RenoCell®

Title: **Electrolytic Cell Field Experience — The Role of Field Operations and Feedback in the Commercialization of the RenoCell¨**

Authors: **B. George Kniazewycz and Charles E. Lemon, Renovare International, Inc., Walnut Creek, California, USA**

Most individual metal removal techniques used in the treatment of process and waste streams have the disadvantage of the requiring other technologies to meet process and effluent limits, and/or they produce a secondary effluent metal-bearing solution or mixed solid requiring further treatment. For example, the performance of conventional electrolytic cells (usually based upon metal plate or mesh cathodes in a tank) is limited at low metal ion concentrations of around 100 - 50 mg/l or ppm while effluent discharge levels are generally less than 5 mg/l and often below 1 mg/l. This limitation has been addressed by a patented electrochemical technology developed by EA Technology, being commercialized by Renovare International, Inc., and known as RenoCell¨. The RenoCell product line, announced at this Forum in 1997, allows effective use of three-dimensional porous cathodes. The 3-D cathode greatly enhances the performance of the cell since the porous cathode has >500 time greater effective surface area than a 2-D electrode of the same nominal size. RenoCell's high surface area allows metal deposition at higher deposition rates, lower current densities and higher current efficiencies and thus achieve lower final metal concentrations.

RenoCell's applications range from process water treatment to metal recovery to effluent treatment. For example, the cell is placed at point sources of copper and other metal releases such as dragout and rinse tanks. Instead of these waters being released to waste treatment, the RenoCell recovers the metal at the source, allows the rinse water to be used longer thus reducing water use and discharges all at a substantial cost advantage over conventional technology. Field experience with pre-production cells in a variety of applications and with a myriad of metals (focus on heavy metals— e.g., Cd, Cu, Pb and precious metals) provided invaluable feedback to the design of RenoCell product line. RenoCell has demonstrated the capability to achieve discharge limits without further treatment; collect metals as elements ready for sale or reuse; use removable cartridges for ease of operations and maintenance; and improve cost effectiveness and reduce life cycle costs. This operational experience and performance data are presented and reviewed.

For more information, contact:
B. George Kniazewycz or Charles E. Lemon
Renovare International, Inc.
1401 N. Broadway, Suite 225
Walnut Creek, CA 94596

Phone: 925.945.7576
Fax: 925.945.0131
renocell@renovare.com

Introduction

Metal ion removal and recovery are necessary in many industrial and chemical process treatments. Metals may be present as a result of corrosion of process equipment, raw material contamination, catalyst carryover or plating rinse streams. Contaminating metal ions can occur as cationic or anionic metal complexes.

Such situations represent a loss of metal and in many cases an effluent problem that has to be dealt with, particularly now that discharge of metals and disposal of metal sludges is much more rigorously controlled. The U.S. EPA and other national regulatory bodies are focused on heavy metals including Cd, Cr, Cu, Pb, Hg, Ni and Zn.

There is a need to address this problem in an economic manner and considerable effort has been devoted to the development of technologies that can offer an answer, e.g., ion exchange, reverse osmosis, solvent extraction and electrolysis. The goal has been to supplant the most commonly used method of effluent treatment—chemical precipitation, with improved methods that can recover the metal in a reusable form, and hopefully solve the effluent problem in a cost-effective manner.

The recovery methods available are technically quite satisfactory and ultimately the recovered metal can be refined from concentrates and sludges to produce whatever form and purity is desired. Their economic justification, however, seems to be more difficult, and so far, they appear to be competitive only where large throughputs, single metal streams and particularly stringent or difficult discharge conditions are encountered. This generally rules out the great majority of applications. Furthermore, after recovery, the solutions often require conditioning before discharge, e.g., neutralization, cyanide destruction, etc., since the single stage recovery effluent treatment approach is often not entirely satisfactory.[1]

An alternative, electrolysis, is generally used in the metals industry when high purity products are desirable and where different finished metal surface coatings are required. Electrolysis has the potential therefore of producing a directly reusable product from an effluent solution. Ideally the metal should be in a solid form (as opposed to powders) so that direct reuse can be achieved by melting or dissolving as anodes in the main processes, e.g., plating, electrorefining.

There are two major problems in the electrolysis of dilute (i.e., $<1g/l$) metal ion bearing solutions:

- The process becomes mass transport limited, therefore either capital costs are high or current efficiencies and quality of the deposit are often poor.

- The economic return from dilute solutions of metals is generally very small, and when associated with the relatively small amounts of throughput generally found, impose a serious limitation to the sophistication and costs a process system or application can afford. The exceptions to this are toxic metals and precious metals.

