1	Q.	Reference: Application, Schedule 1: Upgrade Report – Penstock 1 Life Extension – Bay		
2		d'Espoir, Appendix J, Page 26 of 51		
3 4 5 6 7 8 9		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.		
10		Has Hydro completed the more detailed scale removal and magnetic particle inspection as		
11		recommended by Hatch? If yes, please provide the inspection report. If not, why not?		
12				
13				
14	A.	Yes. Please refer to NP-NLH-011, Attachments 1, 2, 3, and 4 for further details.		

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

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#### LIST OF ABBREVIATIONS

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
СН	CHAINAGE (IN METRES)
CMS	CUBIC METRES PER SECOND
Fu	ULTIMATE TENSILE STRESS
Fy	YIELD STRESS
GWH	GIGAWATT HOURS
кРа	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

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## 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.

<u>Kleinschmidt</u>

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.

## 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<sup>3</sup>/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<sup>1</sup> 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.

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 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

<sup>&</sup>lt;sup>1</sup> 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.

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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, 2<sup>nd</sup> Edition. The allowable primary stress intensity is the lesser of the material yield stress (F<sub>y</sub>) divided by 1.5 or of the ultimate tensile stress (F<sub>u</sub>) 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.

CAN	MAX JOINT STRESS <sup>1,3</sup> (psi)	DYNAMIC HOOP STRESS INCREASE <sup>1,3</sup> (psi)	TOTAL WATER HAMMER STRESS <sup>1,3</sup> (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO <sup>1,2,3</sup>	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

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

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	Page 20 of					
CAN	MAX JOINT STRESS <sup>1,3</sup> (psi)	DYNAMIC HOOP STRESS INCREASE <sup>1,3</sup> (psi)	TOTAL WATER HAMMER STRESS <sup>1,3</sup> (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO <sup>1,2,3</sup>	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

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Page 21 of						
CAN	MAX JOINT STRESS <sup>1,3</sup> (psi)	DYNAMIC HOOP STRESS INCREASE <sup>1,3</sup> (psi)	TOTAL WATER HAMMER STRESS <sup>1,3</sup> (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO <sup>1,2,3</sup>	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

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CAN	MAX JOINT STRESS <sup>1,3</sup> (psi)	DYNAMIC HOOP STRESS INCREASE <sup>1,3</sup> (psi)	TOTAL WATER HAMMER STRESS <sup>1,3</sup> (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO <sup>1,2,3</sup>	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

<sup>1</sup> Joint efficiency of 0.7 included

<sup>2</sup> Total stress / Allowable stress

<sup>3</sup> Uses 97.5% confidence thickness

<sup>4</sup> 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.

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

TABLE 4-2	SUMMARY OF SURCHARGE LOAD ANALYSIS
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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

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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 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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## **REPORT SIGNATURE PAGE**

#### KLEINSCHMIDT ASSOCIATES CANADA INC.

. Ville

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

CMV:FSH:SCB



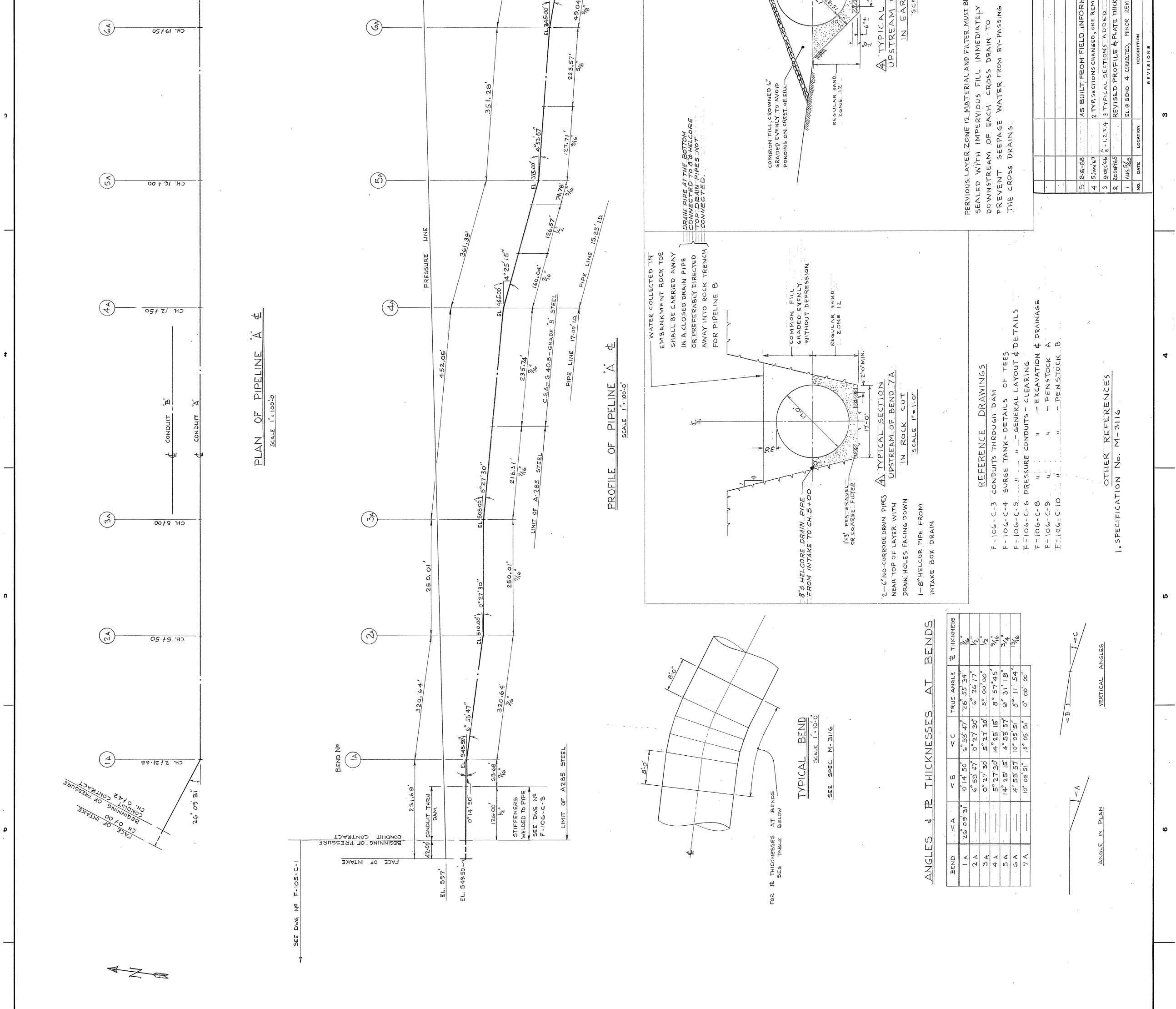
<b>PROVINCE OF NEW</b>	FOUNDLAND AND LABRADOR
PEGN	PERMIT HOLDER This Permit Allows
KLEINSCHMIDT	ASSOCIATES CANADA INC.
To practice Pro in Newfoundlan Permit No. as is which is valid for	fessional Engineering Ind and Labrador. Issued by PEGNL <u>NO703</u> or the year 2020

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APPENDIX A

PENSTOCK LAYOUT DRAWINGS

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PRESSURE CONOLITS SHALL BE CALLED "Å" A LIT "Å" IS SOLTH OF CONDLIT "E" AND COMPLETED IN 1966. UIT "Å" ONSISTS OF PIPELINE "Å" AND PENS	THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION N° M-3116 EXCEPT FOR BENDS WHERE by Shall be Added to plate THICKNESSES calculated to Resist Hoop Tension plus the Effects of the torus shape of bends. THIS Extra THICKNESS of bg Shall Extend Over the Bends and at Least b feet upstream and downstream of the Last mitre Joint.				NEWFOUNDLAND AND LABRADOR POWER COMMISSION BAY D'E S POIR DE VELO PMENT BAY D'E S POIR DE VELO PMENT ENGINEERING AND DESIGN BY SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED MONTREAL. QUEBEC MONTREAL. QUEBEC MONTREAL. QUEBEC PLAN & PROFILE PIPELINE Å PLAN & PROFILE PIPELINE Å PLAN & PROFILE PIPELINE Å PD-11 JULY 16, 1965 F-106-C-7 5
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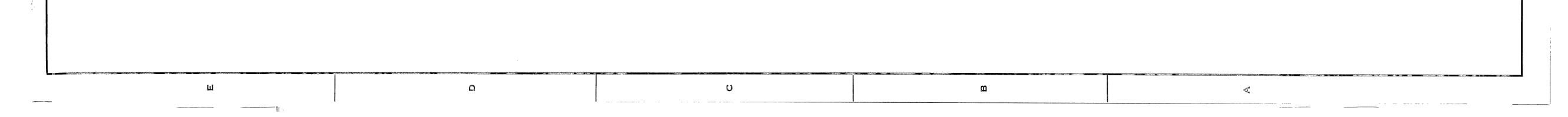


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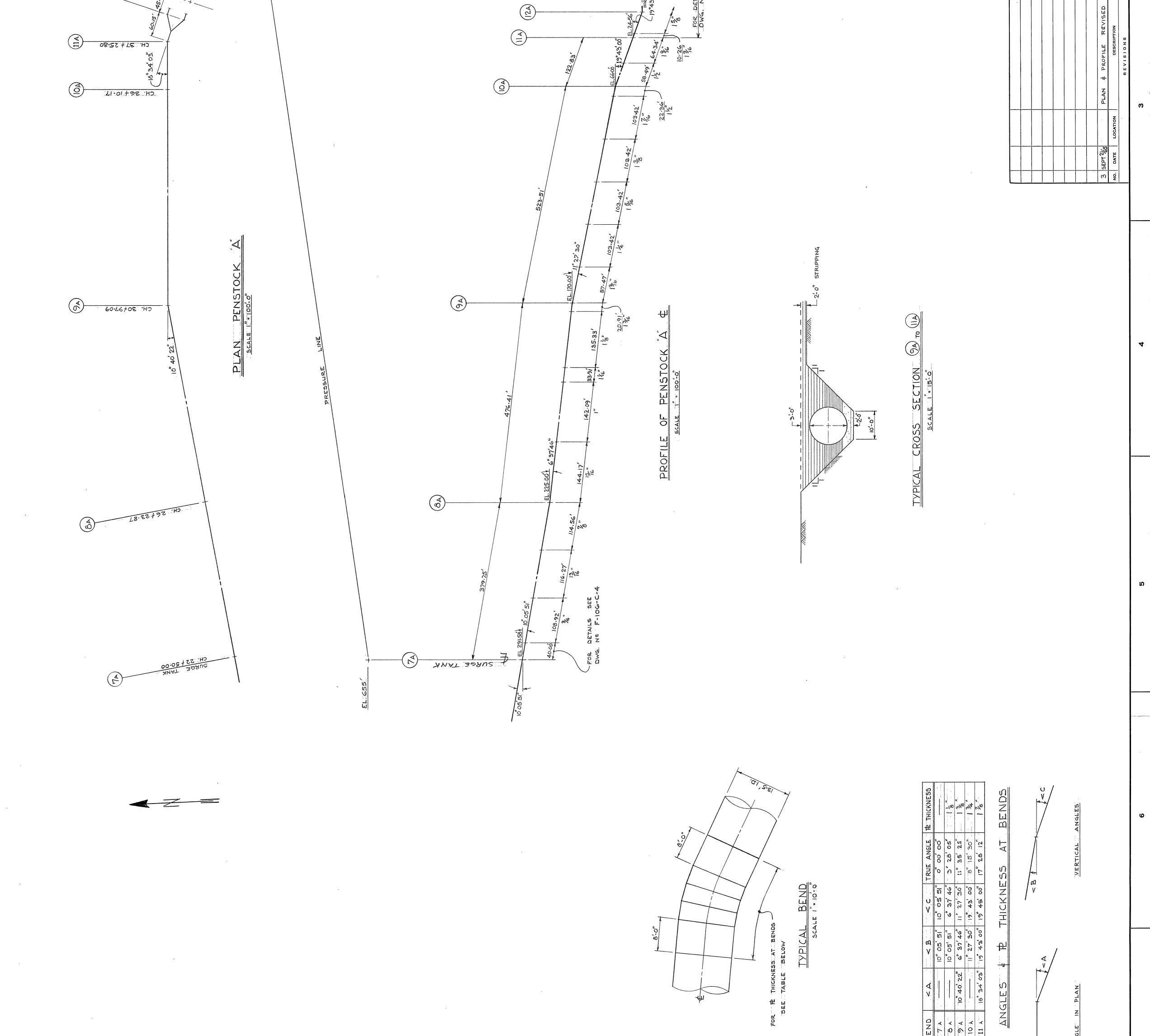
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STOWLE STOWLE	EL. 890       I. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-SILG EXCEPT FOR BENDS WHERE "SPECIFICATION Nº M-SILG EXCEPT FOR BENDS WHERE "SPECIFICATION Nº M-SILG EXCEPT FOR BENDS WHERE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE REFECTS OF THE TRRUSS SHARE OF THE BENDS AND AT LEAST OF THE TRRUS SHARE AND DOWNSTREAM OF THE LAST MITTRE JOINT.         2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6''       3. STEEL SHALL BE C.S.A. 940-8 GRADE 'S''         3. STEEL SHALL BE C.S.A. 940-8 GRADE 'S''       4. FOR TVPICAL CROSS SECTION FROM (N) TO (N) SEE DWG. Nº F: 106-C-T.			REFERENCE       DRAWINGS         1.       F = 106 - C - 2       PRESSURE CONDUITS - LAYOUT & DETAILS OF BIFURCATION.         2.       F = 106 - C - 3       DERESSURE CONDUITS - LAYOUT & DETAILS OF BIFURCATION.         3.       F = 106 - C - 5       SURGE TANKS - DETAILS OF TERES.         4.       F = 106 - C - 6       PRESSURE CONDUITS - CLEARING.         5.       F = 106 - C - 7       PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE W	ASSOCIATION OF REFERENCES ASSOCIATION OF REPEATION Nº M-3116 ANTEONNEAR MAT	APPROVED     R.Mac D.     Newfoundland and labrador power commission Registering and the segment of the se
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NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

Page 34 of 92



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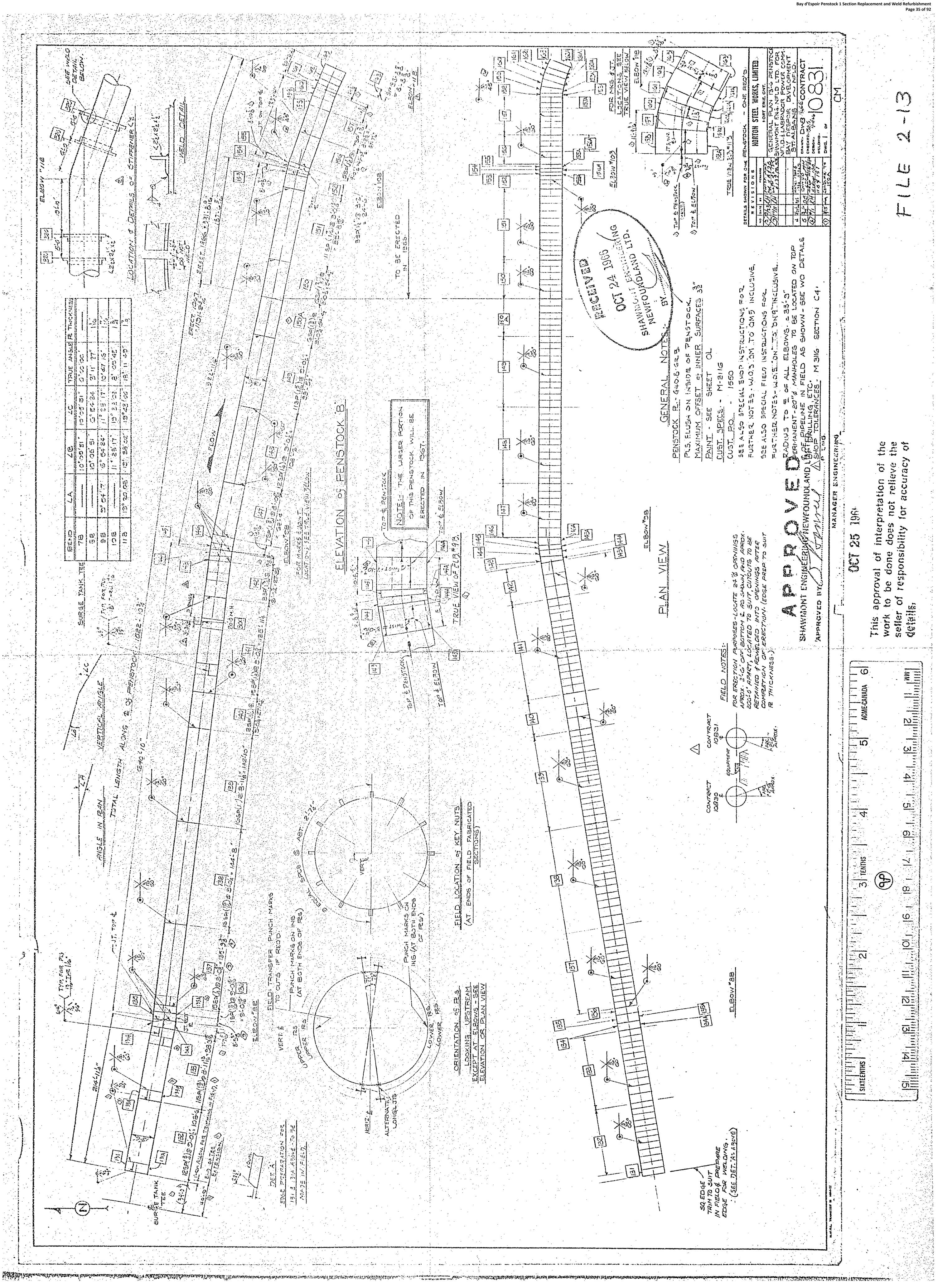
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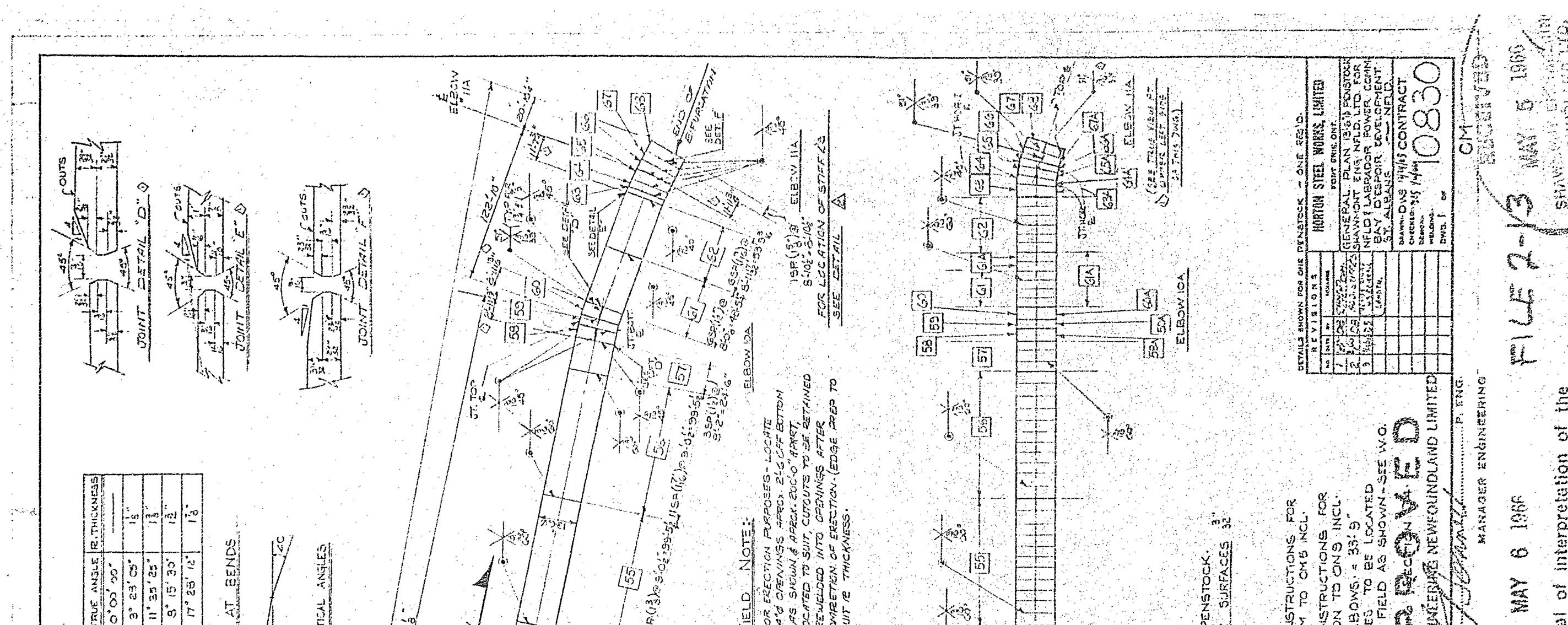
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NP-NLH-011, Attachment 1



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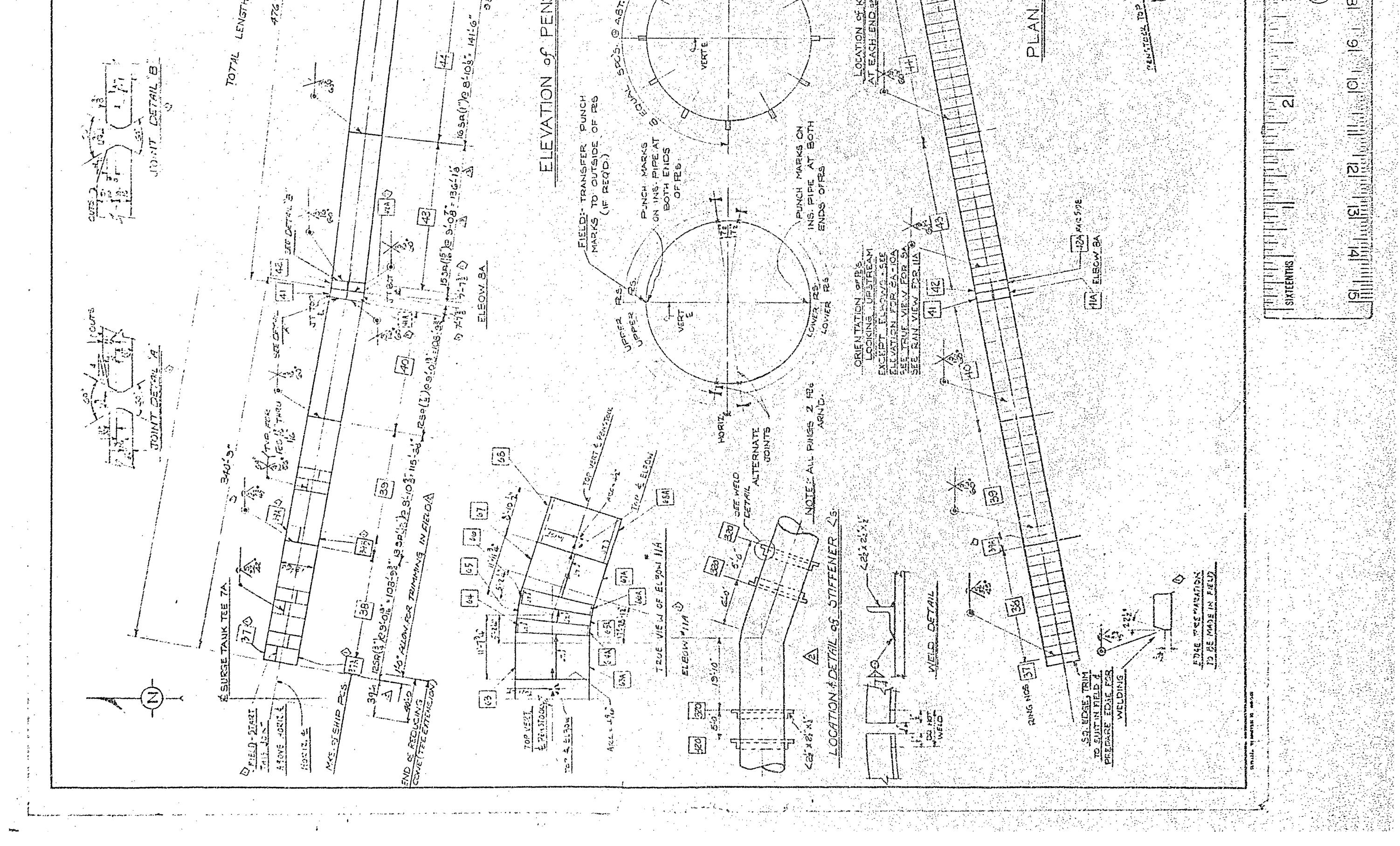
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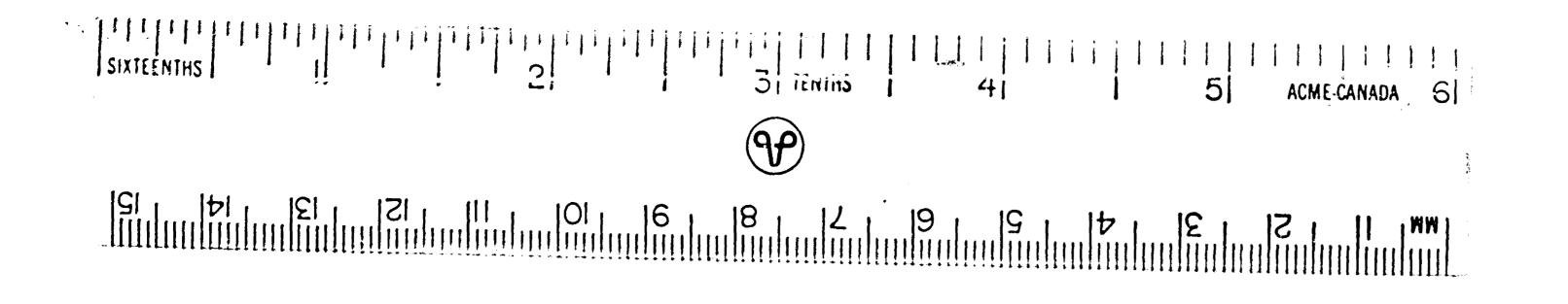
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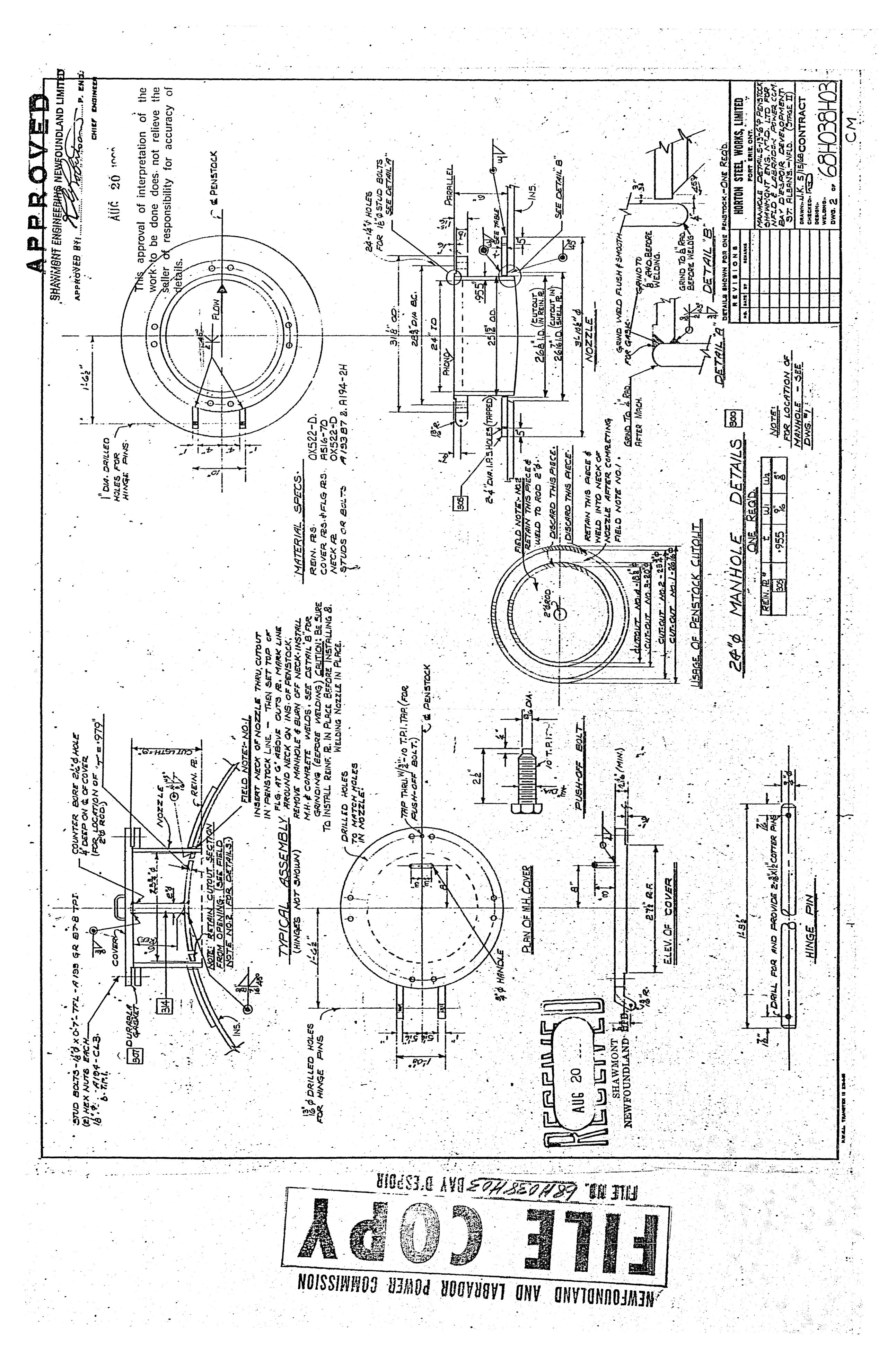
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**APPENDIX B** 

**Photographs** 

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PHOTO 1 LEAK IN BOTTOM LEFT CORNER OF GATE



PHOTO 2 CONCRETE DETERIORATION AT CONCRETE TO STEEL TRANSITION

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PHOTO 3 OLD ORGANIC GROWTH ON INSIDE OF PENSTOCK



PHOTO 4 PREVIOUSLY REPAIRED WELD WITH CONTRAST PAINT

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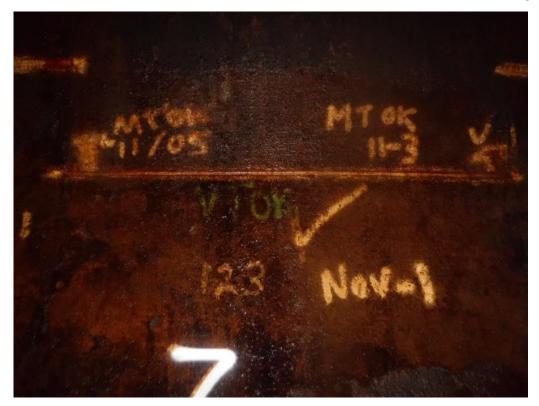


PHOTO 5 PREVIOUSLY REPAIRED AND TESTED WELD – CAN 7

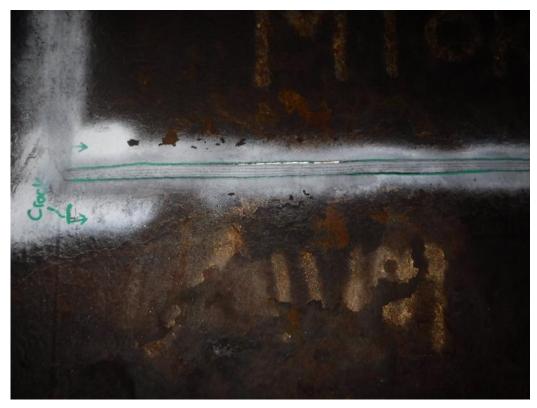


PHOTO 6 CRACKED WELD RIGHT SIDE OF CAN 106 NEAR SPRING LINE



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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

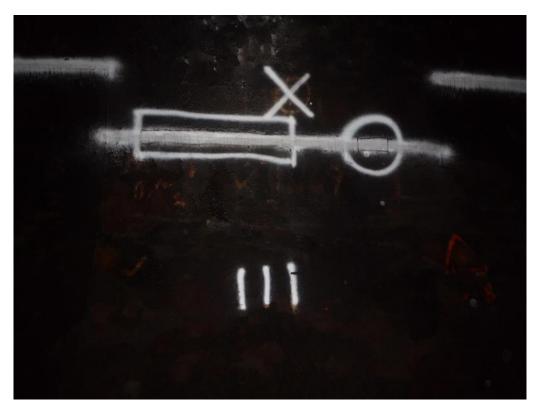


PHOTO 10 MT TEST SHOWED INDICATION OF ISSUE LEFT SIDE CAN 111 NEAR SPRING LINE

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PHOTO 11 INDICATION OF ISSUE CAN 111 WELD NEAR SPRING LINE



PHOTO 12 DOUBLER PLATE REPAIR

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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

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PHOTO 19 SURFACE SCRAPED DOWN TO SHOW LIGHT PITTING



PHOTO 20 SURFACE CORROSION AND FLAKING CAN 200

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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

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PHOTO 25 MANHOLE 1 COVER WITH REINFORCING PLATES



PHOTO 26 LOOKING DOWNSTREAM TOWARD SURGE TANKS ALONG PREVIOUSLY REPAIRED AREA

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PHOTO 27 PIEZOMETER LOCATION JUST UPSTREAM OF CRACK LOCATION



PHOTO 28 LOOKING DOWNSTREAM AT CRACK LOCATION COVERED IN TARPS



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PHOTO 29 LOOKING DS ALONG PENSTOCK JUST DS OF SURGE TANK



PHOTO 30 LOOKING UPSTREAM TOWARD SURGE TANKS FROM TRANSMISSION LINE



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PHOTO 31 LOOKING DS ALONG PENSTOCK JUST DS OF TRANSMISSION LINE



PHOTO 32 PRESSURE MONITOR

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PHOTO 33 MANHOLE 3 AT TOP OF STEEP SLOPE

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APPENDIX C

WELD TEST

Acuren Group Inc.       1 Austin Street       209.753.2         Acuren Group Inc.       1 Austin Street       209.753.2         St. John's, NL, Canada A1B 4C1       Www.acuren.com       200.753.2         Www.acuren.com       A Higher Level of Reliability       200.753.2         NONDESTRUCTIVE EXAMINATION       A Higher Level of Reliability       200.753.2         NONDESTRUCTIVE EXAMINATION       Page 57 of 92       200.7         To:       Nalcor Energy       Page 57 of 92         Correct 3rd, 2019       201.7       201.7         Acuren Job #: 183-19-10NAL001-0001       RePORt #: 183-19-10NAL001-0001       201.7         Report #: MT-GW031019-001 R0       PO: N/A       WO: N/A         Project:       Penstock # 1 Emergency Repair       200.7         Item(s) Examined:       Can #106 insert plate (Interior & Exterior) & reinforcement plate (Exterior)       201.7         PART #:       See Below       MATERIAL:       Carbon Steel       THICKNESS: Varies         Scope:       Magnetic Particle       Inspection to be completed as per client's request.       201.7         Pre OF INSPECTION:       Magnetic Particle       THICKNESS: Varies       200.7         Scope:       Magnetic Particle       Thickness: Varies       200.7         Scope:       Magn	Ва	ay d'Espoir Penstock 1 Section Replacement and Weld Refurbishme	nt
TO: Nalcor Energy PAGE: 1 of 2 DATE: Oct 3 <sup>rd</sup> , 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: 2018/ 2017 PROCEDURE/TECHNIQUE: CAN-MT-14P001 TYPE: Vet Visible METHOD: Yoke PARTICLE BRAND: Magnaflux PRODUCT NO.: 7HF PARTICLE BLACK MT INSTRUMENT: Magnaflux Y-1 PARTICLE BLACK MT INSTRUMENT S/N: 2102 CAL DUE: Jan 29/2020 LIGHT MI INSTRUMENT 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 22 <sup>nd</sup> /20	ACUREN	Acuren Group Inc. 1 Austin Street Phone: 709.7 St. John's, NL, Canada A1B 4C1 Fax: 709.7 www.acuren.com	753.21
DATE: Oct 3 <sup>rd</sup> , 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         PROCEDURE/TECHNIQUE:       CAN-MT-14P001         Revision:       15         TYPE:       Wethod:       Yoke         PARTICLE BRAND:       Magnafilux       PRODUCT NO.: 7HF         CURENT:       AC       MT INSTRUMENT: Magnafilux Y-1         PARTICLE COLOUR:       Black       MT INSTRUMENT S/N: 2102       CaL DUE: Jan 29/2020         SUSPENSION:       OII       Contrast Paint:       Magnafilux       PRODUCT NO.: WCP-2         Mag Time (SECONDS):       10       DEMAG REQUIRED?: NO       Light Marke: N/A       S/N: N/A         Mag T	NONDESTRUCTIVE EXAMINA	ATION	
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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:       REVISION: 2018/ 2017         ACCEPTANCE STANDARD:       ASME B31.3NFS, ASME Sec. IX         PROCEDURE/TECHNIQUE:       CAN-MT-14P001         REVISION:       15         TYPE:       WeTHOD:         Yoke       Varies Course:         PARTICLE BRAND:       Magnafilux         PRODUCT NO.:       TH INSTRUMENT S/N:       2102         Suspension:       Oil       Cal Due:       Jan 29/2020         Suspension:       Oil       LightT Maters S/N:       15/N:         Contrast Paint:       Magnafilux       PRODUCT NO:: WCP-2       BlackLightT Make:       N/A         Suspension:       O		-	
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TYPE OF INSPECTION: Magnetic Particle         TEST DETAILS:         ACCEPTANCE STANDARD: ASME B31.3NFS, ASME Sec. IX         PROCEDURE/TECHNIQUE:       CAN-MT-14P001       Revision: 2018/ 2017         TYPE:       Wet Visible       METHOD:       Yoke         PARTICLE BRAND:       Magnafilux       PRODUCT NO.: 7HF       CURRENT:       MT INSTRUMENT:       Magnafilux 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         BLACKLIGHT MAKE:       N/A       S/N:       N/A         Mag Time (SECONDS):       10       DEMAG REQUIRED?: No       LIGHT METER S/N:       150803637       CAL DUE:       Feb 22 <sup>nd</sup> /20			
C         TEST DETAILS:         ACCEPTANCE STANDARD: ASME B31.3NFS, ASME Sec. IX         Revision: 2018/ 2017         PROCEDURE/TECHNIQUE:       CAN-MT-14P001         TYPE:       Wet Visible       METHOD:       Yoke         PARTICLE BRAND:       Magnaflux       PRODUCT NO.:       THF       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 Meters S/N:       150803637       Cal Due:       Feb 22 <sup>nd</sup> /20		be completed as per client's request.	
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         Mag TIME (SECONDS):       10       DEMAG REQUIRED?: No       LIGHT METER S/N: 150803637       CAL DUE:       Feb 22 <sup>nd</sup> /20	TYPE OF INSPECTION: Magnetic Particle		
PROCEDURE/TECHNIQUE:       CAN-MT-14P001       REVISION:       15         Type:       Wet Visible       METHOD:       Yoke         PARTICLE BRAND:       Magnafilux       PRODUCT NO.:       THF       CURRENT:       AC       MT INSTRUMENT:       Magnafilux 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:       Magnafilux       PRODUCT NO.:       WCP-2       BLACKLIGHT MAKE:       N/A         MG TIME (SECONDS):       10       DEMAG REQUIRED?:       No       LIGHT METER S/N:       150803637       CAL DUE:       Feb 22 <sup>nd</sup> /20	TEST DETAILS:		
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       MAG TIME (SECONDS):     10     DEMAG REQUIRED?:     No     LIGHT METER S/N:     150803637     CAL DUE:     Feb 22 <sup>nd</sup> /20	ACCEPTANCE STANDARD: ASME B31.3NFS, ASME S	ec. IX REVISION: 2018/ 2017	
PARTICLE BRAND:       Magnaflux       PRODUCT NO.:       THF       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:       10         CONTRAST PAINT:       Magnaflux       PRODUCT NO.::       WCP-2       BLACKLIGHT MAKE:       N/A         MAG TIME (SECONDS):       10       DEMAG REQUIRED?:       No       LIGHT METER S/N:       150803637       CAL DUE:       Feb 22 <sup>nd</sup> /20	PROCEDURE/TECHNIQUE: CAN-MT-14P001		
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 22 <sup>nd</sup> /20			
SUSPENSION:     Oil     LIGHTING EQUIP:YOKE LEG LIGHT     LIFT WEIGHT S/N: 10917       CONTRAST PAINT:     Magnaflux     PRODUCT NO.: WCP-2     BLACKLIGHT MAKE:     N/A       MAG TIME (SECONDS):     10     DEMAG REQUIRED?: No     LIGHT METER S/N: 150803637     CAL DUE:     Feb 22 <sup>nd</sup> /20	C C	-	
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 22 <sup>nd</sup> /20			
MAG TIME (SECONDS):         10         DEMAG REQUIRED?:         No         LIGHT METER S/N:         150803637         Cal due:         Feb 22 <sup>nd</sup> /20			
	-		

## See Page 2 for results

TEST SURFACE TEMPERATURE: Varies

lient acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (<u>www.acuren.com/serviceterms</u>) in effect when the services were ordered.

CLIENT:			DTR No.: N/A
	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	
ACUREN	Shipping		
TECHNICIAN:	Glenn Whitten		
	1 <sup>st</sup> Technician CGSB II - 16212		
REVIEWER:	Curran 10/04/2019		(G

TEST SURFACE CONDITION: As Welded

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

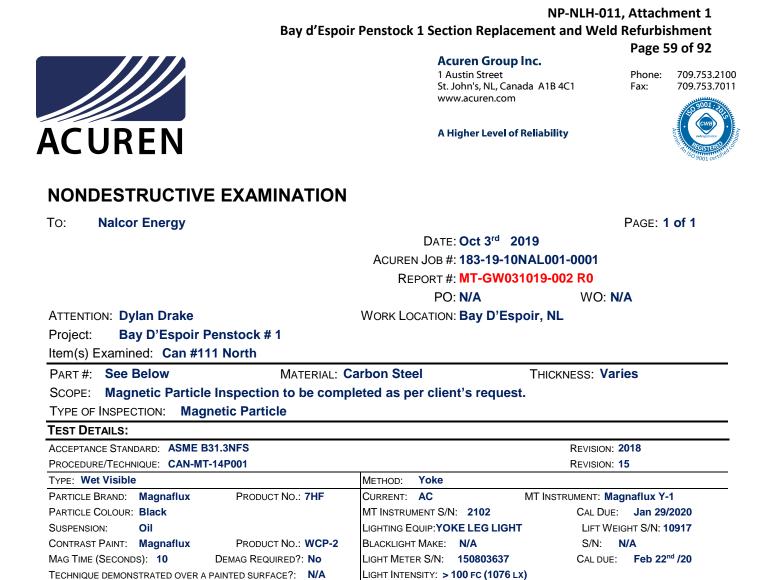
NP-NLH-011, Attachment 1



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

Page 2 of 2

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	<b>Temporary Attachments</b>	03/10/19 - 1200	Accept



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

TEST SURFACE TEMPERATURE: Varies

TEST SURFACE CONDITION: As Welded

lient acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (<u>www.acuren.com/serviceterms</u>) in effect when the services were ordered.

CLIENT:			DTR No.: N/A
	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	-
ACUREN	Shippont		
TECHNICIAN:	Glenn Whitten		
	1 <sup>st</sup> Technician CGSB II - 16212		-
REVIEWER:	Cuitor 10/04/2019		(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)

Bay d'Espo	ir Penstock 1 Section Replaceme	ent and Weld Refurbi	ishment
		Page	60 of 92
	Acuren Group Inc 1 Austin Street St. John's, NL, Canada www.acuren.com	Phone:	709.753.210
ACUREN	A Higher Level of Reli	ability	
NONDESTRUCTIVE EXAMINATION			
To: Nalcor Energy		PAGE:	1 of 6
	DATE: Sept 24 <sup>th</sup> 20	19	
	ACUREN JOB #: 183-19-10NA		
	REPORT #: MT-GW24091		
	PO: N/A	WO: N/A	
ATTENTION Dulan Drake			
ATTENTION: Dylan Drake	WORK LOCATION: Bay D'Espoin	, NL	
Project: Bay D'Espoir Penstock # 1			
Item(s) Examined: Penstock # 1			
PART #: See Below MATERIAL: (	Carbon Steel T	HICKNESS: Varies	
SCOPE: Magnetic Particle Inspection to be comp	pleted 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	<b>/-1</b>
PARTICLE COLOUR: Black	MT INSTRUMENT S/N: 2102	CAL DUE: Jan 29	)/2020
SUSPENSION: OII	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 22	2 <sup>nd</sup> /20
TECHNIQUE DEMONSTRATED OVER A PAINTED SURFACE?: N/A	LIGHT INTENSITY: > 100 FC (1076 LX)		

NP-NLH-011, Attachment 1

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

TEST SURFACE TEMPERATURE: Varies

TEST SURFACE CONDITION: As Welded, As Cleaned

lient acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (<u>www.acuren.com/serviceterms</u>) in effect when the services were ordered.

