Q. Reference: *Refurbish Penstock 2, Bay d'Espoir Generating Station*, *March 3, 2017,* Page 3, Lines 14-16.

"As a follow-up to the work on Penstock 1, a root cause analysis was performed by a third party consultant. The root cause analysis report is expected to be submitted to Hydro by mid-March and will be forwarded to the Board at that time."

Please provide a copy of this report when it becomes available.

A. The final Penstock 1 Root Cause Analysis Report is attached as NP-NLH-003, Attachment 1.

HATCH

Newfoundland and Labrador Hydro

Root Cause Analysis Report

For

Bay d'Espoir Penstock No. 1 Refurbishment

H352666-00000-220-066-0002
Rev. 1
March 17, 2017

Newfoundland and Labrador Hydro

Root Cause Analysis Report

For

Bay d'Espoir Penstock No. 1 Refurbishment

H352666-00000-220-066-0002
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HATCH

Newfoundland and Labrador Hydro
Bay d'Espoir Penstock No. 1 Refurbishment
H352666

Engineering Report
Mechanical Engineering
Root Cause Analysis

Report

Root Cause Analysis

H352666-00000-220-066-0002

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PEG Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
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which is valid for the year 2017

REGISTERED PROFESSIONAL ENGINEER
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GREGORY SAUNDERS
SIGNATURE
March 17, 2017
DATE
NEWFOUNDLAND & LABRADOR

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2017-03-17	1	Final	M. Pyne	D. French	G. Saunders
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY

Ver: 04.03

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1. Introduction

Hydro engaged Hatch on September 22, 2016 to investigate the condition of some of the welded joints on Bay d'Espoir Penstock No. 1. In September of 2016, Penstock No. 1 experienced a failure to one of the longitudinal welded joints. The joint was repaired, but further inspection by Hydro indicated there were problems with other longitudinal joints.

Upon completion of the inspection plan developed by Hatch, it was confirmed that the majority of the longitudinal weld joints from the intake down to Section 117 (Refer to Appendix H), approximately 900 m of penstock seams, had experienced a significant amount of weld metal loss.

As a result of the recent repairs to the welded joints and the amount of weld metal loss to the longitudinal seams, Hydro requested Hatch to complete a Root Cause Analysis (RCA) on the problem.

The purpose of the RCA is to, where possible, identify any design, metallurgical, operational and environmental factors that either separately or collectively caused the corrosion issues, which have been found through inspection, in the longitudinal weld joints and resulted in the failure of the longitudinal joints.

Incidents and improvement opportunities may arise anywhere in an organization and can vary a great deal in nature, severity or impact, or underlying causes. Despite the large range of issues and conditions, the same basic process is applicable to any improvement/problem solving initiative. The RCA is a multi-step process, and generally involves the following:

- Data Collection
- Defining the factors
- Root Cause Identification
- Recommendations

2. Data Collection

The following data was collected to determine the factors that caused and/or accelerated the failures:

1. Drawings of Penstock No.1.
2. Material properties were identified from the drawings and samples from the penstock shell plate and welds were tested.
3. Kleinschmidt Crack Investigation and Repair Report Penstock No. 1 Bay d'Espoir Hydroelectric Development, June 2016.
4. Bay d'Espoir Pressure Conduit #1 Inspection Report 1987.
5. Water and Organic growth samples were collected and tested.
6. Discussions with engineering and operations personnel.
7. Internal inspections of penstock and welding seams.
8. External inspections of backfill.

3. Failure Factors

3.1 Construction Methods

Penstock No.1 is constructed from a series of cans that vary in length depending on location, but in general the cans are approximately 9 ft long. Each can consists of two rolled steel plates that are welded together longitudinally. This form of assembly requires two longitudinal welded joints.

The penstock varies in diameter from 17 ft to 15 ft 3", and the thickness varies depending on the location. The penstock is also constructed of two grades of steel, ASTM 285 Gr. C steel from the intake up to and including section 16, and CSA G40.8 Gr. B. for the remainder.

During the era in which Penstock No. 1 was constructed, plate rolling was generally completed utilizing a three roll single pinch point roll. When rolling plates with this type of roll, the start and end of each plate will be flat. Figure 3-1 shows an exaggerated peaking (in red) compared to the desired tubular structure (in blue).

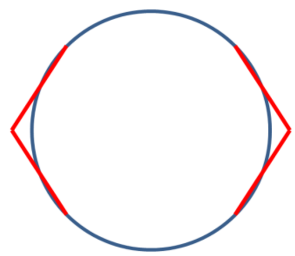


Figure 3-1: Peaking (Red) As Welded (Blue)

Difficulties with lining up the longitudinal seams at the time of construction in the 1960s are evident when examining the internals of the penstock and seeing evidence of extensive dogging[1] of the joints to bring the longitudinal seams together. The flat spots and induced stress from fitting the straight ends increase the residual stress at the joints. Below is an image of the longitudinal seam that failed in September. Large amounts of peaking were observed at the initial crack location, see Figure 3-2, and this would mean the weld was resisting significant residual stresses to maintain a round shape at the seam. The increased stress also makes the longitudinal joints more susceptible to material loss as they become sensitized to corrosion.

[1] Utilization of welded horseshoe shaped brackets and wedges to force plates into alignment prior to welding and to limit distortion during welding.

Figure 3-2: Longitudinal Weld Failure Showing Peaking

3.2 Internal Coating

The existing internal coating is original to the penstock and was specified as a two coat system manufactured by The Standard Manufacturing Company of Newfoundland. The primer coat consisted of 5 mils dry film thickness (DFT) of Matflint #7-Primer and the finish coat was 6 mils dry film thickness of Matflint #7-Black Coal Tar Epoxy (Bay d'Espoir Pressure Conduit #1 Inspection Report 1987).

After a review of a previous inspection report, it is evident that initial coating deterioration occurred prior to 1987 and the deterioration has steadily progressed since then. In the report it also mentions that failure of the coating initiated at the welds. This inspection also completed a review of the interior surface but did not identify any excessive corrosion of the longitudinal joints and did not make any recommendations for further inspection or refurbishing of the corroded areas.

Visual inspection of the penstock interior surface indicated some of the coating to be present; however, a physical inspection showed there was no bond between the coating and the steel, as the coating was easily lifted off by scraping the surface. Visual inspection of all exposed surfaces (welds and parent metal) showed varying signs of pitting corrosion which is typical for a penstock of this age.

At the time of construction (1960's), Coal Tar Epoxies were being utilized as one of the industry standards for penstocks internal protection coatings on penstocks (Centre for Energy Advancement through technological Innovation (CEATI) Technology Review Hydro-Electric Coating Strategies for Corrosion Prevention). Penstock guidelines and best practices commonly reference internal coatings per AWWA C203 Standard for Coal-tar Protection Coatings and Linings (Steel Penstocks 2012 (2nd Edition)).

In general, coal tar epoxy coatings have a lifespan of 10-20 years depending on the service. For internal penstock coating, in particular, CEATI estimates the expected life for this particular system to be on average 15 years. The coating on penstock No. 1 has been in place since the original installation and has exceeded the standard life expectancy.

Failure modes for Coal Tar Epoxy coating systems are typically as outlined below. However, due to lack of available information from the original fabrication/construction we cannot determine if either of these contributed to the coating failure:

1. Insufficient surface preparation. Surface preparation needs to be completed on the entire internal surface including welds. In other industries we have seen instances where welds were insufficiently prepped which leads to localized coating failure along weld seams. This localized failure allows the spread by water getting behind the coating and "lifting" the coating and therefore progressing the failure outward from the welds.
2. Insufficient curing time/environment. Coal tar epoxies are typically high DFT (approximately 10-14 mils) systems built up in multiple coats. Typical DFT of a single coat should not exceed 3-4 mils. Thicker coats should be avoided as it causes increased curing times and possible curing issues. It is possible that the system was applied in two thick coats, leading to improper curing.
3. As coal tar epoxies age, they become brittle and crack. This embrittlement and cracking allows localized failures which eventually lead to moisture penetrating the system and ultimately system failure. This embrittlement and cracking would be exacerbated by any dimensional changes from increasing/decreasing ovality. The penstock tends to flatten during extended periods of being de-watered (the degree of which is directly related to the exterior backfill support), but rounds out after re-pressurizing.

3.3 Organic Growth

The internal surface of Penstock No. 1 has a layer of organic growth, approximately 2 inches thick, extending from the intake to Section 117. The layer of organic growth reduces in thickness as you progress downstream towards the powerhouse. The penstock (welds and parent metal), downstream of the surge tank, appeared to be corroding at a rate that would be expected for similar penstocks without a protective coating. When inspecting the penstock in the scroll case area the organic growth was not present and corrosion was substantially reduced with no signs of accelerated pitting corrosion of the weld metal or heat affected zone (HAZ).

To assess the possibility of microbiologically influenced corrosion (MIC) a series of organic samples were taken and sent for testing. The following organic tests were performed by Acuren, Mississauga, Ontario.

- Low Nutrient Bacteria (LNB)
- Iron-Related Bacteria (IRB)
- Anaerobic Bacteria (ANA)
- Acid-Producing Bacteria (APB)
- Sulfate-Reducing Bacteria (SRB)

In general, microbiologically influenced corrosion testing is completed on wetted specimens; this allows standard testing to be completed. Final readings of testing indicate the following:

- Negative readings for IRB and SRB
- Weak Positive readings for LNB, ANA and APB

Based on these findings it would appear that the organic growth provides an environment that is more susceptible to pitting corrosion and allows ions to flow more freely.

3.4 Water Analysis

Water testing data was collected from 1965, 1980, 1988, 1992, 1993, 1994, 1995, 1996 and 2016. Testing between 1965 and 2016 yielded similar Langelier saturation index (LSI) results. However, the most recent water test indicates a change in water chemistry. We recommend additional testing to confirm these results.

The available data from 1965-2016 was used to compute the LSI, which is used to quantify the corrosive behavior of a specific water source. This calculation takes the pH, alkalinity, Total Dissolved Solids (TDS), temperature and calcium all into account rather than strictly depending on the pH value.

The LSI ranks water corrosion potential on a scale typically between -5 to 4, with -5 being highly corrosive and 4 having a high likely hood of scale buildup. When applying the LSI to the Bay d'Espoir water samples the following values were obtained:

Table 3-1: LSI vs Water Sample Year

Year	LSI	Year	LSI
1965	-4.77	1994	-5.72
1980	-6.57	1995	-5.69
1988	-5.02	1996	-4.75
1992	-5.71	-	-
1993	-5.65	2016	-3.9

In several instances the LSI ratings calculated were outside of the typical range, indicating the water is more corrosive than typical water bodies. These values would indicate that the water flowing through the penstock would be considered highly corrosive. Refer to Appendix E for further information on samples and the LSI index.

3.5 Base Metal and Weld Analysis

Throughout the upper section of the penstock it was noted that longitudinal seams were experiencing extensive pitting corrosion, material loss and well defined notches along the heat affected zone of the welds. This excess material loss and notching contributes to high stresses, crack initiation and propagation. Refer to Figure 3-3 and Figure 3-4 for images of the notching, excessive pitting corrosion, and material loss.

Figure 3-3: Longitudinal Seams in Penstock No.1 Section 16

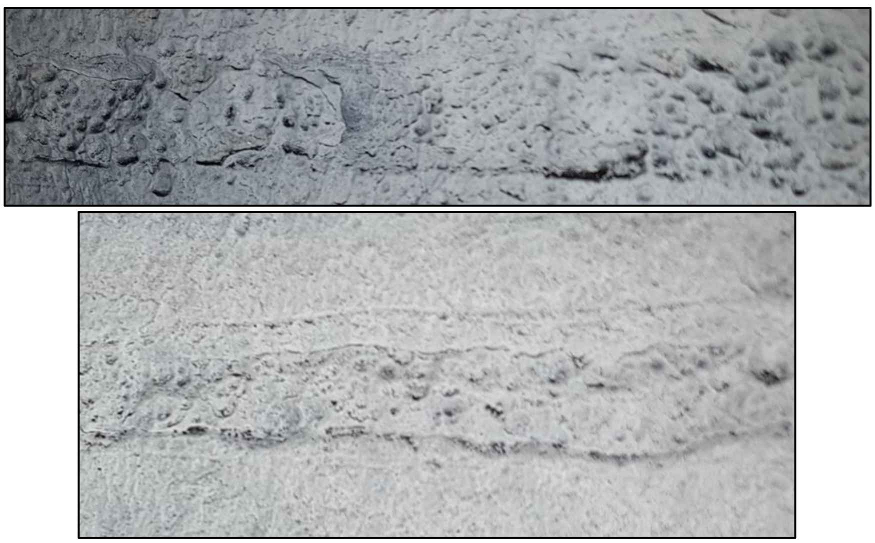


Figure 3-4: Longitudinal Seams in Penstock No.1 Section 16

To assess the metallurgy, mechanical and chemical properties of the parent metal and weld metal, a series of non-destructive and destructive testing was carried out.

The following non-destructive testing (NDT) was performed by TEAM Industrial Services, St. John's, NL, to aid the RCA investigation:

- Radiographic Examination

The following destructive testing was performed by Cambridge Materials Testing Limited, Cambridge, Ontario, to aid the RCA investigation:

- Microetch Evaluation
- Macroetch Evaluation
- Vickers Hardness Traverse
- Transverse Weld Tensile
- Weld Metal Chemical Analysis Test
- Base Metal Chemical Analysis Test

The following destructive testing was performed by Acuren, Mississauga, Ontario, to aid the RCA investigation:

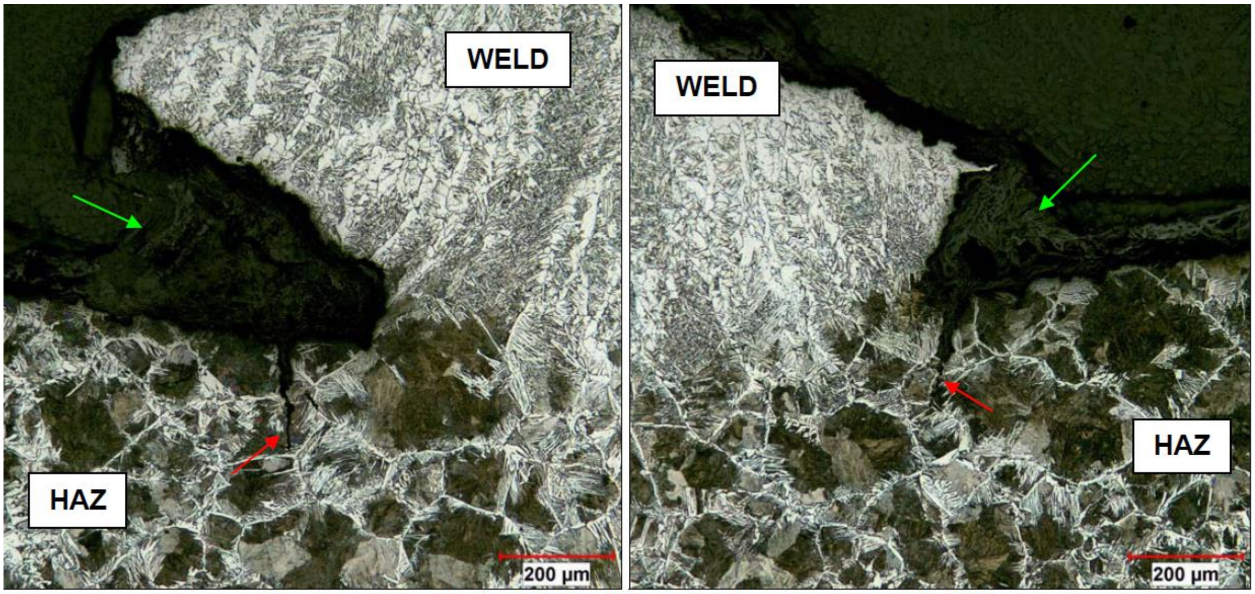
- Potential Difference Measurements (Weld/Base Metal Galvanic Testing)

The above tests were completed for three separate coupons:

1. Longitudinal seam between ASTM 285 Gr. C (Coupon #1 Section 16)
2. Circumferential seam between CSA G40.8 Gr. B (Coupon #2 Section 17)
3. Circumferential seam between ASTM 285 Gr. C (Coupon #3 Section 8)

Detailed results of the testing can be found in Appendix A, B & C. The Vickers Hardness test, weld tensile test, and chemical analysis are all consistent with the base metals listed on the design drawings and shield metal arc (SMAW) E4918 welding consumables.

As indicated in the attached reports, both the weld metal and parent metal are high in Sulphur. High amounts of Sulphur, by itself, can produce porosity in the weld metal and heat affected zones, primarily at the surface. Surface porosity is one of the main contributors to pitting corrosion. The presence of pitting corrosion would accelerate the effects of preferential corrosion and stress corrosion cracking.



Specimen examined at 100X, photos shown at approximately 85X
Etched in 2% Nital

Figure 3-5: Coupon #1 Micro of Heat Affected Zone Transgranular Cracks

The macroetch and microetch of coupon #1 (longitudinal) show surface pitting corrosion and advanced stages of preferential pitting corrosion with cracks initiated from the cavities and are progressing through the heat affected zone.

The macroetch and microetch of coupon #2 & 3 (circumferential) show surface pitting corrosion and preliminary stages of preferential pitting corrosion without any cracks.

The results of the Weld/Base Metal Galvanic Testing generally indicate that a galvanic cell between the weld metal and base metal is present and the weld metal, in particular the heat affected zone, was more susceptible to pitting corrosion than the base metal.

3.6 Weld Seam Stresses

Penstock pressure from the static head or dynamic head cause stresses in the penstock shell that can be categorized as "longitudinal stress" and "hoop stress", which occur simultaneously. The "hoop stress" is twice as high as the "longitudinal stress". The "hoop stress" is the stress found in the longitudinal joints. The stress in circumferential weld seams is known as the "longitudinal stress". As a result, virtually all failures in penstocks or pressure piping where there is a crack or split in a seam occur in the longitudinal direction.

3.6.1 Stress in Longitudinal Joints "Hoop Stress"

Longitudinal seams are more susceptible to failure due to higher stresses.

The stress in longitudinal weld seams is known as the "hoop stress". The "hoop stress" (σ_h) is dependent upon the pressure (P), diameter (D) and wall thickness (t).

$$\sigma_h = \frac{PD}{2t}$$

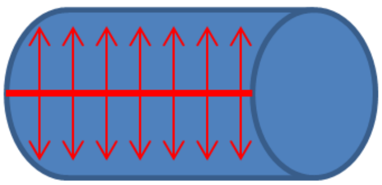


Figure 3-6: "Hoop Stress" Pulls Longitudinal Seams Apart

3.6.2 Stress in Circumferential Joints "Longitudinal Stress"

Circumferential seams are less susceptible to failure due to lower stresses.

The stress in circumferential weld seams is known as the "longitudinal stress". The "longitudinal stress" (σ_L) is dependent upon the pressure (P), diameter (D) and wall thickness (t).

$$\sigma_L = \frac{PD}{4t}$$

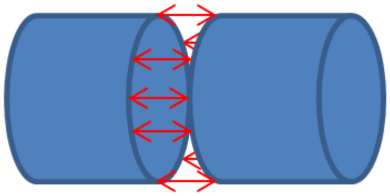


Figure 3-7: "Longitudinal Stress" Pulls Circumferential Seams Apart

3.7 Backfill

When reviewing the backfill requirements of Penstock No. 1 it was noted that there is a difference between the design specification and the "As Built" drawings. The specification states the penstocks were to be covered with soil to a minimum depth of 3 ft. The "As Built" drawing, Figure 3-8 is similar to the condition currently found in the field. The surrounding fill is part of the penstock construction, and serves to keep the penstock in shape when it is unwatered, to prevent collapse due to the pressure in the penstock falling below atmospheric, and by insulating to prevent excessive thermal stresses.

The "As Built" drawing shows a detail that has cover thicknesses in multiple locations below 1 ft.

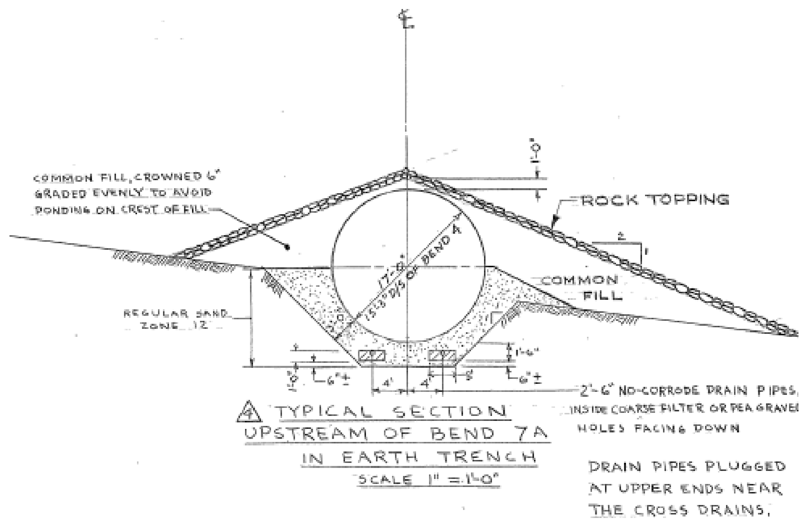


Figure 3-8: Drawing Half Trench as per "As Built" Drawing

Current reference material shows typical half trench buried penstock cover details (Buried Steel Penstocks – Steel Plate Engineering Data –Volume 4) of 2 ft minimum of cover and can be seen below:

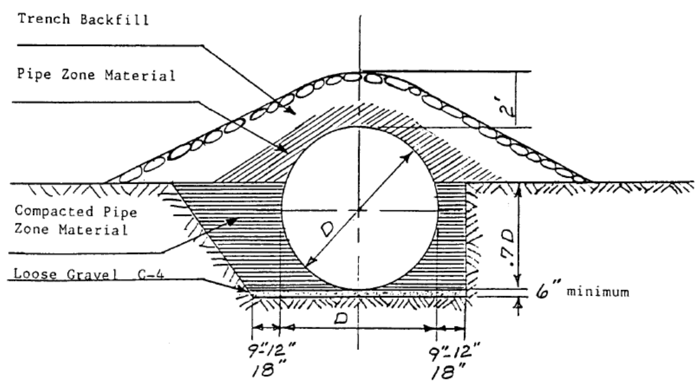


Figure 3-9: Typical Half Trench

When analyzing the backfill it was determined that backfill is structurally integral to the penstock and provides needed support along the center line. In the area where the penstock cracks occurred, the depth of backfill is less than 2 ft and some sliding and sloughing of the backfill has occurred. This has been shown to increase the stress level by approximately 100% in the area of longitudinal welds locations. Refer to the finite element stress analysis completed for the backfilling of the excavated areas in Appendix G.

4. Heat Affected Zone Pitting Corrosion Contributing Factors

The results of the testing included in the preceding sections indicate that the longitudinal seams, from the intake downstream to Section 117, experienced weld metal loss, primarily in the heat affected zone, attributed to "Preferential Heat Affected Zone Pitting Corrosion".

The problem arises from the fact that weld metal compositions (which are normally optimized for mechanical properties) tend to be slightly anodic to the parent steel. This issue arises across all welded structures. Therefore, the weld metal corrodes at a higher rate than the base metal.

The preferential corrosive attack of welds can occur for a number of reasons:

1. Differences in composition between the weld metal and the base metal can generate a potential difference in certain environments, thus setting up a galvanic cell, leading to pitting corrosion.
2. Differences in as-welded microstructure could make the weld metal sufficiently different from and even less corrosion resistant than the base metal.
3. Microstructural differences between the base metal and as-welded heat affected zones can lead to localized attack of the heat affected zone.
4. Preferential pitting corrosion is more prone to occur when the weld metal is exposed to aqueous environments that are fairly high in conductivity, and can occur at pH values below approximately 7 to 8 (Indicating low LSI numbers). Historical data (recorded for NL Hydro) indicates pH levels as low as 5.2 (Appendix E). In addition, the microbiologically influenced corrosion causing bacteria in the organic growth, and the sulfur content in the base metal and weld metal could accelerate pitting corrosion.
5. Due to the construction methods of the penstock, the longitudinal seams would have inherent residual stresses that would be intensified by the heating and cooling of the welding process. High residual stresses can contribute to another phenomenon known as "Stress Corrosion Cracking" which would exacerbate the preferential pitting corrosion and contribute to the reasons why the longitudinal seams experienced a more accelerated corrosion rate than the circumferential seams. Due to the construction methods, the circumferential weld seams would experience lower residual stresses.

5. Identification of Root Cause

Although the method or tool used to conduct RCA varies, the principle is the same regardless of the tool used. Methods and tools should be selected in accordance with the particular problem requirements. In this case, an Events and Casual Factor Analysis was completed. A Casual Factor Summary Table (see below) was generated to organize the information by the defining factors, their primary effects and their contribution to the Root Cause Mapping.

Table 5-1: Corrosion Casual Factor Summary Table

Defining Factor	Primary Effect	Root Cause Mapping
Construction Methods	High residual stresses	High residual stresses combined with exposure to harsh environments lead to stress corrosion cracking.
Internal Coating	Failure of coating	Exposure to harsh environment.
Organic Growth	Generates microbiologically influenced corrosion (MIC)	Presence of microbiologically influenced corrosion (MIC) amplifies harsh environment
Water Analysis	Low Langelier Saturation Index numbers	Confirmed harsh environment exists
Base Metal and Weld Metal Analysis	High Sulphur in base metal and weld metal.	High susceptibility to porosity and pitting corrosion when exposed to harsh environment.
	Galvanic couple between heat affected zone and base metal	Heat affected zone acts sacrificially to base metal and weld metal when exposed to harsh environment.
Weld Seam Stresses	High operating stresses in longitudinal seams	Increases sensitivity to pitting corrosion when exposed to harsh environment.
Backfill	Insufficient backfill and sloughing leads to high stresses.	High stresses increases sensitivity to pitting corrosion when exposed to harsh environment.

In this case, the analysis links the "exposure to the harsh environment" as a path through the Root Cause Mapping to all of the casual factors. The primary effect that leads to the "exposure to the harsh environment" is the failure of the internal coating system.

Table 5-2: Cracking Casual Factor Summary Table

Defining Factor	Primary Effect	Root Cause Mapping
Corrosion (Table 5-1)	Material loss	Reduced thickness of longitudinal seams below critical values.
	Notching along heat affected zone	Intensified stresses along longitudinal weld seams.
Weld Seam Stresses	High operating stresses in longitudinal seams	Reached critical stress due to insufficient material and notching which lead to failure.
Backfill	Insufficient backfill and sloughing leads to high stresses.	Reached critical stress due to insufficient material and notching which lead to failure.

The Casual Factor Summary Table links reaching the critical stress to the material loss and notching.

6. Conclusions

This report addresses two predominant issues, the pitting corrosion of the longitudinal seams in the section of the penstock located between the intake and the surge tank, and the failure of the longitudinal seams resulting in two cracks.

The section of the penstock that is located between the surge tank and the powerhouse is corroding as the original coating is no longer effectively protecting the steel, but at a rate that is normal for uncoated penstocks. There are no signs of excessive pitting corrosion of the longitudinal welds in this area. There is no reason to be concerned provided this section of the penstock is inspected to ensure the corrosion rate remains the same.

6.1 Penstock Pitting Corrosion

The interior of the penstock was originally coated with a coal tar epoxy that protected the interior surface. The coating has exceeded the normal service life of this type of product and no longer protects the interior surface of the steel penstock.

In general, the entire interior of the penstock is no longer protected from corrosion by a coating system. The corrosion attack is primarily focused on the longitudinal weld seams in the weld and heat affected zones. Based on our analysis, in our opinion the penstock is experiencing stress corrosion cracking.

Stress corrosion cracking requires two main contributing factors:

1. Harsh environment

The water flowing through the penstock has a low pH and a low LSI making it a harsh environment. Further to this, a microbiologically influenced corrosion generating organic growth has attached itself to the interior surface which also adds to the harshness of the environment.

2. High stresses

The high stresses in the longitudinal weld seams causes stress corrosion sensitization. This can be broken down into three factors:

- High residual stresses in longitudinal joints from fabrication, which was common fabrication practice at the time of construction.
- Insufficient/sloughing backfill
- Longitudinal joints have higher stresses than circumferential joints due to "hoop stress".

These factors have made the longitudinal seams the primary point for corrosion attack in the penstock.

Further corrosion accelerants were found during the investigation:

- The metallurgy also contributed to the susceptibly to corrosion. After completing a chemical analysis, it was determined that the weld metal and base metal used during construction, were both high in Sulphur. This high Sulphur can increase pitting corrosion and exacerbate stress corrosion cracking.
- Galvanic testing also indicated a galvanic couple that caused pitting corrosion in the heat affected zones.

Each of these factors could cause or accelerate the pitting corrosion when the weld metal and base metal were exposed to a harsh environment.

6.2 Penstock Cracks

The probable cause of the failure of the longitudinal seam was a function of the general corroded condition of the welds and the location of the joint.

The failed joint occurred in the highest pressure area of the largest diameter portion of the penstock and in an area with the least amount of backfill.

The existing backfill in the area of the cracked joints provided insufficient cover due to local sloughing/sliding of the fill material.

Consequently due to high stress concentrations along the weld seam due to pitting corrosion, a reduced thickness of heat affected zone metal, high pressure stress due to hydraulic head and lack of backfill support in the area, the metal reached a critical stress and failed.

7. Recommendations

The objective of root cause analysis is to identify the underlying cause(s) that led to the problem so that these root cause(s) can be potentially eliminated for this and other penstocks. By treating the root cause(s) and not just the symptoms, future occurrences can be prevented.

Since the major contributing factor to the pitting corrosion of the welds is "exposure to the harsh environment", and its root cause is "failure of the internal coating system", the primary recommendation is to reinstate the coating system.

The original design of the penstock included a coal tar epoxy coating. In our opinion, due to the corrosive nature of the water, organic growth and identified corrosion problems the entire length of the penstock should be coated with a suitable corrosion resistant system. The recommended timeline for this work is within the next 5 years.

Other mitigating alternatives were considered, such as cathodic protection, and treating the water to raise the pH and minimize the organic growth. However, attaching anodes to the interior of a penstock creates a hazard to the turbine equipment and the volume of water flowing through the penstock makes water treatment impractical.

Based on a preliminary review of the design of the penstock and backfill interaction, we have determined the backfill is integral to the structural integrity of the penstock. Hatch determined through analysis that even small excavated areas are required to be reinstated prior to watering up the penstock. Visual inspection of the backfill in the area where the re-welding and crack repairs occurred indicated there is a possible interrelationship between the location of the cracks and the condition of the backfill. Hydro is currently having an assessment of the backfill design completed by Hatch to confirm the required backfill cross section. Further recommendations will be detailed in this assessment.

We anticipate there could be similar corrosion issues in Penstocks No. 2 and No. 3 as were found in Penstock No. 1. These three penstocks were designed, fabricated and installed by the same contractor and used identical materials in their construction.

There is one marked difference between these two penstocks and Penstock No. 1, and that is the backfill. There does not appear to be the same sloughing and sliding of the backfill for Penstocks No. 2 and No. 3, thus the stresses in the longitudinal joints is anticipated to be less.

These penstocks have a different profile due to the bedrock elevation at each location. Hatch will be assessing the stresses in these two penstocks due to their backfill and providing recommendations if any remedial action is required.

For all Hydro's penstocks throughout the province that have been internally coated, we recommend that Hydro implement inspection procedures that check the functional quality of any internal coatings system to ensure there is sufficient adhesion of the coating to the steel and there is no underside corrosion occurring. This may require inspection procedures that are in accordance with the National Association of Corrosion Engineer (NACE) and removal of some of the coating in areas of high stress.

8. References

1. ASCE Steel Penstocks 2012, Manuals and Reports on Engineering Practice No. 79.
2. CEATI Technology Review Hydro-Electric Coating Strategies for Corrosion Prevention.
3. ASME OM SG 3.
4. Buried Steel Penstocks Steel Plate Engineering Data Volume 4.
5. PLP-131-020-0004 Hatch Root Cause Analysis Method.

Appendix A
Weld Coupon #1 Test Report

1. Introduction

As part of the Root Cause Analysis (RCA) investigation a coupon measuring approximately 460 mm x 460 mm (18" x 18") was removed from Section 16 (A285 Gr C Material) of BDE Penstock #1. The coupon incorporated a portion of one of the longitudinal weld seams that was partially repaired by Hydro's personnel, but did not include the repaired section.

2. Required Tests

The following non-destructive testing was performed by TEAM Industrial Services, St. John's, NL, to aid the RCA investigation:

- Radiographic Examination

The following destructive testing was performed by Cambridge Materials Testing Limited, Cambridge, Ontario, to aid the RCA investigation:

- Macroetch Evaluation
- Vickers Hardness Traverse
- Microetch Evaluation
- Transverse Weld Tensile
- Weld Metal Chemical Analysis Test
- Base Metal Chemical Analysis Test
- Coating System Asbestos and Quantitation Test

3. Test Results

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected, but was in the range of acceptable limits.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed a profile consistent with "Preferential Heat Affected Zone Corrosion".
- Both sections exhibited cracks propagating from the toes of the weld.

- One section exhibited porosity on the face of the weld.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line locations on either side of the weld, where cracks were observed in the macroexamination.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Viewing at a higher magnification, cavities can be seen at both weld toes. Both cavities were filled with corrosion product.
- Transgranular cracking was present within the corrosion cavities. Both cracks were propagating through the HAZ.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 169 to 198
- Hardness values for the HAZ ranged from 143 to 173
- Hardness values for the Base material ranged from 139 to 151

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of base metal = 69.5 ksi (480MPa)

The tensile specimen fractured in the base metal indicating the UTS of the weld metal meets the requirements of being higher than the UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable, it is 2X the normal percentage.

Base Metal Chemical Analysis

The base metal chemistry is consistent with ASTM A285 Gr C material.

Coating System Asbestos and Quantitation Test

Coating system was identified as a Coal Tar Epoxy.

No presence of asbestos was detected in the coating system.

Attachment A
Test Results

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Report For: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory #: **739108-16**

Report Date: October 27, 2016
Received Date: October 17, 2016

Attention: Keith Gowan

Customer P.O.#:

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon

MACROETCH EVALUATION TEST REPORT

Two random transverse sections were cut from the submitted weld coupon and prepared according to ASTM E3-11. The sections were arbitrarily labelled Section 1 and Section 2 by CMTL. The sections were etched in 2% Nital and then examined using a stereo microscope for general comments on weld imperfections.