Many electrolytic cells have been commercialized for metal recovery over the past two decades. They are used mostly as concentrators where further stages of purification are required to obtain the metal in a directly reusable form. The most common configurations include parallel flat plate cathodes, reticulated cathodes, and high surface area cathodes. Various cell configurations have been developed to minimize the mass transport limits and reduce the equipment footprint and costs. Some of the most common cells include the carbon particle packed bed (ER cell); fluidized bed beads within electrodes (Chemelec cell); vertical metal or carbon foam electrodes (Retec cell); and various cylindrical rotating cathodes (Eco-Cell), as identified in Pletcher.[2]

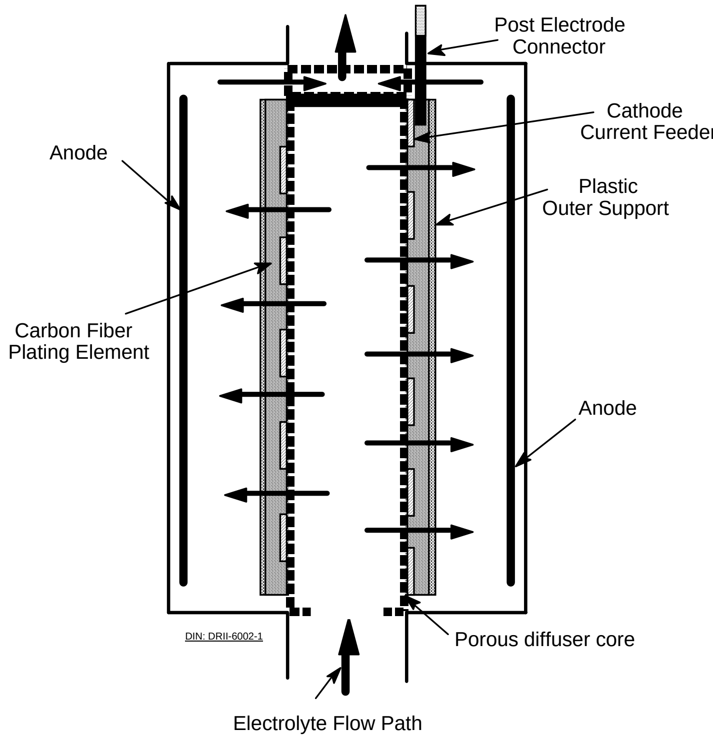
Unfortunately, the performance of these conventional electrochemical cells is limited at dilute or low metal ion concentrations. While some of these cells can be effective down to metal ion concentration levels of around 50 - 100 mg/L, effluent discharge levels are typically less than 5 mg/L and often below 1 mg/L.

The challenge of developing an electrolytic cell capable of removing metal to below 1 mg/L concentrations has been addressed effectively by a patented electrochemical cell technology known as RenoCell¨.

RenoCell Technology

The RenoCell technology (see Figure 1), for the first time, allows effective use of three-dimensional (3-D) cathode materials, in most cases a porous carbon element, through the flow path and current distribution embodied in the RenoCell. The use of a 3-D cathode greatly enhances the performance of the cell since the porous carbon felt has at least 500 times greater effective surface area than a two-dimensional electrode of the same nominal geometric size.

Figure 1
Standard RenoCell (Undivided) Schematic Cross-Section



The patented design of the RenoCell makes this very high surface area available for metal deposition at higher current efficiencies, lower current densities and higher deposition rates for a given nominal cell size than commercial cells with 2-D and 3-D cathodes. The net result is that RenoCell can achieve lower final metal ion concentrations while using less energy to remove a given amount of metal from a metal ion bearing solution. In general, RenoCell is capable of two to three orders of magnitude lower final concentration of metal ions, and three to ten or more times higher current efficiency than other commercial electrochemical cells at concentrations between 50 and 5 mg/L. The current efficiency improvement is even higher (infinite in some cases) between 5 and 0.1 mg/L (or even 0.01 mg/L for some applications). Such low concentration treatment levels are not even possible by present commercial electrochemical cells.

Physically, the standard RenoCell is constructed of plastic tubular sections that are mounted vertically to assure gases escape with effluent solution discharge. A standard RenoCell Model 500 for industrial applications consists of an 0.5 m long polypropylene housing with an outside diameter of 200 mm. The area of the cathode in this device, on a 2-dimensional basis, is approximately 0.11 m^2. The actual plating surface of the carbon element is at least 55 m^2. A larger standard RenoCell Model 1000 is also available consisting of a 1.0 m long housing of the same outside diameter, and having a 2-D cathode area of 0.23 m^2 and 3-D area of 115m^2.

In addition, for certain applications, a variation of the 0.5m standard RenoCell is the “divided” RenoCell Model 500/D, in which a hydroscopic membrane (normally a cation exchange membrane) is positioned concentrically between the cathode and the anode. In this case, two electrolyte solutions, anolyte and catholyte, and consequent dual solution storage, circulation and control systems, are required. The divided cell system can be applied to solutions containing species that can be oxidized at the anode and that would interfere with the cathodic deposition process, e.g., chlorine generation from aqueous chloride solutions.

