Well Water Iron Removal Using Quantum DMI-65 Granular Filter Media

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Background
Southport Power Plant, North Carolina, installed three wells to provide an alternative water supply to address the increased costs associated with the use of city water. The well water quality required the addition of two 300 gpm reverse osmosis (RO) units as pretreatment for the ion exchange demineralizers. The original well water design, however, did not include measures to address iron in the water. The iron contained in the well water supply resulted in fouling to the cartridge filter elements and RO membranes.

Early RO operation during 2004 noted lower than expected well water flow. As a result, the original two RO arrays were derated from 9:5 to 8:4 arrays with product flow reduced from 300 gpm to 250 gpm. RO operation was often performed with only one unit in service in order to lower the iron fouling rate and to increase the membrane cleaning interval. During these times, well supply from the best well flowed to the unit in service with the option to change over to the standby unit when the performance dropped off. Chemical cleanings for each RO were performed once per month with the post cleaning restoring the unit back to baseline.

A well water study was performed in December 2004 and it was determined that multimedia filters, chlorine and filter aid continuous additions were required for iron removal as well as lowered SDI (silt density index) of the well water supply. The pretreatment was installed in early 2006 based on the findings of the well water study. The system included chemical injection of chlorine for iron oxidation, filter aid to accumulate iron particles for removal by multimedia filters and a filtrate storage tank to allow for constant RO water flow and for post filter backwash return to service rinse. After the filtrate tank the filtered water has sodium bisulfite and antiscalant added for removal of residual chlorine and to control against scale formation on the RO membranes.

However, even with the addition of the pretreatment equipment it was found that SDI values could not be maintained at less than 3 and iron content less than 0.1 ppm. Actual experience also found that improper control of the filter aid could and did result in severe fouling to the RO membranes, (reference picture 1) and cartridge filter elements. The membrane fouling associated with the filter aid and iron proved to be very difficult to remove from the membranes using established cleaning in place (CIP) methods.

Multiple CIP membrane cleanings failed to restore RO production back to baseline and as a result net RO product flow was further reduced from 250 gpm to 110 gpm. Additionally, the cartridge filter elements were fouling so rapidly that they had to be changed out at intervals that varied from once per day to once per week.

The following describes the efforts to address the iron fouling with field testing of Quantum DMI-65*, a silica-based filter media that has been used successfully for over 20 years. After confirming the performance of DMI-65 with field testing the MM filter media was removed from the five multimedia filters and replaced with DMI-65 in December 2006. The DMI-65 is designed to remove iron, manganese and arsenic from the feedwater supply when operated in the presence of chlorine. Experience to date has found no further loss in RO production and the cartridge filter elements are no longer fouling at a high rate.

The Quantum material has been tested in applications for reducing iron levels in excess of 50 ppm down to less than 0.05 ppm. Based on the Quantum experience the DMI-65 is expected to have a lifespan of ~8 years with annual attrition losses that varies from 1-5%. Picture 2 shows the granular media and figure 1 lists the physical properties.

The Quantum DMI-65 consists of grains of sand that have had proprietary products infused into them. This means that the active ingredients do not form a coating but become homogenous within the grains of sand. The DMI-65 acts as a catalyst in the presence of an oxidation environment created by the continuous injection of chlorine. The chlorine injection must be maintained to yield a free chlorine residual of 0.1 to 0.3 ppm at the filter effluent. The oxidation reaction causes dissolved iron, manganese and arsenic to form a solid, insoluble precipitate that is captured by the DMI-65 filter media. The captured iron is released during the filter backwash cycle.

Field test:
September 18, 2006: A well water side stream was supplied to the test filter after chlorine injection and prior to the filter aid injection into the well water supply to the existing MM filters, reference picture 3.

The test filter used was a 3.5 cubic foot ion exchange vessel that was filled with Quantum DMI-65 filer media to have a 24 inch bed depth and 40% freeboard for backwashing. The test vessel was prepared and operated for 24 hours to determine iron removal effectiveness and then backwashed. The post backwash return to service performance was monitored. The testing determined that the filter media was removing iron to less than 0.05 ppm and after backwashing continued to remove iron to less than 0.05 ppm. Based on the testing the recommendation was made to replace the media in the existing five filters with DMI-65 media.

