STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Analysis of Life Expectancy for Waste Transfer Lines Located in SY-Farm at Hanford Site

DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

Date submitted:

October 14, 2013

Principal Investigators:

Jennifer Arniella (DOE Fellow Student)
Florida International University

Dennis Washenfelder, Mentor
Washington River Protection Solutions

Florida International University Program Director:

Leonel Lagos Ph.D., PMP®

Submitted to:

U.S. Department of Energy
Office of Environmental Management
Under Grant # DE-EM0000598

FIU | Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

ABSTRACT

The United States Department of Energy Hanford Site Tank Farm has implemented a Fitness-for-Service (FFS) program for the Waste Transfer System. Fitness-for-Service applies to the pressure boundary of the system. The FFS program is based on API-579-1/ASME FFS-1, “Fitness-for-Service.” The FFS work is examining the pressure boundary integrity of the waste transfer system in order to develop wear rates. Data measurements have been collected from pipelines and jumpers from different tank farms. This report includes data measurements and wall thickness analysis pertaining to the 241-SY Tank Farm pipelines. The lines evaluated were 3-in Carbon Steel primary pipelines, and 6-in Carbon Steel secondary pipelines. Despite the fact that the volume passing through the primary pipelines is very large, there is no detectable wear. On the other hand, for the secondary pipelines, there is detectable wear on both pipes that were analyzed and the wear rate for each pipeline was calculated. It was determined that the year when the pipelines will reach their minimum wall thickness due to corrosion was well beyond the lifetime of the Hanford Site mission of removing and storing the radioactive waste. This analysis is only suitable for the straight sections of carbon steel primary and secondary pipelines. Further analysis will be conducted as needed to account for the corrosion/erosion in the elbow sections and pipelines with other materials and sizes. As a result, there will be wear rates representing all of the various pipelines (different materials, sizes, and service performed) that the waste transfer system contains.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The United States Department of Energy Hanford Site Tank Farm has implemented a Fitness-for-Service (FFS) program for the Waste Transfer System. Fitness-for-Service applies to the pressure boundary of the system. The FFS program is based on API-579-1/ASME FFS-1, "Fitness-for-Service." The FFS work is examining the pressure boundary integrity of the waste transfer system in order to develop wear rates. This work is necessary because the system has experienced wall thinning from corrosion and erosion. Once enough data are collected and evaluated, a wear rate will be developed to predict the existing system's remaining useful life if applicable. It will be used to determine design allowances needed for new piping and pipe jumpers. The FFS information is acquired from pipelines listed for inspection in RPP-RPT-42487, *Evaluation of Buried Transfer Lines with Cathodic Protection* and opportunistic evaluations of pipelines that have been removed from service. Eventually, all of the waste transfer system's pipeline materials and materials handling history will be represented. These include: 2-in and 3-in carbon steel and stainless steel process lines; 4-in and 6-in carbon steel encasements; 2-in and 3-in carbon steel and stainless steel jumpers, including wide radius elbows; 5 diameter elbows; straight sections; and slurry and supernatant waste materials.

In order to ensure safe operation of the transfer lines, thickness inspection of a portion of the underground pipelines needed to be made. The selection criteria for lines to be exhumed and inspected are detailed in RPP-RPT-42487, *Evaluation of Buried Transfer Lines with Cathodic Protection.* Based on these criteria, 241-AP Tank Farm lines SL-509 Secondary, SL-510 Secondary, SN-609 Secondary, and SN-610 Secondary were selected for the first set of inspections. In addition, 241-AY Tank Farm line PW-4531, a 2-in process waste line was selected for inspection. There were eight lines replaced in 241-SY Tank Farm because the outer encasement did not fully penetrate inside of the pit wall and thereby did not meet the standards for double contained systems as required by the Washington Administrative Code, WAC 173-303-640. Specimens of five pipelines consisting of primary and secondary lines were taken to the laboratory to acquire wall thickness measurements. These lines include: SN-278 Primary, SN-285 Primary, SN-286 Primary, SN-285 Secondary, and SN-286 Secondary.

Furthermore, several jumpers in the 242-A Evaporator and in the 241-AW-02E Evaporator Feed Pump Pit were removed for disposal. Of the jumpers being removed from the 242-A Evaporator, five of them were selected for wall thickness determination by ultrasonic transducer (UT) inspection. These jumpers are: Jumper 18 to 4, Jumper C to 4 & 5, Jumper J to 13A, Jumper 13 to K, and Jumper 19 to 5 (reinstalled for continuing service). The jumpers removed from the 241-AW-02E Evaporator Feed Pump Pit were Jumper 1-4 and Jumper B-2. For these sets of pipes, secondary lines are being inspected for the rate of corrosion due to contact with the soil, while primary lines and jumpers are being inspected for the wear rate due to the slurry or supernatant transferred.

Data measurements have been collected for all of the pipelines and jumpers listed above. This report only includes data measurements and wall thickness analysis pertaining to the

241-SY Tank Farm pipelines. As time progresses, additional sections will be included which contain the data measurements and wall thickness analysis for all the other pipes. The flow chart in Figure 1 lists all the pipeline materials and sizes that will be tested as part of this program.

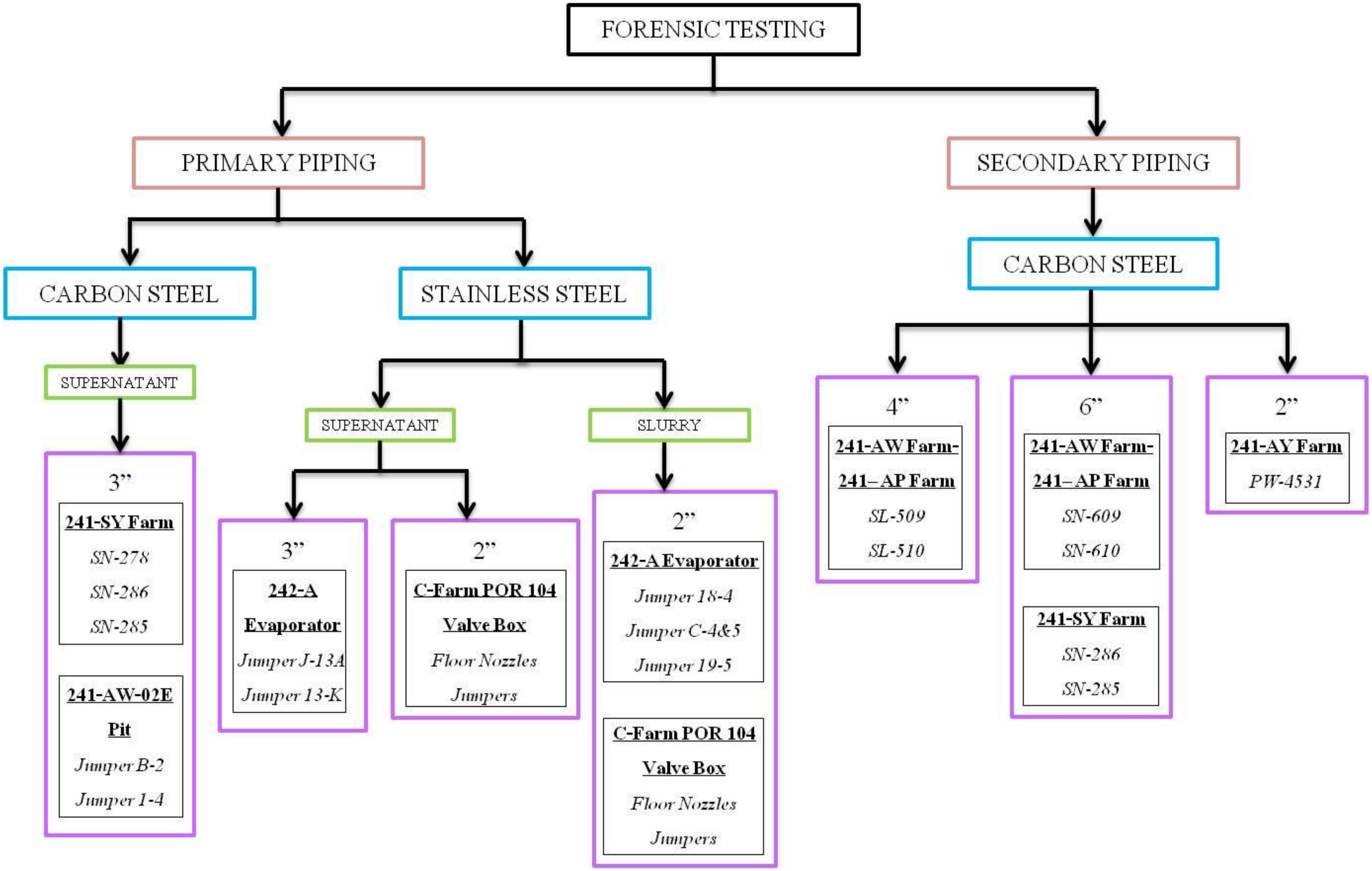

Figure 1. Pipe Tree

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 2013, a DOE Fellow intern (Jennifer Arniella) spent 10 weeks doing a summer internship at the Hanford Site in Richland, WA under the supervision and guidance of Dennis Washenfelder, manager of the Tank and Pipeline Integrity Group at Washington River Protection Solutions. The intern's project was initiated on June 8, 2013, and continued through August 17, 2013 with the objective of assisting in the analysis of the remaining useful life of waste transfer lines and jumpers at the Hanford Site tank farms.

3. RESEARCH DESCRIPTION

Removal and inspection of the transfer lines located in the 241-SY Tank Farm was done to examine the overall condition of the pipelines. In 2010 removal and inspection of the transfer lines were done in accordance with the Independent Qualified Registered Professional Engineer's (IQRPE) recommendation from the 2006 *Double-Shell Tank Integrity Assessment*. There were eight supernatant lines replaced in the 241-SY Tank Farm because the outer encasement did not fully penetrate inside of the pit wall and thereby did not meet the standards for double contained systems as required by the Washington Administrative Code, WAC 173-303-640. These consisted of primary pipelines that carry the supernatant and secondary lines that act as an encasement. They were removed for replacement in 2010 and in 2011 specimens of pipelines SN-278, SN-285, and SN-286 were taken to the lab and wall thickness measurements were collected.

The work scope designated for the duration of the internship consisted of the following tasks:

1. Develop a template in Microsoft Excel to organize and develop statistical analysis of empirical field and laboratory pipeline wall thickness measurements.
2. Create visual representation to present pipeline wear data in ways that allow useful conclusions to be made.
3. Collect available information on the pipelines including:
    - Location of the pipeline in the tank farms
    - Pipeline material and size
    - Service provided
    - Waste transferred
    - Service date
4. Analyze and document the amount of corrosion/erosion in the pipelines by comparing the wall thickness measurements collected in the pipes to their nominal thickness and comparing pipelines with the same material and service to each other.

Considering the duration of the internship, the pipelines that were fully analyzed and documented are the ones located in the 241-SY Tank Farm (SN-285 primary, SN-286 primary, SN-278 primary, SN-285 secondary, SN-286 secondary). A full description of these pipelines is provided in this report as well as their wall thickness measurements, visual representation of the data, and analysis of the corrosion/erosion. For convenience, the results and analysis section is divided into subsections that contain information for each pipeline individually.

4. RESULTS AND ANALYSIS

SN-278 Primary Pipe

Line SN-278 Primary is a 3-in Carbon Steel Schedule 40 ASTM A53, Type S, Gr. B pipeline. It was installed in 1974 and transferred 213 kgal of supernatant in between the dates from 241-SY-01A Central Pump Pit to 241-SY-B Valve Pit in 241-SY Tank Farm. Based on retrieved records the transfers were made from 1978 to 2005. Figure 2 shows the modified drawing of the 241-SY Tank Farm and the line SN-278 route is highlighted in purple for reference. (RPP-RPT-50397 R0, 2013)

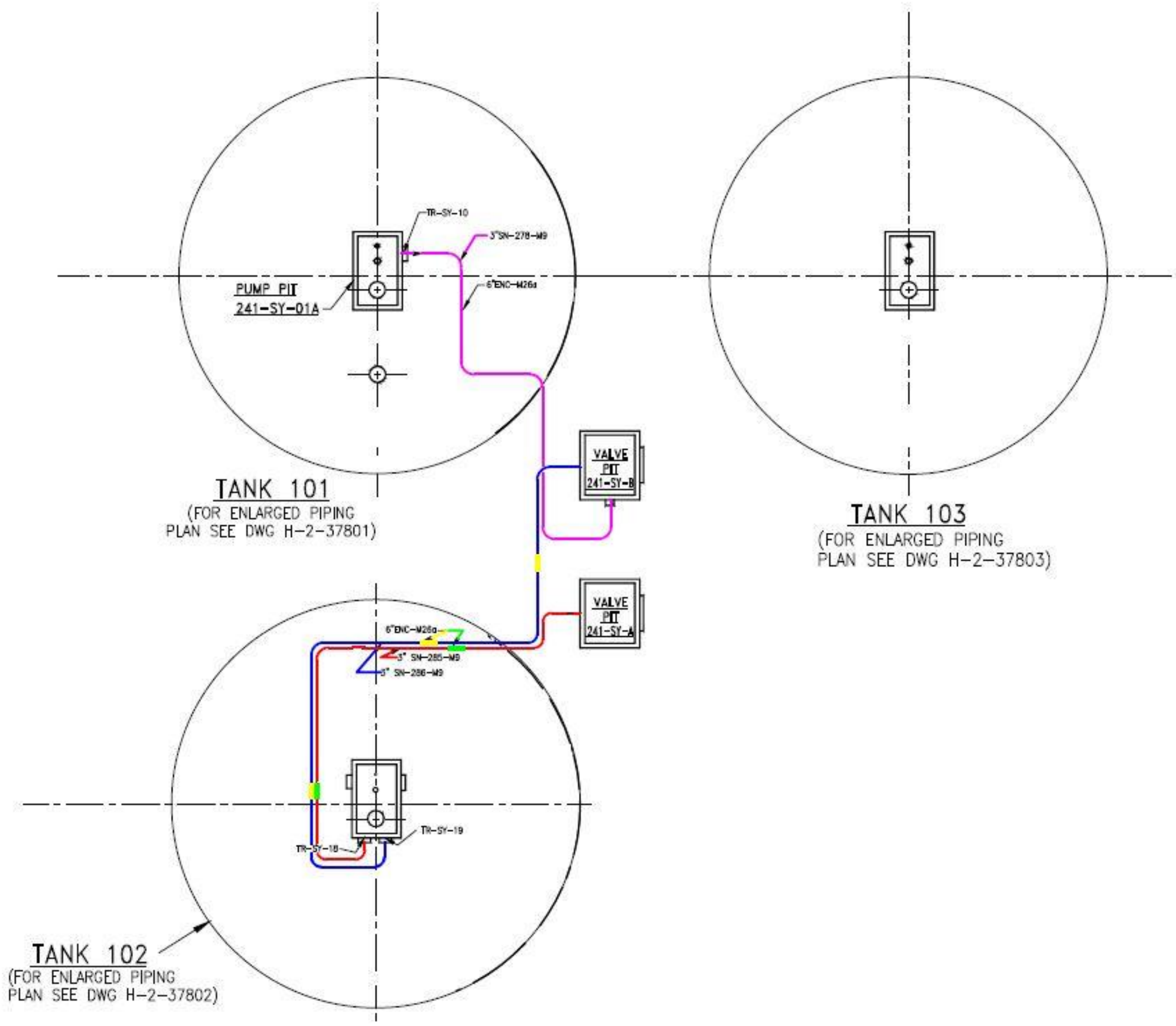

Figure 2. 241-SY Tank Farm Drawing SN-278 Primary (purple), SN-285 Primary (Red) and SN-286 Primary (Blue)

To lower the possibility of contamination, the location where the specimens were cut from was determined based on accessibility and low amount of radiation. Ultrasonic thickness measurements were taken with an Ultrasonic Transducer (Manufacturer: Krautkramer, Model: USN-52L) and a 1-in X 1-in grid pattern on pipe samples using a Mylar plastic template wrapped around the outside diameter (OD) of the part. The grid was labeled alphanumerically with A-K positions running around the circumference and 1-4 positions running horizontally along the length. Figure 3 shows the locations of these measurements around the pipe.