When the cathode is completely laden with metal to the point of blocking virtually all flow through the cell, the cathode must be replaced or otherwise regenerated The spent cathode is recovered from the RenoCell by switching off the power supply and pumps; disconnecting the outlet piping; removing the top end plate; and then extracting the metal-laden cathode cartridge assembly. A new cathode cartridge assembly is then inserted into its locating position within the cell, the end plate, outlet hose and cathode current feed wire replaced, and the cell is ready for operation. Metal-laden cathodes can then be regenerated, smelted or otherwise handled.

Technology Experience

Renovare considers RenoCell as a major extension of electrochemical deposition technology both in terms of effective treatment range and reduced life cycle costs. The technology has been successfully demonstrated or installed on the following metals in a variety of matrices:

Cadmium	Nickel
Copper	Cobalt
Mercury	Rhodium
Platinum	Gold
Iron	Lead
Osmium	Palladium
Ruthenium	Silver
Tin	Zinc

Other metals of possible interests include arsenic, antimony, polonium, molybdenum and tungsten that are recovered as alloys with other platable metals. While no metal electrodeposition occurs with chromium, manganese and titanium, they do electroprecipitate at the RenoCell cathode as oxides or hydroxides and are effectively removed. Other metal recoveries are being continually tested.

Based on over 600 tests performed over the past six years, the RenoCell technology has demonstrated excellent removal capability of a range of heavy metals, value metals and precious metals. Table 1 provides a partial list of installations by industry and application in the UK and U.S. that provided operational and design feedback to the RenoCell commercialization.

Table 2 presents typical experience for a variety of process liquors and rinses and effluent streams. Typical use of RenoCell included plating bath maintenance, rinse bath treatment, enhancing ion exchange resin operating life, ion exchange regenerant treatment and reuse, as well as precious metal recovery and heavy metal removal operations.

Operational Feedback and Design Changes

From 1994 until mid-1998, some 70 pre-production RenoCell were installed and operated in the UK and U.S. as noted in Table 1. These installations, process applications and operations provided needed feedback to allow Renovare to upgrade the design to meet the demand for a robust, industrial grade product line. In mid-1997, Renovare initiated the RenoCell product line development program that focused on design changes to:

- Improve Performance
- Reduce Maintenance Costs
- Reduce Production Cost
- Improve Cell Reliability
- Reflect Lessons Learned in the Field

Table 1
RenoCell Applications & Installations

Industry	***Application***	***Metal(s)***
Electroplating	Dragout tank recovery	Cadmium
Photographic	Photographic wastes	Silver
Chemical	Process effluent	Precious metals
Remediation	Ground water	Various
Electroplating	Rinse baths	Silver
Chemical	Ion exchange regenerants	Various
PWB/Electronics Manufacturer	Process wastes	Copper
Metal Finishing	Etchant solutions	Copper
Chemical Industry	Effluent	Various
Metal Finishing	Process effluent	Cadmium
Metal Finishing	Process treatment	Cadmium
Scotch Whisky	Water treatment	Copper
Remediation	Leachate	Various
Nuclear	Effluent	Various
Electric Utility	Various	Various

A series of design changes was identified and evaluated as new prototypes were introduced and tested. The focus was on the following:

- Cathode design changes
- Anode design changes
- Housing design changes
- Membrane divider design changes

Some 20 changes and improvements were incorporated and resulted in new product design features for RenoCell Model 500 and 500/D including:

- Top lid easily removable
- All electrical and fluid transfer connections now confined to top and bottom lids
- Current feeder post seals now use O-ring
- Dual current feeder posts for both cathode and anode
- Anode can be mounted with current feeder posts exiting either the top or bottom lids
- Catholyte inlet and outlet connections are now both US 3/4 inch (ISO 25 mm) female pipe thread connections
- Anolyte inlet and outlet connections are now both US 1/2 inch (ISO 20 mm) female pipe thread connections
- Bottom lid insert is easily removable for cell cleaning
- Divider assembly allows membrane replacement

