DE NORA

Pinellas County Utilities
St. Petersburg, Florida

SOUTH CROSS BAYOU WRF
FILTRATION SYSTEM INSPECTION

May 9-10, 2018

De Nora Water Technologies
Pittsburgh, Pennsylvania
WO# 3444
July 23, 2018

INTRODUCTION

De Nora Water Technologies visited the South Cross Bayou WWTP operated by Pinellas County Utilities May 9-10, 2018 for a comprehensive filter system inspection. Our last such inspection was in October 2014. De Nora helped start up the filtration system in 2001. It has twelve 9'-8" x 85' denitrification filters. The design basis flow is 33 MGD adf and 66 MGD peak, a filter influent nitrate of 9 mg/L and effluent of 2 mg/L, and a filter influent TSS of 20 mg/L with effluent TSS of 5 mg/L. The orientation of the filters is shown below:

West 12 11 10 9 8 7 6 5 4 3 2 1 East

A clearwell, mudwell, blower room and control room are on the east side of filter 1. There is a filter influent channel on the south side of the filters with a distribution weir for each filter in front of the influent valves. The influent channel is fed from its east side by the clarifier effluent header.

OPERATION

During our 2018 inspection, most filters were operating well below their maximum water levels. This was a large improvement from the time of our 2014 inspection when half of the filters were flooded even before morning peak flow had reached the filters.

Unlike in 2014, filter 1 was also now receiving its fair share of influent water due to a submerged baffle or other object that had been installed in the influent channel to break up the fast flow of water that mostly bypassed the filter 1 entrance weir. This was a major improvement in flow distribution. From the time of filter plant startup until the baffle object was installed, filter 1 had received only about 40% of the flow that other filters got.

On the morning of May 9, 2018, the Chemscan nitrate analyzer was indicating an influent nitrate-nitrogen of 13.01 mg/L and an effluent value of 1.74 mg/L. The effluent goal is 1 mg/L or less which the plant achieves over time. The chlorine contact turbidimeter was reading 0.21 NTU. This is a good but abnormally low turbidity. Many denitrification filter plants average 0.7 NTU effluent. Non-denitrifying filters often produce water in the 0.3-0.4 NTU range. The low turbidity could indicate a temporary methanol underfeed at the time.

There were 12 bumps and 11 backwashes scheduled daily. Bumps were done on even hours starting at midnight and then every two hours. Backwashes were done on odd hours starting at 1 am and then every two hours, except that no backwash was scheduled at 7 am on any day to avoid interfering with scheduled daily sampling.

The Plant has had some concerns meeting its TSS removal requirements. This prompted the request for filter inspection.

FILTER SAND FREEBOARD

Design sand freeboard is 147 inches below top of the backwash troughs. This is over 12 feet, making these filters some of the deepest De Nora filters ever constructed. This should allow for long filter run times with less frequent backwash, or high filtration rates.

Sand levels were measured along the three walkways from the top of handrails down to the sand surface. The handrails averaged about 78.5 inches above the top of the backwash troughs on the south side of the filters, about 77.25 inches down from the middle walkway handrails, and about 77.5 inches along the north walkway. After subtracting the handrail distance at each filter, the freeboard measurements from top of sand to backwash trough were:

Filter #	South	Middle	North	2018 avg	2014 avg	Change
1	155 inches	152 inches	146 inches	155 inches	151 inches	-4 inch
2	150	151	152	152	151	-1
3	151	150	150	151	150	-1
4	149	151	151	151	150	-1
5	152	151	152	150	152	+2
6	148	148	154	147	150	+3
7	148	150	153	149	150	+1
8	148	148	148	148	148	0
9	146	145	146	148	146	-2
10	149	148	148	147	148	+1
11	146	148	149	148	148	0
12	148 inches	150 inches	150 inches	150 inches	149 inches	+1 inch

Filter 1 had the greatest loss of sand (4 inches) since 2014 and is the lowest on sand overall. Most filters that lost sand had lost about 1 inch since 2014. Some filters showed a rise in sand level which could be due to measurement errors. The filters would not drain down to the sand surface in 2014, so sand level measurements are typically being made through at least 1 to 2 feet of water. This hides local high or low spots in the measurement areas, which could cause some variable readings.

While overall sand levels and rates of loss are still acceptable, the Plant was planning a rebuild program before filter bed conditions worsen. This could be done by selecting 2 to 3 filters yearly with the lowest sand levels or highest blower pressures and removing sand, gravel, and underdrain blocks. The air laterals would then be removed, cleaned and replaced. Underdrain blocks should be reusable if they are the plastic-jacket type. If so, procure a few spare full-sized blocks per filter to replace any blocks damaged during removal. New gravel and sand would then be placed.

BACKWASH SEQUENCE

Several backwashes were observed. The main air/water step was 780 seconds. Most of the filters were at already at a relatively low level when their backwash started, so some of this step time was used to fill the deep filters to the overflow point. De Nora saw one filter overflow during the air/water step for only about 300 seconds.

All the filter backwashes that De Nora observed generated white foam throughout the air/water backwash step. This is an indication of only moderate concentrations of TSS solids being removed. Even though the actual air/water overflow times were short, the filters appear to be getting backwashed too often for the operating conditions at the time of the May 2018 inspection. This could be a concern for the overall performance of the filter. The backwashes break loose stored solids and biomass all throughout the filter bed each time they are performed. Doing a shallow cleaning and doing it too often will allow less recovery time for the filters and could allow some TSS solids and nitrate-nitrogen to be discharged from the filter right after the backwash.

De Nora changed two backwash step times. The air/water backwash step was lengthened from 780 seconds to 900 seconds. Operators should further lengthen this step to as much as 1200 seconds to cause the air/water mixture to actually overflow for about 900 seconds. This will allow for deeper, better filter cleaning and to allow for backwashing less often.