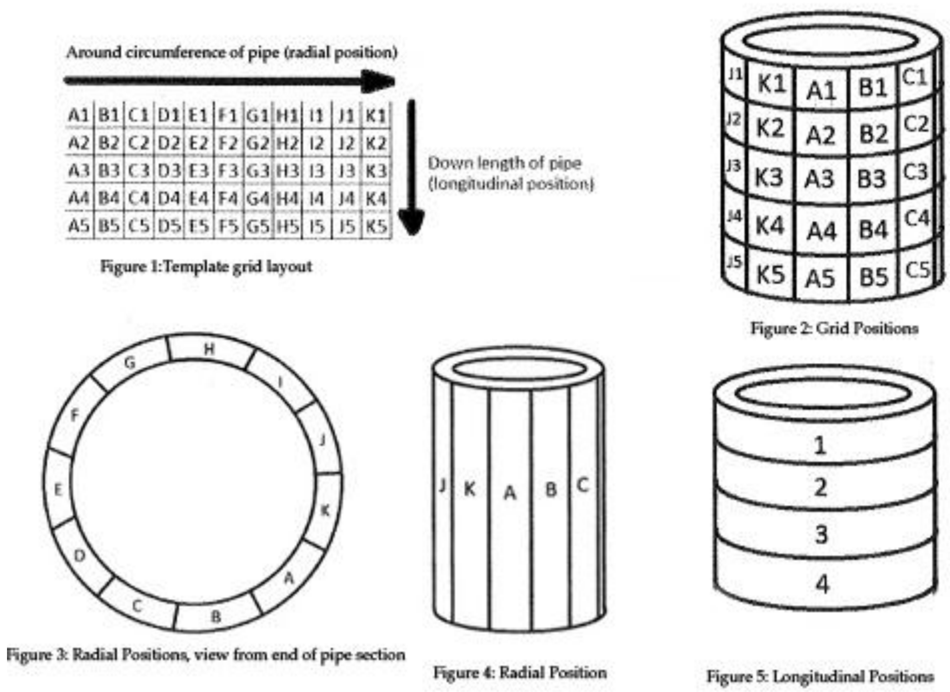

Figure 3. Position of UT thickness measurements around pipes SN-278 Primary, SN-286 Primary, and SN-285 Primary.

The results for the SN-278 Primary pipe wall section thickness measurements are shown in Table 1. The highlighted green cell does not contain a measurement value because a hole was made at this location in the pipeline in order to inject foam to contain the contamination and also to stabilize the pipe segment for packaging and transportation to the laboratory. When these pipelines were removed, there was no marking indicating the top and bottom of the pipeline. Thus, the lab could not label a letter in the circumference as the top. Since the hole in the pipeline is positioned at letter E for the foam injection, it is assumed that was the top of the pipeline. To evaluate the values obtained from the ultrasonic measurements, a 2-in X 2-in coupon was cut from the I-2 location and measurements were made with a digital caliper. The cells representing coupon measurements are surrounded by a dotted line in Table 1. This location was selected because it contains one of the thinner areas in the pipe specimen. Before the measurements were conducted, the remaining foam attached to the surface was removed with acetone and water to obtain a greater accuracy of the wall thickness. The digital caliper measured a thickness of 0.227-in, which corresponds with the UT measurement. In addition, this value is close to the schedule 40 pipe nominal thickness (0.216-in) which indicates minimal, if any, erosion or corrosion in this section (LAB-RPT-12-00007 R0, 2012).

Table 1. Ultrasonic Testing Thickness Measurements for SN-278 Primary

	1	2	3	4
A	0.225	0.230	0.224	0.231
B	0.235	0.230	0.231	0.225
C	0.228	0.224	0.225	0.220
D	0.222	0.235	0.223	0.222
E	0.222		0.220	0.229
F	0.215	0.215	0.219	0.219
G	0.224	0.223	0.223	0.225
H	0.216	0.219	0.218	0.220
I	0.219	0.210	0.215	0.216
J	0.227	0.223	0.225	0.222
K	0.223	0.220	0.219	0.219

A summary of the SN-278 Primary wall thickness measurement calculations is shown in Table 2. The average and standard deviation were calculated and the nominal thickness and tolerance are listed. The nominal thickness is based on 3-in Carbon Steel Schedule 40 pipe. The minimum manufacturing tolerance is listed in ASTM A53-1972a Table X4. However, the maximum manufacturing tolerance is not provided in the standard. Because of this, the maximum manufacturing tolerance is determined from ASTM A53-1972a Paragraph 16.2. This paragraph states that the outside diameter should not vary more than ± 1% from the standard specified. The outside nominal diameter is 3.5-in and can be obtained from ASTM A53-1972a Table X1. Using this information, the maximum thickness can be determined by finding 1% of 3.5-in, dividing the obtained value by 2, and adding the value to the nominal thickness. This calculation gives us a manufacturing maximum tolerance of 0.234-in. (ASTM A53-1972a).

Table 2. Summary of the SN-278 Primary Thickness Measurements

Overall Average Wall Thickness Measurements	0.223
Overall Standard Deviation	0.005
Average -2 Standard Deviation	0.212
Average +2 Standard Deviation	0.233
Manufacturing Nominal Thickness	0.216
Manufacturing Minimum Tolerance	0.189
Manufacturing Maximum Tolerance	0.234
Note: Nominal thickness based on Carbon Steel, 3-in Diameter, Schedule 40	

To conduct additional analyses and determine how the thickness in the pipe varied along the longitudinal position, the average radial measurements were plotted in each longitudinal position as shown in Figure 4. The average thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted. The average radial measurements along the longitude of the pipe are almost identical which indicates that the pipeline thickness along its longitude is not changing. This is consistent with the logic that the fluid traveling through the pipeline should be affecting it equally along the pipeline length.

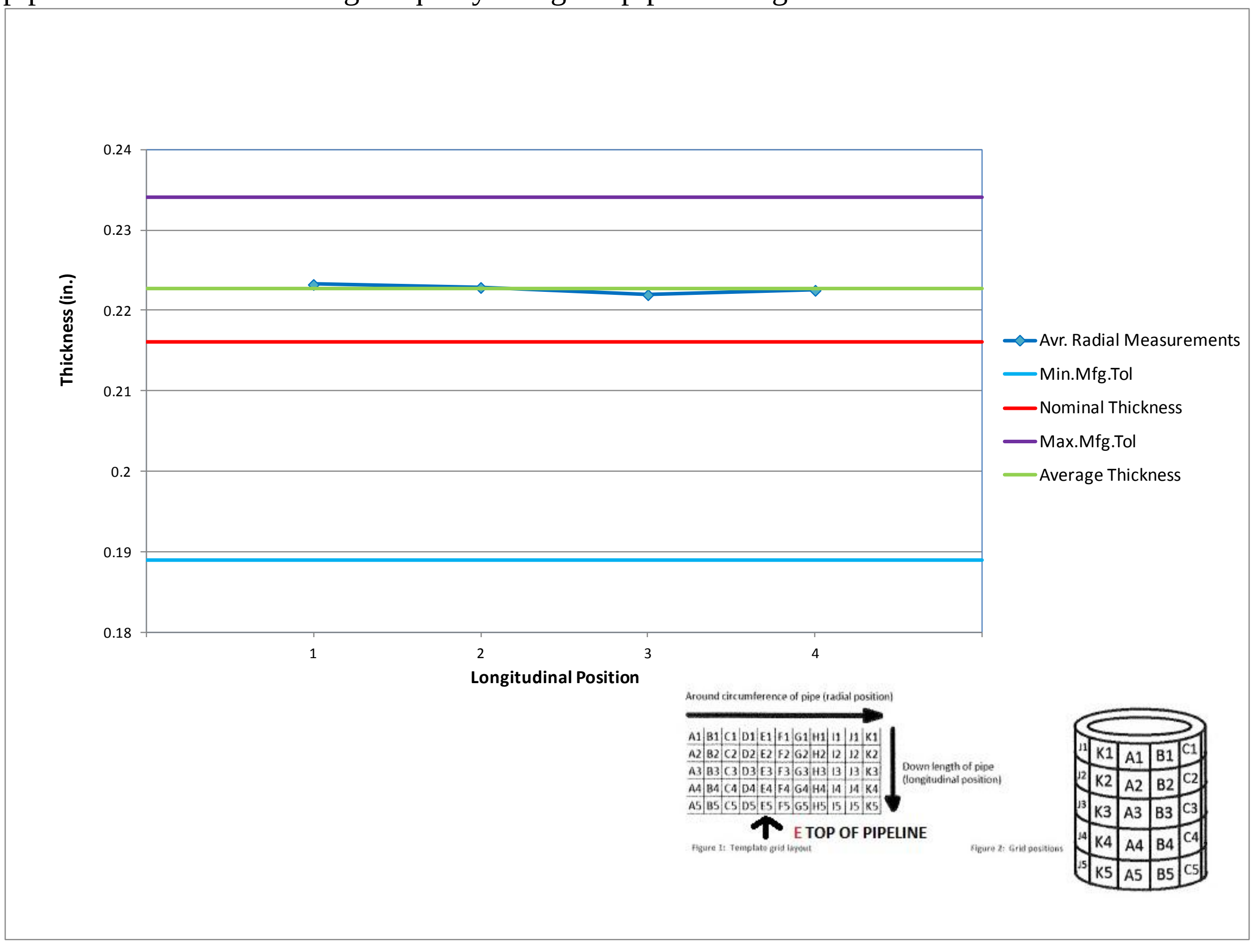

Figure 4. SN-278 primary pipe average radial thickness measurements plotted by longitudinal position.

The average longitudinal thickness measurements were plotted at each radial location in order to determine how the thickness changed along the circumference (Figure 5**).** The average thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted. In this case, the average thickness measurements vary in an oscillatory manner as the circumference location varies. The maximum and minimum of these oscillations are fairly similar and are distributed evenly throughout the circumference. This distinctive pattern does not appear to be due to wear; rather, it is most likely due to the manufacturing process used to produce the pipe.

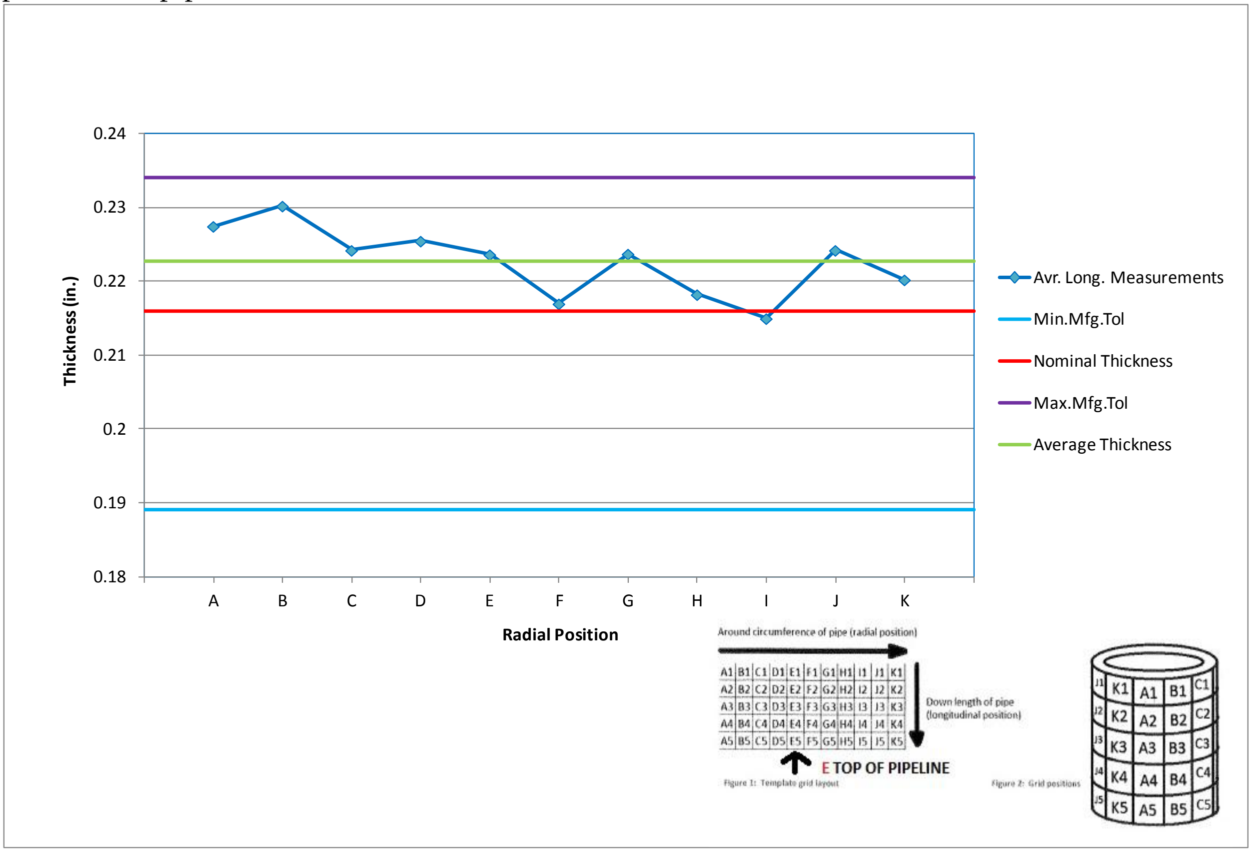

Figure 5. SN-278 primary pipe average longitudinal thickness measurements plotted by radial position.

These graphs demonstrate that the average wall thickness is greater than the nominal wall thickness. This leads to the conclusion that the initial thickness of this pipeline was greater than the nominal thickness. Unfortunately, there is no record of the original thickness of this pipeline prior to installation. Thus the only baseline for comparison of these thickness measurements is the nominal thickness of a 3-in Carbon Steel Schedule 40.[1] As a conclusion, there is no detectable wear in this pipeline and a life expectancy analysis based on the manufacturing nominal wall thickness and present wall thickness is not practical.

[1] For reasons that will become apparent when erosion/corrosion is compared for multiple pipelines differing only by the throughput volume, the use of maximum manufacturer's tolerance to determine the worst case corrosion rate is an unjustified conservatism. Nominal wall thickness is used for all erosion/corrosion rates in this report.

SN-285 Primary Pipe

Line SN-285 Primary is a 3-in Carbon Steel Schedule 40 ASTM A53, Type S, Gr. B pipeline. It was installed in 1974 and transferred 15,500 kgal of supernatant from 241-SY-02A Central Pump Pit to 241-SY-A Valve Pit. Based on retrieved records the transfers were made from 1977 to 2007. Figure 6 shows the 241-SY Tank Farm. The line SN-285 route is highlighted in red for reference. (RPP-RPT-50397 R0, 2013).

