Sulfate Discharge Considerations for FGD System Design

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ABSTRACT

Sulfate and TDS are becoming critical issues in surface water quality. A utility in Indiana with sulfate discharge limits was required to install an FGD system. There were concerns that the FGD blowdown could increase the sulfate discharge from the plant beyond the discharge limit. The plant also had water withdrawal limits and water return requirements to maintain the river level. Working with the sulfate mass balance through the plant, and in cooperation with the FGD vendor, a water balance was developed that maximized the use of plant cooling tower blowdown as makeup to the FGD process.

Three water supply options were reviewed, river water, reclaimed cooling water, and well water. Plant water balances were constructed for the existing plant configuration and for future FGD operation. The future FGD operation was modeled at equilibrium chloride concentrations of 8,000 ppm and 20,000 ppm to determine the impacts of FGD operation upon the plant water supply and the plant discharges.

Installing a new FGD system will increase the amount of water withdrawn from the river by approximately 2000 gpm, and will increase the consumptive use by approximately 1600 gpm. The impact upon compliance with the DNR permit was considered in the evaluation of water supply sources.

INTRODUCTION

This report examines the water supply and water balance impacts of installing new wet flue gas desulfurization (FGD) systems at Rollin M. Schahfer Generating Station Units 14 & 15 (RMSGS) in Wheatfield, Indiana. The objectives of the Study were to determine the impacts of the new FGD systems on overall plant water management and wastewater discharges.

Northern Indiana Public Service Company (NIPSCO) is preparing to build Flue Gas Desulfurization systems for Units 14 and 15 at the Rollin M. Schahfer Generating Station (RMSGS) in Wheatfield, Indiana. Sargent & Lundy (S&L) was contracted to perform a Water Supply and Water Balance Study in support of this effort. The objective of the Study was to determine a suitable supply of makeup water for the FGD system that meets the specific needs and restrictions of the RMSGS site.

This report uses information obtained from RMSGS personnel, environmental permits, existing drawings, and reports. These sources are cited and listed at the end of this document.

LIMITING FACTORS - RMSGS withdraws virtually all of the water it uses from the Kankakee River. The amount of water that can be removed from the river is limited to 47,600 gallons per minute (gpm). Water must be returned to the river so that the total consumed (consumptive use) does not exceed 18,600 gpm[1]. The Station has a Final Settling Basin (FSB) that is approximately 230 acres in area. During dry weather conditions, the Station must discharge enough water from the FSB to the river to maintain the river flow above a specific rate.

The Station's NPDES Permit limits the quality of the water that is returned to the river. In particular, sulfate is limited to 748 ppm, and mercury is also limited. The water quality based effluent limit (WQBEL) is 0.000012 ppm. The facility is subject to interim limits, but the goal for this study was to achieve 0.000012 ppm in the plant discharge. FGD wastewater typically contains mercury and is high in sulfate and chloride.

Chloride presents a concern because it is extremely soluble and there are no economical ways to remove chloride from the wastewater stream. Similarly, sulfate can be very expensive to treat. Any wastewater treatment system designed to remove chloride and sulfate was assumed to also remove mercury, so the initial study effort focused on limiting new sulfate discharges and defining the chloride load so that the station's permitting team could determine whether the new chloride load would trigger a chloride limit that would require the use of brine concentrators or other ZLD equipment.

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[1] Exceptions to the 18,600 gpm limit exist. For example during the initial filling of the on site pond systems, or when replacement filling is required.

Cycle makeup is taken from the river. An on-site well water system exists, but was determined to have insufficient capacity or reliability to supply the FGD system.

WATER BALANCE DEVELOPMENT AND USE - To determine the impact of the new operation on the water consumption and wastewater discharge from the Station, it was necessary to develop a working water balance that reflected the existing operation. To do that, several previous water balances were consulted and combined. The most detailed water balance available was from a water balance study conducted in 2005. This study was produced to help the station meet the sulfate limits in the NPDES permit by operating without sulfuric acid addition in the cooling towers. Because it was focused on cooling tower operation, the 2005 study did not provide detail on the existing Unit 17 & 18 FGD operation, the cycle makeup and losses or the reclaim water use within the plant.

