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HERO PROCESS – RECOVERY/REUSE OF COOLING TOWER BLOWDOWN AND AS A PRECONCENTRATOR FOR ZLD APPLICATION

Charles H. Fritz, Vice President, Black & Veatch Corporation, Kansas City, Missouri

V. J. Nathan, Product Manager - HERO™ Technology, Aquatech International Corp.,
Canonsburg, Pennsylvania

INTRODUCTION

Zero liquid discharge (ZLD) design of power stations is becoming more common. The reasons for this trend include the construction of plants in regions with limited water availability, increasing concern for conservation of fresh water supplies, more restrictive discharge limitations, and a desire to expedite the permitting process for new generating facilities. ZLD facilities address both the environmental and political concerns and are less costly and more efficient than alternative air-cooled condensers.

Wastewater produced by power plants is primarily cooling tower blowdown. Silica concentrations frequently limit the cycles of concentration in the cooling tower circulating water. This is particularly true in areas like the Western and Southwestern states, Mexico, and other landmasses of volcanic origin. The result is high blowdown rates and more wastewater for disposal.

Until recently, alternative treatment methods used to achieve ZLD consisted of combinations of thermal and membrane processes, sometimes coupled with evaporation ponds. These processes include reverse osmosis (RO), electrodialysis reversal, brine concentrators, crystallizers, and spray dryers. While ZLD systems of this type have proven successful, they represent a significant capital and operating cost expenditure.

This paper discusses an innovative new membrane process that has the potential for significant improvement in the economics of ZLD systems. The new process is a high efficiency reverse osmosis process referred to as HERO™. Pilot testing^(1,2) of the HERO process on cooling tower blowdown and other high silica waters has demonstrated that recovery rates on the order of 90% are possible. The process can be used as a preconcentrator ahead of a thermal evaporation system or as the sole volume reduction device prior to discharge of the concentrated reject stream to an evaporation pond or other means of disposal.

