Q. **Reference: Application, Schedule 1: Upgrade Report – Penstock 1 Life Extension – Bay d'Espoir, Appendix J, Page 26 of 51..**

> Based on inspections of the circumferential seams we know there is pitting corrosion in these seams. To understand the condition of these seams in the various sections of the penstock a more detailed scale removal and magnetic particle inspection could be performed, as noted above. It is possible that further inspection could reduce the requirements for significant weld refurbishment and increase the recommended refurbished period from three to five years to five to ten years.

Has Hydro completed the more detailed scale removal and magnetic particle inspection as recommended by Hatch? If yes, please provide the inspection report. If not, why not?

A. Yes. Please refer to NP-NLH-011, Attachments 1, 2, 3, and 4 for further details.

PENSTOCK NO. 1 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:

Newfoundland and Labrador Hydro
St. John's, Newfoundland and Labrador

Prepared by:

Kleinschmidt

Halifax, Nova Scotia
www.KleinschmidtGroup.com

2670021_003RP
April 2020

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LIST OF ABBREVIATIONS

ASCE	AMERICAN SOCIETY OF CIVIL ENGINEERS
ASME	AMERICAN SOCIETY OF MECHANICAL ENGINEERS
CH	CHAINAGE (IN METRES)
CMS	CUBIC METRES PER SECOND
FU	ULTIMATE TENSILE STRESS
FY	YIELD STRESS
GWH	GIGAWATT HOURS
KPA	KILO-PASCALS
KLEINSCHMIDT	KLEINSCHMIDT ASSOCIATES
MW	MEGAWATTS
NLH	NEWFOUNDLAND AND LABRADOR HYDRO
SPRAT	SOCIETY OF PROFESSIONAL ROPE ACCESS TECHNICIANS
STA	STATION (IN FEET)
TRR	TECHNICAL ROPE AND RESCUE
UT	ULTRASONIC THICKNESS

PENSTOCK NO. 1
INSPECTION AND EVALUATION

BAY D'ESPOIR PENSTOCKS 1-3 INSPECTION PROJECT

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in March 2019 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

Kleinschmidt conducted an inspection of Penstock No. 1 in September 2019. Penstock No. 1 is a buried steel penstock approximately 1,100 metres long, tapering from 5.2 metres in diameter at the intake, to 4.1 metres in diameter at the powerhouse bifurcation. At its flattest point, the penstock has a 0.2-degree slope and has a slope of 19.7 degrees at its steepest. There are at least three areas of access for Penstock No. 1: one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Due to the weld issues and corrosion in all three penstocks, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock No. 1 inspection was to assess the integrity of the welds and to complete steel thickness measurements to evaluate current conditions and potential life extension of the penstock.

Kleinschmidt's September 2019 inspection of Penstock No. 1 consisted of an inspection of the recent crack in Penstock No. 1, a visual walk-over of the penstock exterior, and a detailed examination of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which included cleaning and visually inspecting the steel shell and the longitudinal and circumferential welds. The interior inspection also included non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell.

Overall, the penstock plating was in fair condition. The penstock has not significantly ovalized, the plate thickness was comparable to the construction drawings, and the interior of the shell has a layer of rust with moderate corrosion and pitting common for a 50-year-old penstock. The penstock welds are in fair to poor condition depending on location with welds upstream of the surge tank being in poor condition and the welds downstream of the surge tank generally in fair condition. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

The exterior inspection found no areas of significant concern along the Penstock 1 alignment.

Measurements of the penstock shell thickness indicate minimal loss of material thickness. Some mild to moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the plating of the penstock should have significant service life remaining that could be extended another 50 to 80 years with an internal coating. However, the welds do not meet current standards and there have been multiple weld related failures over the last 4 years indicating the welds are at the end of their useful life.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.38 at the joints. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.14, which is not acceptable for late 1960 steel pipe. Note that this is stress at the joints, and assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency alone would result in favourable factors of safety; however, considering the known weld issues, a higher joint efficiency is not justified at this time. A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This could be completed in 2020 to better understand the risks.

The base plate material away from the joints has a maximum stress ratio of 0.97 and a safety factor of 1.55, which is acceptable and could tolerate about 2 mm of material loss from design thickness in most cases.

This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070), provided that the penstock welds are replaced and the interior is coated before the steel deteriorates further and is adequately maintained and monitored. Replacing the welds from the inside of the penstock only may not fully mitigate the issues, and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 5 years.

PENSTOCK NO. 1
INSPECTION AND EVALUATION

BAY D'ESPOIR PENSTOCKS 1-3 INSPECTION PROJECT

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in March 2019 to inspect and evaluate the condition of Penstock No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development (the Project).

In 2016, cracking was identified in Penstock No. 1 due to weld degradation and Kleinschmidt was contracted to assist with the weld repair design. Another crack in Penstock No. 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods and significant refurbishment of the welds followed.

Penstock No. 1 was installed in 1967, at the same time as Penstock No. 2, and before installation of Penstock No. 3 in 1968. Penstock No. 1 has similar plate materials, thicknesses, and weld procedures as Penstock No. 2 and 3. The cracking and weld issues found in Penstock No. 1 in 2016 raised concerns about weld integrity of Penstocks No. 2 and 3 and NLH elected to have Kleinschmidt complete detailed inspections of Penstock No. 2 in 2016 and Penstock No. 3 in 2017. The main focus of the previous inspections was to assess the integrity of the welds and to complete steel thickness measurements to evaluate potential life extension of the penstock and appurtenances. Non-destructive testing of the welds was not part of the 2016 and 2017 Kleinschmidt scope of work, but the welds of Penstocks No.1, 2, and 3 were inspected and tested using magnetic partical testing (MT) methods in 2018 as part of a Level II Condition Assessment performed by Hatch. The Hatch report references multiple ruptures in longitudinal seams in Penstock No. 1 upstream of the surge tank, as well as degradation and repairs to various welds in Penstock No. 1, 2, and 3.

A new weld failure in Penstock No. 1 resulting in a leak was detected by NLH on September 22, 2019. The penstock was dewatered and Kleinschmidt carried out an inspection from September 25-27, 2019. October 2019 was the original inspection date.

This report presents Kleinschmidt's evaluation of Penstock No. 1 in its current condition following significant weld repairs made in 2016 and subsequent years and with consideration of the latest weld failure, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 feet (176 metres) and seven generating units with a total capacity of 604 megawatts (MW). The development comprises four structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks No. 1, 2, and 3 have surge towers approximately 2,400 feet (727 metres) upstream of the powerhouse. The first phase of the project construction involved the installation of two intake structures (Intake 1 and Intake 2) and a four-unit powerhouse with Penstocks No. 1 and 2 connecting the two. The second phase consisted of installing Penstock No. 3, along with two additional units in the powerhouse, and a separate intake structure and powerhouse for Unit No. 7, connected by Penstock No. 4 in 1970. Penstock No. 1 supplies Units No. 1 and 2. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock No. 1 is buried along its entire length from the intake to the powerhouse. There are four original manholes; one manhole upstream of a turbine-isolation valve inside the powerhouse, and three larger manholes on the crown of the penstock: (1) approximately halfway between the powerhouse and surge tower, (2) at the surge tower, and (3) halfway between the intake and the surge tower. A majority of the penstock has a cover of 2 feet (0.61 metres) of clayey soil and 1 foot (0.30 metres) minimum of riprap. The penstock is deeply buried as it crosses under the switchyard and goes into the powerhouse. The penstock has drainage along its length with several weirs where the drainage daylights to the ditches and wells for inspection and monitoring.

Appendix A includes the original 1965 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 11 millimetres (0.4375 inches) at the intake to 41 millimetres (1.625 inches) at the powerhouse. The penstock is constructed of A285 grade steel for the first 1,015 feet, and CSA G40.8 Grade B for the remainder of the penstock. The welds are generally double V groove full penetration welds. The penstock slope varies from approximately 0.2 degrees to 19.7 degrees just upstream of the bifurcation.

3.0 INSPECTION

Christopher Vella, P.Eng. of Kleinschmidt, inspected the interior and exterior of Penstock No. 1 on September 25 through September 27, 2019, with the assistance of personnel from Acuren Group, Inc. (Acuren) and NLH. NLH personnel assisted with safety procedures, isolation, site access, safe access, confined space entry protocols, communication, and were on standby at the penstock entry for rescue, if needed. NLH also answered questions about the history, operation, and maintenance of the station. Acuren assisted with the UT and MT testing of the penstock. Due to the short notice for the inspection resulting from the recent weld failure, Acuren was unable to supply a rope access team.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying any pitting or cracking, and an overall general condition assessment of the interior of the shell. The exterior of the buried penstock was examined for signs of leakage. Acuren personnel performed MT weld tests on approximately 10% of the longitudinal welds from inside the penstock and took ultrasonic thickness (UT) measurements from approximately 10% of the cans[1] for the portion of penstock inspected. The inspection was terminated downstream of the surge tank and upstream of the 19.7 degree slope section of penstock since this section was not completely dewatered and a rope access team was not provided due to the short notice as discussed below. The field data is included in Appendices C and D, respectively.

TABLE 3-1 DEFINITIONS

TERM	DEFINITION
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible and remediation is required within 1 year

[1] A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint.

3.1 WORKING CONDITIONS

Kleinschmidt's inspection team entered the penstock on Wednesday, September 25, 2019 at the upstream most manhole of Penstock No. 1 and walked to the intake gate to start the inspection. NLH assisted with confined space entrance. The lower part of the steep 19.7 degree slope penstock section was not dewatered and the manhole in the scroll case was not open. Manhole No. 3 between the powerhouse and surge tank was also not open. Lack of a rope access team as well as water in the penstock prevented inspection of the steep section of the penstock. Air quality in the penstock remained good for the duration of the inspection.

The inspection started at the headgate. Leakage around the gate was mainly from the left bottom corner as seen in Photo 1, Appendix B. Concrete deterioration at the concrete to steel transition (Photo 2), notably more extensive than at other Bay d'Espoir penstocks, has resulted in the leading edge of steel exposed all the way around but worse in the lower left area. The interior surface of the penstock was fairly wet as the penstock was dewatered two days prior and had not dried out. Much of the organics had been cleaned away during the previous penstock repairs, which facilitated the inspection.

The penstock has varying slopes with two main steep sections. The penstock slopes range from 0.2 degrees to 11 degrees along most of its length, but just upstream of the surge tank there is a section with a 14-degree slope for approximately 110 metres (361 feet) and just upstream of the powerhouse the penstock has a 19.7-degree slope for approximately 58 metres (190 feet) as noted in Appendix A. The slope levels out as the penstock enters the powerhouse.

The exterior of the penstock was inspected on September 26, 2019. The ground surface was generally rock covered with steep slopes in many areas and short vegetation (Photo 26). There was no snow present and the ground was reasonably dry limiting slip potential. The grade nominally followed the penstock slope between the intake and the switchyard. Deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 INTERIOR INSPECTION

The interior of the penstock was inspected from September 25 to September 27, 2019. The penstock was fabricated with about 435 "Cans". A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The

Can number is used in this report to reference location in the penstock during the inspection with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded from the interior at various locations. Shell thickness measurements were taken with a Panametrics Model 38DL Plus Ultrasonic thickness gauge. A dual element D799 transducer was used and the readings were taken in the "standard" mode. In "standard" mode the paint thickness does not affect the steel thickness readings if the paint thickness is below 1/64 (0.0156) inch (15.6 mils). The gauge was calibrated before the field measurements to an accuracy of 0.001 inch. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, this evaluation did so as well. Metric equivalents are given in parenthesis.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the pipe. All references to penstock left and right are also oriented looking downstream. Appendix D provides the Acuren report of shell thickness readings and Table D-1 and Table D-2 in Appendix D summarizes the average shell thickness readings and stresses respectively for each section of penstock. A summary of this data is provided in Table 4-1.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

The interior of the penstock is generally in fair condition with scattered moderate corrosion and pitting with tubercles and growth (Photos 18 to 20). Pitting was minor to moderate, relative to the plate thickness, and detailed pit measurements were not taken.

Penstock No. 1 is fabricated from 20 different plate sizes ranging from 11 millimetres (0.4375-inch) to 42 millimetres (1.625-inch). Inspection thickness readings were taken for plate sizes up to 36.5 millimetres (1.433 inches). Many of these sections exhibited little to no appreciable material loss with some thickness readings averaging up to 23% greater than the listed original plate thickness and the average thickness for all plates being 3.1% greater than the listed original. There are some exceptions such as the 11 millimetre plate (0.4375-inch), approximately 235 feet from the face of the intake, exhibited material loss averaging 1% over four reading locations and 482 feet from the intake exhibiting material loss averaging 2.7% over three readings.

The greater thickness is common for steel construction from this era when steel plate was frequently rolled out slightly thicker than called for in the design to account for fabrication tolerances. The majority of thickness measurements were taken beside the welds where Acuren cleaned the weld and adjacent area with a sandpaper brush wheel on a grinder to facilitate MP testing of the welds and UT readings. Appendix D provides the Acuren report of the MP and UT testing.

Welds in Penstock No. 1 were cleaned with a grinder then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 40 full length longitudinal welds and a few feet of 30 circumferential welds. An initial visual inspection of the weld was conducted concentrating on condition of the bead in regard to pitting, corrosion or cracking, and undermining or washout. The cracked weld that resulted in the leak that was detected on the right exterior side (Photo 8) on September 22, 2019 was identified on the right interior side of Can 106 near the spring line. The weld area was painted with a white contrast paint and the crack was painted with green paint (Photos 6 and 7) to facilitate repairs by NLH. Weld testing was carried out on every can near Can 106 (Photo 9). Indication of an issue was identified in Can 111 near the left spring line and marked with white paint in addition to the white contrast paint to facilitate repairs by NLH. The remaining welded joints including original joints, previously repaired joints, and doubler plate welds were in fair condition (Photos 4, 5, 12, and 13) and did not have any apparent visible cracks and most did not exhibit excessive deterioration. Corrosion of the original welds was moderate for most welds with light to moderate pitting. A few welds were found to have heavier deterioration such as the circumferential weld on Can 194 (Photo 13). These welds also had above average pitting. No significant magnetic partical indications were identified. The repaired welds were in good condition and relatively clean with some surficial rust. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before the penstock was put back into service. The inspection of the welds for this inspection concentrated on the untested welds but also picked up a several of the tested and repaired welds.

3.2.2 APPURTENANCES

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock No. 1 has three large manholes and a bifurcation at the powerhouse.

The manholes were in fair condition with moderate corrosion of the interior surface of the manholes.

The concrete of the intake structure was in fair condition with no significant deterioration or wear, except the transition from the concrete to steel penstock showed significant deterioration all around and especially the lower left side area (Photo 2). The headgate seals appeared to be in good condition with only minor leakage of the headgate apparent from the bottom left corner of the headgate when looking upstream (Photo 1). The headgate skin plate also appeared to be in good condition. A full inspection of the gate members and gate embedments was not performed and was outside the scope of work.

3.2.3 SURGE TANK

The surge tank transition welds were visually inspected from the invert of the penstock (Photo 15). The welds appear to have been tested but not refurbished. This area is incased in concrete so a rupture is unlikely but leakage between the steel and concrete and can occur and cause erosion of the concrete and surrounding soil.

3.3 EXTERIOR INSPECTION

Kleinschmidt began the exterior inspection on September 26 at the intake and moved downstream. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 23 to 32. Kleinschmidt observed the exterior ground surface for signs of leakage while walking the length of the penstock. Signs of leakage include sloughing of the ground over the penstock and other depressions mainly. The penstock exterior was free of snow and fairly dry and the weather was cloudy and cool.

The crack location that resulted in the leak was covered with a tarp (Photo 28). Other features noted along the penstock route included open Manhole No. 1 (Photo 25), a piezometer just upstream of the crack location (Photo 27), and a pressure monitor (Photo 32) and closed Manhole No. 3 (Photo 33) that all appeared to be in good condition. No drainage wells were observed. It is recommended that bushes and alders growing in a few locations on the upper end of the penstock should be removed.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 LOADING CONDITIONS AND ALLOWABLE STRESSES

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix E. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 which extends approximately 1034 feet from the face of the intake, and 24,000 pounds per square inch (psi) was used for CSA G40.8 Grade B for the remainder of the penstock.

The welded seams are not as strong as the original base material; these strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used if further weld testing is performed to verify the integrity of the welds. Per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds needing higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 SHELL STRESSES INDUCED BY INTERNAL PRESSURE

Table 4-1 summarizes the statistical analysis of our steel-shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations. Average thickness and a 97.5% confidence interval (CI) were calculated for each station. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79*, *Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 feet (182 metres) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 feet (271 metres) at the powerhouse and linearly reducing to 655 feet (200 metres) at the surge tower and then matching the FSL of 597 feet (182 metres) at the intake. Appendix A reference drawings provide the pressure gradient used in this analysis. The maximum stress ratio at a joint is 1.38 for this load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.14, which is unacceptable for late 1960 steel pipe. An increase in the joint efficiency through weld testing that verifies the joints integrity would improve these values. For the plate steel away from the joints, the material has a maximum stress ratio of 0.97 and a safety factor of 1.55, which is acceptable for current design practices.

TABLE 4-1 SUMMARY OF THICKNESS DATA AND STRESSES DUE TO INTERNAL PRESSURE

CAN	MAX JOINT STRESS[1,3] (psi)	DYNAMIC HOOP STRESS INCREASE[1,3] (psi)	TOTAL WATER HAMMER STRESS[1,3] (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO[1,2,3]	FACTOR OF SAFETY AGAINST YIELD
1A	5,920.32	1,776.10	7,696.42	17,000	0.45	3.38
1B	5,807.00	1,742.10	7,549.10	17,000	0.44	3.44
1C	5,946.67	1,784.00	7,730.68	17,000	0.45	3.36
10A	5,660.46	1,698.14	7,358.60	17,000	0.43	3.53
10B	5,819.94	1,745.98	7,565.92	17,000	0.45	3.44
10C	6,006.42	1,801.93	7,808.35	17,000	0.46	3.33
20A	6,866.05	2,059.81	8,925.86	17,000	0.53	2.91
20B	6,749.02	2,024.70	8,773.72	17,000	0.52	2.96
20C	6,775.31	2,032.59	8,807.90	17,000	0.52	2.95
30A	7,130.71	2,139.21	9,269.92	17,000	0.55	2.80
30B	7,801.25	2,340.37	10,141.62	17,000	0.60	2.56
30C	7,427.92	2,228.38	9,656.29	17,000	0.57	2.69
40A	9,033.52	2,710.06	11,743.58	17,000	0.69	2.21
40B	9,034.44	2,710.33	11,744.77	17,000	0.69	2.21
40C	8,209.51	2,462.85	10,672.36	17,000	0.63	2.44
48A	9,794.24	2,938.27	12,732.51	17,000	0.75	2.04
48B	9,966.10	2,989.83	12,955.93	17,000	0.76	2.01
48C	9,824.02	2,947.21	12,771.23	17,000	0.75	2.04
58A	12,271.80	3,681.54	15,953.34	17,000	0.94	1.63
58B	11,900.46	3,570.14	15,470.60	17,000	0.91	1.68
58C	11,715.60	3,514.68	15,230.28	17,000	0.90	1.71
69A	13,215.58	3,964.68	17,180.26	17,000	1.01	1.51
69B	12,691.83	3,807.55	16,499.38	17,000	0.97	1.58
69C	12,322.69	3,696.81	16,019.49	17,000	0.94	1.62
79A	12,986.02	3,895.81	16,881.83	17,000	0.99	1.54
79B	12,779.10	3,833.73	16,612.83	17,000	0.98	1.57
79C	12,805.18	3,841.55	16,646.73	17,000	0.98	1.56
89A	11,490.41	3,447.12	14,937.53	17,000	0.88	1.74
89B	11,452.84	3,435.85	14,888.69	17,000	0.88	1.75
89C	10,852.53	3,255.76	14,108.29	17,000	0.83	1.84
101A	13,774.10	4,132.23	17,906.32	17,000	1.05	1.45
101B	14,110.87	4,233.26	18,344.13	17,000	1.08	1.42
101C	13,954.91	4,186.47	18,141.38	17,000	1.07	1.43
120A	15,826.34	4,747.90	20,574.24	24,000	0.86	1.94
120B	17,677.62	5,303.29	22,980.91	24,000	0.96	1.74

CAN	MAX JOINT STRESS[1,3] (psi)	DYNAMIC HOOP STRESS INCREASE[1,3] (psi)	TOTAL WATER HAMMER STRESS[1,3] (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO[1,2,3]	FACTOR OF SAFETY AGAINST YIELD
120C	16,922.45	5,076.74	21,999.19	24,000	0.92	1.82
123A	16,828.07	5,048.42	21,876.49	24,000	0.91	1.83
123B	17,136.99	5,141.10	22,278.09	24,000	0.93	1.80
123C	17,147.07	5,144.12	22,291.18	24,000	0.93	1.79
131A	17,411.59	5,223.48	22,635.07	24,000	0.94	1.77
131B	18,236.73	5,471.02	23,707.75	24,000	0.99	1.69
131C	18,137.61	5,441.28	23,578.89	24,000	0.98	1.70
139A	19,150.82	5,745.24	24,896.06	24,000	1.04	1.61
139B	20,795.17	6,238.55	27,033.72	24,000	1.13	1.48
139C	19,840.92	5,952.28	25,793.20	24,000	1.07	1.55
148A	17,451.24	5,235.37	22,686.61	24,000	0.95	1.76
148B	17,808.91	5,342.67	23,151.59	24,000	0.96	1.73
148C	18,529.83	5,558.95	24,088.78	24,000	1.00	1.66
168A	21,443.29	6,432.99	27,876.27	24,000	1.16	1.43
168B	21,153.45	6,346.03	27,499.48	24,000	1.15	1.45
168C	21,157.52	6,347.26	27,504.77	24,000	1.15	1.45
170A	22,047.39	6,614.22	28,661.61	24,000	1.19	1.40
170B	23,771.35	7,131.40	30,902.75	24,000	1.29	1.29
170C	24,964.64	7,489.39	32,454.03	24,000	1.35	1.23
180A	20,974.77	6,292.43	27,267.21	24,000	1.14	1.47
180B	20,974.77	6,292.43	27,267.21	24,000	1.14	1.47
180C	20,974.77	6,292.43	27,267.21	24,000	1.14	1.47
192A	22,055.27	6,616.58	28,671.85	24,000	1.19	1.40
192B	21,377.53	6,413.26	27,790.79	24,000	1.16	1.44
192C	21,772.90	6,531.87	28,304.77	24,000	1.18	1.41
201A	20,570.83	6,171.25	26,742.08	24,000	1.11	1.50
201B	20,789.88	6,236.96	27,026.84	24,000	1.13	1.48
201C	20,448.82	6,134.64	26,583.46	24,000	1.11	1.50
210A	21,258.21	6,377.46	27,635.68	24,000	1.15	1.45
210B	21,233.04	6,369.91	27,602.95	24,000	1.15	1.45
210C	21,087.96	6,326.39	27,414.34	24,000	1.14	1.46
220A	22,820.09	6,846.03	29,666.11	24,000	1.24	1.35
220B	22,840.12	6,852.04	29,692.16	24,000	1.24	1.35
220C	23,462.10	7,038.63	30,500.73	24,000	1.27	1.31
228A	22,619.66	6,785.90	29,405.55	24,000	1.23	1.36
228B	21,918.34	6,575.50	28,493.84	24,000	1.19	1.40

CAN	MAX JOINT STRESS[1,3] (psi)	DYNAMIC HOOP STRESS INCREASE[1,3] (psi)	TOTAL WATER HAMMER STRESS[1,3] (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO[1,2,3]	FACTOR OF SAFETY AGAINST YIELD
228C	23,232.01	6,969.60	30,201.62	24,000	1.26	1.32
240A	21,194.69	6,358.41	27,553.10	24,000	1.15	1.38
240B	24,646.46	7,393.94	32,040.39	24,000	1.34	1.19
240C	23,211.34	6,963.40	30,174.74	24,000	1.26	1.26
250A	21,748.70	6,524.61	28,273.31	24,000	1.18	1.34
250B	21,629.06	6,488.72	28,117.78	24,000	1.17	1.35
250C	22,744.15	6,823.24	29,567.39	24,000	1.23	1.29
264A	19,966.75	5,990.03	25,956.78	24,000	1.08	1.46
264B	20,306.65	6,091.99	26,398.64	24,000	1.10	1.44
264C	20,282.80	6,084.84	26,367.63	24,000	1.10	1.44
271A	23,557.63	7,067.29	30,624.92	24,000	1.28	1.24
271B	23,052.86	6,915.86	29,968.72	24,000	1.25	1.27
271C	24,076.76	7,223.03	31,299.79	24,000	1.30	1.21
280A	23,067.52	6,920.26	29,987.77	24,000	1.25	1.27
280B	23,426.80	7,028.04	30,454.84	24,000	1.27	1.25
280C	24,363.84	7,309.15	31,672.99	24,000	1.32	1.20
292A	22,954.36	6,886.31	29,840.66	24,000	1.24	1.27
292B	22,488.55	6,746.57	29,235.12	24,000	1.22	1.30
292C	22,971.14	6,891.34	29,862.48	24,000	1.24	1.27
302A	25,097.08	7,529.12	32,626.20	24,000	1.36	1.16
302B	25,548.82	7,664.65	33,213.47	24,000	1.38	1.14
302C	25,373.63	7,612.09	32,985.71	24,000	1.37	1.15
313A	22,626.34	6,787.90	29,414.24	24,000	1.23	1.29
313B	22,176.24	6,652.87	28,829.11	24,000	1.20	1.32
313C	22,945.21	6,883.56	29,828.78	24,000	1.24	1.27
322A	22,120.96	6,636.29	28,757.25	24,000	1.20	1.32
322B	22,469.71	6,740.91	29,210.63	24,000	1.22	1.30
322C	22,699.27	6,809.78	29,509.05	24,000	1.23	1.29
331A	25,562.60	7,668.78	33,231.38	24,000	1.38	1.14
331B	22,792.35	6,837.70	29,630.05	24,000	1.23	1.28
331C	22,546.43	6,763.93	29,310.36	24,000	1.22	1.30
342A	20,680.03	6,204.01	26,884.04	24,000	1.12	1.34
342B	20,383.15	6,114.94	26,498.09	24,000	1.10	1.36
342C	21,004.55	6,301.37	27,305.92	24,000	1.14	1.32
354A	20,681.70	6,204.51	26,886.21	24,000	1.12	1.34
354B	20,854.02	6,256.20	27,110.22	24,000	1.13	1.33

Can	Max Joint Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress[1,3] (psi)	Allowable Stress (psi)	Stress Ratio[1,2,3]	Factor of Safety Against Yield
354C	20,471.63	6,141.49	26,613.12	24,000	1.11	1.35
364A	19,865.93	5,959.78	25,825.71	24,000	1.08	1.39
364B	20,781.89	6,234.57	27,016.46	24,000	1.13	1.33
364C	20,647.53	6,194.26	26,841.79	24,000	1.12	1.34
372A	19,786.80	5,936.04	25,722.83	24,000	1.07	1.40
372B	19,947.96	5,984.39	25,932.35	24,000	1.08	1.39
372C	19,791.94	5,937.58	25,729.52	24,000	1.07	1.40
381A	19,540.14	5,862.04	25,402.18	24,000	1.06	1.42
381B	19,399.68	5,819.90	25,219.58	24,000	1.05	1.43
381C	20,426.68	6,128.00	26,554.68	24,000	1.11	1.36
391A	20,635.59	6,190.68	26,826.27	24,000	1.12	1.34
391B	20,507.51	6,152.25	26,659.77	24,000	1.11	1.35
391C	20,594.20	6,178.26	26,772.46	24,000	1.12	1.34
399A	20,148.35	6,044.50	26,192.85	24,000	1.09	1.37
399B	20,169.15	6,050.74	26,219.89	24,000	1.09	1.37
399C	20,138.67	6,041.60	26,180.27	24,000	1.09	1.38

[1] Joint efficiency of 0.7 included
[2] Total stress / Allowable stress
[3] Uses 97.5% confidence thickness
[4] SF = Fy/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 psf and the depth of soil cover on the penstock was assumed to be 3 feet. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off road vehicle loads or equipment. The snow and live load combination uses a reduced snow and live load of 75 percent of each.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%).

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis.
- Similar to Penstocks No. 2 and 3, the penstock appears to be located in cohesive fine grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 17-foot-diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was *3.72* psi which is less than the allowable buckling pressure of *3.96* psi. The 15.25-foot-diameter sections were analyzed and the max pressures are summarized in Table 4-2.

4.3.1 SURCHARGE LOAD ANALYSIS

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest average measured steel thickness values were used. See Table 4-2.

TABLE 4-2 SUMMARY OF SURCHARGE LOAD ANALYSIS

PENSTOCK DIAMETER (ft)	ALLOWABLE EXTERNAL PRESSURE (psi)	SNOW LOAD (psi)	SNOW + 100 PSF LIVE LOAD (psi)
17.00	3.96	3.24	3.72
15.25	5.01	4.30	4.78

There were no new vehicular surcharge analysis conducted as we are not expecting changes in the results from the analysis conducted by Kleinschmidt in 2016 for Penstock No. 2. The 2016 analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 14 feet from the front axle to middle axle then variable from 14 feet to 28 feet to the rear axle, was approximately 5 times less than the allowable buckling loads at that location. For the section of penstock analyzed, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.2 Subatmospheric Internal Penstock Pressure Analysis

Subatmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and no detailed hydrodynamic model was created, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 square metres (3.07 square feet), which is well below the area provided by the approximately 5.1-square-metre (55-square-foot) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil so it is unlikely there are excessive local buckling stresses in the penstock.

4.5 Local Weld Conditions

As noted in Section 1.0, NLH discovered a 0.6-metre-long (2-foot-long) crack in Penstock No. 1 in May 2016. Kleinschmidt responded and assisted with the design of the crack repair, *Crack Investigation and Repair Report – Penstock No. 1 Bay d'Espoir Hydroelectric Development* (June 2016). Kleinschmidt's investigation theorized that the crack, which occurred near a weld, was caused by an improper weld procedure during construction that resulted in incomplete fusion. After repairing the crack NLH rewatered the penstock, a second crack then opened in the Penstock No. 1 in September 2016. This crack led to a detailed weld investigation that has found many other microscopic cracks in the welds. In addition, Penstock No. 2 was inspected in 2017 and Penstock No. 3 in 2018. Acuren performed MT tests on the full length of 40 longitudinal welds and a few feet of 30 circumferential welds for this inspection. In addition to the crack found along the longitudinal weld on the right side of Can 106 (Photos 6 to 8) which lead to the dewatering of the penstock, an indication was found along the longitudinal weld on the left side of Can 111 (Photos 10 and 11) . No other cracks or indications were discovered from the MT testing.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life provided that the penstock welds are replaced and the interior is coated before the steel deteriorates further and is adequately maintained and monitored. Replacing the welds from the inside of the penstock only may not fully mitigate the issues, and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 3 years.

5.1 SHELL CONDITION AND THICKNESS

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the penstock should have about 50 years of service life remaining if an internal coating is applied. The base plate material away from the joints can tolerate up to 2 mm further material loss and maintain a stress ratio below 1.0 .

5.2 INTERNAL PRESSURE STRENGTH

More thickness measurements were taken during this inspection than during the 2016 inspection and the measurements had a wider range of values that resulted in CI thickness values that were in some cases lower than previously used in the stress analysis. Stress ratios for a combined static and dynamic internal pressures peak at 1.38 for the joints (Table 4-1). This indicates that the penstock does not meet present day design criteria for a new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.14 at the joints, which is not acceptable for late 1960 steel pipe. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. There is a lack of confidence of the weld integrity for this penstock, and although the plating is acceptable and many welds have been repaired, it is recommended that the penstock undergo further extensive repairs or be replaced. As noted above, RT testing of the welds can be performed to verify weld integrity and allow a higher joint efficiency to be used. The MT testing of welds to date does not satisfy the requirements of ASCE No. 79 to increase the joint efficiency. It is recommended that a more accurate surge analysis be conducted using wicket gate closure times to confirm penstock stresses. With the history of weld failures including the recent failure and another indication found it is recommended that this penstock undergo extensive repairs or be replaced in the next 5 years.

6.0 RECOMMENDATIONS

Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 3 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- Radiographic testing of the welds;
- Surge Analysis to verify peak pressure and resulting stresses
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior.

6.1 COATING

Kleinschmidt recommends coating the interior of the penstock in the next 5 years provided the penstock welds are replaced. At this stage, Kleinschmidt is unable to estimate the rate of corrosions for the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20 to 40 years or more. If the penstock is recoated prior to significant steel deterioration every 20 to 40 years, NLH can anticipate extending the life of the penstock nominally another 50 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated and buried, so it is difficult to tell its condition without excavation. It would be costly and time consuming to uncover enough of the penstock to get a representative sample size of the exterior penstock condition, and some areas, like the invert, cannot be inspected safely. An exterior inspection involving excavation of significant portions of the penstock will not provide enough data to be worth the investment.

6.2 Exterior Inspection

Kleinschmidt recommends the drainage system be cleaned and checked for plugs and also be monitored at times with consistent weather conditions.

6.3 Interior Inspections

6.3.1 General Evaluation

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. These inspections should give a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless if the coating has been replaced or not, the detailed inspections can be extended to a 5- to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval.

A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This should be completed in 2020 to better understand the risks.

7.0 REFERENCES

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Kleinschmidt Associates. 2016. Crack Investigation and Repair Report, Penstock No. 1 Bay d'Espoir Hydroelectric Development. Kleinschmidt Technical Report to Newfoundland and Labrador Hydro.

REPORT SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
April 7, 2020
DATE
NEWFOUNDLAND & LABRADOR

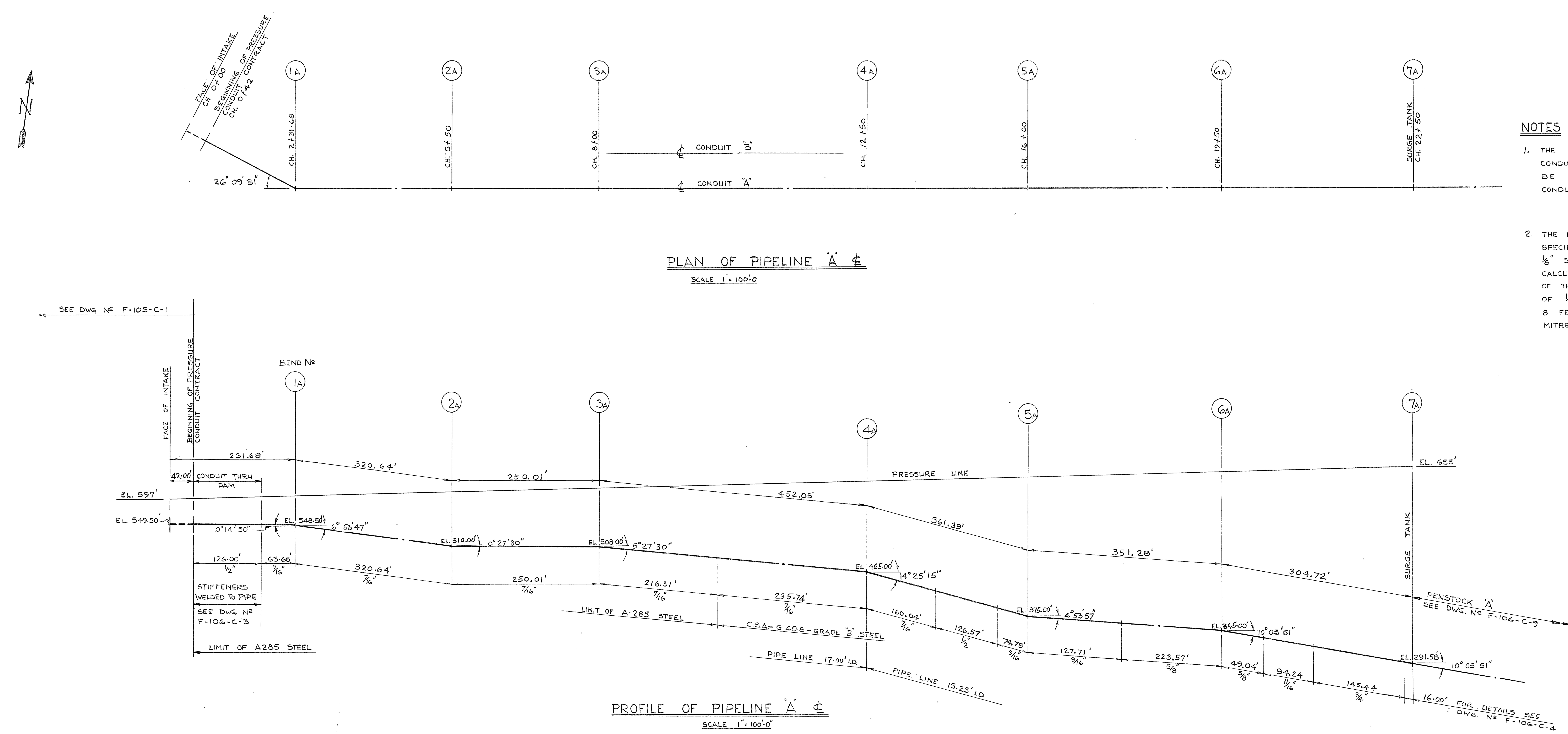
CMV:FSH:SCB

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATES CANADA INC.
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEGNL No708
which is valid for the year 2020

J:\2670\021\Docs\Penstock 1\2670021_003RP_Bay d'Espoir Penstock 1 Inspection Report FINAL.docx

APPENDIX A

PENSTOCK LAYOUT DRAWINGS



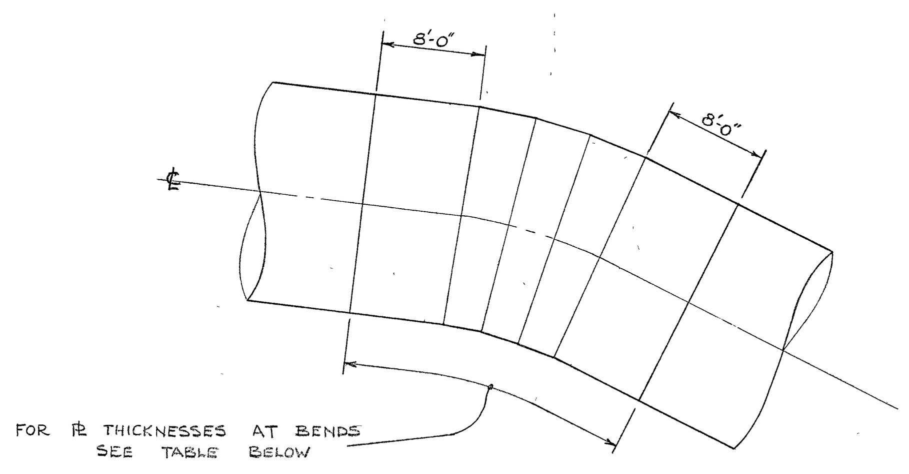
PLAN OF PIPELINE 'A' ℄
SCALE 1" = 100'-0

PROFILE OF PIPELINE 'A' ℄
SCALE 1" = 100'-0"

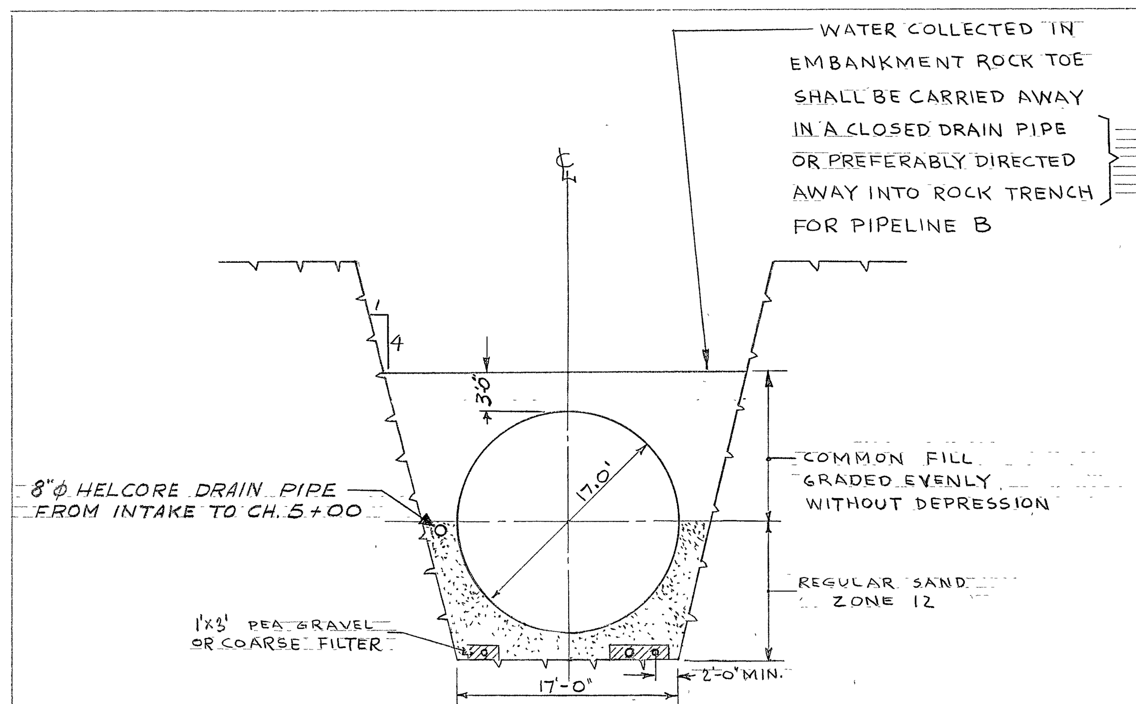
NOTES

1. THE PRESSURE CONDUITS SHALL BE CALLED 'A' AND 'B'. CONDUIT 'A' IS SOUTH OF CONDUIT 'B' AND SHALL BE COMPLETED IN 1966. CONDUIT 'A' CONSISTS OF PIPELINE 'A' AND PENSTOCK 'A'.

2. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION № M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.



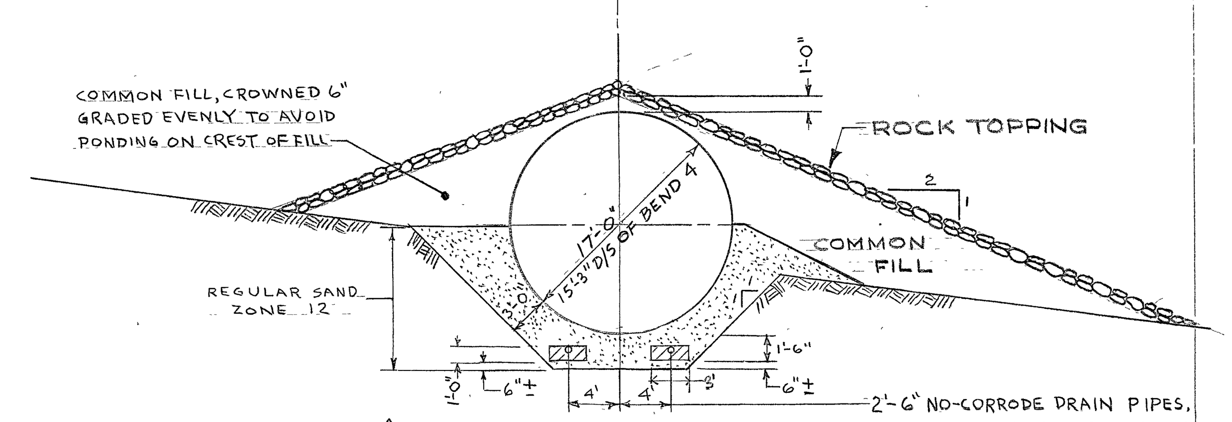
TYPICAL BEND
SCALE 1" = 10'-0"
SEE SPEC. M-3116



2—6" NO-CORRODE DRAIN PIPES NEAR TOP OF LAYER WITH DRAIN HOLES FACING DOWN

1—8" HELCOR PIPE FROM INTAKE BOX DRAIN

4 TYPICAL SECTION UPSTREAM OF BEND 7A IN ROCK CUT
SCALE 1" = 1'-0"



2—6" NO-CORRODE DRAIN PIPES, INSIDE COARSE FILTER OR PEA GRAVEL HOLES FACING DOWN

DRAIN PIPES PLUGGED AT UPPER ENDS NEAR THE CROSS DRAINS.

4 TYPICAL SECTION UPSTREAM OF BEND 7A IN EARTH TRENCH
SCALE 1" = 1'-0"

PERVIOUS LAYER ZONE 12 MATERIAL AND FILTER MUST BE SEALED WITH IMPERVIOUS FILL IMMEDIATELY DOWNSTREAM OF EACH CROSS DRAIN TO PREVENT SEEPAGE WATER FROM BY-PASSING THE CROSS DRAINS.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. F. ICN E.
LICENCE TO PRACTICE

ANGLES & ℞ THICKNESSES AT BENDS

BEND	<A	<B	<C	TRUE ANGLE	℞ THICKNESS
1 A	26° 09' 31"	0° 14' 50"	6° 53' 47"	26° 55' 34"	7/16"
2 A	——	6° 53' 47"	0° 27' 30"	6° 26' 17"	1/2"
3 A	——	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4 A	——	5° 27' 30"	14° 25' 15"	8° 57' 45"	9/16"
5 A	——	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6 A	——	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16"
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	

ANGLE IN PLAN   VERTICAL ANGLES

REFERENCE DRAWINGS

F-106-C-3 CONDUITS THROUGH DAM
F-106-C-4 SURGE TANK - DETAILS OF TEES
F-106-C-5 " " - GENERAL LAYOUT & DETAILS
F-106-C-6 PRESSURE CONDUITS - CLEARING
F-106-C-8 " " - EXCAVATION & DRAINAGE
F-106-C-9 " " - PENSTOCK A
F-106-C-10 " " - PENSTOCK B

OTHER REFERENCES

1. SPECIFICATION No. M-3116

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
5	2-6-68		AS BUILT, FROM FIELD INFORMATION	A.B.	JHM
4	5 JAN '67		2 TYP. SECTIONS CHANGED, ONE REMOVED	A.R.	WEB
3	9 DEC '66	A/B - 1,2,3,4	3 TYPICAL SECTIONS ADDED	A.R.	JHM
2	20 SEPT 65		REVISED PROFILE & PLATE THICKNESSES	A.R.	[illegible]
1	AUG. 5/65		EL. @ BEND 4 CORRECTED, MINOR REVISIONS	J.P.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 16 1965
APPROVED BY: W. E. Bonnell
MANAGER ENGINEERING

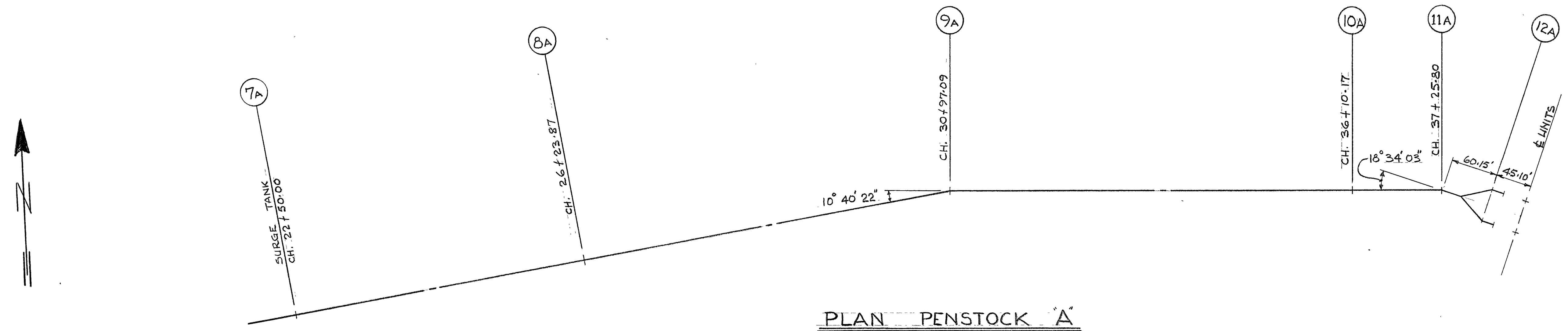
PASSED: TRANS'N | ELECT'L | CIVIL JHM

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED
RECOMMENDED J.H. Manica P.Eng

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

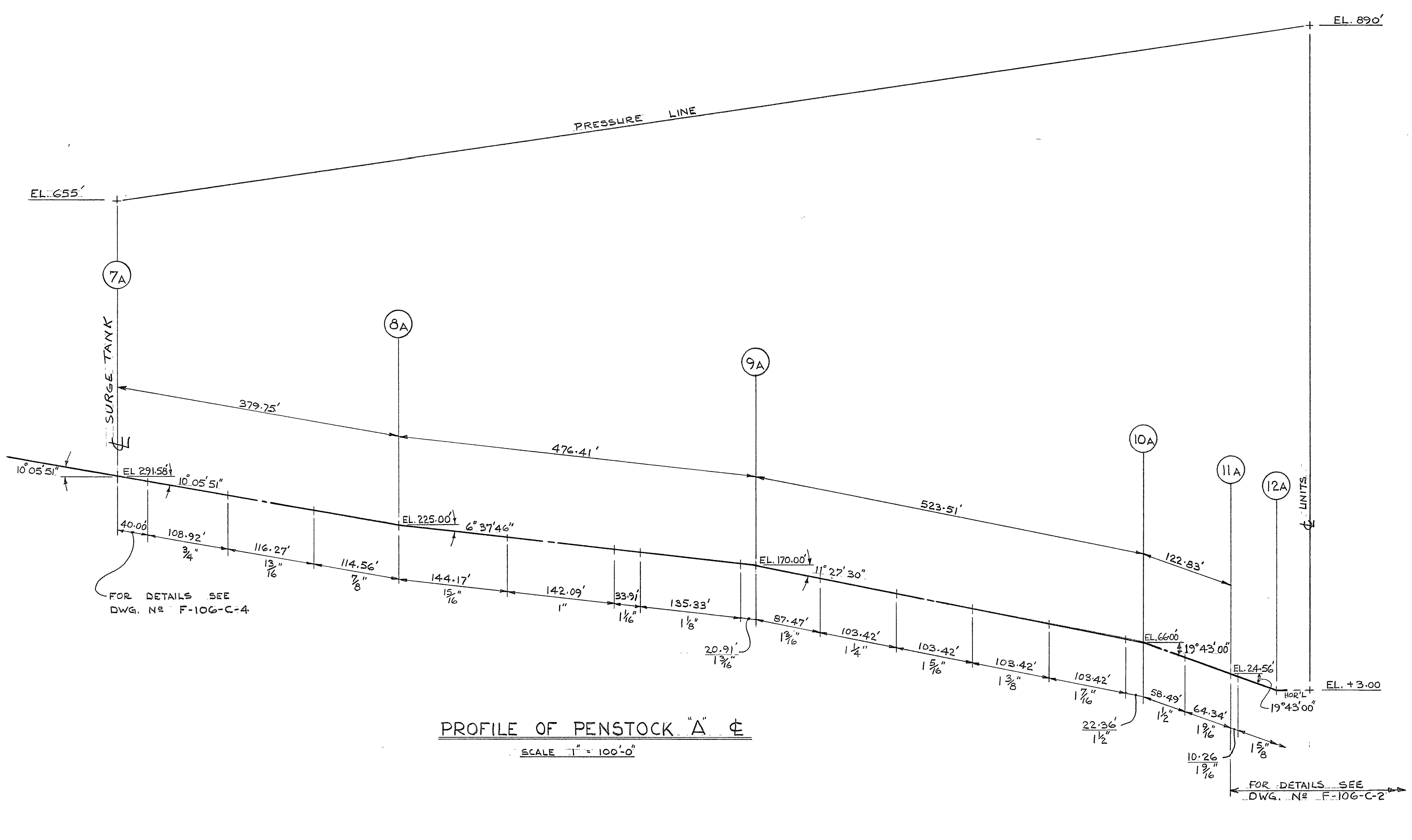
PRESSURE CONDUITS
PLAN & PROFILE PIPELINE 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG NO.	REVISION
	NOTED	PD - 11	JULY 16, 1965	F-106-C-7	5



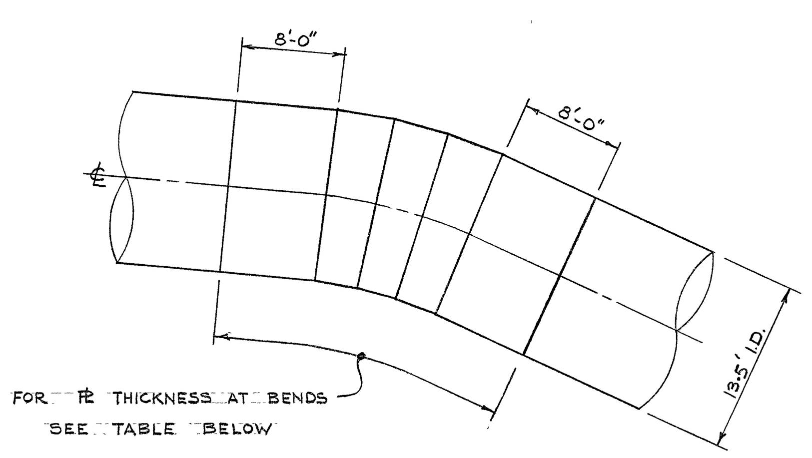
PLAN PENSTOCK 'A'

SCALE 1" = 100'-0"



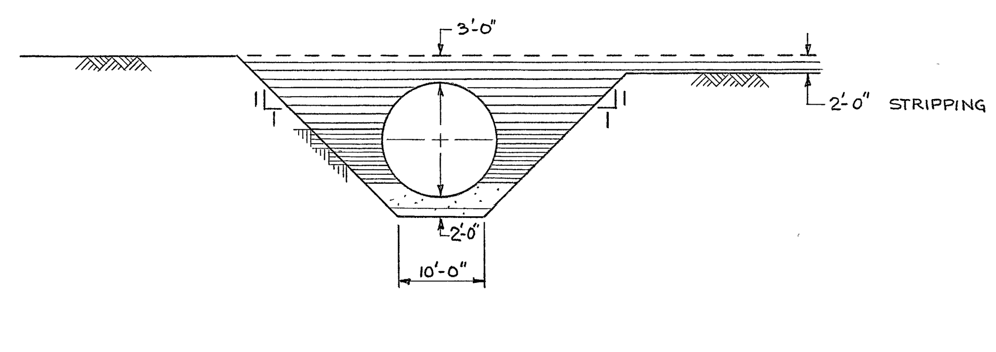
PROFILE OF PENSTOCK 'A' ℄

SCALE 1" = 100'-0"



TYPICAL BEND

SCALE 1" = 10'-0"

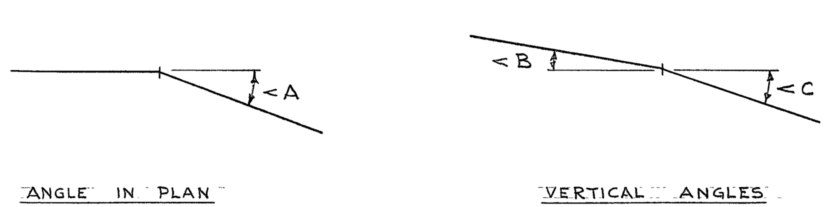


TYPICAL CROSS SECTION (9A) TO (11A)

SCALE 1" = 15'-0"

BEND	< A	< B	< C	TRUE ANGLE	ℙ THICKNESS
7 A	—	10° 05' 51"	10° 05' 51"	0° 00' 00"	—
8 A	—	10° 05' 51"	6° 37' 46"	3° 28' 05"	1 1/8"
9 A	10° 40' 22"	6° 37' 46"	11° 27' 30"	11° 35' 25"	1 3/8"
10 A	—	11° 27' 30"	19° 43' 00"	8° 15' 30"	1 3/4"
11 A	18° 34' 03"	19° 43' 00"	19° 43' 00"	17° 28' 12"	1 7/8"

ANGLES & ℙ THICKNESS AT BENDS



NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6".
3. STEEL SHALL BE C.S.A. G40-8 GRADE 'B'.
4. FOR TYPICAL CROSS SECTION FROM (7A) TO (9A) SEE DWG. Nº F-106-C-7.

REFERENCE DRAWINGS

1. F-106-C-2 PRESSURE CONDUITS-LAYOUT & DETAILS OF BIFURCATION.
2. F-106-C-4 SURGE TANKS - DETAILS OF TEES.
3. F-106-C-5 SURGE TANKS - GENERAL LAYOUT & DETAILS.
4. F-106-C-6 PRESSURE CONDUITS - CLEARING.
5. F-106-C-7 PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE 'A'.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	SEPT 2/66		PLAN & PROFILE REVISED	J.P.	

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 22 1965
APPROVED BY:
MANAGER ENGINEERING

TRANS'N | ELECT'L | CIVIL — PASSED

DESIGNED: R. Mac D.
DRAWN: J.P.
CHECKED: A.P. H.
RECOMMENDED: P. Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 21, 1965	F-106-C-9	3

OCT 25 1966

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

FILE 2-13


ELEVATION of PENSTOCK 'A'
PLAN VIEW
FIELD NOTE:
GENERAL NOTES:-
ANGLES & P. THICKNESS AT BENDS
ANGLE IN PLAN
VERTICAL ANGLES
JOINT DETAIL 'A'
JOINT DETAIL 'B'
JOINT DETAIL 'C'
JOINT DETAIL 'D'
JOINT DETAIL 'E'
JOINT DETAIL 'F'
LOCATION & DETAIL of STIFFENER
WELD DETAIL
TRUE VIEW of ELBOW 11A
HORTON STEEL WORKS, LIMITED
10830
APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MANAGER ENGINEERING
MAY 6 1966
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
FILE 2-13


12X
APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
24"ø MANHOLE DETAILS
TYPICAL ASSEMBLY
MATERIAL SPECS.
NOZZLE
DETAIL "A"
DETAIL "B"
USAGE OF PENSTOCK CUTOUT
PLAN OF M.H. COVER
ELEV. OF COVER
PUSH-OFF BOLT
HINGE PIN
HORTON STEEL WORKS, LIMITED
68H038H03
RECEIVED
SHAWMONT NEWFOUNDLAND
FILE COPY
FILE NO. 68H038H03 BAY D'ESPOIR
NEWFOUNDLAND AND LABRADOR POWER COMMISSION

APPENDIX B

PHOTOGRAPHS

PHOTO 1 LEAK IN BOTTOM LEFT CORNER OF GATE

PHOTO 2 CONCRETE DETERIORATION AT CONCRETE TO STEEL TRANSITION

PHOTO 3 OLD ORGANIC GROWTH ON INSIDE OF PENSTOCK

PHOTO 4 PREVIOUSLY REPAIRED WELD WITH CONTRAST PAINT

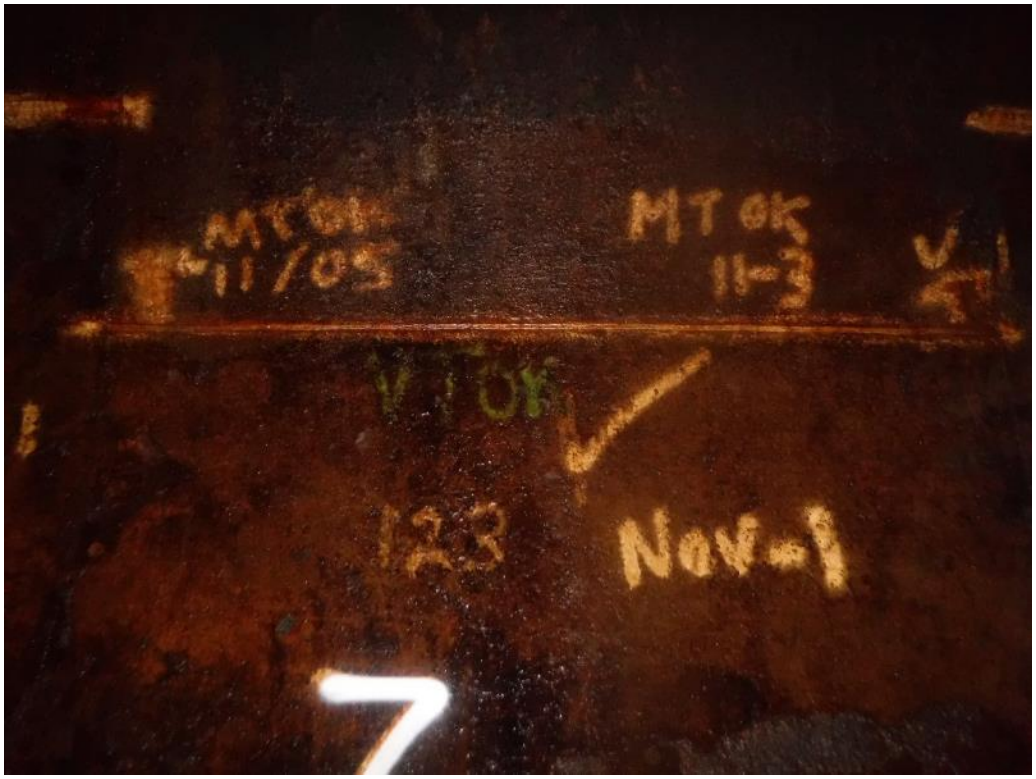


PHOTO 5 PREVIOUSLY REPAIRED AND TESTED WELD – CAN 7

PHOTO 6 CRACKED WELD RIGHT SIDE OF CAN 106 NEAR SPRING LINE

PHOTO 7 CRACKED WELD RIGHT SIDE OF CAN 106 NEAR SPRING LINE

PHOTO 8 CRACKED WELD FROM OUTSIDE RIGHT SIDE OF CAN 106

PHOTO 9 WELD TESTING OF EVERY CAN NEAR CAN 106'S CRACKED WELD

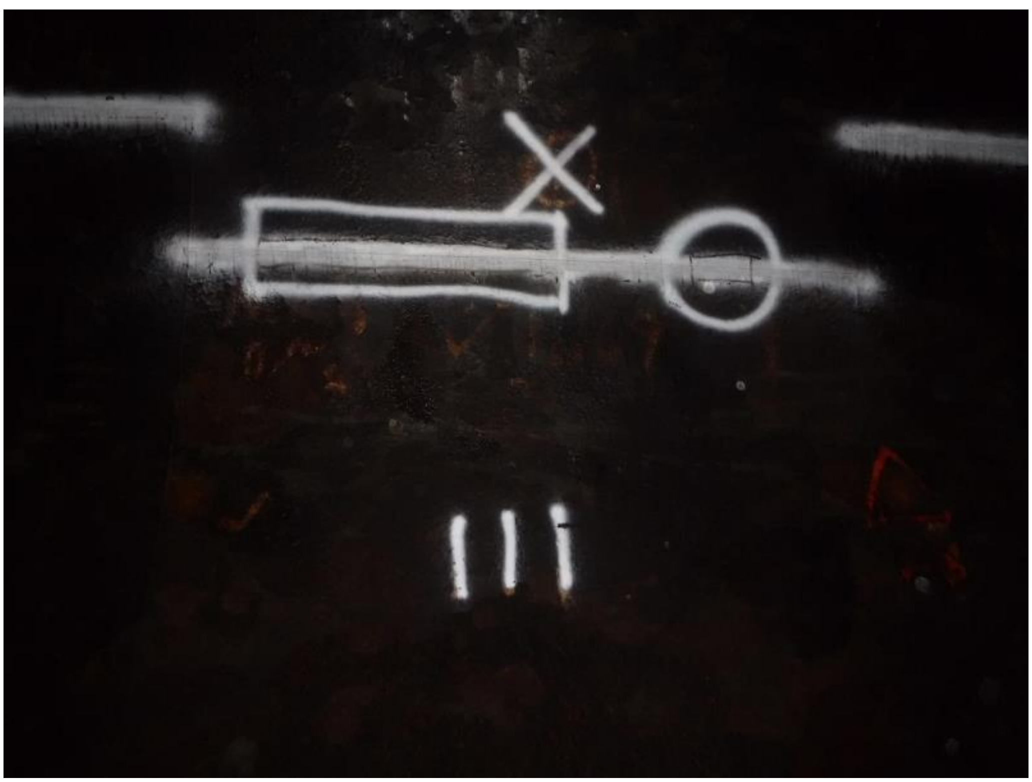


PHOTO 10 MT TEST SHOWED INDICATION OF ISSUE LEFT SIDE CAN 111 NEAR SPRING LINE

PHOTO 11 INDICATION OF ISSUE CAN 111 WELD NEAR SPRING LINE

PHOTO 12 DOUBLER PLATE REPAIR

PHOTO 13 ORIGINAL CIRCUMFERENTIAL WELD CAN 194

PHOTO 14 ORIGINAL HORIZONTAL WELD CAN 201

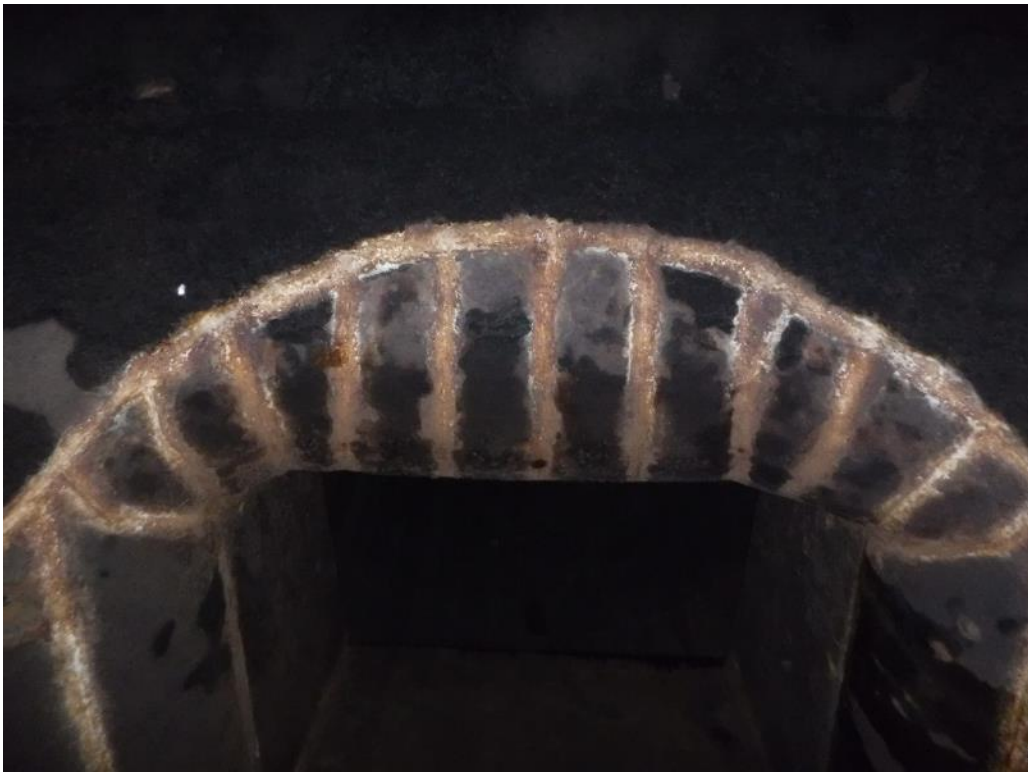


PHOTO 15 TRANSITION OF PENSTOCK TO SURGE TANK

PHOTO 16 WELD TEST INCLUDED PART OF DOUBLER PLATE WELD

PHOTO 17 TEST OF PREVIOUSLY REPAIRED WELD CAN 123

PHOTO 18 SURFACE CORROSION CAN 320 – LESS PITTING THAN HIGHER IN PENSTOCK

PHOTO 19 SURFACE SCRAPED DOWN TO SHOW LIGHT PITTING

PHOTO 20 SURFACE CORROSION AND FLAKING CAN 200

PHOTO 21 MANHOLE 3 NOT OPENED.

PHOTO 22 PRESSURE MONITORING AT TOP OF 19 DEGREE SLOPE

PHOTO 23 LOOKING UPSTREAM ALONG PENSTOCK 1 FROM NEAR TOE OF DAM

PHOTO 24 LOOKING DOWNSTREAM ALONG PENSTOCK 1 FROM NEAR TOE OF DAM

PHOTO 25 MANHOLE 1 COVER WITH REINFORCING PLATES

PHOTO 26 LOOKING DOWNSTREAM TOWARD SURGE TANKS ALONG PREVIOUSLY REPAIRED AREA

PHOTO 27 PIEZOMETER LOCATION JUST UPSTREAM OF CRACK LOCATION

PHOTO 28 LOOKING DOWNSTREAM AT CRACK LOCATION COVERED IN TARPS

PHOTO 29 LOOKING DS ALONG PENSTOCK JUST DS OF SURGE TANK

PHOTO 30 LOOKING UPSTREAM TOWARD SURGE TANKS FROM TRANSMISSION LINE

PHOTO 31 LOOKING DS ALONG PENSTOCK JUST DS OF TRANSMISSION LINE

PHOTO 32 PRESSURE MONITOR

PHOTO 33 MANHOLE 3 AT TOP OF STEEP SLOPE

APPENDIX C

WELD TEST

ACUREN

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1 Austin Street
St. John's, NL, Canada A1B 4C1
www.acuren.com

Phone: 709.753.2100
Fax: 709.753.7011

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ISO 9001 : 2015 CWB REGISTERED Acuren: An ISO 9001 certified company

NONDESTRUCTIVE EXAMINATION

TO: **Nalcor Energy**

DATE: **Oct 3rd, 2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **MT-GW031019-001 R0**
PO: **N/A** WO: **N/A**

ATTENTION: **Dylan Drake** WORK LOCATION: **Bay D'Espoir, NL**
Project: **Penstock # 1 Emergency Repair**
Item(s) Examined: **Can #106 insert plate (Interior & Exterior) & reinforcement plate (Exterior)**

PART #: **See Below** MATERIAL: **Carbon Steel** THICKNESS: **Varies**
SCOPE: **Magnetic Particle Inspection to be completed as per client's request.**
TYPE OF INSPECTION: **Magnetic Particle**

TEST DETAILS:

ACCEPTANCE STANDARD: **ASME B31.3NFS, ASME Sec. IX** REVISION: **2018/ 2017**
PROCEDURE/TECHNIQUE: **CAN-MT-14P001** REVISION: **15**

TYPE: **Wet Visible**	METHOD: **Yoke**
PARTICLE BRAND: **Magnaflux** PRODUCT NO.: **7HF**	CURRENT: **AC** MT INSTRUMENT: **Magnaflux Y-1**
PARTICLE COLOUR: **Black**	MT INSTRUMENT S/N: **2102** CAL DUE: **Jan 29/2020**
SUSPENSION: **Oil**	LIGHTING EQUIP: **YOKE LEG LIGHT** LIFT WEIGHT S/N: **10917**
CONTRAST PAINT: **Magnaflux** PRODUCT NO.: **WCP-2**	BLACKLIGHT MAKE: **N/A** S/N: **N/A**
MAG TIME (SECONDS): **10** DEMAG REQUIRED?: **No**	LIGHT METER S/N: **150803637** CAL DUE: **Feb 22nd /20**
TECHNIQUE DEMONSTRATED OVER A PAINTED SURFACE?: **N/A**	LIGHT INTENSITY: **> 100 FC (1076 LX)**
TEST SURFACE CONDITION: **As Welded**	TEST SURFACE TEMPERATURE: **Varies**

See Page 2 for results

CLIENT: ______ CLIENT PRINTED NAME ______ CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: [signature] **Glenn Whitten**
1st Technician
CGSB II - 16212

REVIEWER: [signature] 10/04/2019

(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # MT-GW031019-001 R0

To: Nalcor Energy
Attention: Dylan Drake

Items :	Weld	Weld Type	Notes:	Date & Time	Accept/Reject
Penstock # 1	FW#1	Prep	Bevel Prep	28/09/19 - 17:45	Accept
Can #106 Insert Plate		CJP	After 12hrs	01/10/19 - 0800	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
	FW#2	Prep	Bevel Prep	28/09/19 - 17:45	Accept
		CJP	After 12hrs	01/10/19 - 0800	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
	FW#3	Prep	Bevel Prep	28/09/19 - 17:45	Accept
	FW#3 R1	CJP	After 12hrs	01/10/19 - 0800	Accept
		CJP	After 40hrs	02/10/19 - 1500	Accept
	FW#4	Prep	Bevel Prep	28/09/19 - 17:45	Accept
		CJP	After 12hrs	01/10/19 - 0800	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
Can # 106 Re-pad	FW#5	CJP	Splice	01/10/19 - 1700	Accept
	FW#6	Fillet	Re-pad to Shell	03/10/19 - 1200	Accept
Can # 106 Attachments	N/A	Removals	Temporary Attachments	03/10/19 - 1200	Accept

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1 Austin Street
St. John's, NL, Canada A1B 4C1
www.acuren.com

Phone: 709.753.2100
Fax: 709.753.7011

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NONDESTRUCTIVE EXAMINATION

TO: **Nalcor Energy**

PAGE: **1 of 1**

DATE: **Oct 3rd 2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **MT-GW031019-002 R0**
PO: **N/A** WO: **N/A**

ATTENTION: **Dylan Drake**
WORK LOCATION: **Bay D'Espoir, NL**
Project: **Bay D'Espoir Penstock # 1**
Item(s) Examined: **Can #111 North**

PART #: **See Below** MATERIAL: **Carbon Steel** THICKNESS: **Varies**
SCOPE: **Magnetic Particle Inspection to be completed as per client's request.**
TYPE OF INSPECTION: **Magnetic Particle**

TEST DETAILS:

ACCEPTANCE STANDARD: **ASME B31.3NFS** REVISION: **2018**
PROCEDURE/TECHNIQUE: **CAN-MT-14P001** REVISION: **15**

TYPE: **Wet Visible**	METHOD: **Yoke**
PARTICLE BRAND: **Magnaflux** PRODUCT NO.: **7HF**	CURRENT: **AC** MT INSTRUMENT: **Magnaflux Y-1**
PARTICLE COLOUR: **Black**	MT INSTRUMENT S/N: **2102** CAL DUE: **Jan 29/2020**
SUSPENSION: **Oil**	LIGHTING EQUIP: **YOKE LEG LIGHT** LIFT WEIGHT S/N: **10917**
CONTRAST PAINT: **Magnaflux** PRODUCT NO.: **WCP-2**	BLACKLIGHT MAKE: **N/A** S/N: **N/A**
MAG TIME (SECONDS): **10** DEMAG REQUIRED?: **No**	LIGHT METER S/N: **150803637** CAL DUE: **Feb 22nd /20**
TECHNIQUE DEMONSTRATED OVER A PAINTED SURFACE?: **N/A**	LIGHT INTENSITY: **> 100 FC (1076 LX)**
TEST SURFACE CONDITION: **As Welded**	TEST SURFACE TEMPERATURE: **Varies**

Items :	Weld #	Weld Type	Notes:	Date & Time	Accept/Reject
Penstock # 1	FW#1	CJP	Weld Prep	01/10/19 - 0900	Accept
Can #111 North	FW#1	CJP	After 12 HRS	02/10/19 - 1200	Accept
-	FW#1	CJP	After 48 HRS	03/10/19 - 1200	Accept
	N/A	Removals	Temporary Attachments	03/10/19 - 1200	Accept

CLIENT: ______ CLIENT PRINTED NAME ______ CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: **Glenn Whitten**
1st Technician
CGSB II - 16212

REVIEWER: 10/04/2019

(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)

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Fax: 709.753.7011

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NONDESTRUCTIVE EXAMINATION

TO: **Nalcor Energy**

PAGE: **1 of 6**

DATE: **Sept 24th 2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **MT-GW240919-001 R0**
PO: **N/A** WO: **N/A**

ATTENTION: **Dylan Drake**
WORK LOCATION: **Bay D'Espoir , NL**
Project: **Bay D'Espoir Penstock # 1**
Item(s) Examined: **Penstock # 1**

PART #: **See Below** MATERIAL: **Carbon Steel** THICKNESS: **Varies**
SCOPE: **Magnetic Particle Inspection to be completed as per client's request.**
TYPE OF INSPECTION: **Magnetic Particle**

TEST DETAILS:

ACCEPTANCE STANDARD: **Client Info** REVISION: **N/A**
PROCEDURE/TECHNIQUE: **CAN-MT-14P001** REVISION: **15**

TYPE: **Wet Visible**	METHOD: **Yoke**
PARTICLE BRAND: **Magnaflux** PRODUCT NO.: **7HF**	CURRENT: **AC** MT INSTRUMENT: **Magnaflux Y-1**
PARTICLE COLOUR: **Black**	MT INSTRUMENT S/N: **2102** CAL DUE: **Jan 29/2020**
SUSPENSION: **Oil**	LIGHTING EQUIP: **YOKE LEG LIGHT** LIFT WEIGHT S/N: **10917**
CONTRAST PAINT: **Magnaflux** PRODUCT NO.: **WCP-2**	BLACKLIGHT MAKE: **N/A** S/N: **N/A**
MAG TIME (SECONDS): **10** DEMAG REQUIRED?: **No**	LIGHT METER S/N: **150803637** CAL DUE: **Feb 22nd /20**
TECHNIQUE DEMONSTRATED OVER A PAINTED SURFACE?: **N/A**	LIGHT INTENSITY: **> 100 FC (1076 LX)**
TEST SURFACE CONDITION: **As Welded , As Cleaned**	TEST SURFACE TEMPERATURE: **Varies**

See page 2 for results & page 3-6 for pictures.