De Nora's standard length for the air/water actual overflow is 900 seconds, with a standard rinse at 300 seconds. The water-only rinse step was shortened from 600 seconds to 400 seconds to reduce the overflow of relatively low-TSS water.

The filters have been upgraded with sonic level indicators. It would be good to use these to add a separate fill step to the backwash sequence. The filter is first drained down to a low level to allow for easier blower starts. Then air flow followed by water flow is added and the filter water level is raised to less than one foot of the overflow weirs. At that point, the main air/water step timer starts, allowing for a consistent amount of air/water overflow during each backwash. This promotes even cleaning. The fill step also has a backup timer so that if the filter level indicator malfunctions, the fill step still advances after a reasonable amount of time.

If the effluent valves are changed to positioning valves, the filter sonic level indicators can also be used for level control in the filters. At the end of backwash or bump, the filters will drain down only a foot or two below the influent weirs to a setpoint level. This will prevent quickly dumping as much as 10 additional feet of water out of the freshly washed filter at a time when it may not have recovered its filtration efficiency yet. Level control will also prevent multiple smaller dumps after bumps. Level control could help to significantly reduce flow surges to the chlorine contact chamber during both backwashes and bumps and could promote more consistent TSS removal.

There are three backwash air blowers, with any two used for backwash and the third as a standby. The two selected blowers have their starts separated which is good, but no air reaches the filter until the air dump valve (or blower unloading valve) closes later. The pneumatically operated air dump valve has its instrument air vent tightly pinched and closes very slowly, but this does not help the combined blower air flows enter the filter slowly. When air flow finally shifts towards the filter, it causes a very violent eruption and uneven air distribution at first. This could disrupt the gravel layers over time. Sand could be thrown up into the backwash troughs, or it could sift down into the effluent flow. This could account for sand loss trends we observed. This could result in shortened filter life.

The blower start portion of the backwash sequence should be changed to the following:

1. Start first blower and wait 10 seconds. Verify run signal and air flow increase.
2. Close the air dump valve slowly. Account for valve travel time in overall step length.
3. Wait 1 additional minute with a single blower running to allow the filter to fully develop an air pattern.
4. Start a second blower. Verify run signal and air flow increase.
5. Confirm good blower run signal and/or air flow rise for at least one blower before starting air scour step timer.
6. Air scour filter 120 seconds with two blowers before proceeding to the air/water backwash step.

The above changes will reduce the initial backwash air surge problem. The second blower will start much easier and with no shock to the filter when the air pattern has already been established by the first blower.

To further reduce the initial air surge into the filter, the air dump valve would need to be changed to an electrically-actuated valve that can be paused at just the right spot to cause partial air flow to shift to the filter. Using an electric air valve, the blower start sequence could be the following:

1. Start first blower and wait 10 seconds. Verify run signal and air flow increase.
2. Start second blower and wait 10 seconds. Verify run signal and air flow increase.
3. Close electric air dump valve just far enough (typically about 65% closed) to divert some air to the filter. Pause valve; wait 60 seconds for a full gentle air pattern to develop.
4. Confirm good blower run signal and/or air flow rise for at least one blower before starting air scour step timer.
5. Close air dump valve fully and air scour the filter for 120 seconds before proceeding to the air/water backwash step.

If the air flow meter cannot read air flow properly with the air dump valve open, the air flow check will need to take place after the valve closes, and the above blower start sequences would need to be modified.

Have a De Nora controls engineer review and help update all of the backwash programming.

BUMP SEQUENCE

The bump sequence's four step times were 5, 5, 5, and 90 seconds in length. De Nora changed this to 10, 10, 10 and 75 seconds. The overall bump length is the same for each filter with more time allowed for valve movements in the first three steps.

Ramp-down time for shutoff of the backwash pump has been reduced to about 15 seconds which seems good. This ramp-down had been 4 minutes in 2014 and had caused filter overflow on the last filter bumped, because the pump took too long to stop producing flow.

The opening of the spent backwash valve on a bumped filter in response to high level is intended as a last resort alarm action. There was a bump cycle setting on the HMI screen showing that the spent backwash valve will open during step 4 of the filter being bumped if all filters are high. The Operators had set this trip level to 99%. It does not sound like this programming has been updated. If not, there may still be a possibility the filters could overflow during a bump.

There is a structural dividing wall between filters 6 and 7 that is higher than the normal dividing walls between filters. High levels during bump need to be evaluated in these two isolated sections of the structure, not as a single structure.

In 2014, De Nora recommend that the spent backwash valve on a bumped filter would only open if two other filters in that half of the filter structure are already high when the bumped filter hits a high level. The high-level filters would have to be detected in either filters 1-6 or 7-12 to trigger the spent backwash valve opening while bumping within either group of filters.

Have a De Nora controls engineer review and help update the bump programming. Remember to save any online or offline PLC program backups with optimized backwash and bump step times and actions, so that old or unintended versions do not get loaded back in again after a program reload or PLC changeout.

BACKWASH WATER SUPPLY

The design backwash flow rate is 4930 gpm. We did a backwash water rise rate on filter 4 and got an actual backwash rate of 4962 gpm. The backwash water flowmeter indicated a flow of 5688 gpm during the test. The flowmeter appears to be reading about 15% higher than the actual rise rate in the filter. However, the difference could be due to backwash water leaking away through clean backwash water valves that are not seating fully.