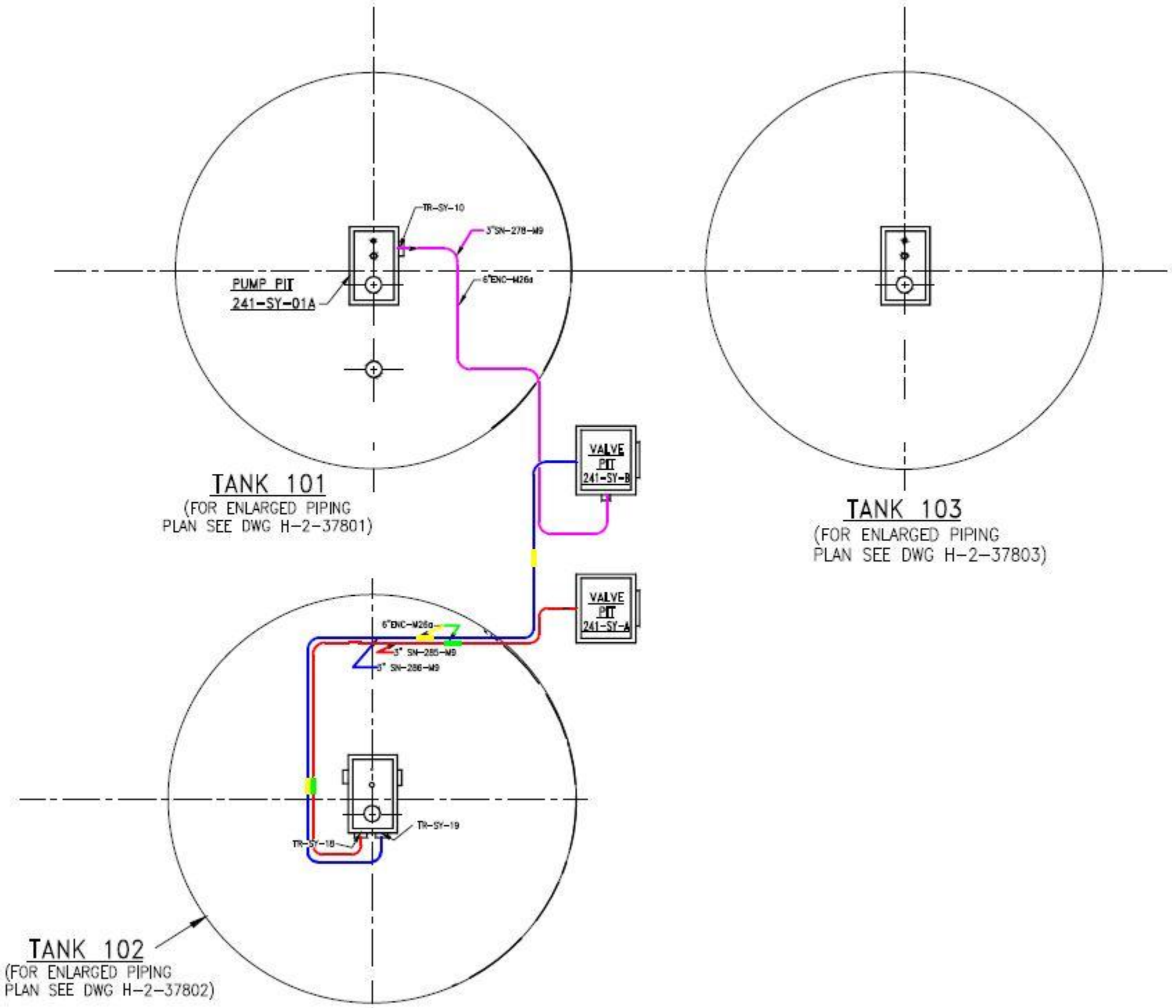

Figure 6. 241-SY Tank Farm Drawing SN-278 Primary (purple), SN-285 Primary (Red) and SN-286 Primary (Blue)

To lower the possibility of contamination, the location where the specimens were cut from was determined based on accessibility and low amount of radiation. Ultrasonic thickness measurements were taken with an Ultrasonic Transducer (Manufacturer: Krautkramer, Model: USN-52L) and a 1-in X 1-in grid pattern on pipe samples using a Mylar plastic template wrapped around the outside diameter (OD) of the part. The grid was labeled alphanumerically with A-K positions running around the circumference and 1-5 positions running horizontally along the length**.** Figure 7 shows the locations of these measurements around the pipe.

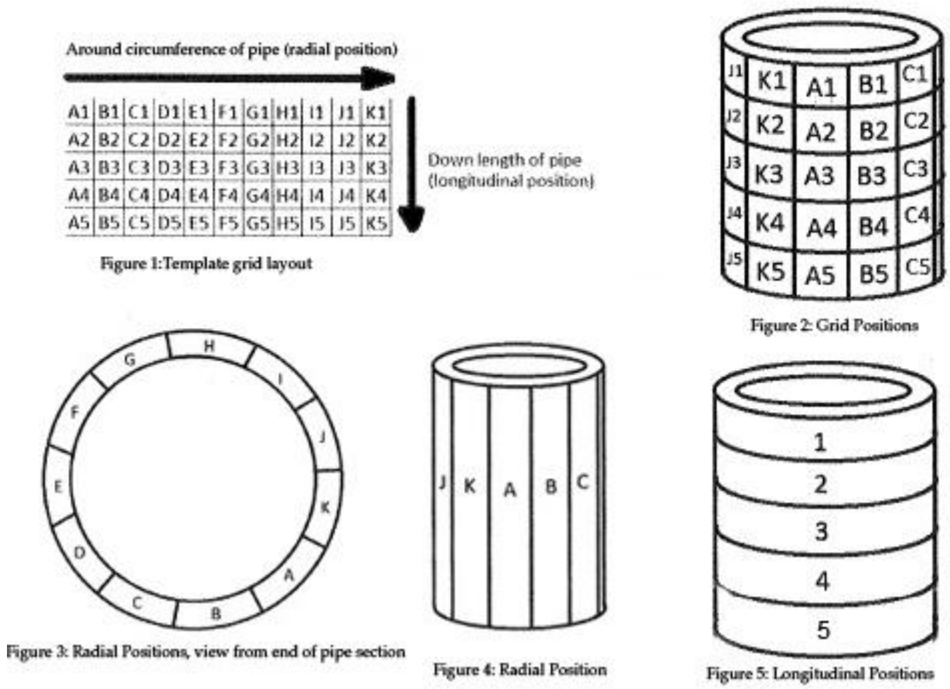

Figure 7. Position of UT thickness measurements around pipes SN-278 Primary, SN-286 Primary, and SN-285 Primary.

The results for the SN-285 pipe section wall thickness measurements are shown in

Table 3. The highlighted green cell does not contain a measurement value because a hole was made at this location in the pipeline in order to inject foam to contain the contamination and also to stabilize the pipe segment for packaging and transportation to the laboratory. When these pipelines were removed, there was no marking indicating the top and bottom of the pipeline. Thus, the lab could not label a letter in the circumference as the top. Since the hole in the pipeline is positioned at letter H for the foam injection, it is assumed that was the top of the pipeline. To evaluate the values obtained from the ultrasonic measurements, a 2-in X 2-in coupon was cut from the H-5 location and measurements were made with a digital caliper. The cells representing coupon measurements are surrounded by a dotted line in

Table 3. This location was selected because it contains one of the thinner areas in the pipe specimen. Before the measurements were conducted, the remaining foam attached to the surface was removed with acetone and water to obtain a greater accuracy of the wall thickness. The digital caliper measured a thickness of 0.210-in which is close to the UT measurement. This

value is close to schedule 40 pipe nominal thickness (0.216-in) which indicates minimal, if any, erosion or corrosion in this section. (LAB-RPT-12-00007 R0, 2012).

Table 3. Ultrasonic Testing Thickness Measurements for SN-285 Primary

	1	2	3	4	5
A	0.219	0.222	0.222	0.226	0.227
B	0.229	0.234	0.234	0.237	0.235
C	0.234	0.239	0.236	0.235	0.234
D	0.226	0.223	0.221	0.221	0.227
E	0.232	0.230	0.227	0.230	0.228
F	0.236	0.233	0.231	0.231	0.231
G	0.231	0.222	0.224	0.222	0.224
H	0.228	0.226	0.231	0.231	
I	0.235	0.234	0.238	0.235	0.232
J	0.219	0.220	0.219	0.219	0.213
K	0.221	0.222	0.227	0.224	0.221

A summary of the SN-285 Primary wall thickness measurement calculations is shown in

Table 4. The average and standard deviation were calculated and the nominal thickness and tolerance are listed. The nominal thickness is based on 3-in Carbon Steel Schedule 40 pipe. The minimum manufacturing tolerance is listed in ASTM A53-1972a Table X4. However, the maximum manufacturing tolerance is not provided in the standard. Because of this, the maximum manufacturing tolerance is determined from ASTM A53-1972a Paragraph 16.2. This paragraph states that the outside diameter should not vary more than ± 1% from the standard specified. The outside nominal diameter is 3.5-in and can be obtained from ASTM A53-1972a Table X1. Using this information, the maximum thickness can be determined by finding 1% of 3.5-in, dividing the obtained value by 2, and adding the value to the nominal thickness. This calculation gives us a maximum manufacturing tolerance of 0.234-in. (ASTM A53-1972a).

Table 4. Summary of SN-285 Primary Thickness Measurements

Overall Average Wall Thickness Measurements	0.228
Overall Standard Deviation	0.006
Average -2 Standard Deviation	0.216
Average +2 Standard Deviation	0.240
Manufacturing Nominal Thickness	0.216
Manufacturing Minimum Tolerance	0.189
Manufacturing Maximum Tolerance	0.234
Note: Nominal thickness based on Carbon Steel, 3-in Diameter, Schedule 40	

To conduct additional analyses and determine how the thickness in the pipe varied along the longitudinal position, the average radial measurements were plotted in each longitudinal position as shown in Figure 8. The average thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted. The average radial measurements along the longitude of the pipe are almost identical, which indicates that the pipeline thickness along its longitude is not changing. This is consistent with the logic that the fluid traveling through the pipeline should be affecting it equally along the pipeline length.

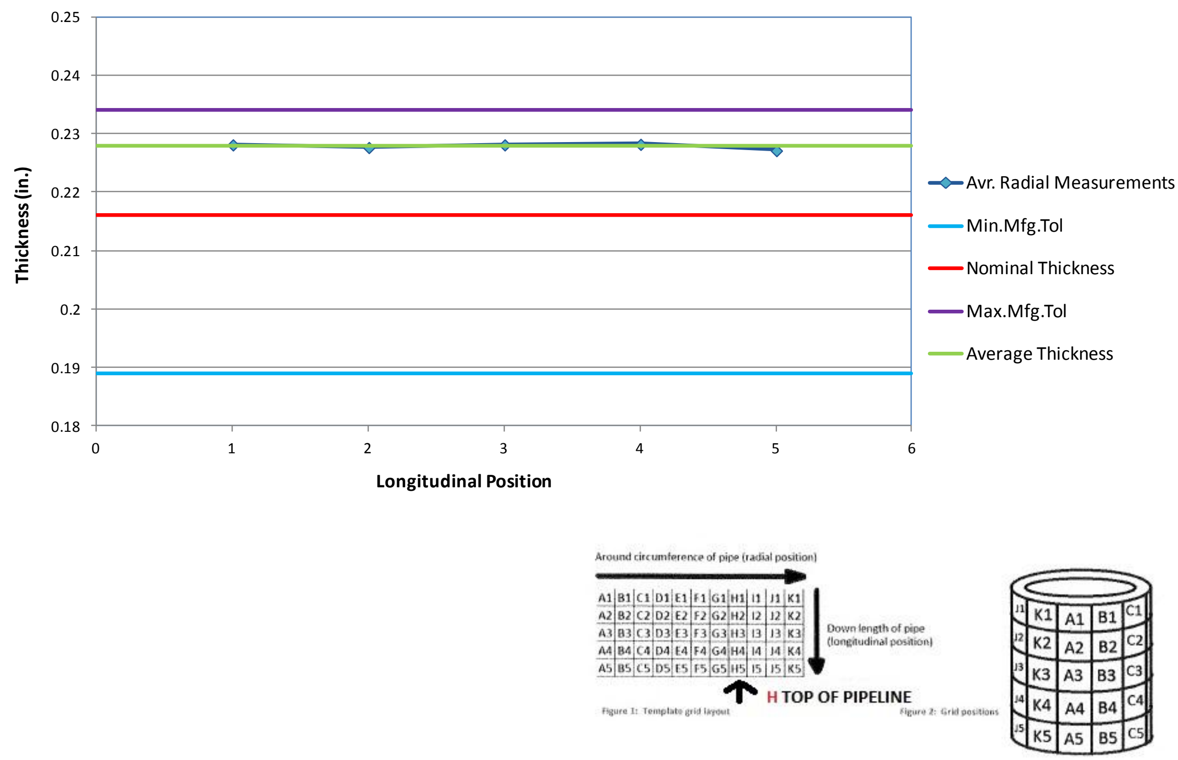

Figure 8. SN-285 Primary pipe average radial thickness measurements plotted by longitudinal position.

The average longitudinal thickness measurements were plotted at each radial location in order to determine how the thickness changed along the circumference (Figure 9). The average thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted. In this case, the average thickness measurements vary in an oscillatory manner as the circumference location varies. The maximum and minimum of these oscillations are fairly similar and are distributed evenly throughout the circumference. This distinctive pattern does not appear to be due to wear; rather, it is most likely due to the manufacturing process used to produce the pipes.

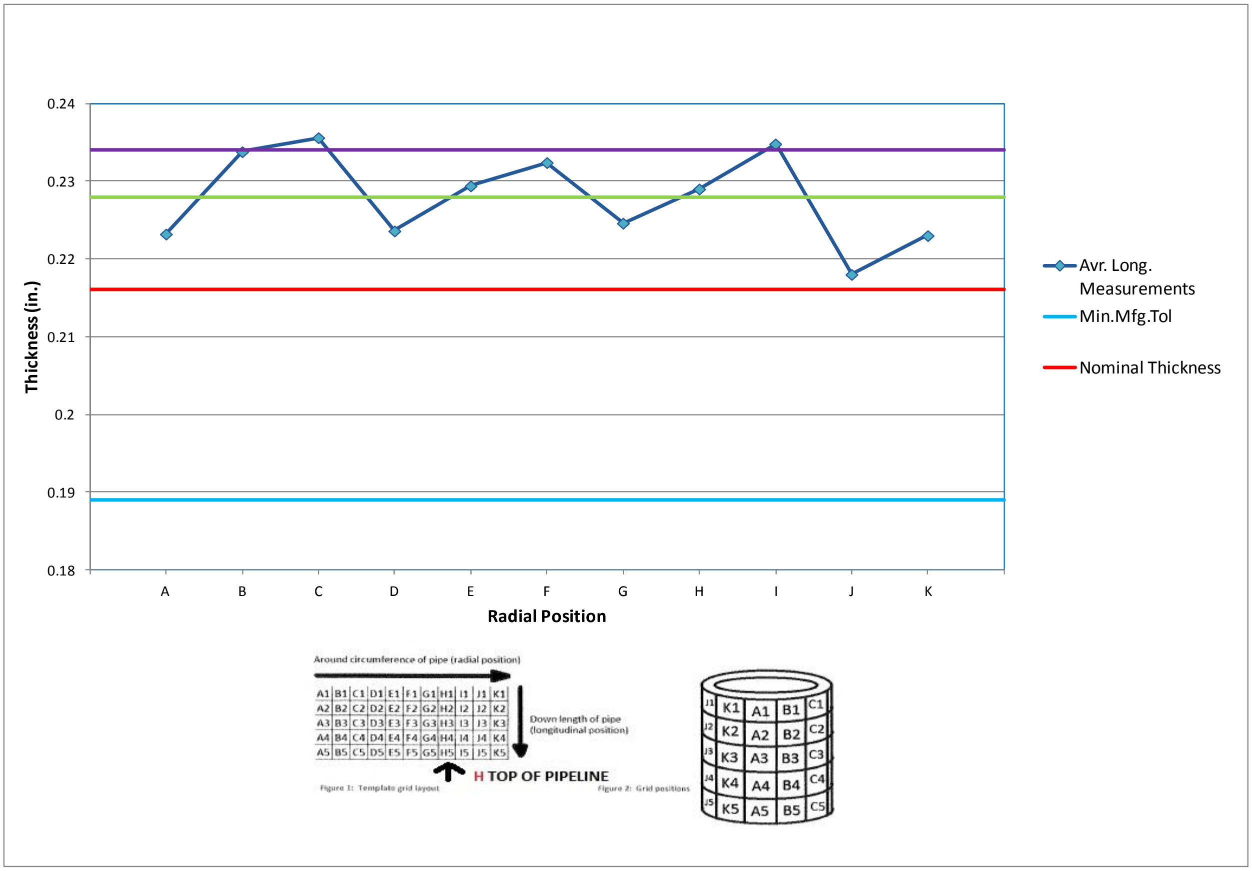

Figure 9. SN-285 primary pipe average longitudinal thickness measurements plotted by radial position.