CLIENT:			DTR No.: N/A
	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	
ACUREN	Shipping		
TECHNICIAN:	Glenn Whitten		
	1 <sup>st</sup> Technician CGSB II - 16212		
REVIEWER:	Cutation 09/25/2019		(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)



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

Page 2 of 6

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
Call # 105-100 Circ.	South	2	No linear indications found at time of inspection
Can # 106	South	9'	Linear indications found on top & bottom toe of weld. Length of
	oouun	, , , , , , , , , , , , , , , , , , ,	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 JOB #

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

Page 3 of 6

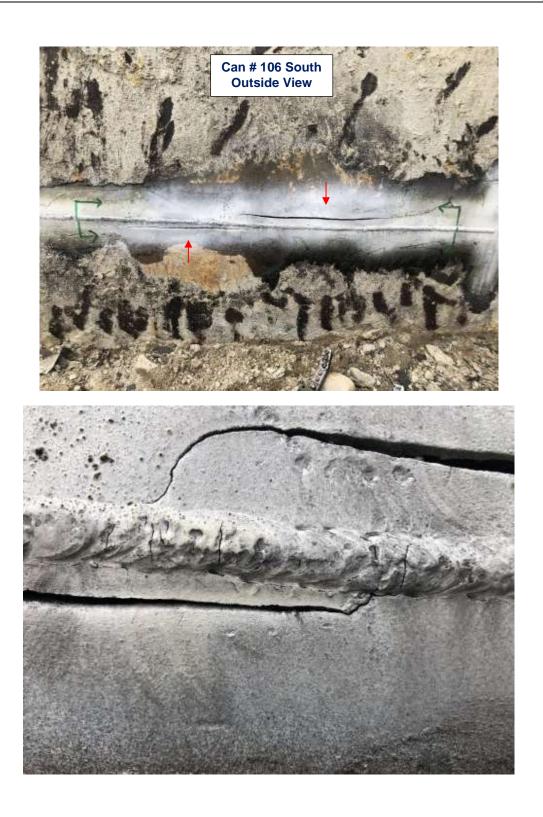




ACUREN JOB #

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

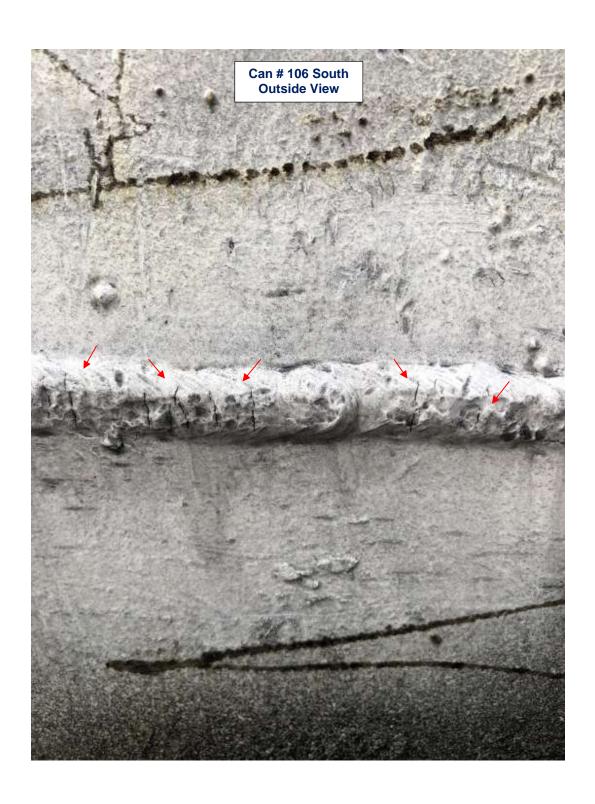
Page 4 of 6



ACUREN JOB #

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

Page 5 of 6



NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 65 of 92



ACUREN JOB #	
REPORT #	

183-19-10NAL001-0001 MT-GW240919-001 R0

Page 6 of 6



Image: Source	Animalian     Animalian       Animalian     France       Provinci     France       Provinci     France       Animalian     France       Provinci     France       Animalian     France <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>up Inc.</th><th></th><th>2 L C</th><th></th></td<>											up Inc.		2 L C	
Higher Level of Reliability         Artighter Level of Reliability           Y         Date: SEPT 30- 0CT 3, 2013         Pace: 1 of 3           Y         Date: SEPT 30- 0CT 3, 2013         Pace: 1 of 3           Y         Current Job #r: 183-19-10001-0001         REPORT #: RT-MP300919-001 R0           PO:         NO:         NO:         NO:           PO:         NO:         NO:         NO:           PO:         NO:         NO:         NO:           Materia:         RePort #: RT-MP300919-001 R0         NO:         NO:           PO:         NO:         NO:         NO:         NO:           PO:         NO:         NO:         NO:         NO:           THORDOR         RePORT #:         RePORT #:         RePORT #:         RePORT #:           Materia:         RePORT MI         RePORT #:         NO:         NO:         NO:           THORDOR         RePORT #:         RePORT #:         RePORT #:         RePORT #:         RePORT #:         RePORT #:           Materia:         Report #:	Attighter Level of falsibility     Date: 1 of 3       Y     Date: SEPT 30-OCT 3, 2013     P.O.E: 1 of 3       ACUREN LOS: NON     DATE: SEPT 30-OCT 3, 2013     REFORT #: RT-MP200919-001 FOI       ORD: DO: MINIMATION     REFORT #: RT-MP200919-001 FOI     P.O.E: 1 of 3       MOREN LOS: NON     DO: MINIMATION     REFORT #: RT-MP200919-001 FOI       MOREN LOS: NON     WO: NIN     WO: NIN       MOREN LOS: NON     WO: NIN     WO: NIN       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MOREN LOS: NON       MOREN LOS: NON     MOREN LOS: NON     MORENCE       MOREN LOS: NON     MORENCE     MORENCE       MORENCE     MORENCE     MORENCE       MOREN LOS: NON     MORE											ada A1B 4C1	Phone: 7 Fax: 7	99.753	3.70
Y         Date: SEP1 30- OCT, 3, 2019         FAGE: 1613           ACUREN JOB #: 183-19-101AL001-0001         REPORT #: RT-MP300919-001 R0         POGE: 1013           ACUREN JOB #: 183-19-101AL001-0001         PO: NA         REPORT #: RT-MP300919-001 R0           PO: NA         PROJECT: PENSTOCK 1         WC: N/A           PROJECT: PENSTOCK 1         WC: N/A         PROJECT: PENSTOCK 1           MITHA         RROLCATION: BAY D'ESPIRI. NL         WC: N/A           MORTINE         REVISION: BAY D'ESPIRI. NL         MITHAL GA           MITHA         REVISION: BAY D'ESPIRI. NL         MITHAL GA           MORTINE         RE	Net: SEPT 3-0. CT 3, 2013     DATE: SEPT 3-0. CT 3, 2013     DATE: SEPT 3-0. CT 3, 2013     DATE: SEPT 3-0. CT 3, 2013       Rate: No.	AAN AAN	ΝΙΝΑΤ	NOL								A Higher Level of Reliability	Acuter		
DATE: SEPT 30- OCT 3, 2013           DATE: SEPT 30- OCT 3, 2013           ACUREN JOB #: 183-19-10NAL001-0001           RENOR 100.1000           RENOR 100.1000           PO: NA           PO: NA           PO: NA           PROJECT: PENSTOCK 1           WO: NA           PROJECT: PENSTOCK 1           VIC: NA           PROVENCION: BAY D'EEPOIR, NL           WO: NA           MATERIA: CS           RENSION: 2018           RENSION: 2018           MATERIA: CS           MATERIA: CS <th>DATE: SEPT 30-OCT 3, 2013 TOTAL OFFICE TEST 30-OCT 3, 2013 FOR INAL OFFICE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 TOTAL OFFICE TEST 30-OCT</th> <th><b>~</b></th> <th></th> <th>PAGE: 1</th> <th>of 3</th> <th></th>	DATE: SEPT 30-OCT 3, 2013 TOTAL OFFICE TEST 30-OCT 3, 2013 FOR INAL OFFICE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 ENCINCE TEST 30-OCT 3, 2013 TOTAL OFFICE TEST 30-OCT	<b>~</b>											PAGE: 1	of 3	
ACUREN JOB #: 183-19-10NAL001-0001         REPORT #: RT-MP300919-001 R0           PO: NA         WO: NA           MORKLOCATION: BAY DESPOIR, NA           REVOLUTION: BAY DESPOIR, NA           REVOLUTION: BAY DESPOIR, NA           REVOLUTION: BAY DESPOIR, NA           MATERIAL CS           REVOLUTION: BAY DESPOIR, NA           MATERIAL CS           MATERIAL CS           REVOLUTION: BAY DESPOIR, NA           MATERIAL CS	ACUERINDER: 183-19-10NAL001-0001     REPORT H: RT-IMP300919-001 R0 DO: MA     CUMA       PO: MA     NO: N/A     NO: N/A       PO: MA     NO: N/A     NO: N/A <td></td> <td></td> <td></td> <td></td> <td></td> <td>ATE: <b>SE</b></td> <td>PT 30- (</td> <td>OCT 3</td> <td>, 201</td> <td>6</td> <td></td> <td></td> <td></td> <td></td>						ATE: <b>SE</b>	PT 30- (	OCT 3	, 201	6				
PO: INA PROJECT: FINATION: AND TARLOCATION: BAY D'ESPOIR, I MATERIAL SARALOCATION: CARALOCATION: CARALOCATION TA4POOL         MATERIAL SA MATERIAL SA REVISION: CARALOCATION: CARALOCATION REVISION: CARALOCATION: CARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOCATION MATERIAL SARALOCATION: CARALOR MATERIAL MATERIAL SARALOCATION: CARALOCATION MATERIAL SARALOCATION MATERIAL SARALOCATION: CARALOR MATERIAL MATERIAL SARALOCATION MATERIAL SARALO	PO: NAT BOLINATION POLICITOR TO BOLINATION POLICITOR TO BOLINATION POLICITOR POLICITOR TO BOLINATION POLICITOR TO BOLINATION TO BOLINATIONO				AC	UREN JO	DB #: 183	3-19-10	VALOC	1-00	01	REPORT #: RT-MP300919-001 R0	0		
MATERIAL DISCOLL           APPENDIX	TATAL LATION IN THE CONTRACT OF A LATION AND						PO: N//		ž			WO: N/A			
B31.3 MFS         Revision: 2018         Revision: 2018         MATERIAL: CS           1.14 PO1         Revision: 8         Revision: 8         Flux Bran: GFA           0         C)         FOOAL SPOT:         138         in         Revision: 8         Flux Bran: GFA           0         VIEW         (in)         (in)         (in)         (in)         (in)         (in)         (in)           1         10-15         NA*         500*         125*         20*         625*         D5         3         1         OR-AMERS         (in)         (in)           1         10-15         NA*         500*         125*         20*         625*         D5         3         1         MATERIA: CS         (in)         (in)           1         10-15         NA*         500*         125*         20*         625*         D5         3         1         (in)	B313.NFS     RENGION: 2018     MATERIAL. CS       7-14.P00     7.3     In.     MATERIAL. CS       7-14.P00     Found     MATERIAL. CS     MATERIAL. CS       7-14.P00     0     FOOL SPOT:     7.33     In.       9.0     0.0     FOOL SPOT:     7.33     In.       9.0     0.00     MATERIAL. CS     MATERIAL. CS       1     0.00     001     MATERIAL     CS       1     0.00     001     MATERIAL     CS     MATERIAL       0     0.01     0.01     0.01     MATERIAL     CS       1     0.00     0.01     0.01     0.01     MATERIAL     CS       1     0.01     0.01     0.01     0.01     0.01     MATERIAL       1     0.01     0.01     0.01     0.01     0.01     MATERIAL       1     0.01     0.01     0.01     0.01     0.01     MATERIAL       1     0.01     0.01     0.01     0.01     MATERIAL     MATERIAL       1     0.01     0.01     0.01     0.01     MATERIAL     MATERIAL       1     0.01     0.01     0.01     0.01     MATERIAL     MATERIAL       1     0.02     0.01     0.01 <td></td> <td></td> <td></td> <td>WOR</td> <td>K Local</td> <td></td> <td></td> <td>POIR,</td> <td>R</td> <td></td> <td></td> <td></td> <td></td> <td></td>				WOR	K Local			POIR,	R					
Matrix         Texastication         Terastication         Terastication </td <td>0         0         FOCUSOF         33         Decision         The concess (p)         The concess (p)</td> <td>B31.3 N</td> <td>JFS 01</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>REVISIO</td> <td>N: 201</td> <td>8</td> <td>MATERIAL: CS FILM REAND: AGEA</td> <td></td> <td></td> <td> </td>	0         0         FOCUSOF         33         Decision         The concess (p)	B31.3 N	JFS 01						REVISIO	N: 201	8	MATERIAL: CS FILM REAND: AGEA			
WE         VEW         OD.         NOM THK         REM         State and	Main         Main         Main         Main         Main         Construents rest rest rest rest rest rest rest re	) 90		FOCAL (	SPOT:	.138	Ŀ.		SCREEN	ks: LE	AD (PB)	.005 IN. (B):	.010 in.		
1         0-15         NA"         500"         725"         205"         625"         D5         3         1           1         15-30         "	0         0-15         NM*         500°         1.25°         20°         6         1 <th1< th=""> <th1< th=""> <th1< th=""> <!--</td--><td>×</td><td></td><td>O.D. (in.)</td><td>NOM. THK. (in.)</td><td>REIN. (in.)</td><td>SOD (in.)</td><td>OFD (in.)</td><td></td><td>TECH #</td><td># of EXP</td><td>One film used per</td><td>tte, unless</td><td>σ</td><td>emarks</td></th1<></th1<></th1<>	×		O.D. (in.)	NOM. THK. (in.)	REIN. (in.)	SOD (in.)	OFD (in.)		TECH #	# of EXP	One film used per	tte, unless	σ	emarks
15-30         " <td>15-30       v<td></td><td>0-15</td><td>"A"</td><td>.500"</td><td>.125"</td><td>20"</td><td>.625"</td><td>D5</td><td>3</td><td>1</td><td></td><td>&gt;</td><td></td><td></td></td>	15-30       v <td></td> <td>0-15</td> <td>"A"</td> <td>.500"</td> <td>.125"</td> <td>20"</td> <td>.625"</td> <td>D5</td> <td>3</td> <td>1</td> <td></td> <td>&gt;</td> <td></td> <td></td>		0-15	"A"	.500"	.125"	20"	.625"	D5	3	1		>		
30-45         i <td>04-45         i<td></td><td>15-30</td><td>77</td><td>u,</td><td>55</td><td>**</td><td></td><td>11</td><td>11</td><td>11</td><td></td><td>&gt;</td><td></td><td></td></td>	04-45         i <td></td> <td>15-30</td> <td>77</td> <td>u,</td> <td>55</td> <td>**</td> <td></td> <td>11</td> <td>11</td> <td>11</td> <td></td> <td>&gt;</td> <td></td> <td></td>		15-30	77	u,	55	**		11	11	11		>		
1         45-50         u         u         u         u         u         u         u         u         u         v         u         v <td>1         1</td> <td></td> <td>30-45</td> <td></td> <td>н</td> <td>23</td> <td></td> <td>11</td> <td>55</td> <td>55</td> <td>11</td> <td></td> <td>~</td> <td></td> <td></td>	1         1		30-45		н	23		11	55	55	11		~		
1         0-15         NA*         .500*         .125*         20*         .625*         D5         3         1         P(1)         Y         Y           1         0-15         NA*         .500*         .125*         20*         .625*         D5         3         1         Y <td>I         0-15         Na<sup>-</sup>         500<sup>-</sup>         125<sup>-</sup>         20<sup>-</sup>         625<sup>-</sup>         10         1         10         11         10         11         10         11         10         11         10         11         10         11         10         11         10<td></td><td>45-50</td><td></td><td>u</td><td>3</td><td>a</td><td>3</td><td>8</td><td>a</td><td>3</td><td>P(1), S(1)</td><td>&gt;</td><td></td><td></td></td>	I         0-15         Na <sup>-</sup> 500 <sup>-</sup> 125 <sup>-</sup> 20 <sup>-</sup> 625 <sup>-</sup> 10         1         10         11         10         11         10         11         10         11         10         11         10         11         10         11         10 <td></td> <td>45-50</td> <td></td> <td>u</td> <td>3</td> <td>a</td> <td>3</td> <td>8</td> <td>a</td> <td>3</td> <td>P(1), S(1)</td> <td>&gt;</td> <td></td> <td></td>		45-50		u	3	a	3	8	a	3	P(1), S(1)	>		
15-30         u         u         u         u         u         u         u         u         u         u         v <td>1         15-30         i<td></td><td>0-15</td><td>"NA"</td><td>.500"</td><td>.125"</td><td>20"</td><td>.625"</td><td>D5</td><td>3</td><td>-</td><td>P(1)</td><td>&gt;</td><td></td><td></td></td>	1         15-30         i <td></td> <td>0-15</td> <td>"NA"</td> <td>.500"</td> <td>.125"</td> <td>20"</td> <td>.625"</td> <td>D5</td> <td>3</td> <td>-</td> <td>P(1)</td> <td>&gt;</td> <td></td> <td></td>		0-15	"NA"	.500"	.125"	20"	.625"	D5	3	-	P(1)	>		
1         30-45         u <td>Image: Note: Note</td> <td></td> <td>15-30</td> <td>33</td> <td>"</td> <td>"</td> <td>33</td> <td>"</td> <td>"</td> <td>**</td> <td>"</td> <td>P(1)</td> <td>&gt;</td> <td></td> <td></td>	Image: Note: Note		15-30	33	"	"	33	"	"	**	"	P(1)	>		
45-50         " <td>Image: Note: Note:</td> <td></td> <td>30-45</td> <td></td> <td>u</td> <td>33</td> <td>33</td> <td>3</td> <td>3</td> <td>8</td> <td>u</td> <td>P(2)</td> <td>&gt;</td> <td></td> <td></td>	Image: Note:		30-45		u	33	33	3	3	8	u	P(2)	>		
0-15         NA"         .500"         .125"         20"         .625"         D5         3         1         S(3) @ 2-5         X         X           1         15-30         "         "         "         "         "         X	Image: Note:       Sec:       Sec: <td></td> <td>45-50</td> <td></td> <td>ä</td> <td>ä</td> <td>8</td> <td>a a</td> <td>33</td> <td></td> <td>u</td> <td></td> <td>&gt;</td> <td></td> <td></td>		45-50		ä	ä	8	a a	33		u		>		
15-30         "         "         "         "         "         "         "         V <td>15-30       u       u       u       u       u       u       u       x         30-45       u       u       u       u       u       u       x(2)       x       x         Anone       30-45       u       u       u       u       u       x       x       x         Anone       Scats       u       u       u       u       x</td> <td></td> <td>0-15</td> <td>NA"</td> <td>.500"</td> <td>.125"</td> <td>20"</td> <td>.625"</td> <td>D5</td> <td>3</td> <td>-</td> <td>S(3) @ 2-5</td> <td></td> <td>×</td> <td></td>	15-30       u       u       u       u       u       u       u       x         30-45       u       u       u       u       u       u       x(2)       x       x         Anone       30-45       u       u       u       u       u       x       x       x         Anone       Scats       u       u       u       u       x		0-15	NA"	.500"	.125"	20"	.625"	D5	3	-	S(3) @ 2-5		×	
30-45 " " " " " " " " X3-45	Image: Note: Note		15-30		77	**	33	22	33	13	**	S(2)	>		
	AND/OR PRODUCTS PROVIDED IN CONNECTION WITH THIS DOCUMENT AND ALL FUTURE BALES ARE SUBJECT TO AND SHALL BE GOVERNED BY THE "ACUREN STANDARD SERVICE TERMS". IN EFFECT UCTS ARE COLLERNIS ARE ANLIABLE AT WWW.ACURENS.OFFERMIS, ARE EXPRESSLY INCORPORATED BY REFERENCE INTO THIS DOCUMENT AND SHALL SUPERSEDE ANY UCTS ARE COLLENT GRACEED OTHERWISE IN THAT OTHER DOCUMENT). Responsible for verifying fathe acceptance standard lised in the report have been received by Clent and point/lying fathen acceptance standard lised in the report have been received by Clent and point/lying fathen acceptance standard lised in the report have been received by Clent and point/lying fathen acceptance standard lised in the report have been received by Clent and point/lying fathen acceptance accomment. TED NAME DELEAT SIGNATURE TED NAME CLEART B& ACHONOMLEDGED BY TED NAME DETED & ACHONOMLEDGED BY TED NOTICED BY TED NOT		30-45	77	77	55	33	77	55	11	11	S(3) @ 36-45		×	
	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY 2 <sup>rd</sup> Technician							DTR NC	.: N/A						
DTR NO · N/A	2 <sup>rd</sup> Technician	CLIENT PRINTED NAME		A	CLIENT SIGNA	TURE MLEDGED BY									
INTED NAME CLIENT SIGNATURE ACKNOWLEDGED BY DTR NO.: N/A	2 <sup>rd</sup> Technician	J.													
NTED NAME CLIENT SIGN/TURE ACCEPTED & ACNOWLEDGED BY	2 <sup>rd</sup> Technician	L PINHOR	N												
CLIENT PRINTED NAME CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY		1 <sup>st</sup> Technician RT II Reg. # 1416	33		2 <sup>nd</sup> Technic	ian									
CLIENT PRINTED NAME     DER NO.: N/A       DLIENT PRINTED NAME     DTR NO.: N/A       CLIENT SIGNATURE     ACCEPTED & ACKNOWLEDGED BY       ACCEPTED & ACKNOWLEDGED BY     ACCEPTED & ACKNOWLEDGED BY       MICHAEL PINHORN     2 <sup>rd</sup> Technician       CGSB RT II Reg. # 14163     2 <sup>rd</sup> Technician		0/07/2016	~									(Generated Usino: CAN-O	JA-02F018 R04	- 05/07/2	(2018)

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# NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

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

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Page 2 of 3

KEJ.	×																							
ACC.		~	>	>	1	>	~	~	~	~	>	>	>	 ~	>	>	1				>	~	~	>
REMARKS	P/S(3) @ 48-50		P(1)												S(2)	S(2)								
# of EXP		1	"	"	22	1	77	22	"	-	**	3	3	1	-	3					1	27	22	3
TECH #	33	3	"	33	11	8	33	33	33	3	"	**		S	3	33	33				3	22	33	33
FILM TYPE	"	D5	"	"	33	<b>D5</b>	33	33	"	D5	"			D5	D5		"				<b>D5</b>	22	33	33
OFD (in.)	33	.625"	"	"	33	.625"	11	33	"	.625"	"	"		.625"	.625"		33				.625"	33	33	77
SOD (in.)	33	20"	"	"	33	02	11	33	"	20"	33	"		20"	20"		33				02		33	77
REIN. (in.)	11	.125"	"	"	"	.125"	11	33	"	.125"	33	**	8	.125"	.125"	3	"				.125"	33	33	77
NOM. THK. (in.)	11	.500"	11	"	11	.500"	11	11	33	.500"	19	3	æ	.500"	.500"	æ	11				.500"	11	11	33
0.D.	11	"A"	"	"	11	"A"	и	11	11	"A"	"	3	8	"AN	"A"	3	11				"A"		11	ų
VIEW (in.)	45-60	60-75	75-90	90-105	105-107	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-107	0-8	0-15	30-45	45-60				0-15	15-30	30-45	45-50
MS																								
IDENTIFICATION	PENSTOCK 1	W3	<b>CAN 106S</b>			PENSTOCK 1	W4	<b>CAN 106S</b>						PENSTOCK 1 CAN 111 N	PENSTOCK 1	W3R1	<b>CAN 106S</b>		RT COMPIETED AFTER		PENSTOCK 1	W1	<b>CAN 106S</b>	

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# NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 68 of 92

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

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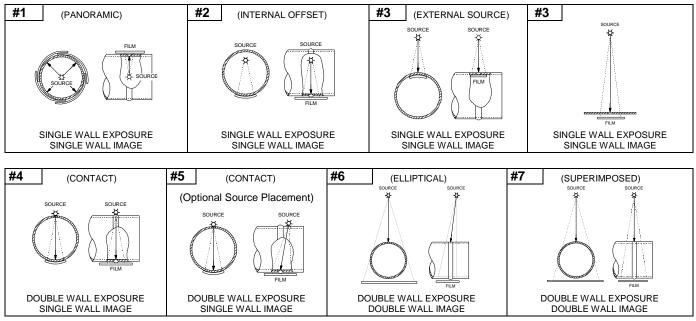
Page 3 of 3

IDENTIFICATION	SW	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	-		>	
		15-30	11	я	3	3	3	a	a	a		>	
		30-45	11	11	77	11	11	н	u.	11		>	
		45-50	11	11	23	11	11	н	11	11		>	
PENSTOCK 1		0-15	"A"	.200"	.125"	20"	.625"	D5	3	1		>	
		15-30	11	77	33	77	3	н	u	3		>	
		30-45	33	33	3	33		11		3		>	
		45-60	3	8	3	3	3			8		>	
		60-75	"A"	.500"	.125"	20"	.625"	D5	3	1		>	
		75-90	3	3	3	3	3	.,	'n			>	
		90-105	3	3	3	3	3	.,	'n			>	
		105-107	23	"	<b>33</b>	"	**	"	**	.,		>	
PENSTOCK 1		0-15	"NA"	.500"	.125"	20"	.625"	D5	3	1		>	
		15-30	77	"	33	"	23					>	
CAN 106S		30-45	11	"	33	"	23					>	
		45-60	77	"	<b>33</b>	"	.,	"		"		>	
		60-75	"NA"	.500"	.125"	20"	.625"	D5	3	+		>	
		75-90	3	3	3	×	3	.,	'n	33		>	
		90-105	77	"	<b>33</b>	**	.,	"	.,	"		>	
		105-107	11	11	11	11	11	н	н	11		>	
PENSTOCK 1 CAN 111 N		0-8	"NA"	.200"	.125"	20"	.625"	D5	3	1		>	
<b>NO CHANGE IN WELD</b>													
INTEGRITY AFTER HOLD						[							



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

# TECHNIQUES:



### **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.

٠	IDENTIFICATION	WS	(cm.)	(NPS)	NOM THK. (ITITI)	REIN (ITIT)	500- 0000	CPD (mm)	TYPE	# TEICH	# of EXP	REMARKS	ACC (*)	(#)
1	BGX-4	MF/CH	0-35	12	9.62	3.0	283.1	12.52	D6	5	1	P(1) cluster, IS(2) @ 4-5cm (4.5mm)	1	
		MF/CH	35-70	12	9.52	3.0	283.1	12.52	05	5	1	IP(2) @ 18-21cm (3mm)	4	
		MF/CH	70-0	12	9.52	3.0	283.1	12.52	Dő	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	DS	5	1		×	
	1,20210000	MF/GH	35-70	12	9.52	3.0	283.1	12.52	05	5	1	ES(1)	1	
		MF/CH	70-0	12	9.52	3.0	283.1	12.52	D5	б.	1		*	

### LEGEND:

### WELDING DISCONTINUITIES:

C = CrackIPIncomplete PenetrationO= OtherER = Excess ReinforcementLC= Low Cover (Insufficient Reinforcement)P= Porce	Alisalignment (hi/low)     TI     = Tungsten Inclusion       Dther Relevant Indications     EUC     = External Undercut       Porosity     IUC     = Internal Undercut       Elongated Slag     State     State
--	---

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 = Bac DIA = Diar		= Front <b>. THK</b> .= Nomi	nal Wall Thickr		Object to Filn     Reinforceme			Pipe schedule Source to obje		WS = Wel	der Symbol
AGFA F	ILM CLAS	SIFICATIO	ON:								
FILM	ASTM	ISO	FILM	ASTM	ISO	FILM	ASTM	ISO	FILM	ASTM	ISO
TYPE	E1815	11699-1	TYPE	E1815	11699-1	TYPE	E1815	11699-1	TYPE	E1815	11699-1
D3		C2	D4		C3	D5		C4	D7		C5

	Bay d'Espoir Penst	ock 1 Section Replacemen	i anu welu	Incrui bis	mient
				Page 7	0 of 92
		Acuren Group Inc. 1 Austin Street St. John's, NL, Canada A1 www.acuren.com	B 4C1	Phone: Fax:	709.753.2 709.753.7
ACUREN		A Higher Level of Reliab	ility		
To: Nalcor Energy				PAGE: 1	of 2
		DATE: Oct 3 <sup>rd</sup> /2019			
	Acu	REN JOB #: 183-19-10NAL0	01-0001		
	100	REPORT #: VT-GW031019-0			
		PO: N/A	WO: N/	^	
ATTENTION: Dylan Drake	Mody	LOCATION: Bay D'Espoir, N		^	
ATTENTION. Dylan Drake	VVORK	LOCATION. Day D Lopoli, N			
Project: Penstock # 1 Emerge	ncy Repair				
		Exterior) & reinforcement	plate (Exter	ior)	
tem(s) Examined: Can 106 South			plate (Exter		
Item(s) Examined: Can 106 South PART #: See below	insert plate (Interior & I MATERIAL: Carbon s				
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F	insert plate (Interior & I MATERIAL: Carbon s				
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual	insert plate (Interior & I MATERIAL: Carbon s				
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS:	insert plate (Interior & I MATERIAL: Carbon s Per Client Request			ies	
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F	insert plate (Interior & I MATERIAL: Carbon s Per Client Request		KNESS: Vari	018/ 2017	017
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS: ACCEPTANCE STANDARD: ASME B31.3NFS PROCEDURE/TECHNIQUE: CAN-VT-14P001	insert plate (Interior & I MATERIAL: Carbon s Per Client Request		REVISION: 2	018/ 2017	017
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS: ACCEPTANCE STANDARD: ASME B31.3NFS PROCEDURE/TECHNIQUE: CAN-VT-14P001 METHOD: Visual	insert plate (Interior & I MATERIAL: Carbon s Per Client Request		REVISION: 2	018/ 2017 206 Dec/ 20	017 I/A
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS: ACCEPTANCE STANDARD: ASME B31.3NFS PROCEDURE/TECHNIQUE: CAN-VT-14P001 METHOD: Visual	insert plate (Interior & I MATERIAL: Carbon s Per Client Request , ASME SEC. IX	steel Thic	REVISION: 2 REVISION: F	018/ 2017 206 Dec/ 20	
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS: ACCEPTANCE STANDARD: ASME B31.3NFS PROCEDURE/TECHNIQUE: CAN-VT-14P001 METHOD: Visual EQUIPMENT TYPE: N/A MA	insert plate (Interior & I MATERIAL: Carbon s Per Client Request , ASME SEC. IX	MODEL: N/A	REVISION: 2 REVISION: F	018/ 2017 206 Dec/ 20 N	I/A
Item(s) Examined: Can 106 South PART #: See below SCOPE: Visual Examination As F TYPE OF INSPECTION: Visual TEST DETAILS: ACCEPTANCE STANDARD: ASME B31.3NFS PROCEDURE/TECHNIQUE: CAN-VT-14P001 METHOD: Visual EQUIPMENT TYPE: N/A MA	insert plate (Interior & I MATERIAL: Carbon s Per Client Request , ASME SEC. IX NUFACTURER: N/A	MODEL: N/A INATION INTENSITY: OUTPUT > 100	REVISION: 2 REVISION: 7 REVISION: F S/N:	018/ 2017 206 Dec/ 20 N	I/A

See page 2 for results

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CLIENT REPRESENTATIVE: DTR No.: N/A **TECHNICIAN:** an la Late All JONATHAN WHITTEN **Glenn Whitten CWB II 3954** CGSB 16212 1st Technician 2nd Technician



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

NP-NLH-011, Attachment 1



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

Page 2 of 2

To: Nalcor	Energy
Attention :	<b>Dylan Drake</b>

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			Accept
Can #106 Re-pad	FW#6	Fillet	Re-pad to Shell	03/10/19 - 1200	Accept

	Bay	d'Espoir Penstock 1 Section Replaceme	ent and Weld Re	furbishment
1 Austin Street       Phone: 709.753.21         St. John's, NL, Canada A1B 4C1       Fax: 709.753.21         WWW.acuren.com       Fax: 709.753.21         ACUREN       A Higher Level of Reliability         NONDESTRUCTIVE EXAMINATION       Fax: 709.753.21         To: Nalcor Energy       Page: 1 of 1         DATE: Oct 3 <sup>rd</sup> /2019       Acuren Job #: 183-19-10NAL001-0001         REPORT #: VT-GW031019-002 R0       PO: N/A         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       Revision: 2018/2017         Receptance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017       Revision: 2018/2017         Macceptrance Standard: CAN-VT-14P001       Revision: 2018/2017       Revision: 2018/2017         Macceptrance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017         Macceptrance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017         Macceptrance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017         Macceptrance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017         Macceptrance Standard: ASME B31.3NFS, ASME SEC, IX       Revision: 2018/2017         Mac				age 72 of 92
NONDESTRUCTIVE EXAMINATION To: Nalcor Energy PAGE: 1 of 1 Date: Oct 3 <sup>rd</sup> /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: Rofe Dec/ 2017 Metho: Visual Equipment Type: NA Manufacturer: NA ModeL: NA S/N: NA LIGHT Source: Head lamp LILUMINATION INTENSITY: OUTPUT > 100 FC LIGHT METER S/N: 150803637 Cal Due: FEB 22 <sup>rd</sup> /2020 Adotinonal Equipment: N/A Magnification Power: N/A		1 Austin Street St. John's, NL, Canada	F	
To: Nalcor Energy PAGE: 1 of 1 DATE: Oct 3 <sup>rd</sup> /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: 2018/ 2017 METHOD: Visual EQUIPMENT TYPE: N/A MANUFACTURER: N/A MODEL: N/A S/N: N/A LIGHT SOURCE: Head Iamp ILLUMINATION INTENSITY: OUTPUT > 100 FC LIGHT METER S/N: 150803637 CAL DUE: FEB 22 <sup>nd</sup> /2020 ADDITIONAL EQUIPMENT: N/A MASURE CATION POWER: N/A			iability	
Date: Oct 3 <sup>rd</sup> /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         Type of INSPECTION:       Visual       Revision:       2018/ 2017         Recoburge:       CAN-VT-14P001       Revision:       2018/ 2017         Method:       Visual       Equipment Type:       N/A       Model:       N/A         Light Source:       Head Iamp       ILLUMINATION INTENSITY:       OUTPUT > 100 FC       Light Meters S/N:       150803637       Cal Due:       FEB 22 <sup>rd</sup> /2020         Additional Equipment:       N/A       Magnification Power:       N/A		lion		
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 REVISION: R06 Dec/ 2017 METHOD: Visual Equipment Type: N/A MANUFACTURER: N/A MODEL: N/A S/N: N/A LIGHT SOURCE: Head Iamp ILLUMINATION INTENSITY: OUTPUT > 100 FC LIGHT METER S/N: 150803637 Cal Due: FEB 22 <sup>nd</sup> /2020 ADDITIONAL EQUIPMENT: N/A MASINE AND POWER: N/A	To: Nalcor Energy		PA	GE: 1 of 1
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:       Revision: 2018/ 2017         Acceptance Standard:       ASME B31.3NFS, ASME SEC. IX         Procedure/Technique:       CAN-VT-14P001         Method:       Visual         Equipment Type:       N/A         Manufacturer:       N/A         Model:       N/A         Source:       Head lamp         ILLUMINATION INTENSITY:       OUTPUT > 100 FC         Light Meters S/N:       150803637       Cal Due:         Additional Equipment:       N/A         Magnification Power:       N/A		DATE: Oct 3 <sup>rd</sup> /2019		
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:         PART #:       See below       MATERIAL:         Carbon steel       THICKNESS:       Varies         SCOPE:       Visual Examination As Per Client Request       THICKNESS:         TYPE OF INSPECTION:       Visual       Test Details:         Acceptance Standard:       ASME B31.3NFS, ASME SEC. IX       Revision:       2018/ 2017         Procedure/Technique:       CAN-VT-14P001       Revision:       R66 Dec/ 2017         Method:       Visual       Equipment Type:       NA       MANUFACTURER:       NA         Equipment Type:       NA       MANUFACTURER:       Model:       N/A       S/N:       N/A         Light Source:       Head Iamp       ILLUMINATION INTENSITY:       OUTPUT > 100 FC       Light Metrer S/N:       150803637       Cal Due:       FEB 22 <sup>nd</sup> /2020         Additional Equipment:       N/A       Magnification Power:       N/A		ACUREN JOB #: 183-19-10NA	L001-0001	
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 REVISION: R06 Dec/ 2017 METHOD: Visual EQUIPMENT TYPE: N/A MANUFACTURER: N/A MODEL: N/A S/N: N/A LIGHT METER S/N: 150803637 CAL DUE: FEB 22 <sup>nd</sup> /2020 ADDITIONAL EQUIPMENT: N/A MAGNIFICATION POWER: N/A		REPORT #: VT-GW03101	9-002 R0	
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 METER S/N: 150803637 CaL DUE: FEB 22 <sup>nd</sup> /2020 Additional Equipment: N/A MAGNIFICATION POWER: N/A		PO: N/A	WO: <b>N/A</b>	
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 METER S/N: 150803637 CAL DUE: FEB 22 <sup>nd</sup> /2020 ADDITIONAL EQUIPMENT: N/A MAGNIFICATION POWER: N/A	ATTENTION: Dvlan Drake	WORK LOCATION: Bay D'Espoir	. NL	
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 Meters S/N:       150803637       Cal Due: FEB 22 <sup>nd</sup> /2020         Additional Equipment:       N/A       Magnification Power: N/A	-	•	,	
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         LIGHT SOURCE:       Head lamp       ILLUMINATION INTENSITY:       OUTPUT > 100 FC         LIGHT METER S/N:       150803637       Cal Due:       FEB 22 <sup>nd</sup> /2020         ADDITIONAL EQUIPMENT:       N/A       MAGNIFICATION POWER:       N/A		-		
SCOPE:       Visual Examination As Per Client Request         TYPE OF INSPECTION:       Visual         TEST DETAILS:       Revision: 2018/ 2017         ACCEPTANCE STANDARD:       ASME B31.3NFS, ASME SEC. IX         PROCEDURE/TECHNIQUE:       CAN-VT-14P001         METHOD:       Visual         EQUIPMENT TYPE:       N/A         MANUFACTURER:       N/A         MODEL:       N/A         S/N:       N/A         LIGHT METER S/N:       150803637         CAL DUE:       FEB 22 <sup>nd</sup> /2020         ADDITIONAL EQUIPMENT:       N/A		RIAL: Carbon steel	HICKNESS: Varies	
TYPE OF INSPECTION:       Visual         TEST DETAILS:       REVISION: 2018/ 2017         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         EQUIPMENT TYPE:       N/A       MANUFACTURER:       N/A         LIGHT SOURCE:       Head lamp       ILLUMINATION INTENSITY:       OUTPUT > 100 FC         LIGHT METER S/N:       150803637       Cal DUE:       FEB 22 <sup>nd</sup> /2020         ADDITIONAL EQUIPMENT:       N/A       MAGNIFICATION POWER:       N/A				
Test Details:         Acceptance Standard: ASME B31.3NFS, ASME SEC. IX         Revision: 2018/ 2017         PROCEDURE/TECHNIQUE: CAN-VT-14P001         METHOD: Visual         EQUIPMENT TYPE: N/A       MANUFACTURER: N/A         MODEL: N/A       S/N:         N/A         LIGHT SOURCE: Head lamp         ADDITIONAL EQUIPMENT: N/A         MAGNIFICATION POWER: N/A				
ACCEPTANCE STANDARD: ASME B31.3NFS, ASME SEC. IX 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 LILLUMINATION INTENSITY: OUTPUT > 100 FC LIGHT METER S/N: 150803637 CAL DUE: FEB 22 <sup>nd</sup> /2020 ADDITIONAL EQUIPMENT: N/A MAGNIFICATION POWER: N/A				
PROCEDURE/TECHNIQUE:       CAN-VT-14P001       REVISION:       R06 Dec/ 2017         METHOD:       Visual		. IX	REVISION: 2018	2017
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 22 <sup>nd</sup> /2020       ADDITIONAL EQUIPMENT:     N/A     MAGNIFICATION POWER:     N/A				
LIGHT SOURCE:       Head lamp       ILLUMINATION INTENSITY:       OUTPUT > 100 FC         LIGHT METER S/N:       150803637       Cal Due:       FEB 22 <sup>nd</sup> /2020         ADDITIONAL EQUIPMENT:       N/A       Magnification Power:       N/A	METHOD: Visual			
LIGHT METER S/N: 150803637       Cal Due: FEB 22 <sup>nd</sup> /2020         Additional Equipment: N/A       Magnification Power: N/A	EQUIPMENT TYPE: N/A MANUFACTURER	: N/A MODEL: N/A	S/N:	N/A
ADDITIONAL EQUIPMENT: N/A MAGNIFICATION POWER: N/A	LIGHT SOURCE: Head lamp	ILLUMINATION INTENSITY: OUTPUT >	100 FC	
		LIGHT METER S/N: 150803637	CAL DUE: FE	B 22 <sup>nd</sup> /2020
SUPPLEMENTAL NDT REPORT ATTACHED?: Yes PROCEDURE DEMONSTRATION REQUIRED?: No	ADDITIONAL EQUIPMENT: N/A	MAGNIFICATION POWER: N/A		
	SUPPLEMENTAL NDT REPORT ATTACHED?: Yes	PROCEDURE DEMONSTRATION REQUIR	RED?: No	

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

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**CLIENT REPRESENTATIVE:** DTR No.: N/A **TECHNICIAN:** an Re have JONATHAN WHITTEN **Glenn Whitten CWB II 3954** CGSB 16212 1st Technician 2nd Technician

**REVIEWER:** 

Curran 10/04/2019

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

NP-NLH-011, Attachment 1

# **APPENDIX D**

THICKNESS MEASUREMENTS DATA

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

Phone: 709.753.2100 709 753 7011 Fax:

A Higher Level of Reliability



# NONDESTRUCTIVE EXAMINATION

CLIENT: Nalcor Energy

PAGE: 1 of 4

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

REVISION: N/A

REVISION: R07 / Nov 30, 2017

SCOPE: To perform a 0 degree ultrasonic survey as per client's request.

TYPE OF INSPECTION: Ultrasonic

**TEST DETAILS:** 

ACCEPTANCE STANDARD: Client's Information PROCEDURE/TECHNIQUE: CAN-UT-14T001

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									Refer	RENCE		
	NGLE (°)	Probe Type	CRYSTAL SIZE	Freq. (MHz)	SERIAL NUMBER	Damping Ω	Test From	REFERENCE REFLECTOR	Transfer Value	Db	% 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 10<sup>th</sup> 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 acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (www.acuren.com/serviceterms) in effect when the services were ordered.

CLIENT:			DTR No.: N/A
Acuren		CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	_
TECHNICIAN:	Andrew Rideout	Glenn Whitten	
	1 <sup>st</sup> Technician CGSB II # 14136	2 <sup>nd</sup> Technician	_
REVIEWER:	Curran 01/28/2020		(Generated Using: CAN-QUA-02F007 R07 – 07/20/





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

Page 2 of 4
Penstock # 1
View downstream
View downstream
North
"A"
Middle
"B"
View downstream

Client acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW) are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provide by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (www.acuren.com/servicelerms) in effect when the services were ordered.

(			
CLIENT:			DTR No.: N/A
Acuren	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	_
TECHNICIAN:	Andrew Rideout	Glenn Whitten	
	1 <sup>st</sup> Technician CGSB II # 14136	2 <sup>nd</sup> Technician	_
REVIEWER:	Culture 01/28/2020		(Generated Using: CAN-QUA-02F007 R07 – 07/20/2018)



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

# **Nalcor Energy**

Page 3 of 4

		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 acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (www.acuren.com/serviceterms) in effect when the services were ordered.

CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

**Glenn Whitten** 

2<sup>nd</sup> Technician

CLIENT: CLIENT PRINTED NAME ACUREN TECHNICIAN:

Andrew Rideout 1<sup>st</sup> Techniciar CGSB II # 14136

DTR No.: N/A

**REVIEWER:** Curran 01/28/2020

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



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

**Nalcor Energy** 

Page 4 of 4

		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 acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (<u>www.acuren.com/serviceterms</u>) in effect when the services were ordered.

CLIENT:			DTR No.: N/A
	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	_
ACUREN	ALA		
TECHNICIAN:	Andrew Rideout	Glenn Whitten	
	1 <sup>st</sup> Technician CGSB II # 14136	2 <sup>nd</sup> Technician	
REVIEWER:	Curran 01/28/2020		(Generated Using: CAN-QUA-02F007 R07 – 07/20/2018

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS



<b>PROJECT TITLE:</b> Penstock 1		Inspection	CLIENT:	Nev Hyc	vfoundland Labrador Iro	
KLEINSCHN	AIDT PR	ROJECT NO:	2670021.01	LOCATIO	N:	Bay D'Espoir
SUBJECT:	Pensto	ock 1 – steel t	hickness measureme	nts		
PROJECT MANAGER: Scott Hancock						
TECHNICAL LEAD/ADVISOR: Chris Vella			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:		
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		
	Performed By:		
	Checked By:		
	TA Approval:		

[Insert PE Stamp]

## NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 80 of 92



## **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:**

#### A285 Steel (upper section of penstock) (Ref.3)

F<sub>yA285</sub> = 26 ksi Yield Stress

F<sub>uA285</sub> = 50 ksi Ultimate Tensile Stress

#### CSA G40.8 Grade B (Ref.10)

- F<sub>y</sub> = 40 ksi (CSA G40.8 Grade B for thicknesses less than and equal to 0.625 inches)
- F<sub>y</sub> = 38 ksi (CSA G40.8 Grade B for thicknesses between 0.625 inches and 1 inch incl.)
- F<sub>y</sub> = 36 ksi (CSA G40.8 Grade B for thicknesses between 1 inch and 1.5 inches)
- F<sub>u</sub> = 65 ksi Ultimate Tensile Stress

## NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 81 of 92

<b>Kleinschmidt</b>	Phone: 888.224.5942 www.KleinschmidtGroup.com	Page:2 Project No.: 2670	021.01
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 <sub>s</sub> = 3.7 kPa	Ground snow load
S <sub>r</sub> = 0 kPa	No ponding on penstock (rain load)
$C_{b} = 0.8$	Basic roof snow load factors
C <sub>w</sub> = 1.0	Wind exposure
$C_{s} = 0.33$	Slope factor
C <sub>a</sub> = 1.0	Shape factor

S = 20.61 psf

#### Live Load

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

## NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 82 of 92

<b>Kleinschmidt</b>	Phone: 888.224.5942 www.KleinschmidtGroup.com	Page:3 Project No.: 2670	021.01
Project: Bay D'Espoir Penstock 1	<u> </u>	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<sup>'</sup> = 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:

 $\gamma_w$  = 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

E) Allowahle pressures (kPa)/External Pressures (kPa) Beference 3	EXTERNAL PI	EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR 3	<u>CK 1 BAY D'ESPOIR</u>		Page 4
				Unit Weight of Water= 62.4 pcf	
Height of water above conduit= 0	feet	Live load: 100.00	psf	P <sub>v</sub> = 0	
Height of rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150 lb/ft <sup>3</sup>	
Height of fill above conduit= 2	feet			Fill Unit Weight= 120 lb/ft <sup>3</sup>	
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) $W_{f}$ 1531.8 lb/ft	100 psf per foot section
	Assume well				
Buoyancy Factor R <sub>w</sub> = 1	drained = $1$			w <sub>s</sub> = 316 lb/ft	
B_prime= 0.2330				~	
(coarse grain soils with fines) E_prime= 500	psi				
E= 3000000	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 $Q/q_a = 0.85677$
l= 0.0057	inches <sup>4</sup>			External pressure with snow and live= 4.78 DSi	Ratio 0/a.= 0.953437
FS= 2					
Allowable pressure $q_a$ = 5.01	psi				
Allowable pressures (kPa)/External Pressures (kPa) Reference	erence 3				
Diameter 17 feet				Unit Weight of Water= 62.4 pcf	
Height of water above conduit= 0	feet	Live load: 100.00	psf		
Height of rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150 lb/ft <sup>3</sup>	
Height of fill above conduit= 2	feet			Fill Unit Weight= 120 lp/ft <sup>3</sup>	
Total Height of Soil= 3	feet	(for DL calc) $t= 0.44$	inches	6655.2	
OD Conduit Diameter= 17.06466667	feet	ID: 17.00	feet	(live load) $W_{f}$ 1706.5 lb/ft	
	Assume well				
Buoyancy Factor R <sub>w</sub> = 1	drained = $1$			w <sub>s</sub> = 351.7 lb/ft	
B_prime= 0.23302752				W <sub>steel</sub> = 957.7 lb/ft	
(coarse grain soils with fines) E_prime= 500	psi				
E= 3000000	psi				
b= 1				External pressure with vacuum= 3.10 psi	Ratio Q/q <sub>a</sub> = 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 <sup>4</sup>			External pressure with snow and live= 3.72 psi	Ratio $Q/q_{a}$ = 0.940645
FS= 2					

psi

```
Allowable pressure q<sub>a</sub>= 3.96
```

```
(coarse grain soils with fines) E_prime= 500
E= 30000000
b= 1
t_{97.5}= 0.388
I= 0.0049
                 OD Conduit Diameter= 17.0646
                                                                         B_prime= 0.23302
                                                         Buoyancy Factor R<sub>w</sub>= 1
                                                                                                                                                                                           FS= 2
Total Height of Soil= 3
```

```
Height of fill above conduit= 2
```

```
Height of rip rap above conduit= 1
```

```
Height of water above conduit= 0
```

```
(coarse grain soils with fines) E_prime= 500
E= 30000000
b= 1
t<sub>97.5</sub>= 0.408
1= 0.0057
FS= 2
Allowable pressure q<sub>a</sub>= 5.01
Allowable pressures (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa) Records (kPa) Records (kPa)/External Pressures (kPa) Records (kPa) Records (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa)/External Pressures (kPa) Records (kPa)/External Pressures (kPa)/Extern
```

Base Material

At Joints

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 <sub>1</sub> ID=	17.00 feet
D <sub>2</sub> ID=	15.25 feet

											Base N	Aaterial	At J	oints	
	ocation	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) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	TERIOR am End of Condui	•													
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
1B	0+00	8.50	3 4	0.5110 0.5210	0.525	0.5	2.2% 4.2%	0.5165	549.50	17000	4064.9	0.24	5807.0	0.34	
			5	0.5250		0.5	5.0%								
1C	0+00	8.50	6 7	0.5300	0.519	0.5	6.0% 5.2%	0.5044	549.50	17000	4162.7	0.24	5946.7	0.35	
10	0.00	0.50	8	0.5210	0.515	0.5	4.2%	0.5044	545.50	1,000	4102.7	0.24	55-10.7	0.00	
10A	00+81	8.50	9 10	0.5110 0.5360	0.544	0.5	2.2% 7.2%	0.5299	549.50	17000	3962.3	0.23	5660.5	0.33	
104	00101	0.50	11	0.5500	0.544	0.5	10.0%	0.5255	545.50	17000	5502.5	0.25	5000.5	0.55	
			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 15	0.5250 0.5290		0.5	5.0% 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 18	0.5130 0.5090		0.5	2.6% 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 21	0.4500 0.4410		0.4375 0.4375	2.9% 0.8%								
20B	01+63	8.50	22	0.4410	0.447	0.4375	2.4%	0.4444	549.50	17000	4724.3	0.28	6749.0	0.40	
			23 24	0.4460 0.4460		0.4375 0.4375	1.9% 1.9%								
20C	01+63	8.50	24	0.4400	0.449	0.4375	3.3%	0.4427	549.50	17000	4742.7	0.28	6775.3	0.40	
			26 27	0.4460 0.4480		0.4375 0.4375	1.9% 2.4%								
30A	02+35	8.50	27	0.4480	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%								
30B	02+35	8.50	30 31	0.4650 0.4940	0.467	0.4375 0.4375	6.3% 12.9%	0.4062	546.8201	17000	5460.9	0.32	7801.2	0.46	
			32	0.4750		0.4375	8.6%								
30C	02+35	8.50	33 34	0.4330 0.4330	0.440	0.4375 0.4375	-1.0% -1.0%	0.4266	546.8201	17000	5199.5	0.31	7427.9	0.44	
			35	0.4470		0.4375	2.2%								
40A	03+23	8.50	36 37	0.4410 0.4470	0.444	0.4375 0.4375	0.8%	0.4251	536.1772	17000	6323.5	0.37	9033.5	0.53	
			38	0.4510		0.4375	3.1%								
40B	03+23	8.50	39 40	0.4330 0.4510	0.444	0.4375 0.4375	-1.0% 3.1%	0.4251	536.1772	17000	6324.1	0.37	9034.4	0.53	
			41	0.4330		0.4375	-1.0%								
40C	03+23	8.50	42 43	0.4480 0.4760	0.473	0.4375 0.4375	2.4% 8.8%	0.4678	536.1772	17000	5746.7	0.34	8209.5	0.48	
			44	0.4710		0.4375	7.7%								
48A	03+92	8.50	45 46	0.4720 0.4520	0.454	0.4375 0.4375	7.9% 3.3%	0.4462	527.7817	17000	6856.0	0.40	9794.2	0.58	
-10/1	03.32	0.50	47	0.4510	0.454	0.4375	3.1%	0.4402	527.7027	1,000	0050.0	0.40	5754.2	0.50	
48B	03+92	8.50	48 49	0.4580 0.4560	0.459	0.4375 0.4375	4.7% 4.2%	0.4386	527.7817	17000	6976.3	0.41	9966.1	0.59	
400	03132	0.50	50	0.4500	0.455	0.4375	2.9%	0.4580	527.7017	17000	0570.5	0.41	5500.1	0.55	
48C	03+92	8.50	51 52	0.4700 0.4640	0.466	0.4375 0.4375	7.4% 6.1%	0.4449	527.7817	17000	6876.8	0.40	9824.0	0.58	
460	03132	0.50	53	0.4770	0.400	0.4375	9.0%	0.4445	527.7017	17000	0070.0	0.40	5024.0	0.50	
58A	04+82	8.50	54 55	0.4560 0.4190	0.426	0.4375 0.4375	4.2%	0.4119	516.9473	17000	8590.3	0.51	12271.8	0.72	
JUN	04102	0.50	56	0.4250	0.420	0.4375	-2.9%	0.4115	510.5475	17000	0550.5	0.51	12271.0	0.72	
58B	04+82	8.50	57 58	0.4330 0.4400	0.450	0.4375 0.4375	-1.0% 0.6%	0.4248	516.9473	17000	8330.3	0.49	11900.5	0.70	
300	04782	8.30	59	0.4460	0.430	0.4375	1.9%	0.4246	510.9475	17000	0330.3	0.45	11900.3	0.70	
58C	04+82	8.50	60 61	0.4650 0.4390	0.450	0.4375 0.4375	6.3% 0.3%	0.4315	516.9473	17000	8200.9	0.48	11715.6	0.69	
560	04102	0.50	62	0.4540	0.450	0.4375	3.8%	0.4515	510.5475	17000	0200.5	0.40	11/15.0	0.05	
69A	05+75	8.50	63 64	0.4560 0.4410	0.447	0.4375 0.4375	4.2% 0.8%	0.4169	509.73	17000	9250.9	0.54	13215.6	0.78	
USA	05+75	8.30	65	0.4410	0.447	0.4375	-0.3%	0.4105	505.75	17000	5250.5	0.34	13213.0	0.78	
69B	05+75	8.50	66 67	0.4650 0.4530	0.448	0.4375 0.4375	6.3% 3.5%	0.4342	509.73	17000	8884.3	0.52	12691.8	0.75	
038	0715	0.00	68	0.4520	0.448	0.4375	3.3%	0.4042	303.73	17000	0004.3	0.52	12051.8	0.75	
69C	05+75	8.50	69 70	0.4400 0.4510	0.455	0.4375	0.6% 3.1%	0.4472	509.73	17000	8625.9	0.51	12322.7	0.72	
090	0715	0.00	71	0.4550	0.435	0.4375 0.4375	4.0%	0.4472	303.73	17000	0023.9	0.51	12322.1	0.72	
70.4	06+64	8 50	72	0.4590	0.432	0.4375	4.9%	0.4278	509.02	17000	9090.2	0.53	12986.0	0.76	
79A	00+04	8.50	73 74	0.4310 0.4310	0.432	0.4375 0.4375	-1.5% -1.5%	0.4278	209.02	17000	3030.5	U.53	12980.0	0.76	
700	06.64	0.50	75	0.4350	0	0.4375	-0.6%	0.0077	F00 00	17000	00.55	0.53	10770 4	0.75	
79B	06+64	8.50	76 77	0.4420 0.4400	0.440	0.4375 0.4375	1.0% 0.6%	0.4347	509.02	17000	8945.4	0.53	12779.1	0.75	
			78	0.4370		0.4375	-0.1%								
79C	06+64	8.50	79 80	0.4430 0.4520	0.445	0.4375 0.4375	1.3% 3.3%	0.4338	509.02	17000	8963.6	0.53	12805.2	0.75	
			81	0.4410	_	0.4375	0.8%								
89A	07+52	8.50	82 83	0.5030 0.5000	0.507	0.4375 0.4375	15.0% 14.3%	0.4873	508.32	17000	8043.3	0.47	11490.4	0.68	
			84	0.5190		0.4375	18.6%								
89B	07+52	8.50	85 86	0.5270 0.5270	0.518	0.4375 0.4375	20.5% 20.5%	0.4889	508.32	17000	8017.0	0.47	11452.8	0.67	
			87	0.5010		0.4375	14.5%								
89C	07+52	8.50	88 89	0.5380 0.5230	0.531	0.4375 0.4375	23.0% 19.5%	0.5160	508.32	17000	7596.8	0.45	10852.5	0.64	
			90	0.5310		0.4375	21.4%								
101A	08+41	8.50	91 92	0.4360 0.4330	0.436	0.4375 0.4375	-0.3% -1.0%	0.4295	503.32	17000	9641.9	0.57	13774.1	0.81	
			92	0.4330		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%								
101C	08+41	8.50	96 97	0.4320 0.4290	0.436	0.4375 0.4375	-1.3% -1.9%	0.4239	503.32	17000	9768.4	0.57	13954.9	0.82	

