.

Hydrometrics, founded in 1979 and located in Helena, Montana, distributes the HERO™ industrial wastewater treatment system, which uses a three-stage reverse osmosis treatment process to remove and concentrate metals for recovery while producing a high quality product water for recycle and reuse. The three steps involved in the HERO™ process are ion-exchange, membrane degasification, and reverse osmosis. The system reportedly recovers nearly 100 percent of valuable metals, which may be suitable for direct recycle back to the process as a liquid or recovered as scrap metal using traditional electrowinning technologies. Treated water produced in the process is reported to be high quality and may be suitable for direct recycle as process water make-up, cooling water make-up, boiler feed water, or direct discharge. The HERO™ technology was developed by Deb Mukhopadhyay in 1996 to provide ultra-pure water to the microelectronics industry. Since that time, the now-patented technology has been tested on several industrial wastewater applications in industries where large quantities of wastewater are typically generated.

FM&T is evaluating a 15 gallon per minute (gpm) pilot scale HERO™ system at the KCP, and upon successful completion of the evaluation, they have the option to install a full-scale 100-200 gpm unit, which will treat all KCP wastewater. The 15 gpm HERO™ system is commercially available from Hydrometrics, Inc. KCP is owned by the U.S. Department of Energy (DOE), and is operated by Honeywell FM&T. KCP manufactures a wide variety of products for national defense systems. More than 95 percent of the work done at the KCP is for the DOE. For over 50 years, the KCP has manufactured some of the DOE's most intricate and technically demanding products. They produce over 40 different lines of products ranging from semiconductors to semi-trailers, which include electronic, mechanical, engineered material, and plastics manufacturing technologies. The large size and wide array of operations associated with the KCP make it an ideal site for demonstrating the diversity of the HERO™ system for metal finishing industries in general.

This project will evaluate the ability of the Hydrometrics HERO™ system to treat and recycle the KCP's combined wastewater for reuse in the plant. A separate Hydrometrics copper recovery unit will also be evaluated in its ability to recover copper from a cyanide waste stream. Metal recovery is normally done within the HERO™ system, but due to precipitation and removal of the copper during a pretreatment step, the installation of a second ion exchange unit is required. This ion exchange unit uses identical resin to the integral HERO™ system ion exchange unit, but on a smaller scale, and must be installed before the KCP's conventional cyanide destruction pretreatment step. Evaluating and verifying the performance of the Hydrometrics system will be accomplished by collecting operational data and in-process samples for analysis. The resultant test data will be used to prepare a material balance and determine the efficiency of water treatment/reuse and metals recovery for a given set of operating conditions.

The test plan described in this document has been structured to allow the above objectives to be met using sound scientific principles. This document explains testing plans with respect to areas such as test methodology, procedures, parameters, and instrumentation. Section 5.0 describes Quality Assurance/Quality Control (QA/QC) requirements of this task that will ensure the accuracy of data. Also presented within this document are data interpretation procedures and hypothesized results. Worker health and safety considerations are covered in section 8.0.

This test plan will be available at the test site, and verification testing will be conducted in accordance with the test plan requirements.

1.1 Background

There are more than 15,000 companies in the U.S. that perform metal finishing operations. These companies discharge their process wastewaters either directly to waterways or indirectly to Publicly Owned Treatment Works (POTWs). Metal finishing generates more individual wastewater discharges than any other industrial category [Ref. 1]. Many pollutants contained in metal finishing process waters are toxic, so to comply with Clean Water Act (CWA) requirements, the wastewaters are treated before being discharged. Regulations, in general, require reduction of hexavalent chromium, oxidation of cyanides, removal of heavy metals, and pH control.

The KCP has several plating, coating, and other metal processing operations that generate wastewaters that are combined with other non-process industrial wastewaters and treated in a conventional on-site wastewater treatment system, and then discharged to a POTW. The HERO™ system will be installed before or after the conventional system to process the wastewater so it can be reused at KCP. Copper from the cyanide process rinse water will be concentrated in a separately installed recovery unit, and calculated using a copper mass balance on the influent and the effluent to this unit. The recycle of metal finishing wastewaters is of great importance, not only from a financial standpoint, but a regulatory standpoint as well. Many of the heavy metals found in metal finishing wastewaters are considered toxic by EPA. Heavy metals such as copper and chromium have also been identified as high priorities for reduction/elimination and off-site recovery from plating operations by the National Metal Finishing Research & Development (R&D) Plan, and are addressed in the Strategic Goals Program regarding toxic metals reduction/utilization.

Typical reverse osmosis (RO) wastewater treatment systems can be costly and difficult to operate. Membranes may foul easily and require replacement, organics in the wastewater are only moderately rejected, and costly anti-scalant additions and activated carbon pretreatment are often required. Conventional RO systems typically exhibit a low operating flux and a product water recovery of only 75 percent. Due to the high operating pH of the reverse osmosis step, Hydrometrics' HERO™ system is essentially immune to fouling, thus extending the membrane life and increasing the operating flux by up to two times that of conventional RO. The HERO™ system exhibits a higher rejection of organics, requires no anti-scalant additions, and has a product water recovery of up to 95 percent. This results in the potential for low-cost, zero-liquid discharge operations, or wastewater that meets most existing discharge permits. Recycling wastewater on-site and metals off-site reduces water consumption and discharge levels, resulting in lower water and waste disposal costs. The HERO™ system reportedly solves the problems normally associated with standard RO systems, and does so with reduced installation investment and operating costs.

1.2 Data Quality Objectives (DQO)

The systematic planning elements of the data quality objectives process identified in "Guidance for the Data Quality Objectives Process" (EPA QA/G-4, August 2000), were specifically utilized during preparation of this verification test plan. The project team, composed of representatives from *CTC*, the testing organization, the technology vendor, the host site, and the US EPA, who assisted in preparing this test plan, jointly developed: the test objectives, critical and non-critical measurements, the test matrix, sample quantity, type, and frequency, analytical methods, and quality assurance objectives to arrive at an optimized test designed to verify the performance of the technology.

2.0 TECHNOLOGY DESCRIPTION

2.1 Theory of Operation

The patented HERO™ process for which Hydrometrics is licensed combines "off-the-shelf" technologies to convert wastewater into reusable water. **Figure 1** shows a simplified diagram of the HERO™ process for wastewater purification.

In the first step of the HERO™ process, ion exchange removes ions that form scale. Removing the hardness from the wastewater results in a waste being generated as a concentrated brine solution. The second step is membrane degasification, which removes the buffering effect from carbon dioxide to lower caustic demands in the final step of the process. Carbon dioxide is the only byproduct of the second step, where the wastewater alkalinity is removed. The final step in the HERO™ process is reverse osmosis. The high pH of the wastewater entering this stage eliminates fouling of the RO membrane. A concentrated brine solution waste is generated from this step as well.

According to Hydrometrics, the combined, concentrated brine solutions from the HERO™ process represent a single waste stream, generally less than five percent of the feed stream and usually suitable for direct discharge to a POTW. Alternatively, the waste stream could be evaporated to dry solids, since the volume of water is greatly reduced compared to waste streams generated in a traditional RO system. Evaporation of the waste stream may help in becoming a zero-liquid discharging facility.

Hydrometrics claims the HERO™ system can handle more total suspended solids (TSS), oil & grease (O&G), residual chlorine, and biological activity than traditional RO systems. They have installed units capable of treating a broad range of wastewater streams with total dissolved solids (TDS) ranging up to 30,000 mg/L.

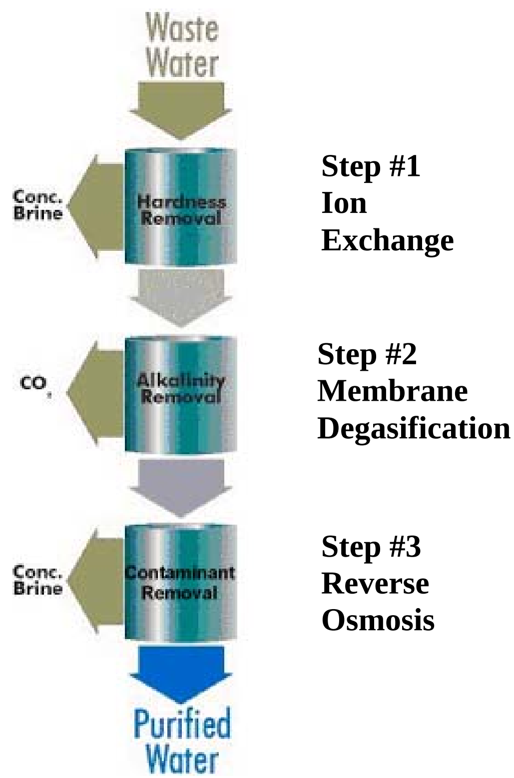

Figure 1: HERO™ Wastewater Treatment Diagram – Simplified

The diagram in **Figure 2** illustrates the reactions that typically take place within each step of the HERO™ process. Hydrometrics has designed permanently installed HERO™ systems in a wide range of wastewater flow. For the verification testing, KCP will have a mobile, 15 gpm unit installed following their conventional wastewater treatment system. The 15 gpm unit will only be treating a portion of the KCP wastewater effluent for demonstration purposes.

2.2 Commercial Status

The HERO™ system was introduced to the market in 1996 by Deb Mukhopadhyay. The target market was providing ultra-pure water to the microelectronics industry. Several units in this application have been operating at electronics manufacturing facilities such as Intel and Micron.

In 1998, Hydrometrics licensed the process and began providing the technology for industrial wastewater applications. The HERO™ process was patented in 1999. Approximately ten wastewater applications have been tested using the HERO™ process. Wastewaters tested came from the following industries: mining and smelting, petroleum refining, water produced from oil and gas drilling, natural gas power generation, and metal finishing. Within the metal finishing industry, a range of potential applications are possible for addressing plating baths, etching baths, or rinse waters from metal finishing operations, circuit board manufacturing, and related processes. The HERO™ system is reportedly especially suited for applications where large quantities of fresh water are required, fresh water is in short supply, or environmental requirements are stringent. The HERO™ system is also reportedly beneficial for applications where traditional RO systems have failed or are too costly to operate. There are approximately a dozen HERO™ systems of various flow capacities in operation in the U.S., Asia, Europe, and South America.

2.3 Pollution Prevention Classification

Hydrometrics' HERO™ system is a wastewater treatment technology that falls under the water use reduction/recycle focus area. Tested industrial wastewaters have exhibited efficient separation of individual metals for recovery and recycle (near 100 percent), and very high product water recovery (up to 95 percent, compared to 75 percent for traditional RO). This results in minimized fresh water consumption and the elimination or reduction of wastewater discharge. The unit also minimizes energy consumption in relation to traditional RO systems. The HERO™ system waste stream is five times more concentrated than traditional RO waste, reducing the required evaporation time associated with mechanical dryers, and thereby reducing energy consumption for zero-liquid discharge applications status.

Due to the rising costs of chemicals, energy, and treatment/disposal fees, and increasingly more stringent environmental requirements, wastewater reduction/reuse has become a greater priority to metal finishing companies, and the methods and technologies they employ have increased in sophistication. Today, firms are willing to expend significant amounts of capital and operating funds for equipment and methods that primarily reduce the disposal frequency and amount of their process wastewaters. By recovering water and valuable metals for reuse/resale, the HERO™ process makes large steps toward achieving these goals.

