STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Stainless Steel Corrosion: Feed Properties Affecting Material Selection for LAWPS Piping at Hanford Site

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

The purpose of this report is to convey the concentration levels of the chemical components of interest present within the waste feed which will be sent to the Hanford Site Low-Activity Waste Pretreatment System (LAWPS) and facilitate material selection for LAWPS components. Additionally, research was conducted on the effects of chemical constituents found in low activity waste (LAW) on the stainless steel transfer lines transporting them. The objectives of this report are:

- To conduct research on the corrosion causing chemical constituents, their role in the degradation/dissolution of the passive layer, and their ability to corrode stainless steel.
- To evaluate the concentration levels of corrosion causing chemical constituents.
- To facilitate material selection for LAWPS components.

The recommended concentration range for chloride, fluoride, nitrite, nitrate, hydroxide, and sulfate are summarized in Table 1. Of the chemical constituents, the halides (chloride and fluoride) are the leading cause of the corrosion mechanisms evaluated. Chloride and fluoride are able to permeate the passive layer and attack stainless steel. Additional research is recommended, particularly focusing on the cumulative effects of all chemical constituents of interest (chloride, fluoride, nitrate, nitrite, hydroxide, and sulfate) on stainless steel. Specifically, observations of the cumulative reaction of the chemicals with the alloy, and more importantly, with the passive layer should be noted.

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TERMS AND ABBREVIATIONS

DFLAW	Direct Feed Low Activity Waste
DOE	United States Department of Energy
DST	Double Shell Tank
HFFACO	Hanford Federal Facility Agreement and Consent Order
HLW	High-Level Waste
HTWOS	Hanford Tank Waste Operating Simulator
LAW	Low Activity Waste
LAWPS	Low Activity Waste Pretreatment System
MMR	Model Modification Request
MT	Metric Tons
ORP	Office of River Protection
ROS	Reference Operating Scenario
RPP	River Protection Project
SS	Stainless Steel
SST	Single Shell Tank
TPA	Tri-Party Agreement
WRPS	Washington River Protection Solutions, LLC.
WTP	Waste Treatment and Immobilization Plant

1. INTRODUCTION

The purpose of this report is to convey the concentration levels of the chemical constituents of interest present within the waste feed which will be sent to the Hanford Site Low-Activity Waste Pretreatment System (LAWPS) and facilitate material selection for LAWPS components. To facilitate LAWPS component material selection, the chemical concentration ranges of specific corrosion causing chemical constituents are evaluated. Of particular interest are the concentration ranges of chloride, fluoride, nitrate, nitrite, hydroxide, and sulfate which are projected be present in the LAWPS waste feed.

The objectives of this report are:

- To conduct research on the corrosion causing chemical constituents, their role in the degradation/dissolution of the passive layer, and their ability to corrode stainless steel.
- To evaluate the concentration levels of corrosion causing chemical constituents.
- To facilitate material selection for LAWPS components.

The U.S. Department of Energy (DOE) Office of River Protection's (ORP) primary mission is to retrieve and treat Hanford's tank waste and close the tank farms to protect the Columbia River. Mixed radioactive waste is stored in 177 underground tanks at the Hanford Site as reported in DOE/ORP-2003-02, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of the Single Shell Tanks at the Hanford Site, Richland WA*, Inventory and Source Term Data Package. As of July 2015, those 177 underground tanks were estimated to contain about 56 million gallons of waste.

The DOE ORP is responsible for management and completion of the River Protection Project (RPP) mission, which comprises both the Hanford Site tank farms and the Waste Treatment and Immobilization Plant (WTP). Hanford Federal Facility Agreement and Consent Order [HFFACO or Tri-Party Agreement (TPA)] requires DOE to complete the RPP tank waste treatment mission by September 30, 2047. A key aspect of implementing that mission is to construct and operate the WTP (ORP-11242, *River Protection Project System Plan*). The WTP is a multi-facility plant that will separate and immobilize the tank high-level waste (HLW) and LAW fractions for final dispositions. The WTP LAW Vitrification Facility is sized to treat about 40% of the approximately 55,000 metric tons (MT) of sodium that makes up the LAW stream requiring treatment by 2047.

The LAWPS Project provides for the early production of immobilized low-activity waste (LAW) by feeding LAW directly from Tank Farms to the WTP LAW Facility, bypassing the Pretreatment Facility. Prior to the transfer of feed to the WTP LAW Vitrification Facility, double-shell tank (DST) supernatant waste will be pretreated in the LAWPS to meet the WTP LAW waste acceptance criteria. The LAWPS will also facilitate the return of secondary liquid wastes from the WTP LAW Vitrification Facility to the DST Farms.

Concentration ranges for chloride, fluoride, nitrate, nitrite, hydroxide, and sulfate were calculated using Hanford Tank Waste Operations Simulator (HTWOS) data. The nominal values specified in RPP-SPEC-56967, *Project T5L01 Low Activity Waste Pretreatment System Specification*, were considered to verify that the specified nominal values fell within the calculated concentration ranges.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2015, a DOE Fellow intern John J. Conley spent 10 weeks doing a summer internship at Washington River Protection Solutions at the Hanford Site under the supervision and guidance of Mario A. Servin and Terry L. Sams. The intern's project was initiated on June 15, 2015, and continued through August 6, 2014 with the objective of conveying the concentration levels of the chemical components of interest present within the waste feed which will be sent to the Low-Activity Waste Pretreatment System (LAWPS) to facilitate material selection for LAWPS components.

3. RESEARCH DESCRIPTION

3.1 Corrosion

Corrosion occurs when metals (or their alloys) enter a chemical union with elements from a corrosive medium in order to form stable compounds. In other words, corrosion is the deterioration of an alloy due to a reaction with its environment. Corrosion of metals ensues because of a chemical or electrochemical attack. A chemical attack occurs when a highly corrosive medium passes over the surface of an alloy. An electrochemical attack occurs in hostile aqueous systems, in which the reaction between different elements leads to corrosion, as well as the flow of electricity from an anodic area to the cathodic area (due to local cells that are on the surface of the alloy, or multiple, dissimilar alloys in contact). One considerable factor that affects corrosion rates in metals is the pH of the medium passing over the surface. Acid-soluble metal corrosion rates are controlled by the rate at which the oxidizer reaches the metal surface. Once at elevated temperatures, the corrosion rate increases with the increasing basicity of the medium (Perry's Chemical Engineers' Handbook).

There are several corrosion mechanisms that can affect a metal. The following corrosion mechanisms were chosen based on the flow conditions of LAW to LAWPS. The flow to LAWPS is expected to be turbulent; therefore, the following five mechanisms are the most likely corrosion types to occur. Alternate corrosion mechanisms (general corrosion, impingement corrosion, stress-corrosion cracking, microbiologically influenced corrosion, etc.) were assumed to be neglible as a result of LAW turbulent flow.

3.1.1 Pitting Corrosion

Pitting corrosion develops in localized areas on the surface of an alloy, is extremely aggressive, and can penetrate an alloy rapidly. Pitting corrosion leaves cavities throughout the surface of the alloy, and while most of the surface area of the alloy can prove unaffected by the pitting, the sites which do have pitting and depressions are usually severely corroded (however miniscule the site may be). This corrosion mechanism is of importance because under turbulent flow, the stainless steel passive layer formed is susceptible to degradation from the incessant abrasion of solid particulates.

Figure 1. Pitting corrosion in stainless steel pipeline.

3.1.2 Crevice Corrosion

Crevice corrosion is characterized as a stagnant medium entrapped within a crevice which is not subjected to an oxygen rich environment, leading to an acidification of the stagnant medium within the crack, and ultimately a corroded alloy. The stagnant medium which becomes acidified creates such a hostile environment within the crevice that it also degrades the passive film of the area surrounding the crevice. This corrosion mechanism was highlighted because corrosion is accelerated where the oxygen concentration dwindles. Once the passive oxide layer has been eroded and this oxygen deficient crevice is filled with highly corrosive medium, this environment will lead to the gradual, but persistent degradation of the surrounding passive oxide layer as well as the inward corrosion of the alloy.

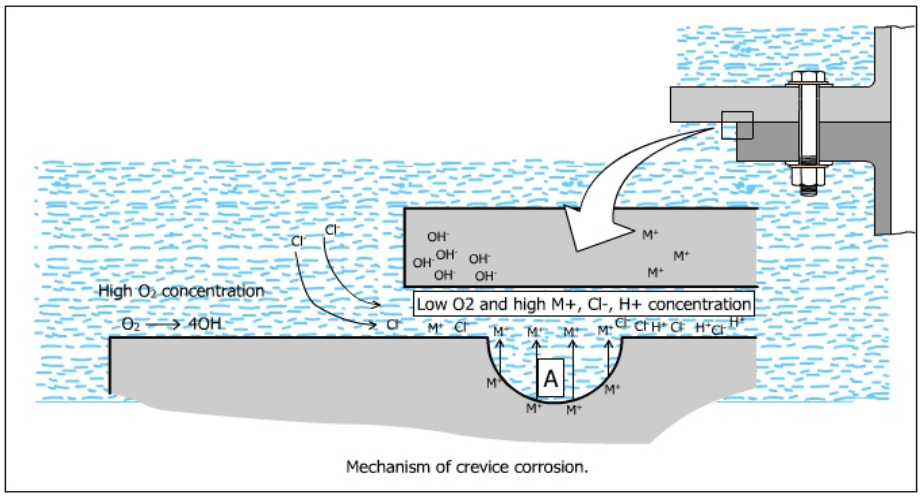

Figure 2. Crevice corrotion in metals.

3.1.3 Erosion Corrosion

Erosion contributes to the degradation of an alloy by means of abrasion, which is due in part to the flow rate of the medium passing over the alloy, as well as the solid content within the medium. Under turbulent flow, the medium degrades and dissolutes the passive oxide layer upon the stainless steel, which in turn allows the corrosive medium to corrode the alloy. Erosion is a sizeable factor to consider when discussing corrosion in stainless steel because of its ability to remove the passive layer that protects the corrosive medium from corroding the alloy.

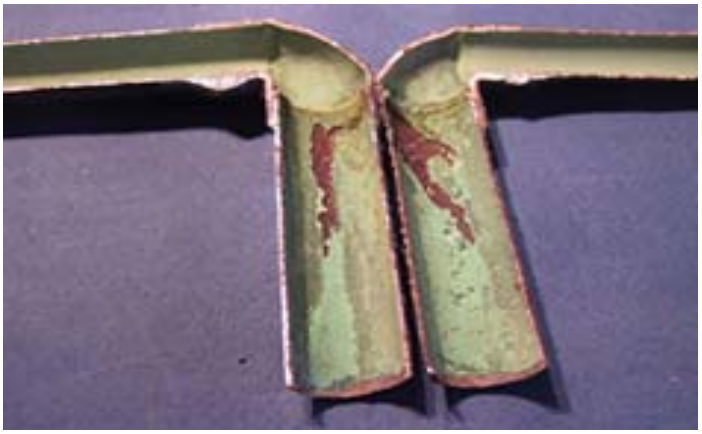

Figure 3. Errosion corrosion within metals.

3.1.4 Intergranular Corrosion

Intergranular corrosion attacks locally along the grain boundaries of the alloy because of a depletion of one of the alloying elements, or impurities along the boundaries. Intergranular corrosion takes place in stainless steel due to chromium depletion in the boundaries. Intergranular corrosion is a concern with stainless steel as well as other alloys due to the process taken when manufacturing the alloy. When stainless steel is subjected to thermal cycles (a process to increase the strength of the alloy), intergranular precipitation of chromium carbides occur, depleting the element from the grains themselves. This allows chloride and fluoride access to the boundary impurities, allowing them to bond with those impurities, creating fractures and ultimately corrosion.

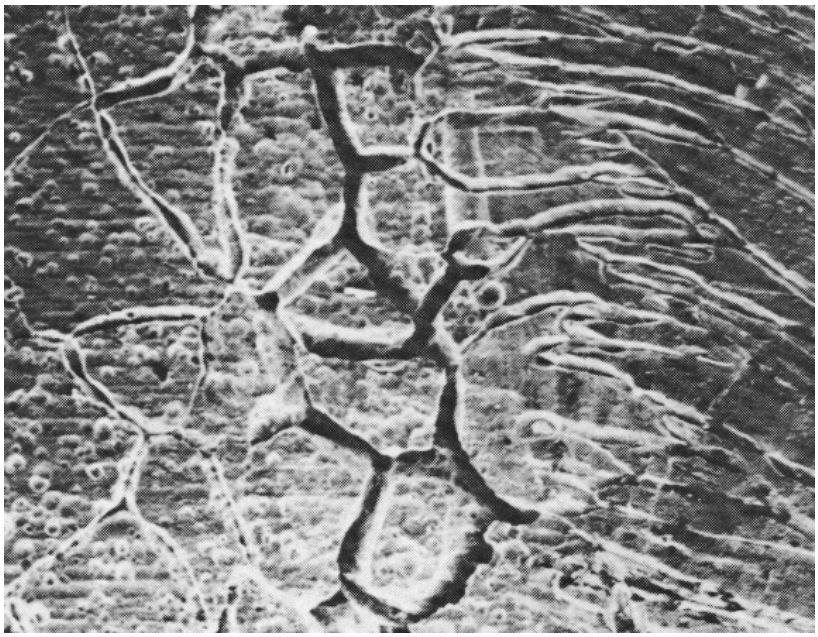

Figure 4. Intergranular corrosion in metals.