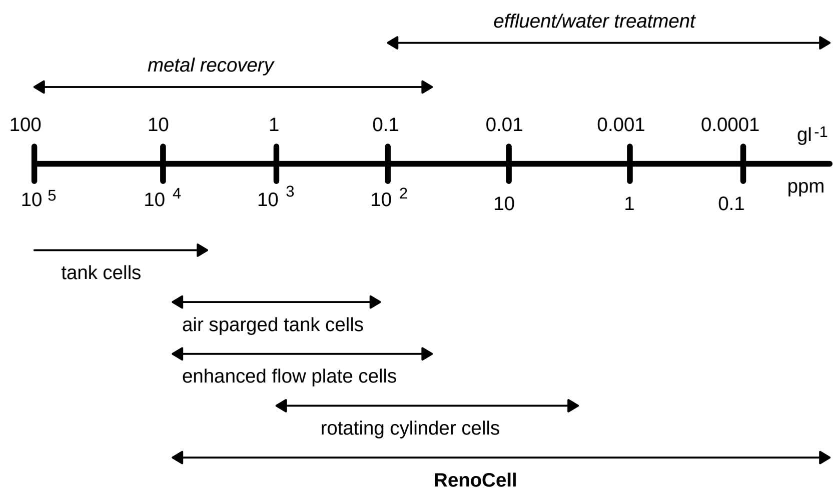
Some 60 commercial RenoCells have been shipped, installed and commissioned since January 1999. The experience to date has been excellent especially in those applications involving divided cell where major changes were necessary and included:

- Tapered membrane flanges with O-rings
- Improved membrane sealing that eliminated sealants that may separate during operation
- Easier replacement of membrane
- Dual-wall membrane divider to minimizes stress on membrane for improved performance and reliability

Technology Performance

As noted, the performance of a "conventional" electrolytic cell is limited at lower metal ion concentrations (generally below 50 mg/L) as illustrated in Figure 2. These devices are usually based on metal plate or mesh cathodes in a tank combined with some means of mass transfer enhancement (e.g., moving the electrodes or achieving turbulent process flow). Thus, to reach 1 mg/L or lower, an additional treatment process, such as ion exchange, is required that increases complexity and costs when compared to RenoCell.

Figure 2 - Electrochemical Cells for Metal Recovery –
The Dependence of Cell Design on the Concentration of Metal Ion in the Feed