RESULTS

Section 1: Examination of the specimen showed that the weld had discontinuities at both toes and porosity on the face on one side of the weld (refer to Figure 2). At higher magnification, the discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (refer to Figure 3). The weld appeared to have no undercut or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Section 2: Examination of the specimen showed that the weld had discontinuities at both toes on one side of the weld (refer to Figure 4). At higher magnification, the discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (refer to Figure 5). The weld appeared to have no porosity, undercut or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

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Per Randi Lee — Randi Lee, *Quality Assurance*

Per Dan Bielby — Dan Bielby, *Technician*

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TEAM Industrial Services (NFLD)
Lab # 739108-16

VICKERS HARDNESS TRAVERSE TEST REPORT

The macroetch sections were then re-polished according to ASTM E3-11 and subjected to a Vickers hardness traverse (refer to Figure 1). The Vickers hardness readings were performed according to ASTM E92-16 using a 10kgf test force. Indentations were measured at 100X magnification.

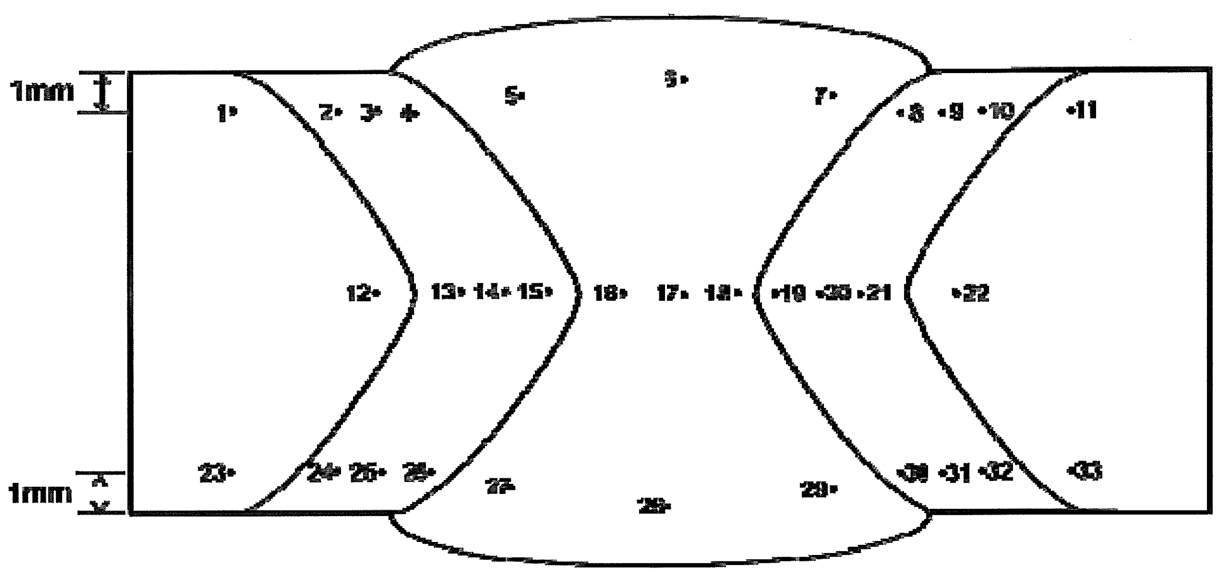

Figure 1: Schematic drawing showing the Vickers hardness indentation locations.

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Lab # 739108-16

RESULTS

Traverse Pass	Location	Indent	Section 1 Hardness (HV 10kgf)	Section 2 Hardness (HV 10kgf)
Top Cap Pass	Base Material	1	143	144
	HAZ	**2**	**158**	**162**
		3	**169**	**154**
		4	**171**	**158**
	Weld	5	183	181
		6	190	193
		7	180	188
	HAZ	**8**	**161**	**173**
		9	**156**	**160**
		10	**151**	**158**
	Base Material	11	144	146
Mid-Thickness Pass	Base Material	12	146	149
	HAZ	**13**	**149**	**166**
		14	**149**	**161**
		15	**160**	**160**
	Weld	16	169	171
		17	172	186
		18	173	181
	HAZ	**19**	**144**	**169**
		20	**144**	**143**
		21	**146**	**147**
	Base Material	22	139	139
Bottom Cap Pass	Base Material	23	150	151
	HAZ	**24**	**167**	**163**
		25	**163**	**154**
		26	**162**	**161**
	Weld	27	198	187
		28	198	198
		29	196	197
	HAZ	**30**	**154**	**160**
		31	**155**	**167**
		32	**161**	**167**
	Base Material	33	142	147

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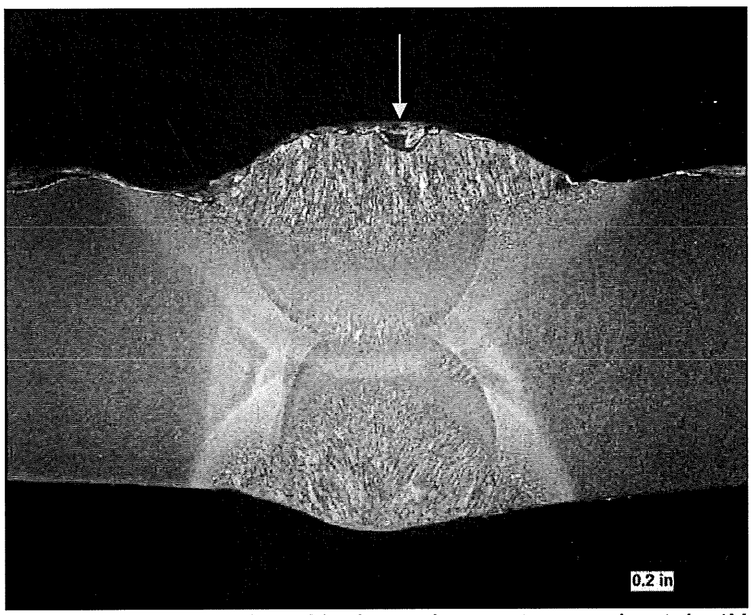
Lab # 739108-16



Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 2: Photomacrograph of the Section 1, which had discontinuities at both toes (red arrows) and porosity (yellow arrow) on the face on one side of the weld.

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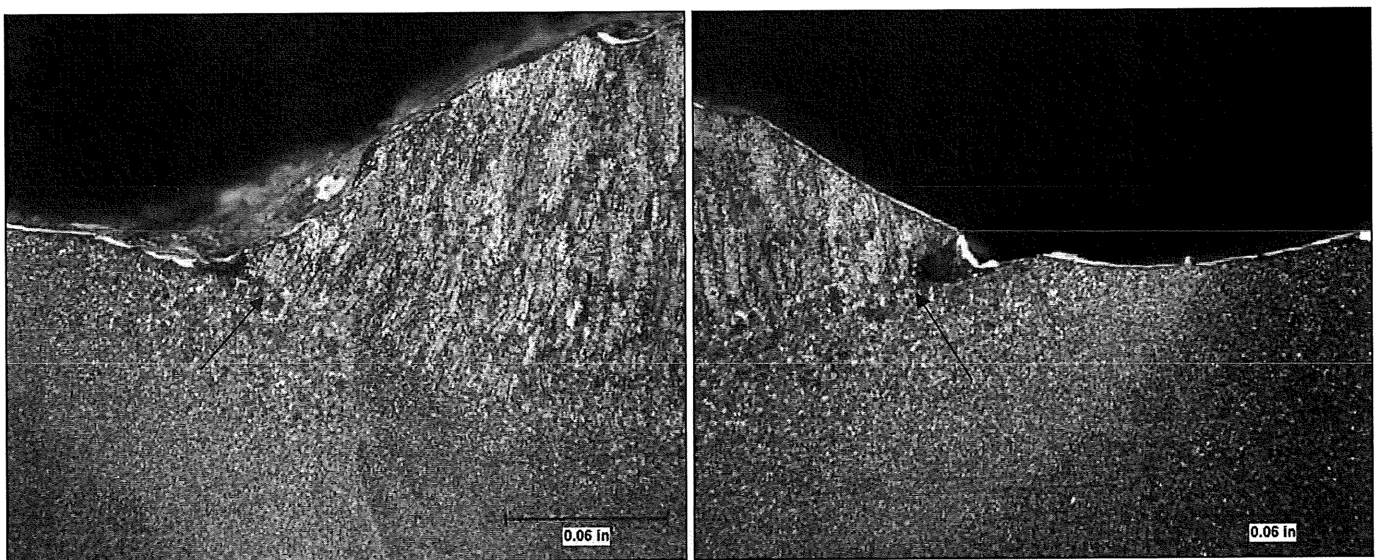

Specimen examined at 16X, photos shown at approximately 15X
Etched in 2% Nital

Figure 3: Photomacrographs of the Section 1. The discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (red arrows).

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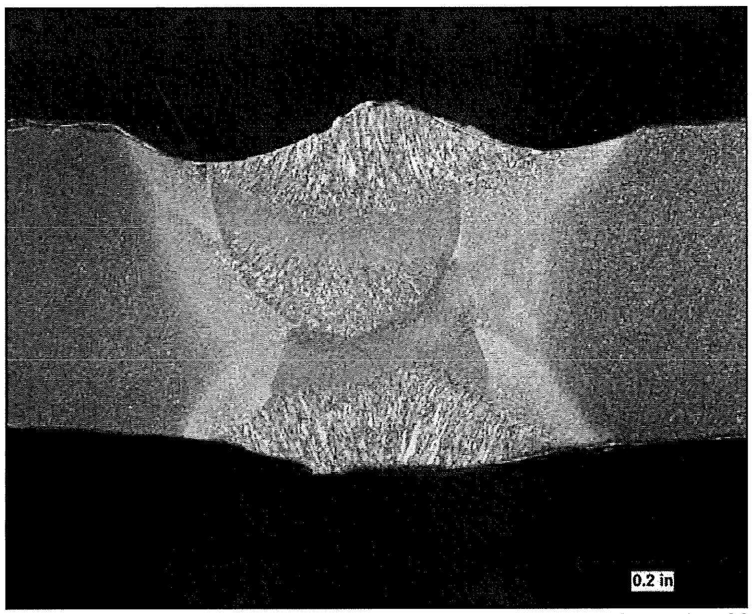

Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 4: Photomacrograph of the Section 2, which had discontinuities at both toes (red arrows) on one side of the weld.

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Report For: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory #: **739108-16**

Report Date: October 27, 2016
Received Date: October 17, 2016

Attention: Keith Gowan

Customer P.O.#:

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon

MACROETCH EVALUATION TEST REPORT

Two random transverse sections were cut from the submitted weld coupon and prepared according to ASTM E3-11. The sections were arbitrarily labelled Section 1 and Section 2 by CMTL. The sections were etched in 2% Nital and then examined using a stereo microscope for general comments on weld imperfections.

RESULTS

Section 1: Examination of the specimen showed that the weld had discontinuities at both toes and porosity on the face on one side of the weld (refer to Figure 2). At higher magnification, the discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (refer to Figure 3). The weld appeared to have no undercut or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Section 2: Examination of the specimen showed that the weld had discontinuities at both toes on one side of the weld (refer to Figure 4). At higher magnification, the discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (refer to Figure 5). The weld appeared to have no porosity, undercut or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

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Per Randi Lee — Randi Lee, *Quality Assurance*

Per Dan Bielby — Dan Bielby, *Technician*

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TEAM Industrial Services (NFLD)
Lab # 739108-16

VICKERS HARDNESS TRAVERSE TEST REPORT

The macroetch sections were then re-polished according to ASTM E3-11 and subjected to a Vickers hardness traverse (refer to Figure 1). The Vickers hardness readings were performed according to ASTM E92-16 using a 10kgf test force. Indentations were measured at 100X magnification.

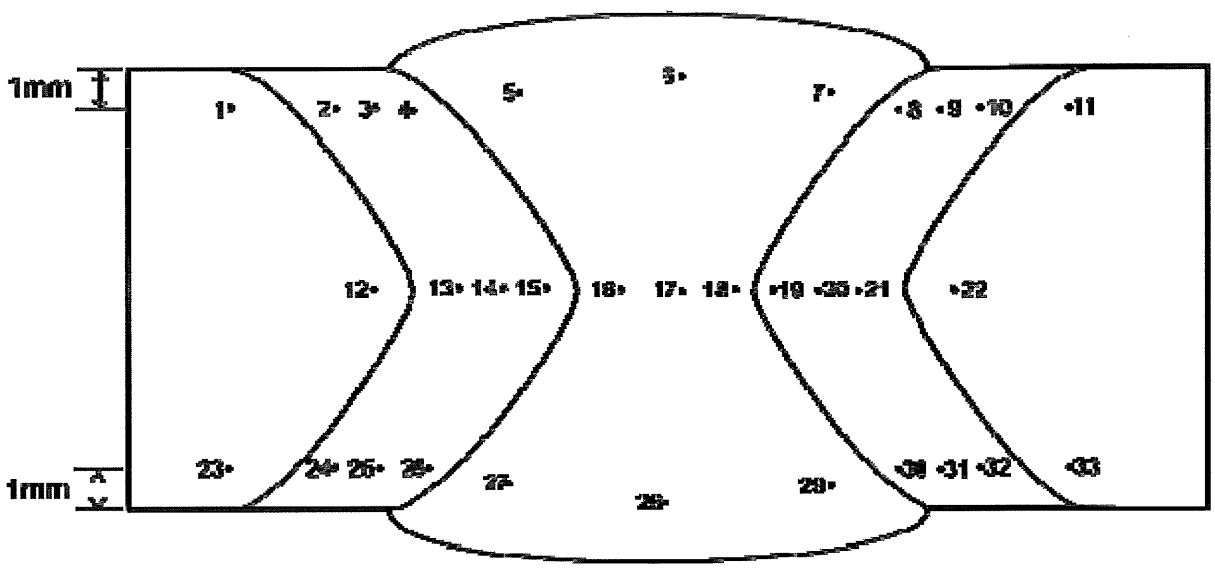

Figure 1: Schematic drawing showing the Vickers hardness indentation locations.

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Lab # 739108-16

RESULTS

Traverse Pass	Location	Indent	Section 1 Hardness (HV 10kgf)	Section 2 Hardness (HV 10kgf)
Top Cap Pass	Base Material	1	143	144
	HAZ	**2**	**158**	**162**
		3	**169**	**154**
		4	**171**	**158**
	Weld	5	183	181
		6	190	193
		7	180	188
	HAZ	**8**	**161**	**173**
		9	**156**	**160**
		10	**151**	**158**
	Base Material	11	144	146
Mid-Thickness Pass	Base Material	12	146	149
	HAZ	**13**	**149**	**166**
		14	**149**	**161**
		15	**160**	**160**
	Weld	16	169	171
		17	172	186
		18	173	181
	HAZ	**19**	**144**	**169**
		20	**144**	**143**
		21	**146**	**147**
	Base Material	22	139	139
Bottom Cap Pass	Base Material	23	150	151
	HAZ	**24**	**167**	**163**
		25	**163**	**154**
		26	**162**	**161**
	Weld	27	198	187
		28	198	198
		29	196	197
	HAZ	**30**	**154**	**160**
		31	**155**	**167**
		32	**161**	**167**
	Base Material	33	142	147

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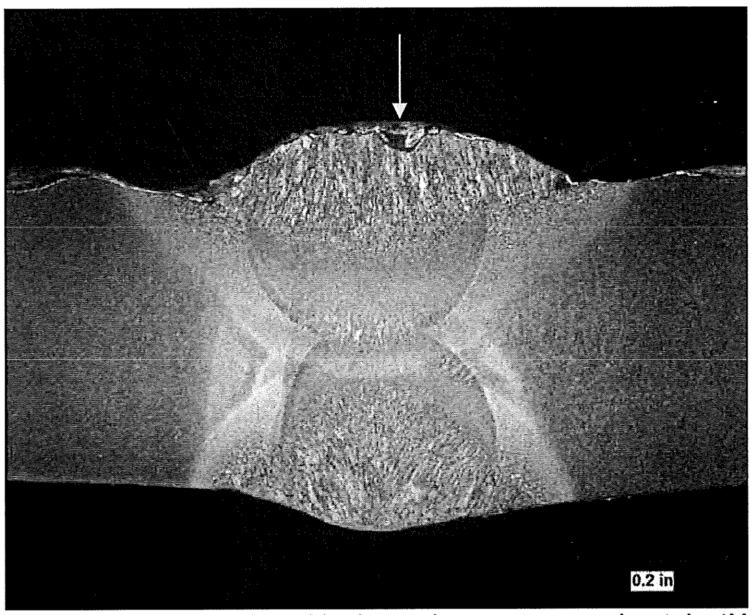

Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 2: Photomacrograph of the Section 1, which had discontinuities at both toes (red arrows) and porosity (yellow arrow) on the face on one side of the weld.

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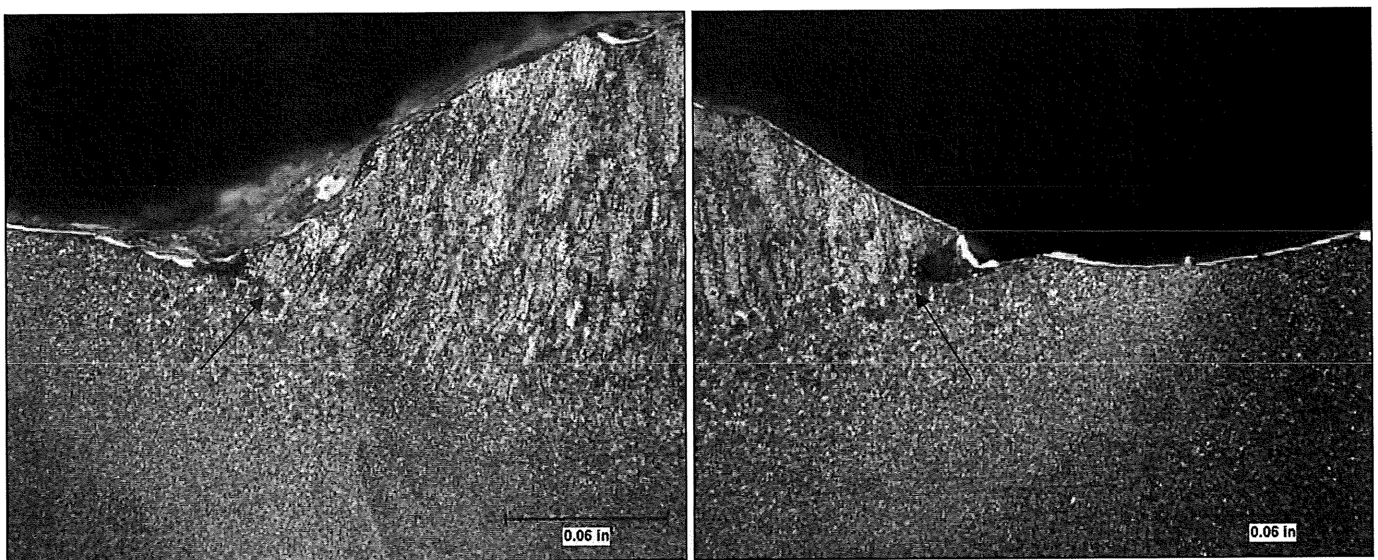

Specimen examined at 16X, photos shown at approximately 15X
Etched in 2% Nital

Figure 3: Photomacrographs of the Section 1. The discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (red arrows).

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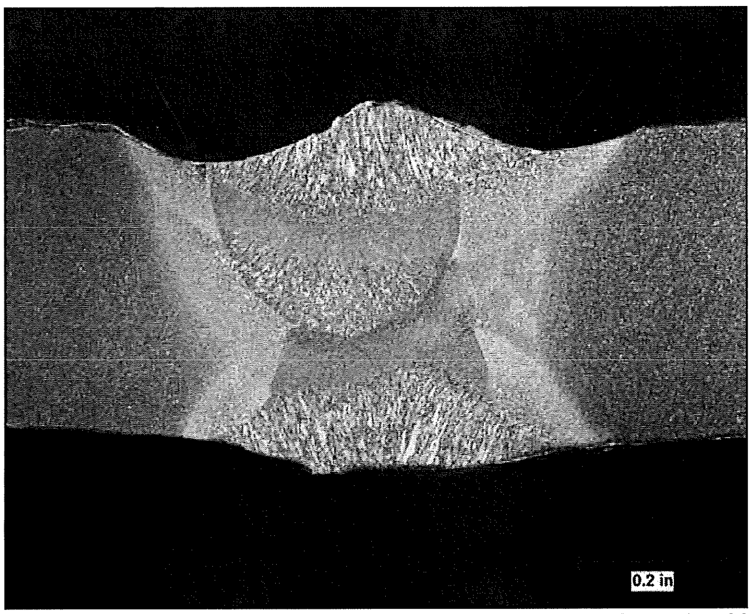

Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 4: Photomacrograph of the Section 2, which had discontinuities at both toes (red arrows) on one side of the weld.

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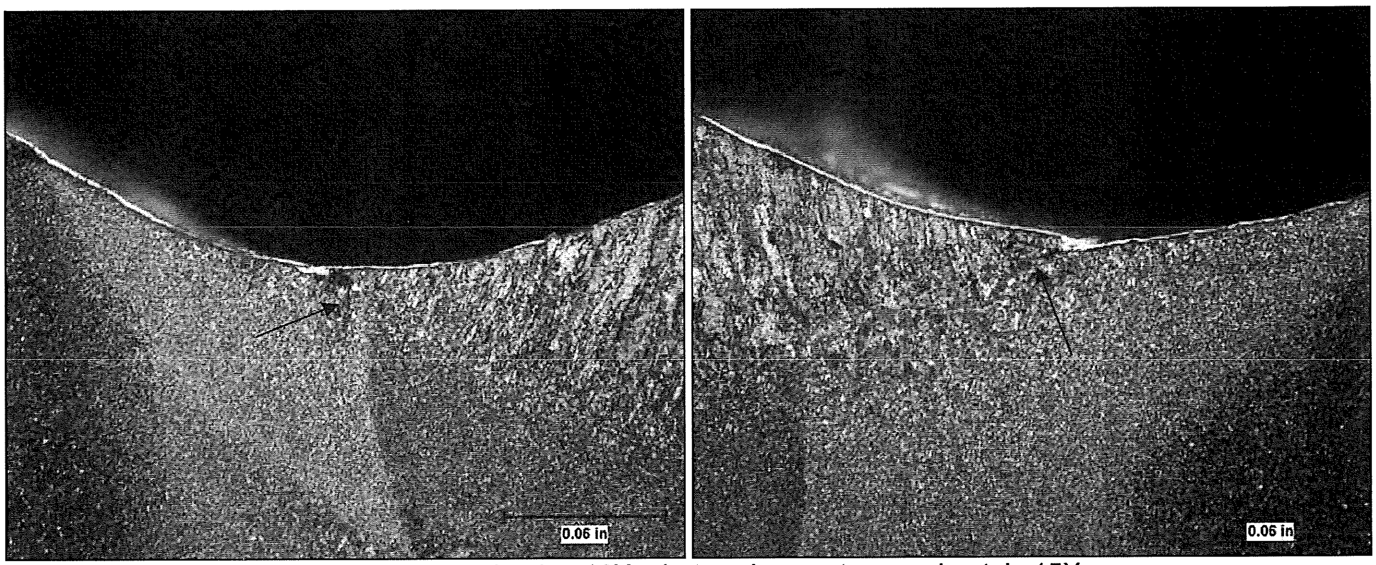

Specimen examined at 16X, photos shown at approximately 15X
Etched in 2% Nital

Figure 5: Photomacrographs of the Section 2. The discontinuities at the toes of the weld were revealed to be cracks propagating along the fusion line of the weld (red arrows).

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Report For:	TEAM Industrial Services (NFLD) 41 Sagona Avenue MOUNT PEARL, Newfoundland A1N 4P9	**Laboratory #:**	**742906-16 (Revised)**
		Report Date:	December 16, 2016
		Received Date:	December 6, 2016
Attention:	Keith Gowan	**Customer P.O.#:**	
Specimen:	For Hatch Limited, "Penstock" Weld Pipe Coupon		

METALLURGICAL TEST REPORT

Two weld coupon specimens, previously subjected to macroscopic examination (CMTL Lab #739108-16), were further sectioned, then mounted and prepared for microscopic examination in accordance with ASTM E3-11. The specimens were etched in 2% Nital and examined using an optical microscope. Examinations were performed at and near fusion line locations on either side of the weld, where the cracks were observed during the previous macroscopic examination. These locations were labelled as "FL" and "FL +1" as instructed by the customer.

RESULTS

Section 1: Examination of the weld coupon specimen at the "FL" locations revealed transgranular cracks propagating through the HAZ of the weld from cavities located at both toes on the face of the weld (refer to Figure 1). Both cavities were filled with corrosion product, indicating the cavities may have formed due to pitting corrosion. The HAZ microstructure at the toe of the weld consisted of relatively coarse-grained pearlite with intergranular ferrite. The weld microstructure consisted of columnar ferrite and pearlite. At the "FL +1" locations, the HAZ microstructure was a heterogeneous mixture of ferrite and pearlite, with a more refined grain size (refer to Figure 2).

Section 2: Examination of the weld coupon specimen at the "FL" locations revealed transgranular cracks propagating through the HAZ of the weld from a cavity located at one toe on the face of the weld, and from an overlap at the other toe on the face of the weld (refer to Figure 3). The cavity was filled with corrosion product, indicating it may have formed due to pitting corrosion. An inclusion was observed within the overlap. The HAZ microstructure at the toe of the weld consisted of relatively coarse-grained pearlite with intergranular ferrite. The weld microstructure consisted of columnar ferrite and pearlite. At the "FL +1" locations, the HAZ microstructure was a heterogeneous mixture of ferrite and pearlite, with a more refined grain size (refer to Figure 4).

Cambridge Materials Testing Limited

Per Randi Lee (signature) — Randi Lee, *Quality Assurance*

Per (signature) — Dan Bielby, *Technician*

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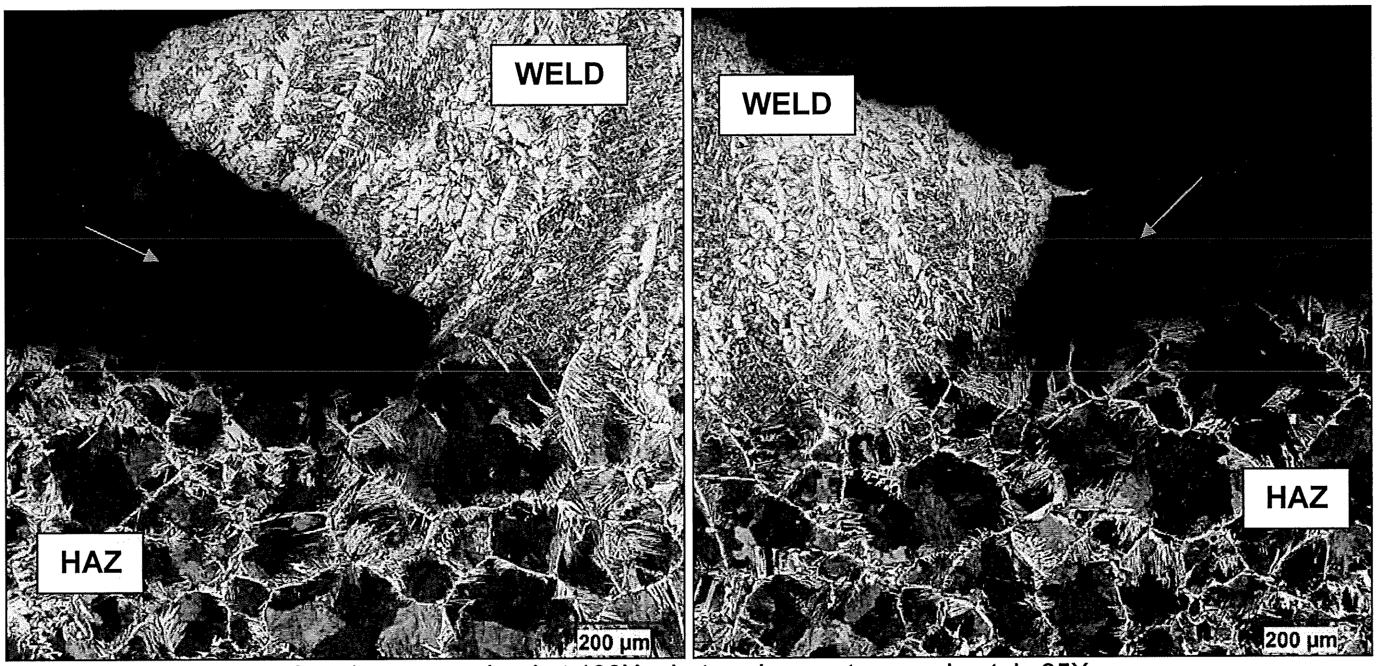
TEAM Industrial Services (NFLD)
Lab #742906-16 (Revised)



Specimen examined at 100X, photos shown at approximately 85X
Etched in 2% Nital

Figure 1: Photomicrographs of the Section 1 weld coupon at the "FL" locations. Transgranular cracks (red arrows) propagated through the HAZ of the weld from cavities located at the both toes on the face of the weld. Both cavities were filled with corrosion product (green arrows). The HAZ microstructure at the toe of the weld consisted of relatively coarse-grained pearlite with intergranular ferrite. The weld microstructure consisted of columnar ferrite and pearlite.

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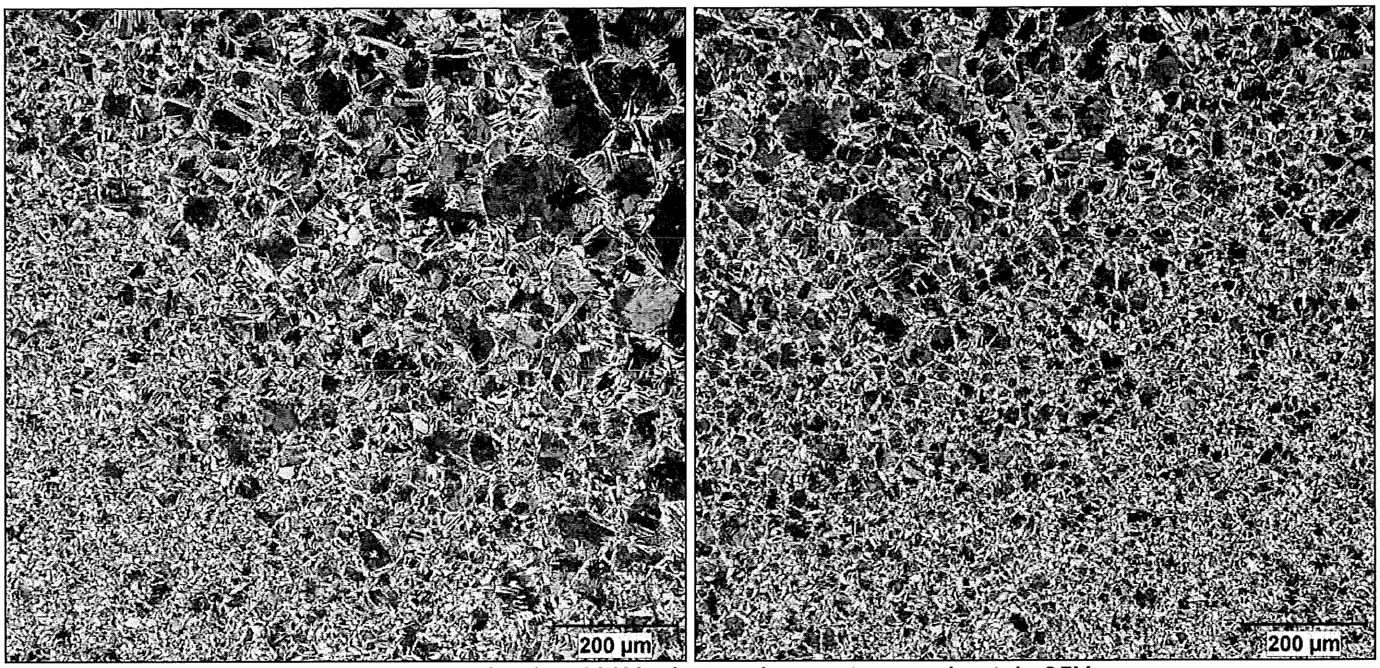
Lab #742906-16 (Revised)



Specimen examined at 100X, photos shown at approximately 85X
Etched in 2% Nital

Figure 2: Photomicrographs of the Section 1 weld coupon at the "FL +1" locations, where the HAZ microstructure was a heterogeneous mixture of ferrite and pearlite, with a more refined grain size.

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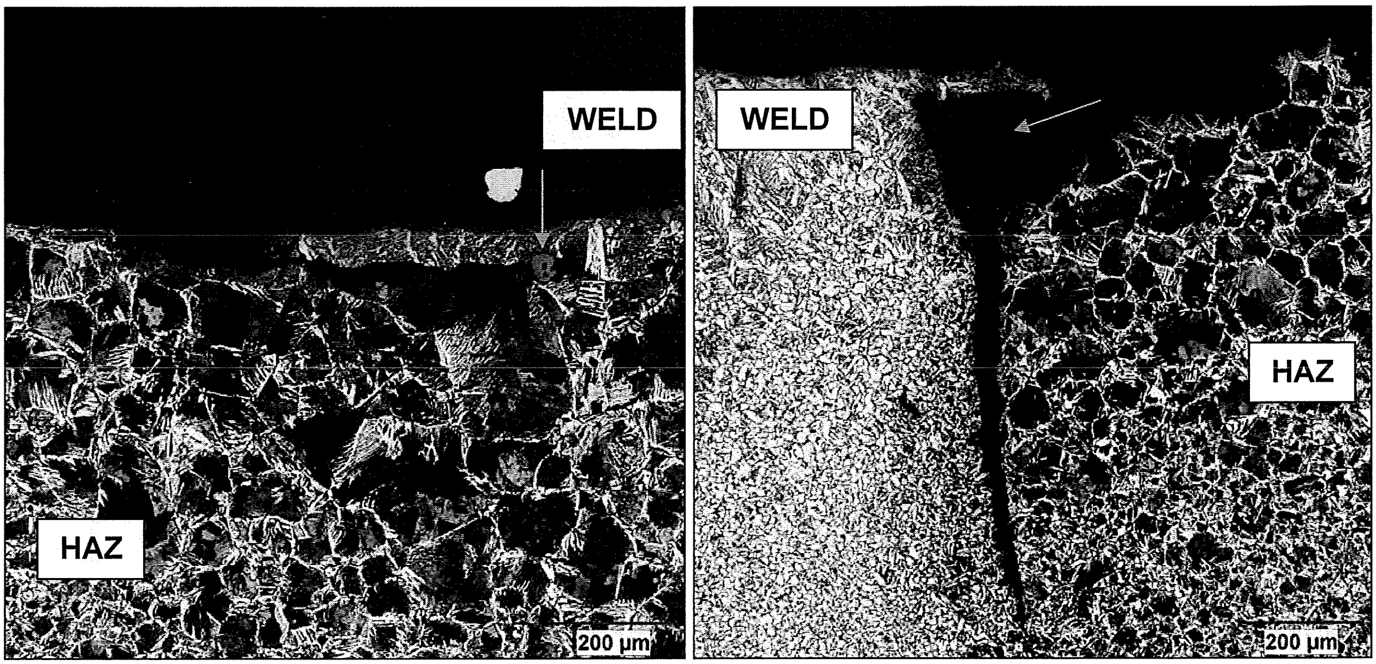

Specimen examined at 100X, photos shown at approximately 85X
Etched in 2% Nital

Figure 3: Photomicrographs of the Section 2 weld coupon at the "FL" locations. Transgranular cracks (red arrows) propagated through the HAZ of the weld from a cavity located at one toe on the face of the weld (right), and from an overlap at the other toe on the face of the weld (left). The cavity was filled with corrosion product (green arrow, right). An inclusion was observed within the overlap (green arrow, left). The HAZ microstructure at the toe of the weld consisted of relatively coarse-grained pearlite with intergranular ferrite. The weld microstructure consisted of columnar ferrite and pearlite.

