REVERSE OSMOSIS APPLICATIONS FOR METAL FINISHING OPERATIONS

The Merit Partnership is a joint venture between the U.S. Environmental Protection Agency (EPA) Region 9, state and local regulatory agencies, private-sector industries, and community representatives that was created to promote pollution prevention (P2), identify P2 technology needs, and accelerate P2 technology transfer within various industries in southern California. One of these industries is metal finishing, which is represented in the Merit Partnership by the Metal Finishing Association of Southern California (MFASC). Together, MFASC, EPA Region 9, and the California Manufacturing Technology Center (CMTC) established the Merit Partnership P2 Project for Metal Finishers. This project involves implementing P2 techniques and technologies at metal finishing facilities in southern California and documenting results. The project is funded by the Environmental Technology Initiative and EPA Region 9.

This fact sheet provides technology transfer information on reverse osmosis (RO) applications for metal finishing operations in general and presents the results of a specific RO application case study conducted at a metal finishing facility in southern California.

WHAT IS REVERSE OSMOSIS?

Reverse osmosis (RO) involves separating water from a solution of dissolved solids by forcing water through a semipermeable membrane. As pressure is applied to the solution, water and other molecules with low molecular weights (specific weight of molecules allowed to pass through is dependent on selected membrane). pass

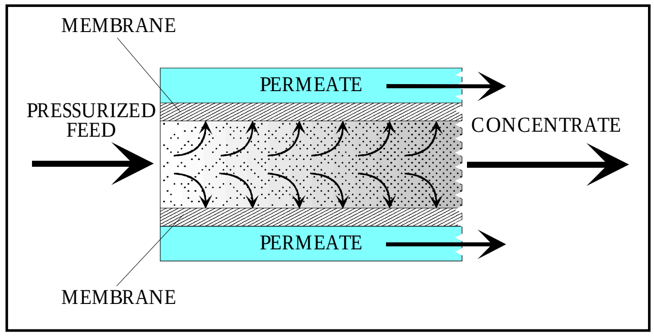

Figure 1. Reverse Osmosis Cross-flow Filtration

through micropores in the membrane. Larger molecules, such as organic dyes and metal complexes, are retained by the membrane. The purified stream that passes through the membrane is called permeate, and the concentrated stream containing a high concentration of dissolved solids is called concentrate. RO membrane systems feature cross-flow filtration (illustrated in Figure 1) to allow the concentrate stream to sweep away retained molecules and prevent the membrane surface from clogging, or fouling.

> **Contaminant Buildup**
>
> Although "closing the loop" has many advantages, it also has disadvantages: contaminant buildup. Contaminants, such as unwanted metals from preceding process operations, may "enter the loop" as a result of drag-in and slowly accumulate in the closed-loop operation, which may impact the process chemistry. Therefore, bath monitoring is essential to successful use of recycling systems such as RO. Built-up contaminants may also precipitate out of solution and cause membrane fouling.

In the past, RO applications for electroplating operations were mostly limited to final treatment of a combined wastewater stream. Such applications typically involved discharging the permeate to a POTW and returning the concentrate to the head of the wastewater treatment system. Because of the high flow rates associated with treating combined wastewater streams, large, costly RO units were required. More recent metal finishing applications of RO have involved installing RO units in specific process operations, allowing return of the concentrate (recovered chemical solution) to the process bath and reuse of the permeate (cleaned rinse water) as fresh rinse water. By "closing the loop," valuable process chemicals are recovered, and less fresh water is needed. Furthermore, a waste stream is eliminated that would otherwise be discharged to the POTW.

> **Proven RO Applications**
> - Copper Electroplating
> - Nickel Electroplating
> - Zinc Electroplating
> - Nickel Acetate Seal
> - Black Dye