To understand the details of water use beyond the cooling tower operation, the original water balance, that was prepared in 1981, was consulted. This water balance addressed the river water users such as cooling and FGD systems and the reclaim water use, but did not address cycle makeup because the cycle makeup at that time was from the water well system. Cycle makeup information was obtained from Station personnel.

The third source of information regarding the Station water use was the water balance provided for the 2010 Steam Electric Power Effluent Guideline Information Collection Request (ICR). This water balance was an update of the water balance provided for the most recent NPDES permit renewal application.

A composite water balance was created from these sources and used to model existing operations at the Station. This balance was modified to incorporate the proposed FGD system and various operational modes were modeled to determine the FGD system impacts on water usage and water discharge. Actual monitoring data was used where available, and flow-weighted averages were used to project the impact of changing cycles of concentration in the cooling towers, and to estimate the concentrations of key parameters in the potential source waters for the FGD system.

The source water characteristics were used as makeup water inputs to the FGD system mass balance model. From this, the FGD makeup and blowdown rates were calculated for operation at 8,000 ppm chloride and 20,000 ppm chloride equilibrium concentrations using 25 different coals. The highest chloride coal was used as the design basis for the FGD blowdown rates. The output from the FGD system model was then input to the water balance to determine the impacts of various operating modes on water withdrawal, consumptive use and water discharge.

WATER SUPPLY ALTERNATIVES - Depending on the equilibrium chloride concentration selected, the FGD system required between 1750 gpm and 2000 gpm of makeup water. The three potential sources of water for the FGD system were:

- River Water
- Well Water
- Reclaimed Water

Of these, river water was the highest quality source, low in chloride and hardness, and presented few challenges with regard to scaling. Using river water would increase the amount of water withdrawn from the river, but the total intake would remain within the total allowed by the permit. River water would be obtained from the intake settling basin (ISB). After initial screening, this option was retained and considered further.

Well water quality was also good, but the well water system was unreliable and required significant rehabilitation. The original design of the well water system was 1500 gpm, but it was not able to provide that much water on a sustained basis. In addition, previous studies had indicated that there was very limited potential to install new wells on the existing property. Therefore, well water was not pursued as a primary source of water to the new FGD system due to inadequate volume and unreliable operation. The well water system could provide some benefits to overall Station operation during drought conditions and was retained as a backup system, but was not studied as a primary water supply.

The Station reclaimed water for several uses. Boiler blowdown and other wastewater was recycled through the bottom ash system and used to sluice ash to the Primary Settling Pond (PSP). Overflow from the PSP passes to the Recycle Basin, where it is reused in the ash system, helping to reduce the amount of water removed from the river for Station uses. The potential sources of reclaimed water that were investigated for the Unit 14 & 15 FGD system were the Material Storage Runoff Basin (MSRB)/Metal Cleaning Waste Basin (MCWB) system, the Recycle Basin, the Final Settling Basin (FSB), and cooling tower blowdown (CTB). Figure 1 is a simplified water balance showing the flow through the pond system at the station.

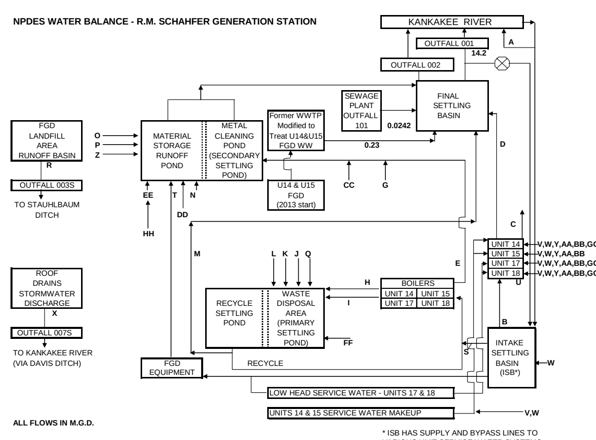

Figure 1- Water Balance Diagram

The MSRB/MCWB system discharge was highly variable in chloride concentration, and provided only about 600 gpm of flow, so was not considered further. There was no water quality data available for the Recycle Basin, but the discharge from that system was only about 400 gpm, so it was not considered further. All wastewater from the Station was sent to the FSB. Therefore, the FSB would have adequate supply for FGD makeup. However, use of final effluent as makeup to the FGD system would cause chloride concentrations in the FGD feed and in the FSB to increase over time.