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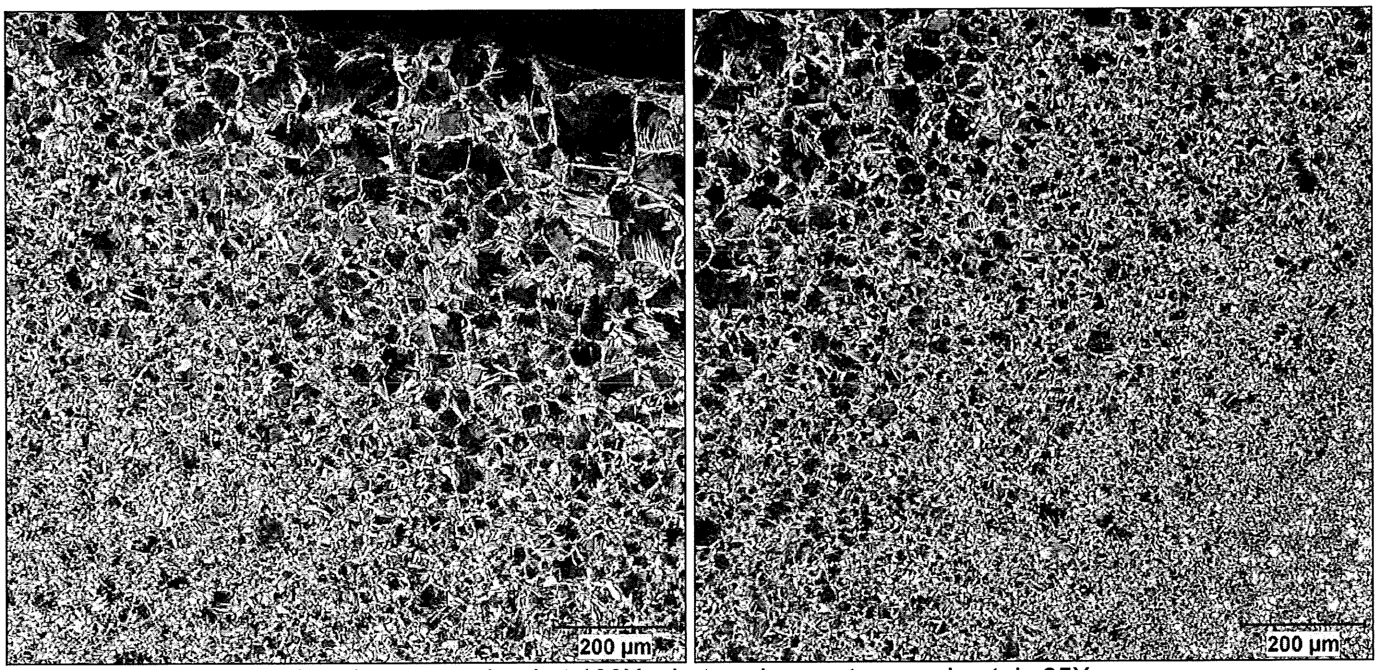

Specimen examined at 100X, photos shown at approximately 85X
Etched in 2% Nital

Figure 4: Photomicrographs of the Section 2 weld coupon at the “FL +1” locations, where the HAZ microstructure was a heterogeneous mixture of ferrite and pearlite, with a more refined grain size.

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 739111-16

Report Date: October 21, 2016
Received Date: October 17, 2016

Attention: Keith Gowan

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon

TRANSVERSE WELD TENSILE REPORT

	RESULT	
Specimen Width:	0.745	in.
Specimen Thickness:	0.370	in.
Cross Sectional Area:	0.276	in^2
Maximum Load:	19,152	lbf
Ultimate Tensile Strength:	69,500	psi

The tensile specimen fractured in the base metal in a ductile manner.

Testing performed according to ASME Boiler and Pressure Vessel Code Section IX (2015 Edition).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Matthew Liska
Matthew Liska — *Technician*

Cambridge materials testing limited

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 739110-16

Report Date: October 21, 2016
Received Date: October 17, 2016

Attention: Keith Gowan

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.073	%	Silicon	0.52	%
Manganese	0.69	%	Titanium	0.02	%
Phosphorus	0.015	%	Vanadium	0.01	%
Sulphur	0.021	%			

Chemistry was performed on the weld metal.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf — *Technician*

Cambridge
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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 739109–16

Report Date: October 21, 2016
Received Date: October 17, 2016

Attention: Keith Gowan

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.21	%
Manganese	0.52	%
Phosphorus	< 0.010	%
Sulphur	0.020	%
Silicon	0.07	%

The above analysis satisfies the chemical composition limits of UNS grade G10200 (1020) and G10230 (1023) steel.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf — *Technician*

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Report For: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory #: **739812-16**

Report Date: October 26, 2016
Received Date: October 25, 2016

Attention: Keith Gowan

Customer P.O.#:

Specimen: For Hatch Limited, Paint (Coal Tar Epoxy) from ID Surface of a "Penstock" Weld Pipe Coupon

TEST REPORT

One pipe section with paint was received for identification and quantitation of asbestos, if present, along with the identification, where possible, of other materials. The paint was removed from the pipe and milled to a powder for purposes of analysis in accordance with EPA/600/R-93/116 (July 1993) using both stereomicroscope and polarized light microscopy. The paint sample was analyzed to evaluate the morphology, colour, refractive index, extinction, sign of elongation, birefringence, and dispersion staining colour characteristics of fibrous matter.

RESULTS

SAMPLE DESCRIPTION	% COMPOSITION (VISUAL AREA ESTIMATION)	
	Asbestos	Other
Homogenous, black, hard, flakey, non-friable	None	Matrix: 100%

Notes: 1. No fibrous matter was identified within the paint material.
2. Testing performed at the CMTL Mississauga location.

File Name

Cambridge Materials Testing Limited

Per Jill Cook *Jill Cook* *Quality Assurance*

Per ____________________ *Technician*

Appendix B
Weld Coupon #2 Test Report

1. Introduction

As part of the Root Cause Analysis (RCA) investigation a coupon measuring approximately 460 mm x 460 mm (18" x 18") was removed from section XX (CSA 40.8 Gr B material, Coupon #2) of BDE Penstock #1. The coupon incorporated a portion of one of the circumferential weld seams.

2. Required Tests

The following non-destructive testing was performed by TEAM Industrial Services, St. John's, NL, to aid the RCA investigation:

- Radiographic Examination

The following destructive testing was performed by Cambridge Materials Testing Limited, Cambridge, Ontario, to aid the RCA investigation:

- Macroetch Evaluation
- Vickers Hardness Traverse
- Microetch Evaluation
- Transverse Weld Tensile
- Weld Metal Chemical Analysis Test
- Base Metal Chemical Analysis Test

3. Test Results

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected, but was in the range of acceptable limits.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).
- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 170 to 214
- Hardness values for the HAZ ranged from 168 to 214
- Hardness values for the Base material ranged from 174 to 185

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld and labeled "FL" and "FL+1mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 84.5 ksi (582.6 MPa)

The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with

E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.018%, it is still above normal levels.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within specifications.

Base Metal Chemical Analysis

The base metal chemistry is consistent with CSA 40.8 Gr B material.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within composition specifications for UNS grade G15240 (1524) steel.

Attachment A
Test Results

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 744803-17

Report Date: January 13, 2017
Received Date: January 09, 2017

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #2 - Circumferential Weld, Material: CSA 40.8 Gr. B

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.21	%
Manganese	1.44	%
Phosphorus	0.010	%
Sulphur	0.020	%
Silicon	0.26	%

Chemistry was performed on the base metal.

The above analysis satisfies the chemical composition limits of UNS grade G15240 (1524) steel.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf *Technician*

Cambridge materials testing limited

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 744805-17

Report Date: January 13, 2017
Received Date: January 09, 2017

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #2 - Circumferential Weld, Material: CSA 40.8 Gr. B

TRANSVERSE WELD TENSILE REPORT

	RESULT	
Specimen Width:	0.748	in.
Specimen Thickness:	0.345	in.
Cross Sectional Area:	0.258	in^2
Maximum Load:	21,842	lbf
Ultimate Tensile Strength:	84,500	psi

The tensile specimen fractured in the weld zone in a ductile manner.

Testing performed according to ASME Boiler and Pressure Vessel Code Section IX (2015 Edition).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Matthew Liska
Matthew Liska — *Technician*

Cambridge materials testing limited

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 744804–17

Report Date: January 13, 2017
Received Date: January 09, 2017

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #2 - Circumferential Weld, Material: CSA 40.8 Gr. B

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.14	%
Manganese	1.60	%
Phosphorus	0.015	%
Sulphur	0.018	%
Silicon	0.39	%

Chemistry was performed on the weld metal.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf — *Technician*

Cambridge materials testing limited

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Report For: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory #: **744802-17**

Report Date: January 13, 2017
Received Date: January 9, 2017

Attention: Cyril Pretty

Customer P.O.#:

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #2 Circumferential Weld
Material: CSA 40.8 Gr. B

METALLURGICAL TEST REPORT

Two random transverse sections were cut from the submitted weld coupon and prepared according to ASTM E3-11. The sections were arbitrarily labelled Section 1 and Section 2 by CMTL and subjected to a macroetch evaluation, microstructural examination and Vickers hardness traverse.

MACROETCH EVALUATION

The sections were etched in 2% Nital and then examined using a stereo microscope for general comments on weld imperfections.

RESULTS

Section 1: Examination of the specimen showed that the weld had pitting along the inside diameter surface within the HAZ (at the weld toes) (refer to Figure 2). The weld appeared to have no cracks or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Section 2: Examination of the specimen showed that the weld had pitting along the inside diameter surface within the HAZ (at the weld toes) (refer to Figure 3). The weld appeared to have no cracks or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Cambridge Materials Testing Limited

Per Randi Lee — Randi Lee, *Quality Assurance*

Per Holly Steele — Holly Steele, *Technician*

Cambridge materials testing limited

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Lab # 744802-17

VICKERS HARDNESS TRAVERSE

The macroetch sections were then re-polished according to ASTM E3-11 and subjected to a Vickers hardness traverse (refer to Figure 1). The Vickers hardness readings were performed according to ASTM E92-16 using a 10kgf test force. Indentations were measured at 100X magnification.

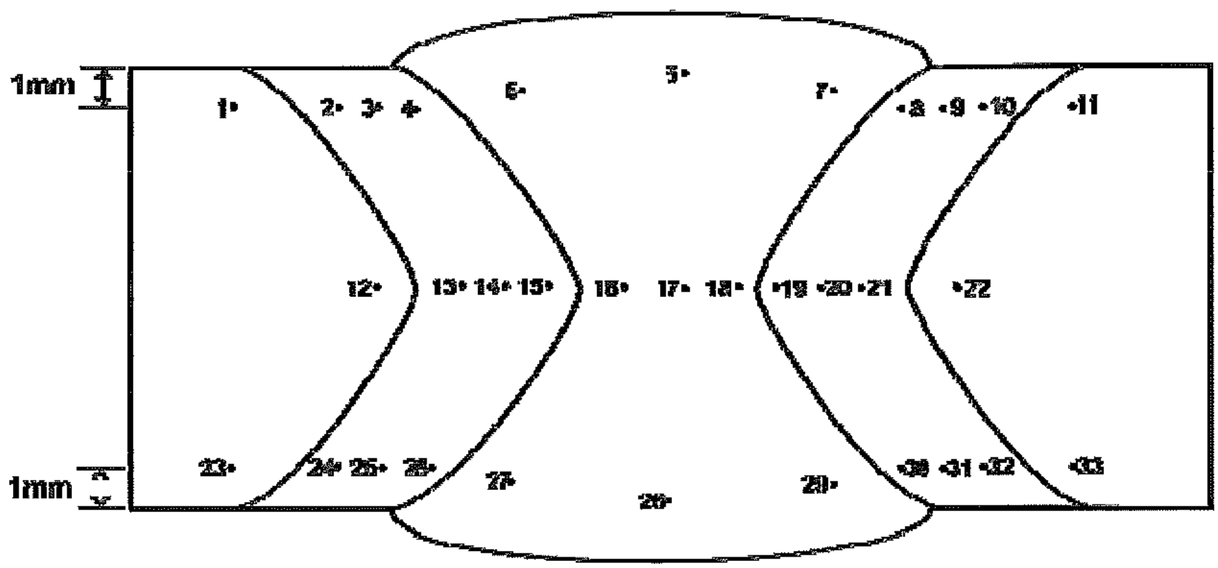

Figure 1: Schematic drawing showing the Vickers hardness indentation locations.

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RESULTS

Traverse Pass	Location	Indent	Section 1 Hardness (HV 10kgf)	Section 2 Hardness (HV 10kgf)
Top Cap Pass	Base Material	1	181	181
	HAZ	**2**	**171**	**168**
		3	**181**	**180**
		4	**184**	**193**
	Weld	5	170	176
		6	173	177
		7	178	175
	HAZ	**8**	**185**	**188**
		9	**183**	**190**
		10	**182**	**176**
	Base Material	11	185	183
Mid-Thickness Pass	Base Material	12	179	185
	HAZ	**13**	**184**	**193**
		14	**192**	**197**
		15	**203**	**212**
	Weld	16	188	197
		17	199	196
		18	195	199
	HAZ	**19**	**209**	**207**
		20	**201**	**196**
		21	**190**	**195**
	Base Material	22	184	184
Bottom Cap Pass	Base Material	23	174	176
	HAZ	**24**	**185**	**187**
		25	**196**	**194**
		26	**214**	**209**
	Weld	27	214	192
		28	198	197
		29	207	195
	HAZ	**30**	**214**	**210**
		31	**209**	**198**
		32	**193**	**188**
	Base Material	33	178	177

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MICROSTRUCTURAL EXAMINATION

The sections used for the Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. Examinations were performed at and near the fusion line on either side of the weld, the weld was arbitrarily labelled "Side A" and "Side B" by CMTL for identification purposes. These locations were labelled as "FL" and "FL+1mm" as instructed by the customer.

RESULTS

Section 1: Examination of the etched specimen revealed a microstructure consisting of ferrite and pearlite. A relatively coarse grain HAZ was observed on either side of the weld at the "FL" locations (refer to Figure 4 and Figure 5). At the "FL+1mm" locations, the HAZ showed a more refined structure consisting of a fairly uniform mixture of ferrite and pearlite. At a higher magnification some sulphide inclusions were observed dispersed throughout the material (refer to Figure 6).

Section 2: Examination of the etched specimen revealed a microstructure consisting of ferrite and pearlite. A relatively coarse grain HAZ was observed on either side of the weld at the "FL" locations (refer to Figure 7 and Figure 8). At the "FL+1mm" locations, the HAZ showed a more refined structure consisting of a fairly uniform mixture of ferrite and pearlite. At a higher magnification some sulphide inclusions were observed dispersed throughout the material (refer to Figure 9).

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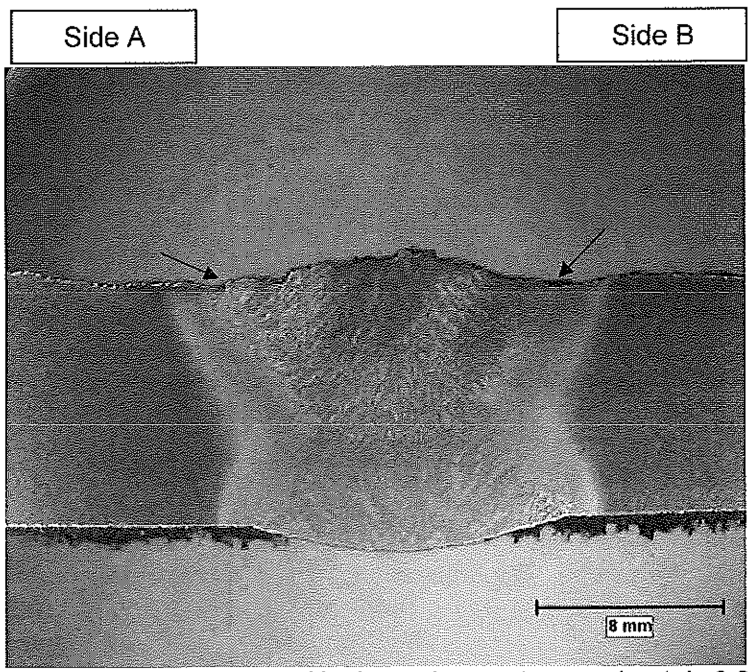

Specimen examined at 3.2X, photo shown at approximately 3.2X
Etched in 2% Nital

Figure 2: Photomacrograph of the Section 1, showing the pitting along the surface within the HAZ/at the weld toes along the inside diameter.

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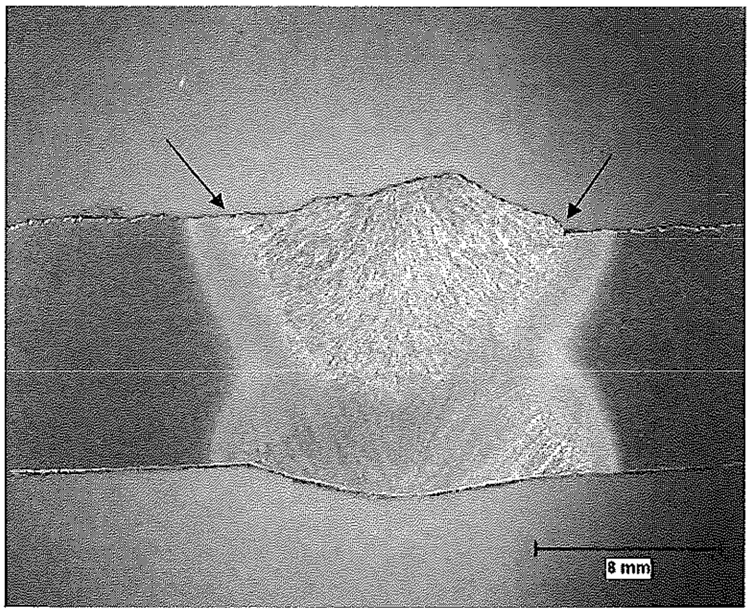
Side A | Side B



Specimen examined at 3.2X, photo shown at approximately 3.2X
Etched in 2% Nital

Figure 3: Photomacrograph of the Section 2, showing the pitting along the surface within the HAZ/at the weld toes along the inside diameter.

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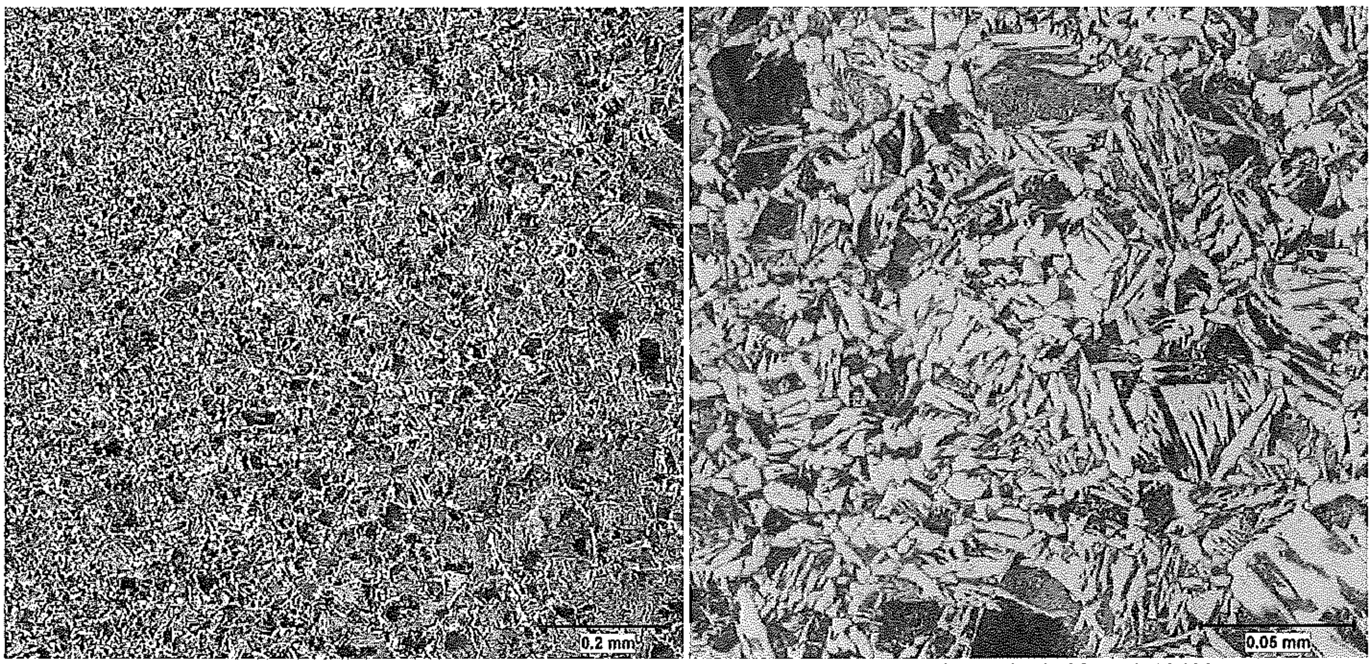

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 4: Photomicrographs of the Section 1 "Side A" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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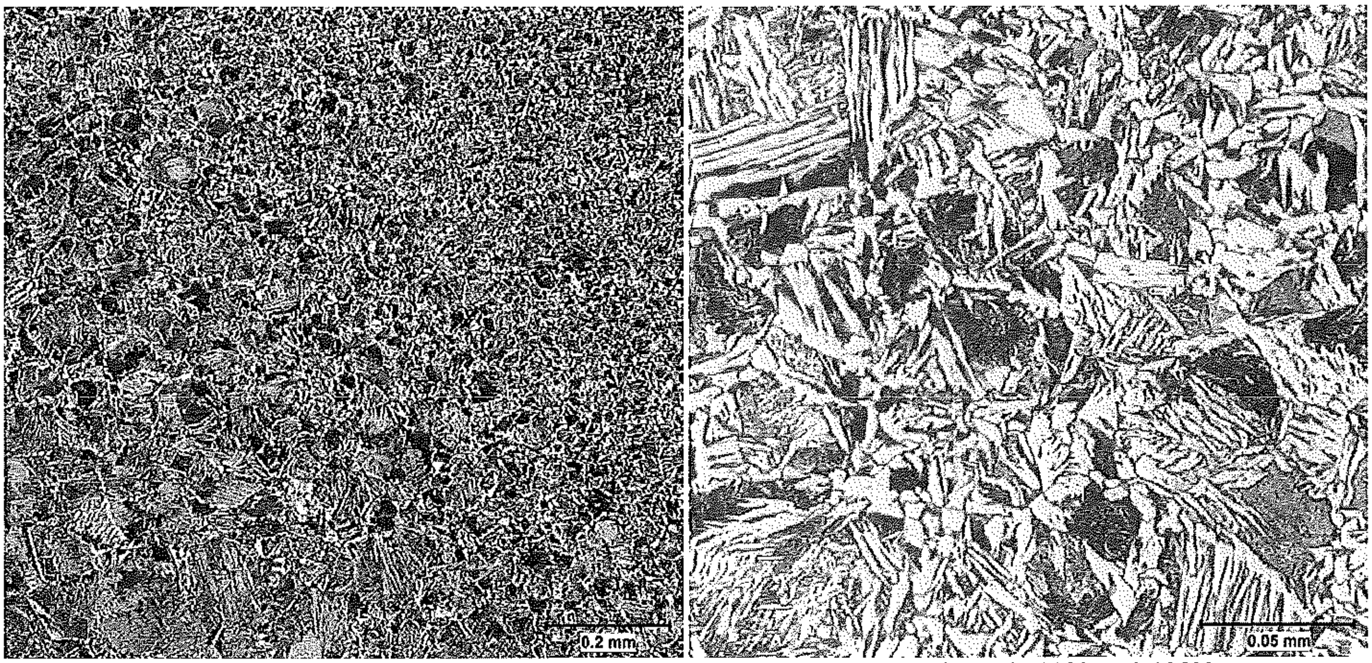

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 5: Photomicrographs of the Section 1 "Side B" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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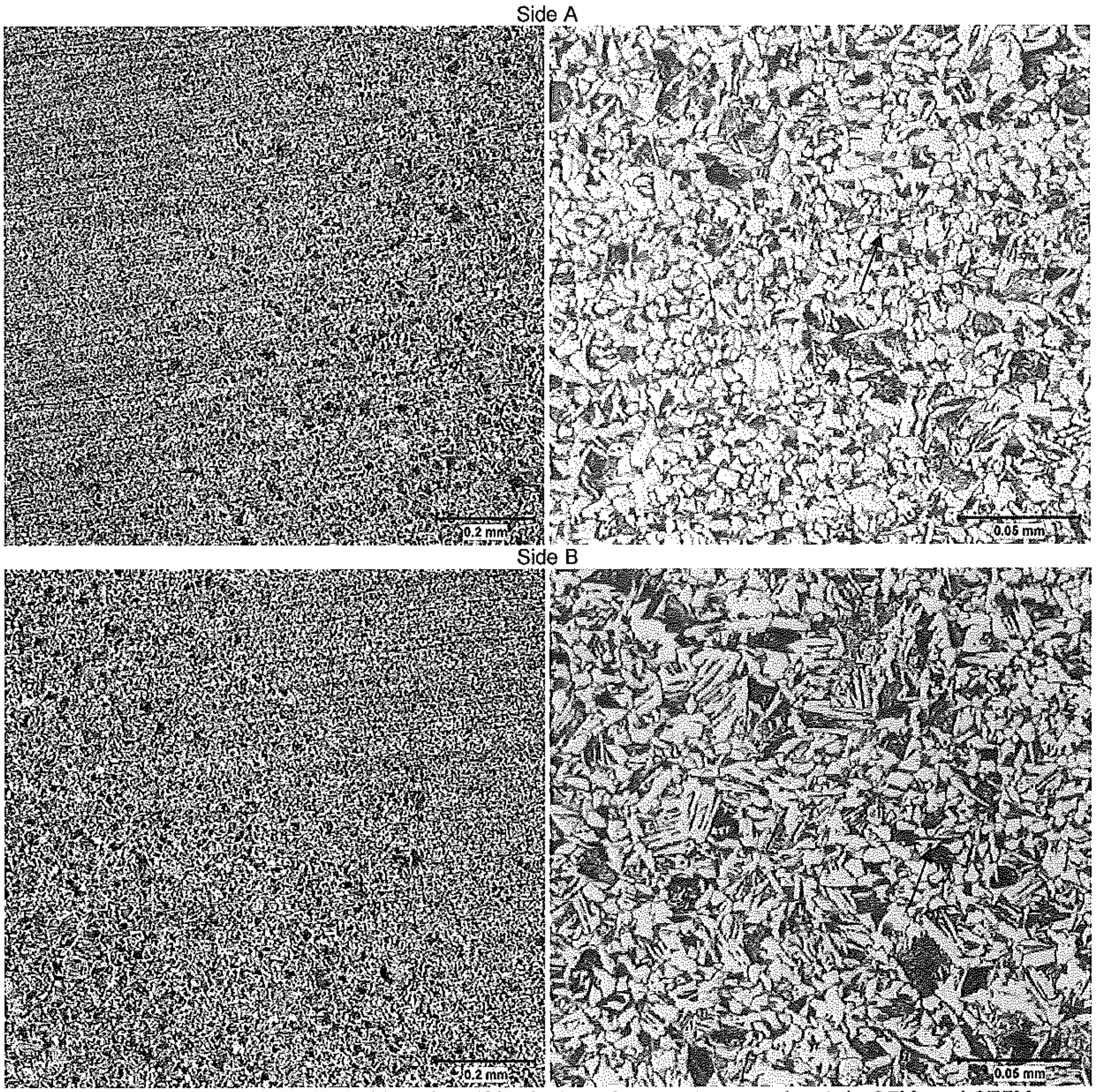

Specimen examined at 100X and 500X, photos shown at approximately 85X and 375X
Etched in 2% Nital

Figure 6: Photomicrographs of the Section 1 "Side A" and "Side B" weld coupon at the "FL +1" locations; where the HAZ microstructure showed a fairly uniform mixture of ferrite and pearlite, with a more refined grain size. At a higher magnification some sulphide inclusions were observed (refer to red arrows).

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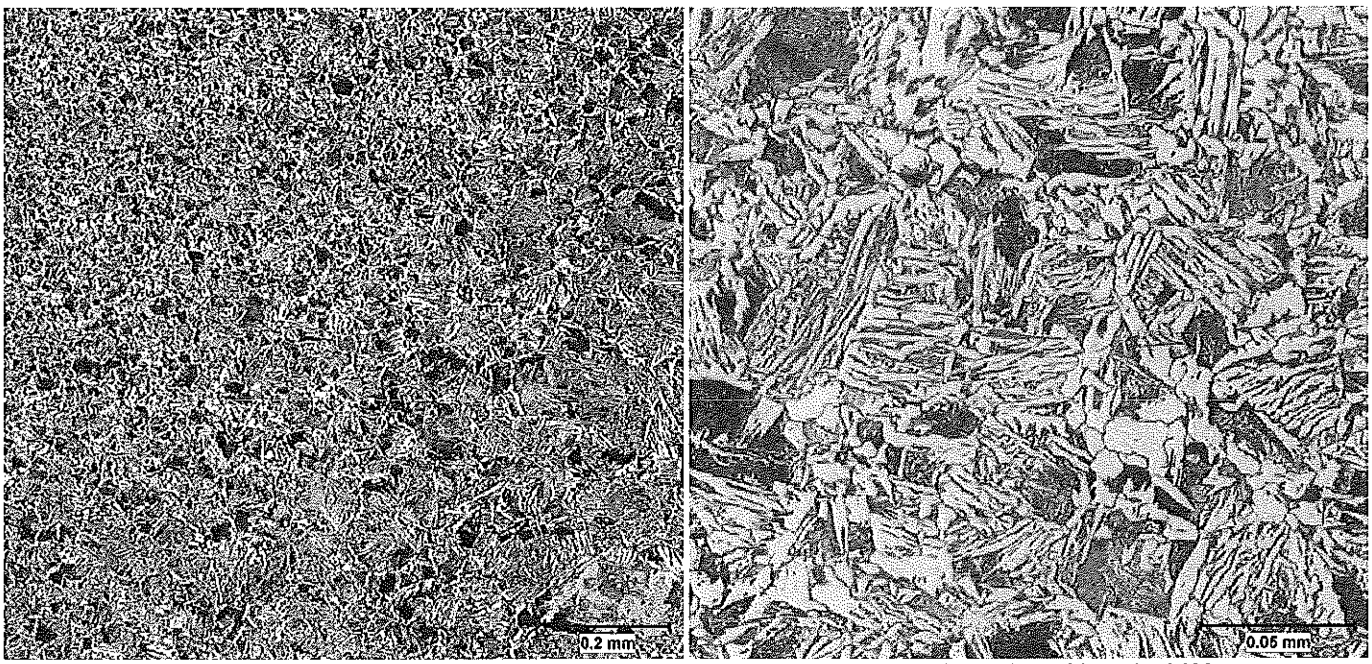

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 7: Photomicrographs of the Section 2 "Side A" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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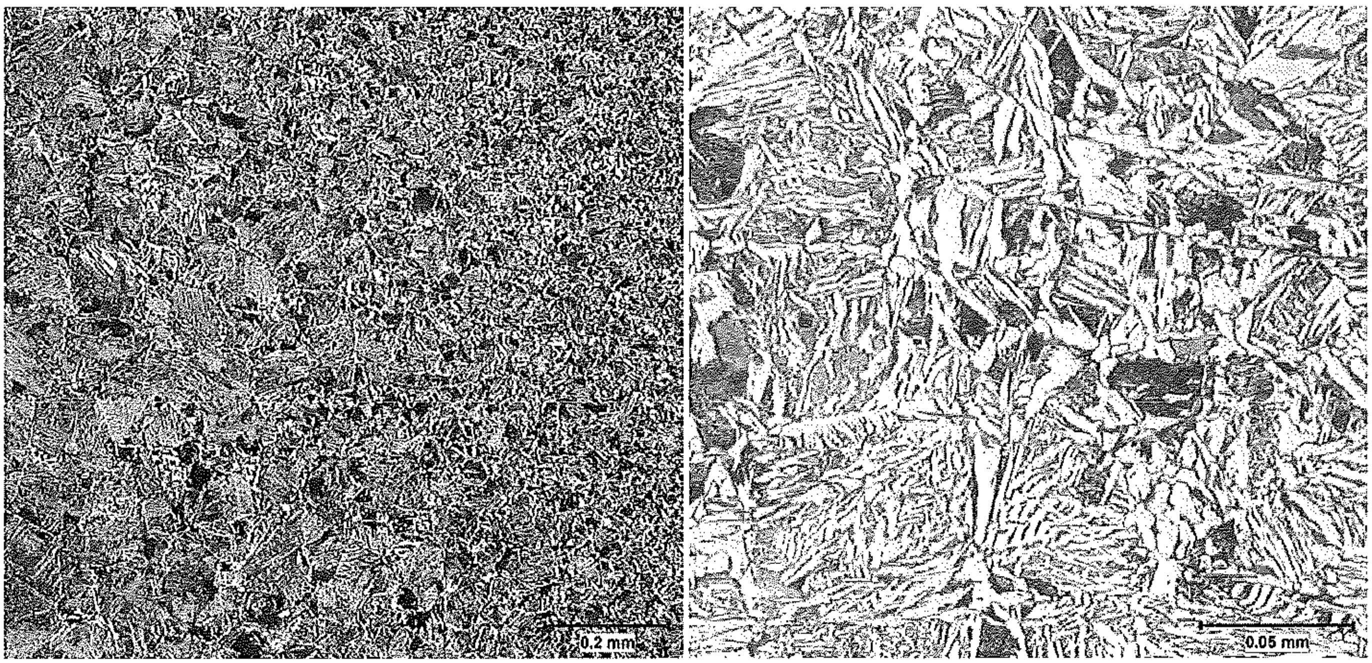

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 8: Photomicrographs of the Section 2 "Side B" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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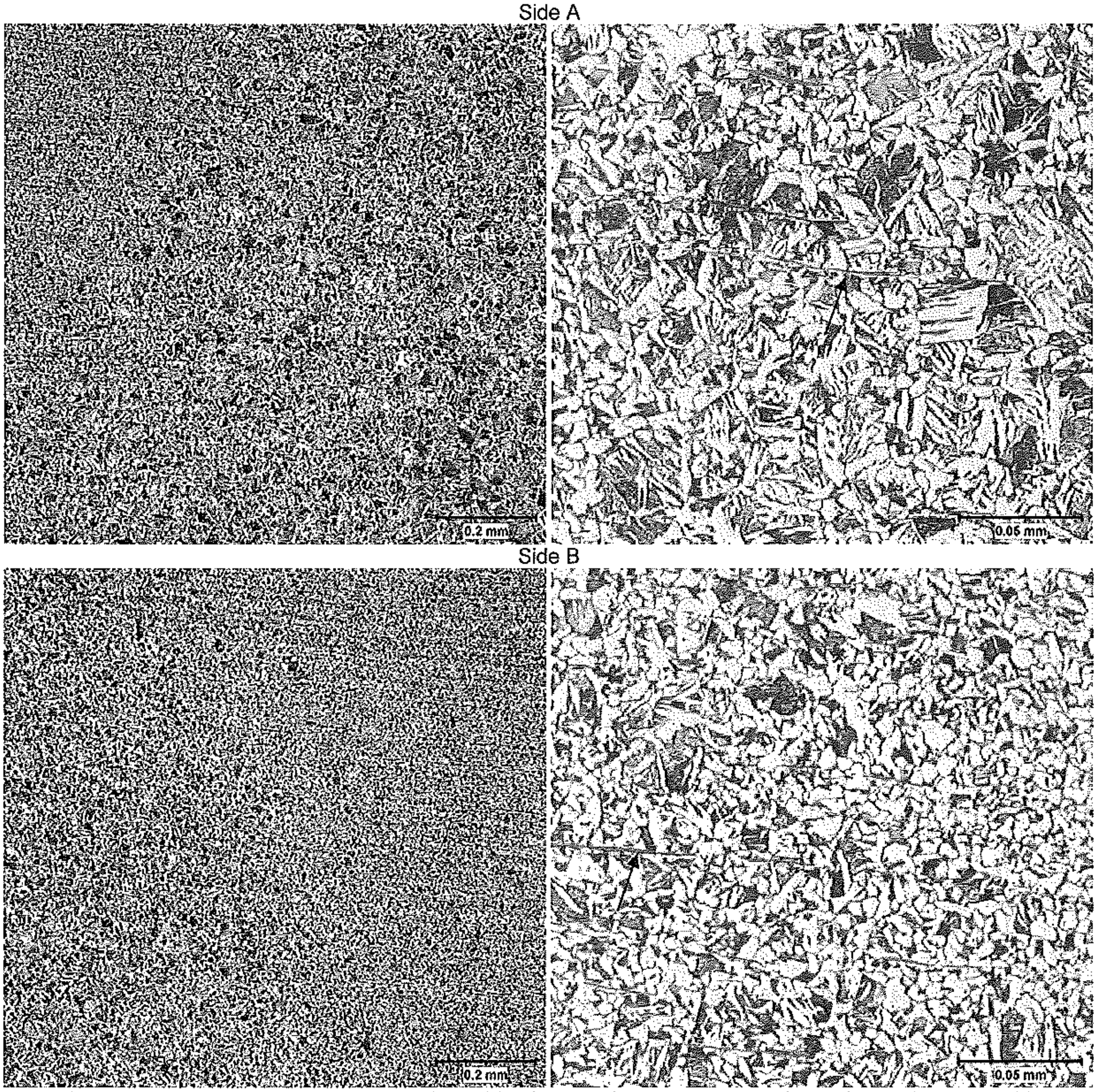
Side A



Specimen examined at 100X and 500X, photos shown at approximately 85X and 375X
Etched in 2% Nital

Figure 9: Photomicrographs of the Section 2 "Side A" and "Side B" weld coupon at the "FL +1" locations; where the HAZ microstructure showed a fairly uniform mixture of ferrite and pearlite, with a more refined grain size. At a higher magnification some sulphide inclusions were observed (refer to red arrows).