Field Test Set Up (reference picture 3):

- A small ion exchange bottle was utilized. Diameter 7” by 44”High, as shown in picture 3.
- Using a 5 gallon bucket filled with DMI-65 media a preconditioning dose of ~100 ppm chlorine was added and allowed to soak for a couple of hours. The chlorine soak activates the media for service as a catalyst to promote the filtering of the oxidized iron.
- After soaking the media was transferred into the exchanger vessel to provide a bed depth of ~24 inches.
- The test filter was setup to have an equivalent service flow of 5 gpm per square foot. Based on the exchanger surface area of 0.267 sq. ft. a service flow rate at 1.34 gpm and backwash flow rate at 3.3 gpm were used.
- After installing media the test filter was backwashed for 10 minutes to remove fines and clear backwash was established.
- Iron testing was performed using the Hach Method 8008

9/18/06 Morning:

11:00 Filter in service, water temperature 21ºC (69.8ºF) & 7.5 pH
11:20 Test filter effluent: 0.06 ppm Fe
11:30 Test Filter effluent turbidity: **0.137** NTU
11:37 MM Filter inlet for well water iron: 1.23 ppm Fe

Afternoon

1:24 Test filter effluent: 0.01 ppm Fe
1:30 MM Filter inlet well water iron: 1.35 ppm Fe
2:30 Test filter effluent turbidity: **0.142** NTU; 2.86 SDI
3:53 Test filter effluent: 0.01 ppm Fe
4:02 MM Filter inlet well water iron: 1.28 ppm Fe

9/19/06 Morning

06:48 Test filter effluent turbidity: **0.215** NTU (very slight color noted in sample)
06:54 Test filter effluent: 0.24 ppm Fe
06:59 RO cartridge filter inlet: 0.21 ppm Fe (existing MMFilters effluent)
07:05 MM Filter inlet well water iron: 1.00 ppm Fe; 4.87 SDI
07:41 Test filter effluent: 0.18 ppm Fe
08:55 Test filter effluent turbidity: **0.198** NTU
08:57 Test filter effluent: 0.15 ppm Fe
09:10 Increased chlorine feed rate to see if there would be a change in iron reduction. Changed chlorine pump setting from 3.5 to 4.0, performed draw down test estimated feed chlorine at 2.3 ppm.
09:15 MM Filter inlet well water iron: 0.91 ppm Fe
09:35 Test filter effluent: 0.24 ppm Fe, secured service run to backwash filter
09:43 Test Filter: Started 10 minute backwash
10:10 Test Filter back in service.
10:36 Test filter effluent: 0.04 ppm Fe
10:47 Test filter effluent: 0.05 ppm Fe

Afternoon

12:22 Test filter effluent: 0.07 ppm Fe; 3.45 SDI
12:45 MM Filter inlet for well water iron: 1.01 ppm Fe
1:01 Test filter effluent turbidity: **0.120** NTU
End of Test:

Recommendation was made to install the DMI-65 into the 5 MM filters.

Filter Media Installation
The MM media was replaced December 11, 2006 in all five MM filters, reference picture 4. Since installation the RO cartridge filters went 9 weeks before plant allowed air entrainment to occur with the well water supply that quickly fouled the cartridge filters.

Due to the membranes having heavy fouling the RO units are being operated at lower service flows. The plant is in the process of rotating 24 spare RO elements on loan from another plant to allow for sequential removal of 24 elements for off site cleaning and testing. RO 2 bank 2 elements (total of 24) were the first to be removed and replaced with the spare elements. This allowed the RO units to be kept in service while having a 1/3 of a unit's total membranes cleaned at a time.

After cleaning the removed bank 2 elements they were then inserted into RO 2 bank 1 to displace the number 4-6 elements from each pressure tube. The removed elements are tested, cleaned and-reinstalled into the bank 1 into the lead position and pushing the original #1-3 elements now in the #4-6 positions out for cleaning. This allowed for RO 2 production to return to normal flow and the RO 1 to be removed from service so that all of the membranes could be removed and sent out for cleaning to restore full production sooner than the sequential swapping, cleaning and replacing in lots of 24 elements. Out side testing of the RO 1 elements found that the membranes were extremely polymer fouled, very difficult to clean off, requires frequent changing of the cleaning solution, and cannot be completed on a "once through" cleaning approach. Sample of the cleaning solution found very high quantities of the polymer still flocking after cleaning. Due to the extra cleanings required the turn around time has been significantly increased.