3.1.5 Cavitation Corrosion

Cavitation is a form of erosion that takes place at the surface of the alloy which has a turbulent medium flowing past. Cavitation occurs due to high flow rates and rapid pressure changes, and essentially is the collapse of vacuum bubbles on the surface of the alloy. Cavitation leads to serious damage on the surface of the alloy because of the explosive force of the collapsing of said vacuum bubbles. The high force applied at the surface of the alloy aids in the removal of the oxide passive layer, which leaves an active surface for corrosion to occur. LAWPS may experience cavitation corrosion as it occurs in areas of high flow (turbulent flow) in a hostile medium.

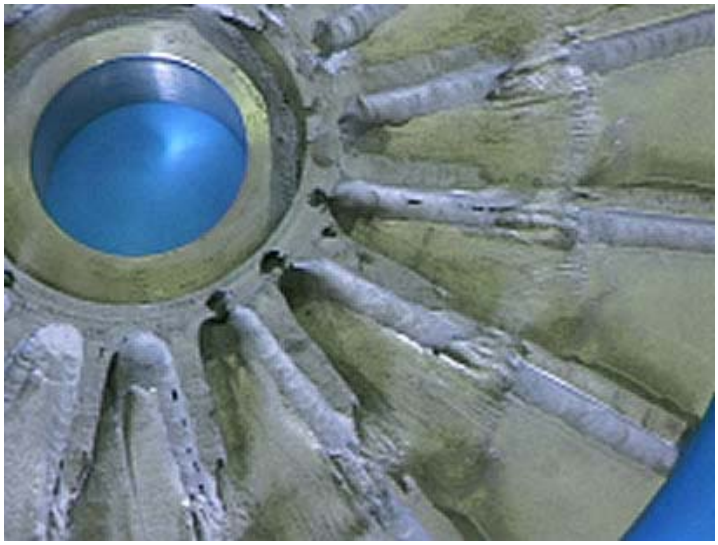

Figure 5. Cavitation corrosion in metal propeller.

3.2 Types of Stainless Steel Considered for LAWPS Components

The main alloy being focused on in this report is SS 304 because the alloys of interest for LAWPS component material selection are all 300 series, austenitic stainless steels (SS). SS schedules 304, 304L, 316, and 316L have chemical compositions that coincide with one another. Therefore, the corrosion assessed in SS 304 should produce findings that coincide with corrosion in the other austenitic alloys. When considering austenitic stainless steels in particular, the passive layer that forms on the surface of these alloys is chromium oxide (assuming the active alloy was subjected to an oxide rich environment after being stripped of any free iron during pickling). Two types of stainless steel are being considered for LAWPS components.

A critical parameter reviewed to select the type of stainless steel is each alloys passivation. Passivation is the process of creating a passive layer upon the surface of a material in regards to its surrounding environment. In relation to corrosion, passivity of an alloy is extremely beneficial as it forms a non-reactive surface film in which corrosion is inhibited. The most frequent layer formed on stainless steel (when subjected to an oxide-rich environment) is chromium oxide. When an alloy is manufactured, it is subject to pickling and then passivation to provide that passive layer upon the alloy. Pickling refers to the submersion of the alloy in an acid solution that removes surface contamination (i.e. dirt and debris, free iron from fabrication) and any other impurities upon the surface of the alloy. Nitric acid is a common acid solution utilized because it is an oxidizer. Thus, once the alloy has been treated, the chromium oxide passive layer forms.

3.2.1 Stainless Steel 304

Stainless steel (SS) 304 is an austenitic stainless steel (structurally it forms face-centered cubically), which has austenite as its primary phase. Austenite is also known as gamma-phase iron, and it is a non-magnetic allotrope of iron. SS 304 consists of carbon, manganese, phosphorus, sulfur, silicon, chromium, nickel, nitrogen, and iron. SS 300 series are amongst the most common types of stainless steel because they are non-magnetic, and prove advantageous when welding is necessary. When welding is required, SS 304 is beneficial because its low carbon content (.08% max) minimizes carbide precipitation which in turn leads to intergranular

corrosion. SS 300 series is noted for its corrosion resistance because of their chromium content. SS 304 utilizes that chromium to form the passive layer (chromium oxide Cr_2O_3) which has a high corrosion resistance to most chemical constituents. Although SS 304 is not as corrosion resistant as SS 316, SS 304 provides adequate corrosion resistance to the chemical constituents in LAW as long as the temperature of the LAW being transferred remains under 45℃.

3.2.2 Stainless Steel 316

Stainless steel (SS) 316 is an austenitic stainless steel (structurally it forms face-centered cubically), which has austenite as its primary phase. SS 316 consists of carbon, manganese, phosphorus, sulfur, silicon, chromium, nickel, molybdenum, nitrogen, and iron. By adding slightly more nickel and molybdenum (~2% by weight) to SS 304, you create SS 316, which has the greatest corrosion resistance among standard stainless alloys. SS 316 is particularly advantageous in solutions containing significantly high concentrations of halides (with respect to the concentration ranges of halides being transferred). The passive layer of SS 316 compares to that of SS 304 in that it consists of chromium and oxygen (chromium oxide Cr_2O_3), but it differs because of the added molybdenum in the alloy, which in turn plays an integral role in forming the passive layer. The addition of molybdenum is the key factor in the added corrosion resistance to halides.

4. ANALYSIS, INPUT DATA & ASSUMPTIONS

4.1 Method of Analysis

For this assessment, data from HTWOS model run MMR-50043, *Preliminary Reference Operating Scenario FY15 Modeling – Integrated V&V – HTWOS v8.1,* was used. With the monthly LAWPS waste feed available, the data were accumulated for each time period to match the transfers, summarizing volumes, moles of each liquid and solid phases for selected chemical constituents of the waste feed batch/transfer from 241-AP-107 to LAWPS. The concentration of each chemical component was then computed by dividing the kg-moles of each chemical constituent (per transfer) by the total volume of each waste feed. Appendix A provides an example for computing the concentration of a single chemical component for a single transfer. Appendix B tabulates the concentration of each chemical component of interest for each transfer from AP-107 to LAWPS.

Bar graphs were created to graphically depict the data compiled. The graphs compare the concentration per g-mole/liter for each feed transfer in order from least to greatest. The plots also include the nominal value for each chemical component specified in RPP-SPEC-56967. These nominal values were included to verify that the specification nominal values fell within the calculated concentration ranges. The plot for each chemical component of interest is presented in the Results section.

The Hanford Tank Waste Operations Simulator (HTWOS) is a flow sheet modeling tool developed by the Washington River Protection Solutions, LLC (WRPS) System Planning and Modeling group. The HTWOS modeling tool is a dynamic event-simulation tool, governed by prescribed initial conditions, constraints, and operating logic used to simulate the full duration of the U.S. Department of Energy (DOE), Office of River Protection (ORP) mission. The HTWOS modeling tool accounts for the major systems required to accomplish the River Protection Project (RPP) mission to store, process, and immobilize the Hanford tank wastes for disposal.

4.2 Input Data & Assumptions

All of the data applied in creating the LAWPS waste feed parameter for concentration profiles were obtained through the HTWOS model run MMR-50043. HTWOS model run MMR-50043 is the final Reference Operating Scenario (ROS) for fiscal year 2015. The HTWOS model run supplied the monthly LAWPS waste feed and transfer data.

The data summary compiled spanned a period of ten years within the MMR, specifically October of 2021 to December of 2031. The time period was constricted as this time span and associated data encompassed the Direct Feed Low-Activity Waste (DFLAW) program waste feed compositions.

Corrosion in alloys have many contributing factors (i.e. temperature, flow rate of medium, environment, etc.), so some assumptions had to be made when performing this research. The temperature of the LAW passing through the transfer lines is not to exceed 45℃, which is consistent with the RPP-SPEC-56967. Flow conditions for LAW to LAWPS is assumed to be turbulent, which coincides with LAWPS feed rate and expected flow conditions (see Appendix C).

In order to select materials for LAWPS components, select chemical constituents in each transfer from DST 241-AP-107 to LAWPS were analyzed. The select chemicals that could influence corrosion parameters in the waste feed include:

- $\boldsymbol{Cl^-}$ (Chloride)
- $\boldsymbol{F^-}$ (Fluoride)
- $\boldsymbol{NO_2^-}$ (Nitrite)
- $\boldsymbol{NO_3^-}$ (Nitrate)
- $\boldsymbol{OH^-}$(Hydroxide)
- $\boldsymbol{SO_4^{2-}}$(Sulfate)

Data sorting and summary were performed and assembled in Appendix A. Assuming additional flush water will be added to the system during and after transfers, the solids would dissolve. Thus, the moles of solid were added to the moles of liquid for each constituent. Simple unit conversions were applied (gallons to liters and kg-moles to g-moles).

5. RESULTS AND DISCUSSION

The concentration levels of each chemical constituent were tabulated and depicted according the transfer. The results for each chemical component of interest are discussed below.

Chloride: The chloride concentration per waste feed transfer to LAWPS is shown in Figure 6. The calculated concentration of chloride in each feed remained relatively close numerically, staying between 0.0527 and 0.0870 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 0.0946 g-mol/liter, is higher than the maximum calculated concentration for chloride.

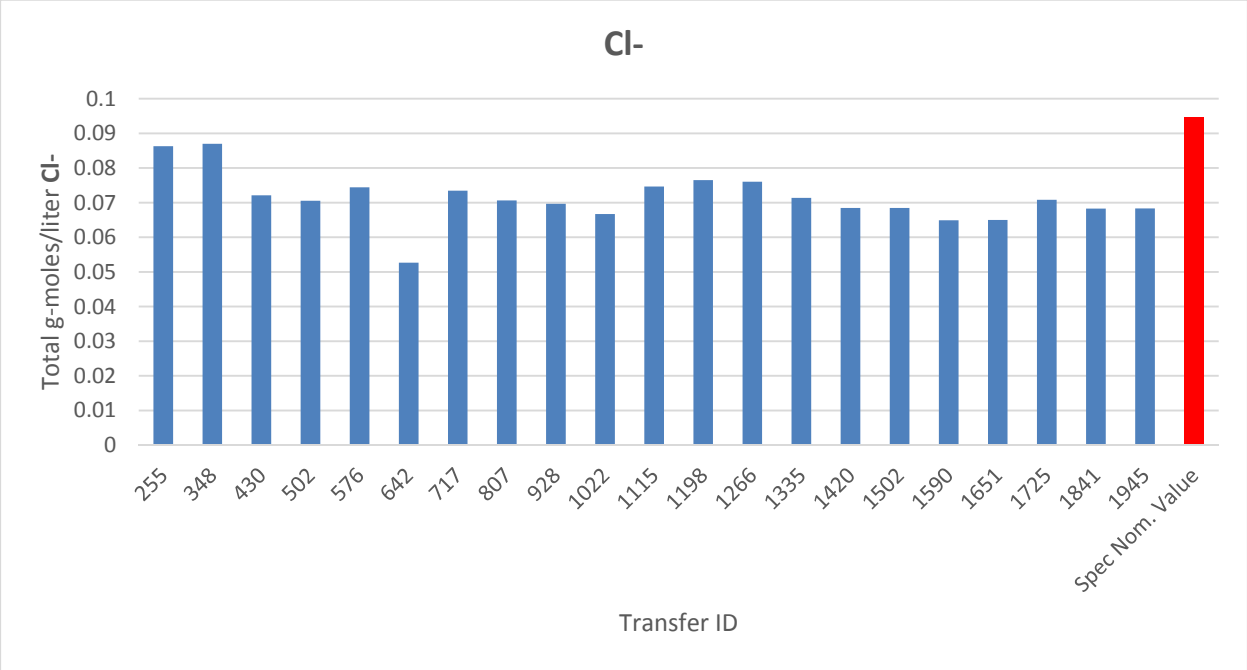

Figure 6. Chloride concentration per batch.

Chloride is a chemical constituent of great importance to consider when selecting component materials for LAWPS. Chloride is the most common cause of pitting corrosion in SS because of its ability to penetrate passivated stainless steel. When SS is subjected to a chloride rich environment and the passive layer is degraded, the active alloy underneath will readily react with chloride ions to corrode the alloy. Once the active alloy is subject to chloride, the chloride will react with chromium to form chromium chloride ($CrCl_3$), leaving the active iron subjected to the chloride rich environment. This leads to iron reacting with the chloride ions, forming ferric chloride ($FeCl_3$) which is highly corrosive to stainless steel. Chloride is the most aggressive, corroding chemical constituent to consider during material selection because of its affinity for metal ions. Thus chloride ions induce many corrosion mechanisms, most notably pitting corrosion. Chloride is detrimental to stainless steel, but when the chloride is found in a corrosive medium which has a low pH and elevated temperatures, its corrosive propensity magnify, which leads to a higher probability of corrosion to occur.