These graphs demonstrate that the average wall thickness is greater than the nominal wall thickness. This leads to the conclusion that the initial thickness of this pipeline was greater than the nominal thickness. Unfortunately, there is no record of the original thickness of this pipeline prior to installation. Thus, the only baseline for comparison of these thickness measurements is the nominal thickness of a 3-in Carbon Steel Schedule 40 pipe. As a conclusion, there is minimal to no wear detected in this pipeline and a life expectance analysis is not practical.[2]

[2] For reasons that will become apparent, when erosion/corrosion is compared for multiple pipelines differing only by the throughput volume, the use of the maximum manufacturer's tolerance to determine the worst case corrosion rate is an unjustified conservatism. Nominal wall thickness is used for all erosion/corrosion rates in this report.

SN-286 Primary Pipe

Line SN-286 Primary is a 3-in Carbon Steel Schedule 40 ASTM A53, Type S, Gr. B pipeline. It was installed in 1974 and transferred 28,000 kgal of supernatant from 241-SY-02A Central Pump Pit to 241-SY-B Valve Pit. Based on retrieved records the transfers were made from 1977 to 2003. Figure 10 shows the 241-SY Tank Farm. The line SN-286 route is highlighted in blue for reference. (RPP-RPT-50397 R0, 2013).

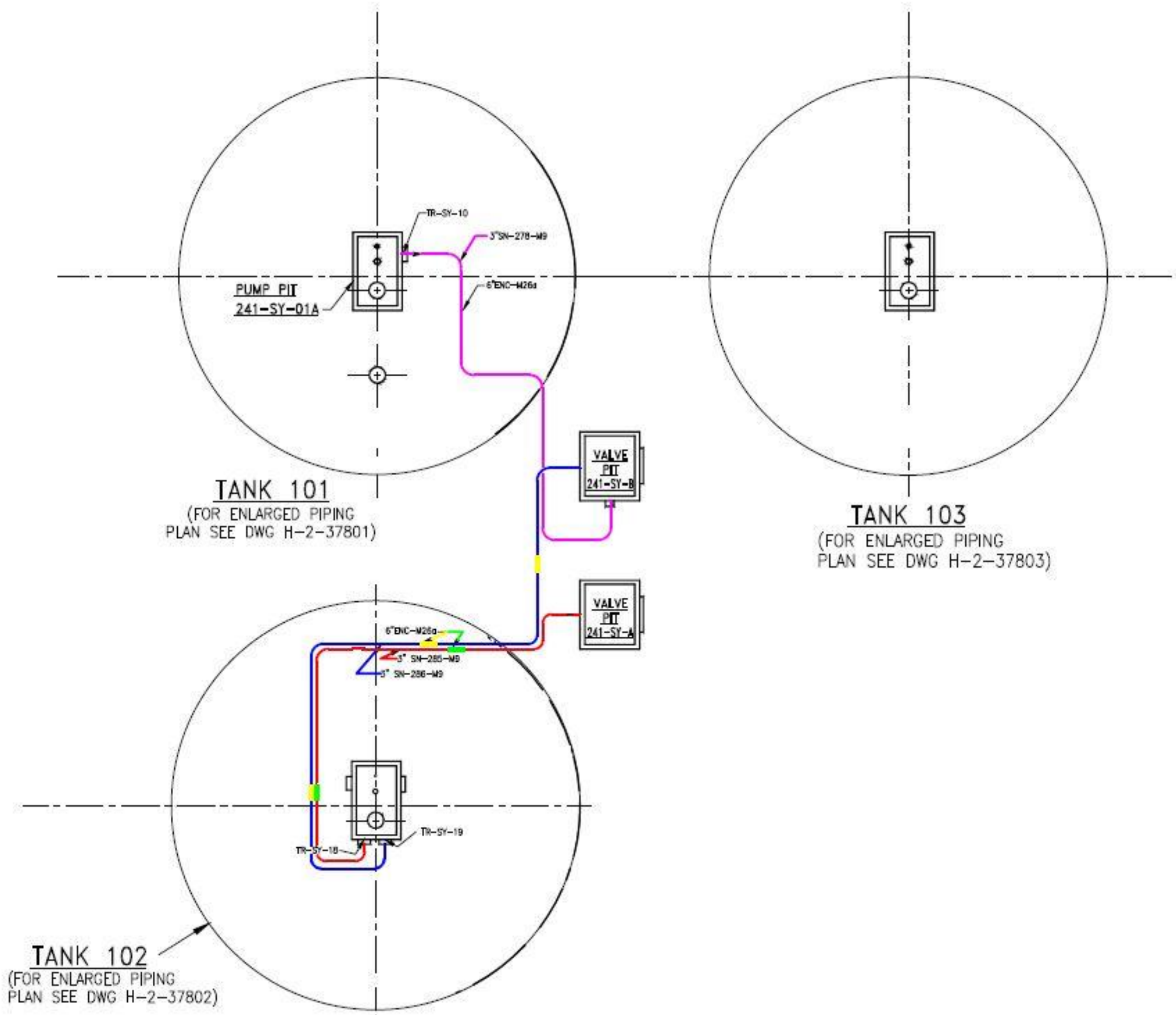

Figure 10. 241-SY Tank Farm Drawing SN-278 Primary (purple) SN-285 Primary (Red) and SN-286 Primary (Blue)

To lower the possibility of contamination, the location where the specimens were cut from was determined based on accessibility and low amount of radiation. Ultrasonic thickness measurements were taken with an Ultrasonic Transducer (Manufacturer: Krautkramer, Model: USN-52L) and a 1-in X 1-in grid pattern on pipe samples using a Mylar plastic template wrapped around the outside diameter (OD) of the part. The grid was labeled alphanumerically with A-K positions running around the circumference and 1-6 positions running horizontally along the length. Figure 11 shows the locations of these measurements around the pipe.

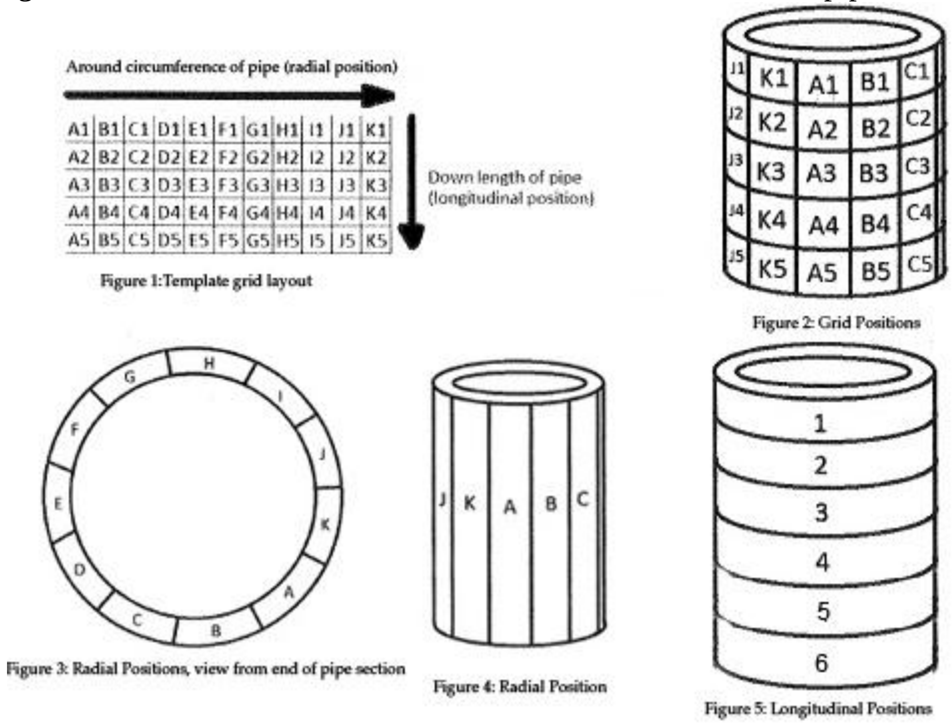

Figure 11. Position of UT thickness measurements around pipes SN-278 Primary, SN-286 Primary, and SN-285 Primary.

The results for the SN-286 Primary pipe section wall thickness measurements are shown in Table 5. When these pipelines were removed, there was no marking indicating the top and bottom of the pipeline. This specimen did not contain a hole that could be used for orientation like SN-278 Primary. Thus, the lab could not label a letter in the circumference as the top. To evaluate the values obtained from the ultrasonic measurements, a 2-in X 2-in coupon was cut from the H-3 location and measurements were made with a digital caliper. The cells representing coupon measurements are surrounded by a dotted line in

Table 5. This location was selected because it contains one of the thinner areas in the pipe specimen. Before the measurements were conducted, the remaining foam attached to the surface was removed with acetone and water to obtain a greater accuracy of the wall thickness. The digital caliper measured a thickness of 0.233-in which corresponds with the UT measurement. This value is close to schedule 40 pipe nominal thickness (0.216-in) which indicates minimal, if any, erosion or corrosion in this section. (LAB-RPT-12-00007 R0, 2012).

Table 5. Ultrasonic Testing Thickness Measurements for SN-286 Primary

	1	2	3	4	5	6
A	0.241	0.237	0.238	0.244	0.234	0.233
B	0.230	0.230	0.228	0.230	0.226	0.228
C	0.240	0.234	0.238	0.234	0.237	0.232
D	0.237	0.236	0.238	0.235	0.236	0.235
E	0.231	0.233	0.231	0.229	0.228	0.225
F	0.244	0.245	0.245	0.243	0.243	0.243
G	0.240	0.240	0.242	0.240	0.237	0.239
H	0.228	0.230	0.225	0.231	0.228	0.236
I	0.241	0.240	0.236	0.237	0.234	0.234
J	0.246	0.241	0.234	0.234	0.232	0.240
K	0.241	0.241	0.232	0.238	0.240	0.239

A summary of the SN-286 Primary wall thickness measurement calculations is shown in Table 6. The average and standard deviation were calculated and the nominal thickness and tolerance are listed. The nominal thickness is based on 3-in Carbon Steel Schedule 40 pipe. The minimum manufacturing tolerance is listed in ASTM A53-1972a Table X4. However, the maximum manufacturing tolerance is not provided in the standard. Because of this, the maximum manufacturing tolerance is determined from ASTM A53-1972a Paragraph 16.2. This paragraph states that the outside diameter should not vary more than $\pm$ 1% from the standard specified. The outside nominal diameter is 3.5-in and can be obtained from ASTM A53-1972a Table X1. Using this information, the maximum thickness can be determined by finding 1% of 3.5-in, dividing the obtained value by 2, and adding the value to the nominal thickness. This calculation gives us a maximum manufacturing tolerance of 0.234 in. (ASTM A53-1972a).

Table 6. Summary of SN-286 Primary Thickness Measurements

Overall Average Wall Thickness Measurement	0.236
Overall Standard Deviation	0.005
Average -2 Standard Deviation	0.225
Average +2 Standard Deviation	0.247
Manufacturing Nominal Thickness	0.216
Manufacturing Minimum Tolerance	0.189
Manufacturing Maximum Tolerance	0.234
Note: Nominal thickness based on Carbon Steel, 3-in Diameter, Schedule 40	

To conduct additional analyses and determine how the thickness in the pipe varied along the longitudinal position, the average radial measurements were plotted in each longitudinal position as shown in Figure 12. The average wall thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted**.** The average radial measurements along the longitude of the pipe are almost identical, which indicates that the pipeline thickness along its longitude is not changing. This is consistent with the logic that the fluid traveling through the pipeline should be affecting it equally along the pipeline length.

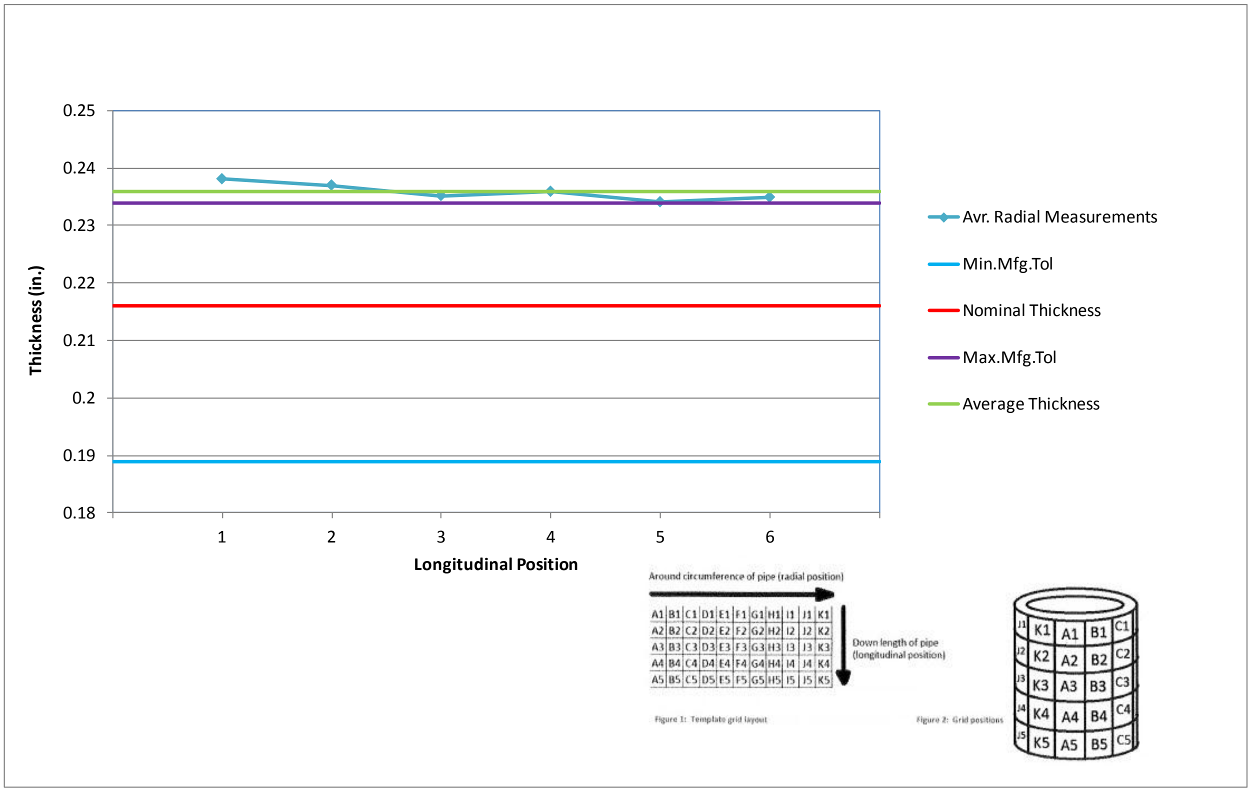

Figure 12. SN-286 Primary pipe average radial thickness measurements plotted by longitudinal position.

The average longitudinal thickness measurements were plotted at each radial location in order to determine how the thickness changed along the circumference **(**Figure 13**)**. The average thickness, nominal thickness, and the manufacturing minimum and maximum tolerance were also plotted. In this case, the average thickness measurements vary in an oscillatory manner as the circumference location varies. The maximum and minimum of these oscillations are fairly similar and are distributed evenly throughout the circumference. This distinctive pattern does not appear to be due to wear; rather, it is most likely due to the manufacturing process used to produce the pipe.

