

CI C0044172

Canso Crossing Vibration Mitigation

REDACTED

Date Revised: June 19, 2026





NSEB APPROVAL SHEET

Project Title: L7005 Canso Crossing Vibration Mitigation

CI Number: C0044172

Date: May 4, 2026

Expenditure Profile			Type of Filing	
Year	Budget Amount	Project Estimate	☒	Capital Project Authorization
			☐	Unforeseen and Unbudgeted (U&U)
			☒	Planned & Advanced (P&A)
			☐	Subsequent Approval Item
2023		93,386	☐	Authorization to Overspend (ATO)
2024		273,790	☐	Scope Change
2025		2,105,997	☐	Final Cost (FIN)
2026		(42,079)		
Total	\$0	\$2,431,095		

COMMENTS

Submitted on behalf of NOVA SCOTIA POWER INCORPORATED

Approved on behalf of NOVA SCOTIA ENERGY BOARD

Authorized Signatory
Dave Pickles
Chief Operating Officer

DATE
May 4, 2026

DATE

CI Number: C0044172

Title: L7005 Canso Crossing Vibration Mitigation

Start Date: 2023/07
In-Service Date: 2025/06
Final Cost Date: 2026/05
Function Class: Transmission
Forecast Amount: 2,431,095

DESCRIPTION:

This project is for the investigation, custom hardware development, testing, and installation of a new vibration dampening solution for the L-7005 transmission line across the Canso Strait. The new vibration mitigation system involves installing 288 custom Preformed Line Products (PLP) dampers and 1,164 PLP airflow spoilers on the L-7005 Canso Crossing spanning structures 729 to 732.

As part of CI 43678 - Separate L8004/L7005 on Canso Crossing Double Circuit Tower (DCT), a new 1.4 km L-7005 transmission line crossing was constructed at the Canso Causeway and went into service in July 2018. During a routine inspection of the crossing towers in 2021, fatigue-related failures were identified in the installed vibration dampers. The increased vibrations also resulted in localized damage to the conductor and loss of structural fasteners from the steel towers. The primary cause of damage to this crossing has been identified as Aeolian vibration and galloping—phenomena typically occurring under low-to-moderate wind speeds combined with ice accumulation. While the original design accounted for the estimated dynamic effects of wind and ice, it has become evident that actual site conditions have introduced variations beyond those original engineering considerations. These conditions have led to the observed fatigue and damage to the original dampers and the conductor. The impact of these dynamic forces is further exacerbated by the crossing’s higher elevation and extended span lengths.

The sequence of events is as follows:

- Q4 2021: Unexpected conductor damage was observed during an inspection at the L-7005 Canso crossing. The damage prompted an engineering assessment completed by a third-party conductor expert. Please refer to Confidential Attachment 1. Due to the significant dynamic effects on conductors and towers resulting from Aeolian vibration and galloping, the expert recommended the development and installation of a more robust system of revised dampers, air flow spoilers, and monitoring devices.
- Q3 2022: Repairs to the conductor were completed and the original dampening system was repaired where there were damages to help mitigate vibration issues on an interim basis while a more permanent solution was developed. Due to long lead times associated with the vendor’s manufacturing and testing requirements as well as subsequent testing by NS Power via a third-party lab, it was not possible to install the new dampening system at this time.
- Q4 2024: Procurement and final testing was completed for the new dampening system and project installation planning was initiated.
- Q3 2025: Installation of custom PLP dampers and PLP airflow spoilers was completed.

Summary of Related CIs +/- 2 years:

Pursuant to Section 11.2 of the CEJC, related CIs for Transmission projects include “work completed on the same asset class (Padmount transformers, Breakers, etc.) or in the same location (feeder, Transmission Line).”

- No other projects in 2023, 2024, 2025, 2026, or 2027

Depreciation Class: Transmission Plant – Overhead Conductor and Devices

Retirement Information:

- Categorization of Retirement: Accounting Policy 6420 - Retirement and Disposal of Capital Assets
- Percentage of Asset Pool: 0.11%

Estimated Life of the Asset: 45 years

JUSTIFICATION:

Justification Criteria: Transmission Plant

Why do this project?

Damage to the original set of dampers as a result of the higher than anticipated aeolian vibrations means the equipment can no longer provide sufficient protection against ongoing conductor vibrations. A third-party engineering assessment indicated that, in the absence of corrective action, the conductor will continue to degrade (please refer to Confidential Attachment 1). This could potentially lead to a conductor failure at the Strait of Canso, presenting a safety risk, compromising the reliable operation of the transmission line, and requiring emergency unplanned repairs in a difficult to access span. The undampened vibrations could also result in additional damage to the steel towers carrying the line, potentially requiring costly structural interventions.

Why do this project now?

The original damper system that was repaired where there were damages on an interim basis in Q3 2022 has reached its end-of-life, and without mitigation the conductor is at risk of damage from ongoing aeolian vibration. Without introducing a new dampening solution, the conductor will continue to degrade and would likely require replacement in the near future. If this conductor failed, not only would it present a public safety risk as the line crosses over highways 104 and 19, but the line also plays a critical role in overall system operation as part of the Cape Breton Export Corridor transporting energy from Cape Breton to the Nova Scotia Mainland.

This project was originally planned to be executed in 2026, but during a routine inspection in Q1 2025, there was additional conductor damage discovered, requiring immediate remediation to avoid further damage to the crossing. Please refer to Attachment 2 for photos of the damage discovered.

Why do this project this way?

Installation of the new dampening system provides a long-term solution to conductor vibration compared with further interventions using the originally installed dampening system which is now at end-of-life. Installing the new dampening system and repairing the broken conductor strands was more cost effective than replacing the entire section of conductor in the future. The cost of replacing the entire span of conductor is estimated at approximately \$2.5 million and would still require installation of the new dampening system to protect from future vibration-induced damage.

Contingency Statement

This project is complete; as such, no contingency has been included in the detailed cost estimate.

Note 1: The labour figures noted above are an average of salaries across a variety of jobs within similar classifications including fringe, and are used solely for budgeting purposes.
Note 2: Small differences in totals are attributable to rounding.



Instructions: Select option in Column B.
Columns C through G will auto-populate.

Document No: XXX-XX-XXXX-XXXX

Project Cost Estimate Input Checklist and Maturity Matrix						
Transmission Line Infrastructure	Required fields:	Estimate Classification				
Project Name: L7005 Canso Crossing Vibration Mitigation	Started or Preliminary	Class 5	Class 4	Class 3	Class 2	Class 1
Maturity Level of Project Definition Deliverables	Defined or Complete					
General Project Data						
A. Scope						
Project Scope of Work Description	Defined (D)	P	P	D	D	D
Site Infrastructure (Access, Construction Power, Camp, etc.)	Defined (D)	NR	P	D	D	D
B. Capacity						
Voltage (kV) and Circuits	Defined (D)	P	P	D	D	D
C. Project Location						
Not Applicable						
D. Requirements						
Codes and/or Standards	Defined (D)	NR	P	D	D	D
Environmental Monitoring	Defined (D)	NR	NR	P	P	D
E. Technology Selection						
Not Applicable						
F. Strategy						
Right-of-Way (ROW)	Defined (D)	P	P	D	D	D
Contracting/Sourcing	Defined (D)	NR	P	D	D	D
Escalation	Defined (D)	NR	P	D	D	D
G. Planning						
System/Grid Planning (including substation and interconnect locations)	Defined (D)	P	P	D	D	D
Logistics Plan	Defined (D)	P	P	P	D	D
Integrated Project Plan	Defined (D)	NR	P	D	D	D
Project Code of Accounts	Defined (D)	NR	P	D	D	D
Project Schedule	Defined (D)	NR	P	D	D	D
Regulatory Approval & Permitting	Defined (D)	NR	P	D	D	D
Risk Register	Defined (D)	NR	P	D	D	D
Stakeholder Consultation/Engagement/Management Plan	Not Applicable (NA)	NR				
Work Breakdown Structure (WBS)	Not Applicable (NA)	NR				
Start-up & Commissioning Plan	Not Applicable (NA)	NR				
H. Studies						
Routing Options	Defined (D)	P	P	D	D	D
Topography & Bathymetry	Defined (D)	P	P	P/D	D	D
Environmental Impact/Sustainability Assessment	Not Applicable (NA)	NR				
Environment/Existing Conditions	Defined (D)	NR	P	D	D	D
Meteorology and/or Oceanographic/Subsea	Not Applicable (NA)	NR				
Soils & Hydrology	Not Applicable (NA)	NR				
Technical Deliverables (Specifications and/or Drawings)						
Conductor, Insulator, Grounding, Joint Design (including protection for buried or subsea)	Complete (C)	S	P	C	C	C
Foundation/Structure (Tower) Design	Complete (C)	S	P	C	C	C
Route Mapping/Survey	Complete (C)	S/P	P/C	C	C	C
Design Specifications	Complete (C)	NR	S/P	C	C	C
Instrument List	Not Applicable (NA)	NR				
Construction Permits	Complete (C)	NR	S/P	P/C	C	C
Geometric Layout, Alignment, Profile, Cross Section	Complete (C)	NR	S/P	P/C	C	C
Land/ROW Title Negotiation	Not Applicable (NA)	NR				
Civil/ Site/Structural/Architectural Discipline Drawings	Not Applicable (NA)	NR				
Crossings and Borings Designs and Drawings	Complete (C)	NR	S/P	P	C	C
Demolition Plans and Drawings	Not Applicable (NA)	NR				
Erosion Control Plan & Drawings	Not Applicable (NA)	NR				
Foundation/Structure (Tower) Discipline Drawings	Complete (C)	NR	S/P	P	C	C
Tower/Structure Location/Spotting	Complete (C)	NR	S/P	P	C	C
Instrument Datasheets	Not Applicable (NA)	NR	NR/S			
Electrical Discipline Drawings	Not Applicable (NA)	NR	NR			
Instrumentation/Control System Discipline Drawings	Not Applicable (NA)	NR	NR			
Total # Deliverables for this Project		10	26	27	27	27
% Defined/Complete towards Class Estimate		100%	100%	100%	100%	100%

Comments:

This project is complete so no contingency is required.

Legend:

The maturity level is an approximation of the completion status of the deliverable. The completion is indicated by the following descriptors:

General Project Data:

- Not Required (NR): May not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- Preliminary (P): Project definition has begun and progressed to at least an intermediate level of completion. Review and approvals for its current status has occurred.
- Defined (D): Project definition is advanced, and reviews have been conducted. Development may be near completion with the exception of final approvals.

Technical Deliverables:

- Not Required (NR): Deliverable may not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- Started (S): Work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.
- Preliminary (P): Work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.
- Complete (C): The deliverable has been reviewed and approved as appropriate.

Inclusions:

For the purposes of this document, the term *power transmission line infrastructure industries* is assumed to include greenfield or brownfield sites for overhead, buried and submarine transmission of electrical power in the infrastructure industries. High voltage is typically >100kV but may be less (e.g., 33 or 66kV) if long distance with light electrical loads. This excludes power supply and distribution scope within a process plant, mining facility, building complex or other facility site. It also excludes power generation facilities and substations. The defining deliverables of those excluded project scopes are covered in other RPs (e.g., 18R-97 for process plants [2]).

Power transmission is considered an element of the infrastructure industry. The Construction Industry Institute has provided a good definition of infrastructure in its Project Definition Rating Index for Infrastructure Projects as follows [3]:

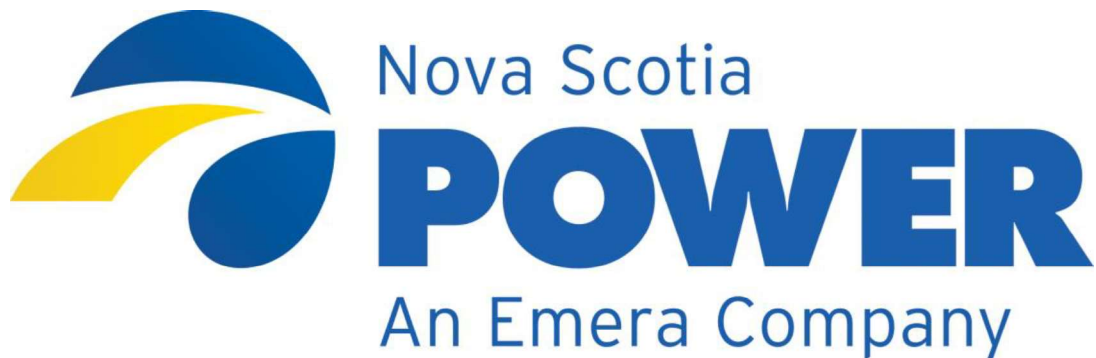
“A capital project that provides transportation, transmission, distribution, collection or other capabilities supporting commerce or interaction of goods, services, or people. Infrastructure projects generally impact multiple jurisdictions, stakeholder groups and/or a wide area. They are characterized as projects with a primary purpose that is integral to the effective operation of a system. These collective capabilities provide a service that is made up of nodes and vectors into a grid or system.”

Using this definition, power transmission lines are a vector or linear scope element that connects substation or other facility nodes at its terminations. The substation nodes may be part of or associated with a generation, consuming or interconnection facility. As such, transmission projects are often executed as part of a program that also involves node project scope or facility operational changes (or at least considerations for integrated system commissioning and startup). As the definition states, a distinguishing feature of these projects is that they often traverse wide areas, cross country or subsea, which puts an emphasis on the definition of routing, land ownership and conditions, and establishing right-of-way (ROW). Associated scope definition challenges include defining stakeholder, permitting and regulatory requirements. Buried and submarine installations increase the focus on the protection philosophy and strategies affecting cable selection, armoring and joint considerations. While many distinguish power transmission (higher voltage, long distances) from power distribution (short distance, lower voltage connections to retail customers), the principles of estimating these elements are similar; i.e., the RP applies to both.

The main physical power transmission line scope elements are conductors and their support structures if installed overhead. Main installation elements include land clearing if over land (including forestry if applicable), foundation and structure erection and conductor stringing if overhead, or trenching, laying and horizontal boring if subsurface or subsea. Special scope elements are involved with crossings of water, road, rail and so on and at terminations. Because conductor (e.g., aluminum) and structure (e.g., steel) material costs are usually a significant cost element, these project estimates are particularly sensitive to escalation uncertainty. In general, the more developed the route, the more complex the installation will be. In urban areas, visual appeal and concern for safety and health can be major issues. Installation in remote location and/or difficult or environmentally sensitive terrain creates its own challenges. Subsea installation adds the need for bathymetry¹ and metocean² studies and specialized installation equipment and vessels. Before any installation work can begin in an area, stakeholder consultation must be advanced (sometimes requiring agreements with local populations with rights), and appropriate land and ROW must be acquired which creates unique scheduling as well as cost challenges.

For the purpose of estimate classification then, the main scope definition deliverables are associated with defining the power requirements (i.e., kV), the conductors and structure, and the routing. Conductors can vary widely in content (copper, aluminum, etc.) and insulation. Overhead structures may be wood, concrete, composite or steel in various configurations with various foundation designs including pilings, concrete and so on. The route's land or subsea characteristics and the nature of developments drive the need for special design features and execution strategies. Operability and maintainability considerations may also affect ROW and access design. Brownfield and revamp projects add their own concerns for interface with existing elements, crowded working conditions, etc. For each scope definition decision, stakeholder requirements need to be considered.

Power substation projects are usually associated with transmission projects. However, substations being equipment-centric and located on a facility site have physical and defining characteristics similar to process plant projects (e.g., reliance on one-line diagrams, plot plans, etc.).



Energy Delivery Engineering

L7005 Vibration Mitigation NSPI Technical Memo

Rev1. Sep. 2024
Page 2 of 27

TABLE OF CONTENTS

1.0	SCOPE AND PURPOSE	4
2.0	REFERENCES	4
3.0	BACKGROUND.....	4
4.0	LOSS OF STRENGTH & CONDUCTIVITY	5
5.0	RESTORATION OF STENGTH & CONDUCTIVITY	6
6.0	IMPACTS OF LOSS OF CONDUCTOR STRENGTH	7
7.0	IMPACTS OF LOSS OF CONDUCTIVITY	8
8.0	DAMPERS & AFS.....	9
9.0	VERTICAL CLEARANCE & PHASE-PHASE SEPARATIONS	10
10.0	TOWER ASSESSMENT.....	10
11.0	EXECUTION PLANNING	11
12.0	NEXT STEPS	11
13.0	CONCLUSIONS & RECOMMENDATIONS.....	12
14.0	APPENDICES.....	13
	APPENDIX O – DR. HAVARD REPORT 2021	14
	APPENDIX A – DR. HAVARD REPORT 2023.....	15
	APPENDIX B – DR. HAVARD REPORT 2024.....	16
	APPENDIX C – ZTT REPORT	17
	APPENDIX D – PLP ARMOR RODS	18
	APPENDIX E – AAB REPORT	19
	APPENDIX F – PLP AIR FLOW SPOILER & DAMPER	20
	APPENDIX G – CANSO CROSSING PERMIT DRAWING (CURRENT VS ESTIMATED)	21
	APPENDIX H – L7005 TOWER CLIMBING INSPECTION SUMMARY	22
	APPENDIX I – SYSTEM PLANNING INFORMATION	23
	APPENDIX J – AIR FLOW SPOILERS PLACEMENT INFORMATION	24
	APPENDIX K – DAMPER PLACEMENT CHARTS.....	25
	APPENDIX L – L7005 TOWER ASSESSMENT REPORT (CIMA+).....	26
	APPENDIX M – VIBRATION MONITORING OPTIONS COMPARISON	27

Rev1. Sep. 2024
Page 3 of 27

REVISION HISTORY

Rev.	Date	Description		Signature
1	4-Sep-24	L7005 Vibration Mitigation - NSPI Technical Memo	Prepared by: Sriram Iyer Transmission Line Engineer, Energy Delivery Engineering, Nova Scotia Power	Sriram Iyer Digitally signed by Sriram Iyer Date: 2024.09.04 16:00:43 -03'00'
			Reviewed by: Krutikkumar Trivedi Transmission Engineering Lead, Energy Delivery Engineering, Nova Scotia Power	KRUTIK TRIVEDI Digitally signed by KRUTIK TRIVEDI Date: 2024.09.05 09:03:02 -03'00'
			Reviewed by: Lance Taylor Senior Manager, Energy Delivery Engineering, Nova Scotia Power	<i>Lance Taylor</i> Digitally signed by Taylor, Lance Reason: Reviewed Date: 2024.09.13 14:12:47 -03'00'
			Reviewed by: Michael Gagnier Senior Engineer, Energy Delivery Capital Execution, Nova Scotia Power	Michael Gagnier Digitally signed by Michael Gagnier Date: 2024.09.13 11:00:30 -03'00'
			Reviewed by: Justin Donovan Senior Manager, Energy Delivery Capital Execution Nova Scotia Power	Justin Donovan Digitally signed by Justin Donovan Date: 2024.09.11 14:44:13 -03'00'
			Approved by: Chris Milligan Director, System Planning & Grid Integration, Nova Scotia Power	

1.0 SCOPE AND PURPOSE

The L7005 230kV Canso Crossing constructed in 2017 has experienced conductor damage due to extreme weather induced vibration and galloping. The location of the crossing is subjected to severe weather, winter storms, channeled winds and accretions of wet snow and ice, which are conducive to the occurrence of conductor aeolian vibration and galloping, especially during the months of Nov to Apr.

A number of mitigation measures were put in place and more measures are planned to be implemented to address the conductor damage and vibration issues. The purpose of this document is to summarize the challenges of this unique crossing, engineering studies and research, engagements with industry experts, identifying solutions/mitigation measures and future work.

2.0 REFERENCES

- [0] Interim report Oct 2021, Assessment of the 230 kV Canso strait crossing, David G. Havard Ph.D., P.Eng.
- [1] Interim report on June 13, 2023, drone-based survey of nova scotia power's L7005 345 kV Canso strait crossing, David G. Havard Ph.D., P.Eng.
- [2] Interim report on May 16, 2024, drone-based survey of nova scotia power's L7005 345 kV Canso strait crossing, David G. Havard Ph.D., P.Eng.
- [3] Report for NS Power conductor damage Canso strait crossing, Jack Roughan, ZTT International Ltd.
- [4] Technical memorandum L7005 Canso Causeway air-flow spoiler and dampers modelling in PLS-CADD, B. Bilkhu, AAB Engineering Inc.
- [5] Plan showing a proposed 345 kV overhead wire crossing of the strait of Canso, Auld's cove, Antigonish county to Port hastings, Inverness County, N.S.

3.0 BACKGROUND

The L7005 crossing was designed with vibration dampers, however, no galloping control devices like Air Flow Spoilers (AFS) were originally designed or installed on the crossing. Salvi dampers were installed for aeolian vibration control. Severe conductor damage on the crossing spans was reported in Sep 2021. The cause of damage was attributed to uncontrolled vibration and galloping [0] resulting in slippage of dampers which in turn damaged the outer aluminum strands of the AACSR conductor. The report completed by Dr. Havard included in Appendix 0 outlines the drawbacks of the original Salvi dampening scheme and testing and proposes mitigation options for aeolian vibration and galloping control.

2022 Inspection & Repair

In May 2022, a climbing inspection was conducted which confirmed the locations of conductor damage, slipped dampers and dampers missing weights. Later in the year, in 2022, conductor repair was completed, and new Preformed Line Products (PLP) dampers were installed. Also, the remaining available Salvi dampers were installed to provide additional dampening as the required special PLP Robust dampers and AFS were not available at the time due to manufacturing and delivery lead times.

Specifically, for conductor damage close to existing suspension clamps (8 to 12'), it was required to replace the existing armor rod under the suspension clamp with a longer one so it would also cover the damage location. Longer armor rods available in the market had a large diameter and wouldn't fit under the existing suspension clamp. Market research was done to identify if there are any suspension clamps available that can accommodate the larger diameter armor rod, however, this effort was not fruitful. Hence, PLP had to create a custom long armor rod that would fit under the existing suspension clamps as well as be long enough to cover conductor damage close to the clamps. This resulted in this armor rod not being available in 2022 when the repairs were completed.

2023 Inspection & Repair

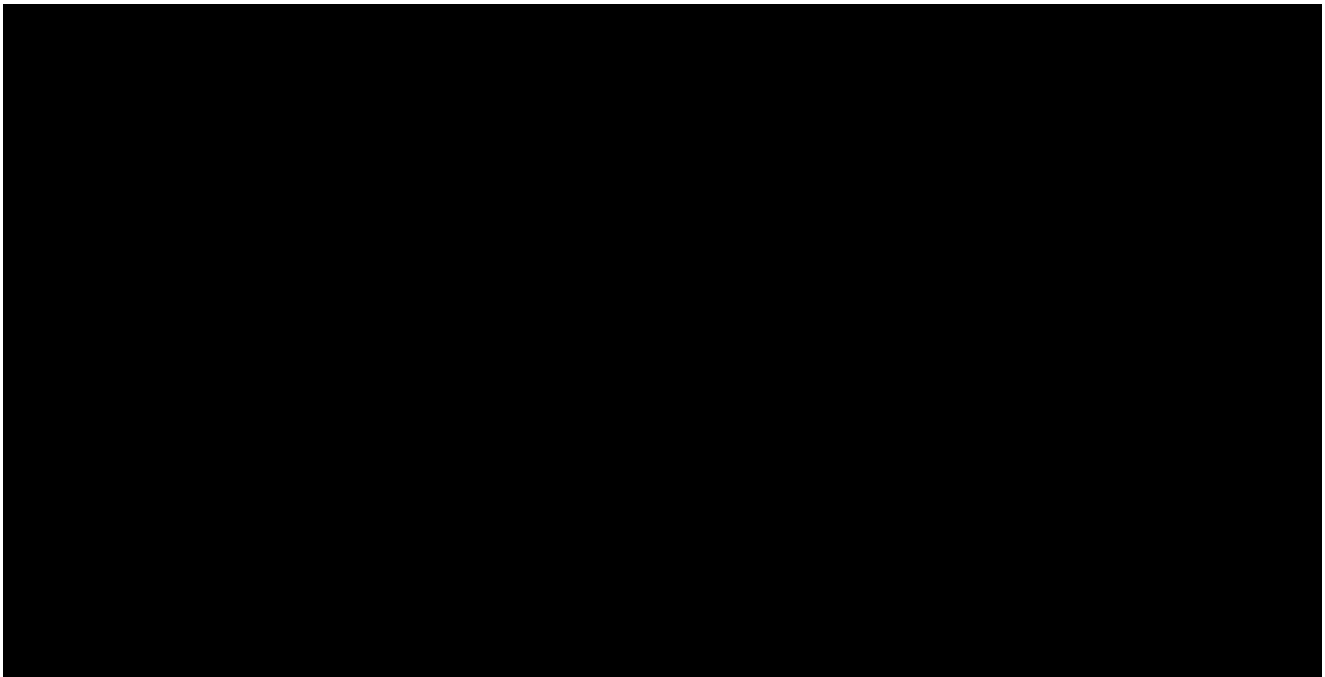
In June 2023, a drone inspection was completed which revealed more minor conductor damage (surface marks and loose wires) which were not as severe as the damage observed in 2021 [1]. A review of the inspection data was completed by Dr. Havard and the report of findings can be found in Appendix A.

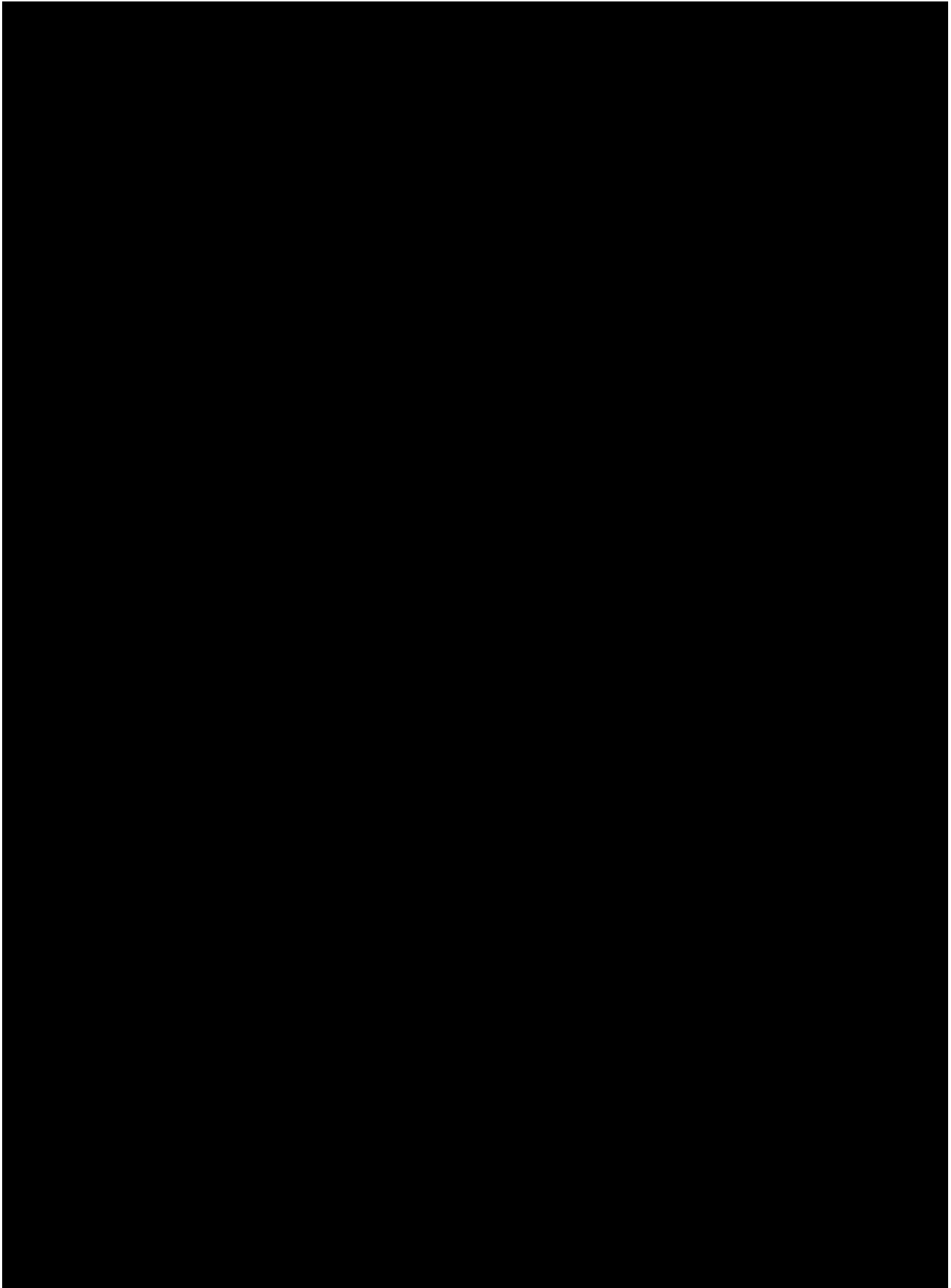
2024 Inspection & Repair

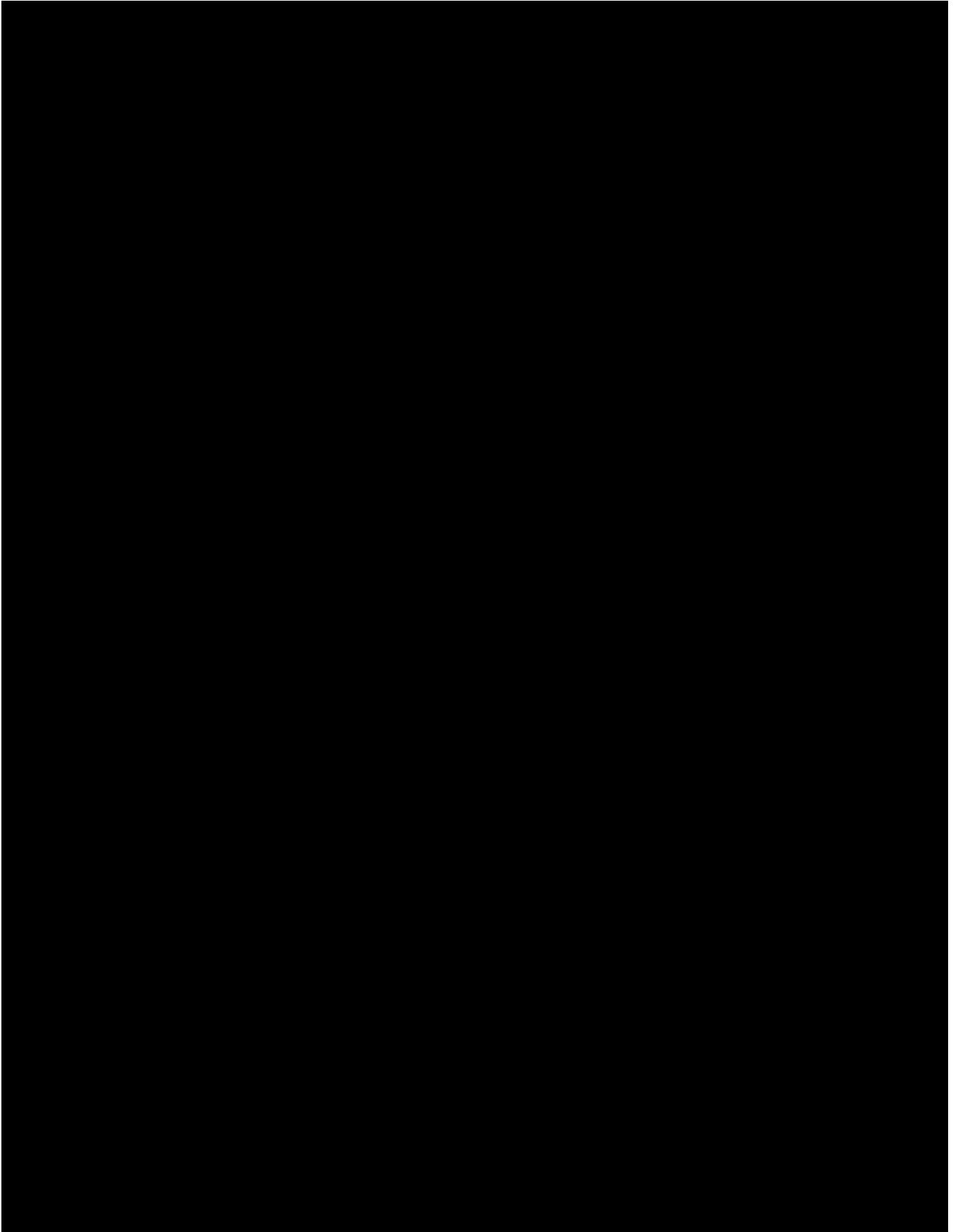
In May 2024, a drone inspection was completed. This identified no broken strands and no new significant damage to the conductor. However, there is some residual conductor damage remaining from 2023, the remaining Salvi dampers and PLP dampers are in service, except one PLP damper had a fractured arm [2]. A review of the inspection data was completed by Dr. Havard and the report can be found in Appendix B.