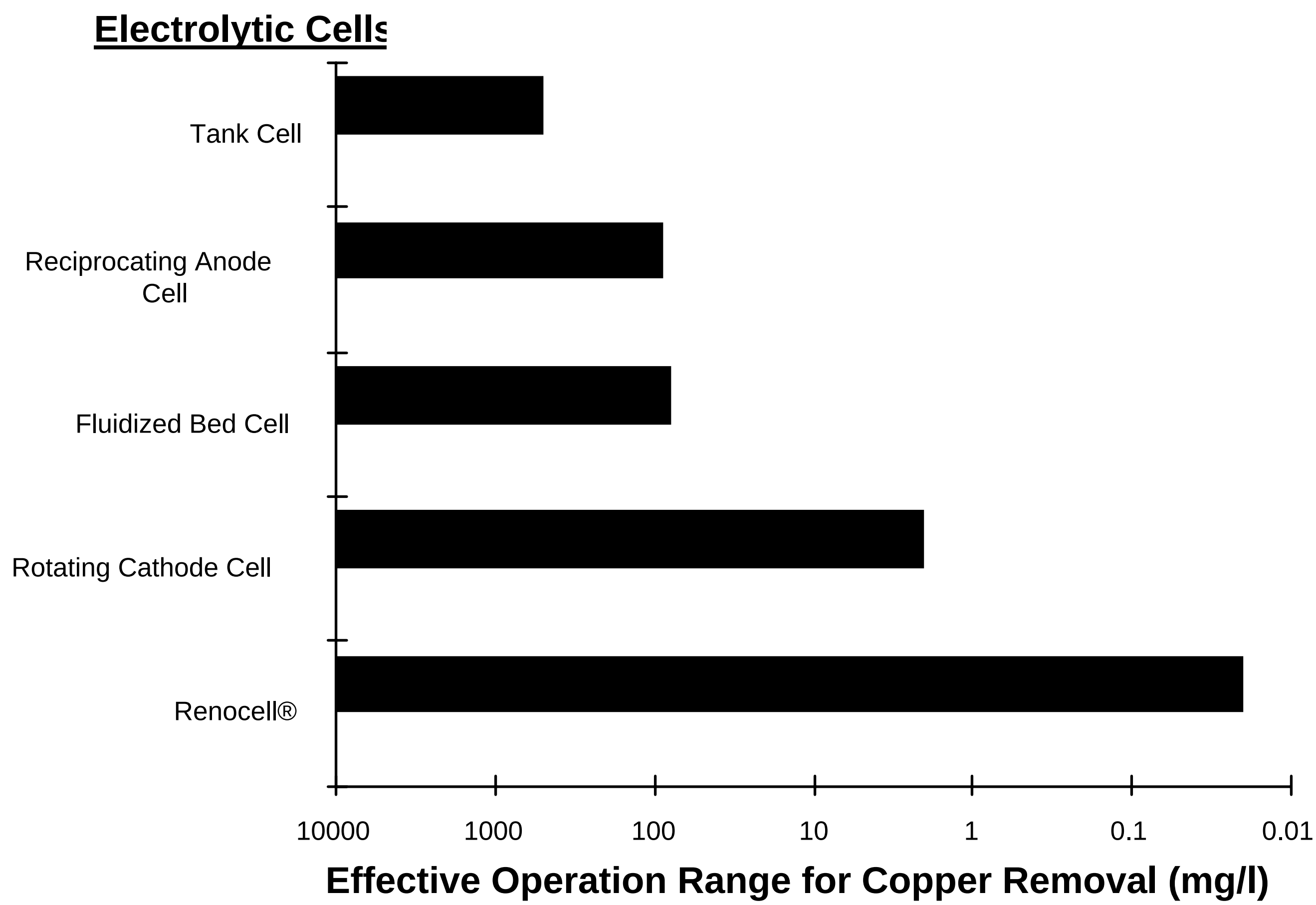

effluent/water treatment
metal recovery
100
10
1
0.1
0.01
0.001
0.0001
gl-1
10 5
10 4
10 3
10 2
10
1
0.1
ppm
tank cells
air sparged tank cells
enhanced flow plate cells
rotating cylinder cells
RenoCell

RenoCell is based upon the effective use of a 3-D cathode in metal ion removal applications. This technology has evolved from 2-D planar and cylindrical cathodes and fluidized bed 3-D cells (Chemelec). By taking advantage of the very high surface area of carbon fiber and other similar materials, RenoCell has extended the metal ion (concentration) removal range two to three orders of magnitude <u>lower</u> than other commercial electrolytic products (see Figure 3).

RenoCell has the potential of being applied to numerous metal ion removal or control applications. Typical results taken from actual pilot tests and installations are given in Table 2. Such applications must be evaluated against the current RenoCell design and capabilities as noted in Table 3.

Figure 3 - Comparison of Conventional Electrolytic Cells on Copper-laden Process Solutions

7075626c01a0000200000852656e6f7661726500000000000000000000000000000000000000b2f5d1d14244000100
0005011b525249492d373032352f454423312f46524f4d585249493730323800000000000000000000000000000000
00000000000000000000000000000000000000000051bb2f5dc57656474705843454c000300030000011000100
0000000000000000000000c313939372052656706f72747300010008000005010000002f0002003952656e6f7661
72653a5245504f5254533a3139393720526570 6f7274733a525249492d373032352f454423312f46524f4d585249493
730323800000900a700a76166706d000000000002001800390059007500 95009e012a0000000000000000000000
000000000000000000000000000000000000852454e4f5641524500000000000000000000000000000000000000
00000000852656e6f7661726500000000000000000000000000000000000000363656c0000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000ffff000001010000b145393
60000000080457b02027b557800000000000000000003f5e1c00000000



‹RII-7028/ED#1

While the following discussion uses U.S. experience, statistics and regulations, it is noted that much of the industrial world has similar or more stringent regulatory environments and operational restraints.

U.S. Industrial Practices

Currently, metals in wastewater are removed by the addition of chemicals that precipitate the dissolved metals as metal hydroxides or sulfates in the plating and surface finishing industry. The solid particles are removed as a wet sludge by filtration or flotation and then disposed to landfill. Due to the addition of chemicals during precipitation treatment, the water generally cannot be recycled to rinse operation and consequently the treated water is discharged. In the mid-90s some 70,000 tons of Cu/Pb compounds and 230,000 tons of metals were disposed annually in the U.S. The cost associated with the transport and disposal of Cu/Pb sludges and metal sludges were in excess of $25M and $65M, respectively, with additional costs associated with the liability of future landfill cleanup. According to the survey of 318 U.S. plating shops in metal plating industry, an average of 160,000 L/day of water is discharged from one plating shop. For the entire printed wiring board industry (i.e. about 800 U.S. shops), this represents 30 billion liters/year of water discharged. With average water and sewer costs of $0.01/liter, this represents an additional cost of $25M/year. In addition, the costs of sewer and water are rising at 150% and 200% of the inflation rate, respectively. The actual cost of in-shop treatment is not included in these figures.

Table 2 - RenoCell Testing and Operating Experience

Effluent	*Metal*	*Concentration* Initial (mg/L)	Final (mg/L)	*Current Efficiency (%)*
Acid sulfate rinse	Cu	910	0.02	41
	Cu	958	0.21	32.1
	Cu	98.4	1.0	27.4
	Cu	98.2	0.22	20.7
Cyanide plating rinse	Cu	105	0.34	2
	Cu	113	0.5	1
Fluoborate plating rinse	Cu	115	0.3	38.7
Electroless Cu rinse	Cu	82	0.8	14.2
Micro etch bath rinse	Cu	44	0.11	20
Cyanide plating rinse	Ag	99.4	0.6	5
	Ag	993	0.24	2.1
	Ag	740	0.34	7.5
Cyanide static dragout	Cd	107	0.34	2
Acid sulfate rinse	Cd	978	0.37	22
	Cd	247	0.51	18.8
Acid sulfate rinse	Zn	77.5	0.23	2
Acid sulfate rinse	Sn	93.2	0.5	7
Fluoborate plating rinse	Pb	85	0.32	6
Watt's bath rinse	Ni	105	0.5	4
Acid sulfate rinse	Cr(III)	124	1	1.6
Cyanide liquor	Au	330	<0.1	–
	Au	380	<0.1	–
Acidic liquors	Pt/Pd	24/110	1/0.01	4
	Pt	2000	0.5	–
	Pd	500	<0.5	–
	Au/Ir	3.2/3	0.8/1.2	–
Groundwater (acidic)	Hg	6.3	0.036	–