Fluoride: The fluoride concentration per waste feed transfer to LAWPS is shown in Figure 7. The fluoride calculated concentration remained between 0.00424 and 0.0546 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 0.0651 g-mol/liter, is higher than the maximum calculated concentration for fluoride.

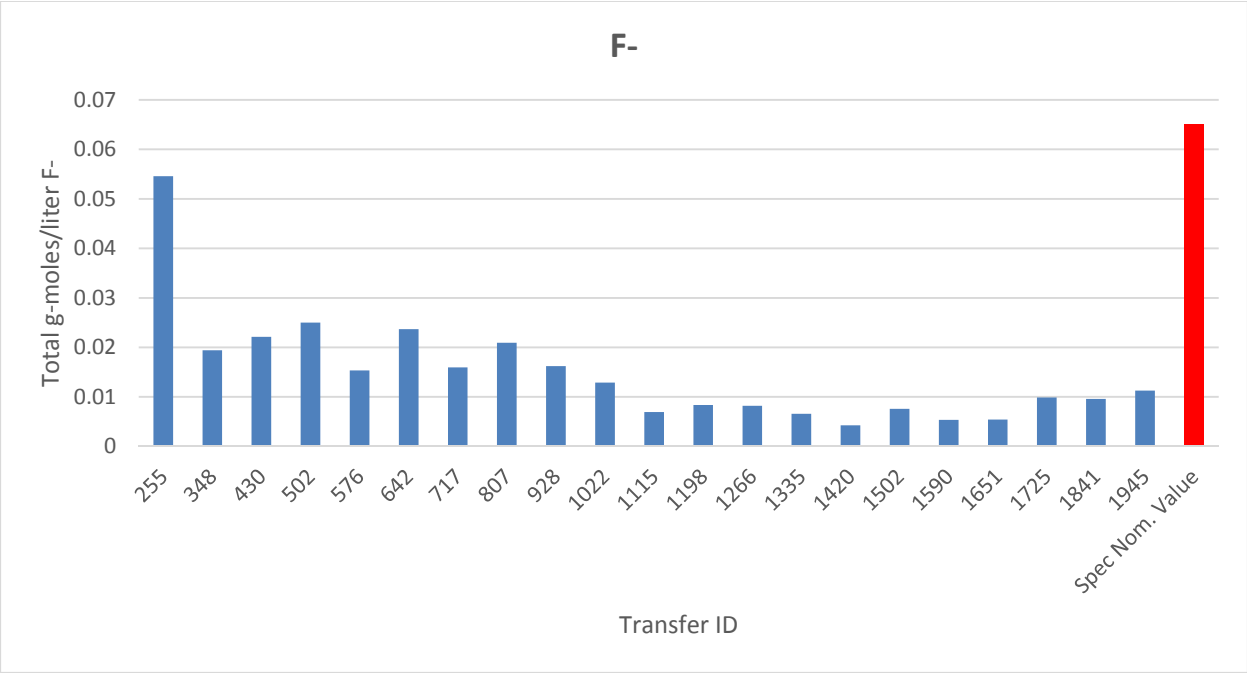

Figure 7. Fluoride concentration per feed batch.

Fluoride is a halide, as is chlorine, with comparable corrosive properties. Fluoride is extremely corrosive like chloride because of its ability to penetrate passivated stainless steel. Under turbulent flow, particulates within the corrosive medium will serve to erode the passive oxide layer of stainless steel, facilitating fluoride's ability to react with chromium. This reaction ultimately exposes the active iron to react with fluoride. Flow conditions make this chemical constituent troublesome because it has the ability to be a driving factor in many of the corrosion mechanisms.

Nitrite: The nitrite concentration per waste feed transfer to LAWPS is shown in Figure 8. The nitrite calculated concentration remains within the bounds of 0.858 and 2.214 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 1.02 g-mol/liter, falls within the lower half of this range.

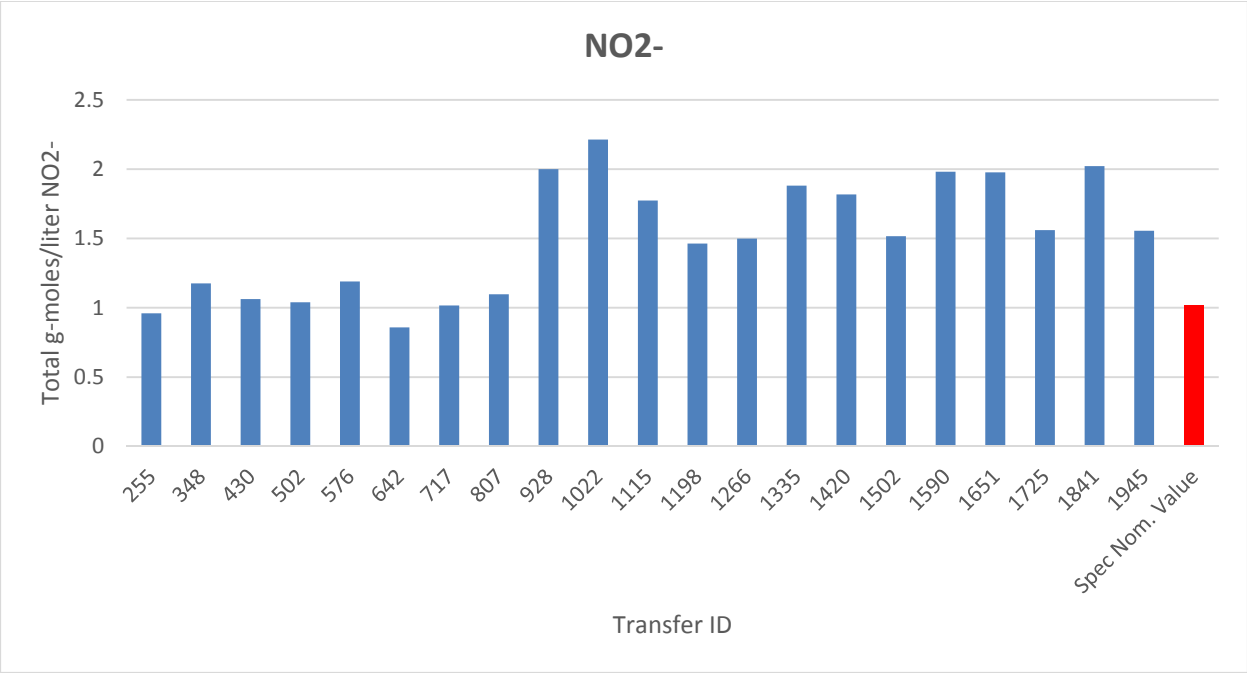

Figure 8. Nitrite concentration per feed batch.

Under the assumption that the LAW being transported to LAWPS will not exceed a temperature of 45℃, nitrite should not be problematic in the corrosion of stainless steel. Although, under turbulent flow, if the passive layer is stripped from the surface of the alloy, nitrite will have the opportunity to react with the chromium and iron elements of the stainless steel. This reaction with iron would lead to the formation of ferrous nitrite ($Fe(NO_2)_2$), which would lead to pitting and crevice corrosion. When considering stainless steel for LAWPS components, nitrite should not prove detrimental to the integrity of the alloy, but when considering nitrite and its corrosive abilities alongside the other chemical constituents that make up the corrosive medium, nitrite can become detrimental.

Nitrate: The nitrate concentration per waste feed transfer batch to LAWPS is shown in Figure 9. The nitrate calculated concentration is between 1.096 and 2.392 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 1.78 g-mol/liter, falls within this range.

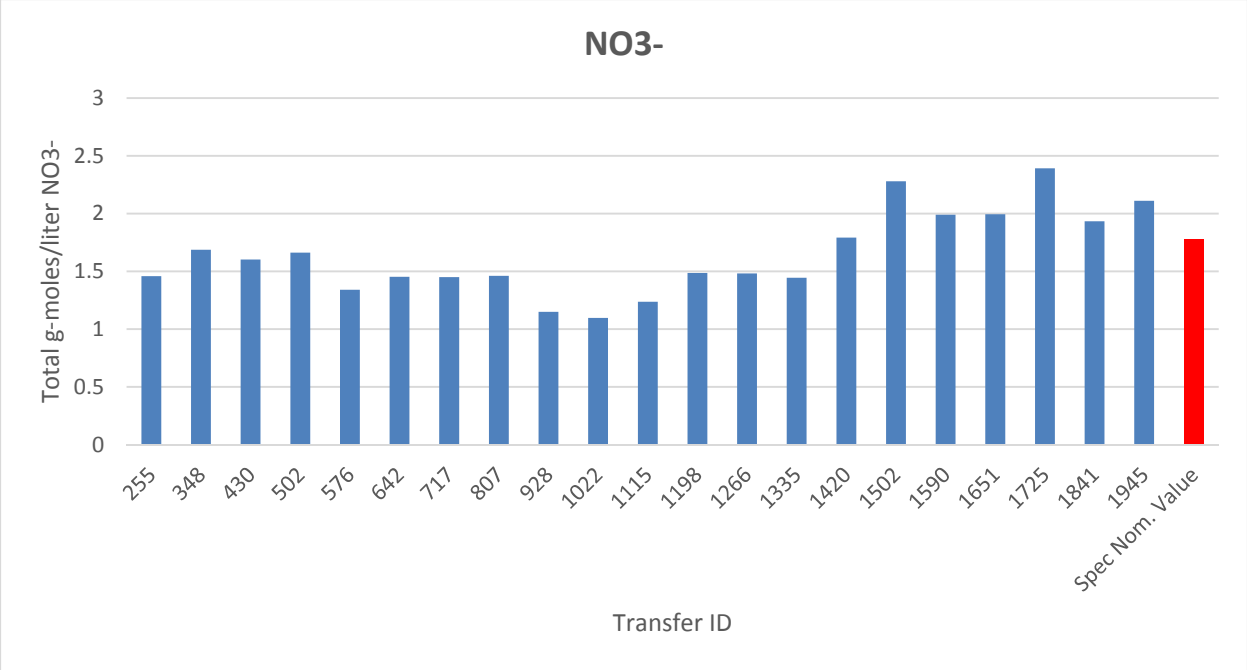

Figure 9. Nitrate concentration per feed batch.

Since LAW being transported to LAWPS will not exceed a temperature of 45℃, nitrate is not expected to penetrate the passive layer. However, considering the turbulent flow to LAWPS, the erosion of the passive layer will lead to exposed surface area in which the chemical constituents can react with chromium and iron. With nitrate reacting with the active iron, iron (III) nitrate ($Fe(NO_3)_3$) would form, degrading the alloy and leading to pitting and crevice corrosion. Although nitrate is not a corrosive constituent acting alone, when part of the halide rich medium passing over the alloy, nitrates and particulates in turbulence will erode the passive layer, increasing the risk of corrosion occurring.

Hydroxide: The hydroxide concentration per waste feed transfer to LAWPS is shown in Figure 10. The hydroxide calculated concentration ranged between 0.656 and 1.914 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 1.41 g-mol/liter, falls within this range.

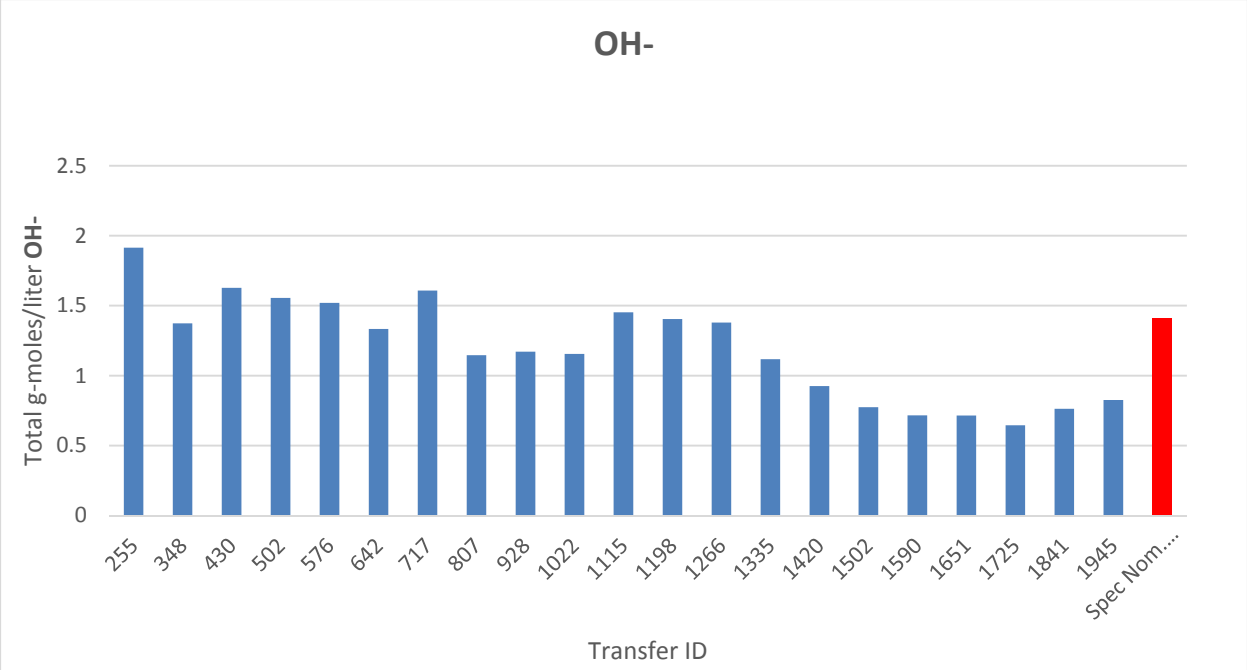

Figure 10. Hydroxide concentration per feed batch.