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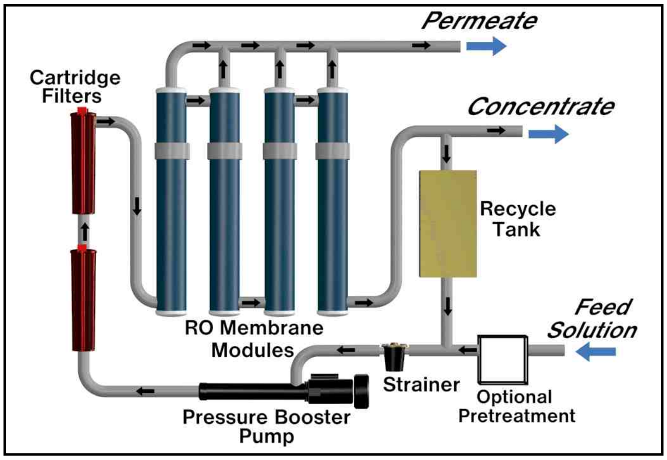

Figure 2. Basic Components of an RO Unit

RO UNIT COMPONENTS

Figure 2 shows a basic RO unit. The essential components include a strainer, a pressure booster pump, cartridge filters, and the RO membrane modules. The strainer removes large, suspended solids from the feed solution to protect the pump. The booster pump increases the pressure of the feed solution; typical operating pressures range from 150 to 800 pounds per square inch (psi). Commercially available cartridge filters are used to remove particulates from the feed solution that would otherwise foul the RO units. Filter pore sizes are typically between 1 and 5 microns.

Membranes are assembled in modules, each of which compacts a membrane of large surface area within a cylindrical shell of small volume. The type of commercially available module most applicable to metal finishing operations is the spiral-wound module. Although a number of membrane materials are under development, two commercially available membrane materials are currently in common use: aromatic polyamides and cellulose acetate. The aromatic polyamide membranes used in spiral-wound modules typically take the form of thin-film composites. Such a membrane consists of a thin film of membrane bonded to layers of other porous materials that support and strengthen the membrane. Thin-film composites can be applied over a relatively broad pH range (2 to 11), can tolerate a maximum temperature of about 160°F, and are more durable than single-material membranes. Cellulose acetate membranes are limited to a fairly narrow pH range (2.5 to 7) and a lower maximum temperature (about 85°F), and such membranes are biologically degradable. The type of RO membrane and module needed depends on feed solution characteristics and the desired performance of the RO unit. RO vendors or consultants often select an off-the-shelf unit that is most appropriate for a given application. Pilot tests are often necessary before a full-scale RO system is implemented.

Before Implementing RO . . .

Before implementing RO, low-cost P2 techniques and other good operating practices such as process monitoring should be adopted. For example, countercurrent rinsing should be implemented to reduce the required rinse water flow rate. This will reduce the RO feed flow rate, and as a result, smaller, less costly RO units and pretreatment systems can be used.

Pretreatment Considerations

Depending on the feed characteristics, optional pretreatment considerations include:

pH Adjustment: If the feed solution pH is outside the acceptable range for the membrane or near the solubility minimum of the feed solution ions, pH adjustment may be necessary to avoid damaging or fouling the membrane.

Oil and Grease (O&G) Separation: O&G may be present in the feed as a result of drag-in from other processes. If the feed contains O&G, it should be removed using an oil-water separator or a coalescer.

Disinfection: Feed should be disinfected to prevent bacteria from building up and fouling the membrane; ultraviolet (UV) light is preferable to chlorine to avoid a subsequent dechlorination step.

Temperature Adjustment: If the feed solution temperature is greater than the maximum allowable temperature for the membrane, heat exchangers or other devices can be used to cool the feed solution and prevent membrane damage.

RO UNIT OPERATION AND MAINTENANCE

RO unit operation involves adjusting valve and pump settings to control the pressure and flow rates of the feed and concentrate streams. The most significant RO maintenance requirement is membrane cleaning or replacement as a resultof fouling. Membrane fouling results from poor feed solution characteristics, which are controlled largely by some of the pretreatment steps discussed above. When fouling is prevented or minimized by effective pretreatment, RO unit maintenance requirements are minimal. For example, cartridge filters may require periodic maintenance or replacement.