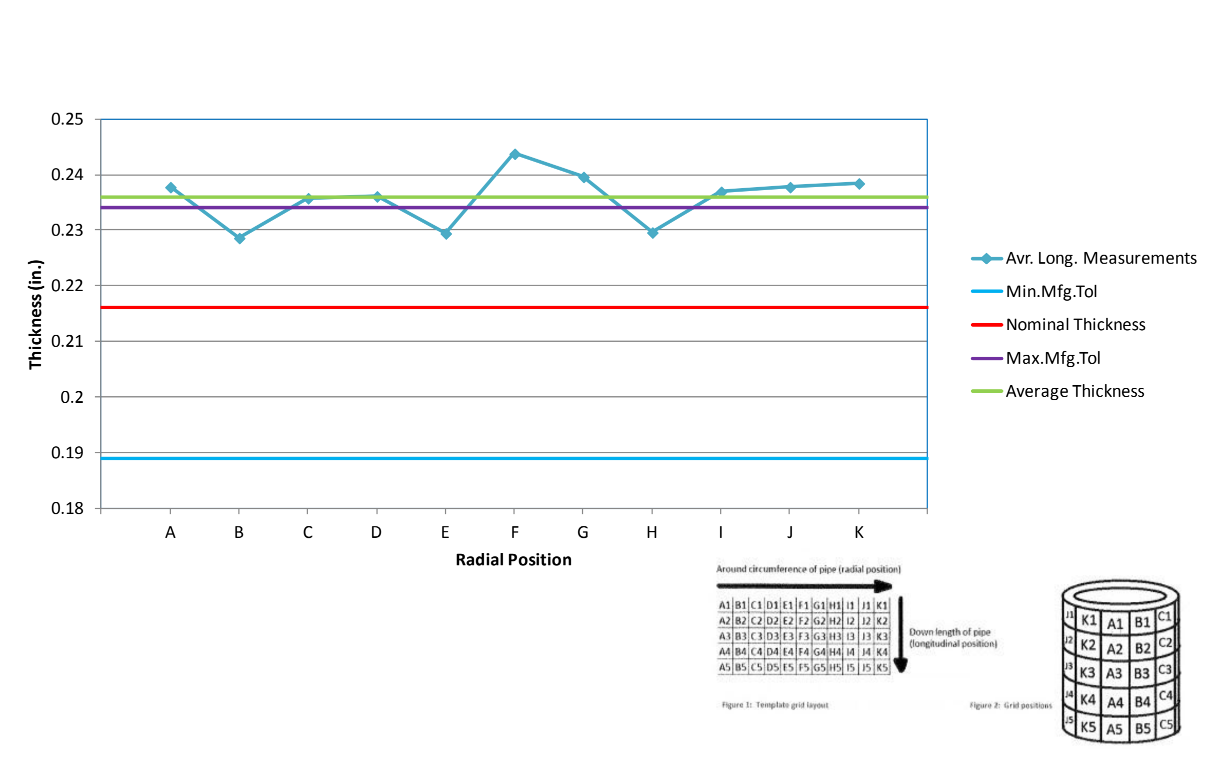

Figure 13. SN-286 Primary pipe average longitudinal thickness measurements plotted by radial position.

These graphs demonstrate that the average wall thickness is greater than the nominal wall thickness. This leads to the conclusion that the initial thickness of this pipeline was greater than the nominal thickness. Unfortunately, there is no record of the original thickness of this pipeline prior to installation. Thus, the only baseline for comparison of these thickness measurements is the nominal thickness of a 3-in Carbon Steel Schedule 40 pipe. As a conclusion, there is minimal to no wear detected in this pipeline and a life expectance analysis is not practical.[3]

[3] For reasons that will become apparent, when erosion/corrosion is compared for multiple pipelines differing only by the throughput volume, the use of the maximum manufacturer's tolerance to determine the worst case corrosion rate is an unjustified conservatism. Nominal wall thickness is used for all erosion/corrosion rates in this report.

SY-Farm Primary Pipelines Comparison

Lines SN-278 Primary, SN-285 Primary, and SN-286 Primary are made of the same material, installed the same year, and performed the same service. However, the volume of supernatant that they transferred was 213 kgal, 15,500 kgal, and 28,000 kgal, respectively. Line SN-278 Primary transferred a significantly lower amount of waste compared to lines SN-285 Primary and SN-286 Primary. As a result, lines SN-285 Primary and SN-286 Primary can be benchmarked against line SN-278 Primary.

The average wall thickness of the SN-278 Primary pipe is plotted in Figure 14. Also, SN-285 Primary average longitudinal wall thickness measurements, average wall thickness, manufacturing nominal wall thickness, average wall thickness of pipeline SN-278 Primary, and manufacturing minimum and maximum tolerance were plotted. The graph shows the average thickness of the SN-278 Primary is lower than the average thickness of the SN-285 Primary.

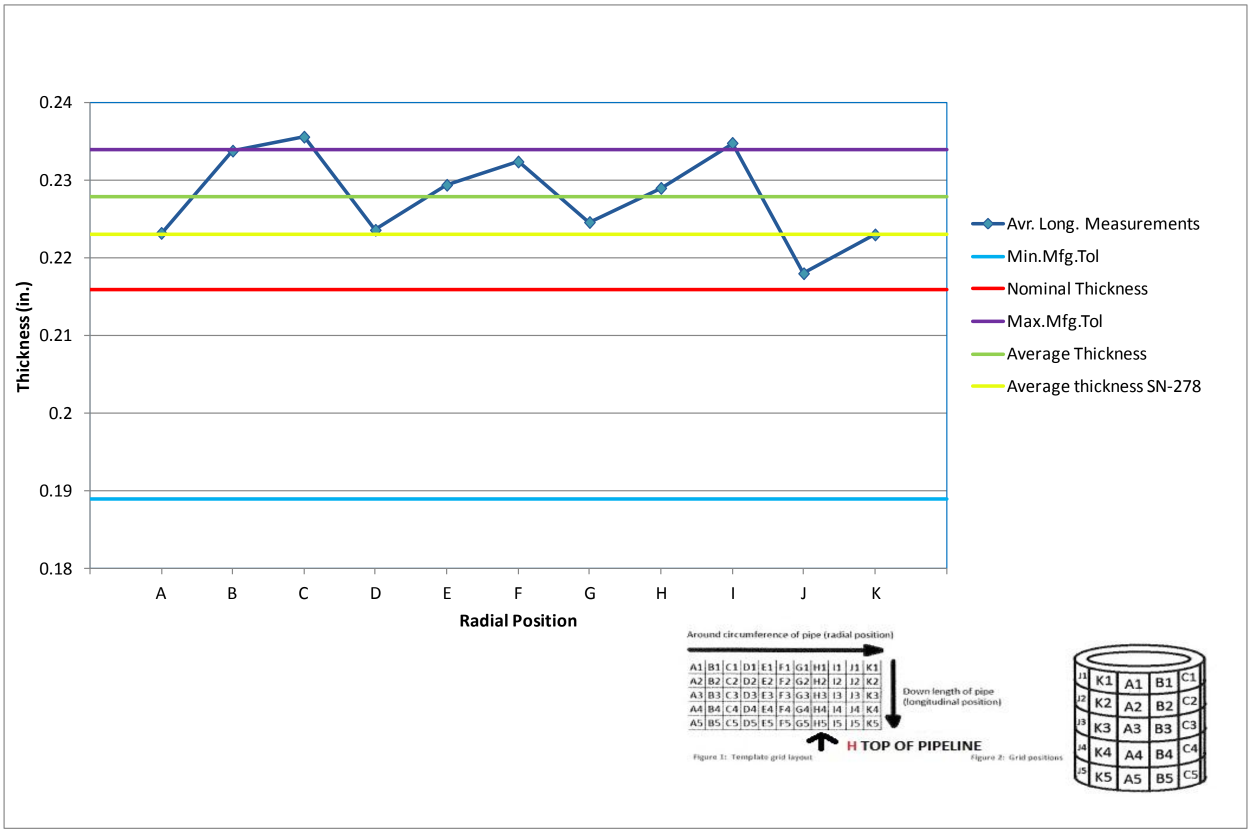

Figure 14. SN-285 Primary pipe average longitudinal thickness measurements grouped by radial position. (Including SN-278 average thickness)

Line SN-286 Primary was also compared to SN-278 Primary and the results were plotted in Figure 15. Also, SN-286 Primary average longitudinal wall thickness measurements, average wall thickness, manufacturing nominal wall thickness, average wall thickness of pipeline SN-278 Primary, and manufacturing minimum and maximum tolerance were plotted. The average longitudinal thickness measurements for SN-286 Primary, average thickness, nominal thickness, average thickness of pipeline SN-278 Primary, minimum and maximum manufacturing tolerance were also plotted. This graph shows the same pattern as Figure 14. The average thickness of the SN-278 Primary is below the average thickness of the SN-286 Primary. It is apparent that the significantly higher amount of waste transferred through pipelines SN-285 Primary and SN-286 Primary did not reduce their wall thicknesses when compared to the SN-278 Primary wall thickness.

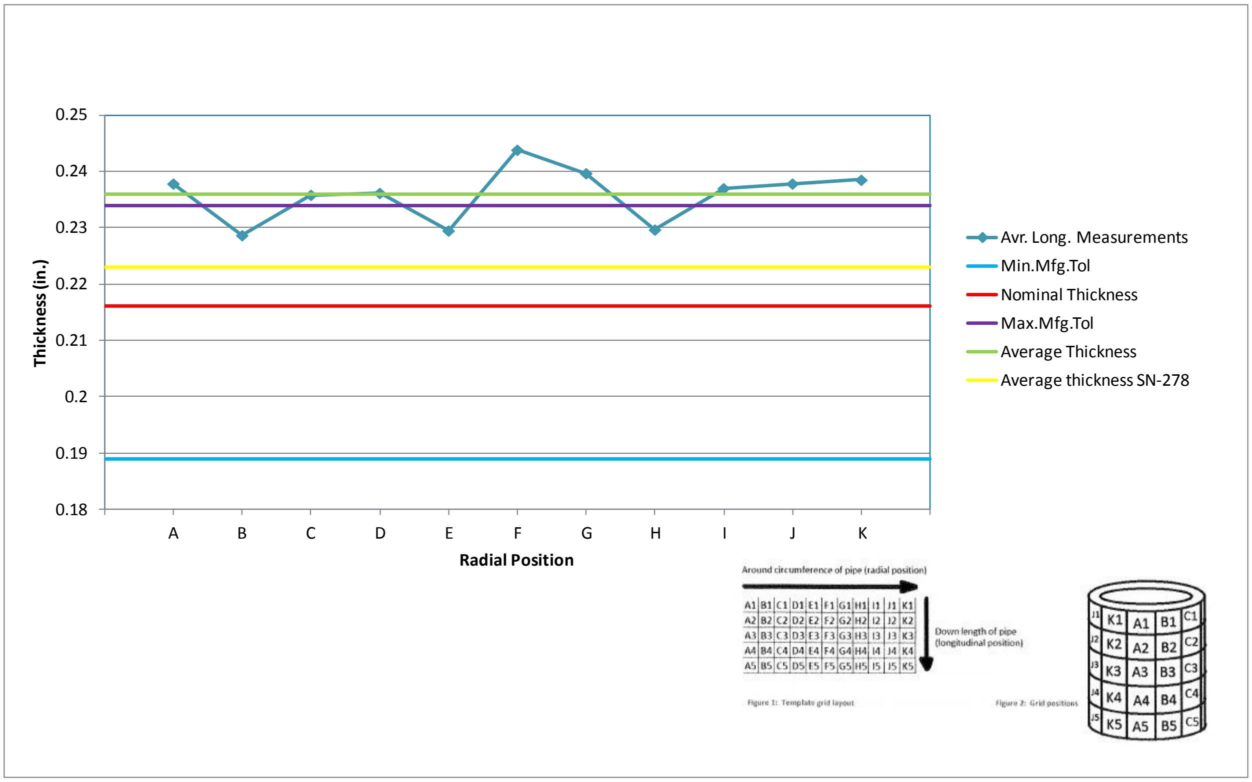

Figure 15. SN-286 Primary pipe average longitudinal thickness measurements grouped by radial position. (Including SN-278 average thickness)

The values of the volume transferred by each pipeline and their average thickness are listed in Table 7.

Table 7. Average Thickness and Flow Volume of SY Pipelines

Pipeline	Average Thickness (in)	Volume (kgal)
SN-278	0.223	212
SN-285	0.228	15453
SN-286	0.236	28009

The wall thicknesses for the three primary pipelines were also plotted against the amount of volume transferred as shown in Figure 16. Contrary to expectations, Figure 16 indicates that the wall thickness is increasing as the volume of waste transferred increases.

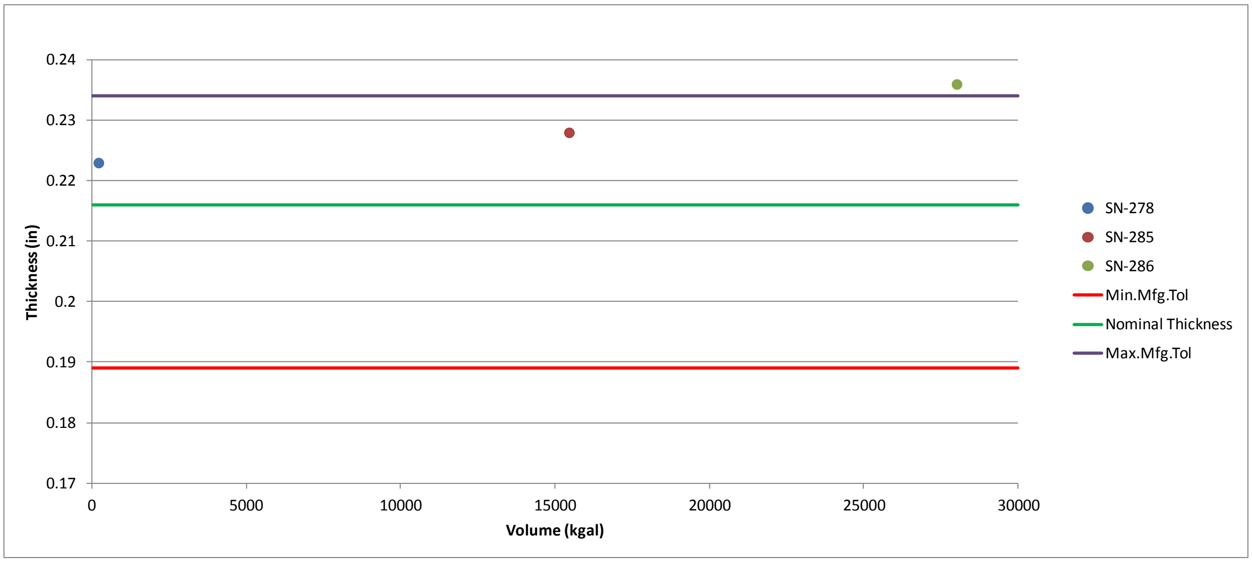

Figure 16. Average thickness of SY-Farm primary pipelines vs. volume transferred.

The difference in volumes transferred for the three pipelines, and the amount of wear detected are listed in Table 8.