Hydroxide alone has a low probability of corroding stainless steel because of its inability to permeate the passive layer. Hydroxide will not actively degrade or dissolute the chromium oxide passive layer present in stainless steel alloys. The primary concern with hydroxide exposure is erosion of the passive layer due to particulates in the medium. In addition, the presence of halides (chloride and fluoride) within the corrosive medium proves detrimental. The erosion of the passive layer due to turbulent flow of LAW increases the chances of hydroxide, as well as the halides, propagating corrosion in the alloy. Once the constituent reaches the active alloy, the hydroxide will react with the iron to form iron (III) oxide (Fe_2O_3) which will corrode the alloy and spread throughout.

Sulfate: The sulfate concentration per waste feed transfer to LAWPS is shown in Figure 11. The sulfate calculated concentration range is between 0.0314 and 0.107 g-mol/liter. The nominal value specified in RPP-SPEC-56967, 0.0661 g-mol/liter, falls within the upper end of this range.

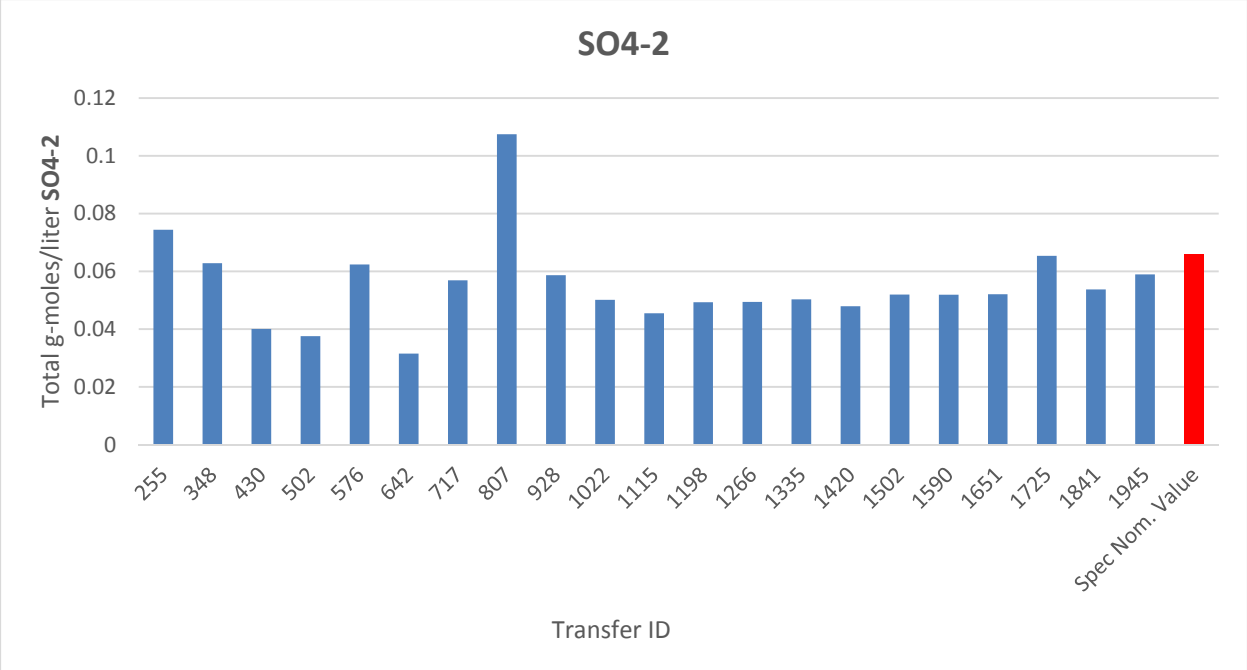

Figure 11. Sulfate concentration per feed batch.

Sulfate is another chemical constituent that does not have the ability to penetrate that chromium oxide passive layer. Due to turbulent flow, consideration of this constituent is necessary because of the erosion of the passive layer by abrasion. The abrasion leads to the reaction between sulfate and iron, forming iron (II) sulfate ($FeSO_4$). This corrosion will affect the reformation of the degraded passive layer and ultimately lead to corrosion within the alloy. Although corrosion is plausible in this case, sulfate should not contribute to the corrosion of stainless steel because of its inability to reach the active layer of the alloy.

6. CONCLUSIONS AND RECOMMENDATIONS

In this document, several corrosion mechanisms were evaluated on their ability to corrode stainless steel. Following the assumptions made when performing research, erosion is the biggest factor that will lead to corrosion in the alloy. Particulates within the medium will degrade the passive layer as they flow turbulently over the alloy, which will give the chemical constituents the opportunity to react with the active metal below. Of the chemical constituents, the halides (chloride and fluoride) are the leading cause of the corrosion mechanisms evaluated. Chloride and fluoride are able to permeate the passive layer, which makes them extremely dangerous to stainless steels. With this in mind, more research should be conducted, particularly focusing on the cumulative effects of the chemical constituents on stainless steel, to observe how the chemicals react with the alloy, and more importantly, how they react to the passive layer.

The recommended concentration range for chloride, fluoride, nitrite, nitrate, hydroxide, and sulfate are summarized in Table 1. For chloride and fluoride, the nominal values specified in RPP-SPEC-56967 were higher than the calculated concentrations using MMR-50043. For these two chemical components, it is recommended that the nominal value in RPP-SPEC-56967 be used as the maximum value for the concentration range. For the other chemical components, it is recommended that the calculated concentration ranges be used for facilitating material selection for LAWPS.

Table 1. Recommended Concentration Ranges For Chemical Components

Chemical Components	Minimum[1] (g-mol/L)	Maximum (g-mol/L)
Cl-	0.0527	0.0946[2]
F-	0.00424	0.0651[2]
NO_2-	0.858	2.022[1]
NO_3-	1.096	2.280[1]
OH-	0.646	1.627[1]
SO_4-[2]	0.0315	0.107[1]

[1] Minimum and maximum concentrations summarized per waste feed transfer from data generated by HTWOS MMR-50043, FY2015 ROS.
[2] Concentration values were taken from RPP-SPEC-56967.

Choosing between SS 304 and SS 316 for LAWPS components requires understanding the cumulative effects of the chemical constituents found in LAW on SS. In this report, the individual effects of chloride, fluoride, nitrite, nitrate, hydroxide, and sulfate in regards to corrosion were investigated. While SS 316 provides superior corrosion resistance, SS 316 is generally more expensive than SS 304 (about 30% more expensive).

7. REFERENCES

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APPENDIX A

A1.0 – CALCULATION EXAMPLE

A2.0 – SORTED AND SUMMARIZED DATA FROM HTWOS MMR-50043

A1.0 CALCULATION EXAMPLE

1. Calculating Solids and Liquid Volumes

The HTWOS model run provided volumes for each liquids and solids fractions for specific time periods. The time periods were correlated to Transfer Identification numbers by additional HTWOS model data outputs. The liquids and solids total volumes for each transfer were calculated by summing the total volumes of solids and liquids fractions for each set of time periods corresponding to each specific Transfer Identification number.

$$Volume\ \ of\ Liquids\ (Gallons) = Data\ point\ 1 + Data\ Point\ 2 + \cdots$$

$$Volume\ of\ Solids\ (Gallons) = Data\ point\ 1 + Data\ Point\ 2 + \cdots$$

For example, when the total volume in gallons for transfer 255 was calculated:

$$Volume\ of\ Liquids\ (Gallons) = 184039.854367055 + 58519.9554611513 + \cdots = 1.15E + 06$$

$$Volume\ of\ Solids\ (Gallons) = 76.1576738917888 + 24.2163181689399 + \cdots = 4.82E + 02$$

2. Calculating Total Volume + Unit Conversion

To calculate the total amount of Volume in Liters for each transfer, the volume of liquid and solids for each transfer were summed. This total Volume was then converted from gallons to liters by multiplying the summed Volume quantity by the conversion factor to obtain total Volume in Liters. The conversion factor of 3.78541 Liters/gallons as referenced in Perry's Chemical Engineers' Handbook (Perry 1997) was used.

$$Total\ Volume\ (Liters) = (Volume\ of\ Liquids\ in\ gallons + Volume\ of\ Solids\ in\ gallons) * 3.78541$$

For example, when the total volume in liters for transfer 255 was calculated:

$$Total\ Volume\ (Liters) = \big((4.36E + 06) + (1.82E + 03)\big) * 3.78541$$

3. Calculating Total kg-moles

To calculate the total kg-moles per chemical constituent, the kg-moles were summed up per each set of time periods corresponding to each Transfer Identification number.

$$Total\ kg - moles\ (per\ chem.compound) = Data\ point\ 1 + Data\ point\ 2 + \cdots$$

For example, when the total kg-moles of Cl- was calculated for transfer 255:

$$Total\ kg - moles\ Cl^{-} = 60.1524429749637 + 19.1269347281388 + \cdots$$

4. Calculating Total Chemical Composition per Waste Feed Transfer Identification Number

To calculate the concentration of each chemical constituent (total kg-moles/liter), the total kg-moles of each chemical was divided by the total volume in liters.

$$Total\ \frac{kg-moles}{liter}(per\ chem.compound) = \frac{total\ kg-moles\ (per\ chemical)}{total\ volume\ in\ liters}$$

For example, when the concentration of Cl- was calculated:

$$Total\ \frac{kg-mol}{liter}Cl^{-} = \frac{3.77E+02}{4.36E+06} = 8.63E-05$$

5. Unit Conversion

The total concentration of each chemical constituent were converted from kg-moles/liter to g-moles/liter by multiplying the concentration value by the conversion factor of 1000.

$$\frac{kg-mol}{liter} = 1000\frac{g-mol}{liter}$$

For example, when the concentration of Cl- was converted from kg-mol/liter to g-mol/liter:

$$8.63E-05\ \frac{kg-mol}{liter}Cl- = 8.63E-02\frac{g-mol}{liter}Cl-$$

A2.0 SORTED AND SUMMARIZED DATA FROM HTWOS MMR-50043

Date	Transfer ID	Constituent	Liquid	Solid
11/1/2021	255	Cl-	6.02E+01	0
11/1/2021	255	F-	3.77E+01	3.24E-01
11/1/2021	255	Na+	4.04E+03	5.33E+00
11/1/2021	255	NO2-	6.69E+02	0
11/1/2021	255	NO3-	1.02E+03	0
11/1/2021	255	OH-	1.33E+03	0
11/1/2021	255	SO4-2	5.19E+01	0
3/1/2022	255	Cl-	1.91E+01	0
3/1/2022	255	F-	1.20E+01	1.03E-01
3/1/2022	255	Na+	1.29E+03	1.69E+00
3/1/2022	255	NO2-	2.13E+02	0
3/1/2022	255	NO3-	3.23E+02	0
3/1/2022	255	OH-	4.24E+02	0
3/1/2022	255	SO4-2	1.65E+01	0
4/1/2022	255	Cl-	5.47E+01	0
4/1/2022	255	F-	3.43E+01	2.95E-01
4/1/2022	255	Na+	3.68E+03	4.85E+00
4/1/2022	255	NO2-	6.09E+02	0
4/1/2022	255	NO3-	9.24E+02	0
4/1/2022	255	OH-	1.21E+03	0
4/1/2022	255	SO4-2	4.72E+01	0
5/1/2022	255	Cl-	2.18E+01	0
5/1/2022	255	F-	1.37E+01	1.17E-01
5/1/2022	255	Na+	1.47E+03	1.93E+00
5/1/2022	255	NO2-	2.42E+02	0
5/1/2022	255	NO3-	3.68E+02	0
5/1/2022	255	OH-	4.83E+02	0
5/1/2022	255	SO4-2	1.88E+01	0
6/1/2022	255	Cl-	1.91E+01	0
6/1/2022	255	F-	1.20E+01	1.03E-01
6/1/2022	255	Na+	1.29E+03	1.70E+00
6/1/2022	255	NO2-	2.13E+02	0
6/1/2022	255	NO3-	3.23E+02	0
6/1/2022	255	OH-	4.24E+02	0
6/1/2022	255	SO4-2	1.65E+01	0
7/1/2022	255	Cl-	1.91E+01	0
7/1/2022	255	F-	1.20E+01	1.03E-01
7/1/2022	255	Na+	1.29E+03	1.70E+00
7/1/2022	255	NO2-	2.13E+02	0
7/1/2022	255	NO3-	3.23E+02	0
7/1/2022	255	OH-	4.24E+02	0
7/1/2022	255	SO4-2	1.65E+01	0
8/1/2022	255	Cl-	1.91E+01	0
8/1/2022	255	F-	1.20E+01	1.03E-01
8/1/2022	255	Na+	1.29E+03	1.70E+00
8/1/2022	255	NO2-	2.13E+02	0
8/1/2022	255	NO3-	3.23E+02	0
8/1/2022	255	OH-	4.24E+02	0
8/1/2022	255	SO4-2	1.65E+01	0
9/1/2022	255	Cl-	4.96E+01	0
9/1/2022	255	F-	3.11E+01	2.68E-01
9/1/2022	255	Na+	3.33E+03	4.42E+00
9/1/2022	255	NO2-	5.52E+02	0
9/1/2022	255	NO3-	8.38E+02	0
9/1/2022	255	OH-	1.10E+03	0
9/1/2022	255	SO4-2	4.28E+01	0
10/1/2022	255	Cl-	4.60E+01	0
10/1/2022	255	F-	2.89E+01	2.51E-01
10/1/2022	255	Na+	3.10E+03	4.13E+00
10/1/2022	255	NO2-	5.12E+02	0
10/1/2022	255	NO3-	7.78E+02	0
10/1/2022	255	OH-	1.02E+03	0
10/1/2022	255	SO4-2	3.97E+01	0
11/1/2022	255	Cl-	3.83E+01	0
11/1/2022	255	F-	2.40E+01	2.10E-01
11/1/2022	255	Na+	2.57E+03	3.46E+00
11/1/2022	255	NO2-	4.26E+02	0
11/1/2022	255	NO3-	6.46E+02	0
11/1/2022	255	OH-	8.48E+02	0
11/1/2022	255	SO4-2	3.30E+01	0
12/1/2022	348	Cl-	2.96E+01	0
12/1/2022	348	F-	1.85E+01	1.67E-01
12/1/2022	348	Na+	1.99E+03	2.76E+00
12/1/2022	348	NO2-	3.29E+02	0

Date	Transfer ID	Constituent	Liquid	Solid
12/1/2022	348	NO3-	5.00E+02	0
12/1/2022	348	OH-	6.56E+02	0
12/1/2022	348	SO4-2	2.55E+01	0
1/1/2023	348	Cl-	5.69E+01	0
1/1/2023	348	F-	1.27E+01	0
1/1/2023	348	Na+	3.68E+03	4.33E+00
1/1/2023	348	NO2-	7.69E+02	0
1/1/2023	348	NO3-	1.10E+03	0
1/1/2023	348	OH-	8.99E+02	0
1/1/2023	348	SO4-2	4.11E+01	0
2/1/2023	348	Cl-	4.82E+01	0
2/1/2023	348	F-	1.08E+01	0
2/1/2023	348	Na+	3.11E+03	3.67E+00
2/1/2023	348	NO2-	6.51E+02	0
2/1/2023	348	NO3-	9.35E+02	0
2/1/2023	348	OH-	7.61E+02	0
2/1/2023	348	SO4-2	3.48E+01	0
3/1/2023	348	Cl-	4.36E+01	0
3/1/2023	348	F-	9.73E+00	0
3/1/2023	348	Na+	2.82E+03	3.32E+00
3/1/2023	348	NO2-	5.89E+02	0
3/1/2023	348	NO3-	8.46E+02	0
3/1/2023	348	OH-	6.89E+02	0
3/1/2023	348	SO4-2	3.15E+01	0
4/1/2023	348	Cl-	5.28E+01	0
4/1/2023	348	F-	1.18E+01	0
4/1/2023	348	Na+	3.41E+03	4.03E+00
4/1/2023	348	NO2-	7.13E+02	0
4/1/2023	348	NO3-	1.02E+03	0
4/1/2023	348	OH-	8.34E+02	0
4/1/2023	348	SO4-2	3.81E+01	0
5/1/2023	348	Cl-	4.30E+01	0
5/1/2023	348	F-	9.60E+00	0
5/1/2023	348	Na+	2.78E+03	3.30E+00
5/1/2023	348	NO2-	5.82E+02	0
5/1/2023	348	NO3-	8.35E+02	0
5/1/2023	348	OH-	6.80E+02	0
5/1/2023	348	SO4-2	3.11E+01	0
6/1/2023	348	Cl-	5.33E+01	0
6/1/2023	348	F-	1.19E+01	0
6/1/2023	348	Na+	3.45E+03	4.13E+00
6/1/2023	348	NO2-	7.21E+02	0
6/1/2023	348	NO3-	1.03E+03	0
6/1/2023	348	OH-	8.43E+02	0
6/1/2023	348	SO4-2	3.85E+01	0
7/1/2023	348	Cl-	3.74E+01	0
7/1/2023	348	F-	8.36E+00	0
7/1/2023	348	Na+	2.42E+03	3.00E+00
7/1/2023	348	NO2-	5.06E+02	0
7/1/2023	348	NO3-	7.27E+02	0
7/1/2023	348	OH-	5.92E+02	0
7/1/2023	348	SO4-2	2.70E+01	0
8/1/2023	430	Cl-	1.54E+01	0
8/1/2023	430	F-	4.72E+00	0
8/1/2023	430	Na+	1.20E+03	1.19E+00
8/1/2023	430	NO2-	2.26E+02	0
8/1/2023	430	NO3-	3.42E+02	0
8/1/2023	430	OH-	3.47E+02	0
8/1/2023	430	SO4-2	8.53E+00	0
9/1/2023	430	Cl-	6.54E+01	0
9/1/2023	430	F-	2.01E+01	0
9/1/2023	430	Na+	5.09E+03	5.06E+00
9/1/2023	430	NO2-	9.64E+02	0
9/1/2023	430	NO3-	1.45E+03	0
9/1/2023	430	OH-	1.48E+03	0
9/1/2023	430	SO4-2	3.63E+01	0
10/1/2023	430	Cl-	4.98E+01	0
10/1/2023	430	F-	1.53E+01	0
10/1/2023	430	Na+	3.87E+03	3.85E+00
10/1/2023	430	NO2-	7.33E+02	0
10/1/2023	430	NO3-	1.11E+03	0
10/1/2023	430	OH-	1.12E+03	0
10/1/2023	430	SO4-2	2.76E+01	0
11/1/2023	430	Cl-	5.23E+01	0
11/1/2023	430	F-	1.60E+01	0
11/1/2023	430	Na+	4.06E+03	4.07E+00
11/1/2023	430	NO2-	7.70E+02	0
11/1/2023	430	NO3-	1.16E+03	0

Date	Transfer ID	Constituent	Liquid	Solid
11/1/2023	430	OH-	1.18E+03	0
11/1/2023	430	SO4-2	2.90E+01	0
12/1/2023	430	Cl-	5.77E+01	0
12/1/2023	430	F-	1.77E+01	0
12/1/2023	430	Na+	4.49E+03	4.54E+00
12/1/2023	430	NO2-	8.51E+02	0
12/1/2023	430	NO3-	1.28E+03	0
12/1/2023	430	OH-	1.30E+03	0
12/1/2023	430	SO4-2	3.20E+01	0
1/1/2024	502	Cl-	2.73E+01	0
1/1/2024	502	F-	8.36E+00	0
1/1/2024	502	Na+	2.12E+03	2.20E+00
1/1/2024	502	NO2-	4.01E+02	0
1/1/2024	502	NO3-	6.06E+02	0
1/1/2024	502	OH-	6.15E+02	0
1/1/2024	502	SO4-2	1.51E+01	0
2/1/2024	502	Cl-	6.21E+01	0
2/1/2024	502	F-	2.27E+01	0
2/1/2024	502	Na+	4.89E+03	3.05E+00
2/1/2024	502	NO2-	9.10E+02	0
2/1/2024	502	NO3-	1.49E+03	0
2/1/2024	502	OH-	1.38E+03	0
2/1/2024	502	SO4-2	3.16E+01	0
3/1/2024	502	Cl-	5.15E+01	0
3/1/2024	502	F-	1.88E+01	0
3/1/2024	502	Na+	4.05E+03	2.53E+00
3/1/2024	502	NO2-	7.54E+02	0
3/1/2024	502	NO3-	1.23E+03	0
3/1/2024	502	OH-	1.14E+03	0
3/1/2024	502	SO4-2	2.62E+01	0
4/1/2024	502	Cl-	4.87E+01	0
4/1/2024	502	F-	1.78E+01	0
4/1/2024	502	Na+	3.83E+03	2.40E+00
4/1/2024	502	NO2-	7.13E+02	0
4/1/2024	502	NO3-	1.17E+03	0
4/1/2024	502	OH-	1.08E+03	0
4/1/2024	502	SO4-2	2.48E+01	0
5/1/2024	502	Cl-	4.52E+01	0
5/1/2024	502	F-	1.65E+01	0

Date	Transfer ID	Constituent	Liquid	Solid
5/1/2024	502	Na+	3.55E+03	2.24E+00
5/1/2024	502	NO2-	6.62E+02	0
5/1/2024	502	NO3-	1.08E+03	0
5/1/2024	502	OH-	1.00E+03	0
5/1/2024	502	SO4-2	2.30E+01	0
6/1/2024	502	Cl-	5.81E+01	0
6/1/2024	502	F-	2.12E+01	0
6/1/2024	502	Na+	4.57E+03	2.91E+00
6/1/2024	502	NO2-	8.50E+02	0
6/1/2024	502	NO3-	1.39E+03	0
6/1/2024	502	OH-	1.29E+03	0
6/1/2024	502	SO4-2	2.96E+01	0
7/1/2024	576	Cl-	3.99E+01	0
7/1/2024	576	F-	1.12E+01	0
7/1/2024	576	Na+	3.06E+03	1.95E+00
7/1/2024	576	NO2-	6.12E+02	0
7/1/2024	576	NO3-	8.29E+02	0
7/1/2024	576	OH-	8.47E+02	0
7/1/2024	576	SO4-2	2.73E+01	0
8/1/2024	576	Cl-	6.45E+01	0
8/1/2024	576	F-	1.33E+01	0
8/1/2024	576	Na+	4.84E+03	2.98E+00
8/1/2024	576	NO2-	1.03E+03	0
8/1/2024	576	NO3-	1.16E+03	0
8/1/2024	576	OH-	1.32E+03	0
8/1/2024	576	SO4-2	5.41E+01	0
9/1/2024	576	Cl-	5.85E+01	0
9/1/2024	576	F-	1.21E+01	0
9/1/2024	576	Na+	4.40E+03	2.71E+00
9/1/2024	576	NO2-	9.35E+02	0
9/1/2024	576	NO3-	1.05E+03	0
9/1/2024	576	OH-	1.19E+03	0
9/1/2024	576	SO4-2	4.91E+01	0
10/1/2024	576	Cl-	4.74E+01	0
10/1/2024	576	F-	9.77E+00	0
10/1/2024	576	Na+	3.56E+03	2.21E+00
10/1/2024	576	NO2-	7.58E+02	0
10/1/2024	576	NO3-	8.54E+02	0
10/1/2024	576	OH-	9.68E+02	0

Date	Transfer ID	Constituent	Liquid	Solid
10/1/2024	576	SO4-2	3.97E+01	0
11/1/2024	576	Cl-	5.51E+01	0
11/1/2024	576	F-	1.13E+01	0
11/1/2024	576	Na+	4.14E+03	2.59E+00
11/1/2024	576	NO2-	8.80E+02	0
11/1/2024	576	NO3-	9.92E+02	0
11/1/2024	576	OH-	1.12E+03	0
11/1/2024	576	SO4-2	4.62E+01	0
12/1/2024	642	Cl-	2.96E+01	0
12/1/2024	642	F-	6.11E+00	0
12/1/2024	642	Na+	2.23E+03	1.43E+00
12/1/2024	642	NO2-	4.74E+02	0
12/1/2024	642	NO3-	5.34E+02	0
12/1/2024	642	OH-	6.05E+02	0
12/1/2024	642	SO4-2	2.49E+01	0
1/1/2025	642	Cl-	4.41E+01	0
1/1/2025	642	F-	2.04E+01	0
1/1/2025	642	Na+	4.59E+03	2.93E+00
1/1/2025	642	NO2-	7.24E+02	0
1/1/2025	642	NO3-	1.24E+03	0
1/1/2025	642	OH-	1.12E+03	0
1/1/2025	642	SO4-2	2.59E+01	0
2/1/2025	642	Cl-	3.64E+01	0
2/1/2025	642	F-	1.69E+01	0
2/1/2025	642	Na+	3.79E+03	2.43E+00
2/1/2025	642	NO2-	5.98E+02	0
2/1/2025	642	NO3-	1.02E+03	0
2/1/2025	642	OH-	9.29E+02	0
2/1/2025	642	SO4-2	2.14E+01	0
3/1/2025	642	Cl-	3.54E+01	0
3/1/2025	642	F-	1.64E+01	0
3/1/2025	642	Na+	3.68E+03	2.36E+00
3/1/2025	642	NO2-	5.81E+02	0
3/1/2025	642	NO3-	9.91E+02	0
3/1/2025	642	OH-	9.02E+02	0
3/1/2025	642	SO4-2	2.08E+01	0
4/1/2025	642	Cl-	3.71E+01	0
4/1/2025	642	F-	1.72E+01	0
4/1/2025	642	Na+	3.86E+03	2.49E+00