2.4 Environmental Significance

Wastewaters containing up to 30,000 parts per million (ppm) TDS and heavy metals have been treated by the HERO™ process to meet drinking water standards. Purified water from the HERO™ system is normally suitable for reuse or direct discharge, meeting existing wastewater discharge compliance limits. With reuse, facilities can make significant strides toward zero-liquid discharge, water conservation, and reduced environmental liability.

The high recovery, concentration, and possible reuse/recycle of heavy metals from the HERO™ process results in a reduction of metals emissions to the environment, a high priority in the Metal Finishing Industry's Strategic Goals Program regarding toxic metals reduction/utilization, and is consistent with the recommendations of the National Metal Finishing R&D Plan.

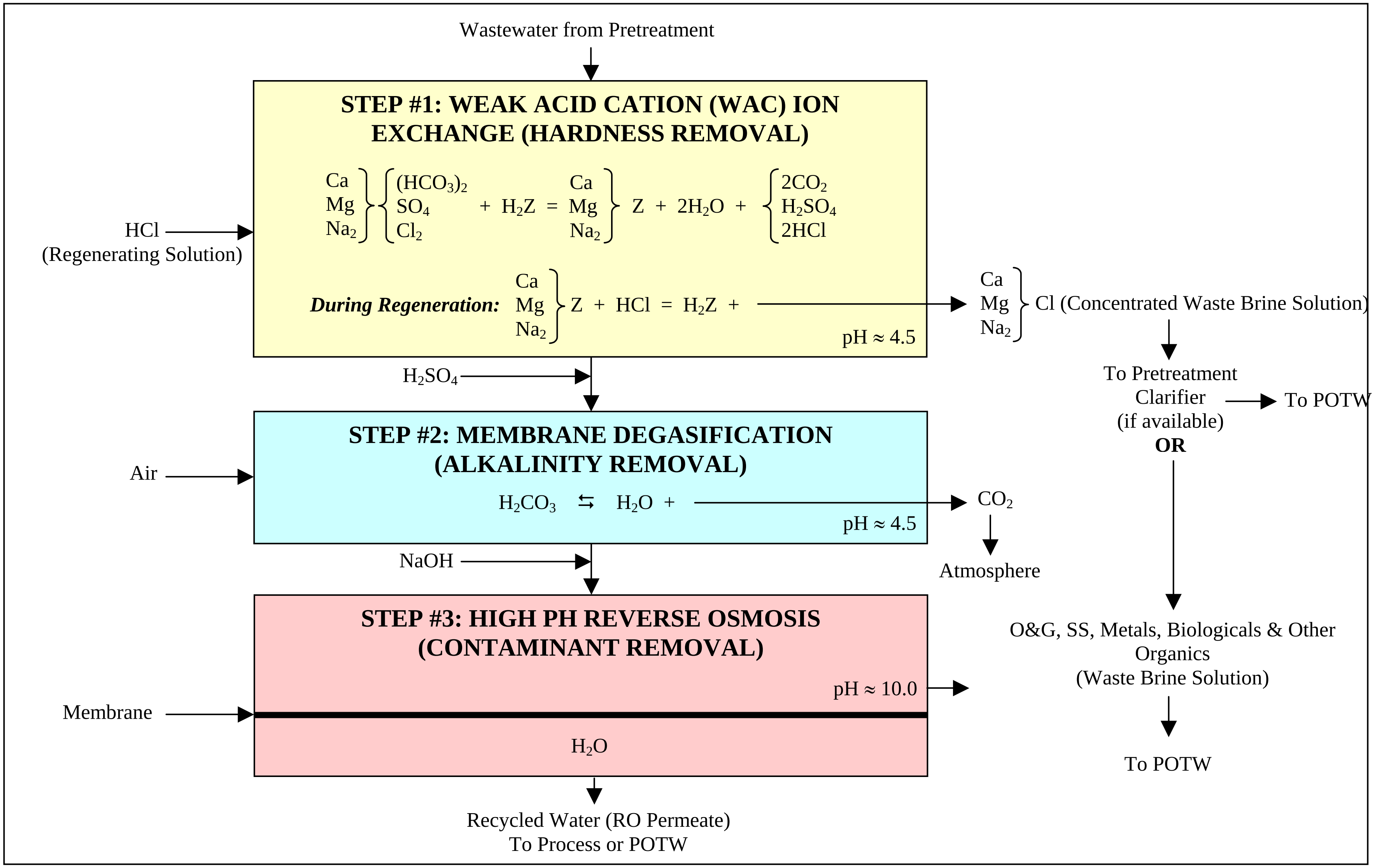

Figure 2: HERO™ System Chemical Reactions

3.0 PROCESS DESCRIPTION

3.1 Equipment and Flow Diagram

The technology utilizes proven and available "off-the-shelf" equipment components. The equipment is compact (about 8' x 20' depending on flow and application), skid mounted, and modular for simple expansion. Electrical service of 480 volt, 50 amp, 3-phase, 60 Hz is required. Operations are automated and simple, reportedly resulting in low operation and maintenance costs. The unit usually operates in a continuous mode, although it also has the capability to operate in a batch mode. Existing RO systems can be easily retrofitted to operate in the HERO™ configuration.

In the HERO™ process, weak acid cation (WAC) ion exchange is used to remove sodium and hardness associated with alkalinity. Other cations (such as copper, barium, iron, manganese and zinc) are also removed. Treated water is slightly acidic. The bicarbonate alkalinity in the water is converted to carbon dioxide. Additional acid may be added to convert the remaining alkalinity to carbon dioxide. After degasification in the next step, the TDS is reduced according to Hydrometrics. The WAC is regenerated periodically using sulfuric or hydrochloric acid. The concentrated waste brine solution is mixed with the RO reject stream for disposal. Alternatively, Hydrometrics says the brine solution could be recirculated to a clarifier, if one is used as pretreatment to the HERO™ system for further precipitation of any remaining contaminants.

After WAC ion exchange treatment, the water is passed through a counter-current air stripper (membrane degasifier) to remove the carbon dioxide created in the WAC ion exchange process. This step removes the buffering capacity of the water, thereby minimizing caustic addition in the next step. In the high pH RO step, a small amount of caustic is used to increase the pH prior to treatment. Operating at high pH has several important advantages:

- Fats and oils are emulsified. These materials are kept in solution and rejected rather than plating out on the membrane surface.

- Silt fouling is eliminated. Membranes used in normal RO systems become fouled with silt, biological growth and organic matter. When this occurs, the membranes are cleaned with softened water at pH 10. HERO™ systems operate continuously with softened feed water at pH 10. Silt and organic matter are continuously cleaned from the membrane surface and biological growth is eliminated.

- Silica solubility is increased. Increased silica solubility at high pH prevents silica scaling on the membrane. Silica can often be a limiting factor controlling the recovery limit of an RO system.

- Weak organic acids are ionized. Low concentrations of these acids can foul membranes unless they are ionized. Once ionized at high pH, the membranes reject these acids.

Industrial wastewater quality is inherently site-specific. Accordingly, wastewater treatment systems are generally designed for specific applications. For example, feed water with elevated hardness, total hardness in excess of total alkalinity, high TSS, or high oil and grease may require additional pretreatment prior to the HERO™ system. This pretreatment may include filters, strong acid cation (SAC) ion exchange, or clarifiers. For reasons like this, HERO™ systems are designed to address the specific wastewater quality characteristics of the host facility.

Figure 3 shows a photograph of a full-scale, 90 gpm, permanently installed HERO™ system.

Figure 3: HERO™ Wastewater Treatment System

3.2 Test Site

The host site selected for testing is Honeywell FM&T's KCP in Kansas City, Missouri. Honeywell FM&T, a prime contractor for the DOE, manages and operates the approximately one million square foot KCP. Honeywell FM&T is a division of Honeywell, headquartered in Morristown, New Jersey. Honeywell and its divisions produce many high-tech products for consumer and government use. Virtually every form of air transportation depends on at least one of Honeywell's systems, including every manned space flight since the beginning of the U.S. space program.

The KCP is a state-of-the-art facility that manufactures a wide array of mechanical, electrical, and engineered material components for the DOE. The KCP was established in 1949.

The KCP manufactures electronic, mechanical, and engineered material components for national defense systems. Within the engineered material components operations they have capabilities for applying and evaluating low and zero volatile organic carbon (VOC) paints, dry film lubricants, and powder coatings. Plasma, electrophoresis, and chemical surface pretreatments are also available. Electroplated coating applications include copper, tin, tin-lead, zinc, cadmium, nickel, electroless nickel, hard and soft gold, rhodium, and black and brown oxides. They electroform copper, nickel, and gold. On difficult-to-plate substrates, a combination of vacuum deposition and electroplating is used to achieve adherent coatings.

The microelectronics manufacturing division of the facility consists of 19,000 square feet (ft^2) of clean-rooms, 1,800 ft^2 of laser rooms, and 26,000 ft^2 of manufacturing and support area.

Capabilities include Thin Film Networks, Thick Film Networks, and Low Temperature Co-fired Ceramic Networks. Several film materials including titanium, palladium, palladium-gold, platinum-gold, gold, silver, copper, and chromium are applied to a variety of substrate materials using processes such as electroplating, sputtering and physical vapor deposition (PVD).

Figure 4 shows a detailed schematic of the HERO™ industrial wastewater treatment application complete with sampling points.

3.3 KCP Conventional Wastewater Treatment System

3.3.1 Copper Recovery & Cyanide Oxidation

Copper will be recovered from the plating shop cyanide rinse water waste stream by employing a separate WAC ion exchange unit supplied by Hydrometrics, Inc. Copper/cyanide bearing rinse waters are formed when drag-out or drippage from cyanide plating baths contaminate rinse baths during normal copper plating operations. This separate unit will remove copper that is complexed with cyanide. Normally, metals recovery with the HERO™ process is achieved in the WAC ion exchange unit that is integral to the three-step treatment process. However, since cyanide oxidation results in copper precipitation, copper removal is more efficient prior to the cyanide oxidation process. A full-scale separate WAC ion exchange unit would be regenerated with sulfuric acid; however, no regeneration will be necessary during the verification test. The quantity of recovered copper will be calculated by doing a mass balance for copper on the influent and effluent of the WAC unit. The treated water will then go through the normal cyanide oxidation process. This is necessary to prevent health and safety issues associated with the release of cyanide gas later in the treatment system.