CLIENT: ______ CLIENT PRINTED NAME ______ CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: **Glenn Whitten**
1st Technician
CGSB II - 16212

REVIEWER: 09/25/2019

(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # MT-GW240919-001 R0

To: **Nalcor Energy**
Attention: **Dylan Drake**

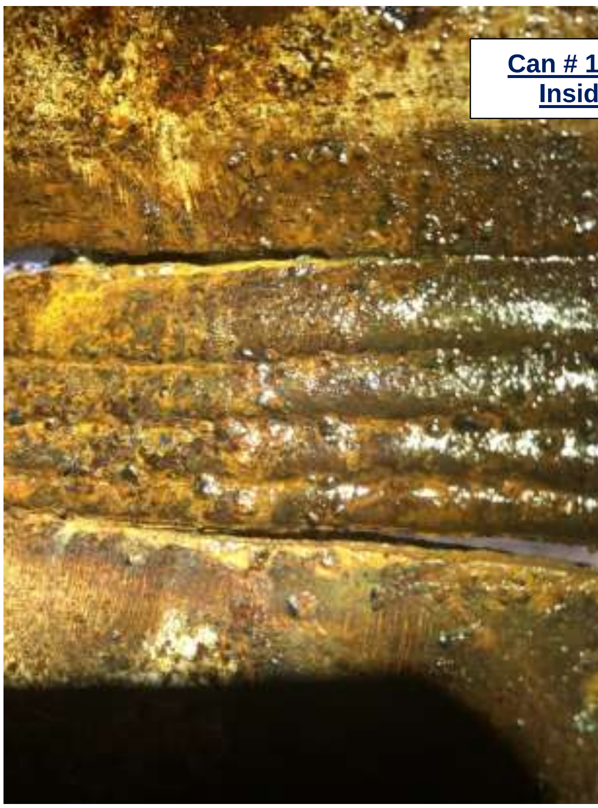
Item Description	Direction	Length	Notes :
Can # 101	North	9'	No indications found during time of inspection.
Can # 101	South	9'	No indications found during time of inspection.
Can # 102	North	9'	No indications found during time of inspection.
Can # 102	South	9'	No indications found during time of inspection.
Can # 103	North	9'	No indications found during time of inspection.
Can # 103	South	9'	No indications found during time of inspection.
Can # 104	North	9'	No indications found during time of inspection.
Can # 104	South	9'	No indications found during time of inspection.
Can # 105	North	9'	No indications found during time of inspection.
Can # 105	South	9'	No indications found during time of inspection.
Can # 106	North	9'	No indications found during time of inspection.
Can # 105-106 Circ.	South	2'	Excessive erosion. Pitting No linear indications found at time of inspection
Can # 106	South	9'	Linear indications found on top & bottom toe of weld. Length of indications are approx. 9' in length (inside). See pictures on page 3-4
Can # 106-107 Circ.	South	2'	Excessive erosion. Pitting No linear indications found at time of inspection
Can # 107	North	9'	No indications found during time of inspection.
Can # 107	South	9'	No indications found during time of inspection.
Can # 108	North	9'	No indications found during time of inspection.
Can # 108	South	9'	No indications found during time of inspection.
Can # 109	North	9'	No indications found during time of inspection.
Can # 109	South	9'	No indications found during time of inspection.
Can # 110	North	9'	No indications found during time of inspection.
Can # 110	South	9'	No indications found during time of inspection.
Can # 111	North	9'	Linear indications found on bottom toe of weld. Length of indications are approx. 6' in length. See pictures on page 6
Can # 111	South	9'	No indications found during time of inspection.
Can # 112	North	9'	No indications found during time of inspection.
Can # 112	South	9'	No indications found during time of inspection.
Can # 113	North	9'	No indications found during time of inspection.
Can # 113	South	9'	No indications found during time of inspection.
Can # 114	North	9'	No indications found during time of inspection.
Can # 114	South	9'	No indications found during time of inspection.
Can # 115	North	9'	No indications found during time of inspection.
Can # 115	South	9'	No indications found during time of inspection.
Can # 116	North	9'	No indications found during time of inspection.
Can # 116	South	9'	No indications found during time of inspection.

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # MT-GW240919-001 R0

To: **Nalcor Energy**
Attention: **Dylan Drake**

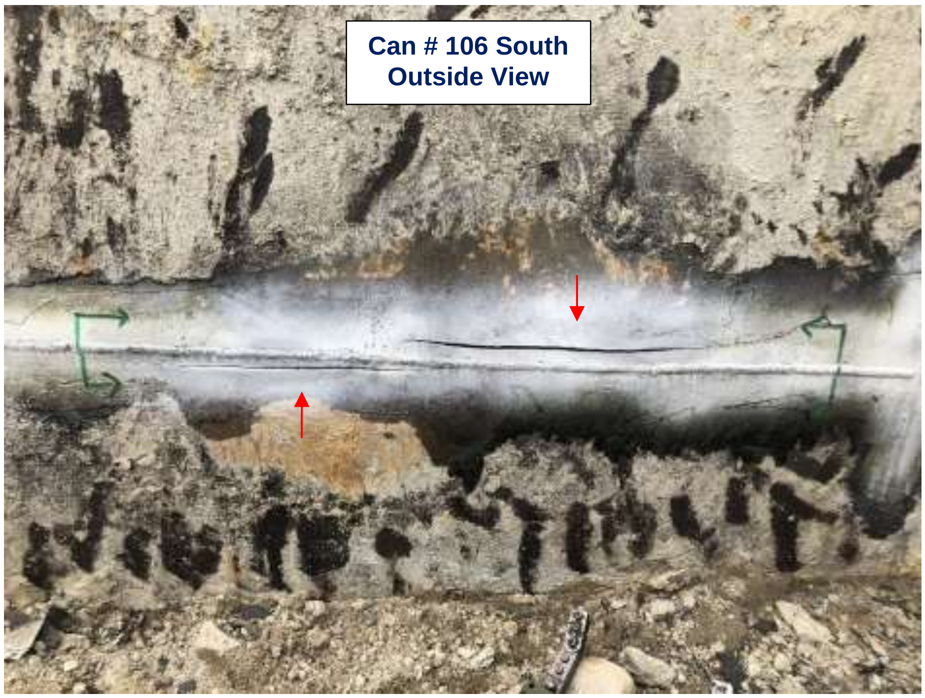
Can # 106 South
Inside view



ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # MT-GW240919-001 R0

To: **Nalcor Energy**
Attention: **Dylan Drake**



ACUREN

To: **Nalcor Energy**
Attention: **Dylan Drake**

ACUREN JOB # **183-19-10NAL001-0001**
REPORT # **MT-GW240919-001 R0**

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # MT-GW240919-001 R0

To: **Nalcor Energy**
Attention: **Dylan Drake**

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Fax: 709.753.7011

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RADIOGRAPHIC EXAMINATION

TO: **NALCOR ENERGY**

PAGE: **1 of 3**

DATE: **SEPT 30- OCT 3, 2019**
ACUREN JOB #: 183-19-10NAL001-0001
PO: N/A
PROJECT: PENSTOCK 1
WORK LOCATION: **BAY D'ESPOIR, NL**

REPORT #: **RT-MP300919-001 R0**
WO: N/A

ATTENTION: **Dylan Drake**

ACCEPTANCE STANDARD: **ASME B31.3 NFS** REVISION: **2018** MATERIAL: **CS**
PROCEDURE/TECHNIQUE: **CAN-RT-14P001** REVISION: **8** FILM BRAND: **AGFA**
RT SOURCE: **Ir 192** **90** CI FOCAL SPOT: **.138** in. SCREENS: **LEAD (PB)** THICKNESS (F): **.005 IN.** (B): **.010 in.**

One film used per cassette, unless noted in remarks

#	IDENTIFICATION	WS	VIEW (in.)	O.D. (in.)	NOM. THK. (in.)	REIN. (in.)	SOD (in.)	OFD (in.)	FILM TYPE	TECH #	# of EXP	REMARKS	ACC. (✓)	REJ. (×)
1	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W1		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-50	"	"	"	"	"	"	"	"	P(1), S(1)	✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1	P(1)	✓	
	W2		15-30	"	"	"	"	"	"	"	"	P(1)	✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"	P(2)	✓	
			45-50	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1	S(3) @ 2-5		x
	W3		15-30	"	"	"	"	"	"	"	"	S(2)	✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"	S(3) @ 36-45		x

CLIENT: ______________________ ______________________
CLIENT PRINTED NAME — CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN

TECHNICIAN: **MICHAEL PINHORN**
1st Technician
CGSB RT II Reg. # 14163
2nd Technician

REVIEWER: 10/07/2019

(Generated Using: CAN-QUA-02F018 R04 - 05/07/2018)

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # RT-MP300919-001 R0

#	IDENTIFICATION	WS	VIEW (in.)	O.D. (in.)	NOM. THK. (in.)	REIN. (in.)	SOD (in.)	OFD (in.)	FILM TYPE	TECH #	# of EXP	REMARKS	ACC. (✓)	REJ. (×)
	PENSTOCK 1		45-60	"	"	"	"	"	"	"	"	P/S(3) @ 48-50		x
	W3		60-75	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	CAN 106S		75-90	"	"	"	"	"	"	"	"	P(1)	✓	
			90-105	"	"	"	"	"	"	"	"		✓	
			105-107	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W4		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-60	"	"	"	"	"	"	"	"		✓	
			60-75	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
			75-90	"	"	"	"	"	"	"	"		✓	
			90-105	"	"	"	"	"	"	"	"		✓	
			105-107	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1 CAN 111 N		0-8	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1	S(2)	✓	
	W3R1		30-45	"	"	"	"	"	"	"	"	S(2)	✓	
	CAN 106S		45-60	"	"	"	"	"	"	"	"		✓	
	RT COMPLETED AFTER													
	HOLD TIME													
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W1		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-50	"	"	"	"	"	"	"	"		✓	

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # RT-MP300919-001 R0

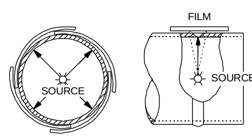
#	IDENTIFICATION	WS	VIEW (in.)	O.D. (in.)	NOM. THK. (in.)	REIN. (in.)	SOD (in.)	OFD (in.)	FILM TYPE	TECH #	# of EXP	REMARKS	ACC. (✓)	REJ. (×)
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W2		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-50	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W3		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-60	"	"	"	"	"	"	"	"		✓	
			60-75	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
			75-90	"	"	"	"	"	"	"	"		✓	
			90-105	"	"	"	"	"	"	"	"		✓	
			105-107	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1		0-15	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	W4		15-30	"	"	"	"	"	"	"	"		✓	
	CAN 106S		30-45	"	"	"	"	"	"	"	"		✓	
			45-60	"	"	"	"	"	"	"	"		✓	
			60-75	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
			75-90	"	"	"	"	"	"	"	"		✓	
			90-105	"	"	"	"	"	"	"	"		✓	
			105-107	"	"	"	"	"	"	"	"		✓	
	PENSTOCK 1 CAN 111 N		0-8	NA"	.500"	.125"	20"	.625"	D5	3	1		✓	
	NO CHANGE IN WELD													
	INTEGRITY AFTER HOLD													
	TIME													

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # **RT-MP300919-001 R0**

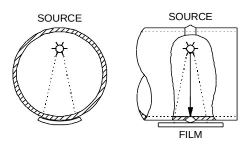
TECHNIQUES:

#1 (PANORAMIC)



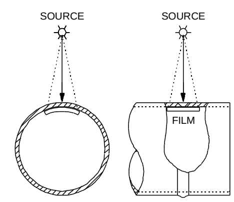
SINGLE WALL EXPOSURE
SINGLE WALL IMAGE

#2 (INTERNAL OFFSET)



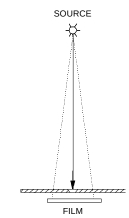
SINGLE WALL EXPOSURE
SINGLE WALL IMAGE

#3 (EXTERNAL SOURCE)



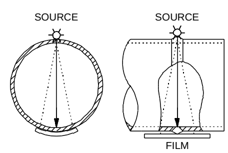
SINGLE WALL EXPOSURE
SINGLE WALL IMAGE

#3



SINGLE WALL EXPOSURE
SINGLE WALL IMAGE

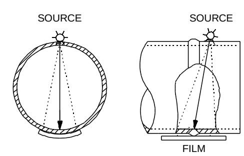
#4 (CONTACT)



DOUBLE WALL EXPOSURE
SINGLE WALL IMAGE

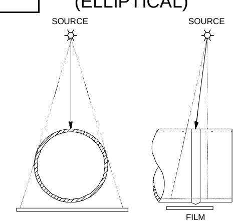
#5 (CONTACT)

(Optional Source Placement)



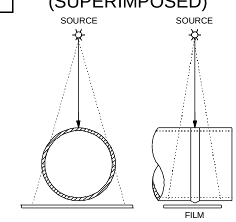
DOUBLE WALL EXPOSURE
SINGLE WALL IMAGE

#6 (ELLIPTICAL)



DOUBLE WALL EXPOSURE
DOUBLE WALL IMAGE

#7 (SUPERIMPOSED)



DOUBLE WALL EXPOSURE
DOUBLE WALL IMAGE

DEFECT RATINGS:

1-Minor (<75% of reject criteria), 2-Moderate (75% to <100% of reject criteria), 3-Severe (>100% of reject criteria, Rejectable)
Location(s) are not required for acceptable level 1 indications. Location(s) and size(s) are required for acceptable level 2, and rejectable level 3 indications.

#	IDENTIFICATION	WS	VIEW (cm.)	O.D. (NPS)	NOM. THK. (mm)	REIN (mm)	SOD (mm)	OFD (mm)	FILM TYPE	TECH #	# of EXP	REMARKS	ACC (✓)	REJ (•)
1	BGX-4	MF/CH	0-35	12	9.52	3.0	283.1	12.52	D5	5	1	P(1) cluster, IS(2) @ 4-5cm (4.5mm)	✓	
		MF/CH	35-70	12	9.52	3.0	283.1	12.52	D5	5	1	IP(2) @ 18-21cm (3mm)	✓	
		MF/CH	70-0	12	9.52	3.0	283.1	12.52	D5	5	1	LC(1), LF(3) @ 37-44cm (7mm)		•
2	BGX-12	MF/CH	0-35	12	9.52	3.0	283.1	12.52	D5	5	1		✓	
		MF/CH	35-70	12	9.52	3.0	283.1	12.52	D5	5	1	ES(1)	✓	
		MF/CH	70-0	12	9.52	3.0	283.1	12.52	D5	5	1		✓	

LEGEND:

WELDING DISCONTINUITIES:

AB = Arc Burn
BT = Burn Through
C = Crack
ER = Excess Reinforcement
HB = Hollow Bead
IC = Internal Concavity
IFC = Incomplete Fusion due to Cold Lap
IP = Incomplete Penetration
LC = Low Cover (Insufficient Reinforcement)
LCP = Lack of Cross Penetration
LF = Lack of, or Incomplete Fusion
M = Misalignment (hi/low)
O = Other Relevant Indications
P = Porosity
ES = Elongated Slag
IS = Isolated Slag
TI = Tungsten Inclusion
EUC = External Undercut
IUC = Internal Undercut

- **EXCESS REINFORCEMENT** (add location: Weld Root or Cap). *Reporting Example: ER (root) @ 25 cm* (Excessive Reinforcement to be noted when the radiograph density or sensitivity is not able to be achieved due to this condition. **DO NOT** indicate a severity level; comment on condition for client information only.)
- **OTHER RELEVANT INDICATIONS** (*add type*: Debris, Mill Mark, Gouge, Corrosion, Weld Profile, Pre-Existing Discontinuities in Adjacent Weld Areas, etc.)
- **POROSITY** (*add type*: Rounded, Piping, Cluster) *Example*: *P(3) rounded @ 25 cm (4.2 mm)*

Note: DO NOT ACCEPT or REJECT when an acceptance criterion is not provided; report for client information only.

OTHER:

B = Back
F = Front
OFD = Object to Film Distance
SCH = Pipe schedule
WS = Welder Symbol
DIA = Diameter
NOM. THK.= Nominal Wall Thickness
REIN = Reinforcement
SOD = Source to object distance

AGFA FILM CLASSIFICATION:

FILM TYPE	ASTM E1815	ISO 11699-1	FILM TYPE	ASTM E1815	ISO 11699-1	FILM TYPE	ASTM E1815	ISO 11699-1	FILM TYPE	ASTM E1815	ISO 11699-1
D3	I	C2	**D4**	I	C3	**D5**	I	C4	**D7**	II	C5

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ACUREN

NONDESTRUCTIVE EXAMINATION

TO: **Nalcor Energy**

PAGE: **1 of 2**

DATE: **Oct 3rd /2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **VT-GW031019-001 R0**
PO: **N/A** WO: **N/A**

ATTENTION: **Dylan Drake** WORK LOCATION: **Bay D'Espoir, NL**
Project: **Penstock # 1 Emergency Repair**
Item(s) Examined: **Can 106 South insert plate (Interior & Exterior) & reinforcement plate (Exterior)**

PART #: **See below** MATERIAL: **Carbon steel** THICKNESS: **Varies**
SCOPE: **Visual Examination As Per Client Request**
TYPE OF INSPECTION: **Visual**

TEST DETAILS:

ACCEPTANCE STANDARD: **ASME B31.3NFS , ASME SEC. IX** REVISION: **2018/ 2017**
PROCEDURE/TECHNIQUE: **CAN-VT-14P001** REVISION: **R06 Dec/ 2017**
METHOD: **Visual**
EQUIPMENT TYPE: **N/A** MANUFACTURER: **N/A** MODEL: **N/A** S/N: **N/A**
LIGHT SOURCE: **Head lamp** ILLUMINATION INTENSITY: **OUTPUT > 100 FC**
LIGHT METER S/N: **150803637** CAL DUE: **FEB 22nd 2020**
ADDITIONAL EQUIPMENT: **N/A** MAGNIFICATION POWER: **N/A**
SUPPLEMENTAL NDT REPORT ATTACHED?: **Yes** PROCEDURE DEMONSTRATION REQUIRED?: **No**
TEST SURFACE CONDITION: **Clean bare metal**

See page 2 for results

CLIENT REPRESENTATIVE:
TECHNICIAN:

JONATHAN WHITTEN
CWB II 3954
1st Technician

Glenn Whitten
CGSB 16212
2nd Technician

DTR No.: N/A

REVIEWER: 10/04/2019

(Generated Using: CAN-QUA-02F007 R05 - 03/07/2018)

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # VT-GW031019-001 R0

To: Nalcor Energy
Attention : Dylan Drake

Items :	Weld	Weld Type	Notes:	Date & Time	Accept/Reject
Penstock # 1	FW#1	Prep	Fit-up	29/09/19 - 0945	Accept
Can #106 Insert Plate		CJP	After Welding	30/09/19- 1500	Accept
		CJP	After 12hrs	01/10/19 - 0730	Accept
		CJP	After Ground Flush	01/10/19 - 12:00	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
	FW#2	Prep	Fit-up	29/09/19 - 0945	Accept
		CJP	After Welding	30/09/19 - 1500	Accept
		CJP	After 12hrs	01/10/19 - 0700	Accept
		CJP	After Ground Flush	01/10/19 - 12:00	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
	FW#3	Prep	Fit-up	29/09/19 - 0945	Accept
		CJP	After Welding	30/09/19 - 1500	Accept
	FW#3 R1	CJP	After RT Repairs	30/09/19 - 20:00	Accept
		CJP	After 12hrs	01/10/19 - 0800	Accept
		CJP	After Ground Flush	01/10/19 - 12:00	Accept
		CJP	After 40hrs	02/10/19 - 1500	Accept
	FW#4	Prep	Fit-up	29/09/19 - 0945	Accept
		CJP	After Welding	30/09/19 - 1500	Accept
		CJP	After 12hrs	01/10/19 - 0730	Accept
		CJP	After Ground Flush	01/10/19 - 12:00	Accept
		CJP	After 48hrs	02/10/19 - 1500	Accept
Penstock # 1	FW#5	CJP	Splice	01/10/19 - 1700	Accept
Can #106 Re-pad	FW#6	Fillet	Re-pad to Shell	03/10/19 - 1200	Accept

ACUREN
NONDESTRUCTIVE EXAMINATION

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1 Austin Street
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TO: **Nalcor Energy**

PAGE: **1 of 1**

DATE: **Oct 3rd /2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **VT-GW031019-002 R0**
PO: **N/A** WO: **N/A**

ATTENTION: **Dylan Drake** WORK LOCATION: **Bay D'Espoir, NL**
Project: **Penstock # 1 Emergency Repair**
Item(s) Examined: **Can 111 North repair**

PART #: **See below** MATERIAL: **Carbon steel** THICKNESS: **Varies**
SCOPE: **Visual Examination As Per Client Request**
TYPE OF INSPECTION: **Visual**

TEST DETAILS:

ACCEPTANCE STANDARD: **ASME B31.3NFS, ASME SEC. IX** REVISION: **2018/ 2017**
PROCEDURE/TECHNIQUE: **CAN-VT-14P001** REVISION: **R06 Dec/ 2017**
METHOD: **Visual**
EQUIPMENT TYPE: **N/A** MANUFACTURER: **N/A** MODEL: **N/A** S/N: **N/A**
LIGHT SOURCE: **Head lamp** ILLUMINATION INTENSITY: **OUTPUT > 100 FC**
LIGHT METER S/N: **150803637** CAL DUE: **FEB 22nd /2020**
ADDITIONAL EQUIPMENT: **N/A** MAGNIFICATION POWER: **N/A**
SUPPLEMENTAL NDT REPORT ATTACHED?: **Yes** PROCEDURE DEMONSTRATION REQUIRED?: **No**
TEST SURFACE CONDITION: **As Welded**

Items :	Weld #	Weld Type	Notes:	Date & Time	Accept/Reject
Penstock # 1	FW#1	CJP	Weld Prep	01/10/19 - 0900	Accept
Can #111 North	FW#1	CJP	After 12 HRS	02/10/19 - 1200	Accept
-	FW#1	CJP	After 48 HRS	03/10/19 - 1200	Accept

CLIENT REPRESENTATIVE:
TECHNICIAN:

JONATHAN WHITTEN
CWB II 3954
1st Technician

Glenn Whitten
CGSB 16212
2nd Technician

DTR No.: N/A

REVIEWER: 10/04/2019

(Generated Using: CAN-QUA-02F007 R05 - 03/07/2018)

APPENDIX D

THICKNESS MEASUREMENTS DATA

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Fax: 709.753.7011

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ACUREN

NONDESTRUCTIVE EXAMINATION

CLIENT: **Nalcor Energy**

DATE: **Sept. 24th, 2019**
ACUREN JOB #: **183-19-10NAL001-0001**
REPORT #: **UT-GW240919-001 R0**
CONTRACT/PO: **3092 OS** WO: **N/A**
WORK LOCATION: **Bay D'Espoir, NL**

ATTENTION: **Dylan Drake**
PROJECT: **Bay D'Espoir Penstock # 1**
ITEM(S) EXAMINED: **Penstock # 1**

PART #: **Penstock Number 1** MATERIAL: **Carbon Steel** THICKNESS: **See Below**
SCOPE: **To perform a 0 degree ultrasonic survey as per client's request.**
TYPE OF INSPECTION: **Ultrasonic**

TEST DETAILS:

ACCEPTANCE STANDARD: **Client's Information** REVISION: **N/A**
PROCEDURE/TECHNIQUE: **CAN-UT-14T001** REVISION: **R07 / Nov 30, 2017**

TYPE: **Thickness**		METHOD: **Contact**	
INSTRUMENT: **Olympus**	MODEL: **38 DL Plus**	S/N: **120467507**	CAL DUE: **July 17, 2020**
CAL. BLOCK: **Step Block**	S/N: **2210 15**	CABLE-TYPE: **Coaxial**	LENGTH: **N/A**
CAL. BLOCK:	S/N:	COUPLANT: **Sonotech – Sono 600**	

Probe & Technique Details:

	Test Angle (°)	Probe Type	Crystal Size	Freq. (MHz)	Serial Number	Damping Ω	Test From	Reference Reflector	Transfer Value	Reference Db	Reference % FSH	Scan Db	Range
1	**0**	**D799**	**0.375"**	**5**	**990973**	**N/A**	**Front**	**FBW**	**N/A**	**46-72**	**80**	**As Req**	**0.5" -5"**
2													
3													

TEST SURFACE CONDITION: **Clean bare metal** TEST SURFACE TEMPERATURE: **Ambient**

RESULTS: **(Note: all readings in inches)**

As per client's request a 0 degree ultrasonic survey was performed on penstock # 1 internal.
Three locations were examined on approximately every 10th can starting at the head gate (Can # 1) continuing downstream with Can #10, 20, 30 etc.
At each location three readings were taken.

See page 2 - 4

CLIENT: ______ (CLIENT PRINTED NAME) ______ (CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY)

DTR NO.: N/A

ACUREN TECHNICIAN: **Andrew Rideout** (1st Technician, **CGSB II # 14136**) **Glenn Whitten** (2nd Technician)

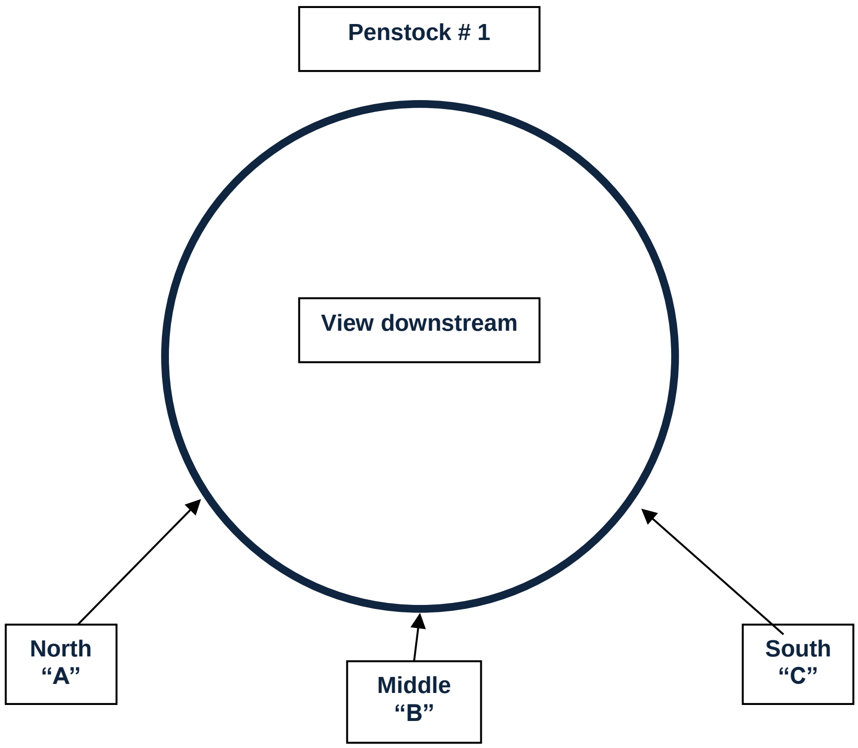
REVIEWER: 01/28/2020

(Generated Using: CAN-QUA-02F007 R07 – 07/20/2018)

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # UT-GW240919-001 R0

Nalcor Energy



CLIENT: ______ CLIENT PRINTED NAME ______ CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: **Andrew Rideout** — 1st Technician, **CGSB II # 14136**; **Glenn Whitten** — 2nd Technician

REVIEWER: 01/28/2020

ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # UT-GW240919-001 R0

Nalcor Energy

	North "A"			Middle "B"			South "C"		
Can #	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Reading 6	Reading 7	Reading 8	Reading 9
1	0.518	0.521	0.511	0.521	0.525	0.530	0.526	0.521	0.511
10	0.536	0.550	0.546	0.541	0.525	0.529	0.525	0.513	0.509
20	0.446	0.450	0.441	0.448	0.446	0.446	0.452	0.446	0.448
30	0.461	0.486	0.465	0.494	0.475	0.433	0.433	0.447	0.441
40	0.447	0.451	0.433	0.451	0.433	0.448	0.476	0.471	0.472
48	0.452	0.451	0.458	0.456	0.450	0.470	0.464	0.477	0.456
58	0.419	0.425	0.433	0.440	0.446	0.465	0.439	0.454	0.456
69	0.441	0.436	0.465	0.453	0.452	0.440	0.451	0.455	0.459
79	0.431	0.431	0.435	0.442	0.440	0.437	0.443	0.452	0.441
89	0.503	0.500	0.519	0.527	0.527	0.501	0.538	0.523	0.531
101	0.436	0.433	0.440	0.446	0.459	0.432	0.429	0.440	0.440
120	0.470	0.462	0.455	0.462	0.433	0.424	0.425	0.427	0.435
123	0.444	0.464	0.472	0.460	0.441	0.439	0.433	0.444	0.453
131	0.456	0.453	0.473	0.438	0.438	0.461	0.433	0.426	0.428
139	0.425	0.426	0.431	0.431	0.401	0.427	0.446	0.428	0.421
148	0.438	0.436	0.441	0.447	0.452	0.433	0.415	0.421	0.413
168	0.492	0.503	0.484	0.490	0.496	0.486	0.514	0.496	0.495
170	0.503	0.509	0.485	0.464	0.457	0.485	0.485	0.458	0.442
180	0.589	0.610	0.585	0.583	0.583	0.577	0.570	0.595	0.587
192	0.587	0.590	0.603	0.619	0.610	0.603	0.598	0.622	0.605
201	0.659	0.665	0.646	0.666	0.646	0.647	0.666	0.660	0.649
210	0.645	0.656	0.644	0.656	0.662	0.644	0.646	0.653	0.646
220	0.620	0.638	0.639	0.637	0.619	0.636	0.644	0.613	0.655
228	0.646	0.635	0.646	0.653	0.651	0.652	0.629	0.665	0.657
240	0.755	0.738	0.737	0.740	0.681	0.669	0.725	0.734	0.683
250	0.795	0.763	0.775	0.779	0.772	0.759	0.731	0.769	0.769
264	0.882	0.878	0.877	0.875	0.864	0.872	0.900	0.873	0.901
271	0.764	0.769	0.768	0.792	0.783	0.787	0.812	0.808	0.766
280	0.835	0.823	0.823	0.825	0.816	0.809	0.817	0.879	0.820
292	0.880	0.878	0.896	0.885	0.888	0.889	0.901	0.879	0.883
302	0.886	0.857	0.851	0.828	0.860	0.859	0.846	0.854	0.888
313	0.965	0.977	0.960	0.978	0.974	0.983	0.975	0.960	0.950
322	0.993	0.991	0.993	1.000	0.987	0.985	0.980	1.010	0.993

CLIENT: ____________________ ____________________
CLIENT PRINTED NAME — CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: Andrew Rideout — 1st Technician, CGSB II # 14136 | Glenn Whitten — 2nd Technician

REVIEWER: 01/28/2020

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ACUREN

ACUREN JOB # 183-19-10NAL001-0001
REPORT # UT-GW240919-001 R0

Nalcor Energy

	North "A"			Middle "B"			South "C"		
Can #	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Reading 6	Reading 7	Reading 8	Reading 9
331	0.921	1.010	0.994	1.000	0.994	0.994	1.000	1.000	1.000
342	1.167	1.141	1.142	1.144	1.143	1.151	1.138	1.191	1.148
354	1.164	1.181	1.191	1.159	1.169	1.189	1.169	1.179	1.181
364	1.264	1.270	1.266	1.242	1.221	1.222	1.236	1.231	1.220
372	1.313	1.322	1.314	1.318	1.305	1.325	1.312	1.322	1.325
381	1.389	1.408	1.388	1.389	1.394	1.401	1.390	1.392	1.338
391	1.358	1.368	1.360	1.363	1.363	1.361	1.361	1.357	1.363
399	1.437	1.455	1.440	1.438	1.436	1.428	1.429	1.436	1.433

CLIENT: ______ CLIENT PRINTED NAME ______ CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

DTR NO.: N/A

ACUREN TECHNICIAN: **Andrew Rideout** — 1st Technician, **CGSB II # 14136**; **Glenn Whitten** — 2nd Technician

REVIEWER: 01/28/2020

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

Kleinschmidt

PROJECT TITLE:	Penstock 1 Inspection	**CLIENT:**	Newfoundland Labrador Hydro
KLEINSCHMIDT PROJECT NO:	2670021.01	**LOCATION:**	Bay D'Espoir
SUBJECT:	Penstock 1 – steel thickness measurements		
PROJECT MANAGER:	Scott Hancock		
TECHNICAL LEAD/ADVISOR:	Chris Vella		
ENGINEER:	**NANCY SUTHERLAND**		

REV.	NAME		DATE	COMMENTS
	Performed By:	NS	02/05/2020	
	Checked By:			
	TA Approval:			
	Performed By:			
	Checked By:			
	TA Approval:			
	Performed By:			
	Checked By:			
	TA Approval:			
	Performed By:			
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	Performed By:			
	Checked By:			
	TA Approval:			

[Insert PE Stamp]

Kleinschmidt	Phone: 888.224.5942 www.KleinschmidtGroup.com	Page:1 Project No.: 2670021.01	
Project: Bay D'Espoir Penstock 1		By: NS	Date: March 6, 2020
Subject: Assumptions and Notes		Checked:	Date:

OBJECTIVE:
Determine the structural integrity of Bay d'Espoir Penstock 1 under external loading.

ASSUMPTIONS: For the following analyses, it is assumed that penstock 1 is buried with a compacted earth cover of approximately 3 feet in depth. It is also assumed that there is no vehicular traffic in the area of the penstock and any subsequent live loads include maintenance workers, etc. or environmental loads.

REFERENCES:
1. Site Visit Notes - CMV 9/25/2019
2. Acuren Report #UT-GW240919-001 RO; September 14, 2019
3. ASCE No. 79, Steel Penstocks, 2nd Edition, 2012
4. Existing Drawings: Penstock 1, Profile 1; Penstock 2, Profile 2 (attachments to RFP 2019-78573TB)
5. National Building Code of Canada, current version.
6. ASCE7-10 Minimum Design Loads For Buildings and Other Structures, current version
7. AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.
8. AISC, Manual of Steel Construction, current version
9. Hydroelectric Handbook Justin & Creager 1950
10. Obsolete Canadian Structural Steel Grades 1935-1971, CISC
11. CSA S-16 Design of Steel Structures. Handbook of Steel Construction, current version

MATERIAL PROPERTIES:

<u>A285 Steel (upper section of penstock) (Ref.3)</u>

F_{yA285} = 26 ksi Yield Stress

F_{uA285} = 50 ksi Ultimate Tensile Stress

<u>CSA G40.8 Grade B (Ref.10)</u>

F_y = 40 ksi (CSA G40.8 Grade B for thicknesses less than and equal to 0.625 inches)

F_y = 38 ksi (CSA G40.8 Grade B for thicknesses between 0.625 inches and 1 inch incl.)

F_y = 36 ksi (CSA G40.8 Grade B for thicknesses between 1 inch and 1.5 inches)

F_u = 65 ksi Ultimate Tensile Stress

Kleinschmidt	Phone: 888.224.5942 www.KleinschmidtGroup.com	Page:2 Project No.: 2670021.01	
Project: Bay D'Espoir Penstock 1		By: NS	Date: March 6, 2020
Subject: Assumptions and Notes		Checked:	Date:

ALLOWABLE STRESS:
The allowable stress is calculated as per Ref.3:

S_A = min (F_y/1.5, F_u/2.4)

Allowable stress for A285 steel = 17 ksi
Allowable stress for CSA G40.8 Grade B = 24 ksi

JOINT EFFICIENCY:

Assume all welds (longitudinal and circumferential) are double welded butt joints with no RT or UT; Ref.3, section 3.5.1, Table 3-3.

EXTERNAL LOADS:

Snow Load Ref. 5

Design snow load as per Division B, Section 4.1.6.2 NBCC.

$S = I_s(S_s(C_bC_wC_sC_a) + S_r)$

Where;

I_s = 1.0	Importance factor
S_s = 3.7 kPa	Ground snow load
S_r = 0 kPa	No ponding on penstock (rain load)
C_b = 0.8	Basic roof snow load factors
C_w = 1.0	Wind exposure
C_s = 0.33	Slope factor
C_a = 1.0	Shape factor

S = 20.61 psf

Live Load

LL = 100 psf Live load is assumed; maintenance work above penstock.

Kleinschmidt	Phone: 888.224.5942 www.KleinschmidtGroup.com	Page:3 Project No.: 2670021.01	
Project: Bay D'Espoir Penstock 1		By: NS	Date: March 6, 2020
Subject: Assumptions and Notes		Checked:	Date:

ALLOWABLE BUCKLING PRESSURE:

The allowable buckling pressure is calculated as per Ref.3:

$q_a = (1/FS)*(32R_wB'E'(EI/D^3)^{0.5}$

Where:

FS = Factor of Safety = 2
R_w = Water Buoyancy Factor = 1
B' = Empirical coefficient of elastic support = 0.23
E' = Modulus of soil reaction; assumed fine grained soils with less than 25% sand @ 85% compaction; 500 psi.
EI = Pipe wall stiffness
D = Outside diameter of penstock

The external loads are calculated as per Ref.3.

1. External Pressure Vacuum= $\gamma_w h_w + R_w(W_c/D) + Pv + (W_{steel}/D)$
2. External Pressure (Snow)= $\gamma_w h_w + R_w(W_c/D) + (W_s/D) + (W_{steel}/D)$
3. External Pressure (Live and Snow Load)= $\gamma_w h_w + R_w(W_c/D) + 0.75(W_s/D)+ 0.75(W_l/D) + (W_{steel}/D)$

Where:

γ_w = Unit weight of water = 62.4 pcf
h_w = Height of water (external) = 0 (well drained)
W_c = Weight of soil
W_{steel} = Dead weight of steel
W_s = Snow load
W_l = Live load
P_v = 0 (surge tank) Vacuum Pressure

EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa) Reference 3

Diameter 15.25 feet						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	(soil load) W_c=	5974.0	lb/ft	
OD Conduit Diameter=	15.318	feet	ID:	15.25	feet	(live load) W_l=	1531.8	lb/ft	100 psf per foot section
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	316	lb/ft	
B_prime=	0.2330					W_{steel}=	3193	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	4.15	psi	Ratio Q/q_a= 0.828246
$t_{97.5}$=	0.408	inches				External pressure with snow load=	4.30	psi	Ratio Q/q_a= 0.85677
I=	0.0057	$inches^4$				External pressure with snow and live=	4.78	psi	Ratio Q/q_a= 0.953437
FS=	2								
Allowable pressure q_a=	5.01	psi							

Allowable pressures (kPa)/External Pressures (kPa) Reference 3

Diameter 17 feet						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	(soil load) W_c=	6655.2	lb/ft	
OD Conduit Diameter=	17.06466667	feet	ID:	17.00	feet	(live load) W_l=	1706.5	lb/ft	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	351.7	lb/ft	
B_prime=	0.23302752					W_{steel}=	957.7	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	3.10	psi	Ratio Q/q_a= 0.78207
$t_{97.5}$=	0.388	inches				External pressure with snow load=	3.24	psi	Ratio Q/q_a= 0.8182
I=	0.0049	$inches^4$				External pressure with snow and live=	3.72	psi	Ratio Q/q_a= 0.940645
FS=	2								
Allowable pressure q_a=	3.96	psi							

TABLE 1 - Full Supply Level (FSL)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	(per Penstock #2 assessment)
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material Stress (psi)[1]	Base Material Stress Ratio[2]	At Joints Stress (psi)[3]	At Joints Stress Ratio[4]	Notes
INTERIOR From Upstream End of Conduit															
1A	0+00	8.50	1	0.5180	0.517	0.5	3.6%	0.5066	549.50	17000	4144.2	0.24	5920.3	0.35	A285 Steel (grade unknown)
			2	0.5210		0.5	4.2%								17 ft diameter penstock
			3	0.5110		0.5	2.2%								
1B	0+00	8.50	4	0.5210	0.525	0.5	4.2%	0.5165	549.50	17000	4064.9	0.24	5807.0	0.34	
			5	0.5250		0.5	5.0%								
			6	0.5300		0.5	6.0%								
1C	0+00	8.50	7	0.5260	0.519	0.5	5.2%	0.5044	549.50	17000	4162.7	0.24	5946.7	0.35	
			8	0.5210		0.5	4.2%								
			9	0.5110		0.5	2.2%								
10A	00+81	8.50	10	0.5360	0.544	0.5	7.2%	0.5299	549.50	17000	3962.3	0.23	5660.5	0.33	
			11	0.5500		0.5	10.0%								
			12	0.5460		0.5	9.2%								
10B	00+81	8.50	13	0.5410	0.532	0.5	8.2%	0.5153	549.50	17000	4074.0	0.24	5819.9	0.34	
			14	0.5250		0.5	5.0%								
			15	0.5290		0.5	5.8%								
10C	00+81	8.50	16	0.5250	0.516	0.5	5.0%	0.4993	549.50	17000	4204.5	0.25	6006.4	0.35	
			17	0.5130		0.5	2.6%								
			18	0.5090		0.5	1.8%								
20A	01+63	8.50	19	0.4460	0.446	0.4375	1.9%	0.4368	549.50	17000	4806.2	0.28	6866.0	0.40	
			20	0.4500		0.4375	2.9%								
			21	0.4410		0.4375	0.8%								
20B	01+63	8.50	22	0.4480	0.447	0.4375	2.4%	0.4444	549.50	17000	4724.3	0.28	6749.0	0.40	
			23	0.4460		0.4375	1.9%								
			24	0.4460		0.4375	1.9%								
20C	01+63	8.50	25	0.4520	0.449	0.4375	3.3%	0.4427	549.50	17000	4742.7	0.28	6775.3	0.40	
			26	0.4460		0.4375	1.9%								
			27	0.4480		0.4375	2.4%								
30A	02+35	8.50	28	0.4610	0.471	0.4375	5.4%	0.4443	546.8201	17000	4991.5	0.29	7130.7	0.42	
			29	0.4860		0.4375	11.1%								
			30	0.4650		0.4375	6.3%								
30B	02+35	8.50	31	0.4940	0.467	0.4375	12.9%	0.4062	546.8201	17000	5460.9	0.32	7801.2	0.46	
			32	0.4750		0.4375	8.6%								
			33	0.4330		0.4375	-1.0%								
30C	02+35	8.50	34	0.4330	0.440	0.4375	-1.0%	0.4266	546.8201	17000	5199.5	0.31	7427.9	0.44	
			35	0.4470		0.4375	2.2%								
			36	0.4410		0.4375	0.8%								
40A	03+23	8.50	37	0.4470	0.444	0.4375	2.2%	0.4251	536.1772	17000	6323.5	0.37	9033.5	0.53	
			38	0.4510		0.4375	3.1%								
			39	0.4330		0.4375	-1.0%								
40B	03+23	8.50	40	0.4510	0.444	0.4375	3.1%	0.4251	536.1772	17000	6324.1	0.37	9034.4	0.53	
			41	0.4330		0.4375	-1.0%								
			42	0.4480		0.4375	2.4%								
40C	03+23	8.50	43	0.4760	0.473	0.4375	8.8%	0.4678	536.1772	17000	5746.7	0.34	8209.5	0.48	
			44	0.4710		0.4375	7.7%								
			45	0.4720		0.4375	7.9%								
48A	03+92	8.50	46	0.4520	0.454	0.4375	3.3%	0.4462	527.7817	17000	6856.0	0.40	9794.2	0.58	
			47	0.4510		0.4375	3.1%								
			48	0.4580		0.4375	4.7%								
48B	03+92	8.50	49	0.4560	0.459	0.4375	4.2%	0.4386	527.7817	17000	6976.3	0.41	9966.1	0.59	
			50	0.4500		0.4375	2.9%								
			51	0.4700		0.4375	7.4%								
48C	03+92	8.50	52	0.4640	0.466	0.4375	6.1%	0.4449	527.7817	17000	6876.8	0.40	9824.0	0.58	
			53	0.4770		0.4375	9.0%								
			54	0.4560		0.4375	4.2%								
58A	04+82	8.50	55	0.4190	0.426	0.4375	-4.2%	0.4119	516.9473	17000	8590.3	0.51	12271.8	0.72	
			56	0.4250		0.4375	-2.9%								
			57	0.4330		0.4375	-1.0%								
58B	04+82	8.50	58	0.4400	0.450	0.4375	0.6%	0.4248	516.9473	17000	8330.3	0.49	11900.5	0.70	
			59	0.4460		0.4375	1.9%								
			60	0.4650		0.4375	6.3%								
58C	04+82	8.50	61	0.4390	0.450	0.4375	0.3%	0.4315	516.9473	17000	8200.9	0.48	11715.6	0.69	
			62	0.4540		0.4375	3.8%								
			63	0.4560		0.4375	4.2%								
69A	05+75	8.50	64	0.4410	0.447	0.4375	0.8%	0.4169	509.73	17000	9250.9	0.54	13215.6	0.78	
			65	0.4360		0.4375	-0.3%								
			66	0.4650		0.4375	6.3%								
69B	05+75	8.50	67	0.4530	0.448	0.4375	3.5%	0.4342	509.73	17000	8884.3	0.52	12691.8	0.75	
			68	0.4520		0.4375	3.3%								
			69	0.4400		0.4375	0.6%								
69C	05+75	8.50	70	0.4510	0.455	0.4375	3.1%	0.4472	509.73	17000	8625.9	0.51	12322.7	0.72	
			71	0.4550		0.4375	4.0%								
			72	0.4590		0.4375	4.9%								
79A	06+64	8.50	73	0.4310	0.432	0.4375	-1.5%	0.4278	509.02	17000	9090.2	0.53	12986.0	0.76	
			74	0.4310		0.4375	-1.5%								
			75	0.4350		0.4375	-0.6%								
79B	06+64	8.50	76	0.4420	0.440	0.4375	1.0%	0.4347	509.02	17000	8945.4	0.53	12779.1	0.75	
			77	0.4400		0.4375	0.6%								
			78	0.4370		0.4375	-0.1%								
79C	06+64	8.50	79	0.4430	0.445	0.4375	1.3%	0.4338	509.02	17000	8963.6	0.53	12805.2	0.75	
			80	0.4520		0.4375	3.3%								
			81	0.4410		0.4375	0.8%								
89A	07+52	8.50	82	0.5030	0.507	0.4375	15.0%	0.4873	508.32	17000	8043.3	0.47	11490.4	0.68	
			83	0.5000		0.4375	14.3%								
			84	0.5190		0.4375	18.6%								
89B	07+52	8.50	85	0.5270	0.518	0.4375	20.5%	0.4889	508.32	17000	8017.0	0.47	11452.8	0.67	
			86	0.5270		0.4375	20.5%								
			87	0.5010		0.4375	14.5%								
89C	07+52	8.50	88	0.5380	0.531	0.4375	23.0%	0.5160	508.32	17000	7596.8	0.45	10852.5	0.64	
			89	0.5230		0.4375	19.5%								
			90	0.5310		0.4375	21.4%								
101A	08+41	8.50	91	0.4360	0.436	0.4375	-0.3%	0.4295	503.32	17000	9641.9	0.57	13774.1	0.81	
			92	0.4330		0.4375	-1.0%								
			93	0.4400		0.4375	0.6%								
101B	08+41	8.50	94	0.4460	0.446	0.4375	1.9%	0.4192	503.32	17000	9877.6	0.58	14110.9	0.83	
			95	0.4590		0.4375	4.9%								
			96	0.4320		0.4375	-1.3%								
101C	08+41	8.50	97	0.4290	0.436	0.4375	-1.9%	0.4239	503.32	17000	9768.4	0.57	13954.9	0.82	

											Base Material		At Joints		
Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	Notes
			98	0.4400		0.4375	0.6%								
			99	0.4400		0.4375	0.6%								
120A	10+34	8.50	100	0.4700	0.462	0.4375	7.4%	0.4476	484.81	24000	11078.4	0.46	15826.3	0.66	CSA G40.8 Grade B Steel
			101	0.4620		0.4375	5.6%								
			102	0.4550		0.4375	4.0%								
120B	10+34	8.50	103	0.4620	0.440	0.4375	5.6%	0.4007	484.81	24000	12374.3	0.52	17677.6	0.74	
			104	0.4330		0.4375	-1.0%								
			105	0.4240		0.4375	-3.1%								
120C	10+34	8.50	106	0.4250	0.429	0.4375	-2.9%	0.4186	484.81	24000	11845.7	0.49	16922.5	0.71	
			107	0.4270		0.4375	-2.4%								
			108	0.4350		0.4375	-0.6%								
123A	10+64	8.50	109	0.4440	0.460	0.4375	1.5%	0.4317	481.94	24000	11779.6	0.49	16828.1	0.70	
			110	0.4640		0.4375	6.1%								
			111	0.4720		0.4375	7.9%								
123B	10+64	8.50	112	0.4600	0.447	0.4375	5.1%	0.4239	481.94	24000	11995.9	0.50	17137.0	0.71	
			113	0.4410		0.4375	0.8%								
			114	0.4390		0.4375	0.3%								
123C	10+64	8.50	115	0.4330	0.443	0.4375	-1.0%	0.4237	481.94	24000	12002.9	0.50	17147.1	0.71	
			116	0.4440		0.4375	1.5%								
			117	0.4530		0.4375	3.5%								
131A	11+29	8.50	118	0.4560	0.461	0.4375	4.2%	0.4395	475.80	24000	12188.1	0.51	17411.6	0.73	
			119	0.4530		0.4375	3.5%								
			120	0.4730		0.4375	8.1%								
131B	11+29	8.50	121	0.4380	0.446	0.4375	0.1%	0.4196	475.80	24000	12765.7	0.53	18236.7	0.76	
			122	0.4380		0.4375	0.1%								
			123	0.4610		0.4375	5.4%								
131C	11+29	8.50	124	0.4330	0.429	0.4375	-1.0%	0.4219	475.80	24000	12696.3	0.53	18137.6	0.76	
			125	0.4260		0.4375	-2.6%								
			126	0.4280		0.4375	-2.2%								
139A	11+97	8.50	127	0.4250	0.427	0.4375	-2.9%	0.4210	469.30	24000	13405.6	0.56	19150.8	0.80	
			128	0.4260		0.4375	-2.6%								
			129	0.4310		0.4375	-1.5%								
139B	11+97	8.50	130	0.4310	0.420	0.4375	-1.5%	0.3877	469.30	24000	14556.6	0.61	20795.2	0.87	
			131	0.4010		0.4375	-8.3%								
			132	0.4270		0.4375	-2.4%								
139C	11+97	8.50	133	0.4460	0.432	0.4375	1.9%	0.4064	469.30	24000	13888.6	0.58	19840.9	0.83	
			134	0.4280		0.4375	-2.2%								
			135	0.4210		0.4375	-3.8%								
148A	12+50	7.63	136	0.4380	0.438	0.4375	0.1%	0.4334	463.47	24000	12215.9	0.51	17451.2	0.73	15.25 ft diameter penstock
			137	0.4360		0.4375	-0.3%								
			138	0.4410		0.4375	0.8%								
148B	12+50	7.63	139	0.4470	0.444	0.4375	2.2%	0.4247	463.47	24000	12466.2	0.52	17808.9	0.74	
			140	0.4520		0.4375	3.3%								
			141	0.4330		0.4375	-1.0%								
148C	12+50	7.63	142	0.4150	0.416	0.4375	-5.1%	0.4082	463.47	24000	12970.9	0.54	18529.8	0.77	
			143	0.4210		0.4375	-3.8%								
			144	0.4130		0.4375	-5.6%								
168A	14+29	7.63	145	0.4920	0.493	0.5	-1.6%	0.4743	417.44	24000	15010.3	0.63	21443.3	0.89	
			146	0.5030		0.5	0.6%								
			147	0.4840		0.5	-3.2%								
168B	14+29	7.63	148	0.4900	0.491	0.5	-2.0%	0.4808	417.44	24000	14807.4	0.62	21153.4	0.88	
			149	0.4960		0.5	-0.8%								
			150	0.4860		0.5	-2.8%								
168C	14+29	7.63	151	0.5140	0.502	0.5	2.8%	0.4807	417.44	24000	14810.3	0.62	21157.5	0.88	
			152	0.4960		0.5	-0.8%								
			153	0.4950		0.5	-1.0%								
170A	14+49	7.63	154	0.5030	0.499	0.5	0.6%	0.4745	412.30	24000	15433.2	0.64	22047.4	0.92	
			155	0.5090		0.5	1.8%								
			156	0.4850		0.5	-3.0%								
170B	14+49	7.63	157	0.4640	0.469	0.5	-7.2%	0.4401	412.30	24000	16639.9	0.69	23771.3	0.99	
			158	0.4570		0.5	-8.6%								
			159	0.4850		0.5	-3.0%								
170C	14+49	7.63	160	0.4850	0.462	0.5	-3.0%	0.4191	412.30	24000	17475.2	0.73	24964.6	1.04	
			161	0.4580		0.5	-8.4%								
			162	0.4420		0.5	-11.6%								
180A	15+40	7.63	163	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	14682.3	0.61	20974.8	0.87	
			164	0.5625		0.5625	0.0%								
			165	0.5625		0.5625	0.0%								
180B	15+40	7.63	166	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	14682.3	0.61	20974.8	0.87	
			167	0.5625		0.5625	0.0%								
			168	0.5625		0.5625	0.0%								
180C	15+40	7.63	169	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	14682.3	0.61	20974.8	0.87	
			170	0.5625		0.5625	0.0%								
			171	0.5625		0.5625	0.0%								
192A	16+35	7.63	172	0.5870	0.593	0.5625	4.4%	0.5767	372.46	24000	15438.7	0.64	22055.3	0.92	
			173	0.5900		0.5625	4.9%								
			174	0.6030		0.5625	7.2%								
192B	16+35	7.63	175	0.6190	0.611	0.5625	10.0%	0.5949	372.46	24000	14964.3	0.62	21377.5	0.89	
			176	0.6100		0.5625	8.4%								
			177	0.6030		0.5625	7.2%								
192C	16+35	7.63	178	0.5980	0.608	0.5625	6.3%	0.5841	372.46	24000	15241.0	0.64	21772.9	0.91	
			179	0.6220		0.5625	10.6%								
			180	0.6050		0.5625	7.6%								
201A	17+17	7.63	181	0.6590	0.657	0.5625	17.2%	0.6376	365.43	24000	14399.6	0.60	20570.8	0.86	
			182	0.6650		0.5625	18.2%								
			183	0.6460		0.5625	14.8%								
201B	17+17	7.63	184	0.6660	0.653	0.5625	18.4%	0.6309	365.43	24000	14552.9	0.61	20789.9	0.87	
			185	0.6460		0.5625	14.8%								
			186	0.6470		0.5625	15.0%								
201C	17+17	7.63	187	0.6660	0.658	0.5625	18.4%	0.6414	365.43	24000	14314.2	0.60	20448.8	0.85	
			188	0.6600		0.5625	17.3%								
			189	0.6490		0.5625	15.4%								
210A	17+97	7.63	190	0.6450	0.648	0.625	3.2%	0.6353	358.58	24000	14880.8	0.62	21258.2	0.89	
			191	0.6560		0.625	5.0%								
			192	0.6440		0.625	3.0%								
210B	17+97	7.63	193	0.6560	0.654	0.625	5.0%	0.6360	358.58	24000	14863.1	0.62	21233.0	0.88	
			194	0.6620		0.625	5.9%								
			195	0.6440		0.625	3.0%								
210C	17+97	7.63	196	0.6460	0.648	0.625	3.4%	0.6404	358.58	24000	14761.6	0.62	21088.0	0.88	
			197	0.6530		0.625	4.5%								
			198	0.6460		0.625	3.4%								
220A	18+89	7.63	199	0.6200	0.632	0.625	-0.8%	0.6114	350.69	24000	15974.1	0.67	22820.1	0.95	
			200	0.6380		0.625	2.1%								
			201	0.6390		0.625	2.2%								
220B	18+89	7.63	202	0.6370	0.631	0.625	1.9%	0.6108	350.69	24000	15988.1	0.67	22840.1	0.95	
			203	0.6190		0.625	-1.0%								
			204	0.6360		0.625	1.8%								
220C	18+89	7.63	205	0.6440	0.637	0.625	3.0%	0.5946	350.69	24000	16423.5	0.68	23462.1	0.98	
			206	0.6130		0.625	-1.9%								
			207	0.6550		0.625	4.8%								
228A	19+50	7.63	208	0.6460	0.642	0.625	3.4%	0.6299	345.46	24000	15833.8	0.66	22619.7	0.94	
			209	0.6350		0.625	1.6%								
			210	0.6460		0.625	3.4%								

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material Stress (psi)[1]	Base Material Stress Ratio[2]	At Joints Stress (psi)[3]	At Joints Stress Ratio[4]	Notes
228B	19+50	7.63	211	0.6530	0.652	0.625	4.5%	0.6500	345.46	24000	15342.8	0.64	21918.3	0.91	
			212	0.6510		0.625	4.2%								
			213	0.6520		0.625	4.3%								
228C	19+50	7.63	214	0.6290	0.650	0.625	0.6%	0.6133	345.46	24000	16262.4	0.68	23232.0	0.97	
			215	0.6650		0.625	6.4%								
			216	0.6570		0.625	5.1%								
240A	20+62	7.63	217	0.7550	0.743	0.6875	9.8%	0.7235	326.28	24000	14836.3	0.62	21194.7	0.88	
			218	0.7380		0.6875	7.3%								
			219	0.7370		0.6875	7.2%								
240B	20+62	7.63	220	0.7400	0.697	0.6875	7.6%	0.6222	326.28	24000	17252.5	0.72	24646.5	1.03	
			221	0.6810		0.6875	-0.9%								
			222	0.6690		0.6875	-2.7%								
240C	20+62	7.63	223	0.7250	0.714	0.6875	5.5%	0.6606	326.28	24000	16247.9	0.68	23211.3	0.97	
			224	0.7340		0.6875	6.8%								
			225	0.6830		0.6875	-0.7%								
250A	21+50	7.63	226	0.7950	0.778	0.75	6.0%	0.7460	310.57	24000	15224.1	0.63	21748.7	0.91	
			227	0.7630		0.75	1.7%								
			228	0.7750		0.75	3.3%								
250B	21+50	7.63	229	0.7790	0.770	0.75	3.9%	0.7501	310.57	24000	15140.3	0.63	21629.1	0.90	
			230	0.7720		0.75	2.9%								
			231	0.7590		0.75	1.2%								
250C	21+50	7.63	232	0.7310	0.756	0.75	-2.5%	0.7133	310.57	24000	15920.9	0.66	22744.1	0.95	
			233	0.7690		0.75	2.5%								
			234	0.7690		0.75	2.5%								
264A	22+76	7.63	235	0.8820	0.879	0.875	0.8%	0.8738	288.98	24000	13976.7	0.58	19966.8	0.83	Downstream of surge tank
			236	0.8780		0.875	0.3%								
			237	0.8770		0.875	0.2%								
264B	22+76	7.63	238	0.8750	0.870	0.875	0.0%	0.8592	288.98	24000	14214.7	0.59	20306.6	0.85	
			239	0.8640		0.875	-1.3%								
			240	0.8720		0.875	-0.3%								
264C	22+76	7.63	241	0.9000	0.891	0.875	2.9%	0.8602	288.98	24000	14198.0	0.59	20282.8	0.85	
			242	0.8730		0.875	-0.2%								
			243	0.9010		0.875	3.0%								
271A	23+26	7.63	244	0.7640	0.767	0.75	1.9%	0.7618	280.16	24000	16490.3	0.69	23557.6	0.98	
			245	0.7690		0.75	2.5%								
			246	0.7680		0.75	2.4%								
271B	23+26	7.63	247	0.7920	0.787	0.75	5.6%	0.7785	280.16	24000	16137.0	0.67	23052.9	0.96	
			248	0.7830		0.75	4.4%								
			249	0.7870		0.75	4.9%								
271C	23+26	7.63	250	0.8120	0.795	0.75	8.3%	0.7454	280.16	24000	16853.7	0.70	24076.8	1.00	
			251	0.8080		0.75	7.7%								
			252	0.7660		0.75	2.1%								
280A	24+07	7.63	253	0.8350	0.827	0.815	2.5%	0.8134	265.74	24000	16147.3	0.67	23067.5	0.96	
			254	0.8230		0.815	1.0%								
			255	0.8230		0.815	1.0%								
280B	24+07	7.63	256	0.8250	0.817	0.815	1.2%	0.8009	265.74	24000	16398.8	0.68	23426.8	0.98	
			257	0.8160		0.815	0.1%								
			258	0.8090		0.815	-0.7%								
280C	24+07	7.63	259	0.8170	0.839	0.815	0.2%	0.7701	265.74	24000	17054.7	0.71	24363.8	1.02	
			260	0.8790		0.815	7.9%								
			261	0.8200		0.815	0.6%								
292A	25+16	7.63	262	0.8800	0.885	0.875	0.6%	0.8653	246.33	24000	16068.0	0.67	22954.4	0.96	
			263	0.8780		0.875	0.3%								
			264	0.8960		0.875	2.4%								
292B	25+16	7.63	265	0.8850	0.887	0.875	1.1%	0.8833	246.33	24000	15742.0	0.66	22488.6	0.94	
			266	0.8880		0.875	1.5%								
			267	0.8890		0.875	1.6%								
292C	25+16	7.63	268	0.9010	0.888	0.875	3.0%	0.8647	246.33	24000	16079.8	0.67	22971.1	0.96	
			269	0.8790		0.875	0.5%								
			270	0.8830		0.875	0.9%								
302A	26+07	7.63	271	0.8860	0.865	0.875	1.3%	0.8280	230.14	24000	17568.0	0.73	25097.1	1.05	
			272	0.8570		0.875	-2.1%								
			273	0.8510		0.875	-2.7%								
302B	26+07	7.63	274	0.8280	0.849	0.875	-5.4%	0.8133	230.14	24000	17884.2	0.75	25548.8	1.06	
			275	0.8600		0.875	-1.7%								
			276	0.8590		0.875	-1.8%								
302C	26+07	7.63	277	0.8460	0.863	0.875	-3.3%	0.8190	230.14	24000	17761.5	0.74	25373.6	1.06	
			278	0.8540		0.875	-2.4%								
			279	0.8880		0.875	1.5%								
313A	27+06	7.63	280	0.9650	0.967	0.935	3.2%	0.9502	217.43	24000	15838.4	0.66	22626.3	0.94	
			281	0.9770		0.935	4.5%								
			282	0.9600		0.935	2.7%								
313B	27+06	7.63	283	0.9780	0.978	0.935	4.6%	0.9695	217.43	24000	15523.4	0.65	22176.2	0.92	
			284	0.9740		0.935	4.2%								
			285	0.9830		0.935	5.1%								
313C	27+06	7.63	286	0.9750	0.962	0.935	4.3%	0.9370	217.43	24000	16061.6	0.67	22945.2	0.96	
			287	0.9600		0.935	2.7%								
			288	0.9500		0.935	1.6%								
322A	27+67	7.63	289	0.9930	0.992	0.935	6.2%	0.9901	210.34	24000	15484.7	0.65	22121.0	0.92	
			290	0.9910		0.935	6.0%								
			291	0.9930		0.935	6.2%								
322B	27+67	7.63	292	1.0000	0.991	0.935	7.0%	0.9747	210.34	24000	15728.8	0.66	22469.7	0.94	
			293	0.9870		0.935	5.6%								
			294	0.9850		0.935	5.3%								
322C	27+67	7.63	295	0.9800	0.994	0.935	4.8%	0.9648	210.34	24000	15889.5	0.66	22699.3	0.95	
			296	1.0100		0.935	8.0%								
			297	0.9930		0.935	6.2%								
331A	28+65	7.63	298	0.9210	0.975	1	-7.9%	0.8820	198.95	24000	17893.8	0.75	25562.6	1.07	
			299	1.0100		1	1.0%								
			300	0.9940		1	-0.6%								
331B	28+65	7.63	301	1.0000	0.996	1	0.0%	0.9892	198.95	24000	15954.6	0.66	22792.3	0.95	
			302	0.9940		1	-0.6%								
			303	0.9940		1	-0.6%								
331C	28+65	7.63	304	1.0000	1.000	1	0.0%	1.0000	198.95	24000	15782.5	0.66	22546.4	0.94	
			305	1.0000		1	0.0%								
			306	1.0000		1	0.0%								
342A	29+62	7.63	307	1.1670	1.150	1.125	3.7%	1.1211	187.68	24000	14476.0	0.60	20680.0	0.86	
			308	1.1410		1.125	1.4%								
			309	1.1420		1.125	1.5%								
342B	29+62	7.63	310	1.1440	1.146	1.125	1.7%	1.1375	187.68	24000	14268.2	0.59	20383.1	0.85	
			311	1.1430		1.125	1.6%								
			312	1.1510		1.125	2.3%								
342C	29+62	7.63	313	1.1380	1.159	1.125	1.2%	1.1038	187.68	24000	14703.2	0.61	21004.6	0.88	

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material Stress (psi)[1]	Base Material Stress Ratio[2]	At Joints Stress (psi)[3]	At Joints Stress Ratio[4]	Notes
			314	1.1910		1.125	5.9%								
			315	1.1480		1.125	2.0%								
354A	30+59	7.63	316	1.1640	1.179	1.125	3.5%	1.1519	176.41	24000	14477.2	0.60	20681.7	0.86	
			317	1.1810		1.125	5.0%								
			318	1.1910		1.125	5.9%								
354B	30+59	7.63	319	1.1590	1.172	1.125	3.0%	1.1424	176.41	24000	14597.8	0.61	20854.0	0.87	
			320	1.1690		1.125	3.9%								
			321	1.1890		1.125	5.7%								
354C	30+59	7.63	322	1.1690	1.176	1.125	3.9%	1.1637	176.41	24000	14330.1	0.60	20471.6	0.85	
			323	1.1790		1.125	4.8%								
			324	1.1810		1.125	5.0%								
364A	31+43	7.63	325	1.2640	1.267	1.1875	6.4%	1.2607	154.85	24000	13906.2	0.58	19865.9	0.83	
			326	1.2700		1.1875	6.9%								
			327	1.2660		1.1875	6.6%								
364B	31+43	7.63	328	1.2420	1.228	1.1875	4.6%	1.2051	154.85	24000	14547.3	0.61	20781.9	0.87	
			329	1.2210		1.1875	2.8%								
			330	1.2220		1.1875	2.9%								
364C	31+43	7.63	331	1.2360	1.229	1.1875	4.1%	1.2130	154.85	24000	14453.3	0.60	20647.5	0.86	
			332	1.2310		1.1875	3.7%								
			333	1.2200		1.1875	2.7%								
372A	32+13	7.63	334	1.3130	1.316	1.25	5.0%	1.3067	140.55	24000	13850.8	0.58	19786.8	0.82	
			335	1.3220		1.25	5.8%								
			336	1.3140		1.25	5.1%								
372B	32+13	7.63	337	1.3180	1.316	1.25	5.4%	1.2961	140.55	24000	13963.6	0.58	19948.0	0.83	
			338	1.3050		1.25	4.4%								
			339	1.3250		1.25	6.0%								
372C	32+13	7.63	340	1.3120	1.320	1.25	5.0%	1.3063	140.55	24000	13854.4	0.58	19791.9	0.82	
			341	1.3220		1.25	5.8%								
			342	1.3250		1.25	6.0%								
381A	32+97	7.63	343	1.3890	1.395	1.3125	5.8%	1.3729	123.39	24000	13678.1	0.57	19540.1	0.81	
			344	1.4080		1.3125	7.3%								
			345	1.3880		1.3125	5.8%								
381B	32+97	7.63	346	1.3890	1.395	1.3125	5.8%	1.3829	123.39	24000	13579.8	0.57	19399.7	0.81	
			347	1.3940		1.3125	6.2%								
			348	1.4010		1.3125	6.7%								
381C	32+97	7.63	349	1.3900	1.373	1.3125	5.9%	1.3133	123.39	24000	14298.7	0.60	20426.7	0.85	
			350	1.3920		1.3125	6.1%								
			351	1.3380		1.3125	1.9%								
391A	33+89	7.63	352	1.3580	1.362	1.375	-1.2%	1.3516	104.59	24000	14444.9	0.60	20635.6	0.86	
			353	1.3680		1.375	-0.5%								
			354	1.3600		1.375	-1.1%								
391B	33+89	7.63	355	1.3630	1.362	1.375	-0.9%	1.3601	104.59	24000	14355.3	0.60	20507.5	0.85	
			356	1.3630		1.375	-0.9%								
			357	1.3610		1.375	-1.0%								
391C	33+89	7.63	358	1.3610	1.360	1.375	-1.0%	1.3543	104.59	24000	14415.9	0.60	20594.2	0.86	
			359	1.3570		1.375	-1.3%								
			360	1.3630		1.375	-0.9%								
399A	34+60	7.63	361	1.4370	1.444	1.375	4.5%	1.4251	90.08	24000	14103.8	0.59	20148.3	0.84	
			362	1.4550		1.375	5.8%								
			363	1.4400		1.375	4.7%								
399B	34+60	7.63	364	1.4380	1.434	1.375	4.6%	1.4236	90.08	24000	14118.4	0.59	20169.1	0.84	
			365	1.4360		1.375	4.4%								
			366	1.4280		1.375	3.9%								
399C	34+60	7.63	367	1.4290	1.433	1.375	3.9%	1.4258	90.08	24000	14097.1	0.59	20138.7	0.84	
			368	1.4360		1.375	4.4%								
			369	1.4330		1.375	4.2%								

Notes:

[1] Hoop stress = $Pr/t_{97.5}$ 3.1%

[2] Hoop stress / S_A

[3] Hoop stress / $0.7_{\text{joint efficiency}}$ -2.7%

[4] Joint stress / S_A

TABLE 2 - Full Supply Level (FSL) Including Transient (X 1.3)

PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	(per Penstock #2 assessment)
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
INTERIOR															
From Upstream End of Conduit															
1A	0+00	8.50	1	0.5180	0.517	0.5	3.6%	0.5066	549.50	17000	5387.5	0.32	7696.4	0.45	A285 Steel (grade unknown)
			2	0.5210		0.5	4.2%								
			3	0.5110		0.5	2.2%								
1B	0+00	8.50	4	0.5210	0.525	0.5	4.2%	0.5165	549.50	17000	5284.4	0.31	7549.1	0.44	
			5	0.5250		0.5	5.0%								
			6	0.5300		0.5	6.0%								
1C	0+00	8.50	7	0.5260	0.519	0.5	5.2%	0.5044	549.50	17000	5411.5	0.32	7730.7	0.45	
			8	0.5210		0.5	4.2%								
			9	0.5110		0.5	2.2%								
10A	00+81	8.50	10	0.5360	0.544	0.5	7.2%	0.5299	549.50	17000	5151.0	0.30	7358.6	0.43	
			11	0.5500		0.5	10.0%								
			12	0.5460		0.5	9.2%								
10B	00+81	8.50	13	0.5410	0.532	0.5	8.2%	0.5153	549.50	17000	5296.1	0.31	7565.9	0.45	
			14	0.5250		0.5	5.0%								
			15	0.5290		0.5	5.8%								
10C	00+81	8.50	16	0.5250	0.516	0.5	5.0%	0.4993	549.50	17000	5465.8	0.32	7808.3	0.46	
			17	0.5130		0.5	2.6%								
			18	0.5090		0.5	1.8%								
20A	01+63	8.50	19	0.4460	0.446	0.4375	1.9%	0.4368	549.50	17000	6248.1	0.37	8925.9	0.53	
			20	0.4500		0.4375	2.9%								
			21	0.4410		0.4375	0.8%								
20B	01+63	8.50	22	0.4480	0.447	0.4375	2.4%	0.4444	549.50	17000	6141.6	0.36	8773.7	0.52	
			23	0.4460		0.4375	1.9%								
			24	0.4460		0.4375	1.9%								
20C	01+63	8.50	25	0.4520	0.449	0.4375	3.3%	0.4427	549.50	17000	6165.5	0.36	8807.9	0.52	
			26	0.4460		0.4375	1.9%								
			27	0.4480		0.4375	2.4%								
30A	02+35	8.50	28	0.4610	0.471	0.4375	5.4%	0.4443	546.8201	17000	6488.9	0.38	9269.9	0.55	
			29	0.4860		0.4375	11.1%								
			30	0.4650		0.4375	6.3%								
30B	02+35	8.50	31	0.4940	0.467	0.4375	12.9%	0.4062	546.8201	17000	7099.1	0.42	10141.6	0.60	
			32	0.4750		0.4375	8.6%								
			33	0.4330		0.4375	-1.0%								
30C	02+35	8.50	34	0.4330	0.440	0.4375	-1.0%	0.4266	546.8201	17000	6759.4	0.40	9656.3	0.57	
			35	0.4470		0.4375	2.2%								
			36	0.4410		0.4375	0.8%								
40A	03+23	8.50	37	0.4470	0.444	0.4375	2.2%	0.4251	536.1772	17000	8220.5	0.48	11743.6	0.69	
			38	0.4510		0.4375	3.1%								
			39	0.4330		0.4375	-1.0%								
40B	03+23	8.50	40	0.4510	0.444	0.4375	3.1%	0.4251	536.1772	17000	8221.3	0.48	11744.8	0.69	
			41	0.4330		0.4375	-1.0%								
			42	0.4480		0.4375	2.4%								
40C	03+23	8.50	43	0.4760	0.473	0.4375	8.8%	0.4678	536.1772	17000	7470.7	0.44	10672.4	0.63	
			44	0.4710		0.4375	7.7%								
			45	0.4720		0.4375	7.9%								
48A	03+92	8.50	46	0.4520	0.454	0.4375	3.3%	0.4462	527.7817	17000	8912.8	0.52	12732.5	0.75	
			47	0.4510		0.4375	3.1%								
			48	0.4580		0.4375	4.7%								
48B	03+92	8.50	49	0.4560	0.459	0.4375	4.2%	0.4386	527.7817	17000	9069.2	0.53	12955.9	0.76	
			50	0.4500		0.4375	2.9%								
			51	0.4700		0.4375	7.4%								
48C	03+92	8.50	52	0.4640	0.466	0.4375	6.1%	0.4449	527.7817	17000	8939.9	0.53	12771.2	0.75	
			53	0.4770		0.4375	9.0%								
			54	0.4560		0.4375	4.2%								
58A	04+82	8.50	55	0.4190	0.426	0.4375	-4.2%	0.4119	516.9473	17000	11167.3	0.66	15953.3	0.94	
			56	0.4250		0.4375	-2.9%								
			57	0.4330		0.4375	-1.0%								
58B	04+82	8.50	58	0.4400	0.450	0.4375	0.6%	0.4248	516.9473	17000	10829.4	0.64	15470.6	0.91	
			59	0.4460		0.4375	1.9%								
			60	0.4650		0.4375	6.3%								
58C	04+82	8.50	61	0.4390	0.450	0.4375	0.3%	0.4315	516.9473	17000	10661.2	0.63	15230.3	0.90	
			62	0.4540		0.4375	3.8%								
			63	0.4560		0.4375	4.2%								
69A	05+75	8.50	64	0.4410	0.447	0.4375	0.8%	0.4169	509.73	17000	12026.2	0.71	17180.3	1.01	
			65	0.4360		0.4375	-0.3%								
			66	0.4650		0.4375	6.3%								
69B	05+75	8.50	67	0.4530	0.448	0.4375	3.5%	0.4342	509.73	17000	11549.6	0.68	16499.4	0.97	
			68	0.4520		0.4375	3.3%								

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			69	0.4400		0.4375	0.6%								
69C	05+75	8.50	70	0.4510	0.455	0.4375	3.1%	0.4472	509.73	17000	11213.6	0.66	16019.5	0.94	
			71	0.4550		0.4375	4.0%								
			72	0.4590		0.4375	4.9%								
79A	06+64	8.50	73	0.4310	0.432	0.4375	-1.5%	0.4278	509.02	17000	11817.3	0.70	16881.8	0.99	
			74	0.4310		0.4375	-1.5%								
			75	0.4350		0.4375	-0.6%								
79B	06+64	8.50	76	0.4420	0.440	0.4375	1.0%	0.4347	509.02	17000	11629.0	0.68	16612.8	0.98	
			77	0.4400		0.4375	0.6%								
			78	0.4370		0.4375	-0.1%								
79C	06+64	8.50	79	0.4430	0.445	0.4375	1.3%	0.4338	509.02	17000	11652.7	0.69	16646.7	0.98	
			80	0.4520		0.4375	3.3%								
			81	0.4410		0.4375	0.8%								
89A	07+52	8.50	82	0.5030	0.507	0.4375	15.0%	0.4873	508.32	17000	10456.3	0.62	14937.5	0.88	
			83	0.5000		0.4375	14.3%								
			84	0.5190		0.4375	18.6%								
89B	07+52	8.50	85	0.5270	0.518	0.4375	20.5%	0.4889	508.32	17000	10422.1	0.61	14888.7	0.88	
			86	0.5270		0.4375	20.5%								
			87	0.5010		0.4375	14.5%								
89C	07+52	8.50	88	0.5380	0.531	0.4375	23.0%	0.5160	508.32	17000	9875.8	0.58	14108.3	0.83	
			89	0.5230		0.4375	19.5%								
			90	0.5310		0.4375	21.4%								
101A	08+41	8.50	91	0.4360	0.436	0.4375	-0.3%	0.4295	503.32	17000	12534.4	0.74	17906.3	1.05	
			92	0.4330		0.4375	-1.0%								
			93	0.4400		0.4375	0.6%								
101B	08+41	8.50	94	0.4460	0.446	0.4375	1.9%	0.4192	503.32	17000	12840.9	0.76	18344.1	1.08	
			95	0.4590		0.4375	4.9%								
			96	0.4320		0.4375	-1.3%								
101C	08+41	8.50	97	0.4290	0.436	0.4375	-1.9%	0.4239	503.32	17000	12699.0	0.75	18141.4	1.07	
			98	0.4400		0.4375	0.6%								
			99	0.4400		0.4375	0.6%								
120A	10+34	8.50	100	0.4700	0.462	0.4375	7.4%	0.4476	484.81	24000	14402.0	0.60	20574.2	0.86	CSA G40.8 Grade B Steel
			101	0.4620		0.4375	5.6%								
			102	0.4550		0.4375	4.0%								
120B	10+34	8.50	103	0.4620	0.440	0.4375	5.6%	0.4007	484.81	24000	16086.6	0.67	22980.9	0.96	
			104	0.4330		0.4375	-1.0%								
			105	0.4240		0.4375	-3.1%								
120C	10+34	8.50	106	0.4250	0.429	0.4375	-2.9%	0.4186	484.81	24000	15399.4	0.64	21999.2	0.92	
			107	0.4270		0.4375	-2.4%								
			108	0.4350		0.4375	-0.6%								
123A	10+64	8.50	109	0.4440	0.460	0.4375	1.5%	0.4317	481.94	24000	15313.5	0.64	21876.5	0.91	
			110	0.4640		0.4375	6.1%								
			111	0.4720		0.4375	7.9%								
123B	10+64	8.50	112	0.4600	0.447	0.4375	5.1%	0.4239	481.94	24000	15594.7	0.65	22278.1	0.93	
			113	0.4410		0.4375	0.8%								
			114	0.4390		0.4375	0.3%								
123C	10+64	8.50	115	0.4330	0.443	0.4375	-1.0%	0.4237	481.94	24000	15603.8	0.65	22291.2	0.93	
			116	0.4440		0.4375	1.5%								
			117	0.4530		0.4375	3.5%								
131A	11+29	8.50	118	0.4560	0.461	0.4375	4.2%	0.4395	475.80	24000	15844.6	0.66	22635.1	0.94	
			119	0.4530		0.4375	3.5%								
			120	0.4730		0.4375	8.1%								
131B	11+29	8.50	121	0.4380	0.446	0.4375	0.1%	0.4196	475.80	24000	16595.4	0.69	23707.8	0.99	
			122	0.4380		0.4375	0.1%								
			123	0.4610		0.4375	5.4%								
131C	11+29	8.50	124	0.4330	0.429	0.4375	-1.0%	0.4219	475.80	24000	16505.2	0.69	23578.9	0.98	
			125	0.4260		0.4375	-2.6%								
			126	0.4280		0.4375	-2.2%								
139A	11+97	8.50	127	0.4250	0.427	0.4375	-2.9%	0.4210	469.30	24000	17427.2	0.73	24896.1	1.04	
			128	0.4260		0.4375	-2.6%								
			129	0.4310		0.4375	-1.5%								
139B	11+97	8.50	130	0.4310	0.420	0.4375	-1.5%	0.3877	469.30	24000	18923.6	0.79	27033.7	1.13	
			131	0.4010		0.4375	-8.3%								
			132	0.4270		0.4375	-2.4%								
139C	11+97	8.50	133	0.4460	0.432	0.4375	1.9%	0.4064	469.30	24000	18055.2	0.75	25793.2	1.07	
			134	0.4280		0.4375	-2.2%								
			135	0.4210		0.4375	-3.8%								
148A	12+50	7.63	136	0.4380	0.438	0.4375	0.1%	0.4334	463.47	24000	15880.6	0.66	22686.6	0.95	
			137	0.4360		0.4375	-0.3%								
			138	0.4410		0.4375	0.8%								
148B	12+50	7.63	139	0.4470	0.444	0.4375	2.2%	0.4247	463.47	24000	16206.1	0.68	23151.6	0.96	
			140	0.4520		0.4375	3.3%								
			141	0.4330		0.4375	-1.0%								
148C	12+50	7.63	142	0.4150	0.416	0.4375	-5.1%	0.4082	463.47	24000	16862.1	0.70	24088.8	1.00	
			143	0.4210		0.4375	-3.8%								
			144	0.4130		0.4375	-5.6%								
168A	14+29	7.63	145	0.4920	0.493	0.5	-1.6%	0.4743	417.44	24000	19513.4	0.81	27876.3	1.16	
			146	0.5030		0.5	0.6%								
			147	0.4840		0.5	-3.2%								
168B	14+29	7.63	148	0.4900	0.491	0.5	-2.0%	0.4808	417.44	24000	19249.6	0.80	27499.5	1.15	

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			149	0.4960		0.5	-0.8%								
			150	0.4860		0.5	-2.8%								
168C	14+29	7.63	151	0.5140	0.502	0.5	2.8%	0.4807	417.44	24000	19253.3	0.80	27504.8	1.15	
			152	0.4960		0.5	-0.8%								
			153	0.4950		0.5	-1.0%								
170A	14+49	7.63	154	0.5030	0.499	0.5	0.6%	0.4745	412.30	24000	20063.1	0.84	28661.6	1.19	
			155	0.5090		0.5	1.8%								
			156	0.4850		0.5	-3.0%								
170B	14+49	7.63	157	0.4640	0.469	0.5	-7.2%	0.4401	412.30	24000	21631.9	0.90	30902.8	1.29	
			158	0.4570		0.5	-8.6%								
			159	0.4850		0.5	-3.0%								
170C	14+49	7.63	160	0.4850	0.462	0.5	-3.0%	0.4191	412.30	24000	22717.8	0.95	32454.0	1.35	
			161	0.4580		0.5	-8.4%								
			162	0.4420		0.5	-11.6%								
180A	15+40	7.63	163	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	19087.0	0.80	27267.2	1.14	
			164	0.5625		0.5625	0.0%								
			165	0.5625		0.5625	0.0%								
180B	15+40	7.63	166	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	19087.0	0.80	27267.2	1.14	
			167	0.5625		0.5625	0.0%								
			168	0.5625		0.5625	0.0%								
180C	15+40	7.63	169	0.5625	0.563	0.5625	0.0%	0.5625	388.71	24000	19087.0	0.80	27267.2	1.14	
			170	0.5625		0.5625	0.0%								
			171	0.5625		0.5625	0.0%								
192A	16+35	7.63	172	0.5870	0.593	0.5625	4.4%	0.5767	372.46	24000	20070.3	0.84	28671.9	1.19	
			173	0.5900		0.5625	4.9%								
			174	0.6030		0.5625	7.2%								
192B	16+35	7.63	175	0.6190	0.611	0.5625	10.0%	0.5949	372.46	24000	19453.6	0.81	27790.8	1.16	
			176	0.6100		0.5625	8.4%								
			177	0.6030		0.5625	7.2%								
192C	16+35	7.63	178	0.5980	0.608	0.5625	6.3%	0.5841	372.46	24000	19813.3	0.83	28304.8	1.18	
			179	0.6220		0.5625	10.6%								
			180	0.6050		0.5625	7.6%								
201A	17+17	7.63	181	0.6590	0.657	0.5625	17.2%	0.6376	365.43	24000	18719.5	0.78	26742.1	1.11	
			182	0.6650		0.5625	18.2%								
			183	0.6460		0.5625	14.8%								
201B	17+17	7.63	184	0.6660	0.653	0.5625	18.4%	0.6309	365.43	24000	18918.8	0.79	27026.8	1.13	
			185	0.6460		0.5625	14.8%								
			186	0.6470		0.5625	15.0%								
201C	17+17	7.63	187	0.6660	0.658	0.5625	18.4%	0.6414	365.43	24000	18608.4	0.78	26583.5	1.11	
			188	0.6600		0.5625	17.3%								
			189	0.6490		0.5625	15.4%								
210A	17+97	7.63	190	0.6450	0.648	0.625	3.2%	0.6353	358.58	24000	19345.0	0.81	27635.7	1.15	
			191	0.6560		0.625	5.0%								
			192	0.6440		0.625	3.0%								
210B	17+97	7.63	193	0.6560	0.654	0.625	5.0%	0.6360	358.58	24000	19322.1	0.81	27602.9	1.15	
			194	0.6620		0.625	5.9%								
			195	0.6440		0.625	3.0%								
210C	17+97	7.63	196	0.6460	0.648	0.625	3.4%	0.6404	358.58	24000	19190.0	0.80	27414.3	1.14	
			197	0.6530		0.625	4.5%								
			198	0.6460		0.625	3.4%								
220A	18+89	7.63	199	0.6200	0.632	0.625	-0.8%	0.6114	350.69	24000	20766.3	0.87	29666.1	1.24	
			200	0.6380		0.625	2.1%								
			201	0.6390		0.625	2.2%								
220B	18+89	7.63	202	0.6370	0.631	0.625	1.9%	0.6108	350.69	24000	20784.5	0.87	29692.2	1.24	
			203	0.6190		0.625	-1.0%								
			204	0.6360		0.625	1.8%								
220C	18+89	7.63	205	0.6440	0.637	0.625	3.0%	0.5946	350.69	24000	21350.5	0.89	30500.7	1.27	
			206	0.6130		0.625	-1.9%								
			207	0.6550		0.625	4.8%								
228A	19+50	7.63	208	0.6460	0.642	0.625	3.4%	0.6299	345.46	24000	20583.9	0.86	29405.6	1.23	
			209	0.6350		0.625	1.6%								
			210	0.6460		0.625	3.4%								
228B	19+50	7.63	211	0.6530	0.652	0.625	4.5%	0.6500	345.46	24000	19945.7	0.83	28493.8	1.19	
			212	0.6510		0.625	4.2%								
			213	0.6520		0.625	4.3%								
228C	19+50	7.63	214	0.6290	0.650	0.625	0.6%	0.6133	345.46	24000	21141.1	0.88	30201.6	1.26	
			215	0.6650		0.625	6.4%								
			216	0.6570		0.625	5.1%								
240A	20+62	7.63	217	0.7550	0.743	0.6875	9.8%	0.7235	326.28	24000	19287.2	0.80	27553.1	1.15	
			218	0.7380		0.6875	7.3%								
			219	0.7370		0.6875	7.2%								
240B	20+62	7.63	220	0.7400	0.697	0.6875	7.6%	0.6222	326.28	24000	22428.3	0.93	32040.4	1.34	
			221	0.6810		0.6875	-0.9%								
			222	0.6690		0.6875	-2.7%								
240C	20+62	7.63	223	0.7250	0.714	0.6875	5.5%	0.6606	326.28	24000	21122.3	0.88	30174.7	1.26	
			224	0.7340		0.6875	6.8%								
			225	0.6830		0.6875	-0.7%								
250A	21+50	7.63	226	0.7950	0.778	0.75	6.0%	0.7460	310.57	24000	19791.3	0.82	28273.3	1.18	
			227	0.7630		0.75	1.7%								
			228	0.7750		0.75	3.3%								

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
250B	21+50	7.63	229	0.7790	0.770	0.75	3.9%	0.7501	310.57	24000	19682.4	0.82	28117.8	1.17	
			230	0.7720		0.75	2.9%								
			231	0.7590		0.75	1.2%								
250C	21+50	7.63	232	0.7310	0.756	0.75	-2.5%	0.7133	310.57	24000	20697.2	0.86	29567.4	1.23	
			233	0.7690		0.75	2.5%								
			234	0.7690		0.75	2.5%								
264A	22+76	7.63	235	0.8820	0.879	0.875	0.8%	0.8738	288.98	24000	18169.7	0.76	25956.8	1.08	Downstream of surge tank
			236	0.8780		0.875	0.3%								
			237	0.8770		0.875	0.2%								
264B	22+76	7.63	238	0.8750	0.870	0.875	0.0%	0.8592	288.98	24000	18479.1	0.77	26398.6	1.10	
			239	0.8640		0.875	-1.3%								
			240	0.8720		0.875	-0.3%								
264C	22+76	7.63	241	0.9000	0.891	0.875	2.9%	0.8602	288.98	24000	18457.3	0.77	26367.6	1.10	
			242	0.8730		0.875	-0.2%								
			243	0.9010		0.875	3.0%								
271A	23+26	7.63	244	0.7640	0.767	0.75	1.9%	0.7618	280.16	24000	21437.4	0.89	30624.9	1.28	
			245	0.7690		0.75	2.5%								
			246	0.7680		0.75	2.4%								
271B	23+26	7.63	247	0.7920	0.787	0.75	5.6%	0.7785	280.16	24000	20978.1	0.87	29968.7	1.25	
			248	0.7830		0.75	4.4%								
			249	0.7870		0.75	4.9%								
271C	23+26	7.63	250	0.8120	0.795	0.75	8.3%	0.7454	280.16	24000	21909.9	0.91	31299.8	1.30	
			251	0.8080		0.75	7.7%								
			252	0.7660		0.75	2.1%								
280A	24+07	7.63	253	0.8350	0.827	0.815	2.5%	0.8134	265.74	24000	20991.4	0.87	29987.8	1.25	
			254	0.8230		0.815	1.0%								
			255	0.8230		0.815	1.0%								
280B	24+07	7.63	256	0.8250	0.817	0.815	1.2%	0.8009	265.74	24000	21318.4	0.89	30454.8	1.27	
			257	0.8160		0.815	0.1%								
			258	0.8090		0.815	-0.7%								
280C	24+07	7.63	259	0.8170	0.839	0.815	0.2%	0.7701	265.74	24000	22171.1	0.92	31673.0	1.32	
			260	0.8790		0.815	7.9%								
			261	0.8200		0.815	0.6%								
292A	25+16	7.63	262	0.8800	0.885	0.875	0.6%	0.8653	246.33	24000	20888.5	0.87	29840.7	1.24	
			263	0.8780		0.875	0.3%								
			264	0.8960		0.875	2.4%								
292B	25+16	7.63	265	0.8850	0.887	0.875	1.1%	0.8833	246.33	24000	20464.6	0.85	29235.1	1.22	
			266	0.8880		0.875	1.5%								
			267	0.8890		0.875	1.6%								
292C	25+16	7.63	268	0.9010	0.888	0.875	3.0%	0.8647	246.33	24000	20903.7	0.87	29862.5	1.24	
			269	0.8790		0.875	0.5%								
			270	0.8830		0.875	0.9%								
302A	26+07	7.63	271	0.8860	0.865	0.875	1.3%	0.8280	230.14	24000	22838.3	0.95	32626.2	1.36	
			272	0.8570		0.875	-2.1%								
			273	0.8510		0.875	-2.7%								
302B	26+07	7.63	274	0.8280	0.849	0.875	-5.4%	0.8133	230.14	24000	23249.4	0.97	33213.5	1.38	
			275	0.8600		0.875	-1.7%								
			276	0.8590		0.875	-1.8%								
302C	26+07	7.63	277	0.8460	0.863	0.875	-3.3%	0.8190	230.14	24000	23090.0	0.96	32985.7	1.37	
			278	0.8540		0.875	-2.4%								
			279	0.8880		0.875	1.5%								
313A	27+06	7.63	280	0.9650	0.967	0.935	3.2%	0.9502	217.43	24000	20590.0	0.86	29414.2	1.23	
			281	0.9770		0.935	4.5%								
			282	0.9600		0.935	2.7%								
313B	27+06	7.63	283	0.9780	0.978	0.935	4.6%	0.9695	217.43	24000	20180.4	0.84	28829.1	1.20	
			284	0.9740		0.935	4.2%								
			285	0.9830		0.935	5.1%								
313C	27+06	7.63	286	0.9750	0.962	0.935	4.3%	0.9370	217.43	24000	20880.1	0.87	29828.8	1.24	
			287	0.9600		0.935	2.7%								
			288	0.9500		0.935	1.6%								
322A	27+67	7.63	289	0.9930	0.992	0.935	6.2%	0.9901	210.34	24000	20130.1	0.84	28757.3	1.20	
			290	0.9910		0.935	6.0%								
			291	0.9930		0.935	6.2%								
322B	27+67	7.63	292	1.0000	0.991	0.935	7.0%	0.9747	210.34	24000	20447.4	0.85	29210.6	1.22	
			293	0.9870		0.935	5.6%								
			294	0.9850		0.935	5.3%								
322C	27+67	7.63	295	0.9800	0.994	0.935	4.8%	0.9648	210.34	24000	20656.3	0.86	29509.0	1.23	
			296	1.0100		0.935	8.0%								
			297	0.9930		0.935	6.2%								
331A	28+65	7.63	298	0.9210	0.975	1	-7.9%	0.8820	198.95	24000	23262.0	0.97	33231.4	1.38	
			299	1.0100		1	1.0%								
			300	0.9940		1	-0.6%								
331B	28+65	7.63	301	1.0000	0.996	1	0.0%	0.9892	198.95	24000	20741.0	0.86	29630.1	1.23	
			302	0.9940		1	-0.6%								
			303	0.9940		1	-0.6%								
331C	28+65	7.63	304	1.0000	1.000	1	0.0%	1.0000	198.95	24000	20517.3	0.85	29310.4	1.22	
			305	1.0000		1	0.0%								
			306	1.0000		1	0.0%								
342A	29+62	7.63	307	1.1670	1.150	1.125	3.7%	1.1211	187.68	24000	18818.8	0.78	26884.0	1.12	
			308	1.1410		1.125	1.4%								

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			309	1.1420		1.125	1.5%								
342B	29+62	7.63	310	1.1440	1.146	1.125	1.7%	1.1375	187.68	24000	18548.7	0.77	26498.1	1.10	
			311	1.1430		1.125	1.6%								
			312	1.1510		1.125	2.3%								
342C	29+62	7.63	313	1.1380	1.159	1.125	1.2%	1.1038	187.68	24000	19114.1	0.80	27305.9	1.14	
			314	1.1910		1.125	5.9%								
			315	1.1480		1.125	2.0%								
354A	30+59	7.63	316	1.1640	1.179	1.125	3.5%	1.1519	176.41	24000	18820.3	0.78	26886.2	1.12	
			317	1.1810		1.125	5.0%								
			318	1.1910		1.125	5.9%								
354B	30+59	7.63	319	1.1590	1.172	1.125	3.0%	1.1424	176.41	24000	18977.2	0.79	27110.2	1.13	
			320	1.1690		1.125	3.9%								
			321	1.1890		1.125	5.7%								
354C	30+59	7.63	322	1.1690	1.176	1.125	3.9%	1.1637	176.41	24000	18629.2	0.78	26613.1	1.11	
			323	1.1790		1.125	4.8%								
			324	1.1810		1.125	5.0%								
364A	31+43	7.63	325	1.2640	1.267	1.1875	6.4%	1.2607	154.85	24000	18078.0	0.75	25825.7	1.08	
			326	1.2700		1.1875	6.9%								
			327	1.2660		1.1875	6.6%								
364B	31+43	7.63	328	1.2420	1.228	1.1875	4.6%	1.2051	154.85	24000	18911.5	0.79	27016.5	1.13	
			329	1.2210		1.1875	2.8%								
			330	1.2220		1.1875	2.9%								
364C	31+43	7.63	331	1.2360	1.229	1.1875	4.1%	1.2130	154.85	24000	18789.3	0.78	26841.8	1.12	
			332	1.2310		1.1875	3.7%								
			333	1.2200		1.1875	2.7%								
372A	32+13	7.63	334	1.3130	1.316	1.25	5.0%	1.3067	140.55	24000	18006.0	0.75	25722.8	1.07	
			335	1.3220		1.25	5.8%								
			336	1.3140		1.25	5.1%								
372B	32+13	7.63	337	1.3180	1.316	1.25	5.4%	1.2961	140.55	24000	18152.6	0.76	25932.3	1.08	
			338	1.3050		1.25	4.4%								
			339	1.3250		1.25	6.0%								
372C	32+13	7.63	340	1.3120	1.320	1.25	5.0%	1.3063	140.55	24000	18010.7	0.75	25729.5	1.07	
			341	1.3220		1.25	5.8%								
			342	1.3250		1.25	6.0%								
381A	32+97	7.63	343	1.3890	1.395	1.3125	5.8%	1.3729	123.39	24000	17781.5	0.74	25402.2	1.06	
			344	1.4080		1.3125	7.3%								
			345	1.3880		1.3125	5.8%								
381B	32+97	7.63	346	1.3890	1.395	1.3125	5.8%	1.3829	123.39	24000	17653.7	0.74	25219.6	1.05	
			347	1.3940		1.3125	6.2%								
			348	1.4010		1.3125	6.7%								
381C	32+97	7.63	349	1.3900	1.373	1.3125	5.9%	1.3133	123.39	24000	18588.3	0.77	26554.7	1.11	
			350	1.3920		1.3125	6.1%								
			351	1.3380		1.3125	1.9%								
391A	33+89	7.63	352	1.3580	1.362	1.375	-1.2%	1.3516	104.59	24000	18778.4	0.78	26826.3	1.12	
			353	1.3680		1.375	-0.5%								
			354	1.3600		1.375	-1.1%								
391B	33+89	7.63	355	1.3630	1.362	1.375	-0.9%	1.3601	104.59	24000	18661.8	0.78	26659.8	1.11	
			356	1.3630		1.375	-0.9%								
			357	1.3610		1.375	-1.0%								
391C	33+89	7.63	358	1.3610	1.360	1.375	-1.0%	1.3543	104.59	24000	18740.7	0.78	26772.5	1.12	
			359	1.3570		1.375	-1.3%								
			360	1.3630		1.375	-0.9%								
399A	34+60	7.63	361	1.4370	1.444	1.375	4.5%	1.4251	90.08	24000	18335.0	0.76	26192.8	1.09	
			362	1.4550		1.375	5.8%								
			363	1.4400		1.375	4.7%								
399B	34+60	7.63	364	1.4380	1.434	1.375	4.6%	1.4236	90.08	24000	18353.9	0.76	26219.9	1.09	
			365	1.4360		1.375	4.4%								
			366	1.4280		1.375	3.9%								
399C	34+60	7.63	367	1.4290	1.433	1.375	3.9%	1.4258	90.08	24000	18326.2	0.76	26180.3	1.09	
			368	1.4360		1.375	4.4%								
			369	1.4330		1.375	4.2%								

Notes:

[1] Hoop stress = $Pr/t_{97.5}$

[2] Hoop stress / S_A

[3] Hoop stress / $0.7_{\text{joint efficiency}}$

[4] Joint stress / S_A

PENSTOCK NO. 1 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:

Newfoundland and Labrador Hydro

Prepared by:

Kleinschmidt Associates

September 2020

Kleinschmidt

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ACRONYMS

A	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
C	
cfs	Cubic feet per second
E	
ETS	Eastern Technical Services
F	
Fu	Ultimate Tensile Stress
G	
GWh	Gigawatt Hours
K	
kPa	Kilo-Pascals
Kleinschmidt	Kleinschmidt Associates
P	
PSI	Pounds per square inch
M	
m^3s	Cubic metres per second
MW	Megawatts
N	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
S	
STA	Station (in feet)
T	
TRR	Technical Rope and Rescue
U	
UT	Ultrasonic Thickness

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in April 2020 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

Kleinschmidt conducted an inspection of Penstock No. 1 in June 2020. Penstock No. 1 is a buried steel penstock approximately 1,100 metres long, tapering from 5.2 metres in diameter at the intake, to 4.1 metres in diameter at the powerhouse bifurcation. At its flattest point, the penstock has a 0.2-degree slope and has a slope of 19.7 degrees at its steepest. There are at least three areas of access for Penstock No. 1: one at the well in the intake structure, five manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Due to the weld issues and corrosion in all three penstocks, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock No. 1 inspection was to assess the integrity of the welds and to complete steel thickness measurements to evaluate current conditions and potential life extension of the penstock. This year's inspection concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected last year in the upper end of the penstock

Kleinschmidt's June 2020 inspection of Penstock No. 1 consisted of an inspection of the repaired crack areas in Penstock No. 1, a detailed examination of the condition of the interior of the penstock, and a visual walk-over of the penstock exterior. The exterior of Penstock No. 3 was also inspected at this time as the internal inspection had been canceled in May due to Covid concerns. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which included cleaning and visually inspecting the steel shell and the longitudinal and circumferential welds. The interior inspection also included non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell.

Overall, the penstock plating was in fair condition. The penstock has not significantly ovalized, the plate thickness was comparable to the construction drawings, and the interior of the shell has a layer of rust with moderate corrosion and pitting common for a 50-year-old penstock. The penstock welds are in fair to poor condition depending on location with the old/original welds upstream of the surge tank being in poor condition and the old welds downstream of the surge tank generally in fair condition. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3. The new welds (within the last 4 years) were in good condition with no significant deterioration noted, only light surface rust. No significant changes were noted compared to last years inspection.

The exterior inspection found no areas of significant concern along the Penstock 1 alignment. The exterior inspection of Penstock No. 3 found some drains that should be cleaned to insure accurate flow monitoring. During the inspection a leaking transducer was discovered on Penstock No. 2 at the monitoring point adjacent to Station 0+900 downstream of the surge tank. Ray Buffett was notified and shown the issue. The leak did not present threat to the integrity of the penstock and was repaired after the inspection and before this report was completed.

The exterior inspection found no areas of significant concern along the Penstock 1 alignment.

Measurements of the penstock shell thickness indicate minimal loss of material. Some mild to moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the plating of the penstock should have significant service life remaining that could be extended another 50 to 80 years with an internal coating. However, the welds do not meet current standards and there have been multiple weld related failures over the last 4 years indicating the welds are at the end of their useful life.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.42 at the joints. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.1, which is not acceptable for late 1960 steel pipe. Note that this is stress at the joints, and assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency alone would result in favourable factors of safety; however, considering the known weld issues, a higher joint efficiency is not justified at this time. A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This could be completed in 2021 and 2022 to better understand the risks.

The base plate material away from the joints has a maximum stress ratio of 1.0 and a safety factor of 1.59, which is acceptable and could tolerate about 2 mm of material loss from design thickness in most cases.

This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070), provided that the penstock welds are replaced and the interior is coated before the steel deteriorates further and is adequately maintained and monitored. Replacing the welds from the inside of the penstock only may not fully mitigate the issues, and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 5 years. It is our understanding that NLH is planning to proceed with replacing the 17 ft diameter portion of the penstock located at the upstream end and refurbish the remainder of the welds. It is our opinion that this is an acceptable refurbishment and repair plan that will help realize the remainder of the penstocks expected service life (about 50 more years).

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in April 2020 to inspect and evaluate the condition of Penstock No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development (the Project). The May inspection of Penstock No. 3 was subsequently cancelled due to Covid-19 concerns.

In 2016, cracking was identified in Penstock No. 1 due to weld degradation and Kleinschmidt was contracted to assist with the weld repair design. Another crack in Penstock No. 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods and significant refurbishment of the welds followed.

Penstock No. 1 was installed in 1967, at the same time as Penstock No. 2, and before installation of Penstock No. 3 in 1968. Penstock No. 1 has similar plate materials, thicknesses, and weld procedures as Penstock No. 2 and 3. The cracking and weld issues found in Penstock No. 1 in 2016 raised concerns about weld integrity of Penstocks No. 2 and 3 and NLH elected to have Kleinschmidt complete detailed inspections of Penstock No. 2 in 2016 and Penstock No. 3 in 2017. The main focus of the previous inspections was to assess the integrity of the welds and to complete steel thickness measurements to evaluate potential life extension of the penstock and appurtenances. Non-destructive testing of the welds was not part of the 2016 and 2017 Kleinschmidt scope of work, but the welds of Penstocks No.1, 2, and 3 were inspected and tested using magnetic partical testing (MT) methods in 2018 as part of a Level II Condition Assessment performed by Hatch. The Hatch report references multiple ruptures in longitudinal seams in Penstock No. 1 upstream of the surge tank, as well as degradation and repairs to various welds in Penstock No. 1, 2, and 3.

A new weld failure in Penstock No. 1 resulting in a leak was detected by NLH on September 22, 2019. The penstock was dewatered and Kleinschmidt carried out an inspection from September 25-27, 2019. The leak was repaired by cutting out the welded area and welding in a replacement plate. This is a little different than the doubler plates used on other repaired welds and was made possible by excavating out the exterior of the pipe.

This report presents Kleinschmidt's evaluation of Penstock No. 1 in its current condition following significant weld repairs made in 2016 and subsequent years and with consideration of the latest weld failure, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 feet (176 metres) and seven generating units with a total capacity of 604 megawatts (MW). The development comprises four structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks No. 1, 2, and 3 have surge towers approximately 2,400 feet (727 metres) upstream of the powerhouse. The first phase of the project construction involved the installation of two intake structures (Intake 1 and Intake 2) and a four-unit powerhouse with Penstocks No. 1 and 2 connecting the two. The second phase consisted of installing Penstock No. 3, along with two additional units in the powerhouse, and a separate intake structure and powerhouse for Unit No. 7, connected by Penstock No. 4 in 1970. Penstock No. 1 supplies Units No. 1 and 2. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock No. 1 is buried along its entire length from the intake to the powerhouse. There are four original manholes; one manhole upstream of a turbine-isolation valve inside the powerhouse, and three larger manholes on the crown of the penstock: (1) approximately halfway between the powerhouse and surge tower, (2) at the surge tower, and (3) halfway between the intake and the surge tower. There are two newer manholes added at the upstream end both upstream of the original upstream most manhole. A majority of the penstock has a cover of 2 feet (0.61 metres) of clayey soil and 1 foot (0.30 metres) minimum of riprap. The penstock is deeply buried as it crosses under the switchyard and goes into the powerhouse. The penstock has drainage along its length with several weirs where the drainage daylights to the ditches and wells for inspection and monitoring.

Appendix A includes the original 1965 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 11 millimetres (0.4375 inches) at the intake to 41 millimetres (1.625 inches) at the powerhouse. The penstock is constructed of A285 grade steel for the first 1,015 feet, and CSA G40.8 Grade B for the remainder of the penstock. The welds are generally double V groove full penetration welds. The penstock slope varies from approximately 0.2 degrees to 19.7 degrees just upstream of the bifurcation.

3.0 INSPECTION

Christopher Vella, P.Eng. of Kleinschmidt, inspected the interior and exterior of Penstock No. 1 on June 22 thru June 25, 2020, with the assistance of personnel from Technical Rope and Rescue (TRR), Eastern Technical Services (ETS), and NLH. Ray Buffett of NLH participated in safety talks and assisted with site access and communication. NLH also answered questions about the history, operation, and maintenance of the station. ETS assisted with the UT and MT testing of the penstock.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying any pitting or cracking, and an overall general condition assessment of the interior of the shell. The exterior of the buried penstock was examined for signs of leakage. ETS personnel performed MT weld tests on approximately 10% of the longitudinal welds from inside the penstock and took ultrasonic thickness (UT) measurements from approximately 10% of the cans[1] for the penstock. The field data is included in Appendices C and D, respectively.

Table 3-1 Definitions

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible and remediation is required within 1 year

[1] A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on site in the afternoon of Monday June 22, 2020. The inspection team entered the penstock on Tuesday, June 23, 2020 at the upstream most open manhole of Penstock No. 1 and walked to the intake gate to start the inspection. TRR assisted with confined space entrance. The internal inspection was completed on Thursday June 25, 2020. The exterior inspection was started and completed on Wednesday June 24, 2020 and was performed by Kleinschmidt. Kleinschmidt pre-marked welds to be inspected inside the pipe so that TRR and ETS could continue the internal inspection while Kleinschmidt performed the external inspection. Air quality in the penstock remained good for the duration of the inspection.

The internal inspection started at the headgate. Leakage around the gate was mainly from the right and left bottom corners as seen in Photos 1 and 2, Appendix B, with some leakage also from the bottom left corner. Concrete deterioration at the concrete to steel transition (Photo 3), notably more extensive than at other Bay d'Espoir penstocks, has resulted in the leading edge of steel exposed all the way around but worse in the lower left area. The interior surface of the penstock was moist but not as wet as in 2019. The penstock was dewatered more than a week prior and had a chance to dry some. Much of the organics had been cleaned away during the previous penstock repairs and inspections which facilitated the inspection upstream of the surge tank. The penstock had more organic buildup present downstream of the surge tank as less work has been done downstream and this slowed the inspection team some as more time was required to clean welds that had never been cleaned before.

The penstock has varying slopes with two main steep sections. The penstock slopes range from 0.2 degrees to 11 degrees along most of its length, but just upstream of the surge tank there is a section with a 14-degree slope for approximately 110 metres (361 feet) and just upstream of the powerhouse the penstock has a 19.7-degree slope for approximately 58 metres (190 feet) as noted in Appendix A. The slope levels out as the penstock enters the powerhouse.

The exterior of the penstock was inspected on June 24, 2020. The ground surface was generally rock covered with steep slopes in many areas and short vegetation. The ground was reasonably dry limiting slip potential. The grade nominally followed the penstock slope between the intake and the switchyard. Deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

The interior of the penstock was inspected from June 23 to June 25, 2020. The penstock was fabricated with about 435 "Cans". A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location in the penstock during the inspection with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded from the interior at various locations. Shell thickness measurements were taken with a Krautkramer DMS 2 Ultrasonic thickness gauge. A dual element D799 transducer was used and the readings were taken in the "standard" mode. In "standard" mode the paint thickness does not affect the steel thickness readings if the paint thickness is below 1/64 (0.0156) inch (15.6 mils). The gauge was calibrated before the field measurements to an accuracy of 0.001 inch. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, this evaluation did so as well. Metric equivalents are given in parenthesis.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the pipe. All references to penstock left and right are also oriented looking downstream. Appendix D provides the ETS report of shell thickness readings, and Table D-1 and Table D-2 in Appendix D summarizes the average shell thickness readings and stresses respectively for each section of penstock. A summary of this data is provided in Table 4-1. A list of welds inspected over the last few years is contained in Appednix F.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

The interior of the penstock is generally in fair condition with scattered moderate corrosion and pitting with tubercles and growth (Photos 21 to 25). Pitting was minor to moderate, relative to the plate thickness, and detailed pit measurements were not taken.

Penstock No. 1 is fabricated from 20 different plate sizes ranging from 11 millimetres (0.4375-inch) to 42 millimetres (1.625-inch). Inspection thickness readings were taken for plate sizes up to 36.5 millimetres (1.433 inches). Many of these sections exhibited little to no appreciable material loss with some thickness readings averaging up to 22% greater than the listed original plate thickness and the average thickness for all plates being 3.0% greater than the listed original. There are some exceptions such as the 11 millimetre plate (0.4375-inch), approximately 235 feet from the face of the intake, exhibited material loss averaging 1% over four reading locations and 482 feet from the intake exhibiting material loss averaging 2.7% over three readings.

The greater thickness is common for steel construction from this era when steel plate was frequently rolled out slightly thicker than called for in the design to account for fabrication tolerances. The majority of thickness measurements were taken beside the welds where ETS cleaned the weld and adjacent area with a sandpaper brush wheel on a grinder to facilitate MP testing of the welds and UT readings. Appendix D provides the ETS report of the MP and UT testing.

Welds in Penstock No. 1 were cleaned with a grinder then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 82 full length longitudinal welds and a few feet of 150 circumferential welds. An initial visual inspection of the weld was conducted concentrating on condition of the bead in regard to pitting, corrosion or cracking, and undermining or washout. Particular attention was paid to welds not previously tested or repaired. This was primarily downstream of the surge tank as many of the welds upstream of the surge tank have been repaired. The welded joints including original joints, previously repaired joints, and doubler plate welds were in fair condition (Photos 6 to 10) and did not have any apparent visible cracks and most did not exhibit excessive deterioration. Corrosion of the original welds was moderate for most welds with light to moderate pitting. A few welds were found to have heavier deterioration. These welds also had above average pitting. No significant magnetic partical indications were identified. The repaired welds were in good condition and relatively clean with some surficial rust. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before the penstock was put back into service. The inspection of the welds for this inspection concentrated on the untested welds but also picked up a several of the tested and repaired welds.

3.2.2 Appurtenances

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock No. 1 has five manholes and a bifurcation at the powerhouse.

The manholes were in fair condition with moderate corrosion of the interior surface of the manholes (Photo 27).

The concrete of the intake structure was in fair condition with no significant deterioration or wear, except the transition from the concrete to steel penstock showed significant deterioration all around and especially the lower left side area (Photo 3). The headgate seals appeared to be in good condition with only minor leakage of the headgate apparent from the bottom left corner of the headgate when looking upstream (Photo 1). The headgate skin plate also appeared to be in good condition. A full inspection of the gate members and gate embedments was not performed and was outside the scope of work.

3.2.3 Surge Tank

The surge tank transition welds were visually inspected from the invert of the penstock (Photos 28 and 29). The welds appear to have been tested but not refurbished. This area is encased in concrete so a rupture is unlikely but leakage between the steel and concrete can occur and cause erosion of the concrete and surrounding soil.

3.3 Exterior Inspection

Kleinschmidt began the exterior inspection on June 24 around 9:30 am at the intake and moved downstream. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 30 to 38. Kleinschmidt observed the exterior ground surface for signs of leakage while walking the length of the penstock. Signs of leakage include sloughing of the ground over the penstock and other depressions mainly. The penstock exterior was free of snow and fairly dry and the weather was cloudy and cool. No condition was found requiring immediate repair or remediation.

About 1 gpm was found coming from the flow pipe at FP 3. The newer manhole near Station 100 m was not opened and appear to be in good condition from the outside. The alder bushes upstream of manhole 1 and covering Penstocks 1 and 2 should be cut back (Photo 30). The new rip rap areas are in good condition and do not appear to have changed since they were installed a few years ago. The cover over the remainder of the penstock remains fairly uneven.

3.3.1 Penstock 2 Transducer Leakage

During the inspection of Penstock 1 the sound of spraying water was heard from a Penstock 2 well just upstream of Station 900 m. Further investigation found a jet of water coming from the end of the pressure transducer (Photo 39). Ray Buffet noted it and was going to have the transducer replaced. We were notified that the transducer was replaced prior to submission of this report.

3.3.2 Penstock 3 Exterior Inspection

The exterior of Penstock 3 was inspected during the Penstock 1 inspection visit because the Penstock 3 internal inspection had been cancelled earlier in the year. The sink hole that was discovered last year 9 feet downstream of the surge tank concrete on the left side of the penstock was filled last year but has continued to erode (Photo 40). It is possible there is ongoing leakage from this area that is travelling between the steel and concrete and eroding the soil on its way to the drainage system. Because the area is encased in concrete the leakage and weld crack, if present, is unlikely to result in a blowout. The area should be reviewed, tested, and repaired as needed during the next dewatering. It is also possible that this area has internal erosion from snow melt and rain over the years through this poorly graded soil and when the frost melted in this area it resulted in collapse of a void that had been forming. The surrounding area also shows various signs of settlement that have occurred over time. Another potential cause is that the known and ongoing leakage from the winterization system inside the building has produced enough flow to cause the erosion. The soil around and below the sink hole should be removed to confirm the extent of erosion and the area repaired with properly graded rock when the penstock is dewatered to restore a uniform surface with an erosion resistant material.

There is an observation well just downstream of the surge tank on the left side. The lid was removed, and no flow was observed at the bottom. The sink hole and visual evidence of previous settlement in the area suggests the drainage system in the area is not functioning properly. It is recommended that the well be inspected from the bottom, which will require fall protection and confined space access procedures. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage.

There is a depression in the crown near Station 810 m that is approximately 3 m long by 3m wide by 1m deep. It appears the riprap covering was removed at some point in the past as there is no riprap noted in the depression but there is a pile to the side.

Vegetation inside the fencing around the surge tank should be removed in the next year to improve visibility for routine inspections.

At monitoring point N2 the flow was about 2 to 3 gpm as estimated by eye (Photo 42). The weir bucket has significant moss and organics making it difficult to determine sediment load though no sediment is obvious. The bucket should be cleaned to facilitate sediment monitoring.

At monitoring point N1 the flow was about 5 gpm as estimated by eye (Photo 43). There is significant gravel build up obstructing the incoming pipes. The gravel should be cleaned out of the two upstream culverts to facilitate flow and monitoring.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix E. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 which extends approximately 1034 feet from the face of the intake, and 24,000 pounds per square inch (psi) was used for CSA G40.8 Grade B for the remainder of the penstock.

The welded seams are not as strong as the original base material; these strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used if further weld testing is performed to verify the integrity of the welds. Per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds needing higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the statistical analysis of our steel-shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations. Average thickness and a 97.5% confidence interval (CI) were calculated for each station. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 feet (182 metres) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 feet (271 metres) at the powerhouse and linearly reducing to 655 feet (200 metres) at the surge tower and then matching the FSL of 597 feet (182 metres) at the intake. Appendix A reference drawings provide the pressure gradient used in this analysis. The maximum stress ratio at a joint is 1.42 for this load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.1, which is unacceptable for late 1960 steel pipe. An increase in the joint efficiency factor through weld testing, which would provide verification of the pipe joint integrity, will increase these values. For the plate steel away from the joints, the material has a maximum stress ratio of 1.0 and a safety factor of 1.59, which is acceptable for current design practices.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Max Joint Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress[1,3] (psi)	Allowable Stress (psi)	Stress Ratio[1,2,3]	Factor of Safety Against Yield
4	6,481.3	1,944.4	8,425.7	17,000	0.50	3.1
12	6,629.4	1,988.9	8,618.3	17,000	0.51	3.0
26	7,180.9	2,154.2	9,335.1	17,000	0.55	2.8
33	7,966.9	2,390.1	10,357.0	17,000	0.61	2.5
44	10,852.4	3,255.7	14,108.1	17,000	0.83	1.8
55	12,476.5	3,742.9	16,219.4	17,000	0.95	1.6
65	14,296.1	4,288.8	18,584.9	17,000	1.09	1.4
66	14,163.5	4,249.0	18,412.5	17,000	1.08	1.4
74	13,652.8	4,095.8	17,748.6	17,000	1.04	1.5
86	14,060.0	4,218.0	18,278.0	17,000	1.08	1.4
94	14,763.3	4,429.0	19,192.3	17,000	1.13	1.4
99	14,557.7	4,367.3	18,925.0	17,000	1.11	1.4
106	16,495.6	4,948.7	21,444.3	17,000	1.26	1.2
110	16,923.1	5,077.0	22,000.1	17,000	1.29	1.2
120	18,507.2	5,552.2	24,059.4	24,000	1.00	1.7
130	19,502.4	5,850.7	25,353.1	24,000	1.06	1.6
140	16,014.5	4,804.4	20,818.9	24,000	0.87	1.9
150	20,852.5	6,255.7	27,108.2	24,000	1.13	1.5
157	22,376.4	6,713.0	29,089.4	24,000	1.21	1.4
166	20,994.6	6,298.3	27,292.9	24,000	1.14	1.5
174	21,170.9	6,351.2	27,522.1	24,000	1.15	1.5
184	24,979.9	7,494.0	32,473.9	24,000	1.35	1.2
196	25,340.3	7,602.1	32,942.4	24,000	1.37	1.2
204	22,302.0	6,690.6	28,992.6	24,000	1.21	1.4
214	23,047.1	6,914.1	29,961.2	24,000	1.25	1.3
223	23,765.1	7,129.6	30,894.7	24,000	1.29	1.3
233	24,254.3	7,276.4	31,530.7	24,000	1.31	1.2
243	22,740.7	6,822.2	29,562.9	24,000	1.23	1.3
257	23,550.4	7,065.1	30,615.5	24,000	1.28	1.2
266	25,069.4	7,520.8	32,590.2	24,000	1.36	1.2
276	25,860.6	7,758.2	33,618.8	24,000	1.40	1.1
286	26,264.2	7,879.3	34,143.5	24,000	1.42	1.1
296	25,409.7	7,622.9	33,032.6	24,000	1.38	1.2
306	23,630.7	7,089.2	30,719.9	24,000	1.28	1.2

Can	Max Joint Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress[1,3] (psi)	Allowable Stress (psi)	Stress Ratio[1,2,3]	Factor of Safety Against Yield
316	25,473.6	7,642.1	33,115.7	24,000	1.38	1.1
326	22,831.4	6,849.4	29,680.8	24,000	1.24	1.2
336	22,151.5	6,645.5	28,797.0	24,000	1.20	1.3
346	21,184.1	6,355.2	27,539.3	24,000	1.15	1.3
356	20,389.9	6,116.9	26,506.8	24,000	1.10	1.4
366	20,957.5	6,287.3	27,244.8	24,000	1.14	1.3
375	20,345.8	6,103.8	26,449.6	24,000	1.10	1.4
385	20,731.9	6,219.5	26,951.4	24,000	1.12	1.3
396	20,422.5	6,126.8	26,549.3	24,000	1.11	1.4
406	20,668.4	6,200.5	26,868.9	24,000	1.12	1.3
416	20,690.5	6,207.2	26,897.7	24,000	1.12	1.3
425	19,611.5	5,883.5	25,495.0	24,000	1.06	1.4
430	21,299.6	6,389.8	27,689.4	24,000	1.15	1.3

1 Joint efficiency of 0.7 included
2 Total stress / Allowable stress
3 Uses 97.5% confidence thickness
4 SF = Fy/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 psf and the depth of soil cover on the penstock was assumed to be 3 feet. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off road vehicle loads or equipment.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1) DL (water and steel) + internal vacuum pressure
2) DL (water and steel) + snow load
3) DL (water and steel) + combination snow (75%) and live load (75%).

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis.
- The penstock appears to be located in cohesive fine grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 17-foot-diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was 3.72 psi which is less than the allowable buckling pressure of 3.90 psi. The 15.25-foot-diameter sections were analyzed and the max pressures are summarized in Table 4-2.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest average measured steel thickness values were used. See Table 4-2.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	3.90	3.24	3.72
15.25	4.59	4.30	4.78

There were no new vehicular surcharge analysis conducted as we are not expecting changes in the results from the analysis conducted by Kleinschmidt in 2016 for Penstock No. 2. The 2016 analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 14 feet from the front axle to middle axle then variable from 14 feet to 28 feet to the rear axle, was approximately 5 times less than the allowable buckling loads at that location. For the section of penstock analyzed, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.2 Subatmospheric Internal Penstock Pressure Analysis

Subatmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and no detailed hydrodynamic model was created, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 square metres (3.07 square feet), which is well below the area provided by the approximately 5.1-square-metre (55-square-foot) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil so it is unlikely there are excessive local buckling stresses in the penstock.

4.5 Local Weld Conditions

As noted in Section 1.0, NLH discovered a 0.6-metre-long (2-foot-long) crack in Penstock No. 1 in May 2016. Kleinschmidt responded and assisted with the design of the crack repair, *Crack Investigation and Repair Report – Penstock No. 1 Bay d'Espoir Hydroelectric Development* (June 2016). Kleinschmidt's investigation theorized that the crack, which occurred near a weld, was caused by an improper weld procedure during construction that resulted in incomplete fusion. After repairing the crack NLH rewatered the penstock, a second crack then opened in the Penstock No. 1 in September 2016. This crack led to a detailed weld investigation that has found many other microscopic cracks in the welds. In addition, Penstock No. 2 was inspected in 2017 and Penstock No. 3 in 2018. ETS performed MT tests on the full length of 82 longitudinal welds and a few feet of 140 circumferential welds for this inspection. No cracks or indications were discovered from the MT testing.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life provided that the penstock welds are replaced and the interior is coated before the steel deteriorates further and is adequately maintained and monitored. Replacing the welds from the inside of the penstock only may not fully mitigate the issues, and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 5 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the penstock should have about 50 years of service life remaining if an internal coating is applied. The base plate material away from the joints can tolerate up to 2 mm further material loss and maintain a stress ratio below 1.0 .

5.2 Internal Pressure Strength

More thickness measurements were taken during this inspection than during the 2016 inspection and the measurements had a wider range of values that resulted in CI thickness values that were in some cases lower than previously used in the stress analysis. Stress ratios for a combined static and dynamic internal pressures peak at 1.42 for the joints (Table 4-1). This indicates that the penstock does not meet present day design criteria for a new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.10 at the joints, which is not acceptable for late 1960 steel pipe. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. There is a lack of confidence of the weld integrity for this penstock, and although the plating is acceptable and many welds have been repaired, it is recommended that the penstock undergo further extensive repairs or be replaced. As noted above, RT testing of the welds can be performed to verify weld integrity and allow a higher joint efficiency to be used. The MT testing of welds to date does not satisfy the requirements of ASCE No. 79 to increase the joint efficiency. It is recommended that a more accurate surge analysis be conducted using wicket gate closure times to confirm penstock stresses. With the history of weld failures including the recent failure and another indication found it is recommended that this penstock undergo extensive repairs or be replaced in the next 5 years.

6.0 RECOMMENDATIONS

Penstock No. 1 should either have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively or be replaced within 5 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- Radiographic testing of the welds;
- Surge Analysis to verify peak pressure and resulting stresses
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 5 years provided the penstock welds are replaced. At this stage, Kleinschmidt is unable to estimate the rate of corrosions for the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20 to 40 years or more. If the penstock is recoated prior to significant steel deterioration every 20 to 40 years, NLH can anticipate extending the life of the penstock nominally another 50 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated and buried, so it is difficult to tell its condition without excavation. It would be costly and time consuming to uncover enough of the penstock to get a representative sample size of the exterior penstock condition, and some areas, like the invert, cannot be inspected safely. An exterior inspection involving excavation of significant portions of the penstock will not provide enough data to be worth the investment.

6.2 Exterior Inspection

Kleinschmidt recommends the drainage system be cleaned and checked for plugs and also be monitored at times with consistent weather conditions.

6.3 Interior Inspections

6.3.1 General Evaluation

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. These inspections should give a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless if the coating has been replaced or not, the detailed inspections can be extended to a 5- to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval.

A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This should be completed in 2021 and 2022 to better understand the risks.

7.0 REFERENCES

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Hatch. 2019. Newfoundland and Labrador Hydro Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3. Rev 0. March 28, 2019.

Kleinschmidt Associates. 2016. Crack Investigation and Repair Report, Penstock No. 1 Bay d'Espoir Hydroelectric Development. Kleinschmidt Technical Report to Newfoundland and Labrador Hydro.

REPORT SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
Sept. 4, 2020
DATE
NEWFOUNDLAND & LABRADOR

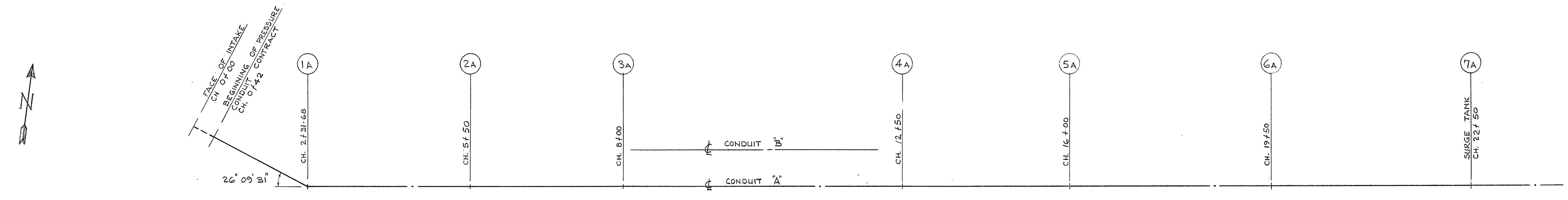
CMV:NSS:SCB

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATES CANADA INC.
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEGNL N0708
which is valid for the year 2020

\\kleinschmidtusa.com\Condor\Jobs\2670\030\Docs\Penstock 1 Report\2670030_003RP_Bay d'Espoir Penstock 1 Inspection Report FINAL.docx

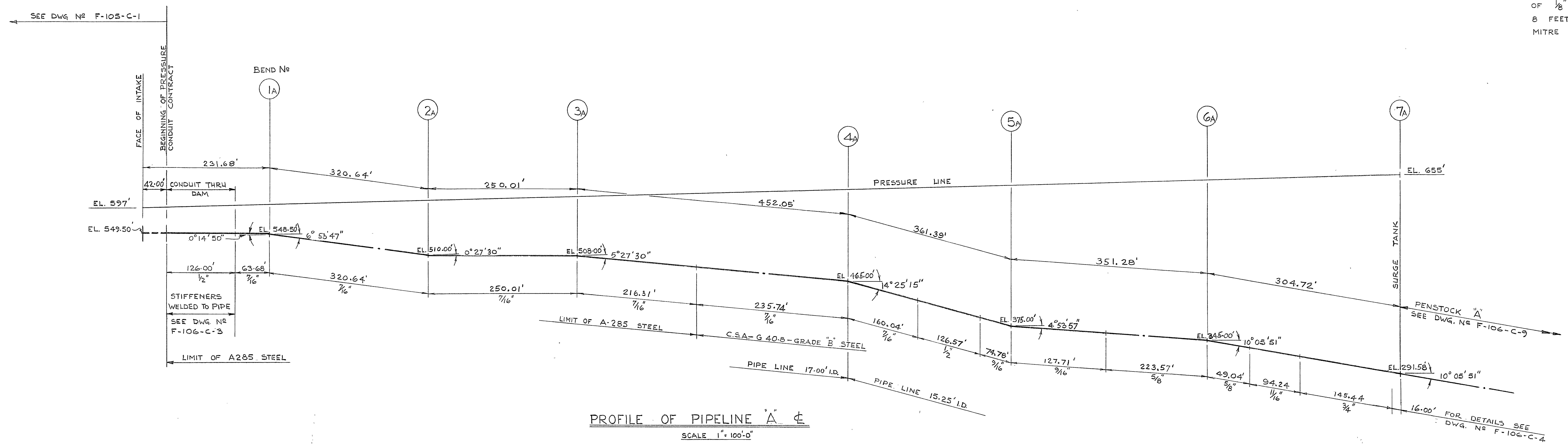
APPENDIX A

PENSTOCK LAYOUT DRAWINGS



PLAN OF PIPELINE 'A' ℄

SCALE 1" = 100'-0"



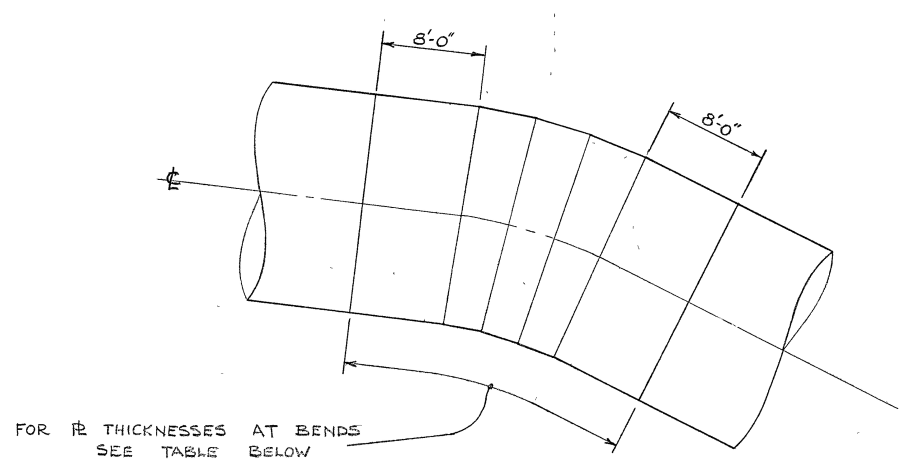
PROFILE OF PIPELINE 'A' ℄

SCALE 1" = 100'-0"

NOTES

1. THE PRESSURE CONDUITS SHALL BE CALLED 'A' AND 'B'. CONDUIT 'A' IS SOUTH OF CONDUIT 'B' AND SHALL BE COMPLETED IN 1966. CONDUIT 'A' CONSISTS OF PIPELINE 'A' AND PENSTOCK 'A'.

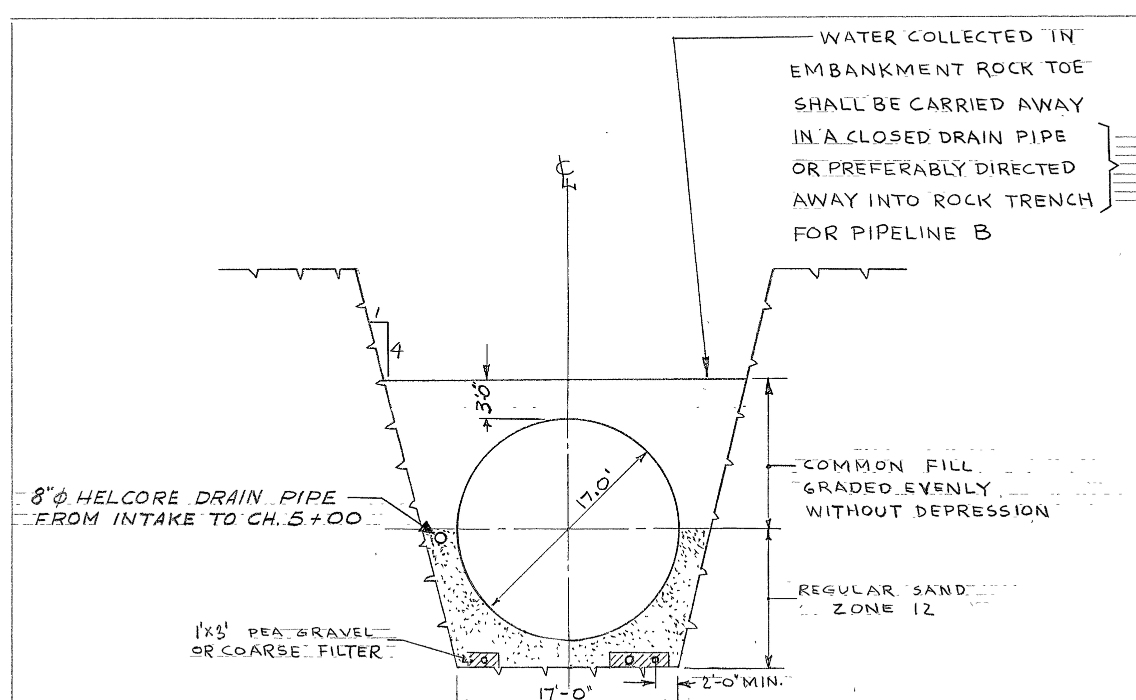
2. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION № M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.



TYPICAL BEND

SCALE 1" = 10'-0"

SEE SPEC. M-3116

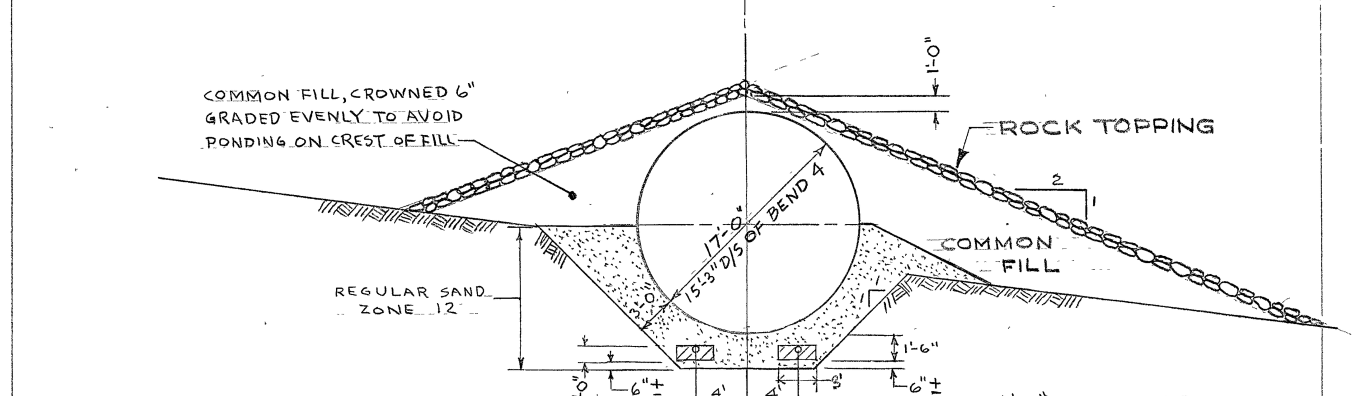


2—6" NO-CORRODE DRAIN PIPES NEAR TOP OF LAYER WITH DRAIN HOLES FACING DOWN

1—8" HELCOR PIPE FROM INTAKE BOX DRAIN

△4 TYPICAL SECTION UPSTREAM OF BEND 7A IN ROCK CUT

SCALE 1" = 1'-0"



2—6" NO-CORRODE DRAIN PIPES. INSIDE COARSE FILTER OR PEA GRAVEL HOLES FACING DOWN

DRAIN PIPES PLUGGED AT UPPER ENDS NEAR THE CROSS DRAINS.

△4 TYPICAL SECTION UPSTREAM OF BEND 7A IN EARTH TRENCH

SCALE 1" = 1'-0"

PERVIOUS LAYER ZONE 12 MATERIAL AND FILTER MUST BE SEALED WITH IMPERVIOUS FILL IMMEDIATELY DOWNSTREAM OF EACH CROSS DRAIN TO PREVENT SEEPAGE WATER FROM BY-PASSING THE CROSS DRAINS.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
LICENCE TO PRACTICE

ANGLES & PL THICKNESSES AT BENDS

BEND	<A	<B	<C	TRUE ANGLE	PL THICKNESS
1 A	26° 09' 31"	0° 14' 50"	6° 53' 47"	26° 55' 34"	7/16"
2 A	——	6° 53' 47"	0° 27' 30"	6° 26' 17"	1/2"
3 A	——	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4 A	——	5° 27' 30"	14° 25' 15"	8° 57' 45"	9/16"
5 A	——	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6 A	——	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16"
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	

ANGLE IN PLAN　　VERTICAL ANGLES

REFERENCE DRAWINGS

F-106-C-3 CONDUITS THROUGH DAM
F-106-C-4 SURGE TANK - DETAILS OF TEES
F-106-C-5 " " - GENERAL LAYOUT & DETAILS
F-106-C-6 PRESSURE CONDUITS - CLEARING
F-106-C-8 " " - EXCAVATION & DRAINAGE
F-106-C-9 " " - PENSTOCK A
F-106-C-10 " " - PENSTOCK B

OTHER REFERENCES

1. SPECIFICATION No. M-3116

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
5	2-6-68		AS BUILT, FROM FIELD INFORMATION	A.B.	JHM
4	5 JAN '67		2 TYP. SECTIONS CHANGED, ONE REMOVED	A.R.	
3	9 DEC '66	A/B - 1, 2, 3, 4	3 TYPICAL SECTIONS ADDED	A.R.	JHM
2	20 SEPT '65		REVISED PROFILE & PLATE THICKNESSES	A.R.	
1	AUG. 5/65		EL. @ BEND 4 CORRECTED, MINOR REVISIONS	J.P.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 16 1965
APPROVED BY:
MANAGER ENGINEERING

TRANS'N	ELECT'L	CIVIL
		JHM

PASSED

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED
RECOMMENDED J H Marica P Eng

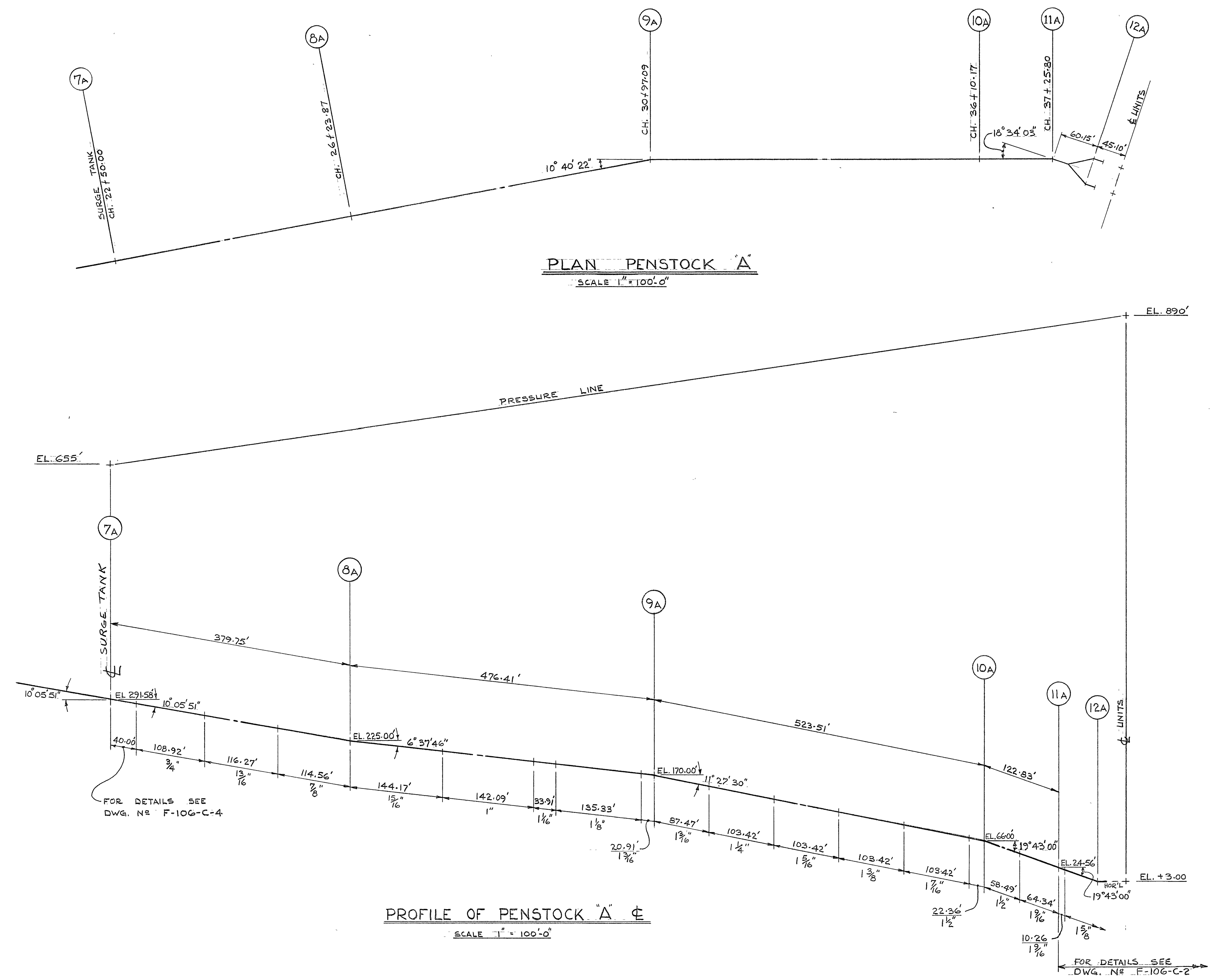
NEWFOUNDLAND AND LABRADOR POWER COMMISSION

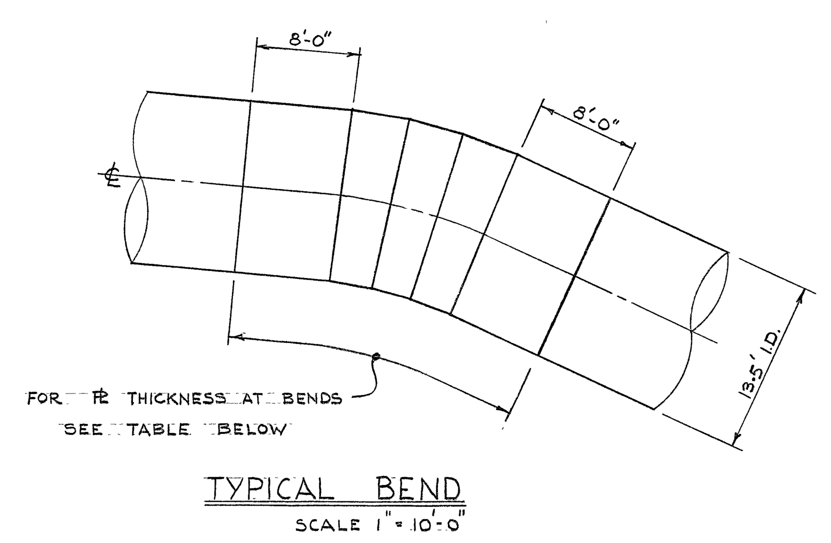
BAY D'ESPOIR DEVELOPMENT

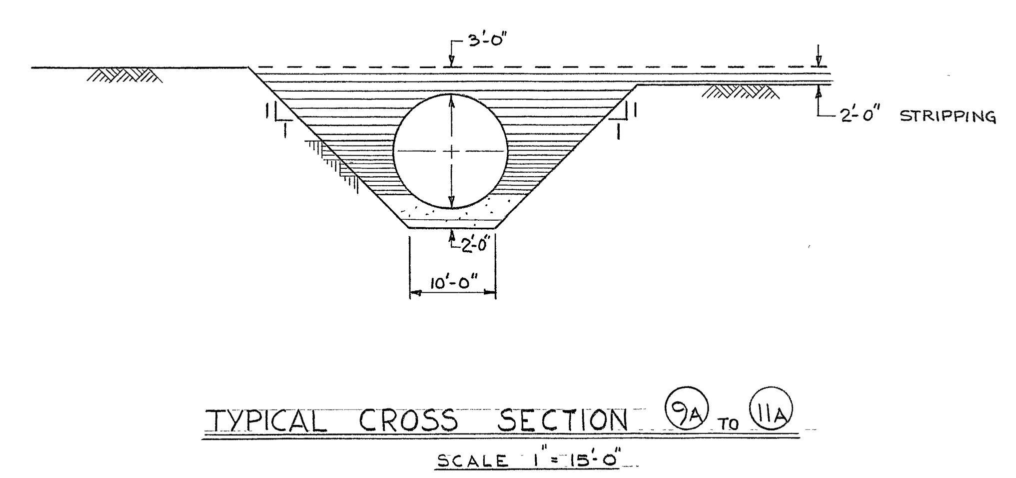
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PIPELINE 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG NO.	REVISION
	NOTED	PD - 11	JULY 16, 1965	F-106-C-7	5







NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6".
3. STEEL SHALL BE C.S.A. G40-8 GRADE 'B'.
4. FOR TYPICAL CROSS SECTION FROM (7A) TO (9A) SEE DWG. Nº F-106-C-7.