In 2014, filter 7 was identified as having a clean backwash water leak. This leak still exists. Refer to the valve leak detection procedure that is attached to this report. Try adjusting the closed mechanical stop bolt on a leaking valve. Filters that have leaking closed clean backwash valves will have higher flows when tested, because their leak will not come into play when the clean backwash valve on that filter is already wide open. After leaks are fixed, reduce the backwash pump rate to 4930 gpm.

The backwash pumps used to be single speed pumps using a flow control valve. The flow control valve failed after several years and the system was said to have been used without flow control for some time. The backwash flow control valve air supply is disconnected. De Nora could not see how far open the valve now is.

The backwash pump motors have been converted to variable speed. The speed indications and flow control are confusing. The backwash flow setpoint on the control screens is 5200 gpm, but the system is not controlling to this flow. De Nora saw backwash pump 1 running at an indicated speed of 66%, producing an indicated flow of about 5700 gpm. Later, backwash pump 2 was observed running at an indicated 97% speed, but also producing an indicated flow of 5700 gpm. For backwash pump 2, De Nora changed the flow control from auto to manual and tried a manual speed adjustment. Neither the flow nor the indicated pump speed would change. It appears the flow control logic is not functioning, is not Operator-accessible and may be using an actual speed that is different from what the control screen indicates.

Ideally the backwash pump would have a steady ramp-up lasting about 30 seconds to reach the required speed and flow, to avoid stressing the filters with flow surges.

Have a De Nora controls engineer verify the backwash pump control logic.

BACKWASH AIR SYSTEM

There are three backwash air blowers with any two operating and one as a spare. Each can provide 50% of the backwash air flow requirement. The blowers operate during the backwash air scour and air/water scrub to provide essential agitation energy to clean the filters. By comparison, the relatively low velocity backwash water flow can remove very few solids on its own unless they have been broken loose by the backwash air.

There is a blower air flow meter. It does not appear to read the exact flow from the blowers. This is the case with most air flow meters De Nora has observed. Air flow measurement requires good temperature and pressure compensation to read correctly. The best way to use this meter is to observe the typical flows that either one blower or two blowers produces (make sure blower belts are tight), and then set high and low air flow alarms about 15% above or below those readings.

The Plant had difficulty with the original multiple single belts design, and had switched to wider sheaves to allow use of wide single bands with four joined ribs.

De Nora opened the blower belt guard covers to check condition of the belts. Some fresh rubber dust was visible inside the belt guard on the south blower 0701. This is a sign of loose belts.

We then watched the south blower in operation during a backwash. The non-driven side sagged slightly, which is caused by the loose band slinging away from the blower pulley after it has applied force on the driven side. As the band heated up and stretched a little more, the tone of the blower was heard to rise and fall. This is from the blower speeding up and slowing down as the band slipped slightly. If the band loosens further, the slippage may start creating a screeching sound. The other two blowers were checked and showed signs of loose band belts as well, although not as bad as south blower 0701.

Blower belt tension should be checked with a tension gauge appropriate for the type of belt or band. If single rib belts are used, a single barrel tension gauge should be used. The tension is often in the 10 to 15 lb range when the belt is deflected. Multi-rib belts, like the Plant now uses, need this much tension per rib. The Plant’s bands have four ribs and thus need a combined tension that may be 40-60 lbs overall. This requires a heavy-duty gauge with two or three joined spring barrels. The Plant was still using a single-barrel spring gauge useful only for single rib belts, and only tensioning the large bands to about 16 lbs at an unknown deflection.

A good source for a heavy-duty belt tension gauge is on the following website: http://www.hmc-international.com/. Look for part number AWI-II or AWI-III. Refer to gauge instructions. The amount of deflection under tension needed is the span between motor and blower pulleys in inches divided by 64. The Plant's blowers have a span of 29 inches, thus 29/64 or 0.45 inch of deflection is needed at the given tension.

For more information, see the blower supplemental maintenance instructions attached to this report.

VALVE INSPECTION

The Plant is considering changing to all new valves with electric actuators. This would be a good upgrade. Many pneumatic actuators still need replacement, and any remaining original valves are in danger of leaking or become too hard to turn. See the list below. Consider that converting to electric actuators will require more I/O at the PLC, many new lines of PLC ladder logic, and additional conduit to each valve to provide 4-20 mA signal wiring separated from 120 volt wiring presently supplying solenoids and limit switches.

Clean dry instrument air is vital for proper operation of the pneumatic filtration system valves. New instrument air compressors have been installed since 2014. Many old actuators have been switched to quarter-turn vane-powered actuators to restore reliability.

De Nora saw a constant instrument air leak out of the air dump valve (blower unloading valve). The solenoid valve may be worn or stuck by debris. Clean it or replace the solenoid valve.

There was also a lot of entrained oil also flowing out with the air leak at the dump valve. This oil could be escaping from the new air compressors. Check operation of inline filters downstream of the air compressors to make sure they are working. Oil leaks could deteriorate valve actuator seals or break down over time and become a source of sludge and debris in the air piping.

De Nora noticed filter 1 clean backwash valve was slow to close after the filter had been bumped automatically. Determine if the valve is sticking or if it needs limit switch adjustment.

De Nora closed filter 3 effluent valve in manual. Then it would not reopen in manual or automatic. 10 minutes later, the valve showed it was open again. Check the valve's actual movement. Check if the open limit switch is properly adjusted.

Filter 7 was isolated for a leak check and it rose slightly when another filter backwashed. This is a sign of a leaking clean backwash valve. This was first reported in 2014. This leak will reduce the backwash water rate to all other filters, so it should be a high priority to fix. Review additional discussion in the backwash water supply section earlier in this document about how indicated backwash flow to filter 4 was higher than the actual delivered flow.