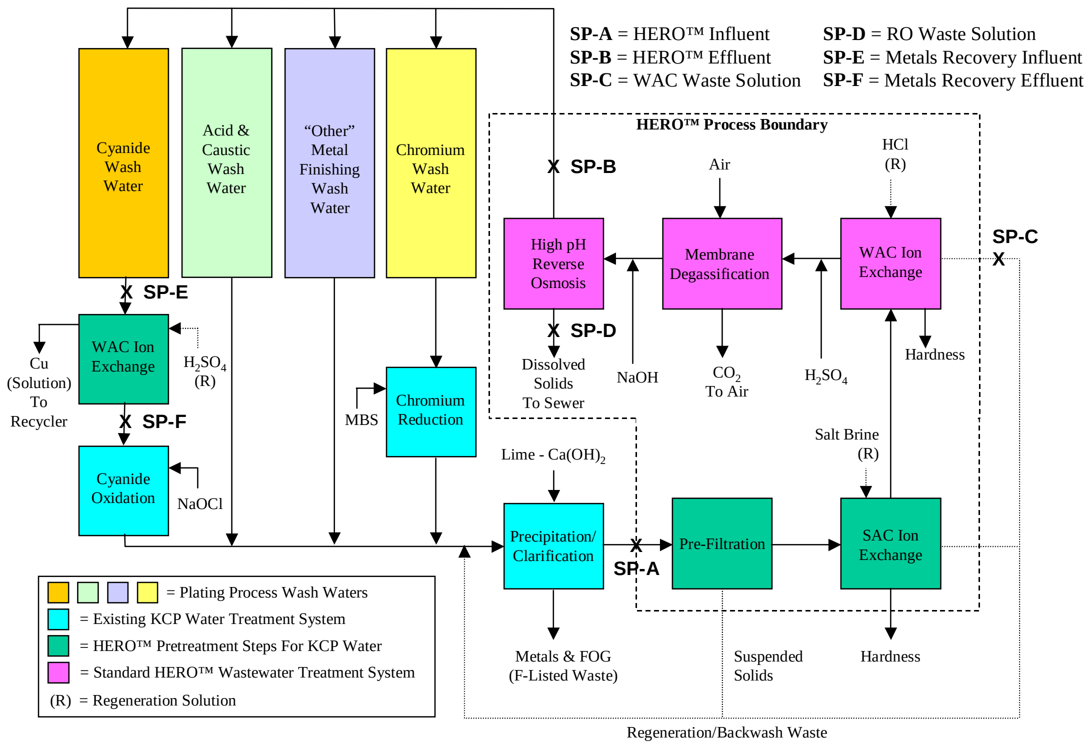

Figure 4: HERO™ Wastewater Treatment System Diagram – Detailed

3.3.2 Chromium Reduction

A conventional step of the KCP wastewater treatment process is the reduction of chromium in the chromium plating rinse waters. The chromium plating rinse waters are treated with metabisulfite (MBS) in order to reduce chromium in the hexavalent state to the more stable and less toxic trivalent chromium state. The effluent from this step moves directly to the next step, precipitation/clarification.

3.3.3 Lime Precipitation & Clarification

Spent rinse water from the cyanide oxidation, chromium reduction, acid and caustic rinse water, and other finishing rinse water (aqueous degreasing, cleaning and rinsing) are then commingled in 3,750 gal flash mix tanks, where they are treated with a sodium hydroxide/lime slurry and mechanically mixed. They are pumped at a rate of approximately 170 gpm into the conventional wastewater treatment system. Up to 80,000 gal of combined wastewater per day are treated in this conventional lime precipitation/clarification unit during the single 10-hour operating shift. This system removes metals and O&G, and provides a consistent water quality feed to the remainder of the treatment system.

The concentrated reject from the clarifier will continue to be pressed, dried, and sent for disposal as an F006 waste.

3.4 Hydrometrics Mobile HERO™ Unit Installation at KCP

3.4.1 Pretreatment

3.4.1.1 Prefiltration & SAC Ion Exchange Treatment

The HERO™ system will be installed online and operated continuously. Wastewater from the prefilter is pumped through the HERO™ system at a flow rate of about 15 gpm. In addition to the normal three-step HERO™ process, prefiltration of the post-clarified feed water to remove residual suspended solids and a SAC ion exchange process will be used for verification testing due to the high hardness-to-alkalinity ratio. (SAC ion exchange treatment will not be required for full-scale treatment if pre-softened water is used. A standard water softener would be used to treat all make-up water and eliminate hardness from the process water circuit.) SAC ion exchange treated water is then sent to the first step in the standard HERO™ process, the WAC ion exchange unit.

3.4.2 HERO™ System

3.4.2.1 WAC Ion Exchange Treatment

Wastewater from the SAC ion exchange flows into the WAC ion exchange step of the HERO™ process to remove all remaining hardness. Because the WAC resin is in acid form, this step also lowers the pH of the water to 4.5, and converts carbonate and bicarbonate to carbon dioxide. This unit is regenerated using a dilute solution of hydrochloric acid.

3.4.2.2 Membrane Degasification

From the WAC ion exchange outlet, the wastewater goes through degasification to remove carbon dioxide. This inexpensive step removes the buffering capacity of the water, minimizing pH adjustment costs. Acid addition prior to the degasifiers may be necessary to lower the pH to 4.5 for complete carbon dioxide conversion.

3.4.2.3 pH Adjustment and Reverse Osmosis (RO)

The final step in the HERO™ system is adjustment to pH 10 and RO treatment. Operating the RO at high pH avoids bio-fouling and silica scaling, and enhances silt rejection. Treated wastewater is returned to the rinse water make-up system at a flow of about 15 gpm. Dissolved solids are discharged to the sewer.

The 15 gpm unit installed at the KCP for verification will process about 7,200 gallons per day (gpd) (based on 8 hrs/day operation). If selected for permanent installation, a 100–200 gpm HERO™ system would be scheduled to be installed in late 2001/early 2002 and will treat all of the KCP process wastewater, with a capacity of 48,000–96,000 gpd (based on 8 hrs/day operation). The concentrated brine solution that is generated during the ion exchange step will be recirculated back to the conventional wastewater treatment system where any remaining metal cations will settle out in the clarifier. The waste brine solution from the reverse osmosis step of the HERO™ process will be directly discharged to the sewer in the permanent installation configuration. Zero liquid discharge is not being pursued at the Honeywell facility. With the 15 gpm unit, Hydrometrics estimates that about 5 percent or 360 gpd of waste brine solution will be generated by the HERO™ process (also based on 8 hrs/day operation). If selected for permanent installation at the KCP, the full-scale, 100–200 gpm HERO™ system waste brine generation will increase to about 4,000 gpd (based on 5 percent of 80,000 gpd – KCP's current treatment flow). This wastewater discharge volume sounds like a large quantity, but would be a 95 percent reduction in wastewater discharges to the POTW from their current 80,000 gpd.

Pictures of a 15 gpm, mobile HERO™ system like the one that will be installed at the KCP for the verification test are provided for reference in **Figure 5**.

Figure 5: KCP's Mobile HERO™ System

4.0 EXPERIMENTAL DESIGN

4.1 Test Goals and Objectives

The overall goal of this project is to establish the technical and economic performance parameters that will enable a potential user to determine if the Hydrometrics HERO™ wastewater treatment system is appropriate and feasible under their specific operating conditions. The objective of testing is to generate the analytical data and performance observations required in supporting these technology verification efforts.

The following are statements of specific project objectives:

- Evaluate, document, and verify the performance of the separate HERO™ wastewater WAC ion exchange treatment technology for the recovery of copper that builds up in the process rinse water during the cyanide-containing finishing operations. Characterize the recovered copper for salability options.

- Evaluate, document, and verify the HERO™ wastewater treatment technology's removal efficiency for TDS, O&G (as HEM), Ag, Al, As, Ba, Ca, Cd, Cl, CN, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni, Pb, Sn, Zn, total residual chlorine, sulfate, nitrate, sulfides, chloride, fluoride, dissolved silica, total alkalinity, TOC, and TSS that accumulate in process rinse waters during finishing operations.

- Quantify the energy required to operate the system. Primary energy users include the electrical service to the automated system, instrument readouts, and the liquid feed pumps. This information will be used to estimate operating costs for the HERO™ wastewater treatment system.

- Quantify environmental benefit by determining the reduction in wastewater disposal quantities versus HERO™ waste sludge quantities/characteristics.

4.2 Critical and Non-Critical Measurements

Measurements that will be taken during testing are classified below as either critical or non-critical. Critical measurements are those that are necessary to achieve project objectives. Non-critical measurements are those related to process control or general background readings.

Operational data will be collected on the HERO™ wastewater treatment system performance during the treatment of process wastewater. The following operational data will be collected:

Critical Measurements

- Concentrations of TDS, O&G (as hexane extractable material (HEM)), Ag, Al, As, Ba, Ca, Cd, CN, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni, Pb, Sn, Zn, total residual chlorine, sulfate, nitrate, sulfides, chloride, fluoride, dissolved silica, TOC, total alkalinity, and TSS in the HERO™ system influent and effluent
- Specific conductivity and total alkalinity of rinse water influent/effluent
- Rinse water processing rate and total volume
- Waste volumes, characteristics (TDS, O&G (as HEM), Ag, Al, As, Ba, Ca, Cd, CN, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni, Pb, Sn, Zn, total residual chlorine, sulfate, nitrate, sulfides, chloride, fluoride, dissolved silica, total alkalinity, TOC, and TSS), and disposal costs
- Concentrations and volumes of copper in cyanide rinse water, WAC process influent and effluent

Non-Critical Measurements

- Membrane flux/fouling
- Membrane vessel pressure
- pH of rinse water influent/effluent and waste products
- Temperature of rinse water influent/effluent and waste products
- Operating and Maintenance (O&M) labor requirements
- Reagent (lime, sulfuric acid and caustic) use rates

This data will be used to determine the system material balance, wastewater purification rate, O&M requirements, and the cost-effectiveness for a given set of operating conditions.

Historical Data

Historical data on the KCP's wastewater disposal quantities prior to installation of the HERO™ wastewater treatment system will be collected and provided in the verification report to determine the environmental benefit.

The KCP's records regarding plating rinse water quality measurements will also be reviewed and summarized in the verification report in order to alleviate plating quality concerns regarding the implementation of the HERO™ wastewater treatment system.

4.3 Test Matrix

The unit will be evaluated on its ability to efficiently treat and recover metal finishing process wastewater. The specific tests planned are described in **Table 1**. In order to gain the valuable system performance information desired for the ETV-MF Program, sampling, testing, and documentation will take place over a four-day period.

4.3.1 HERO™ System Wastewater Recovery – Test #1

A large portion (46 percent) of the combined KCP wastewater is dilute, non-production wastewater. This non-production wastewater consists of non-contact cooling water, boiler blow-down water, laboratory sink water, etc. The remaining 54 percent of the KCP's spent process water consist of non-metal-finishing industrial process wastewaters, and rinse waters from metal finishing. The HERO™ system will be evaluated on its ability to separate chemical contaminants from the wastewater and recycle the water back to the metal finishing process rinse tanks.

4.3.2 WAC Ion Exchange Unit Copper Recovery – Test #2

A very small amount or KCP's wastewater, about 330 gpd, is cyanide-bearing rinse water from the KCP metal finishing shop's copper plating operations. Copper is a potential recyclable/salable metal, and this verification test will include a separate WAC ion exchange unit installed between the cyanide rinse water storage tank and the first step of the cyanide oxidation process. This WAC unit uses resin identical to the WAC unit within the HERO™ system where metals recovery would normally take place, but on a smaller scale. Due to KCP's conventional wastewater treatment system, a separate WAC unit must be installed upstream of that system in order to recover the copper. Because of the small amount of cyanide-bearing rinse water generated at KCP, copper recovery will not be economically feasible at KCP. The verification on this WAC unit will demonstrate the HERO™ system's ability to remove valuable metals for recovery, recycle and/or sale.

4.3.3 HERO Effluent Water Recycling

The rinse water used in KCP metal finishing operations is standard Kansas City tap water. Recycled water from the HERO™ system must meet the minimum quality standards equal to this tap water. A sample of KCP's tap water was analyzed before the verification test for TDS, O&G (as HEM), Ag, Al, As, Ba, Ca, Cd, Cl, CN, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni, Pb, Sn, Zn, total residual chlorine, sulfate, nitrate, chloride, sulfides, fluoride, dissolved silica, total alkalinity, TOC, and TSS and will be compared to recycled water from the HERO™ treatment system in the verification report.

