Improving

Membrane technology

By Michael Chan

In the past two decades, photovoltaic (PV) manufacturing has become one of the fastest growing industries, emerging as an economically and environmentally sustainable source of energy and surpassing the growth rate of the traditional fuel-based power generation. The PV industry has made significant strides in process productivity gains, but controlling water and energy costs and ensuring reliability continue to be key goals for improvement.

The Role of Membrane Technology

A PV company was planning to construct a new solar mirror manufacturing facility in Arizona. The production was to operate on a 24/7 basis, generating approximately 50 gal per minute (gpm) of wastewater, including 3 to 5 gpm of side streams from the high-purity water treatment system. The wastewater would contain heavy metals, ammonia, tartrate, total suspended solids (TSS) and chemical oxygen demand as the major contaminants.

Water shortage at the selected plant location caused by continuous drought and rapid population growth presented a great challenge to the water-intensive production processes. Realizing that wastewater recycling was not an option in this area, the company decided to move forward and build the new plant in the selected location after all other alternatives were thoroughly investigated.

Technology Evaluation

Both reverse osmosis (RO) and ion exchange (IX) technologies were evaluated in the project's initial feasibility study. Based on the chemical characteristic of the wastewater, the IX alternative was disqualified for this application primarily due to high TSS and total dissolved solids (TDS), mixed metals, strong chelators, and limited flexibility in wastewater segregation.

RO membranes are well suited for the removal of dissolved solids, but could be adversely affected or fouled by suspended solids, colloidal material or scale. Once fouled, limited by its inherent membrane properties, only mild cleaning chemicals like citric acid and detergent can be used. Stronger, more effective cleaning chemicals—such as sulfuric acid, hydrochloric acid and bleach—will cause detrimental damage to the RO membrane. In wastewater recycling applications, RO must be protected from fouling materials; therefore, appropriate pretreatment must be provided to achieve satisfactory performance of RO membranes.

Based on historical success rates for similar applications, two RO pre-treatment methods were investigated in the Arizona project for their technological and economic viabilities for the solar mirror wastewater: hollow fiber ultrafiltration (UF) and tubular micro-filtration (MF).

Limited by the UF membrane's low tolerance for TSS, additional conventional equipment for flocculation, clarification and multimedia filtration was required to maintain the performance of

the Solar System

useful for photovoltaic wastewater recycling

the UF membrane process.

After the chemical reaction step, the pretreated wastewater was processed through the tubular MF membrane filters. The tubular configuration allows the MF membrane to handle TSS levels greater than 5,000 mg/L. Hence, unlike the UF, the highly TSS tolerant tubular MF would not require additional pretreatment equipment.

After weighing out the data it was presented, the PV company selected the tubular MF pretreatment methodology based on its simple operation, fewer operating units, lower lifecycle cost and less floor space requirement.

Process Design Considerations

Through a series of bench-scale and pilot testing, a chelate-breaking chemistry using ferrous iron was developed for the precipitation of the metal complexes. A two-stage reaction process was implemented and proceeds as follows:

Polyvinylidene fluoride MF membranes are cast on the surface of porous polymeric tubes to produce a nominal pore size of 0.1 μ. Then, the chemically pretreated wastewater is processed through the MF membrane modules designed for separation of the precipitates from water. The wastewater is pumped at a velocity of 12 to 15 ft per second through the modules connected in series. The turbulent flow, parallel to the membrane surface, produces a high-shear scrubbing action, minimizing deposition of solids on the membrane surface. Throughout operation, filtrate permeates through the membrane, while the suspended solids retained in the recirculation loop are periodically purged for further dewatering. An automatic back-pulse mechanism provides periodic surface cleaning by reversing the filtrate flow direction.

The MF filtrate is further treated by a two-pass RO process for salt removal. RO feed usually is pressured between 200 to 600 psig depending on the TDS concentration, and processed through thin-film composite RO membranes. The RO process retains the high molecular weight compounds and allows a small percentage of very low molecular weight ions to pass through the membrane. The feed stream is separated into permeate and concentrated brine containing the separated salts (reject). Depending on the percent recovery, the brine may have four to five times the concentration of salt than the feed water. From the RO unit, permeate is collected and recycled to the selected solar mirror production process, while the brine (reject) is transferred to an onsite evaporation pond for disposal.

Realizing Independence

Membrane technology has proven itself to be a technically and economically viable approach in the Arizona project and for the recycling of solar mirror wastewater in the PV industry at large. Chemical pretreatment that transforms wastewater into a membrane-compatible form provides the needed flexibility to cope with complicated wastewater. The success of the Arizona installation further supports the logic that, in the midst of today's water shortage crisis, industries are beginning to recognize the value of becoming more independent by way of recycling their own resource—water—for their own production processes. **iWWD**

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The photovoltaic industry aims to improve its control of water and energy costs.