Date	Transfer ID	Constituent	Liquid	Solid
4/1/2025	642	NO2-	6.09E+02	0
4/1/2025	642	NO3-	1.04E+03	0
4/1/2025	642	OH-	9.46E+02	0
4/1/2025	642	SO4-2	2.18E+01	0
5/1/2025	642	Cl-	4.05E+01	0
5/1/2025	642	F-	1.88E+01	0
5/1/2025	642	Na+	4.22E+03	2.75E+00
5/1/2025	642	NO2-	6.66E+02	0
5/1/2025	642	NO3-	1.14E+03	0
5/1/2025	642	OH-	1.03E+03	0
5/1/2025	642	SO4-2	2.38E+01	0
6/1/2025	717	Cl-	2.78E+01	0
6/1/2025	717	F-	9.85E+00	0
6/1/2025	717	Na+	2.55E+03	1.66E+00
6/1/2025	717	NO2-	4.25E+02	0
6/1/2025	717	NO3-	6.77E+02	0
6/1/2025	717	OH-	6.65E+02	0
6/1/2025	717	SO4-2	1.86E+01	0
7/1/2025	717	Cl-	6.26E+01	0
7/1/2025	717	F-	1.36E+01	0
7/1/2025	717	Na+	4.76E+03	2.93E+00
7/1/2025	717	NO2-	8.66E+02	0
7/1/2025	717	NO3-	1.24E+03	0
7/1/2025	717	OH-	1.37E+03	0
7/1/2025	717	SO4-2	4.85E+01	0
8/1/2025	717	Cl-	5.19E+01	0
8/1/2025	717	F-	1.13E+01	0
8/1/2025	717	Na+	3.95E+03	2.44E+00
8/1/2025	717	NO2-	7.18E+02	0
8/1/2025	717	NO3-	1.03E+03	0
8/1/2025	717	OH-	1.14E+03	0
8/1/2025	717	SO4-2	4.02E+01	0
9/1/2025	717	Cl-	5.39E+01	0
9/1/2025	717	F-	1.17E+01	0
9/1/2025	717	Na+	4.10E+03	2.54E+00
9/1/2025	717	NO2-	7.46E+02	0
9/1/2025	717	NO3-	1.06E+03	0
9/1/2025	717	OH-	1.18E+03	0
9/1/2025	717	SO4-2	4.17E+01	0

Date	Transfer ID	Constituent	Liquid	Solid
10/1/2025	717	Cl-	4.88E+01	0
10/1/2025	717	F-	1.06E+01	0
10/1/2025	717	Na+	3.71E+03	2.32E+00
10/1/2025	717	NO2-	6.76E+02	0
10/1/2025	717	NO3-	9.64E+02	0
10/1/2025	717	OH-	1.07E+03	0
10/1/2025	717	SO4-2	3.78E+01	0
11/1/2025	717	Cl-	4.30E+01	0
11/1/2025	717	F-	9.33E+00	0
11/1/2025	717	Na+	3.27E+03	2.10E+00
11/1/2025	717	NO2-	5.94E+02	0
11/1/2025	717	NO3-	8.48E+02	0
11/1/2025	717	OH-	9.41E+02	0
11/1/2025	717	SO4-2	3.33E+01	0
12/1/2025	807	Cl-	5.26E+01	0
12/1/2025	807	F-	1.56E+01	0
12/1/2025	807	Na+	4.17E+03	1.97E+00
12/1/2025	807	NO2-	8.17E+02	0
12/1/2025	807	NO3-	1.09E+03	0
12/1/2025	807	OH-	8.53E+02	0
12/1/2025	807	SO4-2	8.00E+01	0
1/1/2026	807	Cl-	3.36E+01	0
1/1/2026	807	F-	9.96E+00	0
1/1/2026	807	Na+	2.66E+03	1.26E+00
1/1/2026	807	NO2-	5.22E+02	0
1/1/2026	807	NO3-	6.95E+02	0
1/1/2026	807	OH-	5.45E+02	0
1/1/2026	807	SO4-2	5.12E+01	0
2/1/2026	807	Cl-	3.69E+01	0
2/1/2026	807	F-	1.09E+01	0
2/1/2026	807	Na+	2.93E+03	1.39E+00
2/1/2026	807	NO2-	5.74E+02	0
2/1/2026	807	NO3-	7.64E+02	0
2/1/2026	807	OH-	5.99E+02	0
2/1/2026	807	SO4-2	5.62E+01	0
3/1/2026	807	Cl-	2.34E+01	0
3/1/2026	807	F-	6.93E+00	0
3/1/2026	807	Na+	1.85E+03	8.79E-01
3/1/2026	807	NO2-	3.63E+02	0

Date	Transfer ID	Constituent	Liquid	Solid
3/1/2026	807	NO3-	4.84E+02	0
3/1/2026	807	OH-	3.79E+02	0
3/1/2026	807	SO4-2	3.56E+01	0
4/1/2026	807	Cl-	3.13E+01	0
4/1/2026	807	F-	9.28E+00	0
4/1/2026	807	Na+	2.48E+03	1.18E+00
4/1/2026	807	NO2-	4.86E+02	0
4/1/2026	807	NO3-	6.48E+02	0
4/1/2026	807	OH-	5.08E+02	0
4/1/2026	807	SO4-2	4.76E+01	0
5/1/2026	807	Cl-	3.13E+01	0
5/1/2026	807	F-	9.28E+00	0
5/1/2026	807	Na+	2.48E+03	1.18E+00
5/1/2026	807	NO2-	4.86E+02	0
5/1/2026	807	NO3-	6.48E+02	0
5/1/2026	807	OH-	5.08E+02	0
5/1/2026	807	SO4-2	4.76E+01	0
6/1/2026	807	Cl-	3.13E+01	0
6/1/2026	807	F-	9.28E+00	0
6/1/2026	807	Na+	2.48E+03	1.19E+00
6/1/2026	807	NO2-	4.86E+02	0
6/1/2026	807	NO3-	6.48E+02	0
6/1/2026	807	OH-	5.08E+02	0
6/1/2026	807	SO4-2	4.76E+01	0
7/1/2026	807	Cl-	3.13E+01	0
7/1/2026	807	F-	9.28E+00	0
7/1/2026	807	Na+	2.48E+03	1.21E+00
7/1/2026	807	NO2-	4.86E+02	0
7/1/2026	807	NO3-	6.48E+02	0
7/1/2026	807	OH-	5.08E+02	0
7/1/2026	807	SO4-2	4.76E+01	0
8/1/2026	928	Cl-	1.32E+01	0
8/1/2026	928	F-	3.92E+00	0
8/1/2026	928	Na+	1.05E+03	5.23E-01
8/1/2026	928	NO2-	2.05E+02	0
8/1/2026	928	NO3-	2.74E+02	0
8/1/2026	928	OH-	2.14E+02	0
8/1/2026	928	SO4-2	2.01E+01	0
9/1/2026	928	Cl-	3.87E+01	0

Date	Transfer ID	Constituent	Liquid	Solid
9/1/2026	928	F-	9.01E+00	0
9/1/2026	928	Na+	3.11E+03	1.45E+00
9/1/2026	928	NO2-	1.11E+03	0
9/1/2026	928	NO3-	6.39E+02	0
9/1/2026	928	OH-	6.50E+02	0
9/1/2026	928	SO4-2	3.26E+01	0
10/1/2026	928	Cl-	4.09E+01	0
10/1/2026	928	F-	9.52E+00	0
10/1/2026	928	Na+	3.29E+03	1.53E+00
10/1/2026	928	NO2-	1.17E+03	0
10/1/2026	928	NO3-	6.75E+02	0
10/1/2026	928	OH-	6.87E+02	0
10/1/2026	928	SO4-2	3.44E+01	0
11/1/2026	928	Cl-	4.13E+01	0
11/1/2026	928	F-	9.62E+00	0
11/1/2026	928	Na+	3.32E+03	1.55E+00
11/1/2026	928	NO2-	1.19E+03	0
11/1/2026	928	NO3-	6.82E+02	0
11/1/2026	928	OH-	6.94E+02	0
11/1/2026	928	SO4-2	3.48E+01	0
12/1/2026	928	Cl-	5.13E+01	0
12/1/2026	928	F-	1.20E+01	0
12/1/2026	928	Na+	4.12E+03	1.94E+00
12/1/2026	928	NO2-	1.47E+03	0
12/1/2026	928	NO3-	8.47E+02	0
12/1/2026	928	OH-	8.62E+02	0
12/1/2026	928	SO4-2	4.32E+01	0
1/1/2027	928	Cl-	4.63E+01	0
1/1/2027	928	F-	1.08E+01	0
1/1/2027	928	Na+	3.72E+03	1.76E+00
1/1/2027	928	NO2-	1.33E+03	0
1/1/2027	928	NO3-	7.65E+02	0
1/1/2027	928	OH-	7.78E+02	0
1/1/2027	928	SO4-2	3.90E+01	0
2/1/2027	928	Cl-	3.98E+01	0
2/1/2027	928	F-	9.28E+00	0
2/1/2027	928	Na+	3.20E+03	1.55E+00
2/1/2027	928	NO2-	1.14E+03	0
2/1/2027	928	NO3-	6.58E+02	0
2/1/2027	928	OH-	6.70E+02	0
2/1/2027	928	SO4-2	3.36E+01	0
3/1/2027	1022	Cl-	4.33E+01	0
3/1/2027	1022	F-	8.36E+00	0
3/1/2027	1022	Na+	3.63E+03	1.69E+00
3/1/2027	1022	NO2-	1.44E+03	0
3/1/2027	1022	NO3-	7.12E+02	0
3/1/2027	1022	OH-	7.50E+02	0
3/1/2027	1022	SO4-2	3.26E+01	0
4/1/2027	1022	Cl-	5.16E+01	0
4/1/2027	1022	F-	9.96E+00	0
4/1/2027	1022	Na+	4.33E+03	2.01E+00
4/1/2027	1022	NO2-	1.71E+03	0
4/1/2027	1022	NO3-	8.48E+02	0
4/1/2027	1022	OH-	8.93E+02	0
4/1/2027	1022	SO4-2	3.88E+01	0
5/1/2027	1022	Cl-	4.43E+01	0
5/1/2027	1022	F-	8.56E+00	0
5/1/2027	1022	Na+	3.72E+03	1.73E+00
5/1/2027	1022	NO2-	1.47E+03	0
5/1/2027	1022	NO3-	7.29E+02	0
5/1/2027	1022	OH-	7.68E+02	0
5/1/2027	1022	SO4-2	3.33E+01	0
6/1/2027	1022	Cl-	5.04E+01	0
6/1/2027	1022	F-	9.73E+00	0
6/1/2027	1022	Na+	4.23E+03	1.98E+00
6/1/2027	1022	NO2-	1.67E+03	0
6/1/2027	1022	NO3-	8.28E+02	0
6/1/2027	1022	OH-	8.72E+02	0
6/1/2027	1022	SO4-2	3.79E+01	0
7/1/2027	1022	Cl-	5.31E+01	0
7/1/2027	1022	F-	1.03E+01	0
7/1/2027	1022	Na+	4.45E+03	2.11E+00
7/1/2027	1022	NO2-	1.76E+03	0
7/1/2027	1022	NO3-	8.72E+02	0
7/1/2027	1022	OH-	9.19E+02	0
7/1/2027	1022	SO4-2	3.99E+01	0
8/1/2027	1115	Cl-	2.64E+01	0
8/1/2027	1115	F-	5.09E+00	0