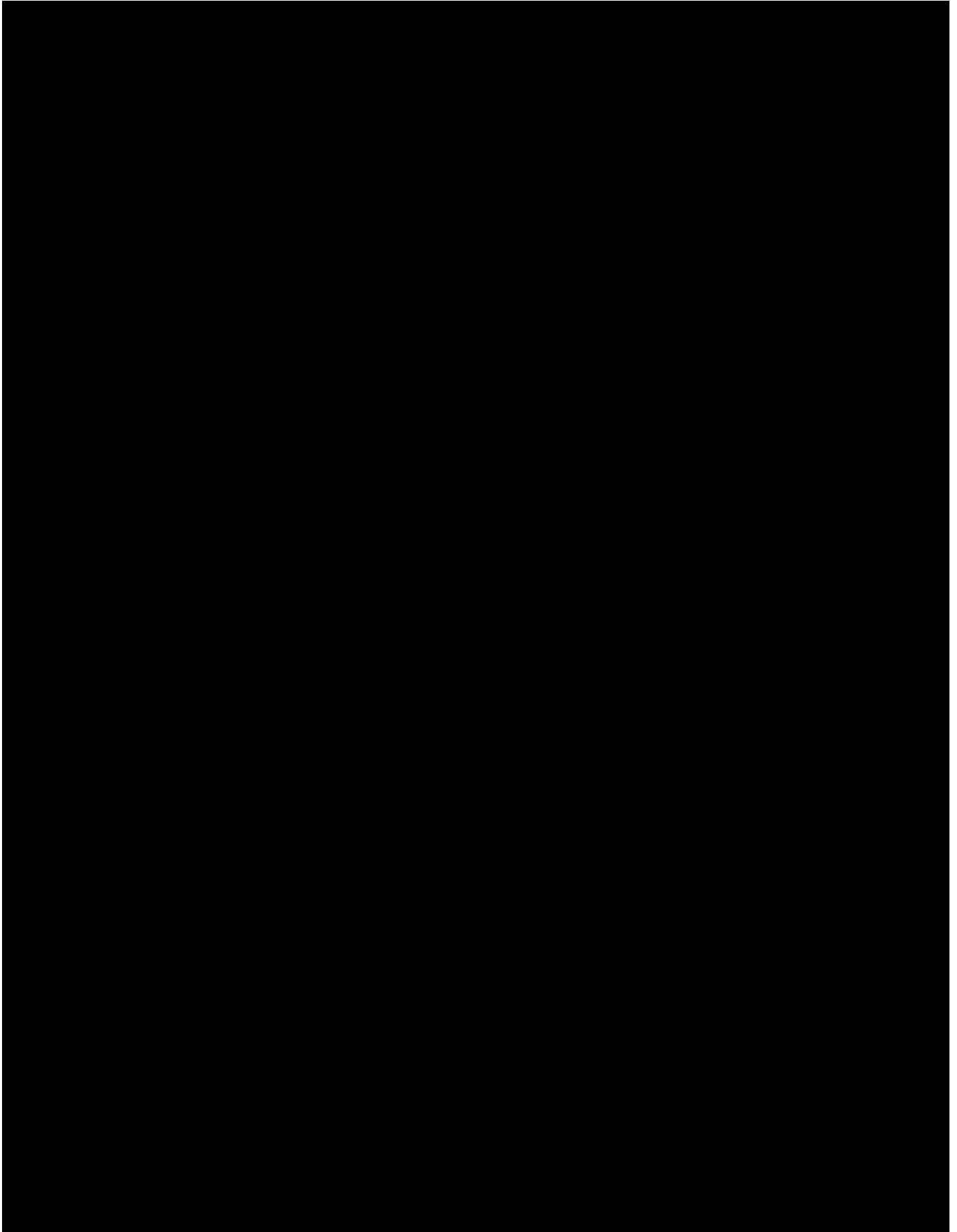
In Jul 2024, a tower climbing inspection was completed on the Canso crossing lattice towers, bolts were re-torqued, and members were checked for any damages. The tower inspection summary report can be found in Appendix H. No major issues were identified on the towers. A couple of issues including a damaged tower member on STR 723 (SW foundation) are being investigated to identify the appropriate mitigation measures.

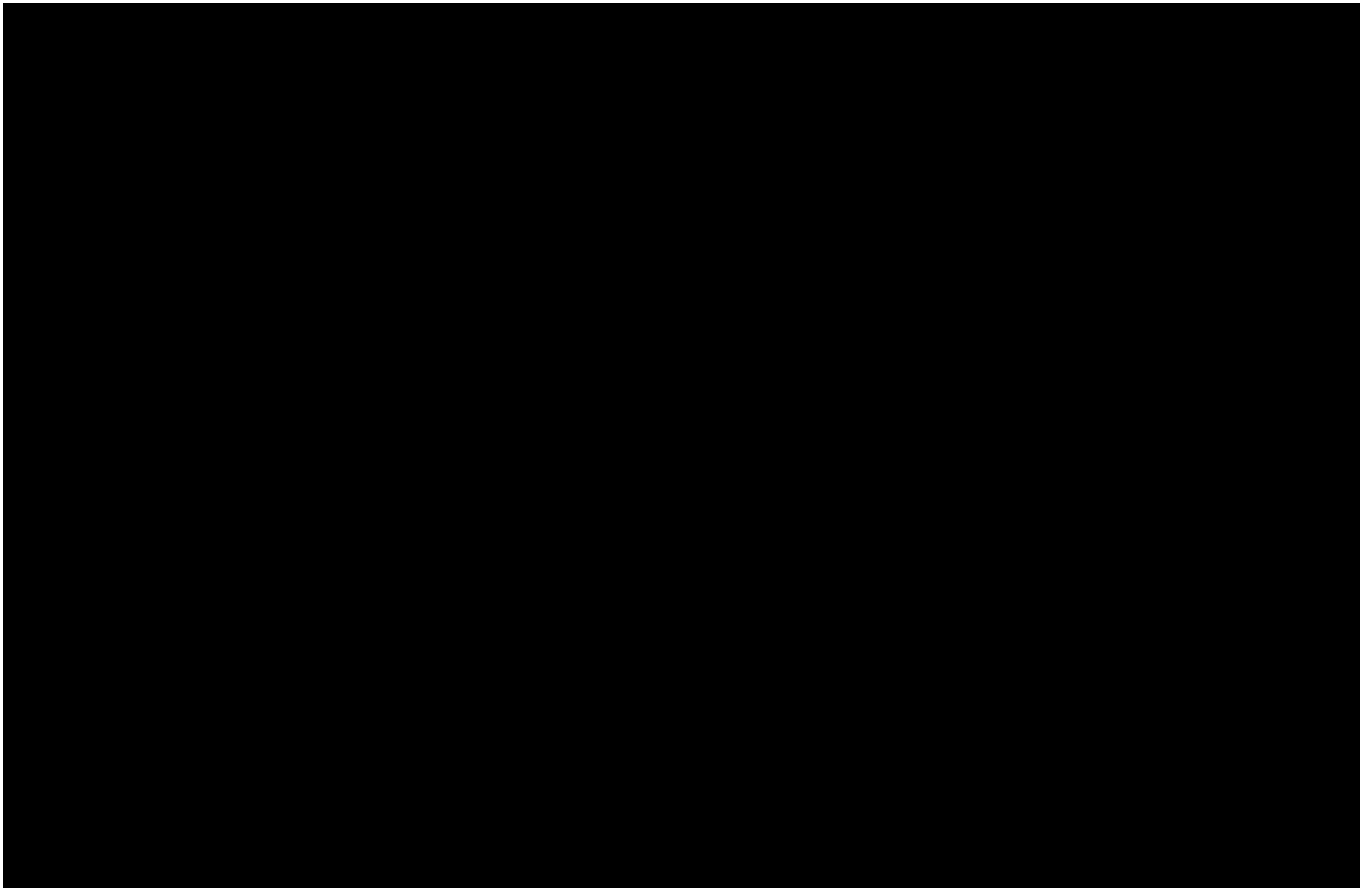
Considering all the required material is now available and delivered, before winter 2024/25, it is planned that the remaining conductor damages be addressed, new special PLP dampers and Air Flow Spoilers be installed using a conductor cart as recommended in Dr. Havard's reports [0] [1] [2].









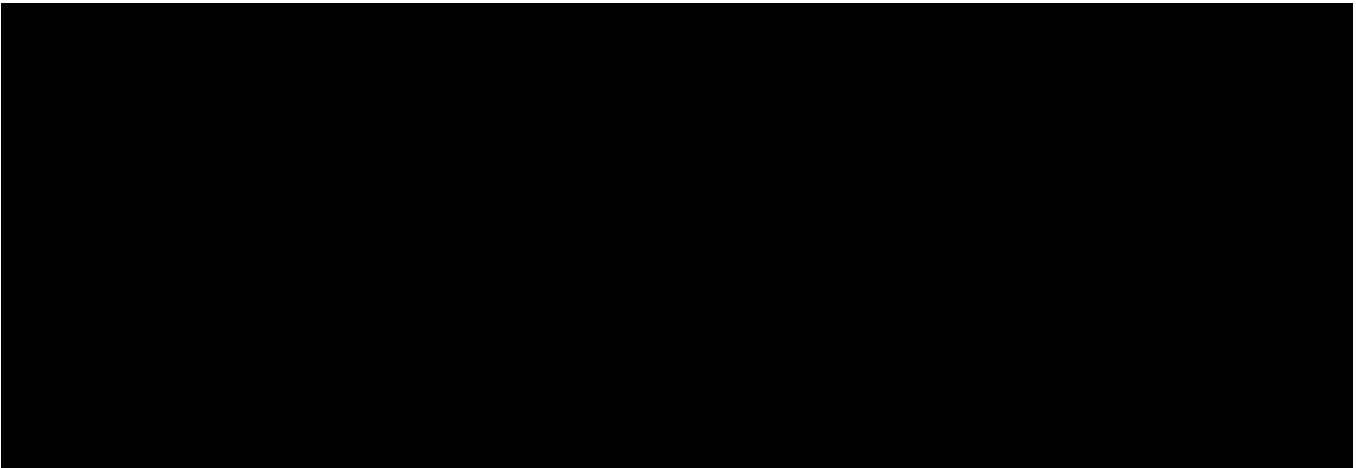


8.0 DAMPERS & AFS

In addition to repairing any conductor damages, the mitigation measure for aeolian vibration and galloping consists of PLP special dampers and Air Flow Spoilers (Refer Appendix F). L8004 Canso strait crossing which is located adjacent to the^{L7005} crossing did not experience similar issues due to severe galloping. This was due to the installation of air flow spoilers to the phase conductors on L8004. This prevented galloping and is a convenient reference/benchmark as this mitigated L8004 crossing has been satisfactorily in service.

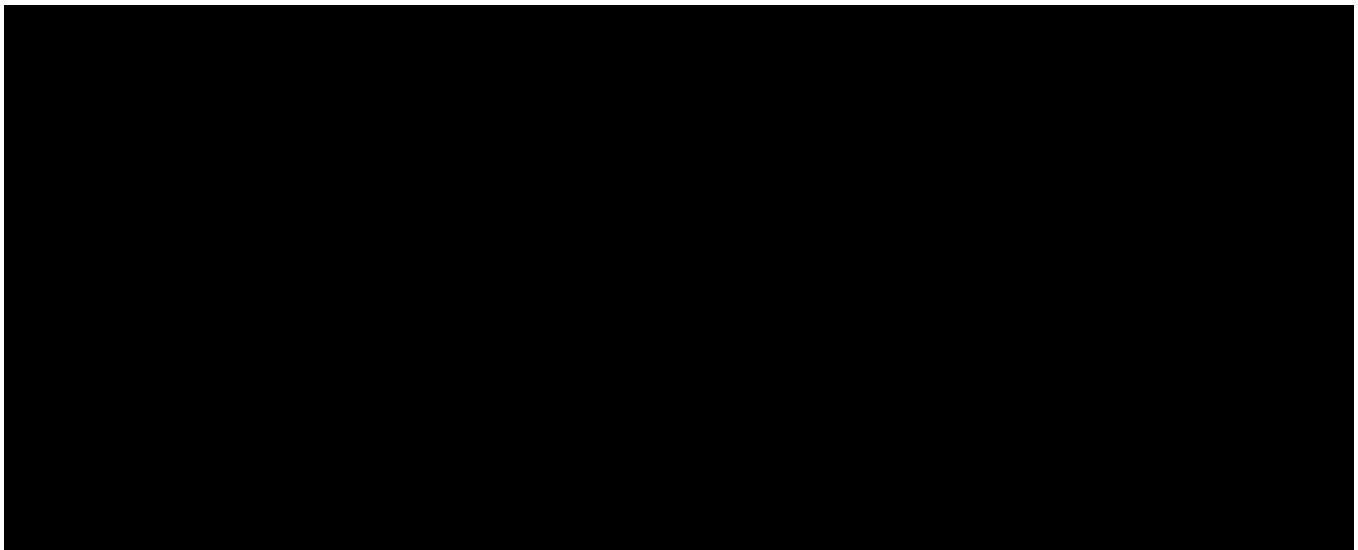
NSPI has engaged Kinectrics Inc. to complete Damper characteristic and Damper fatigue tests and provide a detailed test report summarizing the results and comparison to original Salvi dampers. The required dampers to complete the testing have already been provided to Kinectrics. As per Dr. Havard's report [0], the damper testing on the new dampers has to be carried out for the full range of frequencies that can actually occur on the line including frequencies as low as 3.8 Hz. The testing procedure by Kinectrics for testing the new PLP dampers covers an expanded range of frequencies including 3.8 Hz.

To facilitate PLP to produce an updated damper placement chart, NSPI provided them with the locations of conductor repairs closest to suspension clamps (see table below). This is so that the 1st group of dampers closest to the suspension clamp can be placed sufficiently away from the repair location. Also, in one location, the repairs are very close to the suspension clamp (8'), hence, the special longer armor rod is required to be used. The updated AFS placement and Damper placement charts can be found in Appendix J and K.



Based on discussions with PLP, the following requirements were established for placement of the dampers and AFS:

- The updated placement chart for the dampers shall be utilized by the crew when installing the dampers. If there is any additional conductor damage in the location identified, the entire group of dampers shall be placed away from that location. The group of dampers shall be moved together and dampers within a group shall not be separated. The updated placement chart from PLP will include additional guidelines for this scenario.
- For AFS, the requirement is that a certain percentage of the total conductor length has to be covered and the AFS have to be evenly distributed along the span. PLP will provide guidelines on allowable tolerances for number of AFS per span if during installation, it becomes impossible to accommodate all the identified number of AFS within that span based on the wire lengths.



10.0 TOWER ASSESSMENT

Due to the additional weight of the proposed dampers and AFS, the impact on the towers, foundations and insulator assemblies needs to be studied. NSPI has engaged CIMA+ to complete this study as part of their tower assessment. The additional vertical loads on the towers were calculated as shown in the table below. This exercise is only required to be completed for the suspension towers 730 and 731 as there are no major impacts on the dead-end towers due to the

additional weight of the AFS and dampers. Based on the study, it was concluded that the towers can accommodate the additional vertical loads introduced by the dampers and AFS without compromising structural integrity. Minor increases in member utilization and foundation loads were noted and are within acceptable limits. Refer Appendix L for the study report from CIMA+.

This study in addition to the climbing inspection that was recently completed are efforts to ensure the towers are in good condition to support the additional weights of the AFS/Dampers and conductor cart.

11.0 EXECUTION PLANNING

- Conductor cart work method, project emergency plan and conductor cart rescue procedure.
- Test trial of the cart work.
- Fit checks of AFS, dampers, armor rods and suspension clamps prior to execution.
- Outage coordination with ECC.

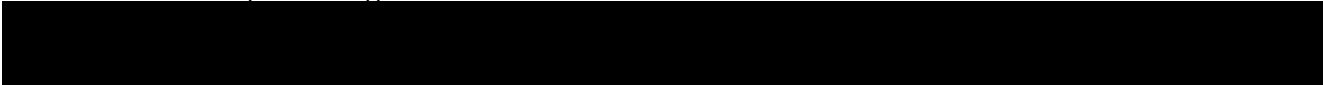
12.0 NEXT STEPS

- Share damage repair procedure (as detailed in Section 5.0).
- Share updated damper and AFS placement charts.
- Procure cold galvanizing spray.
- Procure gritted inhibitor grease.
- Coordinate vibration and galloping monitoring device (PLP AEOLUS) procurement, installation and schedule. These devices are planned to be installed at the same time as the AFS and dampers when the crew is on the cart. A cost comparison was conducted to determine the optimal solution for monitoring devices from what is available in the market, and it was concluded to proceed with the PLP AEOLUS devices (Refer Appendix M for

Rev1. Sep. 2024
Page 12 of 27

details).

- Coordinate and review tower assessment/assembly checks report from CIMA+.
- Coordinate interim work permit on the water crossing with Ron Parker due to reduction in vertical clearance. An interim permit drawing has been created and provided for this purpose.
- Investigate mitigation measures (if required) based on the tower climbing inspection findings.
- Witness damper testing on Oct 3rd at Kinectrics Labs in Ontario.

- 
- Post-repair / post-installation summary report of findings.
 - As-built survey of the crossing upon completion of the required work to produce an updated crossing permit drawing for submission to Transport Canada for approval.
 - Once the repairs are completed, AFS and special dampers are installed, it would be recommended to employ a line robot type device that can be deployed on the conductor to further assess if there are any loss of galvanization or corrosion to the steel strands. NSPI Transmission Engineering is currently in discussions with NUCLEOM with respect to their LineCore devices.

13.0 CONCLUSIONS & RECOMMENDATIONS

- NSPI Transmission Engineering reviewed all existing assessments, inspections, correspondences to date completed internally and externally by industry experts.
- Further required analysis and assessment on conductor and towers were performed to determine the impact of the reported conductor damages and additional weights of AFS and dampers.
- Upon a comprehensive review of all the information, it is recommended to install the required AFS and dampers, and any outstanding conductor damages be repaired.
- The calculations to estimate the residual strength of the conductor with the current and expected damages, as well as installation of AFS and dampers were completed.
- Based on the available residual conductor strength, the installation of vibration and galloping mitigation devices are recommended.
- The risks associated with applying the mitigation and monitoring far outweigh the risks associated with leaving this long crossing unprotected against vibration and galloping.
- Similar mitigation measures were applied to an equivalent L8004 span located adjacent to the L7005 span and were found adequate to protect the long crossing span against vibration and galloping.

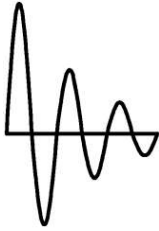
Rev1. Sep. 2024
Page 13 of 27

14.0 APPENDICES

**Rev1. Sep. 2024
Page 14 of 27**

APPENDIX 0 – DR. HAVARD REPORT 2021

Canso Strait 230 kV Crossing Assessment



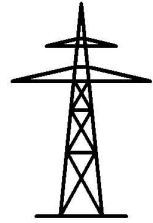
HAVARD ENGINEERING INC.

3142 Lindenlea Drive, Mississauga, Ontario, Canada, L5C 2C2

Telephone: (905) 273-3076

<http://www.havardengineering.com>

E-mail: dhavard@rogers.com



To: Balraj Bilkhu, P.Eng.,
Sr. T-Lines Engineer
Nova Scotia Power
T: 902-471-4849
balraj.bilkhu@nspower.ca

DRAFT
INTERIM REPORT No. 1
FOR NOVA SCOTIA POWER
ASSESSMENT OF THE 230 kV CANSO STRAIT CROSSING
By

David G Havard Ph.D., P.Eng.
President, Havard Engineering Inc.
3142 Lindenlea Drive.,
Mississauga, Ontario, Canada, L5C 2C2

EXECUTIVE SUMMARY

David G. Havard, Ph.D., P.Eng.,
President, Havard Engineering Inc.
October, 2021

Canso Strait 230 kV Crossing Assessment

1. INTRODUCTION

The 345 kV crossing of the Canso Strait is the second crossing span and was built in 2017. Figure 1 shows the plan of the crossing including the new towers. Initial operation is at 230 kV, but the line was designed for ultimate use at 345 kV. The location is across a narrow waterway between the mainland of Nova Scotia and Cape Breton Island. Damage to the main conductor during the first years of service is severe and attributed to the limited capability of the design to control wind induced vibrations. This interim report is intended to review the available data, and to propose short term and long-term corrective measures going forward.

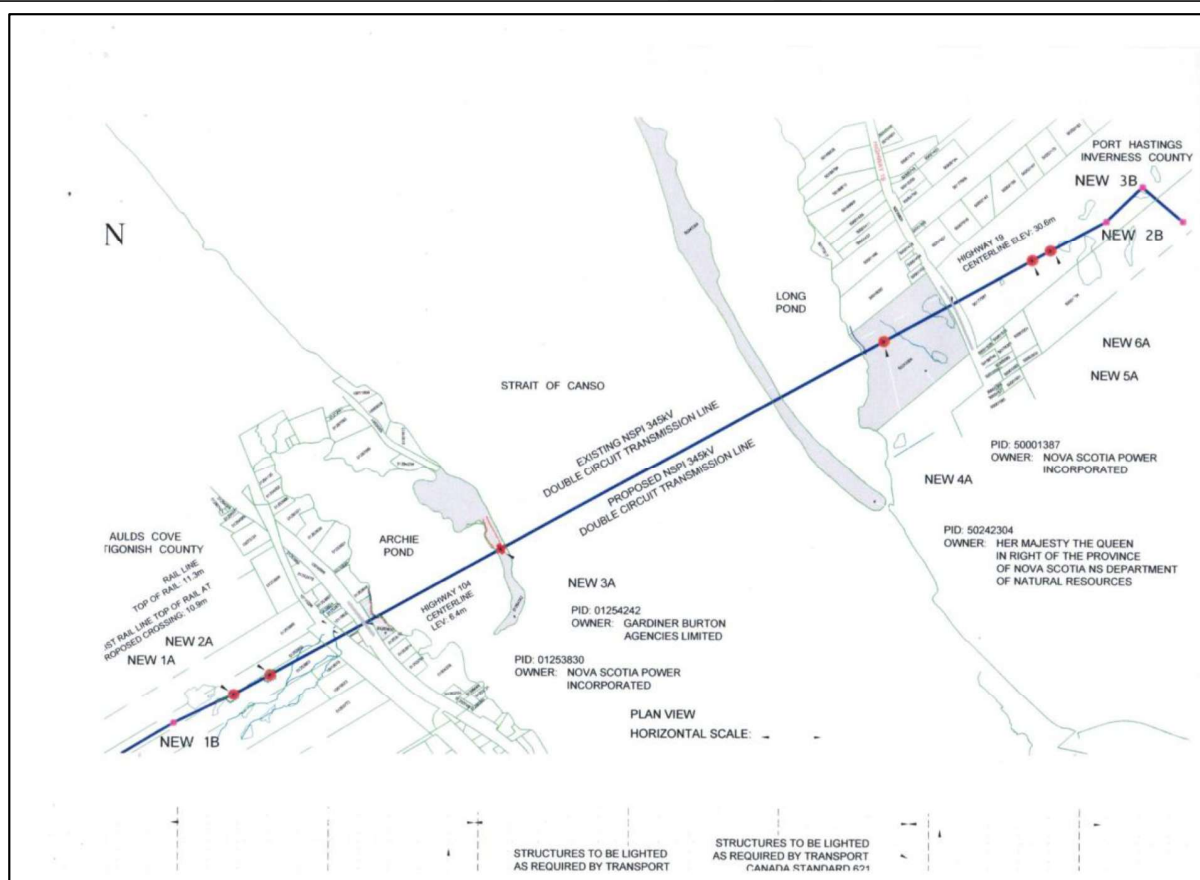
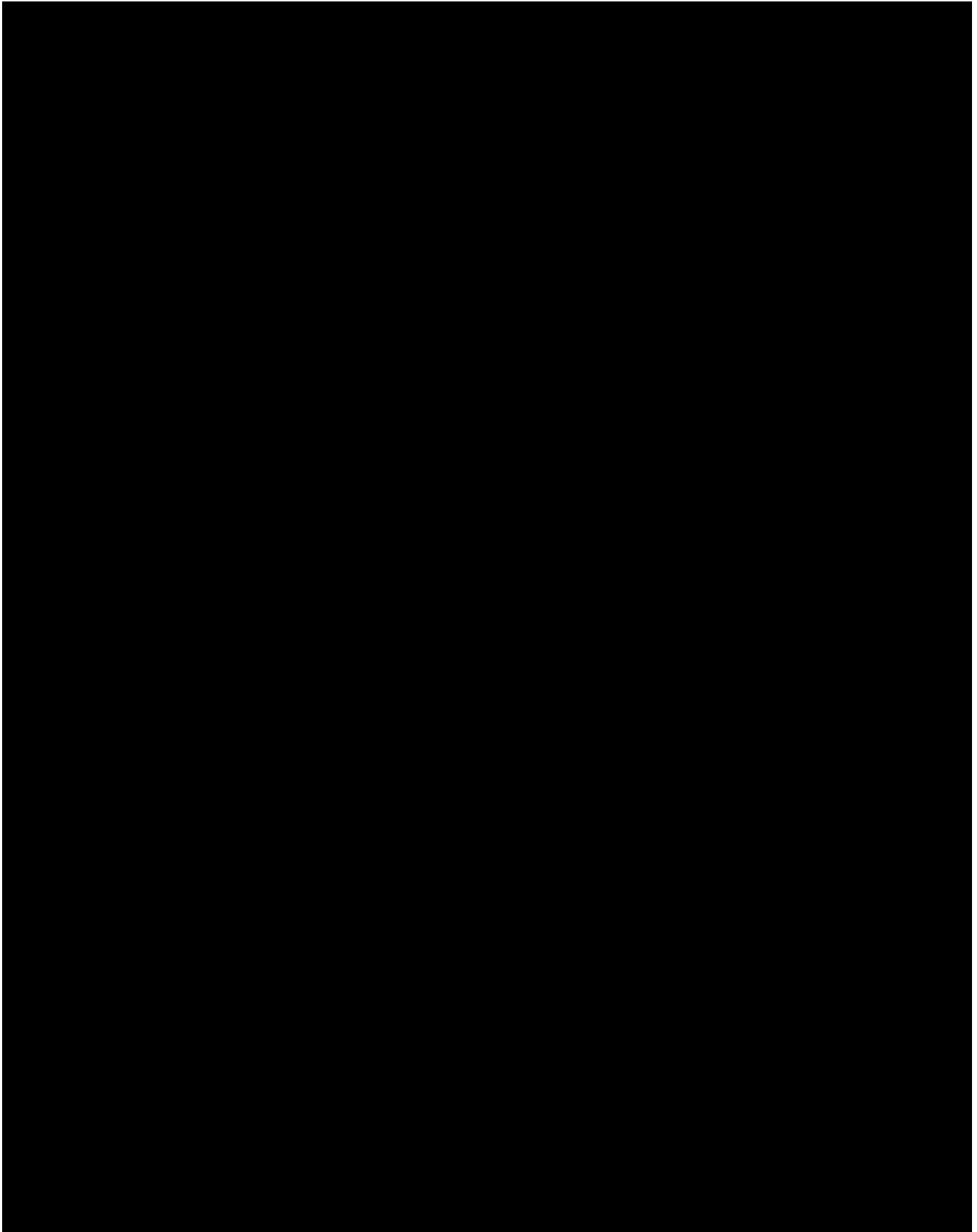


Figure 1 Plan of the new towers and 345 kV double circuit spans across the Strait of Canso

(Hatch file H349324-0000-70-012-0003 E V4.pdf)



Photos of the damper status in 2019

Photos of the damper status in 2021

A complete listing of these documents is provided in Appendix 1. That appendix summarized the contents of each document and the author's commentary of the impact on the reliability of the crossing.

Additional information provided verbally by Staff on Nova Scotia Power in a video conference call on October 5, 2021, was used in this report.

Certain information that would be expected but is missing from the information package includes:

- Report on the installation of the towers, conductor, insulators, and hardware.

- Record of maintenance and repairs to the line since construction.

- Reports of any service outages on the line.

- Test data on the SALVI damper showing the energy absorbed as a function of test frequency.

Other data relevant to this study, but missing, include the weather records for the past four years, particularly records of winter storms that would be expected to create build ups of ice or wet snow on the conductors.

2. WEATHER CONDITIONS & VIBRATION

The location of the crossing is noted for multiple winter storms with high winds, heavy snow and icing. The design requirements for the crossing reflect these weather conditions. Wind loads are up to 125 km/h winds, and ice loads up to a radial thickness of 60 mm. These weather loads are based on a 150-year return. (Hatch document H349324-00000-35-197-0001-001.pdf). But the various signs of damage now apparent on the crossing span and hardware are indicative of uncontrolled aeolian vibration or galloping. Aeolian vibration is caused by steady winds, not necessarily high winds, and this crossing is boldly exposed to channelled winds along the strait ideally suited to produce aeolian vibration.

Galloping occurs when there is a layer of ice or wet snow on the conductor, and it is driven by moderate to high winds. The severity of that motion increases with increase of wind speed. Galloping typically occurs with thin ice layers, but when the deposit is made up of wet snow the accretion can be comparable to the conductor diameter. Dynamic loads due to galloping can be very high and are repeated hundreds of times during a winter storm. As much as two times the weight of the span including the ice has been recorded on suspension insulator strings (“Dynamic Loads on Transmission Line Structures During Galloping”, by D. G. Havard, IWAIS 2002, Brno, Czech Republic, 17-20 June 2002). Damage due to galloping affects the same locations in a line as aeolian vibration and it is very difficult to tell from the appearance of the damage which type of vibration or oscillation caused it.

A further effect of ice is to change the effective diameter of the conductor and increase the aeolian energy transfer, requiring enhanced damping for control, and also changes the frequency of the aeolian vibration to a lower range that is not controlled by dampers designed for bare conductors. This effect undermines the design requirement that damping be controlled by Stockbridge dampers, that are known to be ineffective at these lower vibration frequencies. (Hatch document H349324-00000-35-197-0001-001.pdf). Alternative types of damping need to be considered for the long-term protection of this crossing. Dampers for aeolian vibration do not protect against galloping motions and further control methods need to be introduced. Due to its length and thickness this span is outside the range of conductors for which galloping controls are normally available. But galloping controls must also be considered, with use of high strength interphase spacers being the most likely option.

Canso Strait 230 kV Crossing Assessment

Verbal information supplied by NSPI staff, indicated that the towers are very noisy. This is probably another manifestation of uncontrolled vibration or galloping or both, that has loosened tower bolts. It indicates one of the actions required following up this review, that is to tighten all bolts on the tower to prevent further deterioration, such a cracking of the tower members, especially those in the tower arms.

DRAFT

3. DAMPING DESIGN

The design of damping system for the crossing spans was contracted to the A. Salvi & C., Milano, Italy, and that company developed a six-damper scheme for each end of each of the main and back spans. (Canso-Strait 345kV project_Damper effectiveness study_DS612-16.pdf) The design was backed up by analysis using the ESANEM software and tested in an indoor span at Dervaux laboratories in France.

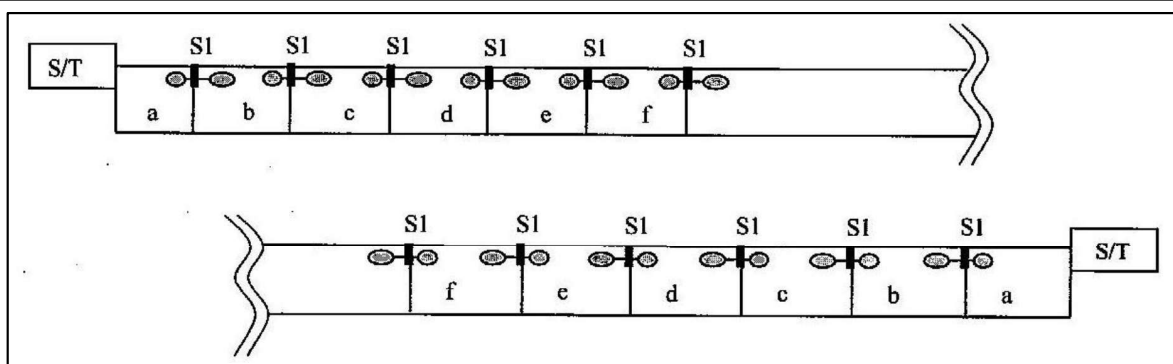


Figure 3 Array of 6 Salvi 4MS529VZ0952X vibration dampers on AACSR conductor for each end of the 1445 m Canso crossing span.

Dimensions: a 1.8m, b 2.0m, c 2.3m, d 1.5m, e 0.8m, f 1.3m

(Salvi document: Canso-Strait 345kV project_Damper effectiveness study_DS612-16.pdf)

But the document includes a detailed commentary by Professor Giorgio Diana explaining that the damping scheme would not be effective in a range of conditions. Notably this damping scheme would not be effective when there is significant, but for this location not unusual, ice on the line. His commentary suggests that it might be effective against aeolian vibration with ice up to 10 mm in radial thickness. He states that it would not be possible with current Stockbridge damper technology to protect against aeolian vibration with the specified maximum ice coating of 60 mm, due to the magnitude of the wind energy transferred being according to the fourth power of the effective diameter. The comment does not specifically identify that it would not protect against galloping motions. But this statement clearly warned against limitations of the damping scheme before the dampers were installed.

Canso Strait 230 kV Crossing Assessment

The damping scheme was replicated on the Dervaux indoor test span. The test is described in Dervaux' document PV20_17 Damper Efficiency Test on AACSR 900-510.pdf. Figure 4 shows the resulting comparison between the computed aeolian wind power transferred to the 1445 m length of conductor (with no ice), and the scaled energy absorbed by the six-damper array at each end of the span. The figure shows that the energy absorbed exceeds the wind energy applied over the test range.