COST CONSIDERATIONS

The **capital and installation cost** for an RO unit is highly variable depending on application. As illustrated by the case study below, an RO unit used for a multi-line electroplating application with flow rates of 10 to 15 gallons per minute (gpm) can cost approximately $50,000. Smaller units with a 3 to 5 gpm flow rate may cost between $10,000 and $20,000. Basic costs cover the strainer, pressure booster pump, cartridge filters, RO membrane modules, plumbing, and installation. The capital cost of an RO system increases with the amount of pretreatment required (see "Pretreatment Considerations" on previous page). Many RO units are compact and have low floor space requirements. For example, a 3 gpm unit needs only 6 square feet (ft^2) and a 12 gpm unit needs 27 ft^2 of floor space. **Operation and maintenance (O&M) costs** for RO units are relatively low. Because RO units are automated, little operator attention is required and therefore labor costs are low (less than 3 hours a month). Maintenance costs are driven by membrane cleaning and replacement schedules, which are dictated by influent characteristics and pretreatment effectiveness. To prevent membrane fouling, cartridge filters typically are changed once a week and the RO membrane is cleaned once a month.

Figure 3. Perfection Plating's RO System

Applying RO to existing process lines may also involve other costs associated with rearranging tanks, replumbing water and process chemistry lines, and other modifications to create space or adjust rinse water flows.

RO CASE STUDY: PERFECTION PLATING AND ECOSYSTEMS

With a goal of eliminating nickel from their wastewater, Perfection Plating (Elk Grove Village, Illinois) purchased an RO system from Ecosystems of Costa Mesa, California, in December 2000 to treat rinse water from its nickel baths. Perfection Plating installed the RO system to improve its treatment of nickel-bearing wastewater compared to conventional chemical precipitation and to assure that its effluent is well below its discharge limits to account for normal operational variations. Perfection Plating provides electroplating services to a variety of industries, including automotive and electronics, and specializes in plating electrical connectors and switches. Perfection Plating has approximately 70 employees and operates two shifts per day. The facility is approximately 65,000 ft^2 and includes several barrel, rack, and reel-to-reel nickel sulfamate plating lines. The nickel rinse water is consolidated and fed into one RO system. The wastewater originates from the first tank of each multi-stage, counter-current rinse, and the RO unit returns reclaimed rinse water (permeate) to the final rinse bath and the concentrated chemicals (concentrate) to the process baths. Figure 3 is a photograph of the RO unit and Figure 4 shows the RO system schematic.

Table 1
Specifications of Ecosystems Nickel RO Unit

Dimensions	Footprint: 3 ft. by 9 ft. (27 ft^2) Height: 6 ft.
Power	20 HP, 230V, 47 amps
Flow Rate:	12 gpm
Operating Pressure:	500 psi
pH Range:	4 to 8
Max. Temperature:	110°F