De Nora conducted a series of tests to check for water leaks through closed valves. The main part of this involved raising the filters exactly to backwash trough level and looking for rises or subsidence with all valves on a filter closed. We would vary valve positions and levels on other filters to try to affect the filter we were checking. We could then drain the backwash troughs to verify influent and spent backwash valve leaks. In some cases, we would estimate the leak rates either visually or by doing rise rate or draw down tests. Here was what we could conclude:

Filter #	Valve Condition
1	Clean backwash valve slow to close after auto bump
2	Effluent valve leaks 159 gpm (all valve leaks are when valve is closed)
3	Influent valve 100 gpm leak
3	Effluent valve was commanded open, took 10 minutes to show open
4	No leaks
5	No leaks
5	No leaks
6	Influent valve leaks 10 gpm
7	Effluent valve leaks 40 gpm
7	Clean backwash leaks (rate not known; will reduce other filters' bw rates)
8	Influent valve leaks 75 gpm
10	Influent valve leaks 10 gpm
11	Influent valve leaks 600 gpm (valve stuck open, shaft key sheared off)
11	Effluent valve leaks 38 gpm
12	Influent valve leaks 40 gpm

Plant mechanics began to work on the filter 11 influent valve immediately after the conclusion of our inspection.

Valve leaks make it hard to isolate and work on a filter. Adjust closed mechanical stops to lessen leaks. Replace valve if necessary. Influent valve leaks will waste water and unreacted methanol to the spent backwash tank during backwashes. Effluent valve leaks will bleed away clean backwash water during backwash and make backwashes less effective for that filter. Clean backwash valve leaks will take clean backwash water away from any other filter that is trying to backwash and make their backwashes less effective. Spent backwash valve leaks will waste water and send unreacted methanol to the mudwell all during the filtration cycle. Backwash air valve leaks will cause the affected filter to become air bound, reduce its ability to retain solids, reduce its ability to denitrify, and will reduce backwash air to any other backwashing filter. For more information, refer to the valve leak detection procedure that is attached to this report.

INFLUENT FLOW DISTRIBUTION

Operators said a flowmeter upstream of the filters used for pacing methanol was reading lower flow than other flowmeters in the Plant. De Nora did a flow distribution test on the filters with assistance from the Operators.

Operators put the filter feed pumps in manual to provide a steady flow to the filters. Then De Nora closed effluent valves on four filters at a time and measured the actual rise rate within each filter over a 4 to 7 minute period. The test was conducted near the top of the filter in the space between the Y-walls (ranging from 69 to 71 inches width). This test was repeated for two more groups of four filters, until all were rise rate tested. Then the filter feed pumps were put back in automatic control. Here were the flow distribution and total flow results:

Filter #	Y-Wall Width	Flow
1	71 inches	1293 gpm
2	71	1082 (with effluent leak of 159 gpm added in)
3	70	1115
4	70	1545
5	69	1489
6	69	1722
7	70	1351
8	70	1475
9	69	1458
10	70	1540
11	69	1302
12	69 inches	1485 gpm
	Total Flow:	16857 gpm or 24.28 mgd

De Nora then looked back at the upstream plant flowmeter trend during the test and it displayed a steady 14.7 MGD. The flowmeter is reading 39% low. Check flowmeter settings and installation to determine the cause of the discrepancy. This flow error would cause problems for flow-pacing methanol. After fixing the flowmeter, re-tune the methanol dosing settings.

The individual filter flows reveal that filter 1 does receive a fair share of the flow now. Filter 2 and 3 received the lowest flows which could be improved by slightly lowering or cutting down their front inlet weirs. Filter 6's weir might need slight raising. Filter 11 received a slightly lower flow than its neighbors which could be because its influent valve was stuck only partially open.

MUDWELL SYSTEM

The mudwell has an automatic drain valve that indicates 55% open on the control screen. There is an auto/manual mode for this valve on the control screen that appears to be disabled. Manually changing the % open will not change the valve position. In automatic mode, a 5% signal is shown as being sent to the valve. This does not change the valve position either. The automatic mode has a setpoint for flow set at 2000 gpm. After a backwash De Nora observed a flow out of the mudwell at 2104 gpm. The mudwell flow control valve appears to be stuck in one position, so flow from the mudwell will change as level in the tank changes.

Flow control from a mudwell is an unusual design feature. However, if this equipment is made to work again, the timing and rate of return of water from the mudwell to the front of the treatment system can be controlled in some beneficial ways. The normal rate of return for these filters is estimated at 830 gpm, which would return a backwash volume in 2 hours. The return rate could be made to vary automatically, based on how long it has been since the last backwash or on the level in the mudwell. This could allow for the minimum appropriate return rate to the Plant under any condition. Dirty backwash water generated late in the evening could also be retained with a timer and released during an overnight low flow period if that would help Plant operation. Look into repairing the mudwell drain flow control system.

METHANOL SYSTEM

Methanol Dose Control Programming

De Nora discussed the methanol dosing control logic with the Plant's control engineer. The dosing logic had been altered in the past and is not well understood. The flow and influent nitrate logic still appears to be functioning, but the effluent nitrate correction logic appears to have been disabled. This would mean that the system will not try to maintain a setpoint level for effluent nitrate. Operators would have to make periodic corrections.

The Plant would benefit significantly from modernized and fully functional methanol dose control programming. This will keep the effluent nitrate more consistent and will minimize methanol usage, which should help overall filter operation as well. De Nora has developed advanced and user-friendly control logic for methanol dosing over a 20 year period. Have a De Nora controls engineer help the Plant to upgrade the methanol dose control logic to a much better system than ever before.

Methanol System Equipment

The methanol storage and feeding system components have been converted to almost all stainless steel including the storage tank and piping. Previously there was a carbon steel tank, pvc piping above ground, and fiberglass discharge pipe below ground that had raised concerns. The underground section of the old discharge pipe had developed a break and was abandoned. Some good thought has been put into improving the methanol system.