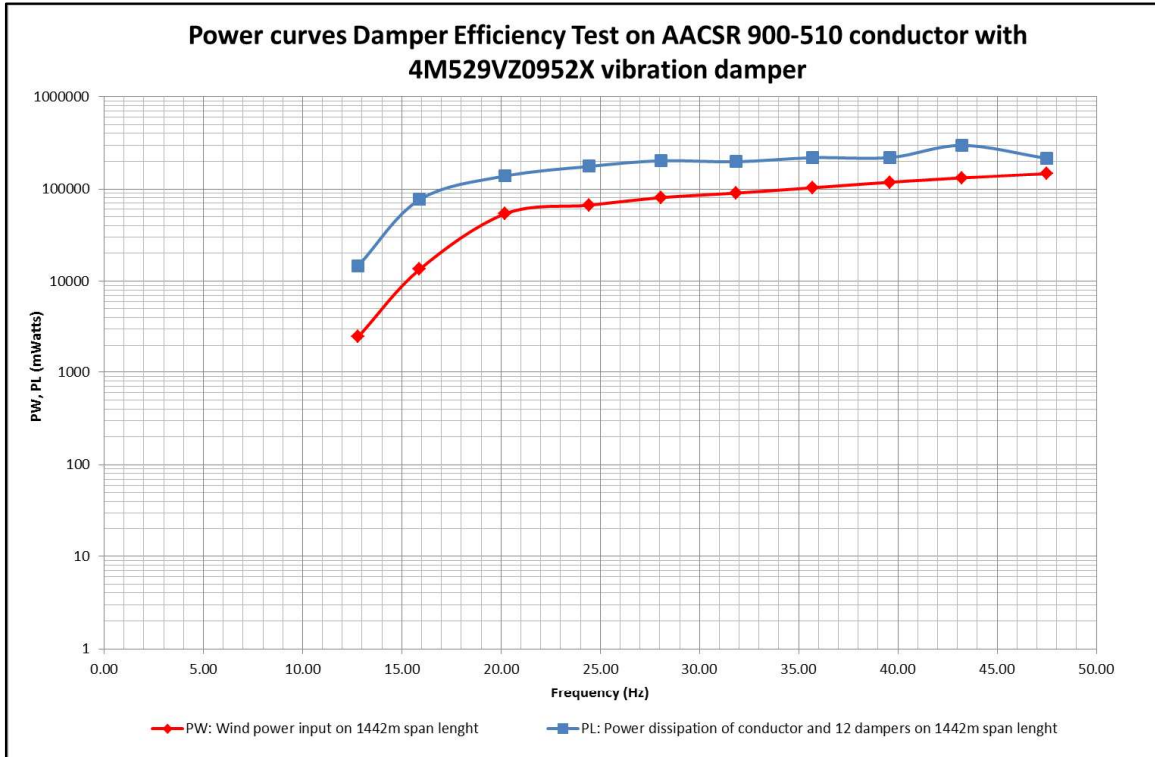


Figure 4 Power versus frequency for array of 6 Salvi 4MS529VZ0952X vibration dampers on AACSR conductor for the 1445 m Canso crossing span

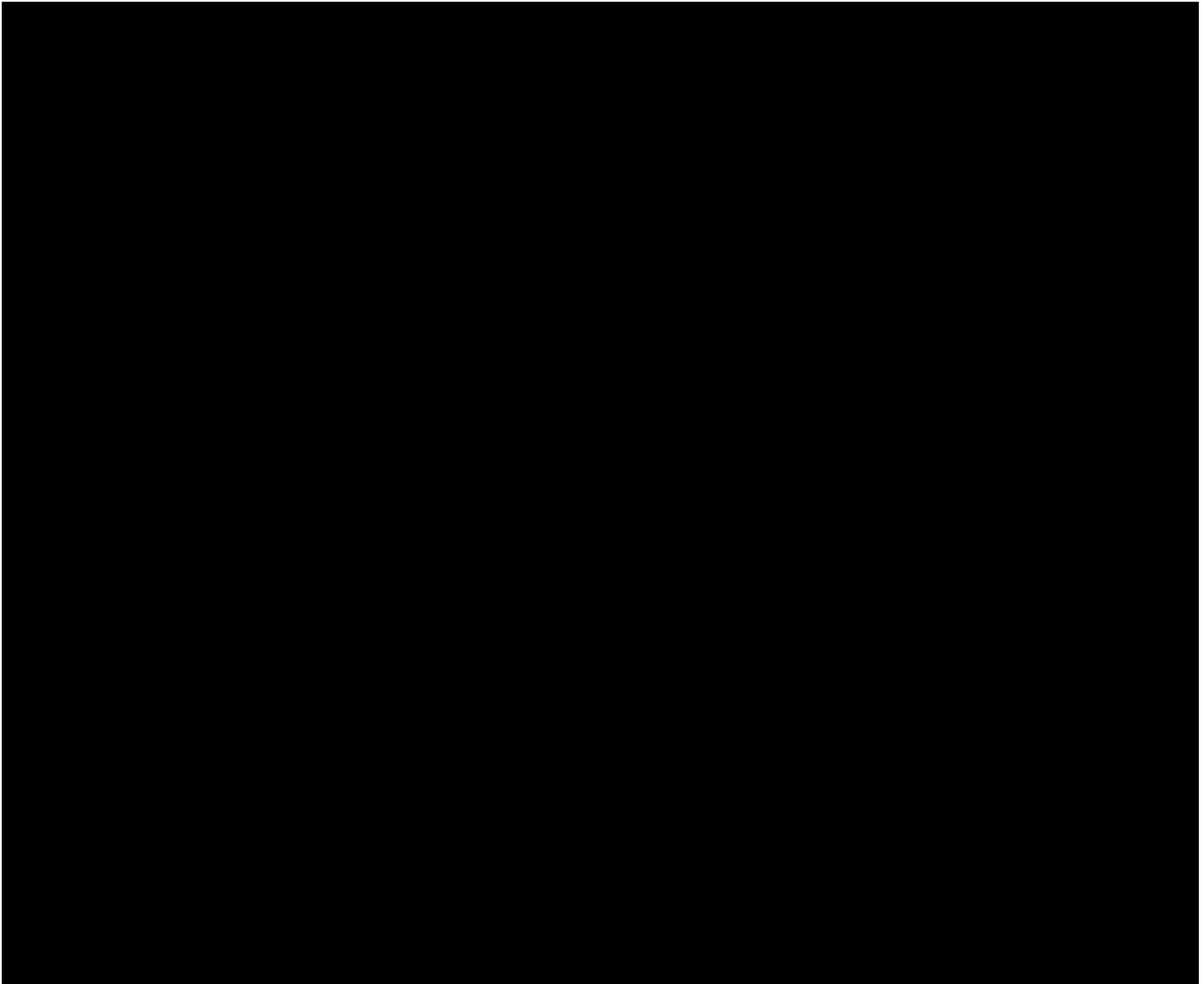
(Dervaux' document PV20_17 Damper Efficiency Test on AACSR 900-510.pdf)

But it must be noted that this is for the bare conductor, and the wind energy with an ice layer would be increased in proportion to the fourth power of the effective diameter, as explained by Professor Diana. Also, the test results are for the frequency range of 12.8 to 47.5 Hz. Aeolian vibration is due to steady winds in the 1 to 7 m/s range. For this diameter of conductor at 1 m/s wind speed the aeolian vibration occurs at 3.8 Hz. Thus, the tests of the damper array were not carried out in the full range of frequencies that can actually occur on the line, even for the bare conductor. In particular, the low frequencies between 12.8 Hz and below were not evaluated. Further, the energy

Canso Strait 230 kV Crossing Assessment

absorption curve for the individual damper included in the data provided. That is important to ensure that the dampers have the capability to absorb wind energy at these low vibration frequencies that can occur on this span.

DRAFT



The conductor was manufactured at ZTT Cable (Jiangsu Zhongtian Technology Co., Ltd) in China and proof testing was performed at ZTT's Nantong Test Centre. Testing was partially observed by a representative of Hatch who provided photos of the various test set ups. Individual tests of steel wires included, diameter, strength, elongation @1% strain, wrap test, coating adherence, mass of zinc were carried out during production and reported in H349324-RV-00007-CA01PDF Cover.pdf. Aluminum alloy wires were tested for diameter, tensile strength, elongation, and resistivity. All wires were within specifications. Material test on ingots of steel and aluminum alloy were also performed and found compliant. (ZTT documents: Chemical position analysis – Al Ingot.compressed.pdf, Completed Production Test.pdf, On-going Production Test.pdf, Steel core Incoming test.compressed.pdf). The complete conductor was tested for condition, diameter, mass,

lay ratio, breaking load, stress-strain and dc resistance test. The creep test on the full conductor was carried out at Shanghai electric cable research institute.

DRAFT

5. ALTERNATIVE DAMPING SCHEMES FOR AEOLIAN VIBRATION.

There are power lines crossing large bodies of water in several countries, many exposed to both channeled winds and accretion of ice or wet snow. Serious vibration problems have been widely experienced. An alternative technology for controlling their vibration was introduced by Ervik et al. (“Erection of and vibration protection on long fjord crossings in Norway” by M. Ervik, T. Horn and R. Johnsen, CIGRE Paper 23-03 1968). These are referred to as “festoon dampers”. Figure 6 shows a modern installation design for a 1.913 km fjord span in Greenland using the same methodology. The loops are constructed from the same conductor as the main span and attached to the main conductor using parallel groove clamps. Other applications have used armor grip suspension clamps for both the loop and main conductors. Some damping scheme designs use lengths of small conductor for the loops farthest from the supports. The selection of loop lengths is related to the positions of maximum amplitude of vibration at the various aeolian frequencies so that the loops are vibrated by the main conductor motion and the internal damping of the loops reduces the motion amplitude. While the procedure is not formalized in a published procedure, Statnett, the Norwegian power utility, provided guidance for the example shown in Figure 6.

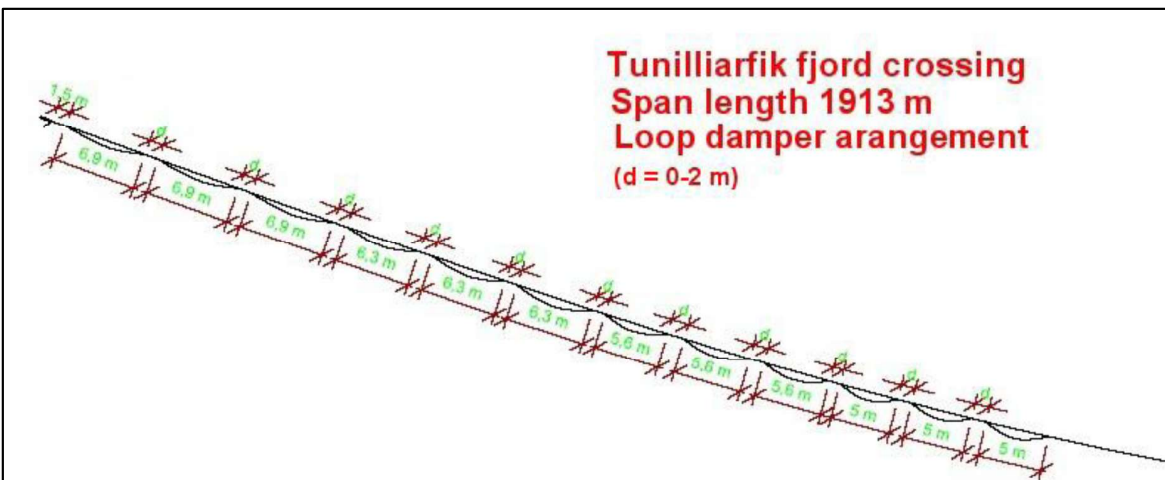


Figure 6 Loop Dampers Installed at each end of the Tunilliarfik Fjord crossing.

Total Length of Loop Dampers is about 84 m

Canso Strait 230 kV Crossing Assessment

ZTT cable was critical of the SALVI damping scheme, and also of the design of the end fitting for the main conductor, before the crossing was erected (About Canso Crossing – 200170203 .docx “Some questions and concerns about 345 kV overhead transmission line Strait of Canso crossing”) The outlined their check of fittings and damper design by Salvi from ZTT and state that the string fittings were comparable to ZTT practice but the tension clamp design and the damping scheme were different. In their opinion, the damping scheme with 6 SALVI dampers per end has long term risks, especially with ice present. ZTT offered an alternative damping scheme with dampers plus damping wire loops. This is shown in Figure 7. The report cites a previous failure of a Yangtse river crossing with a Salvi designed damping scheme.

It also questions the design of the tension clamp and suggests testing before use. There was a failure of the conductor at the dead-end during construction, and while Salvi did redesign the dead end, it is not clear which version was installed at the time.

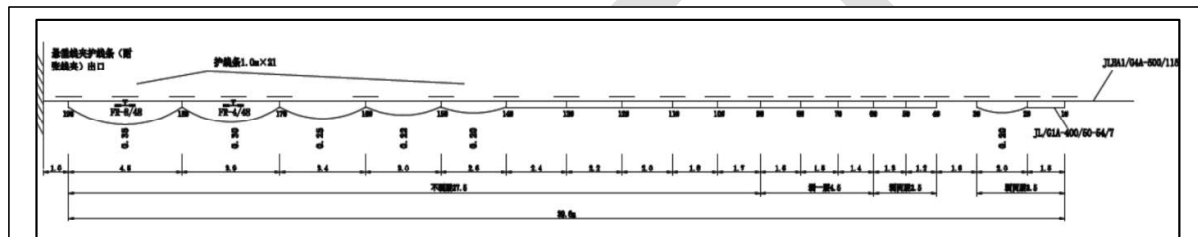


Figure 7 Diagram of combined loop dampers and Stockbridge dampers from ZTT
(ZTT document About Canso Crossing – 20170203.docx)

6. Control of Galloping

6.1 Interphase Spacers

The summarizing statement in the State-of-the-Art report published by CIGRE in 2007 is: “*No control method can guarantee it will prevent galloping under all conditions*”. (CIGRE Technical Brochure No. 322 “State of the Art Conductor Galloping” B2.11.06, 2007, p83). However, several control devices can reduce amplitudes of galloping, and the corresponding dynamic loads on the conductors, hardware, insulators and structures, to acceptably lower levels. Interphase spacers for use in heavy icing locations were tested at Hydro Quebec (“Design and validation of an interphase space for twin bundles”, Fourth International Conference on Cable Dynamics, Montreal, Canada, 2001, by P. van Dyke, M. Hamel, G. Desrochers, P. Guilbault and A. Laneville). The tests were carried out to determine the spacer’s strength needed to withstand the forces applied during artificially induced severe galloping. There were four spacers in each of

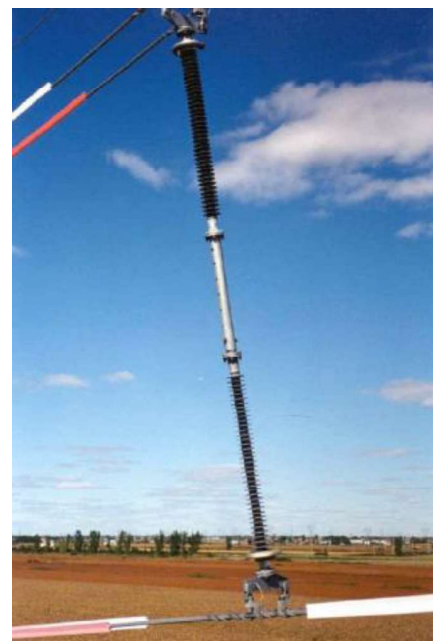


Figure 8 interphase spacer for Hydro Quebec Power lines

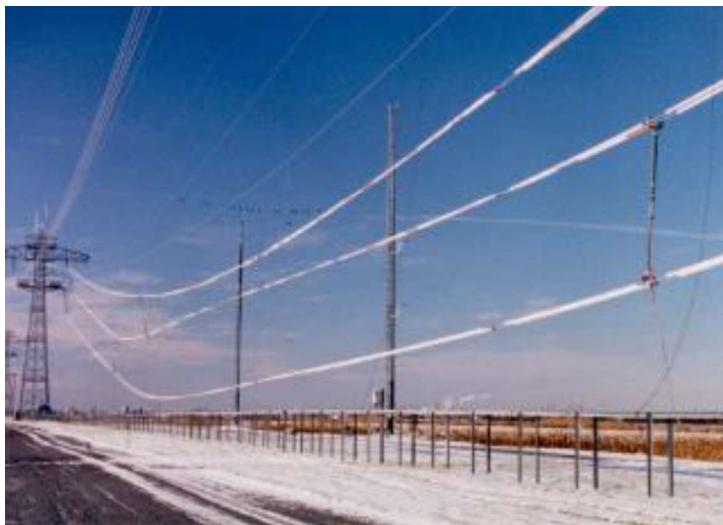


Figure 9 Hydro Quebec outdoor test line with four interphase spacers in the span during galloping.

the three full sized test spans, and the circuit was vertically aligned. But the principle is ready adaptable to the long span and delta configuration of the Canso crossing spans. Figures 8 and 9 shows one of the interphase spacers and the span configuration at the Hydro Quebec outdoor test site.

6.2 Detuning Pendulums

Detuning pendulums are weights attached to the conductor, either single or bundle, at a prescribed arm length to impose a torsional rotation on the conductor that is different from the normal wind driven torsional motion seen during galloping. This torsional motion interferes with the resonance between vertical oscillation and torsional motion that is a natural component of galloping of overhead conductors. In the normal range of span lengths and diameter encountered on overhead transmission lines, their effectiveness is well established

based on extensive field evaluations during naturally occurring galloping events. They have given usable reductions in galloping amplitude on a wide range of “normal” single and bundle overhead conductors, but this application is well beyond the range of span length for which relevant data and experience are available.

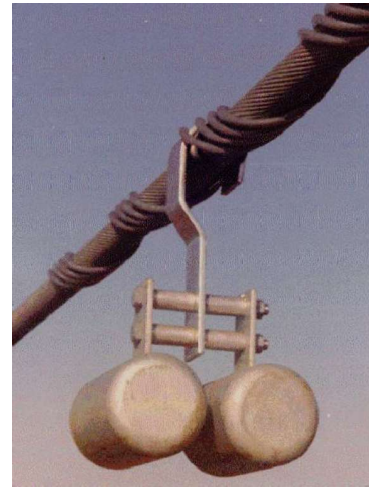


Figure 10 Detuning pendulum

6.3 Air flow spoilers

Air flow spoilers are a wrap of PVC rod designed to modify the flow of the wind around the conductor to break up coordinated eddies from vortex shedding, in a similar fashion to strakes of a vertical chimney. They are most suited for small single conductors, such as overhead ground wires and distribution lines. They are installed in two clusters at the one quarter and three-quarter

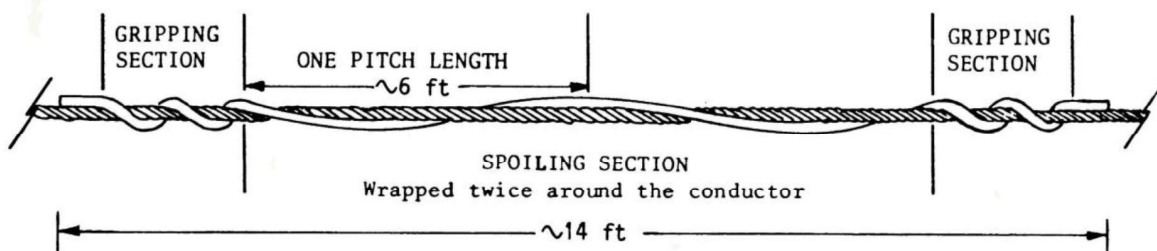
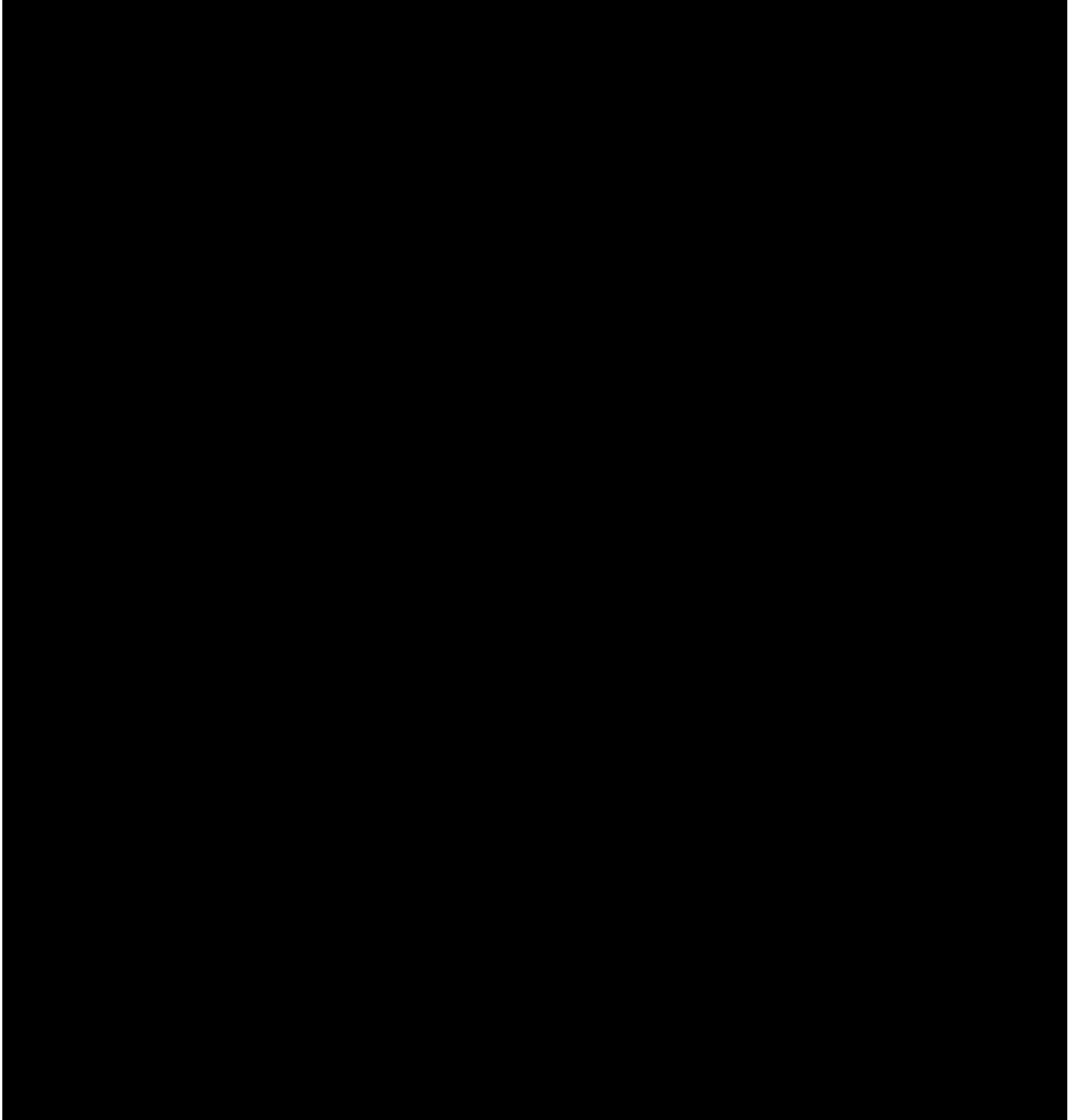
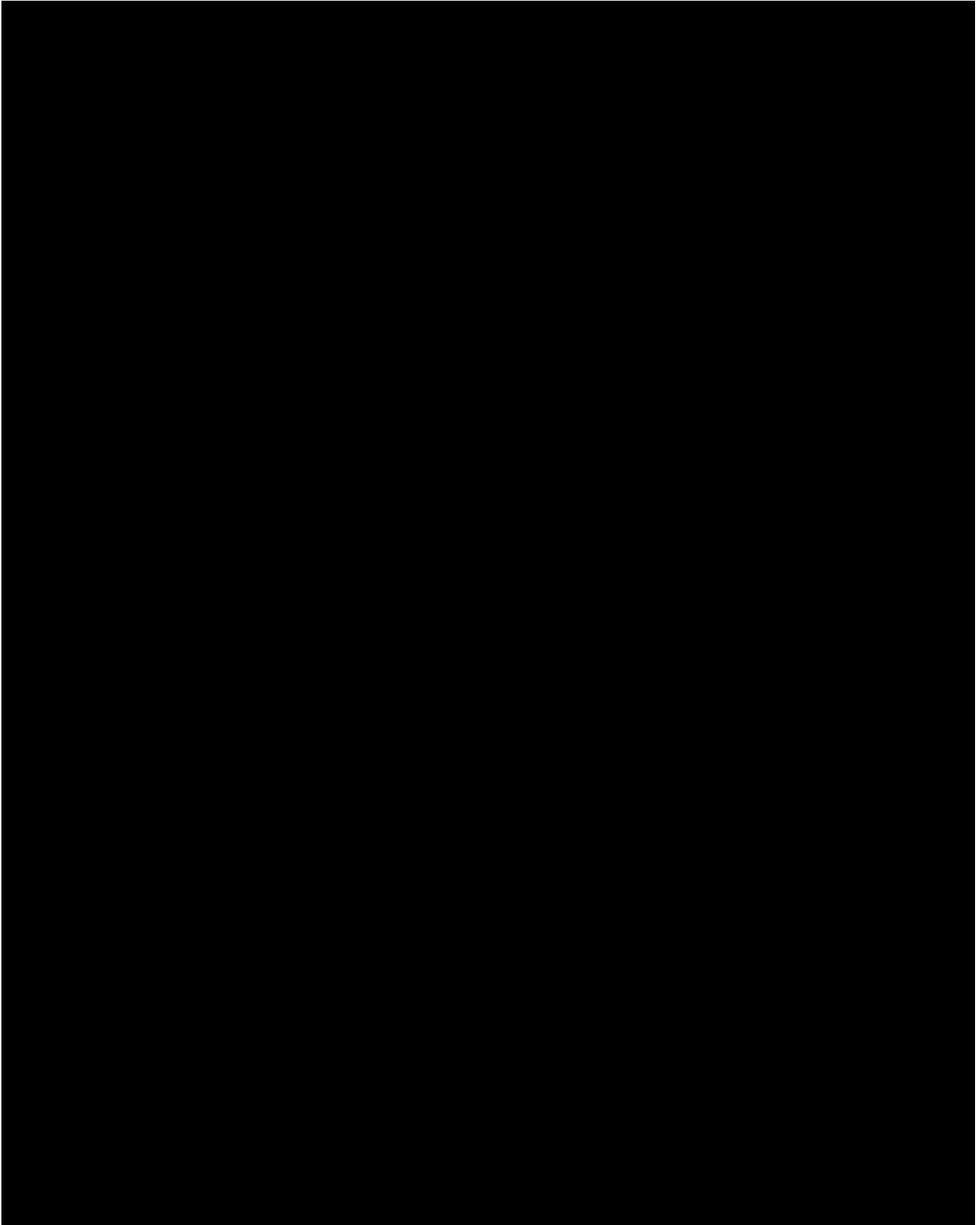


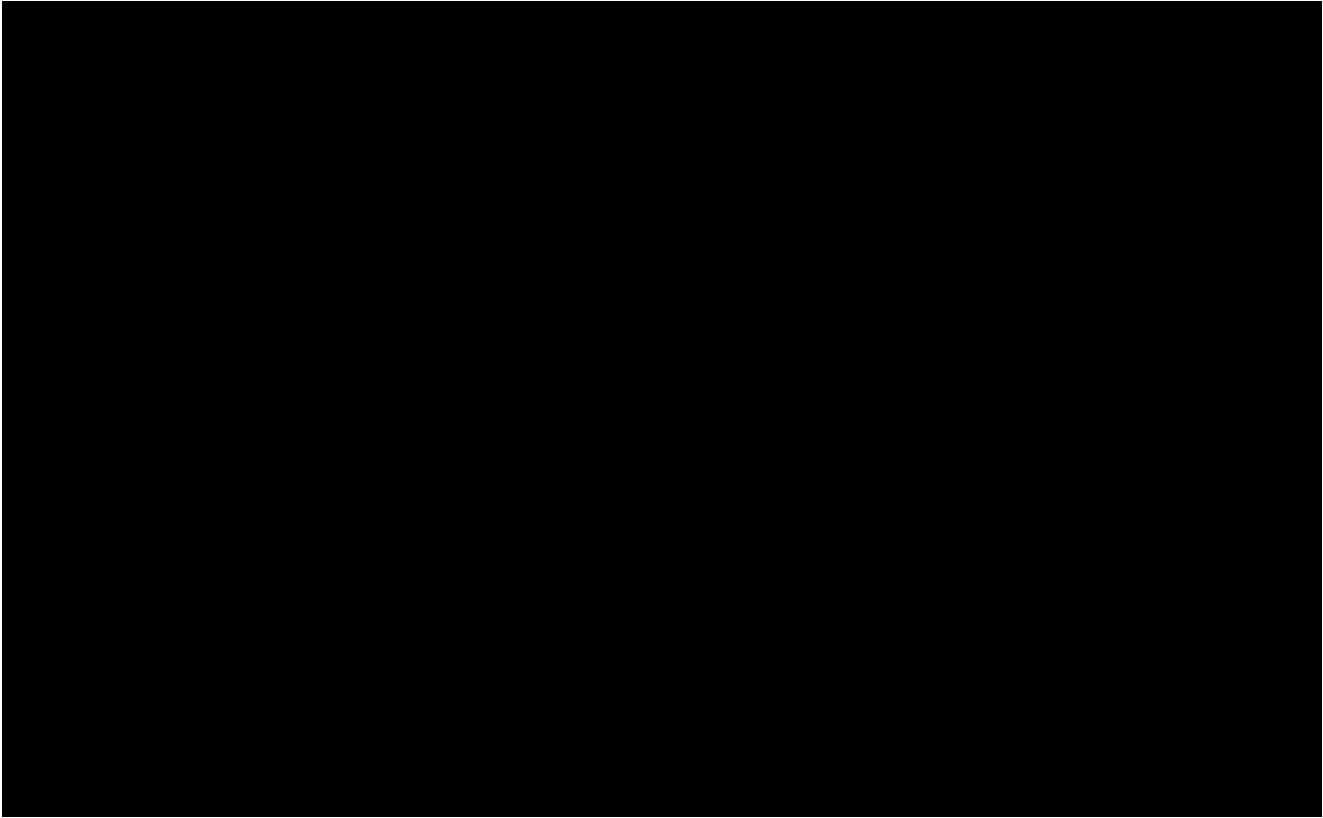
Figure 11 Air flow spoiler

points in the span. Each cluster covers one quarter of the span length. In field trials carried out in the 1980s, they were shown to provide good control of galloping up to ice or wet snow coverage less than about 25 mm (1 inch). [Whapham 1982]. Air flow spoilers were used on the first crossing span to overcome severe galloping motions.

DRAFT







INSIGHTS FROM THE FIRST CROSSING SPAN

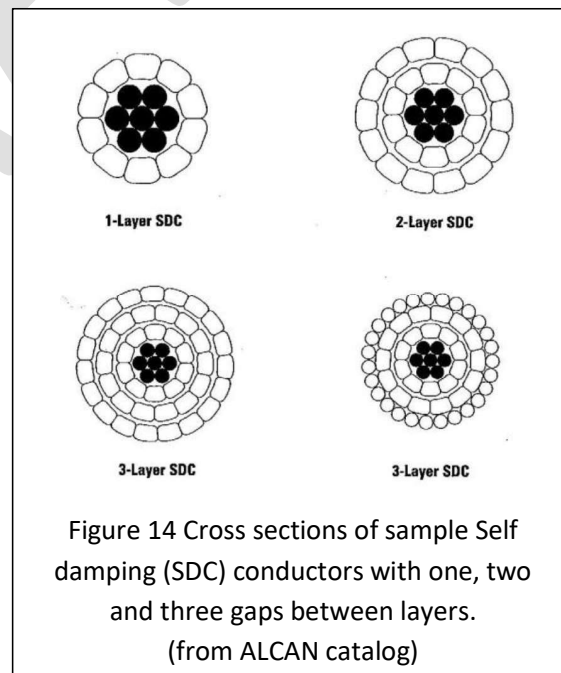
The following is based on discussions with Balraj Bilju of NSPI and a paper from the Havard Engineering archives entitled: "Experience at the Strait of Canso Crossing in Nova Scotia", by Robert Whapham, presented to the CIGRE Task Force on Galloping, Cleveland Ohio, USA, in September 1987. Further details of the damage and remediation of the first crossing were received later.

The first crossing span was completed by the Nova Scotia Power Company in September 1983. One circuit is designed for 230 kV and the other for 345 kV. The main span is 1455m (4770 ft) in length, and the back spans are 1105 and 635 m (3300 and 2083 ft). The conductor is a 43mm diameter, high strength, smooth body, self-damping conductor with two gaps between layers. It was strung at the unusually high tension of 40% of rated tensile strength to keep the towers to an acceptable height. Initial experience included large horizontal and vertical motions of the conductor and flashovers between phases. The self-damping properties of the conductor, that is through impacts between the different layers of the conductor, were not sufficient to control conductor the motions in response to the wind energy at the location. Figure 14 shows examples of the self-damping conductor. Note that there will be a proportionately greater area of steel in the crossing conductor. Other data on the properties of the self-damping conductor [Edwards and Livingston 1968] indicated that it had very good control of the high frequency vibrations due to aeolian wind excitation, but it did not have the same capability to control the lowest frequencies of oscillation such as due to conductor galloping.

Weather records of the period December 1983 to May 1984 showed 50 days in which there were freezing temperatures and rain or snow precipitation. Winds at Port Hasting were about 60% higher than at Eddy Point, the difference attributed to the channeling effect of winds along the strait between the 150 m high cliff each side.

In response to the uncontrolled vibration a study of the aerodynamic benefits of air flow spoilers was undertaken using a wind tunnel. The severe motions had been attributed to either the sudden drop in drag at higher wind speeds, or to galloping instability resulting from a layer of ice on the conductor. The addition of half-length of a $\frac{3}{4}$ inch (19 mm) diameter spoiler to a simulated conductor in the wind tunnel was found to reduce

the drop in drag. This led to the conclusion that the phase-to-phase contacts were the results of violent galloping. Prior field trials had shown the ability of the air flow spoilers to reduce the



motions of galloping on small distribution conductors with coverage of one quarter of the span length at each of the one quarter and three-quarter points in the span. For this crossing span

Whapham 1987 reports that 100 spoilers were installed on each conductor. A later Nova Scotia Power document dated 2011 showed removal of original air flow spoilers and adding 171 on one circuit and 161 on the other, distributed over the main and both back spans. All spoilers were installed over the middle 60 percent of each span.

At the time of this publication, based on three years' experience, with no reported flashovers, the motions were considered to be successfully controlled.