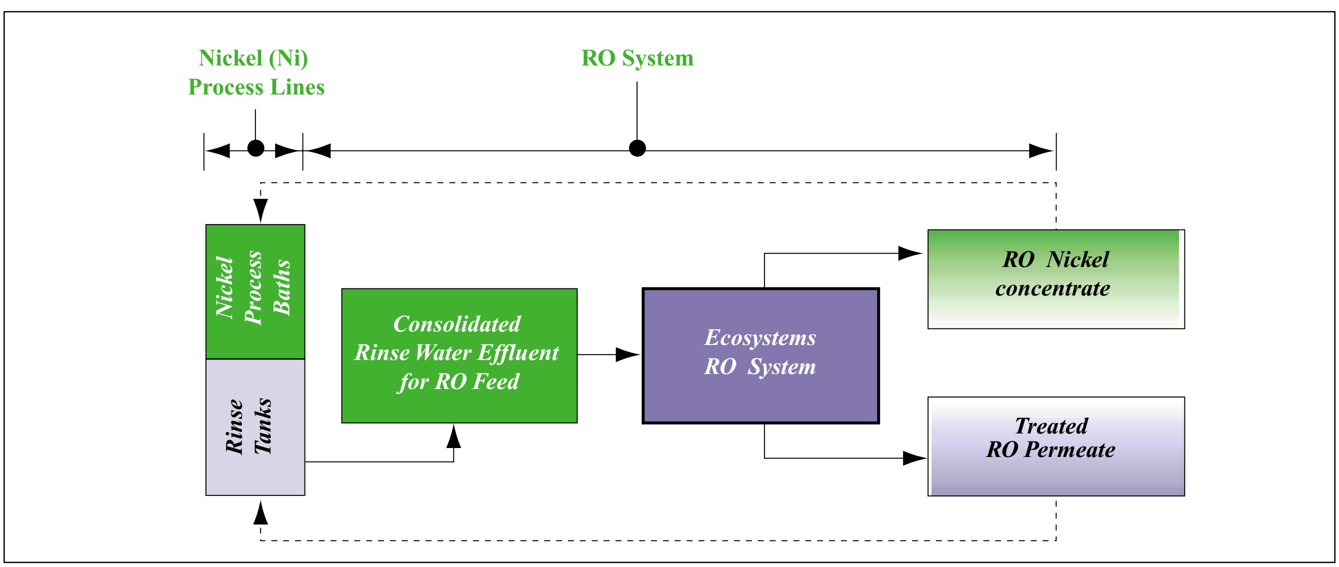

Figure 4. RO System Schematic at Perfection Plating

CASE STUDY COSTS AND PERFORMANCE

Capital and installation costs including engineering support during installation and start up for the RO system totaled $45,000. **O&M costs** include power, filter replacement, system maintenance (pumps, fittings, etc.), and membrane cleaning. For example, both the reclaimed permeate and concentrate pumps must periodically be flushed to assure the reclaimed rinse water and chemicals are not contaminated. Cartridge filters are replaced every week, costing $10.20 per month. Perhaps the most intensive maintenance procedure is the monthly cleaning of the RO membrane. A deionized water and sulfuric acid solution, with a pH of no less than 2.0, is filtered through the system. Sulfuric acid is added until the pH stabilizes at 2.0 using no more than 1 gallon of sulfuric acid. Then, the same process is repeated using a caustic solution, maintaining the pH at 11.0. In total, cleaning the RO membranes costs $114 per month (including deionized water and chemicals) and takes 2 hours to complete. With proper membrane selection and maintenance, an RO membrane will last for 2 to 5 years; membrane replacements for the Perfection Plating system cost approximately $1,800.

RO Case Study Costs

Capital and Installation	**$45,000**
Monthly O & M	
Power	**$276**
Cartridge filters	**$ 10**
Pump maintenance	**$ 41**
RO unit cleaning	**$114**
Labor (2 hours)	**$ 50**
Membrane Replacement (prorated)	**$ 50**
	Total = $541

Table 2 lists the operational savings associated with Perfection Plating's RO unit. The savings are based on data from the 6 months before and after the RO unit was installed, during which time production at Perfection Plating remained constant. In addition to simplifying the wastewater treatment process by eliminating nickel treatment, the RO system provided other environmental and economic benefits.

- ✓ By returning the concentrate to the process baths, Perfection Plating reduced their monthly nickel chemistry additons by over 80 percent, saving $1,939 per month.
- ✓ Rinse water use for the nickel lines decreased from 200,000 gallons to just 2,000 gallons per month, saving $345 per month.
- ✓ The system eliminated the wastewater discharge fees associated with the nickel lines, saving an additional $50 per month.
- ✓ Other savings associated with reduced wastewater treatment costs (treatment chemicals and filter cake associated with conventional chemical precipitation of nickel bearing rinse waters) were achieved but were not quantified and are therefore not included.

Table 2
Monthly Saving

	Before	After	Savings
Chemical Additions:	200 gal	200 gal	$1,939
Water Use:	200,000 gal	2,000 gal	$345
Discharge Savings:	200,000 gal	0	$50
Total Savings:	**$2,334/month**		
Less Operation and Maintenance Costs:	**$541/month**		
Net Savings:	**$1,792/month ($21,504/year)**		
Simple Payback = approximately 2 years			

Perfection Plating's RO system has a simple payback period of approximately 2 years not including RO system depreciation.

RO LESSONS LEARNED

After 6 monthes of operation Perfection Plating has incorporated several techniques to enhance O&M for the RO unit. These include:

(1) Adding a bypass valve to the cartridge filter unit so that employees could replace the cartridge filters while the RO system is in operation;

(2) Using the cartridge filter unit bypass valve while cleaning the RO membranes to prevent the materials cleaned from the RO membranes from lodging in the cartridge filters during back flushing and then coming loose and fouling the membranes once the unit is put back into operation; and

(3) Using a sulfuric acid and a caustic cleaning solution to improve RO membrane cleaning and the length of operation between cleanings.

For more information about RO or the Merit Partnership, contact the following individuals:

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