## NP-NLH-011, Attachment 1 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 85 of 92

b         b																Page 85 of 92
Number         Number        Number        Number </th <th></th> <th>Base N</th> <th>Aaterial</th> <th>At.</th> <th>Joints</th> <th>_</th>												Base N	Aaterial	At.	Joints	_
Image         Image <t< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></t<>																
N         N	Loca	ation	Radius (feet)							C.L. EL. (ft)		Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
11         11				98	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
No.         No. <td></td> <td></td> <td></td> <td>102</td> <td>0.4550</td> <td></td> <td>0.4375</td> <td>4.0%</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>				102	0.4550		0.4375	4.0%								
ADD         ADD <td>120B</td> <td>10+34</td> <td>8.50</td> <td></td> <td></td> <td>0.440</td> <td></td> <td></td> <td>0.4007</td> <td>484.81</td> <td>24000</td> <td>12374.3</td> <td>0.52</td> <td>17677.6</td> <td>0.74</td> <td></td>	120B	10+34	8.50			0.440			0.4007	484.81	24000	12374.3	0.52	17677.6	0.74	
No.         No. <td>1200</td> <td>10+34</td> <td>8 50</td> <td></td> <td></td> <td>0.429</td> <td></td> <td></td> <td>0.4186</td> <td>484 81</td> <td>24000</td> <td>11845 7</td> <td>0.49</td> <td>16922.5</td> <td>0.71</td> <td></td>	1200	10+34	8 50			0.429			0.4186	484 81	24000	11845 7	0.49	16922.5	0.71	
Line         Line <thline< th="">         Line         Line         <th< td=""><td>1200</td><td>10134</td><td>0.50</td><td>107</td><td>0.4270</td><td>0.425</td><td>0.4375</td><td>-2.4%</td><td>0.4100</td><td>404.01</td><td>24000</td><td>11045.7</td><td>0.45</td><td>10522.5</td><td>0.71</td><td></td></th<></thline<>	1200	10134	0.50	107	0.4270	0.425	0.4375	-2.4%	0.4100	404.01	24000	11045.7	0.45	10522.5	0.71	
No.         Ro.         Ro. <td>123A</td> <td>10+64</td> <td>8.50</td> <td></td> <td></td> <td>0.460</td> <td></td> <td></td> <td>0.4317</td> <td>481.94</td> <td>24000</td> <td>11779.6</td> <td>0.49</td> <td>16828.1</td> <td>0.70</td> <td></td>	123A	10+64	8.50			0.460			0.4317	481.94	24000	11779.6	0.49	16828.1	0.70	
Ind         Ind <td></td>																
Add         Add <td>123B</td> <td>10+64</td> <td>8.50</td> <td>112</td> <td>0.4600</td> <td>0.447</td> <td>0.4375</td> <td>5.1%</td> <td>0.4239</td> <td>481.94</td> <td>24000</td> <td>11995.9</td> <td>0.50</td> <td>17137.0</td> <td>0.71</td> <td></td>	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	
Image: Problem				114	0.4390		0.4375	0.3%								
11.0     12.0     12.1     13.1	123C	10+64	8.50	116	0.4440	0.443	0.4375	1.5%	0.4237	481.94	24000	12002.9	0.50	17147.1	0.71	
Image: book of the sector of the s	131A	11+29	8.50			0.461			0.4395	475.80	24000	12188.1	0.51	17411.6	0.73	
11.1     11.3     10.3     10.4				119	0.4530		0.4375	3.5%								
10.0         10.0 </td <td>131B</td> <td>11+29</td> <td>8.50</td> <td>121</td> <td>0.4380</td> <td>0.446</td> <td>0.4375</td> <td>0.1%</td> <td>0.4196</td> <td>475.80</td> <td>24000</td> <td>12765.7</td> <td>0.53</td> <td>18236.7</td> <td>0.76</td> <td></td>	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	
10         100         100																
100         100 <td>131C</td> <td>11+29</td> <td>8.50</td> <td></td> <td></td> <td>0.429</td> <td></td> <td></td> <td>0.4219</td> <td>475.80</td> <td>24000</td> <td>12696.3</td> <td>0.53</td> <td>18137.6</td> <td>0.76</td> <td></td>	131C	11+29	8.50			0.429			0.4219	475.80	24000	12696.3	0.53	18137.6	0.76	
10         10 <th10< th="">         10         10         10&lt;</th10<>	1204	11.07	0.50	126	0.4280	0.427	0.4375	-2.2%	0.4210	460.00	24000	12405.6	0.56	10150.0	0.00	
19         19 <th19< th="">         19         19         19<!--</td--><td>139A</td><td>11+9/</td><td>8.50</td><td>128</td><td>0.4260</td><td>0.427</td><td>0.4375</td><td>-2.6%</td><td>0.4210</td><td>409.30</td><td>24000</td><td>13405.6</td><td>0.56</td><td>19120'8</td><td>0.80</td><td></td></th19<>	139A	11+9/	8.50	128	0.4260	0.427	0.4375	-2.6%	0.4210	409.30	24000	13405.6	0.56	19120'8	0.80	
1         1	139B	11+97	8.50			0.420			0.3877	469.30	24000	14556.6	0.61	20795.2	0.87	
Inf         Inf <thinf< th=""> <thinf< th=""> <thinf< th=""></thinf<></thinf<></thinf<>				131	0.4010		0.4375	-8.3%								
10         10	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	
1         1	148A	12+50	7.63			0.438			0.4334	463.47	24000	12215.9	0.51	17451.2	0.73	15.25 ft diameter penstock
10         10				138	0.4410		0.4375	0.8%								
Matrix     Matrix    Matrix <td>148B</td> <td>12+50</td> <td>7.63</td> <td></td> <td></td> <td>0.444</td> <td></td> <td>3.3%</td> <td>0.4247</td> <td>463.47</td> <td>24000</td> <td>12466.2</td> <td>0.52</td> <td>17808.9</td> <td>0.74</td> <td></td>	148B	12+50	7.63			0.444		3.3%	0.4247	463.47	24000	12466.2	0.52	17808.9	0.74	
Image: box         Image:	148C	12+50	7.63			0.416			0.4082	463.47	24000	12970.9	0.54	18529.8	0.77	
Hate				143	0.4210		0.4375	-3.8%								
10         10         14 <th14< th="">         14         14         14&lt;</th14<>	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	
Image: Problem         Image:																
Parter         Parter<	168B	14+29	7.63			0.491			0.4808	417.44	24000	14807.4	0.62	21153.4	0.88	
100         100 <td>1690</td> <td>14.20</td> <td>7.63</td> <td>150</td> <td>0.4860</td> <td>0 502</td> <td>0.5</td> <td>-2.8%</td> <td>0.4907</td> <td>417 44</td> <td>24000</td> <td>14910.2</td> <td>0.63</td> <td>211575</td> <td>0.99</td> <td></td>	1690	14.20	7.63	150	0.4860	0 502	0.5	-2.8%	0.4907	417 44	24000	14910.2	0.63	211575	0.99	
170         1.44         7.8         1.34         0.300         0.490         0.5         0.68         0.78         4.30         200         56.3         0.80         2017         0.90           170         1.49         7.8         1.37         0.440         0.40<	1080	14729	7.05	152	0.4960	0.302	0.5	-0.8%	0.4807	417.44	24000	14010.5	0.02	21137.5	0.88	
120         140         7.8         158         0.460         0.461         7.8	170A	14+49	7.63			0.499			0.4745	412.30	24000	15433.2	0.64	22047.4	0.92	
11     11    <																
100         140         150         140 <td>170B</td> <td>14+49</td> <td>7.63</td> <td>157</td> <td>0.4640</td> <td>0.469</td> <td>0.5</td> <td>-7.2%</td> <td>0.4401</td> <td>412.30</td> <td>24000</td> <td>16639.9</td> <td>0.69</td> <td>23771.3</td> <td>0.99</td> <td></td>	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	
16.1         0.450         0.5         0.446           180A         15-0         7.6         0.450         0.853         0.87				159	0.4850		0.5	-3.0%								_
Index         Index </td <td>170C</td> <td>14+49</td> <td>7.63</td> <td></td> <td></td> <td>0.462</td> <td></td> <td></td> <td>0.4191</td> <td>412.30</td> <td>24000</td> <td>17475.2</td> <td>0.73</td> <td>24964.6</td> <td>1.04</td> <td></td>	170C	14+49	7.63			0.462			0.4191	412.30	24000	17475.2	0.73	24964.6	1.04	
140         141         0.25         0.25         0.05         0	180A	15+40	7.63			0.563			0.5625	388.71	24000	14682.3	0.61	20974.8	0.87	
1868         1.409         7.63         6.56         0.563         0.655         8.71         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         2400         1682         0.57         0.57         0.57         2400         1682         0.57         0.57         0.57         2400         1682         0.56         0.57         0.57         27.5         2400         1682         0.57         0.57         27.5         2400         1683         0.57         0.57         27.5         2400         1684         0.57         27.5         2400         2403         261         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         27.5         <	100/1	10.40	7.05	164	0.5625	0.505	0.5625	0.0%	0.5025	500.71	24000	14002.5	0.01	20374.0	0.07	
Interprese         Interpres         Interpres         Interpres	180B	15+40	7.63	166	0.5625	0.563	0.5625		0.5625	388.71	24000	14682.3	0.61	20974.8	0.87	
IBC         1:40         7.83         100         5.853         0.853         0.855         0.855         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.857         0.77         0.77         0.78         0.78         0.857         0.78         0.78         0.78         0.857         0.78         0.78         0.78         0.867         0.867         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.78         0.87         0.87         0.78         0.87         0.																
124         125         126         127         0.567 </td <td>180C</td> <td>15+40</td> <td>7.63</td> <td>169</td> <td>0.5625</td> <td>0.563</td> <td>0.5625</td> <td>0.0%</td> <td>0.5625</td> <td>388.71</td> <td>24000</td> <td>14682.3</td> <td>0.61</td> <td>20974.8</td> <td>0.87</td> <td></td>	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	
$ \left[ \begin{array}{cccccccccccccccccccccccccccccccccccc$		46.05	7.62	171	0.5625	0.500	0.5625	0.0%	0.5353	272.46	24000	45 400 7		22055.2		
1928       16+35       7.63       1.75       0.619       0.619       0.72.49       24000       1496.3       0.62       2137.5       0.89         1920       16+35       7.63       178       0.600       0.6525       7.6%       7.6%       24000       1241.00       0.64       2177.9       0.91         1920       16+35       7.68       178       0.690       0.652       6.3%       0.541       7.64       24000       16496.0       0.64       2177.9       0.91         201A       17+17       7.63       180       0.660       0.653       17.7%       0.637       365.43       24000       1439.60       0.60       2057.0.8       0.66         1635       17.47       0.630       0.650       0.552       12.8%       0.639       365.43       24000       1439.60       0.60       2057.0.8       0.66         1635       0.640       0.650       0.552       12.8%       0.614       365.43       24000       1431.42       0.60       2057.0.8       0.85       0.85       1.8%       0.640       0.65       0.65       0.65       0.65       0.65       0.65       0.65       0.65       0.65       0.65       0.65       0.65<	192A	16+35	7.63	173	0.5900	0.593	0.5625	4.9%	0.5767	372.46	24000	15438.7	0.64	22055.3	0.92	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1022	46.05	7 67			0.611			0 5040	272.40	34000	14064.3	0.63	212775	0.00	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1958	10+35	1.03			0.011			0.5949	372.40	24000	14904.3	0.02	213/7.5	0.89	
174         174         7.63         162         0.623         7.64         7.64         181         0.659         0.552         7.76         5.63         7.64         1839.6         0.69         2570.8         0.85           2018         17.17         7.63         181         0.660         0.552         18.26         1.839.6         2400.9         1.839.6         0.61         2070.8         0.85           2018         1.71         7.63         0.660         0.532         1.84%         0.60         0.533         1.839.6         2400.9         1.839.6         0.61         2078.9         0.85           2010         17.17         7.63         187         0.660         0.525         15.76%         1.84%         0.614         365.43         2400.9         1.4314.2         0.60         2.048.8         0.85           2010         17.17         7.63         187         0.650         0.625         15.3%         0.6333         358.58         2400.9         1.480.8         0.62         2.1258.2         0.89           2104         17.497         7.63         183         0.652         0.50%         0.6333         358.58         2400.9         1.480.8         0.62         2.125	1020	16+25	7.62	177	0.6030	0.608	0.5625	7.2%	0 59/1	372 46	24000	15241.0	0.64	21772 0	0.01	
2014         17-17         7.63         18.1         0.6590         0.567         17.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.2%         0.5675         18.4%         0.6309         0.563         18.4%         0.614         36.33         24000         133.14.2         0.60         0.67           201C         17.17         7.63         187         0.6660         0.558         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5625         17.3%         0.5635         17.3%         0.5635         16.3%         24000         1480.8         0.62         2125.8.2         0.563         0.565         17.3%         0.5655         17.3%         0.565 <t< td=""><td>1920</td><td>10433</td><td>7.03</td><td>179</td><td>0.6220</td><td>0.008</td><td>0.5625</td><td>10.6%</td><td>0.3041</td><td>372.40</td><td>24000</td><td>13241.0</td><td>0.04</td><td>21//2.9</td><td>0.91</td><td></td></t<>	1920	10433	7.03	179	0.6220	0.008	0.5625	10.6%	0.3041	372.40	24000	13241.0	0.04	21//2.9	0.91	
1018         17+17         7.63         1.84         0.6460         0.6523         14.84%         0.6309         35.43         2400         143.42         0.61         27789.9         0.61         27789.9         0.61           2016         165         0.6460         0.652         14.8%         0.619         35.65         14.8%         0.619         35.65         2400         1431.42         0.61         2048.8         0.85           2016         17+17         7.63         167         0.660         0.552         12.4%         0.613         35.85         2400         1431.42         0.60         2048.8         0.85           2016         17+17         7.63         160         0.652         12.5%         35.85         2400         1438.9         0.62         2048.8         0.85           2104         17+97         7.63         160         0.645         0.62         3.7%         0.635         3.85.8         2400         1486.1         0.62         123.9%         0.88           2104         17+97         7.63         166         0.648         0.62         3.4%         0.640         358.58         2400         1476.16         0.62         120.8%         0.88	201A	17+17	7.63			0.657			0.6376	365.43	24000	14399.6	0.60	20570.8	0.86	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$																
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	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	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$				186	0.6470		0.5625	15.0%								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	201C	17+17	7.63	188	0.6600	0.658	0.5625	17.3%	0.6414	365.43	24000	14314.2	0.60	20448.8	0.85	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	210A	17+97	7.63	189		0.648			0.6353	358.58	24000	14880.8	0.62	21258.2	0.89	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			-	191	0.6560		0.625	5.0%	=							
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	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	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$				195			0.625									
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	210C	17+97	7.63			0.648	0.625		0.6404	358.58	24000	14761.6	0.62	21088.0	0.88	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2201	10.00	7.00	198	0.6460	0.022	0.625	3.4%	0.644	250.00	34000	15074 -	0.07	22022 4	0.05	
2208       18+89       7.63       202       0.6370       0.631       0.625       1.9%       0.6108       350.69       24000       15988.1       0.67       2280.1       0.95         204       0.6360       0.625       1.0%       0.625       1.0%       0.631       0.625       1.0%         2202       18+89       7.63       205       0.640       0.637       0.625       1.0%       1.0%       1.642.3.5       0.68       2346.1       0.98         2202       18+89       7.63       205       0.640       0.637       1.0%       0.5946       350.69       24000       1642.3.5       0.68       2346.1       0.98         2204       19+50       7.63       206       0.640       0.625       4.8%       0.699       345.46       24000       1583.8       0.66       22619.7       0.94         228A       19+50       7.63       208       0.6450       0.642       0.625       1.6%       1583.8       0.66       22619.7       0.94	220A	18+89	7.63	200	0.6380	0.632	0.625	2.1%	U.6114	350.69	24000	15974.1	0.67	22820.1	0.95	
203         0.619         0.625         1.056           220C         18+89         7.63         205         0.640         0.625         1.8%           220C         18+89         7.63         205         0.640         0.625         3.0%         0.5946         350.69         24000         16423.5         0.68         23462.1         0.98           206         0.6130         0.625         4.8%	220B	18+89	7.63			0.631			0.6108	350.69	24000	15988.1	0.67	22840.1	0.95	
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           207         0.6550         0.625         -1.9%         -				203	0.6190		0.625	-1.0%								
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%         5         1.6% </td <td>220C</td> <td>18+89</td> <td>7.63</td> <td>205</td> <td>0.6440</td> <td>0.637</td> <td>0.625</td> <td>3.0%</td> <td>0.5946</td> <td>350.69</td> <td>24000</td> <td>16423.5</td> <td>0.68</td> <td>23462.1</td> <td>0.98</td> <td></td>	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	
209 0.6350 0.625 1.6%				207	0.6550		0.625	4.8%								
	228A	19+50	7.63	209	0.6350	0.642	0.625	1.6%	0.6299	345.46	24000	15833.8	0.66	22619.7	0.94	

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							1			1	1				Page 86 of 92
											Base I	Vaterial	At J	oints	
										Allowable					
		Dedius (feet)	Reading	Thickness	Avg.	Plate	%Change in	97.5% Confidence	C I EI (4)	Steel Stress	Church (ant) <sup>1</sup>	Church Datia <sup>2</sup>	(trail) <sup>3</sup>	Charles Datia	N-+
228B	ation 19+50	Radius (feet) 7.63	Number 211	Reading (in) 0.6530	Thickness (in) 0.652	Thickness (in) 0.625	Material 4.5%	0.6500	C.L. EL. (ft) 345.46	(psi) 24000	Stress (psi) <sup>1</sup> 15342.8	Stress Ratio <sup>2</sup> 0.64	Stress (psi) <sup>3</sup> 21918.3	Stress Ratio <sup>4</sup> 0.91	Notes
			212 213	0.6510 0.6520		0.625 0.625	4.2% 4.3%								
228C	19+50	7.63	213	0.6290	0.650	0.625	4.3%	0.6133	345.46	24000	16262.4	0.68	23232.0	0.97	
			215 216	0.6650 0.6570		0.625 0.625	6.4% 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	
			218 219	0.7380 0.7370		0.6875 0.6875	7.3% 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	
			221 222	0.6810 0.6690		0.6875 0.6875	-0.9% -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	
			224 225	0.7340 0.6830		0.6875 0.6875	6.8% -0.7%								
250A	21+50	7.63	226 227	0.7950 0.7630	0.778	0.75 0.75	6.0% 1.7%	0.7460	310.57	24000	15224.1	0.63	21748.7	0.91	
			227	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%								<b>A A A A A</b>
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%								
264B	22+76	7.63	237 238	0.8770 0.8750	0.870	0.875 0.875	0.2%	0.8592	288.98	24000	14214.7	0.59	20306.6	0.85	
2010			238	0.8730	0.070	0.875	-1.3%	5.0552	_00.90	2.000		5.55	_0000.0	0.00	
			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	
			242 243	0.8730 0.9010		0.875 0.875	-0.2% 3.0%								
271A	23+26	7.63	244 245	0.7640 0.7690	0.767	0.75 0.75	1.9% 2.5%	0.7618	280.16	24000	16490.3	0.69	23557.6	0.98	
			246	0.7680		0.75	2.4%								
271B	23+26	7.63	247 248	0.7920	0.787	0.75 0.75	5.6% 4.4%	0.7785	280.16	24000	16137.0	0.67	23052.9	0.96	
			249	0.7870		0.75	4.9%								
271C	23+26	7.63	250 251	0.8120 0.8080	0.795	0.75 0.75	8.3% 7.7%	0.7454	280.16	24000	16853.7	0.70	24076.8	1.00	
			252	0.7660		0.75	2.1%								
280A	24+07	7.63	253 254	0.8350 0.8230	0.827	0.815 0.815	2.5% 1.0%	0.8134	265.74	24000	16147.3	0.67	23067.5	0.96	
			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%								
292A	25+16	7.63	261 262	0.8200 0.8800	0.885	0.815 0.875	0.6% 0.6%	0.8653	246.33	24000	16068.0	0.67	22954.4	0.96	
232A	23+10	7.05	262	0.8780	0.885	0.875	0.3%	0.8035	240.55	24000	10008.0	0.07	22934.4	0.50	
			263	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 0.8790	0.888	0.875	3.0% 0.5%	0.8647	246.33	24000	16079.8	0.67	22971.1	0.96	
			269 270	0.8830		0.875 0.875	0.9%								
302A	26+07	7.63	271 272	0.8860 0.8570	0.865	0.875 0.875	1.3%	0.8280	230.14	24000	17568.0	0.73	25097.1	1.05	
			273	0.8510		0.875	-2.7%								
302B	26+07	7.63	274 275	0.8280 0.8600	0.849	0.875 0.875	-5.4% -1.7%	0.8133	230.14	24000	17884.2	0.75	25548.8	1.06	
2022	36.07	7.00	276	0.8590	0.002	0.875	-1.8%	0.0102	220.4.4	24000	17764 5	0.74	35333.5	1.05	
302C	26+07	7.63	277 278	0.8460 0.8540	0.863	0.875 0.875	-3.3% -2.4%	0.8190	230.14	24000	17761.5	0.74	25373.6	1.06	
313A	27+06	7.63	279 280	0.8880 0.9650	0.967	0.875 0.935	1.5% 3.2%	0.9502	217.43	24000	15838.4	0.66	22626.3	0.94	
JIDA	27700	7.05	281	0.9770	0.507	0.935	4.5%	0.3302	217.43	24000	13030.4	0.00	22020.3	0.24	
313B	27+06	7.63	282 283	0.9600 0.9780	0.978	0.935 0.935	2.7% 4.6%	0.9695	217.43	24000	15523.4	0.65	22176.2	0.92	
			284	0.9740		0.935	4.2%			1.130					
313C	27+06	7.63	285 286	0.9830 0.9750	0.962	0.935 0.935	5.1% 4.3%	0.9370	217.43	24000	16061.6	0.67	22945.2	0.96	
			287	0.9600		0.935	2.7%		-					-	
322A	27+67	7.63	288 289	0.9500 0.9930	0.992	0.935 0.935	1.6% 6.2%	0.9901	210.34	24000	15484.7	0.65	22121.0	0.92	
			290	0.9910 0.9930		0.935	6.0%								
322B	27+67	7.63	291 292	1.0000	0.991	0.935 0.935	6.2% 7.0%	0.9747	210.34	24000	15728.8	0.66	22469.7	0.94	
			293 294	0.9870 0.9850		0.935 0.935	5.6% 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	
			296 297	1.0100 0.9930		0.935 0.935	8.0% 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	
			299 300	1.0100 0.9940		1	1.0% -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	
			302 303	0.9940 0.9940		1	-0.6% -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	
			305 306	1.0000 1.0000		1	0.0%								
342A	29+62	7.63	307 308	1.1670 1.1410	1.150	1.125 1.125	3.7%	1.1211	187.68	24000	14476.0	0.60	20680.0	0.86	
			309	1.1420		1.125	1.5%								
342B	29+62	7.63	310 311	1.1440 1.1430	1.146	1.125 1.125	1.7% 1.6%	1.1375	187.68	24000	14268.2	0.59	20383.1	0.85	
			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	

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											Base M	Naterial	At J	oints	
			Reading	Thickness	Avg.	Plate	%Change in	97.5% Confidence		Allowable Steel Stress					
Lo	cation	Radius (feet)	Number	Reading (in)	Thickness (in)		Material	Interval	C.L. EL. (ft)	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
			314	1.1910		1.125	5.9%								
354A	30+59	7.63	315 316	1.1480 1.1640	1.179	1.125	2.0% 3.5%	1.1519	176.41	24000	14477.2	0.60	20681.7	0.86	
3344	30133	7.05	317	1.1810	1.175	1.125	5.0%	1.1515	170.41	24000	14477.2	0.00	20001.7	0.00	
			318	1.1910		1.125	5.9%								
354B	30+59	7.63	319 320	1.1590 1.1690	1.172	1.125	3.0% 3.9%	1.1424	176.41	24000	14597.8	0.61	20854.0	0.87	
			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	
			323 324	1.1790 1.1810		1.125 1.125	4.8% 5.0%								
364A	31+43	7.63	324	1.1810	1.267	1.125	6.4%	1.2607	154.85	24000	13906.2	0.58	19865.9	0.83	
			326	1.2700		1.1875	6.9%								
2645	24 . 42	7.62	327	1.2660	4 330	1.1875	6.6%	4 2054	454.05	24000		0.54	20704 0	0.07	
364B	31+43	7.63	328 329	1.2420 1.2210	1.228	1.1875 1.1875	4.6% 2.8%	1.2051	154.85	24000	14547.3	0.61	20781.9	0.87	
			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	
			332 333	1.2310 1.2200		1.1875 1.1875	3.7% 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%								
372B	32+13	7.63	336 337	1.3140 1.3180	1.316	1.25 1.25	5.1% 5.4%	1.2961	140.55	24000	13963.6	0.58	19948.0	0.83	
3720	32+13	7.03	338	1.3050	1.510	1.25	4.4%	1.2501	140.55	24000	13503.0	0.56	15540.0	0.65	
			339	1.3250		1.25	6.0%								
372C	32+13	7.63	340	1.3120	1.320	1.25 1.25	5.0% 5.8%	1.3063	140.55	24000	13854.4	0.58	19791.9	0.82	
			341 342	1.3220 1.3250		1.25	5.8%								
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%								
381B	32+97	7.63	345 346	1.3880 1.3890	1.395	1.3125 1.3125	5.8% 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	349 350	1.3900 1.3920	1.373	1.3125 1.3125	5.9% 6.1%	1.3133	123.39	24000	14298.7	0.60	20426.7	0.85	
			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	
			353 354	1.3680 1.3600		1.375 1.375	-0.5% -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%								
391C	33+89	7.63	357 358	1.3610 1.3610	1.360	1.375 1.375	-1.0% -1.0%	1.3543	104.59	24000	14415.9	0.60	20594.2	0.86	
3910	33765	7.03	359	1.3570	1.300	1.375	-1.3%	1.5545	104.35	24000	14413.9	0.00	20354.2	0.80	
			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	
			362 363	1.4550 1.4400		1.375 1.375	5.8% 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%								
399C	34+60	7.63	366 367	1.4280 1.4290	1.433	1.375 1.375	3.9% 3.9%	1.4258	90.08	24000	14097.1	0.59	20138.7	0.84	
5550	54.00	,	368	1.4360	1	1.375	4.4%	1.1230	50.00	2.000	1-1057.1	0.55	20150.7	0.04	
			369	1.4330		1.375	4.2%								

<sup>1</sup> Hoop stress = Pr/t<sub>97.5</sub>

Notes:

3.1% -2.7%

<sup>2</sup> Hoop stress / S<sub>A</sub> <sup>3</sup> Hoop stress / 0.7 <sub>joint efficiency</sub> <sup>4</sup> Joint stress / S<sub>A</sub>

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TABLE 2 - Full Supply Level (FSL) Including Transient ( X 1.3) PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

essment)

											Base N	Aaterial	At	Joints	
			Reading	Thickness	Avg.	Plate	%Change in	97.5% Confidence		Allowable Steel Stress	Dusen				
L.	ocation	Radius (feet)	Number			Thickness (in)	Material	Interval	C.L. EL. (ft)	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	NTERIOR														
From Upstro 1A	eam End of Condu	uit 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)
IA	0+00	8.50	2	0.5180	0.517	0.5	4.2%	0.5000	349.30	17000	3367.5	0.32	7030.4	0.45	The steer (Brade and own)
			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%								
	0+00	0.50	6	0.5300	0.540	0.5	6.0%	0.5044	540.50	17000			7730.7	0.45	
10	0+00	8.50	7	0.5260	0.519	0.5 0.5	5.2% 4.2%	0.5044	549.50	17000	5411.5	0.32	//30./	0.45	
			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 15	0.5250		0.5 0.5	5.0% 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%								
20B	01+63	8.50	21 22	0.4410 0.4480	0.447	0.4375 0.4375	0.8%	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%								
30A	02+35	8.50	27 28	0.4480	0.471	0.4375 0.4375	2.4% 5.4%	0.4443	546.8201	17000	6488.9	0.38	9269.9	0.55	
30A	02+35	8.50	28	0.4610 0.4860	0.471	0.4375	5.4% 11.1%	0.4443	540.8201	17000	6488.9	0.38	9209.9	0.55	
			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 0.4375	-1.0% 2.2%	0.4266	546.8201	17000	6759.4	0.40	9656.3	0.57	
			35 36	0.4470		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 42	0.4330 0.4480		0.4375 0.4375	-1.0% 2.4%								
40C	03+23	8.50	42	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%								
48B	03+92	8.50	48 49	0.4580 0.4560	0.459	0.4375 0.4375	4.7% 4.2%	0.4386	527.7817	17000	9069.2	0.53	12955.9	0.76	
700	03792	0.50	49 50	0.4500	0.435	0.4375	2.9%	0.4000	521.1011	27000	5005.2	0.33	12333.3	0.76	
			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%								
		0	54	0.4560		0.4375	4.2%							-	
58A	04+82	8.50	55 56	0.4190 0.4250	0.426	0.4375 0.4375	-4.2% -2.9%	0.4119	516.9473	17000	11167.3	0.66	15953.3	0.94	
			55	0.4250		0.4375	-2.9%								
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 63	0.4540		0.4375	3.8%								
69A	05+75	8.50	64	0.4560 0.4410	0.447	0.4375 0.4375	4.2% 0.8%	0.4169	509.73	17000	12026.2	0.71	17180.3	1.01	
			65	0.4360		0.4375	-0.3%							2.01	
			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%								

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		Page 89 of 92													
											Base N	laterial	At	Joints	Ŭ
			Reading	Thickness	Avg.	Plate	%Change in	97.5% Confidence		Allowable Steel Stress					
Loca	ation	Radius (feet)	Number	Reading (in)	Thickness (in)	Thickness (in)	Material	Interval	C.L. EL. (ft)	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
69C	05+75	8.50	69 70	0.4400 0.4510	0.455	0.4375 0.4375	0.6% 3.1%	0.4472	509.73	17000	11213.6	0.66	16019.5	0.94	
09C	03+73	8.50	70	0.4510	0.435	0.4375	4.0%	0.4472	505.75	17000	11213.0	0.00	10015.5	0.54	
			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 77	0.4420	0.440	0.4375 0.4375	1.0% 0.6%	0.4347	509.02	17000	11629.0	0.68	16612.8	0.98	
			78	0.4400		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 84	0.5000 0.5190		0.4375 0.4375	14.3% 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 90	0.5230 0.5310		0.4375 0.4375	19.5% 21.4%								
101A	08+41	8.50	91	0.3310	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%								
101C	08+41	8.50	96 97	0.4320 0.4290	0.436	0.4375 0.4375	-1.3% -1.9%	0.4239	503.32	17000	12699.0	0.75	18141.4	1.07	
1010	00141	0.50	98	0.4400	0.450	0.4375	0.6%	0.4235	505.52	17000	12055.0	0.75	10141.4	1.07	
			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%								
1200	10.24	0.50	102	0.4550	0.440	0.4375	4.0%	0.4007	404.01	24000	10000 0	0.67	22080.0	0.96	
120B	10+34	8.50	103 104	0.4620 0.4330	0.440	0.4375 0.4375	5.6% -1.0%	0.4007	484.81	24000	16086.6	0.67	22980.9	0.96	
			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	109 110	0.4440 0.4640	0.460	0.4375 0.4375	1.5% 6.1%	0.4317	481.94	24000	15313.5	0.64	21876.5	0.91	
			110	0.4840		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	
			116 117	0.4440 0.4530		0.4375 0.4375	1.5% 3.5%								
131A	11+29	8.50	117	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	
			122 123	0.4380 0.4610		0.4375 0.4375	0.1% 5.4%								
131C	11+29	8.50	123	0.4610	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%								
139B	11+97	8.50	129 130	0.4310 0.4310	0.420	0.4375 0.4375	-1.5% -1.5%	0.3877	469.30	24000	18923.6	0.79	27033.7	1.13	
1000	11.37	5.50	130	0.4310	0.420	0.4375	-8.3%	0.3077		2.000	10525.0	0.75	2,000.	1.15	
			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%								
1484	12.50	7.00	135	0.4210	0.430	0.4375	-3.8%	0.4334	463.47	24000	15000 0	0.00	22606.6	0.07	
148A	12+50	7.63	136 137	0.4380 0.4360	0.438	0.4375 0.4375	0.1%	0.4334	463.47	24000	15880.6	0.66	22686.6	0.95	
			137	0.4300		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	
			143 144	0.4210 0.4130		0.4375 0.4375	-3.8% -5.6%								
168A	14+29	7.63	144	0.4130	0.493	0.4375		0.4743	417.44	24000	19513.4	0.81	27876.3	1.16	
			146	0.5030		0.5									
			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	

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														Р	age 90 of 92
											Base P	Aaterial	At	Joints	Ŭ
			Reading	Thickness	Avg.	Plate	%Change in	97.5% Confidence		Allowable Steel Stress					
Loc	ation	Radius (feet)	Number	-	Thickness (in)		Material	Interval	C.L. EL. (ft)	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
			149 150	0.4960		0.5	-0.8% -2.8%								
168C	14+29	7.63	150	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	
			155 156	0.5090		0.5 0.5	1.8% -3.0%								
170B	14+49	7.63	150	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	
			161 162	0.4580		0.5	-8.4% -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	
			167 168	0.5625		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	
			173 174	0.5900		0.5625 0.5625	4.9% 7.2%								
192B	16+35	7.63	174	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	
			179 180	0.6220		0.5625	10.6% 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	
			185 186	0.6460		0.5625	14.8% 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	
			191 192	0.6560		0.625	5.0% 3.0%								
210B	17+97	7.63	192	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	
			197 198	0.6530 0.6460		0.625	4.5% 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	
			203 204	0.6190 0.6360		0.625 0.625	-1.0% 1.8%								
220C	18+89	7.63	204	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	208 209	0.6460	0.642	0.625 0.625	3.4% 1.6%	0.6299	345.46	24000	20583.9	0.86	29405.6	1.23	
			209	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	0.000	0.625	4.3%								
228C	19+50	7.63	214 215	0.6290	0.650	0.625	0.6% 6.4%	0.6133	345.46	24000	21141.1	0.88	30201.6	1.26	
			215	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	
			221 222	0.6810 0.6690		0.6875 0.6875	-0.9% -2.7%								
240C	20+62	7.63	222	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	
			227 228	0.7630		0.75 0.75	1.7% 3.3%								
			225	5.7750		0.75	3.370								

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Location         Reading         Trickness (n)         Plate Trickness (n)         Plat         Plat         Plat		3 Stress Ratio <sup>4</sup>	Stress (psi) <sup>3</sup>			Steel Stress	0 · 5 · (/)		%Change in	Plate	Avg.	Thisburger				
<table-container>          Image         Rading (wind wind wind wind wind wind wind wind</table-container>	1.17 1.23 1.08 Downstream of surge tank 1.10 1.10	1.17		Stress Ratio <sup>2</sup>	Stress (psi) <sup>1</sup>	Steel Stress	0 L TL ((1)		%Change in	Plate	Avg.	Thislance				
2508         21+50         7.63         229         0.779         0.770         0.75         3.9%         0.750         310.57         24000         1962.4         0.82         2817.8           2508         21+50         7.63         229         0.7720         0.75         2.9%         0.75         1.2%         0.75         2.9%         0.75         2.9%         0.713         310.57         24000         1968.4         0.82         2817.8           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           250C         21+50         7.63         235         0.8820         0.875         0.8%         0.8738         288.98         24000         18169.7         0.76         25956.8           264A         22+76         7.63         238         0.8750         0.875         0.2%         288.98         24000         18479.1         0.77         26398.6           2244         0.8750         0.875         0.3%         -0.2%         2400         18457.3         0.77         26367.6           264C         22+76         7.63	1.17 1.23 1.08 Downstream of surge tank 1.10 1.10	1.17		Stress Ratio <sup>2</sup>	Stress (psi)1	(psi)	0 1 F1 ((1)					Thickness	Reading			
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.23 1.08 Downstream of surge tank 1.10 1.10		28117.8				C.L. EL. (π)	Interval	Material	Thickness (in)		Reading (in)	Number	Radius (feet)	ocation	Lo
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.08 Downstream of surge tank 1.10 1.10	1.23		0.82	19682.4	24000	310.57	0.7501			0.770			7.63	21+50	250B
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.08 Downstream of surge tank 1.10 1.10	1.23														
2644       0.769       0.759       0.75       2.5%         2644       0.769       0.75       2.5%         2644       0.769       0.870       0.875       0.870       0.878       28.89       2400       18169.7       0.76       2595.8         2648       22+76       7.63       235       0.8820       0.870       0.875       0.0%       0.8792       28.898       2400       18169.7       0.76       2595.8         2648       22+76       7.63       238       0.870       0.870       0.875       0.2%       28.98       2400       18169.7       0.77       2595.8         2648       22+76       7.63       238       0.870       0.870       0.2%       28.99       28.99       2400       1847.1       0.77       2595.8         2640       0.761       0.870       0.875       0.3%       0.860       28.99       2400       1847.3       0.77       2595.6         2640       0.761       0.870       0.75       1.3%       0.860       28.99       2400       1847.3       0.77       2595.6         271A       2.9-26       7.63       2.44       0.760       0.75       1.9%       0.7618       <	1.08 Downstream of surge tank 1.10 1.10	1.23	20567.4	0.86	20697.2	24000	210.57	0 7133			0.756			7.63	21+50	2500
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.10		25307.4	0.80	20057.2	24000	510.57	0.7155			0.750			7.05	21+50	230C
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.10															
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.10	1.08	25956.8	0.76	18169.7	24000	288.98	0.8738			0.879			7.63	22+76	264A
2648       22+76       7.63       238       0.8750       0.870       0.875       0.0%       0.852       288.98       24000       18479.1       0.77       26398.6         239       0.8640       0.875       0.375       1.3%	1.10															
2476         7.63         0.8640         0.8720         -1.3%           264C         22476         7.63         241         0.900         0.871         0.875         2.9%         0.8602         288.98         24000         18457.3         0.77         26367.6           271A         23+26         7.63         244         0.7640         0.767         0.75         1.9%         0.7618         280.16         24000         21437.4         0.89         3624.9           271A         23+26         7.63         244         0.7640         0.767         0.75         1.9%         0.7618         280.16         24000         21437.4         0.89         3624.9           271A         23+26         7.63         244         0.7690         0.75         2.5%	1.10								0.2%	0.875		0.8770	237			
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		1.10	26398.6	0.77	18479.1	24000	288.98	0.8592	0.0%	0.875	0.870	0.8750	238	7.63	22+76	264B
264C       22+76       7.63       241       0.900       0.891       0.875       2.9%       0.8602       288.98       2400       18457.3       0.77       26367.6         242       0.8730       0.875       6.2%       -0.2%									-1.3%	0.875		0.8640	239			
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         271B       23+26       7.63       247       0.790       0.757       2.5%       246       0.7680       0.775       2.4%       280.16       24000       20978.1       0.87       29968.7         271B       23+26       7.63       247       0.790       0.787       0.75       4.4%       280.16       24000       20978.1       0.87       29968.7         271B       23+26       7.63       247       0.790       0.787       0.75       4.4%       280.16       24000       20978.1       0.87       29968.7         271C       23+26       7.63       250       0.8120       0.755       4.9%       280.16       24000       2190.9       0.91       3129.8         271C       23+26       7.63       250       0.8120       0.755       7.7%       280.16       24000       2190.9       0.91       3129.8																
271A       23+26       7.63       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         245       0.7690       0.75       2.5%       246       0.768       2.4%       280.16       24000       20978.1       0.87       2968.7         271B       23+26       7.63       247       0.790       0.75       5.6%       0.7785       280.16       24000       20978.1       0.87       2968.7         271B       23+26       7.63       247       0.790       0.75       4.4%       24000       24900       20978.1       0.87       2968.7         271C       23+26       7.63       250       0.8120       0.75       0.75       8.3%       0.7454       280.16       24000       2190.9       0.91       3129.8         271C       23+26       7.63       250       0.8120       0.75       8.3%       0.7454       280.16       24000       2190.9       0.91       3129.8         271C       23+26       7.63       250       0.8120       0.75	1.28	1.10	26367.6	0.77	18457.3	24000	288.98	0.8602			0.891			7.63	22+76	264C
271A       23+26       7.63       244       0.7640       0.767       0.75       1.9%       0.7618       28000       21437.4       0.89       30624.9         245       0.7690       0.75       2.5%       -	1.28															
245       0.7690       0.75       2.5%         246       0.7680       0.75       2.4%         2718       2.3+26       7.63       2.47       0.720       0.75       2.4%         248       0.780       0.75       5.6%       0.775       280.16       24000       20978.1       0.87       2968.7         2718       23+26       7.63       0.780       0.75       4.4%       24000       20978.1       0.87       2968.7         2712       23+26       7.63       0.8120       0.755       6.3%       0.7454       280.16       24000       2109.9       0.91       31299.8         2712       23+26       7.63       250       0.8080       0.75       8.3%       0.7454       280.16       24000       2109.9       0.91       31299.8		1.20	20624.0	0.90	21427.4	24000	290.16	0.7619			0.767			7.62	22,26	2714
2718       23+26       7.63       247       0.7920       0.787       0.75       5.6%       0.7785       280.6       2400       20978.1       0.87       29968.7         2718       23+26       7.63       247       0.7920       0.787       0.75       5.6%       0.7785       280.16       24000       20978.1       0.87       29968.7         243       0.7870       0.75       4.4%		1.28	30024.9	0.89	21437.4	24000	280.10	0.7618			0.767			7.05	23+20	271A
2718       23+26       7.63       247       0.7920       0.787       0.75       5.6%       0.7785       280.16       24000       20978.1       0.87       29968.7         248       0.7830       0.75       4.4%       249       0.7870       0.75       4.9%         271C       23+26       7.63       250       0.8120       0.75       4.9%       24000       21909.9       0.91       3129.8         271C       23+26       7.63       250       0.8120       0.75       8.3%       0.7454       280.16       24000       21909.9       0.91       3129.8																
248         0.7830         0.75         4.4%           249         0.7870         0.75         4.9%           271C         23+26         7.63         250         0.8120         0.75         8.3%         0.7454         280.16         24000         21909.9         0.91         31299.8           251         0.8080         0.75         7.7%         2400         21909.9         0.91         31299.8	1.25	1.25	29968.7	0.87	20978.1	24000	280.16	0.7785			0.787			7.63	23+26	271B
271C         23+26         7.63         250         0.8120         0.75         0.75         8.3%         0.7454         280.16         24000         21909.9         0.91         31299.8           251         0.8080         0.75         7.7%																
251 0.8080 0.75 7.7%																
	1.30	1.30	31299.8	0.91	21909.9	24000	280.16	0.7454	8.3%	0.75	0.795	0.8120	250	7.63	23+26	271C
									7.7%	0.75		0.8080	251			
252 U./bbU U./5 2.1%									2.1%	0.75		0.7660	252			
280A 24+07 7.63 253 0.8350 0.827 0.815 2.5% 0.8134 265.74 <b>24000</b> 20991.4 0.87 29987.8	1.25	1.25	29987.8	0.87	20991.4	24000	265.74	0.8134			0.827			7.63	24+07	280A
254 0.8230 0.815 1.0%																
	1.07		2015			2.005	200	0.000-						7.00		205-
2808         24+07         7.63         256         0.817         0.815         1.2%         0.8009         265.74         24000         21318.4         0.89         30454.8           257         0.8160         0.815         0.1%	1.27	1.27	30454.8	0.89	21318.4	24000	265.74	0.8009			0.817			7.63	24+07	280B
257 0.8100 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	1.32	31673.0	0.92	22171.1	24000	265.74	0.7701			0.839			7.63	24+07	2800
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	1.24	29840.7	0.87	20888.5	24000	246.33	0.8653	0.6%	0.875	0.885	0.8800	262	7.63	25+16	292A
263 0.8780 0.875 0.3%									0.3%	0.875		0.8780	263			
264 0.8960 0.875 2.4%									2.4%	0.875		0.8960	264			
292B 25+16 7.63 265 0.8850 0.887 0.875 1.1% 0.8833 246.33 <b>24000</b> 20464.6 0.85 29235.1	1.22	1.22	29235.1	0.85	20464.6	24000	246.33	0.8833	1.1%	0.875	0.887	0.8850	265	7.63	25+16	292B
266 0.880 0.875 1.5%									1.5%	0.875		0.8880	266			
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 2962.5	1.24	1.24	29862.5	0.87	20903.7	24000	246.33	0.8647			0.888			7.63	25+16	292C
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	1 36	32626.2	0.95	22838 3	24000	230.14	0.8280			0.865			7.63	26+07	3024
	1.55	2.50	52020.2	0.55	22050.5	24000	250.14	0.0200			0.005			7.05	20.07	50211
273 0.8510 0.875 -2.7%																
3028 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	1.38	33213.5	0.97	23249.4	24000	230.14	0.8133			0.849			7.63	26+07	302B
275 0.8600 0.875 -1.7%									-1.7%	0.875		0.8600	275			
275 0.8590 0.875 <b>-1.8%</b>									-1.8%	0.875		0.8590	276			
302C 26+07 7.63 277 0.8460 0.863 0.875 -3.3% 0.8190 230.14 <b>24000</b> 2309.0 0.96 32985.7	1.37	1.37	32985.7	0.96	23090.0	24000	230.14	0.8190	-3.3%	0.875	0.863	0.8460	277	7.63	26+07	302C
278 0.8540 0.875 <mark>-2.4%</mark>									-2.4%	0.875		0.8540	278			
279 0.880 0.875 1.5%																
313A 27+06 7.63 280 0.9650 0.967 0.935 3.2% 0.9502 217.43 <b>24000</b> 20590.0 0.86 29414.2	1.23	1.23	29414.2	0.86	20590.0	24000	217.43	0.9502			0.967			7.63	27+06	313A
281 0.9770 0.935 4.5%																
282 0.9600 0.935 2.7% 3138 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	4.00	20020 4		20100 4	24000	217 42	0.0605			0.070			7.62	37.00	2120
3138 2/406 7.63 283 0.9780 0.978 0.935 4.6% 0.9695 217.43 24000 20180.4 0.84 28829.1 284 0.9740 0.935 4.2%	1.20	1.20	20029.1	0.84	20180.4	24000	217.43	0.3030			0.978			7.03	2/+00	2128
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	1.24	29828.8	0.87	20880.1	24000	217.43	0.9370			0.962			7.63	27+06	313C
287 0.9600 0.935 2.7%																
288 0.9500 0.935 1.6%										0.935			288			
322A 27+67 7.63 289 0.9930 0.992 0.935 6.2% 0.9901 210.34 <b>24000</b> 20130.1 0.84 28757.3	1.20	1.20	28757.3	0.84	20130.1	24000	210.34	0.9901			0.992			7.63	27+67	322A
290 0.9910 0.935 6.0%									6.0%	0.935		0.9910	290			
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 <b>24000</b> 20447.4 0.85 29210.6	1.22	1.22	29210.6	0.85	20447.4	24000	210.34	0.9747			0.991	1.0000	292	7.63	27+67	322B
293 0.9870 0.935 5.6%																
294 0.9850 0.935 5.3%	1.22		20500.0		20055.5.2	24062	240.24	0.0642			0.001			7.00	37.57	2222
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           296         1.0100         0.935         8.0%         0	1.23	1.23	29509.0	0.86	20656.3	24000	210.34	0.9648			0.994			7.63	27+67	322C
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	1.38	33231.4	0.97	23262.0	24000	198.95	0.8820			0.975			7.63	28+65	331A
299 10100 1 1 1.0%		2.50		0.57												
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	1.23	29630.1	0.86	20741.0	24000	198.95	0.9892			0.996			7.63	28+65	331B
302 0.9940 1 <mark>-0.6%</mark>									-0.6%	1		0.9940	302			
303 0.9940 1 <u>-0.6%</u>									-0.6%	1		0.9940	303			
331C         28+65         7.63         304         1.000         1         0.0%         1.000         198.95         24000         20517.3         0.85         29310.4	1.22	1.22	29310.4	0.85	20517.3	24000	198.95	1.0000	0.0%		1.000		304	7.63	28+65	331C
305 1.0000 1 0.0%									0.0%	1		1.0000	305			
									0.0%	1		1.0000	306			
306 1.0000 1 0.0%		1.12	26884.0	0.78	18818.8	24000	187.68	1.1211	3.7%	1.125	1.150	1.1670	307	7.63	29+62	342A
306         1.0000         1         0.0%           342A         29+62         7.63         307         1.1670         1.125         3.7%         1.1211         187.68         24000         18818.8         0.78         26884.0	1.12									1.125		1.1410	308			

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										Allowable	Base N	Aaterial	At J	loints	
lo	cation	Radius (feet)	Reading Number	Thickness Reading (in)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
201	cation		309	1.1420		1.125	1.5%			(1)					
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	
			314 315	1.1910 1.1480		1.125 1.125	5.9% 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	
			320 321	1.1690 1.1890		1.125 1.125	3.9% 5.7%								
354C	30+59	7.63	321	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%								
364B	31+43	7.63	327 328	1.2660 1.2420	1.228	1.1875 1.1875	6.6% 4.6%	1.2051	154.85	24000	18911.5	0.79	27016.5	1.13	
304B	51745	7.05	328	1.2420	1.220	1.1875	2.8%	1.2031	134.85	24000	10511.5	0.75	27010.5	1.15	
			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	
			335 336	1.3220 1.3140		1.25	5.8% 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%								
381A	32+97	7.63	342 343	1.3250 1.3890	1.395	1.25 1.3125	6.0% 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%								
2010	22.07	7.62	348	1.4010	1 272	1.3125 1.3125	6.7% 5.9%	1 21 22	122.20	24000	18588.3	0.77	26554.7		
381C	32+97	7.63	349 350	1.3900 1.3920	1.373	1.3125	6.1%	1.3133	123.39	24000	10000.5	0.77	20554.7	1.11	
			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	
			356 357	1.3630 1.3610		1.375 1.375	-0.9% -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%								
399B	34+60	7.63	363 364	1.4400 1.4380	1.434	1.375 1.375	4.7% 4.6%	1.4236	90.08	24000	18353.9	0.76	26219.9	1.09	
5550	54100	,.05	365	1.4360	1.434	1.375	4.0%	12.50	55.00	2.000	10000.0	5.70	20213.5	1.05	
			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:

<sup>1</sup> Hoop stress = Pr/t<sub>97.5</sub>

<sup>2</sup> Hoop stress / S<sub>A</sub>

 $^3$  Hoop stress / 0.7 <sub>joint efficiency</sub>

 $^{\rm 4}$  Joint stress /  $\rm S_A$ 

# 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



Kleinschmidtgroup.com

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# ACRONYMS

A	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
c	
cfs <b>F</b>	Cubic feet per second
<b>e</b> ETS	Eastern Technical Services
<b>F</b>	
- Fu	Ultimate Tensile Stress
G	
GWh	Gigawatt Hours
К	
kPa	Kilo-Pascals
Kleinschmidt <b>P</b>	Kleinschmidt Associates
PSI	Pounds per square inch
M	i ounus per square men
m <sup>3</sup> s	Cubic metres per second
MW	Megawatts
Ν	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
<b>s</b> Sta	Station (in feet)
51A T	Station (in leet)
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<sup>3</sup>/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<sup>1</sup> for the penstock. The field data is included in Appendices C and D, respectively.

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
0000	remedial action is not expected to be required in the next 10 years
	Medium deterioration or defects are visible that do not require
Fair	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
P001	1 to 5 years
Von Poor	Severe deterioration or defect is visible and remediation is required
Very Poor	within 1 year

Table 3-1 Definitions

<sup>&</sup>lt;sup>1</sup> 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 premarked 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, 2<sup>nd</sup> Edition. The allowable primary stress intensity is the lesser of the material yield stress (F<sub>y</sub>) divided by 1.5 or of the ultimate tensile stress (F<sub>u</sub>) 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.

Can	Max Joint Stress <sup>1,3</sup> (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress <sup>1,3</sup> (psi)	Allowable Stress (psi)	Stress Ratio <sup>1,2,3</sup>	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 <sup>1,3</sup> (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress <sup>1,3</sup> (psi)	Allowable Stress (psi)	Stress Ratio <sup>1,2,3</sup>	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

<sup>1</sup> Joint efficiency of 0.7 included

<sup>2</sup> Total stress / Allowable stress

<sup>3</sup> Uses 97.5% confidence thickness

<sup>4</sup> 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.

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

 Table 4-2
 Summary of Surcharge Load Analysis

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.