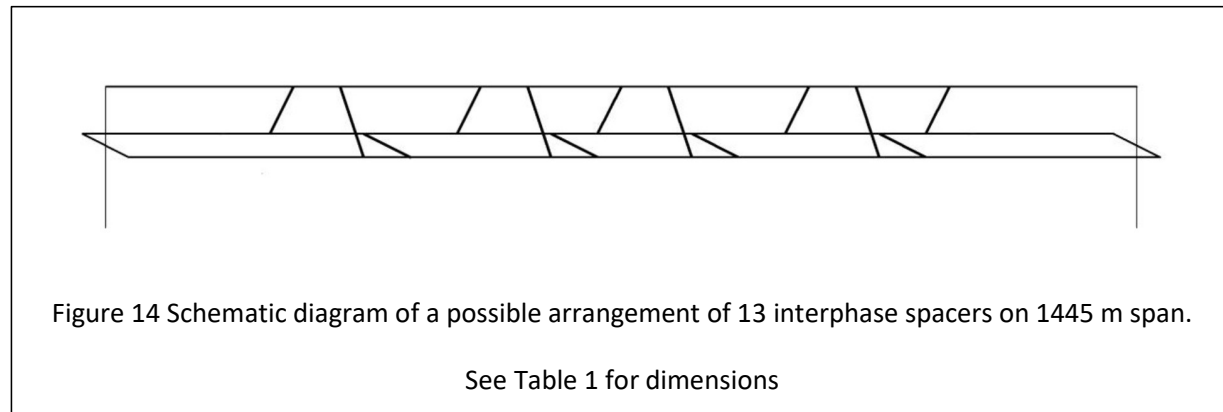
Further data from the first crossing span failure showed that the galloping motions had caused burns of conductors that were on different circuits. The burns and damage positions were at close to the middle of the span. The damage locations were separated by 16 m horizontally and 13 m vertically. The diagonal distance between the damaged conductors was 21m.

For comparison the second crossing tower design has vertical phase separations of 14.5 m and horizontal separations of 19 and 22.3 m. That is a little greater than the first crossing, but still susceptible to the same type of damage from contact between phases during severe galloping. Some form of galloping mitigation is required, the air flow spoilers on all three spans being the most suited, but interphase spacers can be an alternative, and using both airflow spoilers and interphase spacers together will give the most security.

Canso Strait 230 kV Crossing Assessment

GALLOPING CONTROL SOLUTION

Based on this background, a combination of airflow spoilers and interphase spacers may be the best option for an add-on solution for the current problem span. There should be more than normal number of interphase spacers across the span. As a first estimate we can note that the application in Hydro Quebec shown in Figure 9 has 4 interphase spacers in a span of 450m. Pro rating this to



the 1445 m span leads to a minimum of 13 interphase spacers per circuit. A suitable spacing will be an uneven spacing to avoid matching frequencies of oscillation between adjacent span between interphase spacers. Also, it must be noted that this will require some horizontal interphase spacers.

A possible spacing plan using 15 spacers is shown in Figure 14.

Table 1 suggested dimensions for 13 interphase spacers in 1445 m span						
	End to first interphase spacer	First to second interphase spacer	Second to third interphase spacer	Third to fourth interphase spacer	Fourth to end or fifth interphase spacer	Fifth interphase spacer to end
between top and bottom near phase m	262.7	262.7	197.0	262.7	328.4	-
between top and bottom far phase m	197.0	262.7	197.0	262.7	197.0	262.7
between near and far bottom phases m	328.4	262.7	197.0	262.7	262.7	-

The spacing ratios are based on 1/25 of span length: between top and near bottom phase: 5:4:3: 4:6, between top and far bottom phase: 3:4:3: 4:3:4, and between bottom phases: 6:4:3: 4:5.

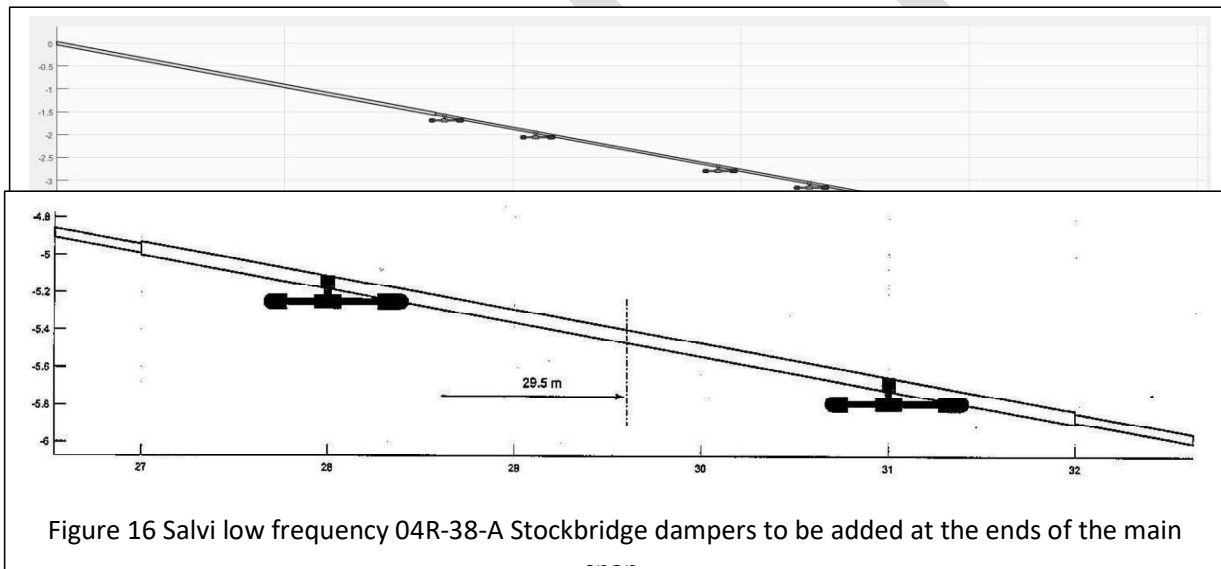
Air flow spoiler coverage should be more than that of the first crossing to compensate for the lack of impact damping in the new conductor.

DRAFT

NEW SALVI DAMPING SCHEME

Salvi have offered another damping solution based on Stockbridge dampers, including some with low frequency capabilities, but this still falls short of damping conductor motions in the really low frequency range, such as occurs during galloping. It is presented for two scenarios: firstly, for aeolian vibration with a 10 m radial ice layer. For this Salvi recommends eight dampers at each end of the span, Figure , plus two low frequency dampers over arm rods and outboard of the array, centered at 29.5 m from the end clamps Figure . Secondly, for an ice layer of 15 mm of radial ice the same damping scheme would be supplemented by replicating the array of six dampers placed at mid span.

However, it is quite possible that even thicker ice layers can occur, and these will further increase the aeolian wind power, requiring more damping to control the dynamic stress to level lower than the endurance limit of the aluminum alloy conductor.



The concern about this is that the likelihood of galloping occurring is not considered. Past experience has not been good with the low frequency Stockbridge dampers. These rely on longer messenger cables to provide the lower frequency response, and those cable can be overstressed by the even lower frequency motions due to galloping. This has caused fatigue failure of the messenger wires.

Additionally, reviewing the state of the SALVI dampers during inspection in 2021, there appears to be a problem with clamping of the dampers. The dampers do not appear seriously impaired but have slipped on the conductor. Whether this is the effect of the clamps vibrating loose, or if the split nuts used to control the clamping force were not functioning properly, or there is an issue with the tolerances between the inner and outer threads of the clamp bolts, or some other problem, is not clear. But the new dampers need to have better control of the clamping forces.



Figure 17 Low frequency Stockbridge damper with messenger wires fatigued due to galloping.
(Havard Engineering In. Archive)

The air flow spoilers suggested above, do add damping to the span. A combination of Stockbridge, or other aeolian vibration dampers, interphase spacer and air flow spoilers may prove able to control both aeolian and galloping motions to non-damaging levels. But even than frequent monitoring will be necessary to stay abreast of any damage that occurs. For this, installing video cameras to continuously record the motions of all conductors from both ends of the line is recommended.

BACK SPAN CONCERNS

This discussion has focused only on the main span. Vibration of conductors such as experienced on this crossing is not limited to a single span. The motions are fed through the suspension clamps to the adjacent span that are in this case, the back spans. As a precaution those conductors, attachment hardware, and the dead-end structures at the ends, should be inspected for damage.

This employs

I hope that our discussion and the progress report was helpful for yesterday's meeting at NSPI.

You gave me several insights about the old Canso crossing in our discussions and I believe that its very good performance must be used to help improve that of the new crossing.

Can you send me the following items that we reviewed?

The photo(s) of the old crossing that show the airflow spoilers.

The cross section of the self damping conductor used in that crossing.

The drawing of the new low frequency damper offered in Salvi's new damping scheme.

Any other data on the new damper.

I found the new damping scheme offered by Salvi to be a step towards a more complete protection, but it falls short.

Salvi's new damping scheme is still limited in the range of frequencies that it will damp.

Canso Strait 230 kV Crossing Assessment

I anticipate that it will suffer from damper failures over the coming winter and further damage to the conductors, hardware and towers can be expected.

Have they done any fatigue tests of the low frequency damper?

I doubt that they will survive any galloping over the coming winter.

I would encourage you to look at applying airflow spoilers, similar to those on the old crossing, in addition to Salvi's dampers, before the winter closes in.

Strakes used on tall chimneys have a well established record of effectiveness for control of that particular type of wind driven motion.

I have participated in application of that approach to solve a problem with transmission line steel poles that were oscillating severely to the point of fatigue failure.

The strakes are similar to airflow spoilers and details of the spoiler installation would be most helpful.

Further to our discussion on Friday, I have located a paper that describes the background studies for the application of airflow spoilers to the first Canso strait crossing conductor.

"Experience at the Strait of Canso Crossing in Nova Scotia", by Robert Whapham, presentation to the CIGRE Task Force on Galloping, 1987

The paper includes an assessment of the weather at the crossing as well as wind tunnel modelling of the large conductor with the spoilers attached. Initially the conductor underwent large motions, likely galloping motions, showing that the self damping effect alone was not sufficient to suppress the motions.

It is quite possible that NSPI already has this paper, and the other paper included in the references (one that I do not have) "Design and installation of 345 kV Canso Crossing" by B.A. Mudge, Presented to Canadian Electrical Association, 1984.

As the conductor on that crossing is a self damping construction it should have been more stable in crosswinds than the current conductor, but even then the motions were of concern. So if air flow spoilers are considered for this one, they should be enhanced over the previous application. By enhanced I have in mind placing them in sets of three in parallel to provide the equivalent air flow

Canso Strait 230 kV Crossing Assessment

modification that is achieved in vertical chimneys by strakes. That concept would almost certainly need to be done in cooperation with PLP who make them and involve some wind tunnel evaluation.

On a second issue, a colleague in Norway has sent me the data on the line monitoring system that they have used for galloping assessments.

Please let me know if you are interested in these items and I will send them in electronic form.

As well as the drawing of the cross section of the self damping conductor used, and the recent photo showing the spoilers, if NSPI has other information on the first crossing that appears to be relevant please send it along.

Notes from Whapham paper of 1987

Construction completed Sept 1983

1445m span

230 kV 345 kV one circuit of each

**SD Conductor has smooth trapezoidal out strands, high strength, 43mm diameter 40%
rts@15C**

Two layer SDC

100 spoilers per phase 3/4 inch diameter,

Channeled winds between 150 m high cliffs

Vertical and horizontal motions

Galloping or drag droop effect

**Port Hastings winter weather with days of freezing temperature, rain and snow 50 days of
precipitation**

60% Higher wind at Port Hastings than at EDDY point

Flashovers -SDC did not control motions alone,

Wind tunnel study inconclusive

Dec 1984-May 1985

CONCLUSIONS

7. SHORT TERM RECOMMENDATIONS

- ❖ Review status of back spans – Add damping if damage is found
- ❖ Repair known damage to conductor with reinforcing layer
- ❖ Locate and install dampers for use over arm rods
- ❖ Inspect tower arm members for signs of cracking
- ❖ Tighten all loose tower bolts
- ❖ Design interphase spacer installation
- ❖ Arrange purchase of interphase spacers
- ❖ Set up video monitoring from both towers
- ❖ Establish regular patrols to monitor and report any changes of towers, conductor hardware, insulators etc.
- ❖ Inspect back span towers for degradation
- ❖ Obtain air flow spoilers
- ❖

8. INTERMEDIATE TERM RECOMMENDATIONS

- ❖ Get help from ZTTcable or Statnett to design alternative long term damping schemes for main span

- ❖ Consider damping needs of back spans
- ❖ Test alternative long term damping scheme(s) in laboratory
- ❖ Procure better suspension clamps
- ❖ Design and test damping to tower members if cracking is seen
- ❖ Based reports from line patrols develop plans to make appropriate repairs
- ❖ Test use of multiple air flow spoilers in parallel.

9. LONG TERM RECOMMENDATIONS

- ❖ Install long term damping scheme if tests are successful
- ❖ anticipate and repair further damage from 2021 install interphase spacers
- ❖ Change suspension clamps to better supports, maybe AGS or long saddle clamps.

10. REALLY LONG TERM CONSIDERATIONS (IF ALL ELSE FAILS)

- ❖ Replace conductor with twin or triple bundle with smaller subconductors
- ❖ Replace conductor with self-damping conductor
- ❖ Install connections for a snow and ice melting loop using both crossings, or two circuits
- ❖ Replace with under-sea cable

DRAFT

APPENDIX

Fundamental information about aeolian vibration of the long span.

This is a large conductor, (48.9 mm diameter) but if it is operated at 345 kV corona and radio interference can be expected. Typical lines for this voltage use bundle conductors to limit these effects.

To assess the damping scheme installed, we need to understand the range of frequencies for which it must provide protection. Aeolian vibration is caused by relatively laminar, or smooth, winds in the range of 1 to 7 m/s, (3.6 to 25 km/hr). The Strouhal relation describes the frequency of shedding of vortices for the conductor based on wind speed and diameter. These vortices are the source of the vertical aeolian vibration of the conductor

The frequency of vortex shedding is governed by the Strouhal relationship:

$$f_{vs} = S_N \left(\frac{V}{D} \right)$$

Where:

- f_{vs} = vortex shedding frequency (Hz)
- S_N = Strouhal number (0.185 for rough cylinders)
- V = wind velocity (m/s)
- D = conductor diameter (m)

The frequency range of aeolian vibration for this conductor is then between 3.8 and 26.5 Hz. The 1445 m span will be oscillating with a series of similar loops across its length. With 1 m/s wind there will be 51 loops each 28.3 m in length and with 7 m/s wind there will be 357 loops each 4 m in length.

When there is ice on the conductor the diameter becomes larger, and the aeolian vibration frequencies are shifted downwards. Also, the wind energy transfer and consequently amplitude of motion is increased. The table below gives the aeolian vibration parameters corresponding to the expected amounts of ice on the conductor.

1445 m CANSO CROSSING SPAN AEOLIAN VIBRATION PROPERTIES				
Radial Ice mm	Wind speed m/s	Vibration frequency Hz	Loop length m	No. of loops
0	1	3.8	28.3	51
0	7	26.5	4.0	357
5	1	3.1	34.1	42
5	7	22.0	4.87	297
10	1	2.7	39.9	36.2

Canso Strait 230 kV Crossing Assessment

10	7	18.8	5.70	254
15	1	2.3	45.7	31.6
15	7	16.4	6.52	221
20	1	2.1	51.4	28.1
20	7	14.6	7.35	197

Also increasing the diameter by adding ice magnifies the energy transferred from the wind to the conductor by the aeolian vibration, approximately as the fourth power of diameter. Thus, a damping scheme adequate for the uniced conductor is inadequate for the same conductor with a build-up of ice.

Alternative damping methods to conventional Stockbridge type dampers is required for such spans. An example of “festoon” or “loop” dampers used for along fiord crossing in Norway is included in the EPRI “Orange” book [1]. A photo of this type of damper is shown below. Loop dampers are attached to the conductor at positions in the span that are in motion and knowledge of the loop lengths for different wind speeds and ice thicknesses given in the table are needed for their design.

DRAFT

Canso Strait 230 kV Crossing Assessment

DRAFT

Canso Strait 230 kV Crossing Assessment

APPENDIX 1 DOCUMENT LIST			
DOCUMENT FILE NAME AND DATE	DOCUMENT TITLE AND AUTHOR	SUMMARY OF CONTENTS	AUTHOR'S COMMENTS
OVERALL DESIGN			
H349324-001-95-122-0001 – Design Bases.PDF 2016-02-12	Design Basis Document 345 kV Overhead Transmission Line Hatch	Criteria for materials, Electrical capability, Conductor tension, Tower loads clearances Details of three main and back spans conductors	Client approval block is not completed.
CLIMATE DATA			
20200820 Phase 2_ Phase2_Technical_report canso_final.pdf August 2020	Nova Scotia Power Inc.: Physical climate risk analysis - Phase 2 Technical Report Acclimatise, Oxford, U.K.	Broadly targeted study of climate risks for NSPI Assets. Focuses on long term changes due to global warming 100 critical sites on lines, substations and power stations. Includes two sites near the Canso crossing. Freezing rain projection not well discriminated as it is convoluted with snow amount.	Appears to provide a methodology for general use by NSPI. Not useful for the current problem

Canso Strait 230 kV Crossing Assessment

Climate management system (data files?)			Inaccessible format
CONDUCTOR TESTS AND REPORTS FROM SALVI, DERVAUX and ZTT			
H349324-0000-70-236-0001_A_V1.pdf 2016	Conductor Testing at ZTT Nantong Test Centre Hatch Report	Structure of conductor, Tests of individual steel wires (diameter, strength, elongation @1% strain, wrap test, coating adherence, mass of zinc) Tests of aluminum alloy wires, diameter, tensile strength, elongation, resistivity) Test of complete conductor (condition, diameter, mass, lay ratio, breaking load, dc resistance) Stress-strain test Full conductor creep test (at Shanghai electric cable research institute) Photos of test set ups	Procedures for testing per ASTM standards Initial set ups and partial tests, witnessed by Hatch Engineer, Data to follow. Could not find this data.

Canso Strait 230 kV Crossing Assessment

		Conductor considered to be in general compliance	
H349324-RV-00007-CA01PDFCover.pdf 2016-05-04	Conductor Testing - Hatch Observations - Issued for Client Review Hatch	Request for client approval to proceed.	Steel wires all exceed design diameter (4.903-4.925mm compared to 3.89mm. All aluminum alloy wires are below design diameter (3.14 to 3.16mm compared to 3.26mm.
Chemical position analysis – Al Ingot.compressed.pdf 2016	Title in Chinese Typo should be “Composition” ZTT	Table of alloying element additions from eight samples With inspector’s stamp	
Completed Production Test.pdf 2016	Title in Chinese ZTT	Tests of individual steel and aluminum alloy wires With inspector’s stamp	Found compliant by Hatch
On-going Production Test.pdf 2016-12-02 to 2016-12-14	Title in Chinese ZTT	Tests of individual steel and aluminum alloy wires With inspector’s stamp	Found compliant by Hatch
Steel core Incoming test.compressed.pdf 2016-12-16	Title in Chinese ZTT	Tests of individual steel wires as received. With inspector’s stamp	
VIBRATION ANALYSIS by ZTT			

Canso Strait 230 kV Crossing Assessment

About Canso Crossing – 200170203.docx 2016	Some questions and concerns about 345 kV overhead transmission line Strait of Canso crossing ZTT (Jiangsu Zhongtian Technology Co., Ltd)	Check of fittings and damper design by Salvi from ZTT. String fittings comparable to ZTT practice but tension clamp and damping scheme are different. The damping scheme with 6 SALVI dampers per end has long term risks, especially with ice present. ZTT offers an alternative damping scheme with dampers plus damping wire loops. The report cites a previous failure of a Yangtse river crossing with Salvi designed damping scheme. Report also questions the design of the tension clamp and suggests testing before use.	This report is prescient in anticipating both the failure at a dead end and conductor damage related to inadequacy of the damping scheme. ZTT have provided a small-scale diagram of an alternative damping scheme including both dampers and loops of cable. This seems to be very worthwhile to follow up to determine if this is actually applicable for this crossing. This company may have experience of similar crossings and could help in developing a suitable damping scheme. The experience of the first Canso Strait crossing is also of value to compare designs and possible reasons for the different reliability.
Annex 1 Fatigue limits of various conductors' materials.docx	Unknown	Table of fatigue endurance limits for common metals	Appears to be part of another document (ZTT?)

Canso Strait 230 kV Crossing Assessment

		including varieties of aluminum and alloys	Shows aluminum alloy to be similar to normal aluminum in fatigue endurance.
Annex 2 AACSR-900-510- with damper and armour rods.pdf 1/24/2017	Tecnosoft III file	Plot and data table for strain and amplitude at damper and suspension clamp - computation with six dampers per end Predictions at frequencies from 8 to 60 Hz: Max'm strains: at suspension clamp >500µε at damper clamps=355 µε Max'm amplitude: at antinodes = 25mm at damper clamps=25 mm	This could be the analysis by ZTT The software does not predict for frequencies below 8 Hz. Ice thickness is not accounted for.
Annex 2 Single conductor without dampers.pdf 1/22/2017	Tecnosoft III file	Shows strains above 1500 microstrain, and amplitude at clamps above 40mm	This could be the analysis by ZTT Results correspond with expectation that dampers are needed.
PHOTOS			

Canso Strait 230 kV Crossing Assessment

2019 Inspection 2019-11-05	NSPI	10 selected photos of suspension tower heads showing damper positions	Both supporting towers photographed from a drone At least one damper has slipped towards the middle of the long span Photo numbering suggests there were over 100 more photos
2021 Inspection 2021-09-14	NSPI	36 selected photos	Show extensive out layer damage to the conductor, many displaced dampers, damper rotated around conductor, birdcaging next to damper clamps, damper clamp opening, possible misplaced corona ring at bottom of insulator string,
DAMPER DESIGN AND ANALYSIS (SALVI)			
4M529VZ0952X_revA_Off16074.pdf 28-04-22016	Drawing No. 4M529VZ0952X SALVI	Stockbridge damper for conductor diameter 42 to 52mm (Conductor diameter: 48.9mm)	Drawing shows both a split nut and torque requirement of 40 Nm for tightening the clamp bolt.

Canso Strait 230 kV Crossing Assessment

			Need to know which procedure was used by the installers.
Canso-Strait 345kV project_ Damper effectiveness study_DS612-16.pdf 26/10/2016	Damper effectiveness evaluation analytical method SALVI Annex 1 by Prof. G. Diana	Analysis of the span with six dampers per end, giving damper spacings. Predicts effective between 2.5 and 42 Hz. Annex discusses effect of ice on the conductor as effectively increasing the diameter and lowering the frequencies of the aeolian vibration. Effectiveness declared for up to 10-mm radial ice but not more. Greater thickness magnifies the wind energy to be dissipated according to the 4th power of the effective diameter.	Warning is explicit that the damping scheme has a limited range especially when ice is on the conductor. No mention of galloping due to wind and ice. The analytical method used requires the energy absorption versus frequency characteristic of the damper, but this is not included.
PV19_17 Self damping test on ZZT AACSR 900-510.pdf 22/05/2017	Self Damping Test AACSR 900-510 ZZT DERVAUX S.A. requested by SALVI	Test of 51 m of conductor at 20% rts in indoor test bench Standard IEC 62567 \ Tests between 12.71 and 48.55 Hz	This is an input to the ESANAM software used by SALVI for damping system design

Canso Strait 230 kV Crossing Assessment

		Includes ZTT conductor specification sheet with cross section	
PV20_17 Damper Efficiency Test on AACSR 900-510.pdf 24/05/2017	Damper Efficiency Test - 4M529VZ0952X damper on AACSR 900-510 conductor Dervaux SA Testing Laboratory	Report shows indoor test of 55 m length of conductor with six dampers as recommended in Salvi's analysis, and in accordance with IEC61897 §7.11.3. Results indicate that the six-damper array at each end of a 1442m span will provide the required damping for vibration frequencies between 12.8 and 47.5 Hz. Uses data from Dervaux's conductor self-damping test PV19_17.and from ZTT's conductor properties.	This test would normally be complemented by data on the energy absorption of a sampling (usually six) of individual dampers to shows the dispersion and adequacy of the damper characteristics. The limited frequency range of the test means that the full range of wind and ice conditions of the line were not evaluated.
10.3 – Installation Instruction Vibration Dampers.pdf Jan 2009	Vibration damper for conductor & earthwire erection instructions SALVI	Instruction for damper installation	Covered both split nut and use of torque wrench for tightening the clamp
Canso-Strait 345kV project_Damper effectiveness study_DS612-16.pdf	Damper effectiveness evaluation analytical method Salvi		The discussion is around aeolian vibration only and does not cover galloping motions.

Canso Strait 230 kV Crossing Assessment

26//10/2016			The consequences of lack of damping under thicker ice layers are implied but not spelled out. The lowest frequency range of aeolian vibration under 10 mm ice is given as 2.8 Hz but normal Stockbridge dampers do not protect below about 5 Hz. This damper characteristic would be an input to the program but is not shown.
Damper study – Tensions – C2BE2B & E2CE2B.xls			File not readable
Damper study – Tensions – C2BE2B & E2CE2B_WM.xls			File not readable
Datasheets damping study	SALVI's input form completed by?	SALVI's input form completed by?	Most input data (conductors, wind, ice, tower lighting, plan and profile) refers to other documents attached and supplied to SALVI

Canso Strait 230 kV Crossing Assessment

DS-093-20rev0.pdf 23/11/2020	Damper effectiveness evaluation analytical method SALVI	Aeolian vibration analysis for 400 and 392 m span of ACSR Curlew conductor Recommends two dampers per span end	Reference to control of subspan oscillation seems out of place for a single conductor. Analysis predicts control from 5 to 60 Hz. Actual aeolian vibration can be at lower frequencies where damping is not evaluated.
DS-093-20rev2.pdf 23/11/2020	Damper effectiveness evaluation analytical method SALVI	Aeolian vibration analysis for 400, 392 and 479 m span of ACSR Curlew conductor	As above for doc. DS-093- 20rev0.pdf
DESIGN			

Canso Strait 230 kV Crossing Assessment

HARDWARE DATA (SALVI)			
180- rev0 Nova Scotia – Canso type test.pdf March 2017	Type test certificate No. 17/180 Rev. 0 Salvi Test Laboratory	Tests: visual examination, dimensions, materials, galvanizing, failure load, slip test, clamp bolt tightening test, breakaway bolt test, damper characteristics (by performed at Dervaux). Items tested: insulator fittings, suspension clamp, tension clamp, vibration dampers. Tests on 3 samples of each according to IEC specifications. Not completely satisfactory due to failure of dead-end tension clamp. Test performed at LATIF according to report 17LA00056	LATIF report 17LA00056 is missing Dead end redesigned and passed test requirements
Acceptance_test_certificate_2017-181[1].pdf April 2017	Acceptance_test_certificate_2017-181[1] Rev. 0 SALVI	Tests: visual examination, dimensions, materials, galvanizing, failure load, slip test, clamp bolt tightening test, breakaway bolt test, damper	Witnessed by Tom Flewwelling over a three-day period.

Canso Strait 230 kV Crossing Assessment

	Witnessed by Tom Flewwelling Tests on April 03-05, 2017	characteristics (by performed at Dervaux). Items tested: insulator fittings, suspension clamp, tension clamp, vibration dampers.	
180-1 rev0 Nova Scotia – CANSO type test .pdf March 30, 2017	NEW COMPRESSION DEAD END <i>TYPE TEST CERTIFICATE</i> No. 17/180-1 Rev. 0 DRAWING – 508U21US-K rev. 0 A. Salvi & C. S.p.A.	Includes SALVI drawing of dead end 508U21IS-K Test carried out at LATIF, independent third-party laboratory, as per enclosed report 17LA00098 Dead end strength test passed at 1132 kN (95% of conductor tension strength - 1168 kN)	Report 17LA00098 not found This could be in response to the failure at a dead end experienced during stringing
CERT.N_2017-0546_- _SALVI [1].pdf 24/03/2017	Testing certificate No. 2017/0546 SALVI	Test report on double clevis and yoke plate (Text in Italian)	Appear to verify both items
Doc16242620170612144749.pdf 10/10/2016	Compression dead end assembly for AACSR 900/510 48.9 mm dia. (48x4.89) + (61x3.26) DRAWING – 508U21US-K rev. 0	Drawing of compression dead end	Item tested at LATIF 180-1 in document: rev0 Nova Scotia – CANSO type test .pdf

Canso Strait 230 kV Crossing Assessment

	SALVI		
LATIF Test certificate17LA00056.pdf 29/03/2017	Test report N 17LA00056 LATIF	Proof and failure test of dead end assembly for SALVI. Drawing 508U21US-K Passed	Test of the modified design of end fitting
LATIF Test certificate17LA00098.pdf 06/06/2017	Test report N 17LA00098 LATIF	Proof and failure test of dead-end assembly for SALVI. Drawing 508U21US-K Passed	Repeat of above – Production test?
Omeco_SPT0217-17.pdf 22/02/2017	Test report SPT/0217/17 OMEKO	Charpy impact tests of string hardware at -20°C for SALVI	All parts exceeded 20-joule requirement.
Politechnico_of_Milano_-_English_translation_test_certificate_2017-0546_(1)[1].pdf 24/03/2017	Test certificate N. 2017/0546 issued in Milan on 05/04/2017 A. SALVI & C. S. p. A. - MILANO	Tension tests of double clevis and Yoke. Photos of test set ups. Tests reaches specified loads, with some bolt deformation, no failures.	Static test satisfactory

Canso Strait 230 kV Crossing Assessment

SALVI drawings_accessories_rev1.pdf Dates various 2012 to 2016	21 drawings SALVI	Drawings of connectors, shackles, clevises, suspension clamps, dead end, armor rods, angle support, link, yokes, and corona rings.	
SALVI stringsdrawings_rev12pdf Dates various 2014 to 2016	7 drawings SALVI	Drawings of quadruple tension set, double suspension set, jumper string, rigid spacer, vibration dampers, and compression repair sleeve,	
Sediver glass drawing_F400-205DC.pdf 31/03/2016	One drawing Sediver ENG 69764 Sediver	Drawing of 90,000 lb glass insulator F400/205 Dc	
TOWERS - HATCH DOCUMENTS			
H349324-0000-70-012-0003_E_V4.pdf	Plan showing a proposed 345 kV overhead wire crossing of the Strait of Canso, Ault's Cove Antigonish County to Port Hastings, Inverness County. N.S	Drawing of plan and elevation of the crossing span and inset map of surroundings.	
H349324-00000-70-012-0001_3_V6.pdf	345kV Transmission Line Strait of Canso crossing Plan and Profile	Plan view is a Google Earth photograph with drawing of the existing and new spans and towers superimposed.	

Canso Strait 230 kV Crossing Assessment

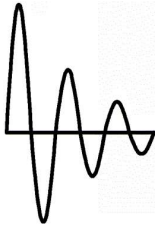
		Elevation drawing shows towers and crossing span and back spans of single conductor AACSR and end spans of single conductor Beaumont ACSR.	
H349324-00000-232-078-0001_A_V1.pdf 20-10-2015	Design, Manufacture, Test and Supply of Steel Towers Technical Sections for RFP Hatch	Codes and standards, Design requirements, Material Manufacturing, Inspection, Shipment, Delivery, Schedule, Drawings 18 pages	Refers to 7 drawings, not included 5 drawings design requirements for five tower types. Drawing of anchor layout. Drawing of aircraft warning lighting and markers.
H349324-00000-.260-078-0003_A_V1.pdf 20-10-2015	Insulator and Hardware Specification 345 kV Canso Strait Crossing Design, Manufacture, Test and Supply of Insulator and Hardware Hatch	Specifications and standards, Insulators assemblies, hardware and accessories, energized maintenance, supply, manufacturing quality assurance tests: type, routine, acceptance, shipping delivery. 10 pages	Conductor type is trapezoidal stranding. Design loads in “DRDs”, not part of this document. Note type test reports required unless available.

Canso Strait 230 kV Crossing Assessment

H349324-00000-30-035-0001_2_V6.pdf 2017-02-20	345 kV Transmission line Strait of Canso crossing rock anchor details Hatch	Drawing	
H349324-00000-35-197-0001-001.pdf 2015-09-09	345 kV transmission line Strait of Canso crossing Design requirement drawing Tower Type 3S2 Hatch	Drawing of 171 m suspension tower with design loadings	60 mm of ice, 125 km/hr wind
H349324-00000-35-197-0002-001.pdf 2015-11-25	345 kV transmission line Strait of canso crossing Design requirement drawing Tower type 3D1 Hatch	Drawing of four designs of braced portal lattice dead end towers.	60 mm of ice, 125 km/hr wind
H349324-00000-70-015-0001_A_V1.pdf 2015-10-06	345kV Transmission Line Strait of Canso Crossing Lighting and Marking layout Tower Type 3S2 Hatch	Drawing showing lights at three elevations and alternate bands of white and orange paint	

Rev1. Sep. 2024
Page 15 of 27

APPENDIX A – DR. HAVARD REPORT 2023



HAVARD ENGINEERING INC.

3142 Lindenlea Drive, Mississauga, Ontario, Canada, L5C 2C2

Telephone: 1-(905) 273-3076

<http://www.havardengineering.com>

E-mail: dhavard@rogers.com



To: Balraj Bilkhu, P.Eng.,
AAB Engineering Inc.
Halifax, N.S., Canada
902-441-7406
bbilkhu@aabengineering.ca

DRAFT
INTERIM REPORT ON JUNE 13, 2023, DRONE-BASED SURVEY
OF NOVA SCOTIA POWER'S L7005 345 kV CANSO STRAIT CROSSING

by

David G. Havard Ph.D., P.Eng.
President, Havard Engineering Inc.
3142 Lindenlea Drive
Mississauga, Ontario, Canada, L5C 2C2

EXECUTIVE SUMMARY

L7005 345 kV line crossing the Canso Strait is a key link in a system of delivery of power from Labrador to load centers in Canada and USA. Due to its history of weather induced damage, the line was surveyed in June 2023 using drone technology. The inspection was focused around the two supporting towers and included the main span and both back spans of both circuits. The extensive portfolio of photographs has been reviewed to assess the current condition of the line. The line has been exposed to winter conditions with only partial protection from wind induced vibrations and galloping. The photos show that the line is in generally good condition and the extensive damage that was reported in 2021 has not recurred. Two dampers show effects that can be attributed to the occurrence of vibration or galloping during the winter. Both were on the bottom conductor of the west circuit, main span, near Tower 731. One Salvi damper has been displaced, and the weights of one PLP-Helix damper are missing. All insulator strings appear undamaged.

