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Coalbed Methane Produced Water – An Evolution in Treatment

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Abstract

This presentation will discuss the pretreatment evolution for the reverse osmosis/ recovery reverse osmosis process (RO/RRO), treating produced water from Powder River Basin coalbed methane wells. The RO/RRO process is approved by Wyoming Chapter 3 permit.

In 2008, Siemens was awarded a contract for the treatment of Powder River Basin, Coalbed Methane produced water. As of the date of this writing, the plant, Mitchell Draw, has not been commissioned. The plant was designed to treat 72,000 bpd (477 m3/h or 2,100 gpm).

Coalbed Methane Production

Coalbed methane recovery techniques are unique when compared with other production methods, as hydrostatic pressure holds the methane in the coal seam so that gas production requires removing the formation water, or dewatering. Removing the formation water depressurizes the formation, releasing the gas. Initial water production is high, but rapidly decreases to allow the methane to be released. Producers must manage the large volumes of water generated during the dewatering process. The Powder River Basin CBM produced water is of high quality, such that much of the water can be disposed of by direct discharge. However, operators must manage produced water of a lower quality according to environmental compliance and economic objectives. This includes volume of water produced, proximity to surface water, rights-of-way, influent chemistry, discharge quality requirements, land use provisions and recycle objectives.

The reverse osmosis/recovery reverse osmosis design (RO/RRO) used at the Mitchell Draw plant is a permitted design through the Wyoming Department of Environmental Quality/Water Quality Division (WDEQ) Chapter 3 process, requiring review and monitoring by the department's water and wastewater division engineers.

The Mitchell Draw plant optimizes costs by maximizing system recovery using pretreatment techniques and an aeration pond for evaporating and concentrating the brine. An example evaporation pond is shown in Figure 1. The plant design includes a bypass and blend provisions so that the plant can ratio blend the product water according to discharge specifications. The plant maximizes membrane performance with filtration and scale control, and it is the scale control that is the focus in this presentation. Also discussed are lessons learned relative to alternative scale control strategies used in an earlier plant design, also in the Powder River Basin.

Figure 1

Influent, Effluent Criteria and System Design

One must clearly understand feedwater characteristics for proper plant design. This includes seasonal variability that may identify influent extremes or complex chemistries. Waste and product stream characteristics must also be understood so that service factor, redundancy, and compliance can be addressed in the plant system design. CBM water is high in sodium and bicarbonate and low in hardness, and may also include suspended solids, iron, silica, and barium.

Application engineers use solubility indices to understand the relationship of the dissolved ions as they move through the treatment process. For instance, one technique for predicting calcium carbonate solubility considers the bicarbonate and calcium concentrations to access the potential for hardness scale formation. This is the concept behind the Langelier Saturation Index (LSI). A positive LSI denotes an increased potential for calcium carbonate scale formation while a negative LSI denotes that calcium carbonate may dissolve in the solution.

Another constituent common in CBM water is silica. Because of its unique chemistry, silica poses special treatment challenges to design engineers. While the silica concentration in Powder River Basin produced water is moderate, the high recovery rate of the membrane system creates ideal conditions for silica to scale membrane surfaces. Silica precipitation control is further complicated because control techniques for other ions conflict with methods for controlling silica.

Treatment systems are designed with sufficient flexibility to meet changing effluent targets. The state permitting authority defines effluent standards to protect aquatic life and downstream uses of the water. Some discharge standards change on a monthly basis according to state permits indexed on assimilative capacity. Sodium is a closely monitored aspect of the plant effluent given its affect to downstream agricultural application. Soils with an excess of sodium ions, as compared to calcium and magnesium ions, affect the way plants adsorb water. The ratio of the sodium to calcium and magnesium is referred to as the Sodium Adsorption Ratio (SAR).

Plants operating with intent to discharge require a Wyoming Pollutant Discharge Elimination System (WYPDES) permit issued by the WDEQ for construction, operation and discharge of the produced water. The treatment plant subject to this paper is designed to discharge greater than 95% of the influent water into the Powder River.