Due to the sulfate discharge limits, the Station was operating cooling towers at only 2 cycles of concentration, to avoid the need to add sulfuric acid to the towers. This eliminated the primary source of added sulfate, but operating at low cycles of concentration required the plant to withdraw more water from the river. Prior to 2005, the operating mode was 3.5 – 4 cycles of concentration, with the addition of sulfuric acid to prevent scaling. At low cycles of concentration, the CTB quality was suitable for FGD makeup. In fact, even at 3.5 – 4 cycles of concentration, the CTB quality was relatively low in chloride, and suitable for many aspects of FGD makeup. It was known that dry FGD systems have been constructed and operated as ZLD systems using wastewater that included CTB as makeup water. Therefore, CTB was further investigated as a source of makeup to the FGD system.

For cooling tower operation, the CTB volume is reduced at increasing cycles of concentration. Operating the Unit 14 cooling tower at 3.45 cycles of concentration (COC) rather than 2 COC would bring the CTB flow from 4900 gpm down to 2000 gpm, a rate equivalent to the makeup water requirement for both units of the FGD system operating at 8000 ppm equilibrium chlorides.

Operating the FGD system at 20,000 ppm equilibrium chlorides, would require even less makeup water; the equivalent of approximately 3.8 COC. Figure 2 is a simplified water balance that illustrates this mode of operation as if all CTB is sent to the FGD.

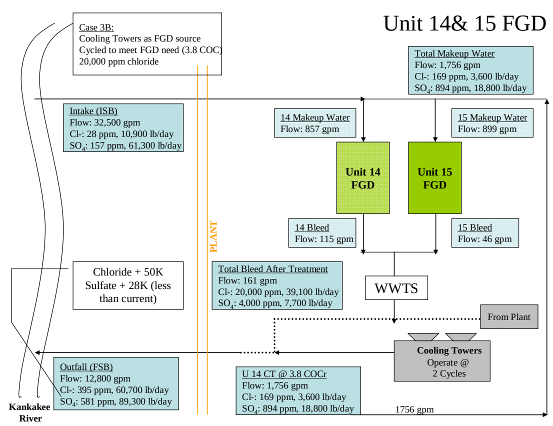

Figure 2. RMSGS Simplified Water Balance using all CTB

MODELED CASES - Two FGD equilibrium chloride alternatives were modeled: 8,000 ppm chloride and 20,000 ppm chloride. Each of these alternatives was modeled with 3 sources of makeup water: the ISB, CTB from cooling towers operated at no change to existing operation (2 COC) and from a single cooling tower operating at elevated cycles of concentration to supply the FGD (3.4 – 3.8 COC). A total of 6 cases were modeled as shown in Table 1.

At higher cycles of concentration, the cooling tower makeup is lessened, which further reduces the amount of water taken from the river, and the overall plant discharge is also lessened. As a result, at high cycles of concentration, the overall water use and sulfate discharge is lower, even though the net evaporation rate has been increased by the addition of the FGD system.

Table 1 summarizes the results of all water balance modeling. As shown in Table 1, the lowest sulfate discharge is achieved using CTB at high cycles of concentration and high chloride equilibrium in the FGD system. The total discharge of sulfate under this operating scenario is actually lower than the existing conditions. For other parameters of limited solubility, a similar condition will exist to a lesser extent. Thus mercury, for example, will be discharged from the FGD wastewater treatment system at its solubility limit, such that reducing the volume of the FGD discharge will also reduce the mass of mercury discharged by the FGD system.