Table 8. Wear Analysis for Volumes Transferred

	Volume Difference (kgal)	Detectable Wear (in/kgal)
SN-286 vs. SN-285	12556	None
SN-285 vs. SN-278	15241	None
SN-286 vs. SN-278	27797	None

There was no wear detected in the pipelines when SN-286 Primary and SN-285 Primary were benchmarked against SN-278 Primary. The difference in waste transferred through pipeline SN-278 Primary (212 kgal) and pipeline SN-285 pipeline (15,453 kgal) is 15,241 kgal. Nevertheless, there is no wear detected in pipeline SN-285 Primary. Additionally, the difference in waste transferred through pipeline SN-278 Primary (212 kgal) and pipeline SN-286 Primary (28,009 kgal) is 27,797 kgal. Despite the fact that the difference in waste transferred is very large, there is still no wear detected. The same results occur when taking the difference in volume transferred between the pipelines SN-285 Primary and SN-286 Primary. Assuming that our data is representative of the rest of the length of the pipeline and noticing the similarities of the results for each pipeline, we can deduce that the wear caused by the waste transferred was very minimal or no wear.

SN-285 Secondary Pipe (Encasement)

Line SN-285 Secondary is a 6-in Carbon Steel Schedule 40 ASTM A106, Gr. B or A pipe. It was installed in 1974 and exhumed for inspection in 2010. It was connected from 241-SY-02A Central Pump Pit to 241-SY-A Valve Pit. This pipeline is the encasement of the SN-285 Primary line and collects leakage in case SN-285 Primary fails. Waste was not transferred through this pipeline; however, it was in contact with the soil. It is cathodically protected and covered with sprayed polyurethane insulation. Figure 17 shows the 241-SY Tank Farm. Line SN-285 Secondary is highlighted in green along the red line which represents SN-285 Primary. (RPP-27097 R1, 2007).

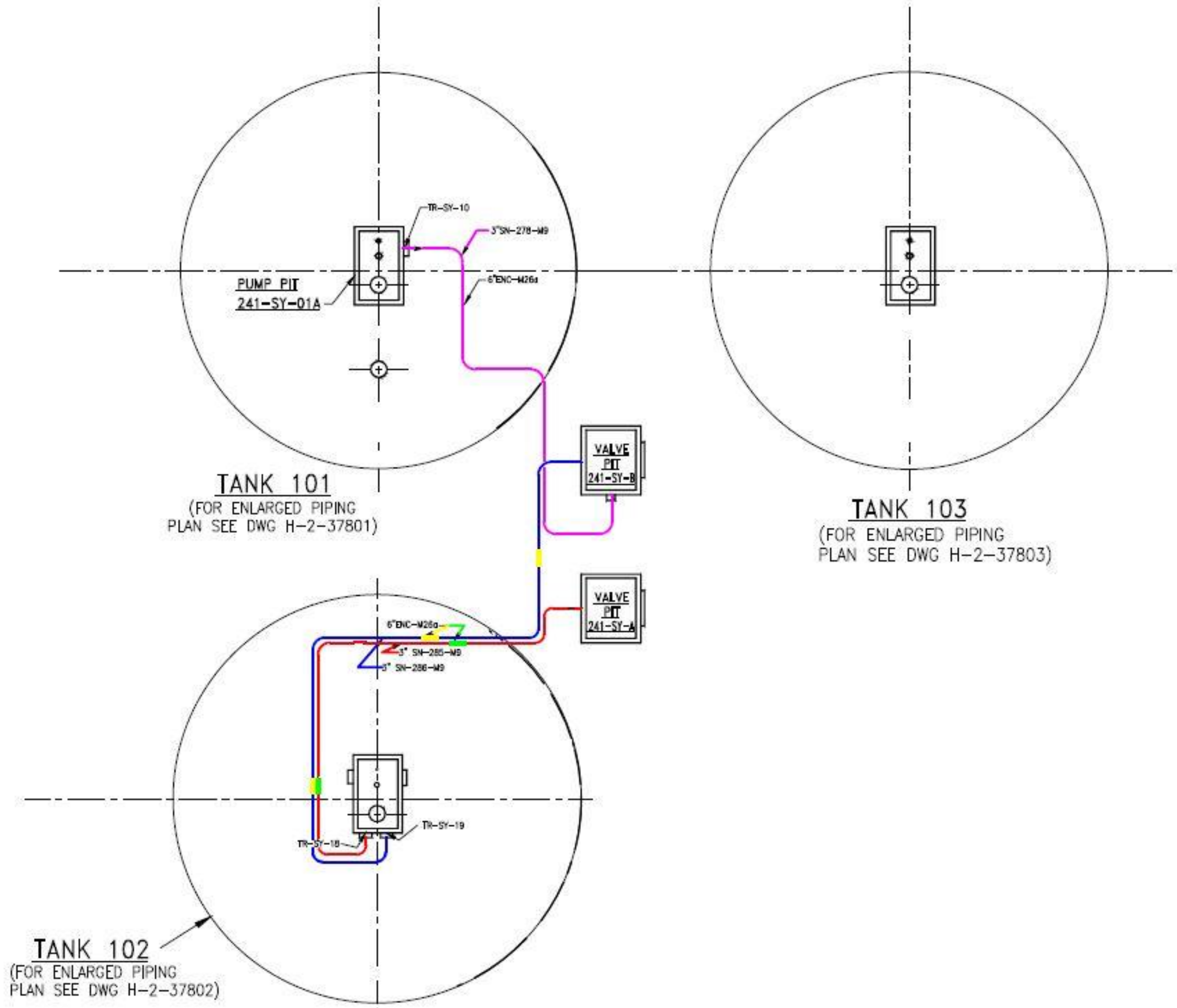

Figure 17. 241-SY Tank Farm Drawing SN-285 encasement (Green), SN-286 encasement (Yellow)

In 2011, a specimen of pipe SN-285 Secondary was received at the 222-S Analytical Laboratory. To lower the possibility of contamination, the location where the specimens were cut from was determined based on accessibility and low amount of radiation. Using a digital caliper, diameter measurements were taken at three radial positions along just one longitudinal position. These measurements were taken approximately 120° from each other. Also, three coupons were cut along the circumference in one longitudinal position. One coupon was cut from the top, another one from the side, and the third was cut from the bottom of the pipe. After the coupons were extracted, the corrosion was removed from the pipe. The process for the corrosion removal involved immersing the coupons in an ammonium citrate solution heated to ~80°C with subsequent scrubbings to remove the corrosion. The immersion and scrubbings were repeated until the corrosion was completely removed. To prevent loss of surface material that was not corroded, this process was repeated until the percent weight loss after the previous cleaning fell below 10% of the cumulative weight loss. After this cleaning process was completed, the coupons were placed in an oven to prevent further corrosion from forming on the surface. Wall thickness measurements were then taken from the coupons with digital calipers. It should be noted that pits due to the corrosion were visible on the surface after the cleaning. Microscopic photographs of the cross-section of the bottom coupon were used to measure the depth of the pits which was found to have a maximum value of 5.236E-03 in. The depths of the residual pits were very small in comparison the average wall thickness (0.268-inch), and were therefore not considered in this analysis.

In order to determine the wall thickness after corrosion was removed, thickness measurements were taken using a digital caliper. Three measurements were taken for each coupon to calculate an average thickness that represents more accurately the overall thickness of the coupon. (LAB-RPT-11-00006 R0, 2011).

The thickness measurements, size of coupons, and thickness averages are listed in Table 9. (LAB-RPT-11-00006 R0, 2011).

Table 9. Thickness and Dimensions of Coupon Cut from SN-285 Secondary Pipe Section

Coupon	Thickness 1	Thickness 2	Thickness 3	Length (in)	Width (in)	Thickness Averages
Top	0.263	0.261	0.264	3.769	1.466	0.263
Bottom	0.266	0.265	0.264	4.073	1.505	0.265
Side	0.276	0.278	0.276	4.186	1.783	0.277

A summary of the SN-285 Secondary wall thickness measurement calculations is shown in Table 10. The average and standard deviation were calculated and the nominal thickness and tolerance are listed. The nominal thickness is based on 6-in Carbon Steel Schedule 40 pipe. The minimum manufacturing tolerance is listed in ASTM A106-1972a Table A2. However, the maximum manufacturing tolerance is not provided in the report. Because of this, the maximum manufacturing tolerance is determined from ASTM A106-1972a Table 3. This table specifies the variation in outside diameter of the pipe. The maximum permissible variation of the nominal diameter is + 0.062-in. We use this information to obtain the maximum tolerance thickness in the pipe by dividing 0.062-in by 2 and adding it to the nominal wall thickness of 0.280-in. Since adding a value to a diameter gives the total increase in diameter, we can divide it by 2 to determine the total increase in radius. If the inner diameter is kept constant, adding the value obtained to the nominal thickness will give a maximum manufacturing tolerance of 0.31-in. (ASTM A106-1972a).

Table 10. Summary of SN-285 Secondary Thickness Measurements

Overall Average Wall Thickness Measurement	0.268
Overall Standard Deviation	0.007
Average -2 Standard Deviation	0.255
Average +2 Standard Deviation	0.281
Manufacturing Nominal Thickness	0.280
Manufacturing Minimum Tolerance	0.245
Manufacturing Maximum Tolerance	0.311
Note: Nominal thickness based on Carbon Steel, 6-in Diameter, (ANSI Schedule 40)	

To conduct additional analyses and determine how the thickness in the pipe varied along the radial position, the wall thickness vs. radial position was plotted in Figure 18. Similarly, the average thickness, nominal thickness, manufacturing minimum and maximum tolerance were also plotted. The values for top coupon, bottom coupon and side coupon never intersect each other and they increase from the top coupon to side coupon. Also, the difference between the points in each position shows how far or how near the thicknesses from each trial were. In the case of the top position, the three trial measurements lie very close to each other (0.003-in is the largest difference). This verifies the accuracy in the measurements as well as consistency in wall thickness in the top position, which is important since it is where the thinnest wall measurement is detected. Overall, there was no major difference between the points in the other two radial positions.

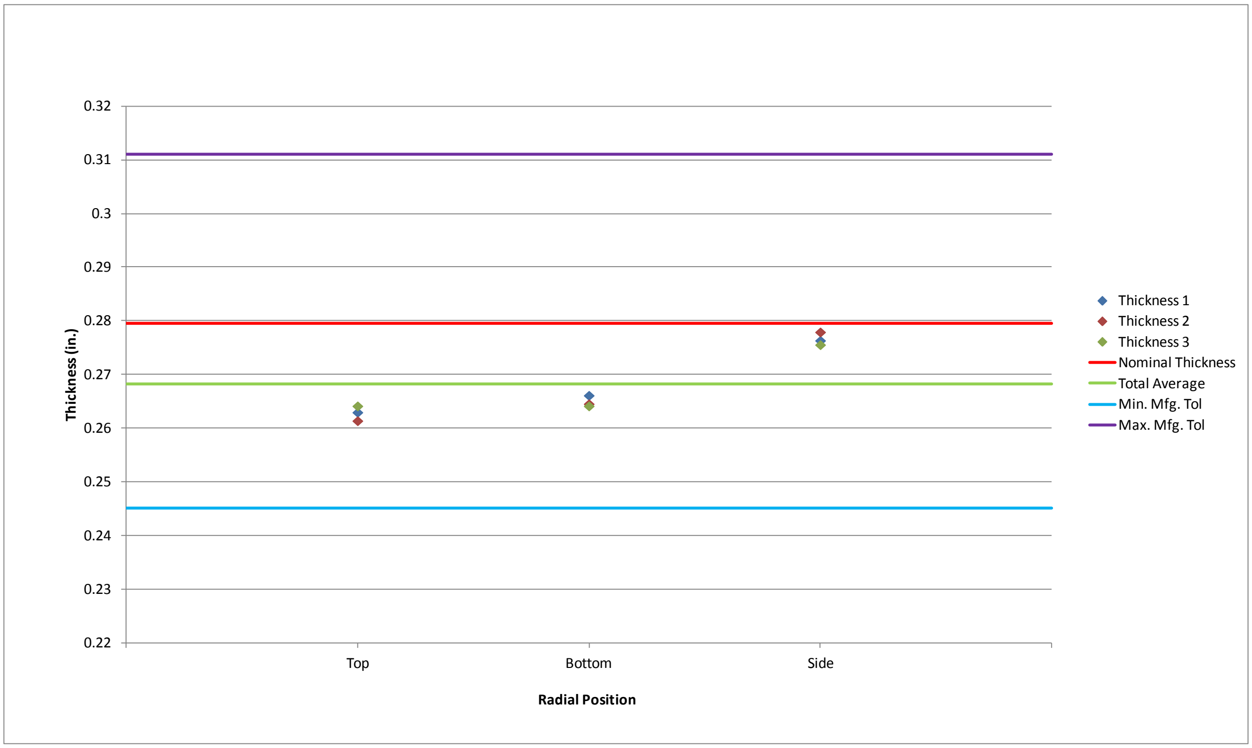

Figure 18. SN-285 Secondary pipe longitudinal thickness measurements grouped by radial position.

Lastly, the average radial thickness measurements grouped by radial position were graphed (Figure 19). Likewise, the average thickness, nominal thickness, minimum and maximum manufacturing tolerance were also plotted. The total average is below the nominal thickness by 0.011-in. With these results, it is apparent that there was detectable wall loss in this pipeline and the corrosion rate should be determined. At this moment, there is not an accurate method to separate the wall loss due to the manufacturing process and the wall loss due to corrosion. Consequently, nominal thickness and total average are used to compare the wall thickness loss and calculate an estimate of the loss rate.

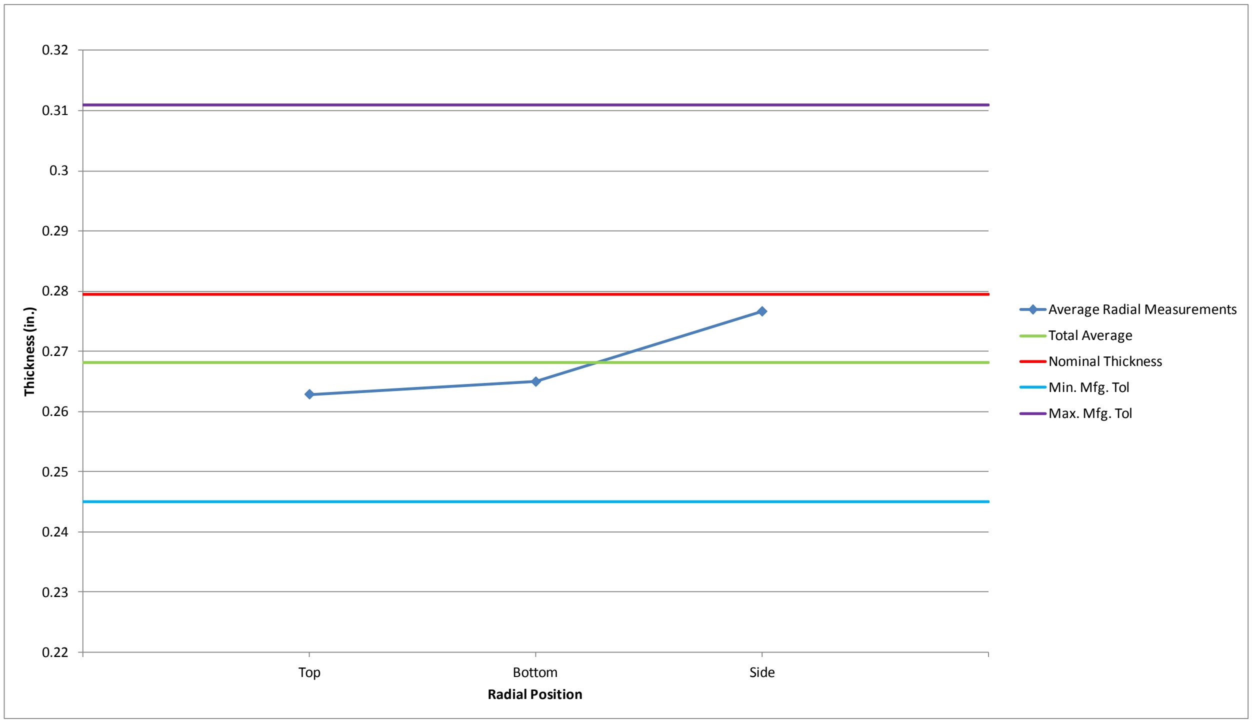

Figure 19. SN-285 Secondary pipe average radial thickness measurements grouped by radial position

To determine the allowable corrosion rate, the minimum thickness required for the pipeline to maintain its required design pressure of 60 psig needs to be calculated. The minimum thickness for SN-285 pipeline is calculated using ASME B31.3 Section 304.1.2 Equation 3a which specifies the minimum wall thickness required for a straight pipe under internal pressure.[4]

$$t = \frac{PD}{2(SEW + PY)} \tag{3a}$$

Table 11 lists all the variables, their description, reference report, and minimum thickness needed for the pipeline to safely operate.