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#### **REPORT SIGNATURE PAGE**

#### **KLEINSCHMIDT ASSOCIATES CANADA INC.**

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



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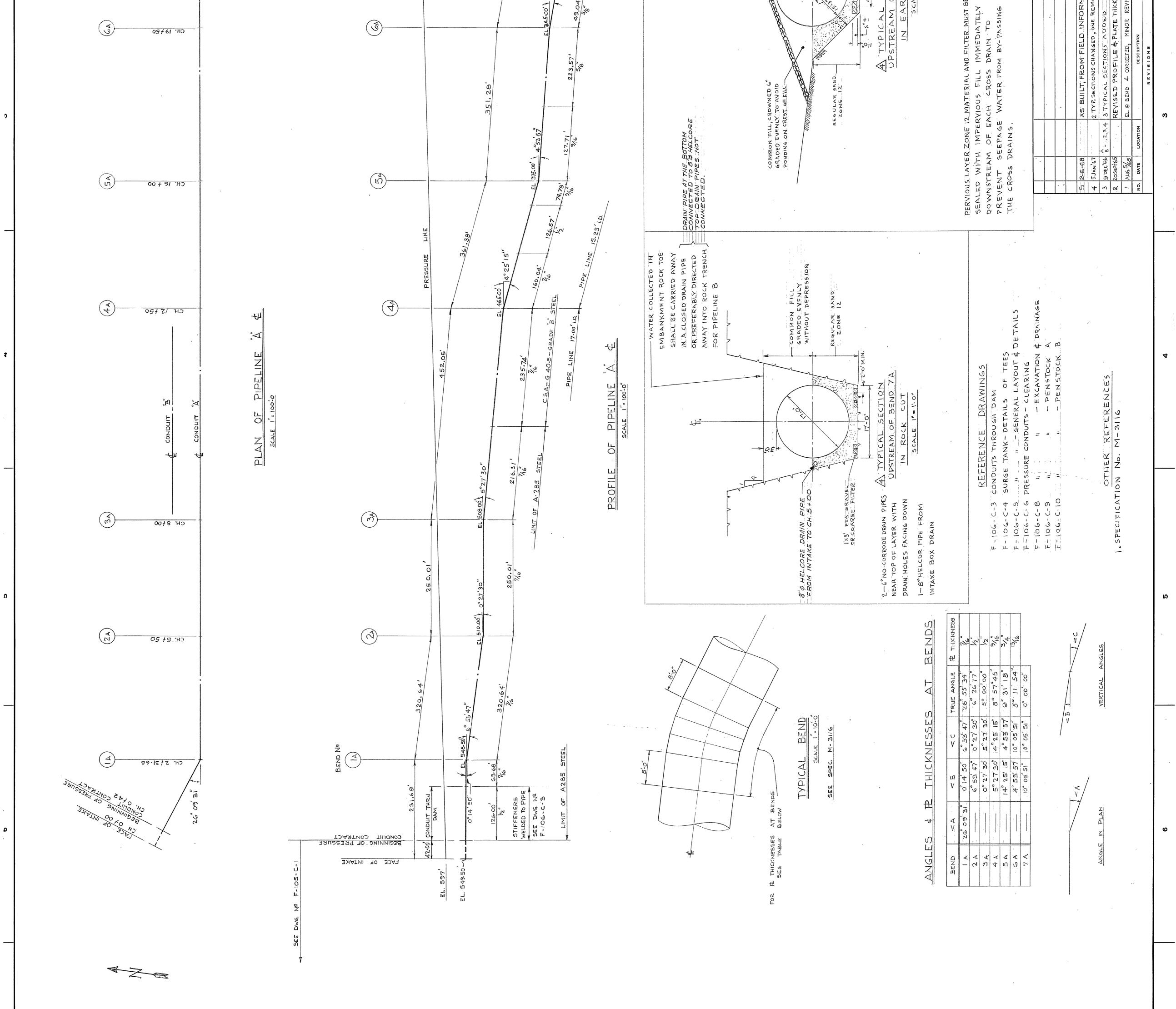
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**Kleinschmidt** 

**APPENDIX A** 

**PENSTOCK LAYOUT DRAWINGS** 

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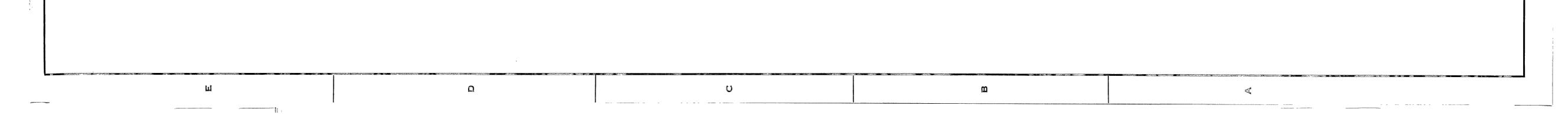


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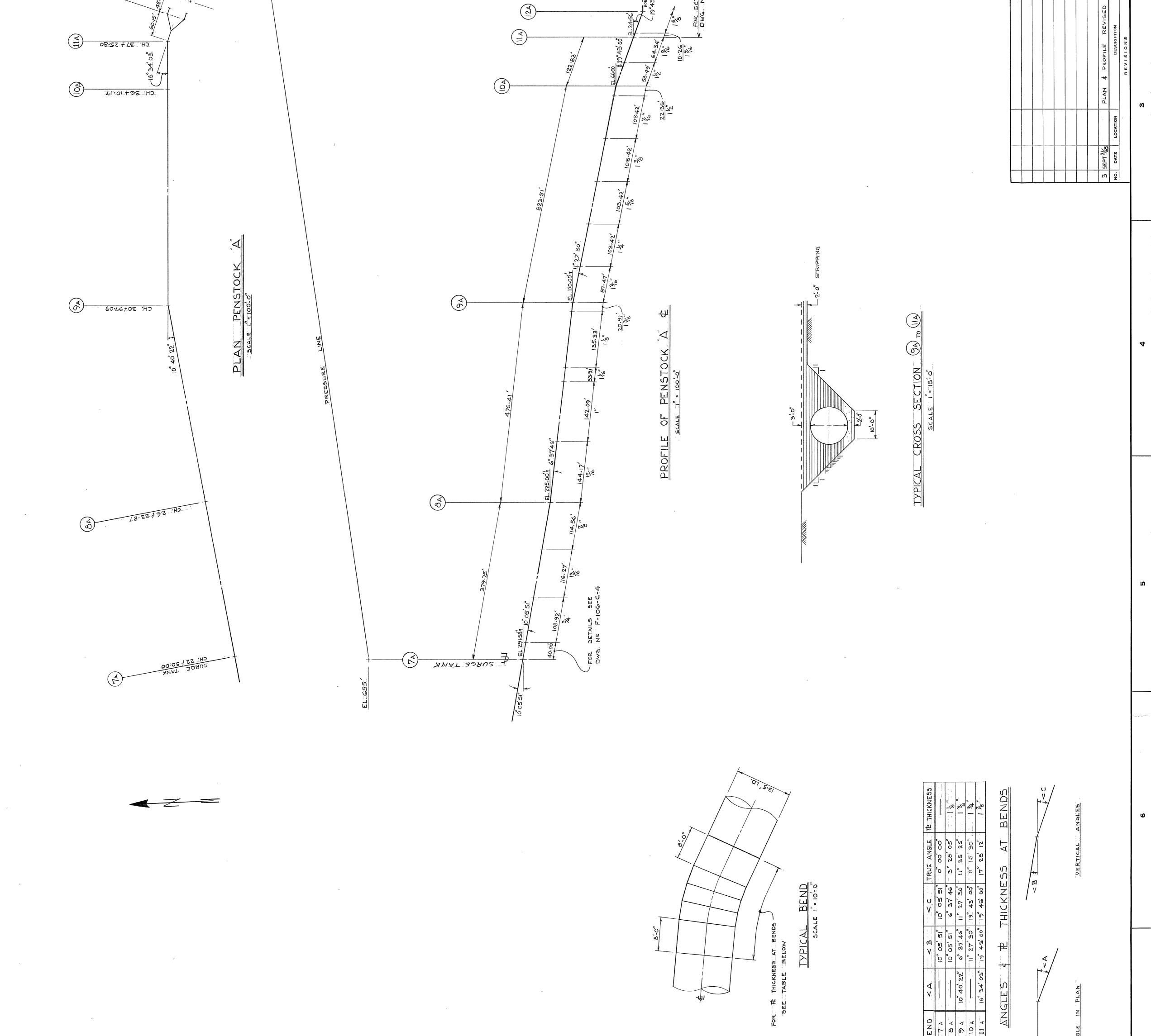
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	NOTES 1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-316 EXCEPT FOR BENDS WHERE 1. SPECIFICATION Nº M-316 EXCEPT FOR BENDS WHERE 1. SHALL BE ADDED TO PLATE THICKNESSES CALLMATED TO RESIST HOOD TENSION AND THE FFECTS OF THE TORUS SHALL DE OVER THE BENDS AND AT LEAST OF HE TORUS STEEN AND DOWNSTREAM OF THE LAST MITTLE JOINT. 2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13-6". 3. STEEL SHALL DE C.S.A. 940-B GRADE "A". 4. FOR TYPICAL ERDES SECTION FROM (A) TO (A) SEE DWG. Nº F-106-C-T.		EL + 3.00 E 10.00 F 106-6-2 F 106 - 6 - 2 F 106 - 6 - 6 FRESURE CONDUTS - ATAILS OF BFURCATION 2. F - 106 - 6 - 5 FRESE CONDUTS - CLEARING OF DEFURCATION 3. F - 106 - 6 - 6 - 6 - 6 - 6 - 6 - 6 - 6 - 6 -	F - 106 - C - 7 PRESSLIRE CON REFERENCES SPECIFICATION Nº M-3116	APPROVED     Reforment     Newfoundland and labrador power commission       POR CONSTRUCTION     PROVED     BAY     D'ESPOIR     EVELOPMENT       POR CONSTRUCTION     J.P.     BAY     D'ESPOIR     EVELOPMENT       PROVED BY:     APPROVED BY:     APPROVED BY:     MONTERLOUNDLAND LIMITED       APPROVED BY:     APPROVED BY:     APPROVED BY:     MONTERLOUNDLAND LIMITED       APPROVED BY:     APPROVED BY:     PONTERLOUNDLAND LIMITED     MONTERLOUNDLAND LIMITED       APPROVED BY:     APPROVED BY:     PONTERLOUNDLAND     PONTERLOUNDLAND LIMITED       APPROVED BY:     APPROVED BY:     PONTERLOUNDLAND     PONTERLOUNDLAND       APPROVED BY:     APPROVED     PONTERLOUNDLAND     PONTERLOUNDLAND
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NP-NLH-011, Attachment 2 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

Page 32 of 88



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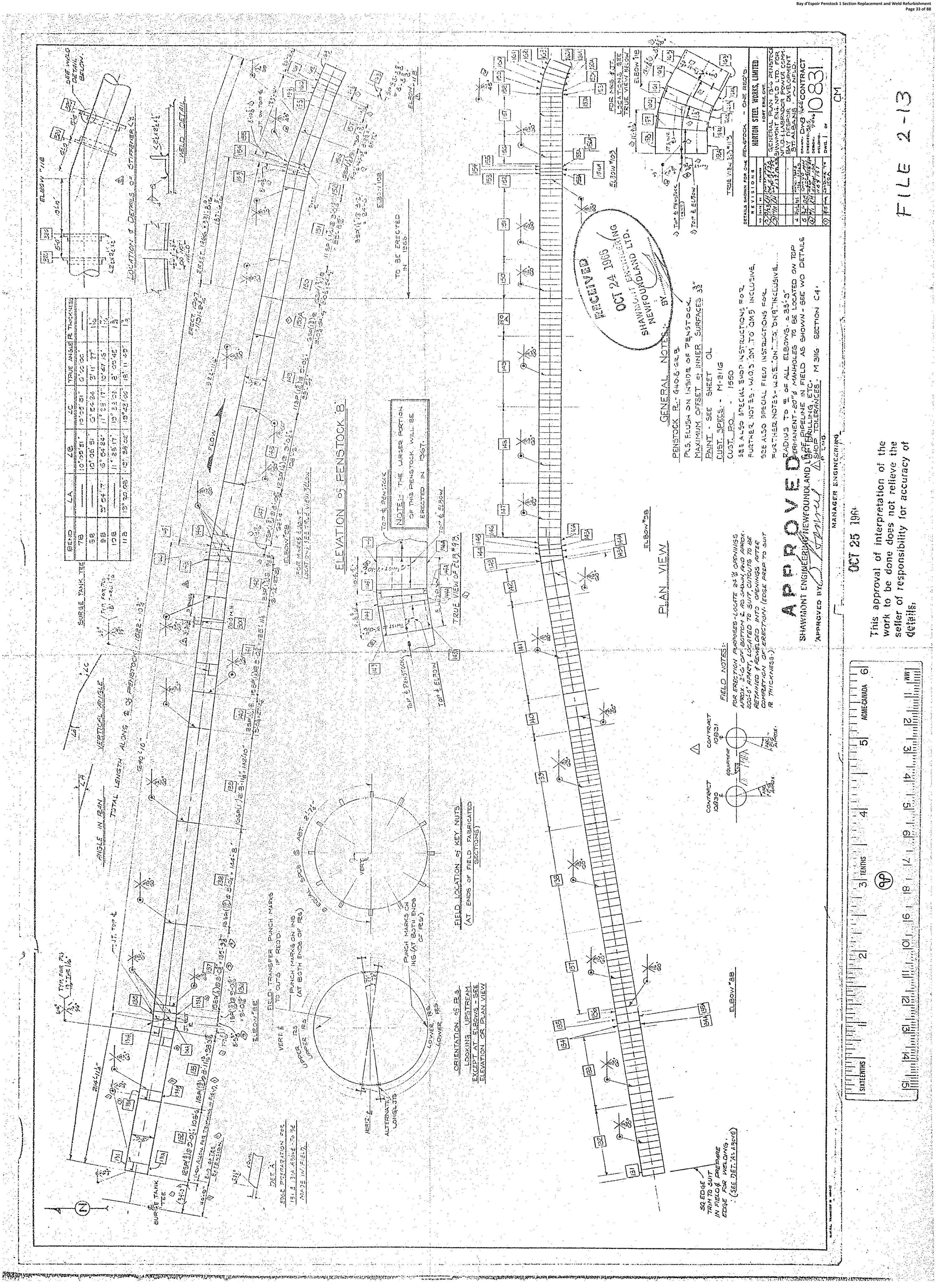
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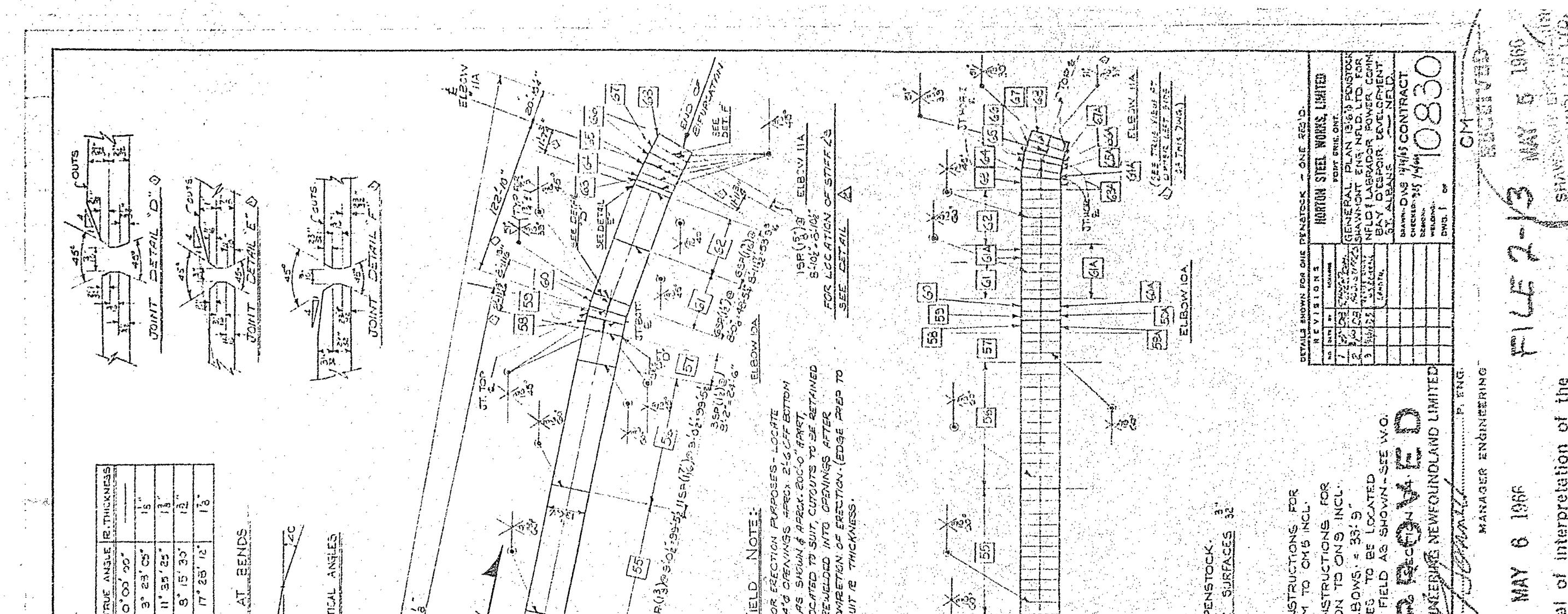
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NP-NLH-011, Attachment 2





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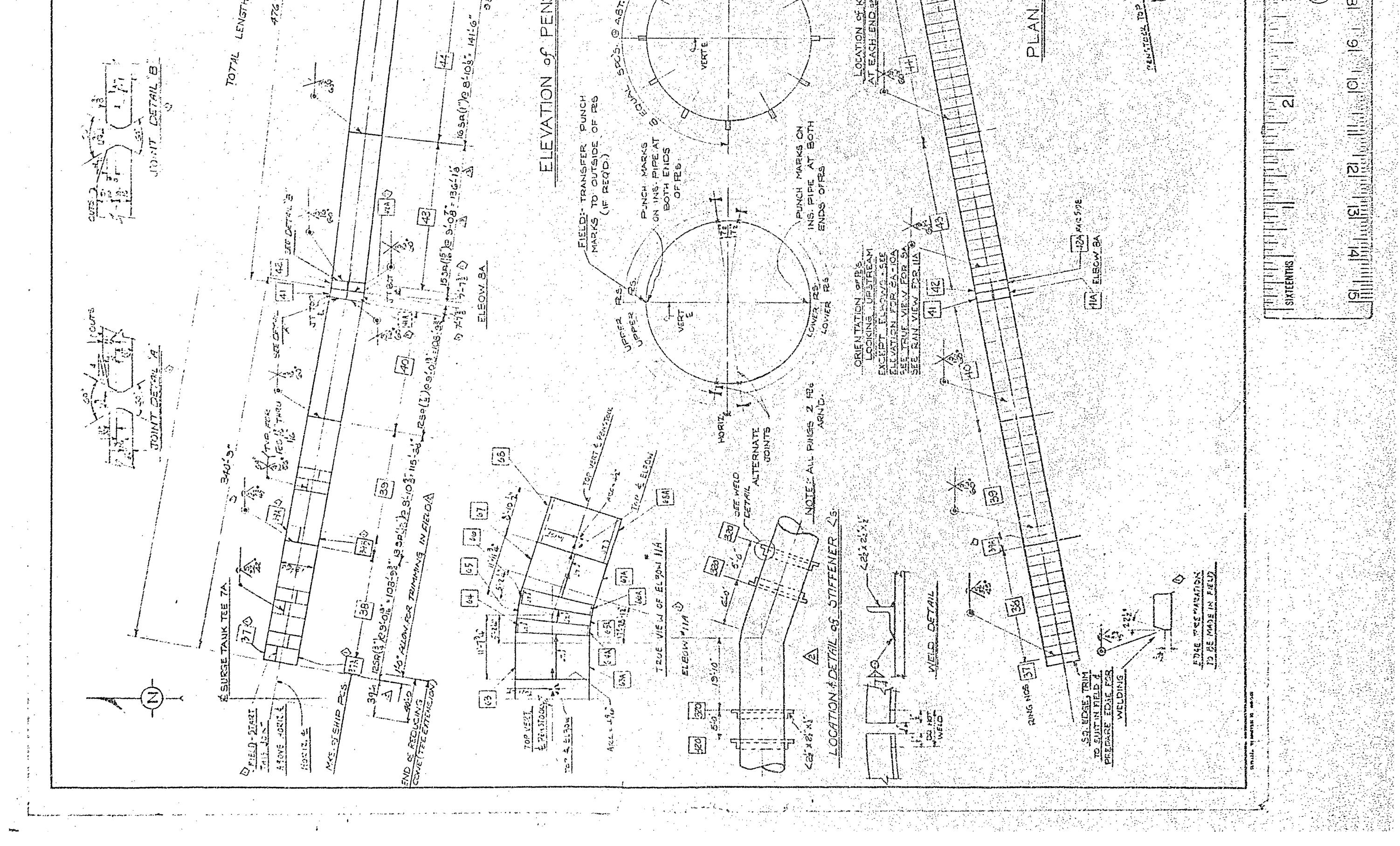
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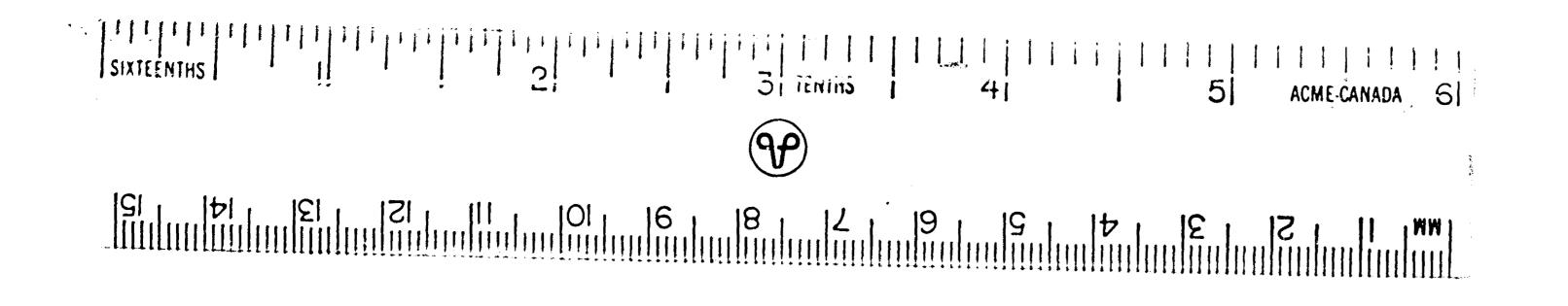
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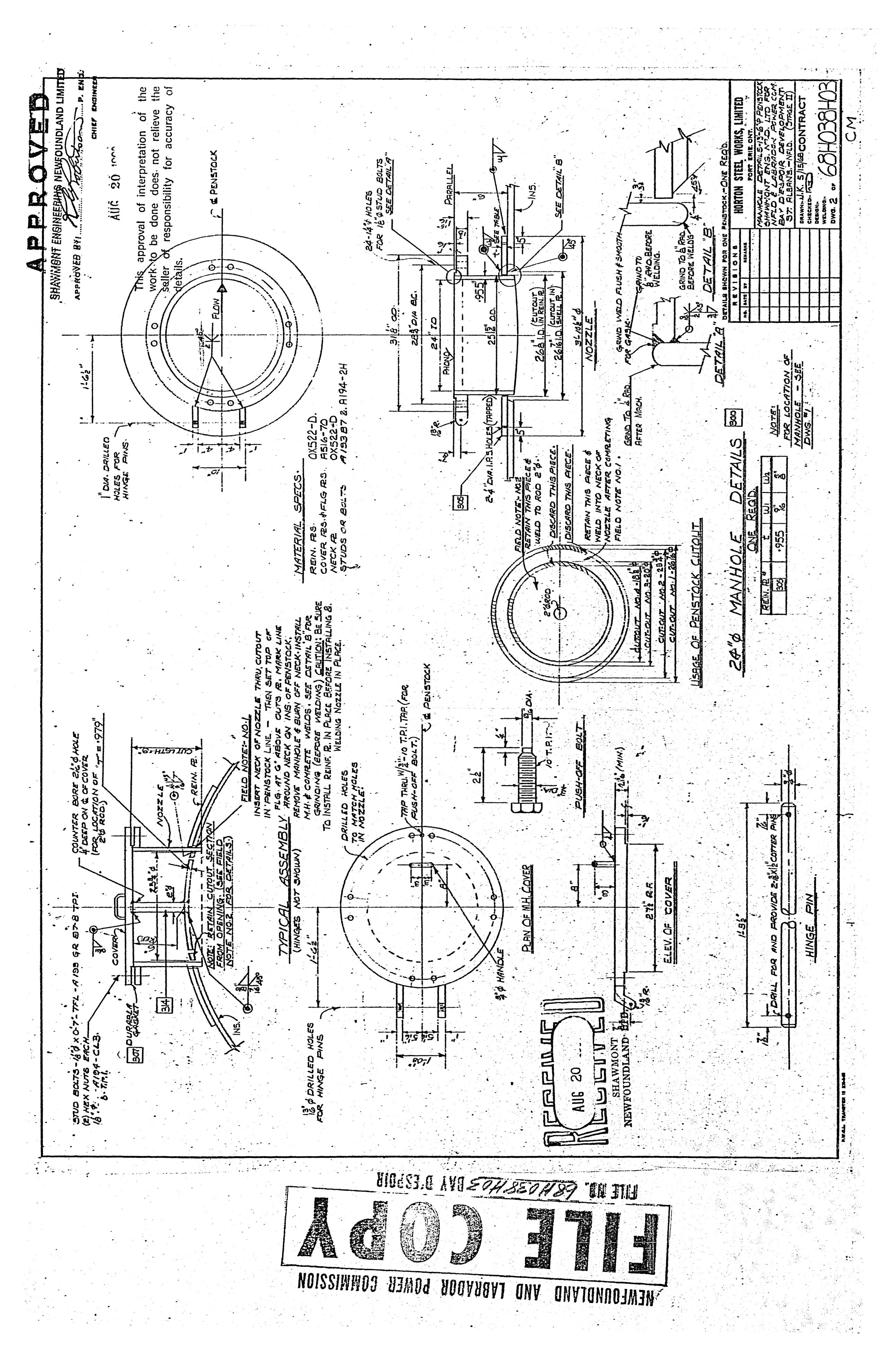
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**APPENDIX B** 

**Photographs** 

NP-NLH-011, Attachment 2 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 37 of 88



Photo 1 Leakage Bottom Left Corner of Gate



Photo 2 Leakage Bottom Right Corner of Gate

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Photo 3 Concrete to Steel Transition Right Side





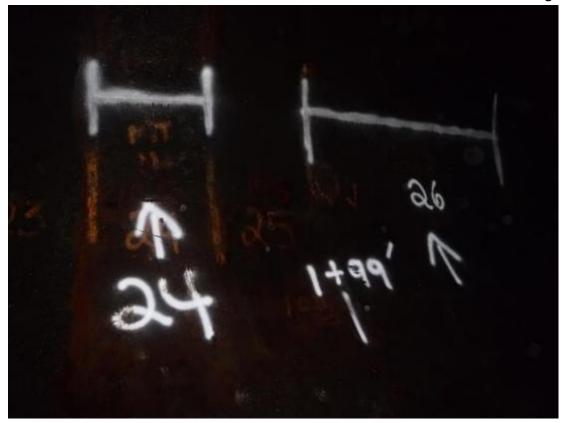


Photo 5 Typical markings for numbering cans, welds, and stationing 2020



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

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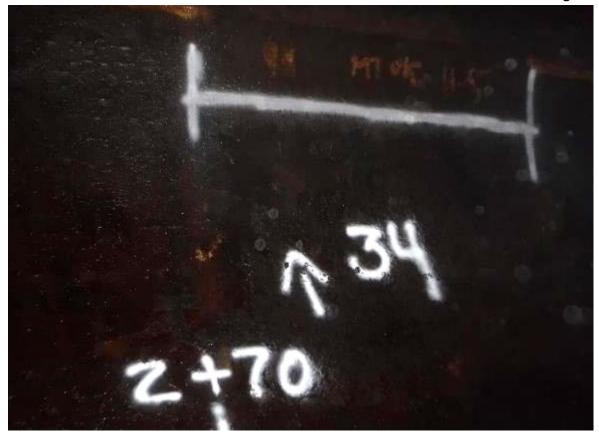


Photo 11 Weld Tested Can 34



Photo 12 Connor performing MT on weld

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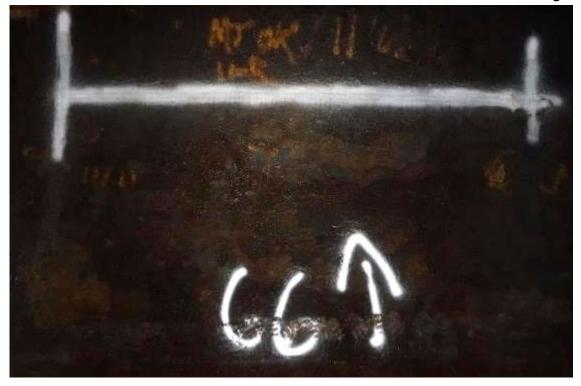


Photo 13 Tested weld Can 66



Photo 14 Tested weld Can 151

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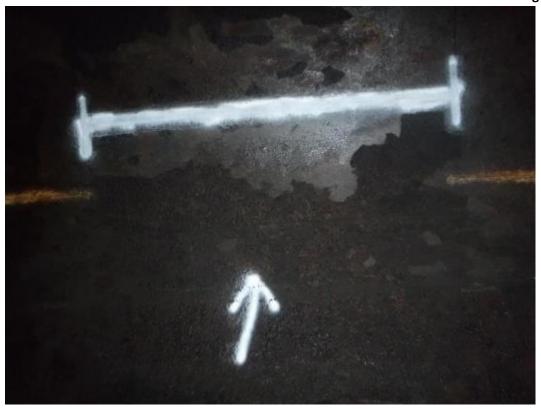


Photo 15 Tested weld. Note organic material



Photo 16 Tested weld Can 233

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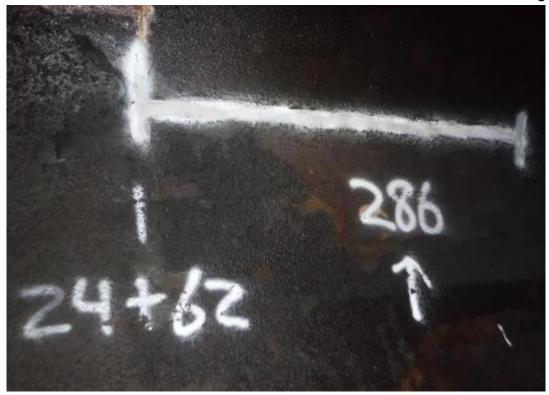


Photo 17 Tested weld Can 286



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

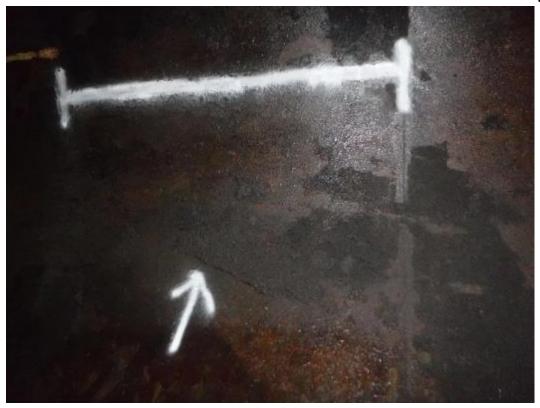


Photo 25 Surface conditions Can 190



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

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# Photo 33 Drain pipes at FP 5



Photo 34 Looking downstream along Penstock 1 upstream of surge tanks

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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

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Photo 43 Drain at N1 upstream of monitoring shed



Photo 44 Inside monitoring shed N1

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

APPENDIX C

WELD TEST

#### NP-NLH-011, Attachment 2 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 61 of 88

Visual Inspectio Radiography & I Mag & Penetrar Eddy Current Te Structural Steel	ns Ultrasonics It Inspections seting & Torque Ultrasonics PO Box 709-726-	13517, St. Johr 4622 27 Austin	<b>I Services Ltd.</b> n's, NL., A1B 4B8 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 CAN/CGSB 48.9712 MT/PT				
Attn:	Colin LeGrow						
P.O. No.	2020-0127						
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1						
Testing Required:	Magnetic Particle Inspection	Signed:	Conor uppy				

**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.

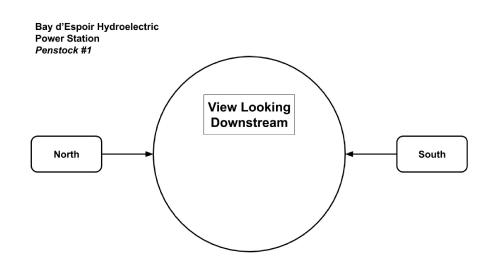
NDT Inspector

#### **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.



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

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

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

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

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

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

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

#### NP-NLH-011, Attachment 2 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 70 of 88

Visual Inspecti Radiography & Mag & Penetra Eddy Current Structural Stee	ant Inspections PO Box	13517, St. Joh	<b>al Services Ltd.</b> nn's, NL., A1B 4B8 n St. Fax 726-4626	Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance Reports
		Repo	ort	
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 CAN/CGSB 48.9712 MT/PT	
Attn:	Colin LeGrow			
P.O. No.	2020-0127			
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1			
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Conor unpay	

NDT Inspector

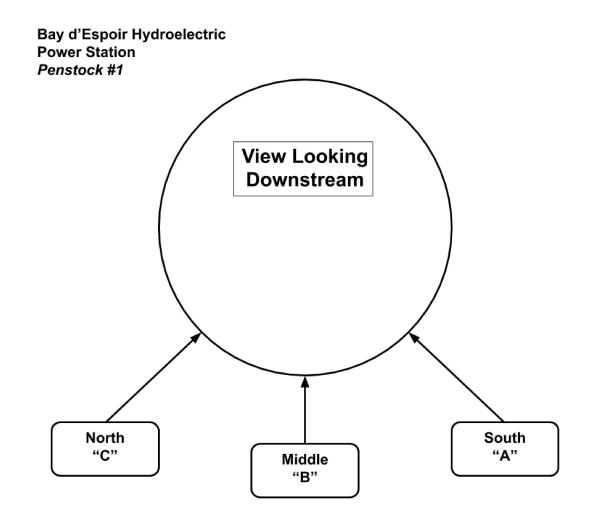
#### **Remarks**

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** 



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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

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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 T	CT TITLE: Penstock 1 Inspection		CLIENT:		ewfoundland Labrador /dro	
KLEINSCHMIDT PROJECT NO:		OJECT NO:	2670030.01	LOCATIO	LOCATION: Bay D'Espoir	
SUBJECT:	SUBJECT:         Penstock 1 – steel thickness measurements					
PROJECT M	PROJECT MANAGER: Nancy Sutherland					
TECHNICAL LEAD/ADVISOR: C		Chris Vella				
ENGINEER: NANCY SUTHERLAND						

<b>REV.</b>	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:		
	Performed By:		
	Checked By:		
	TA Approval:		

[Insert PE Stamp]

Project: Bay d'Espoir Penstock 1 I	99 Wyse Road, Suite 940 Dartmouth, Nova Scotia B3A 4S5 Telephone: 902.708.1082 www.KleinschmidtUSA.com	Designed By: Date: Revised: Date: Checked By:	NS 07/13/2020
Task: Penstock Calculations		Date: Job Number:	2670-030
<b>Dbjective:</b> Determine the structural integrity of Bay d'Esp	bir Penstock 1 under external loading.		
Assumptions: For the following analyses, it is of approximately 3 feet in depth. It is also ass and any subsequent live loads include mainte References: 1. Site Visit Notes - CMV June 22-25, 2020 2. TRR Report ETS No.: 20-435-2 June 29, 20 3. ASCE No. 79, Steel Penstocks, 2nd Edition 4. Existing Drawings: Penstock 1 (attached) 5. National Building Code of Canada, current v 5. ASCE7-10 Minimum Design Loads For Bui	umed that there is no vehicular traffic in the a lance workers, etc. or environmental loads o 20 2012	rea of the penstock	
<ul> <li>AWWA M11, Steel Pipe - A Guide for Desig</li> <li>AISC, Manual of Steel Construction, curren</li> <li>Hydroelectric Handbook Justin &amp; Creager '</li> <li>CSA S-16 Design of Steel Structures. Hand</li> </ul>	version 950 book of Steel Construction, current version		
<ul> <li>AWWA M11, Steel Pipe - A Guide for Desig</li> <li>AISC, Manual of Steel Construction, curren</li> <li>Hydroelectric Handbook Justin &amp; Creager 7</li> <li>CSA S-16 Design of Steel Structures. Hand</li> <li>Notes: Station 0+00 is 17 feet from</li> <li>Penstock Dimensions: (Reference 4)</li> </ul>	version 950 book of Steel Construction, current version downstream side of the gate		
<ul> <li>AWWA M11, Steel Pipe - A Guide for Desig</li> <li>AISC, Manual of Steel Construction, curren</li> <li>Hydroelectric Handbook Justin &amp; Creager '</li> <li>CSA S-16 Design of Steel Structures. Hand</li> <li>Notes: Station 0+00 is 17 feet from</li> <li>Penstock Dimensions: (Reference 4)</li> </ul>	version 950 book of Steel Construction, current version downstream side of the gate		
B. AWWA M11, Steel Pipe - A Guide for Desig         C. AISC, Manual of Steel Construction, curren         B. Hydroelectric Handbook Justin & Creager 7         B. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference of D17) := 17 · ft	version 950 book of Steel Construction, current version <b>downstream side of the gate</b>		
B. AWWA M11, Steel Pipe - A Guide for Desig         C. AISC, Manual of Steel Construction, curren         B. Hydroelectric Handbook Justin & Creager (         B. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference of D17) := 17 · ft	version 950 book of Steel Construction, current version <b>downstream side of the gate</b>		
B. AWWA M11, Steel Pipe - A Guide for Design         AISC, Manual of Steel Construction, currend         B. Hydroelectric Handbook Justin & Creager 2         B. CSA S-16 Design of Steel Structures. Handbook Justin & Creager 2         D. CSA S-16 Design of Steel Structures. Handbook Justin & Creager 2         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference 2         D <sub>17</sub> := 17·ft         PlateThickness: (Reference 2         t <sub>17</sub> := 0.3844in	version 950 book of Steel Construction, current version <b>downstream side of the gate</b>	17' diameter penstock	section
B. AWWA M11, Steel Pipe - A Guide for Design         B. AlSC, Manual of Steel Construction, curren         B. Hydroelectric Handbook Justin & Creager 7         B. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference 4         D <sub>17</sub> := 17·ft         D <sub>15.25</sub> := 15.25·ft         F         Steel PlateThickness: (Reference 2 $t_{17}$ := 0.3844in         ( $t_{15.25}$ := 0.3842in	Version 950 book of Steel Construction, current version downstream side of the gate <u>1)</u> enstock Diameter 17 ft ID enstock Diameter 15.25 ft ID		
B. AWWA M11, Steel Pipe - A Guide for Design         B. AlSC, Manual of Steel Construction, curren         B. Hydroelectric Handbook Justin & Creager 7         B. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference of D <sub>17</sub> := 17·ft         D <sub>15.25</sub> := 15.25·ft         Steel PlateThickness: (Reference 2) $t_{17}$ := 0.3844in         (15.25 := 0.3842in	Version 950 book of Steel Construction, current version <b>downstream side of the gate</b> <u>1)</u> enstock Diameter 17 ft ID enstock Diameter 15.25 ft ID Minimum 97.5% CI steel plate thickness for 7 Reference 2) linimum 97.5% CI steel plate thickness for 1	5.25' diameter penstoo	ck section
B. AWWA M11, Steel Pipe - A Guide for Design         B. AlSC, Manual of Steel Construction, curren         B. Hydroelectric Handbook Justin & Creager 7         B. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference 4         D <sub>17</sub> := 17·ft         D <sub>15.25</sub> := 15.25·ft         Steel PlateThickness: (Reference 2 $t_{17} := 0.3844$ in         ( $t_{15.25} := 0.3842$ in         t_{.4375} := 0.4375in	Version 950 book of Steel Construction, current version <b>downstream side of the gate</b> <u>1)</u> enstock Diameter 17 ft ID enstock Diameter 15.25 ft ID Minimum 97.5% CI steel plate thickness for the Reference 2) linimum 97.5% CI steel plate thickness for 1 Reference 2)	5.25' diameter penstoo enstock dead load 17'	ck section ' pipe
B. AWWA M11, Steel Pipe - A Guide for DesigC. AISC, Manual of Steel Construction, currenB. Hydroelectric Handbook Justin & Creager 7D. CSA S-16 Design of Steel Structures. HandNotes: Station 0+00 is 17 feet fromPenstock Dimensions: (Reference 4)D17 := 17 $\cdot$ ftD15.25 := 15.25 $\cdot$ ftSteel PlateThickness: (Reference 2)t17 := 0.3844 int15.25 := 0.3842 int.4375 := 0.4375 in	Version 950 book of Steel Construction, current version <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>for steel plate thickness for the steel plate the </b>	5.25' diameter penstoo enstock dead load 17'	ck section ' pipe
3. AWWA M11, Steel Pipe - A Guide for Design         3. Also, Manual of Steel Construction, curren         3. Hydroelectric Handbook Justin & Creager         3. CSA S-16 Design of Steel Structures. Hand         Notes: Station 0+00 is 17 feet from         Penstock Dimensions: (Reference of D <sub>17</sub> := 17·ft $D_{17} := 17·ft$ $D_{15.25} := 15.25·ft$ Steel PlateThickness: (Reference 2) $t_{17} := 0.3844in$ (t $t_{4375} := 0.4375in$ $t_{1.625} := 1.625in$	Version 950 book of Steel Construction, current version <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>downstream side of the gate</b> <b>for steel plate thickness for the steel plate the </b>	5.25' diameter penstoo enstock dead load 17' penstock dead load of	ck section ' pipe 15.25' pipe

$F_{u2} := 65 ksi$	Penstock Lower Section - Ultimate Tensile Stress Steel (CSA G40.8 Grade B) Reference 9
$F_{y2} := 40$ ksi	Yield Stress CSA G40.8 Grade B for thicknesses less than and equal to 0.625 inches
$F_{y3} := 38$ ksi	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
$\gamma_w := \textbf{62.4pcf} \qquad \gamma_s := \textbf{490}p$	cf 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:

$S_{\text{MAX}} := \min\left(\frac{F_{y4}}{1.5}, \frac{F_{u2}}{2.4}\right) = 24 \cdot ksi$	Allowable Stress in Penstock Steel G40.8 (Ref. 3, 3.5.3) use 36 ksi; conservative
$(1.3 \ 2.4)$	

# 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 <sub>b</sub> := 0.8	Basic roof snow load factor
$C_w \coloneqq 1.0$	Exposure to wind factor (conservative)
$\alpha := 45 \cdot ^{\circ}$	Average roof slope of penstock.
$C_{s} := \frac{(60^{\circ} - \alpha)}{45 \cdot \circ} = 0.33$	Slope factor.
C <sub>a</sub> := 1.0	
$S_s := 3.7 \text{kPa} = 77.28 \text{·psf}$	Ground snow load (Table C-2)

S <sub>r</sub> := 0kPa	Rain load (no ponding on penstock).								
$S = I_{s} \cdot \left[ S_{s} \cdot \left( C_{b} \cdot C_{w} \cdot C_{s} \cdot C_{a} \right) + S_{r} \right] = 0.99 \cdot kPa \qquad S = 20.61 \cdot psf$									
$D_{17od} := D_{17} + 2 \cdot t_{17} = 17.06  ft$									
$S_{load} := S \cdot D_{17od} = 351.64 \frac{1}{ft} \cdot lbf$	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' D	Diameter Pipe:								
Dead Load on Conduit									
$H_c := 3ft$	Height of fill above conduit								
$D_{17} = 17.00  \text{ft}$	Penstock Diameter ID								
$D_{17} = D_{17} + 2 \cdot t_{17} = 17.06  \text{ft}$									
w := 120pcf									
$\mathbf{w}_{s} \coloneqq \pi \cdot \mathbf{D}_{17od} \cdot \mathbf{t}_{.4375} \cdot \boldsymbol{\gamma}_{s} = 957.69 \cdot \text{plf}$	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:									
$\mathbf{h}_{\mathbf{W}} \coloneqq 0$	Height of Water above penstock	$h_{\rm w}=0.00{\cdot}in$							
$h := H_c$	Height of fill above penstock, (assumed)	$h = 36.00 \cdot in$							
$R_w := 1$	Water Buoyancy factor (assume well-drained)	R <sub>w</sub> = 1.00							
$H_{\rm c} := \frac{H_{\rm c}}{ft}$	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	$B_{prime} = 0.23$							

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E <sub>prime</sub> := 500psi	E <sub>prime</sub> := 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							
$\mathbf{I} := \frac{\left(\mathbf{t}_{17}\right)^3}{12}$	Transverse moment of inertia per unit length of pipe wall $I = 0.0568 \cdot \frac{in^4}{ft}$							
$E \cdot I = 4568733.844  \text{ft} \cdot \text{s}^{-2} \cdot \text{in} \cdot \text{lb}$	Pipe wall stiffness							
$D_{17od} = 17.06  \text{ft}$	Penstock Diameter 1 - OD							
FS := 2.0	Factor of safety per AWWA M-11, 5th Ed., (ASCE No. 79 references 3rd Ed.)							
$q_{a17} := \frac{1}{FS} \cdot \left( 32 \cdot R_{w} \cdot B_{prime} \cdot E_{prime} \cdot \frac{E \cdot I}{D_{170}} \right)$	$ \left(\frac{3}{3}\right)^{0.5} $ Allowable Buckling Pressure on 17' $q_{a17} = 3.93 \cdot psi$ diameter penstock, (Reference 3 EQN 6-7, AWWA 2004)							
External Pressure without Live Load:								
$Q_{17} \coloneqq \gamma_{w} \cdot h_{w} + R_{w} \cdot \frac{\left(W_{D17} + S_{load}\right)}{D_{17od}} + P_{v}$	= $3.03 \text{ psi}$ External Pressure and no vacuum conditions inside penstock (Ref 3, AWWA $Q_{17} = 3.03 \cdot \text{psi}$ 2004) $Q_{17} = 3.03 \cdot \text{psi}$							
External Pressure with Live Load:								
$Q_{L17} := \gamma_{w} \cdot h_{w} + R_{w} \cdot \frac{\left(W_{D17} + S_{load}\right)}{D_{17od}} + \frac{1}{12}$	$\frac{L_{\text{load}}}{D_{17\text{od}}} = 3.15 \text{psi} \qquad \qquad$							
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	<u>' Diameter Pipe:</u>							
Dead Load on Conduit								
H <sub>€</sub> := 3ft	Height of fill above conduit							
$D_{15.25} = 15.25  \text{ft}$	Penstock Diameter 2 ID							
$D_{15.25od} \coloneqq D_{15.25} + 2 \cdot t_{15.25} = 15.31  \mathrm{ft}$	Penstock Diameter 2 OD							
With Weight of fill, assumed saturated								

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Page: <u>P1-5</u> By: <u>NS</u> Date: 07-13-2020

$\mathbf{w}_{s1} \coloneqq \pi \mathbf{D}_{15.25od} \cdot \mathbf{t}_{1.625} \cdot \boldsymbol{\gamma}_s$	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:		
$h_{WW} := 0$	Height of Water above penstock	$h_{\rm w} = 0.00 \cdot in$
$\mathbf{h} := \mathbf{H}_{\mathbf{c}}$	Height of fill above penstock, (assumed)	$h = 36.00 \cdot in$
<u>R</u> .:= 1	Water Buoyancy factor (assume well-drained)	$R_{w} = 1.00$
$\underbrace{H}_{w} := \frac{H_{c}}{\mathrm{ft}}$	Height of fill above penstock, (ft) unitless	H = 3.00
$\mathbf{B}_{\text{prime}} := \frac{1}{1 + 4e^{-0.065 \cdot \text{H}}}$	Empirical coefficient of elastic support	$B_{prime} = 0.23$
E <sub>prime</sub> := 500psi	Modulus of soil reaction,Reference 6, Table 6-1, assumed with w/less than 25% sand @ 85% compaction @ 2ft-5ft	
E.:= 3000000psi	Modulus of elasticity for steel	
$\mathbf{J} := \frac{\left(t_{15.25}\right)^3}{12}$	Transverse moment of inertia per unit length of pipe wall	$I = 0.0567 \cdot \frac{in^4}{ft}$
$E \cdot I = 4561606.336 \text{ ft} \cdot \text{s}^{-2} \cdot \text{in} \cdot \text{lb}$	Pipe wall stiffness	
$D_{15.25} = 15.25  \text{ft}$	Penstock Diameter 2 ID	
$\underline{\mathbf{D}_{15,25000}} \coloneqq \mathbf{D}_{15,25} + \left(2 \cdot \frac{\mathbf{t}_{15,25}}{12}\right) = 15.$	26 fiPenstock Diameter 2 OD	
FS.:= 2.0	Factor of safety per AWWA M-11, 5th Ed., (ASCE No. 79	references 3rd Ed.)
$q_{a15.25} := \frac{1}{FS} \cdot \left( 32 \cdot R_{w} \cdot B_{prime} \cdot E_{prime} \cdot \frac{1}{B_{prime}} \right)$	$\frac{E \cdot I}{D_{15.25 \text{ od}}} \int_{0.5}^{0.5} Allowable Buckling Pressure on 15.25' diameter penstock, (Ref 3, EQN 6-7, AWWA 2004)$	$q_{a15.25} = 4.64 \cdot psi$
External Pressure without Live Load:		
$Q_{15.25} := \gamma_{w} \cdot h_{w} + R_{w} \cdot \frac{\left(W_{D15.25} + S_{loa}\right)}{D_{15.25}}$	$\frac{d}{dt} + P_{v1}$ External Pressure with no vacuum on 15.25' diameter penstock (Ref 3, AWWA 2004)	$Q_{15.25} = 4.12 \cdot psi$

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**External Pressure with Live Load:**  $Q_{L15.25} := \gamma_{w} \cdot h_{w} + R_{w} \cdot \frac{\left(W_{D15.25} + S_{load}\right)}{D_{15.25}} + \frac{L_{load}}{D_{15.25}}$ External Pressure with 100 psf Live Load on 15.25' diameter penstock (Ref  $Q_{L15.25} = 4.26 \cdot psi$ Load on 15.25' diameter penstock (Ref 3, AWWA 2004) **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:  $t_{17USBR} := \frac{(D_{17od} + 20in)}{400} = 0.56 \cdot in$  $t_{15.25USBR} := \frac{\left(D_{15.25od} + 20in\right)}{400} = 0.51 \cdot in$ 

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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 <sub>1</sub> ID=	17.00	feet
D 1D-	15.25	6

D<sub>2</sub> ID= 15.25 feet Note: Station 0+00 is 17 feet from downstream side of the head gate

										Base Material		At Joints		
10	cation	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 <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	ck Interior	Radius (leet)	Number	Reduing (III)	Thickness (iii)	Wateria	interval	C.L. EL. (II)	Steel Stress	Stress (psi)	JUESS RAUU	Stress (psi)	Stress Ratio	Notes
	am End of Condui													
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 4C		8.50 8.50	2 3	0.4684 0.4763	0.5000	-6.3% -4.7%			17000 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	04.00.40	8.50	6	0.4802	0.5000	-4.0%	0.4350	540 5670	17000	5000 0	0.20	7400.0	0.42	
26A 26B	01+99.42	8.50 8.50	7	0.4290 0.4290	0.4375	-1.9% -1.9%	0.4259	548.5670	17000 17000	5026.6	0.30	7180.9	0.42	
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 44A	03+60	8.50 8.50	12	0.4290 0.3936	0.4375	-1.9% -10.0%	0.3844	530.9246	17000 17000	7596.7	0.45	10852.4	0.64	
44B	03100	8.50	14	0.4133	0.4375	-5.5%	0.3044	550.5240	17000	7550.7	0.45	10052.4	0.04	
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 55C		8.50 8.50	17 18	0.4172 0.4133	0.4375 0.4375	-4.6% -5.5%			17000 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	5 . 40.02	8.50	21	0.4133	0.4375	-5.5%	0.0004	500.0040	17000	0044.4	0.50	44462.5	0.02	
66A 66B	5+49.83	8.50 8.50	22 23	0.4015 0.3936	0.4375	-8.2% -10.0%	0.3884	509.8840	17000 17000	9914.4	0.58	14163.5	0.83	
66C		8.50	23	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 86A	7+29.75	8.50 8.50	27 28	0.4093	0.4375	-6.4% -7.3%	0.3977	508.4458	17000 17000	9842.0	0.58	14060.0	0.83	
86A 86B	/=29.75	8.50	28	0.4054	0.4375	-7.3% -8.2%	0.5377	300.4438	17000	5042.0	0.56	14000.0	0.83	
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 94C		8.50 8.50	32 33	0.3897 0.3975	0.4375 0.4375	-10.9% -9.1%			17000 17000					
94C 99A	8+43.5	8.50	33	0.4133	0.4375	-9.1%	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 106C		8.50 8.50	38 39	0.4133 0.3975	0.4375 0.4375	-5.5% -9.1%			17000 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 120B	10+32.34	8.50 8.50	43 44	0.4054 0.3936	0.4375	-7.3% -10.0%	0.3842	484.3984	24000 24000	12955.0	0.54	18507.2	0.77	CSA G40.8 Grade B Steel
120D		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 140A	12+08.67	8.50 8.50	48 49	0.4015	0.4375	-8.2% 23.3%	0.5104	467.5502	24000 24000	11210.1	0.47	16014.5	0.67	
140B	12.00.07	8.50	50	0.5392	0.4375	23.3%	0.5104	407.5502	24000	11110.1	0.47	10014.5	0.07	
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 150C		7.63 7.63	53 54	0.4172 0.4172	0.4375 0.4375	-4.6% -4.6%			24000 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 166B	14+14.34	7.63 7.63	58 59	0.4841 0.4959	0.5000	-3.2% -0.8%	0.4789	419.4953	24000 24000	14696.2	0.61	20994.6	0.87	
166C		7.63	60	0.4959	0.5000	-0.8%			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 184A	15+92.17	7.63 7.63	63 64	0.5314 0.5156	0.5000	6.3% -8.3%	0.5062	373.7668	24000 24000	17485.9	0.73	24979.9	1.04	
184A 184B	13.52.17	7.63	65	0.5156	0.5625	-8.3%	0.5002	373.7000	24000	1/403.5	0.75	243/3.3	1.04	
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 196C		7.63 7.63	68 69	0.5156	0.5625	-8.3% -6.2%			24000 24000					
196C 204A	17+45	7.63	70	0.6022	0.6250	-6.2%	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 214B	18+36.42	7.63 7.63	73 74	0.6140 0.6022	0.6250	-1.8% -3.6%	0.5957	354.6304	24000 24000	16133.0	0.67	23047.1	0.96	
214B 214C		7.63	74	0.6022	0.6250	-3.6%			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 233A	20+00.25	7.63 7.63	78 79	0.5983 0.6455	0.6250	-4.3% -6.1%	0.6298	327.3236	24000 24000	16978.0	0.71	24254.3	1.01	
233A 233B	20100.20	7.63	79 80	0.6652	0.6875	-6.1%	0.0258	327.3230	24000	105/0.0	0.71	24234.3	1.01	
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 257A	22+17	7.63 7.63	84 85	0.7203 0.7242	0.6875	4.8%	0.7204	297.4610	24000 24000	16485.2	0.69	23550.4	0.98	
257A 257B	2271/	7.63	85	0.7242	0.7500	-3.4%	0.7204	257.4010	24000	10403.2	0.03	23330.4	0.70	
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 276A	23+72.25	7.63 7.63	90 91	0.7400	0.7500	-1.3% -1.3%	0.7167	269.8013	24000 24000	18102.5	0.75	25860.6	1.08	
276B		7.63	92	0.7242	0.7500	-3.4%			24000				2.00	