4.3.4 RO Waste Solution

According to Hydrometrics, the single waste stream produced in the process is generally less than 10 percent of the feed stream. This concentrated waste brine solution is generated from the ion exchange and reverse osmosis steps of the HERO™ treatment system, and Hydrometrics claims it is generally suitable for direct discharge to a POTW. This waste consists primarily of sodium sulfate, but may also contain heavy metals, suspended solids, O&G, biological materials, and other organic materials that have been removed from the wastewater. The KCP's waste brine solution has been tested in a bench-top test, and it meets all current KCP wastewater discharge limits. The KCP must sample and test their wastewater every six months, according to their sewer discharge permit; however, they typically sample and test every other month. The RO waste solution will be evaluated to ensure it meets KCP's discharge limits.

Test	Test Objectives	Test Measurement
1. HERO™ System Wastewater Recovery	Prepare a material balance for wastewater constituents.	• Chemical characteristics of influent. • Chemical characteristics of effluent. • Volume and chemical characteristics of the RO waste solution. • Quantity of treatment chemicals used during testing.
	Evaluate the ability of the HERO™ system to process wastewater and separate chemical contaminants from water.	• Chemical characteristics of influent. • Chemical characteristics of effluent.
	Determine the wastewater recovery rate of the system, normalized based on production throughput of wastewater.	• Volume of water recovered. • Production throughput of wastewater.
	Determine the labor requirements needed to operate and maintain the HERO™ system.	• O&M labor requirements during test period.
	Determine the quantity of energy consumed by the HERO™ system during operation.	• Quantity of energy used by pumps and motors.
	Determine the cost of operating the wastewater recycle system for the specific conditions encountered during the testing.	• Costs of O&M labor, materials, and energy required during test period. • Quantity and price of treatment chemicals used during testing.
	Quantify/identify the environmental benefit.	• Review of historical waste disposal records and compare to verification test practices.
2. WAC Ion Exchange Unit Copper Recovery	Prepare a material balance for copper recovered from the cyanide-bearing rinse waster.	• Chemical characteristics (Cu) of influent. • Chemical characteristics (Cu) of effluent. • Volume and chemical characteristics of copper removed from the wastewater. • Quantity of treatment chemicals used to recover the copper.
	Evaluate the ability of the WAC ion exchange unit to process wastewater and separate copper contaminants from water.	• Chemical characteristics (Cu) of influent. • Chemical characteristics (Cu) of effluent.
	Determine the copper recovery rate of the system, normalized based on production throughput of wastewater.	• Volume of copper recovered. • Production throughput of wastewater.
	Determine the labor requirements needed to operate and maintain the WAC ion exchange unit.	• O&M labor requirements during test period.
	Determine the cost of operating the WAC ion exchange unit for the specific conditions encountered during the testing.	• Costs of O&M labor and materials required during the test period. • Quantity and price of chemicals used during copper recovery.
	Quantify/identify the environmental benefit.	• Review of historical waste disposal records and comparison to verification test practices.

Table 1: Objectives and Related Test Measurements for Evaluation of the HERO™ System

4.4 Operating Procedures

The 15 gpm, trailer-mounted HERO™ system will be parked on a concrete pad adjacent to the building housing the existing lime precipitation clarifier wastewater treatment system. A blind sump surrounds the concrete pad, as this is a designated chemical loading/unloading area, complete with secondary containment. The separate copper recovery ion exchange unit will be installed within the KCP wastewater treatment plant, inside the secondary containment wall, next to the cyanide rinse water holding tank. Treated water from KCP's conventional wastewater treatment plant will be piped to the HERO™ system. The HERO™ system will polish pre-treated water from an estimated 80,000 gpd combined flow of non-production wastewater, non-metal finishing process wastewater, acid/caustic rinse water, and metal finishing rinse waters.

Hydrometrics and KCP personnel will perform normal operation and maintenance activities during testing. These activities will be observed and noted by the ETV-MF Project Manager.

The HERO™ system will be operated six to eight hrs/day. The exact number of operating hours will depend on the KCP work-load schedule. The verification test period will be four workdays.

4.5 Sampling, Process Measurements, and Analytical Methods

4.5.1 Sampling Responsibilities & Procedures

By using a dual wastewater holding tank system at the facility, it is anticipated that contaminant concentration should remain relatively stable over each day of testing. The incoming wastewater is stored in large holding tanks where it is isolated at the start of each day from incoming wastewater, and agitated with mixing pumps. The stream is then fed into the traditional wastewater treatment plant and on into the HERO unit at a uniform rate.

Grab samples will be taken from the sampling ports associated with the corresponding sampling points specified in **Figure 4.** Sampling will occur in the quantities listed in **Table 2**, and the frequency listed in **Table 3** for each parameter. The KCP waste treatment operators will use their dual-waste holding tank system to isolate, collect, mix and provide consistent wastewater flows for the duration of the four day verification test.

The appropriate sampling container will be used as outlined in **Table 4** for each test parameter**.** Each sample bottle will be labeled with the date, time, sample identification (ID) number, and test parameters required. Sampling will take place at least one hour after any system shut-down/start-up operations. Sample preparation methods are described in each individual analytical method.

	SP-A HERO™ Unit	SP-B HERO™ Unit	SP-C HERO™ Unit	SP-D HERO™ Unit	SP-E 2nd WAC Unit	SP-F 2nd WAC Unit	Field Blank – Lab DI Water
TSS	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
TDS	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
TOC	10[c] x 500 mL	10[c] x 500 mL	10[c] x 500 mL	10[c] x 500 mL	-	-	2[d] x 500 mL
O&G (as HEM)	12[e] x 1 L	12[e] x 1 L	12[e] x 1 L	12[e] x 1 L	-	-	2[d] x 1 L
Metals	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L (Cu only)	5[a] x 1 L (Cu only)	1[b] x 1 L
Sulfide	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	-	-	1[b] x 500 mL
Total Cyanide	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	-	-	1[b] x 500 mL
Chloride	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
Sulfate	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
Nitrate, as N	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
Fluoride	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
Total Alkalinity	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	5[a] x 1 L	-	-	1[b] x 1 L
Dissolved Silica	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	5[a] x 500 mL	-	-	1[b] x 500 mL

Notes:

[a] Sample quantities of 5 include 1 grab sample on 4 successive days, and 1 duplicate.

[b] Sample quantities of 1 include 1 grab sample (laboratory DI water).

[c] Sample quantities of 10 include 1 grab and 1 archive sample on 4 successive days, 1 duplicate and 1 duplicate archive.

[d] Sample quantities of 2 include 1 sample and 1 archive (laboratory DI water).

[e] Sample quantities of 12 include 1 grab and 1 archive sample on 4 successive days, 1 duplicate, 1 duplicate archive, 1 MS and 1 MSD.

One duplicate sample will be collected from each sample location during the verification test period.

Matrix spike (MS) and matrix spike duplicate (MSD) analysis will be performed on each duplicate sample for all applicable parameters.

The duplicate, MS and MSD samples must be collected on the same day at approximately the same time.

The archive samples will not be analyzed unless necessary; they will be identified as "Archive" and transported in a shipping container separate from the other samples.

Table 2: Sample Quantities

SAMPLE LOCATION	# OF SAMPLES	FIELD BLANK	FREQUENCY	TEST DURATION	PARAMETERS
SP-A HERO™ Influent	5 (4 + one duplicate)	1	1 grab sample/day	4 days	TSS, TDS, TOC, O&G (as HEM), Specific Conductivity, Total Alkalinity, Ag, Al, As, Ba, Ca, Cd, Cl, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni, Pb, Sn, Zn, Total Residual Chlorine, Sulfate, Sulfide, Nitrate, Fluoride, CN, Dissolved Silica, Temp., pH, Flow Rate
SP-B HERO™ Effluent	5 (4 + one duplicate)		1 grab sample/day	4 days	Same as **SP-A**
SP-C WAC Waste Solution	5 (4 + one duplicate)		1 grab sample/day	4 days	Same as **SP-A**
SP-D RO Waste Solution	5 (4 + one duplicate)		1 grab sample/day	4 days	Same as **SP-A**
SP-E Metals Recovery Influent	5 (4 + one duplicate)	1	1 grab sample/day	4 days	Copper, Temp., pH, Flow rate
SP-F Metals Recovery Effluent	5 (4 + one duplicate)		1 grab sample/day	4 days	Same as **SP-E**

Table 3: Test Matrix

ANALYTE	METHOD	SAMPLE BOTTLE	PRESERVATION	HOLD TIME
TSS	EPA 160.2	1 L (HDPE)	Cool to $4^{o}C$	7 days
TDS	EPA 160.1	1 L HDPE	Cool to $4^{o}C$	7 days
TOC	SW-846 9060	500 mL amber glass	H_2SO_4 to pH < 2 & cool to $4^{o}C$	28 days
O&G (as HEM)	EPA 1664	1 L amber glass	H_2SO_4 to pH < 2 & cool to $4^{o}C$	28 days
Metals (except Hg)	EPA 200.7	1 L HDPE	HNO_3 to pH < 2 & cool to $4^{o}C$	6 months
Hg	EPA 245.1	1 L HDPE	HNO_3 to pH < 2 & cool to $4^{o}C$	28 days
Sulfide	EPA 376.1	500 mL HDPE	NaOH to pH>9/Zn Ac, & cool to $4^{o}C$	7 days
Total Cyanide	EPA 335.3	500 mL HDPE	NaOH to pH ≥ 12 & cool to $4^{o}C$	14 days
Chloride	EPA 300.0	1 L HDPE	None	28 days
Sulfate	EPA 300.0	1 L HDPE	Cool to $4^{o}C$	28 days
Nitrate, as N	EPA 300.0	1 L HDPE	Cool to $4^{o}C$	48 hours
Fluoride	EPA 300.0	1 L HDPE	None	28 days
Total Alkalinity	EPA 310.1	1 L HDPE	Cool to $4^{o}C$	14 days
Dissolved Silica [1]	EPA 370.1	500 mL HDPE	Cool to $4^{o}C$	28 days

Table 4: Aqueous Samples

Samples to be analyzed at the off-site laboratory will be accompanied by a chain-of-custody (COC) form. The samples will be stored and transported in appropriate sample transport containers (e.g., coolers with packing and blue ice) by common carrier. The transport containers will be secured with tape seals to ensure sample integrity during the delivery process to the analytical laboratories. The ETV-MF Project Manager will perform sampling and labeling, and ensure that samples are properly stored and secured for transport to the analytical laboratory. Pace Analytical Services Inc. will perform all aqueous analytical transportation and the testing of all samples.

[1] Digestion is not required, due to lack of molybdate unreactive silica. Filtration shall be prepared by the laboratory immediately upon receipt

4.5.2 Process Measurements

Monitoring during the verification test period will be accomplished by recording key operating data. Monitoring instrumentation will be calibrated and used by the ETV-MF Project Manager according to manufacturer recommendations. See section 4.5.4 for specific calibration procedures. Process measurements will be recorded on the test data collection form (**Figure 6**) at the same time that aqueous sampling occurs, that is to say, once a day, in accordance with **Table 3**. On-site measurements will be performed three times for each sampling activity in order to determine compliance with the QA objectives stated in **Table 5**.