The photos illustrated that damage has been most serious on the Cape Breton Island end of the span and on one of the bottom phases. This leads to the recommendation that future vibration recording, video cameras and weather monitoring should be focused on those locations. The greater vibration damage on that end may relate to looseness of Tower 731, indicating the need for a thorough inspection of all bolts.

Due to delivery and manufacturing delays, combined with a short duration outage for installing the planned airflow spoilers and vibration dampers, the line will again endure the coming winter with limited vibration protection. New dampers of the same design as that which failed will be used as part of the temporary protection. Those new units need to be inspected using non-destructive techniques to eliminate any defects such as possibly caused the one damper failure.

The final damper design is attached to the conductor using preformed rods. This design needs to be verified according to IEC Standard 61897, at least for energy absorption, and for grip on the conductor. The conductor vibration during the coming winter needs to be monitored to provide evaluation of the vibration controls. But there is no standard for ensuring the avoidance of fatigue damage to the conductor. However, the old L8004 crossing has endured the prevailing weather for over 40 years and can serve as a benchmark. It is recommended that the monitoring program include one of the top phases of that crossing as reference. The data from the vibration recorders, video camera, for recording galloping, and the weather station needs to be reviewed during the coming winter on an ongoing basis, to allow the evaluation of the protection systems and to develop remedial actions if required.



David G. Havard, Ph.D., P.Eng.,
President, Havard Engineering Inc.
August 2023

LIST OF CONTENTS

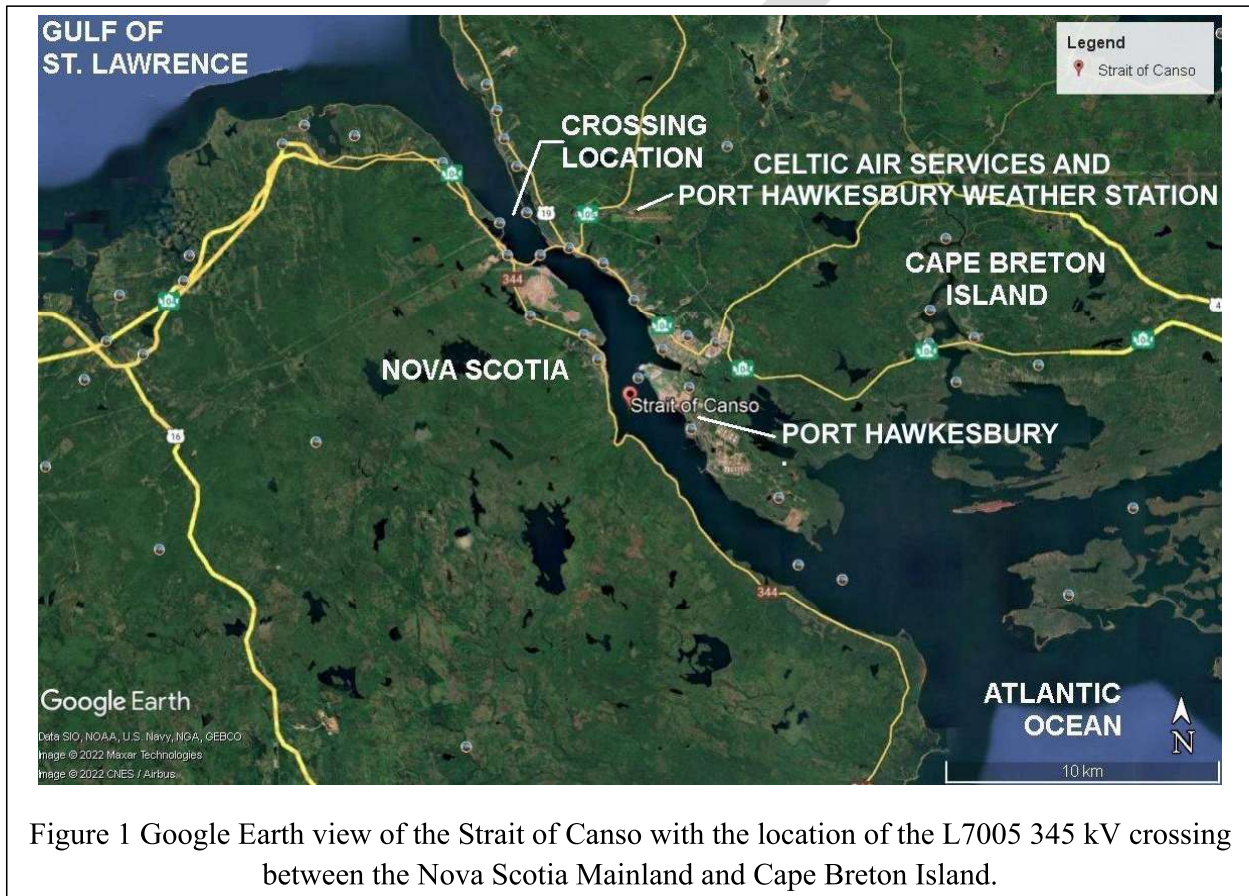
SECTION NO.	TITLE	PAGE
	Executive Summary	1
	List of Contents	3
	List of Figures	4
1	Introduction	5
2	Crossing Inspections	8
2.1	May 2022 Climbing Inspection	8
2.2	Drone-based Inspection	9
2.2.1	Conductor and Damper damage	11
Table 1	Damper and Repair Rod Summary Canso Crossing L7005 - 2023 Inspection	16
3	Weather Impacts	18
4	Monitoring of vibration	20
5	Conclusions	21
6	Recommendations	21
7	References	22
	Appendix 1 Figures A1-1 to A1-10	
	Appendix 2 Figures A2-1 to A2-13	
	Appendix 3 Figures A3-2 to A3-13	

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1	Google Earth view of the Strait of Canso with the location of the L7005 345 kV crossing between the Nova Scotia Mainland and Cape Breton Island.	8
2	Elevation of towers and conductors of the new Strait of Canso crossing (Hatch file H349324-00000-70-012-0001_3_V6.pdf)	9
3	Damper slipped to mid span, West circuit, middle phase, from climbing inspection in May 2022	13
4	Damper arrays on top and middle phases of the west circuit, main span at Tower 730. From drone-based inspection June 2023	14
5	Double Insulator string on Tower 730, bottom phase, west circuit	16
6	Damper arrays on top and middle phases of the east circuit, and repair rods on middle phase west circuit and top phase east circuit, main span. Tower 731	18
7	Displaced Salvi damper on the bottom phase of the west circuit, main span at Tower 731	20
8	Dampers at Tower 731 on the bottom phase of the main span, west circuit. Showing displaced Salvi damper and in-situ PLP-Helix dampers, one with missing weights	21
9	Array of PLP-Helix dampers on the bottom phase of the west circuit at Tower 731 with broken damper	22
10	Clamp of PLP-Helix damper remaining attached to the conductor on the bottom phase of the main span, west circuit at Tower 731	22
11	Unbroken PLP-Helix damper showing square shaped recess in the clamp body that corresponds to the fracture plane of the damper in Figure 10	23
12	Conductor damage from damper clamp loosening on middle phase east circuit, at Tower 730, main span from photo Dji_20230613134722_0003_z.jpg	25
13	Monthly weather data Sydney Nova Scotia, from “ClimaTemps” web page	26

1. INTRODUCTION

The Canso Strait experiences severe weather, including channeled winds and ice or wet snow accretions, that can cause unusually high levels of vibration and oscillation of the conductors that cross it. The location is close to the Atlantic Ocean on the east and the broad estuary of the Saint Lawrence River on the west. The channel lies between high lands on the north and south banks and experiences frequent strong wind and winter storms. Figure 1 shows the strait in a “Google Earth” view.



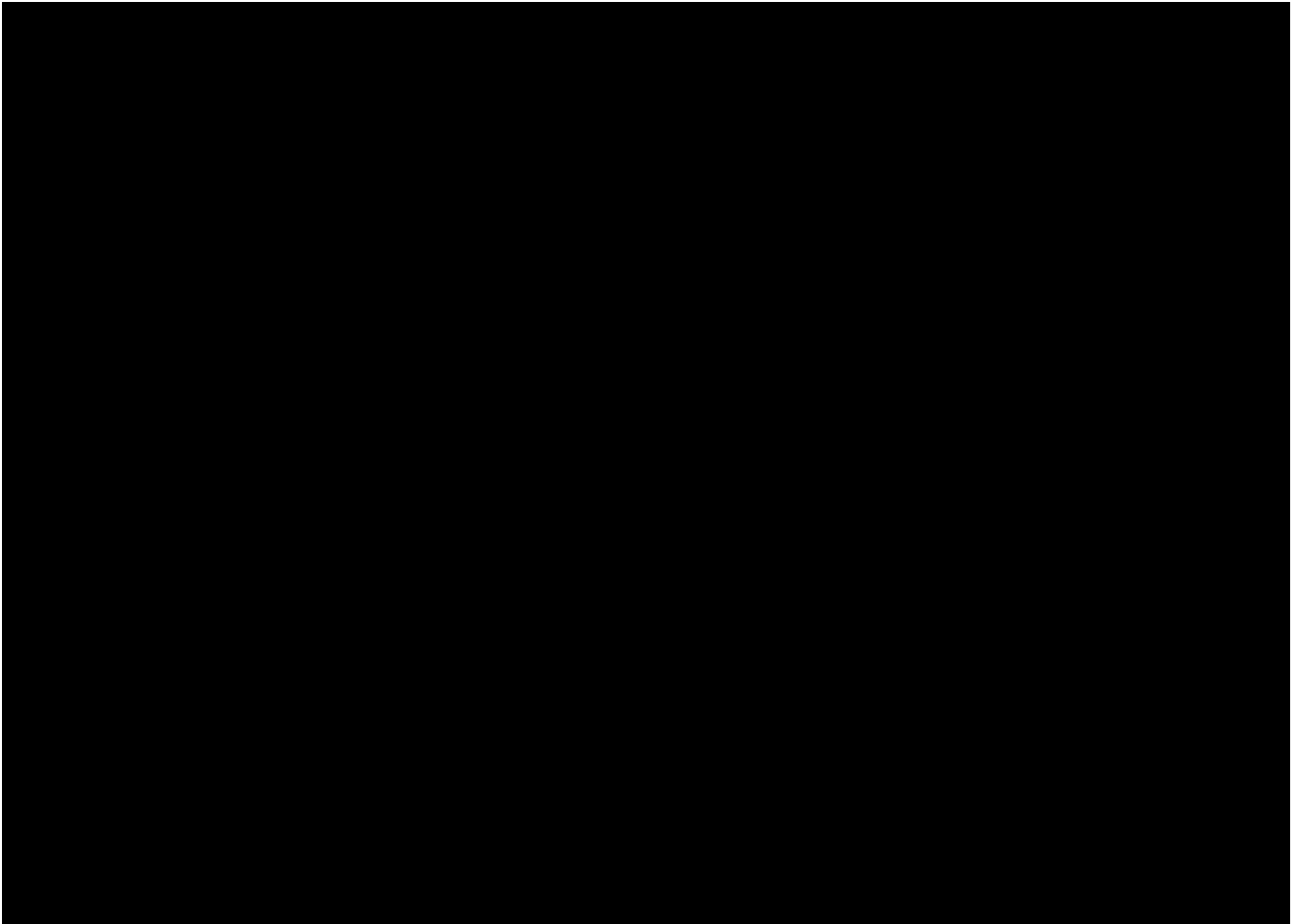
The first power line crossing the strait was a 345 kV double circuit line, designated L8004 and built in 1983. It comprised a main span of 1455m and back spans of 887m and 557m. This used a 43 mm diameter self-damping conductor based on vibration research being developed at ALCAN. In 1984 severe galloping occurred on the line causing flashovers between the conductors that caused melting and breakage of conductor strands. The flashovers and conductor damage were close to mid-span, suggesting that the galloping occurred in the single loop mode. The conductors

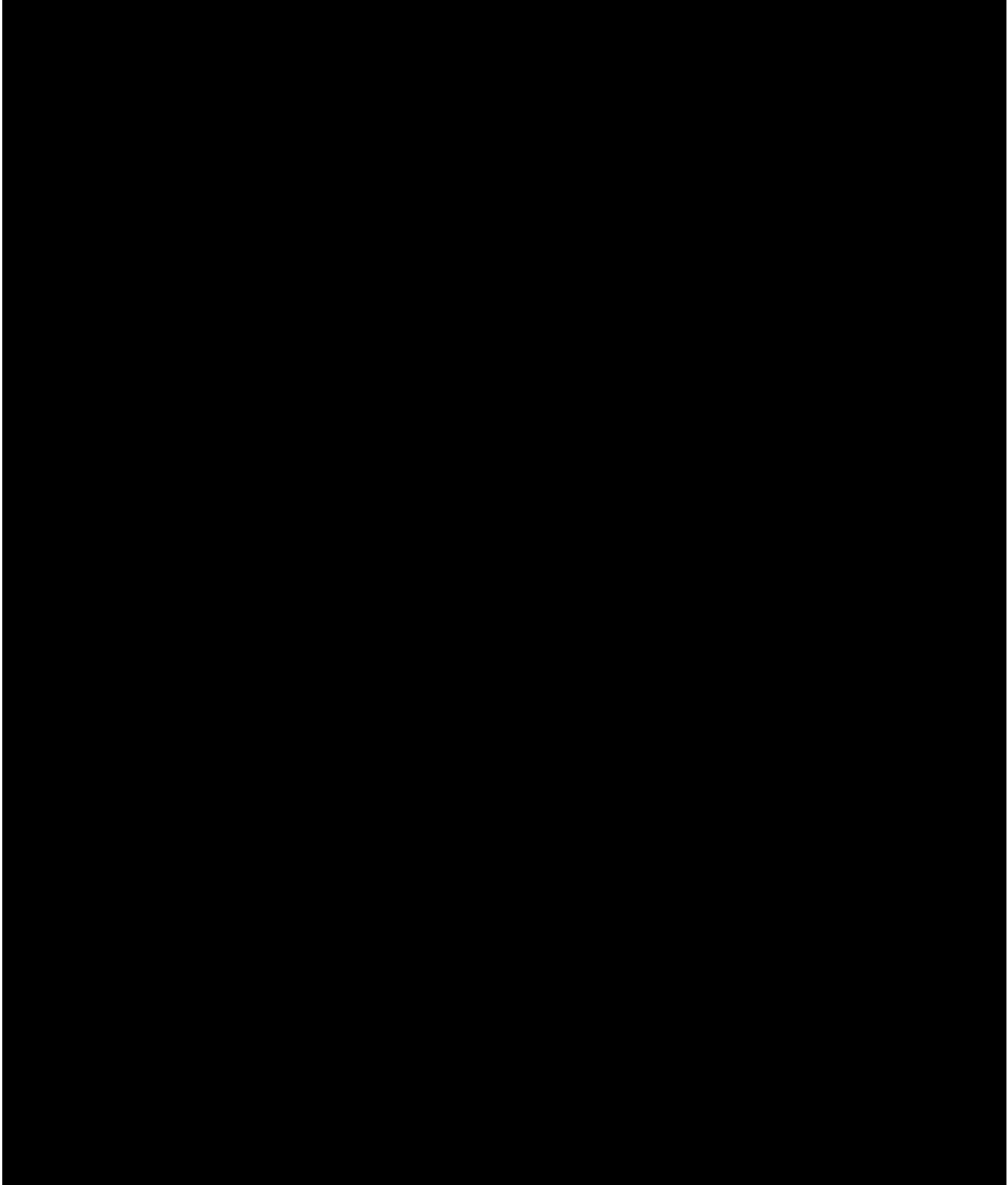
were separated horizontally by 16m and vertically by 13m [1]. The diagonal distance between the damaged conductors was 21m. This is an unusually long distance between conductors and well beyond the normal separations built into transmission lines to avoid flashovers due to galloping. The oscillations were attributed to conductor galloping and successfully remedied, based on there being no subsequent repetitions of the galloping event, by adding air flow spoilers on every conductor in 1984 [2]. Since then, the span has been protected from aeolian vibration by the conductor's self-damping plus some benefit of the air flow spoilers, and from galloping by the air flow spoilers. Based on this performance, the older crossing can be considered a base reference for comparison with the new span after treatment, and thus used in the vibration monitoring program.

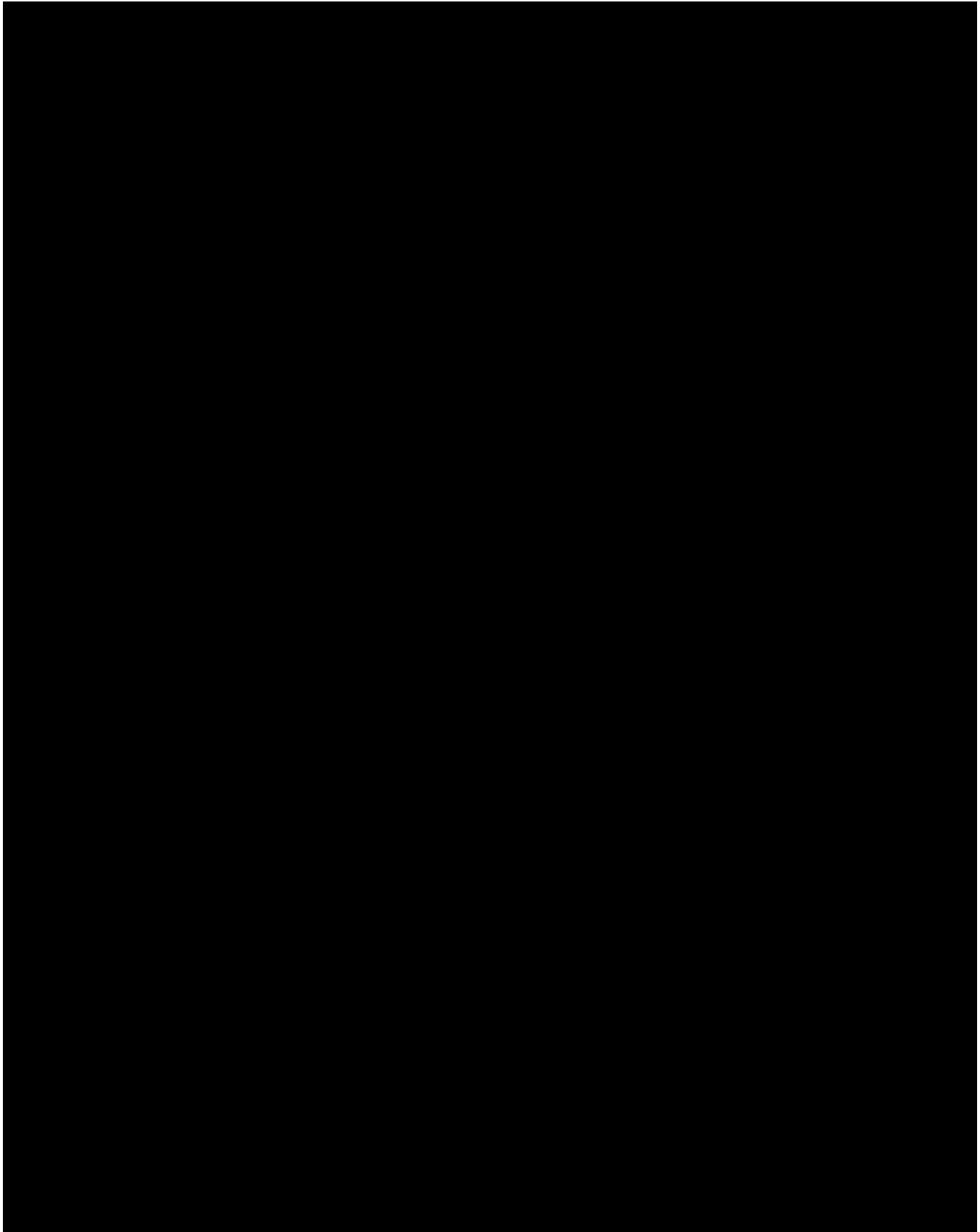
The second 345 kV crossing was built in 2017 and designated L7005. The new line forms part of the transmission grid feeding power from hydroelectric power sources in Labrador to load centres in the maritime provinces and south to the USA. As such it requires a higher than usual level of reliability, which makes controlling the responses to wind in the strait a particular challenge. The crossing has a main span of 1445 m and unequal back spans of 1011m and 873m on the mainland end and 560m and 628m on the Cape Breton Island end. Figure 2 shows a drawing of the elevation of the crossing span.

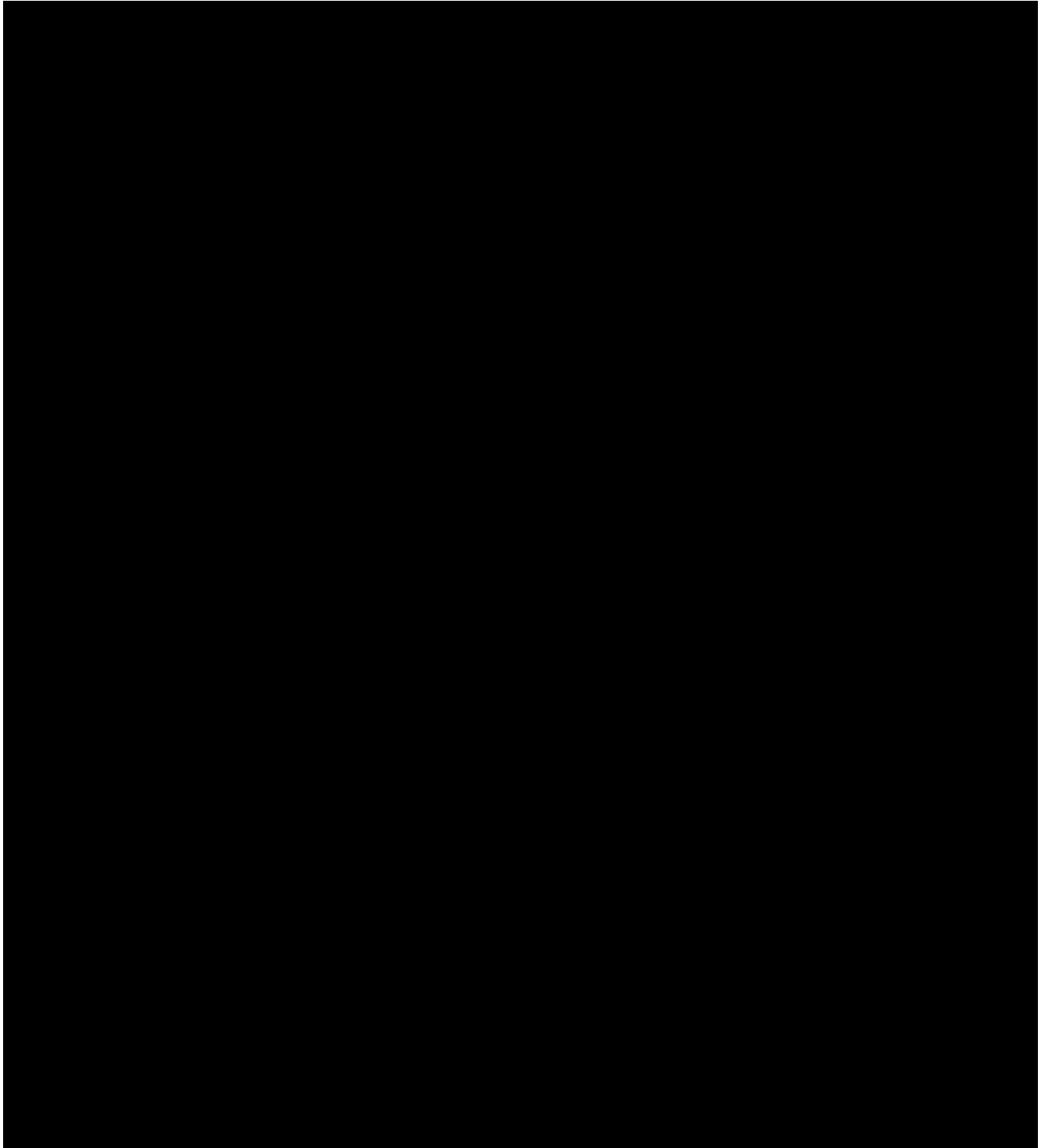
Regarding control of wind induced vibrations, this crossing was designed with vibration dampers to control aeolian vibration, but no galloping control devices. Damage occurred on the conductors of this crossing and remedial actions were recommended as detailed in an earlier report [3] in 2021. The recommendations were to replace the Salvi aeolian vibration dampers with PLP-Helix "robust" dampers attached to the conductors¹, according to the manufacturer's placement, plus to add air flow spoilers across the spans. These changes were not implemented until late in 2022 and then not completely mainly due to the time required for manufacture and delivery of the damping devices. Available Salvi vibration dampers were installed as a stop-gap measure.

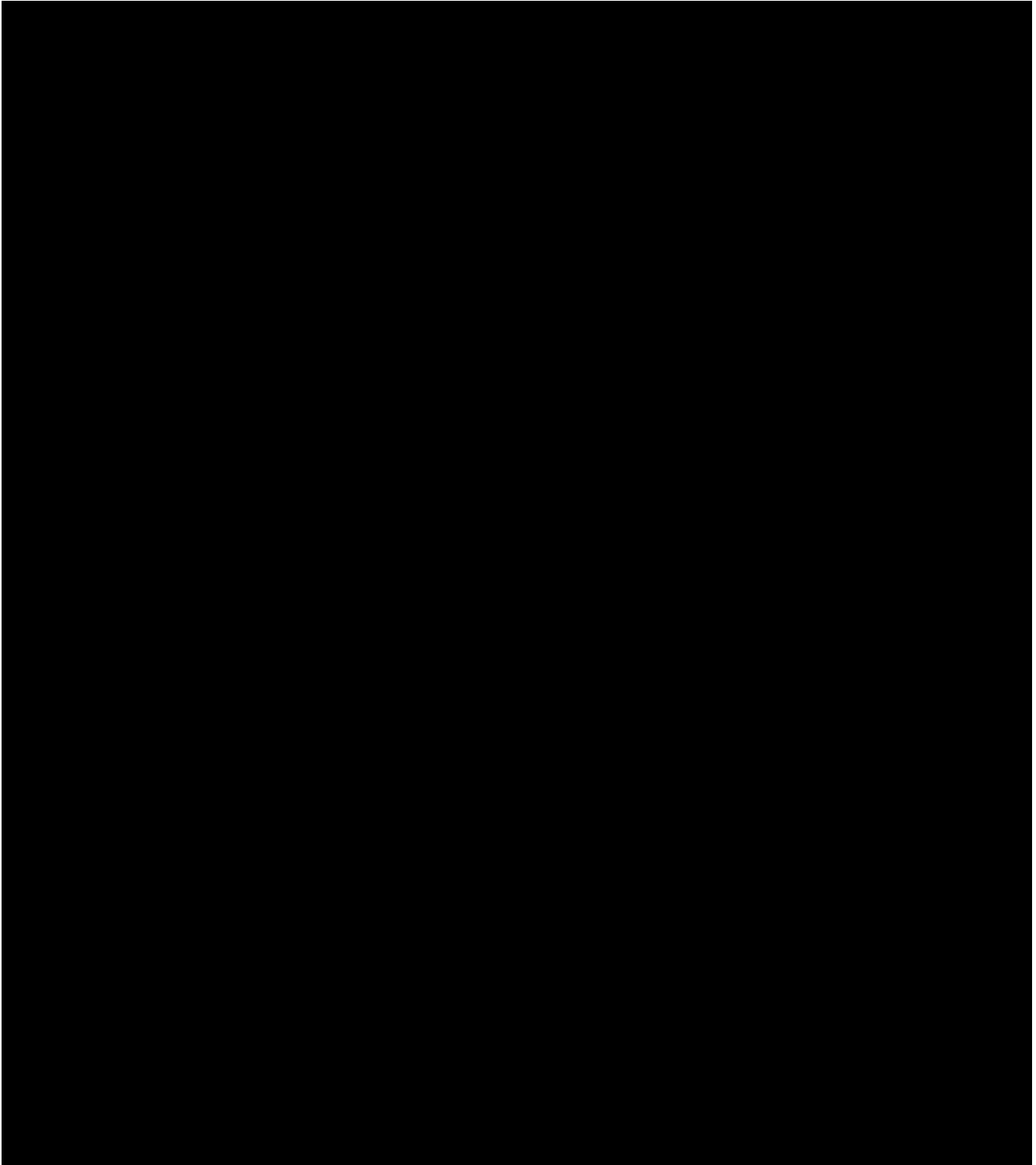
¹ Attached by spirally formed wires as used on Hydro Quebec's St. Lawrence River crossing.