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										Base N	Aaterial	At	loints	
			Reading	Thickness	Plate	%Change in	97.5% Confidence		Allowable				4	
	ation	Radius (feet)	Number	Reading (in)	Thickness (in)	Material	Interval	C.L. EL. (ft)	Steel Stress	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
276C 286A	24+62	7.63 7.63	93 94	0.7321 0.7557	0.7500	-2.4% 0.8%	0.7401	253.8309	24000 24000	18385.0	0.77	26264.2	1.09	
286B	24+02	7.63	94	0.7793	0.7500	3.9%	0.7401	233.8305	24000	18385.0	0.77	20204.2	1.05	
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	25.52.54	7.63	98	0.8580	0.8750	-1.9%	0.0005	25717425	24000	17700.0	0.74	25405.7	1.00	
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	22.22.25	7.63	123	1.2674	1.2500	1.4%	4 2007	101 5745	24000		0.50	20724 0	0.00	
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 385C		7.63 7.63	125 126	1.3343	1.3125	1.7% 0.2%			24000 24000					
396A	34+33.58	7.63	120	1.3146 1.3933	1.3125	1.3%	1.3672	104.0746	24000	14295.8	0.60	20422.5	0.85	
396B	34733.36	7.63	127	1.3555	1.3750	0.2%	1.5072	104.0740	24000	14253.0	0.00	20422.3	0.85	
396D 396C		7.63	128	1.3776	1.3750	1.9%			24000					
406A	35+24.58	7.63	129	1.4012	1.4375	-0.3%	1.4018	85.4810	24000	14467.9	0.60	20668.4	0.86	
406A	33124.30	7.63	130	1.4484	1.4375	0.8%	1.4010	05.4010	24000	14407.3	0.00	20000.4	0.00	
406C		7.63	132	1.4170	1.4375	-1.4%			24000					
416A	36+04.34	7.63	133	0.0000	NA	2.470			2.000					
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					

 $^{1}$  Hoop stress = Pr/t<sub>97.5</sub>

Notes:

<sup>2</sup> Hoop stress / S<sub>A</sub> <sup>3</sup> Hoop stress / 0.7 <sub>joint efficiency</sub> <sup>4</sup> Joint stress / S<sub>A</sub>

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

Unit weight of water=	62.4 pc
Normal pond EL=	597 fe
Joint Efficiency=	0.7 (p
D <sub>1</sub> ID=	17.00 fe
D <sub>2</sub> ID=	15.25 fe

 nit weight of water=
 62.4 pcf

 Normal pond EL=
 597 feet

 Joint Efficiency=
 0.7 (per Penstock #2 assessment)

 D1D=
 17.00 feet

 D2D=
 15.25 feet

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

			Deading	Thislanses	Diata	%Channa in	07.5%		Allawahla	Base M	Material	At J	oints	
	Location	Radius (feet)	Reading Number	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence	C.L. EL. (ft)	Allowable Steel Stress	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
-	INTERIOR													
From Ups 4A	stream End of Condui 0+27	t 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%	0.1010	545.5205	17000	5656.6	0.55	042517	0.50	neos steer (grade dinknown)
4C 12A		8.50 8.50	3	0.4763	0.5000	-4.7% -4.7%	0.4576	548,9590	17000 17000	6032.8	0.35	8618.3	0.51	
12A 12B		8.50	4	0.4644	0.5000	-4.7%	0.4576	548.9590	17000	0032.8	0.35	0010.3	0.51	
12C		8.50	6	0.4802	0.5000	-4.0%			17000					
26A 26B		8.50 8.50	7	0.4290	0.4375	-1.9% -1.9%	0.4259	548.5670	17000 17000	6534.6	0.38	9335.1	0.55	
26C		8.50	9	0.4330	0.4375	-1.0%			17000					
33A		8.50	10	0.4290	0.4375	-1.9%	0.4290	542.8690	17000	7249.9	0.43	10357.0	0.61	
33B 33C		8.50 8.50	11 12	0.4290 0.4290	0.4375 0.4375	-1.9% -1.9%			17000 17000					
44A		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 55A		8.50 8.50	15 16	0.4133 0.4015	0.4375	-5.5% -8.2%	0.3946	519.0312	17000 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 65B		8.50 8.50	19 20	0.4133 0.3936	0.4375	-5.5% -10.0%	0.3844	509.9572	17000 17000	13009.4	0.77	18584.9	1.09	
65C		8.50	21	0.4133	0.4375	-5.5%			17000					
66A		8.50	22	0.4015	0.4375	-8.2%	0.3884	509.8840	17000	12888.8	0.76	18412.5	1.08	
66B 66C		8.50 8.50	23 24	0.3936 0.4054	0.4375 0.4375	-10.0% -7.3%			17000 17000					
74A		8.50	24	0.4034	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%	0 3077	508 4450	17000	12704 6	0.75	18770 0	1.09	
86A 86B		8.50 8.50	28 29	0.4054 0.4015	0.4375 0.4375	-7.3% -8.2%	0.3977	508.4458	17000 17000	12794.6	0.75	18278.0	1.08	
86C		8.50	30	0.4093	0.4375	-6.4%			17000					
94A		8.50	31	0.3975	0.4375	-9.1%	0.3860	506.7493	17000	13434.6	0.79	19192.3	1.13	
94B 94C		8.50 8.50	32 33	0.3897 0.3975	0.4375 0.4375	-10.9% -9.1%			17000 17000					
99A		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 1064		8.50 8.50	36 37	0.4133 0.3975	0.4375	-5.5% -9.1%	0.3850	496.4299	17000 17000	15011.0	0.88	21444.3	1.26	
106		8.50	38	0.4133	0.4375	-5.5%	0.5050	450.4255	17000	15011.0	0.00	21111.5	1.20	
1060		8.50	39	0.3975	0.4375	-9.1%			17000					
110A 110E		8.50 8.50	40 41	0.4133 0.3975	0.4375	-5.5% -9.1%	0.3902	492.4169	17000 17000	15400.1	0.91	22000.1	1.29	
1100		8.50	41	0.4133	0.4375	-5.5%			17000					
1204		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
1208		8.50	44	0.3936	0.4375	-10.0%			24000					
1200 1304		8.50 8.50	45 46	0.3936	0.4375	-10.0% -7.3%	0.3920	475.9346	24000 24000	17747.2	0.74	25353.1	1.06	
1308		8.50	47	0.4172	0.4375	-4.6%			24000					
1300		8.50	48	0.4015	0.4375	-8.2%	0.5404	467 5500	24000	44570.0	0.54	20040.0	0.07	
140A 140E		8.50 8.50	49 50	0.5392 0.5392	0.4375 0.4375	23.3% 23.3%	0.5104	467.5502	24000 24000	14573.2	0.61	20818.8	0.87	
1400		8.50	51	0.5196	0.4375	18.8%			24000					
1504		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
150E 1500		7.63 7.63	53 54	0.4172 0.4172	0.4375 0.4375	-4.6% -4.6%			24000 24000					
1574		7.63	55	0.417216	0.4375	-4.6%	0.3963	440.4550	24000	20362.6	0.85	29089.4	1.21	
1576		7.63	56 57	0.409344	0.4375	-6.4%			24000					
1570 1664		7.63 7.63	57	0.43296 0.4841	0.4375	-1.0% -3.2%	0.4789	419.4953	24000 24000	19105.1	0.80	27292.9	1.14	
1668		7.63	59	0.4959	0.5000	-0.8%			24000					
1660		7.63	60	0.4920	0.5000	-1.6%	0.5356	400 5500	24000	40365.5	0.00	27522.4		
174A 174E		7.63 7.63	61 62	0.5314 0.5274	0.5000	6.3% 5.5%	0.5256	400.5538	24000 24000	19265.5	0.80	27522.1	1.15	
1740	C	7.63	63	0.5314	0.5000	6.3%			24000					
1844		7.63	64	0.5156	0.5625	-8.3%	0.5062	373.7668	24000	22731.7	0.95	32473.8	1.35	
184E 1840		7.63 7.63	65 66	0.5156 0.5274	0.5625	-8.3% -6.2%			24000 24000					
1964	A 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	
196E		7.63	68	0.5156	0.5625	-8.3%			24000					
1960 2044		7.63 7.63	69 70	0.5274 0.6022	0.5625	-6.2% -3.6%	0.5957	362.4662	24000 24000	20294.8	0.85	28992.6	1.21	
204E	В	7.63	71	0.6061	0.6250	-3.0%			24000					
2040		7.63	72	0.6140	0.6250	-1.8%	0.5057	254 6204	24000	20072.0	0.07	20064-2	4.35	
214A 214E		7.63 7.63	73 74	0.6140 0.6022	0.6250	-1.8% -3.6%	0.5957	354.6304	24000 24000	20972.9	0.87	29961.2	1.25	
2140	C	7.63	75	0.6061	0.6250	-3.0%			24000					
2234		7.63	76	0.6061	0.6250	-3.0%	0.5945	347.5737	24000	21626.3	0.90	30894.7	1.29	
223E 2230		7.63 7.63	77 78	0.6022 0.5983	0.6250 0.6250	-3.6% -4.3%			24000 24000					
2334	A 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
233E		7.63	80	0.6652	0.6875	-3.2%			24000					
2330 2434		7.63 7.63	81 82	0.6455	0.6875 0.6875	-6.1% 1.9%	0.6902	319.8851	24000 24000	20694.1	0.86	29562.9	1.23	
2434		7.63	83	0.7008	0.6875	5.3%	0.0002	515.0051	24000	20034.1	0.00	23302.3	1.23	
2430	C	7.63	84	0.7203	0.6875	4.8%			24000					
257A 257E		7.63 7.63	85 86	0.7242 0.7282	0.7500	-3.4% -2.9%	0.7204	297.4610	24000 24000	21430.8	0.89	30615.5	1.28	
2570		7.63	87	0.7282	0.7500	-2.9%			24000					
2664	A 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	
2668		7.63	89 90	0.7242 0.7400	0.7500	-3.4%			24000 24000					
7600	<u>.</u>	7.63			0.7500	-1.3% -1.3%	0.7167	269.8013	24000	23533.2	0.98	33618.8	1.40	
2660 2764		7.63	91	0.7400	0.7500									

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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	26.04.24	7.63	132	1.4170	1.4375	-1.4%			24000					
416A	36+04.34	7.63	133	0.0000	NA 1 4275	1.0%	1.4450	69.1841	24000	10020 4	0.78	26007.7	1.12	
416B 416C		7.63 7.63	134 135	1.4524	1.4375 1.4375	1.0% 0.8%	1.4450	09.1841	24000	18828.4	0.78	26897.7	1.12	
416C 425A	36+96	7.63	135	0.0000	1.4375 NA	0.8%			24000					
425R	30+90	7.63	130	1.5665	1.5625	0.3%	1.5368	64.8998	24000	17846.5	0.74	25495.0	1.06	
425B 425C		7.63	137	1.5508	1.5625	-0.7%	1.3308	04.0998	24000	1/040.5	0.74	20495.0	1.00	
425C 430A	37+41	7.63	138	0.0000	1.5625 NA	-0.776			24000					
430A 430B	3/741	7.63	139	1.5311	1.5625	-2.0%	1.5137	27.8110	24000	19382.6	0.81	27689.4	1.15	
430B 430C		7.63	140	1.5508	1.5625	-0.7%	1.5137	27.3110	24000	15582.0	0.01	27003.4	1.15	
430C 440A		7.63	141	0.0000	1.3023 NA	0.770			24000					
440A 440B		7.63	142	1.2556	110				24000					
440D		7.63	143	1.2713					24000					
4400		7.05	744	1.2/13					24000	I				

Notes:

<sup>1</sup> Hoop stress = Pr/t<sub>97.5</sub> <sup>2</sup> Hoop stress / S<sub>A</sub> <sup>3</sup> Hoop stress / 0.7 joint efficiency <sup>4</sup> Joint stress / S<sub>A</sub>

Live load: 100.00psf $P_{v=} 0$ Snow load: 20.61psfRIp Rap Unit Weight= 150For DL calc) t= 1.63inches(soil load) $W_{r=} 5373$ (for DL calc) t= 1.63inches $(w_{v=e})^{-3} 316$ UD: 15.25feet $(w_{v=e})^{-3} 316$ $W_{see}^{-3} = 1.00$ $W_{see}^{-3} = 316$ $W_{see}^{-3} = 1.00$ $W_{see}^{-3} = 1.16$ $W_{see}^{-3} = 1.00$ $W_{see}^{-3} = 1.10$ $W_{see}^{-3} = 1.00$ $W_{see}^{-3} = 1.10$ $W_{see}^{-3} = 1.00$ $W_{see}^{-3} = 1.10$ $W_{see}^{-3} = 1.00$ <t< th=""></t<>
1 psf feet test psf inches inches
1 psf inches bsf inches
1 psf inches inches
1 psf inches
1 Do psf inches
1 psf inches
1 bsf inches
1 psf inches
00 psf inches
00 psf inches
00 psf inches
00 psf inches
00 psf 1 psf inches
1 psf inches
inches
ID: 17.00 feet
External pressure with vacuum=
External pressure with snow load=
External pressure with snow and live= 3.72

**DENSTOCK 1 RAV D'ESPOIR** EXTERNAL PRESSURES EVALUATION-

Allowable pressure q<sub>a</sub>= 3.90

```
b= 1
t<sub>97.5</sub>= <mark>0.384</mark>
I= 0.0047
                                          OD Conduit Diameter= 17.0640
                                                                                                         B_prime= 0.23302
                                                                                                                              (coarse grain soils with fines) E_prime= 500
E= 300000
                                                                                                                                                                                                                                           FS= 2
                                                                                      Buoyancy Factor R<sub>w</sub>= 1
Height of fill above conduit= 2
                      Total Height of Soil= 3
```

```
Height of rip rap above conduit= 1
```

```
E= 3000000
b= 1
t<sub>97.5</sub>= 0.384
I= 0.0047
FS= 2
```

```
(coarse grain soils with fines) E_prime= 500
```

```
Allowable pressures (kPa)/External Pressures (
Diameter 17 feet
```

```
Height of water above conduit= 0
```

APPENDIX F

WELD TRACKER

	NI         NI         NI         FP         NI         NI         FP         NI         NI<	FP         NI           112         113         B           IW         NI         B	NI         NI         NI         FP         NI         NI         NI         FP           117         117         117         117         117         117         111	NI         NI         FP         NI         NI         NI         FP           225         226         227         228         229         231         233         233           NI         NI         FP         NI         NI         NI         FP           NI         NI         FP         NI         NI         FP         P	FP         FP         NI         NI         NI         NI         NI         State         <	NI         FP         NI         NI<					<ul> <li>Not Inspected</li> <li>Pressure Washed</li> </ul>	Ground/Cleaned     Inspection Passed     Inspection Failed			[
	FP         NI         NI         NI         I           7         48         49         50         51           6         NI         NI         NI         NI	NI         FP         NI         FP           108         109         110         111         FP           NI         NI         FP         NI         FP	NI         NI         FP         NI           161         162         163         164           181         182         183         164           NI         NI         FP         NI	NI         NI         FP         NI           0         221         222         223         224           0         MI         MI         MI         MI	NI         NI         NI         NI           281         282         283         284           NI         NI         NI         NI           NI         NI         NI         NI	NI         FP         NI         NI           341         342         343         344           NI         FP         NI         NI	• I								Instrument Tree
	NI         NI         FP         NI         FP         NI           8         8         44         45         46         47           1         1         14         45         86         47           1         1         1         1         1         1         1           1	FP         NI         NI         NI         FP         NI           16         102         103         104         105         106         107           102         103         104         105         106         107         107           WW         NI         NI         NI         NI         NI         NI	NI         NI<	MAL SCOPE FP FP FP FP FP FP 215 216 217 218 219 220 OW OW OW OW OW OW WR FP FP FP FP FP FP	FP         FP         NI         NI         FP         FP<	NI         FP         NI         NI         NI         FN           335         336         337         338         339         340           315         336         337         338         339         340           NI         FP         NI         NI         FP         FP	NI         NI         NI         NI         FP         FP           395         396         397         398         399         400           395         396         397         398         399         400           NI         NI         NI         FP         FP								Inspection Failed
	NI         NI         NI         FP         NI         A           37         38         39         40         41         4 <td< td=""><td>FP         FP         FP         FP         FP         FP         FP         FI         16         16         16         16         16         16         16         16         16         16         16         16         16         16         16         16         10&lt;</td><td>NI         NI         NI         FP         NI         N           150         151         152         153         154         11           150         151         152         153         154         11           NI         FP         NI         FP         NI         N         N</td><td>FP         FP         FP&lt;</td><td>NI         FP         NI         NI         FI           270         271         272         273         274         2           IT?         2         2         2         2         2         2         2           IT?         2         N         NI         NI         1         2         3         2         4         2         2         3         3         4         2         3         3         4         3         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         3         4         3         3         3         4         3         3         3         4         3         3</td><td>FP         NI         NI         N</td><td>FP         FP         NI         NI         N<td>Inspection Progress</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Inspection Passed</td></td></td<>	FP         FP         FP         FP         FP         FP         FP         FI         16         16         16         16         16         16         16         16         16         16         16         16         16         16         16         16         10<	NI         NI         NI         FP         NI         N           150         151         152         153         154         11           150         151         152         153         154         11           NI         FP         NI         FP         NI         N         N	FP         FP<	NI         FP         NI         NI         FI           270         271         272         273         274         2           IT?         2         2         2         2         2         2         2           IT?         2         N         NI         NI         1         2         3         2         4         2         2         3         3         4         2         3         3         4         3         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         4         3         3         3         4         3         3         3         4         3         3         3         4         3         3	FP         NI         NI         N	FP         FP         NI         NI         N <td>Inspection Progress</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Inspection Passed</td>	Inspection Progress							Inspection Passed
RESS TRACKER	NI         NI         NI         NI         FP           32         33         34         35         36           1         FP         F         NI         FP	FP         FP<	NI NI NI FP NI 145 146 147 148 149 1 FP NI NI FP NI	FP         FP         NI         NI         NI           205         206         207         208         209         2           OW	FP         FP         NI         NI         NI           265         267         268         269         2           265         266         267         268         269         2           69         7         7         265         267         268         269         2           7         9         7         7         265         267         268         269         2           7         9         7         7         26         269         2 <td>NI         FP         NI         NI&lt;</td> <td>FP         NI         NI         NI           335         386         387         388         389         3           OW         387         387         388         389         3           OW         387         387         388         399         3           OW         387         387         387         389         3           OW         387         387         387         3         3         3           OW         387         387         387         3</td> <td>Penstock 1 Insp</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Ground/Cleaned Progress Stage</td>	NI         FP         NI         NI<	FP         NI         NI         NI           335         386         387         388         389         3           OW         387         387         388         389         3           OW         387         387         388         399         3           OW         387         387         387         389         3           OW         387         387         387         3         3         3           OW         387         387         387         3	Penstock 1 Insp							Ground/Cleaned Progress Stage
PENSTOCK 1 WELD PROGRESS	NI         NI         NI         FP         NI           7         7         28         29         30         31           27         28         29         30         31           NI         NI         NI         FP         NI	N         FP         FP         N         FP           13         13         15         13         15           87         88         89         90         91           DP         RW         RW         RW         FP	FP         NI         FP         NI         NI           18         70         72         74         20           140         141         142         143         144           NI         NV         NV         NI         NI	NI         FP         NI         NI         FP           200         201         202         203         204           NI         FP         NI         NI         NI	NI         NI         NI         FP           260         261         262         263         264           ST         87         9         1         1           NI         NI         NI         FP         1	FP         NI         FP         NI         NI<	FP         NI         NI         NI           380         381         382         383         384           980         381         382         383         384           FP         NI         NI         NI         NI						ł		Pressure Washed G
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# 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



Kleinschmidtgroup.com

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## ACRONYMS

Α	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
Ε	
ETS	Eastern Technical Services
F	
Fu	Ultimate Tensile Stress
FSL	Full Supply Level
Κ	
Kleinschmidt	Kleinschmidt Associates Canada Inc.
Μ	
MT	Magnetic Partical Testing
Ν	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
S	
STA	Station (in feet)
Τ	
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<sup>3</sup>/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<sup>1</sup> 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.

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action
Excellent	is not required
Good	General or light deterioration where performance is not affected, and remedial
Good	action is not expected to be required in the next 10 years
	Medium deterioration or defects are visible that do not require maintenance in
Fair	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
2001	5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

 Table 3-1
 Definitions for the Condition Assessment

## 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.

<sup>&</sup>lt;sup>1</sup> 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 17foot 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, 2<sup>nd</sup> Edition. The allowable primary stress intensity is the lesser of the material yield stress (F<sub>y</sub>) divided by 1.5 or of the ultimate tensile stress (F<sub>u</sub>) 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.

Can	Max Joint Stress <sup>1,3</sup> (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress <sup>1,3</sup> (psi)	Allowable Stress (psi)	Joint Stress Ratio <sup>1,2,3</sup>	Factor of Safety Against Yield	Base Material Stress Ratio (Joints) <sup>2,3</sup>	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 <sup>1,3</sup> (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress <sup>1,3</sup> (psi)	Allowable Stress (psi)	Joint Stress Ratio <sup>1,2,3</sup>	Factor of Safety Against Yield	Base Material Stress Ratio (Joints) <sup>2,3</sup>	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

<sup>1</sup> Joint efficiency of 0.7 included

<sup>2</sup> Total stress / Allowable stress

<sup>3</sup> Uses minimum can thickness

<sup>4</sup> 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.

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	

Table 4-2 Summary of Surcharge Load Anal	ysis
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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<sup>2</sup> (3.07 ft<sup>2</sup>), which is well below the area provided by the approximately 5.1 m<sup>2</sup> (55 ft<sup>2</sup>) 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.

## 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.

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#### **REPORT SIGNATURE PAGE**

#### **KLEINSCHMIDT ASSOCIATES CANADA INC.**

Ch Ville

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



CMV:NSS:SCB

PROVINCE OF 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 No 705 which is valid for the year 2024

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September 2021 Project Control No. 2670030\_005RP

Kleinschmidt

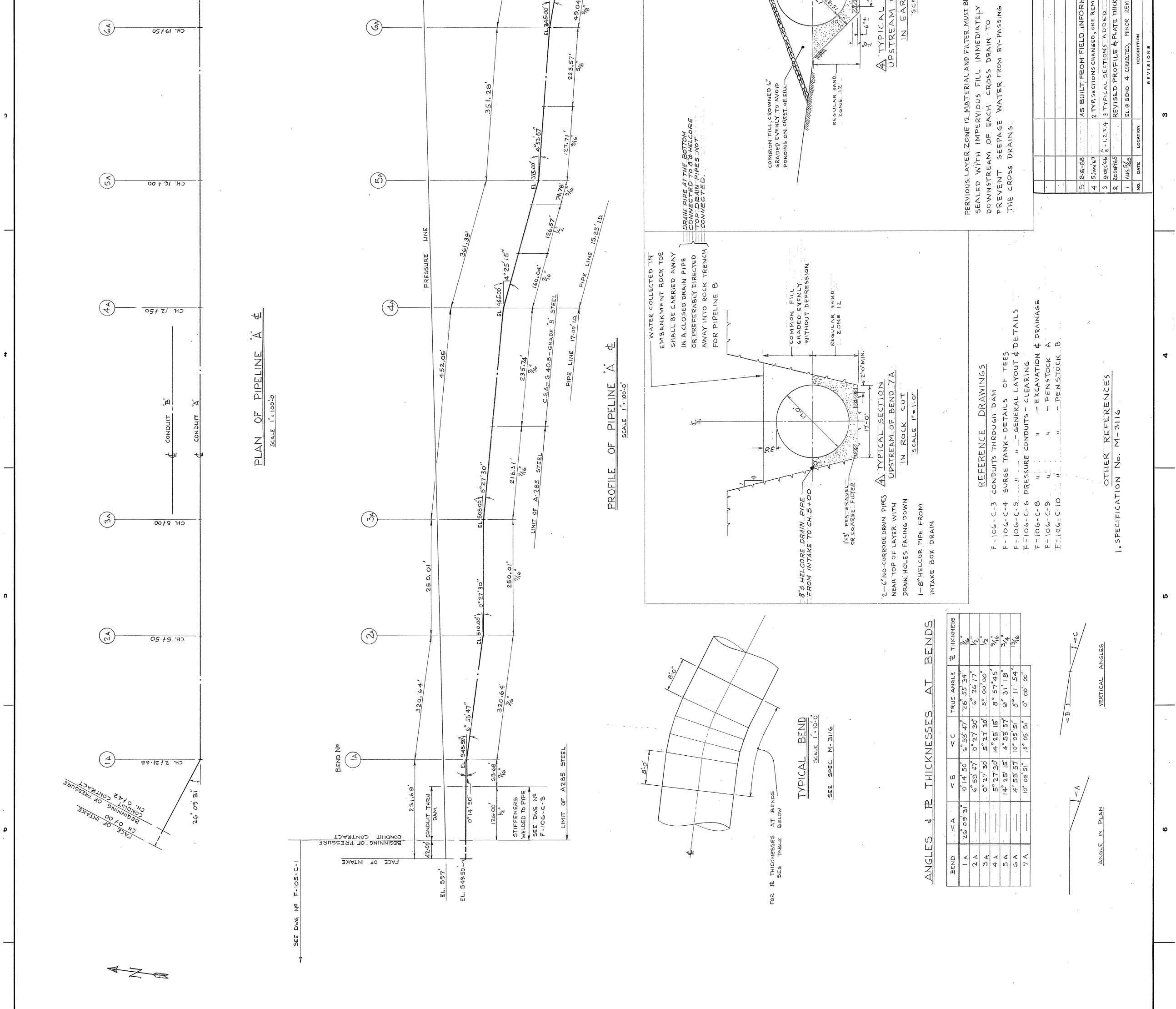
**APPENDIX A** 

**PENSTOCK LAYOUT DRAWINGS** 

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NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

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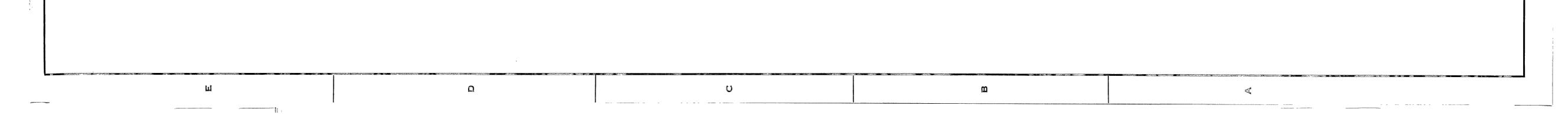


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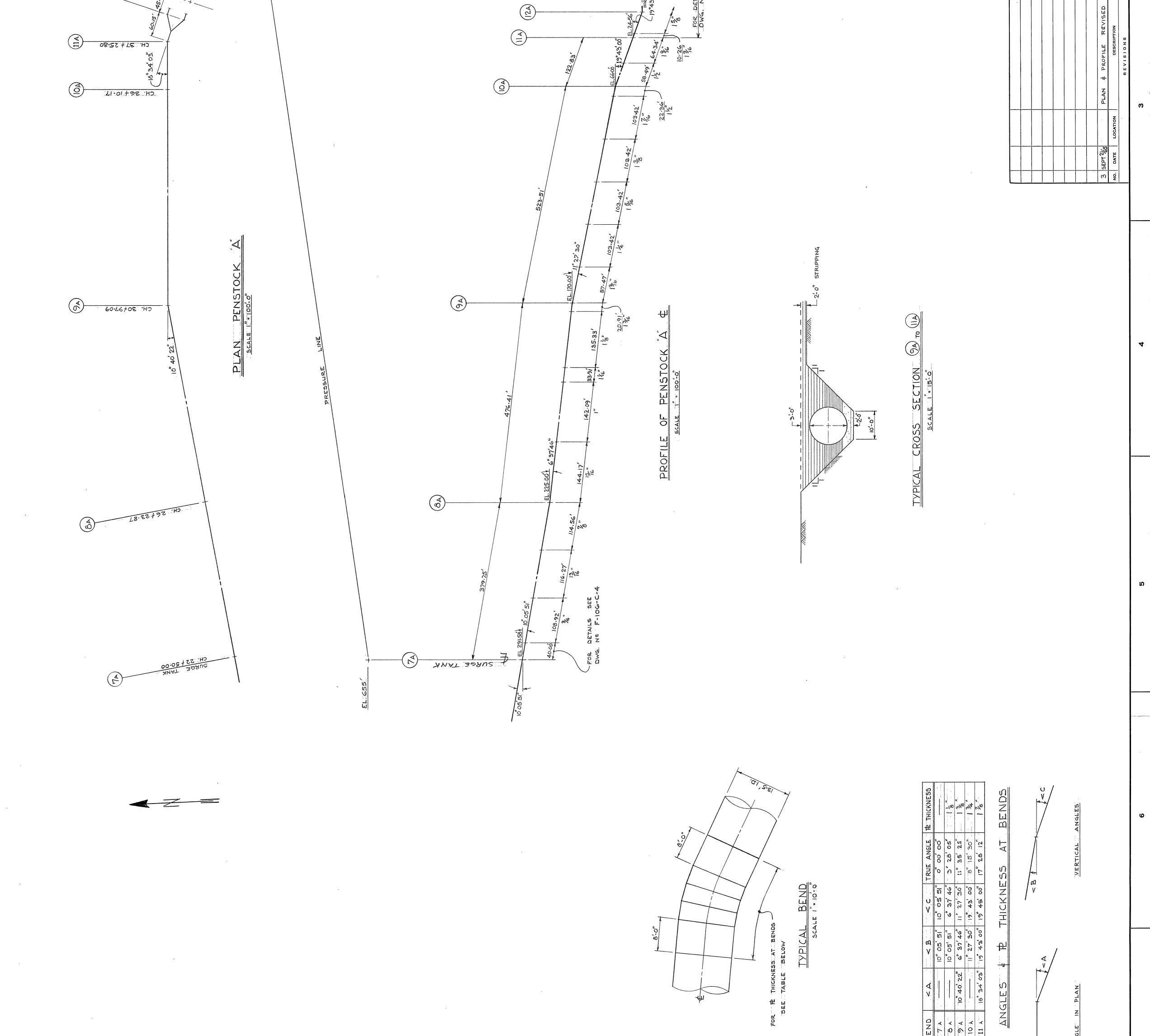
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NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

Page 33 of 77



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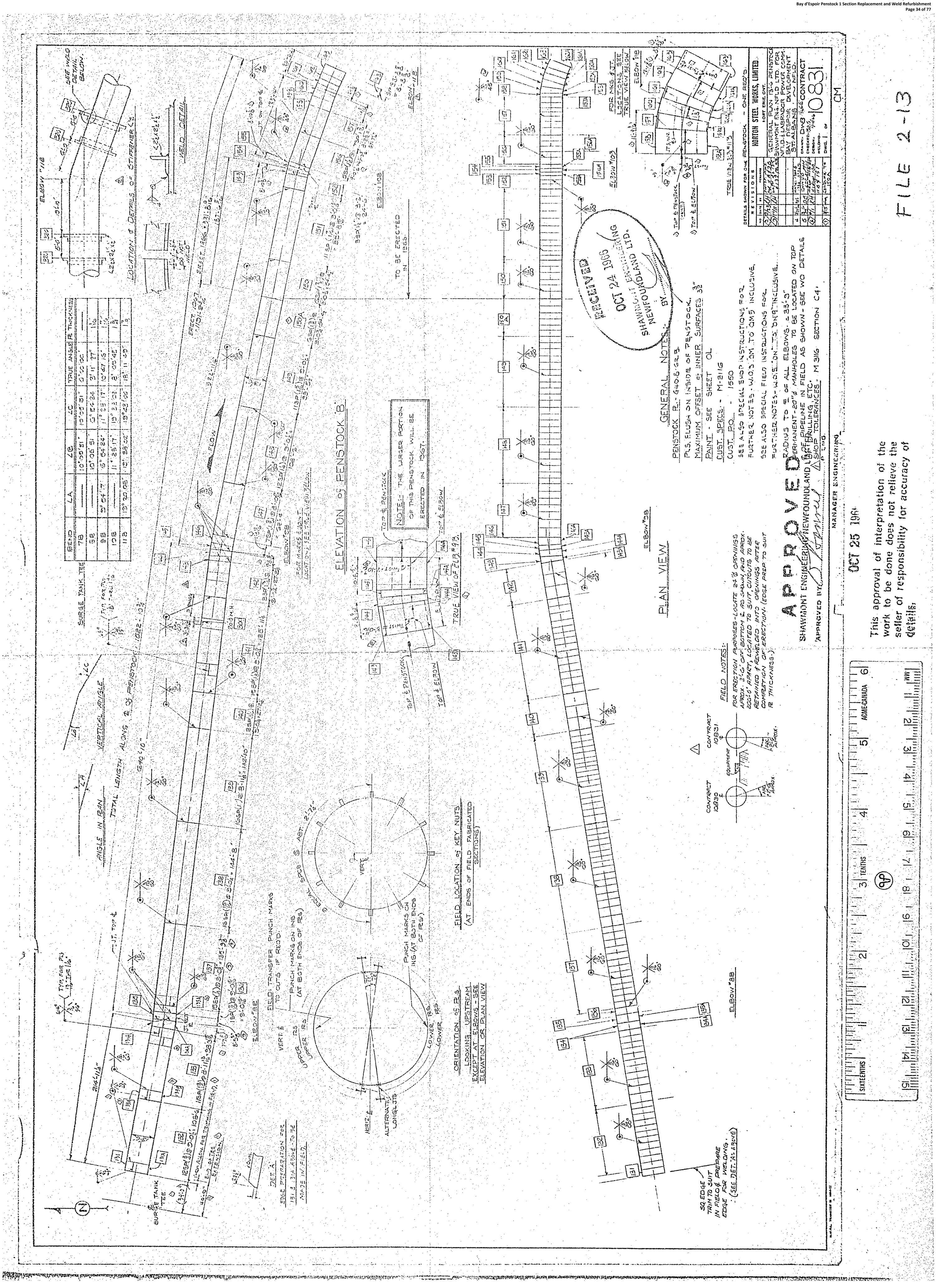
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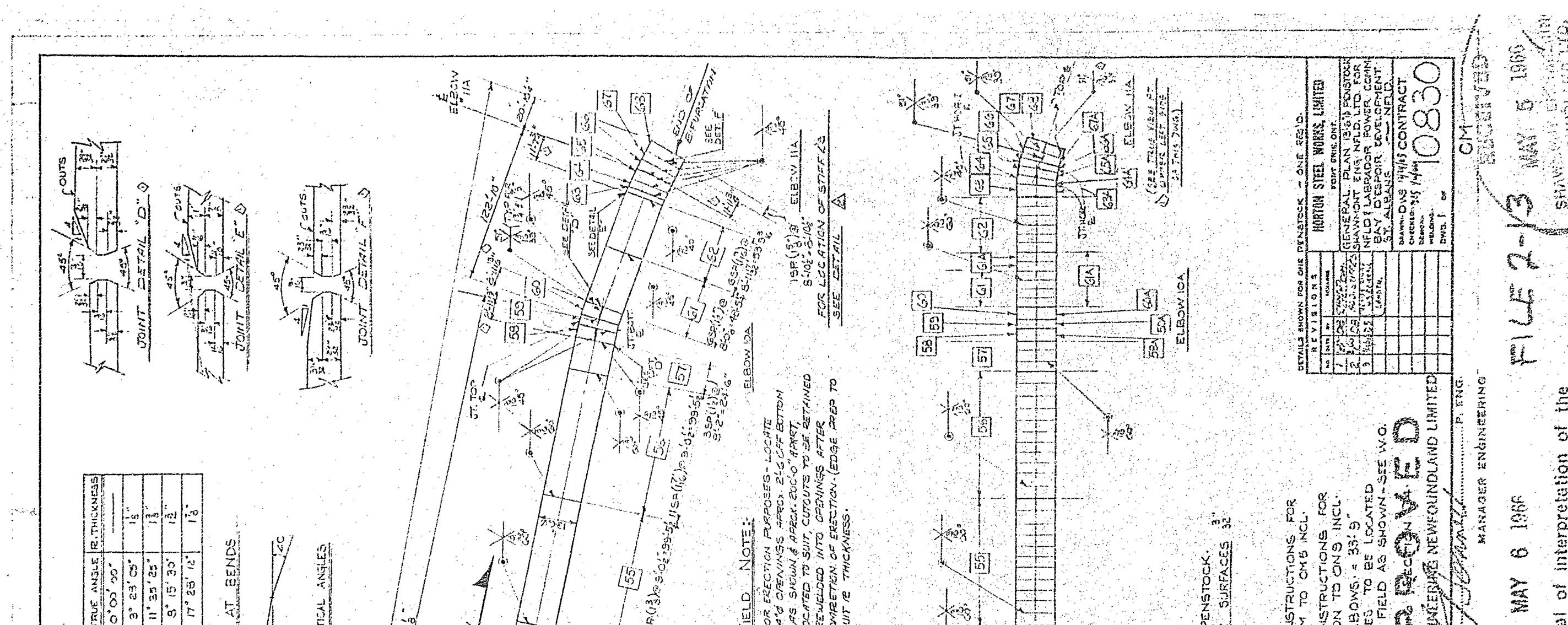
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NP-NLH-011, Attachment 3



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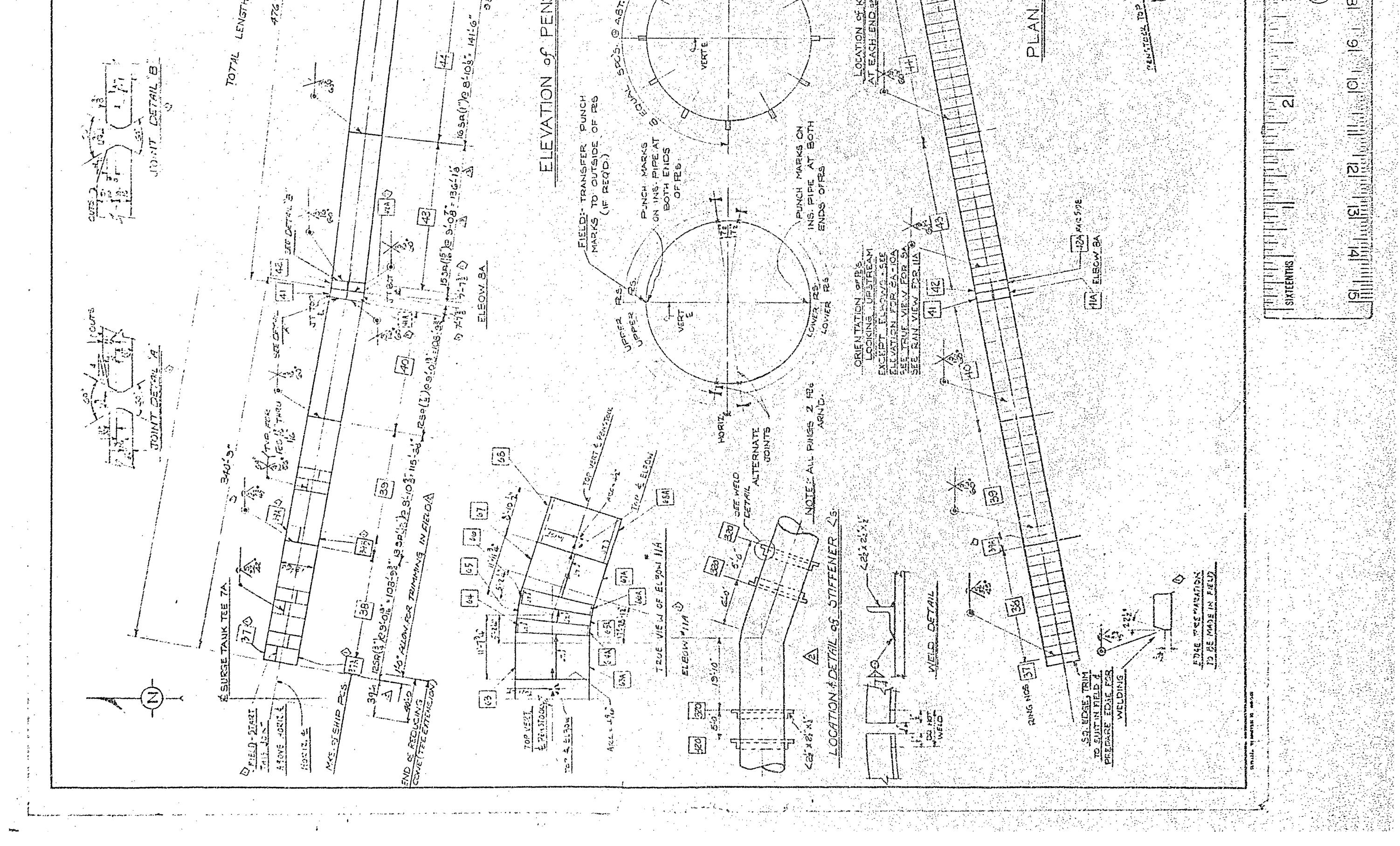
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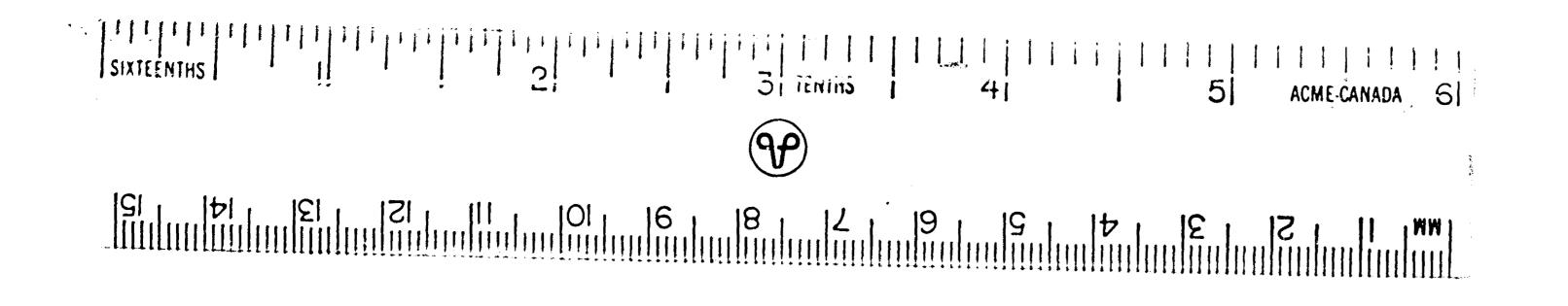
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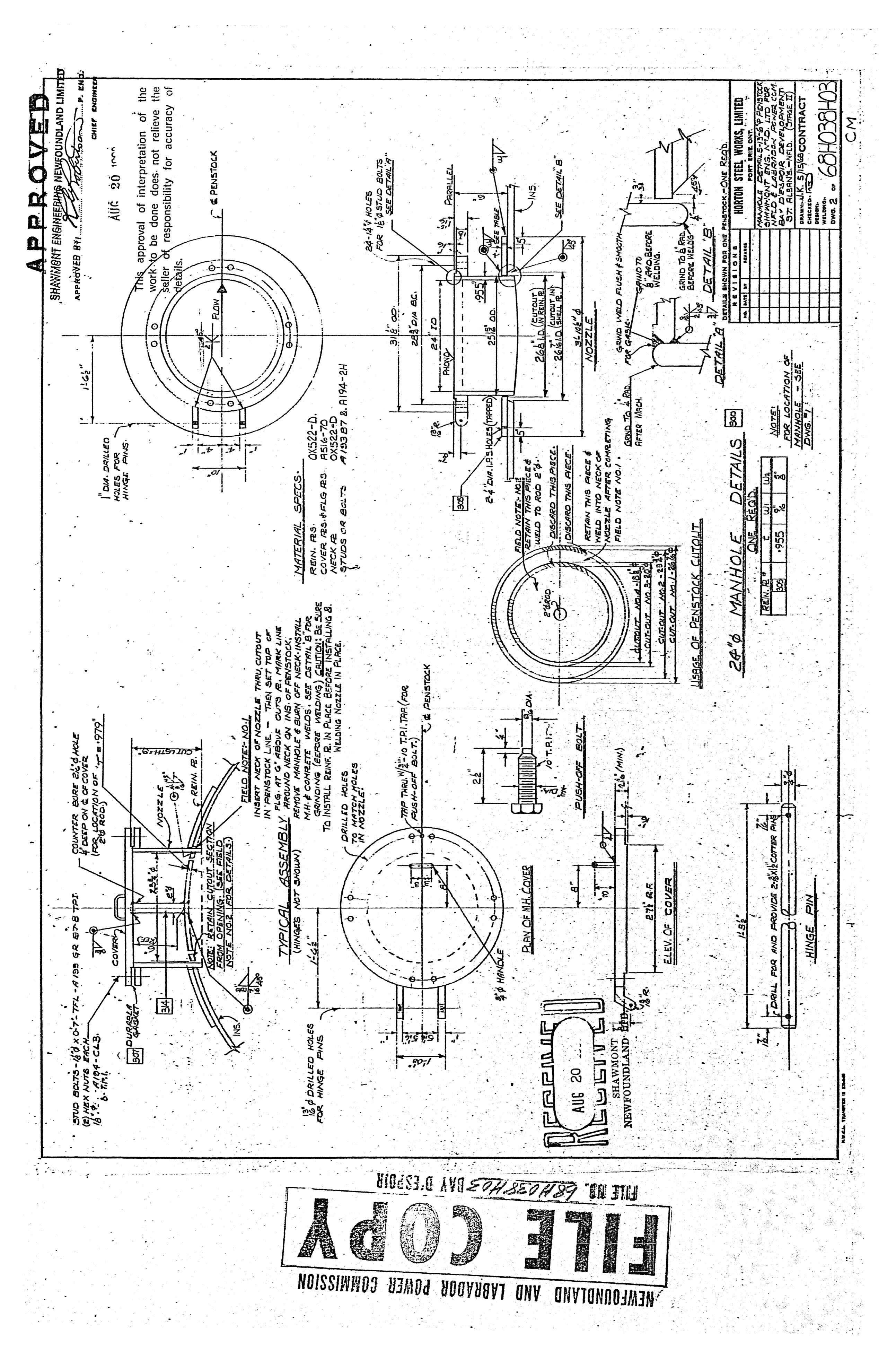
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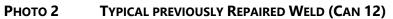
**APPENDIX B** 

**Photographs** 



PHOTO 1 TYPICAL CONDITIONS IN 17 FT DIAMETER SECTION





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PHOTO 3 TYPICAL REINFORCING PLATE



PHOTO 4 CRACK ABOVE LONGITUDINAL WELD NORTH SIDE CAN 126

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

APPENDIX C

WELD TEST

#### NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 42 of 77

Visual Inspectio Radiography & I Mag & Penetrar Eddy Current Te Structural Steel	ns Ultrasonics It Inspections seting & Torque	13517, St. Johr	<b>I Services Ltd.</b> n's, NL., A1B 4B8 St. Fax 726-4626	Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance Reports
		Repo	rt	
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 PAUT, EDO, PMI, LEEA & A	
Attn:	Colin LeGrow			
P.O. No.				
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1			
Testing Required:	Magnetic Particle Inspection	Signed:	mil st	

#### NDT Inspector

#### **Remarks**

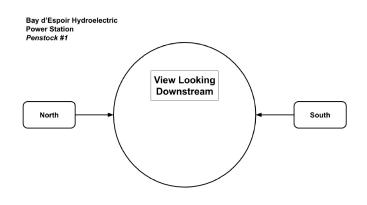
As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements 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.

### <u>Results</u>

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.