Table 3
RenoCell Features and Capabilities

Features	Capabilities
Porous carbon felt cathode	Greatly increased deposition surface area High metal extraction rates Effective at concentrations down to 1 mg/L and below Three to ten times more energy efficient
Metal deposits plated on fiber	Minimizes or eliminates generation of hazardous metal sludges
Replaceable cathode cartridges	Easy metal removal Quick and easy cathode replacement Low operation and manpower requirements
Compact, robust design	Increased reliability in industrial environments Very small footprint Capable of being wall mounted
Optional divided cell design	Allows treatment of anodically-sensitive solutions

Industry-standard components	Allows for modular design

Conventional recovery methods for metal in the U.S. include ion exchange, electrowinning, reverse osmosis, evaporation and freeze crystallization. Two columns of ion exchange (cation and anion exchange) can reduce metal concentration as well as TDS and neutralize pH for recycle to rinse operation. However, strong acid and alkaline solutions are needed to regenerate the cation exchange resin and anion exchange resin, respectively, and the resulting solutions then need to be disposed. While reverse osmosis, evaporation, and freeze crystallization technologies can provide water with low metal concentration for discharge, the concentrated stream generated needs further treatment and often the dilute stream needs to be polished. Conventional electrowinning is not efficient to treat low metal concentrations in wastewater and the treated water cannot by recycled because pH is not neutralized. However, RenoCell, because of its excellent performance on dilute metal bearing solutions, offers a practical alternative to the high cost of waste sludge and long term liability risks.

Against this backdrop, it is noted that the U.S. metal finishing and printed wiring board (PWB) industries have been highly regulated and have been strongly encouraged to reduce waste generation and emissions. Since the passage of the pollution Prevention Act of 1990, the emphasis has been to prevent pollution at the source followed by recycling, treatment and disposal. Thus, waste minimization at the source is a desirable goal though rarely practical with conventional technology.

General Metal Finishing

RenoCell electrodeposition technology is applicable to the prevalent metals, and their complexes, that abound in the metal finishing industry. These metals include nickel, copper, cadmium, zinc, lead, tin, gold, silver, palladium, and chromium. In these industrial applications, RenoCell technology focuses on waste minimization and metal recovery in the context of a complex and diverse set of issues associated with chemical-based solutions used in metal finishing operations.

These issues involve:

- different types and concentrations of metals, concentrates and rinses;
- various volumes of metal contaminated liquids;
- more stringent metal effluent compliance levels; and
- increasing process and water treatment costs.

One of the higher profile industrial sectors of metal finishing is PWB and electronics manufacturing. This multi-billion dollar industry is a large user of water and major generator of metal contaminated waste water.

PWB Plating Operations

The conducting circuitry of a PWB contains copper as the most prevalent conductor along with the lesser use of nickel, silver, tin, tin/lead, and gold as etch resists or top-level metals. RenoCell electrodeposition technology has proven applications in removing these metals from process rinse waters.

PWB manufacturing involves over 50 different process steps. Subtractive processing involves the selective removal of copper to form the conductive circuit patterns. Initially, a photosensitive resist material is transferred to the virgin copper surface and the circuit patterns are exposed to UV light, and with the circuit pattern developed, the remaining unwanted exposed copper surface is then etched away by chemicals and rinsed by water.

The image resist material is then removed and a final protective solder resist is applied. Plated through-hole PWBs require the selective deposition of copper and tin or tin/lead on an image formed in a similar way. The plating resist forms the circuit pattern and, on its removal after plating, the etch resist (the tin or tin/lead) protects the circuit during etching of the newly exposed substrate copper. Subsequent similar processes selectively plate nickel and gold on the edge contact of the circuit.

RenoCell technology focuses on the removal of metals from these complex chemistries and provides for waste minimization and continued reuse of the rinse waters. RenoCell addresses the important management issues of:

- Increase in process and water treatment costs
- More stringent metal compliance levels associated with effluent regulations
- Various volumes of, and concentrations in, metal contaminated water rinses
- Reclaim of valuable metals

A typical PWB plating lines is reviewed for application of RenoCell for point source treatment opportunities.