Both methanol pumps are set to their highest stroke setting. One of the two large methanol pumps was changed to a smaller pump in the past. The control system was said to switch to the smaller pump during low flow periods for better control. This is an unusual approach. The logic controlling this switchover should be reviewed by a De Nora controls engineer.

Some of the methanol system equipment had problems in 2014 and has not yet been repaired. There are also a few new problems. The large gauge on the west methanol pump is sprung and is stuck below the 0 psi reading. The fill station enclosure box at the methanol tank has rusted out. That box has a drain pipe that is supposed to conduct spilled methanol down to the tank sump station. The methanol flowmeter local display is burned out, which may make it hard to do calibration procedures. The display was working in 2014 but the flowmeter was believed to be reading about 50% of the actual methanol flow at that time. Repair or replace any failing methanol system components.

When the west methanol pump runs, the east pressure gauge still pulsates. The gauges are upstream of the backpressure valves. The downstream pressure pulses that make it upstream past the east backpressure valve indicates that it at least is no longer sealing properly. Correctly operating backpressure valves help the chemical feed pumps deliver precise dosing. They help guard against leaks forward or backward through the piping. For reliable dosing, clean, repair or replace both backpressure valves and set them at 15 psi backpressure.

There are separate pressure relief valves that route any pump overpressure back to the top of the methanol tank. These protect the system against blocked pipes or valves that get closed downstream. These valves look to be original to the installation and are in unknown condition. They may also be installed incorrectly near the pumps at a low elevation instead of at the high point in the piping. To ensure this important safety feature will function if needed, replace the old pressure relief valves with new ones set them at 40 psi, and place them in the correct place in the piping according to instructions.

There is a pulsation dampener remaining on the west pump only. These devices can reduce stress on all components including pump diaphragms, pressure gauges, backpressure valves and discharge piping. They allow the methanol to flow steadily through its long discharge pipe instead of requiring that entire length and mass of fluid to start and stop with each pump stroke. Pulsation dampener diaphragms periodically need to be pumped back up with a hand air pump to close to the backpressure valve setting until pressure fluctuations reduce. These diaphragms can eventually break. The remaining dampener is not working presently and probably has failed. There may be upgraded pulsation dampeners available that will be more reliable. Install new pulsation dampeners at the discharge of each methanol pump.

Consult with PULSAfeeder or another reputable supplier for the current correct models of backpressure valves and pulsation dampeners for this application including compatibility with methanol. Refer to the following pumping system design guide for additional information: http://pulsa.salesmrc.com/pdfs/Pulsar-Series-Pulsa-Series-Installation-Specifications-EN.pdf
If this link fails, visit the literature page on the PULSAfeeder Engineered Products website.

BACKWASH INTERVAL

The backwashes we observed during the May 2018 inspection produced white foam throughout. It appears the backwashes were being done too often. Verify using the calculation below.

As the filtration system removes suspended solids and nitrate-nitrogen from the water, flow resistance increases in the filters. The accumulation of TSS solids and denitrifying biomass eventually will approach the maximum loading capacity of the filter. The backwash interval (time between successive backwash starts) can be predicted by calculating how long one filter would run if the entire plant flow was filtered through it.

$$\text{Backwash Interval (BI)} = \frac{\text{Specific solids loading x single filter area x conversion factors}}{\text{TSS and nitrate reduction x filter plant flow}}$$

The specific solids loading of these filters is about 1 lb per square foot of filter area per backwash based on actual experience of other plants. At 9.67 ft x 85 ft, each filter has 822 ft^2 surface area. Use this report to optimize the filter plant condition. Assuming that TSS reduces from 7 mg/L to 1 mg/L, nitrate-nitrogen reduces from 13 mg/L to 1.0 mg/L and plant flow is 24 MGD, the backwash interval is:

$$\text{BI} = \frac{1\ \text{lb/ft}^2\cdot\text{bw x } 822\ \text{ft}^2 \text{ x } 454\ \text{g/lb x } 1000\ \text{mg/g x gal/3.785L x MGD}\cdot\text{day}/10^6\ \text{gal x } 24\ \text{hr/day}}{[(7 - 1) + (13 - 1)]\ \text{mg/L x } 24\ \text{MGD}}$$

The product of the top terms can be considered a constant for this plant, equal to 2366. The units cancel to give hours between backwashes. Use the following simplified form:

$$\text{Backwash Interval} = \frac{2366}{[(7 - 1) + (13 - 1)]\ \text{mg/L x } 24\ \text{MGD}} = 5.5\ \text{hrs/bw}$$

Divide this interval into a 24-hour day and round up to get about 5 backwashes daily. The calculation should be conservative based on the significant depth and filtration driving force available in these filters. Adjust for changing flows or water quality. Expect to do more backwashes on higher flow/rainy days. Try to backwash filters in numerical order to keep track better.

CONCLUSIONS

1. There are opportunities for significant improvements to most aspects of the filter system control programming. The list grew longer as we closely checked out the operation.

2. Most of the filter were operating well below their influent weirs, unlike in 2014.

3. De Nora did a steady-state filtration flow test on each filter which showed an actual 24 MGD total flow. The plant flowmeter showed a steady 14.7 MGD which is incorrect.

4. Filter 1 was verified to be receiving its fair share of water due to an added baffle.

5. De Nora observed nitrate-nitrogen of 13 mg/L in and 1.74 mg/L out at the start of our inspection. The methanol dose logic may no longer be making effluent corrections.

6. Filter effluent turbidity was observed to be 0.21 NTU, lower than the typical denitrification filter plant. This could have been from a temporary underfeed of methanol.