MM Filters initial service run:
First hour after being placed in service:
Iron 0.08 ppm and declined 0.02; 0.00 ppm
SDI 5.9

After 15 hours:
Iron 0.00 ppm
SDI 2.3
Filters are backed washed based on daily 24 hour program.

After back washing all five filters: Chlorine @filter effluent 0.17 ppm free

After 2 hours:	SDI 4.03	Iron: 0.01 ppm
After 3.5 hours:	SDI 3.58	Iron: 0.00 ppm
After 24 hours:	SDI 2.48	Iron: 0.00 ppm (Normal backwash cycle)
After 40 hours:	SDI 5.85	Iron: 0.17 ppm (Extended for observation)

Cartridge filter Delta P trending after DMI 65 filter media installation:

	RO1	RO2	
12/13/06:	6 psi	3 psi	
12/14/06	6 psi	3 psi	
12/15/06	6 psi	3 psi	
12/28/06	7 psi	4 psi	
12/29/06		3 psi	
1/4/07		3 psi	
1/16/07	7 psi	3 psi	
2/15/07	5 psi	9 psi	dP change due to increase feed water flow

2/15 RO 1 removed from service to have all of the membranes removed and sent out for cleaning, RO 2 now at full service flow.
2/23 RO 2 well water air entrainment into MM filters resulted in cartridge filters fouling and were changed out. As of March 7, 2007 differential pressure 2 psi.

RO performance as the RO membranes were batch cleaned:
Because the well water costs are lower than the citywater the two RO trains were kept in service at reduced production. A set of 24 RO elements were sent in for use in partial sequential removal of fouled elements for sending out for off side cleaning because the cleaning in place methods were not successful.

The set of spare membranes was enough to displace all of bank 2 membranes and when the set of displaced membranes were returned from cleaning provided 50% exchange of the bank 1 membranes. It took from late December 28, 2006 through February 8 to have RO 2 bank 1 membranes cleaned and replaced with bank 2 using the spare membranes. During this period the RO 2 product would be increased as each sequence of fouled membranes were replaced with cleaned membranes. Also observed was that both units experienced a slight lowering of the differential pressures that would indicate the feedwater quality was such that no further buildup was occurring and the in place foulant was slowly being dislodged.

Summary:

The DMI-65 filter media has performed well in removing iron contained in the well water. In addition to iron removal lowered SDI's has addressed the fouling to down stream cartridge filter elements and RO membranes that was previously a fouling problem from filter aid chemical passage through the MM filters. Fouling associated with filter aid use resulted in cartridge filter elements fouling at a rate that the filter elements were changed from once every 1-7 days and changed with DMI-65 media to more than once per two month interval. The RO membrane fouling caused by the filter aid polymer could not be reversed with cleaning in place methods as well as a loss in performance. Based on the RO operation since DMI-65 filter media installation has filtrate iron levels are less than 0.05 ppm with no evidence of any further increase in differential pressures across the cartridge filters and the RO units. Each RO is now in the process of restoring back to baseline performance.

As noted in the field testing the turbidity does not reflect breakthrough of the filters as compared to increase in iron and SDI's. During April an evaluation using particle counter instrument will be performed. The goal is to have continuous filtrate monitoring to provide operations an indication that well operation, chlorine injection or filters have a problem prior to fouling down stream RO equipment.