<u>Pattern Plate Acid Copper and Tin/Lead Plating Line</u>

PWB process lines include concentrated chemistries for cleaning, etching, electroplating, and stripping, each followed by rinsing process steps.

Both acid sulfate and copper pyrophosphate copper plating solutions find use today industrially. Acid sulfate solutions are the predominant copper plating solutions used in the PWB industry, although pyrophosphate solutions are specified by some military applications where ductility of the deposit is of paramount importance. Both solutions are also used in the plating-on-plastics industry after an electroless strike has been applied to the non conductive surfaces. Acid sulfate copper solutions are also used to plate steel wire, stainless steel cooking utensils and zinc die castings (after a cyanide copper strike). Pyrophosphate solutions are often used in electroforming applications and in the plating of zinc, aluminum, and steel die castings.

Typical formulations for acid sulfate copper solutions are:

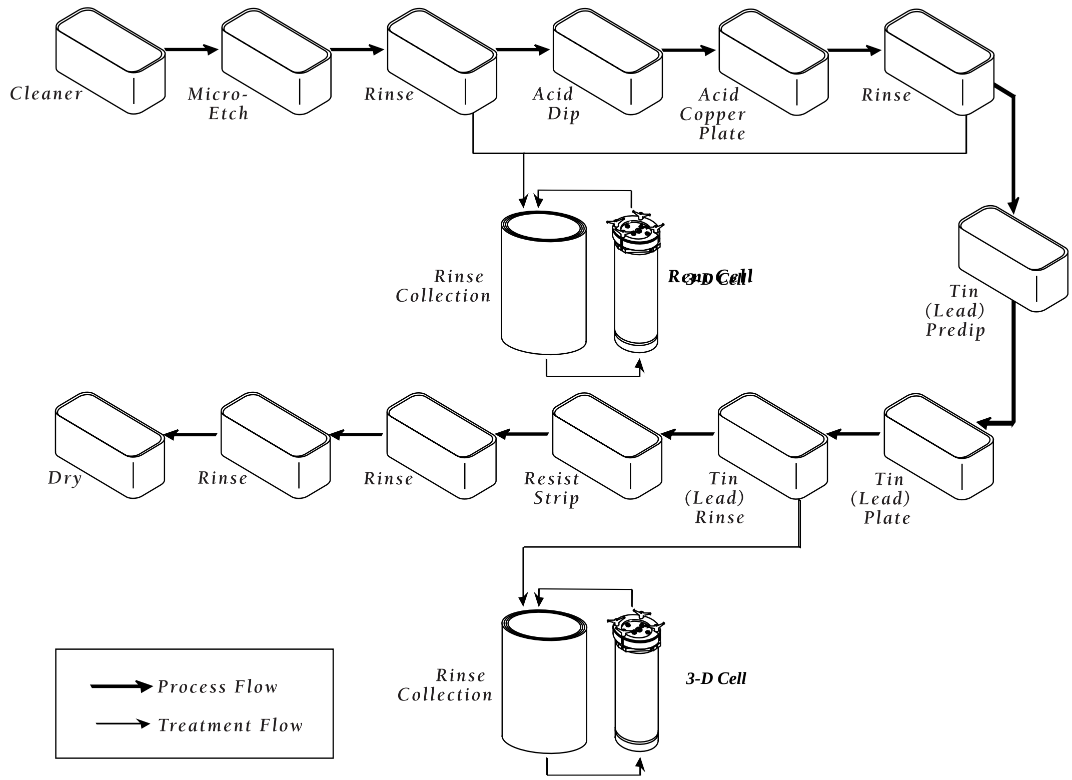
<u>General Purpose</u>	
Copper sulfate	190 - 300 g/L
Sulfuric acid	38 - 75 g/L
Chloride ion	30 - 60 mg/L

<u>High-Throw</u>	
Copper sulfate	60 - 90 g/L
Sulfuric acid	150 - 225 g/L
Chloride ion	30 - 60 mg/L

These solutions are made up by adding the chemical constituents to deionized water. As can be seen from the difference in the formulations, high-throw solutions result from increasing the conductivity of the solution by increasing the acid/metal ratio. The purpose of the chloride ion is to promote the copper anode corrosion. Proprietary additives are normally employed to level and brighten the deposit, improve the throwing power and enhance the deposit's physical properties. It is these baths and rinse water contaminated by drag out from these baths that require treatment.

In a typical pattern plate acid copper and tin/lead line shown in Figure 4, the PWBs are passed through a tin/lead stripper etch, an acid cleaner, microetch, and then copper plated to build up the circuit patterns, which are then further covered by plated tin or tin/ lead etch resist. RenoCells are placed in the process stream to treat rinse waters at the source where they can be readily reused in the process. A specific pattern plating line capable of handling 100 boards per hour was referenced here to gather typical PWB volumes, values and other key parameters.