Date	Transfer ID	Constituent	Liquid	Solid
8/1/2027	1115	Na+	2.21E+03	1.08E+00
8/1/2027	1115	NO2-	8.74E+02	0
8/1/2027	1115	NO3-	4.33E+02	0
8/1/2027	1115	OH-	4.56E+02	0
8/1/2027	1115	SO4-2	1.98E+01	0
9/1/2027	1115	Cl-	5.77E+01	0
9/1/2027	1115	F-	5.37E+00	0
9/1/2027	1115	Na+	4.32E+03	2.01E+00
9/1/2027	1115	NO2-	1.37E+03	0
9/1/2027	1115	NO3-	9.55E+02	0
9/1/2027	1115	OH-	1.12E+03	0
9/1/2027	1115	SO4-2	3.51E+01	0
10/1/2027	1115	Cl-	5.90E+01	0
10/1/2027	1115	F-	5.49E+00	0
10/1/2027	1115	Na+	4.42E+03	2.06E+00
10/1/2027	1115	NO2-	1.40E+03	0
10/1/2027	1115	NO3-	9.77E+02	0
10/1/2027	1115	OH-	1.15E+03	0
10/1/2027	1115	SO4-2	3.59E+01	0
11/1/2027	1115	Cl-	5.24E+01	0
11/1/2027	1115	F-	4.87E+00	0
11/1/2027	1115	Na+	3.92E+03	1.83E+00
11/1/2027	1115	NO2-	1.24E+03	0
11/1/2027	1115	NO3-	8.67E+02	0
11/1/2027	1115	OH-	1.02E+03	0
11/1/2027	1115	SO4-2	3.19E+01	0
12/1/2027	1115	Cl-	5.05E+01	0
12/1/2027	1115	F-	4.69E+00	0
12/1/2027	1115	Na+	3.78E+03	1.77E+00
12/1/2027	1115	NO2-	1.20E+03	0
12/1/2027	1115	NO3-	8.35E+02	0
12/1/2027	1115	OH-	9.81E+02	0
12/1/2027	1115	SO4-2	3.07E+01	0
1/1/2028	1115	Cl-	5.73E+01	0
1/1/2028	1115	F-	5.33E+00	0
1/1/2028	1115	Na+	4.29E+03	2.06E+00
1/1/2028	1115	NO2-	1.36E+03	0
1/1/2028	1115	NO3-	9.48E+02	0
1/1/2028	1115	OH-	1.11E+03	0

Date	Transfer ID	Constituent	Liquid	Solid
1/1/2028	1115	SO4-2	3.49E+01	0
2/1/2028	1198	Cl-	4.66E+01	0
2/1/2028	1198	F-	5.10E+00	0
2/1/2028	1198	Na+	3.41E+03	1.59E+00
2/1/2028	1198	NO2-	8.92E+02	0
2/1/2028	1198	NO3-	9.06E+02	0
2/1/2028	1198	OH-	8.56E+02	0
2/1/2028	1198	SO4-2	3.01E+01	0
3/1/2028	1198	Cl-	5.26E+01	0
3/1/2028	1198	F-	5.75E+00	0
3/1/2028	1198	Na+	3.85E+03	1.79E+00
3/1/2028	1198	NO2-	1.01E+03	0
3/1/2028	1198	NO3-	1.02E+03	0
3/1/2028	1198	OH-	9.66E+02	0
3/1/2028	1198	SO4-2	3.39E+01	0
4/1/2028	1251	Cl-	8.92E+00	0
4/1/2028	1251	F-	9.75E-01	0
4/1/2028	1251	Na+	6.53E+02	3.04E-01
4/1/2028	1251	NO2-	1.71E+02	0
4/1/2028	1251	NO3-	1.73E+02	0
4/1/2028	1251	OH-	1.64E+02	0
4/1/2028	1251	SO4-2	5.75E+00	0
5/1/2028	1266	Cl-	1.88E+01	0
5/1/2028	1266	F-	2.05E+00	0
5/1/2028	1266	Na+	1.37E+03	6.40E-01
5/1/2028	1266	NO2-	3.59E+02	0
5/1/2028	1266	NO3-	3.65E+02	0
5/1/2028	1266	OH-	3.45E+02	0
5/1/2028	1266	SO4-2	1.21E+01	0
6/1/2028	1266	Cl-	5.67E+01	0
6/1/2028	1266	F-	6.20E+00	0
6/1/2028	1266	Na+	4.15E+03	1.93E+00
6/1/2028	1266	NO2-	1.08E+03	0
6/1/2028	1266	NO3-	1.10E+03	0
6/1/2028	1266	OH-	1.04E+03	0
6/1/2028	1266	SO4-2	3.65E+01	0
7/1/2028	1266	Cl-	5.26E+01	0
7/1/2028	1266	F-	5.75E+00	0
7/1/2028	1266	Na+	3.85E+03	1.80E+00

Date	Transfer ID	Constituent	Liquid	Solid
7/1/2028	1266	NO2-	1.01E+03	0
7/1/2028	1266	NO3-	1.02E+03	0
7/1/2028	1266	OH-	9.65E+02	0
7/1/2028	1266	SO4-2	3.39E+01	0
8/1/2028	1266	Cl-	6.02E+01	0
8/1/2028	1266	F-	6.58E+00	0
8/1/2028	1266	Na+	4.41E+03	2.10E+00
8/1/2028	1266	NO2-	1.15E+03	0
8/1/2028	1266	NO3-	1.17E+03	0
8/1/2028	1266	OH-	1.11E+03	0
8/1/2028	1266	SO4-2	3.88E+01	0
9/1/2028	1335	Cl-	2.98E+01	0
9/1/2028	1335	F-	2.95E+00	0
9/1/2028	1335	Na+	2.27E+03	1.08E+00
9/1/2028	1335	NO2-	6.98E+02	0
9/1/2028	1335	NO3-	5.93E+02	0
9/1/2028	1335	OH-	4.98E+02	0
9/1/2028	1335	SO4-2	2.03E+01	0
10/1/2028	1335	Cl-	5.65E+01	0
10/1/2028	1335	F-	5.20E+00	0
10/1/2028	1335	Na+	4.43E+03	2.05E+00
10/1/2028	1335	NO2-	1.49E+03	0
10/1/2028	1335	NO3-	1.14E+03	0
10/1/2028	1335	OH-	8.84E+02	0
10/1/2028	1335	SO4-2	3.98E+01	0
11/1/2028	1335	Cl-	5.69E+01	0
11/1/2028	1335	F-	5.24E+00	0
11/1/2028	1335	Na+	4.46E+03	2.07E+00
11/1/2028	1335	NO2-	1.50E+03	0
11/1/2028	1335	NO3-	1.15E+03	0
11/1/2028	1335	OH-	8.91E+02	0
11/1/2028	1335	SO4-2	4.01E+01	0
12/1/2028	1335	Cl-	4.66E+01	0
12/1/2028	1335	F-	4.30E+00	0
12/1/2028	1335	Na+	3.66E+03	1.71E+00
12/1/2028	1335	NO2-	1.23E+03	0
12/1/2028	1335	NO3-	9.44E+02	0
12/1/2028	1335	OH-	7.30E+02	0
12/1/2028	1335	SO4-2	3.29E+01	0

Date	Transfer ID	Constituent	Liquid	Solid
1/1/2029	1335	Cl-	5.22E+01	0
1/1/2029	1335	F-	4.81E+00	0
1/1/2029	1335	Na+	4.09E+03	1.92E+00
1/1/2029	1335	NO2-	1.37E+03	0
1/1/2029	1335	NO3-	1.06E+03	0
1/1/2029	1335	OH-	8.17E+02	0
1/1/2029	1335	SO4-2	3.67E+01	0
2/1/2029	1420	Cl-	3.45E+01	0
2/1/2029	1420	F-	3.18E+00	0
2/1/2029	1420	Na+	2.70E+03	1.31E+00
2/1/2029	1420	NO2-	9.09E+02	0
2/1/2029	1420	NO3-	6.98E+02	0
2/1/2029	1420	OH-	5.40E+02	0
2/1/2029	1420	SO4-2	2.43E+01	0
3/1/2029	1420	Cl-	5.87E+01	0
3/1/2029	1420	F-	3.51E+00	0
3/1/2029	1420	Na+	4.80E+03	1.99E+00
3/1/2029	1420	NO2-	1.57E+03	0
3/1/2029	1420	NO3-	1.52E+03	0
3/1/2029	1420	OH-	7.99E+02	0
3/1/2029	1420	SO4-2	4.10E+01	0
4/1/2029	1420	Cl-	5.61E+01	0
4/1/2029	1420	F-	3.35E+00	0
4/1/2029	1420	Na+	4.59E+03	1.91E+00
4/1/2029	1420	NO2-	1.50E+03	0
4/1/2029	1420	NO3-	1.45E+03	0
4/1/2029	1420	OH-	7.64E+02	0
4/1/2029	1420	SO4-2	3.92E+01	0
5/1/2029	1420	Cl-	4.36E+01	0
5/1/2029	1420	F-	2.60E+00	0
5/1/2029	1420	Na+	3.56E+03	1.48E+00
5/1/2029	1420	NO2-	1.17E+03	0
5/1/2029	1420	NO3-	1.13E+03	0
5/1/2029	1420	OH-	5.93E+02	0
5/1/2029	1420	SO4-2	3.04E+01	0
6/1/2029	1420	Cl-	4.75E+01	0
6/1/2029	1420	F-	2.83E+00	0
6/1/2029	1420	Na+	3.88E+03	1.62E+00
6/1/2029	1420	NO2-	1.27E+03	0

Date	Transfer ID	Constituent	Liquid	Solid
6/1/2029	1420	NO3-	1.23E+03	0
6/1/2029	1420	OH-	6.46E+02	0
6/1/2029	1420	SO4-2	3.31E+01	0
7/1/2029	1420	Cl-	4.96E+01	0
7/1/2029	1420	F-	2.96E+00	0
7/1/2029	1420	Na+	4.06E+03	1.72E+00
7/1/2029	1420	NO2-	1.33E+03	0
7/1/2029	1420	NO3-	1.28E+03	0
7/1/2029	1420	OH-	6.76E+02	0
7/1/2029	1420	SO4-2	3.46E+01	0
8/1/2029	1502	Cl-	3.34E+01	0
8/1/2029	1502	F-	2.66E+00	0
8/1/2029	1502	Na+	2.74E+03	9.52E-01
8/1/2029	1502	NO2-	8.35E+02	0
8/1/2029	1502	NO3-	9.62E+02	0
8/1/2029	1502	OH-	4.25E+02	0
8/1/2029	1502	SO4-2	2.41E+01	0
9/1/2029	1502	Cl-	6.86E+01	0
9/1/2029	1502	F-	7.61E+00	0
9/1/2029	1502	Na+	5.61E+03	1.16E+00
9/1/2029	1502	NO2-	1.52E+03	0
9/1/2029	1502	NO3-	2.29E+03	0
9/1/2029	1502	OH-	7.76E+02	0
9/1/2029	1502	SO4-2	5.21E+01	0
10/1/2029	1502	Cl-	4.55E+01	0
10/1/2029	1502	F-	5.05E+00	0
10/1/2029	1502	Na+	3.72E+03	7.72E-01
10/1/2029	1502	NO2-	1.01E+03	0
10/1/2029	1502	NO3-	1.52E+03	0
10/1/2029	1502	OH-	5.15E+02	0
10/1/2029	1502	SO4-2	3.45E+01	0
11/1/2029	1502	Cl-	5.00E+01	0
11/1/2029	1502	F-	5.55E+00	0
11/1/2029	1502	Na+	4.09E+03	8.52E-01
11/1/2029	1502	NO2-	1.11E+03	0
11/1/2029	1502	NO3-	1.67E+03	0
11/1/2029	1502	OH-	5.66E+02	0
11/1/2029	1502	SO4-2	3.79E+01	0
12/1/2029	1502	Cl-	4.98E+01	0

Date	Transfer ID	Constituent	Liquid	Solid
12/1/2029	1502	F-	5.53E+00	0
12/1/2029	1502	Na+	4.07E+03	8.57E-01
12/1/2029	1502	NO2-	1.10E+03	0
12/1/2029	1502	NO3-	1.66E+03	0
12/1/2029	1502	OH-	5.63E+02	0
12/1/2029	1502	SO4-2	3.78E+01	0
1/1/2030	1590	Cl-	2.67E+01	0
1/1/2030	1590	F-	2.96E+00	0
1/1/2030	1590	Na+	2.19E+03	4.73E-01
1/1/2030	1590	NO2-	5.92E+02	0
1/1/2030	1590	NO3-	8.90E+02	0
1/1/2030	1590	OH-	3.02E+02	0
1/1/2030	1590	SO4-2	2.03E+01	0
2/1/2030	1590	Cl-	5.40E+01	0
2/1/2030	1590	F-	4.47E+00	0
2/1/2030	1590	Na+	4.66E+03	0
2/1/2030	1590	NO2-	1.65E+03	0
2/1/2030	1590	NO3-	1.66E+03	0
2/1/2030	1590	OH-	5.95E+02	0
2/1/2030	1590	SO4-2	4.32E+01	0
3/1/2030	1626	Cl-	5.00E+01	0
3/1/2030	1626	F-	4.13E+00	0
3/1/2030	1626	Na+	4.31E+03	0
3/1/2030	1626	NO2-	1.53E+03	0
3/1/2030	1626	NO3-	1.53E+03	0
3/1/2030	1626	OH-	5.51E+02	0
3/1/2030	1626	SO4-2	4.00E+01	0
4/1/2030	1644	Cl-	5.90E-01	0
4/1/2030	1644	F-	4.88E-02	0
4/1/2030	1644	Na+	5.09E+01	0
4/1/2030	1644	NO2-	1.80E+01	0
4/1/2030	1644	NO3-	1.81E+01	0
4/1/2030	1644	OH-	6.50E+00	0
4/1/2030	1644	SO4-2	4.72E-01	0
5/1/2030	1651	Cl-	3.59E+01	0
5/1/2030	1651	F-	2.97E+00	0
5/1/2030	1651	Na+	3.10E+03	0
5/1/2030	1651	NO2-	1.10E+03	0
5/1/2030	1651	NO3-	1.10E+03	0