Wastewater flow rates for this verification test will be measured by an Omega Engineering, Inc., Model FD-7000 multi-liquid ultrasonic flowmeter with non-penetrating transducers. Wastewater pH and temperature will be measured on-site with a Davis Instruments Model #9214 microprocessor controlled, automatic temperature compensated pH meter with built-in temperature sensor. See **Table 5** for equipment performance details. Wastewater specific conductivity will be measured with an Oakton Acorn® Series CON 5 microprocessor controlled, automatic temperature compensated conductivity meter with built-in temperature sensor. See **Table 5** for equipment performance details. Total residual chlorine will be measured on-site immediately after sampling with a Hach© Pocket Colorimeter™ filter photometer with total chlorine reagent set. See **Table 5** for equipment performance details.

Membrane flux is the decrease in permeate flow rate due to membrane performance deterioration, caused by the membrane becoming fouled with contaminants. Flux will be calculated as the gallons of permeate product per square foot of membrane per day (gfd). Increasing the flux results in lower capital costs and better effluent quality. In conventional RO systems, membranes foul with scale (divalent metal precipitates), organics (oil and hydrocarbons), and microbial growth. The HERO™ process reportedly eliminates this by removing the divalent metal ions and then operating the RO at a high pH where organics are emulsified and biological growth does not occur. Hydrometrics claims the HERO™ system achieves an operating flux that is up to two times that of traditional RO. RO reject flowrate will be collected, then membrane flux will be calculated upon completion of the verification test.

Test Data Collection Form

DATE:____________ **OPERATION:** **HERO™ Wastewater Treatment System**

SAMPLE DATA				INFLUENT (FEED) WATER PARAMETERS					RO REJECT / WAC WASTE PARAMETERS				EFFLUENT (PERMEATE) WATER PARAMETERS				
Date	Time	Sample Location	Initials	Temp. (°C)	pH	Flow Rate (gpm)	SC (µS)	Total Cl_2 (mg/L)	Temp. (°C)	pH	Flow Rate (gpm)	Total Volume (gal)	Temp. (°C)	pH	Flow Rate (gpm)	SC (µS)	Total Cl_2 (mg/L)

Figure 6: Test Data Collection Form

Measurement	Matrix	Method	Units	Method of Determination	MRL	Precision (RPD)	Accuracy (% Recovery)	Completeness
TOC	Aqueous	EPA 9060	mg/L	Combustion / Oxidation	10.0	< 30	70–130	90
O&G (as HEM)	Aqueous	EPA 1664	mg/L	Gravimetric	5.68	< 30	70–130	90
Metals (- Hg)	Aqueous	EPA 200.7	mg/L	ICP-AES	0.004–1.0	< 30	70–130	90
Hg	Aqueous	EPA 245.1	mg/L	Manual Cold Vapor	0.0002	< 30	70–130	90
Sulfide	Aqueous	EPA 376.1	mg/L	Titrimetric, Iodine	0.5	< 30	70–130	90
Total Cyanide	Aqueous	EPA 335.3	mg/L	Colorimetric, Automated UV	0.005	< 30	70–130	90
Chloride	Aqueous	EPA 300.0	mg/L	Ion Chromatography	1.0	< 30	70–130	90
Sulfate	Aqueous	EPA 300.0	mg/L	Ion Chromatography	1.0	< 30	70–130	90
Nitrate	Aqueous	EPA 300.0	mg/L	Ion Chromatography	1.0	< 30	70–130	90
Fluoride	Aqueous	EPA 300.0	mg/L	Ion Chromatography	0.2	< 30	70–130	90
Total Alkalinity	Aqueous	EPA 310.1	mg/L	Colorimetric (Methyl Orange)	1.0	< 30	70–130	90
Dissolved Silica	Aqueous	EPA 370.1	mg/L	Colorimetric	1.0	< 30	70–130	90
TSS	Aqueous	EPA 160.2	mg/L	Gravimetric	5.0	< 30	N/A	90
TDS	Aqueous	EPA 160.1	mg/L	Gravimetric	5.0	< 30	N/A	90
Total Residual Cl_2	Aqueous	EPA 330.5	mg/L	DPD-Colorimetric	0.01	< 2	N/A	90
Flow Rate	Aqueous	EPA 3.1.9	L/hr	Ultrasonic Flowmeter	0.3–3.6	< 1	N/A	90
Temperature	Aqueous	EPA 170.1	°C	Thermometric	0.1	< 1	N/A	90
pH	Aqueous	EPA 150.1	pH	Electrometric	0.01	< 0.2	N/A	90
Specific Cond.	Aqueous	EPA 9050A	µS/cm	Wheatstone Bridge-Type	1.0	< 2	N/A	90
Membrane Flux	Aqueous	-	gfd	Calculated	N/A	N/A	N/A	N/A

EPA/821/C-99/004: EPA Methods and Guidance for Analysis of Water
EPA SW-846: EPA Test Methods for Evaluating Solid Waste
N/A – Not applicable

Table 5: QA Objectives for Precision, Accuracy, and Detection Limits

4.5.3 Testing Parameters

4.5.3.1 Flow Rate

Liquid transfer pumps deliver process water to various parts of the HERO™ system during the purification process. The rate at which these liquids are transferred is of major importance in the HERO™ system. Liquid flow rates will be determined at all liquid sampling points (SP-A through SP-F) with an Omega Engineering, Inc., Model FD-7000 multi-liquid ultrasonic flowmeter with non-penetrating transducers. (EPA Method 3.1.9 and equipment manufacturer's instructions)

4.5.3.2 Temperature

While temperature is not a critical parameter in the HERO™ process, it will be monitored at all liquid sampling points (SP-A through SP-F) in order to determine the temperature range of the wastewaters being treated as they enter and exit the HERO™ process during the verification test (EPA Method 170.1 and equipment manufacturer's instructions). Temperature will be measured with a Davis Instruments Model #9214 microprocessor controlled, automatic temperature compensated pH meter with built-in temperature sensor. Wastewater entering the HERO™ system is not temperature controlled, and is typically ambient temperature.

4.5.3.3 pH

pH of the wastewater is a critical parameter in the HERO™ process. The wastewater is acidified before the degasification step, and the pH is increased before the reverse osmosis step. The pH of the wastewater will be monitored at all liquid sampling points (SP-A through SP-F) in order to determine the pH range of the wastewaters being treated as they enter and exit the HERO™ process during the verification test (EPA Method 150.1 and equipment manufacturer's instructions). pH will be measured with a Davis Instruments Model #9214 microprocessor controlled, automatic temperature compensated pH meter with built-in temperature sensor.

4.5.3.4 Specific Conductivity

Conductivity is the measurement of a material's ability to conduct electric current. The ability to transmit an electrical current depends on the concentration of charged or ionic species in the material. Hence, the measure of the conductance is used to approximate the total concentration of ionic species present. This measurement is an estimator of water contamination. Specific conductivity will be measured at the HERO™ system influent and effluent (SP-A & SP-B), and waste products (SP-C & SP-D). (EPA Method 9050A and equipment manufacturer's instructions).

Specific conductivity will be measured with an Oakton Acorn® Series CON 5 microprocessor controlled, automatic temperature compensated conductivity meter with built-in temperature sensor.

4.5.3.5 Total Suspended Solids (TSS)

TSS are non-filterable particles of solids dispersed but undissolved in the wastewater, which cloud the water's appearance and impair the efficiency of the rinse waters. It is important to remove these contaminants in order to meet regulatory requirements and give the recovered wastewater a clean and clear appearance. Samples will be collected at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D) and analyzed for TSS according to EPA Method 160.2.

4.5.3.6 Total Dissolved Solids (TDS)

TDS are the total of disintegrated organic and inorganic materials contained in the wastewater. TDS also impair the efficiency of the rinse waters; therefore, it is critical to remove TDS in order to make the water fit for recycling back to the industrial processes. Samples will be collected at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D) and analyzed for TDS according to EPA Method 160.1.

4.5.3.7 Oil & Grease (O&G)

Oil and grease are contributed to the wastewater as oily parts are rinsed. The O&G is a combination of machining and cutting oils and coolants that are used in metalworking. These fluids may contain mineral oils, natural oils, fats and derivatives, or synthetic lubricants. O&G in the wastewater must be removed before the water can be recycled to the process rinse baths. Samples for total recoverable O&G (as HEM) will be collected at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D), and analyzed for O&G (as HEM) by EPA Method 1664.

4.5.3.8 Metals

Certain contaminant metals will accumulate in the process rinse waters based on the type of substrate being finished and the finishing processes. Most of these metals will come from drag-out or drippage into the rinse waters. These metals need to be removed before the water can be recycled to the process rinse baths. Samples will be collected at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D) and will be analyzed according to EPA Method 200.7 for all metals except mercury, which will be analyzed by EPA Method 245.1.

For the 2nd WAC unit installed on the KCP CN wastewater stream, only copper will be sampled and analyzed in the influent and effluent of this unit (SP-E and SP-F).

4.5.3.9 Additional Proposed MP&M Limits

The proposed Metal Products & Machinery (MP&M) rule discharge limits will have a major impact on the metal finishing industry. Fortunately for the KCP, they are already monitoring their wastewater effluent for most of the proposed MP&M contaminants. Installing the HERO™ system should enable the KCP to recycle approximately 95 percent of their current wastewater for reuse. The remaining five percent consist of the regeneration waste from the ion exchange step and the waste brine solution from the reverse osmosis step. These waste streams will be commingled and tested for the standard contaminants that the KCP is required to monitor for discharge to the sanitary sewer. In addition to these standard contaminants, the waste stream will be tested for additional contaminant parameters, which will require monitoring under the new proposed MP&M limits for metal finishers. These new parameters for the KCP are: manganese, molybdenum, tin, sulfide, total cyanide, TSS, and total organic carbon (TOC). Samples will be taken at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D) (MP&M metals: EPA Method 200.7; total cyanide: EPA Method 335.3; TSS: EPA Method 160.2; TOC: SW-846 Method 9060; sulfide: EPA Method 376.1).

4.5.3.10 Additional KCP Recycled Water Quality Standards

KCP has stated that the recycled water from the HERO™ system should be of a water quality that meets or exceeds the Kansas City tap water that KCP currently used for rinse bath make-up, non-contact cooling water, boiler water, etc. The Missouri Code of State Regulations (CSR), Department of Natural Resources, Public Drinking Water Program, Contaminant Levels and Monitoring Regulations (10 CSR Division 60 - Chapter 4) sets forth the maximum allowable contaminant levels for drinking water. It is to these standards that KCP would like to polish their wastewater. Fortunately for the KCP, they are already monitoring their wastewater effluent for most of the contaminants. The recycled water will be tested for the following additional contaminant parameters that require monitoring under the drinking water program: chloride, total residual chlorine, sulfate, nitrate as N, fluoride, total alkalinity and dissolved silica. Samples will be taken at the HERO™ system influent, effluent, and waste streams (SP-A through SP-D) (chloride, fluoride, nitrate as N and sulfate: EPA Method 300.0; total residual chlorine: EPA Method 330.5; total alkalinity: EPA Method 310.1; dissolved silica: EPA Method 370.1).

4.5.4 Calibration Procedures and Frequency

The following procedures will be used to calibrate the instruments/equipment that will be used to collect critical measurements:

2) Instruments used to perform aqueous analytical methods will be calibrated according to the laboratory quality assurance plan by Pace Analytical Services.