Figure 4
Pattern Plate Acid Copper and Tin/Lead Plating Line



Conventional practice would be to have the drains and overflows from the rinse tanks go to a central treatment facility for eventual treatment by chemical precipitation. The opportunity to reduce waste generation and practice rinse water reuse is minimal since present treatment options cannot selectively remove metal and maintain process water specifications.

Micro-etch and Copper Plate Spray Rinse Water

In a typical process, the rinsing of the panels after micro-etch and copper plating is often performed in the same process stage, and often this is a spray rinse. The common copper concentrations of 25 g/L for micro-etch and 15 g/L for copper plate are used in this process sequence. When the rinse waters from these operations are treated with RenoCell, more than 1200 kg pounds of copper per year are recovered and rinse water usage is substantially reduced as are discharges to the facility’s waste treatment system.

Tin Spray Rinse Water

Immediately after copper plating, tin/lead, as an etch resist, has been the predominant metal finish plated over the copper. Now, due to environmental concerns about lead, tin/lead is largely replaced with tin when a reflow finish is not required. Tin concentration of 14 g/L is used in this process sequence. RenoCell treatment of rinse water after the tin plating process recovers approximately 430 kg of tin per year. Tin reclaim by refiners is enabled because tin metal is not considered hazardous.

Waste Treatment

In general, copper is the only constituent of these plating solutions that is controlled by the U.S. EPA. As with most other controlled metals, the allowable discharge limits have fallen sharply in recent years. Current EPA wastewater effluent standards for existing metal finishing sources discharging to a Publicly Owned Treatment Works (POTW) for copper are 3.38 mg/L for a single day and 2.07 mg/L monthly average. In most shops the plating solution and its associated rinses are but one of many processes that contribute copper to the waste stream. Specific requirements are controlled by local regulations and can be much more stringent; each facility must deal with local as well as state and federal requirements. One facility discharging into surface waters in Ohio is limited to 23 µg/L as an average with a 35 µg/L daily maximum while a Detroit facility, discharging into the city sewer system, has a pretreatment daily maximum 24-hr composite sample of 4.5 mg/L of copper. This factor of over 100 in concentration limits severely challenge the available technologies.

Treatment requirements for wastes can be fairly extensive. Routine waste treatment by pH adjustment and clarification, ion exchange, or membrane technology has proven successful in meeting these requirements. Sludge from plating shops is classified as F006 waste and is affected by the land ban legislation. Copper-bearing sludges generated by platers must be disposed of in an EPA-approved manner. Recent changes in disposal regulations of metal-hydroxide sludges are coming into effect and require additional fixation or stabilization to prevent redissolution. Recycling of plating wastes is becoming a more viable alternative as new technology provides improved reclaiming processes.

Conclusion

PWB process lines include concentrated chemistries for cleaning, etching, electroplating, and stripping each, followed by rinsing process steps. RenoCell provides PWB manufacturers with several major benefits:

- Virtual elimination of all metal-bearing hazardous sludges, saving over 40% in overall treatment costs
- Total operational cost savings of 70% over conventional treatment methods
- Lower initial capital costs with faster pay back periods (less than 2 years)
- Reduced wastewater loading on existing waste treatment facilities
- Conformance with national and local discharge compliance standards

When used as source treatment, the RenoCells remove copper, tin and tin/lead contaminant's without the manufacturer having to form metal-bearing sludges. Savings in disposal costs and water reuse minimize annual operating costs and results in less than two years of amortization of capital costs. The use of RenoCell further results in a reduction of both rinse water volume and removal of metal contaminates sent to end-of-pipe treatment prior to discharge. These waste minimization practices clearly allow the user additional flexibility such as expansion of operations without an increase in the waste treatment system.

In the broader metal finishing operation, RenoCell has application in various operations involving concentrated baths, rinse and effluent treatment. These point source uses of RenoCell include bath dumps, rinse maintenance and ion exchange enhancement. The potential of waste minimization is currently being realized in both new plating line installations and retrofit upgrades of existing operations.

The company has found that systems based upon this cell are very cost effective on a life cycle basis and studies have indicated that pay back typically ranges from nine months to two years depending upon the application and particular installation. The cell has a major operating cost advantage that, when coupled with the lack of secondary waste generation and subsequent cost of handling F006 sludges, provides an exciting new application of electrolytic technology that is capable of meeting effluent discharge standards anywhere in the world.

The principle of electrodeposition is the same for all electrochemical cells. However, simply put, RenoCell's 3-D porous cathode technology works substantially better.

References

1. Ludwig Hartman, *Handbook of Effluent Treatment and Recycling for the Metal Finishing Industry*, 2nd Edition, Finishing Publications Ltd. and ASM International, Materials Park, OH, 1994

2. Derek Pletcher and Frank C. Walsh, *Industrial Electrochemistry*, 2nd Edition, Blackie Academic & Professional, London, 1993; p. 336-353.