REFERENCE DRAWINGS

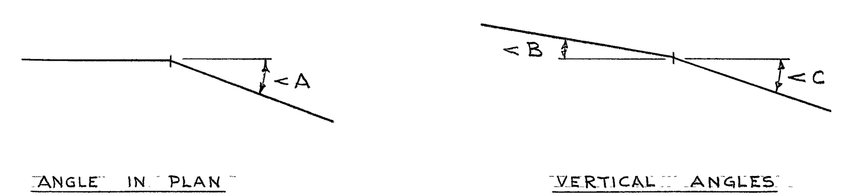
1. F-106-C-2 PRESSURE CONDUITS-LAYOUT & DETAILS OF BIFURCATION.
2. F-106-C-4 SURGE TANKS - DETAILS OF TEES.
3. F-106-C-5 SURGE TANKS - GENERAL LAYOUT & DETAILS.
4. F-106-C-6 PRESSURE CONDUITS - CLEARING.
5. F-106-C-7 PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE 'A'.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

BEND	< A	< B	< C	TRUE ANGLE	ℙ THICKNESS
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	——
8 A	——	10° 05' 51"	6° 37' 46"	3° 28' 05"	1 1/8"
9 A	10° 40' 22"	6° 37' 46"	11° 27' 30"	11° 35' 25"	1 3/8"
10 A	——	11° 27' 30"	19° 43' 00"	8° 15' 30"	1 3/4"
11 A	18° 34' 03"	19° 43' 00"	19° 43' 00"	17° 28' 12"	1 7/8"

ANGLES & ℙ THICKNESS AT BENDS



ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	SEPT 2/66		PLAN & PROFILE REVISED	J.P.	

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 22 1965
APPROVED BY: [signature]
MANAGER ENGINEERING

TRANS'N | ELECT'L | CIVIL
PASSED

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED A.P. [signature]
RECOMMENDED [signature] P.Eng.

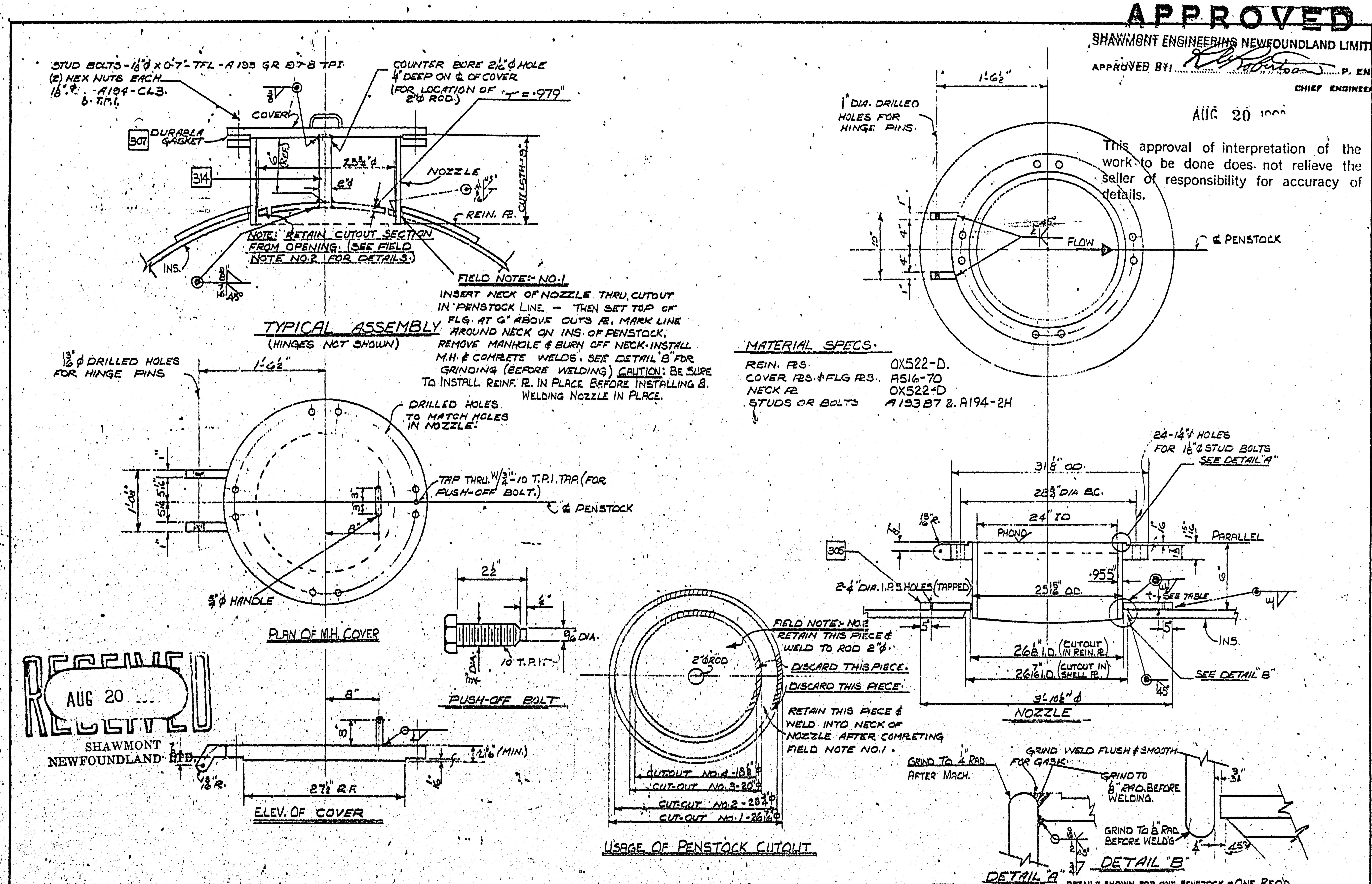
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 21, 1965	F-106-C-9	3


ELEVATION of PENSTOCK 'B'
PLAN VIEW
GENERAL NOTES
FIELD NOTES
TO BE ERECTED IN 1968
RECEIVED OCT 24 1966 SHAWINIGAN ENGINEERING NEWFOUNDLAND LTD.
APPROVED
OCT 25 1966
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
HORTON STEEL WORKS, LIMITED
10831
FILE 2-13


ELEVATION of PENSTOCK 'A'
PLAN VIEW
FIELD NOTE:
GENERAL NOTES:-
ANGLES & P. THICKNESS AT BENDS
ANGLE IN PLAN
VERTICAL ANGLES
HORTON STEEL WORKS, LIMITED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MANAGER ENGINEERING
MAY 6 1966
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
10830



24"ϕ MANHOLE DETAILS [300]

ONE REQ'D.

REIN. PL. #	t	W1	W2
305	.955	9/16	5/8

NOTE: FOR LOCATION OF MANHOLE - SEE DWG. #1

DETAILS SHOWN FOR ONE PENSTOCK. - ONE REQ'D.

NO.	DATE	BY	REMARKS
REVISIONS			

HORTON STEEL WORKS, LIMITED
FORT ERIE, ONT.

MANHOLE DETAILS - 13'-6"ϕ PENSTOCK
SHAWMONT ENG. N'FD. LTD. FOR NFLD & LABRADOR POWER COM.
BAY D'ESPOIR DEVELOPMENT
ST. ALBAN'S - NFLD. (STAGE II)

DRAWN: J.K. 5/15/68
CHECKED:
DESIGN:
WELDING:
DWG. 2 OF
CONTRACT 68H038H03

CM

12 X

APPENDIX B

PHOTOGRAPHS

Photo 1　　Leakage Bottom Left Corner of Gate

Photo 2　　Leakage Bottom Right Corner of Gate

Photo 3 Concrete to Steel Transition Right Side

Photo 4 Old Organics and Bare Steel

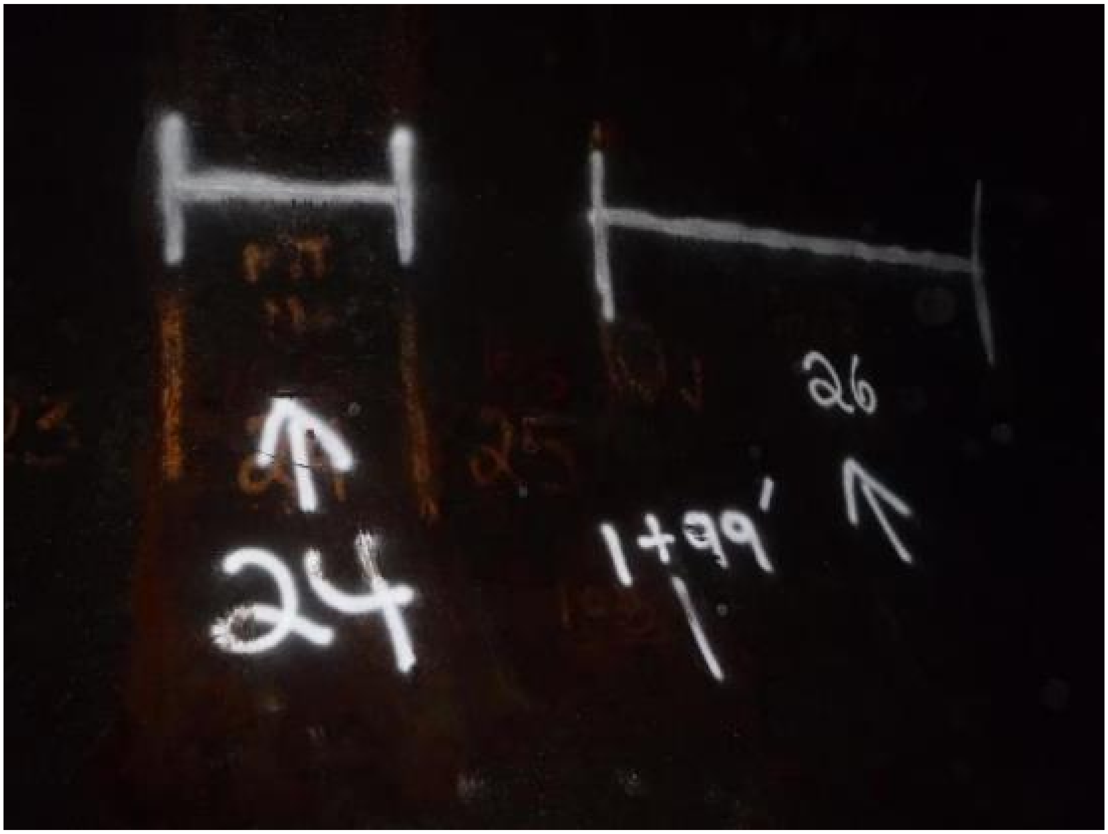


Photo 5 Typical markings for numbering cans, welds, and stationing 2020

Photo 6 Typical repaired weld with contrast paint tested this year

Photo 7 Typical repaired weld not tested this year

Photo 8 Typical original weld not previously tested

Photo 9 Typical original weld previously tested but not in 2020

Photo 10 Typical original weld with contrast paint tested this year

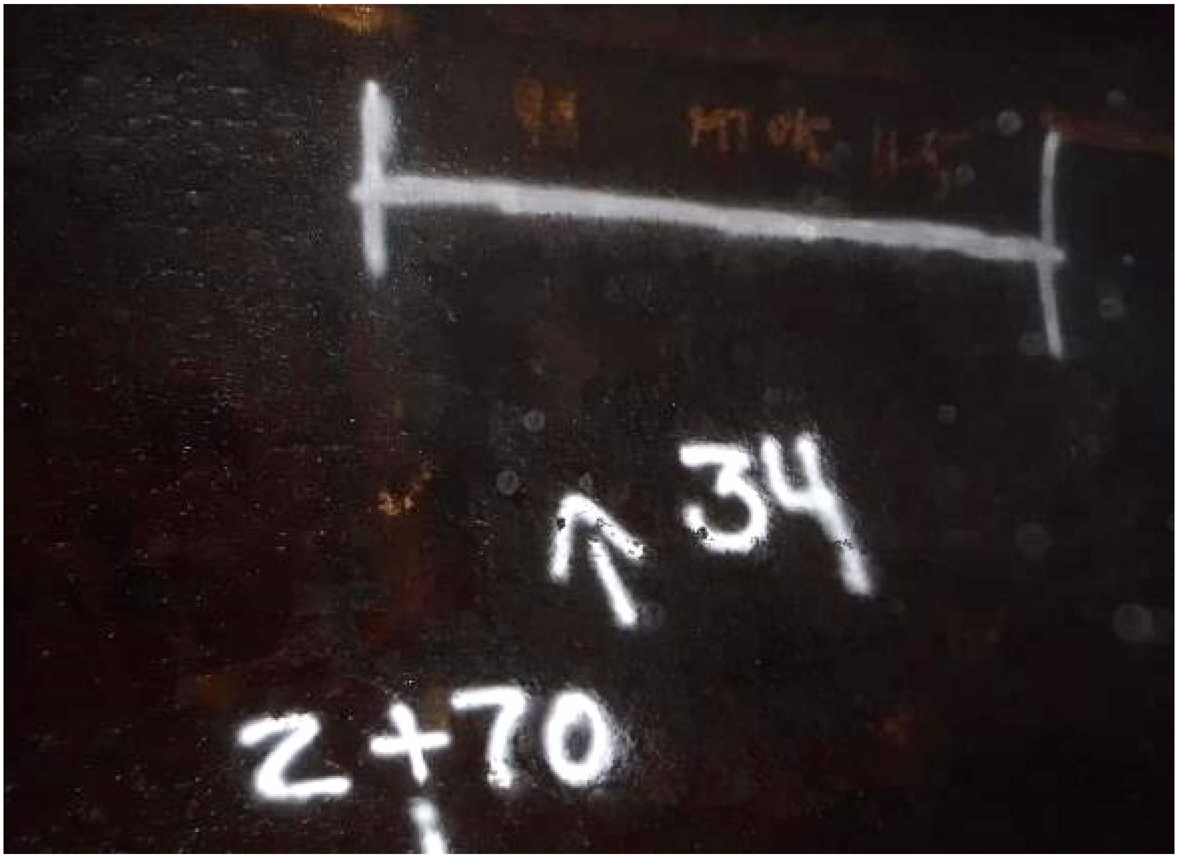


Photo 11 Weld Tested Can 34

Photo 12 Connor performing MT on weld

Kleinschmidt

Photo 13 Tested weld Can 66

Photo 14 Tested weld Can 151

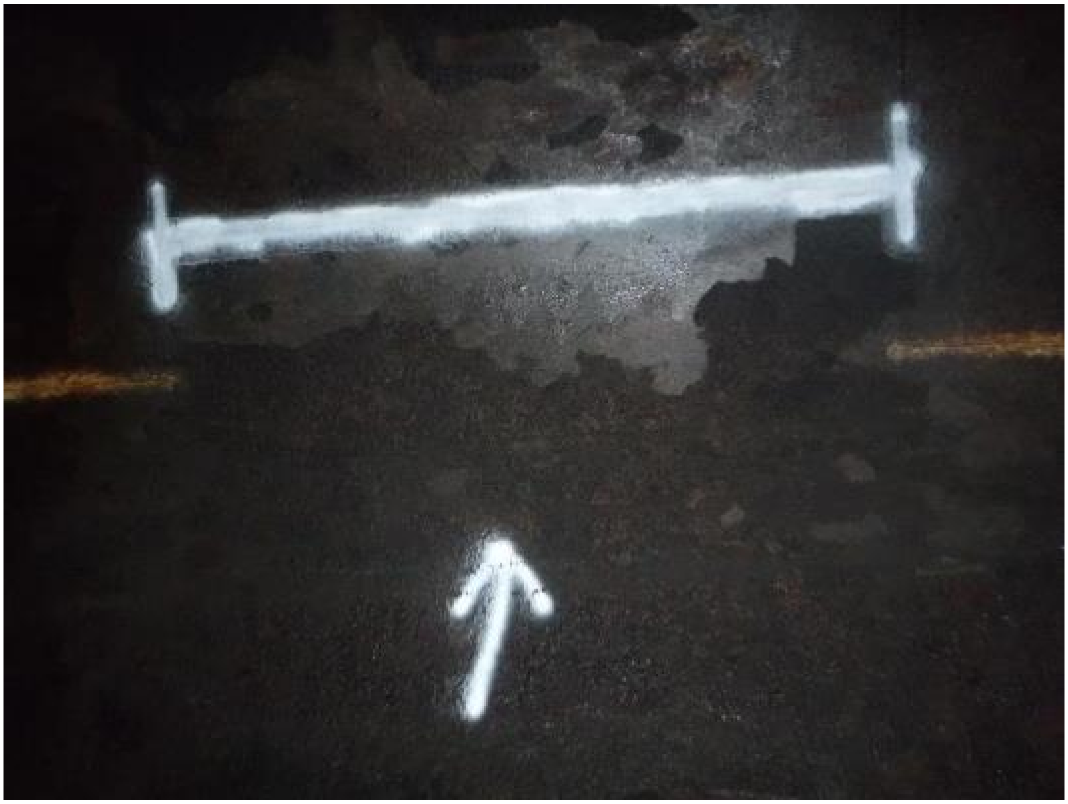


Photo 15 Tested weld. Note organic material

Photo 16 Tested weld Can 233

Photo 17 Tested weld Can 286

Photo 18 Tested weld Can 355

Photo 19 Tested weld Can 396

Photo 20 Tested weld Can 406

Photo 21 Surface of plating Can 370

Photo 22 Surface of plating Can 400

Photo 23 Surface conditions and original weld covered in organics Can 316

Photo 24 Surface conditions and original weld covered in organics Can 352

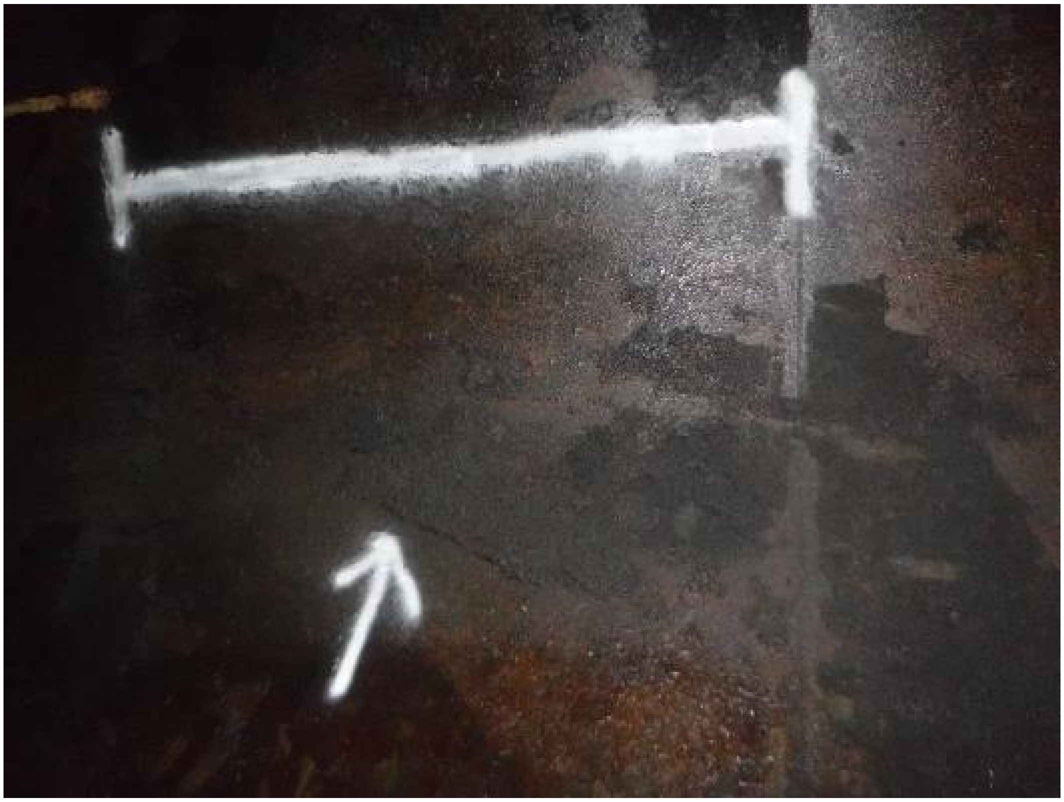


Photo 25 Surface conditions Can 190

Photo 26 Surface conditions Can 130

Photo 27 Cover for Manhole No. 2 (Second Downstream of Intake)

Photo 28 Surge tank transition welds

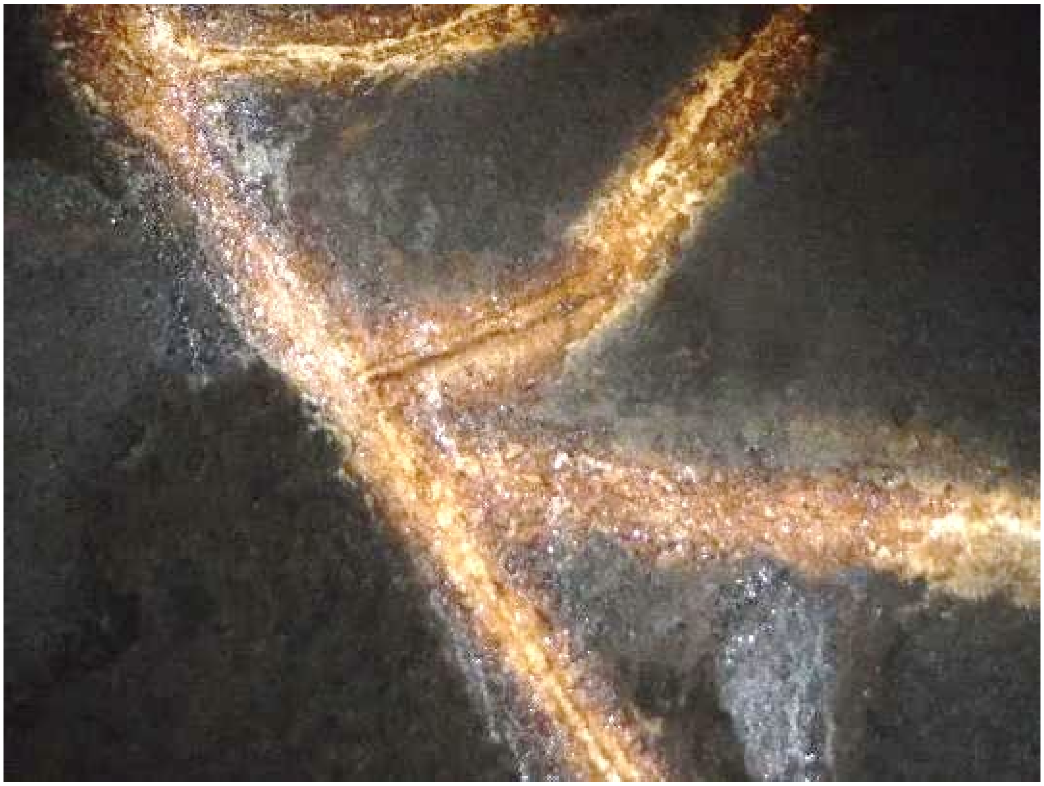


Photo 29 Surge tank transition welds

Photo 30 Looking downstream along Penstock 1 from the intake

Photo 31 Upstream Drain at FP 3

Photo 32 Riprap over repaired area of penstock

Photo 33 Drain pipes at FP 5

Photo 34 Looking downstream along Penstock 1 upstream of surge tanks

Photo 35 Manhole access immediately upstream of surge tank

Photo 36 Looking downstream from surge tank

Photo 37 Looking downstream from surge tank

Photo 38 Looking Upstream from the switch yard

Photo 39 Leaking pressure transducer Penstock 2 upstream Station 900m

Photo 40 Sink hole downstream of penstock 3 surge tank

Photo 41 Looking upstream along Penstock 3 from last downstream manhole

Photo 42 Drain outlet at N2

Photo 43 Drain at N1 upstream of monitoring shed

Photo 44 Inside monitoring shed N1

Photo 45 Typical Penstock 2 cover conditions. Looking upstream at Intake.

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	20-435-1	Copy:	
Date:	29 June, 2020	Date Received:	10 June, 2020
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin LeGrow		
P.O. No.	2020-0127		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1		
Testing Required:	Magnetic Particle Inspection	Signed:	Conor Murphy NDT Inspector

Remarks

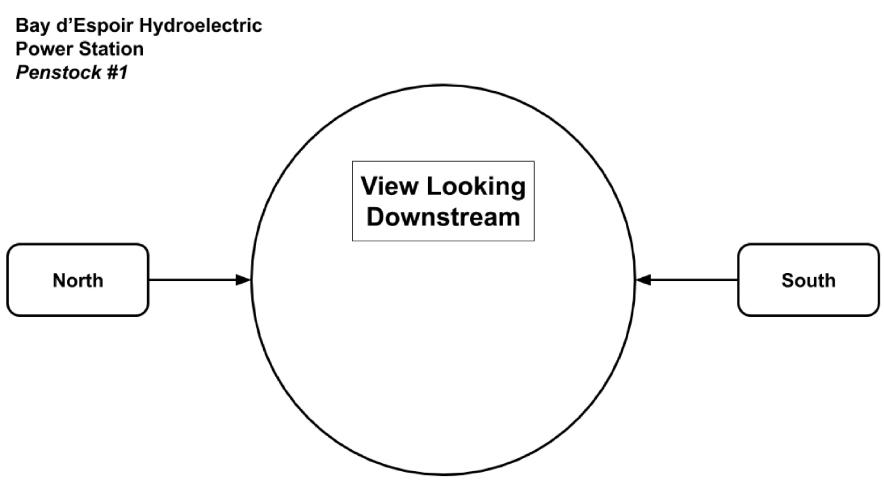
As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds for the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

The above areas were found to be acceptable as per the noted criteria.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
4	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
13	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
24	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
26	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
33	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
34	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
44	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
47	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
55	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
65	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
66	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
74	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
75	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
86	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
94	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
96	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
99	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
106	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
109	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
110	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
111	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
130	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
132	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
140	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
145	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
151	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
157	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
166	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
167	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
174	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
175	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
187	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
196	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
204	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
206	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
214	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
223	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
233	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
243	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
245	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
257	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
266	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
276	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
286	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
296	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
306	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
316	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
326	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
336	- Longitudinal right (south) weld. *Pitting noted in this area - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**Figure 1 & Figure 2**
346	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
355	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
356	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
365	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 20-435-1 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inpsection

Can Number	Details	Result	Image #
375	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
385	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
396	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
406	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

Figure 1. Can 336 - Pitting in Right Horizontal Weld
Pre-Inspection (12" Section)

Figure 2. Can 336 - Pitting in Right Horizontal Weld
Post-Inspection (12" Section)

APPENDIX D

THICKNESS MEASUREMENTS DATA

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
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Gas Free Testing
Destructive Testing
Insurance Reports

Report

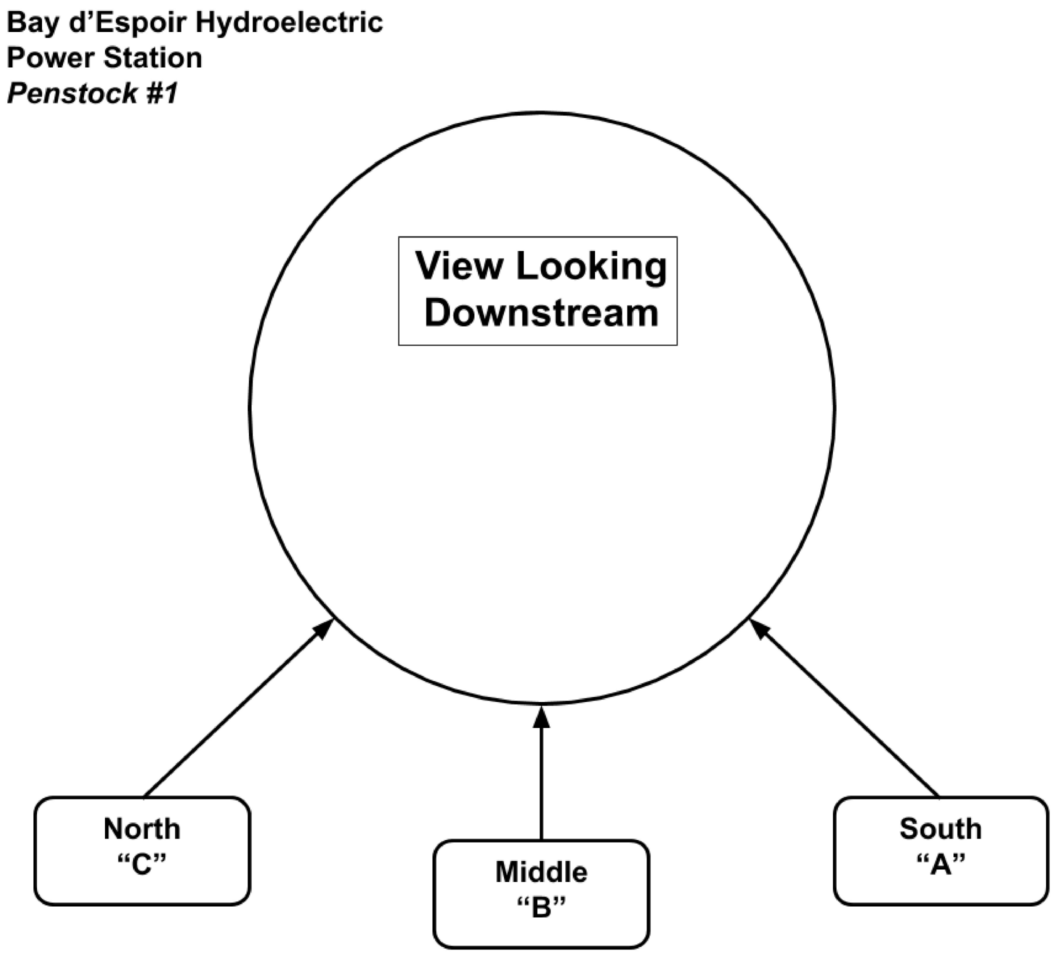
ETS No.:	20-435-2	Copy:	
Date:	29 June 2020	Date Received:	10 June, 2020
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin LeGrow		
P.O. No.	2020-0127		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Conor Murphy NDT Inspector

Remarks
As directed, ultrasonic thickness measurements were taken on Penstock #1 in areas as requested. Readings are shown in mm's on the attached tables.

Equipment Used
Krautkramer DMS 2 digital thickness gauge (S/N 01YL2P).
Krautkramer TC560 probe (S/N 14A01G28).
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 20-435-2 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Location Of Readings



ETS No.: 20-435-2 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A	Location B	Location C
4	12.0	11.9	12.1
12	12.1	11.8	12.2
26	10.9	10.9	11.0
33	10.9	10.9	10.9
44	10.0	10.5	10.5
55	10.2	10.6	10.5
65	10.5	10.0	10.5
66	10.2	10.0	10.3
74	10.5	10.6	10.4
86	10.3	10.2	10.4
94	10.1	9.9	10.1
99	10.5	10.6	10.5
106	10.1	10.5	10.1
110	10.5	10.1	10.5
120	10.3	10.0	10.0
130	10.3	10.6	10.2
140	13.7	13.7	13.2
150	10.1	10.6	10.6
157	10.6	10.4	11.0
166	12.3	12.6	12.5
174	13.5	13.4	13.5
184	13.1	13.1	13.4
196	13.3	13.1	13.4
204	15.3	15.4	15.6
214	15.6	15.3	15.4
223	15.4	15.3	15.2

ETS No.: 20-435-2 Date: 29 June 2020
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A	Location B	Location C
233	16.4	16.9	16.4
243	17.8	18.4	18.3
257	18.4	18.5	18.6
266	18.2	18.4	18.8
276	18.8	18.4	18.6
286	19.2	19.8	19.3
296	20.8	21.8	21.4
306	22.9	23.0	22.8
316	22.0	22.8	22.9
326	25.0	25.4	25.3
336	26.5	26.5	26.8
346	28.4	28.9	28.6
356	30.3	30.6	30.2
366	30.2	30.9	30.8
375	32.4	32.3	32.2
385	33.2	33.9	33.4
396	35.4	35.0	35.6
406	36.4	36.8	36.0
416	N/A	36.9	36.8
425	N/A	39.8	39.4
430	N/A	38.9	39.4
440	N/A	31.9	32.3

Appendix E

Penstock Evaluation Calculations

Kleinschmidt

PROJECT TITLE:	Penstock 1 Inspection	**CLIENT:**	Newfoundland Labrador Hydro
KLEINSCHMIDT PROJECT NO:	2670030.01	**LOCATION:**	Bay D'Espoir
SUBJECT:	Penstock 1 – steel thickness measurements		
PROJECT MANAGER:	Nancy Sutherland		
TECHNICAL LEAD/ADVISOR:	Chris Vella		
ENGINEER:	**NANCY SUTHERLAND**		

REV.	NAME	DATE	COMMENTS
	Performed By: NS	08/05/2020	
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
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	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		

[Insert PE Stamp]

Kleinschmidt

99 Wyse Road, Suite 940
Dartmouth, Nova Scotia
B3A 4S5
Telephone: 902.708.1082
www.KleinschmidtUSA.com

Designed By:	NS
Date:	07/13/2020
Revised:	
Date:	
Checked By:	
Date:	
Job Number:	2670-030

Project: Bay d'Espoir Penstock 1 Inspection

Task: Penstock Calculations

Objective:
Determine the structural integrity of Bay d'Espoir Penstock 1 under external loading.

Assumptions: For the following analyses, it is assumed that Penstock 1 is buried with a compacted earth cover of approximately 3 feet in depth. It is also assumed that there is no vehicular traffic in the area of the penstock and any subsequent live loads include maintenance workers, etc. or environmental loads only.

References:
1. Site Visit Notes - CMV June 22-25, 2020
2. TRR Report ETS No.: 20-435-2 June 29, 2020
3. ASCE No. 79, Steel Penstocks, 2nd Edition, 2012
4. Existing Drawings: Penstock 1 (attached)
5. National Building Code of Canada, current version.
5. ASCE7-10 Minimum Design Loads For Buildings and Other Structures, current version
6. AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.
7. AISC, Manual of Steel Construction, current version
8. Hydroelectric Handbook Justin & Creager 1950
9. CSA S-16 Design of Steel Structures. Handbook of Steel Construction, current version

Notes: Station 0+00 is 17 feet from downstream side of the gate

Penstock Dimensions: (Reference 4)

$D_{17} := \mathbf{17} \cdot ft$ — *Penstock Diameter 17 ft ID*

$D_{15.25} := \mathbf{15.25} \cdot ft$ — *Penstock Diameter 15.25 ft ID*

Steel PlateThickness: (Reference 2)

$t_{17} := 0.3844in$ — *Minimum 97.5% CI steel plate thickness for 17' diameter penstock section (Reference 2)*

$t_{15.25} := 0.3842in$ — *Minimum 97.5% CI steel plate thickness for 15.25' diameter penstock section (Reference 2)*

$t_{.4375} := 0.4375in$ — *Use 7/16 inch plate thickness for calculating penstock dead load 17' pipe*

$t_{1.625} := 1.625in$ — *Use 1 5/8 inch plate thickness for calculating penstock dead load of 15.25' pipe*

Material Properties:

$F_{u1} := 50ksi$ — *Penstock Upper Section - Ultimate Tensile Stress Steel (A285) Reference 3*

$F_{y1} := 26ksi$ — *Yield Stress A285 Steel*

$F_{u2} := 65ksi$ — *Penstock Lower Section - Ultimate Tensile Stress Steel (CSA G40.8 Grade B) Reference 9*

$F_{y2} := 40ksi$ — *Yield Stress CSA G40.8 Grade B for thicknesses less than and equal to 0.625 inches*

$F_{y3} := 38ksi$ — *Yield Stress CSA G40.8 Grade B for plate thicknesses between 0.625 inches and 1 inch incl.*

$F_{y4} := 36ksi$ — *Yield Stress CSA G40.8 Grade B for plate thicknesses between 1 inches and 1.5 inch*

$\gamma_w := \mathbf{62.4}pcf \qquad \gamma_s := \mathbf{490}pcf$ — *Unit Weight of Water and Steel*

$HW := 597ft$ — *Headwater Elevation (Max Normal Pond) (Reference 4)*

Allowable Stress:

$S_A := \min\left(\frac{F_{y1}}{1.5}, \frac{F_{u1}}{2.4}\right) = 17 \cdot ksi$ — *Allowable Stress in Penstock Steel A285 (Ref. 3, 3.5.3)*

Allowable Stress:

$S_A := \min\left(\frac{F_{y4}}{1.5}, \frac{F_{u2}}{2.4}\right) = 24 \cdot ksi$ — *Allowable Stress in Penstock Steel G40.8 (Ref. 3, 3.5.3) use 36 ksi; conservative*

Joint Efficiency:

Assume all welds (longitudinal and circumferential) are double-welded butt joints with no RT or UT ; Reference 3; Section 3.5.1. Table 3-3.

$J_{eL} := 0.70$ — *Joint Efficiency of welded longitudinal joints*

$J_{eC} := 0.70$ — *Joint Efficiency of welded circumferential joints*

External Loads: (Reference 5)

Snow:

$S = I_s \cdot \left[S_s \cdot \left(C_b \cdot C_w \cdot C_s \cdot C_a\right) + S_r\right]$ — *Design snow load, (Div. B, Section 4.1.6.2)*

$I_s := 1.0$ — *Importance factor. (Normal, Ultimate Limit State ULS)*

$C_b := 0.8$ — *Basic roof snow load factor*

$C_w := 1.0$ — *Exposure to wind factor (conservative)*

$\alpha := 45 \cdot °$ — *Average roof slope of penstock.*

$C_s := \frac{(60° - \alpha)}{45 \cdot °} = 0.33$ — *Slope factor.*

$C_a := 1.0$

$S_s := 3.7kPa = 77.28 \cdot psf$ — *Ground snow load (Table C-2)*

$S_r := 0kPa$ — *Rain load (no ponding on penstock).*

$S := I_s \cdot \left[S_s \cdot \left(C_b \cdot C_w \cdot C_s \cdot C_a\right) + S_r\right] = 0.99 \cdot kPa$ $\quad S = 20.61 \cdot psf$

$D_{17od} := D_{17} + 2 \cdot t_{17} = 17.06\,ft$

$S_{load} := S \cdot D_{17od} = 351.64 \frac{1}{ft} \cdot lbf$ — *Snow load*

Live:

$LL := 100psf$ — *Live load (assumed, maintenance above penstock)*

$L_{load} := LL \cdot 3ft = 300.00 \frac{1}{ft} \cdot lbf$ — *Live load - assume 3 ft width*

External Pressure on 17' Diameter Pipe:

Dead Load on Conduit

$H_c := 3ft$ — *Height of fill above conduit*

$D_{17} = 17.00\,ft$ — *Penstock Diameter ID*

$D_{17od} := D_{17} + 2 \cdot t_{17} = 17.06\,ft$ — *Penstock Diameter OD (using 97.5% CI thickness)*

$w := 120pcf$ — *Unit Weight of fill, assumed saturated*

$w_s := \pi \cdot D_{17od} \cdot t_{.4375} \cdot \gamma_s = 957.69 \cdot plf$ — *Weight of steel penstock per foot* — $w_s = 957.69 \cdot plf$

$W_{D17} := w \cdot H_c \cdot D_{17od} + w_s$ — *Total Dead Load on 17' diameter penstock, (Reference 6 Eqn. 5-3)* — $W_{D17} = 7.101 \cdot klf$

Vacuum Pressure:

$P_v := 0.0psi$ — *Pressure Vacuum (surge tank)*

Allowable Buckling Pressure:

$h_w := 0$ — *Height of Water above penstock* — $h_w = 0.00 \cdot in$

$h := H_c$ — *Height of fill above penstock, (assumed)* — $h = 36.00 \cdot in$

$R_w := 1$ — *Water Buoyancy factor (assume well-drained)* — $R_w = 1.00$

$H := \frac{H_c}{ft}$ — *Height of fill above penstock, (ft) unitless* — $H = 3.00$

$B_{prime} := \frac{1}{1 + 4e^{-0.065 \cdot H}}$ — *Empirical coefficient of elastic support* — $B_{prime} = 0.23$

$E_{prime} := 500psi$ — *Modulus of soil reaction, Reference 6, Table 6-1, assumed for fine grained soils with w/less than 25% sand @ 85% compaction @ 2ft-5ft cover*

$E := 30000000psi$ — *Modulus of elasticity for steel*

$I := \frac{(t_{17})^3}{12}$ — *Transverse moment of inertia per unit length of pipe wall* — $I = 0.0568 \cdot \frac{in^4}{ft}$

$E \cdot I = 4568733.844\, ft \cdot s^{-2} \cdot in \cdot lb$ — *Pipe wall stiffness*

$D_{17od} = 17.06\, ft$ — *Penstock Diameter 1 - OD*

$FS := 2.0$ — *Factor of safety per AWWA M-11, 5th Ed., (ASCE No. 79 references 3rd Ed.)*

$q_{a17} := \frac{1}{FS} \cdot \left(32 \cdot R_w \cdot B_{prime} \cdot E_{prime} \cdot \frac{E \cdot I}{D_{17od}^{\ 3}}\right)^{0.5}$ — *Allowable Buckling Pressure on 17' diameter penstock, (Reference 3 EQN 6-7, AWWA 2004)* — $q_{a17} = 3.93 \cdot psi$

External Pressure without Live Load:

$Q_{17} := \gamma_w \cdot h_w + R_w \cdot \frac{(W_{D17} + S_{load})}{D_{17od}} + P_v = 3.03\, psi$ — *External Pressure and no vacuum conditions inside penstock (Ref 3, AWWA 2004)* — $Q_{17} = 3.03 \cdot psi$

External Pressure with Live Load:

$Q_{L17} := \gamma_w \cdot h_w + R_w \cdot \frac{(W_{D17} + S_{load})}{D_{17od}} + \frac{L_{load}}{D_{17od}} = 3.15\, psi$ — *External Pressure with Live Load (including snow) on 17' diameter penstock (Ref 3, AWWA 2004)* — $Q_{L17} = 3.15 \cdot psi$

Stress Ratios:

$\frac{Q_{17}}{q_{a17}} = 0.77$ — *External Pressure with No Vacuum 17' diameter penstock*

$\frac{Q_{L17}}{q_{a17}} = 0.80$ — *External Pressure with 100 psf Live Load on 17' diameter penstock*

External Pressure on 15.25' Diameter Pipe:

Dead Load on Conduit

$H_c := 3ft$ — *Height of fill above conduit*

$D_{15.25} = 15.25\, ft$ — *Penstock Diameter 2 ID*

$D_{15.25od} := D_{15.25} + 2 \cdot t_{15.25} = 15.31\, ft$ — *Penstock Diameter 2 OD*

$w := 120pcf$ — *Unit Weight of fill, assumed saturated*

$w_{s1} := \pi D_{15.25od} \cdot t_{1.625} \cdot \gamma_s$	*Weight of steel conduit per foot*	$w_s = 957.69 \cdot plf$
$W_{D15.25} := w \cdot H_c \cdot D_{15.25od} + w_{s1}$	*Dead Load on 15.25' diameter penstock, Reference 6 Eqn. 5-3)*	$W_{D15.25} = 8.705 \cdot klf$

Live Load on Conduit:

$P_{v1} := 0.0psi$	*Pressure Vacuum (surge tank)*	

Allowable Buckling Pressure:

$h_w := 0$	*Height of Water above penstock*	$h_w = 0.00 \cdot in$
$h := H_c$	*Height of fill above penstock, (assumed)*	$h = 36.00 \cdot in$
$R_w := 1$	*Water Buoyancy factor (assume well-drained)*	$R_w = 1.00$
$H := \frac{H_c}{ft}$	*Height of fill above penstock, (ft) unitless*	$H = 3.00$
$B_{prime} := \frac{1}{1 + 4e^{-0.065 \cdot H}}$	*Empirical coefficient of elastic support*	$B_{prime} = 0.23$
$E_{prime} := 500psi$	*Modulus of soil reaction,Reference 6, Table 6-1, assumed for fine grained soils with w/less than 25% sand @ 85% compaction @ 2ft-5ft cover*	
$E := 30000000psi$	*Modulus of elasticity for steel*	
$I := \frac{(t_{15.25})^3}{12}$	*Transverse moment of inertia per unit length of pipe wall*	$I = 0.0567 \cdot \frac{in^4}{ft}$
$E \cdot I = 4561606.336 ft \cdot s^{-2} \cdot in \cdot lb$	*Pipe wall stiffness*	
$D_{15.25} = 15.25 ft$	*Penstock Diameter 2 ID*	
$D_{15.25od} := D_{15.25} + \left(2 \cdot \frac{t_{15.25}}{12}\right) = 15.26 ft$	*Penstock Diameter 2 OD*	
$FS := 2.0$	*Factor of safety per AWWA M-11, 5th Ed., (ASCE No. 79 references 3rd Ed.)*	
$q_{a15.25} := \frac{1}{FS} \cdot \left(32 \cdot R_w \cdot B_{prime} \cdot E_{prime} \cdot \frac{E \cdot I}{D_{15.25od}^3}\right)^{0.5}$	*Allowable Buckling Pressure on 15.25' diameter penstock, (Ref 3, EQN 6-7, AWWA 2004)*	$q_{a15.25} = 4.64 \cdot psi$

External Pressure without Live Load:

$Q_{15.25} := \gamma_w \cdot h_w + R_w \cdot \frac{(W_{D15.25} + S_{load})}{D_{15.25}} + P_{v1}$	*External Pressure with no vacuum on 15.25' diameter penstock (Ref 3, AWWA 2004)*	$Q_{15.25} = 4.12 \cdot psi$

External Pressure with Live Load:

$$Q_{L15.25} := \gamma_w \cdot h_w + R_w \cdot \frac{(W_{D15.25} + S_{load})}{D_{15.25}} + \frac{L_{load}}{D_{15.25}}$$

External Pressure with 100 psf Live Load on 15.25' diameter penstock (Ref 3, AWWA 2004)

$$Q_{L15.25} = 4.26 \cdot psi$$

Stress Ratios:

$$\frac{Q_{15.25}}{q_{a15.25}} = 0.89$$

External Pressure with No Vacuum in 15.25' diameter penstock

$$\frac{Q_{L15.25}}{q_{a15.25}} = 0.92$$

External Pressure with 100 psf Live Load on 15.25' diameter penstock

Recommended thickness for shipping and handling per Reference 3

PG & E formula:

$$t_{17\_PGE} := \frac{D_{17}}{288} = 0.71 \cdot in$$

*t_{17} is **less** than minimum recommended for 17' diameter*

$$t_{15.25\_PGE} := \frac{D_{15.25}}{288} = 0.64 \cdot in$$

*$t_{15.25}$ is **less** than minimum recommended for 15'-6" diameter*

USBR formula:

$$t_{17USBR} := \frac{(D_{17od} + 20in)}{400} = 0.56 \cdot in$$

$$t_{15.25USBR} := \frac{(D_{15.25od} + 20in)}{400} = 0.51 \cdot in$$

TABLE 1 - Full Supply Level (FSL)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	(per Penstock #2 assessment)
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet

Note: Station 0+00 is 17 feet from downstream side of the head gate

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress	Base Material		At Joints		Notes
										Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
Penstock Interior From Upstream End of Conduit														
4A	0+27	8.50	1	0.4723	0.5000	-5.5%	0.4646	549.3103	17000	4536.9	0.27	6481.3	0.38	A285 Steel (grade unknown)
4B		8.50	2	0.4684	0.5000	-6.3%			17000					
4C		8.50	3	0.4763	0.5000	-4.7%			17000					
12A	01+08.5	8.50	4	0.4763	0.5000	-4.7%	0.4576	548.9590	17000	4640.6	0.27	6629.4	0.39	
12B		8.50	5	0.4644	0.5000	-7.1%			17000					
12C		8.50	6	0.4802	0.5000	-4.0%			17000					
26A	01+99.42	8.50	7	0.4290	0.4375	-1.9%	0.4259	548.5670	17000	5026.6	0.30	7180.9	0.42	
26B		8.50	8	0.4290	0.4375	-1.9%			17000					
26C		8.50	9	0.4330	0.4375	-1.0%			17000					
33A	02+61.67	8.50	10	0.4290	0.4375	-1.9%	0.4290	542.8690	17000	5576.8	0.33	7966.9	0.47	
33B		8.50	11	0.4290	0.4375	-1.9%			17000					
33C		8.50	12	0.4290	0.4375	-1.9%			17000					
44A	03+60	8.50	13	0.3936	0.4375	-10.0%	0.3844	530.9246	17000	7596.7	0.45	10852.4	0.64	
44B		8.50	14	0.4133	0.4375	-5.5%			17000					
44C		8.50	15	0.4133	0.4375	-5.5%			17000					
55A	4+58.34	8.50	16	0.4015	0.4375	-8.2%	0.3946	519.0312	17000	8733.5	0.51	12476.5	0.73	
55B		8.50	17	0.4172	0.4375	-4.6%			17000					
55C		8.50	18	0.4133	0.4375	-5.5%			17000					
65A	5+40.67	8.50	19	0.4133	0.4375	-5.5%	0.3844	509.9572	17000	10007.3	0.59	14296.1	0.84	
65B		8.50	20	0.3936	0.4375	-10.0%			17000					
65C		8.50	21	0.4133	0.4375	-5.5%			17000					
66A	5+49.83	8.50	22	0.4015	0.4375	-8.2%	0.3884	509.8840	17000	9914.4	0.58	14163.5	0.83	
66B		8.50	23	0.3936	0.4375	-10.0%			17000					
66C		8.50	24	0.4054	0.4375	-7.3%			17000					
74A	6+21.83	8.50	25	0.4133	0.4375	-5.5%	0.4056	509.3085	17000	9556.9	0.56	13652.8	0.80	
74B		8.50	26	0.4172	0.4375	-4.6%			17000					
74C		8.50	27	0.4093	0.4375	-6.4%			17000					
86A	7+29.75	8.50	28	0.4054	0.4375	-7.3%	0.3977	508.4458	17000	9842.0	0.58	14060.0	0.83	
86B		8.50	29	0.4015	0.4375	-8.2%			17000					
86C		8.50	30	0.4093	0.4375	-6.4%			17000					
94A	7+98.42	8.50	31	0.3975	0.4375	-9.1%	0.3860	506.7493	17000	10334.3	0.61	14763.3	0.87	
94B		8.50	32	0.3897	0.4375	-10.9%			17000					
94C		8.50	33	0.3975	0.4375	-9.1%			17000					
99A	8+43.5	8.50	34	0.4133	0.4375	-5.5%	0.4101	502.4419	17000	10190.4	0.60	14557.7	0.86	
99B		8.50	35	0.4172	0.4375	-4.6%			17000					
99C		8.50	36	0.4133	0.4375	-5.5%			17000					
106A	9+06.42	8.50	37	0.3975	0.4375	-9.1%	0.3850	496.4299	17000	11546.9	0.68	16495.6	0.97	
106B		8.50	38	0.4133	0.4375	-5.5%			17000					
106C		8.50	39	0.3975	0.4375	-9.1%			17000					
110A	9+48.42	8.50	40	0.4133	0.4375	-5.5%	0.3902	492.4169	17000	11846.2	0.70	16923.1	1.00	
110B		8.50	41	0.3975	0.4375	-9.1%			17000					
110C		8.50	42	0.4133	0.4375	-5.5%			17000					
120A	10+32.34	8.50	43	0.4054	0.4375	-7.3%	0.3842	484.3984	24000	12955.0	0.54	18507.2	0.77	CSA G40.8 Grade B Steel
120B		8.50	44	0.3936	0.4375	-10.0%			24000					
120C		8.50	45	0.3936	0.4375	-10.0%			24000					
130A	11+20.92	8.50	46	0.4054	0.4375	-7.3%	0.3920	475.9346	24000	13651.7	0.57	19502.4	0.81	
130B		8.50	47	0.4172	0.4375	-4.6%			24000					
130C		8.50	48	0.4015	0.4375	-8.2%			24000					
140A	12+08.67	8.50	49	0.5392	0.4375	23.3%	0.5104	467.5502	24000	11210.1	0.47	16014.5	0.67	
140B		8.50	50	0.5392	0.4375	23.3%			24000					
140C		8.50	51	0.5196	0.4375	18.8%			24000					
150A	12+80.08	7.63	52	0.3975	0.4375	-9.1%	0.3884	454.0198	24000	14596.7	0.61	20852.5	0.87	15.25 ft diameter penstock
150B		7.63	53	0.4172	0.4375	-4.6%			24000					
150C		7.63	54	0.4172	0.4375	-4.6%			24000					
157A	13+32.83	7.63	55	0.417216	0.4375	-4.6%	0.3963	440.4553	24000	15663.5	0.65	22376.4	0.93	
157B		7.63	56	0.409344	0.4375	-6.4%			24000					
157C		7.63	57	0.43296	0.4375	-1.0%			24000					
166A	14+14.34	7.63	58	0.4841	0.5000	-3.2%	0.4789	419.4953	24000	14696.2	0.61	20994.6	0.87	
166B		7.63	59	0.4959	0.5000	-0.8%			24000					
166C		7.63	60	0.4920	0.5000	-1.6%			24000					
174A	14+88	7.63	61	0.5314	0.5000	6.3%	0.5256	400.5538	24000	14819.6	0.62	21170.9	0.88	
174B		7.63	62	0.5274	0.5000	5.5%			24000					
174C		7.63	63	0.5314	0.5000	6.3%			24000					
184A	15+92.17	7.63	64	0.5156	0.5625	-8.3%	0.5062	373.7668	24000	17485.9	0.73	24979.9	1.04	
184B		7.63	65	0.5156	0.5625	-8.3%			24000					
184C		7.63	66	0.5274	0.5625	-6.2%			24000					
196A	16+72.67	7.63	67	0.5235	0.5625	-6.9%	0.5104	368.6658	24000	17738.2	0.74	25340.3	1.06	
196B		7.63	68	0.5156	0.5625	-8.3%			24000					
196C		7.63	69	0.5274	0.5625	-6.2%			24000					
204A	17+45	7.63	70	0.6022	0.6250	-3.6%	0.5957	362.4662	24000	15611.4	0.65	22302.0	0.93	
204B		7.63	71	0.6061	0.6250	-3.0%			24000					
204C		7.63	72	0.6140	0.6250	-1.8%			24000					
214A	18+36.42	7.63	73	0.6140	0.6250	-1.8%	0.5957	354.6304	24000	16133.0	0.67	23047.1	0.96	
214B		7.63	74	0.6022	0.6250	-3.6%			24000					
214C		7.63	75	0.6061	0.6250	-3.0%			24000					
223A	19+18.75	7.63	76	0.6061	0.6250	-3.0%	0.5945	347.5737	24000	16635.6	0.69	23765.1	0.99	
223B		7.63	77	0.6022	0.6250	-3.6%			24000					
223C		7.63	78	0.5983	0.6250	-4.3%			24000					
233A	20+00.25	7.63	79	0.6455	0.6875	-6.1%	0.6298	327.3236	24000	16978.0	0.71	24254.3	1.01	
233B		7.63	80	0.6652	0.6875	-3.2%			24000					
233C		7.63	81	0.6455	0.6875	-6.1%			24000					
243A	20+91.08	7.63	82	0.7006	0.6875	1.9%	0.6902	319.8851	24000	15918.5	0.66	22740.7	0.95	
243B		7.63	83	0.7242	0.6875	5.3%			24000					
243C		7.63	84	0.7203	0.6875	4.8%			24000					
257A	22+17	7.63	85	0.7242	0.7500	-3.4%	0.7204	297.4610	24000	16485.2	0.69	23550.4	0.98	
257B		7.63	86	0.7282	0.7500	-2.9%			24000					
257C		7.63	87	0.7321	0.7500	-2.4%			24000					
266A	22+82.83	7.63	88	0.7164	0.7500	-4.5%	0.7033	285.7378	24000	17548.6	0.73	25069.4	1.04	
266B		7.63	89	0.7242	0.7500	-3.4%			24000					
266C		7.63	90	0.7400	0.7500	-1.3%			24000					
276A	23+72.25	7.63	91	0.7400	0.7500	-1.3%	0.7167	269.8013	24000	18102.5	0.75	25860.6	1.08	
276B		7.63	92	0.7242	0.7500	-3.4%			24000					

										Base Material		At Joints		
Location		Radius (feet)	Reading Number	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress	Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	Notes
276C		7.63	93	0.7321	0.7500	-2.4%			24000					
286A	24+62	7.63	94	0.7557	0.7500	0.8%	0.7401	253.8309	24000	18385.0	0.77	26264.2	1.09	
286B		7.63	95	0.7793	0.7500	3.9%			24000					
286C		7.63	96	0.7596	0.7500	1.3%			24000					
296A	25+52.34	7.63	97	0.8187	0.8750	-6.4%	0.8009	237.7429	24000	17786.8	0.74	25409.7	1.06	
296B		7.63	98	0.8580	0.8750	-1.9%			24000					
296C		7.63	99	0.8423	0.8750	-3.7%			24000					
306A	26+41.5	7.63	100	0.9013	0.9375	-3.9%	0.8936	224.1888	24000	16541.5	0.69	23630.7	0.98	
306B		7.63	101	0.9053	0.9375	-3.4%			24000					
306C		7.63	102	0.8974	0.9375	-4.3%			24000					
316A	27+23.5	7.63	103	0.8659	0.9375	-7.6%	0.8502	214.6590	24000	17831.5	0.74	25473.6	1.06	
316B		7.63	104	0.8974	0.9375	-4.3%			24000					
316C		7.63	105	0.9013	0.9375	-3.9%			24000					
326A	28+22.58	7.63	106	0.9840	1.0000	-1.6%	0.9771	203.1442	24000	15982.0	0.67	22831.4	0.95	
326B		7.63	107	0.9997	1.0000	0.0%			24000					
326C		7.63	108	0.9958	1.0000	-0.4%			24000					
336A	29+11.75	7.63	109	1.0430	1.0000	4.3%	1.0336	192.7812	24000	15506.1	0.65	22151.5	0.92	
336B		7.63	110	1.0430	1.0000	4.3%			24000					
336C		7.63	111	1.0548	1.0000	5.5%			24000					
346A	29+97.92	7.63	112	1.1178	1.1250	-0.6%	1.1076	182.7668	24000	14828.9	0.62	21184.1	0.88	
346B		7.63	113	1.1375	1.1250	1.1%			24000					
346C		7.63	114	1.1257	1.1250	0.1%			24000					
356A	30+86	7.63	115	1.1926	1.1250	6.0%	1.1792	172.5304	24000	14272.9	0.59	20389.9	0.85	
356B		7.63	116	1.2044	1.1250	7.1%			24000					
356C		7.63	117	1.1887	1.1250	5.7%			24000					
366A	31+51.58	7.63	118	1.1887	1.1875	0.1%	1.1765	161.6942	24000	14670.3	0.61	20957.5	0.87	
366B		7.63	119	1.2162	1.1875	2.4%			24000					
366C		7.63	120	1.2123	1.1875	2.1%			24000					
375A	32+42.5	7.63	121	1.2753	1.2500	2.0%	1.2636	143.1170	24000	14242.1	0.59	20345.8	0.85	
375B		7.63	122	1.2713	1.2500	1.7%			24000					
375C		7.63	123	1.2674	1.2500	1.4%			24000					
385A	33+33.25	7.63	124	1.3068	1.3125	-0.4%	1.2907	124.5745	24000	14512.3	0.60	20731.9	0.86	
385B		7.63	125	1.3343	1.3125	1.7%			24000					
385C		7.63	126	1.3146	1.3125	0.2%			24000					
396A	34+33.58	7.63	127	1.3933	1.3750	1.3%	1.3672	104.0746	24000	14295.8	0.60	20422.5	0.85	
396B		7.63	128	1.3776	1.3750	0.2%			24000					
396C		7.63	129	1.4012	1.3750	1.9%			24000					
406A	35+24.58	7.63	130	1.4327	1.4375	-0.3%	1.4018	85.4810	24000	14467.9	0.60	20668.4	0.86	
406B		7.63	131	1.4484	1.4375	0.8%			24000					
406C		7.63	132	1.4170	1.4375	-1.4%			24000					
416A	36+04.34	7.63	133	0.0000	NA									
416B		7.63	134	1.4524	1.4375	1.0%	1.4450	69.1841	24000	14483.4	0.60	20690.5	0.86	
416C		7.63	135	1.4484	1.4375	0.8%			24000					
425A	36+96	7.63	136	0.0000	NA									
425B		7.63	137	1.5665	1.5625	0.3%	1.5368	64.8998	24000	13728.1	0.57	19611.5	0.82	
425C		7.63	138	1.5508	1.5625	-0.7%			24000					
430A	37+41	7.63	139	0.0000	NA									
430B		7.63	140	1.5311	1.5625	-2.0%	1.5137	27.8110	24000	14909.7	0.62	21299.6	0.89	
430C		7.63	141	1.5508	1.5625	-0.7%			24000					
440A		7.63	142	0.0000	NA									
440B		7.63	143	1.2556					24000					
440C		7.63	144	1.2713					24000					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$

[2] Hoop stress / S_A

[3] Hoop stress / 0.7 $_{\text{joint efficiency}}$

[4] Joint stress / S_A

TABLE 2 - Transient (Factored x 1.3)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	(per Penstock #2 assessment)
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet

Note: Station 0+00 is 17 feet from downstream side of the head gate

Location		Radius (feet)	Reading Number	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence	C.L. EL. (ft)	Allowable Steel Stress	Base Material		At Joints		Notes
										Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
INTERIOR From Upstream End of Conduit														
4A	0+27	8.50	1	0.4723	0.5000	-5.5%	0.4646	549.3103	17000	5898.0	0.35	8425.7	0.50	A285 Steel (grade unknown)
4B		8.50	2	0.4684	0.5000	-6.3%			17000					
4C		8.50	3	0.4763	0.5000	-4.7%			17000					
12A	01+08.5	8.50	4	0.4763	0.5000	-4.7%	0.4576	548.9590	17000	6032.8	0.35	8618.3	0.51	
12B		8.50	5	0.4644	0.5000	-7.1%			17000					
12C		8.50	6	0.4802	0.5000	-4.0%			17000					
26A	01+99.42	8.50	7	0.4290	0.4375	-1.9%	0.4259	548.5670	17000	6534.6	0.38	9335.1	0.55	
26B		8.50	8	0.4290	0.4375	-1.9%			17000					
26C		8.50	9	0.4330	0.4375	-1.0%			17000					
33A	02+61.67	8.50	10	0.4290	0.4375	-1.9%	0.4290	542.8690	17000	7249.9	0.43	10357.0	0.61	
33B		8.50	11	0.4290	0.4375	-1.9%			17000					
33C		8.50	12	0.4290	0.4375	-1.9%			17000					
44A	03+60	8.50	13	0.3936	0.4375	-10.0%	0.3844	530.9246	17000	9875.6	0.58	14108.1	0.83	
44B		8.50	14	0.4133	0.4375	-5.5%			17000					
44C		8.50	15	0.4133	0.4375	-5.5%			17000					
55A	4+58.34	8.50	16	0.4015	0.4375	-8.2%	0.3946	519.0312	17000	11353.6	0.67	16219.4	0.95	
55B		8.50	17	0.4172	0.4375	-4.6%			17000					
55C		8.50	18	0.4133	0.4375	-5.5%			17000					
65A	5+40.67	8.50	19	0.4133	0.4375	-5.5%	0.3844	509.9572	17000	13009.4	0.77	18584.9	1.09	
65B		8.50	20	0.3936	0.4375	-10.0%			17000					
65C		8.50	21	0.4133	0.4375	-5.5%			17000					
66A	5+49.83	8.50	22	0.4015	0.4375	-8.2%	0.3884	509.8840	17000	12888.8	0.76	18412.5	1.08	
66B		8.50	23	0.3936	0.4375	-10.0%			17000					
66C		8.50	24	0.4054	0.4375	-7.3%			17000					
74A	6+21.83	8.50	25	0.4133	0.4375	-5.5%	0.4056	509.3085	17000	12424.0	0.73	17748.6	1.04	
74B		8.50	26	0.4172	0.4375	-4.6%			17000					
74C		8.50	27	0.4093	0.4375	-6.4%			17000					
86A	7+29.75	8.50	28	0.4054	0.4375	-7.3%	0.3977	508.4458	17000	12794.6	0.75	18278.0	1.08	
86B		8.50	29	0.4015	0.4375	-8.2%			17000					
86C		8.50	30	0.4093	0.4375	-6.4%			17000					
94A	7+98.42	8.50	31	0.3975	0.4375	-9.1%	0.3860	506.7493	17000	13434.6	0.79	19192.3	1.13	
94B		8.50	32	0.3897	0.4375	-10.9%			17000					
94C		8.50	33	0.3975	0.4375	-9.1%			17000					
99A	8+43.5	8.50	34	0.4133	0.4375	-5.5%	0.4101	502.4419	17000	13247.5	0.78	18925.0	1.11	
99B		8.50	35	0.4172	0.4375	-4.6%			17000					
99C		8.50	36	0.4133	0.4375	-5.5%			17000					
106A	9+06.42	8.50	37	0.3975	0.4375	-9.1%	0.3850	496.4299	17000	15011.0	0.88	21444.3	1.26	
106B		8.50	38	0.4133	0.4375	-5.5%			17000					
106C		8.50	39	0.3975	0.4375	-9.1%			17000					
110A	9+48.42	8.50	40	0.4133	0.4375	-5.5%	0.3902	492.4169	17000	15400.1	0.91	22000.1	1.29	
110B		8.50	41	0.3975	0.4375	-9.1%			17000					
110C		8.50	42	0.4133	0.4375	-5.5%			17000					
120A	10+32.34	8.50	43	0.4054	0.4375	-7.3%	0.3842	484.3984	24000	16841.6	0.70	24059.4	1.00	CSA G40.8 Grade B Steel 40 ksi
120B		8.50	44	0.3936	0.4375	-10.0%			24000					
120C		8.50	45	0.3936	0.4375	-10.0%			24000					
130A	11+20.92	8.50	46	0.4054	0.4375	-7.3%	0.3920	475.9346	24000	17747.2	0.74	25353.1	1.06	
130B		8.50	47	0.4172	0.4375	-4.6%			24000					
130C		8.50	48	0.4015	0.4375	-8.2%			24000					
140A	12+08.67	8.50	49	0.5392	0.4375	23.3%	0.5104	467.5502	24000	14573.2	0.61	20818.8	0.87	
140B		8.50	50	0.5392	0.4375	23.3%			24000					
140C		8.50	51	0.5196	0.4375	18.8%			24000					
150A	12+80.08	7.63	52	0.3975	0.4375	-9.1%	0.3884	454.0198	24000	18975.7	0.79	27108.2	1.13	15.25 ft diameter penstock
150B		7.63	53	0.4172	0.4375	-4.6%			24000					
150C		7.63	54	0.4172	0.4375	-4.6%			24000					
157A	13+32.83	7.63	55	0.417216	0.4375	-4.6%	0.3963	440.4550	24000	20362.6	0.85	29089.4	1.21	
157B		7.63	56	0.409344	0.4375	-6.4%			24000					
157C		7.63	57	0.43296	0.4375	-1.0%			24000					
166A	14+14.34	7.63	58	0.4841	0.5000	-3.2%	0.4789	419.4953	24000	19105.1	0.80	27292.9	1.14	
166B		7.63	59	0.4959	0.5000	-0.8%			24000					
166C		7.63	60	0.4920	0.5000	-1.6%			24000					
174A	14+88	7.63	61	0.5314	0.5000	6.3%	0.5256	400.5538	24000	19265.5	0.80	27522.1	1.15	
174B		7.63	62	0.5274	0.5000	5.5%			24000					
174C		7.63	63	0.5314	0.5000	6.3%			24000					
184A	15+92.17	7.63	64	0.5156	0.5625	-8.3%	0.5062	373.7668	24000	22731.7	0.95	32473.8	1.35	
184B		7.63	65	0.5156	0.5625	-8.3%			24000					
184C		7.63	66	0.5274	0.5625	-6.2%			24000					
196A	16+72.67	7.63	67	0.5235	0.5625	-6.9%	0.5104	368.6658	24000	23059.7	0.96	32942.4	1.37	
196B		7.63	68	0.5156	0.5625	-8.3%			24000					
196C		7.63	69	0.5274	0.5625	-6.2%			24000					
204A	17+45	7.63	70	0.6022	0.6250	-3.6%	0.5957	362.4662	24000	20294.8	0.85	28992.6	1.21	
204B		7.63	71	0.6061	0.6250	-3.0%			24000					
204C		7.63	72	0.6140	0.6250	-1.8%			24000					
214A	18+36.42	7.63	73	0.6140	0.6250	-1.8%	0.5957	354.6304	24000	20972.9	0.87	29961.2	1.25	
214B		7.63	74	0.6022	0.6250	-3.6%			24000					
214C		7.63	75	0.6061	0.6250	-3.0%			24000					
223A	19+18.75	7.63	76	0.6061	0.6250	-3.0%	0.5945	347.5737	24000	21626.3	0.90	30894.7	1.29	
223B		7.63	77	0.6022	0.6250	-3.6%			24000					
223C		7.63	78	0.5983	0.6250	-4.3%			24000					
233A	20+00.25	7.63	79	0.6455	0.6875	-6.1%	0.6298	327.3236	24000	22071.5	0.92	31530.7	1.31	CSA G40.8 Grade B Steel 38 ksi
233B		7.63	80	0.6652	0.6875	-3.2%			24000					
233C		7.63	81	0.6455	0.6875	-6.1%			24000					
243A	20+91.08	7.63	82	0.7006	0.6875	1.9%	0.6902	319.8851	24000	20694.1	0.86	29562.9	1.23	
243B		7.63	83	0.7242	0.6875	5.3%			24000					
243C		7.63	84	0.7203	0.6875	4.8%			24000					
257A	22+17	7.63	85	0.7242	0.7500	-3.4%	0.7204	297.4610	24000	21430.8	0.89	30615.5	1.28	
257B		7.63	86	0.7282	0.7500	-2.9%			24000					
257C		7.63	87	0.7321	0.7500	-2.4%			24000					
266A	22+82.83	7.63	88	0.7164	0.7500	-4.5%	0.7033	285.7378	24000	22813.1	0.95	32590.2	1.36	
266B		7.63	89	0.7242	0.7500	-3.4%			24000					
266C		7.63	90	0.7400	0.7500	-1.3%			24000					
276A	23+72.25	7.63	91	0.7400	0.7500	-1.3%	0.7167	269.8013	24000	23533.2	0.98	33618.8	1.40	
276B		7.63	92	0.7242	0.7500	-3.4%			24000					

276C		7.63	93	0.7321	0.7500	-2.4%			24000					
286A	24+62	7.63	94	0.7557	0.7500	0.8%	0.7401	253.8309	24000	23900.4	1.00	34143.5	1.42	
286B		7.63	95	0.7793	0.7500	3.9%			24000					
286C		7.63	96	0.7596	0.7500	1.3%			24000					
296A	25+52.34	7.63	97	0.8187	0.8750	-6.4%	0.8009	237.7429	24000	23122.8	0.96	33032.6	1.38	
296B		7.63	98	0.8580	0.8750	-1.9%			24000					
296C		7.63	99	0.8423	0.8750	-3.7%			24000					
306A	26+41.5	7.63	100	0.9013	0.9375	-3.9%	0.8936	224.1888	24000	21503.9	0.90	30719.9	1.28	
306B		7.63	101	0.9053	0.9375	-3.4%			24000					
306C		7.63	102	0.8974	0.9375	-4.3%			24000					
316A	27+23.5	7.63	103	0.8659	0.9375	-7.6%	0.8502	214.6590	24000	23181.0	0.97	33115.7	1.38	
316B		7.63	104	0.8974	0.9375	-4.3%			24000					
316C		7.63	105	0.9013	0.9375	-3.9%			24000					
326A	28+22.58	7.63	106	0.9840	1.0000	-1.6%	0.9771	203.1442	24000	20776.6	0.87	29680.8	1.24	CSA G40.8 Grade B Steel 36 ksi
326B		7.63	107	0.9997	1.0000	0.0%			24000					
326C		7.63	108	0.9958	1.0000	-0.4%			24000					
336A	29+11.75	7.63	109	1.0430	1.0000	4.3%	1.0336	192.7812	24000	20157.9	0.84	28797.0	1.20	
336B		7.63	110	1.0430	1.0000	4.3%			24000					
336C		7.63	111	1.0548	1.0000	5.5%			24000					
346A	29+97.92	7.63	112	1.1178	1.1250	-0.6%	1.1076	182.7668	24000	19277.5	0.80	27539.3	1.15	
346B		7.63	113	1.1375	1.1250	1.1%			24000					
346C		7.63	114	1.1257	1.1250	0.1%			24000					
356A	30+86	7.63	115	1.1926	1.1250	6.0%	1.1792	172.5304	24000	18554.8	0.77	26506.8	1.10	
356B		7.63	116	1.2044	1.1250	7.1%			24000					
356C		7.63	117	1.1887	1.1250	5.7%			24000					
366A	31+51.58	7.63	118	1.1887	1.1875	0.1%	1.1765	161.6942	24000	19071.3	0.79	27244.8	1.14	
366B		7.63	119	1.2162	1.1875	2.4%			24000					
366C		7.63	120	1.2123	1.1875	2.1%			24000					
375A	32+42.5	7.63	121	1.2753	1.2500	2.0%	1.2636	143.1170	24000	18514.7	0.77	26449.5	1.10	
375B		7.63	122	1.2713	1.2500	1.7%			24000					
375C		7.63	123	1.2674	1.2500	1.4%			24000					
385A	33+33.25	7.63	124	1.3068	1.3125	-0.4%	1.2907	124.5745	24000	18866.0	0.79	26951.4	1.12	
385B		7.63	125	1.3343	1.3125	1.7%			24000					
385C		7.63	126	1.3146	1.3125	0.2%			24000					
396A	34+33.58	7.63	127	1.3933	1.3750	1.3%	1.3672	104.0746	24000	18584.5	0.77	26549.3	1.11	
396B		7.63	128	1.3776	1.3750	0.2%			24000					
396C		7.63	129	1.4012	1.3750	1.9%			24000					
406A	35+24.58	7.63	130	1.4327	1.4375	-0.3%	1.4018	85.4810	24000	18808.2	0.78	26868.9	1.12	
406B		7.63	131	1.4484	1.4375	0.8%			24000					
406C		7.63	132	1.4170	1.4375	-1.4%			24000					
416A	36+04.34	7.63	133	0.0000	NA									
416B		7.63	134	1.4524	1.4375	1.0%	1.4450	69.1841	24000	18828.4	0.78	26897.7	1.12	
416C		7.63	135	1.4484	1.4375	0.8%			24000					
425A	36+96	7.63	136	0.0000	NA									
425B		7.63	137	1.5665	1.5625	0.3%	1.5368	64.8998	24000	17846.5	0.74	25495.0	1.06	
425C		7.63	138	1.5508	1.5625	-0.7%			24000					
430A	37+41	7.63	139	0.0000	NA									
430B		7.63	140	1.5311	1.5625	-2.0%	1.5137	27.8110	24000	19382.6	0.81	27689.4	1.15	
430C		7.63	141	1.5508	1.5625	-0.7%			24000					
440A		7.63	142	0.0000	NA									
440B		7.63	143	1.2556					24000					
440C		7.63	144	1.2713					24000					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / $0.7_{\text{joint efficiency}}$
[4] Joint stress / S_A

EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa) Reference 3

Diameter 15.25 feet						Unit Weight of Water=	62.4	pcf		
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0			
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3		
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3		
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	(soil load) W_c=	5972.5	lb/ft		
OD Conduit Diameter=	15.31403333	feet	ID:	15.25	feet	(live load) W_l=	1531.4	lb/ft	100 psf per foot section	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	316	lb/ft		
B_prime=	0.2330					W_{steel}=	3192	lb/ft		
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf		
E=	30000000	psi								
b=	1					External pressure with vacuum=	4.15	psi	Ratio Q/q_a=	0.905686
$t_{97.5}$=	0.384	inches				External pressure with snow load=	4.30	psi	Ratio Q/q_a=	0.936877
I=	0.0047	$inches^4$				External pressure with snow and live=	4.78	psi	Ratio Q/q_a=	1.042582
FS=	2									
Allowable pressure q_a=	4.59	psi								

Allowable pressures (kPa)/External Pressures (kPa) Reference 3

Diameter 17 feet						Unit Weight of Water=	62.4	pcf		
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0			
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3		
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3		
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	(soil load) W_c=	6655.0	lb/ft		
OD Conduit Diameter=	17.06406667	feet	ID:	17.00	feet	(live load) W_l=	1706.4	lb/ft		
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	351.7	lb/ft		
B_prime=	0.23302752					W_{steel}=	957.7	lb/ft		
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf		
E=	30000000	psi								
b=	1					External pressure with vacuum=	3.10	psi	Ratio Q/q_a=	0.792999
$t_{97.5}$=	0.384	inches				External pressure with snow load=	3.24	psi	Ratio Q/q_a=	0.829634
I=	0.0047	$inches^4$				External pressure with snow and live=	3.72	psi	Ratio Q/q_a=	0.95379
FS=	2									
Allowable pressure q_a=	3.90	psi								

APPENDIX F

WELD TRACKER

Date: August 14,2020 updated

PENSTOCK 1 WELD PROGRESS TRACKER

North	I	FP	NI	NI	FP	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP
SECTION #	N	1																			2		3		4	5	6	7	8		
CAN#	T A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Other	K																										RW				
South	E	FP	NI	NI	FP	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	NI	NI	NI	FP

North	NI	NI	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	
SECTION #																															
CAN#	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	A
Other						RW			MH							RW									RW						
South	NI	NI	FP	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	FP	FP	NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	

North		NI	NI	NI	NI	FP	NI	FP	NI	FP	NI	NI	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	NI
SECTION #		9	10	11	12																									13	15
CAN#	A	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Other								RW	MH							RW													DP	RW	
South		NI	NI	NI	NI	NI	FP	FP	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	NI

North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	
SECTION #	16																							
CAN#	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	B
Other	RW	RW	RW	DP	IP	IP	RW	RW	RW	RW	RW	RW										RW		
South	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	

North		NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	FP	NI
SECTION #		17																										18	70	72	74
CAN #	B	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
Other											RW						MH					RW								RW	
South		NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	NI	NI	FP	FP	FP	NI	FP	NI	NI	NI	NI	FP	NI	NI	FP	NI

North	NI	NI	NI	NI	FP	NI	NI	NI	NI	FP	NI	NI	NI	NI	NI	NI	NI	NI	NI	FP	NI	NI	NI	NI	FP	NI	NI	NI	NI	FP	
SECTION #	20	21																	117												
CAN #	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	C
Other										RW										RW										RW	
South	NI	FP	NI	NI	FP	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	NI	NI	FP	FP	NI	NI	FP	NI	NI	FP	

North		FP	FP	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	FP	NI	NI	NI	NI	FP	NI	NI
CAN #	C	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203
Other											OW										OW										
South		NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	NI	NI	NI	FP	NI	NI

ADDITIONAL SCOPE (cans 210–220)

North	FP	FP	FP	NI	NI	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP	
CAN #	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	D
Other		OW					OW	OW	OW	OW	OW	OW	OW	OW	OW	OW	OW														
South	NI	FP	NI	NI	NI	NI	FP	FP	FP	FP	FP	WR	FP	FP	FP	FP	FP	NI	NI	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP	

North		NI	FP	NI	NI	NI	NI	FP	NI	NI	FP	NI	FP	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI
CAN #	D	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263
Other																	IT?										ST	ST			
South		NI	FP	NI	NI	NI	NI	FP	NI	NI	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI

North	FP	FP	FP	NI	NI	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	NI	FP	NI	
CAN #	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	E
Other							IT?										IT?														
South	FP	FP	FP	NI	NI	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	NI	FP	NI	

North		NI	FP	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	FP	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI
CAN #	E	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323
Other																															
South		NI	FP	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	FP	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI

North	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	
CAN #	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	F
Other																															
South	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	

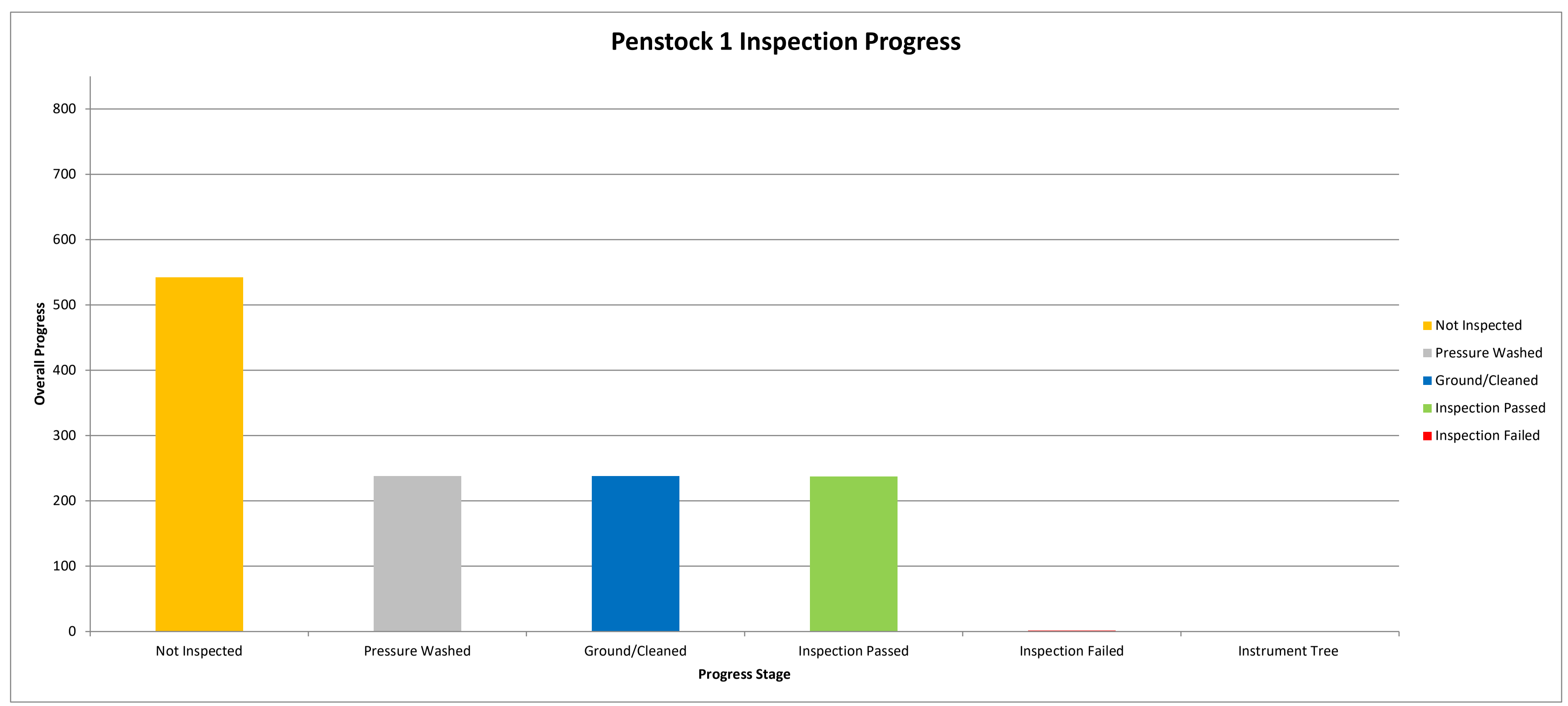
North		FP	NI	NI	NI	NI	NI	NI	NI	FP	NI	FP	FP	NI	NI	NI	NI	FP	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI
CAN #	F	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383
Other																							OW								
South		FP	FP	FP	NI	NI	NI	NI	NI	FP	NI	FP	FP	NI	NI	NI	NI	FP	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI

North	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	NI	NI	NI	FP	FP	
CAN #	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	P H
Other		OW					OW											
South	NI	FP	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	NI	NI	NI	FP	FP	

Legend		
NI	=	NOT INSPECTED
PW	=	PRESSURE WASHED
P	=	Weld Preperation Complete
FP	=	Final Inspection Passed
FF	=	Final Inspection Failed
WR	=	Weld Repair
FIP	=	Final Inspection Passed
IT?		Possible Intstrument Tee Location
ST	=	SURGE TANK
RW	=	REFUBISHED WELD
OW	=	ORIGINAL WELD
MH	=	MAN HOLE

Original Scope	
Total welds :	800
Not Inspected	542
Pressure Washed	238
Ground/Cleaned	238
Inspection Passed	237
Inspection Failed	1
Instrument Tree	0

Original Scope	
Total welds :	800
Percent Complete	221%
Pressure Washed	233%
Ground/Cleaned	233%
Inspection Passed	232%
Inspection Failed	1%
Instrument Tree	0%



PENSTOCK NO. 1 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:

Newfoundland and Labrador Hydro

Prepared by:

Kleinschmidt Associates

September 2021

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ACRONYMS

A	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
E	
ETS	Eastern Technical Services
F	
Fu	Ultimate Tensile Stress
FSL	Full Supply Level
K	
Kleinschmidt	Kleinschmidt Associates Canada Inc.
M	
MT	Magnetic Partical Testing
N	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
S	
STA	Station (in feet)
T	
TRR	Technical Rope and Rescue
U	
UT	Ultrasonic Thickness

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in December of 2020 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development in 2021.

Kleinschmidt conducted an inspection of Penstock No. 1 in May 2021. Penstock No. 1 is a buried steel penstock approximately 1,100 metres (m) long, tapering from 5.2 m in diameter at the intake, to 4.1 m in diameter at the powerhouse bifurcation. At its flattest point, the penstock has a 0.2-degree slope and has a slope of 19.7 degrees at its steepest. There are three areas of access for Penstock No. 1: one at the well in the intake structure, five manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Due to weld issues and corrosion in all three penstocks, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock No. 1 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year .

The May 2021 inspection of Penstock No. 1 consisted of weld inspections and plate thickness measurements completed by Eastern Technical Services and Technical Rope and Rescue. Kleinschmidt's engineer, Chris Vella, did not travel to site due to Covid-19 restrictions. Mr. Vella provided inspection oversight remotely by staying in communication with the inspection team throughout the inspection and providing an inspection plan, test locations, and updated directions as required when conditions changed. A detailed examination of the condition of the interior of the penstock and an exterior walk of the penstock alignment was not conducted by Kleinschmidt this year. The welds were inspected by Eastern Technical Service and the data reviewed and analysed by Kleinschmidt.

The 2021 inspections, as part of Kleinschmidt's inspection program, concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected in the previous year in the upper end of the penstock. The quantity of longitudinal welds tested was planned to be doubled in the 17-ft diameter section this year and in the end, it was more than triple for this section of penstock when compared to previous years. The increase in weld inspections was due to weld indications discovered in the 17-ft section of Penstock 1. An extra labourer assisted with weld preparation and grinding, and the weld indications were urgently repaired before the penstock was returned to service.

Of significant note, weld indications (cracks) were identified in 14 cans. There were 32 individual lengths of weld indications totalling about 64 ft. The weld indications were located at previously repaired welds, either in the heat effected zone or at the toe of the weld. Five doubler plates had weld indications around the perimeter at the toe of the fillet weld in the original penstock plating. Finding the first indication in Can 126 triggered extensive testing of adjacent cans upstream and downstream which resulted in finding weld indications in other cans as listed in Appendix C. Testing continued in the area until five consecutive cans were found without indication. Every can from 115 to 155 was tested in order to clear the affected area. The crew transitioned from the inspection scope, to assisting with the weld repairs, and transitioned back to the inspections when the welds repairs were complete.

Measurements of the penstock shell thickness indicate minimal loss of material. However, the welds do not meet current standards and there have been multiple weld related failures over the last 5 years indicating the welds are at the end of their useful life. All 32 indications found during this inspection were at previously repaired welds, including repairs made with doubler plates, which are about 5 years old. The findings are indicative that the weld repair may not have a long service life. There are multiple factors that could be involved here including the difficulty welders are having with the base metal, pressure fluctuations causing fatigue in the toe of the welds, and the existing residual stresses from joint peaking.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.40 at the joints. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.1, which is not acceptable for late 1960 steel pipe. Note that the calculations of stresses at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used however, considering the known weld issues, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has a maximum stress ratio of 0.97 at Can 274 and a safety factor of 1.64, which is acceptable and could tolerate about 2 mm of material loss from design thickness in most cases.

Penstock 1 is approximately 50 years old and has shown minimal loss of metal due to corrosion compared to the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070). However, because of the condition of the existing welds, the 17-ft section of penstock will need to be replaced, the remaining penstock welds refurbished, and the interior re-coated before the steel deteriorates further.

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in April 2020 to inspect and evaluate the condition of Penstock No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

In 2016, weld indications were identified in Penstock No. 1 due to weld degradation and Kleinschmidt was contracted to assist with the weld repair design. The weld indications prompted NLH to conduct a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods and significant refurbishment of the welds followed.

Penstock No. 1 and No. 2 were installed in 1967, before installation of Penstock No. 3 in 1968. However, Penstock No. 1 was designed with similar plate materials, plate thicknesses, and weld procedures as Penstock No. 2 and 3.

Due to the similar design, the indications and weld issues discovered in Penstock No. 1 in 2016 raised concerns about the weld integrity of Penstocks No. 2 and 3. NLH elected to have Kleinschmidt complete detailed inspections of Penstock No. 2 in 2016 and Penstock No. 3 in 2017. The primary focus of the past inspections was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the remaining life span of the penstock. Non-destructive testing of the welds were not included in the 2016 and 2017 Kleinschmidt scope of work.

However, in 2018, the welds of Penstocks No.1, 2, and 3 were inspected and tested using magnetic particle testing (MT) methods as part of a Level II Condition Assessment performed by Hatch. The Hatch 2017 and 2018 reports reference multiple ruptures in the longitudinal weld seams in Penstock No. 1 upstream of the surge tank, as well as degradation and welds indications requiring repairs in Penstock No. 1, 2, and 3.

On September 22, 2019, a weld failure resulting in a leak was discovered by NLH in Penstock No. 1. The penstock was dewatered, and Kleinschmidt carried out an inspection from September 25-27, 2019. The leak was repaired by cutting out the welded area and welding in a replacement plate.

For this year's inspection Kleinschmidt's engineer did not travel to site due to Covid-19 restrictions. This year's inspection was performed by Kleinschmidt's Team with Technical Rope and Rescue (TRR) and Eastern Technical Services (ETS) on site to perform the weld tests and take UT thickness readings while Kleinschmidt's engineer, Chris Vella, provided inspection oversight remotely by providing an inspection plan, test locations, and communicated with the inspection team throughout the inspection.

This report presents Kleinschmidt's evaluation of Penstock No. 1 in its current condition following significant weld repairs made in 2016 and subsequent years, with consideration of the latest weld failures, and indications discovered during this 2021 inspection. This report provides recommendations for inspection procedures in the future and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 m) and seven generating units with a total capacity of 604 megawatts (MW). The development comprises four structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks No. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the project construction involved the installation of two intake structures (Intake 1 and Intake 2) and a four-unit powerhouse with Penstocks No. 1 and 2 connecting the two. The second phase consisted of installing Penstock No. 3, along with two additional units in the powerhouse. Phase three involved building a separate intake structure and powerhouse for Unit No. 7, connected by Penstock No. 4 in 1970. Penstock No. 1 supplies Units No. 1 and 2. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock No. 1 is buried along its entire length from the intake to the powerhouse. There are four original manholes:

- (1) one manhole upstream of a turbine-isolation valve inside the powerhouse; and
- (3) three larger manholes on the crown of the penstock:
  - (1) approximately halfway between the powerhouse and surge tower;
  - (2) at the surge tower; and
  - (3) halfway between the intake and the surge tower.

There are two newer manholes added at the upstream end of the original upstream most manhole. A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum of riprap. The penstock is deeply buried as it crosses under the switchyard and goes into the powerhouse. The penstock has drainage along its length with several weirs where the drainage daylights to the ditches and wells for inspection and monitoring.

Appendix A includes the original 1965 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 11 millimetres (mm) (0.4375 inches) at the intake to 41 mm (1.625 inches) at the powerhouse. The penstock is constructed of A285 grade steel for the first 1,015 ft, and CSA G40.8 Grade B for the remainder of the penstock. The welds are generally double V groove full penetration welds. The penstock slope varies from approximately 0.2 degrees to 19.7 degrees just upstream of the bifurcation.

3.0 INSPECTION

The 2021 inspection of Penstock 1 consisted of measuring shell thicknesses with a UT gage and inspecting the welds. ETS personnel performed MT weld tests on approximately 20% of the longitudinal welds in the 17-ft diameter section and 10% of the longitudinal welds for the remainder the penstock. Ultrasonic thickness (UT) measurements were taken from approximately 10% of the cans[1] for the penstock. The field data is included in Appendices C and D, respectively. A detailed interior visual inspection and an exterior walk of the penstock alignment was not performed by the lead inspecting engineer from Kleinschmidt due to Covid precautions.

In Table 3-1, definitions are provided for the descriptive terms used for the condition assessment.

Table 3-1 Definitions for the Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on site in the morning of Monday, May 10, 2021. The inspection team entered the penstock Monday morning at the upstream most open manhole of Penstock No. 1 and walked to the intake gate to start the inspection. TRR assisted with confined space entrance. The planned interior inspection was completed on Saturday, May 16, 2021. An exterior inspection was not performed.

[1] A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint.

Kleinschmidt provided a list of welds to be tested by can number. TRR and ETS walked the penstock and measured stationing and marked the cans with welds to be tested based on the list provided. If a weld was not accessible due to the position and height of the weld, the next can with accessible welds was chosen as a replacement. Seven changes were made to the original list of welds. Air quality in the penstock remained good for the duration of the inspection.

The interior inspection started at the headgate. Leakage around the gate was mainly from the right and left bottom corners as has been noted in the past. Leakage was not significant enough to hinder the inspection. Concrete deterioration at the concrete to steel transition (Photo 3), notably more extensive than at other Bay d'Espoir penstocks, has resulted in the leading edge of steel exposed all the way around but worse in the lower left area. This does not require repair in the short term, but the concrete should be patched to smooth the transition as part of future remediation following the FEED project. The interior surface of the penstock was moist but not as wet as in 2019. The penstock was dewatered more than a week prior and had a chance to dry. Much of the organics had been cleaned away during the previous penstock repairs and inspections which facilitated the inspection upstream of the surge tank. The penstock had more organic buildup present downstream of the surge tank as less work has been done downstream and this slowed the inspection team as more time was required to clean welds that had never been cleaned before.

The penstock has varying slopes with two main steep sections. The penstock slopes range from 0.2 degrees to 11 degrees along most of its length, but just upstream of the surge tank there is a section with a 14-degree slope for approximately 110 m (361 ft) and just upstream of the powerhouse the penstock has a 19.7-degree slope for approximately 58 m (190 ft) as noted in Appendix A. The slope levels out as the penstock enters the powerhouse.

3.2 Interior Inspection

The penstock was fabricated with about 435 "cans". A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The can number is used in this report to reference location in the penstock during the inspection with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded from the interior at various locations. Shell thickness measurements were taken with a Krautkramer DMS 2 Ultrasonic thickness gauge. A dual element D799 transducer was used, and the readings were taken in the "standard" mode. In "standard" mode the paint thickness does not affect the steel thickness readings if the paint thickness is below 1/64 (0.0156) inch (15.6 mils). The gauge was calibrated before the field measurements to an accuracy of 0.001 inch. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, this evaluation did so as well. Metric equivalents are given in parenthesis.

Thickness readings were recorded from the interior of the penstock generally near 4 o'clock, 6 o'clock, and 8 o'clock positions based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the pipe. All references to penstock left and right are also oriented looking downstream. Appendix D provides the ETS report of shell thickness readings. A summary of this data is provided in Table 4-1. An updated list of welds inspected over the last few years is contained in Appendix F.

The following section describes the findings of the weld inspections; however, a detailed visual inspection of the penstock interior was not performed.

3.2.1 Weld Inspection

Welds in Penstock No. 1 were cleaned with a grinder then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 168 full length longitudinal welds and approximately two feet of each of the 336 circumferential welds adjacent the tested longitudinal welds. This is twice as many welds tested compared to the 2020 inspection. The frequency of weld inspections was increased primarily in the 17-foot diameter section and accounts for the increase in testing. An initial visual inspection of the weld was conducted concentrating on condition of the bead with regards to pitting, corrosion, or cracking, undermining or washout. Particular attention was paid to welds not previously tested or repaired as part of Kleinschmidt's annual inspections. The welded joints inspected included original joints, previously repaired joints, and doubler plate welds (Photos 1 to 3).

The first indication was found on Tuesday May 11, 2021 in Can 126 (Photo 4). When each indication was found Mr. Vella was notified and provided photographs and relevant information regarding length, location, and position. NLH was immediately notified, and a repair crew was mobilized on site the following day. The planned inspection was modified such that cans upstream and downstream of the indications were tested until five consecutive cans upstream and five downstream were tested without finding further indications. When testing upstream of Can 126 where the first indication was found indications were found in Cans 124, 123, and 122. Testing continued for every can from 121 to 115 with no further indications upstream. Moving downstream every can was tested to Can 155 with the last indications found in Can 150. Following this the planned inspection sequence continued and had moved beyond the 17-ft diameter section and the plate thickness and plate material changed. Our NDT Technician (Mike Granter) helped the repair crew determine the limits of the indications as they were gouged out, tested the weld repairs when complete, and retested the repaired welds after 48 hours. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before the penstock was put back into service.

Indications were identified in 14 cans with the magnetic particle method of testing. There were 32 individual lengths of indications totalling 773 inches and their location and position are provided in Appendix C. All of the indications were located at previously repaired welds, either in the heat effected zone or the toe of the weld. Five (5) doubler plates had indications around their perimeter at the toe of the fillet weld in the original penstock plating.

The remainder of the weld inspection concentrated on the untested welds, but the team did pick up a few of the tested and repaired welds. There were no further indications and weld condition has not changed notably from previous years.

Appendix C provides the ETS report of the MP testing. Appendix F provides the weld tracking sheet. Next years inspection should take note of every repaired weld, doubler plate location, and previously inspected weld to create an accurate and simplified list.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix E. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 which extends approximately 1,034 ft from the face of the intake, and 24,000 psi was used for CSA G40.8 Grade B for the remainder of the penstock.

The welded seams are not as strong as the original base material; these strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. Per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds needing higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of the steel-shell thickness data and internal pressure steel stress analysis results. See Appendix D for detailed thickness data and stress calculations. The minimum thickness measurement was determined for each penstock can measured and was used to calculate the allowable stresses within each penstock section. To calculate the allowable stresses, the minimum thickness measurement was used in contrast to the 97.5% confidence interval (CI) used in previous years. This was done as too few measurements were collected per can to justify the use of CI. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

Three thickness measurements were taken at each location, A, B, and C, for each can that was inspected with a UT gauge, with nine thickness measurements in total for each can. When analyzing the thickness measurements using the 97.5% CI method, the calculated thickness was significantly less than the minimum thickness measured during inspection in many cases. This is due to the 97.5% CI being applied to a small data group: three to nine thickness measurements. Small sample sizes result in wider confidence intervals in contrast to large sample sizes, which result in narrower confidence intervals, and less error. Using the minimum steel-shell thickness measurement for the purpose of analysis in lieu of the 97.5% CI thickness, more accurately describes the penstock thickness in this situation.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 ft (182 m) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 ft (271 m) at the powerhouse and linearly reducing to 655 ft (200 m) at the surge tower and then matching the FSL of 597 ft (182 m) at the intake. Appendix A reference drawings provide the pressure gradient used in this analysis. The maximum stress ratio at a joint is 1.40 for this load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.1, which is unacceptable for late 1960 steel pipe. An increase in the joint efficiency factor through weld testing, which would provide verification of the pipe joint integrity, will increase these values. For the plate steel away from the joints, the material has a maximum stress ratio of 0.97 and a safety factor of 1.64, which is acceptable for current design practices.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Max Joint Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress[1,3] (psi)	Allowable Stress (psi)	Joint Stress Ratio[1,2,3]	Factor of Safety Against Yield	Base Material Stress Ratio (Joints)[2,3]	Factor of Safety Against Yield (Base Material)
2	6,486.0	1,945.8	8,431.8	17,000	0.5	3.1	5,902	4.4
7	6,514.2	1,954.2	8,468.4	17,000	0.5	3.1	5,928	4.4
12	6,710.6	2,013.2	8,723.7	17,000	0.5	3.0	6,107	4.3
17	7,989.4	2,396.8	10,386.2	17,000	0.6	2.5	7,270	3.6
22	7,855.9	2,356.8	10,212.7	17,000	0.6	2.5	7,149	3.6
28	8,198.5	2,459.6	10,658.1	17,000	0.6	2.4	7,461	3.5
38	9,471.2	2,841.4	12,312.6	17,000	0.7	2.1	8,619	3.0
43	10,981.5	3,294.5	14,276.0	17,000	0.8	1.8	9,993	2.6
52	13,201.5	3,960.5	17,162.0	17,000	1.0	1.5	12,013	2.2
57	12,530.9	3,759.3	16,290.1	17,000	1.0	1.6	11,403	2.3
72	14,081.2	4,224.4	18,305.6	17,000	1.1	1.4	12,814	2.0
77	14,138.9	4,241.7	18,380.6	17,000	1.1	1.4	12,866	2.0
82	14,196.7	4,259.0	18,455.7	17,000	1.1	1.4	12,919	2.0
92	14,393.1	4,317.9	18,711.0	17,000	1.1	1.4	13,098	2.0
104	14,994.4	4,498.3	19,492.7	17,000	1.1	1.3	13,645	1.9
108	15,936.9	4,781.1	20,717.9	17,000	1.2	1.3	14,503	1.8
123	17,328.8	5,198.7	22,527.5	24,000	0.9	1.8	15,769	2.5
133	19,328.7	5,798.6	25,127.3	24,000	1.0	1.6	17,589	2.3
138	20,355.7	6,106.7	26,462.4	24,000	1.1	1.5	18,524	2.2
148	20,769.1	6,230.7	26,999.9	24,000	1.1	1.5	18,900	2.1
155	23,026.4	6,907.9	29,934.4	24,000	1.2	1.3	20,954	1.9
165	24,116.5	7,235.0	31,351.5	24,000	1.3	1.3	21,946	1.8
176	21,855.2	6,556.6	28,411.8	24,000	1.2	1.4	19,888	2.0
194	24,327.4	7,298.2	31,625.7	24,000	1.3	1.3	22,138	1.8
203	22,290.9	6,687.3	28,978.2	24,000	1.2	1.3	20,285	1.9
213	24,981.0	7,494.3	32,475.3	24,000	1.4	1.2	22,733	1.7
227	24,098.9	7,229.7	31,328.6	24,000	1.3	1.2	21,930	1.7
235	24,361.8	7,308.5	31,670.4	24,000	1.3	1.2	22,169	1.7
243	22,292.4	6,687.7	28,980.1	24,000	1.2	1.3	20,286	1.9
254	24,051.3	7,215.4	31,266.7	24,000	1.3	1.2	21,887	1.7
274	25,512.7	7,653.8	33,166.5	24,000	1.4	1.1	23,217	1.6
284	25,012.2	7,503.7	32,515.9	24,000	1.4	1.2	22,761	1.7
294	24,665.6	7,399.7	32,065.3	24,000	1.3	1.2	22,446	1.7

Can	Max Joint Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress[1,3] (psi)	Allowable Stress (psi)	Joint Stress Ratio[1,2,3]	Factor of Safety Against Yield	Base Material Stress Ratio (Joints)[2,3]	Factor of Safety Against Yield (Base Material)
313	23,576.8	7,073.1	30,649.9	24,000	1.3	1.2	21,455	1.8
324	22,652.0	6,795.6	29,447.7	24,000	1.2	1.2	20,613	1.7
334	23,146.8	6,944.0	30,090.9	24,000	1.3	1.2	21,064	1.7
344	21,054.9	6,316.5	27,371.4	24,000	1.1	1.3	19,160	1.9
368	19,018.2	5,705.5	24,723.6	24,000	1.0	1.5	17,307	2.1
378	19,024.7	5,707.4	24,732.1	24,000	1.0	1.5	17,312	2.1
388	18,462.6	5,538.8	24,001.3	24,000	1.0	1.5	16,801	2.1
398	18,548.4	5,564.5	24,112.9	24,000	1.0	1.5	16,879	2.1
408	17,974.3	5,392.3	23,366.6	24,000	1.0	1.5	16,357	2.2
425	18,180.2	5,454.1	23,634.2	24,000	1.0	1.5	16,544	2.2

[1] Joint efficiency of 0.7 included
[2] Total stress / Allowable stress
[3] Uses minimum can thickness
[4] SF = Fy/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 psf and the depth of soil cover on the penstock was assumed to be 3 ft. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1) DL (water above conduit, soil load and steel) + internal vacuum pressure
2) DL (water above conduit, soil load and steel) + snow load
3) DL (water above conduit, soil load and steel) + combination snow (75%) and live load (75%)

To determine the external soil load, 1 ft of riprap at a density of 150 lbs per cubic foot and 2 ft of fill at a density of 120 lbs per cubic foot were used to calculate the soil loading above the penstock.

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis. An earthquake analysis could be performed but would be a more involved and time consuming and was not included in the scope of work.
- We assume the penstock is located in cohesive fine-grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 17-ft-diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was 3.72 psi which is less than the allowable buckling pressure of 3.75 psi. The 15.25-ft and 13.5-ft-diameter sections were analyzed, and the max pressures are summarized in Table 4-2.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot (psf) external live load with the snow load combination. Lowest average measured steel thickness values were used. See Table 4-2.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	3.75	3.24	3.72
15.25	4.76	3.91	4.39
13.50	28.92	4.30	4.78

There was no new vehicular surcharge analysis conducted as we are not expecting changes in the results from the analysis conducted by Kleinschmidt in 2016 for Penstock No. 2. The 2016 analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 14 ft from the front axle to middle axle then variable from 14 ft to 28 ft to the rear axle, was approximately 5 times less than the allowable buckling loads at that location. For the section of penstock analyzed, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.2 Sub-atmospheric Internal Penstock Pressure Analysis

Sub-atmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1 m^2 (55 ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads, but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil, so it is unlikely there are excessive local buckling stresses in the penstock.

4.5 Local Weld Conditions

As noted in Section 1.0, NLH discovered a 0.6-m-long (2-ft-long) indication in Penstock No. 1 in May 2016. Kleinschmidt responded and assisted with the design of the crack repair, *Crack Investigation and Repair Report – Penstock No. 1 Bay d'Espoir Hydroelectric Development* (June 2016). Kleinschmidt's investigation theorized that the indication, which occurred near a weld, was caused by an improper weld procedure during construction. After repairing the indication NLH rewatered the penstock, and a second indication then opened in the Penstock No. 1 in September 2016. The second indication led to a detailed weld investigation which revealed other microscopic indications in the welds.

Due to the findings in Penstock 1, Penstock No. 2 was inspected in 2017 and Penstock No. 3 in 2018.

ETS performed MT tests on the full length of 168 longitudinal welds and a few feet of 336 circumferential welds for this May 2021 inspection. Multiple indications were discovered from Cans 122 to 150. A total of 64 ft of weld repairs were made to the discovered indications. ETS performed MT testing on the weld repairs and were found to be acceptable.

4.6 Measurement Error

During the analysis, erroneous shell thickness measurements were discovered for Cans 61, 115, 126, 185, 263, 304, 357, 417, 432, and 435. Thickness readings within these cans were over 10% of the actual plate thickness of the penstock. For example, a thickness reading of 0.7480 inches was recorded in Can 185 at location B, however, this section of penstock is only 0.5625 inches in thickness as depicted in drawing F-106-C-7, attached in Appendix A, and equates to a 33% increase in shell thickness. It is expected that there will be UT thickness readings that correlate to an increase in shell thickness due to variances in the shell thickness, surface irregularities, and overall accuracy of the UT gauge. Furthermore, an increase in section thickness may be due to the steel plate being rolled out thicker than was specified in the design to account for fabrication tolerances, which was not uncommon for this era of construction. For the purpose of this analysis, all thickness readings which correlate to a plate-thickness increase of 10%, or greater are deemed erroneous and have been omitted from the analysis. We obtained enough reliable data to assess the penstock and the plates associated with erroneous measurements will be revisited next year.

Erroneous shell thickness readings can be caused by various sources of error including, but not limited to:

- surface irregularities;
- improper use of the UT gauge;
- accuracy of the gauge; and
- human error.

Surface irregularities may include steel corrosion, pitting, and the curvature of the surface. UT gauges work at their best on clean, smooth, and flat surfaces due to the transducer being able to make better contact with the plate surface. The likelihood of obtaining an inaccurate reading increases with the presence of surface irregularities.

During the inspection, thickness measurements were taken in the "standard" mode on the gauge. It is possible that measurements were accidently taken in an alternative mode other than the "standard" mode which may explain the erroneous data but is unlikely. Other modes include the coating thickness within the reading and could explain why there is an increase in some shell thicknesses.

Kleinschmidt is confident that the remaining data provides adequate information to determine the extent of corrosion and steel material loss of the steel plate.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, the 17 ft section of the penstock should be replaced, the remaining welds refurbished and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted this year with multiple indications discovered in previously repaired welds. Indications found in 5-year-old welds indicates that the weld repairs may have a limited life expectancy. All indications were found in the 17-ft diameter section this year indicating again that this section of penstock is particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock No. 1 should be replaced to remove the risk of future failures during operation and to provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 5 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal loss of material thickness over the design specification. A significant amount of moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the penstock should have about 50 years of service life remaining, based on wear, if an internal coating is applied. The base plate material away from the joints can tolerate up to 2 mm further material loss and maintain a stress ratio below 1.0. However, if the interior of the penstock is not coated, corrosion will progress to the point where stresses will no longer be acceptable. This could happen in as few as 10 years.

5.2 Internal Pressure Strength

More thickness measurements were taken during this inspection than during the 2016 inspection and the measurements had a wider range of values that resulted in CI thickness values that were in some cases lower than previously used in the stress analysis. Stress ratios for a combined static and dynamic internal pressures peak at 1.40 for the joints

(Table 4-1). This indicates that the penstock does not meet present day design criteria for a new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.10 at the joints, which is not acceptable for late 1960 steel pipe.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. There is a lack of confidence of the weld integrity for this penstock, and although the plating is acceptable and many welds have been refurbished, it is recommended that the penstock undergo further extensive refurbishments and the 17-ft section be replaced. The MT testing of welds to date does not satisfy the requirements of ASCE No. 79 to increase the joint efficiency. With the history of weld failures including the operational failure in 2020 and several indications found this year it is recommended that this penstock undergo extensive refurbishments and the 17-ft section be replaced in the next 5 years.

6.0 RECOMMENDATIONS

Penstock No. 1 should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively and the 17-ft diameter section should be replaced within 5 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- Radiographic testing of the welds if possible;
- Surge Analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior including MP weld testing.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 5 years provided the penstock welds are replaced. At this stage, Kleinschmidt is unable to estimate the rate of corrosion for the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20 to 40 years or more. If the penstock is recoated prior to significant steel deterioration every 20 to 40 years, NLH can anticipate extending the life of the penstock nominally another 50 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated and buried, so it is difficult to tell its condition without excavation. It would be costly and time consuming to uncover enough of the penstock to get a representative sample size of the exterior penstock condition, and some areas, like the invert, cannot be inspected safely. An exterior inspection involving excavation of significant portions of the penstock will not provide enough data to be worth the investment.

6.2 Interior Inspections

6.2.1 General Evaluation

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. These inspections should give a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless of if the coating has been replaced or not, the detailed inspections can be extended to a 5- to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval.

Next years inspection should take note of every previously repaired weld, doubler plate location, and inspected weld to create an accurate and simplified list.

7.0 REFERENCES

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REPORT SIGNATURE PAGE

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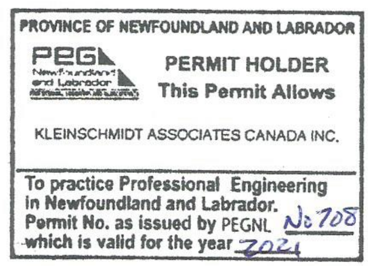

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APPENDIX A

PENSTOCK LAYOUT DRAWINGS

NOTES

1. THE PRESSURE CONDUITS SHALL BE CALLED "A" AND "B". CONDUIT "A" IS SOUTH OF CONDUIT "B" AND SHALL BE COMPLETED IN 1966. CONDUIT "A" CONSISTS OF PIPELINE "A" AND PENSTOCK "A".

2. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION No M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.

ANGLES & PL THICKNESSES AT BENDS

BEND	∠A	∠B	∠C	TRUE ANGLE	PL THICKNESS
1 A	26° 09' 31"	0° 14' 50"	6° 53' 47"	26° 55' 34"	7/16"
2 A	—	6° 53' 47"	0° 27' 30"	6° 26' 17"	1/2"
3 A	—	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4 A	—	5° 27' 30"	14° 25' 15"	8° 57' 45"	9/16"
5 A	—	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6 A	—	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16"
7 A	—	10° 05' 51"	10° 05' 51"	0° 00' 00"	

REFERENCE DRAWINGS

F-106-C-3 CONDUITS THROUGH DAM
F-106-C-4 SURGE TANK - DETAILS OF TEES
F-106-C-5 " " - GENERAL LAYOUT & DETAILS
F-106-C-6 PRESSURE CONDUITS - CLEARING
F-106-C-8 " " - EXCAVATION & DRAINAGE
F-106-C-9 " " - PENSTOCK A
F-106-C-10 " " - PENSTOCK B

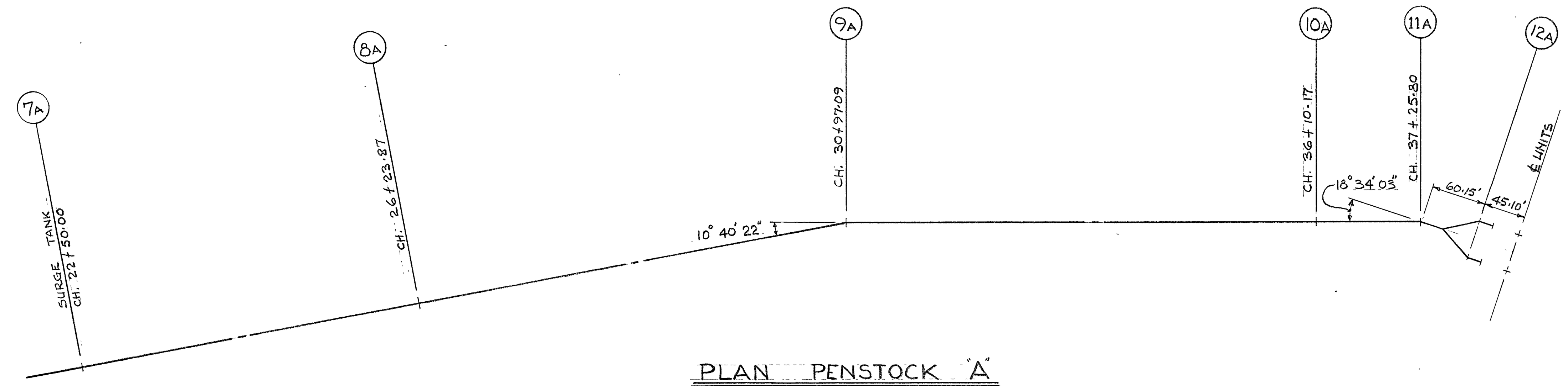
OTHER REFERENCES

1. SPECIFICATION No. M-3116

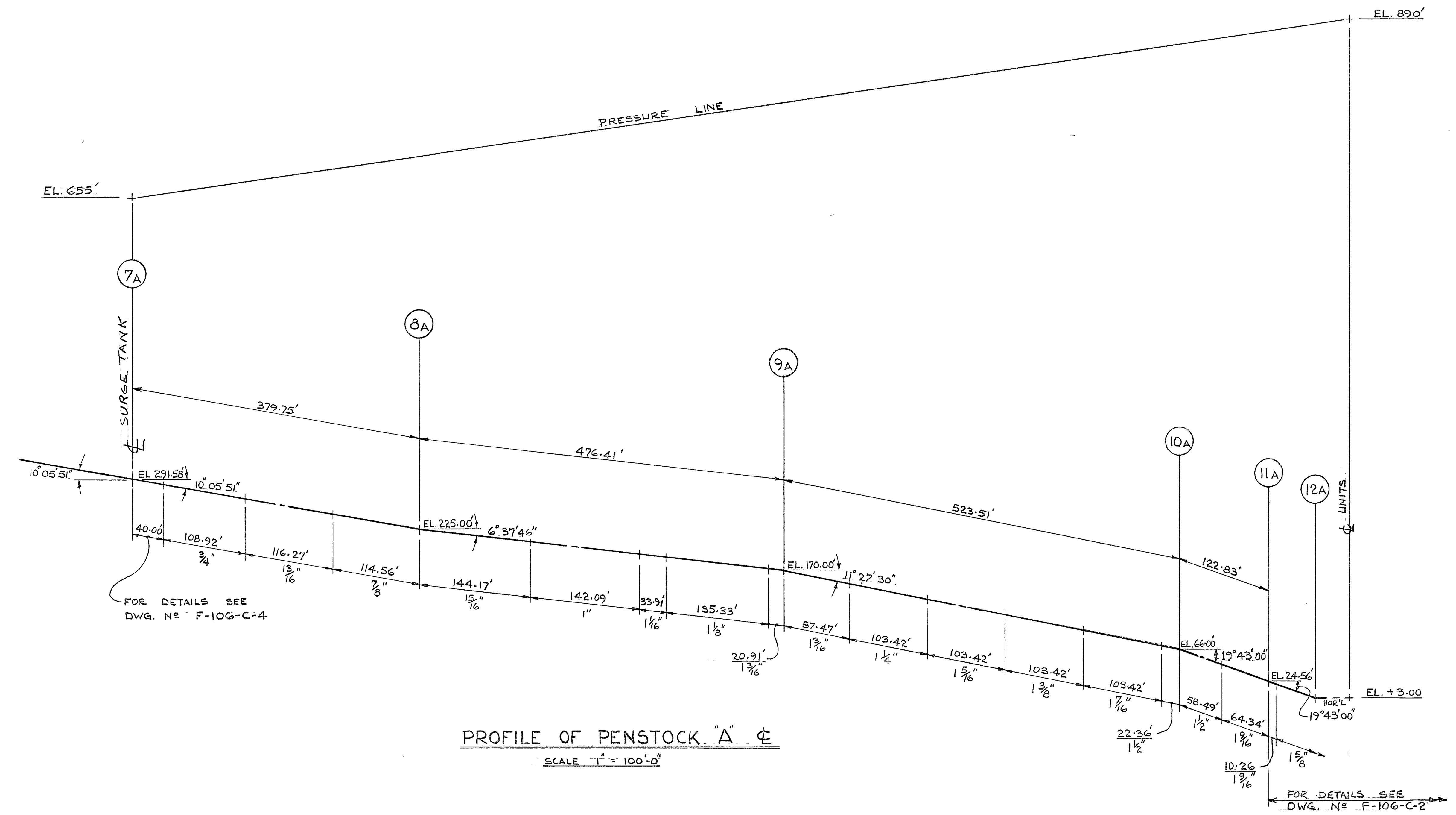
PERVIOUS LAYER ZONE 12 MATERIAL AND FILTER MUST BE SEALED WITH IMPERVIOUS FILL IMMEDIATELY DOWNSTREAM OF EACH CROSS DRAIN TO PREVENT SEEPAGE WATER FROM BY-PASSING THE CROSS DRAINS.

REVISIONS

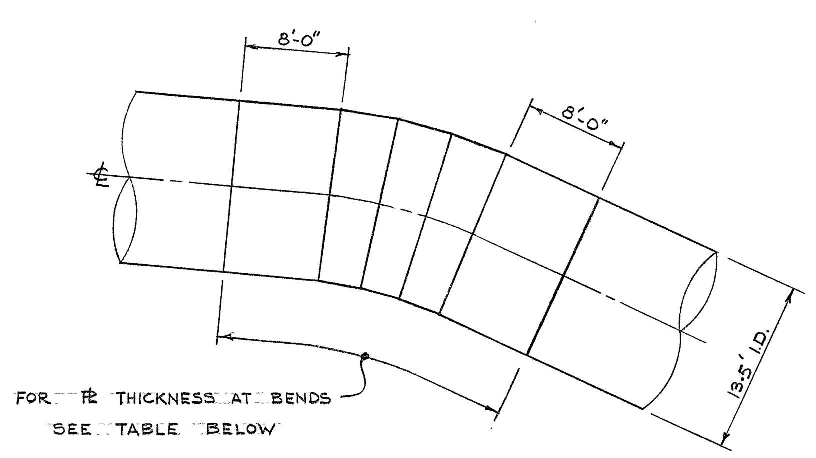
NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
5	2-6-68		AS BUILT, FROM FIELD INFORMATION	A.B.	JHM
4	5 JAN'67		2 TYP. SECTIONS CHANGED, ONE REMOVED	A.R.	
3	9 DEC'66	A/8-1,2,3,4	3 TYPICAL SECTIONS ADDED	A.R.	JHM
2	20 SEP'65		REVISED PROFILE & PLATE THICKNESSES	A.R.	
1	AUG 9/65		EL @ BEND 4 CORRECTED, MINOR REVISIONS	J.R.	JHM



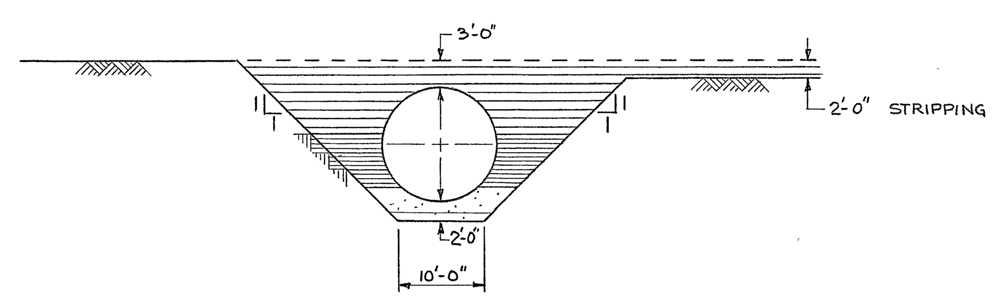
PLAN PENSTOCK 'A'
SCALE 1" = 100'-0"



PROFILE OF PENSTOCK 'A' ℄
SCALE 1" = 100'-0"



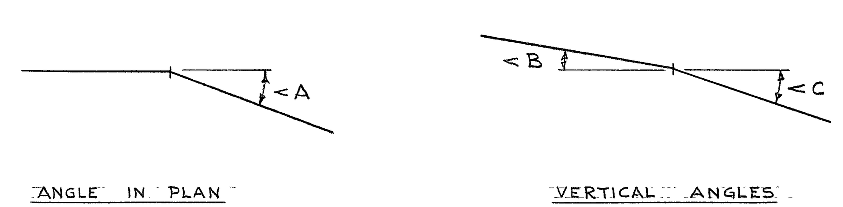
TYPICAL BEND
SCALE 1" = 10'-0"



TYPICAL CROSS SECTION (9A) TO (11A)
SCALE 1" = 15'-0"

BEND	< A	< B	< C	TRUE ANGLE	℞ THICKNESS
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	——
8 A	——	10° 05' 51"	6° 37' 46"	3° 28' 05"	1 1/8"
9 A	10° 40' 22"	6° 37' 46"	11° 27' 30"	11° 35' 25"	1 3/8"
10 A	——	11° 27' 30"	19° 43' 00"	8° 15' 30"	1 3/4"
11 A	18° 34' 03"	19° 43' 00"	19° 43' 00"	17° 28' 12"	1 7/8"

ANGLES & ℞ THICKNESS AT BENDS



NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6".
3. STEEL SHALL BE C.S.A. G40-8 GRADE 'B'.
4. FOR TYPICAL CROSS SECTION FROM (7A) TO (9A) SEE DWG. Nº F-106-C-7.

REFERENCE DRAWINGS

1. F-106-C-2 PRESSURE CONDUITS - LAYOUT & DETAILS OF BIFURCATION.
2. F-106-C-4 SURGE TANKS - DETAILS OF TEES.
3. F-106-C-5 SURGE TANKS - GENERAL LAYOUT & DETAILS.
4. F-106-C-6 PRESSURE CONDUITS - CLEARING.
5. F-106-C-7 PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE 'A'.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	SEPT 2/66		PLAN & PROFILE REVISED	J.P.	

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 22 1965
APPROVED BY: [signature]
MANAGER ENGINEERING

TRANS'N | ELECT'L | CIVIL
PASSED

DESIGNED: R. Mac D.
DRAWN: J.P.
CHECKED: A.P. [signature]
RECOMMENDED: [signature] P.Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 21, 1965	F-106-C-9	3


ELEVATION of PENSTOCK 'B'
PLAN VIEW
GENERAL NOTES
FIELD NOTES
ORIENTATION of P.S.
FIELD LOCATION of KEY NUTS
ANGLE IN PLAN
VERTICAL ANGLE
TO BE ERECTED IN 1966
NOTE:- THE LARGER PORTION OF THIS PENSTOCK WILL BE ERECTED IN 1967.
RECEIVED OCT 24 1966 SHAWMONT ENGINEERING NEWFOUNDLAND LTD.
APPROVED
OCT 25 1966
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
HORTON STEEL WORKS, LIMITED
10831
FILE 2-13


ELEVATION of PENSTOCK 'A'
PLAN VIEW
FIELD NOTE:
GENERAL NOTES:
ANGLES & PL. THICKNESS AT BENDS
ANGLE IN PLAN
VERTICAL ANGLES
HORTON STEEL WORKS, LIMITED
SHAWMONT NEWFOUNDLAND LIMITED
MAY 6 1966
MANAGER ENGINEERING
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
10830


APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
24"Φ MANHOLE DETAILS
TYPICAL ASSEMBLY
(HINGES NOT SHOWN)
MATERIAL SPECS:
NOZZLE
DETAIL "A"
DETAIL "B"
USAGE OF PENSTOCK CUTOUT
PLAN OF M.H. COVER
ELEV. OF COVER
PUSH-OFF BOLT
HINGE PIN
HORTON STEEL WORKS, LIMITED
FORT ERIE, ONT.
68H038H03
CONTRACT
RECEIVED
AUG 20
SHAWMONT NEWFOUNDLAND
FILE COPY
FILE NO. 68H038H03 BAY D'ESPOIR
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
12X

Appendix B

Photographs

PHOTO 1 TYPICAL CONDITIONS IN 17 FT DIAMETER SECTION

PHOTO 2 TYPICAL PREVIOUSLY REPAIRED WELD (CAN 12)

PHOTO 3 TYPICAL REINFORCING PLATE

PHOTO 4 CRACK ABOVE LONGITUDINAL WELD NORTH SIDE CAN 126

PHOTO 5 CRACKING AROUND WELD REINFORCING PLATE, CAN 146 NORTH SIDE

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	21-336-1	Copy:	
Date:	19 May, 2021	Date Received:	9 May, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	Mike Granter CAN/CGSB 48.9712 ET, UT, MT, PT Level ll PAUT, EDO, PMI, LEEA & AME
Attn:	Colin LeGrow		
P.O. No.			
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

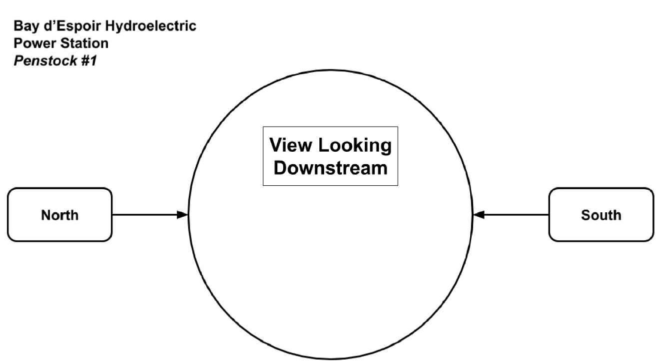
As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

Defects noted in below table are detailed in reports No. ETS 21-375. All outer welds were crack free at the time of inspection.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
2	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
7	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
12	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
17	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
22	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
28	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
33	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
38	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
43	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
52	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
57	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
63 Requested Doubler Plate 61 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
72	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
77	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
82	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
92	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
104	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
108	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
115	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
116	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
117	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
118	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
119	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
120	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
121	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
122	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 1 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted ETS Report TRR 21-375 for Details	**N/A**
123	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 3 Cracks noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
124	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 1 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted ETS Report TRR 21-375 for Details	**N/A**
125	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable ETS Report TRR 21-375 for Details	**N/A**
126	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 2 Cracks noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
127	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 1 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted ETS Report TRR 21-375 for Details	**N/A**
128	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
129	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
130	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
131	- Longitudinal right (south) 1 Crack noted. - Longitudinal left (north) 1 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
132	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
133	- Longitudinal right (south) 2 Cracks noted. - Longitudinal left (north) weld. Ok - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
134	- Longitudinal right (south) 3 Cracks noted. - Longitudinal left (north) weld. Ok - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
135	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
136	- Longitudinal right (south) weld. Ok - Longitudinal left (north) 4 Cracks noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
137	- Longitudinal right (south) 1 Crack noted. - Longitudinal left (north) weld. Ok - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted ETS Report TRR 21-375 for Details	**N/A**
138	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
139	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
142	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
145	- Longitudinal right (south) weld. - Longitudinal left (north) 1 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted ETS Report TRR 21-375 for Details	**N/A**
146	- Longitudinal right (south) weld. - Longitudinal left (north) 4 Cracks noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**

\

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
147	- Longitudinal right (south) weld. - Longitudinal left (north) 2 Cracks noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
148	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
149	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
150	- Longitudinal right (south) 3 Crack noted. - Longitudinal left (north) 2 Crack noted. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Cracks Noted ETS Report TRR 21-375 for Details	**N/A**
151	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
152	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
153	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
154	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
155	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
165	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
176	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
185	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
195 Requested Doubler Plate 194 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
203	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
214 Requested Maybe done last year 213 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
224 Requested To High 227 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
234 Requested To High 235 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
244 Requested To High 243 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
254	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
263	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
274	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
284	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
294	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
304	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
314 Requested To High 313 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
324	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
334	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
344	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
358 Requested To High 357 Inspected	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
368	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
378	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
388	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 21-336 Date: 19 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
398	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
408	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
417	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
425	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
432	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
435	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

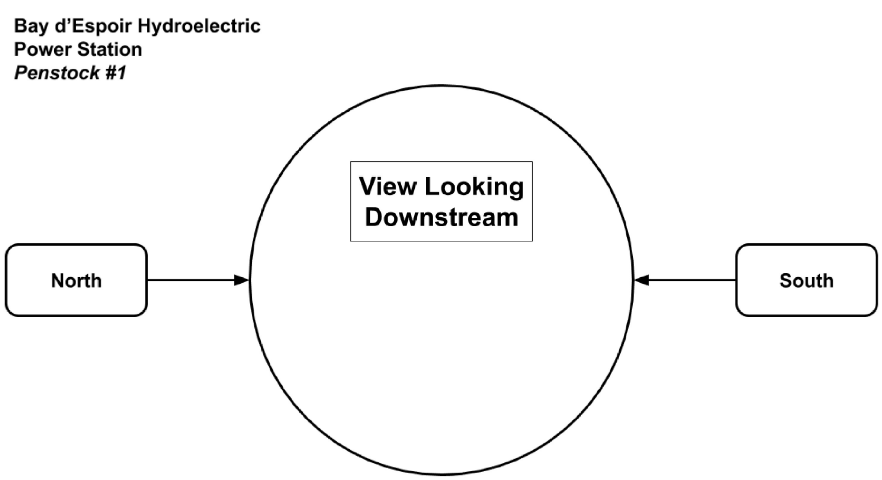
Report

ETS No.:	21-375	Copy:	
Date:	19 May, 2021	Date Received:	9 May, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	Mike Granter CAN/CGSB 48.9712 ET, UT, MT, PT Level ll PAUT, EDO, PMI, LEEA & AME
Attn:	Colin LeGrow	Inspected by:	C. Murphy, ASNT TC-1A RT, UT, ET, MT, PT level II. CAN/CGSB 48.9712 MT & PT level II, UT level I
P.O. No.			
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1 Scope 2. Weld Repairs.		
Testing Required:	Magnetic Particle Inspection	Signed:	[signature] NDT Inspector

Remarks

As directed, our technicians performed magnetic particle inspections on the below listed weld repairs. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). The inspected cans are listed on page 2 of 2

* Note. Multiple cracks in the same can are listed in order, upstream to down stream.



Results

MPI carried out on all gouged areas to ensure defects were removed. All MPI inspections were carried out after 48 hr hold time and found acceptable. Nil cracks.

ETS No.: 21-375 Date: 20 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
122 North	One crack. 14" long, top section of weld. 1/4" deep. Toe of weld. 8 o'clock position	MT Acceptable	122 N
123 North	Three cracks. 4" & 7" long in top section of weld, 5" long in bottom section. 1/8" deep. Toe of weld. 9 o'clock position.	MT Acceptable	123 N
124 North	One crack. 50" long, bottom section of weld. 1/4" deep. Toe of weld. 8 o'clock position	MT Acceptable	124 N
126 North	Two cracks. 10" long in top section of weld, 36" long in bottom section. 1/4" deep. Toe of weld. 8:30 position.	MT Acceptable	126 N
127 North	One crack. 8" long, bottom section of weld. 1/4" deep. Toe of weld. 9 o'clock position	MT Acceptable	127 N
131 North	One crack. 15" long, top section of weld. 3/16" deep. Toe of weld. 8 o'clock position	MT Acceptable	131 N
131 South	One crack. 41" long, top section of weld. 3/16" deep. Toe of weld. 2 o'clock position	MT Acceptable	131 S
133 South	Two cracks. 8" & 10" long, bottom section of weld. 1/8" deep. Toe of weld. 2 o'clock position	MT Acceptable	133 S
134 South	Three cracks. 8", 6" & 12" long in top section of weld. 1/8" deep. Toe of weld. 9:00 o'clock position.	MT Acceptable	134 S
136 North	Four cracks. 62" long in top section of weld, 24", 13" & 17" in bottom section. 1/8" deep. Toe of weld. 8:00 o'clock position. Doubler plate.	MT Acceptable	136 N
137 South	One crack. 39" long bottom, section of weld. 3/16" deep. Toe of weld. 3 o'clock position	MT Acceptable	137 S
145 North	One crack. 12" long bottom, section of weld. 3/16" deep. Toe of weld. 8 o'clock position. Doubler plate.	MT Acceptable	145 N
146 North	Four cracks. 43", 38" & 14" long in top section of weld, 52" in bottom section. 3/16" deep. Toe of weld. 8:30 position. Doubler plate	MT Acceptable	146 N
147 North	Two cracks. 21" & 78" long, bottom section of weld. 1/8" deep. Toe of weld. 8 o'clock position. Doubler plate.	MT Acceptable	147 N
150 North	Two cracks. 18" & 27" long, bottom section of weld. 1/8" deep. Toe of weld. 8 o'clock position.	MT Acceptable	150 N
150 South	Three cracks. 14" & 38" long, top section of weld, 29" long in bottom section. 1/8" deep. Toe of weld. 2 o'clock position. Doubler plate.	MT Acceptable	150 S

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.

APPENDIX D

THICKNESS MEASUREMENTS DATA

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

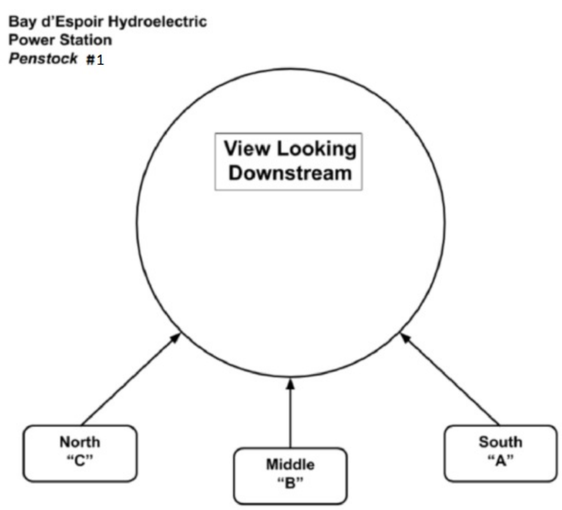
Report

ETS No.:	21-336-2 R1	Copy:	
Date:	20 May, 2021	Date Received:	20 May, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin LeGrow	Inspected by:	Mike Granter CAN/CGSB 48.9712 ET, UT, MT, PT Level II PAUT, EDO, PMI, LEEA & AME
P.O. No.	2021-0158-1		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	[signature] NDT Inspector

Remarks

As directed, ultrasonic thickness measurements were taken on Penstock #1. 3 Readings were taken at each location as requested. Readings are shown in mm's on the attached tables.