Date	Transfer ID	Constituent	Liquid	Solid
5/1/2030	1651	OH-	3.96E+02	0
5/1/2030	1651	SO4-2	2.87E+01	0
6/1/2030	1651	Cl-	5.04E+01	0
6/1/2030	1651	F-	4.16E+00	0
6/1/2030	1651	Na+	4.34E+03	0
6/1/2030	1651	NO2-	1.54E+03	0
6/1/2030	1651	NO3-	1.54E+03	0
6/1/2030	1651	OH-	5.55E+02	0
6/1/2030	1651	SO4-2	4.03E+01	0
7/1/2030	1651	Cl-	4.43E+01	0
7/1/2030	1651	F-	3.66E+00	0
7/1/2030	1651	Na+	3.82E+03	0
7/1/2030	1651	NO2-	1.35E+03	0
7/1/2030	1651	NO3-	1.36E+03	0
7/1/2030	1651	OH-	4.88E+02	0
7/1/2030	1651	SO4-2	3.54E+01	0
8/1/2030	1725	Cl-	2.84E+01	0
8/1/2030	1725	F-	2.46E+00	0
8/1/2030	1725	Na+	2.44E+03	0
8/1/2030	1725	NO2-	8.51E+02	0
8/1/2030	1725	NO3-	8.77E+02	0
8/1/2030	1725	OH-	3.10E+02	0
8/1/2030	1725	SO4-2	2.30E+01	0
9/1/2030	1725	Cl-	6.83E+01	0
9/1/2030	1725	F-	9.53E+00	0
9/1/2030	1725	Na+	5.40E+03	0
9/1/2030	1725	NO2-	1.51E+03	0
9/1/2030	1725	NO3-	2.31E+03	0
9/1/2030	1725	OH-	6.23E+02	0
9/1/2030	1725	SO4-2	6.30E+01	0
10/1/2030	1725	Cl-	4.71E+01	0
10/1/2030	1725	F-	6.57E+00	0
10/1/2030	1725	Na+	3.72E+03	0
10/1/2030	1725	NO2-	1.04E+03	0
10/1/2030	1725	NO3-	1.59E+03	0
10/1/2030	1725	OH-	4.29E+02	0
10/1/2030	1725	SO4-2	4.35E+01	0
11/1/2030	1725	Cl-	4.71E+01	0
11/1/2030	1725	F-	6.57E+00	0

Date	Transfer ID	Constituent	Liquid	Solid
11/1/2030	1725	Na+	3.72E+03	0
11/1/2030	1725	NO2-	1.04E+03	0
11/1/2030	1725	NO3-	1.59E+03	0
11/1/2030	1725	OH-	4.29E+02	0
11/1/2030	1725	SO4-2	4.35E+01	0
12/1/2030	1725	Cl-	4.71E+01	0
12/1/2030	1725	F-	6.57E+00	0
12/1/2030	1725	Na+	3.72E+03	0
12/1/2030	1725	NO2-	1.04E+03	0
12/1/2030	1725	NO3-	1.59E+03	0
12/1/2030	1725	OH-	4.29E+02	0
12/1/2030	1725	SO4-2	4.35E+01	0
1/1/2031	1725	Cl-	4.71E+01	0
1/1/2031	1725	F-	6.57E+00	0
1/1/2031	1725	Na+	3.72E+03	0
1/1/2031	1725	NO2-	1.04E+03	0
1/1/2031	1725	NO3-	1.59E+03	0
1/1/2031	1725	OH-	4.29E+02	0
1/1/2031	1725	SO4-2	4.35E+01	0
2/1/2031	1841	Cl-	2.36E+01	0
2/1/2031	1841	F-	3.31E+00	0
2/1/2031	1841	Na+	1.92E+03	0
2/1/2031	1841	NO2-	6.72E+02	0
2/1/2031	1841	NO3-	6.86E+02	0
2/1/2031	1841	OH-	2.56E+02	0
2/1/2031	1841	SO4-2	1.90E+01	0
3/1/2031	1841	Cl-	5.22E+01	0
3/1/2031	1841	F-	7.33E+00	0
3/1/2031	1841	Na+	4.28E+03	0
3/1/2031	1841	NO2-	1.55E+03	0
3/1/2031	1841	NO3-	1.47E+03	0
3/1/2031	1841	OH-	5.84E+02	0
3/1/2031	1841	SO4-2	4.10E+01	0
4/1/2031	1841	Cl-	5.38E+01	0
4/1/2031	1841	F-	7.56E+00	0
4/1/2031	1841	Na+	4.42E+03	0
4/1/2031	1841	NO2-	1.60E+03	0
4/1/2031	1841	NO3-	1.52E+03	0
4/1/2031	1841	OH-	6.03E+02	0

Date	Transfer ID	Constituent	Liquid	Solid
4/1/2031	1841	SO4-2	4.23E+01	0
5/1/2031	1841	Cl-	4.34E+01	0
5/1/2031	1841	F-	6.10E+00	0
5/1/2031	1841	Na+	3.56E+03	0
5/1/2031	1841	NO2-	1.29E+03	0
5/1/2031	1841	NO3-	1.23E+03	0
5/1/2031	1841	OH-	4.86E+02	0
5/1/2031	1841	SO4-2	3.41E+01	0
6/1/2031	1841	Cl-	5.40E+01	0
6/1/2031	1841	F-	7.58E+00	0
6/1/2031	1841	Na+	4.43E+03	0
6/1/2031	1841	NO2-	1.60E+03	0
6/1/2031	1841	NO3-	1.53E+03	0
6/1/2031	1841	OH-	6.05E+02	0
6/1/2031	1841	SO4-2	4.24E+01	0
7/1/2031	1841	Cl-	4.54E+01	0
7/1/2031	1841	F-	6.37E+00	0
7/1/2031	1841	Na+	3.72E+03	0
7/1/2031	1841	NO2-	1.35E+03	0
7/1/2031	1841	NO3-	1.28E+03	0
7/1/2031	1841	OH-	5.08E+02	0
7/1/2031	1841	SO4-2	3.56E+01	0
8/1/2031	1945	Cl-	3.79E+01	0
8/1/2031	1945	F-	6.12E+00	0
8/1/2031	1945	Na+	3.11E+03	0
8/1/2031	1945	NO2-	9.01E+02	0
8/1/2031	1945	NO3-	1.16E+03	0
8/1/2031	1945	OH-	4.54E+02	0
8/1/2031	1945	SO4-2	3.23E+01	0
9/1/2031	1945	Cl-	5.29E+01	0
9/1/2031	1945	F-	8.76E+00	0
9/1/2031	1945	Na+	4.34E+03	0
9/1/2031	1945	NO2-	1.19E+03	0
9/1/2031	1945	NO3-	1.64E+03	0
9/1/2031	1945	OH-	6.41E+02	0
9/1/2031	1945	SO4-2	4.57E+01	0
10/1/2031	1945	Cl-	4.55E+01	0
10/1/2031	1945	F-	7.54E+00	0
10/1/2031	1945	Na+	3.73E+03	0
10/1/2031	1945	NO2-	1.03E+03	0
10/1/2031	1945	NO3-	1.41E+03	0
10/1/2031	1945	OH-	5.52E+02	0
10/1/2031	1945	SO4-2	3.94E+01	0
11/1/2031	1945	Cl-	5.47E+01	0
11/1/2031	1945	F-	9.05E+00	0
11/1/2031	1945	Na+	4.48E+03	0
11/1/2031	1945	NO2-	1.23E+03	0
11/1/2031	1945	NO3-	1.69E+03	0
11/1/2031	1945	OH-	6.62E+02	0
11/1/2031	1945	SO4-2	4.73E+01	0
12/1/2031	1945	Cl-	2.80E+01	0
12/1/2031	1945	F-	4.64E+00	0
12/1/2031	1945	Na+	2.30E+03	0
12/1/2031	1945	NO2-	6.33E+02	0
12/1/2031	1945	NO3-	8.68E+02	0
12/1/2031	1945	OH-	3.40E+02	0
12/1/2031	1945	SO4-2	2.42E+01	0

APPENDIX B: CALCULATION SHEET

Table B: Summary Calculations

Transfer ID	Total Volume (Liters)	Total g-moles/liter Cl-	Total g-moles/liter F-	Total g-moles/liter NO2-	Total g-moles/liter NO3-	Total g-moles/liter OH-	Total g-moles/liter SO4-2	Total g-moles/liter Na+
255	4.36E+06	8.63E-02	5.46E-02	9.60E-01	1.46E+00	1.91E+00	7.44E-02	5.81E+00
348	3.86E+06	8.70E-02	1.94E-02	1.18E+00	1.69E+00	1.37E+00	6.28E-02	5.63E+00
430	3.71E+06	7.21E-02	2.21E-02	1.06E+00	1.60E+00	1.63E+00	4.00E-02	5.61E+00
502	4.33E+06	7.05E-02	2.50E-02	1.04E+00	1.66E+00	1.56E+00	3.76E-02	5.54E+00
576	3.43E+06	7.44E-02	1.53E-02	1.19E+00	1.34E+00	1.52E+00	6.24E-02	5.60E+00
642	4.20E+06	5.27E-02	2.37E-02	8.58E-01	1.45E+00	1.33E+00	3.15E-02	5.41E+00
717	3.54E+06	7.35E-02	1.59E-02	1.02E+00	1.45E+00	1.61E+00	5.69E-02	5.59E+00
807	4.03E+06	7.07E-02	2.09E-02	1.10E+00	1.46E+00	1.15E+00	1.07E-01	5.60E+00
928	3.71E+06	6.96E-02	1.62E-02	2.00E+00	1.15E+00	1.17E+00	5.87E-02	5.60E+00
1022	4.03E+06	6.67E-02	1.29E-02	2.21E+00	1.10E+00	1.15E+00	5.01E-02	5.60E+00
1115	3.71E+06	7.47E-02	6.94E-03	1.77E+00	1.24E+00	1.45E+00	4.55E-02	5.60E+00
1198	1.30E+06	7.65E-02	8.36E-03	1.46E+00	1.49E+00	1.40E+00	4.93E-02	5.60E+00
1266	2.87E+06	7.60E-02	8.21E-03	1.50E+00	1.48E+00	1.38E+00	4.94E-02	5.60E+00
1335	3.46E+06	7.14E-02	6.58E-03	1.88E+00	1.44E+00	1.12E+00	5.03E-02	5.60E+00
1420	4.22E+06	6.84E-02	4.24E-03	1.82E+00	1.79E+00	9.25E-01	4.79E-02	5.60E+00
1502	3.52E+06	6.85E-02	7.60E-03	1.52E+00	2.28E+00	7.74E-01	5.20E-02	5.60E+00
1590	1.60E+06	6.49E-02	5.37E-03	1.98E+00	1.99E+00	7.15E-01	5.19E-02	5.60E+00
1651	2.45E+06	6.50E-02	5.42E-03	1.98E+00	1.99E+00	7.15E-01	5.21E-02	5.60E+00
1725	3.62E+06	7.08E-02	9.88E-03	1.56E+00	2.39E+00	6.46E-01	6.54E-02	5.60E+00
1841	3.99E+06	6.83E-02	9.59E-03	2.02E+00	1.93E+00	7.63E-01	5.37E-02	5.60E+00
1945	3.21E+06	6.83E-02	1.13E-02	1.56E+00	2.11E+00	8.26E-01	5.89E-02	5.60E+00

APPENDIX C: PROJECT COMMUNICATION

Terry L. Sams, **PMP**

Manager, Process Engineering Analysis

WRPS Central Engineering

business: 509-376-4653

cell: 509-619-6502

contractor to the United States Department of Energy

From: Winkler, Clifford J
Sent: Wednesday, July 15, 2015 10:08 AM
To: Sams, Terry L
Subject: RE: LAWPS

Turbulent up to the IX columns.

From: Sams, Terry L
Sent: Wednesday, July 15, 2015 10:05 AM
To: Winkler, Clifford J
Subject: LAWPS

Cliff

Are the input waste flow laminar or turbulent?

Terry L. Sams, **PMP**

Manager, Process Engineering Analysis

WRPS Central Engineering

business: 509-376-4653

cell: 509-619-6502

contractor to the United States Department of Energy