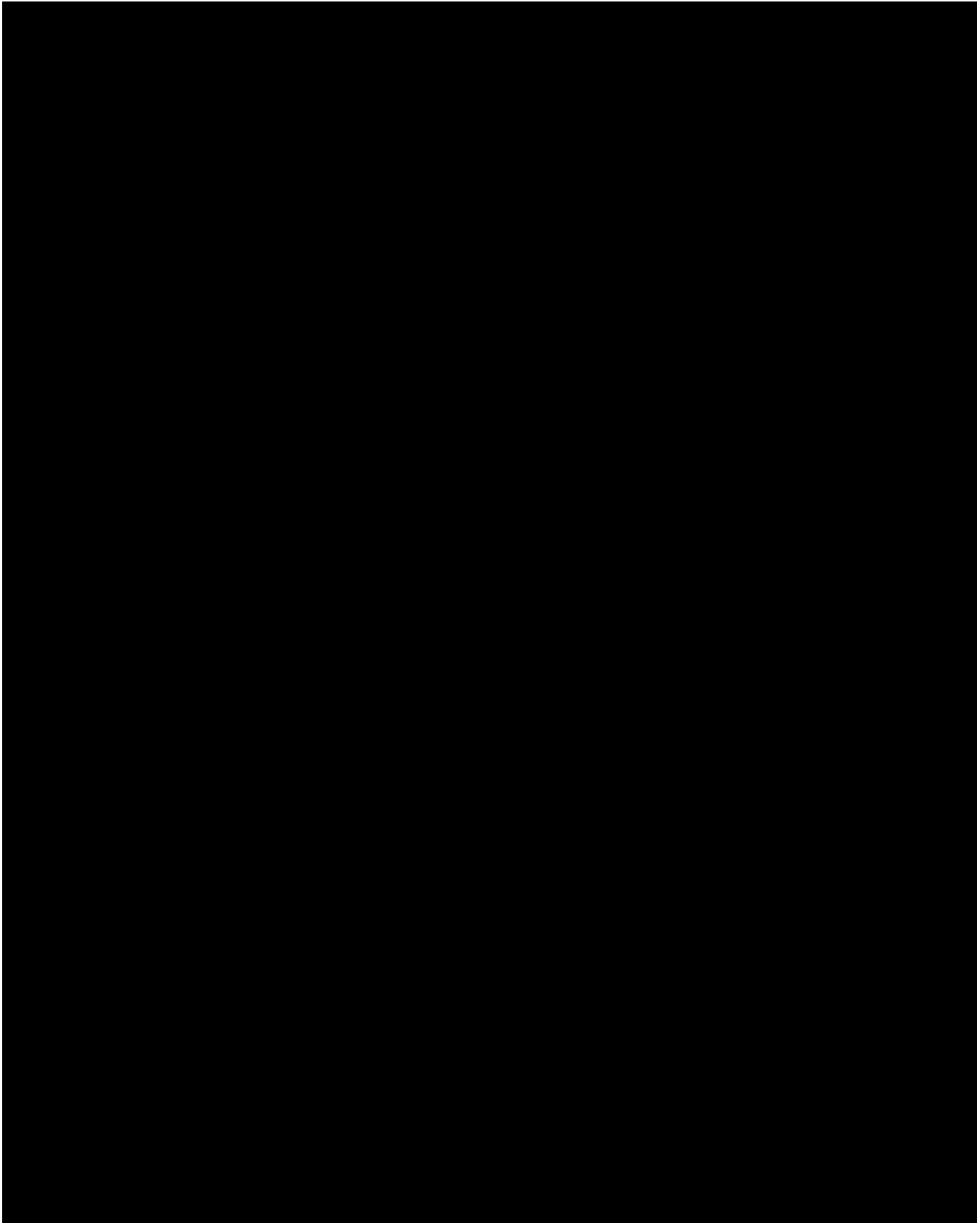


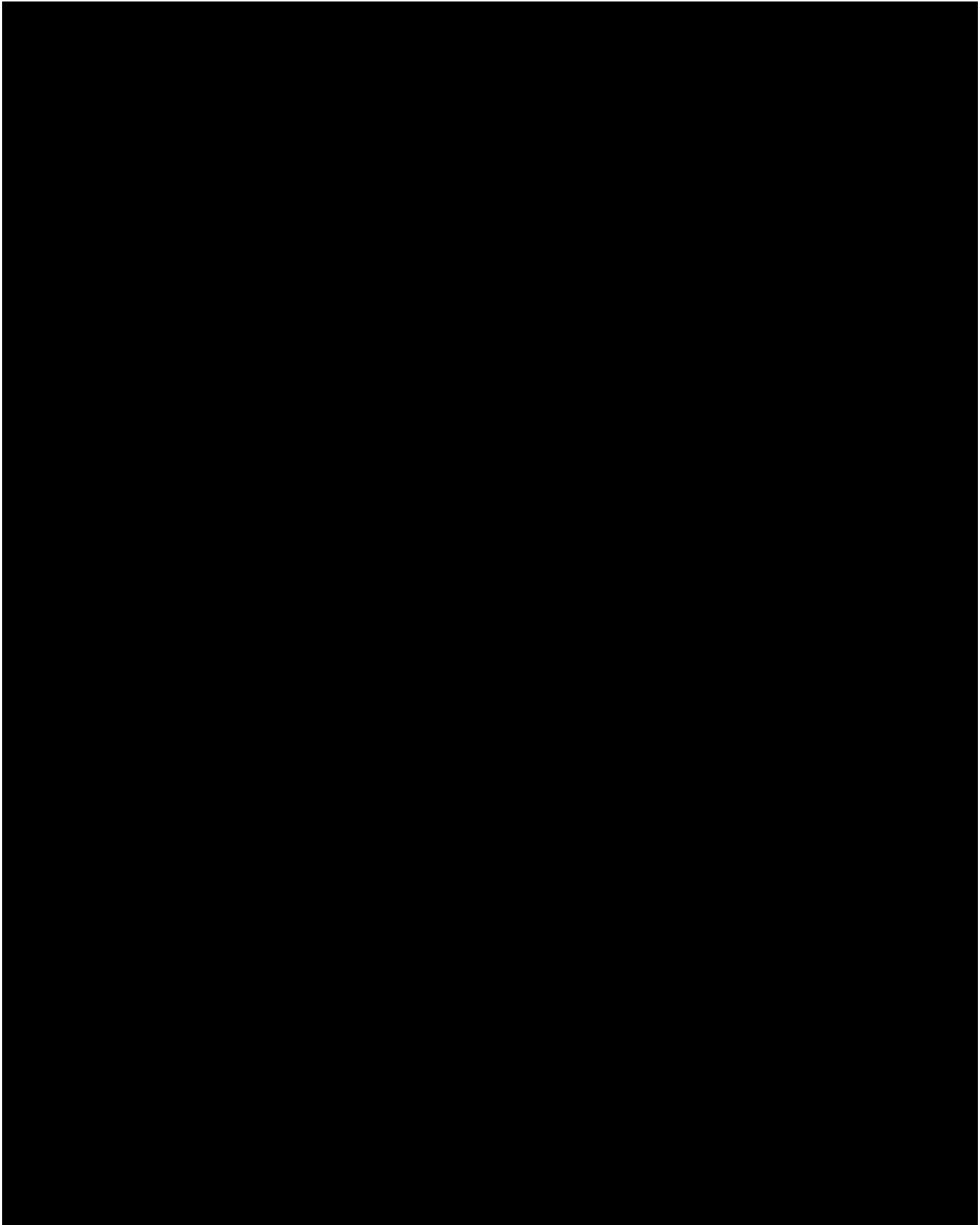


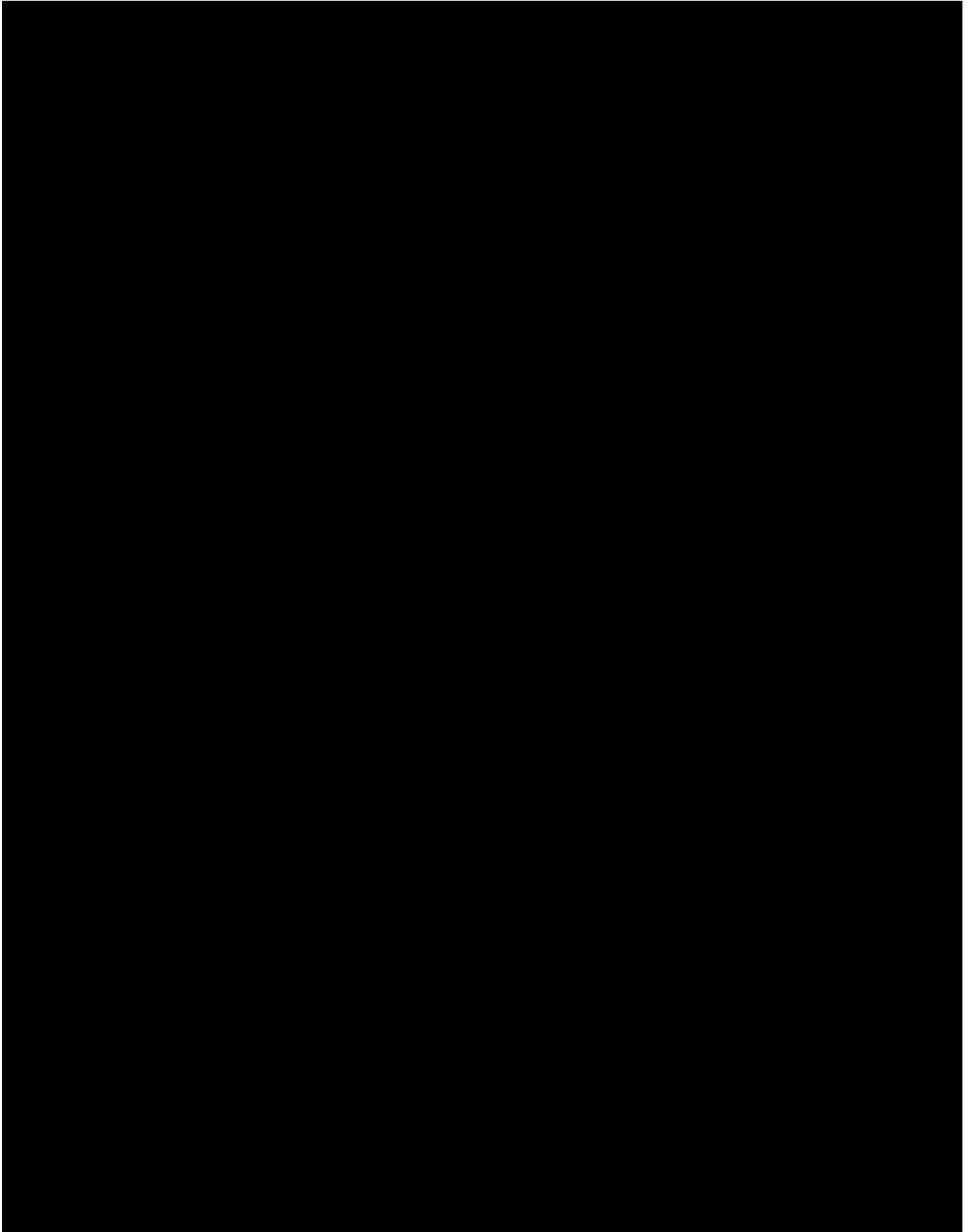






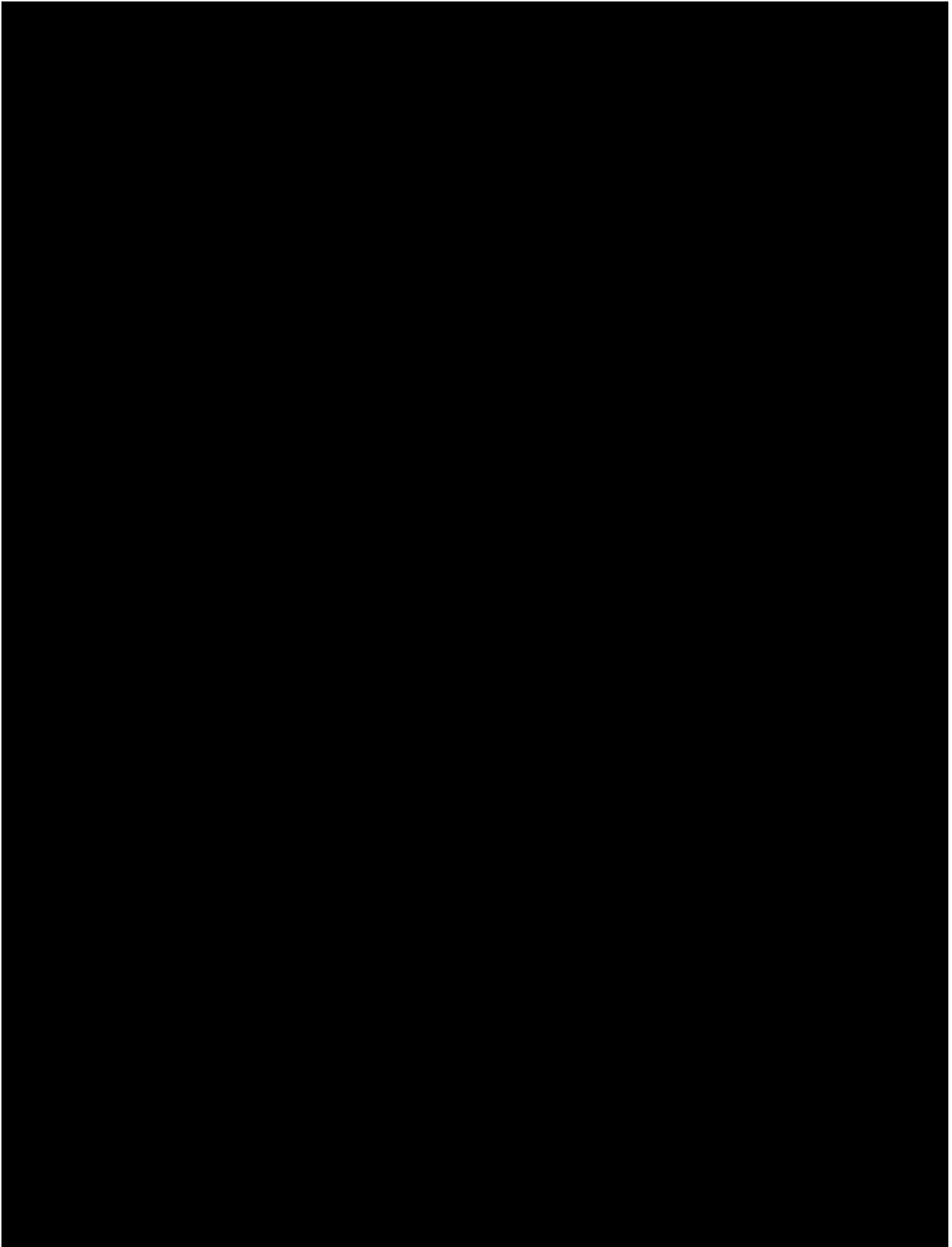


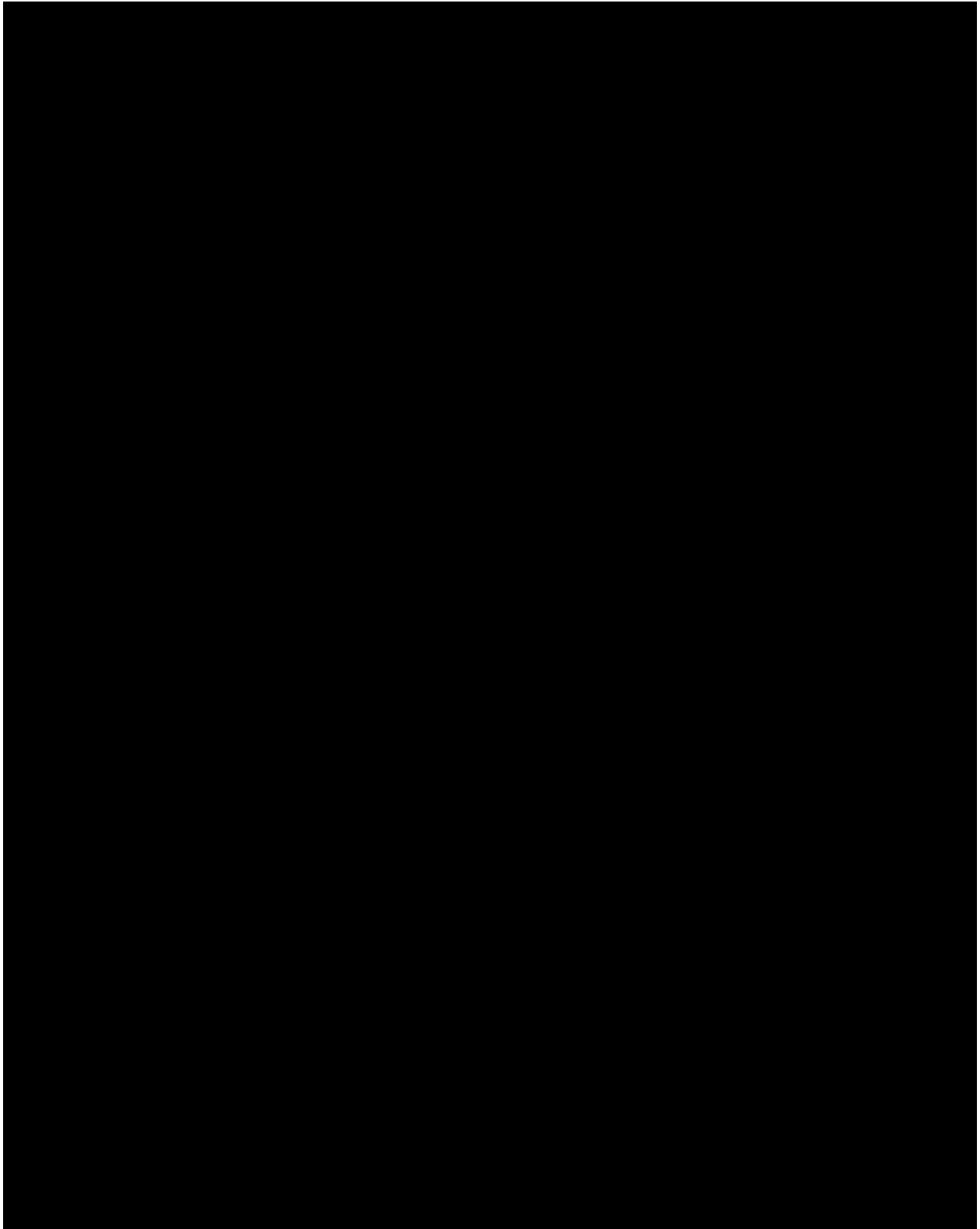






DRAFT

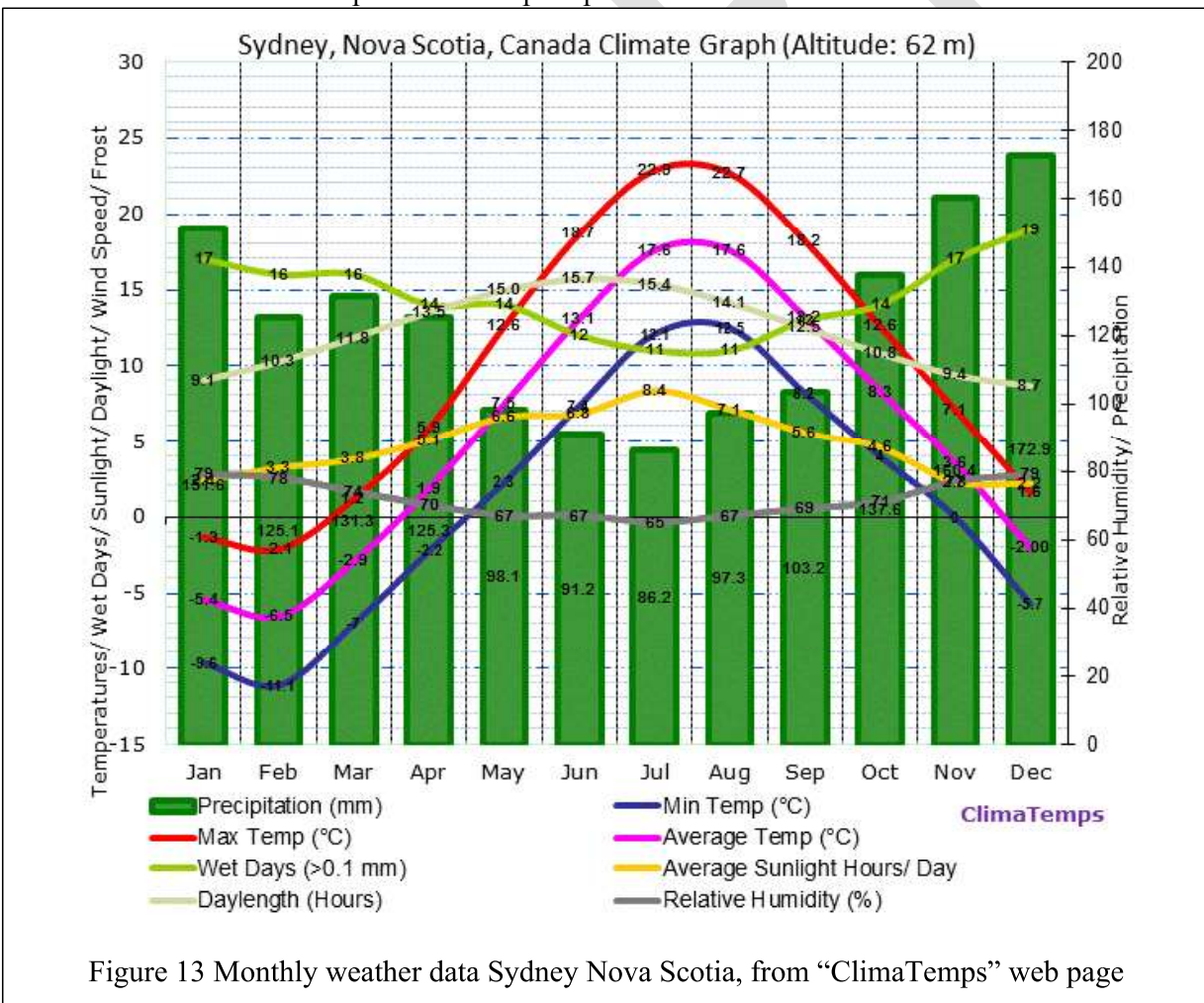




3. WEATHER IMPACTS

The damage to the conductor and dampers reported in the last review in 2021 [1] was much more severe than that seen in this latest drone-based inspection. While there are differences in the degree of protection from wind-driven motions there may also have been exceptional weather conditions. So an effort was made to search out available records of wind, temperature and precipitation that were relevant to the crossing. This search did not reveal any records that were truly representative of the conditions impinging on the crossing conductors, nor any giving recent historical data.

The closest data set is that shown in Figure 13, from a weather station in Sydney, on Cape Breton Island. This is approximately 110 km north-east of the crossing and the other side of the high point in the island. The data shown are the long-term monthly averages of maximum wind speed, maximum and minimum temperatures and precipitation in all forms.



A weather station is planned to be installed at the crossing and the specific parameters that will be recorded are uncertain at the time of writing. Conventional weather stations record temperature, wind speed and wind direction, usually averaged over but not precipitation. It will be most desirable to have a record of future weather especially the storm conditions that can produce extreme conductor oscillation and galloping.

Considering future weather monitoring with respect to the possibility of galloping events, Figure 13 offers an insight as to the months when the temperature is below freezing, and glaze ice or wet snow can occur. The figure shows that the minimum temperatures fall below 0°C during the six months from November until April. Experience of galloping events suggests that they occur most often when the temperature is around freezing at the beginning and the end of winter, but not so often at the coldest part of the winter.

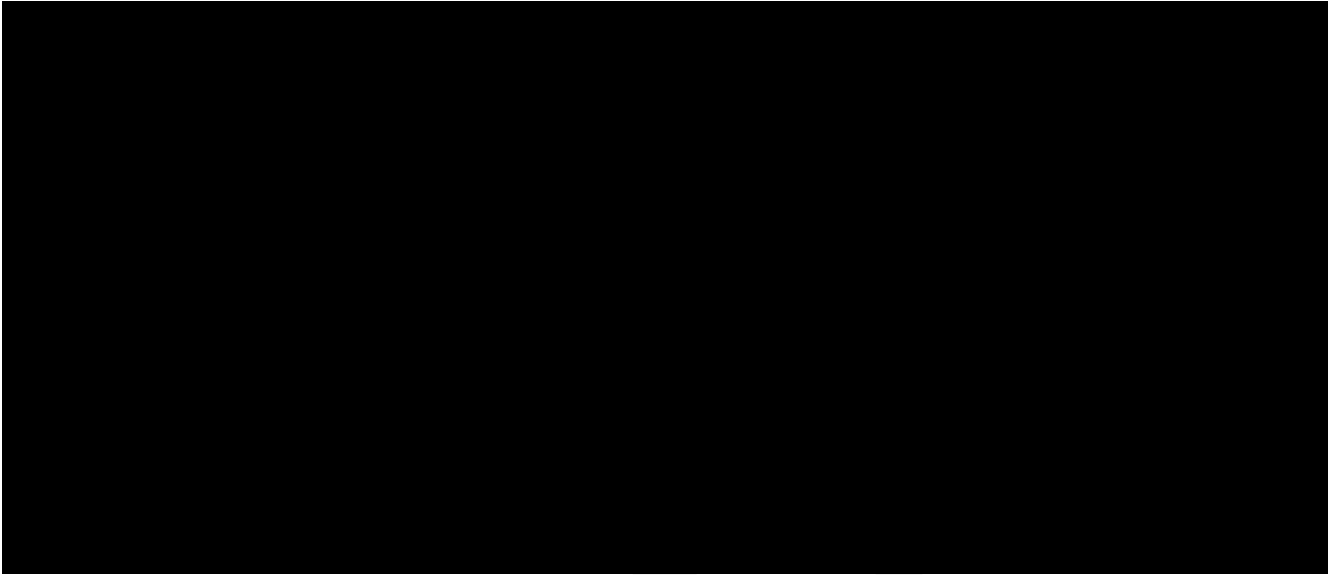
4. MONITORING OF VIBRATION

The damping arrays of PLP-Helix dampers to be installed are sized based on analytical models derived from wind tunnel studies of aeolian vibration of conductors. While this approach is widely used, this crossing is far from typical due to its length, the large conductor diameter and the specific weather exposure. Also, when the wind induced control devices are fully installed there will be two distinct types of vibration control, the aeolian vibration dampers and the airflow spoilers.

The analytical model³ does not represent this complex arrangement. The model relies on measured self-damping properties of the conductor at a nominal tension, usually at the average annual temperature, of the conductor. In this case the self-damping properties are estimated values and the tension variations due to the possible ranges of temperature and wind and ice load are estimates at best. The wind energy imparted to the conductor depends on its effective diameter, including any ice or wet snow layer present, to the fourth power. Aeolian vibration dampers cannot control that level of wind energy. The model prediction can only provide rough estimates of the actual vibration conditions. The model only considers aeolian vibration and does not describe galloping due to wind forces acting on the conductor with ice or wet snow accretions. The planned installation of a video camera will allow the occurrence of galloping on the crossing to be documented.

While the early developments of the air flow spoilers were mainly intended for galloping control of small distribution conductors, some aeolian vibration reduction was also attributed to them. So, there is confidence that the aeolian vibration will be more than adequately controlled by the combination. But there is a need to verify the performance for long term reliability and therefore some measurement of the vibration of the crossing is necessary. However, the standards for safe levels of vibration are for conductors supported in metal clamps or in elastomer lined clamps. There are no similar standards of conductor in metal clamps with armor rods as used in this crossing. There is a convenient reference in that the old crossing (L8004) has been satisfactory in service for over 40 years and that crossing uses the conductor similarly supported in metal clamps with armor rods. So, a measurement of the vibration of that conductor can be used as the base line for future vibration levels.

³ The analytical model used was developed at the University of Milan and has been calibrated against field measurements in a number of studies [6,7].



6. RECOMMENDATIONS

- ❖ Vibration recording, video cameras and weather monitoring should be at the Cape Breton end of the span.
- ❖ The cause of the weight falling off the PLP-Helix damper should be investigated.
- ❖ All new Helix dampers should be inspected by non-destructive methods.
- ❖ Tower 731 should be fully inspected for looseness of bolts.
- ❖ Damage to the outer layer of the conductor should be repaired using custom repair rods to fit the suspension clamps,
- ❖ The new damper design using preformed rods needs to be tested for energy absorption and conductor grip strength.
- ❖ Monitoring of the vibration of the crossing needs to include a conductor of the old L8004 crossing for reference.
- ❖ Vibration monitoring should be performed on a bottom phase of L7005 and an upper phase of L8004 to be at comparable elevation.
- ❖ Data from the weather station, vibration recorders and the video camera should be reviewed on an on-going basis.

7. REFERENCES

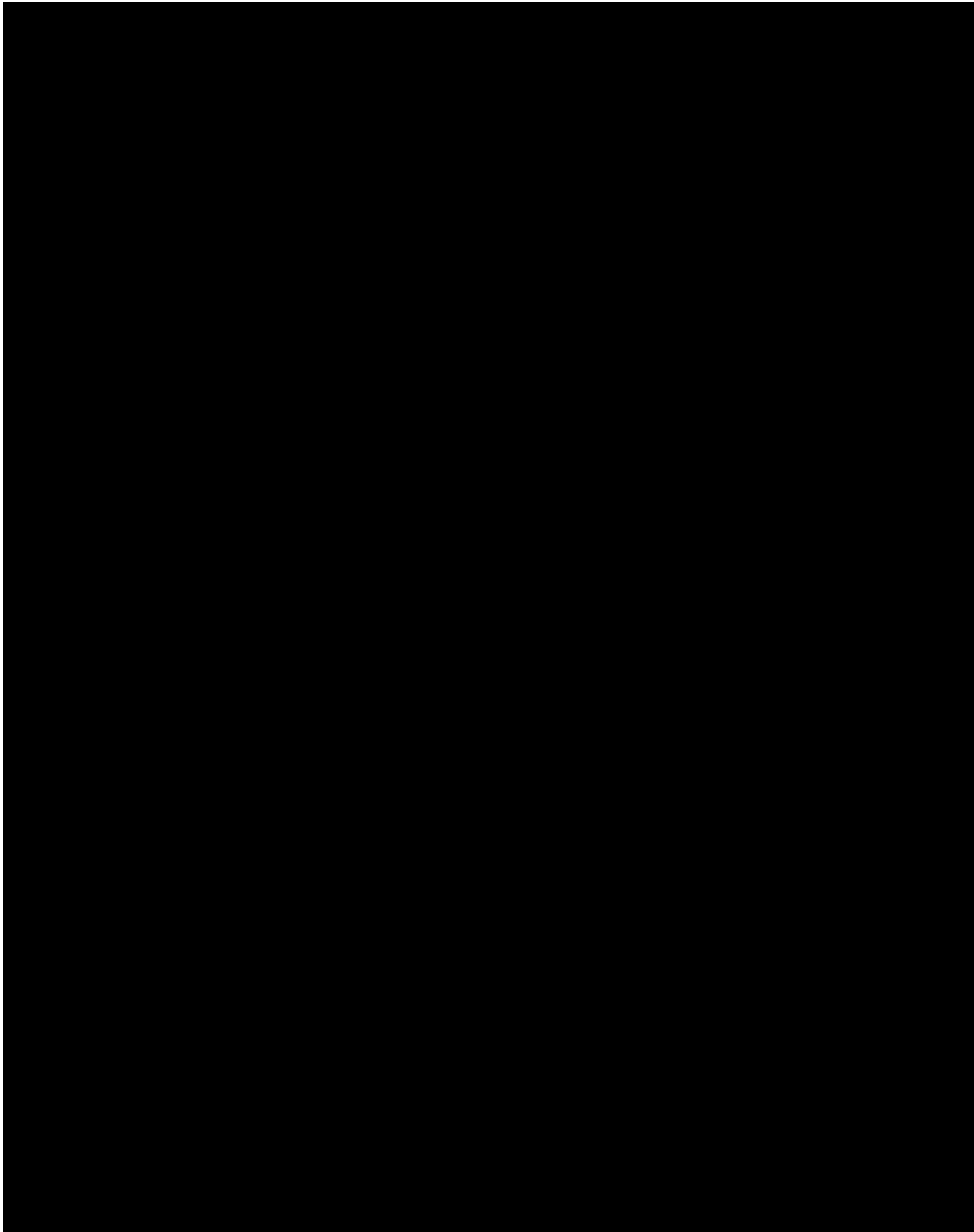
1. “Investigation of Damaged Conductor, Canso Crossing, Phase “A”, ALCAN Report, J.M. Asselin, Jan 1984.
2. “Experiences at the Strait of Canso Crossing in Nova Scotia”, presentation to the CIGRE WG 22-11, Task force on galloping, by Robert Whapham, Sept 1987.
3. “Assessment of the L7005 345 kV Canso Strait Crossing”, Interim Report for Nova Scotia Power, CIMA+ file no. M06496A, by D.G. Havard, Dec 2021
4. NSPI File “Tower Power 2”, containing 98 photos from a climbing inspection of Tower 730, May 2022
5. NSPI File “2023 Assessment”, subdirectories “730” and “731”, containing 1444 drone-based images. June 2023.
6. Modelling of aeolian vibrations of single conductors: assessment of the technology - (SC 22 - WG 11 – TF 01, Convenor Prof G. Diana) Electra 1998-N°181 (December 1998)
7. Aeolian vibrations of single conductor plus damper: assessment of the technology - (SC 22 WG 11 – TF 01, Convenor Prof G. Diana) Electra 2005-N°223 (December 2005)

L7005 345 kV CANSO STRAIT CROSSING

PREPARED FOR:
NOVA SCOTIA POWER

PREPARED BY:
Jon Kell, P. Eng

SEPTEMBER 12, 2023
REV. 00



Based on the review of all information, the following is recommended:

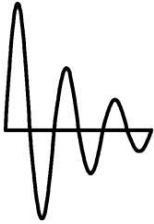
1. A thorough climbing inspection should be completed including checking of bolt torques. All bolts should be torqued and marked as shown in Figure 2. Periodic inspections should be carried out, confirming bolt tightness through visual inspection of previously applied marking.
2. The bolts used to connect the suspension insulator hardware to the towers should have a washer, of appropriate thickness, added to minimize the bending and/or wear on the bolt.



Figure 2 - Bolt Marking after torque

Rev1. Sep. 2024
Page 16 of 27

APPENDIX B – DR. HAVARD REPORT 2024



HAVARD ENGINEERING INC.

3142 Lindenlea Drive, Mississauga, Ontario, Canada, L5C 2C2

Telephone: 1-(905) 273-3076

http://www.havardengineering.com

E-mail: dhavard@rogers.com



To: Balraj Bilkhu, P.Eng.,
AAB Engineering Inc.
Halifax, N.S., Canada
902-441-7406
bbilkhu@aabengineering.ca

DRAFT

**INTERIM REPORT ON MAY 16, 2024, DRONE-BASED SURVEY
OF NOVA SCOTIA POWER'S L7005 345 kV CANSO STRAIT CROSSING**

by

**David G. Havard Ph.D., P.Eng.
President, Havard Engineering Inc.
3142 Lindenlea Drive
Mississauga, Ontario, Canada, L5C 2C2**

EXECUTIVE SUMMARY

An earlier report gave a detailed description of the Strait of Canso crossing, the technical problems and damage due to vibration and galloping and included suggestions for remedial action. [1]¹ In the intervening year, damage to the conductor was mainly repaired. Control devices for aeolian vibration and galloping motions were procured and some, but not all of them, were installed.

A drone-based fly-by using video recording to inspect the back spans and the conductors next to the suspension towers, was carried out on February 1 and 2, 2024, but unfortunately the images were too blurred for useful interpretation.

Some sections of the crossing spans were inspected a second time by a drone-based survey, this time using high resolution still photos, on May 16, 2024. The photographs

¹ Numbers in square brackets indicate sources listed below in "References".

included details of the six conductor phases, including repairs and dampers. Both suspension towers and the dead-end structures were photographed. These photographs were of the back spans on the Nova Scotia mainland and on Cape Breton Island and the damper arrays close to the two suspension towers. The survey did not include the more remote sections of the main span. This report is a review of those photographs emphasizing the signs of damage. The photographs do not suggest that bolts on the hardware and tower members have loosened but they will need to be checked in a climbing inspection.

The damage observed was minor compared to previous winters. It appears to be mostly some residual damage that was not included in the repairs carried out during 2023, but there is apparently no significant new damage on the crossing. Repairs of that minor damage and early installation of the vibration and galloping controls on all six phases are recommended.