Geographical, Environmental Concerns

Given the pristine remoteness of the Powder River Basin, where inclement weather is a given, inventory controls must incorporate the possibility for restricted site access during seasonal extremes. For instance, one must carefully design acid feed systems to minimize risks to personnel and facility. The volume of acid needed to neutralize the alkalinity inherent in the CBM water is considerable. Plant designs may require tanker truck deliveries of acid down lease roads and potentially during severe weather. Treatment plants designed in this fashion should:

- Store the acid outdoors in double-contained tanks
- Provide storage volumes that consider order delays and weather interruptions
- Have double-contained feed lines and valves.
- Locate tanks as close as possible to injection points to minimize feed line length.

The Mitchell Draw Plant

In 2008, Siemens was awarded a contract for treating Powder River Basin CBM water at Mitchell Draw. To date, the company has not yet commissioned the plant, designed for treating 72,000 b/d. Siemens' engineers focused on system recovery and eliminating acid feed and therefore added ion exchange softening into the process flow. Ion exchange removes polyvalent cations from the feed water. The process removes constituents such as calcium, magnesium, barium and soluble iron to very low levels by exchanging them for sodium on the ion exchange resin.

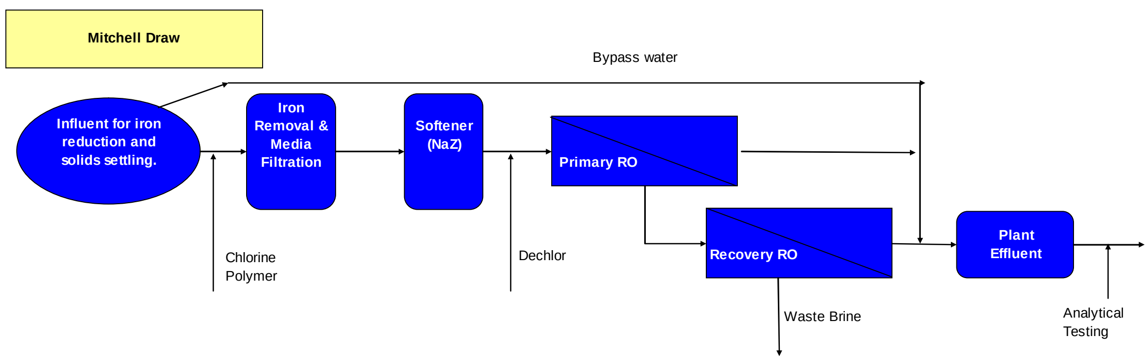
Ion exchange is routinely used in front of reverse osmosis applications to protect the downstream membranes as the reduced hardness lowers the LSI of the feed stream.

Given the low hardness of the CBM water, softener regeneration frequency is manageable and sodium contribution to the feed stream moderate. The softener provides several advantages. First, it reduces the potential for scale formation by removing dissolved cations such as calcium, magnesium and barium. This reduces the antiscalant and acid chemical requirement typically used for controlling solubility when influent concentration or system design affects the solubility limits. The process typically feeds acid to a neutral or slightly acidic pH range to control hardness scale. Without acid feed, the bicarbonate alkalinity concentration increases, resulting in an alkaline feedwater condition and scale formation.

The high pH in the Mitchell Draw water offers preferred operating parameters that increase the solubility of residual organics, thus reducing the potential for organic fouling on the membrane surface. The higher pH shifts the boric acid to borate equilibrium so that the membrane more easily rejects the boron, resulting in lower boron concentrations in the effluent water. Hardness removal reduces the potential for silicate scale formation enabling higher system recovery while the higher pH increases silica solubility, thus lowering the potential for silica fouling.

Figure 2 shows a flow schematic of the Mitchell Draw plant.