[4] The minimum thickness required is in ASME B31.3 Section 304.1.1 and the formula account for a c value which is mechanical allowances plus corrosion and erosion allowances. Since we are interested in the minimum thickness after the corrosion and erosion have occurred, we do not use this equation. Instead we use the equation in ASME B31.3 Section 304.1.2.

Table 11. Minimum Thickness Equation and Variables for Pipeline to Operate Safely (Carbon Steel, 6-in Diameter, (ANSI Schedule 40)

P (Internal Design Gauge Pressure) (psi)	60	B-101-C3 R01, 1974, Pg. 42, Pipe Code M-26
D (Outside Diameter of pipe) (in)	6.630	ASTM A106-1972a
S (Stress value for materials) (psi)	16000	ASME B31.3 Table A-1
E (Quality factor)	1	ASME B31.3, Table A-1A or A-1B
Y (Coefficient)	0.4	ASME B31.3 Table 304. 1.1
W (Weld joint strength reduction factor)	1	ASME B31.3 Paragraph 302.3.5 (e)
t (minimum thickness)= PD/2*(SEW+PY) (in) t (minimum thickness)= 0.012 (in)		

Table 12 provides the nominal thickness with the corresponding year when the pipeline was installed, the average wall thickness measured in 2010, and the minimum thickness required for the pipeline to continue operating. With this data, a simple linear relationship can be determined for the life expectancy of the pipeline. As shown in the table, the pipeline life expectancy far exceeds the projected life of the Waste Treatment and Immobilization Plant (WTP). Based on this analysis, it is very unlikely that other cathodically protected carbon steel encasements with similar designs and service performance will require replacement during the WTP's projected lifetime.

Table 12. List of Thickness with Corresponding Year and Wear Rate Equation (SN-285 Secondary)

	Year	Thickness
Nominal Thickness	1974	0.280
Average Thickness	2010	0.268
Minimum Thickness	2820	0.012
Corrosion Rate equation assuming linear relationship	y=-0.000315933x+0.903179257	
Corrosion Rate (inch/year)	-3.16E-04	

Figure 20 shows the wear rate for the SN-285 Secondary Pipeline with the experimental values and the wear rate equation graphed.

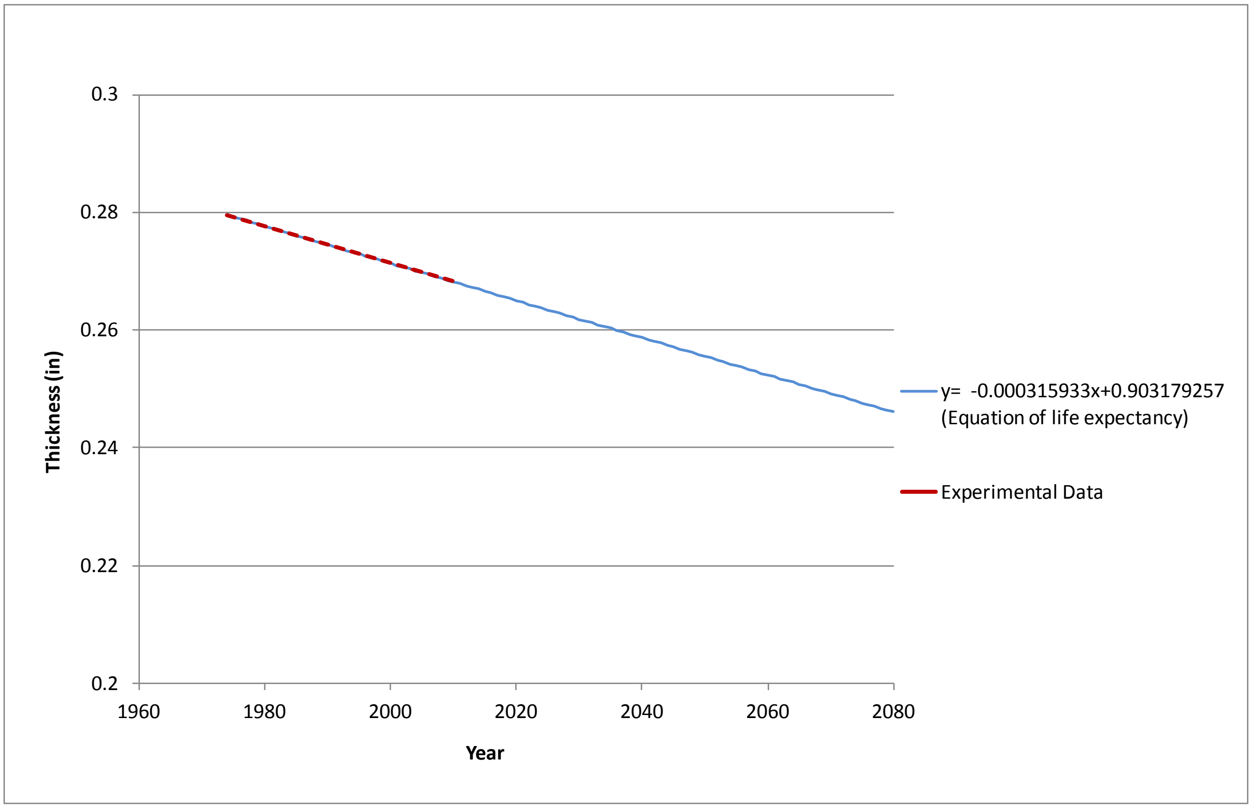

Figure 20. SN-285 Secondary pipeline life expectancy.

After analyzing the data collected, it has been concluded that SN-285 has experienced very minimal corrosion. The wall loss for carbon steel in contact with soil is very low.

SN-286 Secondary Pipe (Encasement)

Line SN-286 Secondary is a 6-in Carbon Steel Schedule 40 ASTM A106, Gr.B or A pipe. It was installed in 1974 and exhumed for inspection in 2010. It was connected from 241-SY-02A Central Pump Pit to 241-SY-B Valve Pit. This pipeline is the encasement of the SN-286 Primary line and collects leakage in case SN-286 Primary fails. Waste was not transferred through this pipeline; however, it was in contact with the soil. It is cathodically protected and covered with sprayed polyurethane insulation. Figure 21 shows the 241-SY Tank Farm, line SN-286 Secondary is highlighted in yellow along the blue line which represents SN-286 Primary. (RPP-27097 R1, 2007).

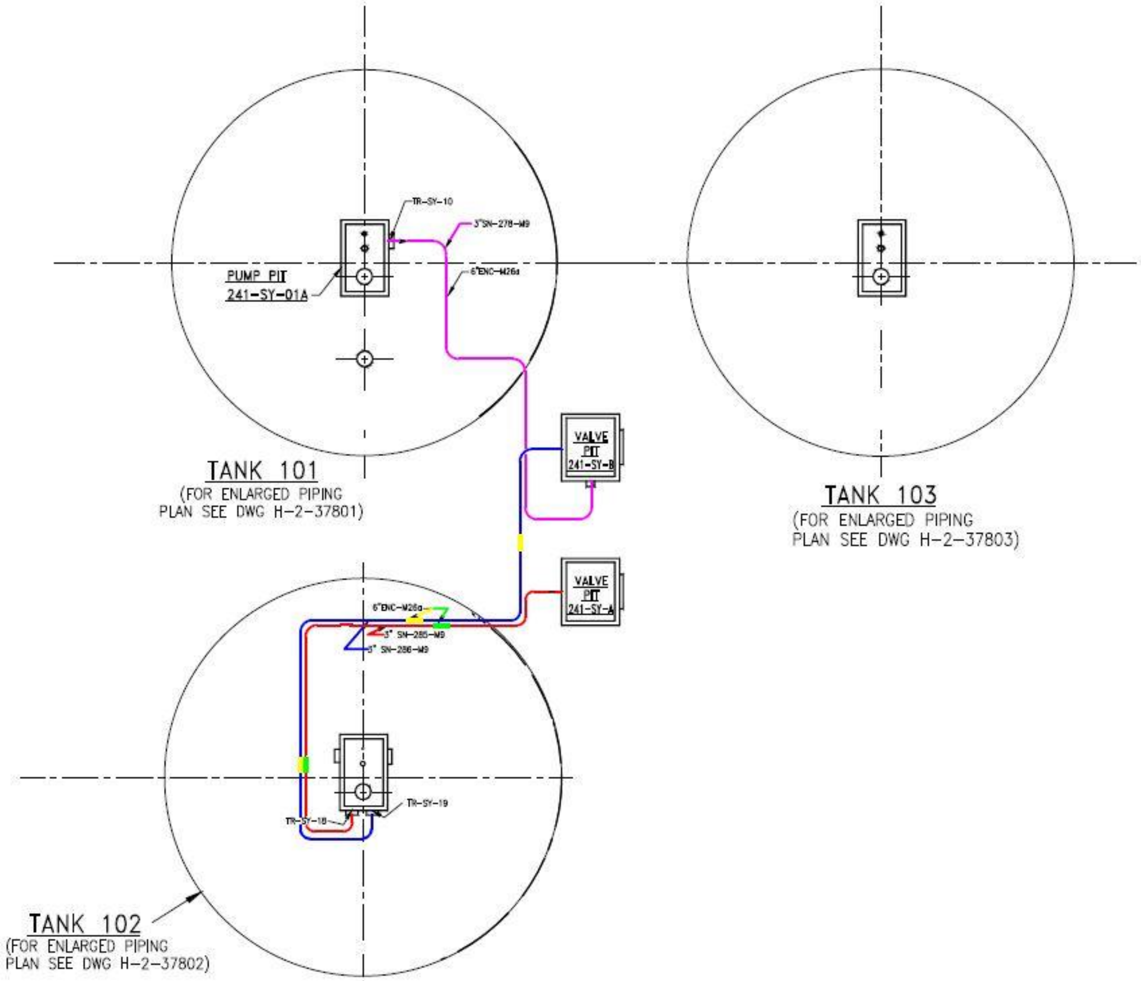

Figure 21. 241-SY Tank Farm Drawing SN-285 encasement (Green), SN-286 encasement (Yellow).

In 2011 a specimen of pipe SN-286 Secondary was received at the 222-S Analytical Laboratory. To lower the possibility of contamination, the location where the specimens were cut from was determined based on accessibility and low amount of radiation. Using a digital caliper, diameter measurements were taken at three radial positions along just one longitudinal position. These measurements were taken approximately 120° from each other. Also, three coupons were cut along the circumference in just one longitudinal position. One coupon was cut from the top, another one from the side, and the third was cut from the bottom of the pipe. After the coupons were extracted, the corrosion was removed from the pipe. The process for the corrosion removal involved immersing the coupons in an ammonium citrate solution heated to ~80°C with subsequent scrubbings to remove the corrosion. The immersion and scrubbings were repeated until the corrosion was completely removed. To prevent loss of surface material that was not corroded, this process was repeated until the percent weight loss after the previous cleaning fell below 10% of the cumulative weight loss. After this cleaning process was completed, the coupons were placed in an oven to prevent further corrosion from forming on the surface. Wall thickness measurements were then taken from the coupons with digital calipers. It should be noted that pits due to the corrosion were visible on the surface after the cleaning. Microscopic photographs of the cross-section of the bottom coupon were used to measure the depth of the pits which was found to have a maximum value of 6.732E-03 in. The depths of the residual pits were very small in comparison the average wall thickness (0.263-inch), and were therefore not considered in this analysis.

In order to determine the wall thickness after corrosion was removed, thickness measurements were taken using a digital caliper. Three measurements were taken for each coupon to calculate an average thickness that represents more accurately the overall thickness of the coupon. (LAB-RPT-11-00006 R0, 2011).

The thickness measurements, size of coupons, and thickness averages are listed in Table 13. (LAB-RPT-11-00006 R0, 2011).

Table 13. Thickness and Dimensions of Coupon Cut from the SN-286 Secondary Pipe Section

Coupon	Thickness 1	Thickness 2	Thickness 3	Length (in)	Width (in)	Thickness Averages
Top	0.239	0.238	0.237	3.769	1.466	0.238
Bottom	0.272	0.257	0.261	4.191	1.505	0.263
Side	0.280	0.291	0.289	4.186	1.783	0.286

A summary of SN-286 Secondary wall thickness measurement calculations is shown in Table 14. The average and standard deviation were calculated and the nominal thickness and tolerance are listed. The nominal thickness is based on 6-in Carbon Steel Schedule 40 pipe. The minimum manufacturing tolerance is listed in ASTM A106-1972a Table A2. However, the maximum manufacturing tolerance is not provided in the report. Because of this, the maximum manufacturing tolerance is determined from ASTM A106-1972a Table 3. This table specifies the variation in outside diameter of the pipe. The maximum permissible variation of the nominal diameter is +0.062-in. We use this information to obtain the maximum tolerance thickness in the pipe by dividing 0.062-in by 2 and adding it to the nominal wall thickness of 0.280-in. Since adding a value to a diameter gives the total increase in diameter, we can divide it by 2 to determine the total increase in radius. If the inner diameter is kept constant, adding the value obtained to the nominal thickness will give a maximum manufacturing tolerance of 0.311-in. (ASTM A106-1972a).

Table 14. Summary of SN-286 Secondary Thickness Measurements

Overall Average Wall Thickness Measurement	0.263
Overall Standard Deviation	0.022
Average -2 Standard Deviation	0.219
Average +2 Standard Deviation	0.306
Manufacturing Nominal Thickness	0.280
Manufacturing Minimum Tolerance	0.245
Manufacturing Maximum Tolerance	0.311
Note: Nominal thickness based on Carbon Steel, 6-in Diameter, (ANSI Schedule 40)	

To conduct additional analyses and determine how the thickness in the pipe varied along the radial position, the wall thickness vs. radial position was plotted in Figure 22. Furthermore, the average thickness, nominal thickness, manufacturing minimum and maximum tolerance were also plotted. The values for top coupon, bottom coupon and side coupon never intersect each other and they decrease from side coupon to top coupon. Also, the spread between the points in each position shows how far or how near the thicknesses from each trial were. In the case of the top position, the three trial measurements lie fairly close to each other (less 0.002-in is the largest difference). This verifies the accuracy in the measurements as well as consistency in wall thickness in the top position, which is important since it is where the thinnest wall measurement is detected. Overall, there was no major spread between the points in the other two radial positions.

It is important to note how this graph shows the same characteristics as the graph in Figure 19. Both of these graphs show the side position to have the smallest wall thickness loss and the top position to have the greatest wall thickness loss. This pattern could arise due to the manufacturing process used to make these pipes. In LAB-RPT-11-00006 R0, photographs of the coupons are provided as well as an analysis of which position had more corrosion. It was determined that the bottom had the most corrosion and the top had the least corrosion. This information does not correlate with the wall thickness measured. One explanation for this strange outcome is that the wall thickness measurements are representative of variation in the original wall thickness due to the manufacturing process used to produce the pipe and also the wall thickness loss due to corrosion.