David G. Havard, Ph.D., P.Eng.,
President, Havard Engineering Inc.
June 2024

LIST OF CONTENTS

Section No.	TITLE	PAGE
	Executive Summary	1
	List of Contents	3
	List of Figures	4
1	Introduction	6
2	Video inspection February 1 and 2, 2024	8
3	Photos of Cape Breton Island back span: May 26 2024	9
4	Photos around the Suspension Structure on Cape Breton Island: May 26 2024	11
5	Photos around the Suspension Structure on the Nova Scotia Mainland: May 26 2024	14
6	Photos of the Back Span on the Nova Scotia Mainland: May 26 2024	16
7	Main span over the Canso strait	18
8	Conclusions	19
9	Recommendations	20
10	References	21
App'x A	Summary of videos of Canso crossing taken February 2 & 3, 2024	22

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1	Dead end structure on Cape Breton Island from the drone. From photo No. DJI_20240116014927_0004_Z.jpg	9
2	View along back span on Cape Breton Island from the drone. Structures supporting the new (left) and old (right) spans across the Canso Strait are shown in the far distance. Detail from Photo No. DJI_20240116015020_0011_Z.jpg	9
3	Salvi dampers on the back span on Cape Breton Island showing impressions of previous damper clamp positions, or possible slippage. Detail from Photo No. DJI_20240118000143_0026_Z.jpg	10
4	General view looking west along the Canso Strait including the suspension structure on Cape Breton Island. Detail from Photo No. DJI_20240117231058_0029_w.jpg.	11
5	View of suspension structure on Cape Breton Island looking east, showing undamaged suspension insulator string and dampers on conductors, including the failed PLP damper on bottom conductor of the west circuit. Detail from photo No. DJI_20240117232158_0053_w.jpg	11
6	Closer view of bottom phases on crossing side of the suspension structure on Cape Breton Island looking west along the strait. Photo includes the slipped Salvi and broken PLP dampers. Repair sleeves can be seen between the array of dampers and the suspension clamp. Detail from photo No. DJI_20240117231347_0033_Z.jpg	12
7	Loose Salvi damper clamp and conductor damage. Bottom phase, west circuit, near suspension tower on Cape Breton Island. Detail from Photo No. DJI_20240117232412_0059_Z.jpg	12
8	Clamp from broken PLP damper. Bottom phase, west circuit, near suspension tower on Cape Breton Island. Detail from Photo No. DJI_20240116023210_0199_Z.jpg	13
9	Suspension structure on Nova Scotia Mainland looking east along the Canso Strait. Detail from Photo No. DJI_20240116032428_0047_w.jpg	14
10	Suspension structure on Nova Scotia Mainland looking west along the Canso Strait. Detail from Photo No. DJI_20240116033733_0148_w.jpg	14

11	Impressions of previous damper clamp locations on conductor near Suspension structure on Nova Scotia Mainland. Detail from Photo No. DJI_20240116033733_0148_w.jpg	15
12	Three PLP dampers on conductor near Suspension structure on Nova Scotia Mainland. Detail from Photo No. DJI_20240116033733_0148_w.jpg	15
13	Conductor damage on middle phase, west circuit, near Suspension structure on Nova Scotia Mainland. Detail from Photo No. DJI_20240116033733_0148_w.jpg	15
14	Conductor damage on middle phase, west circuit, near Suspension structure on Nova Scotia Mainland. Detail from Photo No. DJI_20240116033733_0148_w.jpg	15
15	View of the back span looking north towards the suspension structures on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031218_0001_w.jpg	16
16	View looking south showing dead end structures on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031338_0010_w.jpg	16
17	Ground end of insulators on the dead-end structure on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031651_0028_Z.jpg	17
18	High voltage end of insulators on the dead-end structure on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031655_0029_Z.jpg	17
19	Conductor impressions where previous Salvi damper clamps were located, or clamp slippage had occurred on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240118000131_0025_Z.jpg	17
20	Conductor impressions where Salvi damper clamps were located, or clamp slippage had occurred on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031756_0035_Z.jpg	17
21	Damper slipped to mid span West circuit, middle phase, from climbing inspection in May 2022. (Figure 3 of August 2023 report)	18

1. Introduction

An earlier report gave a detailed description of the Strait of Canso crossing, the technical problems and damage due to vibration and galloping and included suggestions for remedial action [1]. In the intervening year, damage to the conductor was mainly repaired. Control devices for aeolian vibration and galloping motions were procured but they were not installed.

As the crossing conductors were not completely protected from aeolian and galloping motions, and the resulting dynamic stresses over the 2023-2024 winter, an inspection was implemented. Initially this was a drone-based fly-by taking videos to inspect mainly the back spans. This was carried out on February 1 and 2, 2024, but unfortunately the images were too blurred for useful interpretation.

A subsequent drone-based inspection comprised high resolution still photographs of some sections of the crossing spans and took place on May 16, 2024. The weather that day was clear, but the photos did show snow falling some of the time, and the ground was snow covered.

The photographs included:

- The six conductor phases including repairs to the conductors where the old damper clamps had badly worn the outer layer of wires
- All remaining Salvi dampers
- All “Robust” PLP dampers including one with a fractured arm
- Both suspension towers
- Both dead-end structures
- Insulator strings
- String hardware.

These photographs were of the back spans on the Nova Scotia mainland and on Cape Breton Island, but did not include the main span, except the damper arrays close to the two suspension towers. This report is a review of those photographs emphasizing the signs of damage. The photographs do not suggest that bolts on the hardware and tower members have loosened but they will need to be checked in a climbing inspection.

The damage observed was minor compared to previous winters. There is some residual damage that was not included in the repairs carried out during 2023, but apparently no significant new

damage on the crossing. This report is focused on the signs of damage needing further checking, and possible repairs. Most photos showed no damage and those are not specifically commented on in this report.

Repair of the minor conductor damage and early installation of the vibration and galloping controls on all six phases are recommended.

DRAFT

2. Video inspection February 1 and 2, 2024

(The following comments were made after review of the drone-based videos)

Viewing conditions at the time were far from optimum. Snow was falling on the second day and the conductor was out of focus. The most useful video was of the long span (3A-4A). That span is the most exposed to the various effects of wind including swing out and vibration. The video suggests the presence of surface markings that may be the result of impacts between conductors. But the conductor's surface is blurred, and important details cannot be identified.

It was recommended to carry out another drone pass across the main span of the other conductors with better control of the focus. Complementary still photos of the conductor with a telescopic lens would help clarify the details of the surface of the conductor. A file of comments on the videos is attached in Appendix A.

There are three spans in the Canso crossing and six phases in each span. Viewing from both sides of each conductor to see the damage, if any, by a similar technique as in these videos, would require 36 videos. The most important span is the middle span where damage has occurred previously. No damage had been reported on the two back spans. Thus, of the ten videos only two are from the span of greatest interest. And those two, on span A3-A4, are practically impossible to interpret because of the poor visibility when the videos were created, and the out of focus photography. The other eight videos, while limited in the details of conductor and dampers that can be discerned, show no signs of damage on the A4-A5 back span.

If the drone had been made to hover and still photos had been taken, and properly focused, some useful record of the conductors' conditions would have been created. The drone travelled across the ~1400 m main span in 16 minutes. As it zipped past the conductor the blurred images did suggest that there were differences in reflectivity of the surface, maybe the results of impacts between conductors. Frame by frame examination of the video did not reveal further details of the shiny sections. Some sections showed individual strands sitting proud of the conductor profile. No projecting strands indicative of strand breaks could be seen.

This warrants a return to the crossing in clear weather with more specific instructions for the drone operating team. An NSPI engineer/inspector should accompany them and observe the images as they are received to guide the inspection. They should take a series of high magnification still photos of the six conductors, from both sides. Perhaps these should be spaced every 50 m, so that they show clear photos of the conductor surfaces from both sides. Locations with the most signs of impact should be recorded in greater detail. The photos need to be fully labelled to record their locations, conductor phase and circuit and which direction of view. If damage is found and likely due to clashing between conductors, that needs to be paired with the corresponding locations on the next conductor.

3. Photos of Cape Breton Island back span: May 26 2024

Figure 1 shows a general view of the dead-end structure at the north end of the back span on Cape Breton Island. The collection of photos shows many details of the structure and includes nuts and bolts all of which appear secure. But a close-up climbing inspection would be required to establish more definitively that no nuts are coming loose. The ends of the conductor in this section are protected by the original



Figure 1 Dead end structure on Cape Breton Island from the drone. From photo No. DJI_20240116014927_0004_Z.jpg



Figure 2 View along back span on Cape Breton Island from the drone. Structures supporting the new (left) and old (right) spans across the Canso Strait are shown in the far distance. Detail from Photo No. DJI_20240116015020_0011_Z.jpg

array of six Salvi dampers.

Figure 2 shows the view looking south along the length of the back span on Cape Breton Island and includes the new and old structures at the edge of the Canso Strait, on the upper left and right respectively. The terrain on each side of this span can be seen to be forested and provides shelter from the cross-winds, reducing the effects of aeolian vibration and galloping on this span.

Many damper locations on the back span include impressions of previous damper clamps on the nearby conductor surfaces. Figure 3 shows an example of two of these impressions. It is not clear whether these are from adjustments made to the damper positions during the original installation or are the results of some slippage of the Salvi damper clamps. The photos were not well labelled and consequently it is unclear which dampers, which phase, and which of the two circuits are shown in

Figure 3. All similar damper clamps need to be checked to ensure that they are firmly attached to the conductors.



Figure 3 Salvi dampers on the back span on Cape Breton Island showing impressions of previous damper clamp positions, or possible slippage. Detail from Photo No. DJI_20240118000143_0026_Z.jpg

4. Photos around the Suspension Structure on Cape Breton Island : May 26 2024

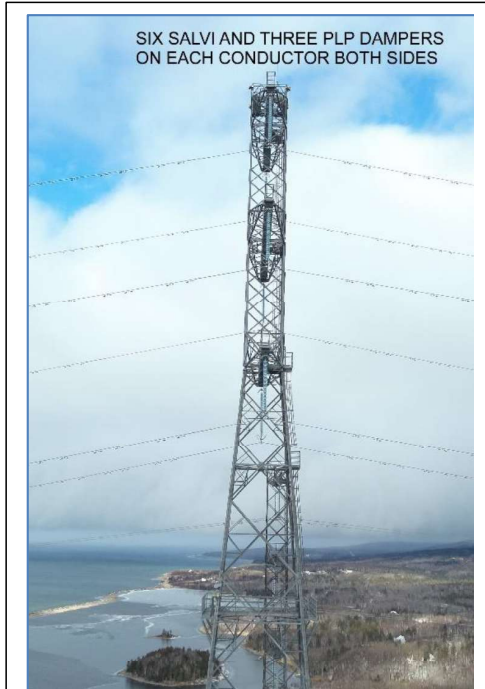


Figure 4 General view looking west along the Canso Strait including the suspension structure on Cape Breton Island. Detail from Photo No. DJI_20240117231058_0029_w.jpg.

closer view of the suspension tower, looking east along the Strait, including one of the insulator strings as well as the conductors and dampers. The bottom phase includes the PLP damper that was fractured during the previous winter and remained in place. No damage was visible on the insulators, and all nuts, cotter pins etc., seem to be in place. But the photographs are not a substitute for a proper climbing inspection and if necessary, retightening of all bolts.

During the 2022-2023 winter considerable damage occurred on the span across the strait next to this tower, including many examples of Salvi

The photographs from the drone survey of the “L7005” 345 kV power line crossing the Canso strait, around the suspension tower on Cape Breton Island are captured in file “7005-4a”. The photo in Figure 4 provides a general view of the situation showing the Canso Strait looking toward the west. The conductors crossing this strait are exposed to uninterrupted winds and subject to severe stresses from aeolian vibration, and from galloping when ice or wet snow is present if appropriate damping and galloping controls are not in place. The conductors near this structure have undergone many repairs from damage from these effects that were not controlled in the initial design of the crossing.

The drone-based inspection provides a valuable record of the conditions of the conductors and dampers adjacent to the tower. It also documents the conditions of the tower hardware and insulators. Figure 5 shows a

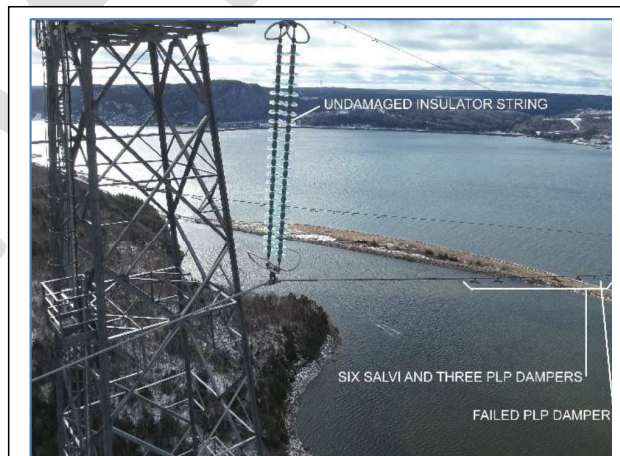


Figure 5 View of suspension structure on Cape Breton Island looking east, showing undamaged suspension insulator string and dampers on conductors, including the failed PLP damper on bottom conductor of the west



Figure 6 Closer view of bottom phases on crossing side of the suspension structure on Cape Breton Island looking west along the strait. Photo includes the slipped Salvi and broken PLP dampers. Repair sleeves can be seen between the array of dampers and the suspension clamp. Detail from photo No. DJI_20240117231347_0033_Z.jpg

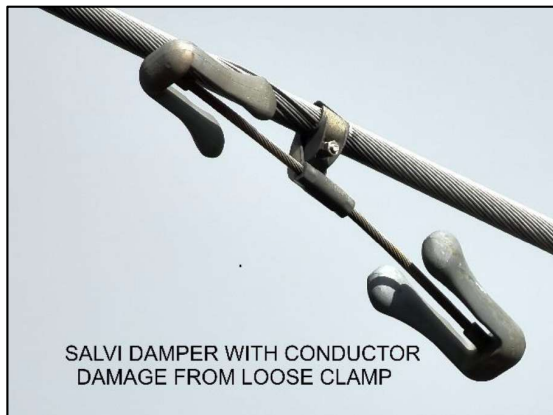


Figure 7 Loose Salvi damper clamp and conductor damage. Bottom phase, west circuit, near suspension tower on Cape Breton Island. Detail from Photo No. DJI_20240117232412_0059_Z.jpg

damper clamps becoming loose and causing wear and breakage if the outer layer of strands of the conductor, and the fracture of the arm one of the PLP dampers². Figure 6 includes the section of the bottom conductor of the west circuit that has been repaired using preformed rods between the suspension clamps and the damper array.

Figures 7 and 8 show the images of the slipped Salvi damper and the PLP damper with the fractured arm. These were damaged during the previous winter and the damage does not appear to have been worsened over the last winter. The damage to the conductor from the Salvi clamp will need to be repaired before additional vibration and galloping controls are installed.

² This damage is described in the early report [1]

The photographs do not suggest that conductor damage has occurred under the PLP damper clamp, but visual inspections of this, and all other similar clamp locations that will be changed, are recommended.

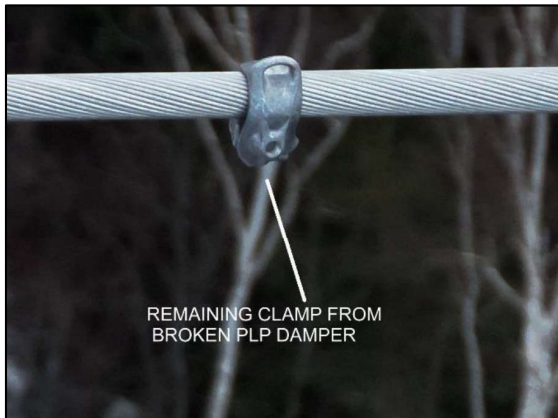


Figure 8 Clamp from broken PLP damper.
Bottom phase, west circuit, near suspension
tower on Cape Breton Island. Detail from
Photo No.

DJI_20240116023210_0199_Z.jpg

5. **Photos around the Suspension Structure on the Nova Scotia Mainland: May 26 2024**

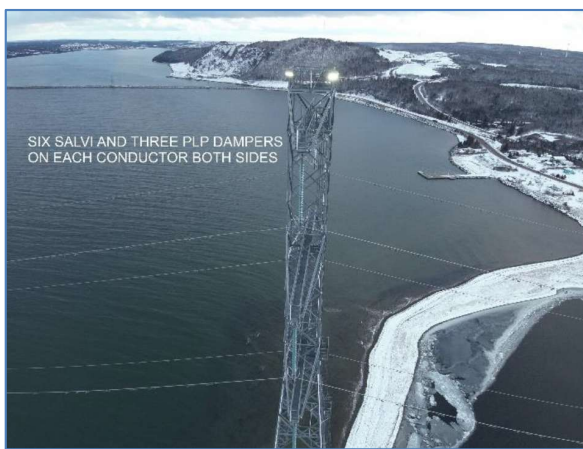


Figure 9 Suspension structure on Nova Scotia Mainland looking east along the Canso Strait.

Detail from Photo No.

DJI_20240116032428_0047_w.jpg

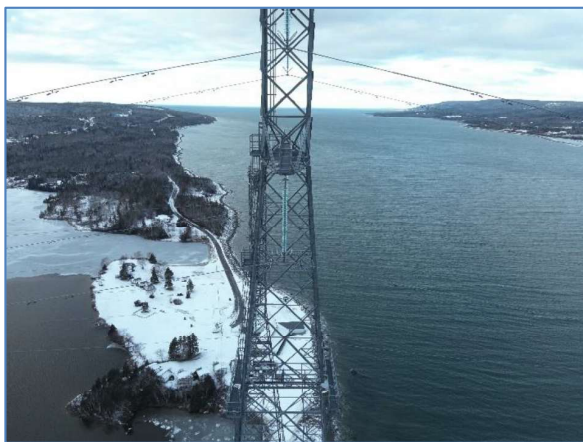


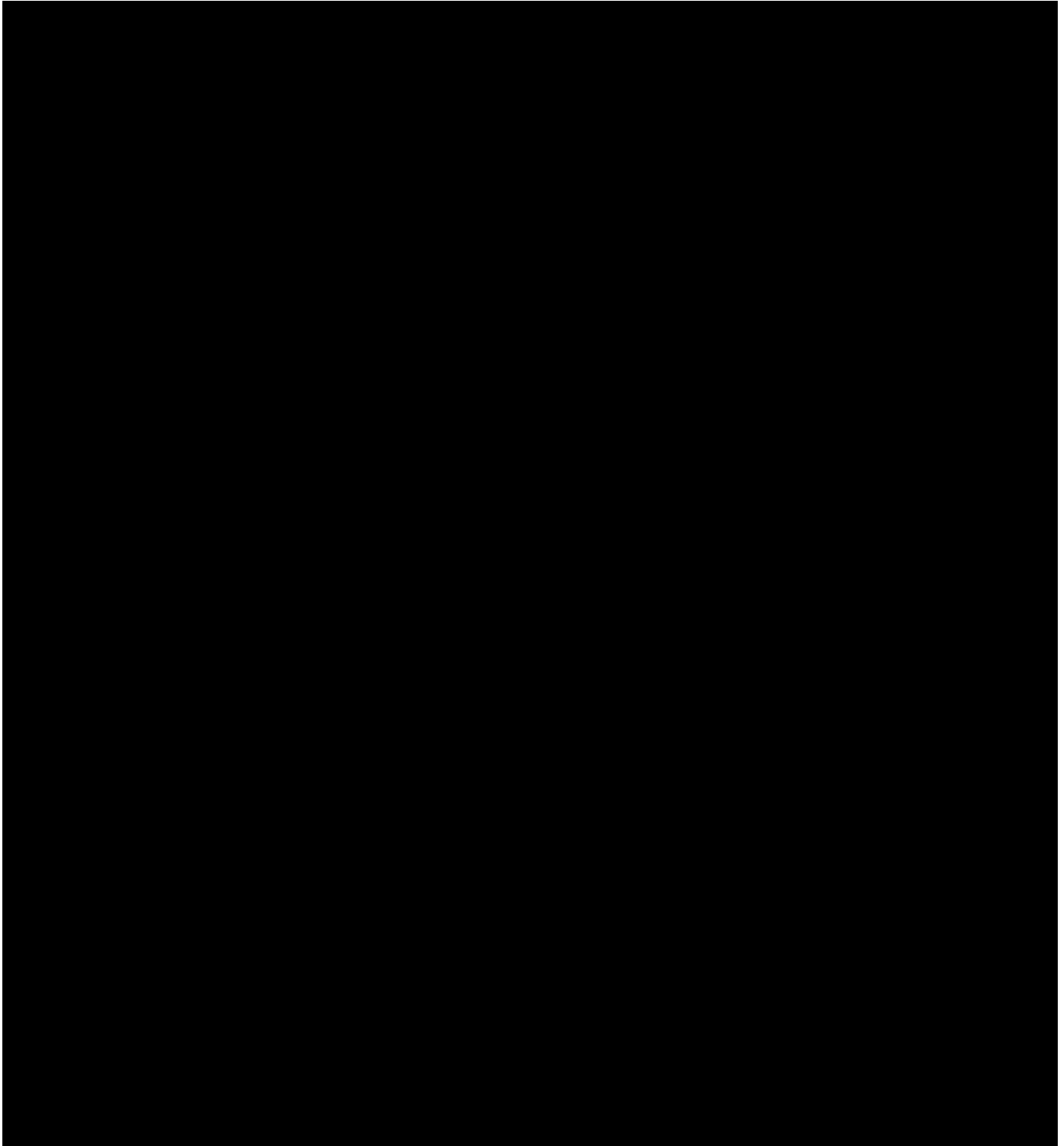
Figure 10 Suspension structure on Nova Scotia Mainland looking west along the Canso Strait.

Detail from Photo No.

DJI_20240116033733_0148_w.jpg

Figure 9 shows the suspension structure on the mainland side of the Canso strait looking east, and Figure 10 shows the same tower looking west. All conductors are protected against aeolian vibration by the arrays of Salvi and PLP dampers similar to those shown on the four phases visible in the photograph. The conductors on this end of the main span did not suffer the same amount of damage as on the Cape Breton Island end. Figure 11 shows one of the Salvi dampers and marks on the conductor, from a damper's previous location. One of the sets of three PLP dampers used on each conductor is shown in Figure 12.

But the conductors in the main span close to the suspension tower on the Nova Scotia mainland show a number of repairs from past winter's wind induced damage. Also, some unrepaired minor damage on the middle phase west circuit was identified from the drone-based photographs as presented below. Figure 13 shows a location where the damper clamp has made a more serious impression in the outer layer that would possibly need to be protected by a layer of armor rods. Similarly Figure 14 shows a location where an outer layer strand is projecting beyond the normal diameter of the conductor. These two examples were found on the middle phase, west circuit.



6. **Photos of the Back Span on the Nova Scotia Mainland: May 26 2024**



Figure 15 View of the back span looking north towards the suspension structures on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031218_0001_w.jpg



Figure 16 View looking south showing dead end structures on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031338_0010_w.jpg

The back span on the mainland side of the Canso Strait crossing has a similar exposure to aeolian vibration and galloping as that on the Cape Breton Island side. Figures 15 and 16 show the two ends of this span, and they show that the terrain is covered with trees, and consequently winds impacting the conductors will be turbulent and less likely to lead to either of these modes of vibration. The drone-based survey did not reveal damage that is likely to be due to such motions. Details of the dead-end insulator strings are shown in Figures 17 and 18, and no damage is visible in the photographs of this or any other strings supporting the crossing. There are few locations where there are clamp impressions on the outer surface of the conductor. Figures 19 and 20 show samples of these impressions. These may indicate the damper has been removed and the clamp retightened, possibly as part of an inspection program. There is a remote possibility that such impressions could be due to slippage consequent to severe vibration.



Figure 17 Ground end of insulators on the dead-end structure on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240116031651_0028_Z.jpg



Figure 18 High voltage end of insulators on the dead-end structure on the back span on the Nova Scotia Mainland Detail from Photo No. DJI_20240116031655_0029_Z.jpg



Figure 19 Conductor impressions where previous Salvi damper clamps were located, or clamp slippage had occurred on the back span on the Nova Scotia Mainland. Detail from Photo No. DJI_20240118000131_0025_Z.jpg



Figure 20 Conductor impressions where Salvi damper clamps were located or clamp slippage had occurred on the back span on the Nova Scotia Mainland Detail from Photo No. DJI_20240116031756_0035_Z.jpg

7. Main span over the Canso strait

A serious omission in the recent drone-based survey is recording of the condition of the main span across the Strait beyond the immediate vicinity of the towers. It should be noted that in the earlier, tower-based inspection in May 2022, one photograph looking toward the center of the strait showed a Salvi damper that had loosened and slipped towards the middle of the span³ That figure is reproduced here as Figure 21. That damper type is associated with many occurrences of damage to the outer layer of the conductors near the span ends. That loose damper may have damaged the in-span region where it was located.

Any similar events or remote damage to the conductors need to be known and corrective actions planned accordingly, before the major installation of the necessary vibration and galloping controls. It should be recognized that serious damage can occur from conductor galloping, and that the older crossing of this strait experienced a well-documented galloping event that caused extensive damage to the outer layers of two of the conductors [2]. After some wind tunnel investigations, air flow spoilers were installed, and no further galloping events have been recorded. Galloping events can cause motions that can bring adjacent phases into contact, especially vertically aligned phases. The resulting flashovers can cause major service interruptions and so would be clearly indicated in the operating records of the circuits.



Figure 21 Damper slipped to mid span West circuit, middle phase, from climbing inspection in May 2022. (Figure 3 of August 2023 report)

³ Figure 3 of [1]

8. Conclusions

- ❖ The line has survived the past winter with far less damage than in previous winters.
- ❖ The photos show a few surface marks where dampers had been installed.
- ❖ There is some minor conductor damage from previous damper clamps.
- ❖ Damage from the past few winters is greater at the Cape Breton Island end of the main span.
- ❖ Back spans are protected by the terrain from serious vibration and galloping damage.
- ❖ The condition of the conductors across the main span remains unknown.

DRAFT

9. Recommendations

- ❖ The main span needs to be surveyed or photographed to determine whether there is a need for any repairs before the new vibration and galloping hardware is installed.
- ❖ Any vibration recording, video cameras and weather monitoring should be at the Cape Breton end of the span.
- ❖ Both suspension structures should be fully inspected for looseness of bolts.
- ❖ The site should be visited regularly by an experienced lineman or engineer to check for tower noise indicating bolts becoming loose.
- ❖ Any vibration monitoring should be performed on a bottom phase of L7005 and an upper phase of L8004 to be at comparable elevation.
- ❖ Data from the weather station, vibration recorders and the video camera should be reviewed on an on-going basis.
- ❖ Vibration and galloping controls recommended have been supplied and need to be installed before the winter of 2024.
- ❖ Any future drone-based video or still photography of the line need to be fully planned and documented.
- ❖ The drone inspections need to be carried out accompanied by an experienced lineman or engineer to review the results and guide the process in real time.
- ❖ Photos and videos from drone inspections need to be labeled to show the conductor phase, side, distance along the span and direction of view.

10. **References**

1. Interim Report, “Drone-Based Survey of Nova Scotia Power’s L7005 345 kV Canso Strait Crossing”. Report for Balraj Bilkhu, P.Eng., President AAB Engineering Inc. by David G. Havard, Ph.D., P.Eng. President, Havard Engineering Inc. June 13, 2023
2. “Investigation of Damaged Conductor, Canso Crossing, Phase “A”, ALCAN Report, J.M. Asselin, Jan 1984.
3. “Experiences at the Strait of Canso Crossing in Nova Scotia”, presentation to the CIGRE WG 22-11, Task force on galloping, by Robert Whapham, Sept 1987.

Canso Strait 345 kV Crossing: Drone Inspection May 2024

Appendix A

Summary of Videos of Canso Crossing

VIDEO TITLE	DATE	DURATION OF VIDEO	SPAN	COND'R HEIGHT	CIRCUIT	VIEW FROM	COMMENTS
DJI_20240202005423_0001_S.mp4	2024-02-02	12 mins	A4-A5	middle	north	south	mainland side, back span, detail of stranding not visible, near conductor out of focus, air flow spoilers shown on old span conductors. Dampers on old and new conductors. No broken strands
DJI_20240202015153_0002_S.mp4	2024-02-02	9 mins	A4-A5	upper	south	north	mainland side, back span, some strands prominent, indistinct against snow background, better against dark foliage, three PLP and five Salvi dampers in place, No broken strands
DJI_20240202015520_0001_S.mp4	2024-02-02	9 mins	A4-A5	upper	south	north	mainland side, back span, some strands prominent, indistinct against snow background, better against dark foliage, three PLP and five Salvi dampers in place, No broken strands
DJI_20240202021557_0001_S.mp4	2024-02-02	10 mins	A4-A5	upper	south	south	mainland side, back span, some strands prominent, indistinct against snow background, better against dark foliage, eight Salvi dampers in place at tension structure, three PLP and five Salvi dampers in place at suspension end, AFS on old span, No broken strands.
DJI_20240202024241_0001_S.mp4	2024-02-02	9 mins	A4-A5	middle	south	north	mainland side, back span, out of focus, some strands prominent, very indistinct against snow background, better against dark foliage, three PLP

Canso Strait 345 kV Crossing: Drone Inspection May 2024

							and five Salvi dampers in place at suspension end, No broken strands.
DJI_2024020222554_0001_S.mp4	2024-02-02	1 min	A4-A5	lower	south	north	mainland side, back span, out of focus, very dark, cannot see stranding.
DJI_2024020222738_0001_S.mp4	2024-02-02	10 min	A4-A5	lower	south	north	CBI side, back span, out of focus, cannot see stranding, lot of jumping around, three PLP and five Salvi dampers in place at suspension end,
DJI_2024020224252_0001_S.mp4	2024-02-02	9 min	A4-A5	middle	north	north	CBI side, back span, out of focus, cannot see stranding, six Salvi dampers at dead end, three PLP and six Salvi dampers in place at suspension end, no broken strands visible
DJI_20240202233030_0001_S.mp4	2024-02-02	16 minutes	A3-A4	middle	north	north	Main span, some wires proud of conductor profile, out of focus, cannot discern individual strands, No broken strands.
DJI_20240203014442_0001_S.mp4	2024-02-03	16 minutes	A3-A4	bottom	east	east	main span, visibility poor, due to snow storm, surface has mottled appearance, possible impact damage, includes view of broken PLP damper, No broken strands.

Rev1. Sep. 2024
Page 17 of 27

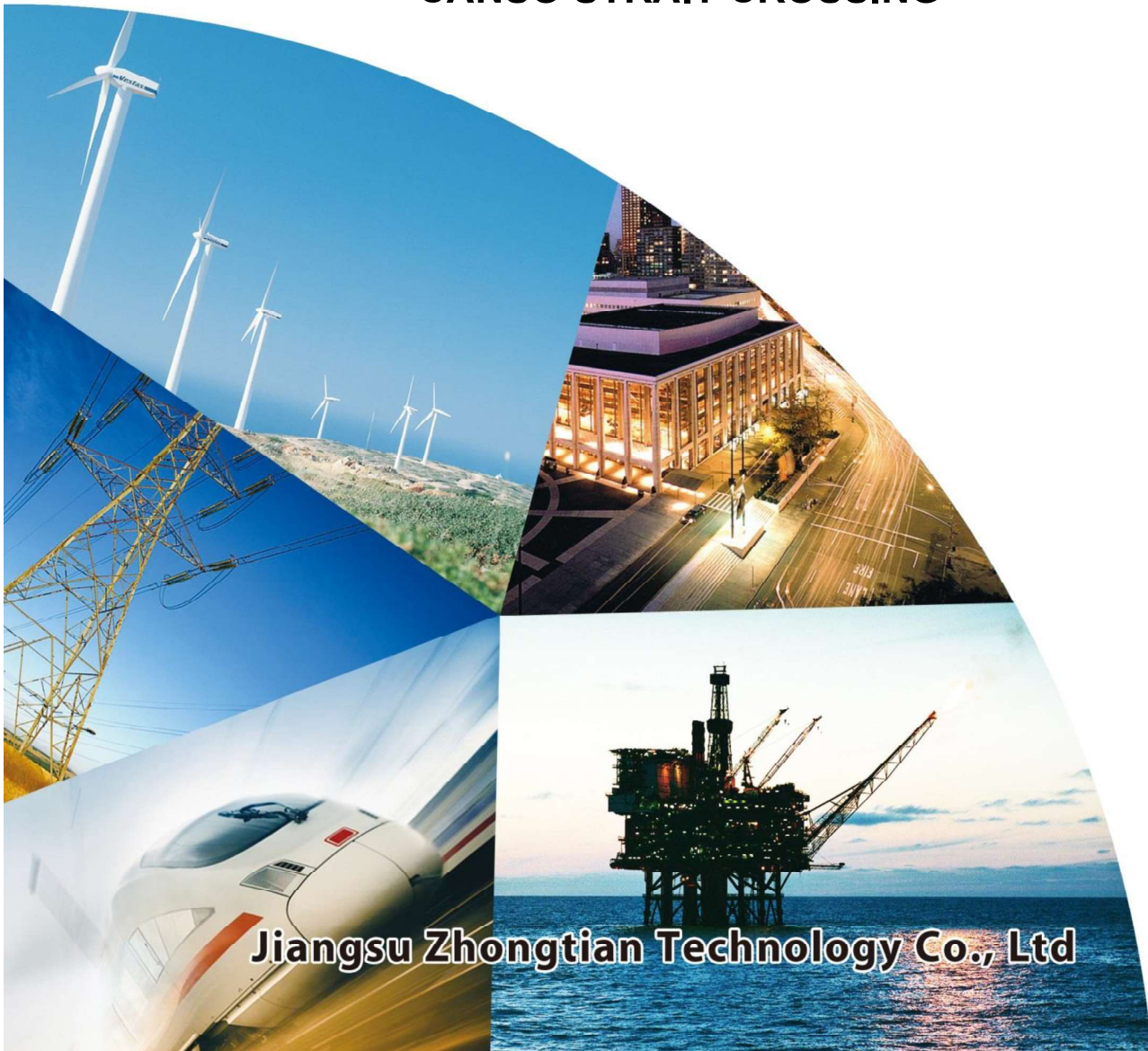
APPENDIX C – ZTT REPORT

Ref: 55141- 010724JR(3)

Date :15 July 2024



REPORT FOR NS POWER CONDUCTOR DAMAGE CANSO STRAIT CROSSING



Jiangsu Zhongtian Technology Co., Ltd

REPORT FOR NS POWER CONDUCTOR DAMAGE CANISO STRAIT CROSSING

Report considers

- the damage to the conductor,
- resulting reduction in strength of the Conductor,
- resulting loss of conductivity,
- potential repair of the conductor, and
- recommendation for damping system