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

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

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

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

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

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

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

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

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

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

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

### NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 54 of 77

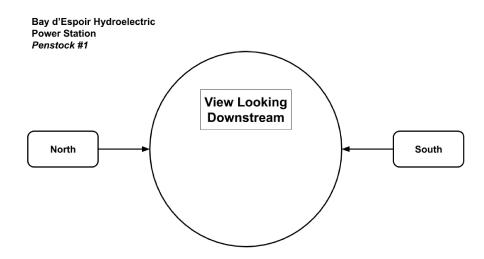
Visual Inspectic Radiography & Mag & Penetrar Eddy Current Te Structural Steel	ns Ultrasonics It Inspections esting & Torque Decision A Torque Decision A Torque A Torque Decision A	13517, St. Joh	I Services Ltd.Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance ReportsNS. Fax 726-4626Insurance Reports
ETS No.:	21-375	Сору:	
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 II PAUT, EDO, PMI, LEEA & AME
Attn:	Colin LeGrow	Inspected by:	C. Murphy, ASNT TC-1A RT, UT, ET, MT, PT level II.
P.O. No.			CAN/CGSB 48.9712 MT & PT level II, UT level I
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #1 Scope 2. Weld Repairs.		
Testing Required:	Magnetic Particle Inspection	Signed:	mil st

#### 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.

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** 

### NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 57 of 77

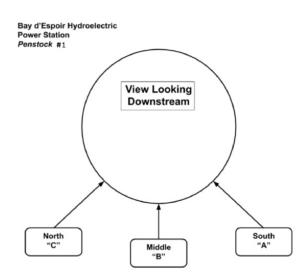
Visual Inspecti Radiography & Mag & Penetra Eddy Current Structural Stee	A Ultrasonics Eastern ant Inspections PO Box	: 13517, St. Joh	Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance Reports
ETS No.:	21-336-2 R1	Copy:	
Date:	20 May, 2021	Date Received:	20 May, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by: Inspected	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	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:	mil st
			NDT have a star

NDT Inspector

### <u>Remarks</u>

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	Lo	cation	Α	Lo	ocatior	ιВ	Lo	ocation	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	Lo	ocation	Α	Lo	ocatior	ו B	Lo	cation	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	Lo	cation	Α	Lo	ocatior	ו B	Lo	cation	С	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

U	nit weight of water= Normal pond EL= Joint Efficiency <sup>5</sup> = D <sub>1</sub> ID= D <sub>2</sub> ID= D <sub>3</sub> ID= Note: S	62.4 597 0.7 17.00 15.25 13.50 Starting point is	feet feet feet feet	e face of the Ini	take										
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 F Stress (psi) <sup>1</sup>	Material Stress Ratio <sup>2</sup>	At I Stress (psi) <sup>3</sup>	Joints Stress Ratio <sup>4</sup>	Notes
Penstock Inte	erior am End of Conduit														
From opsile			1	11.9000	0.4685	0.5000	-6.3%		549.2799	17000					A285 Steel (grade unknown)
2A			2 3	11.8000 12.1000	0.4646 0.4764	0.5000 0.5000	-7.1% -4.7%		549.2799 549.2799	17000 17000					
			4	11.9000	0.4764	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 7	11.8000 11.9000	0.4646 0.4685	0.5000 0.5000	-7.1% -6.3%		549.2799 549.2799	17000 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					
7A			10 11	12.6000 12.8000	0.4961 0.5039	0.5000 0.5000	-0.8% 0.8%		549.0728 549.0728	17000 17000					
			12	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
7B	57	8.50	13	11.9000	0.4685	0.5000	-6.3%	0.4646	549.0728	17000	4559.9	0.27	6514.2	0.38	
,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	57	3.50	14 15	12.0000 11.8000	0.4724 0.4646	0.5000 0.5000	-5.5% -7.1%	5.9090	549.0728 549.0728	17000 17000	-1333.3	0.27	5514.2	0.50	
			16	12.5000	0.4921	0.5000	-1.6%		549.0728	17000					
7C			17 18	12.7000 12.4000	0.5000 0.4882	0.5000 0.5000	0.0%		549.0728 549.0728	17000 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 22	12.0000 11.6000	0.4724 0.4567	0.5000 0.5000	-5.5% -8.7%		548.8829 548.8829	17000 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					
12C			25 26	12.2000 12.2000	0.4803 0.4803	0.5000 0.5000	-3.9% -3.9%		548.8829 548.8829	17000 17000					
			27	12.0000	0.4724	0.5000	-5.5%		548.8829	17000					
17A			28 29	9.9000	0.3898	0.4375 0.4375	-10.9%		548.6801 548.6801	17000 17000					
1/A			29 30	10.1000 9.7000	0.3976	0.4375	-9.1% -12.7%		548.6801 548.6801	17000					
			31	10.2000	0.4016	0.4375	-8.2%		548.6801	17000					
17B	148	8.50	32 33	10.3000 10.0000	0.4055 0.3937	0.4375 0.4375	-7.3% -10.0%	0.3819	548.6801 548.6801	17000 17000	5592.6	0.33	7989.4	0.47	
			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 37	9.9000 10.2000	0.3898	0.4375	-10.9% -8.2%		548.6801 548.5075	17000 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					
22B	188	8.50	40 41	10.4000 10.4000	0.4094	0.4375 0.4375	-6.4% -6.4%	0.3898	548.5075 548.5075	17000 17000	5499.1	0.32	7855.9	0.46	
			42	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
22C			43 44	10.0000 9.9000	0.3937 0.3898	0.4375 0.4375	-10.0% -10.9%		548.5075 548.5075	17000 17000					
220			44	10.3000	0.3898	0.4375	-10.9%		548.5075 548.5075	17000					
			46	10.3000	0.4055	0.4375	-7.3%		544.8593	17000					
28A			47 48	10.2000 10.5000	0.4016 0.4134	0.4375 0.4375	-8.2% -5.5%		544.8593 544.8593	17000 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 52	10.3000 10.6000	0.4055 0.4173	0.4375 0.4375	-7.3% -4.6%		544.8593 544.8593	17000 17000					
28C			53	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
			54 55	10.4000 10.9000	0.4094	0.4375	-6.4% -1.9%		544.8593	17000 17000					
33A			55	11.0000	0.4291	0.4375	-1.9%			17000					
			57	10.8000	0.4252	0.4375	-2.8%			17000					
33B	Missing	8.50	58 59	11.1000 11.0000	0.4370 0.4331	0.4375 0.4375	-0.1% -1.0%	0.4252		17000 17000					
			60	11.3000	0.4449	0.4375	1.7%			17000					
220			61	11.2000	0.4409	0.4375	0.8%			17000					
33C			62 63	11.1000 11.1000	0.4370 0.4370	0.4375 0.4375	-0.1% -0.1%			17000 17000					
			64	10.8000	0.4252	0.4375	-2.8%		533.8125	17000					
38A			65 66	10.7000 10.9000	0.4213 0.4291	0.4375 0.4375	-3.7% -1.9%		533.8125 533.8125	17000 17000					
			67	11.1000	0.4291 0.4370	0.4375	-1.9%		533.8125 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 70	11.2000 10.8000	0.4409 0.4252	0.4375 0.4375	0.8% -2.8%		533.8125 533.8125	17000 17000					
38C			70	10.8000	0.4252	0.4375	-2.8%		533.8125 533.8125	17000					
			72	11.0000	0.4331	0.4375	-1.0%		533.8125	17000					

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				Thickness						Allowable					
Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Reading	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Steel Stress	Base M Stress (psi) <sup>1</sup>	laterial Stress Ratio <sup>2</sup>	At Jo Stress (psi) <sup>3</sup>	ints Stress Ratio <sup>4</sup>	Notes
			73	(mm) 10.1000	0.3976	0.4375	-9.1%		528.5292	(psi) 17000	Stress (psi)	Stress Ratio	Stress (psi)	Stress Ratio	
43A			74	10.1000	0.3976	0.4375	-9.1%		528.5292	17000					
			75 76	10.1000 10.7000	0.3976 0.4213	0.4375 0.4375	-9.1% -3.7%		528.5292 528.5292	17000 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 79	10.9000	0.4291	0.4375	-1.9%		528.5292	17000					
43C			79 80	10.2000 10.0000	0.4016 0.3937	0.4375 0.4375	-8.2% -10.0%		528.5292 528.5292	17000 17000					
			81	10.0000	0.3937	0.4375	-10.0%		528.5292	17000					
52A			82 83	9.5000 9.6000	0.3740 0.3780	0.4375 0.4375	-14.5% -13.6%		518.8032 518.8032	17000 17000					
			84	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
52B	437	8.50	85	10.2000	0.4016	0.4375	-8.2%	0.3740	518.8032	17000	9241.1	0.54	13201.5	0.78	
526	437	8.50	86 87	10.5000 10.0000	0.4134 0.3937	0.4375 0.4375	-5.5% -10.0%	0.3740	518.8032 518.8032	17000 17000	5241.1	0.34	13201.5	0.78	
			88	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
52C			89 90	10.8000 10.8000	0.4252 0.4252	0.4375 0.4375	-2.8% -2.8%		518.8032 518.8032	17000 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 94	11.0000 11.3000	0.4331 0.4449	0.4375 0.4375	-1.0% 1.7%		513.3999 513.3999	17000 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	
1			96 97	11.1000 11.3000	0.4370 0.4449	0.4375 0.4375	-0.1% 1.7%		513.3999 513.3999	17000 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					
61A			100 101	12.2000 12.0000	0.4803	0.4375 0.4375	9.8% 8.0%		509.9386 509.9386	17000 17000					
1			102	12.4000	0.4882	0.4375	11.6%		509.9386	17000					
61B	518	8.50	103 104	12.7000 12.7000	0.5000	0.4375 0.4375	14.3% 14.3%	0.4724	509.9386 509.9386	17000 17000	8145.2	0.48	11636.0	0.68	
015	518	8.50	104	12.7000	0.4882	0.4375	14.3%	0.4724	509.9386	17000	0143.2	0.48	11030.0	0.08	
			106	12.9000	0.5079	0.4375	16.1%		509.9386	17000					
61C			107 108	12.6000 13.0000	0.4961 0.5118	0.4375 0.4375	13.4% 17.0%		509.9386 509.9386	17000 17000					
			100	10.1000	0.3976	0.4375	-9.1%		509.2026	17000					
72A			110	10.2000	0.4016	0.4375	-8.2%		509.2026	17000					
			111 112	10.0000 10.2000	0.3937 0.4016	0.4375 0.4375	-10.0% -8.2%		509.2026 509.2026	17000 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					
72C			115 116	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%		509.2026 509.2026	17000 17000					
			117	10.7000	0.4213	0.4375	-3.7%		509.2026	17000					
77A			118 119	11.0000	0.4331	0.4375	-1.0%		508.8427	17000					
			119	11.0000 10.8000	0.4331 0.4252	0.4375 0.4375	-1.0% -2.8%		508.8427 508.8427	17000 17000					
			121	10.8000	0.4252	0.4375	-2.8%		508.8427	17000					
77B	655	8.50	122 123	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%	0.3937	508.8427 508.8427	17000 17000	9897.2	0.58	14138.9	0.83	
			125	10.1000	0.3976	0.4375	-9.1%		508.8427	17000					
77C			125 126	10.0000 10.2000	0.3937 0.4016	0.4375 0.4375	-10.0% -8.2%		508.8427 508.8427	17000 17000					
			120	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
82A			128	11.4000	0.4488	0.4375	2.6%		508.4827	17000					
1			129 130	11.7000 11.4000	0.4606 0.4488	0.4375 0.4375	5.3% 2.6%		508.4827 508.4827	17000 17000					
82B	700	8.50	130	11.4000	0.4488	0.4375	3.5%	0.3937	508.4827	17000	9937.7	0.58	14196.7	0.84	
1			132	11.6000	0.4567	0.4375	4.4%		508.4827	17000					
82C			133 134	10.0000 10.2000	0.3937 0.4016	0.4375 0.4375	-10.0% -8.2%		508.4827 508.4827	17000 17000					
			135	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
92A			136 137	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%		505.4631 505.4631	17000 17000					
52M			137	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
			139	10.2000	0.4016	0.4375	-8.2%		505.4631	17000					
92B	787	8.50	140 141	10.2000 10.3000	0.4016	0.4375 0.4375	-8.2% -7.3%	0.4016	505.4631 505.4631	17000 17000	10075.2	0.59	14393.1	0.85	
1			141	10.9000	0.4055	0.4375	-7.5%		505.4631	17000					
92C			143	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
┣───			144 145	10.9000	0.4291 0.4370	0.4375	-1.9% -0.1%		505.4631 495.0948	17000 17000					
104A			146	11.3000	0.4449	0.4375	1.7%		495.0948	17000					
			147 148	10.9000 11.0000	0.4291 0.4331	0.4375 0.4375	-1.9% -1.0%		495.0948 495.0948	17000 17000					
104B	896	8.50	148 149	11.0000	0.4331	0.4375	-1.0%	0.4291	495.0948 495.0948	17000	10496.0	0.62	14994.4	0.88	
			150	11.1000	0.4370	0.4375	-0.1%		495.0948	17000					
104C			151 152	11.3000 11.0000	0.4449 0.4331	0.4375 0.4375	1.7%		495.0948 495.0948	17000 17000					
			152	11.1000	0.4331	0.4375	-1.0%		495.0948 495.0948	17000					
			154	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108A			155 156	11.0000 10.9000	0.4331 0.4291	0.4375 0.4375	-1.0% -1.9%		491.6704 491.6704	17000 17000					
			150	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	
1			159 160	10.9000 10.8000	0.4291 0.4252	0.4375 0.4375	-1.9% -2.8%		491.6704 491.6704	17000 17000					
108C			161	10.6000	0.4173	0.4375	-4.6%		491.6704	17000					
L			162	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					

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			<b>D</b>	Thickness	-	Plat.		ant which and the		Allowable					
Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Steel Stress (psi)	Base M Stress (psi) <sup>1</sup>	laterial Stress Ratio <sup>2</sup>	At J Stress (psi) <sup>3</sup>	oints Stress Ratio <sup>4</sup>	Notes
			163	11.2000	0.4409	0.4375	0.8%		485.6778	(psi) 24000	Stress (hai)	Stress Ratio	Stress (bsi)	Suess Naul	CSA G40.8 Grade B Steel
115A			164	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			165 166	11.2000 12.2000	0.4409 0.4803	0.4375 0.4375	0.8% 9.8%		485.6778 485.6778	24000 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	
			168 169	12.1000 11.2000	0.4764 0.4409	0.4375 0.4375	8.9% 0.8%		485.6778 485.6778	24000 24000					
115C			105	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
			171	11.1000	0.4370	0.4375	-0.1%		485.6778	24000					
123A			172 173	10.6000 10.5000	0.4173 0.4134	0.4375 0.4375	-4.6% -5.5%		484.6314 484.6314	24000 24000					
			174	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
123B	1006	8.50	175 176	10.4000 10.5000	0.4094 0.4134	0.4375 0.4375	-6.4% -5.5%	0.4094	484.6314 484.6314	24000 24000	12130.2	0.51	17328.8	0.72	
			170	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
123C			178 179	10.5000 11.5000	0.4134 0.4528	0.4375 0.4375	-5.5% 3.5%		484.6314 484.6314	24000 24000					
1250			175	11.4000	0.4488	0.4375	2.6%		484.6314	24000					
126A			181	11.0000	0.4331	0.4375	-1.0%		476.3558	24000					
126A			182 183	11.2000 11.1000	0.4409 0.4370	0.4375 0.4375	0.8%		476.3558 476.3558	24000 24000					
			184	12.5000	0.4921	0.4375	12.5%		476.3558	24000					
126B	1093	8.50	185 186	12.7000 12.5000	0.5000 0.4921	0.4375 0.4375	14.3% 12.5%	0.4331	476.3558 476.3558	24000 24000	12313.2	0.51	17590.2	0.73	
			180	11.5000	0.4521	0.4375	3.5%		476.3558	24000					
126C			188 189	11.5000 11.6000	0.4528 0.4567	0.4375	3.5% 4.4%		476.3558 476.3558	24000 24000					
<b> </b>			189	10.5000	0.4567	0.4375	-5.5%		470.4583	24000					
133A			191	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
1			192 193	10.6000 10.7000	0.4173 0.4213	0.4375 0.4375	-4.6% -3.7%		470.4583 470.4583	24000 24000					
133B	1155	8.50	193	10.9000	0.4213	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					
133C			196 197	11.2000 11.0000	0.4409 0.4331	0.4375 0.4375	0.8%		470.4583 470.4583	24000 24000					
			198	11.1000	0.4370	0.4375	-0.1%		470.4583	24000					
138A			199 200	10.4000 10.3000	0.4094 0.4055	0.4375 0.4375	-6.4% -7.3%		466.2729 466.2729	24000 24000					
			200	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
1300	1100	0.50	202	10.9000	0.4291	0.4375	-1.9%	0.4055	466.2729	24000	14240.0	0.50	20255 7	0.85	
138B	1199	8.50	203 204	10.9000 10.8000	0.4291 0.4252	0.4375 0.4375	-1.9% -2.8%	0.4055	466.2729 466.2729	24000 24000	14249.0	0.59	20355.7	0.85	
			205	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
138C			206 207	10.8000 10.8000	0.4252	0.4375 0.4375	-2.8% -2.8%		466.2729 466.2729	24000 24000					
			208	10.0000	0.3937	0.4375	-10.0%		452.6425	24000					15.25 I.D. Penstock
148A			209 210	10.1000 10.1000	0.3976 0.3976	0.4375 0.4375	-9.1% -9.1%		452.6425 452.6425	24000 24000					
			210	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	
			213 214	10.7000 10.8000	0.4213 0.4252	0.4375 0.4375	-3.7% -2.8%		452.6425 452.6425	24000 24000					
148C			215	10.6000	0.4173	0.4375	-4.6%		452.6425	24000					
			216 217	10.6000	0.4173	0.4375	-4.6% -3.7%		452.6425 436.9529	24000 24000					
155A			217	10.6000	0.4173	0.4375	-4.6%		436.9529	24000					
			219	10.8000	0.4252	0.4375	-2.8%		436.9529	24000					
155B	1325	7.63	220 221	10.9000 10.9000	0.4291 0.4291	0.4375 0.4375	-1.9% -1.9%	0.3937	436.9529 436.9529	24000 24000	16118.5	0.67	23026.4	0.96	
			222	11.0000	0.4331	0.4375	-1.0%		436.9529	24000					
155C			223 224	10.0000 10.1000	0.3937 0.3976	0.4375 0.4375	-10.0% -9.1%		436.9529 436.9529	24000 24000					
			225	10.1000	0.3976	0.4375	-9.1%		436.9529	24000					
165A			226 227	11.1000 10.9000	0.4370 0.4291	0.5000 0.5000	-12.6% -14.2%		414.2901 414.2901	24000 24000					
1006			228	11.0000	0.4331	0.5000	-14.2%		414.2901	24000					
1000	1410	7.02	229	11.6000	0.4567	0.5000	-8.7%	0 4301	414.2901	24000	16001 6	0.70	34110 5	1.00	
165B	1416	7.63	230 231	11.7000 11.5000	0.4606 0.4528	0.5000	-7.9% -9.4%	0.4291	414.2901 414.2901	24000 24000	16881.6	0.70	24116.5	1.00	
			232	11.7000	0.4606	0.5000	-7.9%		414.2901	24000					
165C			233 234	11.5000 11.9000	0.4528 0.4685	0.5000	-9.4% -6.3%		414.2901 414.2901	24000 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					
			237 238	14.2000 14.2000	0.5591 0.5591	0.5625 0.5625	-0.6% -0.6%		388.8879 388.8879	24000 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	
			240 241	14.2000 13.7000	0.5591 0.5394	0.5625	-0.6% -4.1%		388.8879 388.8879	24000 24000					
176C			241 242	13.7000 13.7000	0.5394	0.5625	-4.1% -4.1%		388.8879 388.8879	24000					
			243	13.8000	0.5433	0.5625	-3.4%		388.8879	24000					
185A			244 245	18.6000 18.8000	0.7323	0.5625	30.2% 31.6%		373.2723 373.2723	24000 24000					
			246	18.4000	0.7244	0.5625	28.8%		373.2723	24000					
185B	1594	7.63	247 248	18.8000 19.0000	0.7402 0.7480	0.5625 0.5625	31.6% 33.0%	0.7047	373.2723 373.2723	24000 24000	12587.6	0.52	17982.3	0.75	
2000	2334		248	19.0000	0.7480	0.5625	33.0%	0., 047	373.2723	24000	12557.0	0.32	1, 202.3	5.75	
			250	18.0000	0.7087	0.5625	26.0%		373.2723	24000					
185C			251 252	17.9000 18.1000	0.7047 0.7126	0.5625 0.5625	25.3% 26.7%		373.2723 373.2723	24000 24000					
			-32	10.1000	5.7 120	5.5025	20.770		5, 5.2725	2.000					

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	Distance From Fwd		Reading	Thickness	Thickness	Plate	%Change in	Min Thickness (in)		Allowable	Base M	atorial	A+ 1	loints	
Can #	Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)		Material	(3)	C.L. EL. (ft)	Steel Stress (psi)		Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
			253	13.8000	0.5433	0.5625	-3.4%		367.0379	24000					
194A			254 255	13.6000 13.9000	0.5354 0.5472	0.5625 0.5625	-4.8% -2.7%		367.0379 367.0379	24000 24000					
			255	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	
			258 259	14.1000 14.0000	0.5551 0.5512	0.5625	-1.3% -2.0%		367.0379 367.0379	24000 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					
203A			262 263	15.4000 15.4000	0.6063	0.6250 0.6250	-3.0% -3.0%		359.9495 359.9495	24000 24000					
2054			265	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	266 267	16.0000 15.9000	0.6299 0.6260	0.6250 0.6250	0.8% 0.2%	0.6024	359.9495 359.9495	24000 24000	15603.7	0.65	22290.9	0.93	
			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 24000					
213A			271 272	14.8000 14.6000	0.5827 0.5748	0.6250	-6.8% -8.0%		352.1779 352.1779	24000					
			273	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
213B	1841	7.63	274 275	14.4000 14.5000	0.5669 0.5709	0.6250 0.6250	-9.3% -8.7%	0.5551	352.1779 352.1779	24000 24000	17486.7	0.73	24981.0	1.04	
2130	1041	7.03	275	14.5000	0.5709	0.6250	-8.7%	0.3331	352.1779	24000	1/400.7	0.73	24561.0	1.04	
Ι.			277	14.2000	0.5591	0.6250	-10.6%		352.1779	24000					
213C			278 279	14.1000 14.1000	0.5551 0.5551	0.6250 0.6250	-11.2% -11.2%		352.1779 352.1779	24000 24000					
<u> </u>			279	15.8000	0.5551	0.6250	-11.2%		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					
227B	1959	7.63	283 284	15.8000 15.6000	0.6220 0.6142	0.6250	-0.5% -1.7%	0.6063	339.0478 339.0478	24000 24000	16869.2	0.70	24098.9	1.00	
			285	15.9000	0.6260	0.6250	0.2%		339.0478	24000					
227C			286	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
2270			287 288	15.4000 15.4000	0.6063	0.6250 0.6250	-3.0% -3.0%		339.0478 339.0478	24000 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					
			291 292	16.0000 16.8000	0.6299 0.6614	0.6875 0.6875	-8.4% -3.8%		326.0738 326.0738	24000 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					
235C			295 296	16.1000 16.0000	0.6339 0.6299	0.6875 0.6875	-7.8% -8.4%		326.0738 326.0738	24000 24000					
			297	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
243A			298	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243A			299 300	18.3000 18.3000	0.7205	0.7500	-3.9% -3.9%		313.4505 313.4505	24000 24000					This can showed a maximum thickness 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	
			303 304	18.4000 18.3000	0.7244	0.7500	-3.4% -3.9%		313.4505 313.4505	24000 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					
254A			307 308	18.6000 18.5000	0.7323 0.7283	0.7500	-2.4% -2.9%		296.0934 296.0934	24000 24000					
			309	18.5000	0.7283	0.7500	-2.9%		296.0934	24000					
25.45	2204	7.02	310	18.4000	0.7244	0.7500	-3.4%	0 7007	296.0934	24000	46035.0	0.70	24054.2	4.00	
254B	2204	7.63	311 312	18.4000 18.5000	0.7244 0.7283	0.7500	-3.4% -2.9%	0.7087	296.0934 296.0934	24000 24000	16835.9	0.70	24051.3	1.00	
			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					
			315 316	18.4000 22.6000	0.7244	0.7500	-3.4% 18.6%		296.0934 283.6501	24000 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					
263B	2275	7.63	319 320	23.8000 23.8000	0.9370 0.9370	0.7500	24.9% 24.9%	0.8622	283.6501 283.6501	24000 24000	14409.9	0.60	20585.6	0.86	
			321	23.5000	0.9252	0.7500	23.4%		283.6501	24000					
2626			322	22.0000	0.8661	0.7500	15.5%		283.6501	24000					
263C			323 324	21.9000 22.4000	0.8622 0.8819	0.7500	15.0% 17.6%		283.6501 283.6501	24000 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					
			327 328	18.9000 18.8000	0.7441 0.7402	0.7500	-0.8% -1.3%		267.1697 267.1697	24000 24000					
274B	2369	7.63	328	18.7000	0.7362	0.7500	-1.3%	0.7323	267.1697	24000	17858.9	0.74	25512.7	1.06	
1			330	19.0000	0.7480	0.7500	-0.3%		267.1697	24000					
274C			331 332	18.7000 19.0000	0.7362	0.7500	-1.8% -0.3%		267.1697 267.1697	24000 24000					
2740			332 333	19.0000 18.6000	0.7480	0.7500	-0.3% -2.4%		267.1697 267.1697	24000 24000					
			334	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284A			335 336	20.1000 20.2000	0.7913 0.7953	0.8125 0.8125	-2.6% -2.1%		251.0399 251.0399	24000 24000					
			336	20.2000	0.7953	0.8125	-2.1%		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	
1			339	20.6000	0.8110	0.8125	-0.2%		251.0399	24000					
284C			340 341	20.2000 19.9000	0.7953 0.7835	0.8125 0.8125	-2.1% -3.6%		251.0399 251.0399	24000 24000					
			341	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					

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				Thickness						Allowable					
Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Reading	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in) (3)	C.L. EL. (ft)	Steel Stress		Naterial		loints	Notes
			242	(mm)					225 2607	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	
294A			343 344	21.2000 21.2000	0.8346 0.8346	0.8750 0.8750	-4.6% -4.6%		235.2607 235.2607	24000 24000					
			345	21.1000	0.8307	0.8750	-5.1%		235.2607	24000					
2045	2554	7.62	346	22.2000	0.8740	0.8750	-0.1%	0.8307	235.2607	24000	47265.0	0.72	24665.6	4.00	
294B	2551	7.63	347 348	22.2000 22.1000	0.8740 0.8701	0.8750	-0.1% -0.6%	0.8307	235.2607 235.2607	24000 24000	17265.9	0.72	24665.6	1.03	
			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 24000					
304A			352 353	28.5000 28.5000	1.1220	0.9375 0.9375	19.7% 19.7%		221.3657 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	
			357 358	28.5000 28.6000	1.1220 1.1260	0.9375 0.9375	19.7% 20.1%		221.3657 221.3657	24000 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					
313A			361 362	23.8000 23.8000	0.9370 0.9370	0.9375 0.9375	-0.1% -0.1%		211.8990 211.8990	24000 24000					
525/1			363	23.8000	0.9331	0.9375	-0.1%		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	
1			366 367	23.7000 24.0000	0.9331 0.9449	0.9375 0.9375	-0.5% 0.8%		211.8990 211.8990	24000 24000					
313C			368	23.9000	0.9449	0.9375	0.8%		211.8990	24000					
<b></b>			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			371 372	25.2000 25.5000	0.9921 1.0039	1.0000 1.0000	-0.8% 0.4%		200.2388 200.2388	24000 24000					
1			372	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					
324C			376 377	25.4000 25.3000	1.0000 0.9961	1.0000 1.0000	0.0%		200.2388 200.2388	24000 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					
			381 382	25.5000 26.4000	1.0039 1.0394	1.0625 1.0625	-5.5% -2.2%		189.9640 189.9640	24000 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					
334C			385 386	25.4000 25.7000	1.0000 1.0118	1.0625 1.0625	-5.9% -4.8%		189.9640 189.9640	24000 24000					
5540			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					
			390 391	28.9000 28.9000	1.1378 1.1378	1.1250 1.1250	1.1% 1.1%		179.9200 179.9200	24000 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					
2446			394	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344C			395 396	29.0000 28.6000	1.1417 1.1260	1.1250 1.1250	1.5% 0.1%		179.9200 179.9200	24000 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					
357B	3114	6.75	400 401	35.6000 35.5000	1.4016 1.3976	1.1875 1.1875	18.0% 17.7%	1.3937	164.4237 164.4237	24000 24000	10894.3	0.45	15563.3	0.65	
1			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			404 405	35.6000 35.6000	1.4016 1.4016	1.1875 1.1875	18.0% 18.0%		164.4237 164.4237	24000 24000					
			405	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
368A			407	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
1			408	30.2000	1.1890	1.2500	-4.9%		147.5381	24000					
368B	3199	6.75	409 410	31.3000 31.3000	1.2323 1.2323	1.2500 1.2500	-1.4% -1.4%	1.1850	147.5381 147.5381	24000 24000	13312.7	0.55	19018.2	0.79	
			410	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
			412	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
368C			413 414	31.2000 31.3000	1.2283 1.2323	1.2500 1.2500	-1.7% -1.4%		147.5381 147.5381	24000 24000					
			414	31.5000	1.2323	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					
378B	3290	6.75	418 419	31.9000 32.0000	1.2559 1.2598	1.3125 1.3125	-4.3% -4.0%	1.2323	129.4604 129.4604	24000 24000	13317.3	0.55	19024.7	0.79	
5/00	-1.50	2.75	419	31.7000	1.2598	1.3125	-4.0%		129.4604	24000				2.7.5	
1			420	31.8000	1.2520	1.3125	-4.6%		129.4604	24000					
378C			422	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
			423 424	31.8000 33.9000	1.2520	1.3125 1.3750	-4.6% -2.9%		129.4604 111.3828	24000 24000					
388A			424	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
			426	34.0000	1.3386	1.3750	-2.6%		111.3828	24000					
388B	3381	6.75	427	33.6000	1.3228	1.3750	-3.8%	1.3189	111.3828	24000	12923.8	0.54	18462.6	0.77	
308D	1000	0.75	428 429	33.5000 33.5000	1.3189 1.3189	1.3750 1.3750	-4.1% -4.1%	1.3103	111.3828 111.3828	24000 24000	12723.0	0.54	10402.0	0.77	
1			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					
L			432	34.2000	1.3465	1.3750	-2.1%		111.3828	24000					

	Distance From Fwd		Reading	Thickness	Thickness	Plate	%Change in	Min Thickness (in)		Allowable	Base N	Base Material		oints	
Can #	Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)	Thickness (in)	Material	(3)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
			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					
408A			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					
408B	3565	6.75	445	37.8000	1.4882	1.4375	3.5%	1.4567	74.8303	24000	12582.0	0.52	17974.3	0.75	
4086	3000	0.75	446 447	37.8000	1.4882	1.4375	3.5% 2.4%	1.4567	74.8303 74.8303	24000 24000	12582.0	0.52	1/9/4.3	0.75	
I			447	37.4000 37.2000	1.4724 1.4646	1.4375 1.4375	2.4%		74.8303	24000					
408C			448 449	37.5000	1.4646	1.4375	2.7%		74.8303	24000					
-000			449	37.5000	1.4764	1.4375	2.7%		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					1.5025 31015 2211 0/5
			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					
L			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					
I			471	46.8000	1.8425	1.6250	13.4%		10.8199	24000					
432B	3773	6.75	472	47.6000	1.8740	1.6250	15.3%	1.8425	10.8199	24000	11166.7	0.47	15952.5	0.66	
4320	5//5	0.75	473 474	47.4000	1.8661	1.6250	14.8%	1.0423	10.8199 10.8199	24000 24000	11100.7	0.47	13532.3	0.00	
I			474	47.9000 47.2000	1.8858	1.6250	16.1% 14.4%			24000					
432C			475	47.2000	1.8583 1.8661	1.6250 1.6250	14.4%		10.8199 10.8199	24000					
-540			476	47.4000	1.8583	1.6250	14.8% 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	14.4%		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:

<sup>1</sup> Hoop stress =  $Pr/t_{97.5}$ <sup>2</sup> Hoop stress /  $S_A$ <sup>3</sup> Hoop stress / 0.7 joint efficiency <sup>4</sup> Joint stress /  $S_A$ 

<sup>5</sup>Per ASCE No. 79, Steel Penstocks, 2nd Edition, 2012

TABLE 1 - TRANSIENT PENSTOCK 1 THICKNESS MEASURMENTS AND STRESSES

						r i	NJIOCKI	THERNESS N		NIS AND ST	LJJLJ				
Unit v	veight of water=	62.4	pcf												
N	ormal pond EL=	597	feet												
	Joint Efficiency=	0.7	(per Penstock	#2 assessment	)										
	D <sub>1</sub> ID=	17.00													
	D <sub>2</sub> ID=	15.25													
	D <sub>3</sub> ID=	13.50													
	Note	: Starting point	is 42ft D/S of t	he face of the I	ntake										
	Distance														
Can #	From Fwd	Radius (ft)	Reading	Thickness Reading	Thickness	Plate	%Change in	Min	C.L. EL. (ft)	Allowable Steel Stress	Base	Material	At J	pints	Notes
	Edge of Can 1	100105 (11)	Number	(mm)	Reading (in)	Thickness (in)	Material	Thickness (in)	0.2. 22. ()	(psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	notes
Pensto	(Ft) ck Interior														
	am End of Condu	uit													
			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					
2B	9	8.50	4 5	11.9000 11.9000	0.4685 0.4685	0.5000	-6.3% -6.3%	0.4646	549.2799	17000 17000	5902.3	0.35	8431.8	0.50	
20	9	8.50	6	11.9000	0.4685	0.5000	-0.3%	0.4040	549.2799 549.2799	17000	5902.3	0.35	6431.8	0.50	
			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 13	12.5000 11.9000	0.4921 0.4685	0.5000	-1.6% -6.3%		549.0728 549.0728	17000 17000					
7B	57	8.50	15	12.0000	0.4685	0.5000	-0.3%	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					
12A			19 20	11.9000 11.9000	0.4685 0.4685	0.5000	-6.3% -6.3%		548.8829 548.8829	17000 17000					
120			20	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 27	12.2000 12.0000	0.4803 0.4724	0.5000	-3.9% -5.5%		548.8829 548.8829	17000 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 34	10.0000 9.8000	0.3937 0.3858	0.4375 0.4375	-10.0% -11.8%		548.6801 548.6801	17000 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 40	10.3000	0.4055	0.4375	-7.3%		548.5075	17000					
22B	188	8.50	40 41	10.4000 10.4000	0.4094 0.4094	0.4375 0.4375	-6.4% -6.4%	0.3898	548.5075 548.5075	17000 17000	7148.9	0.42	10212.7	0.60	
_10	200		41	10.3000	0.4054	0.4375	-7.3%		548.5075	17000	10.5				
			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					
28A			46 47	10.3000 10.2000	0.4055	0.4375 0.4375	-7.3% -8.2%		544.8593 544.8593	17000 17000					
-54			47	10.2000	0.4010	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					
200			52	10.6000	0.4173	0.4375	-4.6%		544.8593	17000					
28C			53 54	10.6000 10.4000	0.4173 0.4094	0.4375 0.4375	-4.6% -6.4%		544.8593 544.8593	17000 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 60	11.0000 11.3000	0.4331	0.4375	-1.0% 1.7%	0.4252		17000					
			60 61	11.3000 11.2000	0.4449 0.4409	0.4375 0.4375	1.7%			17000 17000					
33C			62	11.1000	0.4409	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 67	10.9000	0.4291	0.4375	-1.9%		533.8125 533.8125	17000					
38B	312	8.50	67 68	11.1000 11.1000	0.4370 0.4370	0.4375 0.4375	-0.1% -0.1%	0.4213	533.8125 533.8125	17000 17000	8618.8	0.51	12312.6	0.72	
300	312	0.30	69	11.2000	0.4370	0.4375	0.1%	0.4213	533.8125	17000	0010.0	0.31	12312.0	0.72	
			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					

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	Distance			Thickness						Allowable	Base Material		At Joints		
Can #	From Fwd Edge of Can 1	Radius (ft)	Reading Number	Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup> Stress Ratio <sup>4</sup>		Notes
	(Ft)		73	10.1000	0.3976	0.4375	-9.1%		528.5292	17000	50,655 (p51)	Sucos nado	54(655(p5))	Stress hallo	
43A			74 75	10.1000 10.1000	0.3976 0.3976	0.4375 0.4375	-9.1% -9.1%		528.5292 528.5292	17000 17000					
			76	10.7000	0.4213	0.4375	-3.7%		528.5292	17000					
43B	356	8.50	77 78	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%	0.3937	528.5292 528.5292	17000 17000	9993.2	0.59	14276.0	0.84	
			79	10.2000	0.4016	0.4375	-8.2%		528.5292	17000					
43C			80 81	10.0000 10.0000	0.3937 0.3937	0.4375 0.4375	-10.0% -10.0%		528.5292 528.5292	17000 17000					
			82	9.5000	0.3740	0.4375	-14.5%		518.8032	17000					
52A			83 84	9.6000 9.5000	0.3780	0.4375 0.4375	-13.6% -14.5%		518.8032 518.8032	17000 17000					
			85	10.2000	0.4016	0.4375	-8.2%		518.8032	17000					
52B	437	8.50	86 87	10.5000 10.0000	0.4134 0.3937	0.4375 0.4375	-5.5% -10.0%	0.3740	518.8032 518.8032	17000 17000	12013.4	0.71	17162.0	1.01	
			88	10.8000	0.4252	0.4375	-2.8%		518.8032	17000					
52C			89 90	10.8000 10.8000	0.4252 0.4252	0.4375 0.4375	-2.8% -2.8%		518.8032 518.8032	17000 17000					
			91	10.8000	0.4252	0.4375	-2.8%		513.3999	17000					
57A			92 93	10.7000 11.0000	0.4213 0.4331	0.4375 0.4375	-3.7% -1.0%		513.3999 513.3999	17000 17000					
			94	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57B	482	8.50	95 96	11.1000 11.1000	0.4370 0.4370	0.4375 0.4375	-0.1% -0.1%	0.4213	513.3999 513.3999	17000 17000	11403.1	0.67	16290.1	0.96	
			97	11.3000	0.4449	0.4375	1.7%		513.3999	17000					
57C			98 99	11.5000 11.3000	0.4528 0.4449	0.4375 0.4375	3.5% 1.7%		513.3999 513.3999	17000 17000					
			100	12.2000	0.4803	0.4375	9.8%		509.9386	17000					
61A			101 102	12.0000 12.4000	0.4724 0.4882	0.4375 0.4375	8.0% 11.6%		509.9386 509.9386	17000 17000					
	540	0.50	103 104	12.7000 12.7000	0.5000 0.5000	0.4375 0.4375	14.3% 14.3%	0.472.4	509.9386 509.9386	17000 17000	10500 7	0.62	15136.0	0.84 1.01 0.96 0.89 0.89 0.89 0.89 0.89 0.89 0.89 0.89 0.89 0.89 0.90	
61B	518	8.50	104	12.7000	0.4882	0.4375	14.5%	0.4724	509.9386	17000	10588.7	0.62	15126.8		
616			106 107	12.9000 12.6000	0.5079 0.4961	0.4375 0.4375	16.1% 13.4%		509.9386 509.9386	17000 17000					
61C			107	13.0000	0.4981	0.4375	13.4%		509.9386	17000					
72A			109 110	10.1000 10.2000	0.3976 0.4016	0.4375 0.4375	-9.1% -8.2%		509.2026 509.2026	17000 17000					
/26			111	10.0000	0.3937	0.4375	-10.0%		509.2026	17000					
72B	610	8.50	112 113	10.2000 10.1000	0.4016 0.3976	0.4375 0.4375	-8.2% -9.1%	0.3937	509.2026 509.2026	17000 17000	12813.9	0.75	18305.6	1.08	
			114	10.2000	0.4016	0.4375	-8.2%		509.2026	17000		0.75 18305.0			
72C			115 116	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%		509.2026 509.2026	17000 17000					
			117	10.7000	0.4213	0.4375	-3.7%		509.2026	17000					
77A			118 119	11.0000 11.0000	0.4331 0.4331	0.4375 0.4375	-1.0% -1.0%		508.8427 508.8427	17000 17000					
			120	10.8000	0.4252	0.4375	-2.8%		508.8427	17000		0.76 18380.6			
77B	655	8.50	121 122	10.8000 10.8000	0.4252 0.4252	0.4375 0.4375	-2.8% -2.8%	0.3937	508.8427 508.8427	17000 17000	12866.4		18380.6	1.08	
			123	10.9000	0.4291	0.4375	-1.9%		508.8427	17000					
77C			124 125	10.1000 10.0000	0.3976 0.3937	0.4375 0.4375	-9.1% -10.0%		508.8427 508.8427	17000 17000					
			126	10.2000	0.4016	0.4375	-8.2%		508.8427	17000					
82A			127 128	11.6000 11.4000	0.4567 0.4488	0.4375 0.4375	4.4% 2.6%		508.4827 508.4827	17000 17000					
			129 130	11.7000 11.4000	0.4606 0.4488	0.4375 0.4375	5.3% 2.6%		508.4827 508.4827	17000 17000				1.09	
82B	700	8.50	130	11.4000	0.4528	0.4375	3.5%	0.3937	508.4827	17000	12919.0	0.76	18455.7		
			132 133	11.6000 10.0000	0.4567 0.3937	0.4375 0.4375	4.4%		508.4827 508.4827	17000 17000					
82C			134	10.2000	0.4016	0.4375	-8.2%		508.4827	17000					
			135 136	10.2000 10.8000	0.4016	0.4375	-8.2% -2.8%		508.4827 505.4631	17000 17000					
92A			137	10.9000	0.4291	0.4375	-1.9%		505.4631	17000					
1			138 139	10.8000 10.2000	0.4252 0.4016	0.4375 0.4375	-2.8% -8.2%		505.4631 505.4631	17000 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	
			141 142	10.3000 10.9000	0.4055 0.4291	0.4375 0.4375	-7.3% -1.9%		505.4631 505.4631	17000 17000					
92C			143	10.8000	0.4252	0.4375	-2.8%		505.4631	17000					
┣───			144 145	10.9000 11.1000	0.4291 0.4370	0.4375 0.4375	-1.9% -0.1%		505.4631 495.0948	17000 17000					
104A			146 147	11.3000 10.9000	0.4449 0.4291	0.4375 0.4375	1.7% -1.9%		495.0948 495.0948	17000 17000					
			147	11.0000	0.4291	0.4375	-1.9%		495.0948 495.0948	17000					
104B	896	8.50	149 150	11.0000 11.1000	0.4331 0.4370	0.4375 0.4375	-1.0% -0.1%	0.4291	495.0948 495.0948	17000 17000	13644.9	0.80	19492.7	1.15	
			151	11.3000	0.4370	0.4375	1.7%		495.0948 495.0948	17000					
104C			152 153	11.0000 11.1000	0.4331 0.4370	0.4375 0.4375	-1.0% -0.1%		495.0948 495.0948	17000 17000					
			154	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108A			155 156	11.0000 10.9000	0.4331 0.4291	0.4375 0.4375	-1.0% -1.9%		491.6704 491.6704	17000 17000					
			157	10.9000	0.4291	0.4375	-1.9%		491.6704	17000					
108B	932	8.50	158 159	10.8000 10.9000	0.4252 0.4291	0.4375 0.4375	-2.8% -1.9%	0.4173	491.6704 491.6704	17000 17000	14502.5	0.85	20717.9	1.22	
1			160	10.8000	0.4252	0.4375	-2.8%		491.6704	17000					
108C			161 162	10.6000 10.8000	0.4173 0.4252	0.4375 0.4375	-4.6% -2.8%		491.6704 491.6704	17000 17000			18455.7     1.09       18711.0     1.10       19492.7     1.15		
L			102	10.0000	5.42JZ	5.4375	2.070		-51.0704	1,000					

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	Distance			Thickness						Allowable	Base Material		At Joints		
Can #	From Fwd Edge of Can 1	Radius (ft)	Reading Number	Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	(Ft)		163	11.2000	0.4409	0.4375	0.8%		485.6778	24000					CSA G40.8 Grade B Steel
115A			164 165	11.1000 11.2000	0.4370 0.4409	0.4375 0.4375	-0.1% 0.8%		485.6778 485.6778	24000 24000					
			165	12.2000	0.4803	0.4375	9.8%		485.6778	24000					
115B	995	8.50	167 168	12.4000 12.1000	0.4882 0.4764	0.4375 0.4375	11.6% 8.9%	0.4370	485.6778 485.6778	24000 24000	14637.2	0.61	20910.3	0.87	
			169	11.2000	0.4409	0.4375	0.8%		485.6778	24000					
115C			170 171	11.1000 11.1000	0.4370 0.4370	0.4375 0.4375	-0.1% -0.1%		485.6778 485.6778	24000 24000					
			172	10.6000	0.4173	0.4375	-4.6%		484.6314	24000					
123A			173 174	10.5000 10.5000	0.4134 0.4134	0.4375 0.4375	-5.5% -5.5%		484.6314 484.6314	24000 24000					
			175	10.4000	0.4094	0.4375	-6.4%		484.6314	24000					
123B	1006	8.50	176 177	10.5000 10.5000	0.4134 0.4134	0.4375 0.4375	-5.5% -5.5%	0.4094	484.6314 484.6314	24000 24000	15769.2	0.66 22527.5	0.94		
			178	10.5000	0.4134	0.4375	-5.5%		484.6314	24000					
123C			179 180	11.5000 11.4000	0.4528 0.4488	0.4375 0.4375	3.5% 2.6%		484.6314 484.6314	24000 24000					
126A			181 182	11.0000 11.2000	0.4331 0.4409	0.4375 0.4375	-1.0% 0.8%		476.3558 476.3558	24000 24000					
126A			182	11.2000	0.4409	0.4375	-0.1%		476.3558	24000					
126B	1093	8.50	184 185	12.5000 12.7000	0.4921 0.5000	0.4375 0.4375	12.5% 14.3%	0.4331	476.3558 476.3558	24000 24000	16007.1	0.67	22867.3	0.95	
1200	1055	0.50	186	12.5000	0.4921	0.4375	12.5%	0.4351	476.3558	24000	10007.1	0.07	22007.5	0.55	
126C			187 188	11.5000 11.5000	0.4528 0.4528	0.4375 0.4375	3.5% 3.5%		476.3558 476.3558	24000 24000					
			189	11.6000	0.4567	0.4375	4.4%		476.3558	24000					
133A			190 191	10.5000 10.5000	0.4134 0.4134	0.4375 0.4375	-5.5% -5.5%		470.4583 470.4583	24000 24000					
			192	10.6000	0.4173	0.4375	-4.6%		470.4583	24000					
133B	1155	8.50	193 194	10.7000 10.9000	0.4213 0.4291	0.4375 0.4375	-3.7% -1.9%	0.4134	470.4583 470.4583	24000 24000	17589.1	0.73	22527.5       0.94         22867.3       0.95         25127.3       1.05         26462.4       1.10         26999.9       1.12         29934.4       1.25         31351.5       1.31		
			195	10.5000	0.4134	0.4375	-5.5%		470.4583	24000					
133C			196 197	11.2000 11.0000	0.4409 0.4331	0.4375 0.4375	0.8%		470.4583 470.4583	24000 24000					
			198 199	11.1000 10.4000	0.4370	0.4375 0.4375	-0.1% -6.4%		470.4583 466.2729	24000 24000					
138A			200	10.3000	0.4055	0.4375	-7.3%		466.2729	24000					
			201 202	10.3000 10.9000	0.4055 0.4291	0.4375 0.4375	-7.3% -1.9%		466.2729 466.2729	24000 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		
			204 205	10.8000 10.8000	0.4252 0.4252	0.4375 0.4375	-2.8% -2.8%		466.2729 466.2729	24000 24000					
138C			206	10.8000	0.4252	0.4375	-2.8%		466.2729	24000					
			207 208	10.8000 10.0000	0.4252 0.3937	0.4375 0.4375	-2.8% -10.0%		466.2729 452.6425	24000 24000					15.25 I.D. Penstock
148A			209 210	10.1000 10.1000	0.3976 0.3976	0.4375 0.4375	-9.1%		452.6425 452.6425	24000 24000					
			210	10.1000	0.4252	0.4375	-9.1% -2.8%		452.6425	24000					
148B	1262	7.63	212 213	10.8000 10.7000	0.4252 0.4213	0.4375 0.4375	-2.8% -3.7%	0.3937	452.6425 452.6425	24000 24000	18899.9	0.79 26	26999.9	1.12	
			213	10.8000	0.4213	0.4375	-2.8%		452.6425	24000					
148C			215 216	10.6000 10.6000	0.4173 0.4173	0.4375 0.4375	-4.6% -4.6%		452.6425 452.6425	24000 24000					
			217	10.7000	0.4213	0.4375	-3.7%		436.9529	24000					
155A			218 219	10.6000 10.8000	0.4173 0.4252	0.4375 0.4375	-4.6% -2.8%		436.9529 436.9529	24000 24000		1 0.87			
			220	10.9000	0.4291	0.4375	-1.9%		436.9529	24000					
155B	1325	7.63	221 222	10.9000 11.0000	0.4291 0.4331	0.4375 0.4375	-1.9% -1.0%	0.3937	436.9529 436.9529	24000 24000	20954.1		29934.4	1.25	
			223	10.0000	0.3937	0.4375	-10.0%		436.9529	24000					
155C			224 225	10.1000 10.1000	0.3976 0.3976	0.4375 0.4375	-9.1% -9.1%		436.9529 436.9529	24000 24000					
165A			226 227	11.1000 10.9000	0.4370 0.4291	0.5000 0.5000	-12.6% -14.2%		414.2901 414.2901	24000 24000					
1054			228	11.0000	0.4331	0.5000	-13.4%		414.2901	24000					
165B	1416	7.63	229 230	11.6000 11.7000	0.4567 0.4606	0.5000 0.5000	-8.7% -7.9%	0.4291	414.2901 414.2901	24000 24000	21946.0	0.91	31351.5	1.31	
			231	11.5000	0.4528	0.5000	-9.4%		414.2901	24000					
165C			232 233	11.7000 11.5000	0.4606 0.4528	0.5000 0.5000	-7.9% -9.4%		414.2901 414.2901	24000 24000					
			234	11.9000	0.4685	0.5000	-6.3%		414.2901	24000					
176A			235 236	14.2000 14.2000	0.5591 0.5591	0.5625 0.5625	-0.6% -0.6%		388.8879 388.8879	24000 24000					
			237 238	14.2000 14.2000	0.5591 0.5591	0.5625 0.5625	-0.6% -0.6%		388.8879 388.8879	24000 24000					
176B	1518	7.63	238	14.2000	0.5591	0.5625	-0.6%	0.5394	388.8879 388.8879	24000	19888.3	0.83	28411.8	1.18	
			240 241	14.2000 13.7000	0.5591 0.5394	0.5625 0.5625	-0.6% -4.1%		388.8879 388.8879	24000 24000					
176C			242	13.7000	0.5394	0.5625	-4.1%		388.8879	24000					
┣───			243 244	13.8000 18.6000	0.5433	0.5625	-3.4% 30.2%		388.8879 373.2723	24000 24000					
185A			245	18.8000	0.7402	0.5625	31.6%		373.2723	24000					
			246 247	18.4000 18.8000	0.7244 0.7402	0.5625 0.5625	28.8% 31.6%		373.2723 373.2723	24000 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	
1			249 250	18.8000 18.0000	0.7402 0.7087	0.5625 0.5625	31.6% 26.0%		373.2723 373.2723	24000 24000					
185C			251	17.9000	0.7047	0.5625	25.3%		373.2723	24000					
L			252	18.1000	0.7126	0.5625	26.7%		373.2723	24000					

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	Distance From Fwd		Reading	Thickness	Thickness	Plate	%Change in	Min		Allowable	Base	Material	At J	oints	
Can #	Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)	Thickness (in)	Material	Thickness (in)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	(Ft)		253	13.8000	0.5433	0.5625	-3.4%		367.0379	24000					
194A			254 255	13.6000 13.9000	0.5354 0.5472	0.5625 0.5625	-4.8% -2.7%		367.0379 367.0379	24000 24000					
			256	14.2000	0.5591	0.5625	-0.6%		367.0379	24000					
194B	1667	7.63	257 258	14.4000 14.1000	0.5669 0.5551	0.5625 0.5625	0.8%	0.5354	367.0379 367.0379	24000 24000	22138.0	0.92	31625.7	1.32	
			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					
			261 262	14.1000 15.4000	0.5551	0.5625	-1.3%		367.0379 359.9495	24000 24000					
203A			263	15.4000	0.6063	0.6250	-3.0%		359.9495	24000					
			264 265	15.5000 16.0000	0.6102 0.6299	0.6250	-2.4% 0.8%		359.9495 359.9495	24000 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	
			267 268	15.9000 15.6000	0.6260	0.6250	0.2%		359.9495 359.9495	24000 24000					
203C			268	15.6000	0.6142	0.6250	-1.7%		359.9495	24000					
			270	15.3000	0.6024	0.6250	-3.6%		359.9495	24000					
213A			271 272	14.8000 14.6000	0.5827 0.5748	0.6250	-6.8% -8.0%		352.1779 352.1779	24000 24000					
			273	14.6000	0.5748	0.6250	-8.0%		352.1779	24000					
213B	1841	7.63	274 275	14.4000 14.5000	0.5669	0.6250	-9.3% -8.7%	0.5551	352.1779 352.1779	24000 24000	22732.7	0.95	32475.3	1.35	
2100	1011	7.05	276	14.2000	0.5591	0.6250	-10.6%	0.5551	352.1779	24000	227.52.7	0.55	52475.5	1.55	
213C			277 278	14.2000 14.1000	0.5591 0.5551	0.6250	-10.6% -11.2%		352.1779 352.1779	24000 24000					
2130			278 279	14.1000 14.1000	0.5551	0.6250	-11.2% -11.2%		352.1779 352.1779	24000 24000					
			280	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227A			281 282	15.9000 15.8000	0.6260 0.6220	0.6250	0.2%		339.0478 339.0478	24000 24000					
			283	15.8000	0.6220	0.6250	-0.5%		339.0478	24000					
227B	1959	7.63	284 285	15.6000 15.9000	0.6142 0.6260	0.6250	-1.7% 0.2%	0.6063	339.0478 339.0478	24000 24000	21930.0	0.91	31328.6	1.31	
			285	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
227C			287	15.4000	0.6063	0.6250	-3.0%		339.0478	24000					
			288 289	15.4000 16.1000	0.6063	0.6250	-3.0% -7.8%		339.0478 326.0738	24000 24000					
235A			290	16.0000	0.6299	0.6875	-8.4%		326.0738	24000					
			291 292	16.0000 16.8000	0.6299 0.6614	0.6875 0.6875	-8.4% -3.8%		326.0738 326.0738	24000 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 326.0738	24000					
235C			295 296	16.1000 16.0000	0.6339 0.6299	0.6875 0.6875	-7.8% -8.4%		326.0738	24000 24000					
			297	16.1000	0.6339	0.6875	-7.8%		326.0738	24000					
243A			298 299	18.3000 18.3000	0.7205	0.7500 0.7500	-3.9% -3.9%		313.4505 313.4505	24000 24000					
			300	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243B	2105	7.63	301 302	18.4000 18.3000	0.7244 0.7205	0.7500	-3.4% -3.9%	0.7205	313.4505 313.4505	24000 24000	20286.1	0.85	28980.1	1.21	
2450	2105	7.05	303	18.4000	0.7244	0.7500	-3.4%	0.7205	313.4505	24000	20200.1	0.05	20500.1	1.21	
			304	18.3000	0.7205	0.7500	-3.9%		313.4505	24000					
243C			305 306	18.3000 18.4000	0.7205 0.7244	0.7500 0.7500	-3.9% -3.4%		313.4505 313.4505	24000 24000					
			307	18.6000	0.7323	0.7500	-2.4%		296.0934	24000					
254A			308 309	18.5000 18.5000	0.7283 0.7283	0.7500	-2.9% -2.9%		296.0934 296.0934	24000 24000					
			310	18.4000	0.7244	0.7500	-3.4%		296.0934	24000					
254B	2204	7.63	311 312	18.4000 18.5000	0.7244 0.7283	0.7500 0.7500	-3.4% -2.9%	0.7087	296.0934 296.0934	24000 24000	21886.7	0.91	31266.7	1.30	
			312	18.5000	0.7283	0.7500	-2.9%		296.0934 296.0934	24000					
254C			314	18.4000	0.7244	0.7500	-3.4%		296.0934 296.0934	24000 24000					
			315 316	18.4000 22.6000	0.7244 0.8898	0.7500	-3.4% 18.6%		296.0934 283.6501	24000					
263A			317	22.5000	0.8858	0.7500	18.1%		283.6501	24000					
			318 319	22.4000 23.8000	0.8819 0.9370	0.7500	17.6% 24.9%		283.6501 283.6501	24000 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	
1			321 322	23.5000	0.9252	0.7500	23.4%		283.6501	24000					
263C			322	22.0000 21.9000	0.8661 0.8622	0.7500 0.7500	15.5% 15.0%		283.6501 283.6501	24000 24000					
			324	22.4000	0.8819	0.7500	17.6%		283.6501	24000					
274A			325 326	19.0000 19.3000	0.7480 0.7598	0.7500 0.7500	-0.3% 1.3%		267.1697 267.1697	24000 24000					
			327	18.9000	0.7441	0.7500	-0.8%		267.1697	24000					
274B	2369	7.63	328 329	18.8000 18.7000	0.7402 0.7362	0.7500	-1.3% -1.8%	0.7323	267.1697 267.1697	24000 24000	23216.6	0.97	33166.5	1.38	
2.40	2000	,	325	19.0000	0.7480	0.7500	-0.3%		267.1697	24000		0.57		1.00	
37.0			331 332	18.7000 19.0000	0.7362 0.7480	0.7500 0.7500	-1.8% -0.3%		267.1697 267.1697	24000 24000					
274C			332	19.0000	0.7480	0.7500	-0.3% -2.4%		267.1697 267.1697	24000					
			334	20.2000	0.7953	0.8125	-2.1%		251.0399	24000					
284A			335 336	20.1000 20.2000	0.7913 0.7953	0.8125	-2.6% -2.1%		251.0399 251.0399	24000 24000					
			337	20.4000	0.8031	0.8125	-1.2%		251.0399	24000					
284B	2461	7.63	338 339	20.1000 20.6000	0.7913 0.8110	0.8125 0.8125	-2.6% -0.2%	0.7835	251.0399 251.0399	24000 24000	22761.1	0.95	32515.9	1.35	
			339	20.8000	0.7953	0.8125	-0.2%		251.0399	24000					
284C			341 342	19.9000 20.2000	0.7835 0.7953	0.8125 0.8125	-3.6% -2.1%		251.0399 251.0399	24000 24000					
L			542	20.2000	U./953	0.8125	-2.1%		221.0333	24000					