7. Filter 1 lost 4 inches of sand since 2014 and has the lowest sand level that is 8 inches below design. Other filters' sand levels are little changed from 2014.

8. The Plant was planning a filter rebuilding program. This could be done by selecting the two or three filters with the lowest sand levels or highest blower pressures each year for rebuild.

9. A filter was seen to overflow air/water only about 300 seconds using a 780 sec backwash step. A 900 second actual overflow is needed to allow for better filter cleaning, better filter performance and less frequent backwashing.

10. De Nora observed white foam being produced throughout the backwashes of several filters. The backwashes were probably being done too often before a full load of captured TSS and denitrifying biomass can build up. 11 backwashes were being done daily but 5 daily backwashes were conservatively calculated for the conditions in May 2018.

11. The backwash air blowers start too close together which causes a violent and uneven start to air scour flow in the filter. This could slowly damage gravel layers in the filters, promoting sand loss and shortened filter life.

12. Banded drive belts on the blowers were insufficiently tensioned, especially on south blower 0701 which showed multiple signs of slipping.

13. Backwash flow is not being controlled to the flow setpoints or motor speeds indicated on the control screens. The flow controller does not respond to changes made at the screens.

14. A rise rate check on filter 4 showed the backwash pump produced 5688 gpm, but only 4962 made it to the filter. Other evidence showed that filter 7's clean backwash valve (and possibly others) are leaking backwash water away.

15. De Nora identified valve leaks on 9 of the 12 filters. These leaks make it hard to isolate a filter for maintenance. They can decrease backwash efficiency and increase methanol consumption and pumping costs.

16. The Plant is considering changing to all new valves with electric actuators. This would be a good upgrade. Many pneumatic actuators still need replacement, and any remaining original valves are in danger of leaking or become too hard to turn.

17. The mudwell drain flow control system is not working.

18. The methanol dose control programming has been altered with vital parts of it disabled. It may not be making corrections to effluent nitrate-nitrogen.

19. Several methanol system components are deteriorated or suspect. This includes the fill box enclosure, the pressure gauges, the backpressure valves, the pulsation dampeners, the pressure relief valves and the methanol flowmeter.

RECOMMENDATIONS

1. Determine the cause of the plant flowmeter upstream of the filters reading so low. Accurate flow measurement is vital to dosing methanol properly.

2. Increase the backwash air/water step long enough to cause a 900 second actual overflow. Add a fill step to the backwash programming to make it easier to achieve this overflow period consistently.

3. Backwash about 5 filters daily for the operating conditions prevailing in May 2018. Backwash filters in numerical order. Recheck backwash interval when inlet TSS, nitrate or flow loadings change.

4. Consider changing the effluent valves to positioning valves and doing level control in the filters. This will avoid dumping large quantities of water after backwash through un-ripened filters, avoid multiple smaller dumps after bumps, and avoid hydraulically surging the chlorine contact chamber. This is De Nora's standard design.

5. Change the current backwash blower start sequence to establish the initial air pattern with only one blower running. Then start the second blower. Later, consider changing to an electrically actuated air dump/blower unloading valve for an even better blower start sequence and less chance for filter damage. Have a De Nora controls engineer assist.

6. Adjust the bump cycle to not open the spent backwash valve on high filter level unless two other filters in that half of the filter structure are also high. Have De Nora assist with this.

7. Back up backwash/bump step timing and other program improvements so that they are preserved if the PLC is upset or the program needs to be reloaded.

8. Check for clean backwash valve leaks starting with filter 7 using the supplemental leak detection procedures in this report. Once the leaks are fixed, the backwash flow should be adjusted downward to the standard 4930 gpm.

9. On leaking valves, adjust valve closed mechanical stops slightly to slow the worst identified valve leaks. Replace valves that cannot be adjusted successfully.

10. Troubleshoot movement problems with filter 1 clean backwash and filter 3 effluent valve. Check if limit switches need adjustment.

11. To upgrade the filter plant reliability in a major way, replace all original valves and actuators. Changing to electric actuators will be a major undertaking but will add new capability such as a better suitability for filter level control.

12. Adjust inlet weirs on filters that still have relatively low or high filtration flows.

13. Adjust blower belt tension using an appropriate tension gauge. The multi-rib banded belts will need a high capacity type of gauge. A fair estimate of required band tension is at least 40 lbs at a deflection of 0.45 inches. This is vital for band/belt longevity and blower reliability.

14. Review supplemental blower maintenance instructions attached to the end of this report.

15. Use the backwash air flow meter to observe the typical flows that either one blower or two blowers produces (make sure blower belts are tight), and then set high and low air flow alarms about 15% above or below those readings in the appropriate backwash steps.

16. Solve cause of oil possibly blowing out of new instrument air compressors and appearing at a leaky blower air dump valve solenoid. Then clean or replace that leaking solenoid.

17. Get mudwell drain flow control equipment working again. Reduce drain flow rate to the minimum needed or to shift some return flow to the best time for the Plant.

18. Have a De Nora controls engineer help upgrade the methanol dosing program to be better than ever, so that filter performance can be optimized.

19. Have a De Nora controls engineer review the unusual logic that switches from the large to small methanol pump when plant flow is low, to make sure there is no bump in dosing at switchover.

20. Rebuild methanol fill port enclosure, replace gauges, backpressure valves, pulsation dampeners and replace and possibly relocate pressure relief valves for both methanol pumps. Adjust backpressure valves to 15 psi. and pressure relief valves to 40 psi. Repair and calibrate methanol flowmeter.