Physical Properties	
Color	Black to Brown
Bulk Density	1.46 gr/cm3; 1.46 tonne/m3; 91lb/ft3;
Specific Gravity (Particle Density)	2.69n gr/cm3
Effective Size	0.43 mm
Uniform Coefficient	1.34
Porosity	45.80%
Mesh Size	20-45
Attrition Loss P/Annum	1 - 5 % (depending on water condition)

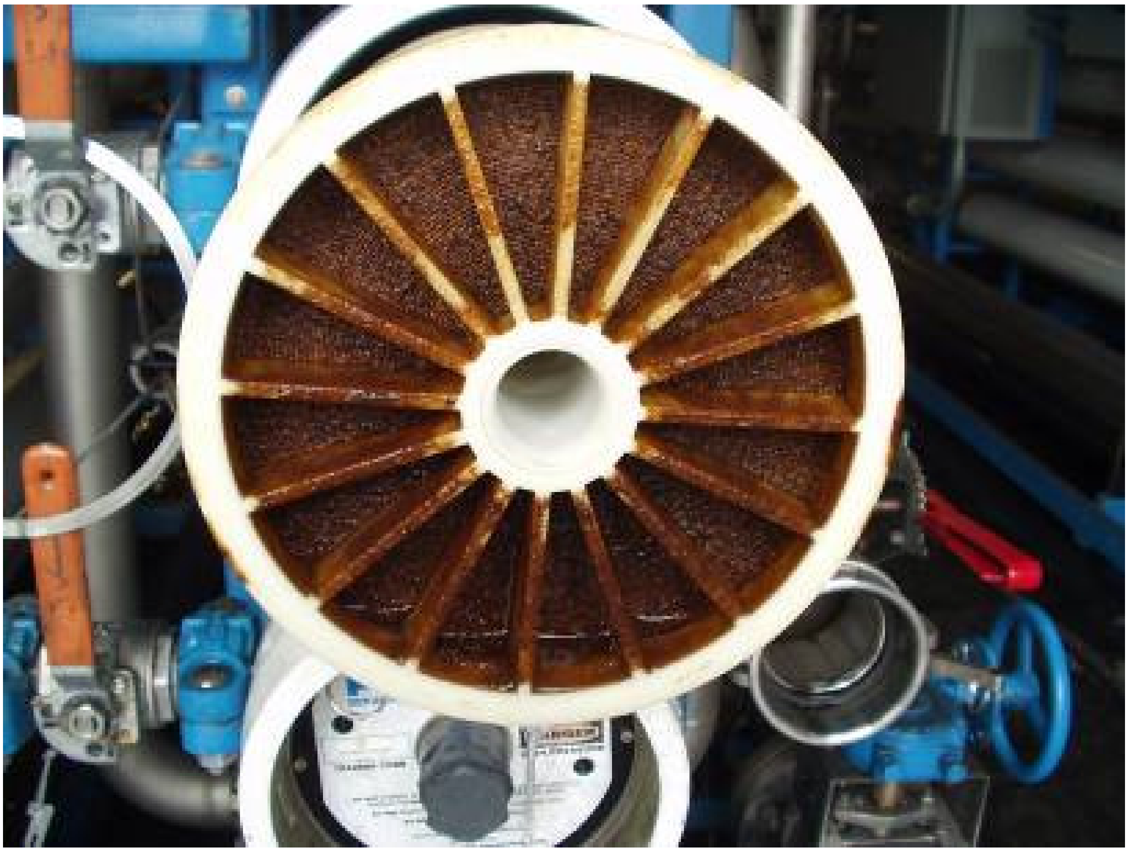
Condition of Operation	
Water pH range	5.8 - 8.6
Maximum water temp	45 degrees C
Bed Depth	600 mm (minimum)
Freeboard	40% of bed depth (Minimum)
Regeneration	Not Required
Service Flow Rate	5- 30 m3/m2 per hr
Backwash Flow Rate	25 - 80 m3/m2 per hr
Backwash Bed Expansion	Between 15 - 50 %

Bag Information	
Net Weight (each bag)	21 kg (44.1 lb)
Volume (each bag)	14.38 liters (0.5 ft3)
Bags per metric ton	48 bags

Figure 1

Quantum DMI-65 filter media shown in picture 2, is an engineered product that has been employed in Australia for more than 20 years in applications that require the reduction of iron, manganese and arsenic from the process water.

* DMI-65 is a registered trade name of Quantum Filtration Medium Pty Ltd.



Picture 1 The RO elements with fouling on the membrane surface and on the feedwater inlet and out let sections of all of the elements.

Picture 2: Quantum DMI 65 filter media.


Picture 3: Filter test unit


Picture 4: Filters that DMI-65 was installed in.