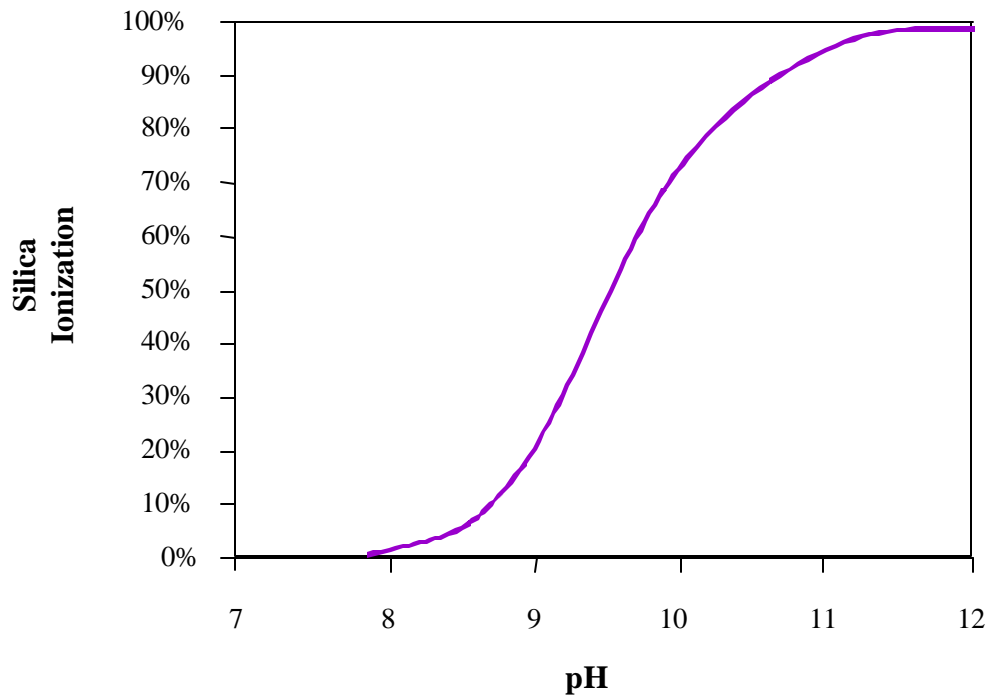


Figure 2. Silica Ionization Curve

WAC ion exchange, when operated in the hydrogen cycle, will efficiently remove hardness associated with alkalinity. Alkali addition may be needed for adjustment of the hardness to alkalinity ratio in the feed water. Hydrogen ions released in the cation exchange reaction react with the alkalinity to form carbonic acid for subsequent removal in the degasifier. The WAC units remove the remaining hardness to less than 0.2 mg/l as required to prevent scaling of the membranes. Series operation of WAC exchangers is recommended to assure consistently low hardness leakage.

Acid is injected into the WAC effluent to neutralize any remaining alkalinity. A forced draft degasifier removes the resulting carbon dioxide. Alternate methods of carbon dioxide removal that may be considered include membrane and vacuum degasification.

The RO system is operated at a pH as high as possible, but not exceeding 11.0 in the RO reject. Control of pH is by injection of sodium hydroxide (liquid caustic) into the feed water. The maximum pH value of 11.0 is the limit established by manufacturers of commercially available thin film composite membranes.

RO permeate is directed back to the cooling tower or may be used as cycle makeup after additional treatment. The highly concentrated RO reject may be disposed of in an evaporation pond if the plant is located in an arid region. Where evaporation ponds are

not feasible, it may be necessary to direct the stream to a crystallizer or spray dryer with landfill disposal of the dry solids.

HERO PROCESS ADVANTAGES

The HERO process combines several industry proven treatment steps into a single process which has the ability to treat difficult water at high recoveries and increased flux rates. The advantages of the process compared to conventional RO are summarized below.

- Scaling of the RO membranes is eliminated by pretreatment to remove hardness, carbonate alkalinity, and other scale forming constituents in the feed water.
- The silica scaling limit is increased substantially as silica solubility increases with pH. Operation with silica concentrations in the range of 1600 to 2000 mg/l in the reject have been demonstrated ⁽²⁾ compared to a limit of about 150 mg/l silica in the case of conventional RO.
- Biological fouling is eliminated at the high pH. The high pH serves as a biostat to control biological fouling. Bacteria, virus, spores, and endotoxins are either lysed or saponified at the operating conditions.⁽³⁾
- Organic fouling is reduced as organics are either emulsified or saponified at the high pH and do not adhere to the membranes.
- Particulate fouling is substantially reduced due to a reduction in surface tension (low beta potential) at high pH. Operating experience indicates that water with high silt density index (SDI) values can be treated without frequent chemical cleaning.
- Tolerance to occasional low levels of oil and grease in the feed water without interruption of operation.
- Operation at high pH protects the RO membranes from attack by chlorine in the cooling tower blowdown by neutralizing the hypochlorous acid content. However, dechlorination is required for protection of the WAC resin.
- Removal of scaling constituents in the pretreatment steps eliminates the need for scale inhibitors in the high efficiency RO.

The HERO process addresses the root causes of fouling and scaling of RO membranes. The result is that the process is capable of operating reliably at 90% or greater recovery unlike conventional RO that typically operates at 75% or lower recovery. Application of the process as a preconcentrator on cooling tower blowdown reduces the waste volume by a factor of 10 or greater. The relatively small quantity of reject can be directed to a solar evaporation pond or treated further with a small brine concentrator and/or crystallizer.

The HERO process operates in a continuous cleaning mode at the elevated pH, similar to the periodic high pH cleaning operation employed for biofouling of conventional RO systems. High pH cleaning is never required for the new process and the frequency of chemical cleaning is substantially reduced. Due to its robust nature, an annual chemical cleaning is estimated for cooling tower blowdown application.

The inherent resistance to scaling, fouling and plugging mechanisms enable the HERO process to operate at higher flux rates than conventional RO. Flux rates in the range of 25 to 35 GFD are possible compared to 10 to 12 GFD used for traditional RO. The higher flux rates means fewer membranes, increased membrane productivity, and lower membrane replacement cost.