21. Have De Nora inspect the filtration system yearly to help optimize operation.

BACKWASH AIR BLOWER MAINTENANCE

The backwash air blowers provide the main source of cleaning energy for backwash and are very important components of the filtration system. Filters that do not receive a good backwash air flow will deteriorate quickly.

Blower Drive Belt Tensioning

A very common problem is under-tensioned belts. If air flow is lost due to slipping belts, the filter system will not backwash efficiently. The Operators should expect the blower drive belts to last five years or longer with only a little attention. Signs of loose belts could be belts vibrating up and down, a hot rubber smell after the blowers have run only a few minutes, black rubber dust sticking to the belt guards, or squealing upon startup or after the blowers have run and the belts have warmed up. The tone a blower makes can also vary if its belts go back and forth from slipping to not slipping.

The actual belt tension required is much more than one would expect or try to use if checking belt tension only by hand pressure. Hand pressure tensioning typically results in tension that seems tight but is only about half what is required. Loose belts eventually slip, heat up, stretch, slip even more and become glazed or cracked. Damaged belts can no longer be tensioned successfully.

The proper belt tension needs to be calculated and verified using a tension gauge. Belt tension calculations take into account the belt type, distance between pulleys, sheave diameters, blower driven speed, and whether the belt is new or used. Tension charts and instructions come with tension gauges to make determining proper tension easier. Belt tension gauges are available at HMC International (item #AWI-2 or -3) at website http://www.hmc-international.com or at Grainger's (item #6AGK7) and other industrial suppliers.

If single rib belts are used, a single barrel tension gauge should be used. For the most common cross-section 5VX belt, the used belt tension is often in the 10 to 15 lb range when the belt is deflected. Look for the specific belt model number in use, and refer to gauge instructions. The amount of deflection is the span between motor and blower pulleys in inches divided by 64. For example if the span is 32 inches, then 32/64 or 0.5 inch of deflection is needed at the given tension. If multi-rib belts are used, it is even more important to use a tension gauge, but it must be a heavy duty one with several joined barrels, as the required tension could be 10 to 15 lbs per rib for a much higher total tension. A four-rib band would require a tension of 40-60 lbs.

New belts should be re-tensioned at 5, 50, and then every 500 hours of blower operation. Also, new belts should be supplied in "matched" sets that are verified to be exact equal length within their part number. This allows even tensioning and load sharing. A typical belt tensioning guide for single rib belts is attached at the end of this report.

Finally, sheave alignment should also be checked whenever tensioning belts, using a straightedge or taut string to see if four spots on the two pulley faces can touch at the same time. Place the straightedge across the faces of the two sheaves and shine a flashlight underneath all four points of contact to make sure they are all flush. It is usually necessary to do most belt tensioning using the front tensioning bolt nearest the belt and to steer the motor base with the rear tensioning bolt by turning it in the opposite direction from the front bolt to correct the sheave alignment. If these procedures are followed, belt life and blower air flow capacity will be maximized.

Gates Corporation has a v-belt preventive maintenance manual available at the following link: https://safety.gates.com/wp-content/uploads/2016/04/Gates-Corporation-Preventive-Maintenance-Safety-for-Belt-Drives-Guide.pdf

Blower Inlet Air Filters

Blower inlet air filters should be cleaned regularly by blowing off lightly with compressed air. Non-paper filter elements may also be able to be cleaned with hot soapy water at 6 month intervals. Heavy duty felt or polyester filter elements with wire mesh support are best. When a cleaned filter does not recover to within 4 inches water column over new condition, replace it. Install a vacuum indicator between the air filter and the blower to show how clean the air filter is. A good vacuum indicator can be found by using the search box on the website http://filterminder.com to look for model 135501.

Lubrication

Blower gear case oil should be changed yearly with synthetic oil or every 6 months if using conventional oil, depending on operating temperature. Motor bearings should receive only a yearly light greasing with grease relief plugs removed or as directed by the motor manufacturer.

Lubricate sliding weighted blower pressure relief valves by taking off all the weight plates and pull off the piston from the closely machined peg it slides up and down on. There should be only slight resistance to pull the piston off, due to creating a vacuum. If the sliding parts have begun to corrode, the piston may need to be turned first with a pipe wrench to free it up. Then remove the piston and oil or lightly grease the bare metal sliding surfaces to prevent wear and corrosion. Replace the piston and the weight plates, using only 2-3 more plates than needed to run smoothly after the initial blow off after blower start. Repeat this servicing every 2 to 6 months depending on how quickly the lubricant dissipates.

Spring-operated blower pressure relief valves are not lubricated and should be replaced if they quit providing the rated blow off pressure.

Make sure all these items are on the preventive maintenance schedule.

HOW TO USE A V-BELT TENSION GAUGE

1. **CAUTION:** Before doing maintenance or tensioning on belt drives, turn equipment off and lock out the power source. Use guards on machinery when running.

   Place a matched set of belts over the sheave grooves. Take up the slack until the belts appear fairly taut.

2. With the drive stopped, measure the belt span length of your drive (see sketch). Set the rubber O-ring on the body of the tension gauge at the dimension equal to 1/64 inch for every inch of span length. For example, the deflection for a 32 inch span is 1/64 inch x 32, 1/2 inch.

3. Set the O-ring on the plunger at 0 against the body of the tension gauge.

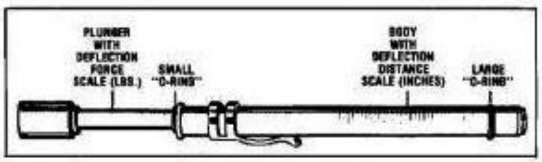
4. With the tension gauge perpendicular to the span, apply a force to a belt in the center of the span. Deflect the belt until bottom of the large O-ring is even with the top of the next belt, or the bottom of a straight edge laid across the top of other belt(s) on the drive. Release pressure and read pounds of force used at O-ring on plunger.