Appendix C
Weld Coupon #3 Test Report

1. Introduction

As part of the Root Cause Analysis (RCA) investigation a coupon measuring approximately 460 mm x 460 mm (18" x 18") was removed from section XX (A285 Gr C section, Coupon #3) of BDE Penstock #1. The coupon incorporated a portion of one of the circumferential weld seams.

2. Required Tests

The following non-destructive testing was performed by TEAM Industrial Services, St. John's, NL, to aid the RCA investigation:

- Radiographic Examination

The following destructive testing was performed by Cambridge Materials Testing Limited, Cambridge, Ontario, to aid the RCA investigation:

- Macroetch Evaluation
- Vickers Hardness Traverse
- Microetch Evaluation
- Transverse Weld Tensile
- Weld Metal Chemical Analysis Test
- Base Metal Chemical Analysis Test

3. Test Results

Radiographic Examination

The radiographic examination showed no rejectable defects.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).
- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Microstructural Examination

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 153 to 181
- Hardness values for the HAZ ranged from 121 to 158
- Hardness values for the Base material ranged from 130 to 158

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld, arbitrarily named "Side A" and "Side B" for CMTL identification purposes. These locations were labeled "FL" and "FL+1mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations; with "Side A" having more ferrite observed and "Side B" having more pearlite with a more distinct coarse grain HAZ.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.

- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 63.5 ksi (437.8 MPa)
- The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.023%, it is still above normal levels.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within specifications.

Base Metal Chemical Analysis

Chemical Analysis is similar to the chemical composition limits of ASTM A285 Grade C steel, with the exception of Sulphur.

Attachment A
Test Results

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Report For:	TEAM Industrial Services (NFLD) 41 Sagona Avenue MOUNT PEARL, Newfoundland A1N 4P9	**Laboratory #:**	**743344-16 (Revised)**
		Report Date:	January 4, 2017
		Received Date:	December 12, 2016
Attention:	Cyril Pretty	**Customer P.O.#:**	
Specimen:	For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #3 Circumferential Seam Material: ASTM A285 Gr. C		

METALLURGICAL TEST REPORT

Two random transverse sections were cut from the submitted weld coupon and prepared according to ASTM E3-11. The sections were arbitrarily labelled Section 1 and Section 2 by CMTL and subjected to a macroetch evaluation, microstructural examination and Vickers hardness traverse.

MACROETCH EVALUATION

The sections were etched in 2% Nital and then examined using a stereo microscope for general comments on weld imperfections.

RESULTS

Section 1: Examination of the specimen showed that the weld had pitting along the surface within the HAZ (at the weld toes) (refer to Figure 2). The weld appeared to have no cracks or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Section 2: Examination of the specimen showed that the weld had pitting along the surface within the HAZ (at the weld toes) (refer to Figure 3). The weld appeared to have no cracks or inclusions, and there was complete penetration and complete fusion observed throughout the weld.

Cambridge Materials Testing Limited

Per Randi Lee — Randi Lee, *Quality Assurance*

Per Holly Steele — Holly Steele, *Technician*

Cambridge materials testing limited

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TEAM Industrial Services (NFLD)
Lab # 743344-16 (Revised)

VICKERS HARDNESS TRAVERSE

The macroetch sections were then re-polished according to ASTM E3-11 and subjected to a Vickers hardness traverse (refer to Figure 1). The Vickers hardness readings were performed according to ASTM E92-16 using a 10kgf test force. Indentations were measured at 100X magnification.

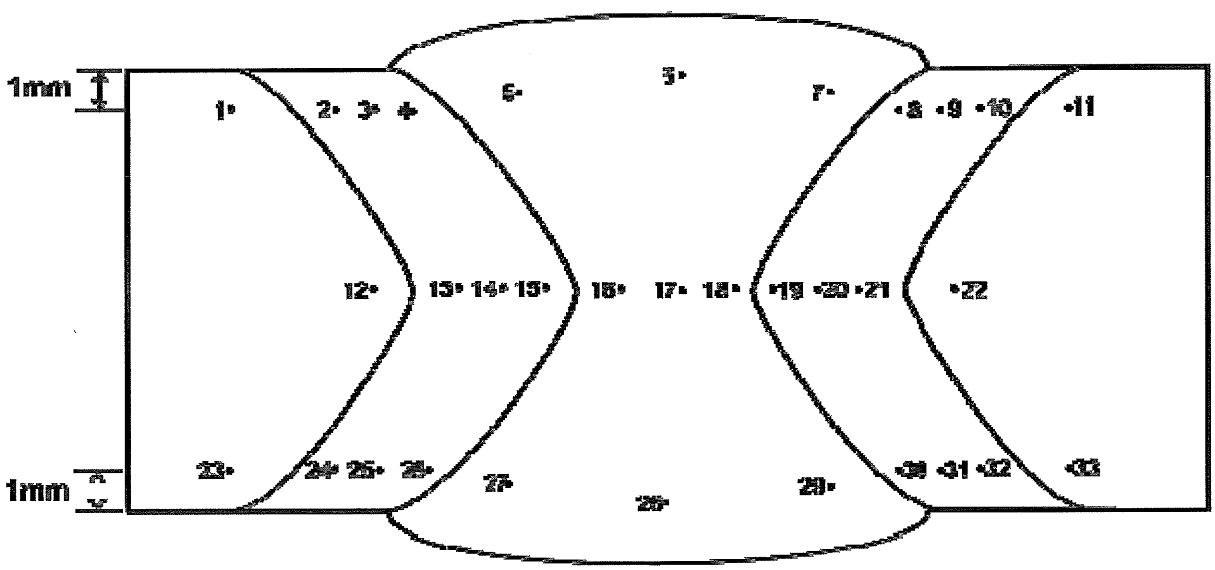

Figure 1: Schematic drawing showing the Vickers hardness indentation locations.

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TEAM Industrial Services (NFLD)
Lab # 743344-16 (Revised)

RESULTS

Traverse Pass	Location	Indent	Section 1 Hardness (HV 10kgf)	Section 2 Hardness (HV 10kgf)
Top Cap Pass	Base Material	1	136	158
	HAZ	**2**	**133**	**155**
		3	**140**	**156**
		4	**136**	**158**
	Weld	5	164	161
		6	156	163
		7	166	180
	HAZ	**8**	**136**	**138**
		9	**138**	**136**
		10	**129**	**126**
	Base Material	11	134	141
Mid-Thickness Pass	Base Material	12	134	138
	HAZ	**13**	**133**	**147**
		14	**138**	**141**
		15	**139**	**142**
	Weld	16	154	153
		17	164	157
		18	161	160
	HAZ	**19**	**137**	**140**
		20	**137**	**138**
		21	**137**	**133**
	Base Material	22	134	131
Bottom Cap Pass	Base Material	23	133	138
	HAZ	**24**	**132**	**126**
		25	**135**	**139**
		26	**139**	**141**
	Weld	27	174	175
		28	181	174
		29	170	171
	HAZ	**30**	**143**	**141**
		31	**140**	**141**
		32	**121**	**143**
	Base Material	33	130	147

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TEAM Industrial Services (NFLD)
Lab # 743344-16 (Revised)

MICROSTRUCTURAL EXAMINATION

The sections used for the Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. Examinations were performed at and near the fusion line on either side of the weld, the weld was arbitrarily labelled "Side A" and "Side B" by CMTL for identification purposes. These locations were labelled as "FL" and "FL+1mm" as instructed by the customer.

RESULTS

Section 1: Examination of the etched specimen revealed a microstructure consisting of ferrite and pearlite. A relatively coarse grain HAZ was observed on either side of the weld at the "FL" locations; with Side A having more ferrite observed and Side B having more pearlite with a more distinct coarse grain HAZ (refer to Figure 4 and Figure 5). At the "FL+1mm" locations, the HAZ showed a more refined structure consisting of a fairly uniform mixture of ferrite and pearlite. At a higher magnification some sulphide inclusions were observed dispersed throughout the material (refer to Figure 6).

Section 2: Examination of the etched specimen revealed a microstructure consisting of ferrite and pearlite. A relatively coarse grain HAZ was observed on either side of the weld at the "FL" locations; with Side A having more ferrite observed and Side B having more pearlite with a more distinct coarse grain HAZ (refer to Figure 7 and Figure 8). At the "FL+1mm" locations, the HAZ showed a more refined structure consisting of a fairly uniform mixture of ferrite and pearlite. At a higher magnification some sulphide inclusions were observed dispersed throughout the material (refer to Figure 9).

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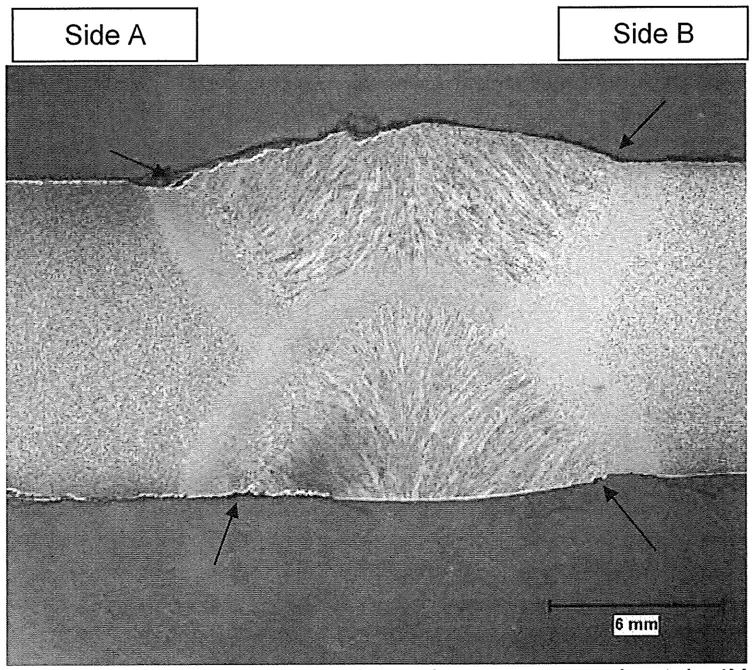

Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 2: Photomacrograph of the Section 1, showing the pitting along the surface within the HAZ/at the weld toes.

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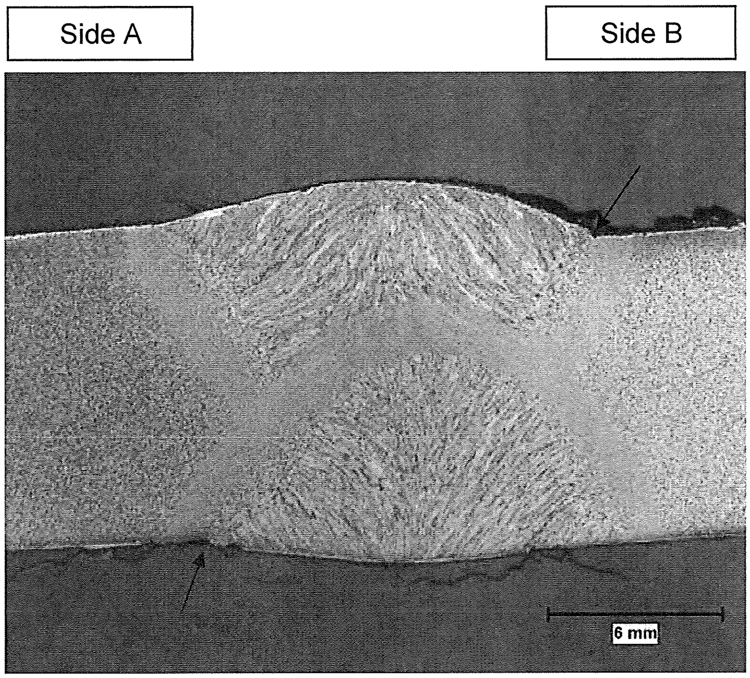

Specimen examined at 4X, photo shown at approximately 4X
Etched in 2% Nital

Figure 3: Photomacrograph of the Section 2, showing the pitting along the surface within the HAZ/at the weld toes.

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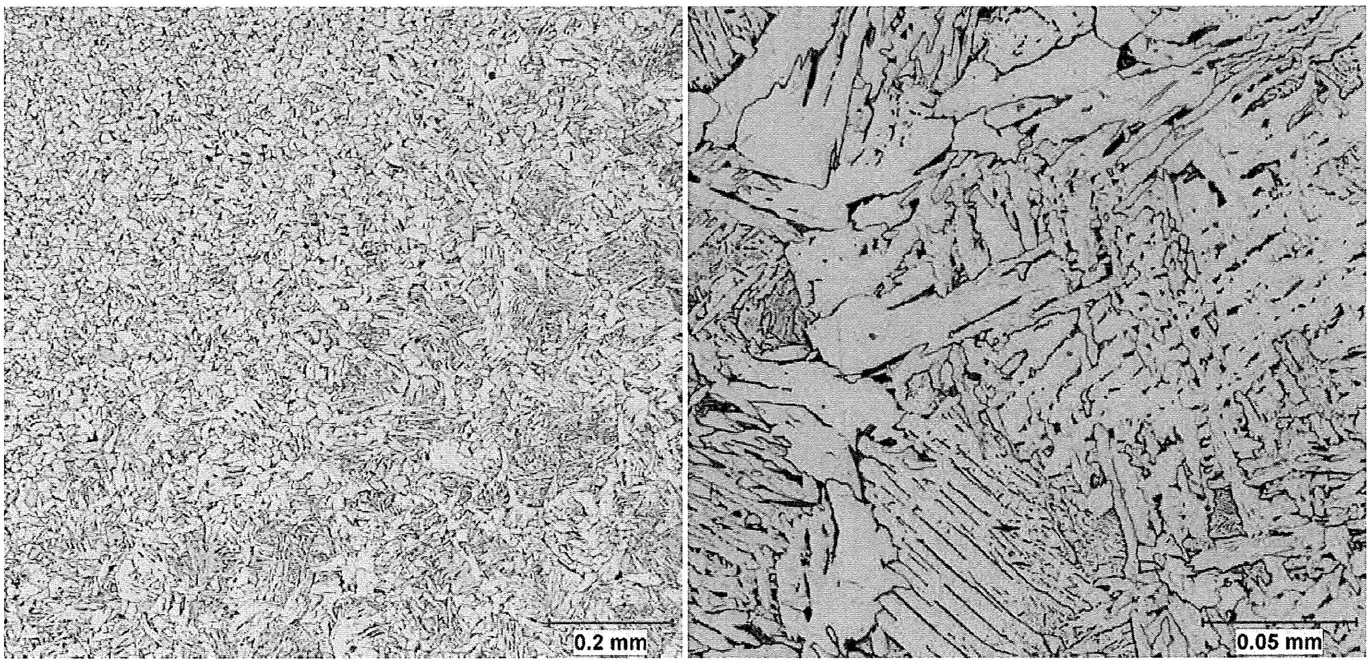

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 4: Photomicrographs of the Section 1 “Side A” weld coupon at the “FL” location, where a relatively coarse grain HAZ of ferrite and some pearlite was observed.

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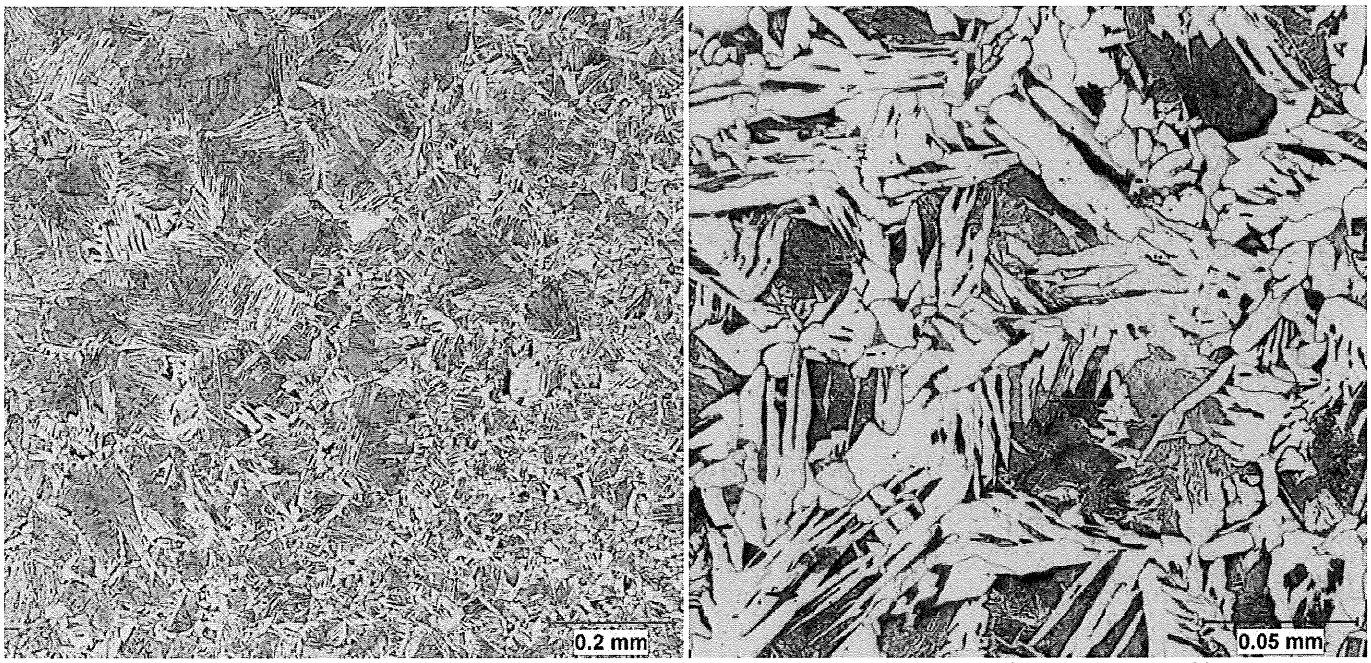

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 5: Photomicrographs of the Section 1 "Side B" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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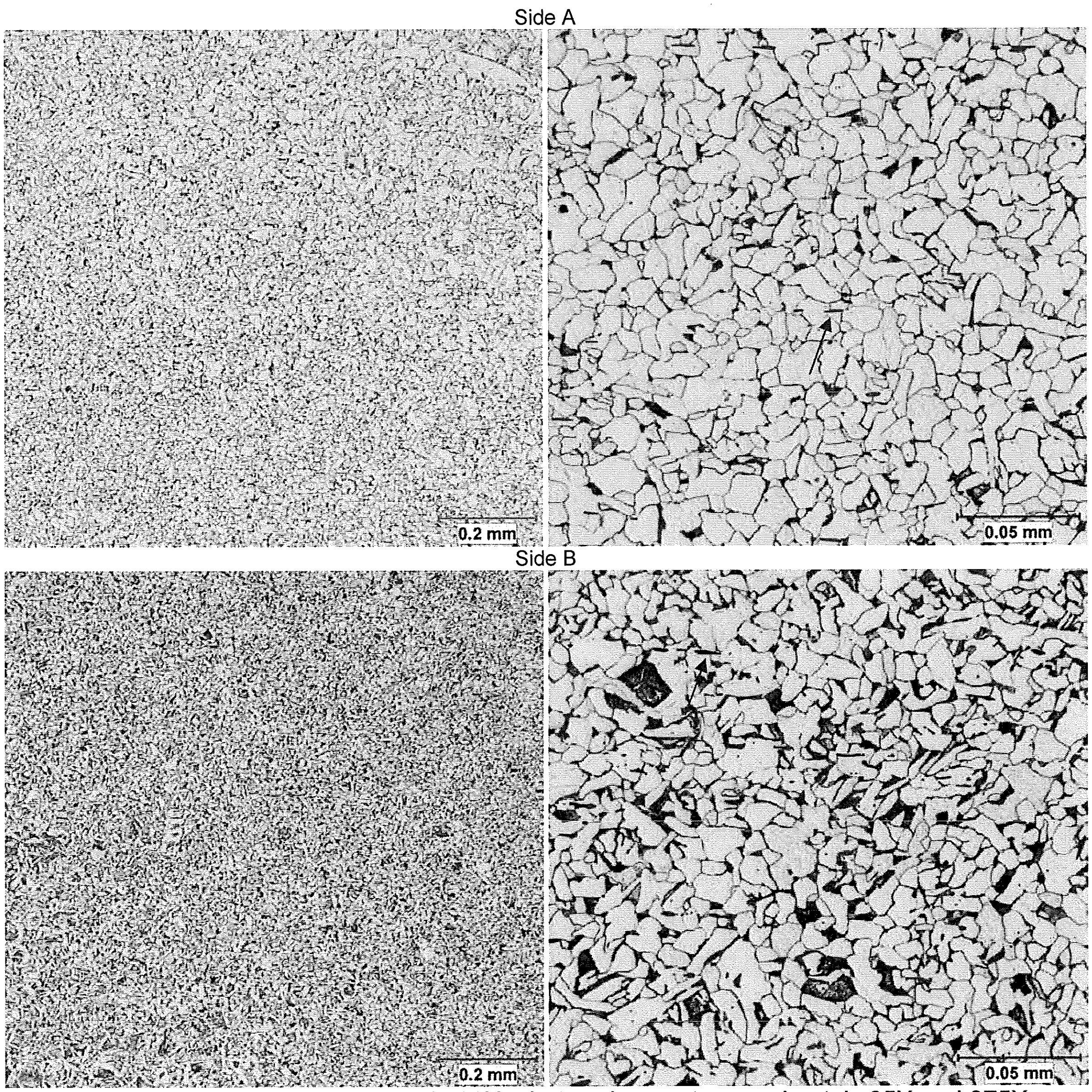

Specimen examined at 100X and 500X, photos shown at approximately 85X and 375X
Etched in 2% Nital

Figure 6: Photomicrographs of the Section 1 "Side A" and "Side B" weld coupon at the "FL +1" locations; where the HAZ microstructure showed a fairly uniform mixture of ferrite and pearlite, with a more refined grain size. At a higher magnification some sulphide inclusions were observed (refer to red arrows).

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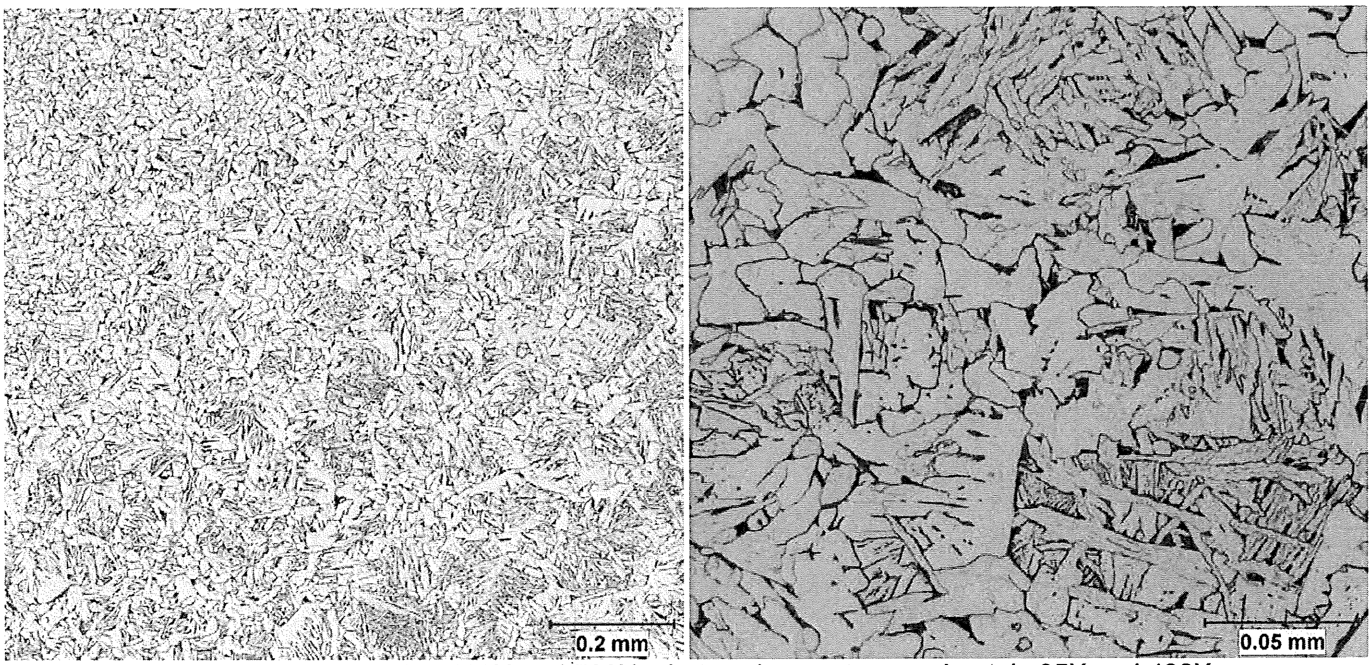

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 7: Photomicrographs of the Section 2 "Side A" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and some pearlite was observed.

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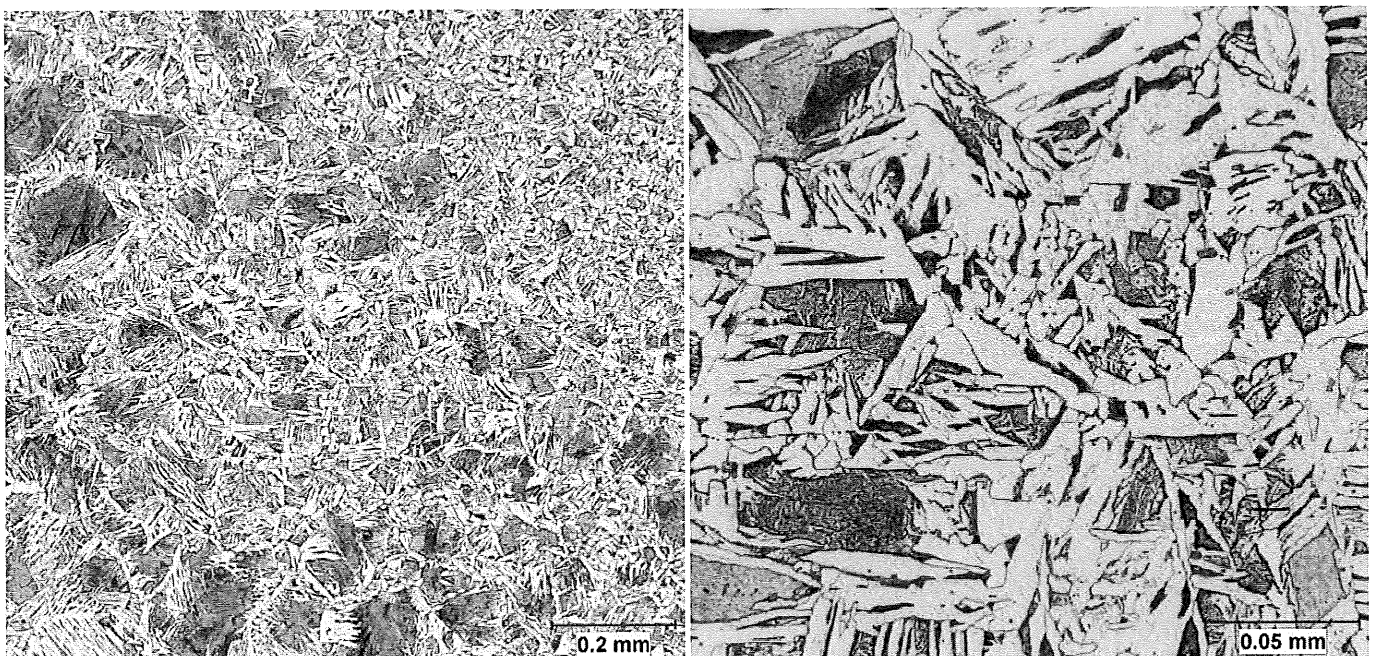

Specimen examined at 100X and 500X, photos shown at approximately 85X and 428X
Etched in 2% Nital

Figure 8: Photomicrographs of the Section 2 "Side B" weld coupon at the "FL" location, where a relatively coarse grain HAZ of ferrite and pearlite was observed.