3) The ultrasonic liquid flowmeter, used to measure the flow rate of liquids within the HERO™ system, is on an annual calibration schedule. The flowmeter is calibrated by the equipment manufacturer. The ETV-MF Project Manager will verify the flowmeter has been calibrated prior to use. An operational check will be conducted at the start of each sampling day, and in accordance with the equipment manufacturer's instructions by the ETV-MF Project Manager.

4) Wastewater temperature is not a controlled parameter; however, pH is controlled throughout the conventional wastewater treatment system. Temperature and pH measurements will be taken each time a sample is drawn from its respective sampling port. The digital pH reader/temperature probe will be calibrated at the start of each sampling day by the ETV-MF Project Manager. The following calibration information will be collected and recorded in the field notebook: buffer supplier, lot number, expiration date, and date of usage.

5) Specific conductivity measurements will be taken each time a sample is drawn from its respective sampling port. The digital conductivity meter will be calibrated at the start of each sampling day by the ETV-MF Project Manager. The following calibration information will be collected and recorded in the field notebook: standard solution supplier, lot number, expiration date, and date of usage.

6) Total residual chlorine measurements will be taken each time a sample is drawn from its respective sampling port. The digital filter photometer has been calibrated by the equipment manufacturer and is on an annual recalibration schedule. The ETV-MF Project Manager will verify the photometer meter has been calibrated prior to use.

4.5.5 Mass Balance

The conservation of mass/energy in any isolated system is one of the most fundamental laws in science and engineering. The mass/energy balance is a tool that was developed to account for the inputs, outputs, consumption, and accumulation in a system. To determine system efficiency, measuring or quantifying all of the elements for a mass balance in an industrial setting is very difficult. The greatest challenge is generally defining the system boundaries and what degree of accuracy is required. Sampling, measurement, and analytical errors preclude absolute precision; however, the mass/energy balance provides us with a fundamental tool for evaluating the performance of environmental technologies where we are generally evaluating some form of efficiency.

Figure 7 illustrates the most fundamental form of the material balance equation. Batch systems and continuous systems can both be modeled using this general form.

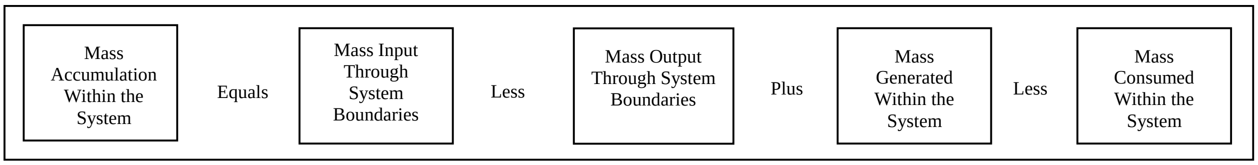

Figure 7: Fundamental Material Balance Equation

Figure 8 illustrates the material flow into and out of the KCP HERO™ system.

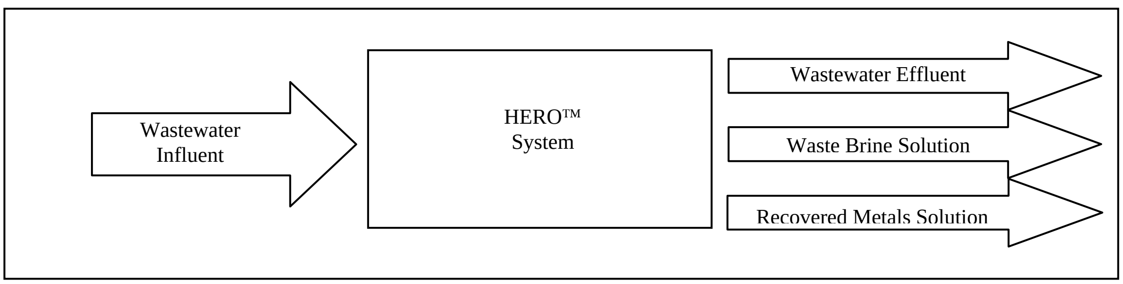

Figure 8: Material Balance Equation for KCP HERO™ System

The goal of the Hydrometrics HERO™ system verification project is to determine performance, and this can generally be measured in terms of efficiency. For water recovery technologies, percent contaminant removal and percent water recovery are measures of system efficiency.

To determine efficiency, the fundamental material balance equation can be simplified as:

$$X_i = X_w + X_e$$

where:

X_i = Mass in influent
X_w = Mass in waste
X_e = Mass in effluent

Sampling will occur in the quantities listed in **Table 2**, at the frequency and duration specified in **Table 3**. Historical operating records at the KCP indicate that there is an average of 78 ppm of copper in the untreated cyanide-bearing rinse water. At the current KCP flow rate, this equates to a potential 50 pounds of copper recovered per year. Conventionally treated KCP wastewater meets current sewer disposal limits, but is not recyclable due to elevated levels of sodium, chloride, nitrates, sulfates, and zinc. The HERO™ system is designed to reduce these contamination levels so that the treated water can be recycled. Four days of sampling was selected in order to show the treatment of a significant volume of wastewater at a steady contaminant-loading rate.

To determine the contaminant removal efficiency for any parameter, the material balance equation for the KCP HERO™ system is expressed as:

$$C_{eff} = \left\{ \frac{\left[\left(C_i \text{ x } I_{vol}\right) - \left(C_e \text{ x } E_{vol}\right)\right]}{\left(C_i \text{ x } I_{vol}\right)} \right\} \text{ x } 100\%$$

where:

C_{eff} = Target contaminant removal efficiency
C_i = Influent target contaminant concentration (mg/L)
I_{vol} = Influent volume processed during the test (L)
C_e = Effluent target contaminant concentration (mg/L)
E_{vol} = Effluent volume processed during test (L)

The removal efficiency will be calculated on a daily basis.

4.5.6 Energy Use

Energy requirements for the HERO™ unit will be calculated by determining the power requirements and cycle times of pumps and other powered devices. For motors and pumps, summing the total quantity of horsepower hours and dividing by 1.341 HP-hr/kWh will determine electrical consumption.

4.5.7 Cost Analysis

This analysis will quantify the accumulative cost benefit of the technology. The cost of operating the mobile HERO™ unit at the KCP will be calculated for comparison to operating costs for a time period prior to utilization of the unit. Operating costs will then be extrapolated, using normalized data, for a full scale HERO™ unit for treating all of the KCP's wastewater. Operating costs may be offset by recovered metals, recycled water, and less waste requiring disposal. For the baseline conditions, the most recent applicable data available, collected by the KCP, will be used. The cost analysis will compare operating costs, including: chemical costs and savings, waste treatment/disposal costs and savings, and costs for labor, utilities, maintenance and other materials.

4.5.8 Waste Generation Analysis

This analysis will quantify the environmental benefit of the technology. The waste generation rates for operating the mobile HERO™ unit at the KCP will be calculated and compared to waste generation rates for a time period prior to utilization of the unit. Waste generation rates will then be extrapolated, using normalized data, for a full scale HERO™ unit for treating all of the KCP's wastewater. For the baseline conditions, the most recent applicable data available, collected by the KCP, will be used. The waste generation analysis will consider type/characteristics, volume, and frequency of waste generated.

5.0 QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

QA/QC activities will be performed according to the applicable sections of the Environmental Technology Verification Program Metal Finishing Technologies Quality Management Plan (ETV-MF QMP) [Ref. 3].

5.1 Quality Assurance Objectives

One QA objective is to ensure that the process operating conditions and test methods are maintained and documented throughout each test and laboratory analysis of samples. Another QA objective is to use standard test methods for laboratory analyses. The test methods to be used are shown in **Tables 3** & **4**. The analytical methods that will be used for analyzing the samples are standard EPA methods.

5.2 Data Reduction, Validation, and Reporting

5.2.1 Internal Quality Control Checks

Raw Data Handling. Raw data is generated and collected by laboratory analysts at the bench and/or sampling site. These include original observations, printouts, and readouts from equipment for sample, standard, and reference QC analyses. Data is collected both manually and electronically. At a minimum, the date, time, sample ID, instrument ID, analyst ID, raw signal or processed signal, and/or qualitative observations will be recorded. Comments to document unusual or non-standard observations also will be included on the forms, as necessary. Data collected on-site will be recorded onto the form presented in **Figure 6.** The ETV-MF Project Manager will complete COC forms that will accompany samples during shipment to the respective labs. Raw data will be processed manually by the analyst, automatically by an electronic program, or electronically after being entered into a computer. The analyst will be responsible for scrutinizing the data according to laboratory precision, accuracy, and completeness policies. Raw data bench sheets and calculation or data summary sheets will be kept together for each sample batch. From the standard operating procedure and the raw data bench files, the steps leading to a final result can be traced. The *CTC* ETV-MF

Program Manager (PM) will maintain process-operating data for use in report preparation.

Data Package Validation. The generating analyst will assemble a preliminary data package, which shall be initialed and dated. This package shall contain all QC and raw data results, calculations, electronic printouts, conclusions, and laboratory sample tracking information. A second analyst will review the entire package and check sample and storage logs, standard logs, calibration logs, and other files, as necessary, to ensure that all tracking, sample treatments, and calculations are correct. After the package is reviewed in this manner, a preliminary data report will be prepared, initialed, and dated. The entire package and final report will be submitted to the Laboratory Manager (LM). The LM shall be ultimately responsible for all final data released from the laboratory. The LM or designee will review the final results for adequacy to the QA objectives. If the manager or designee suspects an anomaly or non-concurrence with expected or historical performance values, the raw data will be reviewed, and the generating and reviewing analysts queried. If suspicion about data validity still exists after internal review of laboratory records, the manager will authorize a re-test. If sufficient sample is not available for re-testing, a re-sampling shall occur. If the sampling window has passed, or re-sampling is not possible, the manager will flag the data as suspect. The LM signs and dates the final data package.

Data Reporting. A report signed and dated by the LM will be submitted in duplicate to the ETV-MF Project Manager and *CTC* Project Manager. The ETV-MF Project Manager will decide the appropriateness of the data for the particular application. The final report contains the laboratory sample ID, date reported, date analyzed, the analyst, the method used for each parameter, the process or sampling point identification, the final result, the units, and the quality control sample results. The *CTC* QA Manager shall review the data packages as required by the ETV-MF QMP [Ref. 3]. The *CTC* ETV-MF Program Manager shall retain the data packages as required by the ETV-MF QMP.

5.2.2 QA/QC Requirements

For those measurements where duplicates, spikes, and spike duplicates are inappropriate (e.g., flow rate, pH, temperature, specific conductivity, total residual chlorine and membrane flux) additional measurements will take place. A minimum of three repetitions will be conducted for each measurement for each sampling day in order to ensure compliance with the QA objectives stated in **Table 5**. The instrument will be recalibrated if the objectives for these measurements are not met.

5.2.2.1 Duplicates

Duplicate samples collected in the field will be used to quantify sample representativeness associated with the entire sampling and analysis system. Duplicate samples (submitted as two aliquots) will be submitted at least once during the test period. Duplicate samples will be collected from both the influent and effluent of the HERO™ system during the treatment of the combined wastewater and cyanide-bearing wastewater. The duplicate samples will be analyzed for all analytical parameters listed in **Table 3**.

