Continuous Flow Seawater RO System for Recovery of Silica-Saturated RO Concentrate

(WRF Contract No. 09-12)

(TWDB No. 0704830769-Amendment No. 4)

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Status Summary

A. Summary of Tasks Completed

Task 1 (*Design, Build, and Install System*) was completed in March 2010. Task 2 (*Collect Data and analyze samples*) and Task 3 (*Analyze Data and Evaluate System Performance*) are 95% complete (one more operating mode will be attempted using a smaller feed tank to reduce fouling and increase recovery rates, if the system can be modified with little or no expense). Task 4 (*Prepare final report*) is underway.

B. Assessment of Actual vs. Planned Progress

The project is on schedule to be completed as planned (by the end of December, 2010).

C. Tasks for Upcoming Period

The upcoming period (i.e. quarter no. 5) will be devoted almost entirely to the preparation of the final report. The only other possible activity that *might* be involved in the upcoming quarter is to modify the feed tank so that the volume of the modified tank becomes one-fifth of the current volume. This modification might help improve the system's recovery. However, the modification of the feed tank depends on the availability of the funds. If the necessary modifications can be made, then a few more sets of data will be collected. This modification will not delay the submission of the final report.

D. Problems Encountered

A few minor problems were encountered with the equipment, but major problems were related to membrane fouling. The equipment problems involved a burned-out fuse and a loose connection that involved three of the sensors. Those problems were easily resolved.
The membrane fouling problems are discussed in the data collection section below.

E. Technical Summary

Response to Comments from WRF or PAC

Reviewer 1:

Comment 1*: I am quite surprised at the number of equipment problems the project team has experienced. RO treatment of brine and saline solutions has been practiced for many decades and I would have expected that most of the challenges encountered by the team would have been resolved previously. I suggest that the final report include a section which analyzes these problems to determine if there are common causes that could be avoided in the future, if they are unique to desalination of ground water in contrast to sea water, and make recommendations for their* *resolution so that future pilot and full scale projects can avoid them.*

Response 1: Most of the equipment problems that were experienced are believed to be unique to this pilot plant. For example, the positive displacement pump was defective from the outset, and the vibrations it created caused problems with loose connections, cracked pipes, etc. Also, the location of the VFD (close to the feed tank) created stray currents in the feed water, which in turn affected some of the sensors. This would not happen in a full-scale system. Nevertheless, the authors will point out some of the problems encountered during the pilot plant testing, so that others may benefit from these experiences.

Comment 2*: pg. 4. When presenting data for runs of the pilot treatment plant, I suggest that the duration of the run be included. The discussion should include an assessment as to whether the runs were of sufficient length to be representative of full scale operation. In subsequent reports I encourage the team to include data indicative of fouling such as normalized specific flux in addition to permeate quality as I think it is a better indicator of process performance than simply plotting pressure versus time.*

Response 2: Data indicative of fouling for the test runs will be included in the final report. This information is discussed in the data collection section below.

Comment 3*: In the results described on pages 4 through 9 it is not clear whether any type of scale inhibitor was added or pH control was included. Please include this information in future reports, perhaps as part of the figure's caption.*

Response 3: The requested information will be included in the final report. It is also discussed below.

Comment 4*: The work plan for the next quarter is pretty vague. I encourage the project team to be more specific by establishing specific objectives and developing a scope of work that will achieve them.*

Response 4: The Project's main objective has been to maximize economic recovery of water from the RO concentrate that is generated at the KBH Desalting plant without fouling the membranes. As such, multiple test conditions were varied to try to affect the outcome. As it turned out, operating conditions have not yet been identified that permit water recovery anywhere close to what was expected at the outset of the project. See data collection section below.

Reviewer 2:

Comment 1*: Can the researchers provide better information regarding feed water quality for the different runs. Instead of simplifying everything to conductivity, can they characterize the feed to the SWRO membrane by providing TDS, conductivity, T and pH as a minimum prior to chemical addition. It would be nice to also include alkalinity, hardness, Cl, SO4, Ba, Sr and silica levels. This information was somewhat provided for the run at 35,000 microsiemens.*

Response 1: Most of the requested data were included in Table 2.2 in the second progress report. The characteristics of the KBH concentrate (which is the project feed water) are extremely constant. Test run parameters will definitely be included it in the final report.

Comment 2: *Can we have more information in terms of acid and scale inhibitor dose for the different runs? How is the chemical feed being adjusted given that the TDS concentration in the feed tank will change overtime. Is acid being added to maintain a feed pH to the SWRO membrane around 3.8-3.9? What about the scale inhibitor? Have the researchers talked to the scale inhibitor manufacturer regarding dose recommendations for the water quality in question? Assuming they are using peristaltic pumps feeding off of a tote?*

Response 2: All of the requested information will be included in the final report, as well as herein. Specifically, the antiscalant and acid dosages are flow-paced. That is, they are added in proportion to the incoming flow. Additionally, acid is added as need (automatically) to maintain the pH at the predetermined the set-point. With respect to communicating with the manufacturer of the scale-inhibitor (King Lee Technologies), such communications are conducted routinely, because this vendor provides the antiscalant free of charge to this project.