ANALYSIS - The impacts of using ISB water or CTB were modeled using the water balance. The Unit 14 & 15 FGD system will evaporate approximately 1600 gpm of water when operating so the discharge from the plant will be lower, and the resulting effluent concentrations for all parameters will increase slightly. Sulfate loading was modeled using a conservative upper limit concentration of 4000 ppm in untreated FGD blowdown based on industry experience. The sulfate concentration in the effluent never exceeded the NPDES permit limits. In general, at high equilibrium chloride concentrations using CTB, the net discharge (mass) of sulfate to the river remained the same as existing levels or was reduced. At low equilibrium chloride concentrations, using river water as makeup the sulfate loading was increased, but the concentration remained within existing limits.

Consumptive Use - The FGD system will evaporate approximately 1600 gpm of water. This consumptive use may raise the overall maximum consumptive use for the station from 18,100 gpm to 19,700 gpm; approximately 1100 gpm more than the 18,600 gpm allowed by the DNR permit. It is expected that this will occur only during periods of maximum use, such as peak operation on hot summer days, where cooling tower evaporation is maximized and the station is operating at peak load. During these times, it may be necessary to use the well water system to supplement the water supply, either by supplying cycle makeup with well water (approximately 600 gpm), or by transferring 1100 gpm of well water into the river to supplement the water supply.

Chloride - The FGD system will capture chloride from the flue gas and it will concentrate in the wastewater. Chloride is completely soluble over the range of concentrations that are possible for this process. Therefore, the total amount of chloride added to the effluent is relatively constant, and the effluent concentration will be controlled by the total volume of water discharged from the Station.

Chloride concentrations were higher than existing levels for all cases modeled, but were not expected to cause the receiving stream to exceed water quality standards with the use of a mixing zone.

Mercury - FGD wastewater will require treatment for metals including mercury. Because mercury has limited solubility (in an organosulfide based treatment process), lowering the volume of wastewater discharged helps to lower the amount of mercury that is discharged. At high equilibrium chloride concentrations, the wastewater discharge is minimized, and is expected to be approximately 161 gpm.

Wastewater treatment vendors were contacted to provide estimates of the expected effluent guarantees for physical-chemical treatment. These values were used to model the impact of the discharge upon the effluent from the facility. For mercury, the effluent guarantee was 0.001 ppm.

Data from existing FGD wastewater treatment systems was also reviewed. The results of this review showed that the reported discharge concentrations of mercury from physical-chemical treatment systems ranged from 0.0000765 ppm to 0.000788 ppm and averaged 0.000284 ppm. One of the surveyed systems used only a settling basin for treatment. The effluent from the FGD settling basin showed a discharge concentration of 0.000043 ppm. Based on these sources, the change in mercury concentrations that would be observed at the effluent from the plant was estimated by assuming zero mercury in the existing discharge, and an average treated mercury concentration of 0.0005 ppm, a value representing half of the effluent guarantee but nearly double the average reported value of 0.000284 ppm.

As shown in Table 1, when operating at 20,000 ppm equilibrium chloride, the resulting increase in mercury discharged amounted to approximately 0.000006 ppm or half of the allowable discharge. Based on the available data, physical-chemical treatment is expected to be sufficient to meet the effluent mercury limitations if FGD blowdown is minimized. The calculated discharge concentration does not provide any margin, so additional mercury treatment may be required.

CONCLUSIONS -The most favorable case (Case 3B), operating the Unit 14 cooling tower at approximately 3.8 cycles of concentration and the FGD system at an equilibrium chloride concentration of 20,000 ppm results in a reduction in the amount of sulfate discharged to the Kankakee River compared to existing operating conditions.

These factors combined to support a design basis of operating the FGD system at 20,000 ppm equilibrium chloride concentration, using CTB at 2 - 4 cycles of concentration to provide the majority of the Unit 14 and 15 FGD makeup water.

Trace metal discharges are lowest when the FGD blowdown is minimized, and treatment to remove mercury is required due to the extremely low discharge limit of 0.000012 ppm.