5.2.2.2 Matrix Spikes

Matrix spike/spike duplicates will be performed at least once during the test period for each applicable parameter. For example, several different process streams will be sampled as shown in Table 3 (SP-A through SP-F). Test parameters that can undergo matrix spike/spike duplicate procedures are: TOC, O&G (as HEM), metals, and sulfide, sulfate, fluoride, nitrate, chloride, dissolved silica and total cyanide (TSS, TDS, and total alkalinity cannot undergo matrix spike/spike duplicate procedures). A matrix spike/spike duplicate for each of these test parameters will be performed on the duplicate sample for each sampling point during the four-day sampling period. Sample splitting will occur at the analytical laboratory with the exception of O&G (as HEM), which requires additional bottles to be collected at the time of sampling in order to provide enough sample to perform matrix spike/spike duplicate procedures.

5.2.2.3 Field Blanks

Field blanks of laboratory-supplied deionized water will be prepared on-site and submitted to the analytical laboratory during the verification test period. The analysis of these samples for the normal test parameters (TOC, TSS, TDS, O&G (as HEM), metals, and sulfide, sulfate, fluoride, nitrate, chloride, dissolved silica, total cyanide and total alkalinity) will ensure that (1) analytical equipment-cleaning protocols adequately remove residual contamination from previous use, (2) sampling and sample-processing procedures do not result in contamination, and (3) equipment handling and transport between periods of sample collection do not introduce contamination.

5.2.3 Calculation of Laboratory Data Quality Indicators

Analytical performance requirements are expressed in terms of precision, accuracy, representability, comparability, completeness, and sensitivity (PARCCS). Summarized below are definitions and QA objectives for each PARCCS parameter.

5.2.3.1 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. The precision of a duplicate determination can be expressed as the relative percent difference (RPD), and calculated as:

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

where:

X_1 = sample result
X_2 = duplicate result

Multiple determinations will be performed for each test on the same test specimen. The replicate analyses must agree within the relative percent deviation limits provided in **Table 5.**

5.2.3.2 Accuracy

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured. Accuracy is estimated through the use of known reference materials or matrix spikes. It is calculated from analytical data and is not measured directly. Spiking of reference materials into a sample matrix is the preferred technique because it provides a measure of the matrix effects on analytical accuracy. Accuracy, defined as percent recovery (P), is calculated as:

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

where:

SSR = spiked sample result
SR = sample result
SA = the concentration added to the spiked sample

Analyses will be performed with periodic calibration checks with traceable standards to verify instrumental accuracy. These checks will be performed according to established procedures in the contracted laboratory that have been acquired for the HERO™ system verification testing. Analysis with spiked samples will be performed to determine percent recoveries as a means of checking method accuracy. QA objectives are satisfied if the *average* recovery is within the goals described in **Table 5.**

5.2.3.3 Comparability

Comparability is another 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 is limited by the other PARCCS parameters because data sets can be compared with confidence only when precision and accuracy are known. Comparability will be achieved in the HERO™ technology verification by the use of consistent methods during sampling and analysis and by traceability of standards to a reliable source.

5.2.3.4 Completeness

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

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

Experience on similar projects has shown that laboratories typically achieve about 90 percent completeness. QA objectives will be satisfied if the percent completeness is greater than the value specified in **Table 5**.

5.2.3.5 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represents the conditions or characteristics of the parameter represented by the data. For the purposes of this demonstration, representativeness will be achieved by presenting identical samples (field duplicates) to the specified lab(s) and executing consistent sample collection and mixing procedures. Three identical samples (one each of influent, effluent, and sludge) will be collected during the course of the verification test. Representativeness will be satisfied if the analytical results for each parameter is less than 30 percent of the results for the associated duplicate sample.

5.2.3.6 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 will be used for this program.

Instrument Detection Limit (IDL) is the minimum concentration that can be measured from instrument background noise.

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 matrix. (Because of the lack of information on analytical precision at this level, sample results greater than the MDL but less than the method reporting limit (MRL) will be flagged).

MDL is defined as follows for all measurements:

$$MDL = t_{(n-1,1-\alpha = 0.99)} \times s$$

where:

MDL	=	method detection limit
$t_{(n-1,1-\alpha = 0.99)}$	=	students t-value for a one-sided 99 percent confidence level and a standard deviation estimate with n-1 degrees of freedom
s	=	standard deviation of the replicate analyses

Method Reporting Limit (MRL) is the concentration of the target analyte that the laboratory has demonstrated the ability to measure within specified limits of precision and accuracy during routine laboratory operating conditions. (This value is variable and highly matrix-dependent. It is the minimum concentration that will be reported as "unqualified" by the laboratory).

5.3 Quality Audits

Technical System Audits. An audit will be performed during verification testing by the *CTC* QA Manager according to section 2.9.3 Technical Assessments of the ETV-MF QMP [Ref. 3] to ensure testing and data collection are performed according to the test plan requirements. In addition to the *CTC* Technical System Audit (TSA), the EPA QA Manager will also conduct an audit to assess the quality of the verification test.

Internal Audits. In addition to the internal laboratory quality control checks, internal quality audits will be conducted to ensure compliance with written procedures and standard protocols.

Data Quality Assessments. The *CTC* QA Manager will also perform data quality (statistical) assessments on data collected during the analysis of one metal and one anion.

Corrective Action. Corrective Action for any deviations to established quality assurance and quality control procedures during verification testing will be performed according to section 2.10 Quality Improvement of the ETV-MF QMP [Ref. 3].

Laboratory Corrective Action. Examples of non-conformances include invalid calibration data, inadvertent failure to perform method-specific QA, process control data outside specified control limits, failed precision and/or accuracy indicators, etc. Such non-conformances will be documented on a standard laboratory form. Corrective action will involve taking all necessary steps to restore a measuring system to proper working order and summarizing the corrective action and results of subsequent system verifications on a standard laboratory form. Some non-conformances are detected while analysis or sample processing is in progress and can be rectified in real time at the bench level. Others may be detected only after a processing trial and/or sample analysis is completed. Typically, the LM detects these types of non-conformances. In all cases of non-conformance, the LM will consider sample re-analysis as one source of corrective action. The LM will contact the ETV-MF Project Manager if reanalysis does not correct the non-conformance. If insufficient sample is available or the holding time has been exceeded, complete re-processing may be ordered to generate new samples if a determination is made by the ETV-MF Project Manager that the non-conformance jeopardizes the integrity of the conclusions to be drawn from the data. In all cases, a non-conformance will be rectified before sample processing and analysis continues.

6.0 PROJECT MANAGEMENT

6.1 Organization/Personnel Responsibilities

The ETV-MF Project Team that is headed by *CTC* will conduct the evaluation of Hydrometrics' HERO™ system. The *CTC* ETV-MF Program Manager, Donn Brown, will have responsibility for all aspects of the technology verification, including appointment of a Project Manager, making ETV-MF Project Team personnel assignments, and coordination of technology testing. The ETV-MF Project Manager assigned to the HERO™ verification is Chris Start of the Michigan Manufacturing Technology Center (MMTC). MMTC is one of four partner organizations under contract to *CTC* for the ETV-MF Program. Mr. Start and/or his staff/subcontractors will conduct or oversee all sampling and related measurements, and ensure that required laboratory QC analyses (spikes/duplicates) are performed.

Hydrometrics will arrange transport of the mobile HERO™ unit to the test site. Hydrometrics will perform start-up. Once the system is performing per the design objectives, verification testing will commence. Hydrometrics personnel will continue to operate the system. A Hydrometrics representative (Steve Ackerlund) will assist in verification testing of the HERO™ system and will be on-call during the test period for response in the event of equipment problems.

Pace Analytical Services is responsible for performing aqueous chemical analysis of all samples taken during the verification test. Pace Analytical Services is accredited by NELAC for the analyses identified in this Test Plan. Jim Dowse is the Pace Analytical Services point of contact (POC).

The ETV-MF Project Manager and the KCP have the authority to stop work when unsafe or unacceptable quality conditions arise. The *CTC* ETV-MF PM will provide periodic assessments of verification testing to the EPA ETV Center Manager.

6.2 Test Plan Modifications

In the course of verification testing, it may become necessary to modify the test plan due to unforeseen events. These modifications will be documented using a Test Plan Modification Request form (**Appendix D**), which must be submitted to the *CTC* ETV-MF Program Manager for approval. Upon arrival, the modification request will be assigned a number, logged, and transmitted to the requestor for implementation.

6.3 Schedule/Milestones

The schedule/milestones will be determined mutually by *CTC*, Hydrometrics, and KCP.

6.4 Documentation/Records

Original documentation generated during verification testing (COC forms, data collection forms, analytical results, etc.) will be maintained at the *CTC* office in Largo, Florida.

7.0 EQUIPMENT

7.1 Equipment List and Utility Requirements

The HERO™ 15 gpm unit consists of the following equipment:

Prefiltration System: 20-micron bag filter (with in-line spare) followed by a 36" diameter by 84" tall multi-media depth filter. These filters are fed by a 5-hp totally enclosed fan-cooled (TEFC) pump that produces approximately 20 gpm at 50 pounds per square inch (psi) during normal operation, and 100 gpm at 45 psi when cleaning the multi-media filter. Filtered solids are periodically back-washed to the clarifier, where they are removed.

SAC System: 36" diameter by 84" tall pressure vessel containing 20 cubic feet (ft^3) of SAC resin (with in-line spare). This vessel is regenerated using a salt brine while the in-line spare is in operation.

WAC System (x2): The HERO™ unit contains a pressure tank containing 10 ft^3 of WAC resin and can be piped for either up-flow or down-flow operation. The copper recovery WAC ion exchange unit will be installed at KCP adjacent to the cyanide rinse water holding tank.

Degasification System: This portion of the HERO™ unit consists of two 4" by 28" Celgard Liqui-Cel Membrane Contractors, which can be operated either in series or parallel. Air for these strippers is provided by a 1-1/2 hp compressor and exits through a stack above the roof of the mobile HERO™ trailer.

RO System: The HERO™ unit RO system consists of five stages of 120" pressure vessels, each containing three or four membranes. The first stage consists of two 4" vessels rated for 600 psi and is fed by a 10-hp open drip-proof (ODP) pump. The reject from the first stage is fed to the second stage (a single 4" vessel rated for 600 psi). The third stage consists of a single 4" pressure vessel rated for 1000 psi and is fed via another 10-hp ODP booster pump. The fourth and fifth stages each consist of a single 2.5" pressure vessel rated for 1000 psi. The permeate from each pass is combined in a single stream with a flow of approximately 15 gpm. The reject from the fifth pass is approximately 1 gpm. Equipment and utility requirements are identified in **Table 6.**

EQUIPMENT		
Number Req'd	**Type of Equipment**	**Comments**
	Prefilter System	
1	20-micron bag filter	Contains in-line spare
1	Multi-media depth filter	36" diameter by 84" tall
1	Pump – 5 hp TEFC	Normal=20 gpm @ 50 psi; Cleaning=100 gpm @ 45 psi
	SAC System	
1	Pressure vessel w/ 20 ft^3 of SAC resin	36" diameter by 84" tall; contains in-line spare
	WAC System(s)	
2	Pressure vessels w/ 15 ft^3 of WAC resin	Can be piped for either up-flow or down-flow operation
	Degasification System	
2	Celgard Liqui-Cel Membrane Contractors	4" x 28" each; can be operated either in series or parallel
1	Air compressor	1-1/2 hp
	RO System	
3	4" Pressure vessels w/ 4 membranes	Rated for 600 psi
2	Pumps – 10 hp ODP	
1	4" Pressure vessel w/ 4 membranes	Rated for 1,000 psi
2	2.5" Pressure vessels w/ 3 membranes	Rated for 1,000 psi
SPARE PARTS		
12	4" Brackish water RO membranes	
4	4" Seawater RO membranes	
6	2.5" Seawater RO membranes	
4	5-micron cartridge filters (set + spare)	
2	1-micron cartridge filters	
10	20-micron bag filters	
Required Utilities		
Utilities to include: Electrical	• Automated control panel: 50 amp, 480 volt, 3-phase, 60 Hz • Liquid transfer pumps: 110 VAC	Air • None Water • None

Table 6: Equipment List and Utility Requirements

7.2 Monitoring/Sampling Equipment

All monitoring/sampling equipment to be used during testing is identified in **Table 7**.