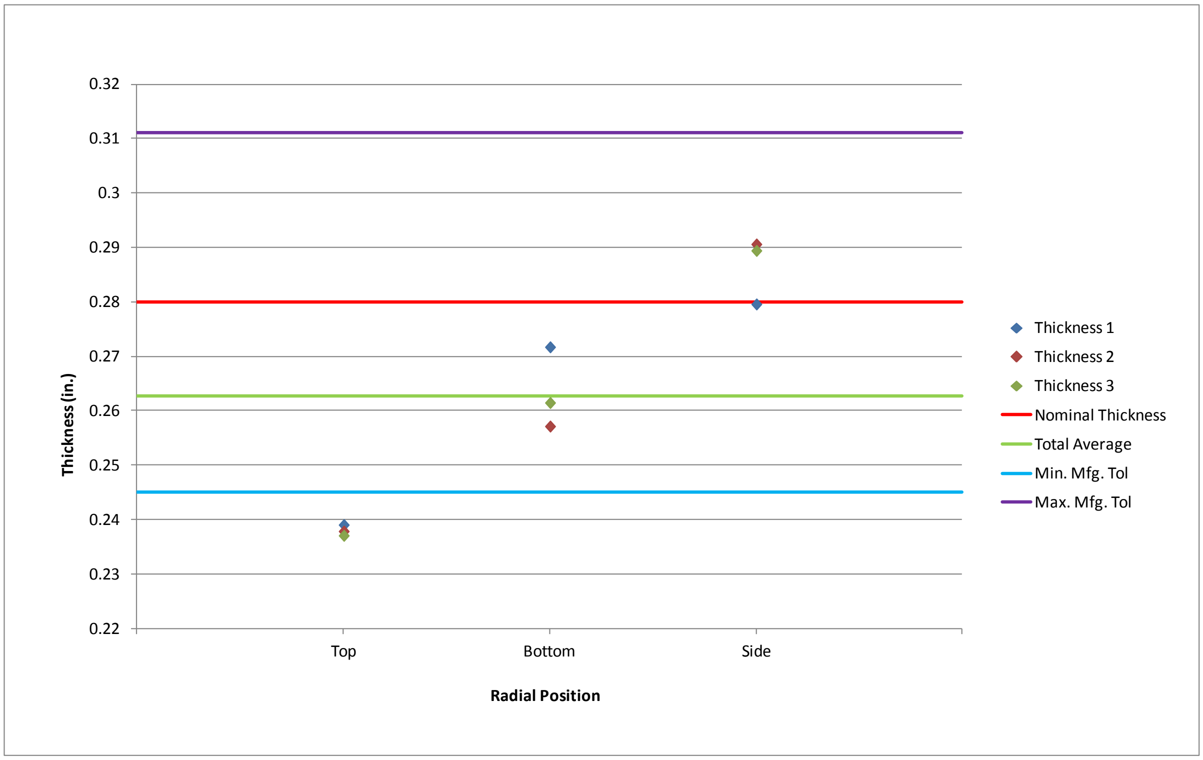

Figure 22. SN-286 Secondary pipe longitudinal thickness measurements grouped by radial position.

Lastly, the average radial thickness measurements grouped by radial position were graphed (Figure 23). Likewise, the average thickness, nominal thickness, minimum and maximum manufacturing tolerance were also plotted. The line connecting the average for each coupon shows a linear relationship. The total average is below the nominal thickness by 0.017-in. With these results, it is apparent that there was detectable wall loss in this pipeline and the corrosion rate should be determined. At this moment, there is not an accurate method to separate the wall loss or gain due to the manufacturing process and the wall loss due to corrosion. Consequently, nominal thickness and total average are used to compare the wall thickness loss and calculate an estimate of the loss rate.

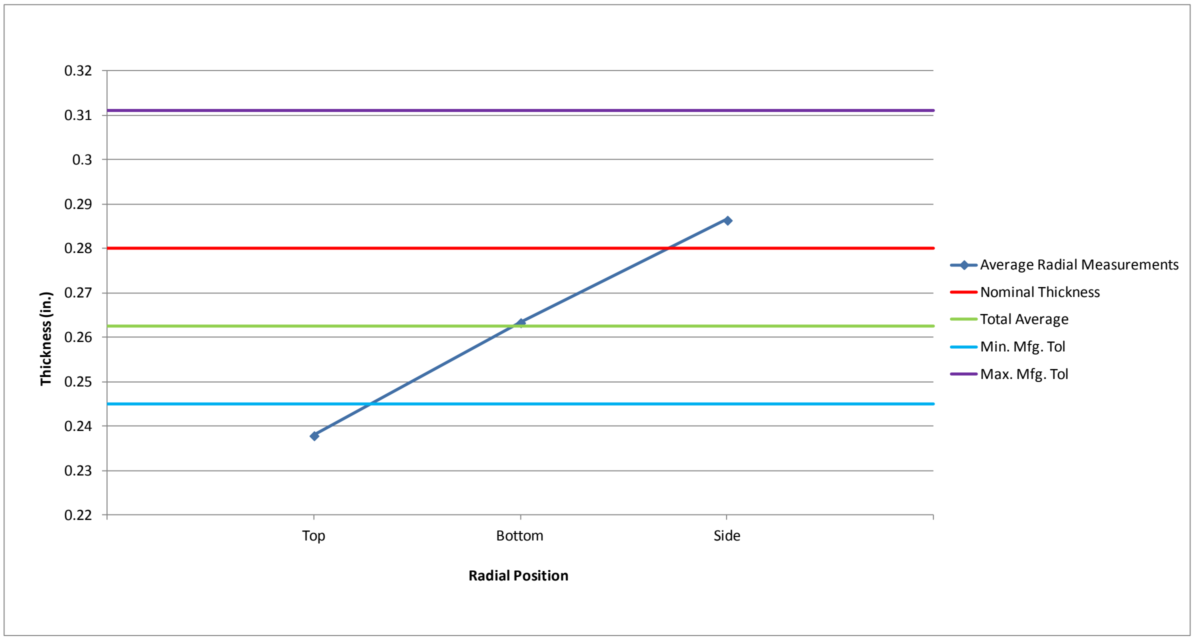

Figure 23. SN-286 Secondary pipe average radial thickness measurements grouped by radial position.

To determine the allowable corrosion rate, the minimum thickness required for the pipeline to maintain its required design pressure of 60 psig needs to be calculated. The minimum thickness for SN-286 pipeline is calculated using ASME B31.3 Section 304.1.2 Equation 3a which specifies the minimum wall thickness required at a specified design pressure.[5]

$$t = \frac{PD}{2(SEW + PY)} \qquad (3a)$$

Table 15 lists all the variables, their description, reference report, and minimum thickness needed for the pipeline to safely operate.

[5] The minimum thickness required is in ASME B31.3 Section 304.1.1 and the formula account for a c value which is mechanical allowances plus corrosion and erosion allowances. Since we are interested in the minimum thickness after the corrosion and erosion have occurred, we do not use this equation. Instead we use the equation in ASME B31.3 Section 304.1.2.

Table 15. Minimum Thickness Equation and Variables for Pipeline to Operate Safely (Carbon Steel, 6-in Diameter, (ANSI Schedule 40)

P (Internal Design Gauge Pressure) (psi)	60	B-101-C3 R01, 1974, Pg. 42, Pipe Code M-26
D (Outside Diameter of pipe) (in)	6.630	ASTM A106-1972a
S (Stress value for materials) (psi)	16000	ASME B31.3 Table A-1
E (Quality factor)	1	ASME B31.3, Table A-1A or A-1B
Y (Coefficient)	0.4	ASME B31.3 Table 304. 1.1
W (Weld joint strength reduction factor)	1	ASME B31.3 Paragraph 302.3.5 (e)
t (minimum thickness)= PD/2*(SEW+PY) (in) t (minimum thickness)= 0.012 (in)		

Table 16 provides the nominal thickness with the corresponding year when the pipeline was installed, the average wall thickness measured in 2010, and the minimum thickness required for the pipeline to continue operating. With this data, a simple linear relationship can be determined for the life expectancy of the pipeline. As shown in the table, the pipeline life expectancy far exceeds the projected life of the Waste Treatment and Immobilization Plant (WTP). Based on this analysis, it is very unlikely that other cathodically protected carbon steel encasements with similar designs and service performance will require replacement during the WTP's projected lifetime.

Table 16. List of Thickness with Corresponding Year and Wear Rate Equation (SN-286 Secondary)

	Year	Thickness
Nominal Thickness	1974	0.280
Average Thickness	2010	0.263
Minimum Thickness	2528	0.012
Wear Rate equation assuming linear relationship	y=-0.0004833x+1.2341	
Corrosion Rate (inch/year)	-4.83E-04	

Figure 24 shows the wear rate for the SN-286 Secondary Pipeline with the experimental values and the wear rate equation graphed.

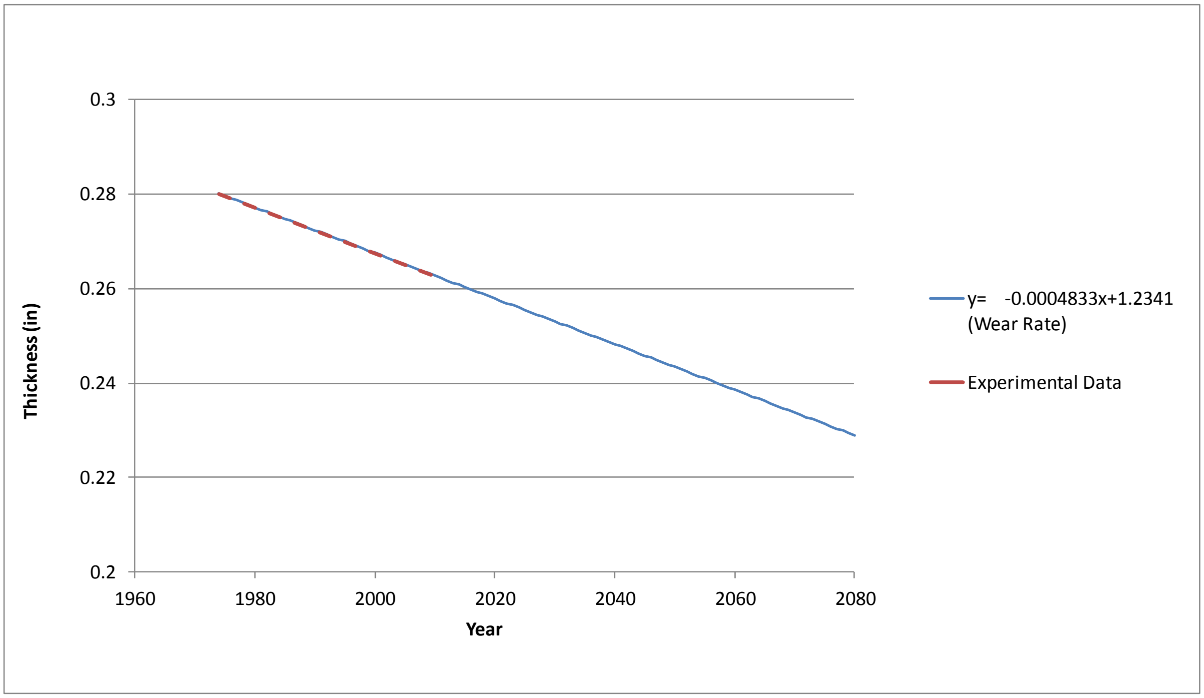

Figure 24. SN-286 Secondary pipeline life expectancy.

After analyzing the data collected, it has been concluded that SN-286 has experienced very minimal corrosion. The wall loss for carbon steel in contact with soil is very low.

Pipelines SN-285 and SN-286 are made of the same material, performed the same service, and have been buried the same amount of time. When analyzing the graphs, it is noted that for both pipelines (SN-285 Secondary and SN-286 Secondary) the top has the thinnest wall thickness and the side has the thickest wall thickness. In LAB-RPT-11-00006, corrosion removal from the coupons was performed and it is reported that the greatest mass lost occurred at the bottom of the pipeline. This demonstrated that the most corrosion was located in the bottom of the pipeline. However, the wall thickness measurements for both pipe specimens show that the bottom of the pipeline was thicker than the top of the pipeline. These results may arise due to the manufacturing techniques used to make the pipelines. When seamless pipelines are produced, the nominal thickness around the pipeline is not constant.

For the set of pipelines analyzed in this report, it is apparent that when produced, the bottom section of the pipelines was thicker than the top section. Consequently, although the bottom of both pipelines contained a higher amount of corrosion, it was still thicker than the top section which contains the least amount of corrosion.

A summary of the estimated corrosion rate in inch/year for 6-in Carbon Steel Schedule 40 encasement pipe in contact with the soil and cathodically protected is listed in Table 17. The rate of corrosion in SN-285 is lower than the rate of corrosion in SN-286. Given the fact that the pipelines are made of the same material and performed the same service, it is apparent that this difference in rate of corrosion is due to the difference in initial thickness which arises due to the process used to manufacture the pipes.

Table 17. 6-in Carbon Steel Encasement in Contact With the Soil and Cathodically Protected Corrosion Rate Summary

Pipeline	Corrosion rate (in/year)
SN-285	-3.16E-04
SN-286	-4.83E-04

5. CONCLUSION

The description of the analysis and evaluation of a portion of the waste transfer system lines located at the Hanford Site are presented in this report. The lines evaluated were 3-in Carbon Steel primary pipelines, and 6-in Carbon Steel secondary pipelines located in the 241-SY Tank Farm. The wear rate due to corrosion and erosion was determined for the straight sections on primary pipelines with transferred volume of supernatant waste of up to 28,000 kgal. In addition, the corrosion rate for a straight section on a secondary pipeline in contact with the soil was also calculated.

Despite the fact that the volume passing through the primary pipelines is very large, there is no detectable wear. On the other hand, for the secondary pipelines, there is detectable wear on both pipes that were analyzed and the wear rate for each pipeline was calculated. It was determined that the year when the pipelines will reach their minimum wall thickness due to corrosion was well beyond the lifetime of the Hanford Site mission of removing and storing the radioactive waste. This analysis is only suitable for the straight section of carbon steel primary carrying supernatant and secondary pipelines. Further analysis will be conducted as needed to account for the corrosion/erosion in the elbows sections. In addition, there will be wear rates representing all of the various pipelines (different materials, sizes, and service performed) that the waste transfer system contains.

Data measurements have been collected for all of the pipelines and jumpers listed in Figure 1. This report only includes data measurements and wall thickness analysis pertaining to the 241-SY Tank Farm pipelines. In the future, additional sections will be included which contain the data measurements and wall thickness analysis for all the other pipes.

6. REFERENCES

RPP-27097 R1, 2007, Volume 5L IQRPE DST System Integrity Assessment-Waste Transfer Line Encasement Integrity Technology Study, CH2M Hill, Richland, Washington.

RPP-RPT-50397 R0, 2013, Operating History of Transfer Lines SN-278, SN-285, and SN-286, Washington River Protection Solutions LLC, Richland, Washington.

RPP-28538 Rev 5, 2008, Volume 1: IQRPE Double-Shell Tank Integrity Assessment Report HFFACO M-48-14.

LAB-RPT-11-00006 R0, 2011, Final Report for the Corrosion Analysis of SN-285 and SN-286 Pipeline SY Tank Farm, Washington River Protection Solutions LLC, Richland, Washington.

LAB-RPT-12-00007 R0, 2012, Final Report for the Erosion and Corrosion Analysis of Waste Transfer Primary Pipeline Sections from 241-SY Tank Farm, Washington River Protection Solutions LLC, Richland, Washington.

B-101-C3 R01, 1974, Construction Specification for Completion of 241-SY Tank Farm Project B-101, Automation Industries, INC. Vitro Engineering Division, Richland, Washington.

ASTM A106-1972a, Seamless Carbon Steel Pipe for High-Temperature Service.

ASTM A53-1972a, Welded and Seamless Steel Pipe.

ASME B31.3-2012, Process Piping, ASME Code for Pressure Piping, B31.