Figure 2



Water Analysis

Table 1 illustrates the changes to feed water quality while applying the pH-adjusted scale control technique versus the softened feed water technique. The feed water data are approximated from actual Powder River Basin produced water analyses. The analyses are then modeled using the Dow Chemical Co's Reverse Osmosis System Analysis (ROSA) program to illustrate the changing conditions. As noted in the table for softened feed water, the design reduces the divalent cations calcium, magnesium, strontium and barium to less than 0.3 ppm in the adjusted feed water. There is a corresponding increase in sodium content as an equivalent amount of sodium is exchanged into the water.

Unlike the acid feed case technique, the pH and total dissolved solids (TDS) stay about the same. The LSI scaling calculation shows –1.3 in the adjusted feed water. Furthermore, the barium sulfate and calcium fluoride scaling calculations also show reduced scaling potential with the softened feed water as used at Mitchell Draw.

Table 1

		pH Adjusted Feed			Softened Feed		
Feed Water	Units	Feed	Adj. Feed	Conc.	Feed	Adj. Feed	Conc.
Potassium	mg/L	35.2	35.2		35.2	35.2	
Sodium	mg/L	880	880		880	941	
Magnesium	mg/L	14.6	14.6		14.6	0.0	
Calcium	mg/L	28.0	28.0		28.0	0.1	
Strontium	mg/L	0.9	0.9		0.9	0.0	
Barium	mg/L	1.4	1.4		1.4	0.0	
Carbonate	mg/L	40.7	2.3		40.7	40.7	
Bicarbonate	mg/L	2,416	2,118		2,416	2,416	
Chloride	mg/L	28.4	247.0		28.4	28.4	
Fluoride	mg/L	1.0	1.0		1.0	1.0	
Sulfate	mg/L	1.0	1.0		1.0	1.0	
Silica	mg/L	12.0	12.0		12.0	12.0	
Boron	mg/L	0.2	0.2		0.2	0.2	
Carbon dioxide	mg/L	18.9	262.5		18.9	18.9	
TDS	mg/L	3,460	3,342		3,463	3,479	
pH		8.2	7.0		8.2	8.2	
		pH Adjusted Feed			Softened Feed		
Scaling Calculations		Feed	Adj. Feed	Conc.	Feed	Adj. Feed	Conc.
pH		8.2	7.0	8.3	8.2	8.2	9.5
Langelier Saturation Index		1.2	-0.1	3.8	1.2	-1.3	2.6
Calcium Sulfate (% Saturation)		0.0	0.0	0.2	0.0	0.0	0.0
Barium Sulfate (% Saturation)		24.6	24.6	532.0	24.6	0.0	0.0
Strontium Sulfate (% Saturation)		0.0	0.0	0.2	0.0	0.0	0.0
Calcium Fluoride (% Saturation)		3.7	3.7	30,251	3.7	0.0	108.0
Silica dioxide (% Saturation)		9.2	11.3	173.0	11.5	11.5	83.5
Magnesium Hydroxide (% Saturation)		0.0	0.0	0.4	0.0	0.0	0.0

Conclusion

After the Mitchell Draw plant is commissioned, Siemens expects the following benefits from the system design:

- CBM water is characteristically high in sodium and low in calcium and magnesium hardness. The low hardness concentration makes it an ideal application for sodium-form ion exchange. Removal of the hardness ions will reduce the risk of hardness scale formation, eliminate the need for acid and increase system recovery.

- CBM water contains relatively high concentrations of bicarbonate alkalinity. Given the concentration affect across a membrane surface, the pH of the feed water will increase to increase the solubility of silica and residual organics and improve the rejection of boron.

- The process eliminates acid for scale control, resulting in improved plant safety and system reliability. Public safety is also improved with fewer acid deliveries.

- The new design removes acid feed equipment and controls from the system because pH control is no longer a primary concern to system operation. In addition, it improves system reliability because inventory control is less vulnerable to delivery interruptions.