Location Of Readings



Equipment Used

Krautkramer DMS 2 digital thickness gauge (S/N 01YL2P).
Krautkramer TC560 probe (S/N 14A01G28).
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 21-336-2 R1 Date: 20 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A			Location B			Location C			Distance From Fwd Edge of Can 1 in Ft.
2	11.9	11.8	12.1	11.9	11.9	11.8	11.9	11.9	11.8	9
7	12.6	12.8	12.5	11.9	12.0	11.8	12.5	12.7	12.4	57
12	11.9	11.9	12.0	11.6	11.5	11.5	12.2	12.2	12.0	101
17	9.9	10.1	9.7	10.2	10.3	10.0	9.8	9.9	9.9	148
22	10.2	10.1	10.3	10.4	10.4	10.3	10.0	9.9	10.3	188
28	10.3	10.2	10.5	10.5	10.4	10.3	10.6	10.6	10.4	220
33	10.9	11.0	10.8	11.1	11.0	11.3	11.2	11.1	11.1	Missing
38	10.8	10.7	10.9	11.1	11.1	11.2	10.8	10.7	11.0	312
43	10.1	10.1	10.1	10.7	10.8	10.9	10.2	10.0	10.0	356
52	9.5	9.6	9.5	10.2	10.5	10.0	10.8	10.8	10.8	437
57	10.8	10.7	11.0	11.3	11.1	11.1	11.3	11.5	11.3	482
61	12.2	12.0	12.4	12.7	12.7	12.4	12.9	12.6	13.0	518
72	10.1	10.2	10.0	10.2	10.1	10.2	10.8	10.9	10.7	610
77	11	11	10.8	10.8	10.8	10.9	10.1	10.0	10.2	655
82	11.6	11.4	11.7	11.4	11.5	11.6	10	10.2	10.2	700
92	10.8	10.9	10.8	10.2	10.2	10.3	10.9	10.8	10.9	787
104	11.1	11.3	10.9	11.0	11.0	11.1	11.3	11.0	11.1	896
108	10.9	11.0	10.9	10.9	10.8	10.9	10.8	10.6	10.8	932
115	11.2	11.1	11.2	12.2	12.4	12.1	11.2	11.1	11.1	995
123	10.6	10.5	10.5	10.4	10.5	10.5	10.5	11.5	11.4	1006
126	11	11.2	11.1	12.5	12.7	12.5	11.5	11.5	11.6	1093
133	10.5	10.5	10.6	10.7	10.9	10.5	11.2	11.0	11.1	1155
138	10.4	10.3	10.3	10.9	10.9	10.8	10.8	10.8	10.8	1199
148	10	10.1	10.1	10.8	10.8	10.7	10.8	10.6	10.6	1262
155	10.7	10.6	10.8	10.9	10.9	11.0	10	10.1	10.1	1325

ETS No.: 21-336-2 R1 Date: 20 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A			Location B			Location C			Distance From Fwd Edge of Can 1 in Ft.
165	11.1	10.9	11.0	11.6	11.7	11.5	11.7	11.5	11.9	1416
176	14.2	14.2	14.2	14.2	14.0	14.2	13.7	13.7	13.8	1518
185	18.6	18.8	18.4	18.8	19.0	18.8	18.0	17.9	18.1	1594
194	13.8	13.6	13.9	14.2	14.4	14.1	14.0	14.1	14.1	1667
203	15.4	15.4	15.5	16.0	16.0	15.9	15.6	15.6	15.3	1750
213	14.8	14.6	14.6	14.4	14.5	14.2	14.2	14.1	14.1	1841
227	15.8	15.9	15.8	15.8	15.6	15.9	15.4	15.4	15.4	1959
235	16.1	16.0	16.0	16.8	16.6	16.7	16.1	16.0	16.1	2033
243	18.3	18.3	18.3	18.4	18.3	18.4	18.3	18.3	18.4	2105
254	18.6	18.5	18.5	18.4	18.4	18.5	18.0	18.4	18.4	2204
263	22.6	22.5	22.4	23.8	23.8	23.5	22.0	21.9	22.4	2275
274	19	19.3	18.9	18.8	18.7	19.0	18.7	19.0	18.6	2369
284	20.2	20.1	20.2	20.4	20.1	20.6	20.2	19.9	20.2	2461
294	21.2	21.2	21.1	22.2	22.2	22.1	22.1	21.9	22.2	2551
304	28.5	28.5	28.5	28.8	28.5	28.5	28.6	28.9	28.5	2641
313	23.8	23.8	23.7	23.5	23.5	23.7	24.0	23.9	24.0	2723
324	25.3	25.2	25.5	25.3	25.5	25.2	25.4	25.3	25.3	2824
334	25.6	25.7	25.5	26.4	26.4	26.6	25.4	25.7	25.3	2913
344	28.9	28.7	28.9	28.9	28.5	29.0	28.9	29.0	28.6	3000
357	35.6	35.6	35.6	35.6	35.5	35.6	35.4	35.6	35.6	3114
368	30.1	30.1	30.2	31.3	31.3	31.2	31.2	31.2	31.3	3199
378	31.5	31.3	31.7	31.9	32.0	31.7	31.8	31.7	31.8	3290

ETS No.: 21-336-2 R1 Date: 20 May 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A			Location B			Location C			Distance From Fwd Edge of Can 1 in Ft.
388	33.9	33.9	34.0	33.6	33.5	33.5	34.4	34.2	34.2	3381
398	34.9	35.0	34.8	34.7	34.6	34.6	35.1	35.1	34.9	3473
408	37.2	37.0	37.3	37.8	37.8	37.4	37.2	37.5	37.0	3565
417	44.4	44.4	44.4	44.4	44.4	44.1	44.4	44.1	44.1	3645
425	40.1	40.0	40.0	39.6	39.7	39.7	39.8	40.0	39.6	3711
432	46.8	46.8	46.8	47.6	47.4	47.9	47.2	47.4	47.2	3773
435	47.8	47.8	47.8	47.8	47.2	47.3	47.2	47.4	47.5	3778

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

TABLE 1 - Full Supply Level (FSL)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency[5]=	0.7	
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet
D_3 ID=	13.50	feet

Note: Starting point is 42ft D/S of the face of the Intake

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
Penstock Interior															
From Upstream End of Conduit															
			1	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					A285 Steel (grade unknown)
2A			2	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			3	12.1000	0.4764	0.5000	-4.7%		549.2799	17000					
			4	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
2B	9	8.50	5	11.9000	0.4685	0.5000	-6.3%	0.4646	549.2799	17000	4540.2	0.27	6486.0	0.38	
			6	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			7	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
2C			8	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
			9	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			10	12.6000	0.4961	0.5000	-0.8%		549.0728	17000					
7A			11	12.8000	0.5039	0.5000	0.8%		549.0728	17000					
			12	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
			13	11.9000	0.4685	0.5000	-6.3%		549.0728	17000					
7B	57	8.50	14	12.0000	0.4724	0.5000	-5.5%	0.4646	549.0728	17000	4559.9	0.27	6514.2	0.38	
			15	11.8000	0.4646	0.5000	-7.1%		549.0728	17000					
			16	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
7C			17	12.7000	0.5000	0.5000	0.0%		549.0728	17000					
			18	12.4000	0.4882	0.5000	-2.4%		549.0728	17000					
			19	11.9000	0.4685	0.5000	-6.3%		548.8829	17000					
12A			20	11.9000	0.4685	0.5000	-6.3%		548.8829	17000					
			21	12.0000	0.4724	0.5000	-5.5%		548.8829	17000					
			22	11.6000	0.4567	0.5000	-8.7%		548.8829	17000					
12B	101	8.50	23	11.5000	0.4528	0.5000	-9.4%	0.4528	548.8829	17000	4697.4	0.28	6710.6	0.39	
			24	11.5000	0.4528	0.5000	-9.4%		548.8829	17000					
			25	12.2000	0.4803	0.5000	-3.9%		548.8829	17000					
12C			26	12.2000	0.4803	0.5000	-3.9%		548.8829	17000					
			27	12.0000	0.4724	0.5000	-5.5%		548.8829	17000					
			28	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
17A			29	10.1000	0.3976	0.4375	-9.1%		548.6801	17000					
			30	9.7000	0.3819	0.4375	-12.7%		548.6801	17000					
			31	10.2000	0.4016	0.4375	-8.2%		548.6801	17000					
17B	148	8.50	32	10.3000	0.4055	0.4375	-7.3%	0.3819	548.6801	17000	5592.6	0.33	7989.4	0.47	
			33	10.0000	0.3937	0.4375	-10.0%		548.6801	17000					
			34	9.8000	0.3858	0.4375	-11.8%		548.6801	17000					
17C			35	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
			36	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
			37	10.2000	0.4016	0.4375	-8.2%		548.5075	17000					
22A			38	10.1000	0.3976	0.4375	-9.1%		548.5075	17000					
			39	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			40	10.4000	0.4094	0.4375	-6.4%		548.5075	17000					
22B	188	8.50	41	10.4000	0.4094	0.4375	-6.4%	0.3898	548.5075	17000	5499.1	0.32	7855.9	0.46	
			42	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			43	10.0000	0.3937	0.4375	-10.0%		548.5075	17000					
22C			44	9.9000	0.3898	0.4375	-10.9%		548.5075	17000					
			45	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			46	10.3000	0.4055	0.4375	-7.3%		544.8593	17000					
28A			47	10.2000	0.4016	0.4375	-8.2%		544.8593	17000					
			48	10.5000	0.4134	0.4375	-5.5%		544.8593	17000					
			49	10.5000	0.4134	0.4375	-5.5%		544.8593	17000					
28B	220	8.50	50	10.4000	0.4094	0.4375	-6.4%	0.4016	544.8593	17000	5739.0	0.34	8198.5	0.48	
			51	10.3000	0.4055	0.4375	-7.3%		544.8593	17000					
			52	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
28C			53	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
			54	10.4000	0.4094	0.4375	-6.4%		544.8593	17000					
			55	10.9000	0.4291	0.4375	-1.9%			17000					
33A			56	11.0000	0.4331	0.4375	-1.0%			17000					
			57	10.8000	0.4252	0.4375	-2.8%			17000					
			58	11.1000	0.4370	0.4375	-0.1%			17000					
33B	Missing	8.50	59	11.0000	0.4331	0.4375	-1.0%	0.4252		17000					
			60	11.3000	0.4449	0.4375	1.7%			17000					
			61	11.2000	0.4409	0.4375	0.8%			17000					
33C			62	11.1000	0.4370	0.4375	-0.1%			17000					
			63	11.1000	0.4370	0.4375	-0.1%			17000					
			64	10.8000	0.4252	0.4375	-2.8%		533.8125	17000					
38A			65	10.7000	0.4213	0.4375	-3.7%		533.8125	17000					
			66	10.9000	0.4291	0.4375	-1.9%		533.8125	17000					
			67	11.1000	0.4370	0.4375	-0.1%		533.8125	17000					
38B	312	8.50	68	11.1000	0.4370	0.4375	-0.1%	0.4213	533.8125	17000	6629.8	0.39	9471.2	0.56	
			69	11.2000	0.4409	0.4375	0.8%		533.8125	17000					
			70	10.8000	0.4252	0.4375	-2.8%		533.8125	17000					
38C			71	10.7000	0.4213	0.4375	-3.7%		533.8125	17000					
			72	11.0000	0.4331	0.4375	-1.0%		533.8125	17000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			73	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
43A			74	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
			75	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
			76	10.7000	0.4213	0.4375	-3.7%		528.5292	17000					
43B	356	8.50	77	10.8000	0.4252	0.4375	-2.8%	0.3937	528.5292	17000	7687.1	0.45	10981.5	0.65	
			78	10.9000	0.4291	0.4375	-1.9%		528.5292	17000					
			79	10.2000	0.4016	0.4375	-8.2%		528.5292	17000					
43C			80	10.0000	0.3937	0.4375	-10.0%		528.5292	17000					
			81	10.0000	0.3937	0.4375	-10.0%		528.5292	17000					
			82	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
52A			83	9.6000	0.3780	0.4375	-13.6%		518.8032	17000					
			84	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
			85	10.2000	0.4016	0.4375	-8.2%		518.8032	17000					
52B	437	8.50	86	10.5000	0.4134	0.4375	-5.5%	0.3740	518.8032	17000	9241.1	0.54	13201.5	0.78	
			87	10.0000	0.3937	0.4375	-10.0%		518.8032	17000					
			88	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
52C			89	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
			90	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
			91	10.8000	0.4252	0.4375	-2.8%		513.3999	17000					
57A			92	10.7000	0.4213	0.4375	-3.7%		513.3999	17000					
			93	11.0000	0.4331	0.4375	-1.0%		513.3999	17000					
			94	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57B	482	8.50	95	11.1000	0.4370	0.4375	-0.1%	0.4213	513.3999	17000	8771.6	0.52	12530.9	0.74	
			96	11.1000	0.4370	0.4375	-0.1%		513.3999	17000					
			97	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57C			98	11.5000	0.4528	0.4375	3.5%		513.3999	17000					
			99	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
			100	12.2000	0.4803	0.4375	9.8%		509.9386	17000					
61A			101	12.0000	0.4724	0.4375	8.0%		509.9386	17000					
			102	12.4000	0.4882	0.4375	11.6%		509.9386	17000					
			103	12.7000	0.5000	0.4375	14.3%		509.9386	17000					
61B	518	8.50	104	12.7000	0.5000	0.4375	14.3%	0.4724	509.9386	17000	8145.2	0.48	11636.0	0.68	
			105	12.4000	0.4882	0.4375	11.6%		509.9386	17000					
			106	12.9000	0.5079	0.4375	16.1%		509.9386	17000					
61C			107	12.6000	0.4961	0.4375	13.4%		509.9386	17000					
			108	13.0000	0.5118	0.4375	17.0%		509.9386	17000					
			109	10.1000	0.3976	0.4375	-9.1%		509.2026	17000					
72A			110	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
			111	10.0000	0.3937	0.4375	-10.0%		509.2026	17000					
			112	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
72B	610	8.50	113	10.1000	0.3976	0.4375	-9.1%	0.3937	509.2026	17000	9856.8	0.58	14081.2	0.83	
			114	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
			115	10.8000	0.4252	0.4375	-2.8%		509.2026	17000					
72C			116	10.9000	0.4291	0.4375	-1.9%		509.2026	17000					
			117	10.7000	0.4213	0.4375	-3.7%		509.2026	17000					
			118	11.0000	0.4331	0.4375	-1.0%		508.8427	17000					
77A			119	11.0000	0.4331	0.4375	-1.0%		508.8427	17000					
			120	10.8000	0.4252	0.4375	-2.8%		508.8427	17000					
			121	10.8000	0.4252	0.4375	-2.8%		508.8427	17000					
77B	655	8.50	122	10.8000	0.4252	0.4375	-2.8%	0.3937	508.8427	17000	9897.2	0.58	14138.9	0.83	
			123	10.9000	0.4291	0.4375	-1.9%		508.8427	17000					
			124	10.1000	0.3976	0.4375	-9.1%		508.8427	17000					
77C			125	10.0000	0.3937	0.4375	-10.0%		508.8427	17000					
			126	10.2000	0.4016	0.4375	-8.2%		508.8427	17000					
			127	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
82A			128	11.4000	0.4488	0.4375	2.6%		508.4827	17000					
			129	11.7000	0.4606	0.4375	5.3%		508.4827	17000					
			130	11.4000	0.4488	0.4375	2.6%		508.4827	17000					
82B	700	8.50	131	11.5000	0.4528	0.4375	3.5%	0.3937	508.4827	17000	9937.7	0.58	14196.7	0.84	
			132	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
			133	10.0000	0.3937	0.4375	-10.0%		508.4827	17000					
82C			134	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
			135	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
			136	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
92A			137	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
			138	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
			139	10.2000	0.4016	0.4375	-8.2%		505.4631	17000					
92B	787	8.50	140	10.2000	0.4016	0.4375	-8.2%	0.4016	505.4631	17000	10075.2	0.59	14393.1	0.85	
			141	10.3000	0.4055	0.4375	-7.3%		505.4631	17000					
			142	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
92C			143	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
			144	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
			145	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
104A			146	11.3000	0.4449	0.4375	1.7%		495.0948	17000					
			147	10.9000	0.4291	0.4375	-1.9%		495.0948	17000					
			148	11.0000	0.4331	0.4375	-1.0%		495.0948	17000					
104B	896	8.50	149	11.0000	0.4331	0.4375	-1.0%	0.4291	495.0948	17000	10496.0	0.62	14994.4	0.88	
			150	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
			151	11.3000	0.4449	0.4375	1.7%		495.0948	17000					
104C			152	11.0000	0.4331	0.4375	-1.0%		495.0948	17000					
			153	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
			154	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108A			155	11.0000	0.4331	0.4375	-1.0%		491.6704	17000					
			156	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
			157	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108B	932	8.50	158	10.8000	0.4252	0.4375	-2.8%	0.4173	491.6704	17000	11155.8	0.66	15936.9	0.94	
			159	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
			160	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					
108C			161	10.6000	0.4173	0.4375	-4.6%		491.6704	17000					
			162	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			163	11.2000	0.4409	0.4375	0.8%		485.6778	24000					CSA G40.8 Grade B Steel
115A			164	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			165	11.2000	0.4409	0.4375	0.8%		485.6778	24000					
			166	12.2000	0.4803	0.4375	9.8%		485.6778	24000					
115B	995	8.50	167	12.4000	0.4882	0.4375	11.6%	0.4370	485.6778	24000	11259.4	0.47	16084.8	0.67	
			168	12.1000	0.4764	0.4375	8.9%		485.6778	24000					
			169	11.2000	0.4409	0.4375	0.8%		485.6778	24000					
115C			170	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			171	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			172	10.6000	0.4173	0.4375	-4.6%		484.6314	24000					
123A			173	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			174	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			175	10.4000	0.4094	0.4375	-6.4%		484.6314	24000					
123B	1006	8.50	176	10.5000	0.4134	0.4375	-5.5%	0.4094	484.6314	24000	12130.2	0.51	17328.8	0.72	
			177	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			178	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
123C			179	11.5000	0.4528	0.4375	3.5%		484.6314	24000					
			180	11.4000	0.4488	0.4375	2.6%		484.6314	24000					
			181	11.0000	0.4331	0.4375	-1.0%		476.3558	24000					
126A			182	11.2000	0.4409	0.4375	0.8%		476.3558	24000					
			183	11.1000	0.4370	0.4375	-0.1%		476.3558	24000					
			184	12.5000	0.4921	0.4375	12.5%		476.3558	24000					
126B	1093	8.50	185	12.7000	0.5000	0.4375	14.3%	0.4331	476.3558	24000	12313.2	0.51	17590.2	0.73	
			186	12.5000	0.4921	0.4375	12.5%		476.3558	24000					
			187	11.5000	0.4528	0.4375	3.5%		476.3558	24000					
126C			188	11.5000	0.4528	0.4375	3.5%		476.3558	24000					
			189	11.6000	0.4567	0.4375	4.4%		476.3558	24000					
			190	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
133A			191	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
			192	10.6000	0.4173	0.4375	-4.6%		470.4583	24000					
			193	10.7000	0.4213	0.4375	-3.7%		470.4583	24000					
133B	1155	8.50	194	10.9000	0.4291	0.4375	-1.9%	0.4134	470.4583	24000	13530.1	0.56	19328.7	0.81	
			195	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
			196	11.2000	0.4409	0.4375	0.8%		470.4583	24000					
133C			197	11.0000	0.4331	0.4375	-1.0%		470.4583	24000					
			198	11.1000	0.4370	0.4375	-0.1%		470.4583	24000					
			199	10.4000	0.4094	0.4375	-6.4%		466.2729	24000					
138A			200	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
			201	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
			202	10.9000	0.4291	0.4375	-1.9%		466.2729	24000					
138B	1199	8.50	203	10.9000	0.4291	0.4375	-1.9%	0.4055	466.2729	24000	14249.0	0.59	20355.7	0.85	
			204	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			205	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
138C			206	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			207	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			208	10.0000	0.3937	0.4375	-10.0%		452.6425	24000					15.25 I.D. Penstock
148A			209	10.1000	0.3976	0.4375	-9.1%		452.6425	24000					
			210	10.1000	0.3976	0.4375	-9.1%		452.6425	24000					
			211	10.8000	0.4252	0.4375	-2.8%		452.6425	24000					
148B	1262	7.63	212	10.8000	0.4252	0.4375	-2.8%	0.3937	452.6425	24000	14538.4	0.61	20769.1	0.87	
			213	10.7000	0.4213	0.4375	-3.7%		452.6425	24000					
			214	10.8000	0.4252	0.4375	-2.8%		452.6425	24000					
148C			215	10.6000	0.4173	0.4375	-4.6%		452.6425	24000					
			216	10.6000	0.4173	0.4375	-4.6%		452.6425	24000					
			217	10.7000	0.4213	0.4375	-3.7%		436.9529	24000					
155A			218	10.6000	0.4173	0.4375	-4.6%		436.9529	24000					
			219	10.8000	0.4252	0.4375	-2.8%		436.9529	24000					
			220	10.9000	0.4291	0.4375	-1.9%		436.9529	24000					
155B	1325	7.63	221	10.9000	0.4291	0.4375	-1.9%	0.3937	436.9529	24000	16118.5	0.67	23026.4	0.96	
			222	11.0000	0.4331	0.4375	-1.0%		436.9529	24000					
			223	10.0000	0.3937	0.4375	-10.0%		436.9529	24000					
155C			224	10.1000	0.3976	0.4375	-9.1%		436.9529	24000					
			225	10.1000	0.3976	0.4375	-9.1%		436.9529	24000					
			226	11.1000	0.4370	0.5000	-12.6%		414.2901	24000					
165A			227	10.9000	0.4291	0.5000	-14.2%		414.2901	24000					
			228	11.0000	0.4331	0.5000	-13.4%		414.2901	24000					
			229	11.6000	0.4567	0.5000	-8.7%		414.2901	24000					
165B	1416	7.63	230	11.7000	0.4606	0.5000	-7.9%	0.4291	414.2901	24000	16881.6	0.70	24116.5	1.00	
			231	11.5000	0.4528	0.5000	-9.4%		414.2901	24000					
			232	11.7000	0.4606	0.5000	-7.9%		414.2901	24000					
165C			233	11.5000	0.4528	0.5000	-9.4%		414.2901	24000					
			234	11.9000	0.4685	0.5000	-6.3%		414.2901	24000					
			235	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
176A			236	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			237	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			238	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
176B	1518	7.63	239	14.0000	0.5512	0.5625	-2.0%	0.5394	388.8879	24000	15298.7	0.64	21855.2	0.91	
			240	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			241	13.7000	0.5394	0.5625	-4.1%		388.8879	24000					
176C			242	13.7000	0.5394	0.5625	-4.1%		388.8879	24000					
			243	13.8000	0.5433	0.5625	-3.4%		388.8879	24000					
			244	18.6000	0.7323	0.5625	30.2%		373.2723	24000					
185A			245	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
			246	18.4000	0.7244	0.5625	28.8%		373.2723	24000					
			247	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
185B	1594	7.63	248	19.0000	0.7480	0.5625	33.0%	0.7047	373.2723	24000	12587.6	0.52	17982.3	0.75	
			249	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
			250	18.0000	0.7087	0.5625	26.0%		373.2723	24000					
185C			251	17.9000	0.7047	0.5625	25.3%		373.2723	24000					
			252	18.1000	0.7126	0.5625	26.7%		373.2723	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			253	13.8000	0.5433	0.5625	-3.4%		367.0379	24000					
194A			254	13.6000	0.5354	0.5625	-4.8%		367.0379	24000					
			255	13.9000	0.5472	0.5625	-2.7%		367.0379	24000					
			256	14.2000	0.5591	0.5625	-0.6%		367.0379	24000					
194B	1667	7.63	257	14.4000	0.5669	0.5625	0.8%	0.5354	367.0379	24000	17029.2	0.71	24327.4	1.01	
			258	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			259	14.0000	0.5512	0.5625	-2.0%		367.0379	24000					
194C			260	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			261	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			262	15.4000	0.6063	0.6250	-3.0%		359.9495	24000					
203A			263	15.4000	0.6063	0.6250	-3.0%		359.9495	24000					
			264	15.5000	0.6102	0.6250	-2.4%		359.9495	24000					
			265	16.0000	0.6299	0.6250	0.8%		359.9495	24000					
203B	1750	7.63	266	16.0000	0.6299	0.6250	0.8%	0.6024	359.9495	24000	15603.7	0.65	22290.9	0.93	
			267	15.9000	0.6260	0.6250	0.2%		359.9495	24000					
			268	15.6000	0.6142	0.6250	-1.7%		359.9495	24000					
203C			269	15.6000	0.6142	0.6250	-1.7%		359.9495	24000					
			270	15.3000	0.6024	0.6250	-3.6%		359.9495	24000					
			271	14.8000	0.5827	0.6250	-6.8%		352.1779	24000					
213A			272	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
			273	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
			274	14.4000	0.5669	0.6250	-9.3%		352.1779	24000					
213B	1841	7.63	275	14.5000	0.5709	0.6250	-8.7%	0.5551	352.1779	24000	17486.7	0.73	24981.0	1.04	
			276	14.2000	0.5591	0.6250	-10.6%		352.1779	24000					
			277	14.2000	0.5591	0.6250	-10.6%		352.1779	24000					
213C			278	14.1000	0.5551	0.6250	-11.2%		352.1779	24000					
			279	14.1000	0.5551	0.6250	-11.2%		352.1779	24000					
			280	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227A			281	15.9000	0.6260	0.6250	0.2%		339.0478	24000					
			282	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
			283	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227B	1959	7.63	284	15.6000	0.6142	0.6250	-1.7%	0.6063	339.0478	24000	16869.2	0.70	24098.9	1.00	
			285	15.9000	0.6260	0.6250	0.2%		339.0478	24000					
			286	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
227C			287	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
			288	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
			289	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
235A			290	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			291	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			292	16.8000	0.6614	0.6875	-3.8%		326.0738	24000					
235B	2033	7.63	293	16.6000	0.6535	0.6875	-4.9%	0.6299	326.0738	24000	17053.3	0.71	24361.8	1.02	
			294	16.7000	0.6575	0.6875	-4.4%		326.0738	24000					
			295	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
235C			296	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			297	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
			298	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243A			299	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					This can showed a maximum thickness
			300	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					of 0.7242" during the 2020 inspection
			301	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
243B	2105	7.63	302	18.3000	0.7205	0.7500	-3.9%	0.7205	313.4505	24000	15604.7	0.65	22292.4	0.93	
			303	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
			304	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243C			305	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
			306	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
			307	18.6000	0.7323	0.7500	-2.4%		296.0934	24000					
254A			308	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			309	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			310	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
254B	2204	7.63	311	18.4000	0.7244	0.7500	-3.4%	0.7087	296.0934	24000	16835.9	0.70	24051.3	1.00	
			312	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			313	18.0000	0.7087	0.7500	-5.5%		296.0934	24000					
254C			314	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
			315	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
			316	22.6000	0.8898	0.7500	18.6%		283.6501	24000					
263A			317	22.5000	0.8858	0.7500	18.1%		283.6501	24000					
			318	22.4000	0.8819	0.7500	17.6%		283.6501	24000					
			319	23.8000	0.9370	0.7500	24.9%		283.6501	24000					
263B	2275	7.63	320	23.8000	0.9370	0.7500	24.9%	0.8622	283.6501	24000	14409.9	0.60	20585.6	0.86	
			321	23.5000	0.9252	0.7500	23.4%		283.6501	24000					
			322	22.0000	0.8661	0.7500	15.5%		283.6501	24000					
263C			323	21.9000	0.8622	0.7500	15.0%		283.6501	24000					
			324	22.4000	0.8819	0.7500	17.6%		283.6501	24000					
			325	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
274A			326	19.3000	0.7598	0.7500	1.3%		267.1697	24000					
			327	18.9000	0.7441	0.7500	-0.8%		267.1697	24000					
			328	18.8000	0.7402	0.7500	-1.3%		267.1697	24000					
274B	2369	7.63	329	18.7000	0.7362	0.7500	-1.8%	0.7323	267.1697	24000	17858.9	0.74	25512.7	1.06	
			330	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
			331	18.7000	0.7362	0.7500	-1.8%		267.1697	24000					
274C			332	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
			333	18.6000	0.7323	0.7500	-2.4%		267.1697	24000					
			334	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284A			335	20.1000	0.7913	0.8125	-2.6%		251.0399	24000					
			336	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
			337	20.4000	0.8031	0.8125	-1.2%		251.0399	24000					
284B	2461	7.63	338	20.1000	0.7913	0.8125	-2.6%	0.7835	251.0399	24000	17508.5	0.73	25012.2	1.04	
			339	20.6000	0.8110	0.8125	-0.2%		251.0399	24000					
			340	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284C			341	19.9000	0.7835	0.8125	-3.6%		251.0399	24000					
			342	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			343	21.2000	0.8346	0.8750	-4.6%		235.2607	24000					
294A			344	21.2000	0.8346	0.8750	-4.6%		235.2607	24000					
			345	21.1000	0.8307	0.8750	-5.1%		235.2607	24000					
			346	22.2000	0.8740	0.8750	-0.1%		235.2607	24000					
294B	2551	7.63	347	22.2000	0.8740	0.8750	-0.1%	0.8307	235.2607	24000	17265.9	0.72	24665.6	1.03	
			348	22.1000	0.8701	0.8750	-0.6%		235.2607	24000					
			349	22.1000	0.8701	0.8750	-0.6%		235.2607	24000					
294C			350	21.9000	0.8622	0.8750	-1.5%		235.2607	24000					
			351	22.2000	0.8740	0.8750	-0.1%		235.2607	24000					
			352	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
304A			353	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			354	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			355	28.8000	1.1339	0.9375	20.9%		221.3657	24000					
304B	2641	7.63	356	28.5000	1.1220	0.9375	19.7%	1.1220	221.3657	24000	13273.9	0.55	18962.7	0.79	
			357	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			358	28.6000	1.1260	0.9375	20.1%		221.3657	24000					
304C			359	28.9000	1.1378	0.9375	21.4%		221.3657	24000					
			360	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			361	23.8000	0.9370	0.9375	-0.1%		211.8990	24000					
313A			362	23.8000	0.9370	0.9375	-0.1%		211.8990	24000					
			363	23.7000	0.9331	0.9375	-0.5%		211.8990	24000					
			364	23.5000	0.9252	0.9375	-1.3%		211.8990	24000					
313B	2723	7.63	365	23.5000	0.9252	0.9375	-1.3%	0.9252	211.8990	24000	16503.8	0.69	23576.8	0.98	
			366	23.7000	0.9331	0.9375	-0.5%		211.8990	24000					
			367	24.0000	0.9449	0.9375	0.8%		211.8990	24000					
313C			368	23.9000	0.9409	0.9375	0.4%		211.8990	24000					
			369	24.0000	0.9449	0.9375	0.8%		211.8990	24000					
			370	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324A			371	25.2000	0.9921	1.0000	-0.8%		200.2388	24000					
			372	25.5000	1.0039	1.0000	0.4%		200.2388	24000					
			373	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324B	2824	7.63	374	25.5000	1.0039	1.0000	0.4%	0.9921	200.2388	24000	15856.4	0.66	22652.0	0.94	
			375	25.2000	0.9921	1.0000	-0.8%		200.2388	24000					
			376	25.4000	1.0000	1.0000	0.0%		200.2388	24000					
324C			377	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
			378	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
			379	25.6000	1.0079	1.0625	-5.1%		189.9640	24000					
334A			380	25.7000	1.0118	1.0625	-4.8%		189.9640	24000					
			381	25.5000	1.0039	1.0625	-5.5%		189.9640	24000					
			382	26.4000	1.0394	1.0625	-2.2%		189.9640	24000					
334B	2913	7.63	383	26.4000	1.0394	1.0625	-2.2%	0.9961	189.9640	24000	16202.8	0.68	23146.8	0.96	
			384	26.6000	1.0472	1.0625	-1.4%		189.9640	24000					
			385	25.4000	1.0000	1.0625	-5.9%		189.9640	24000					
334C			386	25.7000	1.0118	1.0625	-4.8%		189.9640	24000					
			387	25.3000	0.9961	1.0625	-6.3%		189.9640	24000					
			388	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344A			389	28.7000	1.1299	1.1250	0.4%		179.9200	24000					
			390	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
			391	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344B	3000	7.63	392	28.5000	1.1220	1.1250	-0.3%	1.1220	179.9200	24000	14738.4	0.61	21054.9	0.88	
			393	29.0000	1.1417	1.1250	1.5%		179.9200	24000					
			394	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344C			395	29.0000	1.1417	1.1250	1.5%		179.9200	24000					
			396	28.6000	1.1260	1.1250	0.1%		179.9200	24000					
			397	35.6000	1.4016	1.1875	18.0%		164.4237	24000					13.5ft I.D. Penstock
357A			398	35.6000	1.4016	1.1875	18.0%		164.4237	24000					Can thickness of 1.25" starts 59.4 ft
			399	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			400	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
357B	3114	6.75	401	35.5000	1.3976	1.1875	17.7%	1.3937	164.4237	24000	10894.3	0.45	15563.3	0.65	
			402	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			403	35.4000	1.3937	1.1875	17.4%		164.4237	24000					
357C			404	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			405	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			406	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
368A			407	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
			408	30.2000	1.1890	1.2500	-4.9%		147.5381	24000					
			409	31.3000	1.2323	1.2500	-1.4%		147.5381	24000					
368B	3199	6.75	410	31.3000	1.2323	1.2500	-1.4%	1.1850	147.5381	24000	13312.7	0.55	19018.2	0.79	
			411	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
			412	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
368C			413	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
			414	31.3000	1.2323	1.2500	-1.4%		147.5381	24000					
			415	31.5000	1.2402	1.3125	-5.5%		129.4604	24000					
378A			416	31.3000	1.2323	1.3125	-6.1%		129.4604	24000					
			417	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			418	31.9000	1.2559	1.3125	-4.3%		129.4604	24000					
378B	3290	6.75	419	32.0000	1.2598	1.3125	-4.0%	1.2323	129.4604	24000	13317.3	0.55	19024.7	0.79	
			420	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			421	31.8000	1.2520	1.3125	-4.6%		129.4604	24000					
378C			422	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			423	31.8000	1.2520	1.3125	-4.6%		129.4604	24000					
			424	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
388A			425	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
			426	34.0000	1.3386	1.3750	-2.6%		111.3828	24000					
			427	33.6000	1.3228	1.3750	-3.8%		111.3828	24000					
388B	3381	6.75	428	33.5000	1.3189	1.3750	-4.1%	1.3189	111.3828	24000	12923.8	0.54	18462.6	0.77	
			429	33.5000	1.3189	1.3750	-4.1%		111.3828	24000					
			430	34.4000	1.3543	1.3750	-1.5%		111.3828	24000					
388C			431	34.2000	1.3465	1.3750	-2.1%		111.3828	24000					
			432	34.2000	1.3465	1.3750	-2.1%		111.3828	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			433	34.9000	1.3740	1.3750	-0.1%		93.1065	24000					
398A			434	35.0000	1.3780	1.3750	0.2%		93.1065	24000					
			435	34.8000	1.3701	1.3750	-0.4%		93.1065	24000					
			436	34.7000	1.3661	1.3750	-0.6%		93.1065	24000					
398B	3473	6.75	437	34.6000	1.3622	1.3750	-0.9%	1.3622	93.1065	24000	12983.8	0.54	18548.4	0.77	
			438	34.6000	1.3622	1.3750	-0.9%		93.1065	24000					
			439	35.1000	1.3819	1.3750	0.5%		93.1065	24000					
398C			440	35.1000	1.3819	1.3750	0.5%		93.1065	24000					
			441	34.9000	1.3740	1.3750	-0.1%		93.1065	24000					
			442	37.2000	1.4646	1.4375	1.9%		74.8303	24000					
408A			443	37.0000	1.4567	1.4375	1.3%		74.8303	24000					
			444	37.3000	1.4685	1.4375	2.2%		74.8303	24000					
			445	37.8000	1.4882	1.4375	3.5%		74.8303	24000					
408B	3565	6.75	446	37.8000	1.4882	1.4375	3.5%	1.4567	74.8303	24000	12582.0	0.52	17974.3	0.75	
			447	37.4000	1.4724	1.4375	2.4%		74.8303	24000					
			448	37.2000	1.4646	1.4375	1.9%		74.8303	24000					
408C			449	37.5000	1.4764	1.4375	2.7%		74.8303	24000					
			450	37.0000	1.4567	1.4375	1.3%		74.8303	24000					
			451	44.4000	1.7480	1.5000	16.5%		54.0032	24000					1.5625" starts 22ft D/S
417A			452	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
			453	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
			454	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
417B	3645	6.75	455	44.4000	1.7480	1.5000	16.5%	1.7362	54.0032	24000	10977.4	0.46	15682.0	0.65	
			456	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			457	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
417C			458	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			459	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			460	40.1000	1.5787	1.5625	1.0%		31.7368	24000					
425A			461	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			462	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			463	39.6000	1.5591	1.5625	-0.2%		31.7368	24000					
425B	3711	6.75	464	39.7000	1.5630	1.5625	0.0%	1.5591	31.7368	24000	12726.1	0.53	18180.2	0.76	
			465	39.7000	1.5630	1.5625	0.0%		31.7368	24000					
			466	39.8000	1.5669	1.5625	0.3%		31.7368	24000					
425C			467	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			468	39.6000	1.5591	1.5625	-0.2%		31.7368	24000					
			469	46.8000	1.8425	1.6250	13.4%		10.8199	24000					thickest section per drawings is 1.625"
432A			470	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
			471	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
			472	47.6000	1.8740	1.6250	15.3%		10.8199	24000					
432B	3773	6.75	473	47.4000	1.8661	1.6250	14.8%	1.8425	10.8199	24000	11166.7	0.47	15952.5	0.66	
			474	47.9000	1.8858	1.6250	16.1%		10.8199	24000					
			475	47.2000	1.8583	1.6250	14.4%		10.8199	24000					
432C			476	47.4000	1.8661	1.6250	14.8%		10.8199	24000					
			477	47.2000	1.8583	1.6250	14.4%		10.8199	24000					
			478	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
435A			479	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
			480	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
			481	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
435B	3778	6.75	482	47.2000	1.8583	1.6250	14.4%	1.8583	9.1331	24000	11104.0	0.46	15862.8	0.66	
			483	47.3000	1.8622	1.6250	14.6%		9.1331	24000					
			484	47.2000	1.8583	1.6250	14.4%		9.1331	24000					
435C			485	47.4000	1.8661	1.6250	14.8%		9.1331	24000					
			486	47.5000	1.8701	1.6250	15.1%		9.1331	24000					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / $0.7_{\text{joint efficiency}}$
[4] Joint stress / S_A
[5]Per ASCE No. 79, Steel Penstocks, 2nd Edition, 2012

TABLE 1 - TRANSIENT
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	(per Penstock #2 assessment)
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet
D_3 ID=	13.50	feet

Note: Starting point is 42ft D/S of the face of the Intake

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
Penstock Interior From Upstream End of Conduit															
			1	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					A285 Steel (grade unknown)
2A			2	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			3	12.1000	0.4764	0.5000	-4.7%		549.2799	17000					
			4	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
2B	9	8.50	5	11.9000	0.4685	0.5000	-6.3%	0.4646	549.2799	17000	5902.3	0.35	8431.8	0.50	
			6	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			7	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
2C			8	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					
			9	11.8000	0.4646	0.5000	-7.1%		549.2799	17000					
			10	12.6000	0.4961	0.5000	-0.8%		549.0728	17000					
7A			11	12.8000	0.5039	0.5000	0.8%		549.0728	17000					
			12	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
			13	11.9000	0.4685	0.5000	-6.3%		549.0728	17000					
7B	57	8.50	14	12.0000	0.4724	0.5000	-5.5%	0.4646	549.0728	17000	5927.9	0.35	8468.4	0.50	
			15	11.8000	0.4646	0.5000	-7.1%		549.0728	17000					
			16	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
7C			17	12.7000	0.5000	0.5000	0.0%		549.0728	17000					
			18	12.4000	0.4882	0.5000	-2.4%		549.0728	17000					
			19	11.9000	0.4685	0.5000	-6.3%		548.8829	17000					
12A			20	11.9000	0.4685	0.5000	-6.3%		548.8829	17000					
			21	12.0000	0.4724	0.5000	-5.5%		548.8829	17000					
			22	11.6000	0.4567	0.5000	-8.7%		548.8829	17000					
12B	101	8.50	23	11.5000	0.4528	0.5000	-9.4%	0.4528	548.8829	17000	6106.6	0.36	8723.7	0.51	
			24	11.5000	0.4528	0.5000	-9.4%		548.8829	17000					
			25	12.2000	0.4803	0.5000	-3.9%		548.8829	17000					
12C			26	12.2000	0.4803	0.5000	-3.9%		548.8829	17000					
			27	12.0000	0.4724	0.5000	-5.5%		548.8829	17000					
			28	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
17A			29	10.1000	0.3976	0.4375	-9.1%		548.6801	17000					
			30	9.7000	0.3819	0.4375	-12.7%		548.6801	17000					
			31	10.2000	0.4016	0.4375	-8.2%		548.6801	17000					
17B	148	8.50	32	10.3000	0.4055	0.4375	-7.3%	0.3819	548.6801	17000	7270.3	0.43	10386.2	0.61	
			33	10.0000	0.3937	0.4375	-10.0%		548.6801	17000					
			34	9.8000	0.3858	0.4375	-11.8%		548.6801	17000					
17C			35	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
			36	9.9000	0.3898	0.4375	-10.9%		548.6801	17000					
			37	10.2000	0.4016	0.4375	-8.2%		548.5075	17000					
22A			38	10.1000	0.3976	0.4375	-9.1%		548.5075	17000					
			39	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			40	10.4000	0.4094	0.4375	-6.4%		548.5075	17000					
22B	188	8.50	41	10.4000	0.4094	0.4375	-6.4%	0.3898	548.5075	17000	7148.9	0.42	10212.7	0.60	
			42	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			43	10.0000	0.3937	0.4375	-10.0%		548.5075	17000					
22C			44	9.9000	0.3898	0.4375	-10.9%		548.5075	17000					
			45	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
			46	10.3000	0.4055	0.4375	-7.3%		544.8593	17000					
28A			47	10.2000	0.4016	0.4375	-8.2%		544.8593	17000					
			48	10.5000	0.4134	0.4375	-5.5%		544.8593	17000					
			49	10.5000	0.4134	0.4375	-5.5%		544.8593	17000					
28B	220	8.50	50	10.4000	0.4094	0.4375	-6.4%	0.4016	544.8593	17000	7460.6	0.44	10658.1	0.63	
			51	10.3000	0.4055	0.4375	-7.3%		544.8593	17000					
			52	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
28C			53	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
			54	10.4000	0.4094	0.4375	-6.4%		544.8593	17000					
			55	10.9000	0.4291	0.4375	-1.9%			17000					
33A			56	11.0000	0.4331	0.4375	-1.0%			17000					
			57	10.8000	0.4252	0.4375	-2.8%			17000					
			58	11.1000	0.4370	0.4375	-0.1%			17000					
33B	Missing	8.50	59	11.0000	0.4331	0.4375	-1.0%	0.4252		17000					
			60	11.3000	0.4449	0.4375	1.7%			17000					
			61	11.2000	0.4409	0.4375	0.8%			17000					
33C			62	11.1000	0.4370	0.4375	-0.1%			17000					
			63	11.1000	0.4370	0.4375	-0.1%			17000					
			64	10.8000	0.4252	0.4375	-2.8%		533.8125	17000					
38A			65	10.7000	0.4213	0.4375	-3.7%		533.8125	17000					
			66	10.9000	0.4291	0.4375	-1.9%		533.8125	17000					
			67	11.1000	0.4370	0.4375	-0.1%		533.8125	17000					
38B	312	8.50	68	11.1000	0.4370	0.4375	-0.1%	0.4213	533.8125	17000	8618.8	0.51	12312.6	0.72	
			69	11.2000	0.4409	0.4375	0.8%		533.8125	17000					
			70	10.8000	0.4252	0.4375	-2.8%		533.8125	17000					
38C			71	10.7000	0.4213	0.4375	-3.7%		533.8125	17000					
			72	11.0000	0.4331	0.4375	-1.0%		533.8125	17000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			73	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
43A			74	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
			75	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
			76	10.7000	0.4213	0.4375	-3.7%		528.5292	17000					
43B	356	8.50	77	10.8000	0.4252	0.4375	-2.8%	0.3937	528.5292	17000	9993.2	0.59	14276.0	0.84	
			78	10.9000	0.4291	0.4375	-1.9%		528.5292	17000					
			79	10.2000	0.4016	0.4375	-8.2%		528.5292	17000					
43C			80	10.0000	0.3937	0.4375	-10.0%		528.5292	17000					
			81	10.0000	0.3937	0.4375	-10.0%		528.5292	17000					
			82	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
52A			83	9.6000	0.3780	0.4375	-13.6%		518.8032	17000					
			84	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
			85	10.2000	0.4016	0.4375	-8.2%		518.8032	17000					
52B	437	8.50	86	10.5000	0.4134	0.4375	-5.5%	0.3740	518.8032	17000	12013.4	0.71	17162.0	1.01	
			87	10.0000	0.3937	0.4375	-10.0%		518.8032	17000					
			88	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
52C			89	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
			90	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
			91	10.8000	0.4252	0.4375	-2.8%		513.3999	17000					
57A			92	10.7000	0.4213	0.4375	-3.7%		513.3999	17000					
			93	11.0000	0.4331	0.4375	-1.0%		513.3999	17000					
			94	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57B	482	8.50	95	11.1000	0.4370	0.4375	-0.1%	0.4213	513.3999	17000	11403.1	0.67	16290.1	0.96	
			96	11.1000	0.4370	0.4375	-0.1%		513.3999	17000					
			97	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57C			98	11.5000	0.4528	0.4375	3.5%		513.3999	17000					
			99	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
			100	12.2000	0.4803	0.4375	9.8%		509.9386	17000					
61A			101	12.0000	0.4724	0.4375	8.0%		509.9386	17000					
			102	12.4000	0.4882	0.4375	11.6%		509.9386	17000					
			103	12.7000	0.5000	0.4375	14.3%		509.9386	17000					
61B	518	8.50	104	12.7000	0.5000	0.4375	14.3%	0.4724	509.9386	17000	10588.7	0.62	15126.8	0.89	
			105	12.4000	0.4882	0.4375	11.6%		509.9386	17000					
			106	12.9000	0.5079	0.4375	16.1%		509.9386	17000					
61C			107	12.6000	0.4961	0.4375	13.4%		509.9386	17000					
			108	13.0000	0.5118	0.4375	17.0%		509.9386	17000					
			109	10.1000	0.3976	0.4375	-9.1%		509.2026	17000					
72A			110	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
			111	10.0000	0.3937	0.4375	-10.0%		509.2026	17000					
			112	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
72B	610	8.50	113	10.1000	0.3976	0.4375	-9.1%	0.3937	509.2026	17000	12813.9	0.75	18305.6	1.08	
			114	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
			115	10.8000	0.4252	0.4375	-2.8%		509.2026	17000					
72C			116	10.9000	0.4291	0.4375	-1.9%		509.2026	17000					
			117	10.7000	0.4213	0.4375	-3.7%		509.2026	17000					
			118	11.0000	0.4331	0.4375	-1.0%		508.8427	17000					
77A			119	11.0000	0.4331	0.4375	-1.0%		508.8427	17000					
			120	10.8000	0.4252	0.4375	-2.8%		508.8427	17000					
			121	10.8000	0.4252	0.4375	-2.8%		508.8427	17000					
77B	655	8.50	122	10.8000	0.4252	0.4375	-2.8%	0.3937	508.8427	17000	12866.4	0.76	18380.6	1.08	
			123	10.9000	0.4291	0.4375	-1.9%		508.8427	17000					
			124	10.1000	0.3976	0.4375	-9.1%		508.8427	17000					
77C			125	10.0000	0.3937	0.4375	-10.0%		508.8427	17000					
			126	10.2000	0.4016	0.4375	-8.2%		508.8427	17000					
			127	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
82A			128	11.4000	0.4488	0.4375	2.6%		508.4827	17000					
			129	11.7000	0.4606	0.4375	5.3%		508.4827	17000					
			130	11.4000	0.4488	0.4375	2.6%		508.4827	17000					
82B	700	8.50	131	11.5000	0.4528	0.4375	3.5%	0.3937	508.4827	17000	12919.0	0.76	18455.7	1.09	
			132	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
			133	10.0000	0.3937	0.4375	-10.0%		508.4827	17000					
82C			134	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
			135	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
			136	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
92A			137	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
			138	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
			139	10.2000	0.4016	0.4375	-8.2%		505.4631	17000					
92B	787	8.50	140	10.2000	0.4016	0.4375	-8.2%	0.4016	505.4631	17000	13097.7	0.77	18711.0	1.10	
			141	10.3000	0.4055	0.4375	-7.3%		505.4631	17000					
			142	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
92C			143	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
			144	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
			145	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
104A			146	11.3000	0.4449	0.4375	1.7%		495.0948	17000					
			147	10.9000	0.4291	0.4375	-1.9%		495.0948	17000					
			148	11.0000	0.4331	0.4375	-1.0%		495.0948	17000					
104B	896	8.50	149	11.0000	0.4331	0.4375	-1.0%	0.4291	495.0948	17000	13644.9	0.80	19492.7	1.15	
			150	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
			151	11.3000	0.4449	0.4375	1.7%		495.0948	17000					
104C			152	11.0000	0.4331	0.4375	-1.0%		495.0948	17000					
			153	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
			154	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108A			155	11.0000	0.4331	0.4375	-1.0%		491.6704	17000					
			156	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
			157	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108B	932	8.50	158	10.8000	0.4252	0.4375	-2.8%	0.4173	491.6704	17000	14502.5	0.85	20717.9	1.22	
			159	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
			160	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					
108C			161	10.6000	0.4173	0.4375	-4.6%		491.6704	17000					
			162	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			163	11.2000	0.4409	0.4375	0.8%		485.6778	24000					CSA G40.8 Grade B Steel
115A			164	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			165	11.2000	0.4409	0.4375	0.8%		485.6778	24000					
			166	12.2000	0.4803	0.4375	9.8%		485.6778	24000					
115B	995	8.50	167	12.4000	0.4882	0.4375	11.6%	0.4370	485.6778	24000	14637.2	0.61	20910.3	0.87	
			168	12.1000	0.4764	0.4375	8.9%		485.6778	24000					
			169	11.2000	0.4409	0.4375	0.8%		485.6778	24000					
115C			170	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			171	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			172	10.6000	0.4173	0.4375	-4.6%		484.6314	24000					
123A			173	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			174	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			175	10.4000	0.4094	0.4375	-6.4%		484.6314	24000					
123B	1006	8.50	176	10.5000	0.4134	0.4375	-5.5%	0.4094	484.6314	24000	15769.2	0.66	22527.5	0.94	
			177	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
			178	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
123C			179	11.5000	0.4528	0.4375	3.5%		484.6314	24000					
			180	11.4000	0.4488	0.4375	2.6%		484.6314	24000					
			181	11.0000	0.4331	0.4375	-1.0%		476.3558	24000					
126A			182	11.2000	0.4409	0.4375	0.8%		476.3558	24000					
			183	11.1000	0.4370	0.4375	-0.1%		476.3558	24000					
			184	12.5000	0.4921	0.4375	12.5%		476.3558	24000					
126B	1093	8.50	185	12.7000	0.5000	0.4375	14.3%	0.4331	476.3558	24000	16007.1	0.67	22867.3	0.95	
			186	12.5000	0.4921	0.4375	12.5%		476.3558	24000					
			187	11.5000	0.4528	0.4375	3.5%		476.3558	24000					
126C			188	11.5000	0.4528	0.4375	3.5%		476.3558	24000					
			189	11.6000	0.4567	0.4375	4.4%		476.3558	24000					
			190	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
133A			191	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
			192	10.6000	0.4173	0.4375	-4.6%		470.4583	24000					
			193	10.7000	0.4213	0.4375	-3.7%		470.4583	24000					
133B	1155	8.50	194	10.9000	0.4291	0.4375	-1.9%	0.4134	470.4583	24000	17589.1	0.73	25127.3	1.05	
			195	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
			196	11.2000	0.4409	0.4375	0.8%		470.4583	24000					
133C			197	11.0000	0.4331	0.4375	-1.0%		470.4583	24000					
			198	11.1000	0.4370	0.4375	-0.1%		470.4583	24000					
			199	10.4000	0.4094	0.4375	-6.4%		466.2729	24000					
138A			200	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
			201	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
			202	10.9000	0.4291	0.4375	-1.9%		466.2729	24000					
138B	1199	8.50	203	10.9000	0.4291	0.4375	-1.9%	0.4055	466.2729	24000	18523.7	0.77	26462.4	1.10	
			204	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			205	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
138C			206	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			207	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			208	10.0000	0.3937	0.4375	-10.0%		452.6425	24000					15.25 I.D. Penstock
148A			209	10.1000	0.3976	0.4375	-9.1%		452.6425	24000					
			210	10.1000	0.3976	0.4375	-9.1%		452.6425	24000					
			211	10.8000	0.4252	0.4375	-2.8%		452.6425	24000					
148B	1262	7.63	212	10.8000	0.4252	0.4375	-2.8%	0.3937	452.6425	24000	18899.9	0.79	26999.9	1.12	
			213	10.7000	0.4213	0.4375	-3.7%		452.6425	24000					
			214	10.8000	0.4252	0.4375	-2.8%		452.6425	24000					
148C			215	10.6000	0.4173	0.4375	-4.6%		452.6425	24000					
			216	10.6000	0.4173	0.4375	-4.6%		452.6425	24000					
			217	10.7000	0.4213	0.4375	-3.7%		436.9529	24000					
155A			218	10.6000	0.4173	0.4375	-4.6%		436.9529	24000					
			219	10.8000	0.4252	0.4375	-2.8%		436.9529	24000					
			220	10.9000	0.4291	0.4375	-1.9%		436.9529	24000					
155B	1325	7.63	221	10.9000	0.4291	0.4375	-1.9%	0.3937	436.9529	24000	20954.1	0.87	29934.4	1.25	
			222	11.0000	0.4331	0.4375	-1.0%		436.9529	24000					
			223	10.0000	0.3937	0.4375	-10.0%		436.9529	24000					
155C			224	10.1000	0.3976	0.4375	-9.1%		436.9529	24000					
			225	10.1000	0.3976	0.4375	-9.1%		436.9529	24000					
			226	11.1000	0.4370	0.5000	-12.6%		414.2901	24000					
165A			227	10.9000	0.4291	0.5000	-14.2%		414.2901	24000					
			228	11.0000	0.4331	0.5000	-13.4%		414.2901	24000					
			229	11.6000	0.4567	0.5000	-8.7%		414.2901	24000					
165B	1416	7.63	230	11.7000	0.4606	0.5000	-7.9%	0.4291	414.2901	24000	21946.0	0.91	31351.5	1.31	
			231	11.5000	0.4528	0.5000	-9.4%		414.2901	24000					
			232	11.7000	0.4606	0.5000	-7.9%		414.2901	24000					
165C			233	11.5000	0.4528	0.5000	-9.4%		414.2901	24000					
			234	11.9000	0.4685	0.5000	-6.3%		414.2901	24000					
			235	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
176A			236	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			237	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			238	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
176B	1518	7.63	239	14.0000	0.5512	0.5625	-2.0%	0.5394	388.8879	24000	19888.3	0.83	28411.8	1.18	
			240	14.2000	0.5591	0.5625	-0.6%		388.8879	24000					
			241	13.7000	0.5394	0.5625	-4.1%		388.8879	24000					
176C			242	13.7000	0.5394	0.5625	-4.1%		388.8879	24000					
			243	13.8000	0.5433	0.5625	-3.4%		388.8879	24000					
			244	18.6000	0.7323	0.5625	30.2%		373.2723	24000					
185A			245	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
			246	18.4000	0.7244	0.5625	28.8%		373.2723	24000					
			247	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
185B	1594	7.63	248	19.0000	0.7480	0.5625	33.0%	0.7047	373.2723	24000	16363.9	0.68	23377.0	0.97	
			249	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
			250	18.0000	0.7087	0.5625	26.0%		373.2723	24000					
185C			251	17.9000	0.7047	0.5625	25.3%		373.2723	24000					
			252	18.1000	0.7126	0.5625	26.7%		373.2723	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material Stress (psi)[1]	Base Material Stress Ratio[2]	At Joints Stress (psi)[3]	At Joints Stress Ratio[4]	Notes
			253	13.8000	0.5433	0.5625	-3.4%		367.0379	24000					
194A			254	13.6000	0.5354	0.5625	-4.8%		367.0379	24000					
			255	13.9000	0.5472	0.5625	-2.7%		367.0379	24000					
			256	14.2000	0.5591	0.5625	-0.6%		367.0379	24000					
194B	1667	7.63	257	14.4000	0.5669	0.5625	0.8%	0.5354	367.0379	24000	22138.0	0.92	31625.7	1.32	
			258	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			259	14.0000	0.5512	0.5625	-2.0%		367.0379	24000					
194C			260	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			261	14.1000	0.5551	0.5625	-1.3%		367.0379	24000					
			262	15.4000	0.6063	0.6250	-3.0%		359.9495	24000					
203A			263	15.4000	0.6063	0.6250	-3.0%		359.9495	24000					
			264	15.5000	0.6102	0.6250	-2.4%		359.9495	24000					
			265	16.0000	0.6299	0.6250	0.8%		359.9495	24000					
203B	1750	7.63	266	16.0000	0.6299	0.6250	0.8%	0.6024	359.9495	24000	20284.8	0.85	28978.2	1.21	
			267	15.9000	0.6260	0.6250	0.2%		359.9495	24000					
			268	15.6000	0.6142	0.6250	-1.7%		359.9495	24000					
203C			269	15.6000	0.6142	0.6250	-1.7%		359.9495	24000					
			270	15.3000	0.6024	0.6250	-3.6%		359.9495	24000					
			271	14.8000	0.5827	0.6250	-6.8%		352.1779	24000					
213A			272	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
			273	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
			274	14.4000	0.5669	0.6250	-9.3%		352.1779	24000					
213B	1841	7.63	275	14.5000	0.5709	0.6250	-8.7%	0.5551	352.1779	24000	22732.7	0.95	32475.3	1.35	
			276	14.2000	0.5591	0.6250	-10.6%		352.1779	24000					
			277	14.2000	0.5591	0.6250	-10.6%		352.1779	24000					
213C			278	14.1000	0.5551	0.6250	-11.2%		352.1779	24000					
			279	14.1000	0.5551	0.6250	-11.2%		352.1779	24000					
			280	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227A			281	15.9000	0.6260	0.6250	0.2%		339.0478	24000					
			282	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
			283	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227B	1959	7.63	284	15.6000	0.6142	0.6250	-1.7%	0.6063	339.0478	24000	21930.0	0.91	31328.6	1.31	
			285	15.9000	0.6260	0.6250	0.2%		339.0478	24000					
			286	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
227C			287	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
			288	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
			289	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
235A			290	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			291	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			292	16.8000	0.6614	0.6875	-3.8%		326.0738	24000					
235B	2033	7.63	293	16.6000	0.6535	0.6875	-4.9%	0.6299	326.0738	24000	22169.3	0.92	31670.4	1.32	
			294	16.7000	0.6575	0.6875	-4.4%		326.0738	24000					
			295	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
235C			296	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			297	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
			298	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243A			299	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
			300	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
			301	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
243B	2105	7.63	302	18.3000	0.7205	0.7500	-3.9%	0.7205	313.4505	24000	20286.1	0.85	28980.1	1.21	
			303	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
			304	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243C			305	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
			306	18.4000	0.7244	0.7500	-3.4%		313.4505	24000					
			307	18.6000	0.7323	0.7500	-2.4%		296.0934	24000					
254A			308	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			309	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			310	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
254B	2204	7.63	311	18.4000	0.7244	0.7500	-3.4%	0.7087	296.0934	24000	21886.7	0.91	31266.7	1.30	
			312	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
			313	18.0000	0.7087	0.7500	-5.5%		296.0934	24000					
254C			314	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
			315	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
			316	22.6000	0.8898	0.7500	18.6%		283.6501	24000					
263A			317	22.5000	0.8858	0.7500	18.1%		283.6501	24000					
			318	22.4000	0.8819	0.7500	17.6%		283.6501	24000					
			319	23.8000	0.9370	0.7500	24.9%		283.6501	24000					
263B	2275	7.63	320	23.8000	0.9370	0.7500	24.9%	0.8622	283.6501	24000	18732.9	0.78	26761.3	1.12	
			321	23.5000	0.9252	0.7500	23.4%		283.6501	24000					
			322	22.0000	0.8661	0.7500	15.5%		283.6501	24000					
263C			323	21.9000	0.8622	0.7500	15.0%		283.6501	24000					
			324	22.4000	0.8819	0.7500	17.6%		283.6501	24000					
			325	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
274A			326	19.3000	0.7598	0.7500	1.3%		267.1697	24000					
			327	18.9000	0.7441	0.7500	-0.8%		267.1697	24000					
			328	18.8000	0.7402	0.7500	-1.3%		267.1697	24000					
274B	2369	7.63	329	18.7000	0.7362	0.7500	-1.8%	0.7323	267.1697	24000	23216.6	0.97	33166.5	1.38	
			330	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
			331	18.7000	0.7362	0.7500	-1.8%		267.1697	24000					
274C			332	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
			333	18.6000	0.7323	0.7500	-2.4%		267.1697	24000					
			334	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284A			335	20.1000	0.7913	0.8125	-2.6%		251.0399	24000					
			336	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
			337	20.4000	0.8031	0.8125	-1.2%		251.0399	24000					
284B	2461	7.63	338	20.1000	0.7913	0.8125	-2.6%	0.7835	251.0399	24000	22761.1	0.95	32515.9	1.35	
			339	20.6000	0.8110	0.8125	-0.2%		251.0399	24000					
			340	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284C			341	19.9000	0.7835	0.8125	-3.6%		251.0399	24000					
			342	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			343	21.2000	0.8346	0.8750	-4.6%		235.2607	24000					
294A			344	21.2000	0.8346	0.8750	-4.6%		235.2607	24000					
			345	21.1000	0.8307	0.8750	-5.1%		235.2607	24000					
			346	22.2000	0.8740	0.8750	-0.1%		235.2607	24000					
294B	2551	7.63	347	22.2000	0.8740	0.8750	-0.1%	0.8307	235.2607	24000	22445.7	0.94	32065.3	1.34	
			348	22.1000	0.8701	0.8750	-0.6%		235.2607	24000					
			349	22.1000	0.8701	0.8750	-0.6%		235.2607	24000					
294C			350	21.9000	0.8622	0.8750	-1.5%		235.2607	24000					
			351	22.2000	0.8740	0.8750	-0.1%		235.2607	24000					
			352	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
304A			353	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			354	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			355	28.8000	1.1339	0.9375	20.9%		221.3657	24000					
304B	2641	7.63	356	28.5000	1.1220	0.9375	19.7%	1.1220	221.3657	24000	17256.0	0.72	24651.5	1.03	
			357	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			358	28.6000	1.1260	0.9375	20.1%		221.3657	24000					
304C			359	28.9000	1.1378	0.9375	21.4%		221.3657	24000					
			360	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			361	23.8000	0.9370	0.9375	-0.1%		211.8990	24000					
313A			362	23.8000	0.9370	0.9375	-0.1%		211.8990	24000					
			363	23.7000	0.9331	0.9375	-0.5%		211.8990	24000					
			364	23.5000	0.9252	0.9375	-1.3%		211.8990	24000					
313B	2723	7.63	365	23.5000	0.9252	0.9375	-1.3%	0.9252	211.8990	24000	21454.9	0.89	30649.9	1.28	
			366	23.7000	0.9331	0.9375	-0.5%		211.8990	24000					
			367	24.0000	0.9449	0.9375	0.8%		211.8990	24000					
313C			368	23.9000	0.9409	0.9375	0.4%		211.8990	24000					
			369	24.0000	0.9449	0.9375	0.8%		211.8990	24000					
			370	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324A			371	25.2000	0.9921	1.0000	-0.8%		200.2388	24000					
			372	25.5000	1.0039	1.0000	0.4%		200.2388	24000					
			373	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324B	2824	7.63	374	25.5000	1.0039	1.0000	0.4%	0.9921	200.2388	24000	20613.4	0.86	29447.7	1.23	
			375	25.2000	0.9921	1.0000	-0.8%		200.2388	24000					
			376	25.4000	1.0000	1.0000	0.0%		200.2388	24000					
324C			377	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
			378	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
			379	25.6000	1.0079	1.0625	-5.1%		189.9640	24000					
334A			380	25.7000	1.0118	1.0625	-4.8%		189.9640	24000					
			381	25.5000	1.0039	1.0625	-5.5%		189.9640	24000					
			382	26.4000	1.0394	1.0625	-2.2%		189.9640	24000					
334B	2913	7.63	383	26.4000	1.0394	1.0625	-2.2%	0.9961	189.9640	24000	21063.6	0.88	30090.9	1.25	
			384	26.6000	1.0472	1.0625	-1.4%		189.9640	24000					
			385	25.4000	1.0000	1.0625	-5.9%		189.9640	24000					
334C			386	25.7000	1.0118	1.0625	-4.8%		189.9640	24000					
			387	25.3000	0.9961	1.0625	-6.3%		189.9640	24000					
			388	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344A			389	28.7000	1.1299	1.1250	0.4%		179.9200	24000					
			390	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
			391	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344B	3000	7.63	392	28.5000	1.1220	1.1250	-0.3%	1.1220	179.9200	24000	19160.0	0.80	27371.4	1.14	
			393	29.0000	1.1417	1.1250	1.5%		179.9200	24000					
			394	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344C			395	29.0000	1.1417	1.1250	1.5%		179.9200	24000					
			396	28.6000	1.1260	1.1250	0.1%		179.9200	24000					
			397	35.6000	1.4016	1.1875	18.0%		164.4237	24000					13.5 I.D. Penstock
357A			398	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			399	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			400	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
357B	3114	6.75	401	35.5000	1.3976	1.1875	17.7%	1.3937	164.4237	24000	14162.6	0.59	20232.3	0.84	
			402	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			403	35.4000	1.3937	1.1875	17.4%		164.4237	24000					
357C			404	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			405	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
			406	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
368A			407	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
			408	30.2000	1.1890	1.2500	-4.9%		147.5381	24000					
			409	31.3000	1.2323	1.2500	-1.4%		147.5381	24000					
368B	3199	6.75	410	31.3000	1.2323	1.2500	-1.4%	1.1850	147.5381	24000	17306.6	0.72	24723.6	1.03	
			411	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
			412	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
368C			413	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
			414	31.3000	1.2323	1.2500	-1.4%		147.5381	24000					
			415	31.5000	1.2402	1.3125	-5.5%		129.4604	24000					
378A			416	31.3000	1.2323	1.3125	-6.1%		129.4604	24000					
			417	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			418	31.9000	1.2559	1.3125	-4.3%		129.4604	24000					
378B	3290	6.75	419	32.0000	1.2598	1.3125	-4.0%	1.2323	129.4604	24000	17312.4	0.72	24732.1	1.03	
			420	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			421	31.8000	1.2520	1.3125	-4.6%		129.4604	24000					
378C			422	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			423	31.8000	1.2520	1.3125	-4.6%		129.4604	24000					
			424	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
388A			425	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
			426	34.0000	1.3386	1.3750	-2.6%		111.3828	24000					
			427	33.6000	1.3228	1.3750	-3.8%		111.3828	24000					
388B	3381	6.75	428	33.5000	1.3189	1.3750	-4.1%	1.3189	111.3828	24000	16800.9	0.70	24001.3	1.00	
			429	33.5000	1.3189	1.3750	-4.1%		111.3828	24000					
			430	34.4000	1.3543	1.3750	-1.5%		111.3828	24000					
388C			431	34.2000	1.3465	1.3750	-2.1%		111.3828	24000					
			432	34.2000	1.3465	1.3750	-2.1%		111.3828	24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
											Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			433	34.9000	1.3740	1.3750	-0.1%		93.1065	24000					
398A			434	35.0000	1.3780	1.3750	0.2%		93.1065	24000					
			435	34.8000	1.3701	1.3750	-0.4%		93.1065	24000					
			436	34.7000	1.3661	1.3750	-0.6%		93.1065	24000					
398B	3473	6.75	437	34.6000	1.3622	1.3750	-0.9%	1.3622	93.1065	24000	16879.0	0.70	24112.9	1.00	
			438	34.6000	1.3622	1.3750	-0.9%		93.1065	24000					
			439	35.1000	1.3819	1.3750	0.5%		93.1065	24000					
398C			440	35.1000	1.3819	1.3750	0.5%		93.1065	24000					
			441	34.9000	1.3740	1.3750	-0.1%		93.1065	24000					
			442	37.2000	1.4646	1.4375	1.9%		74.8303	24000					
408A			443	37.0000	1.4567	1.4375	1.3%		74.8303	24000					
			444	37.3000	1.4685	1.4375	2.2%		74.8303	24000					
			445	37.8000	1.4882	1.4375	3.5%		74.8303	24000					
408B	3565	6.75	446	37.8000	1.4882	1.4375	3.5%	1.4567	74.8303	24000	16356.6	0.68	23366.6	0.97	
			447	37.4000	1.4724	1.4375	2.4%		74.8303	24000					
			448	37.2000	1.4646	1.4375	1.9%		74.8303	24000					
408C			449	37.5000	1.4764	1.4375	2.7%		74.8303	24000					
			450	37.0000	1.4567	1.4375	1.3%		74.8303	24000					
			451	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
417A			452	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
			453	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
			454	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
417B	3645	6.75	455	44.4000	1.7480	1.5000	16.5%	1.7362	54.0032	24000	14270.6	0.59	20386.6	0.85	
			456	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			457	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
417C			458	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			459	44.1000	1.7362	1.5000	15.7%		54.0032	24000					
			460	40.1000	1.5787	1.5625	1.0%		31.7368	24000					
425A			461	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			462	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			463	39.6000	1.5591	1.5625	-0.2%		31.7368	24000					
425B	3711	6.75	464	39.7000	1.5630	1.5625	0.0%	1.5591	31.7368	24000	16544.0	0.69	23634.2	0.98	
			465	39.7000	1.5630	1.5625	0.0%		31.7368	24000					
			466	39.8000	1.5669	1.5625	0.3%		31.7368	24000					
425C			467	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
			468	39.6000	1.5591	1.5625	-0.2%		31.7368	24000					
			469	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
432A			470	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
			471	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
			472	47.6000	1.8740	1.6250	15.3%		10.8199	24000					
432B	3773	6.75	473	47.4000	1.8661	1.6250	14.8%	1.8425	10.8199	24000	14516.7	0.60	20738.2	0.86	
			474	47.9000	1.8858	1.6250	16.1%		10.8199	24000					
			475	47.2000	1.8583	1.6250	14.4%		10.8199	24000					
432C			476	47.4000	1.8661	1.6250	14.8%		10.8199	24000					
			477	47.2000	1.8583	1.6250	14.4%		10.8199	24000					
			478	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
435A			479	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
			480	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
			481	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
435B	3778	6.75	482	47.2000	1.8583	1.6250	14.4%	1.8583	9.1331	24000	14435.1	0.60	20621.6	0.86	
			483	47.3000	1.8622	1.6250	14.6%		9.1331	24000					
			484	47.2000	1.8583	1.6250	14.4%		9.1331	24000					
435C			485	47.4000	1.8661	1.6250	14.8%		9.1331	24000					
			486	47.5000	1.8701	1.6250	15.1%		9.1331	24000					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / $0.7_{joint\ efficiency}$
[4] Joint stress / S_A

Min Thickness	
All	0.3740
17ft	0.3740
15.25ft	0.3937
13.5ft	1.1850

Max Joint Stress Ratio	
All	1.4001
17ft	1.2295
15.25ft	1.4001
13.5ft	1.0369

Max Material Stress Ratio	
All	0.9674
17ft	0.8531
15.25ft	0.9674
13.5ft	0.7214

EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 15.25 feet						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	1.19	inches	(soil load) W_c=	5973.1	lb/ft	
OD Conduit Diameter=	15.31561683	feet	ID:	15.25	feet	(live load) W_l=	1531.6	lb/ft	100 psf per foot section
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	316	lb/ft	
B_prime=	0.2330					W_{steel}=	2333	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**3.76**	psi	Ratio Q/q_a= 0.791465
$t_{97.5}$=	0.3937	inches				[1]External pressure with snow load=	**3.91**	psi	Ratio Q/q_a= 0.821543
I=	0.0051	inches^4				[1]External pressure with snow and live=	**4.39**	psi	Ratio Q/q_a= 0.923476
[1,2]FS=	2								
[2]Allowable pressure q_a=	**4.76**	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 17 feet						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	(soil load) W_c=	6654.3	lb/ft	
OD Conduit Diameter=	17.062336	feet	ID:	17.00	feet	(live load) W_l=	1706.2	lb/ft	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	351.7	lb/ft	
B_prime=	0.23302752					W_{steel}=	957.6	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**3.10**	psi	Ratio Q/q_a= 0.826001
$t_{97.5}$=	0.3740	inches				[1]External pressure with snow load=	**3.24**	psi	Ratio Q/q_a= 0.864161
I=	0.0044	inches^4				[1]External pressure with snow and live=	**3.72**	psi	Ratio Q/q_a= 0.993484
[1,2]FS=	2								
[2]Allowable pressure q_a=	**3.75**	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 13.5 feet						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	(soil load) W_c=	5342.0	lb/ft	
OD Conduit Diameter=	13.6975065	feet	ID:	13.50	feet	(live load) W_l=	1369.8	lb/ft	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	282.3	lb/ft	
B_prime=	0.23302752					W_{steel}=	2855.4	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**4.15**	psi	Ratio Q/q_a= 0.143599
$t_{97.5}$=	1.1850	inches				[1]External pressure with snow load=	**4.30**	psi	Ratio Q/q_a= 0.148544
I=	0.1387	inches^4				[1]External pressure with snow and live=	**4.78**	psi	Ratio Q/q_a= 0.165304
[1,2]FS=	2								
[2]Allowable pressure q_a=	**28.92**	psi							

References:

[1]ASCE No. 79, Steel Penstocks, 2nd Edition, 2012
[2]AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.

Penstock #1 - UT Thickness Measurements [1]

Can	Location A			Location B			Location C		
	1 (mm)	2 (mm)	3 (mm)	1 (mm)	2 (mm)	3 (mm)	1 (mm)	2 (mm)	3 (mm)
2	11.9	11.8	12.1	11.9	11.9	11.8	11.9	11.9	11.8
7	12.6	12.8	12.5	11.9	12	11.8	12.5	12.7	12.4
12	11.9	11.9	12	11.6	11.5	11.5	12.2	12.2	12
17	9.9	10.1	9.7	10.2	10.3	10	9.8	9.9	9.9
22	10.2	10.1	10.3	10.4	10.4	10.3	10	9.9	10.3
28	10.3	10.2	10.5	10.5	10.4	10.3	10.6	10.6	10.4
33	10.9	11	10.8	11.1	11	11.3	11.2	11.1	11.1
38	10.8	10.7	10.9	11.1	11.1	11.2	10.8	10.7	11
43	10.1	10.1	10.1	10.7	10.8	10.9	10.2	10	10
52	9.5	9.6	9.5	10.2	10.5	10	10.8	10.8	10.8
57	10.8	10.7	11	11.3	11.1	11.1	11.3	11.5	11.3
61	12.2	12	12.4	12.7	12.7	12.4	12.9	12.6	13
72	10.1	10.2	10	10.2	10.1	10.2	10.8	10.9	10.7
77	11	11	10.8	10.8	10.8	10.9	10.1	10	10.2
82	11.6	11.4	11.7	11.4	11.5	11.6	10	10.2	10.2
92	10.8	10.9	10.8	10.2	10.2	10.3	10.9	10.8	10.9
104	11.1	11.3	10.9	11	11	11.1	11.3	11	11.1
108	10.9	11	10.9	10.9	10.8	10.9	10.8	10.6	10.8
115	11.2	11.1	11.2	12.2	12.4	12.1	11.2	11.1	11.1
123	10.6	10.5	10.5	10.4	10.5	10.5	10.5	11.5	11.4
126	11	11.2	11.1	12.5	12.7	12.5	11.5	11.5	11.6
133	10.5	10.5	10.6	10.7	10.9	10.5	11.2	11	11.1
138	10.4	10.3	10.3	10.9	10.9	10.8	10.8	10.8	10.8
148	10	10.1	10.1	10.8	10.8	10.7	10.8	10.6	10.6
155	10.7	10.6	10.8	10.9	10.9	11	10	10.1	10.1
165	11.1	10.9	11	11.6	11.7	11.5	11.7	11.5	11.9
176	14.2	14.2	14.2	14.2	14	14.2	13.7	13.7	13.8
185	18.6	18.8	18.4	18.8	19	18.8	18	17.9	18.1
194	13.8	13.6	13.9	14.2	14.4	14.1	14	14.1	14.1
203	15.4	15.4	15.5	16	16	15.9	15.6	15.6	15.3
213	14.8	14.6	14.6	14.4	14.5	14.2	14.2	14.1	14.1
227	15.8	15.9	15.8	15.8	15.6	15.9	15.4	15.4	15.4
235	16.1	16	16	16.8	16.6	16.7	16.1	16	16.1
243	18.3	18.3	18.3	18.4	18.3	18.4	18.3	18.3	18.4
254	18.6	18.5	18.5	18.4	18.4	18.5	18	18.4	18.4
263	22.6	22.5	22.4	23.8	23.8	23.5	22	21.9	22.4
274	19	19.3	18.9	18.8	18.7	19	18.7	19	18.6
284	20.2	20.1	20.2	20.4	20.1	20.6	20.2	19.9	20.2
294	21.2	21.2	21.1	22.2	22.2	22.1	22.1	21.9	22.2
304	28.5	28.5	28.5	28.8	28.5	28.5	28.6	28.9	28.5
313	23.8	23.8	23.7	23.5	23.5	23.7	24	23.9	24
324	25.3	25.2	25.5	25.3	25.5	25.2	25.4	25.3	25.3
334	25.6	25.7	25.5	26.4	26.4	26.6	25.4	25.7	25.3
344	28.9	28.7	28.9	28.9	28.5	29	28.9	29	28.6
357	35.6	35.6	35.6	35.6	35.5	35.6	35.4	35.6	35.6
368	30.1	30.1	30.2	31.3	31.3	31.2	31.2	31.2	31.3
378	31.5	31.3	31.7	31.9	32	31.7	31.8	31.7	31.8
388	33.9	33.9	34	33.6	33.5	33.5	34.4	34.2	34.2
398	34.9	35	34.8	34.7	34.6	34.6	35.1	35.1	34.9
408	37.2	37	37.3	37.8	37.8	37.4	37.2	37.5	37
417	44.4	44.4	44.4	44.4	44.4	44.1	44.4	44.1	44.1
425	40.10	40.00	40.00	39.60	39.70	39.70	39.80	40.00	39.60
432	46.80	46.80	46.80	47.60	47.40	47.90	47.20	47.40	47.20
435	47.80	47.80	47.80	47.80	47.20	47.30	47.20	47.40	47.50

[1] **Per TRR Report ETS No.: 21-336-2, May 20, 2021**

Appendix F

Weld Tracker

Date: August 14,2020 updated

PENSTOCK 1 WELD PROGRESS TRACKER

INTAKE – A

North	FP	FP	NI	FP	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI	NI	FP	NI	NI	FP
SECTION #	1																			2
CAN#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Other																				
South	FP	FP	NI	FP	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI	NI	FP	NI	NI	FP

North	NI	FP	NI	FP	NI	FP	NI	FP	NI	FP	NI	NI	FP	NI	NI	FP	NI	FP	NI	FP
SECTION #		3		4	5	6	7	8												
CAN#	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Other						RW										RW			MH	
South	NI	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	NI	FP	FP	NI	FP	NI	FP	NI	FP

North	NI	NI	FP	FP	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI
SECTION #																				
CAN#	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Other						RW									RW					
South	NI	NI	FP	NI	NI	FP	FP	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI

A – B

North	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	NI	FP	NI	NI	FP	NI	NI	NI	FP	NI
SECTION #	9	10	11	12																
CAN#	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Other			DP				RW	MH							RW					
South	FP	NI	NI	NI	NI	FP	FP	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI	NI	FP	NI

North	NI	FP	NI	NI	FP	FP	NI	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
SECTION #									13	15	16									
CAN#	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Other								DP	RW		RW	RW	RW	DP	IP	IP	RW	RW	RW	RW
South	NI	FP	NI	NI	FP	FP	NI	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP

North	FP	FP	NI	FP	NI	FP	NI	FP	FP	NI	FP	FP	NI
SECTION #													
CAN#	101	102	103	104	105	106	107	108	109	110	111	112	113
Other	RW	RW										RW	
South	FP	FP	NI	FP	NI	FP	NI	FP	NI	FP	NI	FP	NI

B – C

North	NI	FP	FP	FP	FP	FP	FP	FP	WR	FP	FP	FP	WR	WR	FP	FP	FP	WR	FP	FP
SECTION #	17																			
CAN #	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
Other										RW						MH				
South	NI	FP	FP	FP	FP	FP	FP	FP	FP	WR	FP	FP	FP	FP	FP	FP	FP	WR	FP	WR

North	FP	FP	WR	FP	FP	FP	FP	FP	FP	FP	FP	WR	WR	WR	FP	FP	WR	FP	FP	FP
SECTION #							18	70	72	74	20	21								
CAN #	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153
Other	RW								RW											RW
South	WR	FP	FP	WR	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	WR	FP	FP	FP

North	FP	FP	NI	NI	NI	NI	NI	NI	NI	FP	NI	FP	NI	NI	FP	NI	NI	NI	NI	FP
SECTION #									117											
CAN #	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173
Other										RW										RW
South	FP	FP	NI	FP	NI	NI	NI	NI	NI	FP	NI	FP	FP	FP	NI	NI	FP	NI	NI	FP

C – D (ADDITIONAL SCOPE: 210–220)

North	FP	FP	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	NI	FP	NI	NI	NI	NI	FP	FP
CAN #	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193
Other										OW										OW
South	NI	NI	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI	FP	FP

North	FP	NI	FP	NI	NI	NI	NI	FP	NI	FP	FP	FP	FP	NI	NI	NI	FP	FP	FP	FP
CAN #	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213
Other												OW					OW	OW	OW	OW
South	FP	NI	NI	NI	NI	NI	NI	FP	NI	FP	NI	FP	NI	NI	NI	NI	FP	FP	FP	FP

North	FP	FP	FP	FP	FP	FP	FP	NI	NI	FP	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP
CAN #	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233
Other	OW	OW	OW	OW	OW	OW	OW													
South	FP	WR	FP	FP	FP	FP	FP	NI	NI	NI	NI	NI	NI	FP	FP	NI	NI	NI	NI	FP

D – E

North	NI	FP	NI	NI	NI	NI	FP	NI	NI	FP	NI	FP	NI	FP	NI	NI	FP	NI	NI	NI
CAN #	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253
Other																IT?				
South	NI	FP	NI	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI	FP	NI	NI	FP	NI	NI	NI

North	FP	FP	NI	FP	NI	NI	NI	NI	NI	FP	FP	FP	FP	NI	NI	NI	NI	FP	NI	NI
CAN #	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273
Other						ST	ST										IT?			
South	FP	FP	NI	FP	NI	NI	NI	NI	NI	FP	FP	FP	FP	NI	NI	NI	NI	FP	NI	NI

North	FP	FP	FP	NI	NI	NI	FP	NI	NI	NI	FP	FP	FP	NI	NI	NI	NI	NI	FP	NI
CAN #	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293
Other							IT?													
South	FP	FP	FP	NI	NI	NI	FP	NI	NI	NI	FP	FP	FP	NI	NI	NI	NI	NI	FP	NI

E – F

North	FP	FP	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	FP
CAN #	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313
Other																				
South	FP	FP	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	FP

North	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	NI	NI	FP	FP	NI	NI
CAN #	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333
Other																				
South	NI	NI	FP	NI	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	NI	NI	FP	FP	NI	NI

North	FP	NI	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI
CAN #	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353
Other																				
South	FP	NI	FP	NI	NI	NI	FP	NI	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI

F – PH

North	FP	NI	NI	FP	NI	NI	NI	NI	FP	NI	FP	FP	NI	NI	FP	NI	FP	NI	FP	NI
CAN #	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373
Other																				
South	FP	FP	FP	FP	NI	NI	NI	NI	FP	NI	FP	FP	NI	NI	FP	NI	FP	NI	FP	NI

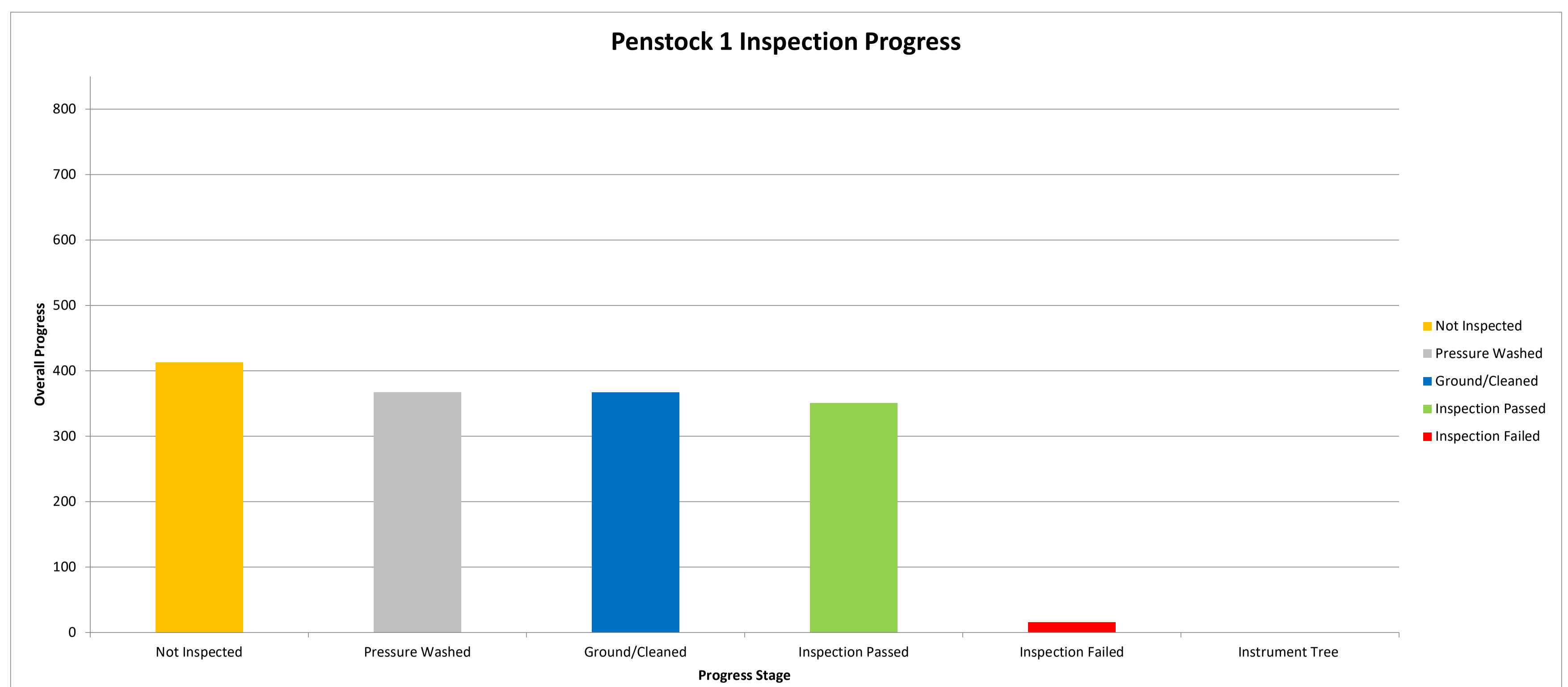
North	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI
CAN #	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393
Other		OW										OW					OW			
South	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI	NI	FP	NI	NI	FP	NI	FP	FP	NI	NI

North	NI	NI	NI	NI	FP	FP	FP
CAN #	394	395	396	397	398	399	400
Other							
South	NI	NI	NI	NI	FP	FP	FP

Legend		
NI	=	NOT INSPECTED
PW	=	PRESSURE WASHED
P	=	Weld Preperation Complete
FP	=	Final Inspection Passed
FF	=	Final Inspection Failed
WR	=	Weld Repair
FIP	=	Final Inspection Passed
IT?		Possible Intstrument Tee Location
ST	=	SURGE TANK
RW	=	REFUBISHED WELD
OW	=	ORIGINAL WELD
MH	=	MAN HOLE

Original Scope	
Total welds :	800
Not Inspected	413
Pressure Washed	367
Ground/Cleaned	367
Inspection Passed	351
Inspection Failed	16
Instrument Tree	0

Original Scope	
Total welds :	800
Percent Complete	338%
Pressure Washed	360%
Ground/Cleaned	360%
Inspection Passed	344%
Inspection Failed	15%
Instrument Tree	0%



Penstock No. 1 Inspection and Evaluation

Bay d'Espoir Hydroelectric Development
Penstocks 1-3 Inspection Project

Prepared for:

Newfoundland and Labrador Hydro

Prepared by:

Kleinschmidt Associates

July 2022

Kleinschmidt

Kleinschmidtgroup.com

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ACRONYMS

A	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
E	
ETS	Eastern Technical Services
F	
Fu	Ultimate Tensile Stress
FSL	Full Supply Level
K	
Kleinschmidt	Kleinschmidt Associates Canada Inc.
M	
MT	Magnetic Partical Testing
N	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
S	
STA	Station (in feet)
T	
TRR	Technical Rope and Rescue
U	
UT	Ultrasonic Thickness

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in December of 2021 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development in 2022.