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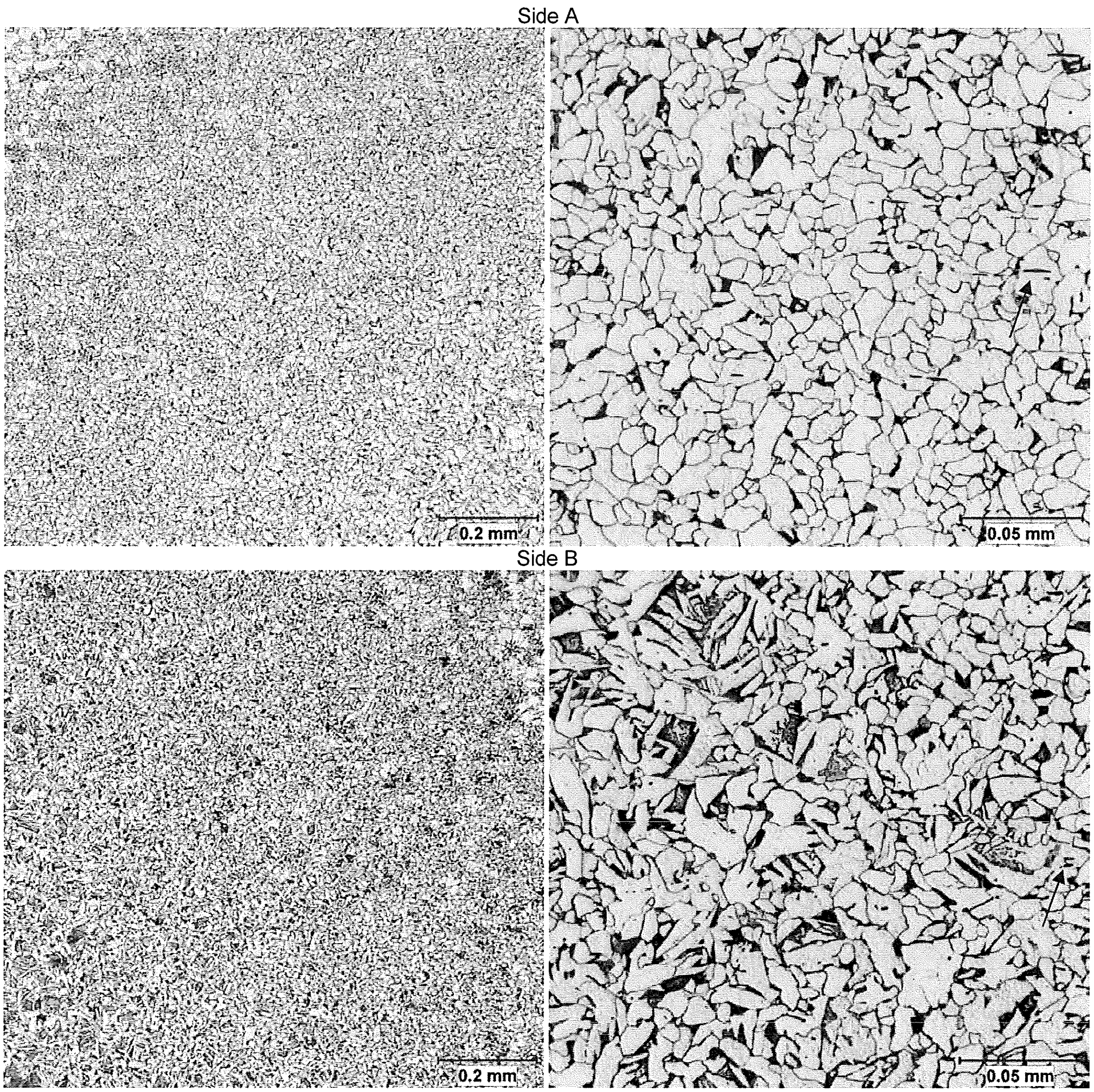

Specimen examined at 100X and 500X, photos shown at approximately 85X and 375X
Etched in 2% Nital

Figure 9: Photomicrographs of the Section 2 "Side A" and "Side B" weld coupon at the "FL +1" locations; where the HAZ microstructure showed a fairly uniform mixture of ferrite and pearlite, with a more refined grain size. At a higher magnification some sulphide inclusions were observed (refer to red arrows).

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 743345–16

Report Date: December 21, 2016
Received Date: December 12, 2016

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #3 - Circumferential Seam, Material: ASTM A285 Gr. C

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.098	%
Manganese	0.63	%
Phosphorus	0.010	%
Sulphur	0.032	%
Silicon	0.22	%

The above analysis is similar to the chemical composition limits of ASTM A285/A285M-12 Grade C steel, with the exception of Sulphur.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf *Technician*

Cambridge
materials testing limited

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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 743346–16

Report Date: December 21, 2016
Received Date: December 12, 2016

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #3 - Circumferential Seam, Material: ASTM A285 Gr. C

CHEMICAL ANALYSIS TEST REPORT

Total Carbon	0.091	%
Manganese	1.18	%
Phosphorus	0.015	%
Sulphur	0.023	%
Silicon	0.30	%

Chemistry was performed on the weld metal.

Chemical analysis performed according to ASTM E1019-11, ASTM E1097-12 (modified) and ASTM E1479-99(2011).

Cambridge Materials Testing Limited

Per Randi Lee
Randi Lee — *Quality Assurance*

Per Brittany DeGraaf
Brittany DeGraaf — *Technician*

Cambridge materials testing limited

1177 Franklin Boulevard,
Cambridge, Ontario N1R 7W4
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Report for: TEAM Industrial Services (NFLD)
41 Sagona Avenue
MOUNT PEARL, Newfoundland
A1N 4P9

Laboratory No. 743347-16

Report Date: December 20, 2016
Received Date: December 12, 2016

Attention: Cyril Pretty

Specimen: For Hatch Limited, "Penstock" Weld Pipe Coupon, Sample #3 - Circumferential Seam, Material: ASTM A285 Gr. C

TRANSVERSE WELD TENSILE REPORT

	RESULT	
Specimen Width:	0.748	in.
Specimen Thickness:	0.377	in.
Cross Sectional Area:	0.282	in^2
Maximum Load:	17,880	lbf
Ultimate Tensile Strength:	63,500	psi

The tensile specimen fractured in the base metal in a ductile manner.

Testing performed according to ASME Boiler and Pressure Vessel Code Section IX (2015 Edition).

Cambridge Materials Testing Limited

Per Randi Lee — *Quality Assurance*

Per Matthew Liska — *Technician*

Appendix D
Bay d'Espoir Pressure Conduit #1
Inspection Report 1987

HYDRO

BAY D'ESPOIR

PRESSURE CONDUIT #1

INSPECTION REPORT

NEWFOUNDLAND AND LABRADOR HYDRO

HYDRO

GENERATION & TRANSMISSION OPERATIONS
Engineering Services (Mech.)

BAY D'ESPOIR
PRESSURE CONDUIT #1
INSPECTION REPORT

Prepared by: Wayne Rice
Kevin J. Dawson

Date: September 9, 1987

HYDRO

INTRODUCTION

On September 2, 1987, Engineering Services personnel conducted an internal inspection of the #1 pressure conduit at the Bay D'Espoir Generating Station. This was the first such inspection of the conduit since it was placed in service in 1967. In general, the conduit appeared to be in excellent condition. No weld cracking, wall thinning or bulging was observed. This report contains details of the inspection procedure, details of the inspection process, which involved visual and ultrasonic methods, used and a listing of the inspection results.

DESCRIPTION OF PRESSURE CONDUIT

The #1 pressure conduit at BDE is an all-welded steel pipe approximately 3837 feet long and consists of three major sections. Between the intake structure and the surge tank the conduit is made up of approx. 1250 feet of 17' - 0" diameter ASTM A-285 Grade B carbon steel pipe and approx. 1000 feet of 15' - 3" diameter CSA Standard G-40.8 steel pipe . This section is known as "Pipeline A". From the surge tank to a point about 80 ft. upstream of the centre line of the units, the conduit consists of approx. 1476 feet of CSA Standard G-40.8 steel pipe. This section is known as "Penstock A". At this point the conduit bifurcates into two 9' - 6" diameter pipes, which are reduced to 7' - 3" diameter pipe and terminate at a spherical valve. There are no expansion joints. The thickness of the steel pipe varies from 7/16 inch to 1 5/8 inch depending on the location. The interior of the pressure conduit is coated with one coat of Matflint No. 7 -primer and one coat of Matflint No.7-black to achieve a total dry film thickness of 11 mils. Full details of the conduit layout, distances, grades and the coating specification can be found in appendix 1.

HYDRO

INSPECTION PROCEDURE

- PROCEDURE

The inspection procedure was as follows. Access to the conduit was gained through the unit scroll case. It should be noted that the original plan was to conduct the inspection at three locations by entering the conduit at the intake, through a manhole adjacent to the surge tank and through the unit scroll case . Due to the unavailability of a rope ladder (required to enter from the intake) and the rusted condition of the manhole cover bolting, it was decided that it would be faster to enter the conduit through the unit and to walk from the unit to the intake with the inspection being carried out on the return trip. The inspection was primarily visual. Each weld was inspected, the general condition of the conduit plating and coating observed and random thickness measurements taken.

- EQUIPMENT

DM-2 Thickness meter and couplant
Flashlights (One per person plus a spare)
Camera
Rain Suits, hard hats, rubber boots and gloves

- SAFETY

The decay of vegetation and animal matter within conduits of this type can produce pockets of methane gas. A substantial air flow, probably due to the venting effect of the surge tank, was observed at the scroll case. Due to this, gas measurements were not considered to be required, however, this decision should be re-assessed each time the conduit is entered. It is also recommended that a radio be carried. None were available for this inspection. The slope in most of the conduit is not extremely steep and therefor it was not necessary to have ropes laid down to aid travel. However, caution was exercised while walking especially on the steeper slope sections. Again, this should be assessed on a case by case basis.

HYDRO

INSPECTION RESULTS

- VISUAL

Inspection of the intake gate revealed only minor leaks around its perimeter, the largest being at the bottom right hand corner. Water seepage was observed at the intake concrete to steel transition section of the conduit. The location of this leakage is indicated on dwg. F 105 C-2 in Appendix 1. In light of the present problems being experienced with the intake dyke, this leakage should be monitored. When the conduit is under pressure, the leakage flow is reversed and blockage of the box drains could allow a build-up of water within the dyke. This information has been passed to Bob Barnes and to Mr John Young of ACRES.

In the conduit itself, all section welds were visually inspected with no damage being found. The conduit plating was also inspected. Throughout the length of the complete conduit there is a heavy build-up of what appears to be rust/organic, magnetic material approx. .200 inch to .300 inch thick. This buildup has sheared off in a sheet fashion at numerous locations, especially adjacent to section welds and by as much as 25% in the following areas: (Ref. Drawing F-106-C-11, Appendix 1).

1. Section 3A - 250.01'
2. Near the lower end of section 8A below the surge tank.

In general, in areas where the heavy build-up has been dislodged only a thin layer of surface corrosion is apparent. The underlying metal appears to be in excellent condition however there appears to be no Matflint coating. It is suspected that the Matflint coating failed and thus allowed water to react with the metal which in turn produced the rust build-up. The black colour of the water side of the build-up suggests that the residue of the Matflint coating is, in fact, the top layer of the deposit. Photographs of the build-up can be found in Appendix 2. A laboratory analysis of the deposit is in progress.

HYDRO

- ULTRASONIC INSPECTION

Random pipe wall thicknesses were recorded at twelve locations along the penstock. These are listed in Table 1, with their locations and corresponding values from drawing F-106-C-11. The approximate locations of these readings are also shown on F-106-C-11, Appendix 1.

TABLE 1

THICKNESS READING NO.	LOCATION	MEASURED THICKNESS (in)	SPECIFIED THICKNESS (in) DWG. F-106-C-11
1	Sect. 1A, 12 welds from start of penstock.	0.540	0.500
2	Sect. 2A, Weld #20	0.462	0.438
3	Sect. 2A, Weld #30	0.462	0.438
4	Sect 3A, Weld #22	0.438	0.438
5	Sect 4A, Weld #42	0.490	0.438
6	Sect 7A-8A, Weld #20	0.725	0.750
7	Sect 7A-8A, Weld #65	0.880	0.813
8	Sect 9A, 3 Welds Upstream of start of 11° Sect 10A	1.167	1.188
9	Sect 10A, Weld #12	1.293	1.250
10	Sect 10A, Weld #24	1.330	1.313
11	Sect 10A, Weld #38	1.393	1.375
12	Sect 10A, Weld #48	1.490	1.438

HYDRO

APPENDIX I

Specifications Page C5 - 1

C5 - PROTECTIVE COATING

C5.1 PREPARATION

The internal surface of the conduit, and the external surface of the conduit within six inches of field welds shall be given a coat of boiled linseed oil or an equal temporary coating to protect them during transit and storage.

The external surface of the conduit which will be bonded to concrete after embedment shall be cleaned by power wire brushing in accordance with Specification SSPC-P53-52T and shall then be given one coat of cement-latex milk prior to shipment. The cement-latex milk shall consist of ten parts Portland Cement (by weight), five parts water, and one part of modified latex emulsion.

All other areas of the external surface of the pipe shall be protected by cleaning and prime coating in the Contractor's shop, followed by finishing coats applied in the field and/or shop.

Necessary safety precautions shall be taken to avoid fire, explosion or danger to human health. All paints shall be applied under dry conditions, when the temperature is not below 55°F and the surface to be painted is devoid of moisture condensation.

(a) Cleaning

Heavy deposits of oil or grease shall be removed by wiping or scrubbing the surface with rags or brushes wetted with solvent. The final wiping shall be done with clean solvents and clean rags or brushes.

(b) Blast Cleaning

All surfaces shall be given a "grey" or "commercial" blast cleaning in accordance with Canadian Government Specification Board Spec. 31-GP-404 latest revision.

(c) Post-Blast Cleaning

After dry-blast cleaning, the surface shall be dusted off or blown off with compressed air, free of detrimental oil and water. If wet-blasted, the surface shall be cleaned by rinsing with fresh water to which sufficient corrosion inhibitor has been added to prevent rusting. This treatment shall be supplemented by brushing, if necessary, to remove any residue.

C5.2 APPLICATION

(a) First Prime Coat

The blast-cleaned surface shall be primed within 8 hours unless other precautions are taken to prevent rusting before application of prime coat. The primer used shall be Crown Diamond Phenix Epoxy Red Lead Primer No. 100. It can be applied only by brush or roller. When applied at the rate of 450-500 square feet per gallon, it will leave a minimum dry film thickness of one mil. These limits must be adhered to and are subject to approval after completion. Care should be taken to avoid any unnecessary damage after painting.

(b) Second Coat of Primer

After all work has been completed, a second coat of the specified primer shall be applied by brush, roller or spray at a rate of 450-500 square feet per gallon resulting in a minimum dry film thickness of one mil. These limits must be adhered to. A minimum period of 24 hours drying time is required before application of the second primer coat.

(c) Finishing Coat

When the priming coats are thoroughly dry, the pipe shall be given one coat of Hilson No. 330 Mastic or equal, containing asbestos fibres. This shall be applied at a minimum rate of 5 gallons per 100 square feet. The temperature must be above 40°F during this application.

Immediately following the application of this coating, and before it dries, the pipe shall be wrapped with a layer of 7 - 1/2 oz jute hessian embedded in the mastic. This jute shall be wrapped so as to have a minimum overlap between turns of three inches.

A second coat of Hilson No. 330 Mastic compound consisting of 2 gallons per 100 square feet shall then be applied over the jute. Each gallon of this coating shall be cut back with one quart of a suitable petroleum solvent.

(C5. 2) (c) Finishing Coat (Cont'd)

The priming coats must be applied in the Contractor's shop but the emulsion and jute hessian protective coatings may be applied in the shop or on Site, at the Contractor's option, provided that a continuous prime coat exists before the bitumastic compound is applied. The Hilson compound must be thoroughly dry before the pipe is moved.

C5. 3 APPLICATION OF INTERIOR COATING

(a) Prime Coat

The blast-cleaned surface (prepared as per Clause C5. 1) shall be primed within 8 hours to prevent rusting. The first coat shall be a Matflint No. 7 primer, applied by brush only at a rate of 260 square feet per gallon. The dry film thickness shall not be less than 5 mils. Care should be taken that no areas are skipped, that pin-holes are avoided and uniformity of the prime coat is assured.

(b) Finishing Coat

When the prime coat is thoroughly dry, the pipe shall be given one coat of Matflint No. 7 - black, applied by brush or roller at a rate of 260 square feet per gallon giving a dry film thickness of not less than 6 mils. If brush is used the finishing strokes shall be made in the direction of flow of water in pipes. The temperature must be above 50°F during this application.

C5. 4 PROVISION FOR CANCELLATION

The work described under Clause C5. 3 above may be cancelled, at any time, at the sole discretion of the Owner. In the event of the Owner exercising such a perogative no payment shall be made under this item.

February 11, 1965.

DRWING #'S F-105-C-2

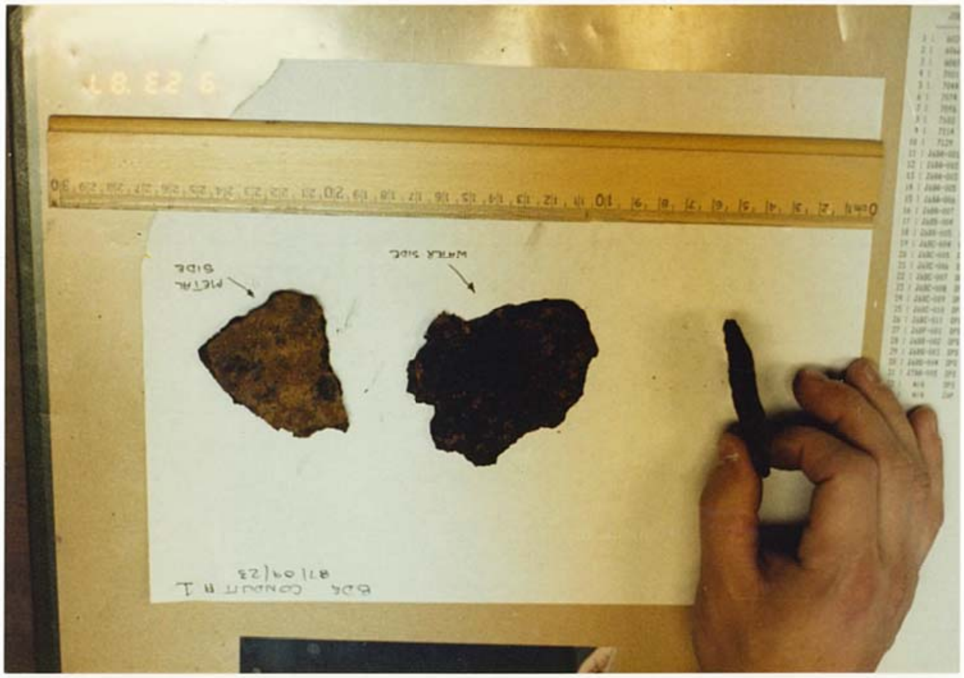
"INTAKES NO.1 & NO.2"
CONCRETE DETAILS.

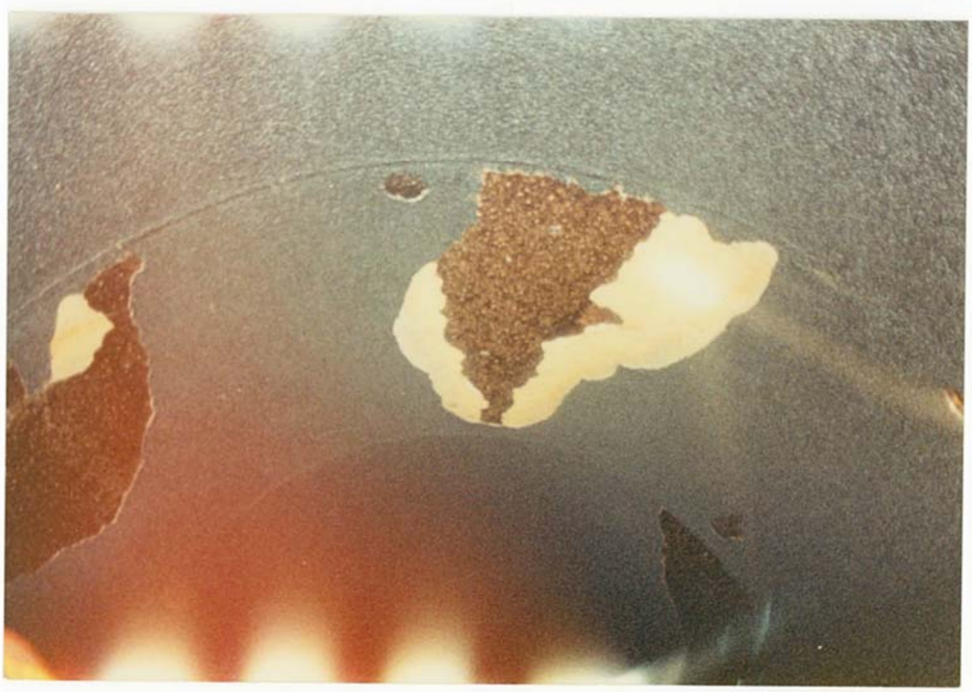
F-106-C-11
"PRESSURE CONDUITS"
LAYOUT & LOCATION DATA.

HYDRO

APPENDIX 2

PHOTOGRAPHS OF
#1 PRESSURE CONDUIT
INTERIOR COATING.





Appendix E
Water Chemistry Reports

ACUREN

Laboratory Report

Client	
Hatch 370 Torbray Road Bally Rou Place, Suite E200 St. John's, NF A1A 3W8	Laboratory Report

Attention	*Client's Order Number*	*Date*	*Report Number*
Michael Pyne	N/A	Jan. 18, 2017	128-17-10HAT004-0001 Rev. 0

Client's Material /Product Description	*Date Sample Received*	*Material / Product Specification*
Quantity: 3 Water samples	Dec. 28, 2017	-----

1. Analysis for pH*

	UNITS	SAMPLE #1	SAMPLE #2	SAMPLE #3
pH	pH	7.67	7.52	7.42

Address
2421 Drew Road
Mississauga, ON
Canada
L5S 1A1

Telephone
(905)673-9899

Facsimile
(905)673-8394

Website
www.acuren.com

ISO 9001:2008 QUASAR REGISTERED

A2LA ACCREDITED
CERT #3977.01 & 3977.04

2. Total Metals Analysis by ICPMS*

Metals	UNITS	SAMPLE #1	SAMPLE #2	SAMPLE #3	RDL
Total Aluminum (Al)	mg/L	0.053	0.050	0.049	0.0050
Total Antimony (Sb)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Arsenic (As)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Barium (Ba)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Beryllium (Be)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Bismuth (Bi)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Boron (B)	mg/L	<0.010	<0.010	<0.010	0.010
Total Cadmium (Cd)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Calcium (Ca)	mg/L	1.1	1.1	1.0	0.20
Total Chromium (Cr)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Cobalt (Co)	mg/L	<0.00050	<0.00050	<0.00050	0.00050

ACUREN

Laboratory Report

Total Copper (Cu)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Iron (Fe)	mg/L	<0.10	<0.10	<0.10	0.10
Total Lead (Pb)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Lithium (Li)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Magnesium (Mg)	mg/L	0.35	0.35	0.34	0.050
Total Manganese (Mn)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Molybdenum (Mo)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Nickel (Ni)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Potassium (K)	mg/L	<0.20	<0.20	<0.20	0.20
Total Selenium (Se)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Silicon (Si)	mg/L	0.47	0.46	0.46	0.050
Total Silver (Ag)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Sodium (Na)	mg/L	1.5	1.4	1.4	0.10
Total Strontium (Sr)	mg/L	0.0053	0.0047	0.0043	0.0010
Total Tellurium (Te)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Thallium (Tl)	mg/L	<0.000050	<0.000050	<0.000050	0.000050
Total Tin (Sn)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Titanium (Ti)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Tungsten (W)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Uranium (U)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Vanadium (V)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Zinc (Zn)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Zirconium (Zr)	mg/L	<0.0010	<0.0010	<0.0010	0.0010

RDL – Reportable Detection Limit

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Jennifer Pollock, EIT
Metallurgist

Dr. Erhan Ulvan, Ph.D, P.Eng
Manager - Central Region Engineering and Laboratory

The Client Representative who receives this report is responsible for verifying that any acceptance standards listed in the report are correct, and promptly notifying Acuren of any issues with this report and/or the work summarized herein. The owner is responsible for notifying Acuren in writing if they would like their samples returned or placed into storage (at their cost) otherwise, all samples/specimens associated with this report will be disposed of 60 days after the report date.

NOTES:

A) Any tests subcontracted to an approved subcontractor are highlighted above (*)

B) Levels of Services :Regular Service: 3 to 5 business days; Next Day Service: 8 to 16 business hours; Same Day Service: within 8 business hours; Super Rush: Work will commence immediately regardless of the time and will continue until it is completed

C) The Client will be notified if completion of test will exceed the time specified as a result of the volume of work or the complexity of the test

D) The Client should specify the standards used for testing/comparison purpose. We have a comprehensive library and online subscription of commonly used standards, however, we may ask the client to supply the standards if not common or the Client requests to purchase standard(s) on his behalf.

E) Please provide all the necessary information/documents (MSDS) pertaining to any Toxic / Dangerous materials prior to their arrival in the Laboratory.

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TABLE I

ANALYSIS OF BAY D'ESPOIR WATER

Parameter	Concentration (ppm except as noted)
pH	5.59
Conductivity (umhos/cm)	28.5
TDS	11.4
Alkalinity (ppm $CaCo_3$)	2.5
Fluoride	<0.1
Chloride	3.0
Nitrite	<0.1
Bromide	<0.1
Nitrate	0.04
Phosphate	<0.1
Sulphite	<0.1
Sulphate	2.6
Cobalt	<0.01
Zinc	1.2
Cadmium	<0.02
Boron	<0.02
Bismuth	<0.2
Phosphorus	<0.5
Beryllium	<0.002
Silicon	0.62
Iron	0.12
Manganese	0.02
Calcium	16
Magnesium	0.54
Copper	<0.01
Aluminum	<0.15
Vanadium	<0.01

Form WAF-3 1M 2/78
WATER ANALYSIS FACILITY
Department of Chemistry (C-411)
Memorial University of Newfoundla

NALYTICAL RESULTS

omitted by: John Noel - Hydro Phone: Date: Nov. 14 19 80

dress: Bill to: Approved: (authorized representative)

ser's sample code: Baie d'Espoir #4

ater analysis code: 3844

te complete: 19 Signed:

	Parameter	Value	Units		Parameter	Value	Un
1.	Alkalinity	2	mg/L $CaCO_3$	12.	Calcium	0.94	mg/L
2.	Acidity		mg/L $CaCO_3$	13.	Magnesium	0.38	mg/L
3.	Apparent colour		TCU	14.	Manganese	< 0.01	mg/L
4.	Hardness	4.09	mg/L $CaCO_3$	15.	Iron	0.10	mg/L
5.	Kjeldahl nitrogen		mg/L N	16.	Copper		mg/L
6.	Nitrate	0.044	mg/L N	17.	Zinc		mg/L
7.	pH	5.19	units	18.	Cadmium		mg/L
.	Total phosphorus	0.016	mg/L PO_4		Lead		mg/L
.	Specific conductance	20	micromhos/cm		Sodium		mg/L
.	Turbidity		NTU		Potassium		mg/L
	Chemical oxygen demand		mg/L COD		silicate	0.328	mg/I
	Fluoride	0.023	mg/L F		nitrite	< 0.005	mg/I
	Chloride	9	mg/L Cl		Bicarb. Alkalinity	2	mg/
	Biochemical Oxygen demand		mL/L		Carb. Alkalinity	< 1	mg/
	Dissolved oxygen		mL/L		Tot. Suspended Solids	< 5	mg/
	Ortho phosphate	< 0.005	mg/L PO_4		Tot. Dissolved solids	31	mg

MENTS:

*Canadian "Drinking Water Standards" upper limit or recommended range.

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CHEMICAL AND ENGINEERING SERVICES
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ESTABLISHED 1880

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MONTREAL 25, CANADA

REPORT OF ANALYSIS

Shawmont Engineering Newfoundland Ltd.,
1010 Beaver Hall Hill,
Montreal, Que.

Attn: Mr. A. Bonnell

LABORATORY NO. 1382

DATE RECEIVED Mar. ?, 1965

SAMPLE OF Water

MARKED

	Parts per Million
Suspended Matter	0.2
Total Iron (Fe)	0.1
Turbidity	0
Analysis of Filtered Sample	
Total Solids on Evaporation	25.8
Silica (SiO_2)	1.4
Calcium (Ca)	1.6
Magnesium (Mg)	0.5
Alkalies as Sodium (Na) Calc.	1.6
Sulphate (SO_4)	0.7
Chloride (Cl)	1.7
Bicarbonate (HCO_3)	7.9
Carbon Dioxide (CO_2)	[illegible]
Colour	[illegible]
pH	6.1
Total Hardness as $CaCO_3$	6.0
Carbonate Hardness as $CaCO_3$	6.0
Non-Carbonate Hardness as $CaCO_3$	Nil
Carbonate Alkalinity as $CaCO_3$	Nil
Bicarbonate Alkalinity as $CaCO_3$	6.5
Hypothetical Combination	
Calcium Bicarbonate $Ca(HCO_3)_2$	6.5
Magnesium Bicarbonate $Mg(HCO_3)_2$	3.0
Sodium Bicarbonate $NaHCO_3$	0.7
Sodium Sulphate Na_2SO_4	1.0
Sodium Chloride NaCl	2.8
Silica SiO_2	1.4
Iron Oxide Fe_2O_3	0.1

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TABLE 3.2A

WATER ANALYSIS REPORT SUMMARY

PARAMETER	UNIT OF MEASURE	CDWQG STANDARD		BAY D'ESPOIR POWERHOUSE NO. 1				
		MAC[1]	AO[2]	OCT.92	NOV.93	NOV.94	MAY 95	MAY 96
Alkalinity	mg/L $CaCO_3$			3.66	3.3	—	—	—
Apparent Color	TCU[3]		≤15	33	48	32	31	33
Hardness (requires Ca,Mg)	mg/L $CaCO_3$		80–100	2.7	3.2	2.6	3.1	3.4
Kjeldahl Nitrogen	mg/L N			0.18	0.10	0.24	0.10	0.10
Nitrate (+nitrite)	mg/L N	45		0.061	0.035	0.060	0.067	0.0043
pH	Units		6.5–8.5	6.21	6.19	6.28	6.18	7.04
Total Phosphorus	mg/L PO_4			<0.02	<0.02	—	—	—
Specific Conductance	μmhos/cm			18.0	14.9	20.2	18.3	15.3
Turbidity	NTU[4]	1.0	5.0[5]	1.05	2.30	0.29	0.44	0.33
Chemical Oxygen Demand	mg/L COD			12	11	10	—	11
Calcium	mg/L Ca			0.62	0.73	0.53	0.72	0.84
Magnesium	mg/L Mg			0.28	0.33	0.31	0.31	0.32
Manganese	mg/L Mn		≤0.05	<0.005	<0.005	—	0.02	<0.005
Iron	mg/L Fe		≤0.30	0.04	0.05	0.08	0.07	0.06
Copper	mg/L Cu		≤1.0	0.19	0.16	0.09	0.06	0.08
Zinc	mg/L Zn		≤5.0	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/L Cd	0.005		<0.005	<0.005	—	—	—
Lead	mg/L Pb	0.010		0.004	0.003	<0.001	0.002	<0.001
Chloride	mg/L Cl		≤250	1.7	1.5	4.1	2.6	1.9
Sodium	mg/L Na		≤200	1.54	1.14	—	—	—
Potassium	mg/L K			0.22	0.18	—	—	—
Ammonia	mg/L N			<0.02	<0.02	—	—	—
Dissolved Oxygen	mg/L O			—	—	—	<0.05	—
Fluoride	mg/L F	1.5		0.08	<0.05	<0.05	—	<0.05
Sulfate	mg/L SO_4		≤500	2.1	1.1	1.7	3.7	2.2
Total Dissolved Solids	mg/L		≤500	12	10	16	15	13
Total Suspended Solids	mg/L			<4	<4	<4	<4	<4
Total Organic Carbon	mg/L C			3.7	—	3.8	3.9	4.1
Mercury	mg/L Hg	0.001		—	<0.00005	—	—	—

[1] MAC Maximum Acceptable Concentration
[2] AO Aesthetic Objective
[3] TCU True Color Units
[4] NTU Nephelometric Turbidity Units
[5] At point of consumption

Appendix F
Acuren Test Reports

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Laboratory Report

Client			Laboratory Report		
Hatch 370 Torbray Road Bally Rou Place, Suite E200 St. John's, NF A1A 3W8					
Attention	*Client's Order Number*		*Date*		*Report Number*
Michael Pyne	RFA		February 7, 2017		128-17-10HAT004-0001 Rev. 0
Client's Material /Product Description		*Date Sample Received*		*Material / Product Specification*	
Quantity: 3 Weld Samples, 3 Water samples, and 2 Algae Samples		December 28, 2017		-----	

1. Galvanic Test

Figure 1 illustrates the as-received samples. In Sample 1, the weld is along the longitudinal direction of the tank, while in Samples 2 and 3, the weld is along the circumferential direction of the tank. Table 1 lists the chemical composition of the base metal and the electrode used for the welding process.

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Figure 1. Low magnification morphology of HAZ-Metal couple sample 1.

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Table 1. Base metal and electrode used for welding process

Sample #	1	2	3
Base Metal	ASTM 285-C	CSA G40.8-B	ASTM 285-C
Welding Electrode	E7018	E7018	E7018

Coupons of approximately 10×10 mm^2 were cut from the fusion zone (weld), heat affected zone (HAZ), and base metal (BM) of all the samples listed in Table 1. Please be advised that as the HAZ was very narrow with a ">" shape on one side and a "<" on the other side, we took utmost care to extract sample from that specific zone, however there is a slight chance that the extracted part would not be completely from one single region (i.e. HAZ, weld, base metal). Sample was then grinded with 600 grit sandpaper, washed with soap and rinsed with deionized water and 99.9% ethanol.
Corrosion tests were carried out at ambient temperature for one hour in an acidic solution with a pH of 6.25 prepared by nitric acid (HNO_3) diluted in deionized water (DI). Each test was repeated twice as per ASTM G71 – 81 (2014). Table 2 lists the results of galvanic tests for all three samples. Corrosion rate is reported in mpy.

Table 2. Galvanic corrosion rate of all samples

Sample #			1	2	3
WELD/HAZ	Test 1	Corrosion Rate (mpy)	1.20	0.09	0.97
		Corroded Part	WELD	Both	HAZ
	Test 2	Corrosion Rate (mpy)	0.51	0.09	0.23
		Corroded Part	WELD	Both	Both
WELD/BM	Test 1	Corrosion Rate (mpy)	0.18	0.05	0.37
		Corroded Part	Both	Both	Both
	Test 2	Corrosion Rate (mpy)	0.51	0.18	1.70
		Corroded Part	BM	Both	Weld
HAZ/BM	Test 1	Corrosion Rate (mpy)	0.28	0.05	0.83
		Corroded Part	Both	Both	HAZ
	Test 2	Corrosion Rate (mpy)	1.24	0.09	1.43
		Corroded Part	BM	Both	Both

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Visual Examinations

Figures 2 to 10 present low magnification morphology of samples after galvanic testing. It should be noted that almost all of the corroded samples show pitting corrosion as well.

Sample 1:

Figure 2 shows that for HAZ/BM couple, both of them were corroded in test 1, while BM was protected in test 2 and there is no sign of pitting corrosion. Figure 3 depicts that both parts were corroded in test 1 for WELD/BM couple, but BM was protected in test 2. As

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Laboratory Report

shown in Figure 4, HAZ was protected in both tests against the WELD. Based on the observations, it can be suggested that the weld has the least corrosion resistance in the galvanic setup and BM shows the best corrosion resistance.