Comment 3: *How often and when is the bleed to waste valve open in the feed tank?*

Response 3: The waste valve opens as soon as the conductivity exceeds the pre-set value, and it closes when the conductivity goes below the pre-set value, thereby maintaining the conductivity near the desired value.

Comment 4: *Have they run any RO projections using any of the RO projection software tools available in the market (ROSA, IMS Design, KMS ROPRO, TorayDS, etc)? That would give us an idea regarding expected results versus pilot results.*

Response 4: The RO performance projection software packages have not been run because it is common knowledge that the feed water is supersaturated with several compounds (as the software would correctly predict). The researchers were expecting to be able to duplicate, to some extent, the results achieved in the batch-treatment system (i.e. 80 – 90% recovery of water from the concentrate). That has turned out not to be the case.

Comment 5: *I am not so worried about the details of the pilot setup. If this technology proves to be competitive, the design of the system would be done by an engineer and that would likely take care of the issues experienced at the pilot.*

Response 5: Completely agree with the comment.

Comment 6: *The focus of the researchers should be on developing a testing protocol that will help them determine the applicability and cost-effectiveness of the proposed technology.*

Response 6: **A**gree with the comment and believe that is exactly the approach attempted by the researchers during the project.

Reviewer 3:

Comment 1: *Other than a general observation that the team has run into more than their fair share of bad luck these past few months and that it's bound to even out in the end, I don't have any comments.*

Response 1: Amen

Data Collection, Data Analysis, and Findings

During this reporting period, we tried to determine the *maximum sustainable recovery*; that is, the recovery at which the test system could be operated continuously for several weeks (without fouling the membranes). When we started the project, we anticipated that we would be able to achieve at least 50% recovery, and probably and as much as 70-80%, so we started the experiments at 50% recovery (conductivity of the feed was 35,000 µS/cm). We were able to run the system for about two days, after that the membranes became fouled from the precipitate in the feed tank. Analysis of the precipitate indicated that it was primarily calcium sulfate. We cleaned the membrane with Diamite CAL (A king Lee solution for cleaning membranes fouled with calcium sulfate).

Since the feed tank temperature got as high as 39 ^{0}C during some of the test runs, we decided to try cooling the water with a heat exchanger. Therefore, for the next test run, the conductivity set point was lowered to 30,000 µS/cm *and* a heat exchange system was fashioned by inserting a coil of ¼” stainless steel tubing connected to a water chiller. The heat exchanger worked well, keeping the temperature below 26 ^{0}C, but precipitation occurred again in day two, even at the lower conductivity of 30,000 µS/cm.

On an assumption that the stainless steel tubing might have had something to do with initiating the precipitation, we replaced the stainless steel coil with an all-plastic heat exchange unit, but we still got precipitation on the second day. We again cleaned the membrane.
For the next test run, we raised the antiscalant concentration from 5 ppm to 20 ppm (the antiscalant is specifically intended for inhibiting calcium sulfate precipitation). We still got precipitation of calcium sulfate on the second day. We again cleaned the membrane.
The last modification that we thought might work would be to reduce the flux. All of the previous test runs were done at a flux of about 9 gallons per square foot per day (gfd). We lowered the permeate flow rate by 40% to a flux of less than 6 gfd, but precipitation still occurred.

The next test run was conducted at a conductivity set point of 27,500 µS/cm and we were able to run over a time span of about 7 days. Although there was no precipitation evident at any time during the run, the run was not continuous because a loose connection to three of the sensors (pH, temperature, and concentrate conductivity) intermittently caused the system to shut down---when the connection was loose, the default pH reading was 14, which is well above the set-point shut-off value. In any case, it appears that with the current pilot system set-up, we will not be able to get recoveries exceeding about 40%. We believe the reason is because with this system design, the feed tank is *maintained* at a solids concentration that is above the saturation value of the majority of the compounds in the feed water, but not all. As soon as one of the compounds in the feed exceeds its saturation index, it starts to precipitatate on the membrane surface, which eventually triggers membrane fouling (this potential problem was discussed at the kick-off meeting that was held at the beginning of the project). In the batch-treatment system that was the fore-runner to this project, the supersaturated condition lasts for only a relatively short period of time before the super-concentrate is dumped. If the large volume of super-saturated concentrate in the feed tank is indeed the problem, a possible solution might be to reduce its volume.

At the time of this report, the positive displacement pump was in the process of being replaced (the supplier believes the pump was defective at the outset of the project, and hence the vibration). After the pump is replaced, we will attempt to modify the feed tank so that the feed volume is much less than the current volume of 165 gallons. We believe that we will be able to reduce the volume to less than 50 gallons by lowering the inlet float valve. After the modification, we will conduct a test run at 30,000 µS/cm to see if the smaller volume allows for recoveries greater than is currently possible.

Work Plan

As stated above, the feed tank will be modified to reduce its volume as much as possible while staying within the budget and within other limitations of the system. If the test run for 30,000 µS/cm is successful, the recovery will be raised until the maximum value at which no fouling occurs is identified. While conducting the final test runs, unaffected portions of the final report will be prepared. A draft of the final report will be submitted shortly after the final tests are completed.

Budget Summary

A copy of the most recent spreadsheet is attached.

Publications

No papers were submitted during this reporting period.