Kleinschmidt conducted an inspection of Penstock No. 1 in April 2022. Penstock No. 1 is a buried steel penstock approximately 1,100 metres (m) long, tapering from 5.2 m in diameter at the intake, to 4.1 m in diameter at the powerhouse bifurcation. At its flattest point, the penstock has a 0.2-degree slope and has a slope of 19.7 degrees at its steepest. There are three areas of access for Penstock No. 1: one at the well in the intake structure, five manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Due to weld issues and corrosion in all three penstocks, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The primary focus of the Penstock No. 1 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year.

The April 2022 inspection of Penstock No. 1 consisted of magnetic particle and visual weld inspections, and plate thickness measurements completed by Eastern Technical Services and Kleinschmidt. Kleinschmidt's engineer, Chris Vella, provided direct inspection oversight on-site throughout the inspection and provided an inspection plan, test locations, and updated directions as required when conditions changed. A detailed examination of the condition of the interior of the penstock and an exterior walk of the penstock alignment was also conducted by Mr. Vella.

The 2022 inspections, as part of Kleinschmidt's inspection program, concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected in the previous year in the upper end of the penstock.

Of significant note, weld indications were identified in four (4) cans. There were two individual lengths of weld indications totalling about 4 inches that required repair. Cans 98 and 103 were both observed to contain a 12-inch section weld which was observed to be eroded along a circumferential weld, on the north side of the penstock. Both eroded welds did not require repair. The weld indications identified in Cans 145 and 146 were located at previously repaired welds, either in the heat effected zone or at the toe of the weld. Both Cans 145 and 146 were repaired in recent years. Can 145 had repairs completed in both 2020 and 2021, while Can 146 was most recently repaired in 2021. Finding the first indication in Can 146 triggered extensive testing of adjacent cans upstream and downstream which resulted in finding just one other weld indication in in Can 145. Testing continued in the area until five (5) consecutive cans upstream and downstream were found without indication. Every can from 137 to 151 was tested to clear the affected area. The crew completed the inspection scope and stay on site to assist with the weld repairs.

Measurements of the penstock shell thickness indicate minimal loss of material. However, the welds do not meet current standards and there have been multiple weld related failures over the last 6 years indicating the welds are at the end of their useful life. The two indications that required repair during this inspection were at previously repaired welds, including one repair made with doubler plates. The indication around the doubler plate on Can 146 was in the weld itself while the indication in Can 145 was located at the toe of the weld. The findings are indicative that the weld repair may not have a long service life. There are multiple factors that could be involved here including the difficulty welders are having with the base metal, pressure fluctuations causing fatigue in the toe of the welds, and the existing residual stresses from joint peaking. The two weld indications found this year are in adjacent cans at a vertical bend in the penstock where thrust forces may be causing higher stresses in these welds.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.40 at the joints. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.1, which is not acceptable for late 1960 steel pipe. Note that the calculations of stresses at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used; however, considering the known weld issues, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has a maximum stress ratio of 0.97 at Can 274 and a safety factor of 1.64, which is acceptable and could tolerate about 2 mm of material loss from design thickness in most cases.

Penstock No. 1 is approximately 50 years old and has shown minimal loss of metal due to corrosion compared to the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070). However, due to the condition of the existing welds, increased stresses at the longitudinal seams caused by plate peaking, and cyclic-loading, the 17-ft section of penstock will need to be replaced. The remaining section of penstock should have the welds refurbished, and the interior re-coated before the steel deteriorates further.

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in April 2020 to inspect and evaluate the condition of Penstock No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

In 2016, weld indications were identified in Penstock No. 1 due to weld degradation and Kleinschmidt was contracted to assist with the weld repair design. The weld indications prompted NLH to conduct a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods and significant refurbishment of the welds followed.

Penstock No. 1 and No. 2 were installed in 1967, before installation of Penstock No. 3 in 1968. However, Penstock No. 1 was designed with similar plate materials, plate thicknesses, and weld procedures as Penstock No. 2 and 3.

Due to the similar design, the indications and weld issues discovered in Penstock No. 1 in 2016 raised concerns about the weld integrity of Penstocks No. 2 and 3. NLH elected to have Kleinschmidt complete detailed inspections of Penstock No. 2 in 2016 and Penstock No. 3 in 2017. The primary focus of the past inspections was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the remaining life span of the penstock. Non-destructive testing of the welds were not included in the 2016 and 2017 Kleinschmidt scope of work.

However, in 2018, the welds of Penstocks No.1, 2, and 3 were inspected and tested using magnetic particle testing (MT) methods as part of a Level II Condition Assessment performed by Hatch. The Hatch 2017 and 2018 reports reference multiple ruptures in the longitudinal weld seams in Penstock No. 1 upstream of the surge tank, as well as degradation and welds indications requiring repairs in Penstock No. 1, 2, and 3.

On September 22, 2019, a weld failure resulting in a leak was discovered by NLH in Penstock No. 1. The penstock was dewatered, and Kleinschmidt carried out an inspection from September 25-27, 2019. The leak was repaired by cutting out the welded area and welding in a replacement plate.

During the 2021 penstock inspection, weld indications were identified in 14 separate cans, with the first indication being identified in Can 126. A total of 32 individual weld indications were identified totaling an approximately length of 64 ft. All weld indications were located at previously repaired welds. Cans in the upstream and downstream direction from Can 126 were extensively inspected until five (5) consecutive cans were found without any indications. The identified welds were repaired during the inspection.

The Aril 2022 inspection of Penstock 1 consisted of weld inspection and steel plate thickness measurements completed by ETS and TRR. Kleinschmidt engineer Chris Vella travelled to the Bay d'Espoir Hydro Site to complete an interior and exterior condition assessment of the penstock and facilitate the weld inspection.

This report presents Kleinschmidt's evaluation of Penstock No. 1 in its current condition following significant weld repairs made in 2016 and subsequent years, with consideration of the latest weld failures, and indications discovered during this 2022 inspection. This report provides recommendations for inspection procedures in the future and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d’Espoir Hydroelectric Development in Bay d’Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d’Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 m) and seven generating units with a total capacity of 604 megawatts (MW). The development comprises four structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks No. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the project construction involved the installation of two intake structures (Intake 1 and Intake 2) and a four-unit powerhouse with Penstocks No. 1 and 2 connecting the two. The second phase consisted of installing Penstock No. 3, along with two additional units in the powerhouse. Phase three involved building a separate intake structure and powerhouse for Unit No. 7, connected by Penstock No. 4 in 1970. Penstock No. 1 supplies Units No. 1 and 2. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock No. 1 is buried along its entire length from the intake to the powerhouse. There are four original access ports:

(1) one access port upstream of a turbine-isolation valve inside the powerhouse; and
(3) three larger access ports on the crown of the penstock:
    (1) approximately halfway between the powerhouse and surge tower;
    (2) at the surge tower; and
    (3) halfway between the intake and the surge tower.

There are two newer access ports that were added in 2016 at the upstream end of the original upstream access port. A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum of riprap. The penstock is deeply buried as it crosses under the switchyard and goes into the powerhouse. The penstock has drainage along its length with several weirs where the drainage daylights to the ditches and wells for inspection and monitoring.

Appendix A includes the original 1965 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 11 millimetres (mm) (0.4375 inches) at the intake to 41 mm (1.625 inches) at the powerhouse. The penstock is constructed of A285 grade steel for the first 1,015 ft, and CSA G40.8 Grade B for the remainder of the penstock. The welds are generally double V groove full penetration welds. The penstock slope varies from approximately 0.2 degrees to 19.7 degrees just upstream of the bifurcation.

3.0 INSPECTION

The 2022 inspection of Penstock No. 1 consisted of measuring shell thicknesses with a UT gage and inspecting the welds. ETS personnel performed MT weld tests on approximately 10% of the longitudinal welds for the entire penstock. Ultrasonic thickness (UT) measurements were taken from approximately 10% of the cans[1] for the penstock. The field data is included in Appendices C and D, respectively. A detailed interior visual inspection and an exterior walk of the penstock alignment was performed by Chris Vella, Kleinschmidt's lead inspecting engineer.

In Table 3-1, definitions are provided for the descriptive terms used for the condition assessment.

Table 3-1 Definitions for the Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

For purposes of this report, a weld indication that can be seen with the naked eye as a split in the weld will be called a crack, otherwise it will be an indication.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on site in the morning of Monday, April 25, 2022. The inspection team entered the penstock Monday morning at the upstream most open manhole of Penstock No. 1 and walked to the intake gate to start the inspection. TRR assisted with confined space entrance and rigging for fall protection. The internal

[1] A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint.

inspection finished on April 27, 2022. The exterior inspection commenced on Tuesday, April 26, 2022 and was completed by Kleinschmidt the same day. Kleinschmidt pre-marked the welds selected for inspection so that TRR and ETS could proceed with the internal inspection and weld testing while Kleinschmidt performed the external inspection. Air quality in the penstock remained acceptable for the duration of the inspection.

The interior inspection commenced at the headgate. A small amount of leakage, approximately 3 gpm, was noted around the headgate. Leakage was primarily from the right and left top corners. Previous inspections noted leakage from the bottom left and right corners. Leakage was not significant enough to hinder the inspection. Concrete deterioration at the concrete to steel transition (Photo 2), is notably more extensive in Penstock 1 compared to the other Bay d'Espoir penstocks. The deterioration has resulted in the leading edge of steel being exposed all the way around the transition but is worse in the lower left area. The deterioration does not require repair in the short term; however, the concrete should be patched to smooth the transition as part of future remediation following the FEED project. The interior surface of the penstock was moist but not as wet during previous inspections conducted by Kleinschmidt. The penstock was dewatered more than a week prior and had a chance to dry. Much of the organics had been cleaned away during the previous penstock repairs and inspections which facilitated the inspection upstream of the surge tank. A larger amount of organic buildup was noted downstream of the surge tank, where less work has been completed. Inspection rate was slowed in this area due to more time being needed to clean welds that have never been cleaned before.

The penstock has varying slopes with two main steep sections. The penstock slopes range from 0.2 degrees to 11 degrees along most of its length, but just upstream of the surge tank there is a section with a 14-degree slope for approximately 110 m (361 ft) and just upstream of the powerhouse the penstock has a 19.7-degree slope for approximately 58 m (190 ft) as noted in Appendix A. The slope levels out as the penstock enters the powerhouse.

The exterior of the penstock was inspected on April 26th. The ground surface was generally rock covered with some steep slopes in many areas and short vegetation. There was no snow, and the ground was reasonably dry limiting slip potential. The grade nominally followed the penstock slope between the intake and the switchyard. Deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

Penstock 1 is fabricated from approximately 435 steel “cans”. A can is defined as one whole penstock pipe section from circumferential weld joint to the next circumferential weld joint, as noted herein. The can number is used in this report to reference location in the penstock during the inspection with Can 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded from the interior at various locations. Shell thickness measurements were taken with a Krautkramer DMS 2 Ultrasonic thickness gauge. A Krautkramer TC560 probe was used, and the readings were taken in the “standard” mode. In “standard” mode the paint thickness does not affect the steel thickness readings if the paint thickness is below 1/64 (0.0156) inch (15.6 mils). The gauge was calibrated before the field measurements to an accuracy of 0.001 inch. Both the field measurements and Appendix A drawings give shell thicknesses in inches, so this evaluation did so as well. Metric equivalents are given in parenthesis.

Thickness readings were recorded from the interior of the penstock generally near 4 o’clock, 6 o’clock, and 8 o’clock positions based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the pipe. All references to penstock left and right are also oriented looking downstream. Appendix D provides the ETS report of shell thickness readings. A summary of this data is provided in Table 4-1. An updated list of welds inspected over the last few years is contained in Appendix F.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

The interior of the penstock is generally in fair condition with scattered moderate corrosion and pitting with tubercles and growth (Photos 3 to 5). Pitting was minor to moderate, relative to the plate thickness, and detailed pit measurements were not taken.

Penstock No. 1 is fabricated from 20 different plate sizes ranging from 11 mm (0.4375-inch) to 42 mm (1.625-inch). Inspection thickness readings were taken for plate sizes up to 36.5 millimetres (1.433 inches). Many of these sections exhibited little material loss with the average thickness for all plates being 5.8% thinner than the listed original though there are some areas with greater than 20% section loss. Appendix D provides the report of the MP and UT testing.

Welds in Penstock No. 1 were cleaned with a grinder then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 114 full length longitudinal welds and approximately 2 ft of each of the 228 circumferential welds adjacent the tested longitudinal welds. In addition, eight (8) doubler plates that were installed as previous repair efforts were inspected. An initial visual inspection of the weld was conducted which concentrated on the condition of the bead with regards to pitting, corrosion, or cracking, undermining or washout. Particular attention was paid to welds not previously tested or repaired as part of Kleinschmidt's annual inspections. The welded joints inspected included original joints, previously repaired joints, and doubler plate welds (Photos 7 to 11).

During the inspection, four (4) indications were identified. The first indication was found in Can 146 at the toe of weld around a doubler-plate. The indication was removed by grinding and did not require welding. The second indication, a 3-inch-long crack, was found in Can 145 along the south longitudinal weld (Photo 13) which required repair by welding. Additionally, a twelve-inch section of weld erosion was noted in both of cans 98 and 103, on the north sides of the penstock. Mr. Vella was notified upon the discovery of each indication or crack. NLH was immediately notified, and a repair crew was mobilized on site the following day with repairs be completed Wednesday April 28th. The planned inspection was modified such that cans upstream and downstream of the crack were inspected and tested. Testing and inspection of the cans continued until five consecutive cans upstream and downstream of each identified indication were tested without finding further indications. MT details for the indications and crack can be found in Appendix C of this report including repair of the crack in Can 145.

The indications identified in Cans 98 and 103 consisted of very small spots of weld erosion in the circumferential weld adjacent to the longitudinal weld. Repair was not required or recommended, and the MT testing found the welds to be acceptable. The indication found in Can 146 was found along the toe of the north longitudinal weld. The indication was removed by light grinding and no welding was required.

The crack found in Can 145 was about three inches long located in the north longitudinal weld. Can 145 is located at the downstream end of the transition between the 17-foot diameter and 15.25-ft diameter penstock and where the penstock has a vertical bend. The crack was approximately 1/8 inch in depth and was located at the toe of the weld. The cans upstream and downstream from the crack location were inspected until five (5) consecutive cans were found to not contain any indications. Another indication was found at the toe of the weld around a doubler plate in Can 146. The indication was removed by only light grinding and was confirmed with MT. The crack in Can 145 was repaired by welding on April 28th and was inspected by the magnetic particle method immediately upon cooling. Our NDT Technician helped the repair crew determine the limits of the indications as they were gouged out, tested the weld repairs when complete, and retested the repaired welds after the 48-hour hold time. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK". The MT results were acceptable, and no additional repairs were required.

Appendix C provides the ETS report of the MT testing which includes the details, location, and position of each indication. Appendix F provides the weld tracking sheet which details the locations of repaired welds, doubler plates, welds that have not been inspected, and appurtenances such as pressure transducers, manholes, etc.

All the indications were located at previously repaired welds, either in the heat effected zone or the toe of the weld. One (1) doubler plate had and indication around the perimeter at the toe of the fillet weld in the original penstock plating.

The remainder of the weld inspection downstream of the surge tank concentrated on untested welds, but the team did pick up a few of the tested and repaired welds. There were no further indications and weld condition has not changed notably from previous years.

3.2.2 Exterior Inspection

Kleinschmidt began the exterior inspection on April 26th, at the intake and proceeded to move downstream. The inspection was completed the same day and terminated at the switchyard. The interior weld testing and UT measurements performed by ETS continued inside the penstock while Mr. Vella walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photo 16. Kleinschmidt observed the exterior ground surface for evidence of signs of leakage such as sloughing of the soil or depressions while walking the length of the penstock. No obvious indications were observed during the 2022 exterior inspection of the penstock.

About 2 gpm was found coming from the flow pipe at FP 3 (Photo 17). The newer manhole near Station 100 m was not opened and appear to be in good condition from the outside. The alder bushes upstream of manhole 1 and covering Penstocks 1 and 2 should be cut back (Photo 18). The new rip rap areas are in good condition and do not appear to have changed since they were installed (Photo 19). The cover over the remainder of the penstock is uneven in places but does not require remediation (Photo 20).

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix E. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 which extends approximately 1,034 ft from the face of the intake, and 24,000 psi was used for CSA G40.8 Grade B for the remainder of the penstock.

The strength of the welded seams is reduced compared to the base material. The strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used for the analysis if weld testing is performed to verify the integrity of the welds. As per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds needing higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of the steel-shell thickness data and internal pressure steel stress analysis results. See Appendix D for detailed thickness data and stress calculations.

The minimum thickness measurement was determined for each penstock can measured and was used to calculate the allowable stresses within each penstock section. To calculate the allowable stresses, the minimum thickness measurement was used in contrast to the 97.5% confidence interval (CI) which was used in previous years. This was done as too few measurements were collected per can to justify the use of CI. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

Three thickness measurements were taken at each location, A, B, and C, for each can that was inspected with a UT gauge, with nine thickness measurements in total for each can. When analyzing the thickness measurements using the 97.5% CI method, the calculated thickness was significantly less than the minimum thickness measured during inspection in many cases. This is due to the 97.5% CI being applied to a small data group: three to nine thickness measurements. Small sample sizes result in wider confidence intervals in contrast to large sample sizes, which result in narrower confidence intervals, and less error. Using the minimum steel-shell thickness measurement for the purpose of analysis in lieu of the 97.5% CI thickness, more accurately describes the penstock thickness in this situation.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 ft (182 m) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 ft (271 m) at the powerhouse and linearly reducing to 655 ft (200 m) at the surge tower and then matching the FSL of 597 ft (182 m) at the intake. Appendix A reference drawings provide the pressure gradient used in this analysis.

The maximum stress ratio at a joint is 1.60 (Can 308) for this load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 0.63 (Can 308), which is unacceptable for late 1960 steel pipe. An increase in the joint efficiency factor can be justified through weld testing to verify the existing pipe joint integrity. A factor of 0.9 to 1.0 could be used for the joint efficiency upon 100% RT or UT of the joints. By utilizing a higher joint efficiency factor, the joint stress ratios would decrease while the factor of safety would increase. The calculations as provided in Appendix E include joint stress ratios calculated with an efficiency factor of 0.7 and 1.0 for comparison purposes. Despite utilizing an efficiency factor of 1.0, Cans 278 to 318 contain calculated joint stress ratios greater than 1.0 from the thickness measurements obtained from the 2022 inspection.

For steel plate away from the joints, the material has a maximum stress ratio of 1.12 and a safety factor of 1.41 at Can 308, which is not acceptable for current design practices.

In addition to Table 4-1 which summarizes the 2022 thickness data and stresses due to internal data, a summary table included within Appendix E summarizes all base material and joint stress ratios calculated from 2019 through 2022. Penstock cans that have not been inspected and analyzed are not included within the table.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Joint Stress (FSL)[1,3] (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress (Surge at Joints)[1,3] (psi)	Allowable Stress (psi)	Max Joint Stress Ratio[1,2,3]	Max Base Material Stress Ratio	Factor of Safety Against Yield (Joints)	Factor of Safety Against Yield (Base Material)
3	6,228	5,667	1,868	8,096	17,000	0.48	0.33	3.21	4.59
14	5,900	5,369	1,770	7,670	17,000	0.45	0.32	3.39	4.84
24	7,121	6,480	2,136	9,257	17,000	0.54	0.38	2.81	4.01
32	8,719	7,934	2,616	11,335	17,000	0.67	0.47	2.29	3.28
42	10,305	9,378	3,092	13,397	17,000	0.79	0.55	1.94	2.77
50	11,506	10,470	3,452	14,958	17,000	0.88	0.62	1.74	2.48
64	13,190	12,003	3,957	17,147	17,000	1.01	0.71	1.52	2.17
71	13,653	12,424	4,096	17,748	17,000	1.04	0.73	1.46	2.09
81	13,632	12,405	4,090	17,722	17,000	1.04	0.73	1.47	2.10
93	13,902	12,651	4,171	18,072	17,000	1.06	0.74	1.44	2.06
103	15,631	14,224	4,689	20,320	17,000	1.20	0.84	1.28	1.83
112	16,669	15,169	5,001	21,669	17,000	1.27	0.89	1.20	1.71
123	18,290	16,643	5,487	23,776	17,000	1.40	0.98	1.09	1.56
132	19,280	17,545	5,784	25,064	24,000	1.04	0.73	1.44	2.05
142	15,475	14,082	4,642	20,117	24,000	0.84	0.59	1.79	2.56
150	19,562	17,802	5,869	25,431	24,000	1.06	0.74	1.42	2.02
160	23,364	21,261	7,009	30,373	24,000	1.27	0.89	1.19	1.69
169	23,285	21,190	6,986	30,271	24,000	1.26	0.88	1.19	1.70
178	24,967	22,720	7,490	32,457	24,000	1.35	0.95	1.11	1.58
188	24,470	22,268	7,341	31,811	24,000	1.33	0.93	1.13	1.62
198	24,559	22,348	7,368	31,926	24,000	1.33	0.93	1.13	1.61
208	23,637	21,510	7,091	30,729	24,000	1.28	0.90	1.24	1.77
218	23,136	21,053	6,941	30,076	24,000	1.25	0.88	1.26	1.80
229	23,129	21,048	6,939	30,068	24,000	1.25	0.88	1.26	1.81
237	23,139	21,057	6,942	30,081	24,000	1.25	0.88	1.26	1.80
248	23,227	21,137	6,968	30,196	24,000	1.26	0.88	1.26	1.80
258	20,501	18,656	6,150	26,651	24,000	1.11	0.78	1.43	2.04
268	24,058	21,893	7,217	31,276	24,000	1.30	0.91	1.22	1.74
278	26,958	24,532	8,088	35,046	24,000	1.46	1.02	1.08	1.55
287	27,188	24,741	8,156	35,345	24,000	1.47	1.03	1.08	1.54
298	28,873	26,274	8,662	37,535	24,000	1.56	1.09	1.01	1.45
308	29,535	26,877	8,860	38,395	24,000	1.60	1.12	0.99	1.41

Can	Joint Stress (FSL)[1,3] (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress (Surge at Joints)[1,3] (psi)	Allowable Stress (psi)	Max Joint Stress Ratio[1,2,3]	Max Base Material Stress Ratio	Factor of Safety Against Yield (Joints)	Factor of Safety Against Yield (Base Material)
318	29,099	26,480	8,730	37,829	24,000	1.58	1.10	1.00	1.44
328	24,410	22,214	7,323	31,734	24,000	1.32	0.93	1.13	1.62
338	22,836	20,781	6,851	29,687	24,000	1.24	0.87	1.21	1.73
348	24,246	22,064	7,274	31,520	24,000	1.31	0.92	1.14	1.63
360	21,947	19,971	6,584	28,531	24,000	1.19	0.83	1.26	1.80
367	21,313	19,395	6,394	27,707	24,000	1.15	0.81	1.30	1.86
377	20,691	18,829	6,207	26,898	24,000	1.12	0.78	1.34	1.91
387	20,220	18,400	6,066	26,286	24,000	1.10	0.77	1.37	1.96
397	20,983	19,094	6,295	27,277	24,000	1.14	0.80	1.32	1.89
407	20,394	18,559	6,118	26,513	24,000	1.10	0.77	1.36	1.94
417	20,821	18,947	6,246	27,067	24,000	1.13	0.79	1.33	1.90
425	19,483	17,730	5,845	25,328	24,000	1.06	0.74	1.42	2.03
432	18,868	17,169	5,660	24,528	24,000	1.02	0.72	1.47	2.10

Notes:
1 Joint efficiency of 0.7 included
2 Total stress / Allowable stress
3 Uses minimum can thickness
4 SF = Fy/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 psf and the depth of soil cover on the penstock was assumed to be 3 ft. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1) DL (water above conduit, soil load and steel) + internal vacuum pressure
2) DL (water above conduit, soil load and steel) + snow load
3) DL (water above conduit, soil load and steel) + combination snow (75%) and live load (75%)

To determine the external soil load, 1 ft of riprap at a density of 150 lbs per cubic foot and 2 ft of fill at a density of 120 lbs per cubic foot were used to calculate the soil loading above the penstock.

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis. An earthquake analysis could be performed but would be a more involved and time consuming and was not included in the scope of work.
- We assume the penstock is located in cohesive fine-grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 17-ft-diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was 3.72 psi which is less than the allowable buckling pressure of 4.23 psi. The 15.25-ft and 13.5-ft-diameter sections were analyzed, and the max pressures are summarized in Table 4-2.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot (psf) external live load with the snow load combination. Lowest average measured steel thickness values were used. See Table 4-2.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	4.23	3.24	3.72
15.25	5.04	3.91	4.39
13.50	16.84	4.30	4.78

There was no new vehicular surcharge analysis conducted as we are not expecting changes in the results from the original analysis conducted by Kleinschmidt in 2016 for Penstock No. 2. The 2016 analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 14 ft from the front axle to middle axle then variable from 14 ft to 28 ft to the rear axle, was approximately 5 times less than the allowable buckling loads at that location. For the section of penstock analyzed, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.2 Sub-atmospheric Internal Penstock Pressure Analysis

Sub-atmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created, but the likelihood of occurrence of sub-atmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1 m^2 (55 ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads, but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil, so it is unlikely there are excessive local buckling stresses in the penstock.

4.5 Local Weld Conditions

ETS performed MT tests on the full length of approximately 116 longitudinal welds and a few feet of 232 circumferential welds for this April 2022 inspection. Three indications and one crack were discovered. Indications were identified in Cans 98, 103, and 146 while a 3-inch-long crack was identified in Can 145. The discovered indication in Can 145 was repaired by grinding, while the crack in Can 146 was repaired via welding. ETS performed MT testing on the weld repairs and were found to be acceptable

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, the 17 ft section of the penstock should be replaced, the remaining welds refurbished and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted again this year with indications discovered in previously repaired welds. Indications found in 6-year-old welds indicates that the weld repairs may have a limited life expectancy. Two indications were found in the 17-ft diameter section while one indication and the 3-inch-long crack were found in the transition to the 15.25′ diameter section during this year's inspection. Historically, these sections of penstock have been particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock No. 1 should be replaced to about Can 147 to extend past the transition piece and Cans 145 and 146 which have had multiple indications over the past 6 years. This replacement will remove the risk of future failures during operation and provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 4 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal to moderate loss of material thickness over the design specification. During this year's inspection of Penstock No. 1, a greater amount of section loss was measured in the 15.25 ft and 13.5 ft sections of penstock compared to previous years. A significant amount of moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the penstock should have about 50 years of service life remaining, based on wear, if an internal coating is applied. The base plate material away from the joints can tolerate up to 2 mm further material loss and maintain a stress ratio below 1.0. However, if the interior of the penstock is not coated, corrosion will progress to the point where stresses will no longer be acceptable. This could happen in as few as 10 years.

5.2 Internal Pressure Strength

Stress ratios for a combined static and dynamic internal pressures peak at 1.60 (Table 4-1) in the joints. This indicates that the penstock does not meet present day design criteria for new penstock design. The thickness of this plate and other plates with high stress ratios should be measured again next year to confirm accurate UT measurement and deterioration in the area. When the hoop stress is compared to the plate yield stress the minimum factor of safety is below acceptable safety factors for late 1960 steel pipe. As noted previously the analysis assumes a joint efficiency of 0.7 which can be improved upon with 100% RT testing of the welds as noted in Section 4.1. The first step should be to perform spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. There is a lack of confidence of the weld integrity for this penstock, and although the plating is acceptable and many welds have been refurbished, it is recommended that the penstock undergo further extensive refurbishments and the 17-ft section be replaced. The MT testing of welds to date does not satisfy the requirements of ASCE No. 79 to increase the joint efficiency. With the history of weld failures including the operational failure in 2020 and several indications found this year it is recommended that this penstock undergo extensive refurbishments and the 17-ft section be replaced in the next 5 years.

6.0 RECOMMENDATIONS

Penstock No. 1 should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively and the 17-ft diameter section should be replaced within 4 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- radiographic testing of the welds if possible;
- surge analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior including MP weld testing.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 5 years provided the penstock welds are replaced. At this stage, Kleinschmidt is unable to estimate the rate of corrosion for the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20 to 40 years or more. If the penstock is recoated prior to significant steel deterioration every 20 to 40 years, NLH can anticipate extending the life of the penstock nominally another 50 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated and buried, so it is difficult to tell its condition without excavation. It would be costly and time consuming to uncover enough of the penstock to get a representative sample size of the exterior penstock condition, and some areas, like the invert, cannot be inspected safely. An exterior inspection involving excavation of significant portions of the penstock will not provide enough data to be worth the investment.

6.2 Annual Inspections

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. These inspections should give a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless of if the coating has been replaced or not, the detailed inspections can be extended to a 5- to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval.

7.0 REFERENCES

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Hatch. 2019. Newfoundland and Labrador Hydro Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3. Rev 0. March 28, 2019.

Kleinschmidt Associates. 2016. Crack Investigation and Repair Report, Penstock No. 1 Bay d'Espoir Hydroelectric Development. Kleinschmidt Technical Report to Newfoundland and Labrador Hydro.

REPORT SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
July 29, 2022
DATE
NEWFOUNDLAND & LABRADOR

CMV:NSS:SCB

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATÉS CANADA INC.
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEGNL N0095
which is valid for the year 2022

\\kleinschmidtusa.com\Condor\Jobs\2670\030\Docs\2670030.04 2022\2022 Inspections and Reports\Penstock 1\2670040_Bay d'Espoir Penstock 1 Inspection Report FINAL Rev1.docx

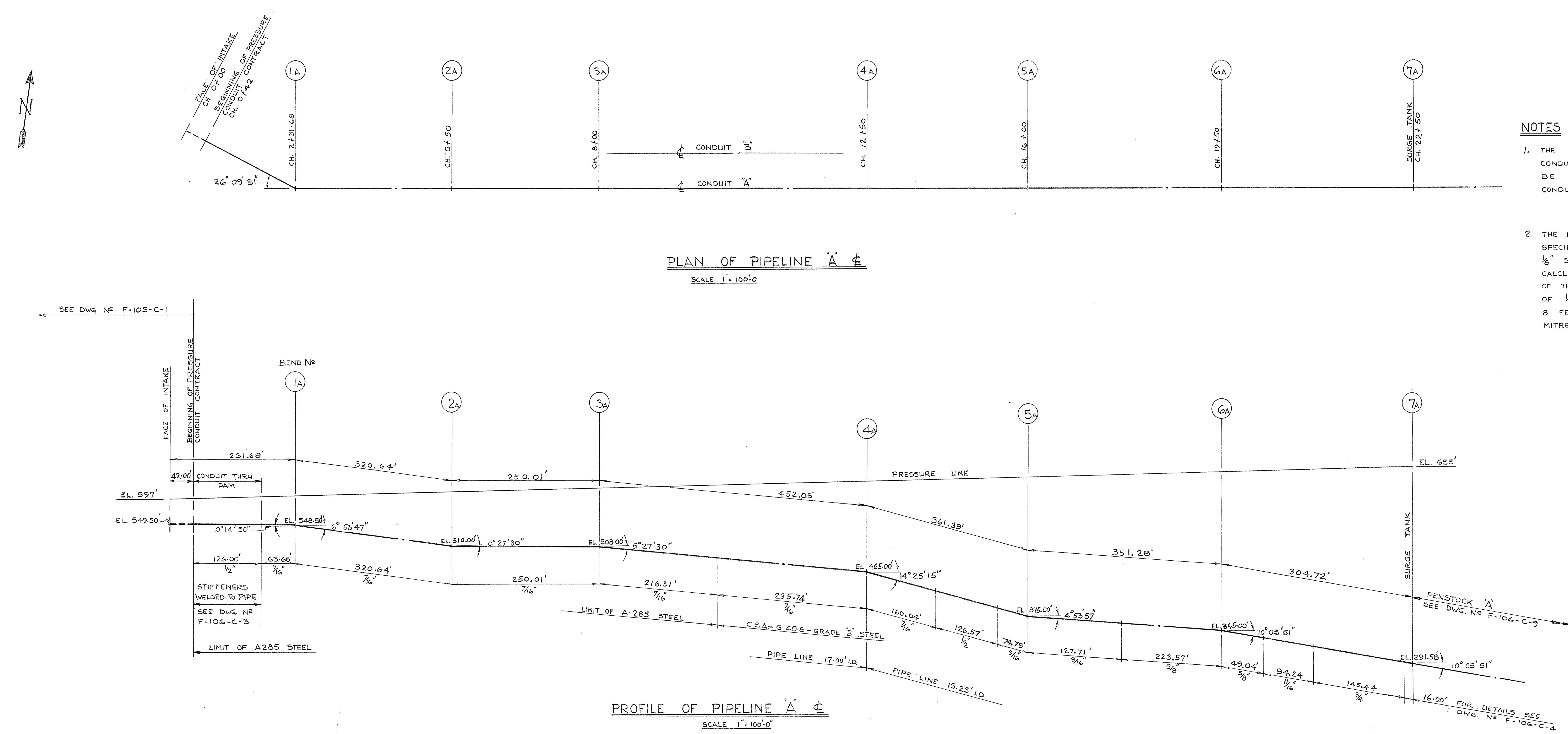
APPENDIX A

PENSTOCK LAYOUT DRAWINGS

NOTES

1. THE PRESSURE CONDUITS SHALL BE CALLED "A" AND "B". CONDUIT "A" IS SOUTH OF CONDUIT "B" AND SHALL BE COMPLETED IN 1966. CONDUIT "A" CONSISTS OF PIPELINE "A" AND PENSTOCK "A".

2. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION No M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.

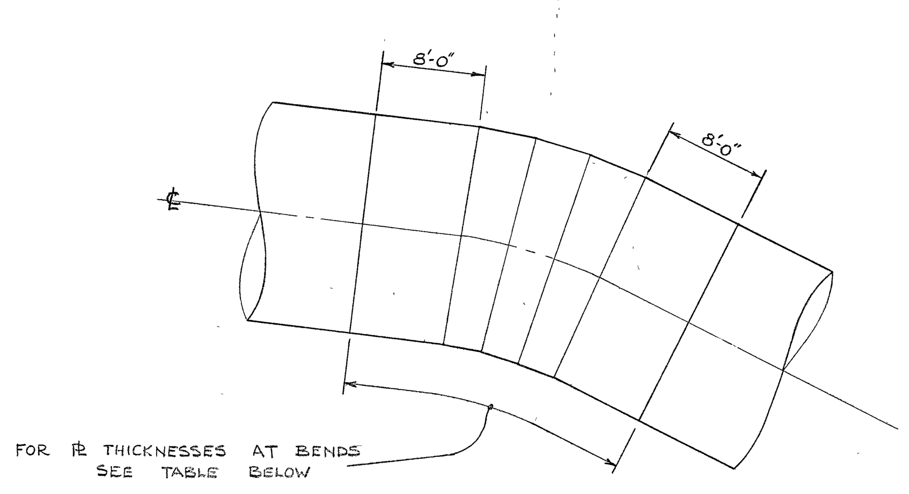


PLAN OF PIPELINE "A" ℄

SCALE 1" = 100'-0

PROFILE OF PIPELINE "A" ℄

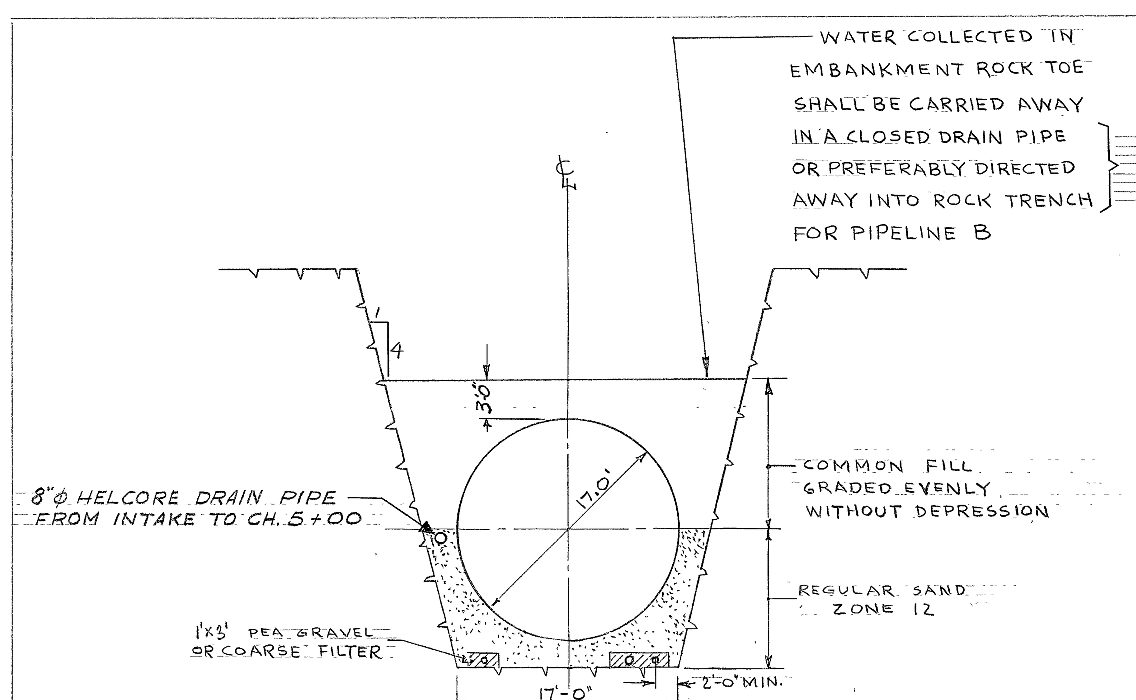
SCALE 1" = 100'-0"



TYPICAL BEND

SCALE 1" = 10'-0"

SEE SPEC. M-3116

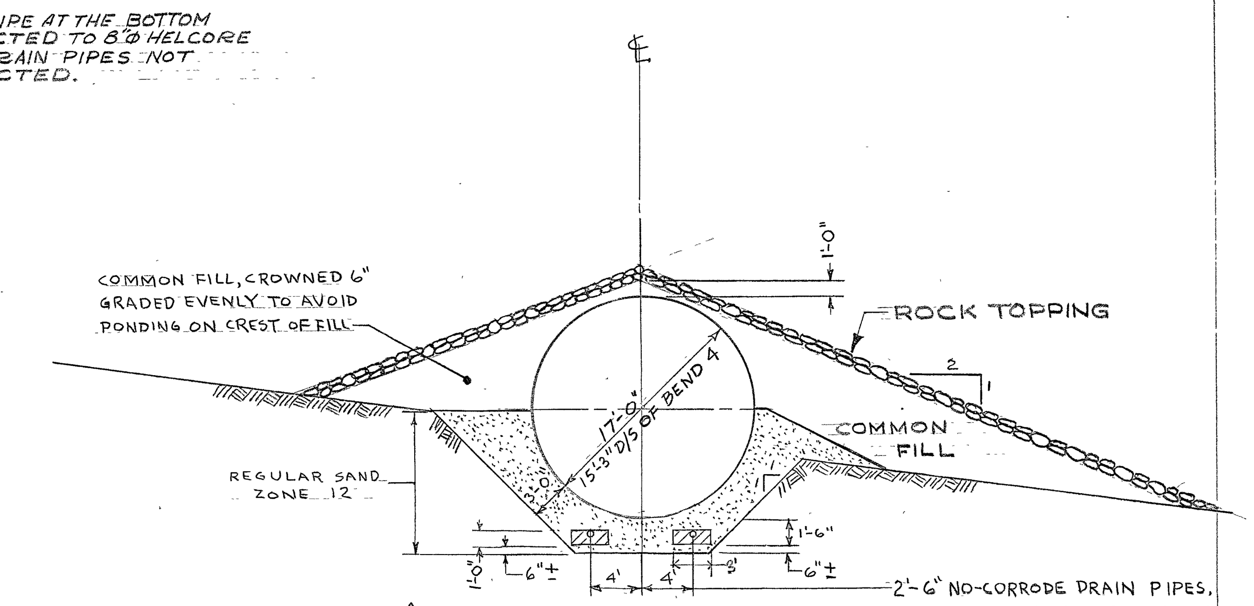


2—6" NO-CORRODE DRAIN PIPES NEAR TOP OF LAYER WITH DRAIN HOLES FACING DOWN

1—8" HELCOR PIPE FROM INTAKE BOX DRAIN

TYPICAL SECTION UPSTREAM OF BEND 7A IN ROCK CUT

SCALE 1" = 1'-0"



2-6" NO-CORRODE DRAIN PIPES, INSIDE COARSE FILTER OR PEA GRAVEL HOLES FACING DOWN

DRAIN PIPES PLUGGED AT UPPER ENDS NEAR THE CROSS DRAINS.

TYPICAL SECTION UPSTREAM OF BEND 7A IN EARTH TRENCH

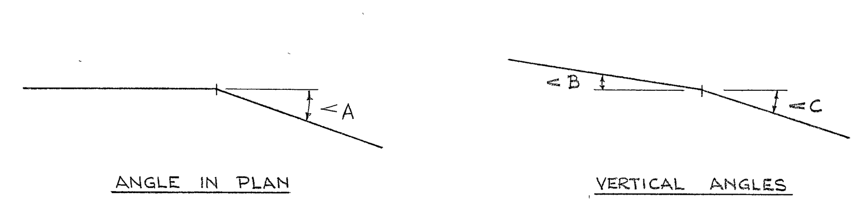
SCALE 1" = 1'-0"

PERVIOUS LAYER ZONE 12 MATERIAL AND FILTER MUST BE SEALED WITH IMPERVIOUS FILL IMMEDIATELY DOWNSTREAM OF EACH CROSS DRAIN TO PREVENT SEEPAGE WATER FROM BY-PASSING THE CROSS DRAINS.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. F. ... LICENCE TO PRACTICE

ANGLES & PL THICKNESSES AT BENDS

BEND	< A	< B	< C	TRUE ANGLE	PL THICKNESS
1 A	26° 09' 31"	0° 14' 50"	6° 53' 47"	26° 55' 34"	7/16"
2 A	——	6° 53' 47"	0° 27' 30"	6° 26' 17"	1/2"
3 A	——	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4 A	——	5° 27' 30"	14° 25' 15"	8° 57° 45"	9/16"
5 A	——	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6 A	——	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	



REFERENCE DRAWINGS

F-106-C-3 CONDUITS THROUGH DAM
F-106-C-4 SURGE TANK - DETAILS OF TEES
F-106-C-5 " " - GENERAL LAYOUT & DETAILS
F-106-C-6 PRESSURE CONDUITS - CLEARING
F-106-C-8 " " - EXCAVATION & DRAINAGE
F-106-C-9 " " - PENSTOCK A
F-106-C-10 " " - PENSTOCK B

OTHER REFERENCES

1. SPECIFICATION No. M-3116

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
5	2-6-68		AS BUILT, FROM FIELD INFORMATION	A.B.	JHM
4	5 JAN '67		2 TYP. SECTIONS CHANGED, ONE REMOVED	A.R.	
3	9 DEC '66	A/B - 1,2,3,4	3 TYPICAL SECTIONS ADDED	A.R.	JHM
2	20 SEPT '65		REVISED PROFILE & PLATE THICKNESSES	A.R.	
1	AUG. 5/65		EL. @ BEND 4 CORRECTED, MINOR REVISIONS	J.P.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 16 1965
APPROVED BY: W. E. Bennell
MANAGER ENGINEERING

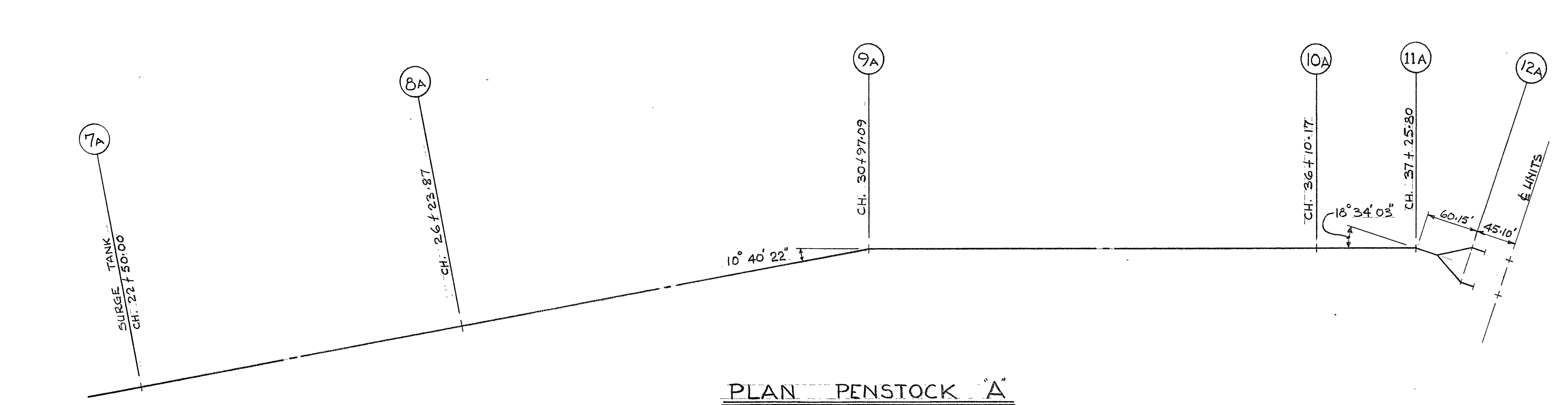
PASSED: TRANS'N | ELECT'L | CIVIL JHM

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED
RECOMMENDED JH Manica P.Eng

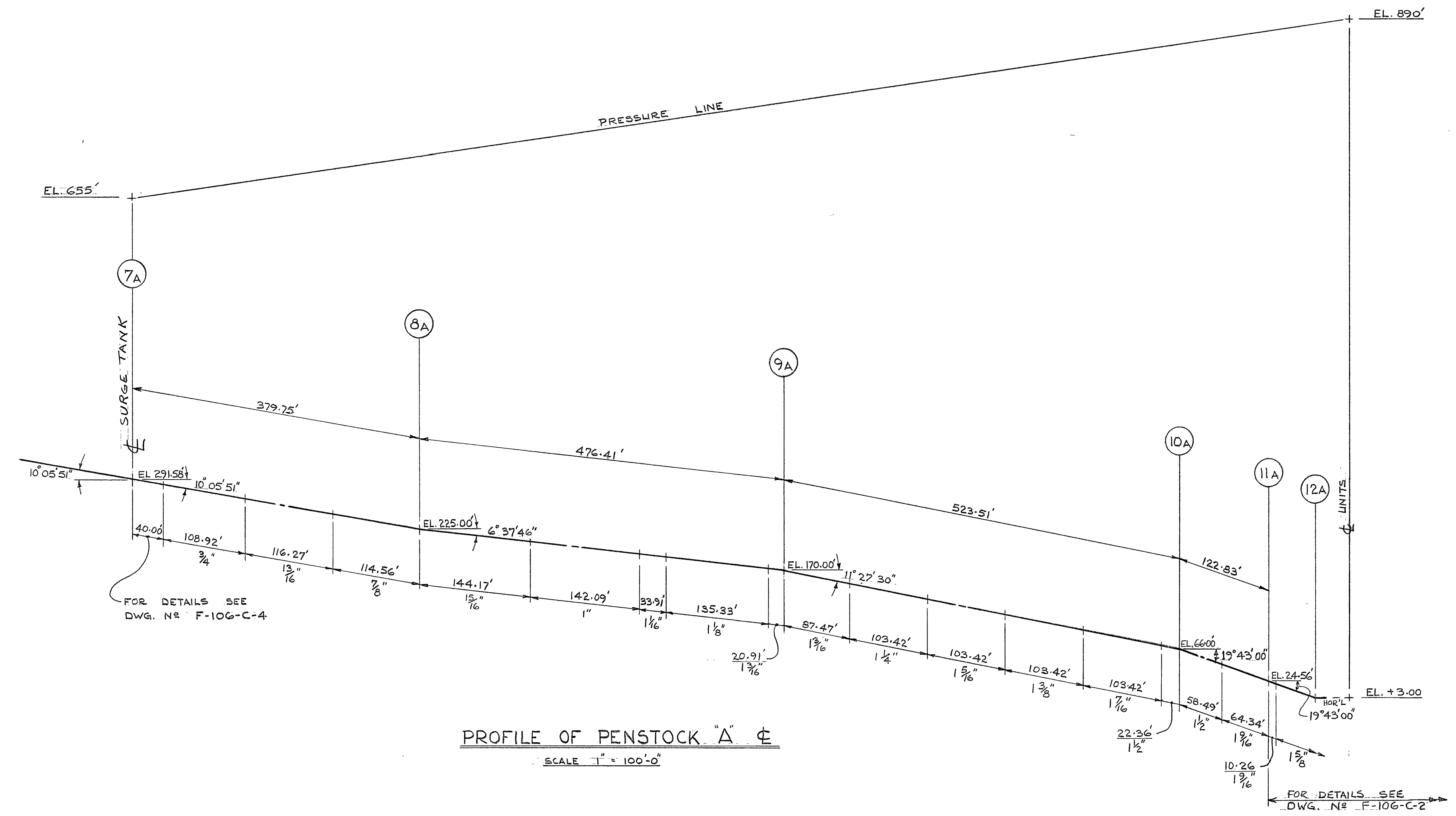
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PIPELINE "A"

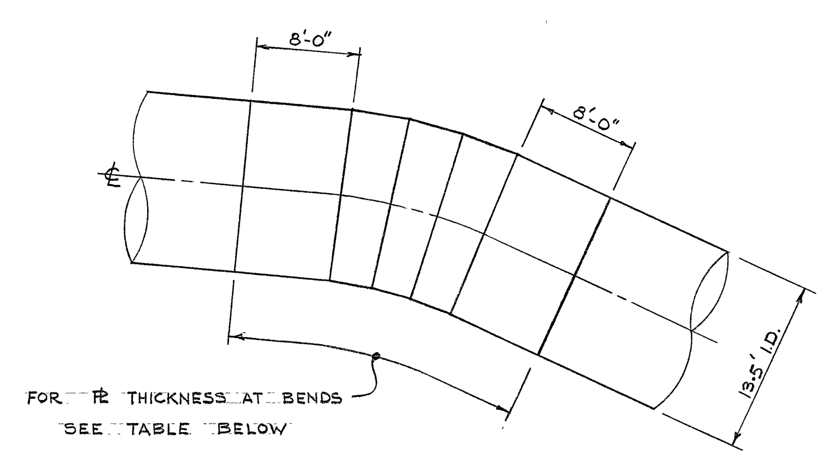
CONTRACT	SCALE	FILE NO.	DATE	DWG NO.	REVISION
	NOTED	PD - 11	JULY 16, 1965	F-106-C-7	5



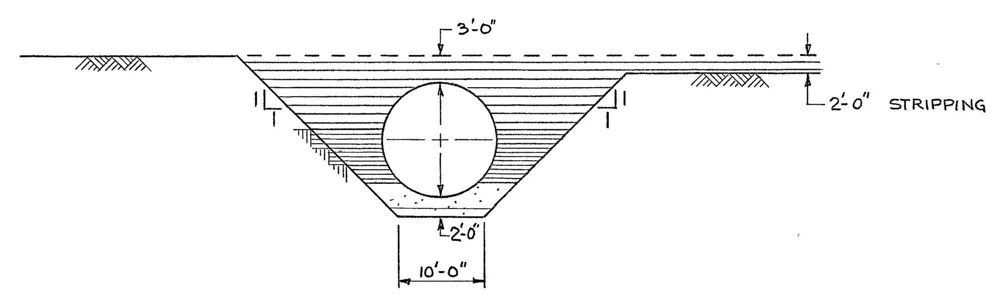
PLAN PENSTOCK 'A'
SCALE 1" = 100'-0"



PROFILE OF PENSTOCK 'A' ℄
SCALE 1" = 100'-0"



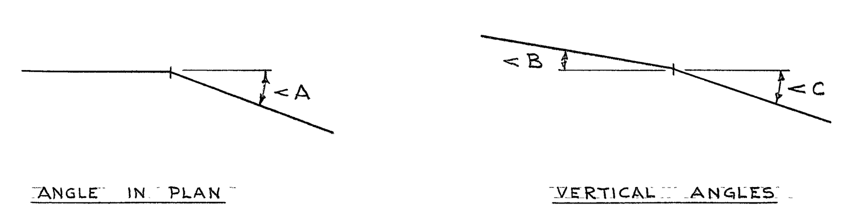
TYPICAL BEND
SCALE 1" = 10'-0"



TYPICAL CROSS SECTION (9A) TO (11A)
SCALE 1" = 15'-0"

BEND	< A	< B	< C	TRUE ANGLE	℞ THICKNESS
7 A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	——
8 A	——	10° 05' 51"	6° 37' 46"	3° 28' 05"	1 1/8"
9 A	10° 40' 22"	6° 37' 46"	11° 27' 30"	11° 35' 25"	1 3/8"
10 A	——	11° 27' 30"	19° 43' 00"	8° 15' 30"	1 3/4"
11 A	18° 34' 03"	19° 43' 00"	19° 43' 00"	17° 28' 12"	1 7/8"

ANGLES & ℞ THICKNESS AT BENDS



NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6".
3. STEEL SHALL BE C.S.A. G40-8 GRADE 'B'.
4. FOR TYPICAL CROSS SECTION FROM (7A) TO (9A) SEE DWG. Nº F-106-C-7.

REFERENCE DRAWINGS

1. F-106-C-2 PRESSURE CONDUITS-LAYOUT & DETAILS OF BIFURCATION.
2. F-106-C-4 SURGE TANKS - DETAILS OF TEES.
3. F-106-C-5 SURGE TANKS - GENERAL LAYOUT & DETAILS.
4. F-106-C-6 PRESSURE CONDUITS - CLEARING.
5. F-106-C-7 PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE 'A'.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
3	SEPT 2/66		PLAN & PROFILE REVISED	J.P.	

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 22 1965
APPROVED BY:
MANAGER ENGINEERING

TRANS'N | ELECT'L | CIVIL
PASSED

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED A.P. H.
RECOMMENDED

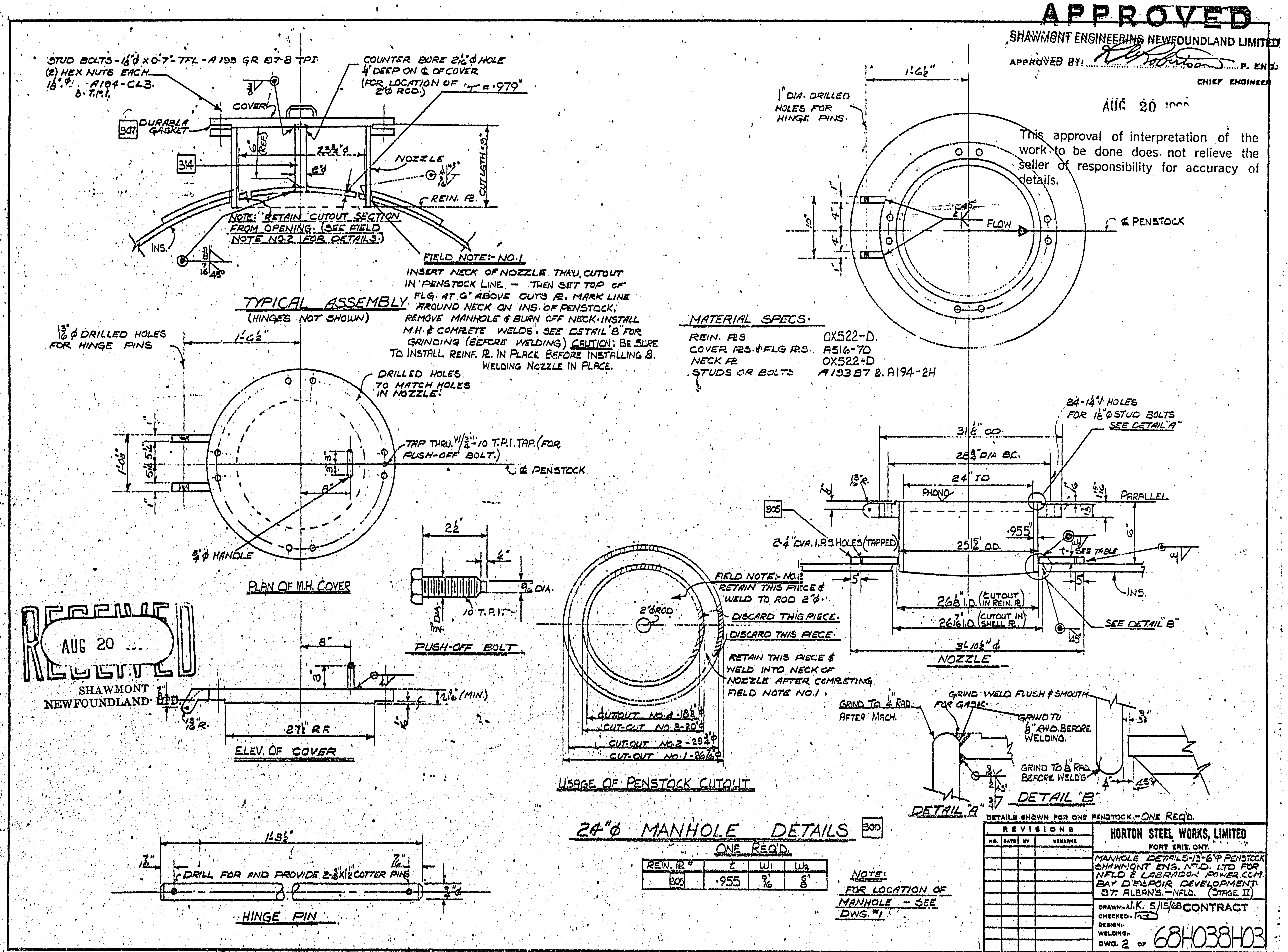
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK 'A'

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 21, 1965	F-106-C-9	3


ELEVATION OF PENSTOCK 'B'
PLAN VIEW
GENERAL NOTES:
FIELD NOTES:
APPROVED
OCT 25 1966
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.
HORTON STEEL WORKS, LIMITED
10831
FILE 2-13

BEND	∠A	∠B	∠C	TRUE ANGLE	PL. THICKNESS
7A	———	10°05'51"	10°05'51"	0°00'00"	———
8A	———	10°00'51"	6°37'46"	3°23'05"	1 1/8"
9A	10°40'22"	6°37'46"	11°27'30"	11°35'25"	1 3/8"
10A	———	11°27'30"	13°43'00"	8°15'30"	1 1/2"
11A	18°34'03"	19°43'00"	15°43'00"	17°28'12"	1 7/8"



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NEWFOUNDLAND AND LABRADOR POWER COMMISSION
FILE COPY
FILE NO. 68H038H03 BAY D'ESPOIR

APPENDIX B

PHOTOGRAPHS

Photo 1 Leakage from Right Top Corner of gate

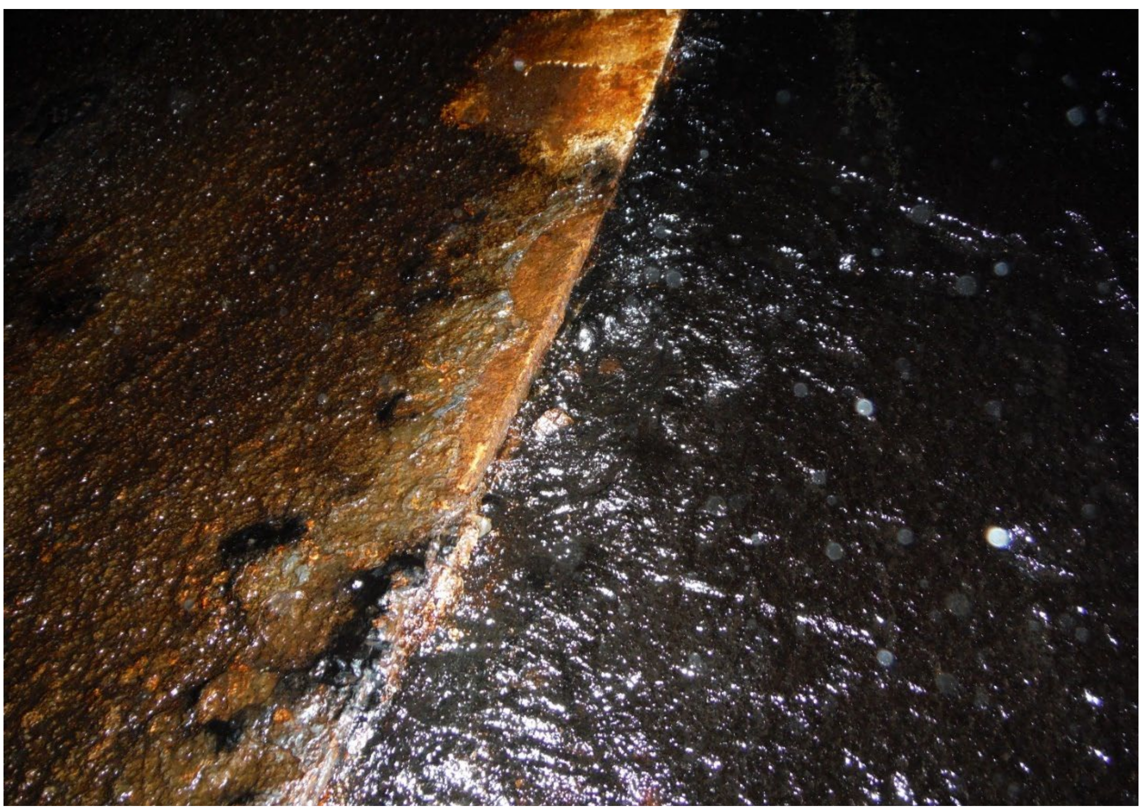


Photo 2 Concrete to Steel Transition

Photo 3 Typical Organic Coating

Photo 4 Organic Layer with Steel Beneath

Photo 5 Steel Without organic layer and not scraped clean; Can 350

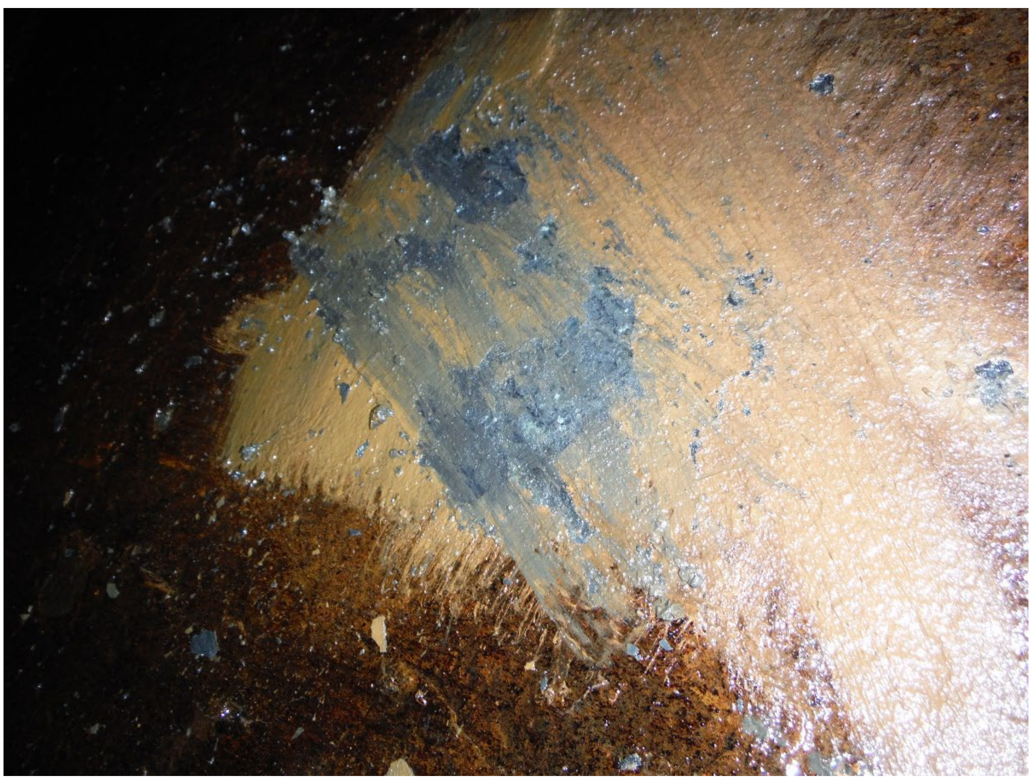


Photo 6 Plating lightly scraped; Shallow pitting and some section loss

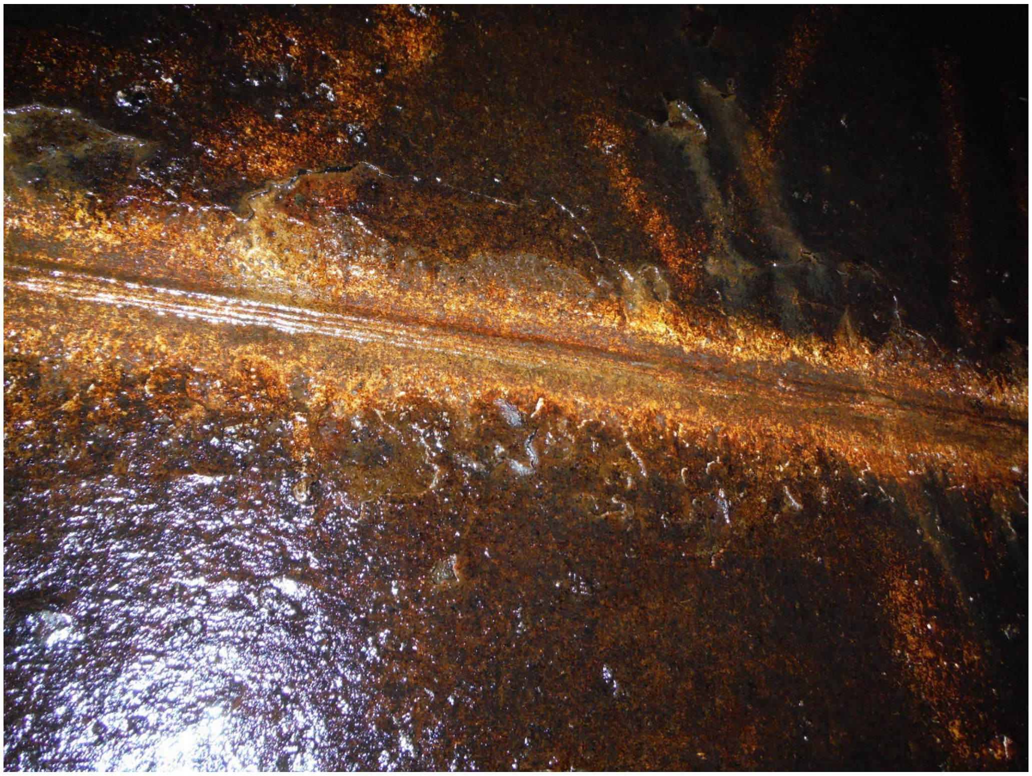


Photo 7 Previously repaired weld not tested this year

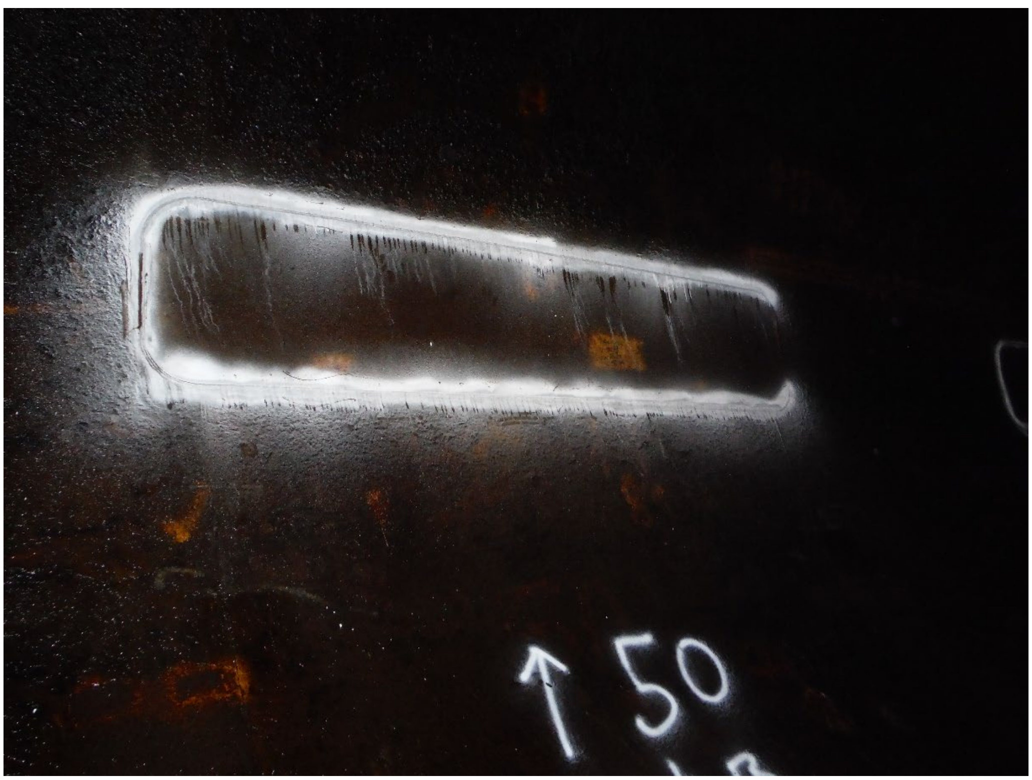


Photo 8 Plate repair welds tested. Can 50

Photo 9 Previously repaired weld retested; Typical Condition

Photo 10 Original weld not tested previously; Can 268; Typical Condition

Photo 11 Original weld not tested previously; Can 188; Typical Condition

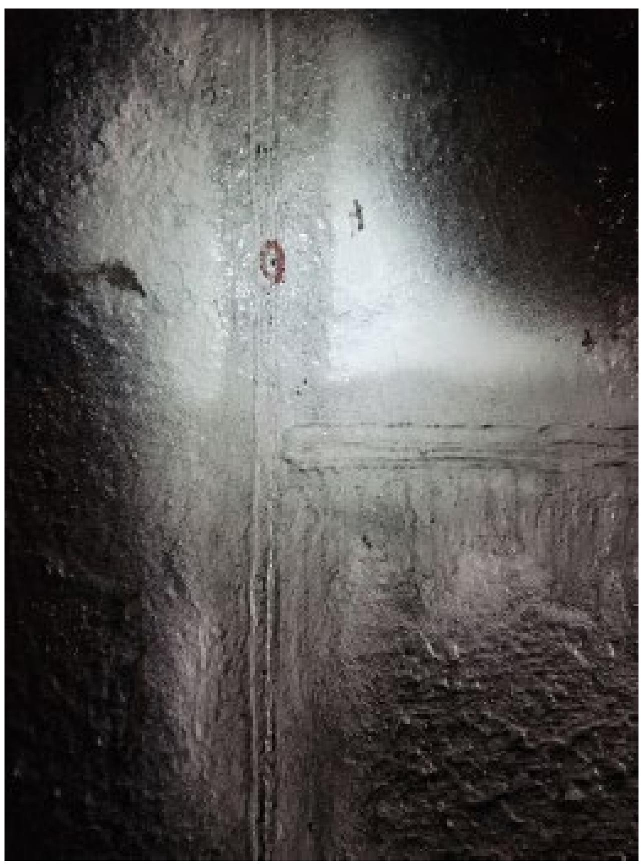


Photo 12 Indication in Circumferential Weld,;Can 98

Photo 13 Longitudinal Weld Crack Can 145 North Side

Photo 14 Weld repaired and marked Can 145

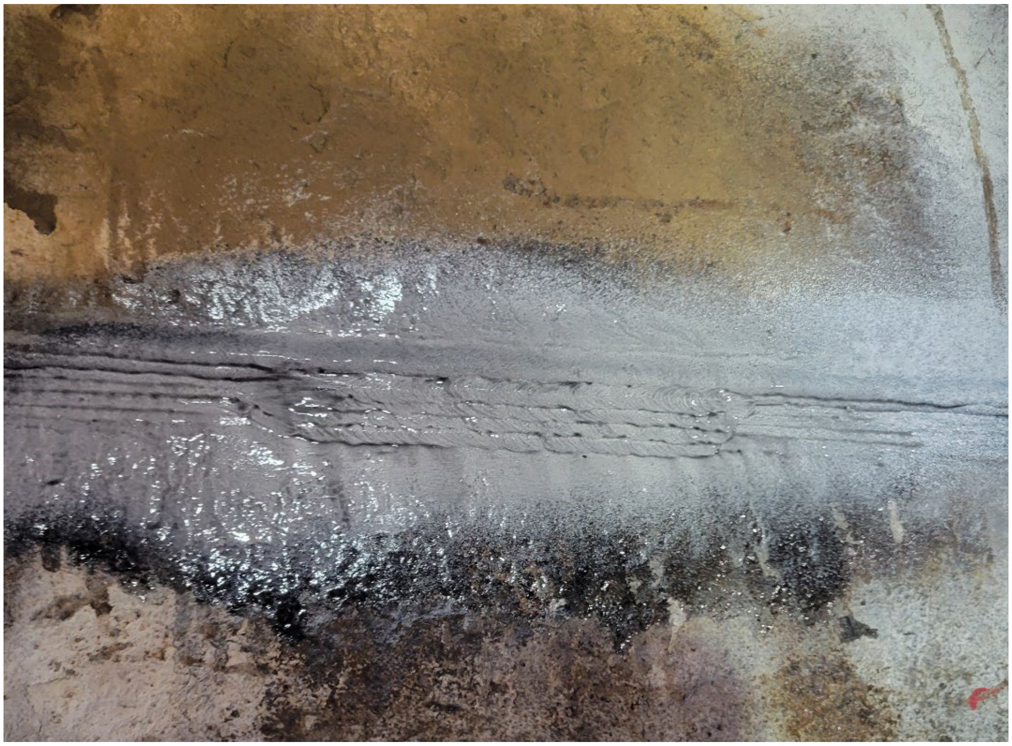


Photo 15 Weld repaired; Can 145

Photo 16 Looking Upstream along exterior of Penstock, Upstream of Surge Tank

Photo 17 Flow Pipe, FP 3

Photo 18 Alder bushes on top of P1 and P2 at Station 100

Photo 19 Previously repaired area; Rip-rap in good shape

Photo 16 Looking Upstream from just downstream of surge tanks

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	22-304	Copy:	
Date:	April 27, 2022	Date Received:	April 24, 2022
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, SNT TC-1A: UT, ET, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I
Attn:	Colin LeGrow		
P.O. No.	2022-0146-1		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1		
Testing Required:	Magnetic Particle Inspection	Signed:	Conor Murphy NDT Inspector