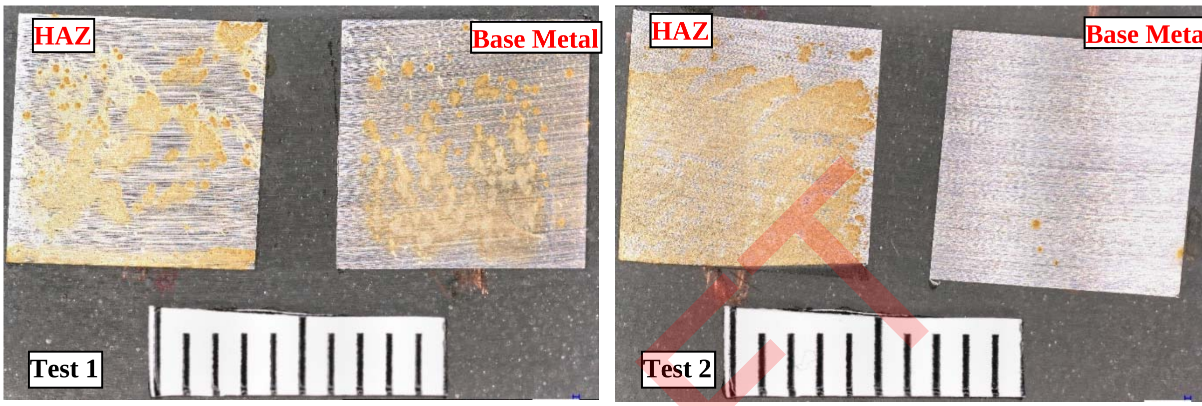

Figure 2. Low magnification morphology of HAZ/BM couple Sample 1.

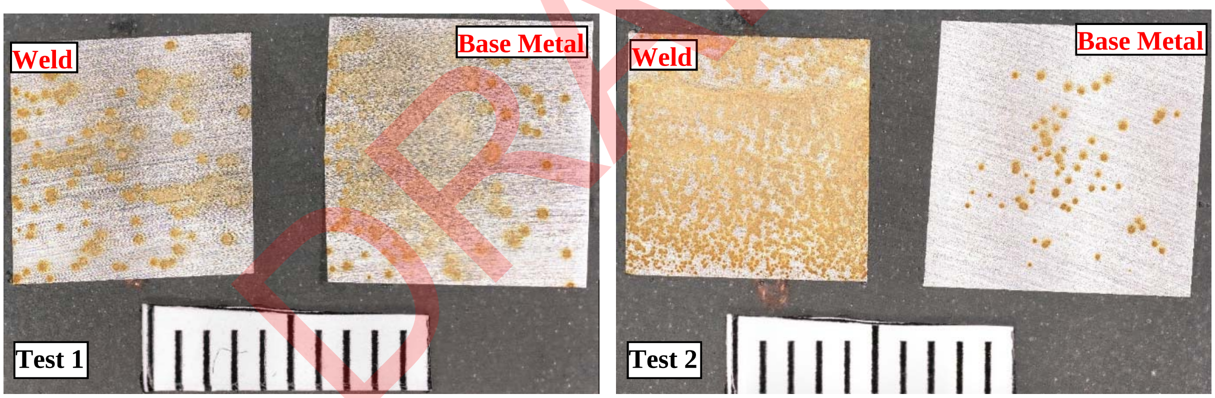

Figure 3. Low magnification morphology of WELD/BM couple Sample 1.

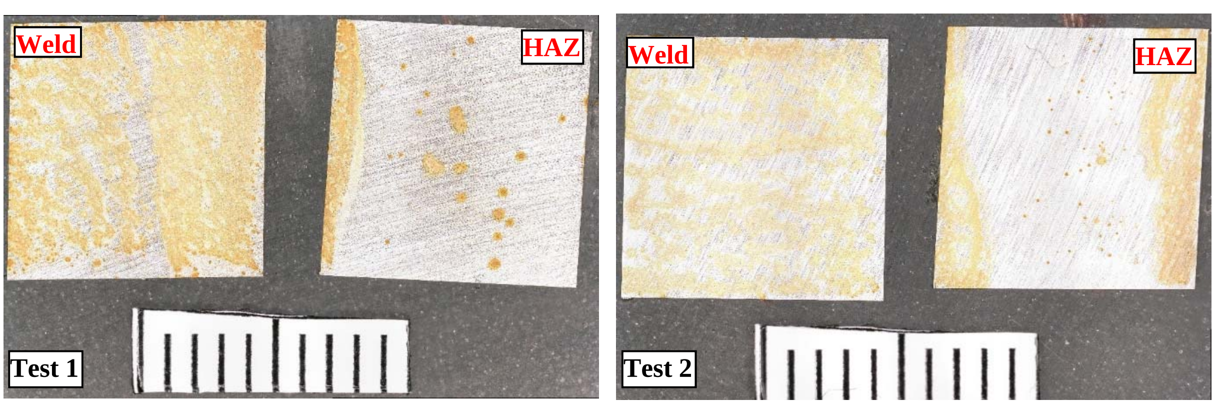

Figure 4. Low magnification morphology of WELD/HAZ couple Sample 1.

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Sample 2:

Figure 5 suggests that both HAZ and BM were corroded in both tests. For WELD/BM couple, both parts were corroded in both tests as shown in Figure 6. Figure 7 depicts that both WELD and HAZ regions were corroded in both tests. In total, it appears that none of the three regions is protected against one another, and pitting corrosion is a major feature on the surfaces of all samples.

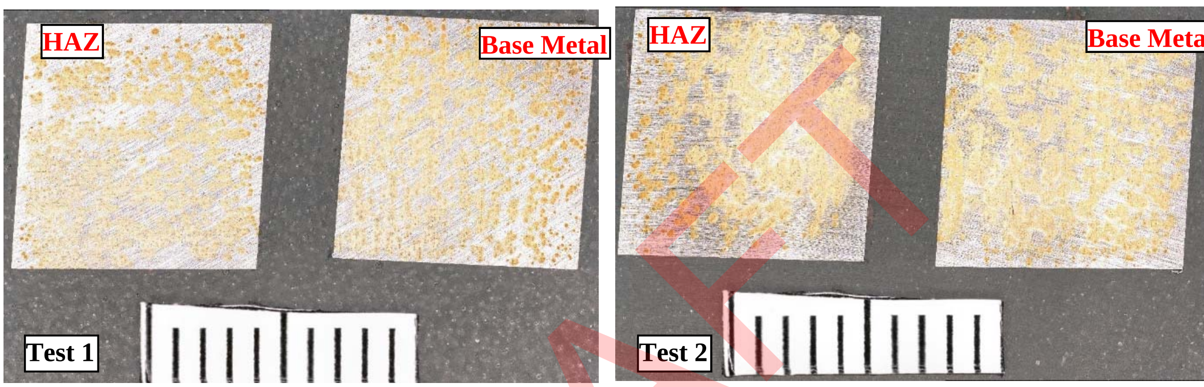

Figure 5. Low magnification morphology of HAZ-Metal couple Sample 2.

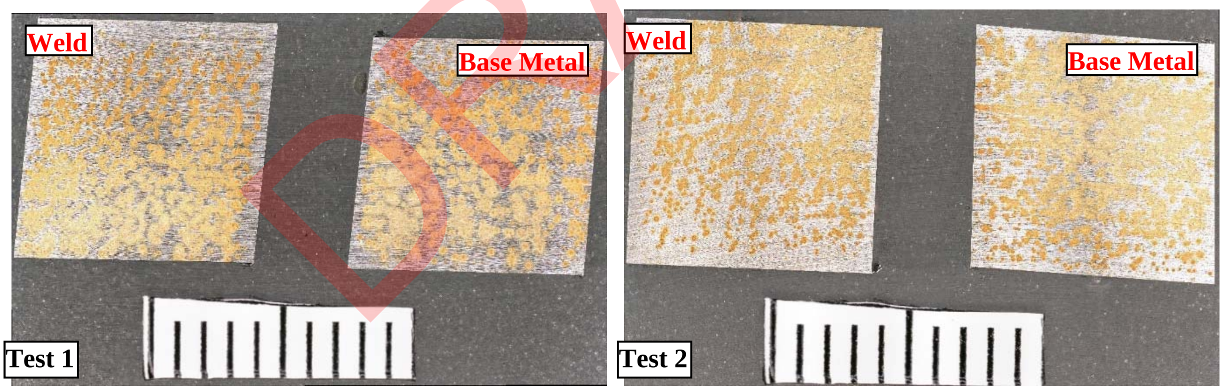

Figure 6. Low magnification morphology of Weld-Metal couple Sample 2.

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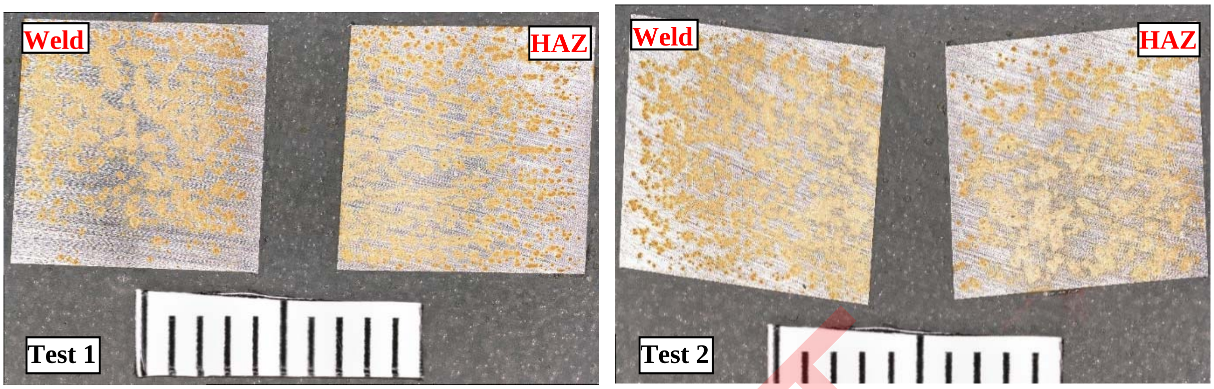

Figure 7. Low magnification morphology of Weld-HAZ couple Sample 2.

Sample 3:

From Figure 8, it appears that HAZ was protected against BM in HAZ/BM galvanic couple. As for WELD/BM couple (Figure 9), both parts were corroded in test 1. In the second test, WELD is corroded, while BM is slightly corroded. As shown in Figure 10, in WELD/HAZ couple, the first test shows HAZ is corroded and WELD is protected, while in the second test, Weld is also corroded similar to HAZ.

In General, it seems that apart from general corrosion of different parts of the weld joint, there is a possibility that HAZ could suffers from galvanic corrosion against WELD.

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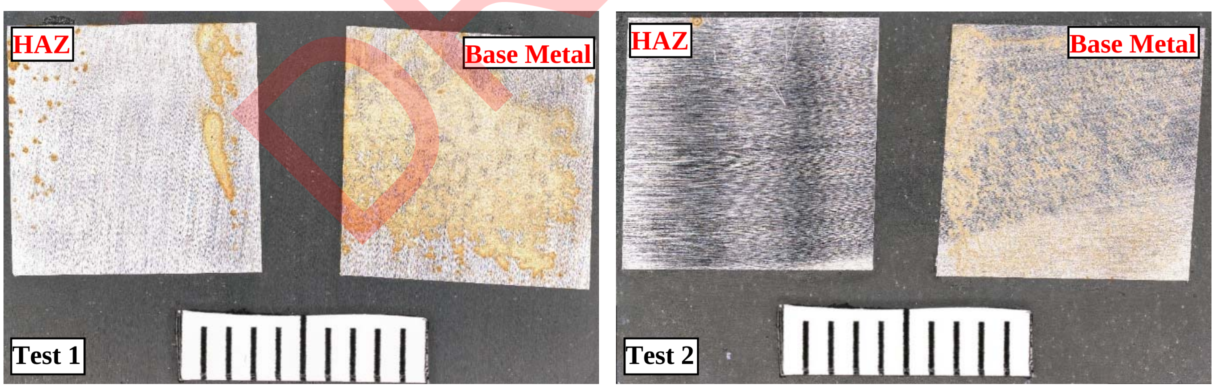

Figure 8. Low magnification morphology of HAZ-Metal couple Sample 3.

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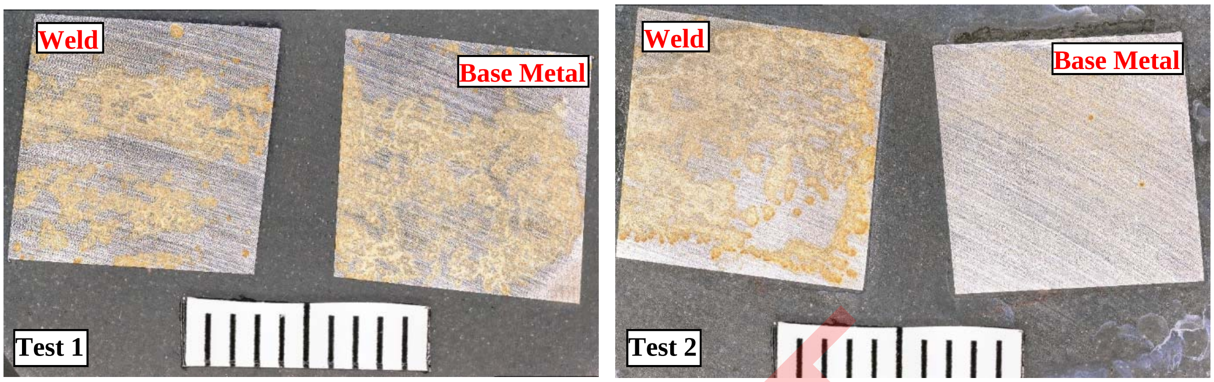

Figure 9. Low magnification morphology of Weld-Metal couple Sample 3.

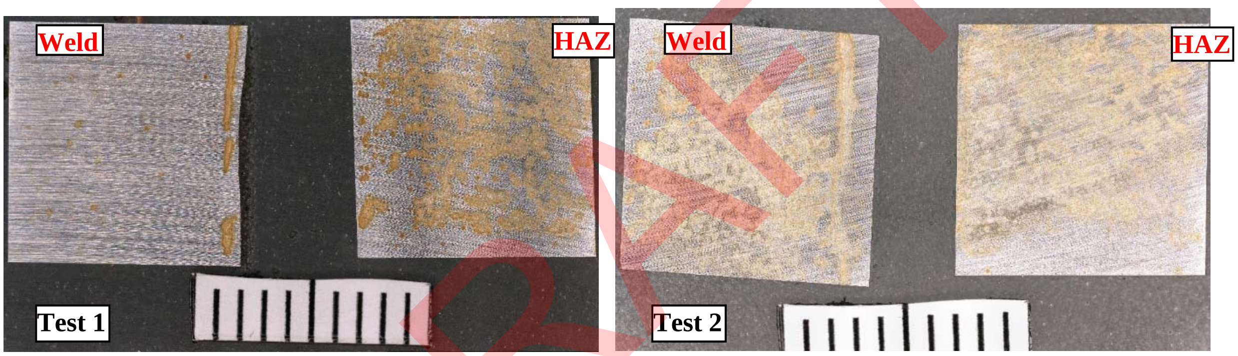

Figure 10. Low magnification morphology of Weld-HAZ couple Sample 3.

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Reference Samples:

As it can be observed in Figure 11, samples show no significant corrosion after on hour of exposure to similar solution used for galvanic test. This indicates the severity of galvanic corrosion for this design.

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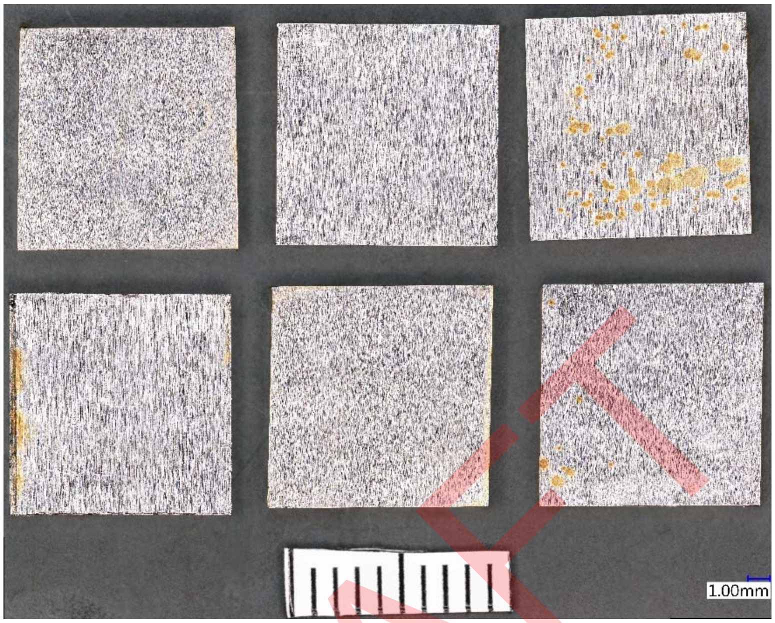

Figure 11. Low magnification morphology of all reference samples after normal corrosion.

2. Water Analysis*

	Units	Sample #1	Sample #2	Sample #3	RDL
pH	pH	7.67	7.52	7.42	N/A
Total Dissolved Solids	mg/L	22	22	14	10
Alkalinity (Total as $CaCO_3$)	mg/L	4.3	2.2	2.1	1.0

RDL – Reportable Detection Limit

3. Total Metals Analysis by ICPMS of Water Samples*

Metals	Units	Sample #1	Sample #2	Sample #3	RDL
Total Aluminum (Al)	mg/L	0.053	0.050	0.049	0.0050
Total Antimony (Sb)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Arsenic (As)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Barium (Ba)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Beryllium (Be)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Bismuth (Bi)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Boron (B)	mg/L	<0.010	<0.010	<0.010	0.010

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Total Cadmium (Cd)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Calcium (Ca)	mg/L	1.1	1.1	1.0	0.20
Total Chromium (Cr)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Cobalt (Co)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Copper (Cu)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Iron (Fe)	mg/L	<0.10	<0.10	<0.10	0.10
Total Lead (Pb)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Lithium (Li)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Magnesium (Mg)	mg/L	0.35	0.35	0.34	0.050
Total Manganese (Mn)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Molybdenum (Mo)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Nickel (Ni)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Potassium (K)	mg/L	<0.20	<0.20	<0.20	0.20
Total Selenium (Se)	mg/L	<0.0020	<0.0020	<0.0020	0.0020
Total Silicon (Si)	mg/L	0.47	0.46	0.46	0.050
Total Silver (Ag)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Sodium (Na)	mg/L	1.5	1.4	1.4	0.10
Total Strontium (Sr)	mg/L	0.0053	0.0047	0.0043	0.0010
Total Tellurium (Te)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Thallium (Tl)	mg/L	<0.000050	<0.000050	<0.000050	0.000050
Total Tin (Sn)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Titanium (Ti)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Tungsten (W)	mg/L	<0.0010	<0.0010	<0.0010	0.0010
Total Uranium (U)	mg/L	<0.00010	<0.00010	<0.00010	0.00010
Total Vanadium (V)	mg/L	<0.00050	<0.00050	<0.00050	0.00050
Total Zinc (Zn)	mg/L	<0.0050	<0.0050	<0.0050	0.0050
Total Zirconium (Zr)	mg/L	<0.0010	<0.0010	<0.0010	0.0010

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4. Microbiological Corrosion of Algae Samples

	Viable bacteria in samples after 15 days (Range per mL)	
	Sample 1	Sample 2
Low Nutrient Bacteria (LNB)	Weak Positive (~1 to 10)	Mild Positive (~10 to 100)
Iron-Related Bacteria (IRB)	Negative	Negative
Anaerobic Bacteria (ANA)	Weak Positive (~1 to 10)	Weak Positive (~1 to 10)
Acid-Producing Bacteria (APB)	Weak Positive (~1 to 10)	Negative
Sulfate-Reducing Bacteria (SRB)	Negative	Negative

Majid Nezakat, Ph.D
Head – Corrosion Engineering Department

Jennifer Pollock, EIT
Metallurgist/ QA

Dr. Erhan Ulvan, Ph.D, P.Eng
Manager - Central Region Engineering and Laboratory

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Appendix G
Backfill Calculations

Nalcor Energy - Bay d'Espoir Penstock 1 - Fill time and soil cover influence

Calculation Cover Sheet

Client: Nalcor Energy

Project Title: Bay d'Espoir Penstock 1 weld repairs

Discipline: Mechanical/Civil

Calculation No: H352666-00000-240-202-0002 **File No:** **Number of Sheets:** 27

Description: This calculation checks penstock fill time.
This calculation checks the influence of soil cover at the top half of the penstock on the stresses in the 17 ft diameter sections

Category of calculation verification required *tick box* ☑ 1 ☐ 2 ☐ 3 ☐ 4

Prepared by: Oleg Belashov O.Belashov **Date:** 28Nov 2016

Print Name > (Responsible Engineer)

Preliminary Review by: **Date:** 28Nov 2016

Print Name > Michael Pyne

Can the calculation now be released for work? ☑ Yes ☐ No **To the Client?** ☑ Yes ☐ No

Checked by: by: **Date:** 28Nov 2016

Print Name > Michael Pyne

Reviewed by: **Date:**

Print Name >

Approved by: **Date:**

Print Name >

General Notes: Internal Rev A-01

Revisions

Rev.	Date	Prepared by	Checked by	Approved by	Description
A	28Nov 2016	O. Belashov OB	M. Pyne	G.Saunders	

Superseded by Calculation No. **Date:**

Reason voided:

Calculation Descriptions and Assumptions

1. This calculation etimates the penstock fill time.
2. This calculation checks the influence of soil cover at the top half of the penstock on the stresses in the 17 ft diameter sections.
3. The soil on the top of the penstock does not provide any radial restrain for the pipe and is modeled as external pressure applied on top half of the pipe
4. The soil underneath the penstock is modeled as elastic support with the subgrade reaction modulus of soil Ks= $11\frac{MPa}{m} = 40.52\cdot\frac{lbf}{in^3}$
5. Penstock thickness at 17 ft diameter sections is 0.422in according to Ref 7
6. Open channel flow Mannings's Equation is used to determine the cross section area inside the penstock available for air to escape.
7. 100% welded joint efficiency, subject to 100% UT or RT

References

1. Applied Fluid Dynamics Handbook; Robert D.Blevins; 1984
2. ASCE Manuals and Reports on Engineering Practice No. 79, Second edition
3. ASTM A285 2012
4. F-105-C-2
5. F-106-C-7
6. F-106-C-11
7. PENSTOCK NO.1 BAY D'ESPOIR HYDROELECTRICDEVELOPMENTCRACK; INVESTIGATION ANDREPAIR REPORT; by Kleinschmidt; June 2016

1) Filling time and pipe area available for air to escape

Input parameters

$EL_{HWL} := 593ft$ Head pond water elevation, Ref 4

$EL_{sill} := 541ft$ Intake gate sill elevation, Ref 4

$w_g := 17ft$ Intake gate clear width

$EL_{ST} := 291.58ft$ Surge tank bottom elevation

$D_{ST} := 13ft + 6in$ Assumed surge tank inlet pipe diameter, no info on the surge tank is available

$n := 13$ Number of penstock sections

$i := 0 .. n - 1$

Penstock geometry, Ref 6

$i + 1 =$	Section length $L_i :=$	Section diameter $D_i :=$
1	231.68ft	17ft + 0in
2	320.64ft	17ft + 0in
3	250.01ft	17ft + 0in
4	452.05ft	17ft + 0in
5	361.39ft	15ft + 3in
6	351.28ft	15ft + 3in
7	304.72ft	15ft + 3in
8	379.75ft	13ft + 6in
9	476.41ft	13ft + 6in
10	523.51ft	13ft + 6in
11	122.83ft	13ft + 6in
12	63.89ft	13ft + 6in
13	45.10ft	13ft + 6in

$G_o := 0.5in, 1in .. 6in$ Range of intake gate openings for consideration

Filling time as function of gate opening

$\sum L = 1184 \cdot m$ Total penstock length

$H := EL_{HWL} - EL_{sill} = 52 \cdot ft$ Head on the intake gate sill

$V_p := \sum_i \left[\frac{\pi \cdot (D_i)^2}{4} \cdot L_i \right] = 19856\, m^3$ Penstock volume

$L_{ST} := EL_{HWL} - EL_{ST} = 301.42 \cdot ft$ Surge tank pipe to be filled

$V_{ST} := \frac{\pi \cdot D_{ST}^{\ 2}}{4} \cdot L_{ST} = 1222\, m^3$ Surge tank pipe volume

$V_{tot} := V_p + V_{ST} = 21078\, m^3$ Total volume to be filled, excluding spiral case since no info is provided.

$Q_g(G_o) := \frac{0.61}{\left(1 + 0.61 \cdot \frac{G_o}{H}\right)^{0.5}} \cdot w_g \cdot G_o \cdot \sqrt{(2 \cdot g \cdot H)}$ Flow rate in volume/time units as function of intake gate opening, Ref 1

$t(G_o) := \frac{V_{tot}}{Q_g(G_o)}$ Filling time as function of gate opening

Pipe cross section area available for air to escape as function of gate opening

The calculation is performed using open channel flow Manning's Equation

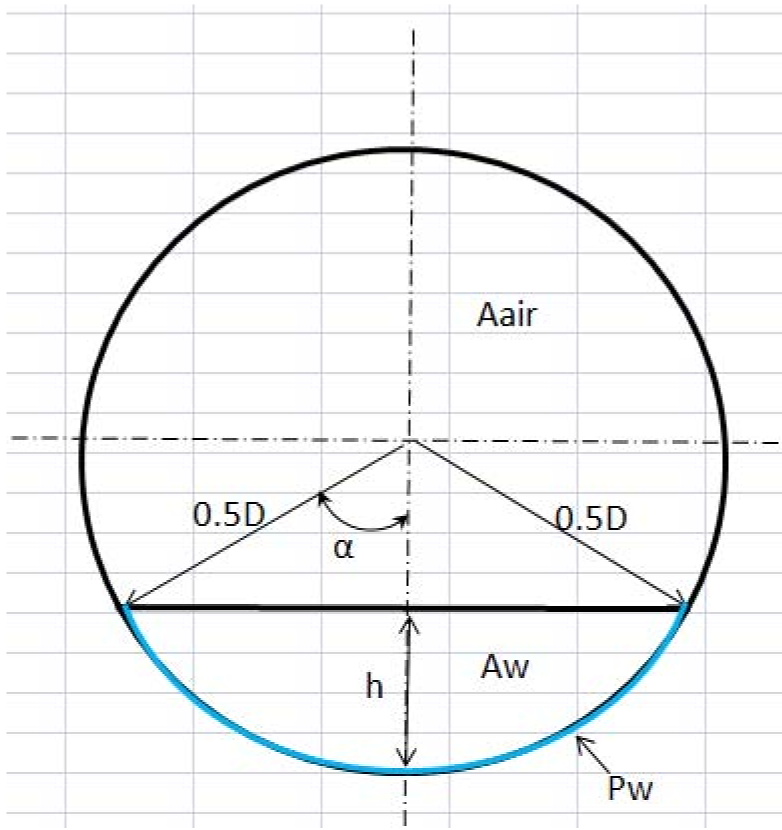


Figure 1: Open channel flow in the penstock

$S_p := \tan(0.25deg)$ Penstock slope, Manning's Equation works with very small pipe slope but the slope cannot be zero

$n := 0.012$ Manning's roughness coefficient for steel pipe

$D_{min} := \min(D) = 13.5 \cdot ft$ Min diameter in the penstock

$A_p := \frac{\pi \cdot D_{min}^2}{4} = 13.3\,m^2$ Penstock cross section area at the minimum diameter

$\alpha(h) := acos\left(\frac{0.5 \cdot D_{min} - h}{0.5 \cdot D_{min}}\right)$ α (Figure 1) as function of h

$A_w(h) := \frac{D_{min}^2}{4} \cdot (\alpha(h) - \sin(\alpha(h)) \cdot \cos(\alpha(h)))$ Flow area as function of h

$P_w(h) := \alpha(h) \cdot D_{min}$ Wetted perimeter

$R_h(h) := \frac{A_w(h)}{P_w(h)}$ Hydraulic radius

$AR(h) := A_w(h) \cdot R_h(h)^{\frac{2}{3}}$ $A \cdot R^{\frac{2}{3}}$ term from Manning's equation

$Q_p(h) := \frac{ft^3}{s} \cdot \left[\left(\frac{1.49}{n} \right) \cdot \left(\frac{1}{ft^2} \cdot \frac{1}{ft^{\frac{2}{3}}} \right) \cdot AR(h) \cdot \sqrt{S_p} \right]$ Manning's equation for volume flow in open channel

$h := 1m$ Initial guess for solver

Given

$Q_p(h) = Q$

$h(Q) := (Find(h))$ Solve for h (Figure 1)

$h(G_o) := h(Q_g(G_o))$ Express h as function of gate opening

$A_{air}(G_o) := 1 - \frac{A_w(h(G_o))}{A_p}$ Area available for air to escape in % of total pipe area as function of intake gate opening

Summary

Gate opening $\frac{G_o}{in}$ =	Flow rate $\frac{Q_g(G_o)}{\frac{m^3}{s}}$ =	Fill time $\frac{t(G_o)}{hr}$ =	Flow area height $\frac{h(G_o)}{m}$ =	Flow area $\frac{A_w(h(G_o))}{m^2}$ =	Air area $\frac{A_{air}(G_o)}{\%}$ =
0.5	0.71	8.27	0.28	0.40	97.00
1.0	1.41	4.14	0.39	0.65	95.14
1.5	2.12	2.76	0.48	0.86	93.55
2.0	2.83	2.07	0.55	1.05	92.11
2.5	3.53	1.66	0.61	1.23	90.78
3.0	4.24	1.38	0.67	1.39	89.52
3.5	4.95	1.18	0.72	1.55	88.32
4.0	5.65	1.04	0.77	1.71	87.17
4.5	6.36	0.92	0.81	1.85	86.06
5.0	7.06	0.83	0.85	2.00	84.99
5.5	7.76	0.75	0.90	2.14	83.94
6.0	8.47	0.69	0.93	2.27	82.92

$A_p = 13.3\, m^2$

There is plenty of room for air to escape for all the considered intake gate openings

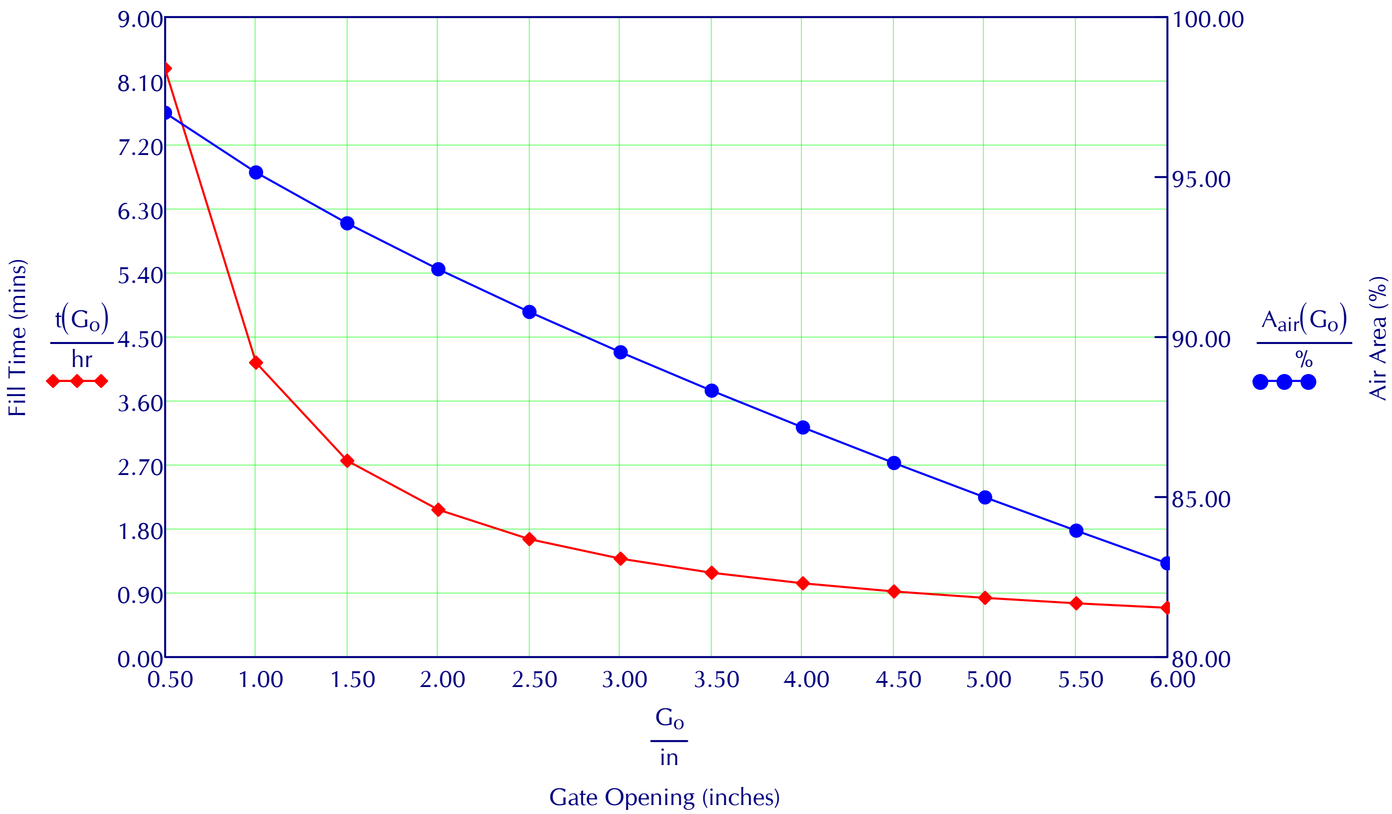


Figure 2: Fill Time and Air Area as Function of Gate Opening

2) Finite Element Analyses of excavation

FE model description

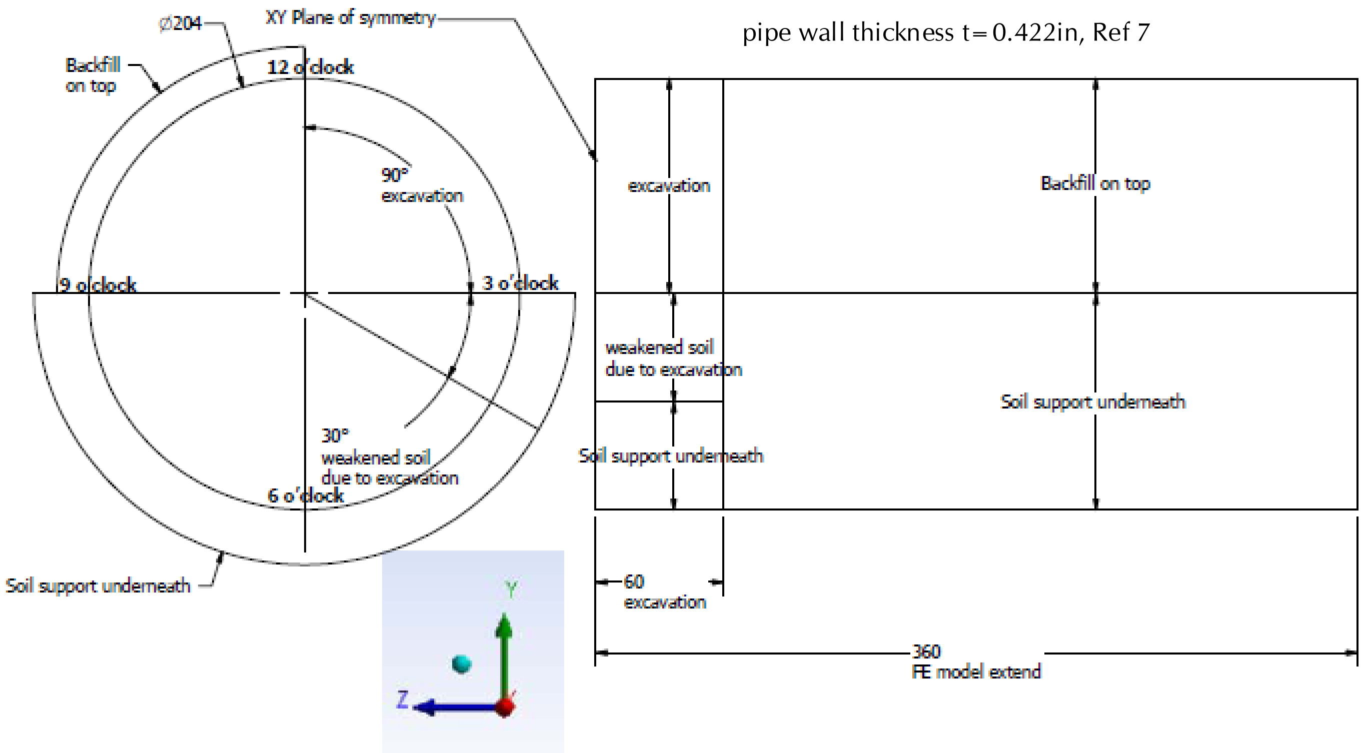


Figure 3: Finite element model dimensions, inches. 60ft long pipe with soil support at the bottom half. Top soil pressure on the top half. Excavation extend from 12 to 3 o'clock 10 ft long. 30deg from 3 o'clock 10 ft long is considered weakened soil (very low Ks value) and is assumed to be part of the excavation. Middle of the excavation is a plane of symmetry thus only half of 60 ft pipe was modeled