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	Distance From Fwd		Reading	Thickness	Thickness	Plate	%Change in	Min		Allowable	Base	Material	At J	oints	
Can #	Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)	Thickness (in)	Material	Thickness (in)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
	(11)		343	21.2000	0.8346	0.8750	-4.6%		235.2607	24000					
294A			344 345	21.2000 21.1000	0.8346 0.8307	0.8750 0.8750	-4.6% -5.1%		235.2607 235.2607	24000 24000					
			346	22.2000	0.8740	0.8750	-0.1%		235.2607	24000					
294B	2551	7.63	347 348	22.2000 22.1000	0.8740 0.8701	0.8750 0.8750	-0.1% -0.6%	0.8307	235.2607 235.2607	24000 24000	22445.7	0.94	32065.3	1.34	
			349	22.1000	0.8701	0.8750	-0.6%		235.2607	24000					
294C			350 351	21.9000 22.2000	0.8622 0.8740	0.8750 0.8750	-1.5% -0.1%		235.2607 235.2607	24000 24000					
			351	28.5000	1.1220	0.9375	19.7%		233.2007	24000					
304A			353	28.5000	1.1220	0.9375	19.7%		221.3657	24000					
			354 355	28.5000 28.8000	1.1220 1.1339	0.9375 0.9375	19.7% 20.9%		221.3657 221.3657	24000 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	
			357 358	28.5000 28.6000	1.1220 1.1260	0.9375 0.9375	19.7% 20.1%		221.3657 221.3657	24000 24000					
304C			359	28.9000	1.1378	0.9375	21.4%		221.3657	24000					
			360 361	28.5000	1.1220	0.9375	19.7%		221.3657	24000 24000					
313A			361	23.8000 23.8000	0.9370 0.9370	0.9375 0.9375	-0.1% -0.1%		211.8990 211.8990	24000					
			363	23.7000	0.9331	0.9375	-0.5%		211.8990	24000					
313B	2723	7.63	364 365	23.5000 23.5000	0.9252	0.9375 0.9375	-1.3% -1.3%	0.9252	211.8990 211.8990	24000 24000	21454.9	0.89	30649.9	1.28	
5155	2725	7.05	366	23.7000	0.9331	0.9375	-0.5%	0.5252	211.8990	24000	21454.5	0.05	50045.5	1.20	
313C			367	24.0000 23.9000	0.9449	0.9375 0.9375	0.8%		211.8990 211.8990	24000 24000					
3130			368 369	23.9000	0.9409	0.9375	0.4%		211.8990 211.8990	24000					
			370	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324A			371 372	25.2000 25.5000	0.9921 1.0039	1.0000 1.0000	-0.8% 0.4%		200.2388 200.2388	24000 24000					
			373	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
324B	2824	7.63	374 375	25.5000 25.2000	1.0039 0.9921	1.0000 1.0000	0.4%	0.9921	200.2388 200.2388	24000 24000	20613.4	0.86	29447.7	1.23	
			376	25.4000	1.0000	1.0000	0.0%		200.2388	24000					
324C			377 378	25.3000	0.9961	1.0000	-0.4%		200.2388	24000					
			378	25.3000 25.6000	0.9961	1.0000	-0.4%		200.2388 189.9640	24000 24000					
334A			380	25.7000	1.0118	1.0625	-4.8%		189.9640	24000					
			381 382	25.5000 26.4000	1.0039 1.0394	1.0625 1.0625	-5.5% -2.2%		189.9640 189.9640	24000 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					
334C			385 386	25.4000 25.7000	1.0000 1.0118	1.0625 1.0625	-5.9% -4.8%		189.9640 189.9640	24000 24000					
			387	25.3000	0.9961	1.0625	-6.3%		189.9640	24000					
344A			388 389	28.9000 28.7000	1.1378 1.1299	1.1250 1.1250	1.1% 0.4%		179.9200 179.9200	24000 24000					
			390	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344B	3000	7.63	391 392	28.9000 28.5000	1.1378 1.1220	1.1250 1.1250	1.1% -0.3%	1.1220	179.9200 179.9200	24000 24000	19160.0	0.80	27371.4	1.14	
5446	3000	7.05	393	29.0000	1.1417	1.1250	1.5%	1.1220	179.9200	24000	15100.0	0.00	27571.4	1.14	
			394	28.9000	1.1378	1.1250	1.1%		179.9200	24000					
344C			395 396	29.0000 28.6000	1.1417 1.1260	1.1250 1.1250	1.5% 0.1%		179.9200 179.9200	24000 24000					
			397	35.6000	1.4016	1.1875	18.0%		164.4237	24000					13.5 I.D. Penstock
357A			398 399	35.6000 35.6000	1.4016 1.4016	1.1875 1.1875	18.0% 18.0%		164.4237 164.4237	24000 24000					
			400	35.6000	1.4016	1.1875	18.0%		164.4237	24000					
357B	3114	6.75	401 402	35.5000 35.6000	1.3976 1.4016	1.1875 1.1875	17.7% 18.0%	1.3937	164.4237 164.4237	24000 24000	14162.6	0.59	20232.3	0.84	
			402	35.6000	1.3937	1.1875	18.0%		164.4237 164.4237	24000					
357C			404 405	35.6000 35.6000	1.4016 1.4016	1.1875 1.1875	18.0% 18.0%		164.4237 164.4237	24000 24000					
<u> </u>			405	30.1000	1.1850	1.1875	-5.2%		147.5381	24000					
368A			407	30.1000	1.1850	1.2500	-5.2%		147.5381	24000					
			408 409	30.2000 31.3000	1.1890 1.2323	1.2500 1.2500	-4.9% -1.4%		147.5381 147.5381	24000 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	
			411 412	31.2000 31.2000	1.2283 1.2283	1.2500 1.2500	-1.7% -1.7%		147.5381 147.5381	24000 24000					
368C			413	31.2000	1.2283	1.2500	-1.7%		147.5381	24000					
L			414 415	31.3000 31.5000	1.2323	1.2500 1.3125	-1.4%		147.5381 129.4604	24000 24000					
378A			415	31.3000	1.2402	1.3125	-5.5% -6.1%		129.4604 129.4604	24000					
			417	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
378B	3290	6.75	418 419	31.9000 32.0000	1.2559 1.2598	1.3125 1.3125	-4.3% -4.0%	1.2323	129.4604 129.4604	24000 24000	17312.4	0.72	24732.1	1.03	
			420	31.7000	1.2480	1.3125	-4.9%		129.4604	24000					
378C			421 422	31.8000 31.7000	1.2520 1.2480	1.3125 1.3125	-4.6% -4.9%		129.4604 129.4604	24000 24000					
3/60			423	31.8000	1.2520	1.3125	-4.5%		129.4604	24000					
200			424	33.9000	1.3346	1.3750	-2.9%		111.3828	24000					
388A			425 426	33.9000 34.0000	1.3346 1.3386	1.3750 1.3750	-2.9% -2.6%		111.3828 111.3828	24000 24000					
			427	33.6000	1.3228	1.3750	-3.8%		111.3828	24000					
388B	3381	6.75	428 429	33.5000 33.5000	1.3189 1.3189	1.3750 1.3750	-4.1% -4.1%	1.3189	111.3828 111.3828	24000 24000	16800.9	0.70	24001.3	1.00	
			430	34.4000	1.3543	1.3750	-4.1%		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					

	Distance From Fwd		Reading	Thickness	Thickness	Plate	%Change in	Min		Allowable	Base I	Material	At Jo	pints	
Can #	Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)	Thickness (in)	Material	Thickness (in)	C.L. EL. (ft)	Steel Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup>	Notes
			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					
			435 436	34.8000 34.7000	1.3701	1.3750 1.3750	-0.4%		93.1065 93.1065	24000 24000					
398B	3473	6.75	436	34.7000	1.3661 1.3622	1.3750	-0.6% -0.9%	1.3622	93.1065 93.1065	24000	16879.0	0.70	24112.9	1.00	
396D	5475	0.75	437	34.6000	1.3622	1.3750	-0.9%	1.3022	93.1065	24000	108/9.0	0.70	24112.9	1.00	
			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			449 450	37.5000 37.0000	1.4764 1.4567	1.4375 1.4375	2.7% 1.3%		74.8303 74.8303	24000 24000					
			451	44.4000	1.4307	1.4373	16.5%		54.0032	24000					
417A			452	44.4000	1.7480	1.5000	16.5%		54.0032	24000					
41/A			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					
	2744	6.75	463	39.6000	1.5591	1.5625	-0.2%	4 5504	31.7368	24000		0.50	22624.2	0.00	
425B	3711	6.75	464 465	39.7000 39.7000	1.5630 1.5630	1.5625 1.5625	0.0%	1.5591	31.7368 31.7368	24000 24000	16544.0	0.69	23634.2	0.98	
			465	39.7000	1.5650	1.5625	0.3%		31.7368	24000					
425C			467	40.0000	1.5748	1.5625	0.8%		31.7368	24000					
4250			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					
435A			478 479	47.8000	1.8819 1.8819	1.6250	15.8%		9.1331	24000					
435A			479	47.8000 47.8000	1.8819	1.6250 1.6250	15.8% 15.8%		9.1331 9.1331	24000 24000					
			480	47.8000	1.8819	1.6250	15.8%		9.1331	24000					
435B	3778	6.75	481	47.2000	1.8583	1.6250	13.8%	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					
		1				bain Th			Man Inint I						

Notes:

<sup>1</sup> Hoop stress =  $Pr/t_{97,S}$ <sup>2</sup> Hoop stress /  $S_A$ <sup>3</sup> Hoop stress / 0.7 joint efficiency <sup>4</sup> Joint stress /  $S_A$ 

Min Th	ickness
All	0.3740
17ft	0.3740
15.25ft	0.3937
13.5ft	1.1850



 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** 

	<u>EXTERNAL</u>	<u>EXTERNAL PRESSURES EVALUATION- PENSTOCK 1 BAY D'ESPOIR</u>	OCK 1 BAY D'ESPOIL		
Allowable pressures (kPa)/External Pressures (kPa)					
Diameter 15.25 feet		1		Unit Weight of Water= 62.4 pcf	
Height of water above conduit= 0	feet	Live load: 100.00	psf	Pv= 0	
Height of rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150 lb/ft <sup>3</sup>	
Height of fill above conduit= 2	feet			Fill Unit Weight= 120 lb/ft <sup>3</sup>	
Total Height of Soil= 3	feet	(for DL calc) t= 1.19	inches	3.1	
5.31561683	feet	ID: 15.25	feet	(live load) W <sub>i</sub> = 1531.6 lb/ft	100 psf per foot section
	Assume well				
Buoyancy Factor R <sub>w</sub> = 1	drained = 1			w <sub>s</sub> = 316 lb/ft	
B_prime= 0.2330				W <sub>steel</sub> = 2333 lb/ft	
(coarse grain soils with fines) E_prime= 500	psi				
E= 3000000	psi				
b= 1				External pressure with vacuum= <b>3.76</b> psi	Ratio Q/q <sub>a</sub> = 0.791465
t <sub>97.5</sub> = 0.3937	inches			<sup>1</sup> External pressure with snow load= <b>3.91</b> psi	Ratio $Q/q_a = 0.821543$
I= 0.0051	inches <sup>4</sup>			<sup>1</sup> External pressure with snow and live= <b>4.39</b> psi	Ratio Q/q <sub>a</sub> = 0.923476
<sup>1,2</sup> FS= 2					
<sup>2</sup> Allowable pressure q <sub>a</sub> = <b>4.76</b>	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 Ib/ft <sup>3</sup>	
Height of fill above conduit= 2	feet			Fill Unit Weight= 120 lb/ft <sup>3</sup>	
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 <sub>i</sub> = 1706.2 lb/ft	
	Accumo woll				

eter 17 feet				
f water above conduit= 0	feet	Live load: 100.00	psf	
rip rap above conduit= 1	feet	Snow load: 20.61	psf	
nt of fill above conduit= 2	feet			
Total Height of Soil= 3	feet	(for DL calc) t= 0.44	inches	
OD Conduit Diameter= 17.062336	feet	ID: 17.00	feet	
	Assume well			
Buoyancy Factor R <sub>w</sub> = 1	drained = 1			
B_prime= 0.23302752				
ils with fines) E_prime= 500	psi			
E= 3000000	psi			
b= 1				
$t_{97.5} = 0.3740$	inches			
I= 0.0044	inches <sup>4</sup>			
<sup>1,2</sup> FS= 2				
Allowable pressure q <sub>a</sub> = <b>3.75</b>	psi			
res (kPa)/External Pressures (kPa)				
ter 13.5 feet				
f water above conduit= 0	feet	Live load: 100.00	psf	

Ratio  $Q/q_a = 0.826001$ Ratio  $Q/q_a = 0.864161$ Ratio Q/q<sub>a</sub>= 0.993484

psi psi

External pressure with vacuum= **3.10** <sup>1</sup>External pressure with snow load= **3.24** 

<sup>1</sup>External pressure with snow and live= **3.72** 

 $W_s$ = 351.7 lb/ft  $W_{steel}$ = 957.6 lb/ft steel= 490 pcf

W<sub>steel</sub>= 957.6 Density steel= 490

(kPa)/External Pressures (kPa)		
13.5 feet		
ater above conduit= 0	feet	Live load: 100.00
rap above conduit= 1	feet	Snow load: 20.61
f fill above conduit= 2	feet	
otal Height of Soil= 3	feet	(for DL calc) t= 1.63
Conduit Diameter= 13.6975065	feet	ID: 13.50
	Assume well	
uoyancy Factor $R_w$ = 1	drained = 1	
B_prime= 0.23302752		
vith fines) E_prime= 500	psi	
E= 3000000	psi	
b= 1		
$t_{97.5} = \frac{1.1850}{1.1850}$	inches	
I= 0.1387	inches <sup>4</sup>	

inches feet

psf psf

Rip Rap Unit Weight= 150

pcf

Unit Weight of Water= 62.4

Pv= 0

W<sub>s</sub>= 282.3 lb/ft W<sub>sted</sub>= 2855.4 lb/ft Density steel= 490 pcf

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

Ratio Q/q<sub>a</sub>= 0.143599 Ratio Q/q<sub>a</sub>= 0.148544

psi psi

External pressure with vacuum= **4.15** 

<sup>1</sup>External pressure with snow load= **4.30** <sup>1</sup>External pressure with snow and live= **4.78** 

Ratio Q/q<sub>a</sub>= 0.165304

References:

<sup>2</sup>Allowable pressure q<sub>a</sub>= **28.92** 

psi

l= 0.1387 <sup>1,2</sup>FS= 2

(coarse grain soils w

OD B Height of rip Height of

Allowable pressures (kf Diameter 13 Height of wate

<sup>2</sup>Allowable

(coarse grain soils with f

Allowable pressures (kPa)/I Diameter 17 fei Height of water ab Height of rip rap ab Height of fill ab Total Ht OD Condu

#### NP-NLH-011, Attachment 3 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 75 of 77

				1 - UT Thicl	kness Meas	urements *			
Can		Location A			Location B	1		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 72	12.2	12	12.4	12.7	12.7	12.4	12.9	12.6	13
72	10.1 11	10.2 11	10	10.2 10.8	10.1	10.2	10.8	10.9	10.7
77			10.8		10.8	10.9	10.1	10 10.2	10.2 10.2
82 92	11.6 10.8	11.4 10.9	11.7 10.8	11.4 10.2	11.5 10.2	11.6 10.3	10 10.9	10.2	10.2
92 104	10.8	10.9	10.8	10.2	10.2	10.3	10.9	10.8	10.9
104	10.9	11.5	10.9	10.9	10.8	10.9	11.3	10.6	10.8
108	10.9	11.1	10.9	10.9	10.8	10.9	10.8	10.0	10.8
113	10.6	10.5	10.5	12.2	12.4	12.1	10.5	11.1	11.1
125	10.0	10.5	10.5	10.4	10.5	10.5	11.5	11.5	11.4
133	10.5	10.5	10.6	12.3	12.7	12.5	11.3	11.5	11.0
135	10.5	10.3	10.0	10.7	10.9	10.5	10.8	10.8	10.8
138	10.4	10.5	10.5	10.5	10.5	10.0	10.8	10.6	10.6
155	10.7	10.1	10.1	10.0	10.0	10.7	10.0	10.0	10.0
165	11.1	10.0	10.0	11.6	10.5	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

Penstock #1 - UT Thickness Measurements<sup>1</sup>

<sup>1</sup> Per TRR Report ETS No.: 21-336-2, May 20, 2021

APPENDIX F

WELD TRACKER

	NI         FP         NI         FP         NI         NI         NI         FP         FP           45         46         47         48         49         50         51         52           RW         FP         FN         NI         NI         FP         FP         FP           NI         FP         FP         NI         NI         NI         FP         FP	FP         NI         FP         FP         NI         FP         FP         NI           104         105         106         107         108         109         110         111         112         113         8           104         105         106         107         108         109         110         111         112         113         8           FP         NI         FP         NI         FP         NI         FP         NI	NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         FP         NI         NI         NI         FP         NI         NI         NI         NI         NI         NI         NI         NI         NI         FP         NI         NI         NI         NI         NI         NI         FP         NI         NI         NI         NI         NI         FP         NI         NI<	FP         FP         FP         NI         FP         FP         NI         NI         FP         FP         NI         NI         FP         FP         FP         NI         NI         NI         NI         FP         NI         NI         NI         FP         FP<	NI         NI         NI         FP         NI         FP         NI         NI         NI<	NI         NI         NI         FP         NI         FP         NI         NI         NI         FP         NI         NI<	NI         FP         FP         FP           337         398         399         400         P           MI         FP         FP         FP         H			Not inspected	Pressure Washed     Ground/Cleaned     Inspection Passed	Inspection Failed		Inspection Failed Instrument Tree
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Date: August 14,2020 updated	N#         I         FP         NI         FP         NI         NI         NI         NI         FP         NI         FP </td <td>North         FP         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         FP         NI         FP         NI         NI         FP         NI         FI         NI         NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         FP         NI         NI         FP         NI</td> <td>North         N         FP         FP         FP         FP         FP         FP         FP         FP         FP         FN         WR         II           SECTION #         B         114         115         116         117         118         119         120         121         123         124         125         126         127         1           CAN #         M         FP         FP&lt;</td> <td>North         FP         FP         NI         NI         FP         NI         NI         NI         FP         NI         NI         FP         NI         NI</td> <td>North         N         FP         NI         NI         NI         FP         NI         FI         NI         FP         F</td> <td>North         FP         FP         NI         NI         NI         FP         NI         FP</td> <td>NI         FP         FN         NI         NI           2         363         364         365         366         367           3         364         365         366         367         367           NI         FP         FP         NI         NI         NI</td> <td>Legend       NI     =     NOT INSPECTED       PW     =     PRESSURE WASHED       P     =     Weld Preperation Complete       FP     =     Final Inscretion Passed</td> <td></td> <td>= = O</td> <td></td> <td>Ground/Cleaned 357 Inspection Passed 351 Inspection Failed 16 Instrument Tree 0</td> <td>Original Scope ete</td> <td>Ground/Cleaned 360% Inspection Passed 344% Inspection Failed 15% Instrument Tree 0%</td>	North         FP         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         FP         NI         FP         NI         NI         FP         NI         FI         NI         NI         FP         NI         NI         NI         NI         FP         NI         NI         NI         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         NI         FP         NI         FP         NI         NI         FP         NI	North         N         FP         FP         FP         FP         FP         FP         FP         FP         FP         FN         WR         II           SECTION #         B         114         115         116         117         118         119         120         121         123         124         125         126         127         1           CAN #         M         FP         FP<	North         FP         FP         NI         NI         FP         NI         NI         NI         FP         NI         NI         FP         NI	North         N         FP         NI         NI         NI         FP         NI         FI         NI         FP         F	North         FP         FP         NI         NI         NI         FP	NI         FP         FN         NI         NI           2         363         364         365         366         367           3         364         365         366         367         367           NI         FP         FP         NI         NI         NI	Legend       NI     =     NOT INSPECTED       PW     =     PRESSURE WASHED       P     =     Weld Preperation Complete       FP     =     Final Inscretion Passed		= = O		Ground/Cleaned 357 Inspection Passed 351 Inspection Failed 16 Instrument Tree 0	Original Scope ete	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



Kleinschmidtgroup.com

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# ACRONYMS

Α	
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
Ε	
ETS	Eastern Technical Services
F	
Fu	Ultimate Tensile Stress
FSL	Full Supply Level
К	
Kleinschmidt	Kleinschmidt Associates Canada Inc.
Μ	
MT	Magnetic Partical Testing
Ν	
NDT	Non-destructive testing
NLH	Newfoundland and Labrador Hydro
S	
STA	Station (in feet)
Т	
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<sup>3</sup>/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<sup>1</sup> 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.

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

 Table 3-1
 Definitions for the Condition Assessment

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

<sup>&</sup>lt;sup>1</sup> 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 premarked 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 28<sup>th</sup> 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, 2<sup>nd</sup> Edition. The allowable primary stress intensity is the lesser of the material yield stress (F<sub>y</sub>) divided by 1.5 or of the ultimate tensile stress (F<sub>u</sub>) 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.

Can	Joint Stress (FSL) <sup>1,3</sup> (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress (Surge at Joints) <sup>1,3</sup> (psi)	Allowable Stress (psi)	Max Joint Stress Ratio <sup>1,2,3</sup>	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

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

Can	Joint Stress (FSL) <sup>1,3</sup> (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase <sup>1,3</sup> (psi)	Total Water Hammer Stress (Surge at Joints) <sup>1,3</sup> (psi)	Allowable Stress (psi)	Max Joint Stress Ratio <sup>1,2,3</sup>	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: <sup>1</sup> Joint efficiency of 0.7 included

<sup>2</sup> Total stress / Allowable stress

<sup>3</sup> Uses minimum can thickness

<sup>4</sup> 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.

Penstock Diameter (ft)	Allowable External Pressure (psi) (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	

 Table 4-2
 Summary of Surcharge Load Analysis

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<sup>2</sup> (3.07 ft<sup>2</sup>), which is well below the area provided by the approximately 5.1 m<sup>2</sup> (55 ft<sup>2</sup>) 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.

# 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.

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#### **REPORT SIGNATURE PAGE**

#### **KLEINSCHMIDT ASSOCIATES CANADA INC.**

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





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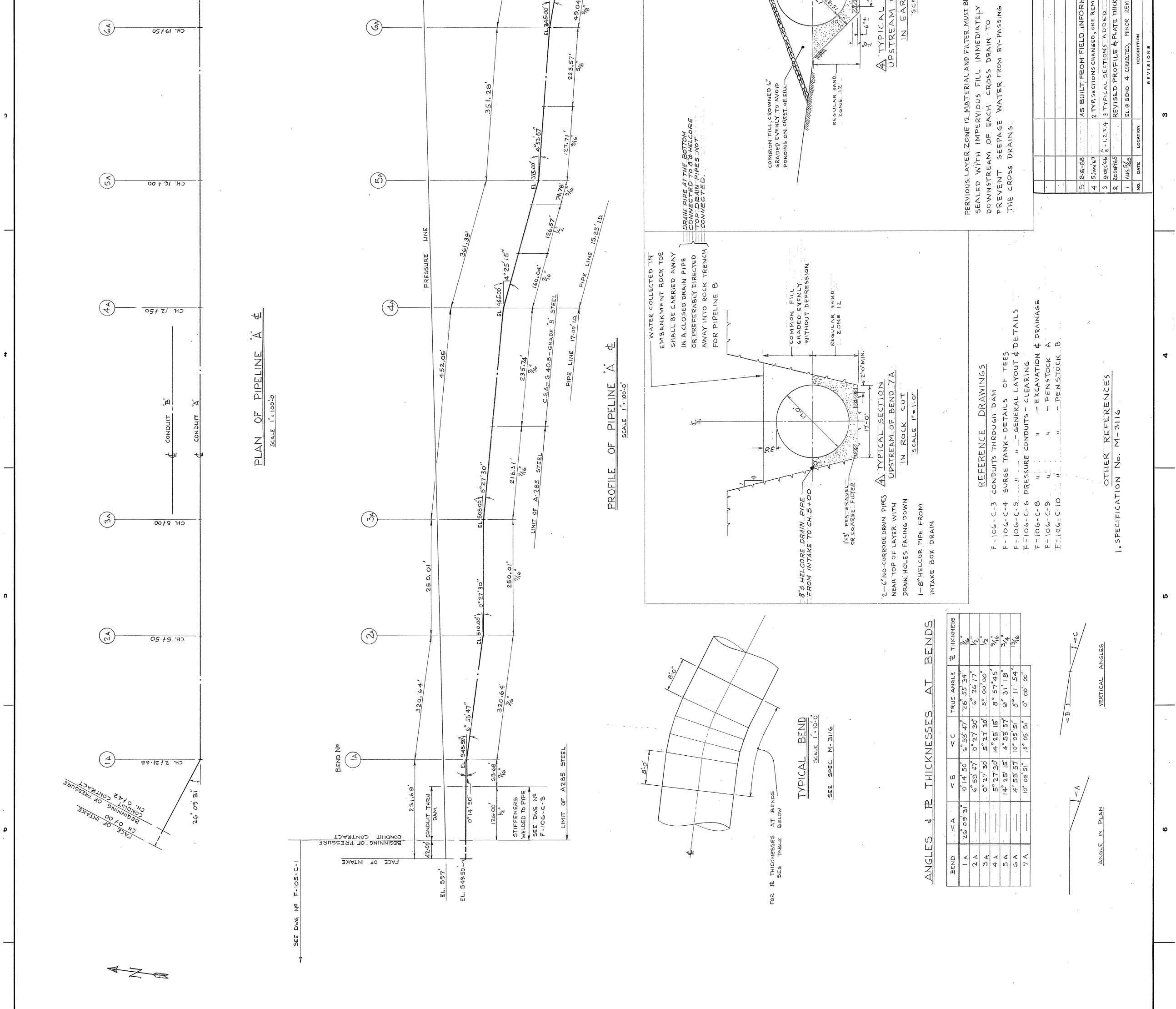
**APPENDIX A** 

**PENSTOCK LAYOUT DRAWINGS** 

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NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

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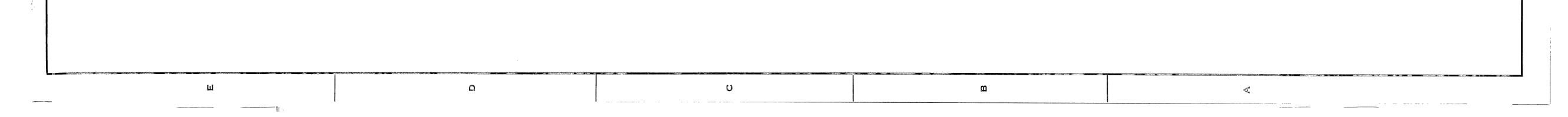


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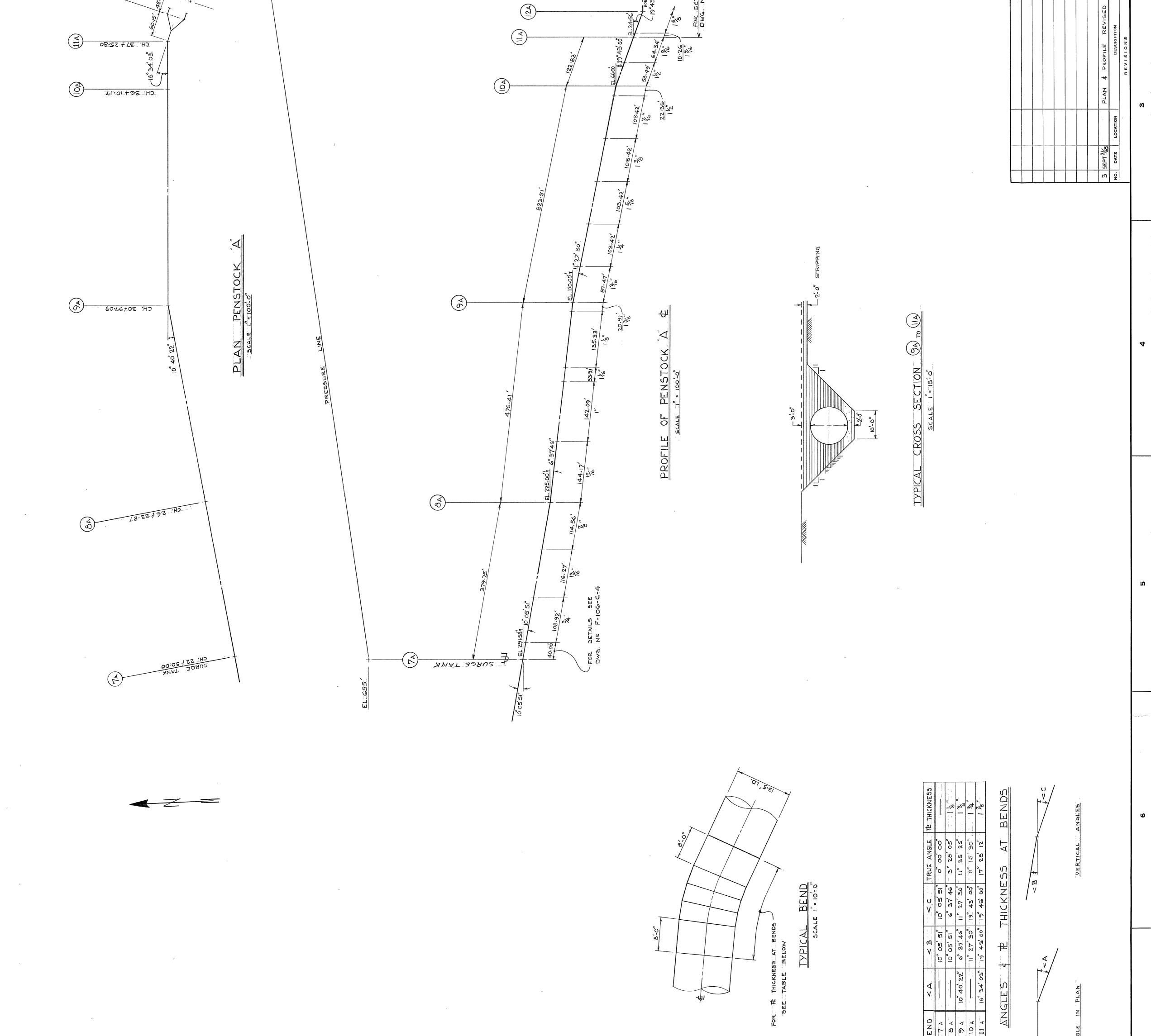
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	NOTES 1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 16° SHALL DE ADDED TO PLATE. THICKNESSES CALLINTED 10° RESIST HOOP TENSION AND THE FRFETS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 8° SHALL EXTEND OF RENDS. THE BENDS AND AT LEAST 0. FRET DIFFERAM AND DOWNSTREAM OF THE LAST MITRE JOINT. 2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'6' 3. STEEL SHALL DE C.S.A. 940-B GRADE 'B'. 3. STEEL SHALL DE C.S.A. 940-B GRADE 'B'. 3. FOR TVPICAL CROSS SECTION FROM (B) TO (B) SEE DWG. Nº F.106-C-T.		EL + 3.00 EL + 3.00 E. 106-C-2 F. 106-C-2 F. 106-C-2 REFERO DRAWINGS 1. F - 106-C-4 BIRGE TANKS - DETAILS OF BIFURCATION 2. F - 106-C-4 BIRGE TANKS - DETAILS OF BIFURCATION 2. F - 106-C-5 BIRGE TANKS - DETAILS OF BIFURCATION 4. F - 106-C-6 PRESSURE CONDUTS - CLEANING.	F - 106 - C - 7 R REFERENCE SPECIFICATION NE	A P P R O V E D     R.M.a. D.     NEWFOUNDLAND AND LABRADOR POWER COMMISSION       FOR CONSTRUCTION     A.M.a.     B.A.Y     D'ESPOIR     EVELOPIN       FOR CONSTRUCTION     J.P.     B.A.Y     D'ESPOIR     EVELOPIN       APPROVED BY:     A.P. M.     J.P.     SHAWMONT ENGINEERING AND DESIGN BY       APPROVED BY:     A.P. M.     B.A.Y     D'ESPOIR     EVELOPINDLAND LIMITED       APPROVED BY:     A.P. M.     B.A.P.     PROVED BY:     MONTREAL QUEERING NEWFOUNDLAND LIMITED       APPROVED BY:     A.P. M.     P.P. M.     PRESSURE CONDUITS     MONTREAL QUEERING NEWFOUNDLAND LIMITED       APPROVED BY:     A.P. M.     P.P. M.     PRESSURE CONDUITS     MONTREAL QUEERING NEWFOUNDLAND LIMITED       APPROVED BY:     A.P. M.     P.P. M.     PRESSURE CONDUITS     MONTREAL QUEERING NEWFOUNDLAND LIMITED       APPROVED BY:     A.P. M.     P.M. MONT ENGINEERING NEWFOUNDLAND LIMITED     MONTREAL QUEERING NEWFOUNDLAND LIMITED       APPROVED BY:     A.P. M.     P.P. M.     PLAN     PROFILE     PLAN       APPROVED BY:     A.P. M.     PLAN     PLAN     PLAN     PLAN       APPROVED BY:     A.P. M.     PLAN     PLAN     PLAN     PLAN
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NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment

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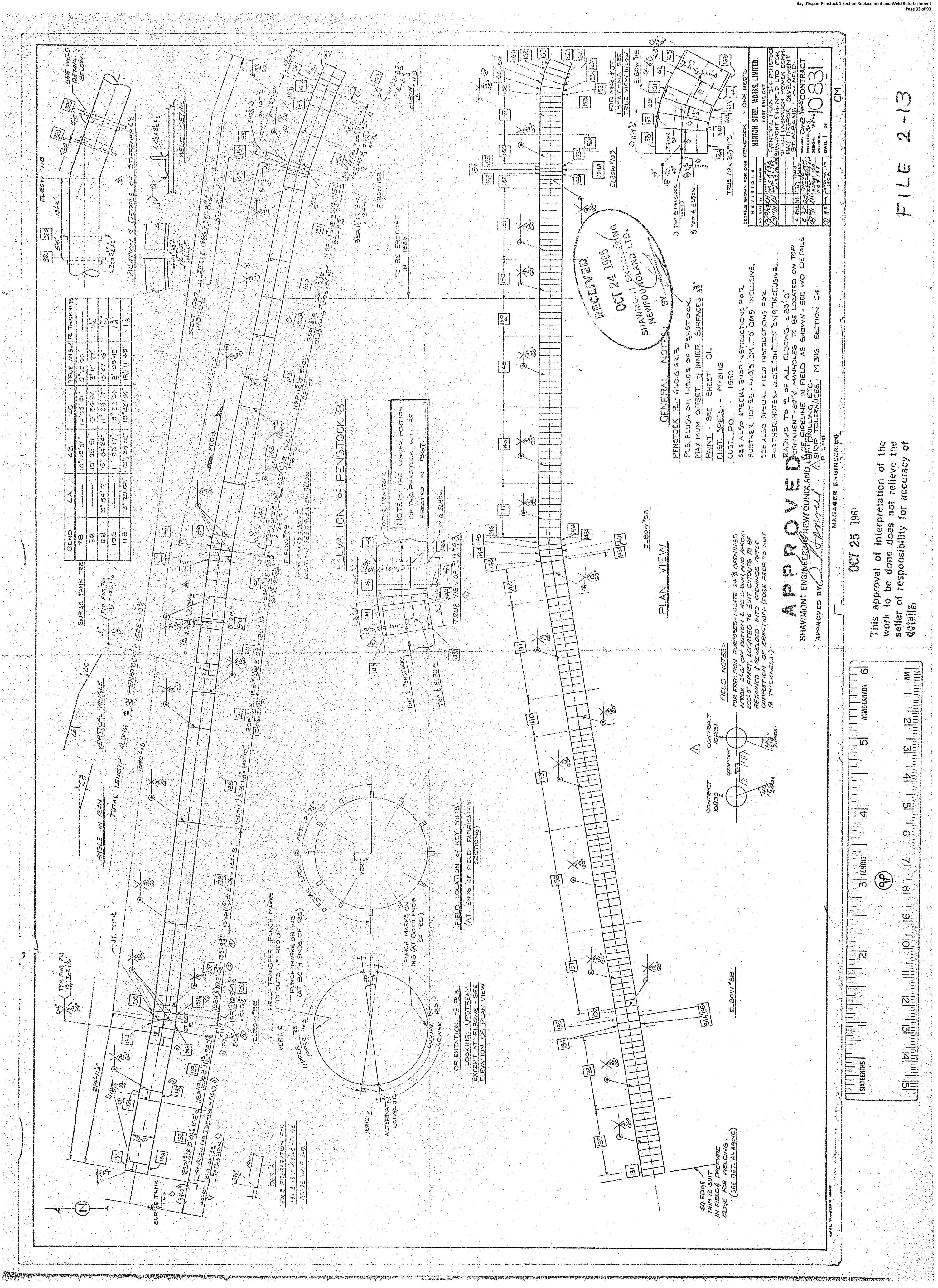
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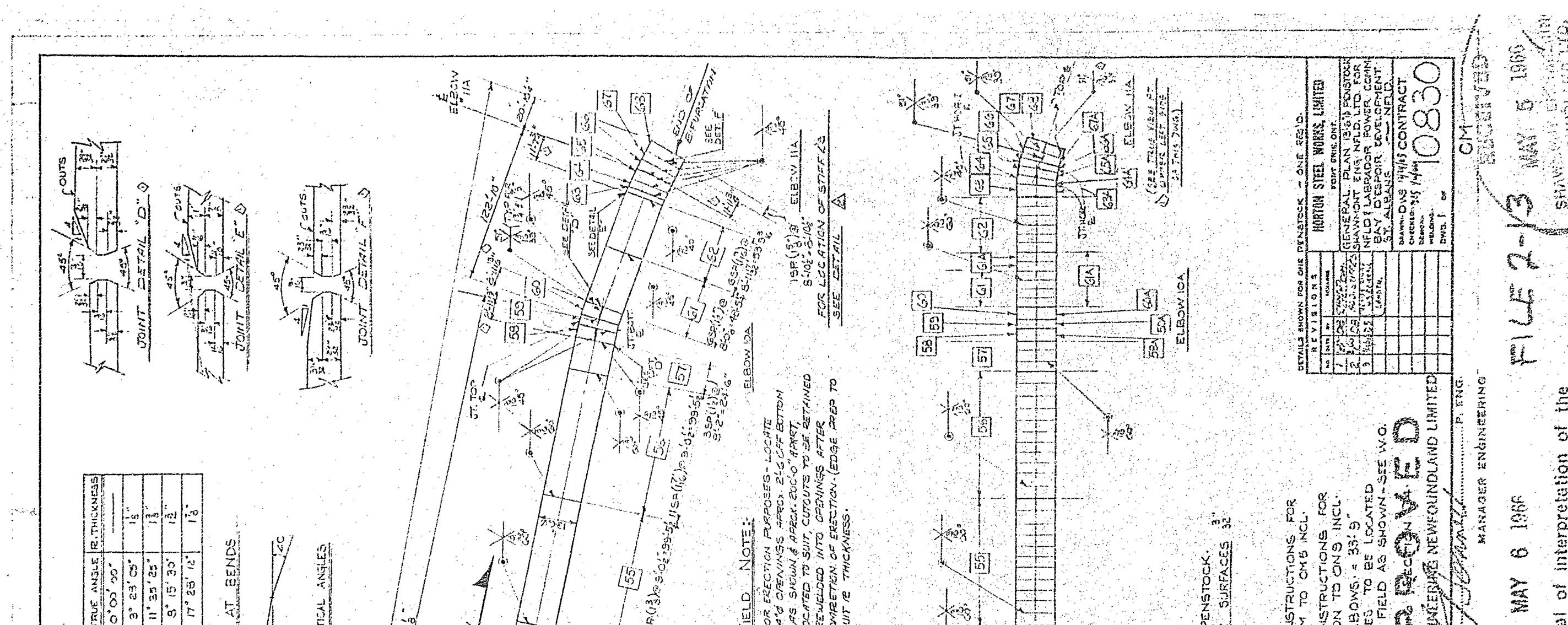
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NP-NLH-011, Attachment 4



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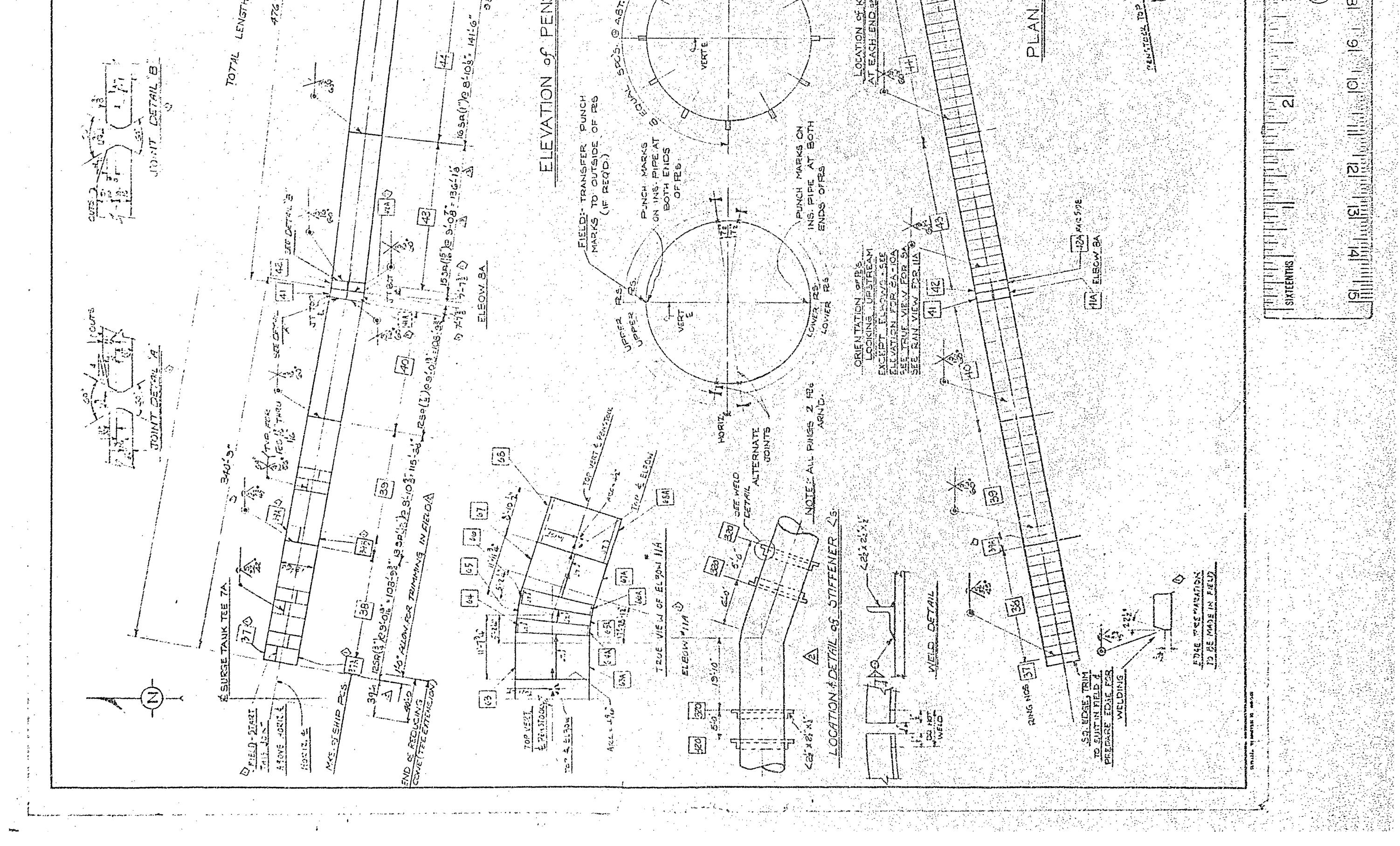
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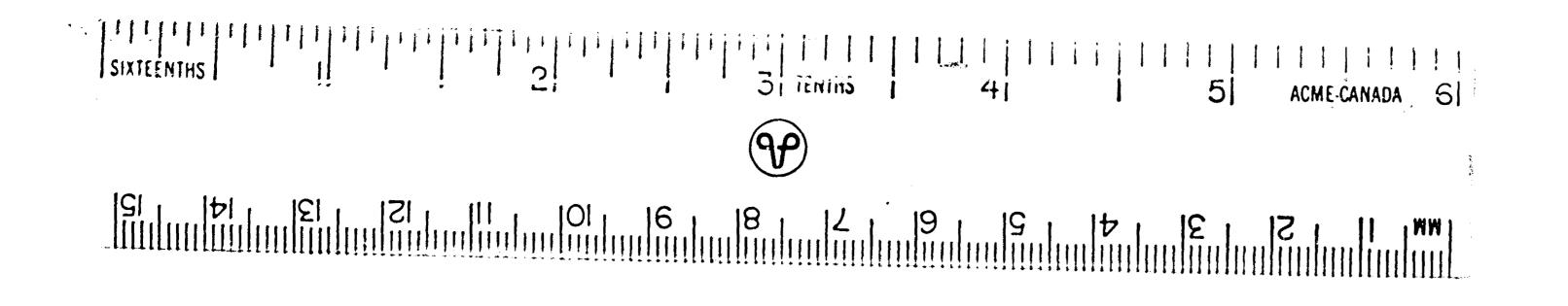
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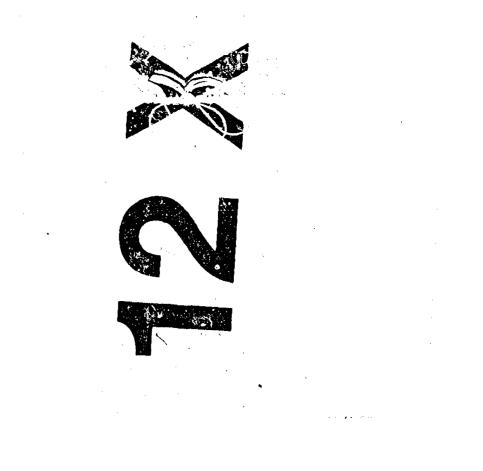
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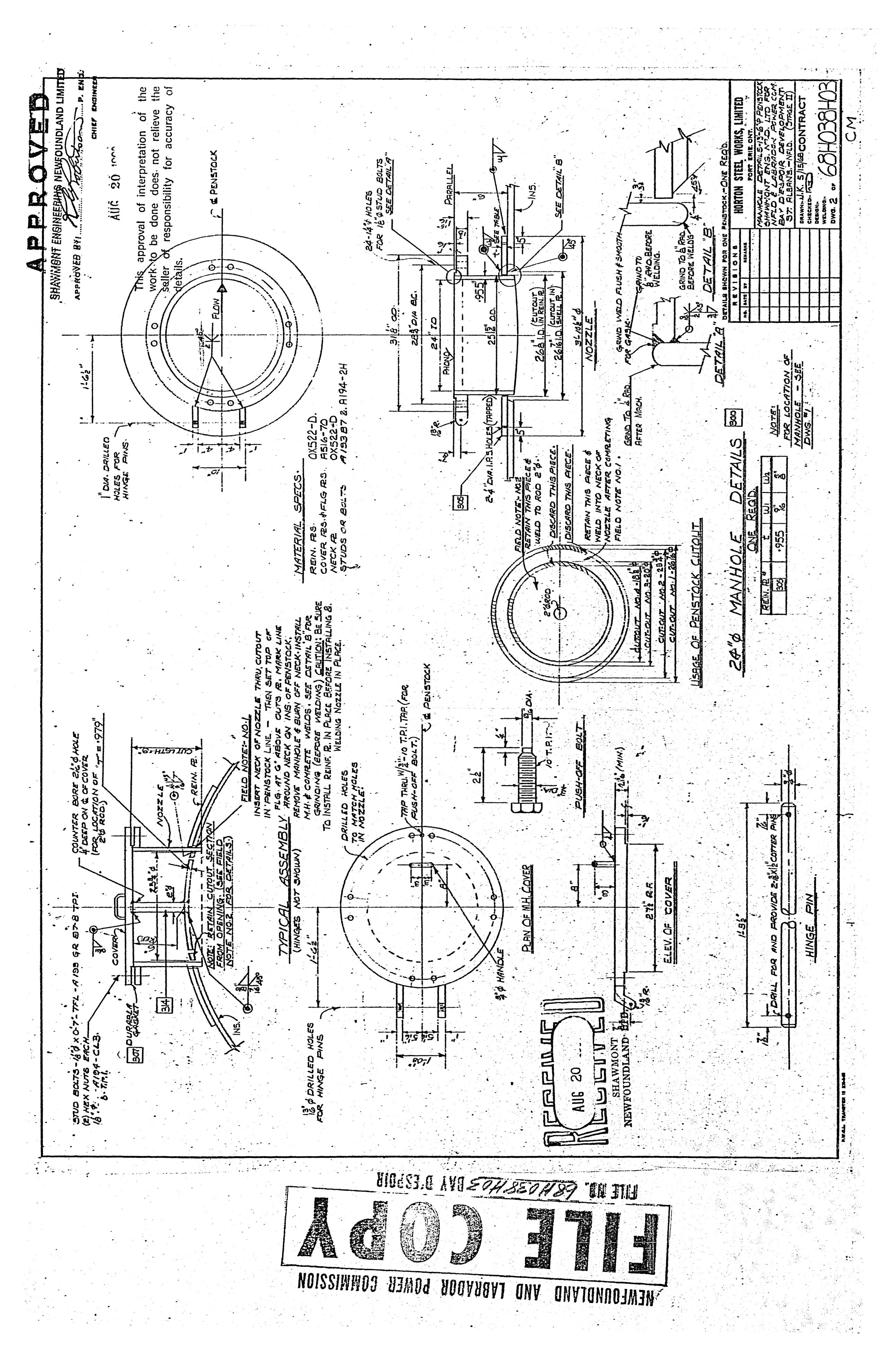
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**APPENDIX B** 

**PHOTOGRAPHS** 



Photo 1 Leakage from Right Top Corner of gate



Photo 2 Concrete to Steel Transition

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Photo 3 Typical Organic Coating



Photo 4 Organic Layer with Steel Beneath

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Photo 5 Steel Without organic layer and not scraped clean; Can 350



Photo 6 Plating lightly scraped; Shallow pitting and some section loss

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Photo 7 Previously repaired weld not tested this year

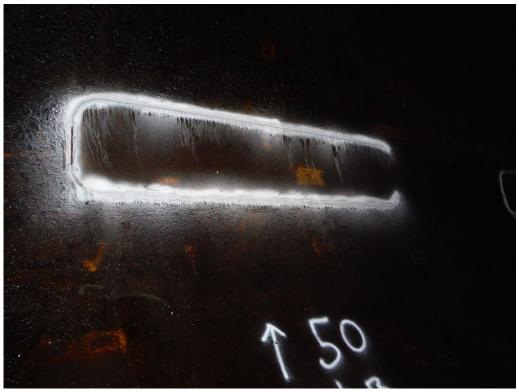


Photo 8 Plate repair welds tested. Can 50



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

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Photo 13 Longitudinal Weld Crack Can 145 North Side



Photo 14 Weld repaired and marked Can 145

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Photo 15 Weld repaired; Can 145



Photo 16 Looking Upstream along exterior of Penstock, Upstream of Surge Tank



Photo 17 Flow Pipe, FP 3





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Photo 19 Previously repaired area; Rip-rap in good shape



Photo 16 Looking Upstream from just downstream of surge tanks

APPENDIX C

WELD TEST

#### NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 48 of 93

Visual Inspectio Radiography & Mag & Penetrar Eddy Current Te Structural Steel	ns Ultrasonics It Inspections seting & Torque Ultrasonics PO Box 709-726-	13517, St. Johr	I Services Ltd.       Technical Reports         n's, NL., A1B 4B8       Gas Free Testing         St. Fax 726-4626       Insurance Reports
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 wypang

NDT Inspector

## **Remarks**

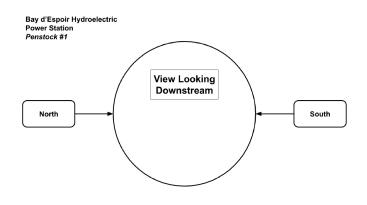
As directed, our technician performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements 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.