Remarks

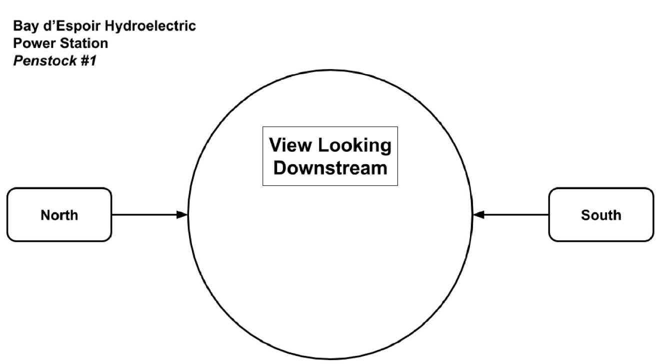
As directed, our technician performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

Defects noted in below table are detailed in reports No. ETS 22-318 and were repaired. All other welds were crack free at the time of inspection.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d’Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
3	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
8	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
14	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
19	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
24	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
27	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
32	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
42 Doubler Plate	Doubler Plate Fillet Weld - Longitudinal left (north) weld. - Top of doubler - Bottom of doubler	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
45 Doubler Plate	Doubler Plate Fillet Weld - Longitudinal left (north) weld. - Bottom of doubler	MT Acceptable	**N/A**
50 Doubler Plate	Doubler Plate Fillet Weld - Longitudinal left (north) weld. - Top of doubler - Bottom of doubler	MT Acceptable	**N/A**
56 Doubler Plate	Doubler Plate Fillet Weld - Longitudinal left (north) weld. - Top of doubler - Bottom of doubler	MT Acceptable	**N/A**
64 Doubler Plate	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - Top of doubler - Bottom of doubler	MT Acceptable	**N/A**
67	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
71	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
76	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
81	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
87	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
93	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
98	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. 1 Indication Noted North Side - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Indication Noted	**Figure 1**
103	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. 1 Indication Noted North Side - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Indication Noted	**Figure 2**
107	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
112	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
118	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
119	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
123	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
127	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
132	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
133	- Longitudinal right (south) weld. Ok - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
137	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
138	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
139	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
140	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
145	- Longitudinal right (south) weld. 1 Crack noted. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Crack Noted Refer to report 22-318 for details	**Figure 3**
146 Doubler Plate	- Longitudinal left (north) doubler- 1 indication noted. - Top of doubler - Bottom of doubler	Indication Noted Refer to report 22-318 for details	**Figure 4**
149	- Longitudinal left (north) - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
150 Doubler Plate	- Longitudinal left (north) weld - Top of doubler - Bottom of doubler	MT Acceptable	**N/A**
151	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
160 Doubler Plate North Only	- Longitudinal left (north) doubler - bottom only - bottom only	MT Acceptable	**N/A**
164	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
169	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
172	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
177	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
178	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
188	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
198	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
208	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

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ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
218	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
229	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
237	- Longitudinal right (south) weld. - Longitudinal left (north) weld not accessible - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
248	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
249	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
258	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
268	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
278	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
287	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
298	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
308	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
318	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
328	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
338	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
348	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
360	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Image #
367	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
377	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
387	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
397	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
407	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
417	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
425	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
432	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
434	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 22-304 Date: 27 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Figure 1. Can 98 North

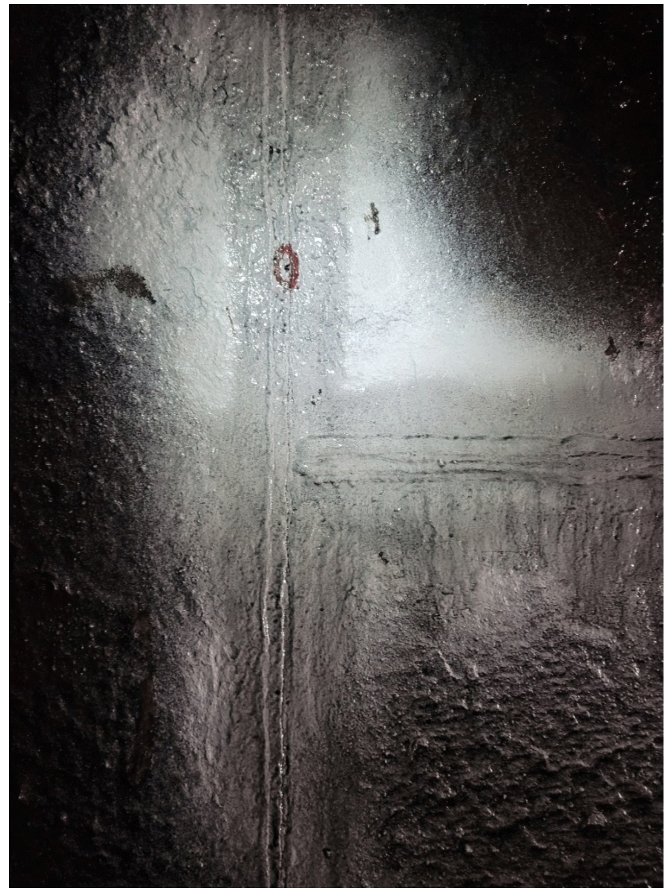


Figure 2. Can 98 North - Indication Noted

ETS No.: 22-304 Date: 28 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

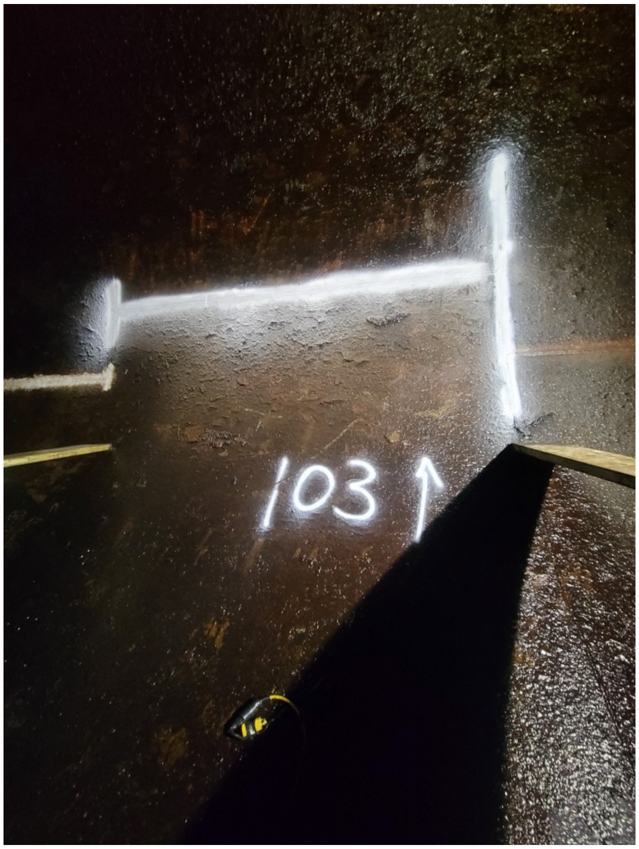


Figure 3. Can 103 North

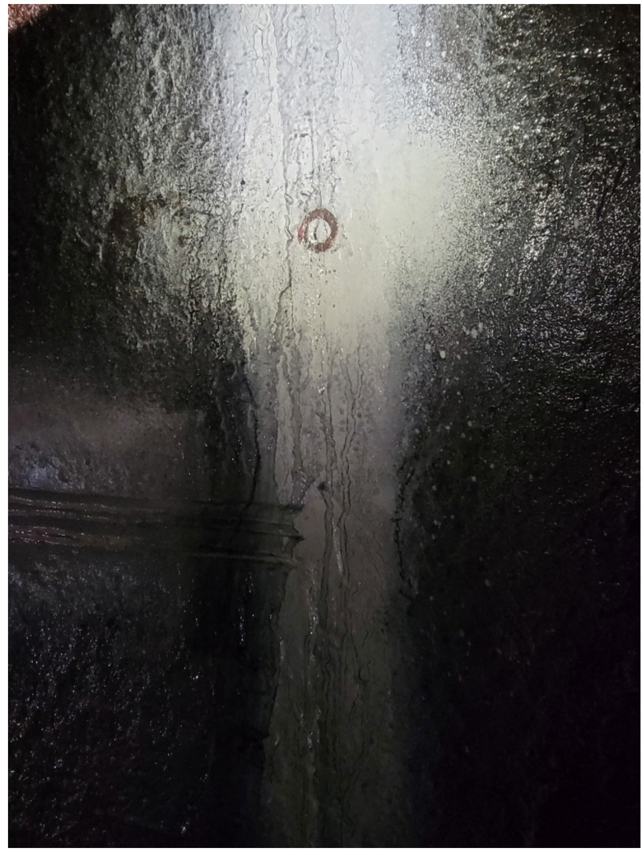


Figure 4. Can 103 North - Indication Noted

ETS No.: 22-304 Date: 28 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

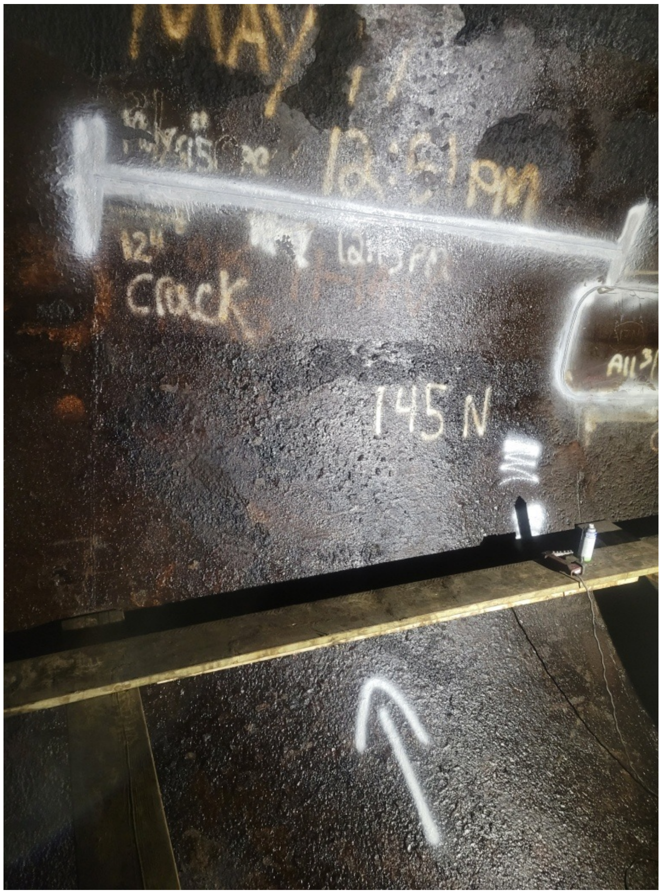


Figure 5. Can 145N

Figure 6. Can 145N - 3" Crack Indication Noted
*Refer To Report 22-318 For Repair

Figure 7. Can 146N

Figure 8. Can 145N - Indication Noted
*Refer To Report 22-318 For Repair

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

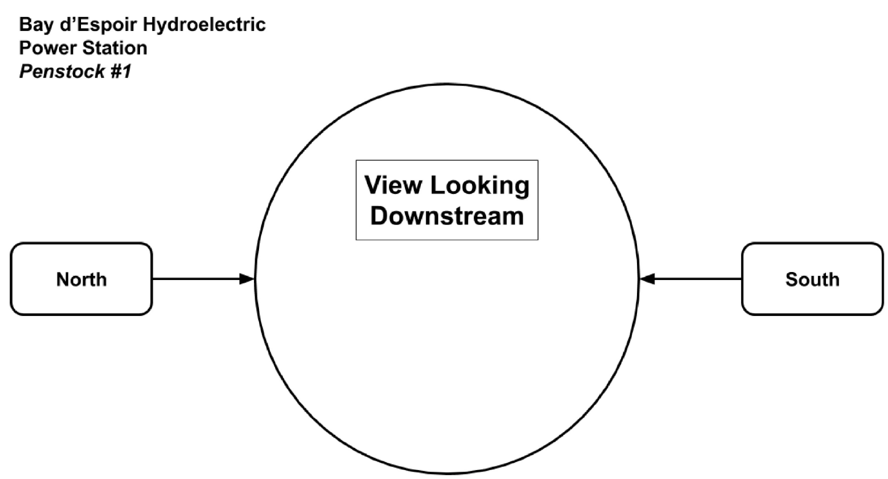
Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	21-318	Copy:	
Date:	30 April, 2022	Date Received:	28 April, 2022
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, ASNT TC-1A RT, UT, ET, MT, PT level II. CAN/CGSB 48.9712 MT & PT level II, UT level I
Attn:	Colin LeGrow		
P.O. No.	2022-0146-2		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1 Scope 2. Weld Repairs.		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

As directed, our technicians performed magnetic particle inspection on the below listed weld repairs. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). The inspected cans are listed on page 2 of 2



Results

MPI carried out on all ground areas to ensure defects were removed. All MPI inspections were carried out after 48 hr hold time and found acceptable. Nil cracks.

ETS No.: 21-318 Date: 30 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Can Number	Details	Result	Figure #
98 North	Weld erosion noted - in the 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. No repairs required	MT Acceptable	N/A
103 North	Weld erosion noted - in the 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. No repairs required	MT Acceptable	N/A
145 North	One crack. 3" long, 1/8" deep. Toe of weld.	MT Acceptable	1,2,3,4
146 North	One Indication - Toe of weld. - Removed With Grinding No Welding Needed	MT Acceptable	5,6,7

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.

Figure 1. 145N 3" crack noted

Figure 2. 145N Crack Removed With Girding.

ETS No.: 21-318 Date: 30 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Figure 3. 145N Weld Repaired - Checked at 11:15 AM April 28th 2022 (Post Welding)

Figure 4. 145N Weld Repairs - Post 48 Hour Hold - Checked at 11:15 AM April 30th 2022

ETS No.: 21-318 Date: 30 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Figure 5. Can 146N - Indication Location

Figure 6. Can 146N - Indication Noted

ETS No.: 21-318 Date: 30 April 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #1
Magnetic Particle Inspection

Figure 7. Can 146N - Indication Removed With Grinding - No Welding Needed

APPENDIX D

THICKNESS MEASUREMENTS DATA

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	22-304-2	Copy:	
Date:	28 April 2022	Date Received:	24 April 2022
Client:	Technical Rope & Rescue 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin Legrow		
P.O. No.	2022-0146-1		
Project:	Penstock Inspection - Penstock #1		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Conor Murphy

Remarks

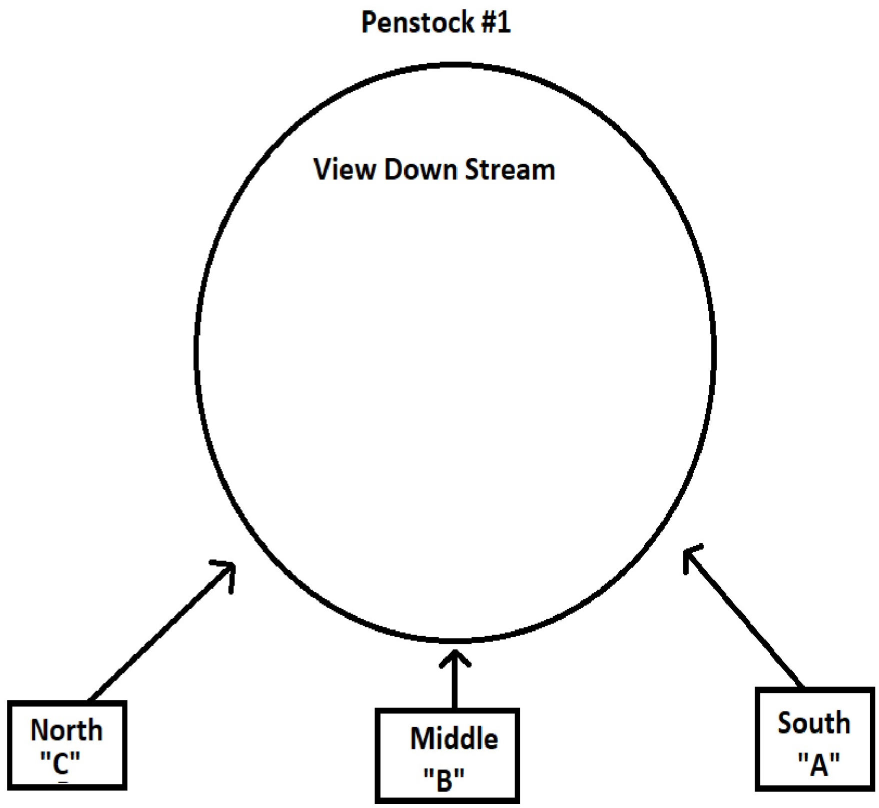
As directed, ultrasonic thickness measurements were taken on Penstock #1 in Areas as requested. 3 readings were taken at each location and averaged, readings are shown in mm’s on the attached tables.

Equipment Used

Krautkramer DMS 2 digital thickness gauge (S/N 01YL2P).
Krautkramer TC560 probe (S/N 14A01G28).
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 22-304-2 Date: 28 April 2022
Client: Technical Rope & Rescue
Location: Penstock #1
Ultrasonic Thickness Measurements

Location Of Readings Taken On Penstock #1



ETS No.: 22-304-2 Date: 28 April 2022
Client: Technical Rope & Rescue
Location: Penstock #1
Ultrasonic Thickness Measurements

Can Number	Location A	Location B	Location C
3	12.3	12.5	12.4
14	13.1	13.1	13.1
24	11.2	11.0	11.0
32	10.9	10.3	10.5
42	10.5	10.5	10.4
50	10.6	10.7	10.5
64	10.8	10.6	10.8
71	10.3	10.9	10.7
81	10.5	11.1	10.4
93	11.0	10.7	10.6
103	10.6	10.7	10.3
112	10.5	10.5	10.4
123	10.3	10.5	10.4
132	10.7	11.4	10.4
142	13.8	14.6	13.8
150	11.1	11.2	10.8
160	10.4	10.6	10.4
169	11.7	12.5	12.2
178	12.1	13.8	13.2
188	13.5	13.6	13.2
198	14.3	14.5	13.6
208	14.6	15.8	15.3
218	15.6	15.6	15.4
229	16.1	16.3	16.9
237	16.9	17.6	16.9
248	19.2	18.9	17.9
258	21.4	22.1	21.9

ETS No.: 22-304-2 Date: 28 April 2022
Client: Technical Rope & Rescue
Location: Penstock #1
Ultrasonic Thickness Measurements

Can Number	**Location A**	**Location B**	**Location C**
268	19	19.9	19.9
278	17.8	18.4	18.3
287	18.4	18.5	18.6
298	18.2	18.4	18.8
308	18.8	18.4	18.6
318	19.2	19.8	19.3
328	20.8	21.8	21.4
338	22.9	23.0	22.8
348	22.0	22.8	22.9
360	25.0	25.4	25.3
367	26.5	26.5	26.8
377	28.4	28.9	28.6
387	30.3	30.6	30.2
397	30.2	30.9	30.8
407	32.4	32.3	32.2
417	34.2	32.7	36.7
425	36.4	37.0	37.6
432	39.4	39.8	39.0

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

TABLE 1 - FULL SUPPLY LEVEL (FSL)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water= 62.4 pcf
Normal pond EL= 597 feet
Joint Efficiency= 0.7
1.0
D_1 ID= 17.00 feet
D_2 ID= 15.25 feet 4a
D_3 ID= 13.50 feet 7a + (Surge Tank)
Note: Starting point is 42ft D/S of the face of the Intake

Project No: 2670030
Date: 5/17/2022
By: NPT
Checked CMV

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (mm)	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material: Stress (psi)[1]	Base Material: Stress Ratio[2]	At Joints: Stress (psi)[3]	At Joints: Stress Ratio[4] (0.7)	At Joints: Stress Ratio[5] (1.0)	Notes
Penstock Interior																	
From Upstream End of Conduit																	
			A	12.3000	0.4843	0.5000	-3.1%				17000	4359.3	0.26	6227.5	0.37	0.26	A285 Steel (grade unknown)
3	18	8.50	B	12.5000	0.4921	0.5000	-1.6%	12.3000	0.4843	549.2402	17000						
			C	12.4000	0.4882	0.5000	-2.4%				17000						
			A	13.1000	0.5157	0.5000	3.1%				17000	4130.0	0.24	5900.0	0.35	0.24	
14	118	8.50	B	13.1000	0.5157	0.5000	3.1%	13.1000	0.5157	548.8092	17000						
			C	13.1000	0.5157	0.5000	3.1%				17000						
			A	11.2000	0.4409	0.4375	0.8%				17000	4984.6	0.29	7120.8	0.42	0.29	
24	193	8.50	B	11.0000	0.4331	0.4375	-1.0%	11.0000	0.4331	548.1614	17000						
			C	11.0000	0.4331	0.4375	-1.0%				17000						
			A	10.9000	0.4291	0.4375	-1.9%				17000	6103.4	0.36	8719.1	0.51	0.36	
32	252	8.50	B	10.3000	0.4055	0.4375	-7.3%	10.3000	0.4055	541.0050	17000						
			C	10.5000	0.4134	0.4375	-5.5%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	7213.8	0.42	10305.5	0.61	0.42	
42	342	8.50	`	10.5000	0.4134	0.4375	-5.5%	10.4000	0.4094	530.1743	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.6000	0.4173	0.4375	-4.6%				17000	8054.1	0.47	11505.9	0.68	0.47	
50	413	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.5000	0.4134	521.6730	17000						
			C	10.5000	0.4134	0.4375	-5.5%				17000						
			A	10.8000	0.4252	0.4375	-2.8%				17000	9232.8	0.54	13189.7	0.78	0.54	
64	532	8.50	B	10.6000	0.4173	0.4375	-4.6%	10.6000	0.4173	509.8266	17000						
			C	10.8000	0.4252	0.4375	-2.8%				17000						
			A	10.3000	0.4055	0.4375	-7.3%				17000	9556.8	0.56	13652.5	0.80	0.56	
71	595	8.50	B	10.9000	0.4291	0.4375	-1.9%	10.3000	0.4055	509.3218	17000						
			C	10.7000	0.4213	0.4375	-3.7%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	9542.5	0.56	13632.1	0.80	0.56	
81	685	8.50	B	11.1000	0.4370	0.4375	-0.1%	10.4000	0.4094	508.6027	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	11.0000	0.4331	0.4375	-1.0%				17000	9731.2	0.57	13901.8	0.82	0.57	
93	791	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.6000	0.4173	505.1207	17000						
			C	10.6000	0.4173	0.4375	-4.6%				17000						
			A	10.6000	0.4173	0.4375	-4.6%				17000	10941.6	0.64	15630.8	0.92	0.64	
103	880	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.3000	0.4055	496.6168	17000						
			C	10.3000	0.4055	0.4375	-7.3%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	11668.1	0.69	16668.7	0.98	0.69	
112	961	8.50	B	10.5000	0.4134	0.4375	-5.5%	10.4000	0.4094	488.9119	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.3000	0.4055	0.4375	-7.3%				17000	12802.7	0.75	18289.5	1.08	0.75	
123	1060	8.50	B	10.5000	0.4134	0.4375	-5.5%	10.3000	0.4055	479.5424	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.7000	0.4213	0.4375	-3.7%				24000	13495.9	0.56	19279.8	0.80	0.56	CSA G40.8 Grade B Steel
132	1139	8.50	B	11.4000	0.4488	0.4375	2.6%	10.4000	0.4094	471.9802	24000						
			C	10.4000	0.4094	0.4375	-6.4%				24000						
			A	13.8000	0.5433	0.4375	24.2%				24000	10832.3	0.45	15474.7	0.64	0.45	
142	1217	8.50	B	14.6000	0.5748	0.4375	31.4%	13.8000	0.5433	463.8494	24000						
			C	13.8000	0.5433	0.4375	24.2%				24000						
			A	11.1000	0.4370	0.4375	-0.1%				24000	13693.7	0.57	19562.4	0.82	0.57	15.25' I.D. Penstock
150	1272	7.63	B	11.2000	0.4409	0.4375	0.8%	10.8000	0.4252	450.1521	24000						
			C	10.8000	0.4252	0.4375	-2.8%				24000						
			A	10.4000	0.4094	0.4375	-6.4%				24000	16354.7	0.68	23363.9	0.97	0.68	
160	1361	7.63	B	10.6000	0.4173	0.4375	-4.6%	10.4000	0.4094	428.1119	24000						
			C	10.4000	0.4094	0.4375	-6.4%				24000						
			A	11.7000	0.4606	0.5000	-7.9%				24000	16299.6	0.68	23285.2	0.97	0.68	
169	1443	7.63	B	12.5000	0.4921	0.5000	-1.6%	11.7000	0.4606	407.6406	24000						
			C	12.2000	0.4803	0.5000	-3.9%				24000						
			A	12.1000	0.4764	0.5625	-15.3%				24000	17477.1	0.73	24967.3	1.04	0.73	
178	1526	7.63	B	13.8000	0.5433	0.5625	-3.4%	12.1000	0.4764	387.0200	24000						
			C	13.2000	0.5197	0.5625	-7.6%				24000						
			A	13.5000	0.5315	0.5625	-5.5%				24000	17128.9	0.71	24469.9	1.02	0.71	
188	1603	7.63	B	13.6000	0.5354	0.5625	-4.8%	13.2000	0.5197	372.4943	24000						
			C	13.2000	0.5197	0.5625	-7.6%				24000						
			A	14.3000	0.5630	0.5625	0.1%				24000	17191.1	0.72	24558.7	1.02	0.72	
198	1693	7.63	B	14.5000	0.5709	0.5625	1.5%	13.6000	0.5354	364.8516	24000						
			C	13.6000	0.5354	0.5625	-4.8%				24000						
			A	14.6000	0.5748	0.6250	-8.0%				24000	16546.2	0.69	23637.4	0.98	0.69	
208	1783	7.63	B	15.8000	0.6220	0.6250	-0.5%	14.6000	0.5748	357.1312	24000						
			C	15.3000	0.6024	0.6250	-3.6%				24000						
			A	15.6000	0.6142	0.6250	-1.7%				24000	16194.9	0.67	23135.5	0.96	0.67	
218	1874	7.63	B	15.6000	0.6142	0.6250	-1.7%	15.4000	0.6063	349.3596	24000						
			C	15.4000	0.6063	0.6250	-3.0%				24000						
			A	16.1000	0.6339	0.6250	1.4%				24000	16190.6	0.67	23129.5	0.96	0.67	
229	1964	7.63	B	16.3000	0.6417	0.6250	2.7%	16.1000	0.6339	338.1711	24000						
			C	16.9000	0.6654	0.6250	6.5%				24000						
			A	16.9000	0.6654	0.6875	-3.2%				24000	16197.4	0.67	23139.1	0.96	0.67	
237	2038	7.63	B	17.6000	0.6929	0.6875	0.8%	16.9000	0.6654	325.1972	24000						
			C	16.9000	0.6654	0.6875	-3.2%				24000						
			A	19.2000	0.7559	0.7500	0.8%				24000	16259.2	0.68	23227.4	0.97	0.68	
248	2136	7.63	B	18.9000	0.7441	0.7500	-0.8%	17.9000	0.7047	308.0155	24000						
			C	17.9000	0.7047	0.7500	-6.0%				24000						
			A	21.4000	0.8425	0.7500	12.3%				24000	14350.8	0.60	20501.1	0.85	0.60	
258	2227	7.63	B	22.1000	0.8701	0.7500	16.0%	21.4000	0.8425	292.0610	24000						
			C	21.9000	0.8622	0.7500	15.0%				24000						
			A	19.0000	0.7480	0.7500	-0.3%				24000	16840.8	0.70	24058.2	1.00	0.70	
268	2300	7.63	B	19.9000	0.7835	0.7500	4.5%	19.0000	0.7480	279.2845	24000						
			C	19.9000	0.7835	0.7500	4.5%				24000						
			A	17.8000	0.7008	0.8125	-13.7%				24000	18870.8	0.79	26958.4	1.12	0.79	
278	2390	7.63	B	18.4000	0.7244	0.8125	-10.8%	17.8000	0.7008	263.4703	24000						
			C	18.3000	0.7205	0.8125	-11.3%				24000						
			A	18.4000	0.7244	0.8125	-10.8%				24000	19031.8	0.79	27188.3	1.13	0.79	
287	2471	7.63	B	18.5000	0.7283	0.8125	-10.4%	18.4000	0.7244	249.2866	24000						
			C	18.6000	0.7323	0.8125	-9.9%				24000						
			A	18.2000	0.7165	0.8750	-18.1%				24000	20211.1	0.84	28873.0	1.20	0.84	
298	2571	7.63	B	18.4000	0.7244	0.8750	-17.2%	18.2000	0.7165	231.7543	24000						
			C	18.8000	0.7402	0.8750	-15.4%				24000						

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (mm)	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints			Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4] (0.7)	Stress Ratio[5] (1.0)	
			A	18.8000	0.7402	0.9375	-21.0%				24000	20674.4	0.86	29534.9	1.23	0.86	
308	2659	7.63	B	18.4000	0.7244	0.9375	-22.7%	18.4000	0.7244	219.2761	24000						
			C	18.6000	0.7323	0.9375	-21.9%				24000						
			A	19.2000	0.7559	0.9375	-19.4%				24000	20369.5	0.85	29099.3	1.21	0.85	
318	2751	7.63	B	19.8000	0.7795	0.9375	-16.9%	19.2000	0.7559	208.6665	24000						
			C	19.3000	0.7598	0.9375	-19.0%				24000						
			A	20.8000	0.8189	1.0000	-18.1%				24000	17087.3	0.71	24410.5	1.02	0.71	13.5' I.D. Penstock
328	2840	6.75	B	21.8000	0.8583	1.0000	-14.2%	20.8000	0.8189	198.3455	24000						
			C	21.4000	0.8425	1.0000	-15.7%				24000						
			A	22.9000	0.9016	1.0625	-15.1%				24000	15985.2	0.67	22836.1	0.95	0.67	
338	2928	6.75	B	23.0000	0.9055	1.0625	-14.8%	22.8000	0.8976	188.1976	24000						
			C	22.8000	0.8976	1.0625	-15.5%				24000						
			A	22.0000	0.8661	1.1250	-23.0%				24000	16972.2	0.71	24245.9	1.01	0.71	
348	3015	6.75	B	22.8000	0.8976	1.1250	-20.2%	22.0000	0.8661	178.1883	24000						
			C	22.9000	0.9016	1.1250	-19.9%				24000						
			A	25.0000	0.9843	1.1875	-17.1%				24000	15362.6	0.64	21946.6	0.91	0.64	
360	3105	6.75	B	25.4000	1.0000	1.1875	-15.8%	25.0000	0.9843	166.2116	24000						
			C	25.3000	0.9961	1.1875	-16.1%				24000						
			A	26.5000	1.0433	1.1875	-12.1%				24000	14919.4	0.62	21313.5	0.89	0.62	
367	3169	6.75	B	26.5000	1.0433	1.1875	-12.1%	26.5000	1.0433	153.5374	24000						
			C	26.8000	1.0551	1.1875	-11.1%				24000						
			A	28.4000	1.1181	1.2500	-10.6%				24000	14483.8	0.60	20691.1	0.86	0.60	
377	3259	6.75	B	28.9000	1.1378	1.2500	-9.0%	28.4000	1.1181	135.6187	24000						
			C	28.6000	1.1260	1.2500	-9.9%				24000						
			A	30.3000	1.1929	1.3125	-9.1%				24000	14154.2	0.59	20220.3	0.84	0.59	
387	3350	6.75	B	30.6000	1.2047	1.3125	-8.2%	30.2000	1.1890	117.5411	24000						
			C	30.2000	1.1890	1.3125	-9.4%				24000						
			A	30.2000	1.1890	1.3750	-13.5%				24000	14687.9	0.61	20982.7	0.87	0.61	
397	3441	6.75	B	30.9000	1.2165	1.3750	-11.5%	30.2000	1.1890	99.4635	24000						
			C	30.8000	1.2126	1.3750	-11.8%				24000						
			A	32.4000	1.2756	1.4375	-11.3%				24000	14276.1	0.59	20394.4	0.85	0.59	
407	3532	6.75	B	32.3000	1.2717	1.4375	-11.5%	32.2000	1.2677	81.3859	24000						
			C	32.2000	1.2677	1.4375	-11.8%				24000						
			A	34.2000	1.3465	1.5000	-10.2%				24000	14574.4	0.61	20820.6	0.87	0.61	
417	3620	6.75	B	32.7000	1.2874	1.5000	-14.2%	32.7000	1.2874	62.4374	24000						
			C	36.7000	1.4449	1.5000	-3.7%				24000						
			A	36.4000	1.4331	1.5250	-6.0%				24000	13638.3	0.57	19483.3	0.81	0.57	
425	3686	6.75	B	37.0000	1.4567	1.5625	-6.8%	36.4000	1.4331	40.1710	24000						
			C	37.6000	1.4803	1.5625	-5.3%				24000						
			A	39.4000	1.5512	1.6250	-4.5%				24000	13207.3	0.55	18867.5	0.79	0.55	13.5ft I.D. Penstock
432	3748	6.75	B	39.8000	1.5669	1.6250	-3.6%	39.0000	1.5354	19.2541	24000						
			C	39.0000	1.5354	1.6250	-5.5%				24000						
											MAX	20674.4	0.86	29534.9	1.23	0.86	

Notes:

[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / $0.7_{joint\ efficiency}$
[4] Joint stress / S_A
[5] Hoop stress / $1.0_{joint\ efficiency}$

TABLE 2 - TRANSIENT (30% Surge)
PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4 pcf	Project No:	2670030
Normal pond EL=	597 feet	Date:	5/17/2022
Joint Efficiency=	0.7	By:	NPT
	1.0	Checked	CMV
D_1 ID=	17.00 feet		
D_2 ID=	15.25 feet		
D_3 ID=	13.50 feet 9a +		

Note: Starting point is 42ft D/S of the face of the Intake

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (mm)	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints			Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4] (0.7)	Stress Ratio[5] (1.0)	
Penstock Interior From Upstream End of Conduit																	
			A	12.3000	0.4843	0.5000	-3.1%				17000	5667.0	0.33	8095.8	0.48	0.33	A285 Steel (grade unknown)
3	18	8.50	B	12.5000	0.4921	0.5000	-1.6%	12.3000	0.4843	549.2402	17000						
			C	12.4000	0.4882	0.5000	-2.4%				17000						
			A	13.1000	0.5157	0.5000	3.1%				17000	5369.0	0.32	7670.0	0.45	0.32	
14	118	8.50	B	13.1000	0.5157	0.5000	3.1%	13.1000	0.5157	548.8092	17000						
			C	13.1000	0.5157	0.5000	3.1%				17000						
			A	11.2000	0.4409	0.4375	0.8%				17000	6479.9	0.38	9257.0	0.54	0.38	
24	193	8.50	B	11.0000	0.4331	0.4375	-1.0%	11.0000	0.4331	548.1614	17000						
			C	11.0000	0.4331	0.4375	-1.0%				17000						
			A	10.9000	0.4291	0.4375	-1.9%				17000	7934.4	0.47	11334.8	0.67	0.47	
32	252	8.50	B	10.3000	0.4055	0.4375	-7.3%	10.3000	0.4055	541.0050	17000						
			C	10.5000	0.4134	0.4375	-5.5%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	9378.0	0.55	13397.1	0.79	0.55	
42	342	8.50	B	10.5000	0.4134	0.4375	-5.5%	10.4000	0.4094	530.1743	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.6000	0.4173	0.4375	-4.6%				17000	10470.3	0.62	14957.6	0.88	0.62	
50	413	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.5000	0.4134	521.6730	17000						
			C	10.5000	0.4134	0.4375	-5.5%				17000						
			A	10.8000	0.4252	0.4375	-2.8%				17000	12002.7	0.71	17146.7	1.01	0.71	
64	532	8.50	B	10.6000	0.4173	0.4375	-4.6%	10.6000	0.4173	509.8266	17000						
			C	10.8000	0.4252	0.4375	-2.8%				17000						
			A	10.3000	0.4055	0.4375	-7.3%				17000	12423.8	0.73	17748.3	1.04	0.73	
71	595	8.50	B	10.9000	0.4291	0.4375	-1.9%	10.3000	0.4055	509.3218	17000						
			C	10.7000	0.4213	0.4375	-3.7%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	12405.2	0.73	17721.8	1.04	0.73	
81	685	8.50	B	11.1000	0.4370	0.4375	-0.1%	10.4000	0.4094	508.6027	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	11.0000	0.4331	0.4375	-1.0%				17000	12650.6	0.74	18072.3	1.06	0.74	
93	791	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.6000	0.4173	505.1207	17000						
			C	10.6000	0.4173	0.4375	-4.6%				17000						
			A	10.6000	0.4173	0.4375	-4.6%				17000	14224.1	0.84	20320.1	1.20	0.84	
103	880	8.50	B	10.7000	0.4213	0.4375	-3.7%	10.3000	0.4055	496.6168	17000						
			C	10.3000	0.4055	0.4375	-7.3%				17000						
			A	10.5000	0.4134	0.4375	-5.5%				17000	15168.5	0.89	21669.3	1.27	0.89	
112	961	8.50	B	10.5000	0.4134	0.4375	-5.5%	10.4000	0.4094	488.9119	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.3000	0.4055	0.4375	-7.3%				17000	16643.4	0.98	23776.4	1.40	0.98	
123	1060	8.50	B	10.5000	0.4134	0.4375	-5.5%	10.3000	0.4055	479.5424	17000						
			C	10.4000	0.4094	0.4375	-6.4%				17000						
			A	10.7000	0.4213	0.4375	-3.7%				24000	17544.7	0.73	25063.8	1.04	0.73	CSA G40.8 Grade B Steel
132	1139	8.50	B	11.4000	0.4488	0.4375	2.6%	10.4000	0.4094	471.9802	24000						
			C	10.4000	0.4094	0.4375	-6.4%				24000						
			A	13.8000	0.5433	0.4375	24.2%				24000	14082.0	0.59	20117.1	0.84	0.59	
142	1217	8.50	B	14.6000	0.5748	0.4375	31.4%	13.8000	0.5433	463.8494	24000						
			C	13.8000	0.5433	0.4375	24.2%				24000						
			A	11.1000	0.4370	0.4375	-0.1%				24000	17801.8	0.74	25431.2	1.06	0.74	15.25' I.D. Penstock
150	1272	7.63	B	11.2000	0.4409	0.4375	0.8%	10.8000	0.4252	450.1521	24000						
			C	10.8000	0.4252	0.4375	-2.8%				24000						
			A	10.4000	0.4094	0.4375	-6.4%				24000	21261.1	0.89	30373.0	1.27	0.89	
160	1361	7.63	B	10.6000	0.4173	0.4375	-4.6%	10.4000	0.4094	428.1119	24000						
			C	10.4000	0.4094	0.4375	-6.4%				24000						
			A	11.7000	0.4606	0.5000	-7.9%				24000	21189.5	0.88	30270.7	1.26	0.88	
169	1443	7.63	B	12.5000	0.4921	0.5000	-1.6%	11.7000	0.4606	407.6406	24000						
			C	12.2000	0.4803	0.5000	-3.9%				24000						
			A	12.1000	0.4764	0.5625	-15.3%				24000	22720.2	0.95	32457.5	1.35	0.95	
178	1526	7.63	B	13.8000	0.5433	0.5625	-3.4%	12.1000	0.4764	387.0200	24000						
			C	13.2000	0.5197	0.5625	-7.6%				24000						
			A	13.5000	0.5315	0.5625	-5.5%				24000	22267.6	0.93	31810.9	1.33	0.93	
188	1603	7.63	B	13.6000	0.5354	0.5625	-4.8%	13.2000	0.5197	372.4943	24000						
			C	13.2000	0.5197	0.5625	-7.6%				24000						
			A	14.3000	0.5630	0.5625	0.1%				24000	22348.4	0.93	31926.3	1.33	0.93	
198	1693	7.63	B	14.5000	0.5709	0.5625	1.5%	13.6000	0.5354	364.8516	24000						
			C	13.6000	0.5354	0.5625	-4.8%				24000						
			A	14.6000	0.5748	0.6250	-8.0%				24000	21510.0	0.90	30728.6	1.28	0.90	
208	1783	7.63	B	15.8000	0.6220	0.6250	-0.5%	14.6000	0.5748	357.1312	24000						
			C	15.3000	0.6024	0.6250	-3.6%				24000						
			A	15.6000	0.6142	0.6250	-1.7%				24000	21053.3	0.88	30076.2	1.25	0.88	
218	1874	7.63	B	15.6000	0.6142	0.6250	-1.7%	15.4000	0.6063	349.3596	24000						
			C	15.4000	0.6063	0.6250	-3.0%				24000						
			A	16.1000	0.6339	0.6250	1.4%				24000	21047.8	0.88	30068.3	1.25	0.88	
229	1964	7.63	B	16.3000	0.6417	0.6250	2.7%	16.1000	0.6339	338.1711	24000						
			C	16.9000	0.6654	0.6250	6.5%				24000						
			A	16.9000	0.6654	0.6875	-3.2%				24000	21056.6	0.88	30080.8	1.25	0.88	
237	2038	7.63	B	17.6000	0.6929	0.6875	0.8%	16.9000	0.6654	325.1972	24000						
			C	16.9000	0.6654	0.6875	-3.2%				24000						
			A	19.2000	0.7559	0.7500	0.8%				24000	21136.9	0.88	30195.6	1.26	0.88	
248	2136	7.63	B	18.9000	0.7441	0.7500	-0.8%	17.9000	0.7047	308.0155	24000						
			C	17.9000	0.7047	0.7500	-6.0%				24000						
			A	21.4000	0.8425	0.7500	12.3%				24000	18656.0	0.78	26651.5	1.11	0.78	
258	2227	7.63	B	22.1000	0.8701	0.7500	16.0%	21.4000	0.8425	292.0610	24000						
			C	21.9000	0.8622	0.7500	15.0%				24000						
			A	19.0000	0.7480	0.7500	-0.3%				24000	21893.0	0.91	31275.7	1.30	0.91	
268	2300	7.63	B	19.9000	0.7835	0.7500	4.5%	19.0000	0.7480	279.2845	24000						
			C	19.9000	0.7835	0.7500	4.5%				24000						
			A	17.8000	0.7008	0.8125	-13.7%				24000	24532.1	1.02	35045.9	1.46	1.02	
278	2390	7.63	B	18.4000	0.7244	0.8125	-10.8%	17.8000	0.7008	263.4703	24000						
			C	18.3000	0.7205	0.8125	-11.3%				24000						
			A	18.4000	0.7244	0.8125	-10.8%				24000	24741.4	1.03	35344.8	1.47	1.03	
287	2471	7.63	B	18.5000	0.7283	0.8125	-10.4%	18.4000	0.7244	249.2866	24000						
			C	18.6000	0.7323	0.8125	-9.9%				24000						
			A	18.2000	0.7165	0.8750	-18.1%				24000	26274.5	1.09	37535.0	1.56	1.09	
298	2571	7.63	B	18.4000	0.7244	0.8750	-17.2%	18.2000	0.7165	231.7543	24000						
			C	18.8000	0.7402	0.8750	-15.4%				24000						
			A	18.8000	0.7402	0.9375	-21.0%				24000	26876.8	1.12	38395.4	1.60	1.12	
308	2659	7.63	B	18.4000	0.7244	0.9375	-22.7%	18.4000	0.7244	219.2761	24000						
			C	18.6000	0.7323	0.9375	-21.9%				24000						

			A	19.2000	0.7559	0.9375	-19.4%				24000	26480.4	1.10	37829.1	1.58	1.10	
318	2751	7.63	B	19.8000	0.7795	0.9375	-16.9%	19.2000	0.7559	208.6665	24000						
			C	19.3000	0.7598	0.9375	-19.0%				24000						
			A	20.8000	0.8189	1.0000	-18.1%				24000	22213.5	0.93	31733.6	1.32	0.93	13.5' I.D. Penstock
328	2840	6.75	B	21.8000	0.8583	1.0000	-14.2%	20.8000	0.8189	198.3455	24000						
			C	21.4000	0.8425	1.0000	-15.7%				24000						
			A	22.9000	0.9016	1.0625	-15.1%				24000	20780.8	0.87	29686.9	1.24	0.87	
338	2928	6.75	B	23.0000	0.9055	1.0625	-14.8%	22.8000	0.8976	188.1976	24000						
			C	22.8000	0.8976	1.0625	-15.5%				24000						
			A	22.0000	0.8661	1.1250	-23.0%				24000	22063.8	0.92	31519.7	1.31	0.92	
348	3015	6.75	B	22.8000	0.8976	1.1250	-20.2%	22.0000	0.8661	178.1883	24000						
			C	22.9000	0.9016	1.1250	-19.9%				24000						
			A	25.0000	0.9843	1.1875	-17.1%				24000	19971.4	0.83	28530.5	1.19	0.83	
360	3105	6.75	B	25.4000	1.0000	1.1875	-15.8%	25.0000	0.9843	166.2116	24000						
			C	25.3000	0.9961	1.1875	-16.1%				24000						
			A	26.5000	1.0433	1.1875	-12.1%				24000	19395.2	0.81	27707.5	1.15	0.81	
367	3169	6.75	B	26.5000	1.0433	1.1875	-12.1%	26.5000	1.0433	153.5374	24000						
			C	26.8000	1.0551	1.1875	-11.1%				24000						
			A	28.4000	1.1181	1.2500	-10.6%				24000	18828.9	0.78	26898.5	1.12	0.78	
377	3259	6.75	B	28.9000	1.1378	1.2500	-9.0%	28.4000	1.1181	135.6187	24000						
			C	28.6000	1.1260	1.2500	-9.9%				24000						
			A	30.3000	1.1929	1.3125	-9.1%				24000	18400.5	0.77	26286.4	1.10	0.77	
387	3350	6.75	B	30.6000	1.2047	1.3125	-8.2%	30.2000	1.1890	117.5411	24000						
			C	30.2000	1.1890	1.3125	-9.4%				24000						
			A	30.2000	1.1890	1.3750	-13.5%				24000	19094.2	0.80	27277.5	1.14	0.80	
397	3441	6.75	B	30.9000	1.2165	1.3750	-11.5%	30.2000	1.1890	99.4635	24000						
			C	30.8000	1.2126	1.3750	-11.8%				24000						
			A	32.4000	1.2756	1.4375	-11.3%				24000	18558.9	0.77	26512.8	1.10	0.77	
407	3532	6.75	B	32.3000	1.2717	1.4375	-11.5%	32.2000	1.2677	81.3859	24000						
			C	32.2000	1.2677	1.4375	-11.8%				24000						
			A	34.2000	1.3465	1.5000	-10.2%				24000	18946.8	0.79	27066.8	1.13	0.79	
417	3620	6.75	B	32.7000	1.2874	1.5000	-14.2%	32.7000	1.2874	62.4374	24000						
			C	36.7000	1.4449	1.5000	-3.7%				24000						
			A	36.4000	1.4331	1.5250	-6.0%				24000	17729.8	0.74	25328.3	1.06	0.74	
425	3686	6.75	B	37.0000	1.4567	1.5625	-6.8%	36.4000	1.4331	40.1710	24000						
			C	37.6000	1.4803	1.5625	-5.3%				24000						
			A	39.4000	1.5512	1.6250	-4.5%				24000	17169.5	0.72	24527.8	1.02	0.72	13.5ft I.D. Penstock
432	3748	6.75	B	39.8000	1.5669	1.6250	-3.6%	39.0000	1.5354	19.2541	24000						
			C	39.0000	1.5354	1.6250	-5.5%				24000						
															1.60		

Notes:
[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / $0.7_{\text{joint efficiency}}$
[4] Joint stress / S_A

SLOPE SUMMARY									
Section	Degrees, Minutes, Seconds	θ	Distance (ft)			Elvation (ft)			Slope
			From (ft)	To (ft)	Delta (ft)	Elevation (Start)	Elevation (End)	Delta (ft)	
1A	0,14,50	0.2472	0	231.68	231.68	549.5	548.5	1.00	0.0043
2A	6,53,47	6.8964	231.68	552.32	320.64	548.5	510	38.50	0.1201
3A	0,27,30	0.4583	552.32	802.33	250.01	510	508	2.00	0.0080
4A	5,27,30	5.4583	802.33	1254.38	452.05	508	465	43.00	0.0951
5A	14,25,15	14.4208	1254.38	1615.77	361.39	465	375	90.00	0.2490
6A	4,53,57	4.8992	1615.77	1967.05	351.28	375	345	30.00	0.0854
7A	10,05,51	10.0975	1967.05	2271.77	304.72	345	291.58	53.42	0.1753
8A	10,05,51	10.0975	2271.77	2651.52	379.75	291.58	225	66.58	0.1753
9A	6,37,46	6.6294	2651.52	3127.93	476.41	225	170	55.00	0.1154
10A	11,27,30	11.4583	3127.93	3651.44	523.51	170	66	104.00	0.1987
11A	19,43,00	19.7167	3651.44	3774.27	122.83	66	24.56	41.44	0.3374

ELEVATION CALCULATIONS								
Can #	Distance (From Can #1)	Distance +42 (ft)	Slope (θ)	Distance from Slope Change (ft)	Change in Elevation (ft)	Final Elevation (ft)	Section	
-						549.50	Intake	42
3	18.17	60.17	0.25	60.17	0.26	549.24	1A	
14	118.08	160.08	0.25	160.08	0.69	548.81	1A	
24	192.42	234.42	6.90	2.74	0.33	548.17	2A	
32	252.83	294.83	6.90	63.15	7.58	540.92	2A	
42	342.25	384.25	6.90	152.57	18.32	530.18	2A	
50	413.83	455.83	6.90	224.15	26.92	521.58	2A	
64	532.00	574.00	0.46	21.68	0.17	509.83	3A	
71	595.08	637.08	0.46	84.76	0.68	509.32	3A	
81	685.00	727.00	0.46	174.68	1.40	508.60	3A	
93	790.50	832.50	5.46	30.17	2.87	505.13	4A	
103	880.00	922.00	5.46	119.67	11.38	496.62	4A	
112	961.00	1003.00	5.46	200.67	19.09	488.91	4A	
123	1059.42	1101.42	5.46	299.09	28.45	479.55	4A	
132	1139.00	1181.00	5.46	378.67	36.02	471.98	4A	
142	1217.00	1259.00	14.42	4.62	1.15	463.85	5A	
150	1272.00	1314.00	14.42	59.62	14.85	450.15	5A	
160	1360.42	1402.42	14.42	148.04	36.87	428.13	5A	
169	1442.58	1484.58	14.42	230.20	57.33	407.67	5A	
178	1525.42	1567.42	14.42	313.04	77.96	387.04	5A	
188	1603.92	1645.92	4.90	30.15	2.57	372.43	6A	
198	1692.50	1734.50	4.90	118.73	10.14	364.86	6A	
208	1783.00	1825.00	4.90	209.23	17.87	357.13	6A	
218	1874.00	1916.00	4.90	300.23	25.64	349.36	6A	
229	1964.00	2006.00	10.10	38.95	6.83	338.17	7A	
237	2038.00	2080.00	10.10	112.95	19.80	325.20	7A	
248	2136.00	2178.00	10.10	210.95	36.98	308.02	7A	
258	2227.00	2269.00	10.10	301.95	52.94	292.06	7A	
268	2299.75	2341.75	10.10	69.98	12.27	279.31	8A	
278	2390.83	2432.83	10.10	161.06	28.24	263.34	8A	
287	2471.00	2513.00	10.10	241.23	42.29	249.29	8A	
298	2571.00	2613.00	10.10	341.23	59.83	231.75	8A	
308	2659.83	2701.83	6.63	50.31	5.81	219.19	9A	
318	2751.00	2793.00	6.63	141.48	16.33	208.67	9A	
328	2840.33	2882.33	6.63	230.81	26.65	198.35	9A	
338	2928.25	2970.25	6.63	318.73	36.80	188.20	9A	
348	3015.00	3057.00	6.63	405.48	46.81	178.19	9A	
360	3105.00	3147.00	11.46	19.07	3.79	166.21	10A	
367	3168.67	3210.67	11.46	82.74	16.44	153.56	10A	
377	3259.00	3301.00	11.46	173.07	34.38	135.62	10A	
387	3350.00	3392.00	11.46	264.07	52.46	117.54	10A	
397	3441.00	3483.00	11.46	355.07	70.54	99.46	10A	
407	3532.00	3574.00	11.46	446.07	88.61	81.39	10A	
417	3620.00	3662.00	19.72	10.56	3.56	62.44	11A	
425	3686.00	3728.00	19.72	76.56	25.83	40.17	11A	
432	3748.00	3790.00	19.72	138.56	46.75	19.25	11A	

PLATE THICKNESS SUMMARY	
From - To (ft)	Thickness (in)
0 - 126	0.5000
126 - 1372	0.4375
1372 - 1499	0.5000
1499 - 1702	0.5625
1702 - 1974	0.6250
1974 - 2068	0.6875
2068 - 2214	0.7500
2214 - 2270	Surge Tank
2270 - 2378.69	0.7500
2378.69 - 2495	0.8125
2495 - 2609.52	0.8750
2609.52 - 2754	0.9375
2754 - 2896	1.0000
2896 - 2930	1.0625
2930 - 3065.02	1.1250
3065.02 - 3173	1.1875
3173 - 3277	1.2500
3277 - 3380	1.3125
3380 - 3484	1.3750
3484 - 3587.08	1.4375
3587.08 - 3668	1.5000
3668 - 3743	1.5625
3743 - Unit	1.6250

Referencing F-106-C-7 & F-106-C-9

Section	Distance(ft)	Cumulative Distance (ft)	Cumulative Distance - 42' (ft)	
Intake Face	start	0	0	
Beginning of conduit	42	42	0	
End of conduit through dam	126	168	126	
1a	63.68	231.68	189.68	
2a	320.64	552.32	510.32	
3a	250.01	802.33	760.33	
4a	452.05	1254.38	1212.38	End of 17' I.D./ Start of 15.25' I.D.
5a	361.39	1615.77	1573.77	
6a	351.28	1967.05	1925.05	
7a	304.72	2271.77	2229.77	End of 15.25' I.D./ Start of 13.5' I.D.
8a	379.75	2651.52	2609.52	
9a	476.41	3127.93	3085.93	
10a	523.51	3651.44	3609.44	
11a	122.83	3774.27	3732.27	

Thickness (in)	Distance (ft)	Cumulative Distance (ft)
0.5000	126	126
0.4375	1246.42	1372.42
0.5000	126.57	1498.99
0.5625	202.49	1701.48
0.6250	272.61	1974.09
0.6875	94.24	2068.33
0.7500	310.36	2378.69
0.8125	116.27	2494.96
0.8750	114.56	2609.52
0.9375	144.17	2753.69
1.0000	142.09	2895.78
1.0625	33.91	2929.69
1.1250	135.33	3065.02
1.1875	108.38	3173.4
1.2500	103.42	3276.82
1.3125	103.42	3380.24
1.3750	103.42	3483.66
1.4375	103.42	3587.08
1.5000	80.85	3667.93
1.5625	74.6	3742.53
1.6250		

EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR

Diameter: 17 feet						Unit Weight of Water=	62.4	pcf		
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0			
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3		
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3		
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	(soil load) W_c=	6656.4	lb/ft		
OD Conduit Diameter=	17.0676	feet	ID:	17.00	feet	(live load) W_l=	1706.8	lb/ft		
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	351.8	lb/ft		
B_prime=	0.2330					W_{steel}=	957.9	lb/ft		
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf		
E=	30000000	psi								
b=	1					External pressure with vacuum=	3.10	psi	Ratio Q/q_a=	0.73
t_{MIN}=	0.4055	inches				External pressure with snow load=	3.24	psi	Ratio Q/q_a=	0.77
I=	0.0056	$inches^4$				External pressure with snow and live=	3.72	psi	Ratio Q/q_a=	0.88
FS=	2									
Allowable pressure q_a=	4.23	psi								

Diameter: 15.25 feet						Unit Weight of Water=	62.4	pcf		
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0			
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3		
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3		
Total Height of Soil=	3	feet	(for DL calc) t=	1.19	inches	(soil load) W_c=	5974.1	lb/ft		
OD Conduit Diameter=	15.3182	feet	ID:	15.25	feet	(live load) W_l=	1531.8	lb/ft	100 psf per foot section	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	316	lb/ft		
B_prime=	0.2330					W_{steel}=	2333	lb/ft		
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf		
E=	30000000	psi								
b=	1					External pressure with vacuum=	3.76	psi	Ratio Q/q_a=	0.75
t_{MIN}=	0.4094	inches				External pressure with snow load=	3.91	psi	Ratio Q/q_a=	0.78
I=	0.0057	$inches^4$				External pressure with snow and live=	4.39	psi	Ratio Q/q_a=	0.87
FS=	2									
Allowable pressure q_a=	5.04	psi								

Diameter: 13.5 feet						Unit Weight of Water=	62.4	pcf		
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0			
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3		
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3		
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	(soil load) W_c=	5318.2	lb/ft		
OD Conduit Diameter=	13.6365	feet	ID:	13.50	feet	(live load) W_l=	1363.6	lb/ft		
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	281.0	lb/ft		
B_prime=	0.2330					W_{steel}=	2842.6	lb/ft		
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf		
E=	30000000	psi								
b=	1					External pressure with vacuum=	4.15	psi	Ratio Q/q_a=	0.25
t_{MIN}=	0.8189	inches				External pressure with snow load=	4.30	psi	Ratio Q/q_a=	0.26
I=	0.0458	$inches^4$				External pressure with snow and live=	4.78	psi	Ratio Q/q_a=	0.28
FS=	2									
Allowable pressure q_a=	16.84	psi								

2022 Analysis Summary									
Can	Joint Stress (FSL) (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase (psi)	Total Water Hammer Stress (Surge at Joints) (psi)	Allowable Stress (psi)	Max Joint Stress Ratio	Max Base Material Stress Ratio	Factor of Safety Against Yield (Joints)	Factor of Safety Against Yield (Base)
3	6228	5667	1868	8096	17000	0.48	0.33	2.10	3.00
14	5900	5369	1770	7670	17000	0.45	0.32	2.22	3.17
24	7121	6480	2136	9257	17000	0.54	0.38	1.84	2.62
32	8719	7934	2616	11335	17000	0.67	0.47	1.50	2.14
42	10305	9378	3092	13397	17000	0.79	0.55	1.27	1.81
50	11506	10470	3452	14958	17000	0.88	0.62	1.14	1.62
64	13190	12003	3957	17147	17000	1.01	0.71	0.99	1.42
71	13653	12424	4096	17748	17000	1.04	0.73	0.96	1.37
81	13632	12405	4090	17722	17000	1.04	0.73	0.96	1.37
93	13902	12651	4171	18072	17000	1.06	0.74	0.94	1.34
103	15631	14224	4689	20320	17000	1.20	0.84	0.84	1.20
112	16669	15169	5001	21669	17000	1.27	0.89	0.78	1.12
123	18290	16643	5487	23776	17000	1.40	0.98	0.71	1.02
132	19280	17545	5784	25064	24000	1.04	0.73	0.96	1.37
142	15475	14082	4642	20117	24000	0.84	0.59	1.19	1.70
150	19562	17802	5869	25431	24000	1.06	0.74	0.94	1.35
160	23364	21261	7009	30373	24000	1.27	0.89	0.79	1.13
169	23285	21190	6986	30271	24000	1.26	0.88	0.79	1.13
178	24967	22720	7490	32457	24000	1.35	0.95	0.74	1.06
188	24470	22268	7341	31811	24000	1.33	0.93	0.75	1.08
198	24559	22348	7368	31926	24000	1.33	0.93	0.75	1.07
208	23637	21510	7091	30729	24000	1.28	0.90	0.78	1.12
218	23136	21053	6941	30076	24000	1.25	0.88	0.80	1.14
229	23129	21048	6939	30068	24000	1.25	0.88	0.80	1.14
237	23139	21057	6942	30081	24000	1.25	0.88	0.80	1.14
248	23227	21137	6968	30196	24000	1.26	0.88	0.79	1.14
258	20501	18656	6150	26651	24000	1.11	0.78	0.90	1.29
268	24058	21893	7217	31276	24000	1.30	0.91	0.77	1.10
278	26958	24532	8088	35046	24000	1.46	1.02	0.68	0.98
287	27188	24741	8156	35345	24000	1.47	1.03	0.68	0.97
298	28873	26274	8662	37535	24000	1.56	1.09	0.64	0.91
308	29535	26877	8860	38395	24000	1.60	1.12	0.63	0.89
318	29099	26480	8730	37829	24000	1.58	1.10	0.63	0.91
328	24410	22214	7323	31734	24000	1.32	0.93	0.76	1.08
338	22836	20781	6851	29687	24000	1.24	0.87	0.81	1.15
348	24246	22064	7274	31520	24000	1.31	0.92	0.76	1.09
360	21947	19971	6584	28531	24000	1.19	0.83	0.84	1.20
367	21313	19395	6394	27707	24000	1.15	0.81	0.87	1.24
377	20691	18829	6207	26898	24000	1.12	0.78	0.89	1.27
387	20220	18400	6066	26286	24000	1.10	0.77	0.91	1.30
397	20983	19094	6295	27277	24000	1.14	0.80	0.88	1.26
407	20394	18559	6118	26513	24000	1.10	0.77	0.91	1.29
417	20821	18947	6246	27067	24000	1.13	0.79	0.89	1.27
425	19483	17730	5845	25328	24000	1.06	0.74	0.95	1.35
432	18868	17169	5660	24528	24000	1.02	0.72	0.98	1.40

APPENDIX F

WELD TRACKER

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
1			I	I		
2			I	I	2021	
3			I	I	2022	
4			I	I	2020	
5						
6						
7			I	I	2021	
8			I	I	2022	
9						
10			I	I		
11						
12			I	I	2021	
13			I	I	2020	
14			I	I	2022	
15						
16						
17			I	I	2021	
18						
19			I	I	2022	
20			I	I		
21						3' Can
22			I	I	2021	3' Can
23						3' Can
24			I	I	North -2020 South - 2022	3' Can
25						3' Can
26			I	I	2020	North only in 2020
27			I	I	2022	
28			I	I	2021	
29						
30			I	I		
31						
32			I	I	2022	
33			I	I	2021	
34				I	2020	
35						
36			I	I		
37						
38			I	I	2021	
39						MH
40			I	I		

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
41						
42			I		2021	DP, Inspected Doubler plate fillet weld
43			I	I	2021	
44			I		2020	
45			I		2022	DP, Inspected Doubler plate fillet weld
46			I	I		
47				I	2020	
48			I	I		
49						
50			I		2022	DP, Inspected Doubler plate fillet weld
51						
52			I	I	2021	
53						
54						
55			I	I	2020	
56			I		2022	DP, Inspected Doubler plate fillet weld
57			I	I	2021	
58			I	I		
59						
60						
61			I	I	2021	
62						
63						DP
64			I	I	2022	DP, Inspected Doubler plate fillet weld
65			I		2020	
66				I	2020	
67			I	I	2022	
68						MH
69			I	I		
70						
71			I	I	2022	
72			I	I	2021	
73						
74				I	2020	
75			I	I	2020	
76			I	I	2022	
77			I	I	2021	
78						
79			I	I		
80						
81			I	I	2022	

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
82			I	I	2021	
83						
84						
85			I	I		
86			I	I	2020	
87			I	I	2022	
88			I	I		DP
89			I	I		
90						
91			I	I		
92			I	I	2021	
93			I	I		
94			I	I	2020	DP, south only in 2020
95			I	I		DP
96			I	I	2020	DP, south only in 2020
97			I	I		
98			I	I	2022	1 inidication found on north side
99			I	I	2020	North only in 2020
100			I	I		
101			I	I		
102			I	I		
103			I	I	2022	1 inidication found on north side
104			I	I	2021	
105						
106			I	I	2020	
107			I	I	2022	
108			I	I	2021	
109			I		2020	
110				I	2020	
111			I		2020	
112			I	I	2022	South only in 2022
113						
114						
115			I	I	2021	
116			I	I	2021	
117			I	I	2021	
118				I	2022	
119				I	2022	
120			I	I	2021	South only in 2021
121				I	2021	
122	P		I	I	2021	1 Crack in North Weld in 2021

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
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I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
123	P		I	I	2022	3 cracks in North Weld in 2021
124	P		I	I	2021	1 Crack in North Weld in 2021
125			I	I	2021	
126	P		I	I	2021	2 cracks in North Weld in 2021
127	P		I	I	2022	1 Crack in North Weld in 2021
128			I	I	2021	
129			I	I	2021	MH
130				I	2020	
131			I	I		
132				I	2022	North Weld not accessible
133		P	I	I	2022	2 cracks in South Weld in 2021, Only south inspected in 2022
134		P	I	I	2021	3 cracks in South Weld in 2021
135			I	I	2021	
136	P		I	I	2021	4 cracks in North Weld in 2021
137		P	I	I	2022	1 cracks in South Weld in 2021
138			I	I	2022	
139			I	I	2022	
140			I		2022	South not accesible
141						
142			I	I	2021	
143						
144						
145	P	P	I	I	2022	1 Crack in North Weld in 2021, 1 crack in South side in 2022
146	P		I	I	2022	DP, 4 cracks in North Weld in 2021, Only North inspected in 2022, 1 inidication found in 2022
147	P		I	I	2021	2 cracks in North Weld in 2021
148			I	I	2021	
149			I	I	2022	Only north inspected in 2022
150	P	P	I	I	2021	DP, 3 cracks on south in 2021, 2 cracks on north 2021, only north inspected in 2022
151				I	2022	North weld not accesible
152			I	I	2021	
153			I	I	2021	
154			I	I	2021	
155			I	I	2021	
156						
157				I	2020	
158						
159						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
160			I		2022	DP,only north inspected
161						
162						
163			I	I		
164			I	I	2022	
165			I	I	2021	
166				I	2020	
167				I	2020	
168			I			
169				I	2022	
170				I		
171						
172			I	I	2022	
173			I	I		
174			I		2020	
175			I		2020	
176			I	I	2021	
177			I		2022	
178			I		2022	
179						
180			I	I		
181						
182						
183			I	I		
184						
185			I	I	2021	
186						
187			I		2020	
188			I	I	2022	
189						
190						
191						
192			I	I		
193			I	I		
194			I	I	2021	
195						DP
196			I		2020	
197						
198			I	I	2022	
199						
200						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
201			I	I		
202						
203			I	I	2021	
204			I		2020	
205			I	I		
206			I		2020	
207						
208			I	I	2022	
209						
210			I	I		
211			I	I		
212			I	I		
213			I	I	2021	
214			I	I	2020	
215			I	I		
216			I	I		
217			I	I		
218			I	I	2022	
219			I	I		
220			I	I		
221						
222						
223			I		2020	
224						
225						
226						
227			I	I	2021	
228			I	I		
229			I	I	2022	
230						
231						
232						
233			I	I	2020	
234						
235			I	I		
236						
237				I	2022	North weld not accessible
238						
239						
240			I	I		
241						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
242						
243			I	I	2021	
244						
245			I		2020	
246						
247			I	I		
248			I		2022	
249			I		2022	
250			I	I		
251						
252						
253						
254			I	I	2021	
255			I	I		
256						
257			I	I	2020	MH
258			I	I	2022	
259						Surge Tank
260						Surge Tank
261						
262						
263			I	I	2021	
264			I	I		
265			I	I		
266			I	I	2020	
267						
268			I	I	2022	
269						
270						
271			I	I		
272						
273						
274			I	I	2021	
275			I	I		
276			I	I	2020	
277						
278			I	I	2022	
279						
280			I	I		
281						
282						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
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I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
283						
284			I	I	2021	
285			I	I		
286			I	I	2020	
287			I	I	2022	
288						
289						
290						
291						
292			I	I		
293						
294			I	I	2021	
295			I	I		
296			I	I	2020	
297						
298			I	I	2022	
299						
300			I	I		
301						
302			I	I		
303						
304			I	I	2021	
305						
306			I	I	2020	
307						
308			I	I	2022	
309						
310			I	I		
311						
312						
313			I	I	2021	
314						
315						
316			I	I	2020	
317						
318			I	I	2022	
319						
320			I	I		
321						
322			I	I		
323						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
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I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
324			I	I	2021	
325						
326			I	I	2020	
327						
328			I	I	2022	
329						
330			I	I		
331			I	I		
332						
333						
334			I	I	2021	
335						
336			I	I		
337						
338			I	I	2022	
339						
340			I	I		
341						
342			I	I		
343						
344			I	I	2021	
345						
346			I	I	2020	
347						
348			I	I	2022	
349						
350			I	I		
351						
352						MH
353						
354			I	I		
355				I	2020	
356				I	2020	
357			I	I	2021	
358						
359						
360			I		2022	
361						
362			I	I		
363						
364			I	I		

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Has Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
365			I	I	2020	
366						
367			I	I	2022	
368			I	I	2021	
369						
370			I	I		
371						
372			I	I		
373						
374						
375			I	I	2020	
376						
377			I	I	2022	
378			I	I	2021	
379						
380			I	I		
381			I	I		
382						
383						
384						
385			I	I	2020	
386						
387			I	I	2022	
388			I	I	2021	
389						
390			I	I		
391						
392			I	I		
393						
394						
395						
396			I	I	2020	
397			I	I	2022	
398			I	I	2021	
399			I	I		
400			I	I		
401						
402						
403						
404						
405						

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
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N =	Weld seam has not been inspected	

Can	Reburbished or Original?		Inspected Status			Notes:
	North	South	North	South	Year Last Inspected?	
406			I	I	2020	
407			I	I	2022	
408			I	I	2021	
409						
410						
411						
412						
413						
414						
415						
416						
417			I	I	2021/2022	Only South weld inspected in 2022
418						
419						
420						
421						
422						
423						
424						
425			I	I	2021/2022	Only South inspected during 2022
426						
427						
428						
429						
430						
431						
432			I	I	2021/2022	Only South inspected in 2022
433						
434				I	2022	
435			I	I	2021	