Another advantage of the process is it that the system can be safely shut down without concern for biofouling. This feature is important for merchant power plants that operate based on energy demand in the market place.

ECONOMICS OF ZLD ALTERNATIVES

The first full scale ZLD installation based on the HERO process is installed and is expected to be in operation by mid-2001. This 500 MW combined cycle power plant located in the Arizona will utilize high silica well water for cooling tower makeup. The cooling tower blowdown treatment system is designed to process approximately 300 gpm with an overall recovery of 88%. Permeate from the RO will be reused in the cooling tower with provisions for possible future use as a source of makeup to the steam cycle after additional treatment. RO reject and miscellaneous wastewater from the pretreatment steps are directed to an on-site disposal pond.

An engineering analysis of the HERO based system and a brine concentrator treatment system was performed to determine the comparative costs of the alternative ZLD systems. Estimated comparative installed costs are illustrated in Table 1. Table 2 is a summary of the estimated annualized operation costs for the two systems.

	HERO w/ Evaporation Pond, \$ x 1000	Brine Concentrator w/ Evaporation Pond, \$ x 1000
Equipment, Installed	3,150	5,250
Buildings	525	525
Sitework	275	230
Electrical	100	170
Evaporation Pond	2,400	1,200
Total Direct Cost	6,450	7,375
Indirect Cost	1,950	1,990
Total Installed Cost	8,400	9,365
Differential Cost	Base	965

Table 1. Estimated Comparative ZLD System Costs

	HERO w/ Evaporation Pond, \$ x 1000	Brine Concentrator w/ Evaporation Pond, \$ x 1000
Power Consumption	48	700
Chemicals	175	28
Operation & Maintenance	206	250
Consumables	8	Nil
Total Operating Cost	437	978

Table 2. Estimated Annual Operating Costs

The capital cost estimates indicate that the brine concentrator based system is expected to be roughly 10% more expensive than the HERO based system. Annual costs for the two systems indicate a significant difference in favor of the HERO based system. Although the HERO system has a higher chemical consumption cost, the brine concentrator power consumption more than offsets this difference. Total annual operating cost differential is estimated to be over \$500,000 in favor of the HERO based system assuming a power cost of \$0.05/kWh. The net present worth, assuming 3.5% escalation and a period of 15 years, is calculated to be approximately \$7,000,000 in favor of the HERO based system.

CONCLUSIONS

The HERO process consists of several tried and proven pretreatment steps in combination with reverse osmosis operating at high pH. The resulting process has several features that make it particularly well suited for the treatment of cooling tower blowdown for recovery of waste water or as a preconcentrator for zero liquid discharge. Attractive features include robust self-cleaning operation, the ability to concentrate dissolved silica to 1600 mg/l and higher, feedwater recovery of 90% and greater, and the suitability for start-stop operation.

HERO has been successfully pilot tested in a number of installations. It has the potential for significant cost savings when used for treatment of cooling tower blowdown. The anticipated benefits of the process will be tested when the first full-scale ZLD installation becomes operational later this year.

The primary cost advantage of HERO based ZLD systems when compared to brine concentrator based systems is improved energy efficiency. A net present value analysis shows an economic advantage of about \$7 million for a typical 500 MW combined cycle power station over a period of 15 years.

REFERENCES

1. Allen R. Boyce, Michael Ferrigno, and Devesh Sharma, “New Zero Liquid Discharge Strategy – Boiler Makeup from Cooling Tower Blowdown”, International Water Conference, Pittsburgh, PA, October 1999.
2. Shuichi Chino, Isamu Sugiyama, Jeffrey Holloway, and Deb Mukhopadhyay, “A New High Efficiency Reverse Osmosis Process”, International Water Conference, Pittsburgh, PA, October 1999.
3. US Patent 5,925,255 “Method and Apparatus for High Efficiency Reverse Osmosis Operation”, Debasish Mukhopadhyay, July 20, 1999.
4. Deb Mukhopadhyay and Sharon Whipple, “High Efficiency Reverse Osmosis System”, Proceedings of the 16th Semiconductor Pure Water and Chemicals Conference, 1977.