## <u>Results</u>

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.



Can Number	Details	Result	Image #
3	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
8	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
14	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
19	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
24	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
27	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
32	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	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

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	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>Top of doubler</li> <li>Bottom of doubler</li> </ul>	MT Acceptable	N/A
67	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
71	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
76	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
81	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

Can Number	Details	Result	Image #
87	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
93	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
98	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	Indication Noted	Figure 1
103	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	Indication Noted	Figure 2
107	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
112	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
118	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
119	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

Can Number	Details	Result	Image #
123	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
127	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
132	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
133	<ul> <li>Longitudinal right (south) weld. Ok</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
137	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
138	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
139	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
140	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

Can Number	Details	Result	Image #
145	<ul> <li>Longitudinal right (south) weld. 1 Crack noted.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	Crack Noted Refer to report 22- 318 for details	Figure 3
146 Doubler Plate	- Longitudinal left (north) doubler- <mark>1 indication noted.</mark> - Top of doubler - Bottom of doubler	Indication Noted Refer to report 22- 318 for details	Figure 4
149	<ul> <li>Longitudinal left (north)</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
150 Doubler Plate	- Longitudinal left (north) weld - Top of doubler - Bottom of doubler	MT Acceptable	N/A
151	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
160 Doubler Plate North Only	- Longitudinal left (north) doubler - bottom only - bottom only	MT Acceptable	N/A
164	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

Can Number	Details	Result	Image #
169	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
172	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
177	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
178	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
188	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
198	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
208	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

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Can Number	Details	Result	Image #
218	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
229	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
237	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld not accessible</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
248	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
249	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
258	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
268	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
278	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A

Can Number	Number Details		Image #
287	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
298	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
308	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.</li> </ul>	MT Acceptable	N/A
318	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A
328	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>		N/A
338	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>		N/A
348	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A
360	<ul> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>		N/A

Can Number	Imber Details		Image #	
367	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
377	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
387	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
397	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
407	<ul> <li>Longitudinal right (south) weld.</li> <li>Longitudinal left (north) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
417	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
425	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
432	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	
434	<ul> <li>Longitudinal right (south) weld.</li> <li>12" Section of upstream circumferential weld adjacent to left and right longitudinal welds.</li> <li>12" Section of downstream circumferential weld adjacent to left and right</li> </ul>	MT Acceptable	N/A	



Figure 1. Can 98 North

Figure 2. Can 98 North - Indication Noted



Figure 3. Can 103 North

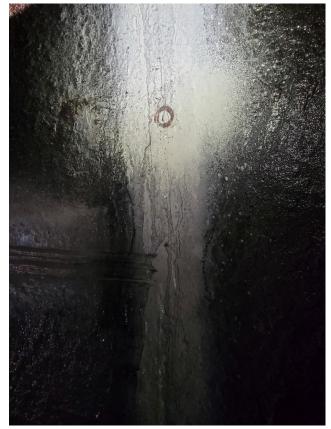


Figure 4. Can 103 North - Indication Noted



Figure 5. Can 145N

**Figure 6.** Can 145N - 3" Crack Indication Noted \*Refer To Report 22-318 For Repair

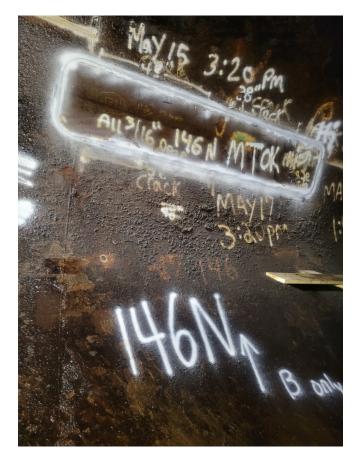




Figure 7. Can 146N

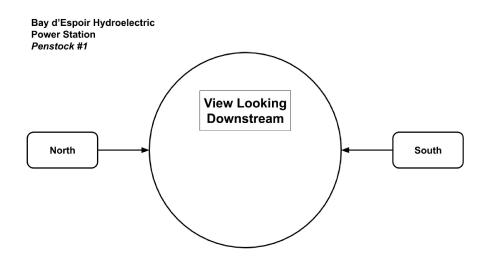
**Figure 8.** Can 145N - Indication Noted \*Refer To Report 22-318 For Repair

#### NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 62 of 93

Visual Inspect Radiography & Mag & Penetra Eddy Current Structural Stee	A Ultrasonics Edstern ant Inspections PO Box	13517, St. Joh	al Services Ltd.Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance Reportsnr/s, NL., A1B 4B8 n St. Fax 726-4626Destructive Testing Insurance Reportsort
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:	Const Mypry 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



#### <u>Results</u>

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.

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.		1,2,3,4
146 North	146 North One Indication - Toe of weld Removed With Grinding No Welding Needed		5,6,7

# Equipment Used

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



Figure 2. 145N Crack Removed With Girding.





**Figure 3.** 145N Weld Repaired - Checked at 11:15 AM April 28<sup>th</sup> 2022 (Post Welding)

**Figure 4.** 145N Weld Repairs - Post 48 Hour Hold - Checked at 11:15 AM April 30<sup>th</sup> 2022

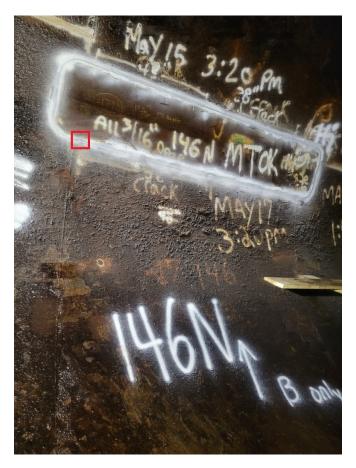




Figure 5. Can 146N - Indication Location

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

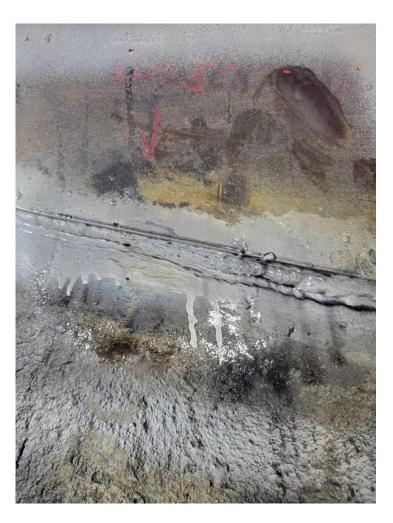


Figure 7. Can 146N - Indication Removed With Grinding - No Welding Needed

**APPENDIX D** 

**THICKNESS MEASUREMENTS DATA** 

#### NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 68 of 93

Visual Inspecti Radiography & Mag & Penetra Eddy Current ∃ Structural Stee	Lutrasonics     Lastern       ant Inspections     PO Box       resting     709-726-	13517, St. Joh	<b>al Services Ltd.</b> n's, NL., A1B 4B8 n St. Fax 726-4626	Technical Reports Engineering Studies Gas Free Testing Destructive Testing Insurance Reports
		Repo	ort	
ETS No.:	22-304-2	Сору:		
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 M CAN/CGSB 48.9712 MT/PT	
Attn:	Colin Legrow			
P.O. No.	2022-0146-1			
Project:	Penstock Inspection - Penstock #1			
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Consi uppy	

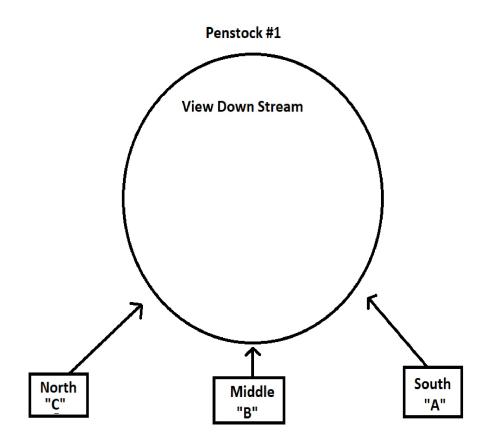
#### <u>Remarks</u>

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

<u>Can</u> 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

<u>Can</u> 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** 

#### NP-NLH-011, Attachment 4 Bay d'Espoir Penstock 1 Section Replacement and Weld Refurbishment Page 73 of 93

TABLE 1 - FULL SUPPLY LEVEL (FSL)

							PENSTOCI		ULL SUPPLY		.) D STRESSES						
Ur	it weight of water=	62.4												Project No:	2670030		
	Normal pond EL= Joint Efficiency=		feet											Date: By:	5/17/2022 NPT		
	D <sub>1</sub> ID= D <sub>2</sub> ID=			4a										Checked	CMV		
	D <sub>3</sub> ID=	13.50	feet	4a 7a + (Surge Tank of the face of the Ir													
	10	te. starting poi	115 4211 5/5 6														
Can #	Distance From Fwd Edge of Can	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
	1 (Ft)		number	incouning (initi)	incouning (ini)	mickness (m)	Materia	()	(,		Siless (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup> (0.7)	Stress Ratio <sup>5</sup> (1.0)	
Penstock Inte From Upstrea	rior m End of Conduit																
3	18	8.50	A B C	12.3000 12.5000 12.4000	0.4843 0.4921 0.4882	0.5000 0.5000 0.5000	-3.1% -1.6% -2.4%	12.3000	0.4843	549.2402	17000 17000 17000	4359.3	0.26	6227.5	0.37	0.26	A285 Steel (grade unknown)
14	118	8.50	AB	13.1000	0.5157	0.5000	-2.4% 3.1% 3.1%	13.1000	0.5157	548.8092	17000	4130.0	0.24	5900.0	0.35	0.24	
- 14	115	8.50	C A	13.1000	0.5157	0.5000	3.1%	13.1000	0.5157	540.0032	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						
32	252	8.50	A B	10.9000 10.3000	0.4291 0.4055	0.4375	-1.9% -7.3%	10.3000	0.4055	541.0050	17000 17000	6103.4	0.36	8719.1	0.51	0.36	
			C A	10.5000 10.5000	0.4134	0.4375	-5.5% -5.5%				17000 17000	7213.8	0.42	10305.5	0.61	0.42	
42	342	8.50	c	10.5000 10.4000	0.4134 0.4094	0.4375 0.4375	-5.5% -6.4%	10.4000	0.4094	530.1743	17000 17000						
50	413	8.50	AB	10.6000 10.7000	0.4173 0.4213	0.4375	-4.6% -3.7%	10.5000	0.4134	521.6730	17000 17000	8054.1	0.47	11505.9	0.68	0.47	
		0.55	A	10.5000	0.4134	0.4375	-5.5%	40			17000	9232.8	0.54	13189.7	0.78	0.54	
64	532	8.50	B	10.6000	0.4173	0.4375	-4.6% -2.8%	10.6000	0.4173	509.8266	17000 17000	0555 -	0.5-	10000-0		A.F	
71	595	8.50	A B C	10.3000 10.9000 10.7000	0.4055 0.4291 0.4213	0.4375 0.4375 0.4375	-7.3% -1.9% -3.7%	10.3000	0.4055	509.3218	17000 17000 17000	9556.8	0.56	13652.5	0.80	0.56	
81	685	8.50	AB	10.5000	0.4213	0.4375 0.4375 0.4375	-5.5% -0.1%	10.4000	0.4094	508.6027	17000 17000 17000	9542.5	0.56	13632.1	0.80	0.56	
			C	10.4000	0.4094	0.4375	-6.4%				17000	9731.2	0.57	13901.8	0.82	0.57	
93	791	8.50	B C	10.7000 10.6000	0.4213 0.4173	0.4375 0.4375	-3.7% -4.6%	10.6000	0.4173	505.1207	17000 17000						
103	880	8.50	A B	10.6000 10.7000	0.4173 0.4213	0.4375 0.4375	-4.6% -3.7%	10.3000	0.4055	496.6168	17000 17000	10941.6	0.64	15630.8	0.92	0.64	
			C A	10.3000	0.4055	0.4375 0.4375	-7.3% -5.5%				17000 17000	11668.1	0.69	16668.7	0.98	0.69	
112	961	8.50	B C	10.5000 10.4000	0.4134 0.4094	0.4375 0.4375	-5.5% -6.4%	10.4000	0.4094	488.9119	17000 17000						
123	1060	8.50	A B C	10.3000 10.5000 10.4000	0.4055 0.4134 0.4094	0.4375 0.4375 0.4375	-7.3% -5.5% -6.4%	10.3000	0.4055	479.5424	17000 17000 17000	12802.7	0.75	18289.5	1.08	0.75	
132	1139	8.50	AB	10.7000	0.4094 0.4213 0.4488	0.4375	-3.7%	10.4000	0.4094	471.9802	24000	13495.9	0.56	19279.8	0.80	0.56	CSA G40.8 Grade B Steel
			C A	10.4000	0.4094	0.4375	-6.4% 24.2%				24000	10832.3	0.45	15474.7	0.64	0.45	
142	1217	8.50	B C	14.6000 13.8000	0.5748	0.4375 0.4375	31.4% 24.2%	13.8000	0.5433	463.8494	24000 24000						
150	1272	7.63	A B	11.1000 11.2000	0.4370 0.4409	0.4375 0.4375	-0.1% 0.8%	10.8000	0.4252	450.1521	24000 24000	13693.7	0.57	19562.4	0.82	0.57	15.25' I.D. Penstock
			C A	10.8000 10.4000	0.4252	0.4375	-2.8% -6.4%				24000 24000	16354.7	0.68	23363.9	0.97	0.68	
160	1361	7.63	B	10.6000 10.4000	0.4173	0.4375	-4.6% -6.4%	10.4000	0.4094	428.1119	24000 24000	16299.6	0.68	23285.2	0.97	0.68	
169	1443	7.63	A B C	11.7000 12.5000 12.2000	0.4606 0.4921 0.4803	0.5000 0.5000 0.5000	-7.9% -1.6% -3.9%	11.7000	0.4606	407.6406	24000 24000 24000	16299.6	0.68	23285.2	0.97	0.68	
178	1526	7.63	A	12.1000	0.4863	0.5625	-15.3%	12,1000	0.4764	387 0200	24000	17477.1	0.73	24967.3	1.04	0.73	
			C A	13.2000	0.5197	0.5625	-7.6%	000			24000 24000 24000	17128.9	0.71	24469.9	1.02	0.71	
188	1603	7.63	B C	13.6000 13.2000	0.5354 0.5197	0.5625 0.5625	-4.8% -7.6%	13.2000	0.5197	372.4943	24000 24000						
198	1693	7.63	A B	14.3000 14.5000	0.5630 0.5709	0.5625 0.5625	0.1% 1.5%	13.6000	0.5354	364.8516	24000 24000	17191.1	0.72	24558.7	1.02	0.72	
			C A	13.6000 14.6000	0.5354	0.5625	-4.8%				24000	16546.2	0.69	23637.4	0.98	0.69	
208	1783	7.63	B C	15.8000 15.3000 15.6000	0.6220 0.6024 0.6142	0.6250 0.6250 0.6250	-0.5% -3.6% -1.7%	14.6000	0.5748	357.1312	24000 24000 24000	16194.9	0.67	23135.5	0.96	0.67	
218	1874	7.63	A B C	15.6000 15.6000 15.4000	0.6142 0.6142 0.6063	0.6250 0.6250 0.6250	-1.7% -1.7% -3.0%	15.4000	0.6063	349.3596	24000 24000 24000	10134.9	0.07	20100.0	0.96	0.07	
229	1964	7.63	A B	16.1000 16.3000	0.6339 0.6417	0.6250	1.4%	16.1000	0.6339	338.1711	24000 24000 24000	16190.6	0.67	23129.5	0.96	0.67	
			C A	16.9000 16.9000	0.6654	0.6250	6.5% -3.2%				24000 24000	16197.4	0.67	23139.1	0.96	0.67	
237	2038	7.63	B C	17.6000 16.9000	0.6929 0.6654	0.6875 0.6875	0.8% -3.2%	16.9000	0.6654	325.1972	24000 24000						
248	2136	7.63	AB	19.2000 18.9000	0.7559	0.7500	0.8%	17.9000	0.7047	308.0155	24000 24000	16259.2	0.68	23227.4	0.97	0.68	
250	2225	3.67	C A	17.9000 21.4000	0.7047	0.7500	-6.0%	21 10	0.0477	202.0515	24000 24000	14350.8	0.60	20501.1	0.85	0.60	
258	2227	7.63	B C	22.1000 21.9000 19.0000	0.8701 0.8622 0.7480	0.7500 0.7500 0.7500	16.0% 15.0% -0.3%	21.4000	0.8425	292.0610	24000 24000 24000	16840.8	0.70	24058.2	1.00	0.70	
268	2300	7.63	A B C	19.0000 19.9000 19.9000	0.7480 0.7835 0.7835	0.7500 0.7500 0.7500	-0.3% 4.5% 4.5%	19.0000	0.7480	279.2845	24000 24000 24000	10040.8	0.70	24008.2	1.00	0.70	
278	2390	7.63	A B	17.8000	0.7008	0.8125	-13.7%	17.8000	0.7008	263.4703	24000 24000 24000	18870.8	0.79	26958.4	1.12	0.79	
			C A	18.3000 18.4000	0.7205	0.8125 0.8125	-11.3% -10.8%				24000 24000	19031.8	0.79	27188.3	1.13	0.79	
287	2471	7.63	B C	18.5000 18.6000	0.7283 0.7323	0.8125 0.8125	-10.4% -9.9%	18.4000	0.7244	249.2866	24000 24000						
298	2571	7.63	A B	18.2000 18.4000	0.7165 0.7244	0.8750 0.8750	-18.1% -17.2%	18.2000	0.7165	231.7543	24000 24000	20211.1	0.84	28873.0	1.20	0.84	
L			С	18.8000	0.7402	0.8750	-15.4%				24000						

	Distance From	B . F . (f)	Reading	Thickness	Thickness	Design Plate	%Change in	Min Thickness	Min Thickness	o	Allowable Steel	Base Material			At Joints		
Can #	Fwd Edge of Can 1 (Ft)	Radius (ft)	Number	Reading (mm)	Reading (in)	Thickness (in)	Material	(mm)	(in)	C.L. EL. (ft)	Stress (psi)	Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	Stress Ratio <sup>4</sup> (0.7)	Stress Ratio <sup>5</sup> (1.0)	Notes
			А	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 24000						
			A	18.6000	0.7559	0.9375	-21.9% -19.4%				24000	20369.5	0.85	29099.3	1.21	0.85	
318	2751	7.63	в	19.8000	0.7795	0.9375	-16.9%	19.2000	0.7559	208.6665	24000	20303.5	0.85	25055.5	1.21	0.85	
			с	19.3000	0.7598	0.9375	-19.0%				24000						
			Α	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	В	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						
220	2928	6.75	A	22.9000	0.9016	1.0625	-15.1%	22.8000	0.8976	188.1976	24000	15985.2	0.67	22836.1	0.95	0.67	
338	2928	0.75	B C	23.0000 22.8000	0.9055	1.0625	-14.8% -15.5%	22.8000	0.8976	188.1976	24000 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	в	22.8000	0.8976	1.1250	-20.2%	22.0000	0.8661	178.1883	24000						
			с	22.9000	0.9016	1.1250	-19.9%				24000						
			А	25.0000	0.9843	1.1875	-17.1%				24000	15362.6	0.64	21946.6	0.91	0.64	
360	3105	6.75	В	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		0.02	24242.5	0.00	0.02	
367	3169	6.75	AB	26.5000 26.5000	1.0433	1.1875	-12.1% -12.1%	26.5000	1.0433	153.5374	24000 24000	14919.4	0.62	21313.5	0.89	0.62	
307	5105	0.75	c	26.8000	1.0455	1.1875	-12.1%	20.5000	1.0455	133.3374	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	в	28.9000	1.1378	1.2500	-9.0%	28.4000	1.1181	135.6187	24000						
			С	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						
			A	30.2000	1.1890	1.3125	-9.4% -13.5%				24000 24000	14687.9	0.61	20982.7	0.87	0.61	
397	3441	6.75	в	30.2000	1.2165	1.3750	-13.5%	30.2000	1.1890	99.4635	24000	14087.5	0.01	20382.7	0.87	0.01	
			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	в	32.3000	1.2717	1.4375	-11.5%	32.2000	1.2677	81.3859	24000						
			С	32.2000	1.2677	1.4375	-11.8%				24000						
417	2620	6.75	A	34.2000	1.3465	1.5000	-10.2%	22 7000	1.2874	62.4374	24000	14574.4	0.61	20820.6	0.87	0.61	
417	3620	0.75	B	32.7000 36.7000	1.2874	1.5000	-14.2% -3.7%	32.7000	1.20/4	02.4374	24000 24000						
			A	36.4000	1.4449	1.5250	-5.7%				24000	13638.3	0.57	19483.3	0.81	0.57	
425	3686	6.75	в	37.0000	1.4567	1.5625	-6.8%	36.4000	1.4331	40.1710	24000						
-			С	37.6000	1.4803	1.5625	-5.3%				24000						
			Α	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	В	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:

<sup>1</sup> Hoop stress =  $Pr/t_{97.5}$ <sup>2</sup> Hoop stress / S<sub>A</sub> <sup>3</sup> Hoop stress / O.7 joint efficiency <sup>4</sup> Joint stress / S<sub>A</sub> <sup>5</sup> Hoop stress / 1.0 joint efficiency

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TABLE 2 - TRANSIENT (30% Surge)

							Р				(30% Surge) RMENTS AND	STRESSES					
Unit w	eight of water=	62.4	pcf											Project No:	2670030		
N	ormal pond EL= pint Efficiency=	597 0.7												Date: By:	5/17/2022 NPT		
	D <sub>1</sub> ID=	1.0 17.00	feet											Checked	CMV		
	D <sub>2</sub> ID= D <sub>3</sub> ID=	15.25 13.50	feet	9a +													
		e: Starting point	t is 42ft D/S of t	he face of the Ir	ntake						r			r			<b></b>
Can #	Distance From Fwd Edge of Can 1	Radius (ft)	Reading Number	Thickness Reading	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base I	Material		At Joints Stress Ratio <sup>4</sup>	Stress Ratio <sup>5</sup>	Notes
Penstock Inter	(Ft)			(mm)				(mm)				Stress (psi) <sup>1</sup>	Stress Ratio <sup>2</sup>	Stress (psi) <sup>3</sup>	(0.7)	(1.0)	
From Upstream	m End of Condu		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 C	12.5000 12.4000	0.4921 0.4882	0.5000	-1.6% -2.4%	12.3000	0.4843	549.2402	17000 17000						
14	118	8.50	A B C	13.1000 13.1000 13.1000	0.5157 0.5157 0.5157	0.5000 0.5000 0.5000	3.1% 3.1% 3.1%	13.1000	0.5157	548.8092	17000 17000 17000	5369.0	0.32	7670.0	0.45	0.32	
24	193	8.50	AB	11.2000 11.0000	0.4409 0.4331	0.4375	0.8%	11.0000	0.4331	548.1614	17000 17000	6479.9	0.38	9257.0	0.54	0.38	
			C A	11.0000 10.9000	0.4331 0.4291	0.4375	-1.0% -1.9%				17000 17000	7934.4	0.47	11334.8	0.67	0.47	
32	252	8.50	B C	10.3000 10.5000	0.4055 0.4134	0.4375 0.4375	-7.3% -5.5%	10.3000	0.4055	541.0050	17000 17000						
42	342	8.50	A B C	10.5000	0.4134 0.4134 0.4094	0.4375 0.4375 0.4375	-5.5% -5.5% -6.4%	10.4000	0.4094	530.1743	17000 17000 17000	9378.0	0.55	13397.1	0.79	0.55	
50	413	8.50	AB	10.4000 10.6000 10.7000	0.4094 0.4173 0.4213	0.4375	-6.4% -4.6% -3.7%	10.5000	0.4134	521.6730	17000 17000 17000	10470.3	0.62	14957.6	0.88	0.62	
			C A	10.7000	0.4213 0.4134 0.4252	0.4375	-5.5% -2.8%				17000 17000	12002.7	0.71	17146.7	1.01	0.71	
64	532	8.50	B C	10.6000 10.8000	0.4173 0.4252	0.4375 0.4375	-4.6% -2.8%	10.6000	0.4173	509.8266	17000 17000						
71	595	8.50	A B C	10.3000	0.4055	0.4375	-7.3% -1.9%	10.3000	0.4055	509.3218	17000 17000	12423.8	0.73	17748.3	1.04	0.73	
81	685	8.50	AB	10.7000 10.5000 11.1000	0.4213 0.4134 0.4370	0.4375 0.4375 0.4375	-3.7% -5.5% -0.1%	10.4000	0.4094	508.6027	17000 17000 17000	12405.2	0.73	17721.8	1.04	0.73	
			C A	10.4000	0.4094	0.4375	-6.4% -1.0%				17000 17000	12650.6	0.74	18072.3	1.06	0.74	
93	791	8.50	B C	10.7000 10.6000	0.4213 0.4173	0.4375 0.4375	-3.7% -4.6%	10.6000	0.4173	505.1207	17000 17000						
103	880	8.50	A B C	10.6000 10.7000 10.3000	0.4173 0.4213 0.4055	0.4375 0.4375 0.4375	-4.6% -3.7% -7.3%	10.3000	0.4055	496.6168	17000 17000 17000	14224.1	0.84	20320.1	1.20	0.84	
112	961	8.50	AB	10.5000	0.4134	0.4375	-5.5%	10.4000	0.4094	488.9119	17000	15168.5	0.89	21669.3	1.27	0.89	
			C A	10.4000 10.3000	0.4094	0.4375	-6.4% -7.3%				17000 17000	16643.4	0.98	23776.4	1.40	0.98	
123	1060	8.50	B C	10.5000 10.4000	0.4134 0.4094	0.4375	-5.5% -6.4%	10.3000	0.4055	479.5424	17000 17000						
132	1139	8.50	A B C	10.7000 11.4000 10.4000	0.4213 0.4488 0.4094	0.4375 0.4375 0.4375	-3.7% 2.6% -6.4%	10.4000	0.4094	471.9802	24000 24000 24000	17544.7	0.73	25063.8	1.04	0.73	CSA G40.8 Grade B Steel
142	1217	8.50	AB	13.8000	0.5433 0.5748	0.4375	24.2%	13.8000	0.5433	463.8494	24000 24000	14082.0	0.59	20117.1	0.84	0.59	
			C A	13.8000 11.1000	0.5433 0.4370	0.4375 0.4375	24.2% -0.1%				24000 24000	17801.8	0.74	25431.2	1.06	0.74	15.25' I.D. Penstock
150	1272	7.63	B C	11.2000	0.4409	0.4375	0.8%	10.8000	0.4252	450.1521	24000 24000						
160	1361	7.63	B	10.4000 10.6000 10.4000	0.4094 0.4173 0.4094	0.4375 0.4375 0.4375	-6.4% -4.6% -6.4%	10.4000	0.4094	428.1119	24000 24000 24000	21261.1	0.89	30373.0	1.27	0.89	
169	1443	7.63	AB	11.7000 12.5000	0.4606	0.5000	-7.9% -1.6%	11.7000	0.4606	407.6406	24000 24000	21189.5	0.88	30270.7	1.26	0.88	
			C A	12.2000 12.1000	0.4803 0.4764	0.5000	-3.9% -15.3%				24000 24000	22720.2	0.95	32457.5	1.35	0.95	
178	1526	7.63	B C	13.8000 13.2000	0.5433	0.5625	-3.4% -7.6%	12.1000	0.4764	387.0200	24000 24000						
188	1603	7.63	A B C	13.5000 13.6000 13.2000	0.5315 0.5354 0.5197	0.5625 0.5625 0.5625	-5.5% -4.8% -7.6%	13.2000	0.5197	372.4943	24000 24000 24000	22267.6	0.93	31810.9	1.33	0.93	
198	1693	7.63	AB	14.3000 14.5000	0.5630 0.5709	0.5625	0.1%	13.6000	0.5354	364.8516	24000 24000 24000	22348.4	0.93	31926.3	1.33	0.93	
			C A	13.6000 14.6000	0.5354 0.5748	0.5625 0.6250	-4.8% -8.0%				24000 24000	21510.0	0.90	30728.6	1.28	0.90	
208	1783	7.63	B C	15.8000 15.3000 15.6000	0.6220	0.6250 0.6250 0.6250	-0.5% -3.6%	14.6000	0.5748	357.1312	24000 24000 24000						
218	1874	7.63	A B C	15.6000 15.6000 15.4000	0.6142 0.6142 0.6063	0.6250 0.6250 0.6250	-1.7% -1.7% -3.0%	15.4000	0.6063	349.3596	24000 24000 24000	21053.3	0.88	30076.2	1.25	0.88	
229	1964	7.63	AB	16.1000 16.3000	0.6339 0.6417	0.6250 0.6250	1.4% 2.7%	16.1000	0.6339	338.1711	24000 24000	21047.8	0.88	30068.3	1.25	0.88	
			C A	16.9000 16.9000	0.6654	0.6250	6.5% -3.2%				24000 24000	21056.6	0.88	30080.8	1.25	0.88	
237	2038	7.63	B C	17.6000 16.9000	0.6929 0.6654	0.6875	0.8%	16.9000	0.6654	325.1972	24000 24000	21125.0	0.00	20105 0	1.00	0.00	
248	2136	7.63	A B C	19.2000 18.9000 17.9000	0.7559 0.7441 0.7047	0.7500 0.7500 0.7500	0.8% -0.8% -6.0%	17.9000	0.7047	308.0155	24000 24000 24000	21136.9	0.88	30195.6	1.26	0.88	
258	2227	7.63	AB	21.4000	0.8425	0.7500	12.3%	21.4000	0.8425	292.0610	24000 24000 24000	18656.0	0.78	26651.5	1.11	0.78	
			C A	21.9000 19.0000	0.8622 0.7480	0.7500	15.0% -0.3%				24000 24000	21893.0	0.91	31275.7	1.30	0.91	
268	2300	7.63	B C	19.9000 19.9000	0.7835	0.7500	4.5% 4.5%	19.0000	0.7480	279.2845	24000 24000						
278	2390	7.63	A B C	17.8000 18.4000 18.3000	0.7008 0.7244 0.7205	0.8125 0.8125 0.8125	-13.7% -10.8% -11.3%	17.8000	0.7008	263.4703	24000 24000 24000	24532.1	1.02	35045.9	1.46	1.02	
287	2471	7.63	A B	18.3000 18.4000 18.5000	0.7205 0.7244 0.7283	0.8125 0.8125 0.8125	-11.3% -10.8% -10.4%	18.4000	0.7244	249.2866	24000 24000 24000	24741.4	1.03	35344.8	1.47	1.03	
207			C A	18.6000	0.7323	0.8125	-9.9%				24000	26274.5	1.09	37535.0	1.56	1.09	
298	2571	7.63	B C	18.4000 18.8000	0.7244 0.7402	0.8750 0.8750	-17.2% -15.4%	18.2000	0.7165	231.7543	24000 24000						_
308	2659	7.63	A B	18.8000 18.4000	0.7402 0.7244	0.9375	-21.0% -22.7%	18.4000	0.7244	219.2761	24000 24000 24000	26876.8	1.12	38395.4	1.60	1.12	
L			С	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	в	19.8000	0.7795	0.9375	-16.9%	19.2000	0.7559	208.6665	24000	20400.4	1.10	5/625.1	1.50	1.10	
310	2751	7.05	c	19.3000	0.7598	0.9375	-19.0%	15.2000	0.7333	208.0005	24000						
			A	20.8000	0.8189	1.0000	-13.0%				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	22213.5	0.93	31/33.6	1.32	0.93	13.5 I.D. Pelistock
520	2640	0.75	c	21.4000	0.8385	1.0000	-14.2%	20.8000	0.0109	198.5455	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% -15.5%	22.8000	0.8976	188.1976	24000 24000						
			-	22.8000		1.0625											
			A	22.0000	0.8661	1.1250	-23.0%				24000	22063.8	0.92	31519.7	1.31	0.92	
348	3015	6.75	В	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	В	25.4000	1.0000	1.1875	-15.8%	25.0000	0.9843	166.2116	24000						
			С	25.3000	0.9961	1.1875	-16.1%				24000						
			А	26.5000	1.0433	1.1875	-12.1%				24000	19395.2	0.81	27707.5	1.15	0.81	
367	3169	6.75	В	26.5000	1.0433	1.1875	-12.1%	26.5000	1.0433	153.5374	24000						
			С	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	В	28.9000	1.1378	1.2500	-9.0%	28.4000	1.1181	135.6187	24000						
			С	28.6000	1.1260	1.2500	-9.9%				24000						
			А	30.3000	1.1929	1.3125	-9.1%				24000	18400.5	0.77	26286.4	1.10	0.77	
387	3350	6.75	в	30.6000	1.2047	1.3125	-8.2%	30.2000	1.1890	117.5411	24000						
			с	30.2000	1.1890	1.3125	-9.4%				24000						
			А	30.2000	1.1890	1.3750	-13.5%				24000	19094.2	0.80	27277.5	1.14	0.80	
397	3441	6.75	в	30.9000	1.2165	1.3750	-11.5%	30.2000	1.1890	99.4635	24000						
			с	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	В	32.3000	1.2717	1.4375	-11.5%	32.2000	1.2677	81.3859	24000	10550.5	0.77	20012.0	1.10	0.77	
407			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	1.3465	1.5000	-10.2%	32.7000	1.2874	62.4374	24000	10340.0	0.75	27000.0	1.15	0.73	
41/	5520	0.75	c	36,7000	1.4449	1.5000	-14.2%	52.7000	1.1074	02.4374	24000						
			A	36.4000	1.4449	1.5250	-5.7%				24000	17729.8	0.74	25220.2	1.00	0.74	
425	2696	6.75	B	36.4000	1.4331	1.5250	-6.8%	26 4000	1 4221	40.1710	24000	1//29.8	U.74	25328.3	1.06	0.74	
425	3686	6.75	в С				-6.8%	36.4000	1.4331	40.1710	24000						
			-	37.6000	1.4803	1.5625											
			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	В	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						

<sup>1</sup> Hoop stress = Pr/t<sub>97.5</sub> <sup>2</sup> Hoop stress / S<sub>A</sub> <sup>3</sup> Hoop stress / 0.7 joint efficiency <sup>4</sup> Joint stress / S<sub>A</sub>

Notes:

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	SLOPE SUMMARY										
	Degrees,		Distance (ft)				Elvation (ft)				
Section	Minutes, Seconds	θ	From (ft)	To (ft)	Delta (ft)	Elevation (Start)	Elevation (End)	Delta (ft)	Slope		
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 C	ALCULATIONS		-		
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	4
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	٦
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	-
225	2038.00	2080.00	10.10	112.95	19.80	325.20	7A 7A	-
248	2136.00	2178.00	10.10	210.95	36.98	308.02	7A 7A	-
248	2227.00	2269.00	10.10	301.95	52.94	292.06	7A	-
258	2299.75	2209.00	10.10	69.98	12.27	279.31	8A	-
208	2390.83	2432.83	10.10	161.06	28.24	263.34	8A 8A	_
278	2390.83	2513.00	10.10	241.23	42.29	249.29	8A 8A	_
287	2571.00	2613.00	10.10	341.23	59.83	231.75	8A 8A	-
308	2659.83	2701.83	6.63	50.31	5.81	219.19	9A	-
318	2751.00	2701.85	6.63	141.48	16.33	208.67	9A 9A	-
318	2751.00	2793.00	6.63	230.81	26.65	198.35	9A 9A	-
328	2840.33	2882.33	6.63	318.73	36.80	198.35	9A 9A	-
338	3015.00	3057.00	6.63	405.48	46.81	178.19	9A 9A	_
348	3105.00	3057.00	11.46	19.07	3.79	178.19	9A 10A	_
360	3105.00	3147.00	11.46	82.74	3.79	153.56	10A 10A	_
367	3168.67	3210.67	11.46	82.74	34.38	135.62	10A 10A	_
377		3301.00			52.46	135.62	10A 10A	_
	3350.00		11.46	264.07				_
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	_
425 432	3686.00 3748.00	3728.00 3790.00	19.72 19.72	76.56 138.56	25.83 46.75	40.17 19.25	11A 11A	

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PLATE THICKN	ESS 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

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	1
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	]

#### Referencing F-106-C-7 & F-106-C-9

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		

Ieel: T/ Ieel						
of water above conduit= 0	feet	Live load: 100.00	psf	Oline weight of water - 02:1	2	
f rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150	lb/ft³	
 .ht of fill above conduit= 2	feet			Fill Unit Weight= 120	lb/ft <sup>3</sup>	
Total Height of Soile 3	feet	(for DL calc) t= 0.44	inches	(soil load) W.= 6656.4		
OD Conduit Diameter= 17.0676	feet	ID: 17.00	feet	(live load) W <sub>i</sub> = 1706.8		
	Assume well					
Buoyancy Factor $R_w=1$	drained = 1			W <sub>s</sub> = 351.8	lb/ft	
B_prime= 0.2330				W <sub>steel</sub> = 957.9	lb/ft	
oils with fines) E_prime= 500	psi			Density steel= 490	pcf	
E= 3000000 psi	) psi					
b= 1				External pressure with vacuum= 3.10	psi	Ratio $Q/q_a = 0.73$
t <sub>MIN</sub> = 0.4055	inches			External pressure with snow load= 3.24	psi	Ratio $Q/q_a = 0.77$
l= 0.0056	inches <sup>4</sup>			External pressure with snow and live= 3.72	psi	Ratio $Q/q_a = 0.88$
FS= 2					_	7
Allowable pressure q <sub>a</sub> = 4.23	psi					
tar: 1E 3E faat				1 Init Wairbt of Water 62 A	ncf	
of water above conduit= 0	feet	Live load: 100.00	psf		2	
of rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150	lb/ft <sup>3</sup>	
tht of fill above conduit= 2	feet		-	Fill Unit Weight= 120	lb/ft <sup>3</sup>	
Total Height of Soil= 3	feet	(for DL calc) t= 1.19	inches	(soil load) W = 5974.1		
	feet	ID: 15.25	feet	(live load) W <sub>i</sub> = 1531.8		100 psf per foot section
	Assume well					
Buoyancy Factor R <sub>w</sub> = 1	drained = 1			W <sub>s</sub> = 316	lb/ft	
B_prime= 0.2330				W <sub>steel</sub> = 2333	lb/ft	
oils with fines) E_prime= 500	psi			Density steel= 490	pcf	
E= 3000000	i psi					
b= 1				External pressure with vacuum= 3.76	psi	Ratio $Q/q_{a}= 0.75$
t <sub>MIN</sub> = 0.4094	inches			External pressure with snow load= 3.91	psi	Ratio $Q/q_{a}= 0.78$
I= 0.0057	inches <sup>4</sup>			External pressure with snow and live= 4.39	psi	Ratio $Q/q_{a}= 0.87$
FS= 2						
Allowable pressure q <sub>a</sub> = 5.04	psi					
eter: 13.5 feet				Unit Weight of Water= 62.4	pcf	
of water above conduit= 0	feet	Live load: 100.00	psf	0 = <sup>A</sup> d	_	
of rip rap above conduit= 1	feet	Snow load: 20.61	psf	Rip Rap Unit Weight= 150	lb/ft³	
	feet		-	Fill Unit Weight= 120	lb/ft <sup>3</sup>	
Total Height of Soils 3	feet	(for DL calc) t= 1.63	inches	(soil load) W_= 5318.2		
	feet		feet			
	Assume well					
Buoyancy Factor R <sub>w</sub> = 1	drained = 1			w <sub>s</sub> = 281.0	lb/ft	
B prime= 0.2330				W <sub>steel</sub> = 2842.6		
oils with fines) E_prime= 500	psi			Density steel= 490	pcf	
E= 3000000 psi	) psi					
b= 1				External pressure with vacuum= 4.15	psi	Ratio $Q/q_{a}= 0.25$
t <sub>MIN</sub> = 0.8189	inches			External pressure with snow load= 4.30	psi	Ratio $Q/q_{a}= 0.26$
l= 0.0458	inches <sup>4</sup>			External pressure with snow and live= 4.78	psi	Ratio $Q/q_a= 0.28$
FS= 2						
Allowable pressure $q_a = 16.84$	psi					
Allowable pressure q <sub>a</sub> = 16.84	psi					

Diameter: Height of wa Height of rip r Height of 7 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 7 7 7 1 7 1	af rip of rip oD OD B B B B B Allc Allc	Diameter: J Height of rip r Height of rip r T T O O O O O O O Allor
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				2022 An	alysis Summ	ary			
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 17802	4642	20117	24000	0.84	0.59	1.19	1.70
150	19562	21261	5869	25431	24000 24000	1.06	0.74	0.94	1.35
160 169	23364	-	7009	30373		1.27	0.89	0.79 0.79	1.13
169	23285 24967	21190 22720	6986 7490	30271 32457	24000 24000	1.26 1.35	0.88 0.95	0.79	1.13 1.06
178			7490					0.74	
100	24470 24559	22268 22348	7368	31811 31926	24000 24000	1.33 1.33	0.93	0.75	1.08 1.07
208	24559	22548	7308	30729	24000	1.35	0.95	0.73	1.07
208	23037	21053	6941	30729	24000	1.28	0.90	0.78	1.12
218	23130	21033	6939	30068	24000	1.25	0.88	0.80	1.14
225	23129	21048	6942	30081	24000	1.25	0.88	0.80	1.14
248	23133	21037	6968	30196	24000	1.25	0.88	0.79	1.14
258	20501	18656	6150	26651	24000	1.20	0.78	0.90	1.14
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

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	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	

	Reburbished	or Original?		Inspecte	ed Status	
Can	North	South	North	South	Year Last	Notes:
	North	South	North	South	Inspected?	
1			I	I		
2			Ι	I	2021	
3			Ι	I	2022	
4			I	I	2020	
5						
6						
7			Ι	I	2021	
8			Ι	I	2022	
9						
10			I	I		
11						
12			I	I	2021	
13			Ι	I	2020	
14			- 1	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	Ι	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		

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	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	

	Reburbished	or Original?		Inspecte	ed Status	
Can	North	South	North	South	Year Last	Notes:
	North	South	North	South	Inspected?	
41						
42			I		2021	DP, Inspected Doubler plate fillet weld
43			- 1	I	2021	
44			I		2020	
45			Ι		2022	DP, Inspected Doubler plate fillet weld
46			Ι	I		
47				I	2020	
48			Ι	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	2021	
58			I	I		
59						
60						
61			I	I	2021	
62						
63			-			DP
64				I	2022	DP, Inspected Doubler plate fillet weld
65			I		2020	
66				I	2020	
67			I	I	2022	
68						МН
69			I	I		
70					2022	
71				1	2022	
72			I	I	2021	
73					2020	
74					2020	
75					2020	
76					2022	
77			I	I	2021	
78						
79				I		
80			,		2022	
81			I	I	2022	

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	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	

	Reburbished	or Original?		Inspect	ed Status	
Can	North	South	North	South	Year Last	Notes:
	North	30000	North	South	Inspected?	
82			Ι	I	2021	
83						
84						
85			-	I		
86			I	- 1	2020	
87			I	- 1	2022	
88			I	- 1		DP
89			- 1	- 1		
90						
91			- 1	- 1		
92			I	- 1	2021	
93			- 1	- 1		
94			I	- 1	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			Ι	I		
101			Ι	I		
102			I	- 1		
103			I	- 1	2022	1 inidication found on north side
104				I	2021	
105						
106			I	I	2020	
107			I		2022	
108			I	I	2021	
109			I		2020	
110				I	2020	
111					2020	
112			I	I	2022	South only in 2022
113						
114						
115					2021	
116					2021	
117			Ι		2021	
118					2022	
119					2022	
120			I	I	2021	South only in 2021
121					2021	
122	Р		I	I	2021	1 Crack in North Weld in 2021

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	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	

	Reburbished	or Original?		Inspect	ed Status	
Can	North	South	North	South	Year Last	Notes:
	North	30000	North	300111	Inspected?	
123	Р		L	I	2022	3 cracks in North Weld in 2021
124	Р		Ι	I	2021	1 Crack in North Weld in 2021
125			L	I	2021	
126	Р		I	- 1	2021	2 cracks in North Weld in 2021
127	Р		I	- 1	2022	1 Crack in North Weld in 2021
128			- 1	- 1	2021	
129			- 1	- 1	2021	МН
130				- 1	2020	
131			I	- 1		
132				- 1	2022	North Weld not accessible
133		Р	1	1	2022	2 cracks in South Weld in 2021, Only south
155			-		2022	inspected in 2022
134		Р	I	- 1	2021	3 cracks in South Weld in 2021
135			Ι	I	2021	
136	Р		Ι	I	2021	4 cracks in North Weld in 2021
137		Р	Ι	I	2022	1 cracks in South Weld in 2021
138			Ι	I	2022	
139			I	I	2022	
140			I		2022	South not accesible
141						
142			I	I	2021	
143						
144						
145	Р	Р	I	I	2022	1 Crack in North Weld in 2021, 1 crack in South side in 2022
						DP, 4 cracks in North Weld in 2021, Only North
146	Р		I	I	2022	inspected in 2022, 1 inidication found in 2022
147	Р		I	I	2021	2 cracks in North Weld in 2021
148			Ι	Ι	2021	
149			I	I	2022	Only north inspected in 2022
150	5	5			2024	DP, 3 cracks on south in 2021, 2 cracks on north
150	Р	Р	I	I	2021	2021, only north inspected in 2022
151				Ι	2022	North weld not accesible
152			I	I	2021	
153			Ι	I	2021	
154			Ι	I	2021	
155			I	I	2021	
156						
157			-	I	2020	
158						
159			-			

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	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	

	Reburbished	or Original?	Inspected Statu		ed Status	
Can	North		North South Year Last	th South	Year Last	Notes:
	North	South	North	South	Inspected?	
160			I		2022	DP,only north inspected
161						
162						
163			Ι	I		
164			Ι	I	2022	
165			Ι	I	2021	
166				- 1	2020	
167				1	2020	
168			I			
169				- 1	2022	
170				- I		
171						
172			- 1	- 1	2022	
173			I	- I		
174			I		2020	
175			Ι		2020	
176			I	- 1	2021	
177			Ι		2022	
178			I		2022	
179						
180			I	- 1		
181						
182						
183			I	I		
184						
185				I	2021	
186						
187					2020	
188			I	I	2022	
189				ļ		
190						
191						
192			Ι	I		
193			I			
194			I	I	2021	
195						DP
196			I		2020	
197				ļ		
198			I	I	2022	
199	ļ					
200						

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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						

	Reburbished	or Original?	Inspected Status		ed Status	
Can	North	South	North	th South Year Last		Notes:
	North	South	North	South	Inspected?	
201			I	I		
202						
203			I	I	2021	
204			Ι		2020	
205			Ι	I		
206			I		2020	
207						
208			- 1	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	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						

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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						

	Reburbished or Original?			Inspect	ed Status	
Can	North	South	North	South	Year Last Inspected?	Notes:
242						
243			I	I	2021	
244						
245			I		2020	
246						
247			I	I		
248			I		2022	
249			Ι		2022	
250			Ι	I		
251						
252						
253						
254			I	I	2021	
255			- 1	I		
256						
257			I	I	2020	МН
258			- 1	I	2022	
259						Surge Tank
260						Surge Tank
261						
262						
263			I	I	2021	
264			I	I		
265				I		
266				I	2020	
267						
268			I	I	2022	
269						
270						
271			I	I		
272						
273						
274					2021	
275						
276			I	I	2020	
277						
278			I	I	2022	
279						
280			I	I		
281						
282						

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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						

	Reburbished	or Original?	Inspected Status		ed Status	
Can	North	South	North	South	Year Last Inspected?	Notes:
283						
284			I	I	2021	
285			Ι	I		
286			Ι	I	2020	
287			I	I	2022	
288						
289						
290						
291						
292			I	I		
293						
294			Ι	I	2021	
295			Ι	I		
296			Ι	I	2020	
297						
298			I	- 1	2022	
299						
300			Ι	I		
301						
302			- 1	- 1		
303						
304			I	- 1	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	Ι		
321						
322			I	I		
323						

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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						

	Reburbished	or Original?	Inspected Status		ed Status	
Can	North	South	North	North South Year Last		Notes:
	North	South	North	South	Inspected?	
324			Ι	I	2021	
325						
326			I	I	2020	
327						
328			I	I	2022	
329						
330			Ι	I		
331			-	I		
332						
333						
334			- 1	- 1	2021	
335						
336			- 1	- 1		
337						
338			I	I	2022	
339						
340			I	I		
341						
342			Ι	I		
343						
344			Ι	I	2021	
345						
346			Ι	I	2020	
347						
348			I	I	2022	
349						
350				I		
351						
352						МН
353						
354			I			
355				I	2020	
356					2020	
357			I	I	2021	
358						
359						
360			I		2022	
361						
362			I	I		
363						
364			I	I		

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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						

	Reburbished	or Original?	Inspected Status		ed Status	
Can	North	South	North South Year Last		Year Last	Notes:
	North	South	North	South	Inspected?	
365			I	I	2020	
366						
367			I	I	2022	
368			I	I	2021	
369						
370			I	I		
371						
372			- 1	I		
373						
374						
375			I	I	2020	
376						
377			I	I	2022	
378			I	I	2021	
379						
380			I	I		
381			- 1	I		
382						
383						
384						
385			I	I	2020	
386						
387			I	I	2022	
388			I	I	2021	
389						
390				Ι		
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						

R = Weld seam has b	een Refurbished	Both Longitudinal Welds Have Been Inspection
<b>O</b> = Original Weld		One Longitudinal Weld Has Been Inspected
P = Weld seam has b	een partially refurbished	No Longitudinal Welds Have Been Inspected
I = Weld seam has b	een inspected	
N = Weld seam has n	ot been inspected	

Can	Reburbished or Original?		Inspected Status			
		Courth	North	South	Year Last	Notes:
	North	South	North		Inspected?	
406			I	- 1	2020	
407			I	1	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			Ι	I	2021/2022	Only South inspected in 2022
433						
434				Ι	2022	
435			Ι	Ι	2021	