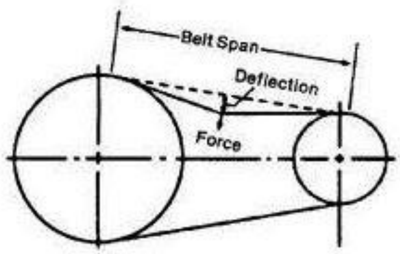
Note: When new belts are installed on a drive, the tension will drop rapidly during the first few hours. Thus, for new belts, tighten to the initial installation defection force shown in the tables below. Check tension frequently during the first 24 hours of operation. Subsequent retensioning should fall between the minimum and maximum forces shown in the tables.

5. Compare the force required in step 4 with the ranges in the tables below.

   Tighten or loosen belts to bring them into the recommened range.

Note: The proper tension for V-belt drive is the lowest tension at which the belts won't slip under peak load conditions.





V-Belt Cross Section	Small Sheave Diameter Range (Inches)	Recommended Deflection Force (Lbs.) Initial Installation	Retensioning Maximum	Retensioning Minimum
A	3.0- 3.4	3.3	2.9	2.2
	3.6- 4.2	3.5	3.1	2.4
	4.6- 6.0	3.7	3.3	2.5
B	4.6- 5.4	6.0	5.1	4.0
	5.6- 7.4	6.3	5.5	4.2
	8.6- 9.4	6.6	5.7	4.4
C	7.0- 8.5	13.2	11.5	8.8
	9.0-12.0	13.9	12.1	9.3
	13.0-16.0	14.6	12.6	9.7
D	12.0-15.5	26.5	22.9	17.6
	16.0-18.0	27.8	24.3	18.7
	22.0-27.0	29.1	25.6	19.6
E	17.7-23.6	39.7	34.4	26.5
	23.7-31.5	41.7	36.2	27.8
	31.6-39.3	43.7	37.9	29.1
AX	2.1- 3.4	4.4	3.7	2.9
	3.6- 4.2	4.6	4.0	3.1
	4.6- 6.0	4.9	4.2	3.3
BX	3.7- 5.4	7.7	6.6	5.1
	5.6- 7.4	8.2	7.1	5.5
	8.6- 9.4	8.6	7.5	5.7
CX	5.8- 8.5	17.2	15.0	11.5
	9.0-12.0	18.1	15.7	12.1
	13.0-16.0	19.0	16.5	12.8

V-Belt Cross Section	Small Sheave Diameter Range (Inches)	Recommended Deflection Force (Lbs.) Initial Installation	Retensioning Maximum	Retensioning Minimum
3V	2.65- 3.35	5.5	4.8	3.9
	3.65- 4.12	6.4	5.7	4.4
	4.50- 5.60	7.5	6.6	5.1
	6.00-10.60	8.6	7.5	5.7
5V	7.10- 8.50	19.2	16.7	13.0
	9.00-11.80	23.3	20.3	15.6
	12.50-16.00	27.3	23.8	18.5
8V	12.50-16.00	50.9	44.3	34.4
	17.00-20.00	57.1	49.8	38.6
	21.20-24.80	61.3	53.3	41.4
3VX	2.20- 3.35	5.5	4.8	3.9
	3.65- 4.12	6.4	5.7	4.4
	4.50- 5.60	7.5	6.6	5.0
	6.00-10.60	8.6	7.5	5.7
5VX	4.40- 8.50	19.2	16.7	13.0
	9.00-11.80	23.3	20.3	15.6
	12.50-16.00	27.3	23.8	18.5

DETECTING VALVE LEAKS

Filter plants have solved many problems by tracing and fixing valve leaks. These leaks could add up to a large quantity of extra water to treat every day or that could reduce backwash efficiency. Most valves have end stops that may be adjusted slightly to reduce leaks.

There is a systematic way to diagnose every possible type of valve leak on filters:

Influent valves- close influent valve on a filter. Open dirty backwash valve to drain trough. Look for water seepage from influent valve. Repeat for each filter. To save time, do on groups of filters as flow conditions allow.

Dirty backwash valves- Perform following steps after influent valves check out. Check dirty backwash tank for continuous seepage even when no backwash or intentional drainage has been done recently. If a continuous seep is detected, close influent valve, then see if influent trough level subsides. Repeat for each filter.

Clean backwash water valves- Fill one filter completely full of water, close all valves and make sure it holds constant level. Then open its clean backwash valve. If the filter drains down continuously, a clean backwash valve on another filter is probably leaking. To determine which one, close all the valves on another filter and measure any rise in level from the water leaking in from the high filter. Keep the high filter full using influent or backwash water and the tested filter at a much lower water level to make it easier to see a rise in the low filter. Repeat for each filter. To save time, do on small groups of filters as flow conditions allow. Test the original high filter last by lowering its level and making another filter high instead. Then test as described above.

Effluent valves- Perform after clean backwash valves check out. Fill filter manually to the level of the overflow trough, and then close all valves. If level subsides, the effluent valve is leaking. However, if two or more clean backwash valves are leaking, water from the tested filter could seep out through them.

Backwash air valves- Backwash a filter and check for bubbling in other filters or a rise in filter water level from air binding. Small backwash air leaks may take a while to show up, as all the submerged headers must be purged of water first before leaking air can reach an air lateral and bubble up through the filter media. To speed the detection process, open the backwash air valve on the tested filter for about 5 seconds to push water out of the way and reveal any continuing small leak faster. Closing the influent valve and allowing the water level in the tested filter to reach a minimum will also make a small air leak worse and easier to spot quicker.