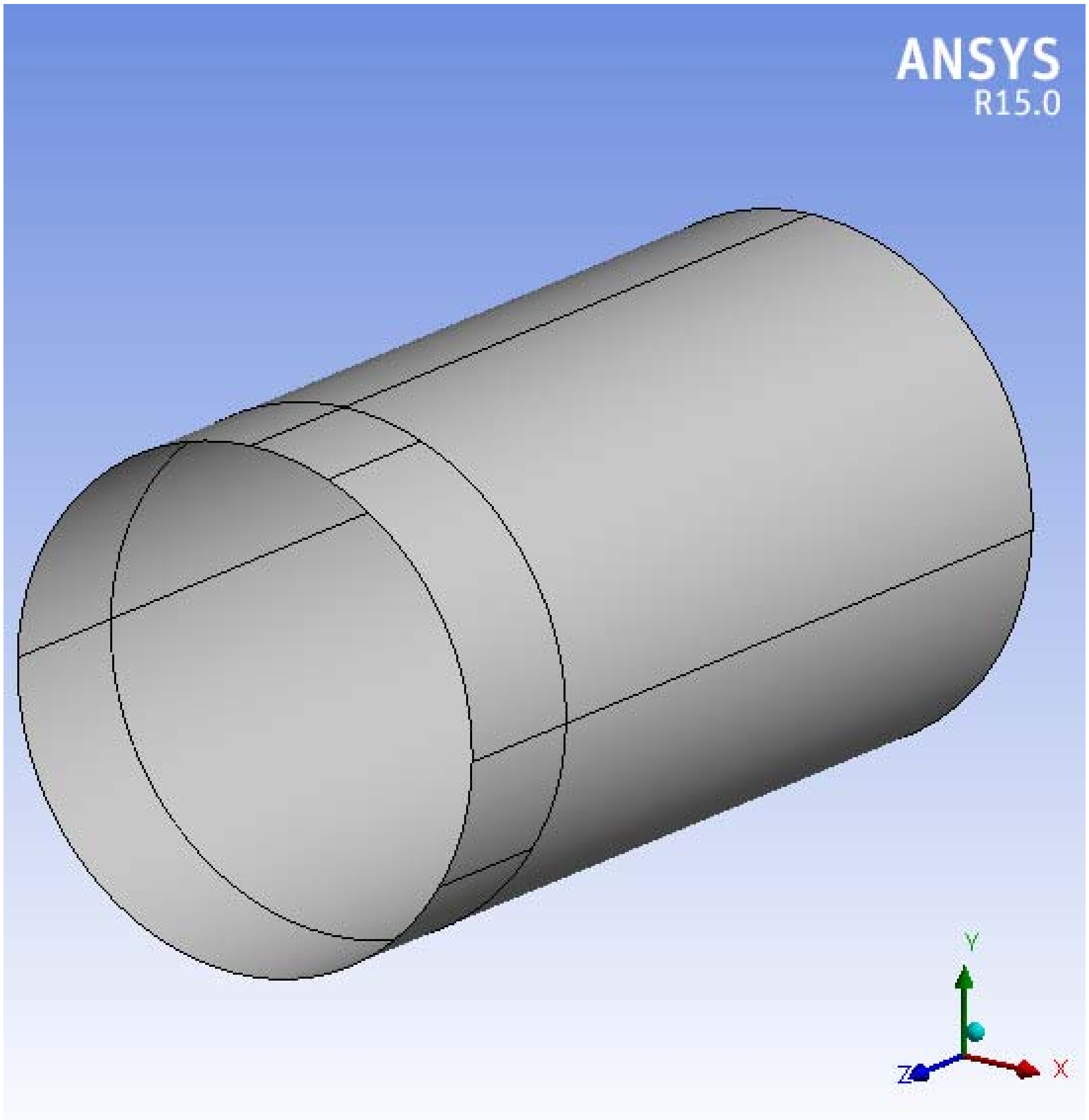


Figure 4: Finite element model. Ansys R15.0 software was used.

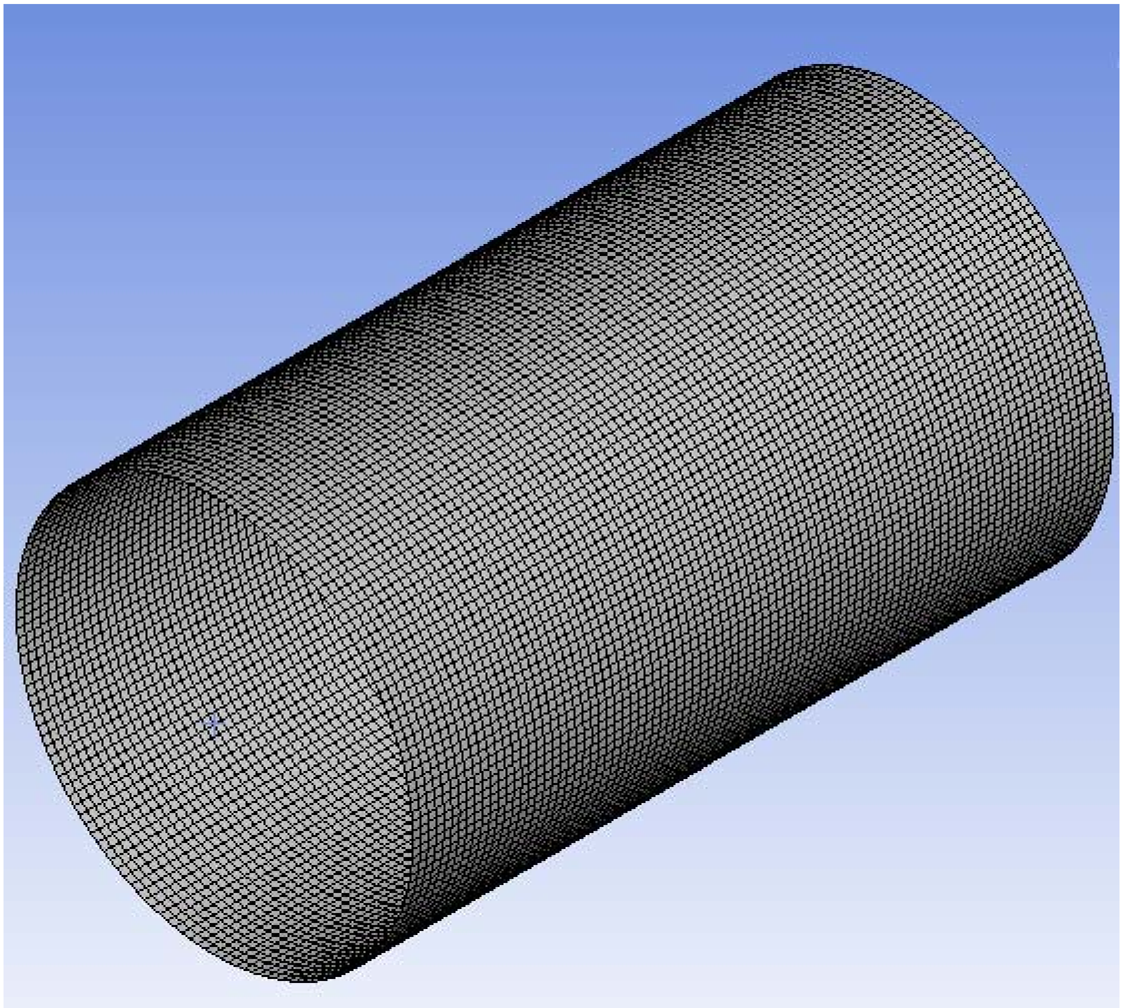
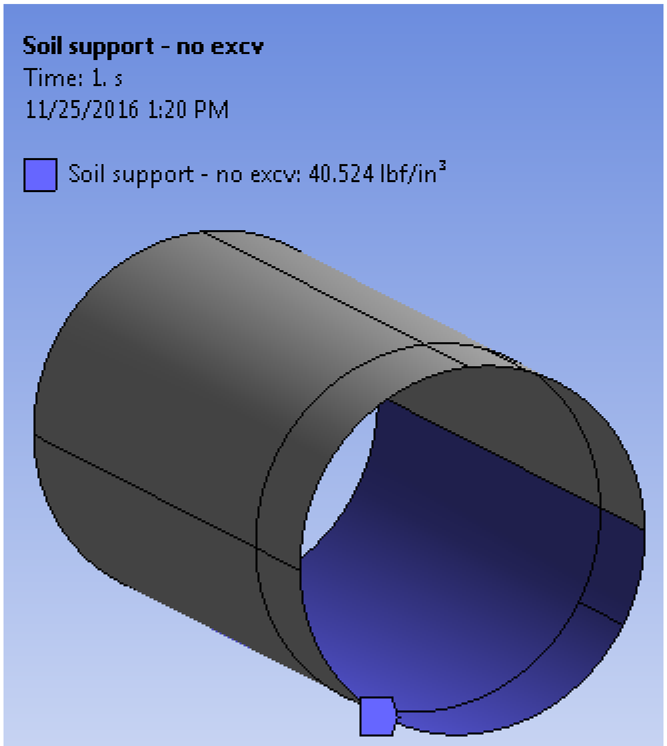
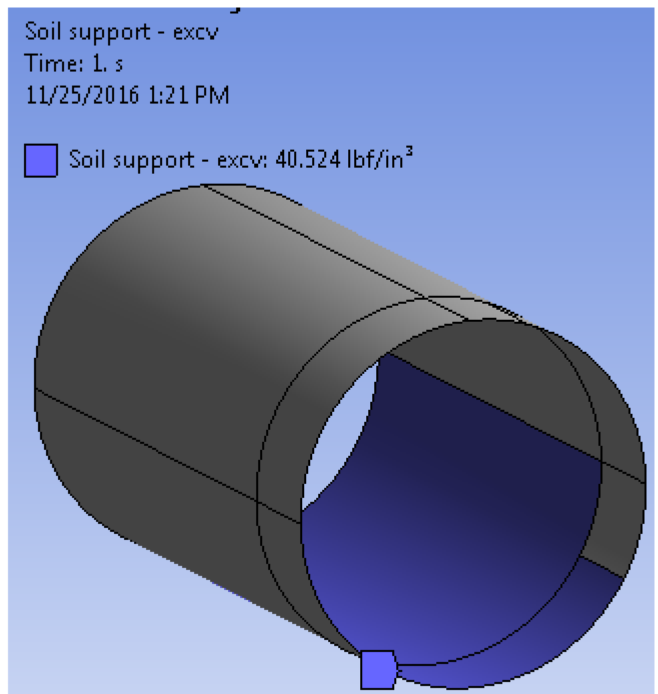


Figure 5: Finite element mesh. The model was meshed with 4-node SHELL181 elements. E = 200GPa, v = 0.3, ρ = 7850kg/m^3

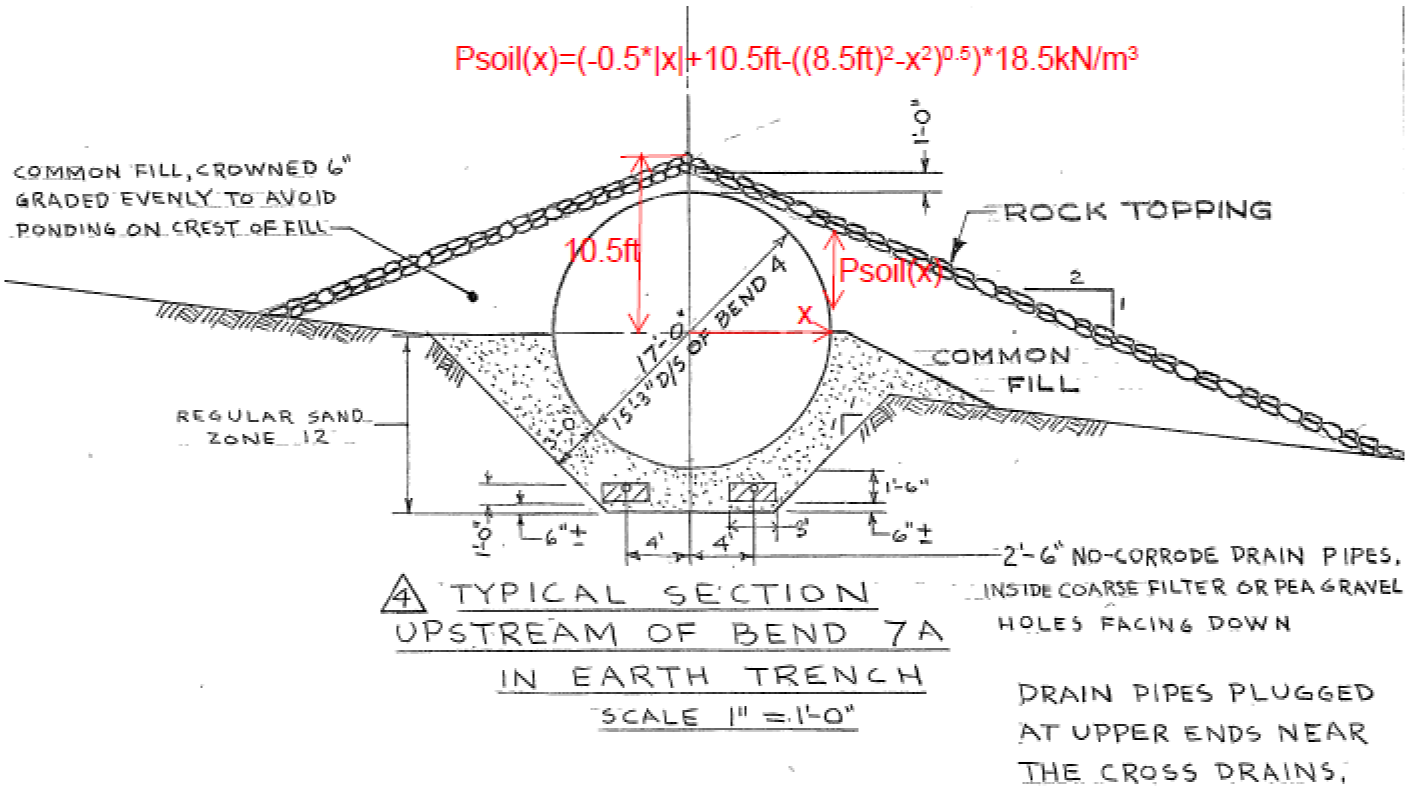


No excavation



With excavation

Figure 6: Subgrade reaction modulus of soil $Ks = 11\frac{MPa}{m} = 40.52 \cdot \frac{lbf}{in^3}$ was applied at the bottom half.



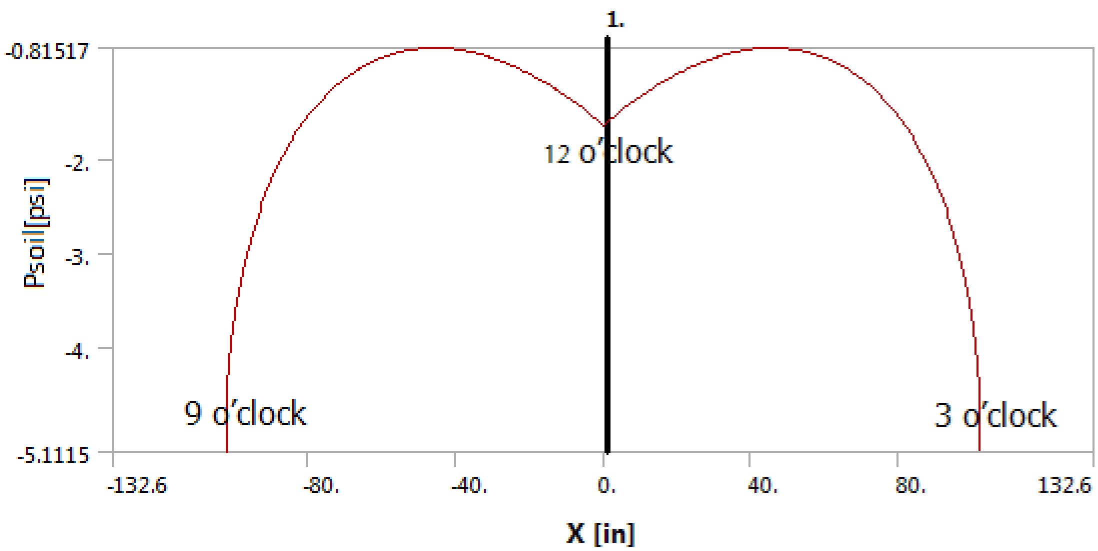
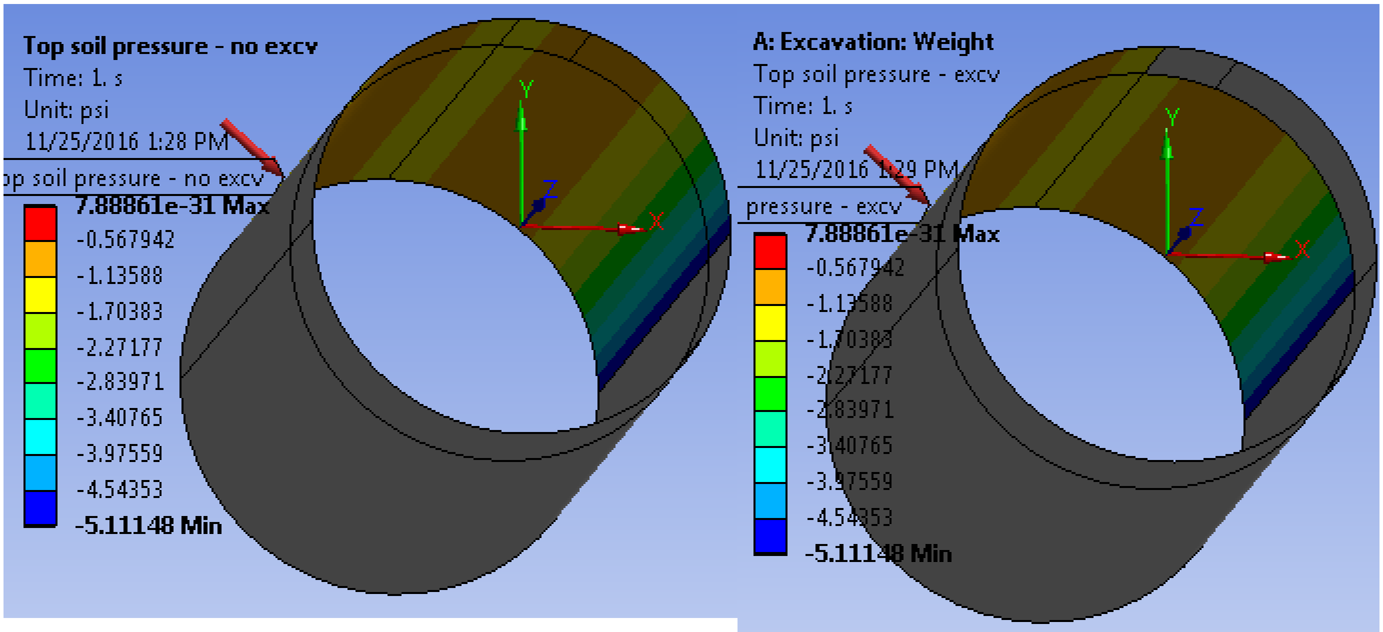


Figure 7:Pressure from the soil on top of pipe. The soil density was assumed at $18.5\frac{kN}{m^3} = 0.0682\cdot\frac{lbf}{in^3}$.



No excavation

With excavation

Figure 8:Pressure from the soil on top of pipe applied as external pressure.

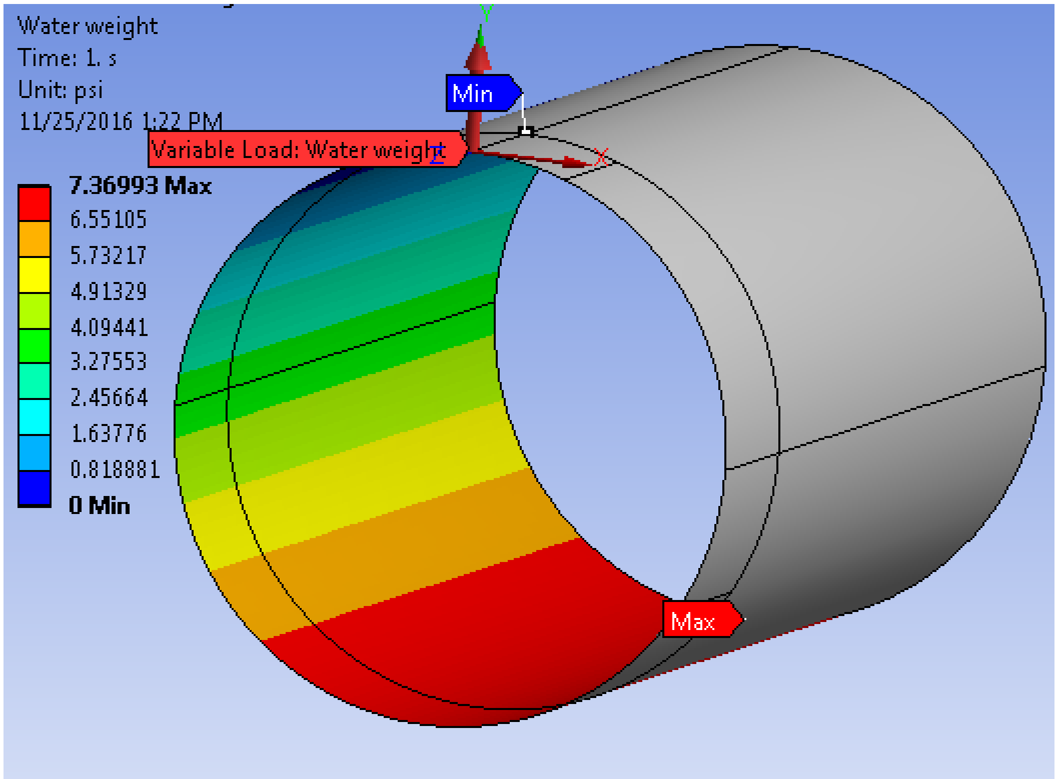


Figure 9: Water weight applied as hydrostatic internal pressure with 0 psi at the top of the pipe

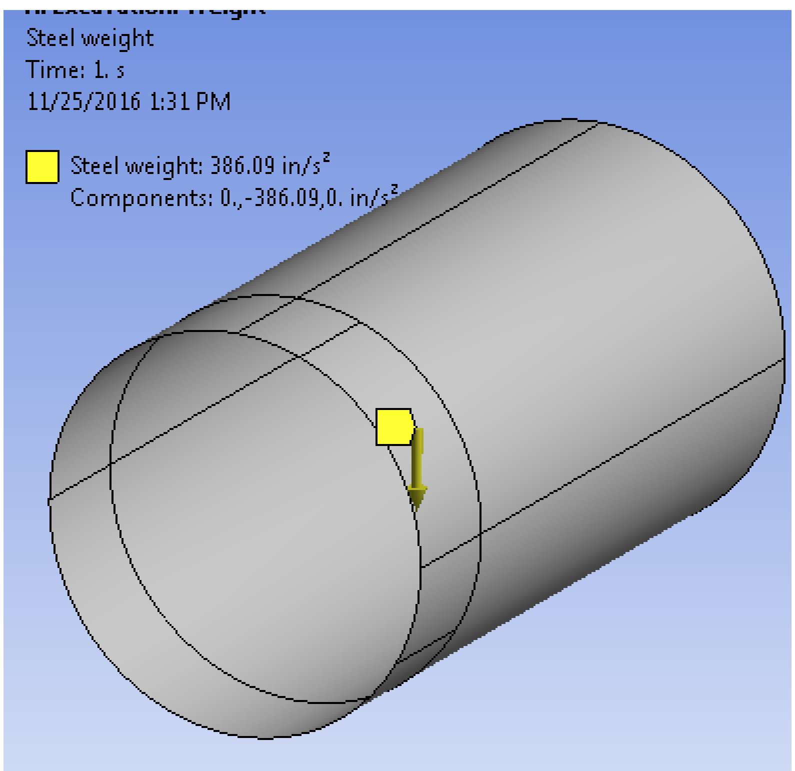


Figure 10: Steel weight

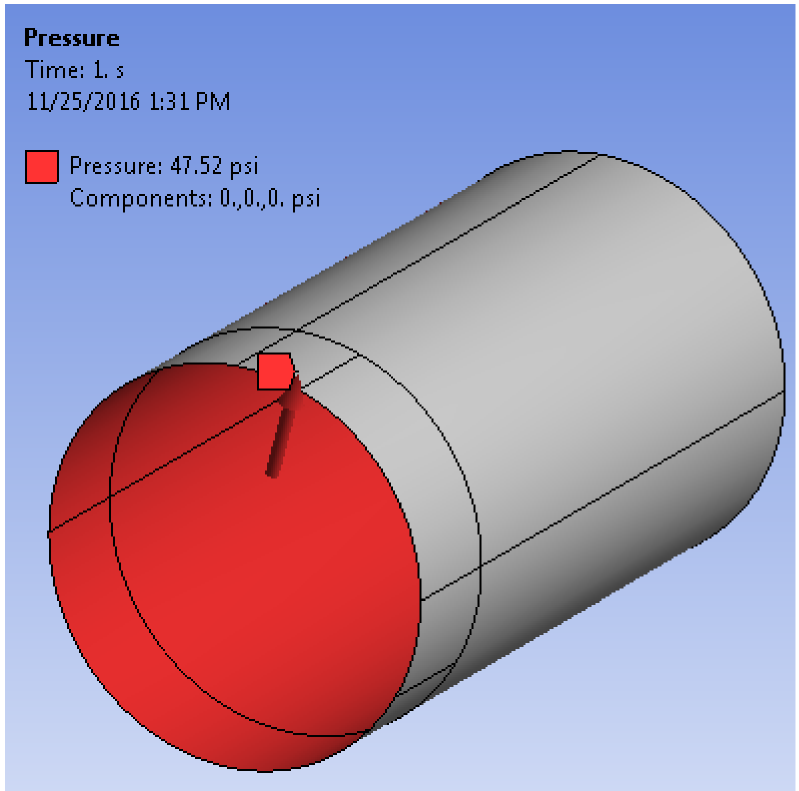


Figure 11: Internal pressure 47.52 psi including pressure surge from pressure line of Ref 5.

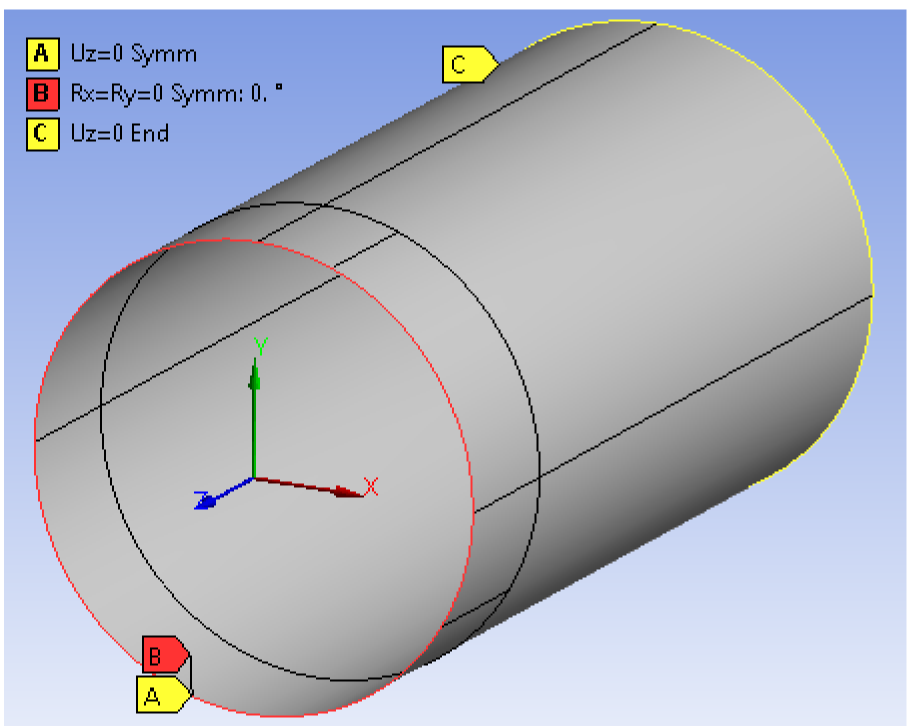


Figure 12: Constrains: Uz = Rx = Ry = 0 at the XY symmetry plane. Uz = 0 at the end.

Results

Three loading scenarios were considered:
LS1 = Water Weight + Steel Weight + Internal Pressure. No soil on top of the penstock, no excavation
LS2 = Water Weight + Steel Weight + Top Soil Weight + Internal Pressure. No excavation
LS3 = Water Weight + Steel Weight + Top Soil Weight + Internal Pressure. With excavation

$F_{uA285} := 55ksi$ Tensile stress $F_{uA285} = 379 \cdot MPa$ Assume Grade C, Ref 3

$F_{yA285} := 30ksi$ Yield stress $F_{yA285} = 207 \cdot MPa$

$Si_{A285} := \min\left(\frac{F_{uA285}}{2.4}, \frac{F_{yA285}}{1.5}\right) = 20000 \cdot psi$ Basic allowable stress intensity according to Ref 2 for continuous plate

$Sa_{pA285} := 1.0 \cdot Si_{A285} = 20000 \cdot psi$ Allowable for primary general membrane stress. Ref 2, for continuous plate

$Sa_{lA285l} := 1.5 \cdot Si_{A285} = 30000 \cdot psi$ Allowable for local membrane stress + pramary bending. Ref 2, for continuous plate

$Sa_{QA285} := \min\left(3 \cdot Si_{A285}, F_{uA285}\right) = 55000 \cdot psi$ Allowable for secondary stress = Local membrane stress + local shell bending. Ref1, for continuous plate

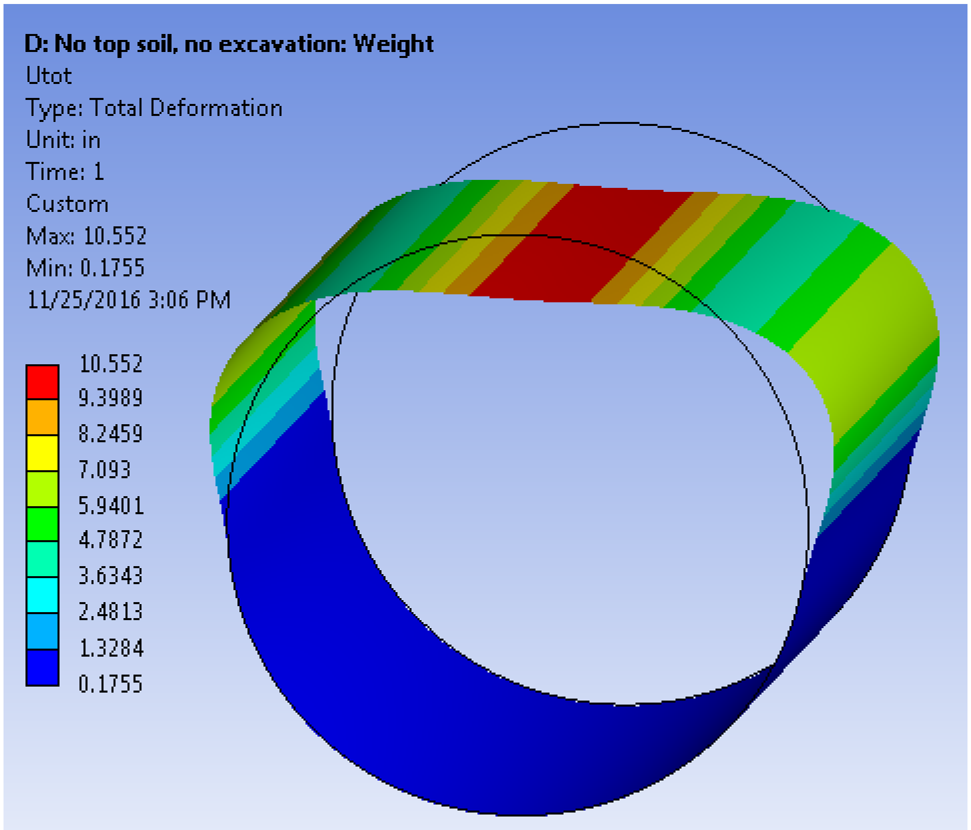


Figure 13: Deformation due LS1 without Internal Pressure.