The outfall sulfate concentration will increase from 503 ppm to 581 ppm. However, because CTB is utilized for FGD makeup, the mass discharge is actually reduced from 106,000 lb/day to 89,300 lb/day.

The outfall chloride concentration will increase from 118 ppm to 395 ppm. A mixing zone is allowed for chloride discharges.

The design FGD wastewater treatment process is physical-chemical precipitation, using an organosulfide compound to maximize mercury removal.

The design configuration is as follows:

- The FGD water supply is predominantly CTB. The FGD system would require all of the available CTB from a single cooling tower unit, but will accept CTB from two units which are expected to operate at 2.0 – 3.0 cycles of concentration.
- For FGD water uses that are sensitive to scaling, such as mist eliminator wash water, river water is recommended, in as small a volume as practical.
- The design equilibrium chloride concentration for the FGD system is 20,000 ppm. At this concentration both water usage and wastewater generation are minimized. Minimizing the amount of wastewater generated also minimizes the amount of sulfate and other regulated parameters that may be discharged.

The FGD process vendors were provided with water quality data for service water (ISB water), and CTB. As part of the proposal, the FGD process vendors were required to define the water quality needs within the FGD process and designate where CTB could be used while still providing their guaranteed performance. Working with the successful bidder, the water supply for the system was designed to use up to 80% CTB as makeup to the FGD system.

References:

1) State of Indiana Department of Natural Resources Permit NR-5, Revision 2, 1988

2) NPDES permit IN 0053201, Effective May 1, 2010

3) Existing Kankakee Aquifer Well Study, Rollin M. Schahfer Generating Station, Northern Indiana Public Service Company, Sargent & Lundy, June 1992.

4) Final Report - Study for Impact of Acid Elimination on RMS Station Overall Water Balance, Burns & McDonnell, 2005

5) Water Usage and Wastewater Treatment System, Rollin M. Schahfer Generating Station, Units 14, 15, 17 and 18, April 17, 1981.

6) 10,000 gpm Make-up Water Feasibility Study, Canonie Environmental, 1988

7) Graver Ecodyne Wastewater Treatment System O&M Manual, Graver Job no. 11857, ca. 1982

8) Steam Electric Power Generating Point Source Category: Final Detailed Study Report, EPA 821-R-09-008 USEPA, October 2009.

Table 1. Modeled Cases	Baseline	Scenario A FGD Chloride Equilibrium = 8,000 mg/L			Scenario B FGD Chloride Equilibrium = 20,000 mg/L		
Case		1A	2A	3A	1B	2B	3B
Source Water		ISB/River	CT Normal (2 COC)	CT Max (3.45 COC)	ISB	CT Normal (2 COC)	CT Max (3.8 COC)
Kankakee River to LHSW Pump House	35,600	37,700	35,700	32,800	37,400	35,700	32,500
FSP Blowdown to Kankakee River (gpm)	17,500	17,900	15,900	13,000	17,700	15,900	12,800
Consumptive Use (gpm)	18,100	19,700	19,700	19,700	19,700	19,700	19,700
Unit 14 & 15 FGD Makeup (gpm)	-	2,000	2,000	2,000	1,800	1,800	1,800
Unit 14 & 15 FGD Equipment Effluent (gpm)	-	379	393	406	161	161	161
Outfall Cl Concentration (ppm)	118	285	343	409	310	335	395
Outfall SO4 Concentration (ppm)	503	577	635	677	550	559	581
Cl (lbs/day)	24,800	61,400	65,700	64,100	66,000	64,100	60,700
Cl Net Change	-	36,600	40,900	39,400	41,200	39,300	35,900
SO4 (lbs/day)	106,000	124,300	121,600	106,000	117,000	107,100	89,300
SO4 Net Change	-	18,200	15,600	0	11,000	1,100	(16,700)
Added Mercury (ppm) Limit = 0.000012 ppm	Baseline	0.000011	0.000012	0.000016	0.000005	0.000005	0.000006

Table 1 – Modeled cases