Equipment	Purpose
Omega Engineering, Inc. Model FD-7000 Multi-Liquid Ultrasonic Flowmeter	Flow of System Liquids
Davis Instruments Model # 9214 ATC pH Meter with Integral Temperature Sensor	Process pH and Temperature
Oakton Acorn® Series CON 5 Conductivity Meter with Integral Temperature Sensor	Process Specific Conductivity
Hach© Pocket Colorimeter™ Filter Photometer with Total Chlorine Reagent Set	Process Total Residual Chlorine

Table 7: Monitoring/Sampling Equipment

8.0 HEALTH AND SAFETY PLAN

This Health and Safety Plan provides guidelines for recognizing, evaluating, and controlling health and physical hazards that could occur during verification testing. More specifically, the Plan specifies for assigned personnel; the training, materials, and equipment necessary to protect them from hazards; and any waste generated. The KCP Hazcom/Personal Protective Equipment (PPE) Plan/Program will be used throughout the HERO™ verification testing for any activities related to the conventional wastewater treatment system that operates at the KCP. For activities involving the HERO™ system, Hydrometrics will provide operating procedures and all associated health and safety plans/procedures.

8.1 Hazard Communication

All personnel assigned to the project will be provided with the potential hazards, signs and symptoms of exposure, methods or materials to prevent exposures, and procedures to follow if there is contact with a particular substance during verification testing. Hazard communication will take place during training and will be reinforced throughout the test period. All appropriate Material Safety Data Sheets (MSDSs) will be available for the chemical solutions used during the testing.

8.2 Emergency Response Plan

The KCP has a contingency plan to protect employees, assigned project personnel, and visitors in the event of an emergency at the facility. This plan will be used throughout the project. All assigned personnel will be provided with information about the plan during training.

8.3 Hazard Controls Including Personal Protective Equipment

All assigned project personnel and visitors will be provided with appropriate PPE and any training needed for its proper use, considering their assigned tasks. The use of PPE will be covered during training.

8.4 Lockout/Tagout Program

The KCP's lockout/tagout procedure will be implemented when necessary and will be explained to anyone required to perform such duties. Equipment installation performed by Hydrometrics and the KCP is not included within the scope of this test plan. No lockout/tagout activities are anticipated during the verification test.

8.5 Material Storage

Any materials used during the project will be kept in proper containers and labeled according to Federal and state law. Proper storage of the materials will be maintained based on associated hazards. Secondary containment, spill trays, or similar devices will be used as needed to prevent material loss to the surrounding area.

8.6 Safe Handling Procedures

All chemicals and wastes or samples will be transported on-site in non-breakable containers used to prevent spills. Emergency spill clean-up will be performed according to the KCP procedures.

9.0 WASTE MANAGEMENT

The HERO™ system will process wastewater generated by manufacturing operations at the KCP. Prior to processing by the HERO™ system, the wastewater will be treated by the conventional wastewater treatment system at the KCP. After treatment by the HERO™ system, the wastewater will be returned to the conventional wastewater treatment system. The existing wastewater treatment system is fully permitted, and achieves compliance with discharge requirements in accordance with local, state, and Federal laws. Hydrometrics says the reagents to be added to the HERO™ process during verification test will increase the TDS, but they will not upset existing clarifier operations. Hydrometrics will retain any unused acid or caustic.

10.0 TRAINING

It is important that the verification activities performed by the ETV-MF Center be conducted with high quality and with regard to the health and safety of the workers and the environment. By identifying the quality requirements, worker safety and health, and environmental issues associated with each verification test, the qualifications or training required for personnel involved can be identified. Training requirements will be identified using the Job Training Analysis (JTA) Plan [Ref. 4].

The purpose of the JTA Plan is to outline the overall procedures for identifying the hazards, quality issues, and training needs for each verification test project. The JTA Plan establishes guidelines for creating a work atmosphere that meets the quality, environmental, and safety objectives of the ETV-MF Center. The JTA Plan describes the method for studying ETV-MF project activity and identifying training needs. The ETV-

MF Operation Planning Checklist (**Appendix A**) will be used as a guideline for identifying potential hazards, and the JTA Form (**Appendix B**) will be used to identify training requirements. After completion of the form, applicable training will be performed. Training will be documented on the ETV-MF Project Training Attendance Form (**Appendix C**).

11.0 REFERENCES

1) Thomas J. Weber, Wastewater Management Inc., "*Wastewater Treatment*" <u>Metal Finishing Guidebook and Directory Issue,</u> 1999, pg. 801.

2) U.S. EPA Office of Environmental Information, "*Guidance for the Data Quality Objectives Process EPA QA/G-4*", EPA/600/R-96/055, August 2000.

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

4) Concurrent Technologies Corporation (*CTC*), "Environmental Technology Verification Program Metal Finishing Technologies (ETV-MF) Pollution Prevention Technologies Pilot Job Training Analysis Plan" May 10, 1999.

5) US EPA Office of Research and Development, "*Waste Reduction in the Metal Fabricated Products Industry*" EPA/600/SR-93/144, September 1993.

6) George C. Cushnie Jr., CAI Engineering, "Pollution Prevention and Control Technology for Plating Operations" NCMS/NAMF, 1994.

12.0 DISTRIBUTION

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APPENDIX A

ETV-MF Operation Planning Checklist

ETV-MF OPERATION PLANNING CHECKLIST

The ETV-MF Project Manager prior to initiation of verification testing must complete this form. If a "yes" is checked for any items below, an action must be specified to resolve the concern on the Job Training Analysis Form.

Project Name:____ Expected Start Date:

ETV-MF Project Manager: ____________________________________ ______________

Will the operation or activity involve the following:	**Yes**	**No**	**Initials & Date Completed**
Equipment requiring specific, multiple steps for controlled shutdown? (e.g., in case of emergency, does equipment require more than simply pressing a "Stop" button to shut off power?) *Special Procedures for emergency shut-down must be documented in Test Plan.*			
Equipment requiring special fire prevention precautions? (e.g., Class D fire extinguishers)			
Modifications to or impairment of building fire alarms, smoke detectors, sprinklers, or other fire protection or suppression systems?			
Equipment lockout/tagout or potential for dangerous energy release? *Lockout/tagout requirements must be documented in Test Plan.*			
Working in or near confined spaces (e.g., tanks, floor pits) or in cramped quarters?			
Personal protection from heat, cold, chemical splashes, abrasions, etc.? *Use Personal Protective Equipment Program specified in Test Plan.*			
Airborne dusts, mists, vapors and/or fumes? *Air monitoring, respiratory protection, and /or medical surveillance may be needed.*			
Noise levels greater than 80 decibels? *Noise surveys are required. Hearing protection and associated medical surveillance may be necessary.*			
X-rays or radiation sources? *Notification to the state and exposure monitoring may be necessary.*			
Welding, arc/torch cutting, or other operations that generate flames and/or sparks outside of designated weld areas? *Follow Hot Work Permit Procedures identified in Test Plan.*			
The use of hazardous chemicals? *Follow Hazard Communication Program, MSDS Review for Products Containing Hazardous Chemicals. Special training on handling hazardous chemicals and spill clean-up may be needed. Spill containment or local ventilation may be necessary.*			
Working at a height of six feet or greater?			

ETV-MF OPERATION PLANNING CHECKLIST

The ETV-MF Project Manager prior to initiation of verification testing must complete this form. If a "yes" is checked for any items below, an action must be specified to resolve the concern on the Job Training Analysis Form.

Project Name: ______________________________
ETV-MF Project Manager: ______________________________

Will the operation or activity involve the following:	**Yes**	**No**	**Initials & Date Completed**
Processing or recycling of hazardous wastes? *Special permitting may be required.*			
Generation or handling of waste?			
Work to be conducted before 7:00 a.m., after 6:00 p.m., and/or on weekends? *Two people must always be in the work area together.*			
Contractors working in *CTC* facilities? *Follow Hazard Communication Program.*			
Potential discharge of wastewater pollutants?			
EHS aspects/impacts and legal and other requirements identified?			
Contaminants exhausted either to the environment or into buildings? *Special permitting or air pollution control devices may be necessary.*			
Any other hazards not identified above? (e.g., lasers, robots, syringes) *Please indicate with an attached list.*			

The undersigned responsible party certifies that all applicable concerns have been indicated in the "yes" column, necessary procedures will be developed, and applicable personnel will receive required training. As each concern is addressed, the ETV-MF Project Manager will initial and date the "initials & date completed" column above.

ETV-MF Project Manager: ____________________ ____________________ ____________
(Name) (Signature) (Date)

APPENDIX B

Job Training Analysis Form

JOB TRAINING ANALYSIS FORM

ETV-MF Project Name: ____

Basic Job Step	Potential EHS Issues	Potential Quality Issues	Training

ETV-MF Project Manager: ______________________

Name

____

Signature

____

Date

APPENDIX C

ETV-MF Project Training Attendance Form

ETV-MF Project Training Attendance Form

ETV-MF Pilot Project: ________________________________

Date Training Completed	Employee Name Last	First	Training Topic

ETV-MF Project Manager: ____

APPENDIX D

Test Plan Modification

Test Plan Modification

In the course of verification testing, it may become necessary to modify the test plan due to unforeseen events. The purpose of this procedure is to provide a vehicle whereby the necessary modifications are documented and approved.

The Test Plan Modification Request form is the document to be used for recording these changes. The following paragraphs provide guidance for filling out the form to ensure a complete record of the changes made to the original test plan.

The person requesting the change should record the date and project name in the form's heading. The *CTC* ETV-MF PM will provide the request number.

Under "Original Test Plan Requirement," reference the appropriate sections of the original test plan, and insert the proposed modifications in the section titled "Proposed Modification." In the "Reason" section, document why the modification is necessary; this is where the change is justified. Under "Impact," give the impact of not making the change, as well as the consequences of making the proposed modification. Among other things, the impact should address any changes to cost estimates and project schedules.

The requestor should then sign the form and obtain the signature of the ETV-MF Project Manager (Partner). The ETV-MF Project Manager (Partner) should sign both lines if he is the requestor. The form should then be transmitted to the *CTC* ETV-MF PM, who will either approve the modification or request clarification. Upon approval, the modification request will be assigned a number, logged, and transmitted to the requestor for implementation.

TEST PLAN MODIFICATION REQUEST

Date:___________ **Number:___________** **Project:__________________________**

Original Test Plan Requirement:____

Proposed Modification:____

Reason: ____

Impact:____

Approvals:

Requestor:_______________________________

ETV-MF Project Manager:__________________________

CTC ETV-MF Program Manager:_________________________