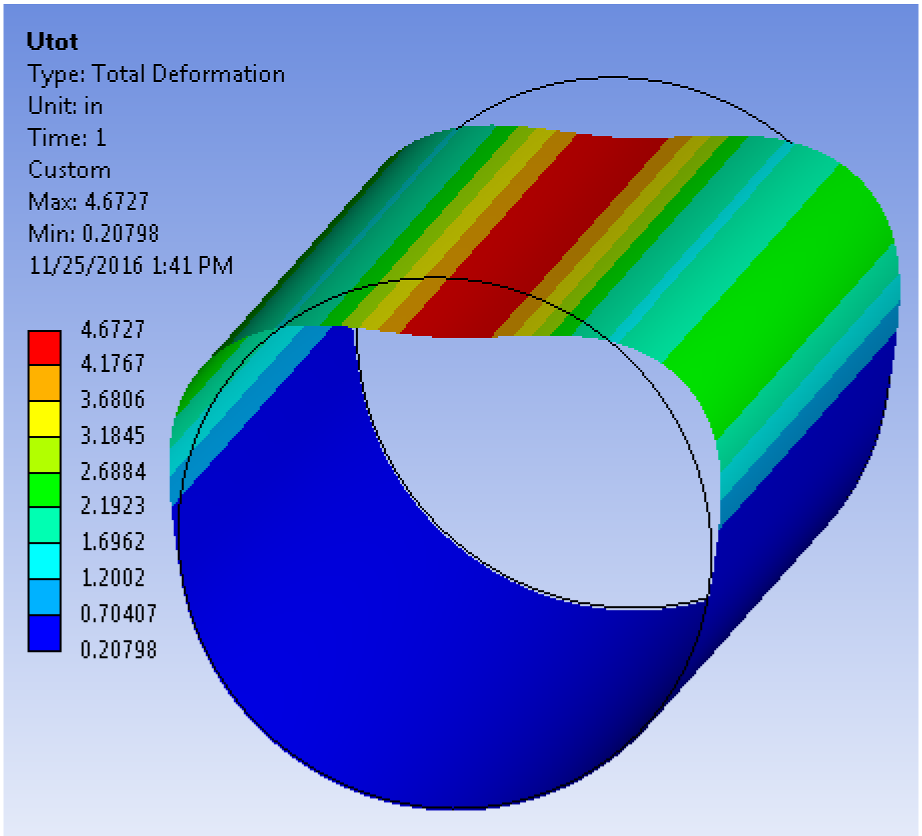


Figure 14: Deformation due LS2 without Internal Pressure.

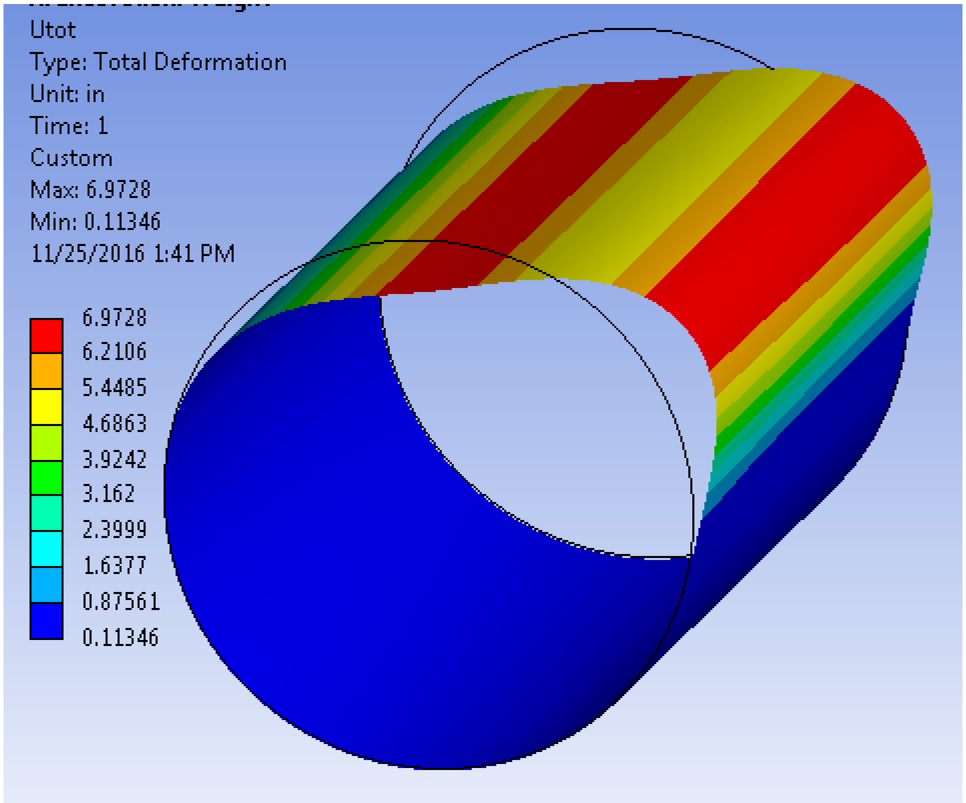


Figure 15: Deformation due LS3 without Internal Pressure.

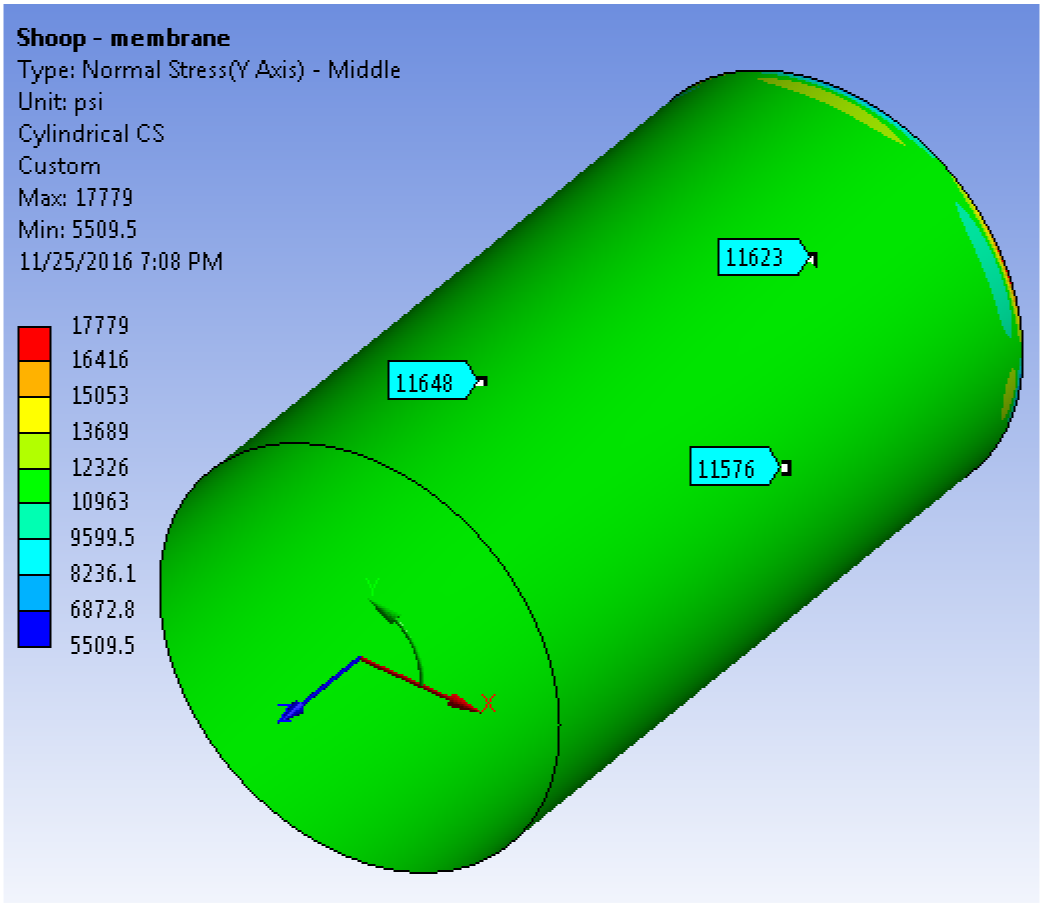


Figure 16: LS1 - Membrane hoop stress. Allowable for continuous plate $Sa_{pA285} = 20000 \cdot psi$. Ignore minor spikes at the boundary. No overstress.

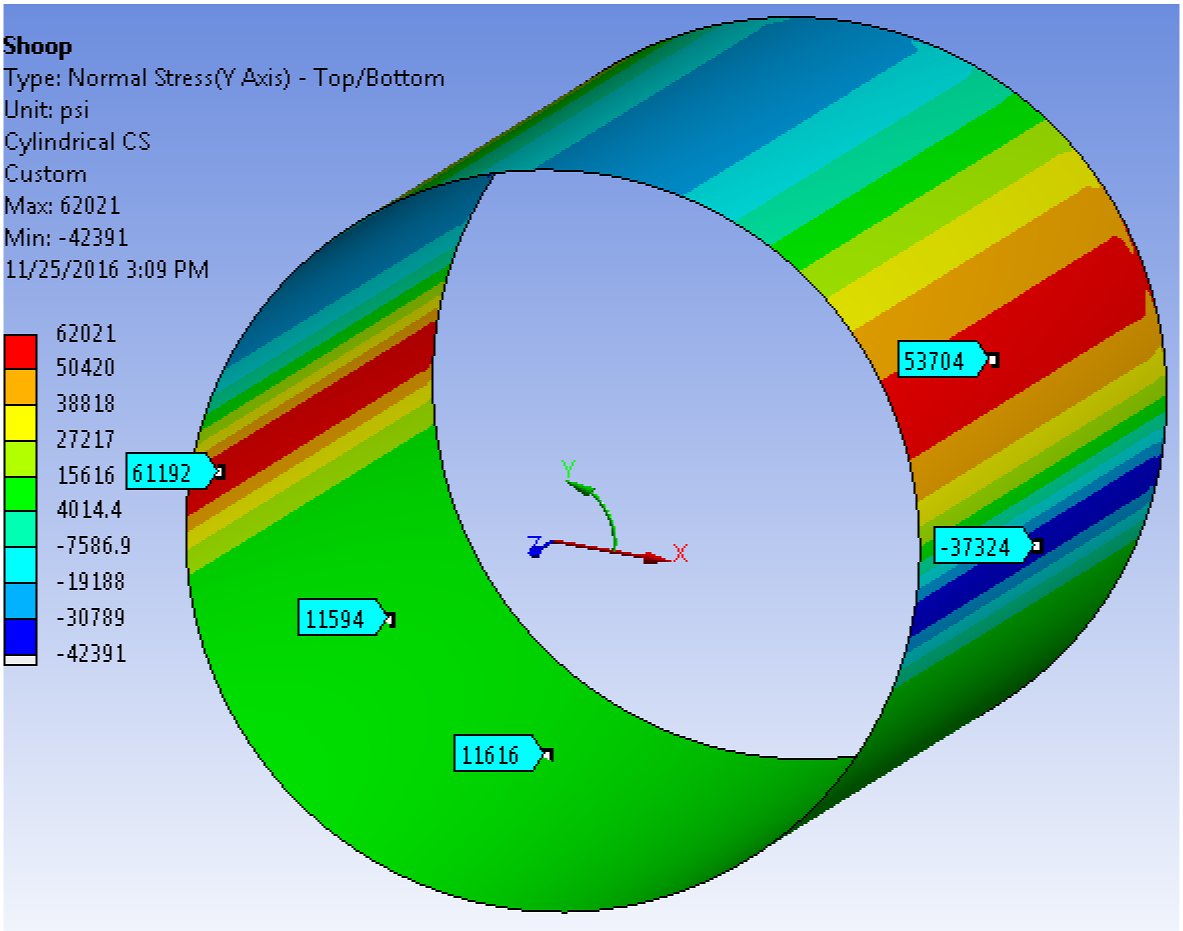


Figure 17: LS1 - Total hoop stress. Allowable for continuous plate $Sa_{|A285|} = 30000 \cdot psi$. 100% overstress, more if longitudinal welded joint efficiency at 3 and 9 o'clock is taken into account.

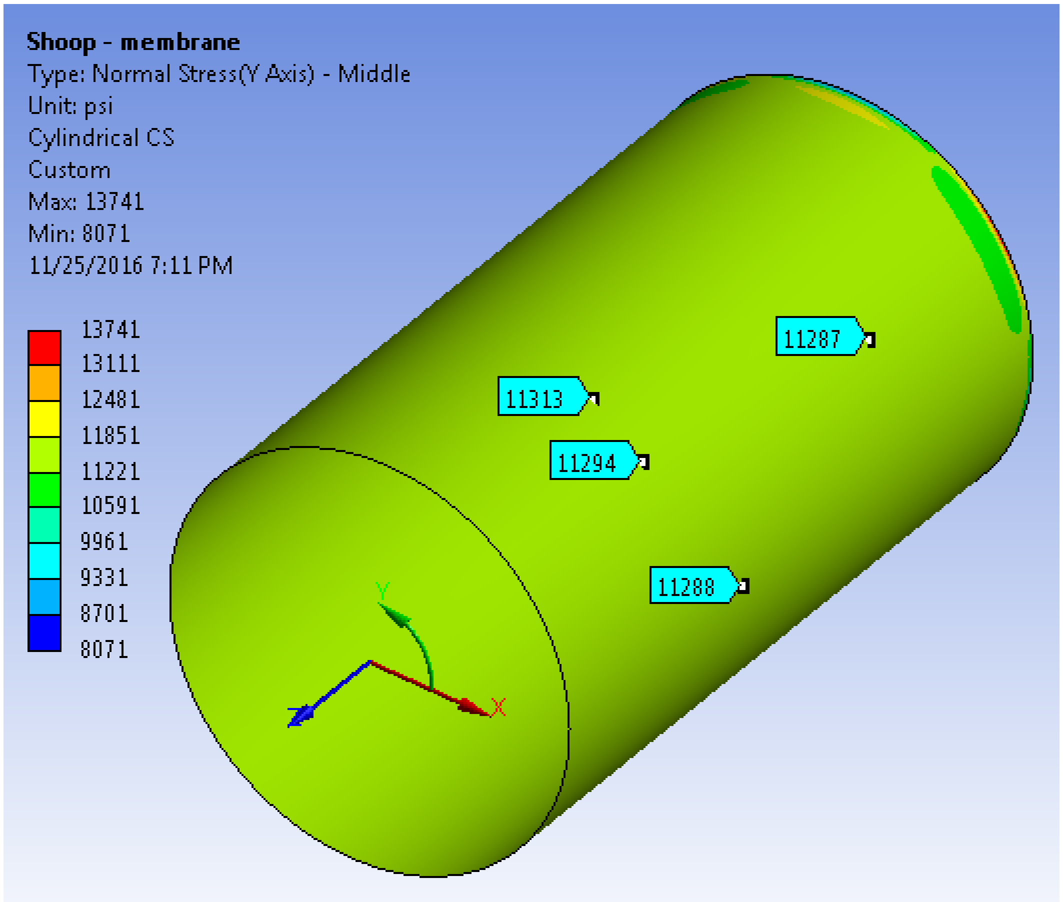


Figure 18: LS2 - Membrane hoop stress. Allowable for continuous plate $Sa_{pA285} = 20000 \cdot psi$. Ignore minor spikes at the boundary. No overstress.

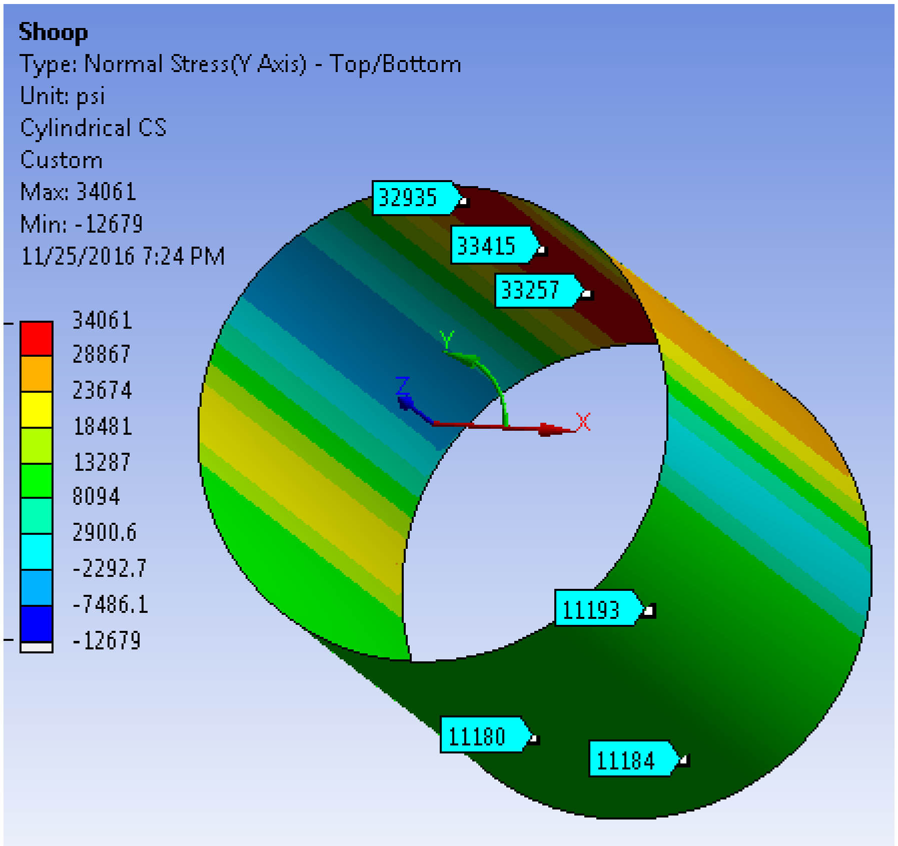


Figure 19: LS2 - Total hoop stress. Allowable for continuous plate $Sa_{|A285|} = 30000 \cdot psi$. 12% overstress.

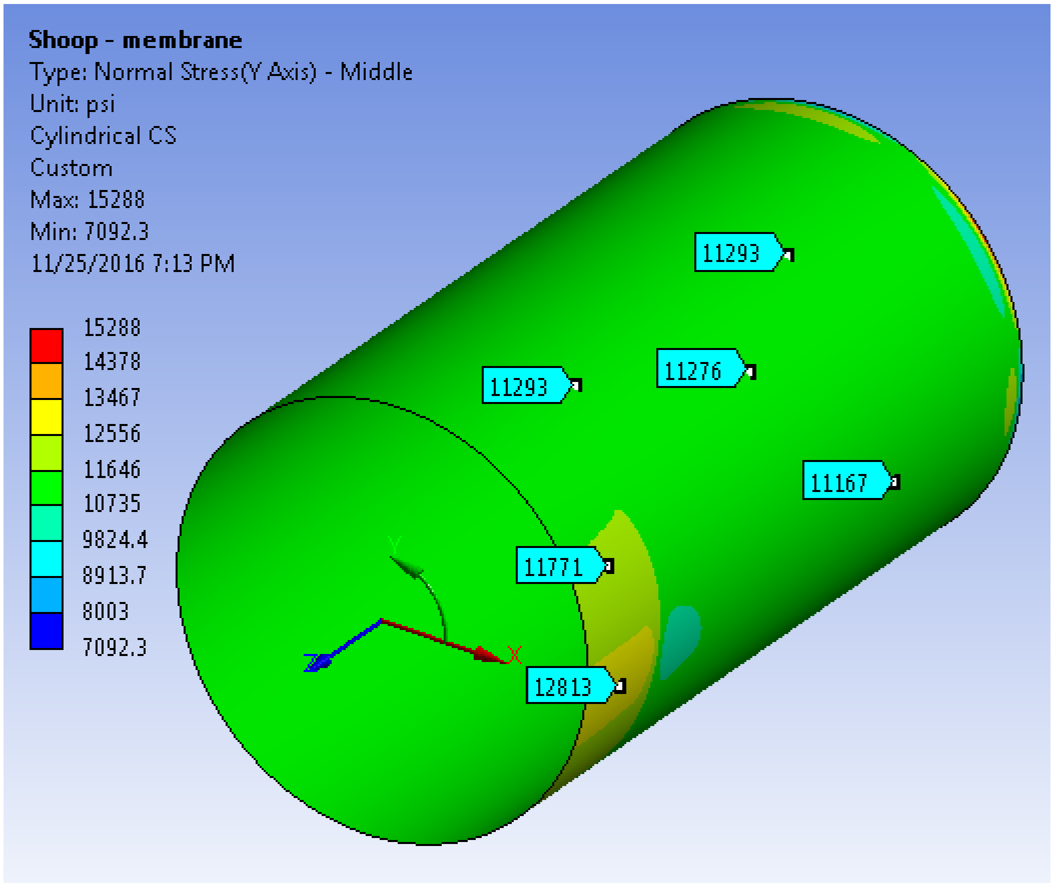


Figure 20: LS3 - Membrane hoop stress. Allowable for continuous plate $Sa_{pA285} = 20000 \cdot psi$. Ignore minor spikes at the boundary. No overstress.

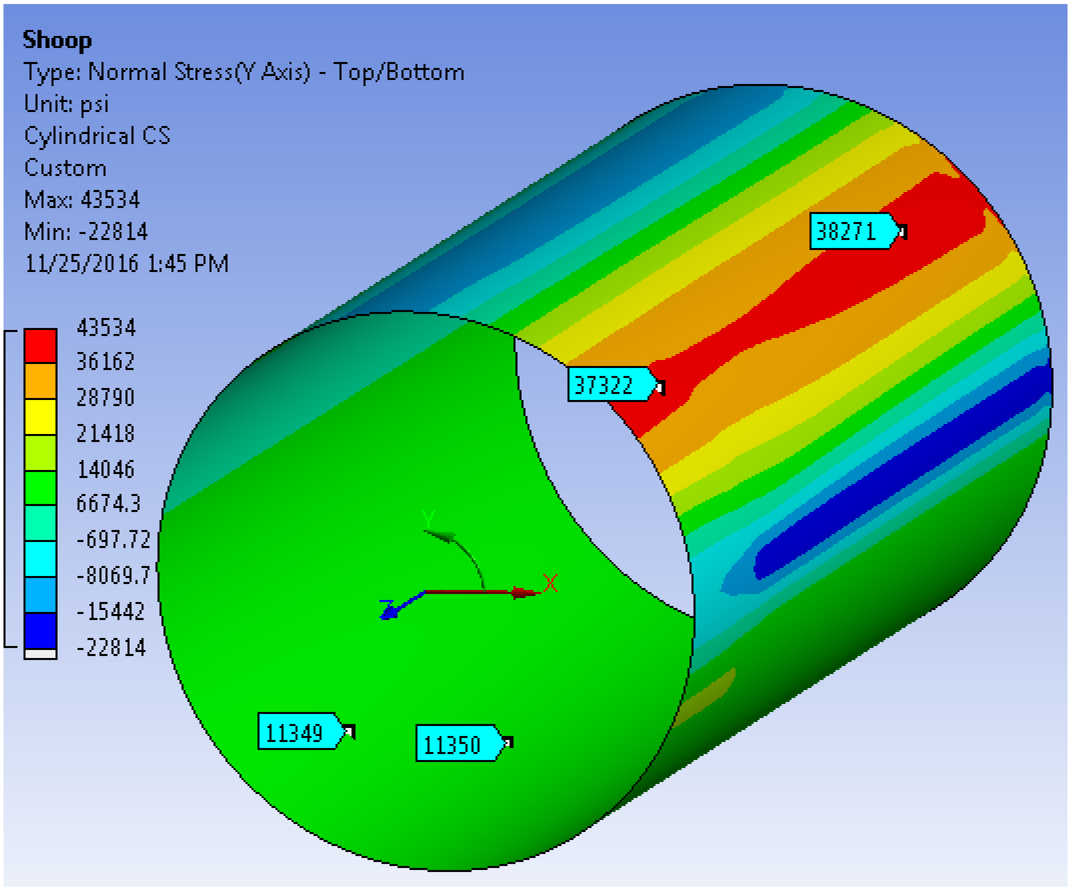


Figure 21: LS3 - Total hoop stress. Allowable for continuous plate $Sa_{|A285|} = 30000 \cdot psi$. 45% overstress, more if longitudinal welded joint efficiency at 3 o'clock is taken into account.

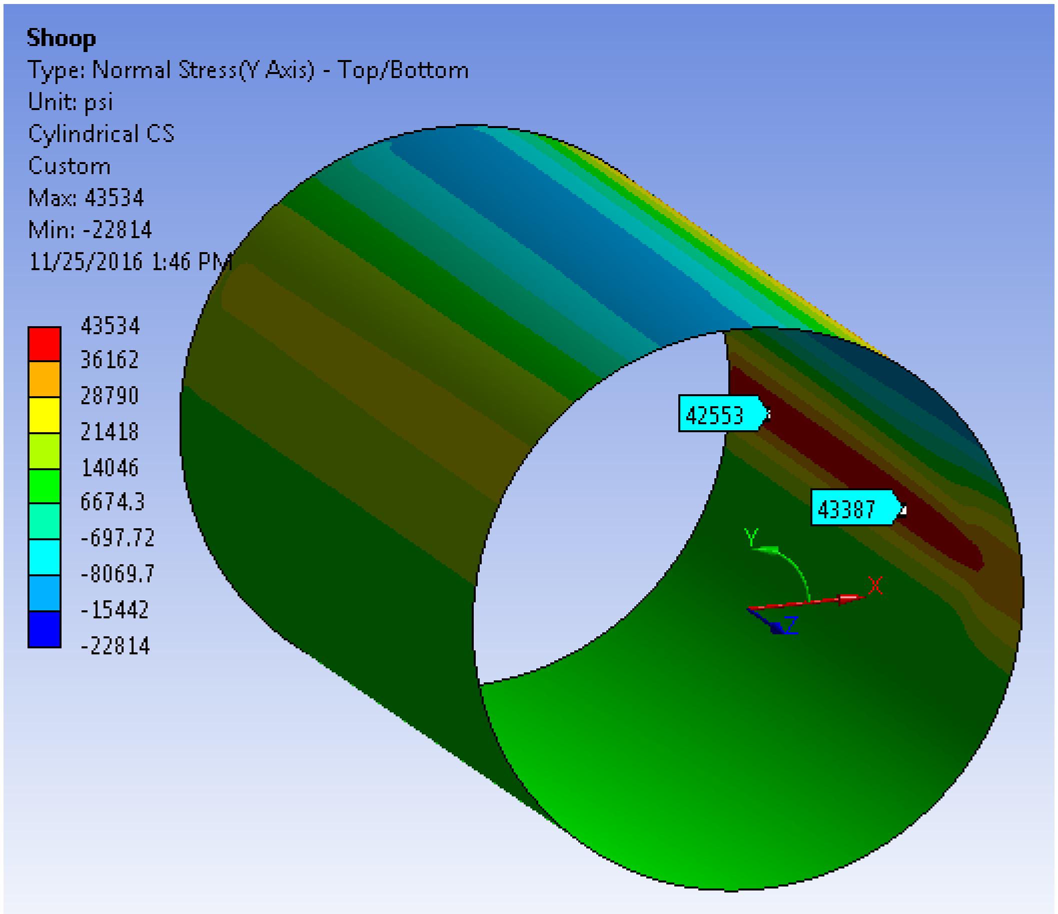
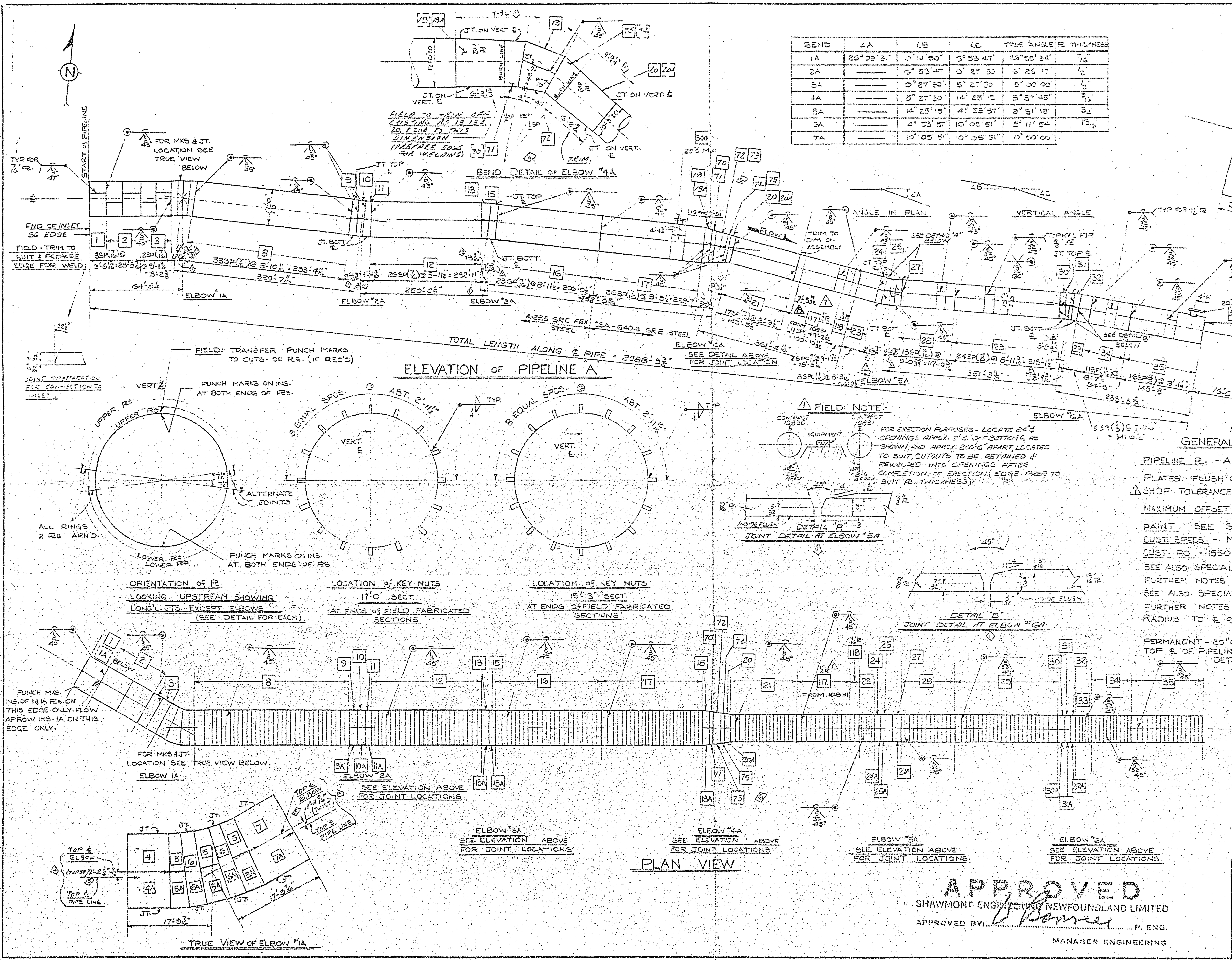


Figure 22: LS3 - Total hoop stress. Allowable for continuous plate $Sa_{A285} = 30000 \cdot psi$. 45% overstress, more if longitudinal welded joint efficiency at 3 o'clock is taken into account.

Conclusions and recommendations

Soil cover on top of the penstock plays an important role in reducing the stresses caused by the water + steel weight.
Excavation causes 100% hoop stress increase (from 22,000psi to 43,500 psi) at 3 o'clock.
It is recommended to restore the excavated sections to their original state (as per Ref 5) prior to filling the penstock.
It is recommended to construct a more comprehensive FE model taking into account soil-steel frictions to study the influence of the soil cover at the top half of the pipe on the stresses in the 17ft diameter penstock sections.

Appendix H
NL Hydro Drawing No. 10830-2 Penstock No. 1 Intake to Surge Tank



BEND	∠A	∠B	∠C	TRUE ANGLE	PL. THICKNESS
1A	26° 03' 31"	0° 14' 50"	5° 53' 47"	26° 55' 34"	7/16"
2A	———	5° 53' 47"	0° 27' 30"	6° 26' 17"	1/2"
3A	———	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4A	———	5° 27' 30"	14° 25' 15"	8° 57' 45"	9/16"
5A	———	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6A	———	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16"
7A	———	10° 05' 51"	10° 05' 51"	0° 00' 00"	

GENERAL NOTES:-

PIPELINE PL. - A285 GR C FBX & G40.8 B

PLATES FLUSH ON INSIDE OF PIPELINE.

⚠ SHOP TOLERANCES - M-3116 SECTION C4.

MAXIMUM OFFSET OF INNER SURFACES 3/32"

PAINT SEE SHEET OL.

CUST. SPECS. - M-3116

CUST. P.O. - 1550

SEE ALSO SPECIAL SHOP INSTRUCTIONS FOR FURTHER NOTES - W.O.S. OM TO OM 5 INCL.

SEE ALSO SPECIAL FIELD INSTRUCTIONS FOR FURTHER NOTES - W.O.S. ON TO ON 9 INCL.

RADIUS TO ℄ OF ALL ELBOWS 17'-0"φ = 45'-0"
15'-3"φ = 38'-6"

PERMANENT - 20"φ MANHOLES TO BE LOCATED ON TOP ℄ OF PIPELINE IN FIELD AS SHOWN - SEE W.O. DETAILS OF DRILLING ETC.

DETAILS SHOWN FOR ONE PIPELINE :- ONE REQ'D.

REVISIONS			
NO.	DATE	BY	REMARKS
1		DB	
2		DB	
3		DB	
4			
5			
6			
7		DB	
8			CNG. PR 117

HORTON STEEL WORKS, LIMITED
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SHAWMONT ENG. NFLD. LTD. FOR NFLD & LABRADOR POWER COMM.
BAY D'ESPOIR DEVELOPMENT
ST. ALBANS — NFLD.

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CHECKED:
DESIGN:
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CONTRACT 10830

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SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
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CM

This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.

FILE 2-13

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