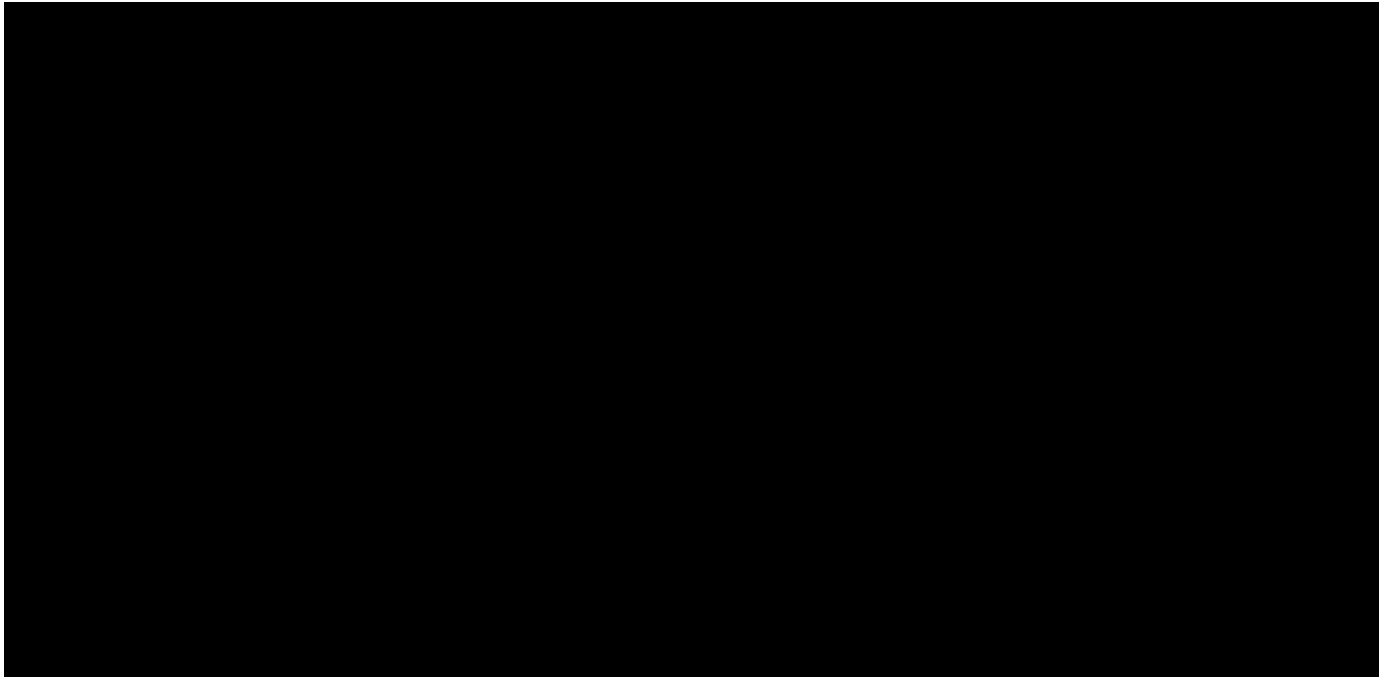
Report Prepared By: Jack Roughan

Approved by: Miao Yaojun

Date: 1 August 2024



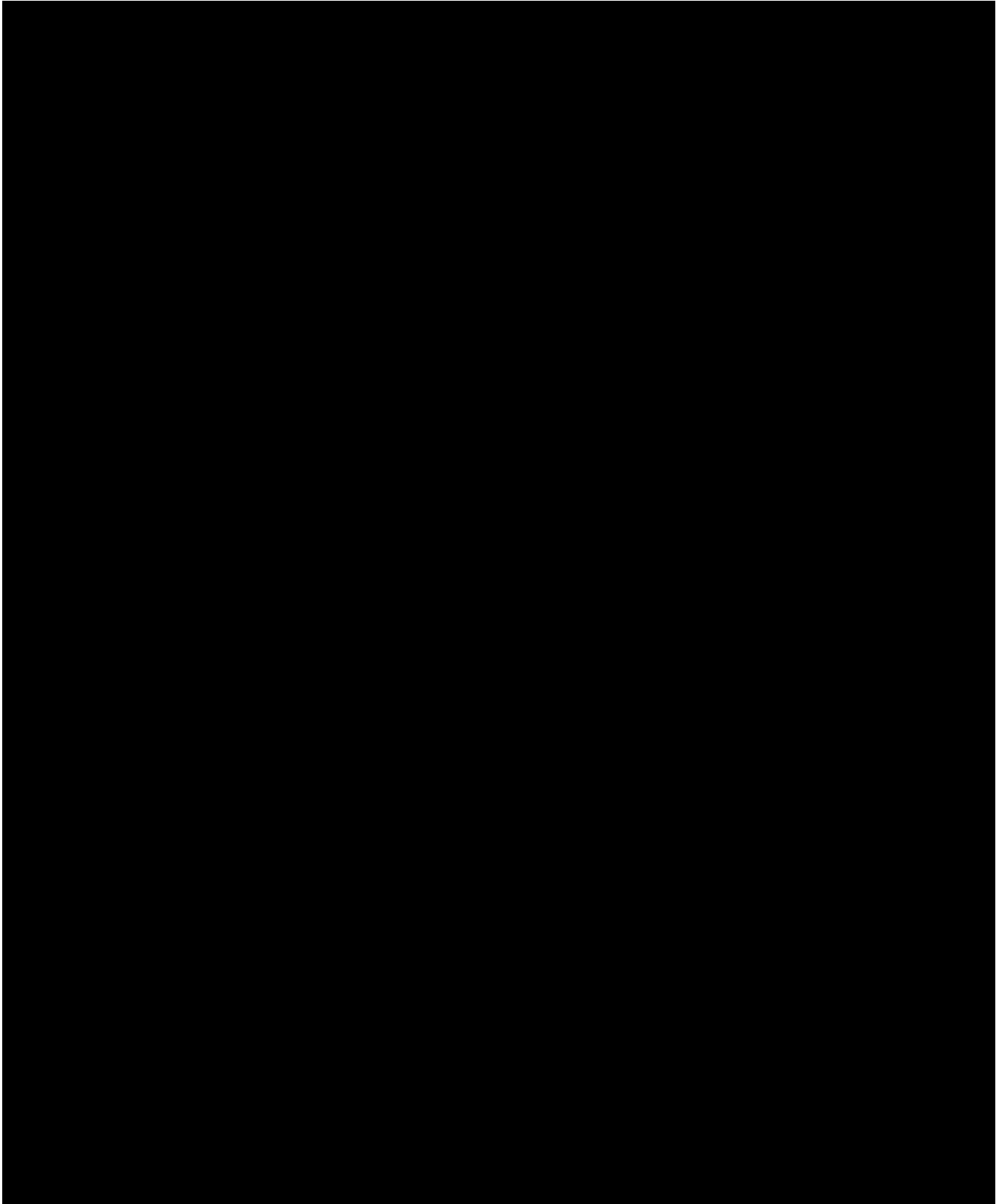
1. Introduction

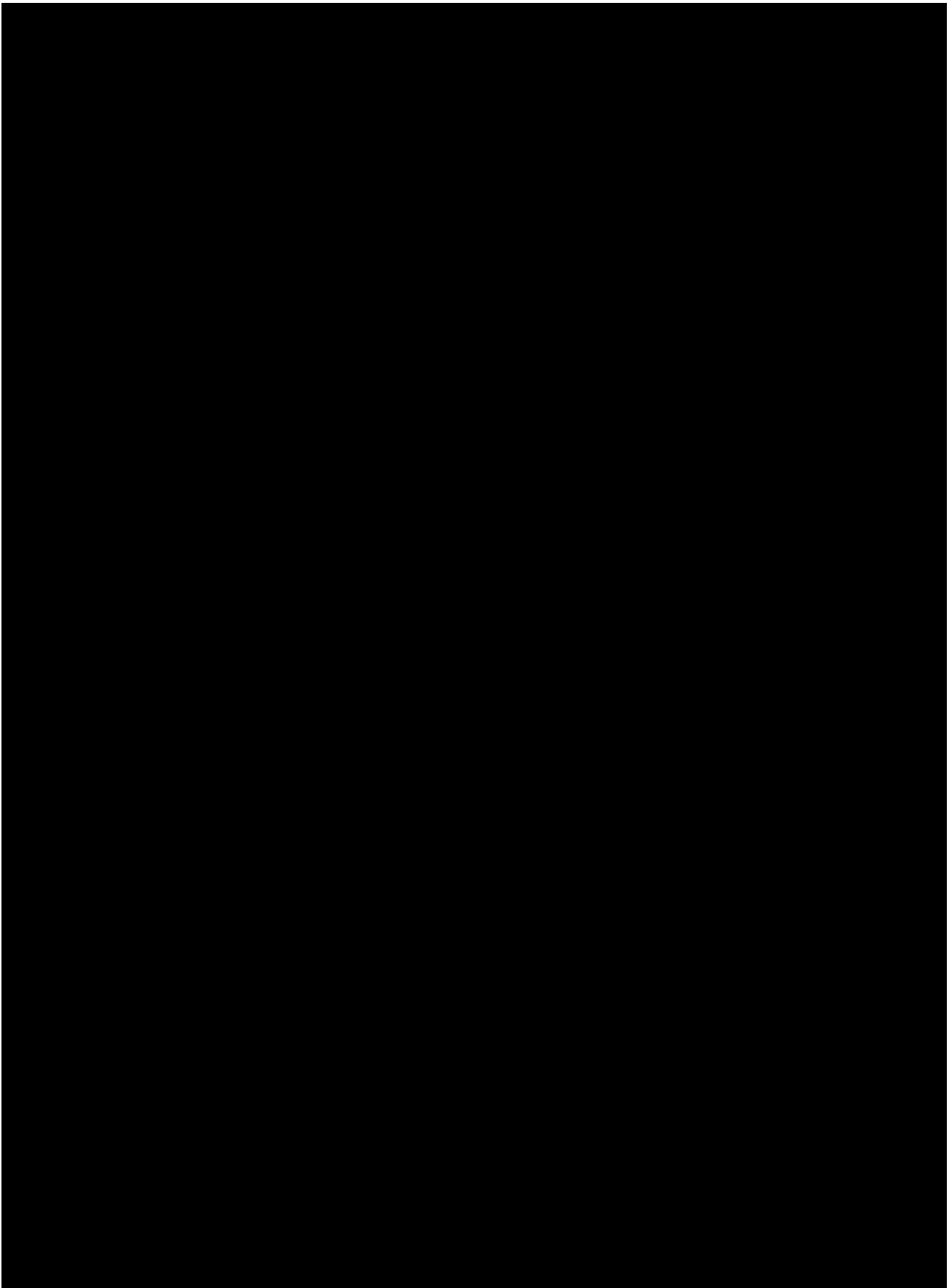


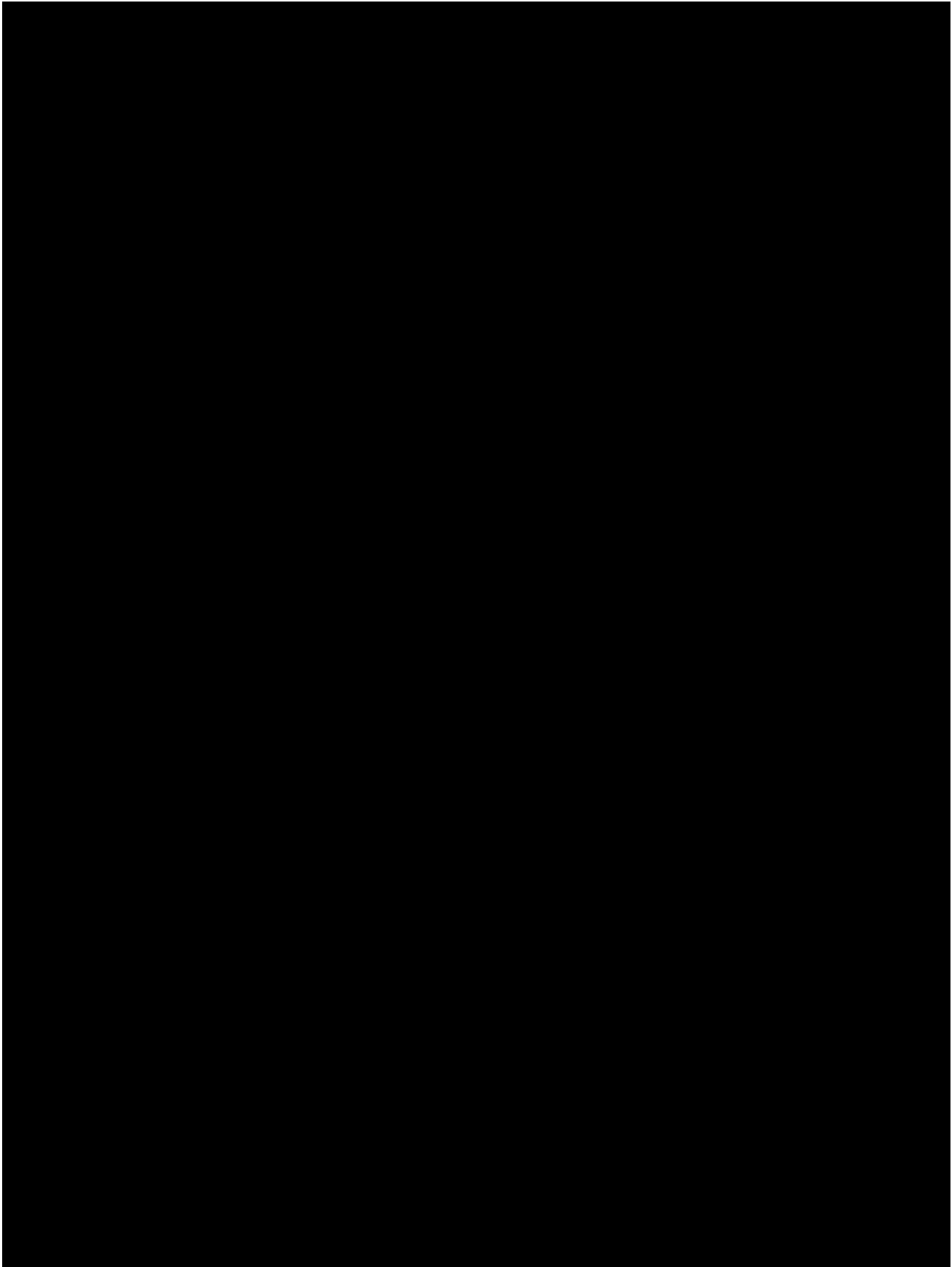


2. Review of information provided by NS Power

A review of the information provided by NS power was conducted.
This review included the photographs and videos.







- Dampers not sitting properly on the conductor

There are a large number of places where the stockbridge dampers have apparently twisted on the conductor. This may be related to the relative to the size of the damper clamps compared to the size of the dampers. Compare to smaller dampers, the clamps seem quite narrow.

This appears to have resulted in an inability of the clamp to hold the damper properly on the conductor. The unbalanced force from each side of the damper applies a significant torque to the damper and it appears that the damper clamp has twisted on the conductor as a result. This has resulted in severe damage to the aluminium strands in a large number of places. This damage and the twist of the clamp on the conductor can be seen in fig X. below



- Dampers may be getting “tired”
 - There are a number of places that the clamps appear to be sitting properly on the conductors, but the weights appear to have sagged. This often indicates that the dampers have been working hard, and may be starting to reach their end of life.



- Failure of elastomer type dampers
 - In one location it appears that the Riganti damper has failed. The cause of this is not apparent, but is of concern.



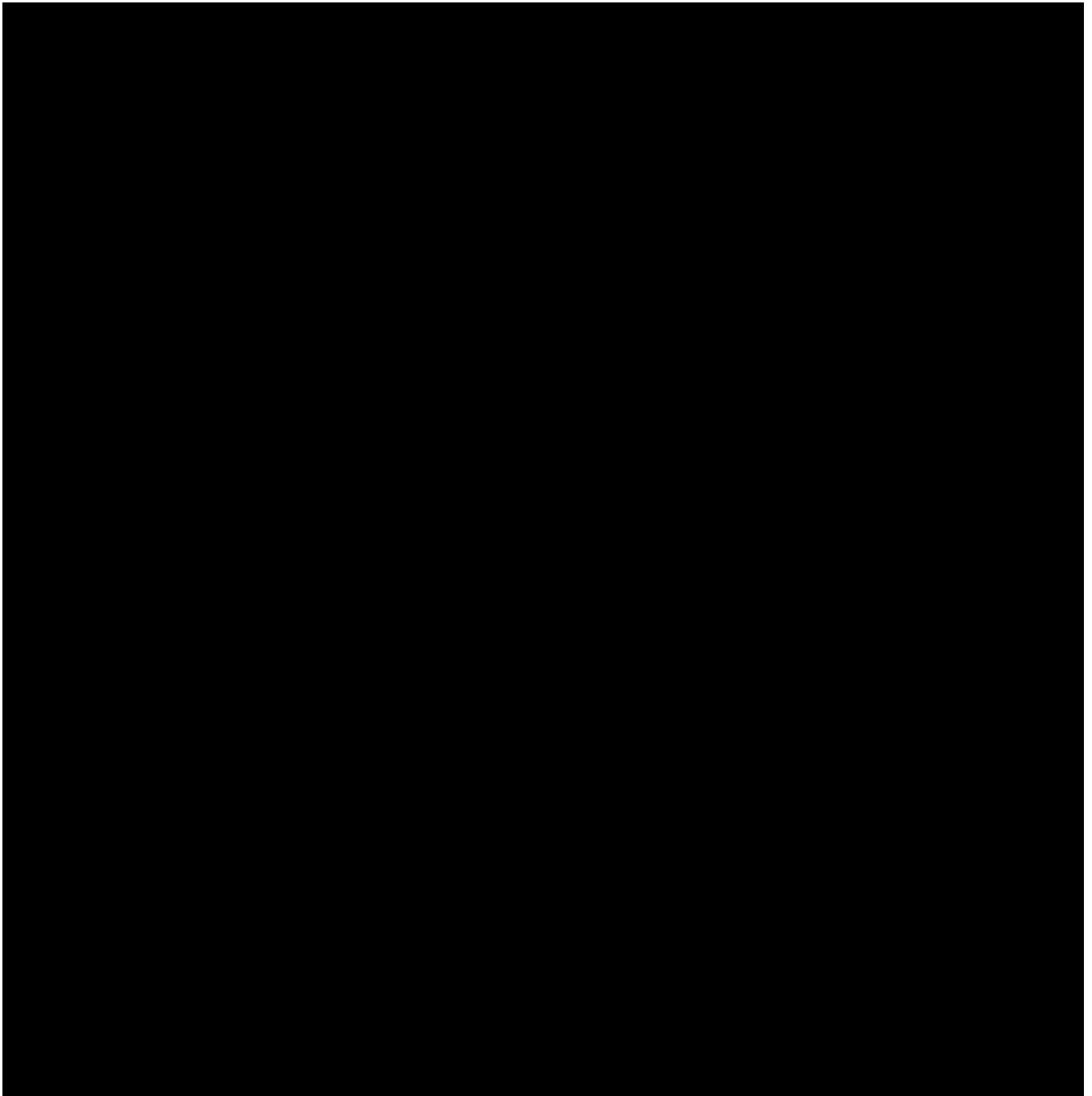
- Armour rods have been installed in some locations. It is not possible to estimate the number of broken strands (if any) under the armour rods

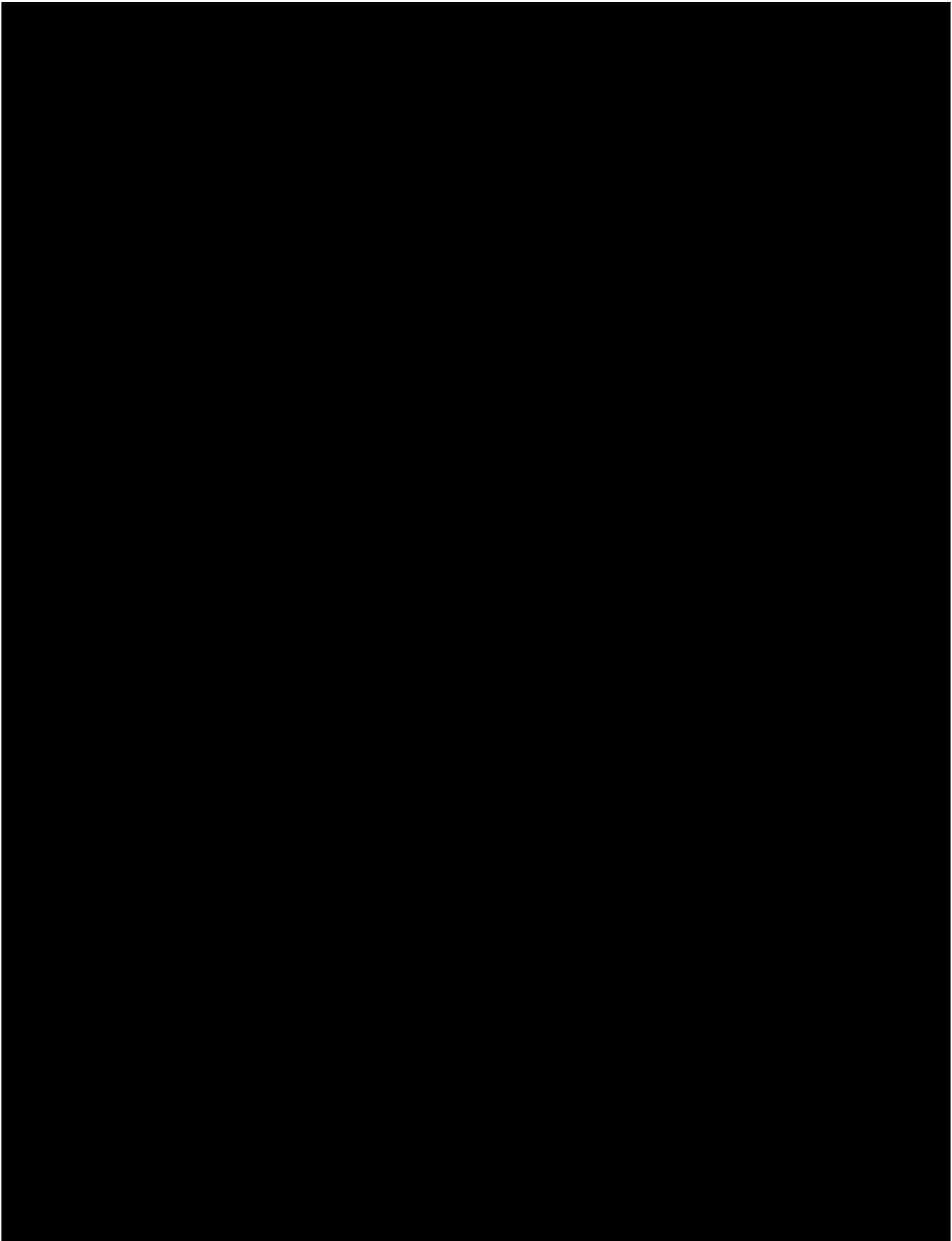


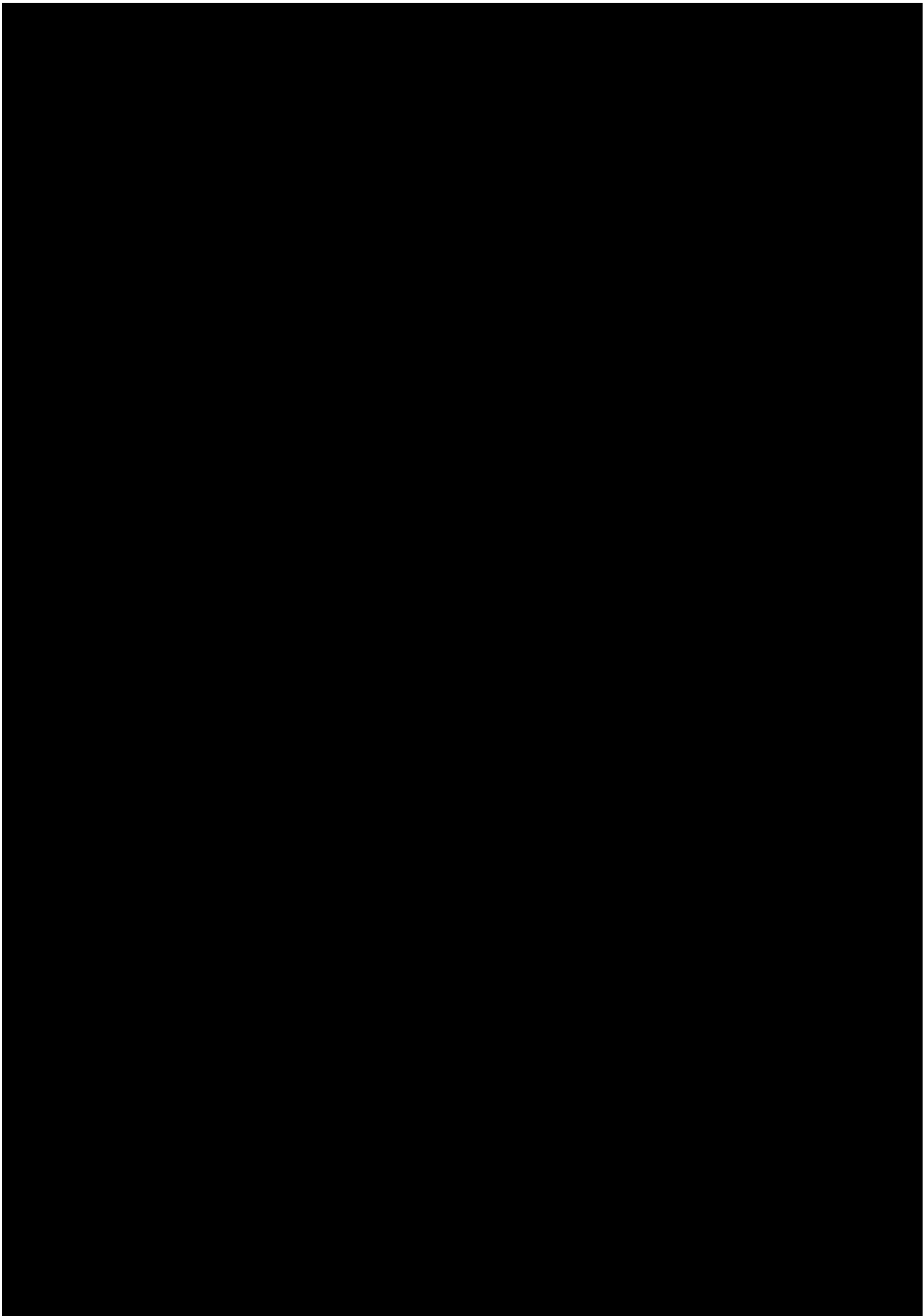
- Spiral “spoilers” have been installed
It is expected that the spiral airflow spoilers will contribute both to suppression of galloping that may be occurring, and also to reduction of the wind energy input that may be driving aeolian vibration



There appear to be no photographs of the airflow spoilers with a water background so it is not known if these are also installed on the strait crossing span









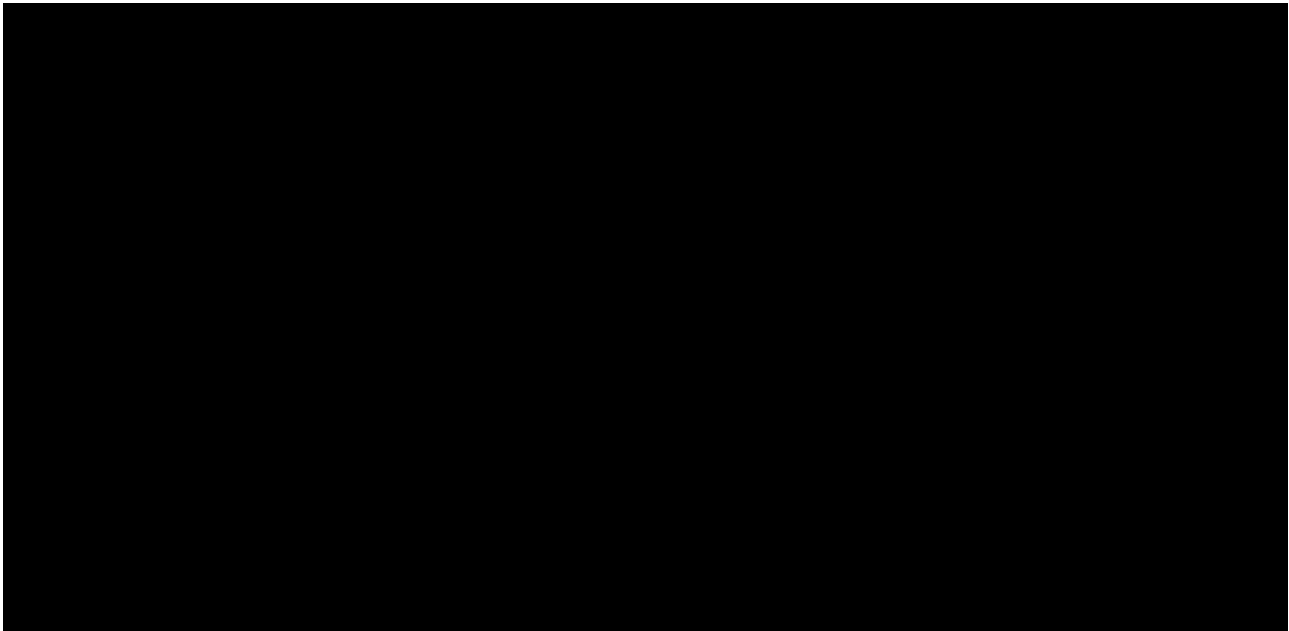
design employed will be able to restore the strength and conductivity for up to half of the aluminium strands.

Use of formed wire rods for repair of conductors on this crossing is evident from the information supplied to us by NS power.

In addition to the formed wire products there are other products including split sleeve designs available. These are compressed onto the conductor in similar manner to midspan splices.

We would expect that suitably designed repair rods or Splices will be able to restore full strength and conductivity to the conductors.

There are also proprietary designs similar to Clamp Star that may restore full conductivity to the damaged strands



5. Recommendation

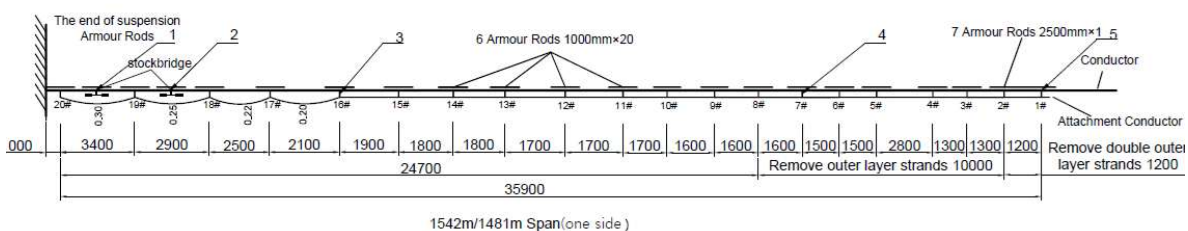
Alternative Solutions for Vibration Control

ZTT has noted the spiral Airflow spoilers have been installed in some places on the conductors. The use of these devices will help control any galloping that may be occurring on these conductors, and will also help to reduce aeolian vibration by reducing the wind power input to the conductors.

However it is evident that both the original stockbridge dampers and also the Riganti dampers that have been installed have suffered in service.

ZTT would like to recommend a “festoon” arrangement, similar to the one shown below, be considered. We have had good results with this type of arrangement for very long spans over a long period of time.

A similar system was installed on the Yangtze crossing in 2013 to replace similar stockbridge dampers which had failed in service. This system is inspected annually and continues to work well. We would be happy to provide further information if this is of interest.





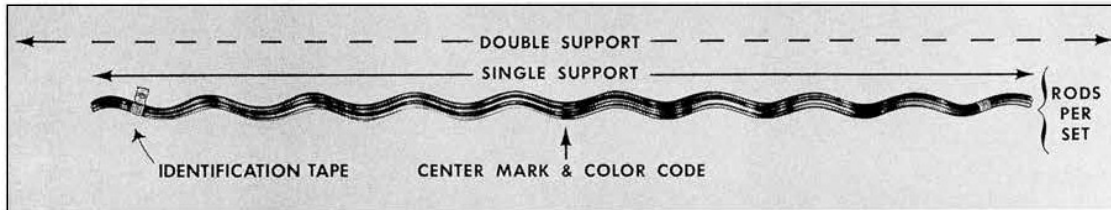
- End of Report -

**Rev1. Sep. 2024
Page 18 of 27**

APPENDIX D – PLP ARMOR RODS

Armor Rods

NOMENCLATURE



Single Support and Double Support Length: Identified by “S” and “D” appearing in the length column on the catalog page. Should the maximum distance between tied supports exceed 12 inches on double crossarm construction, consult PLP.

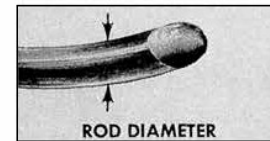
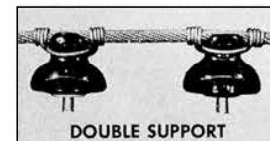
Rod Diameter: Added to conductor O.D., assists in arriving at applied overall diameter.

Rods Per Set: Indicate the proper number of rods for each application.

Center Mark: Establishes recommended alignment of rods during application.

Color Code and Length: Assist in identification of conductor size, corresponding to tabular information appearing on catalog page.

Identification Tape: Shows catalog number, nominal sizes.



Thermal Rating (Continuous)
 Within a high temperature
 Suspension Clamp 250°C
 ACSS Repair 250°C
 ACSR Repair 125°C

GENERAL RECOMMENDATIONS

PROTECTION. PREFORMED™ Armor Rods are intended to protect against bending, compression, abrasion, arc-over, and to provide repair. The degree of protection needed on a specific line depends upon a number of factors such as line design, temperature, tension, exposure to wind flow, and vibration history on similar construction in the same area. As a general guide, the following recommendations may be adopted to the specific conditions.

Armor Rods are recommended as minimum protection for clamp-type supports or suspensions.

Line Guards are recommended as minimum protection for hand-tied spans.

The use of supplementary damping devices, such as Spiral Vibration Dampers, should be considered when conductor vibration is present or expected.

PLP® Factory Formed Ties are recommended as being superior to armor-hand tie combinations in providing protection from abrasion, and equivalent in providing protection from vibration fatigue.

ARMOR-GRIP® Suspension is recommended as being superior to armor-clamp combinations in providing protection from bending stress, compression stress and abrasion.

ARMOR RODS RESTORATIVE-REPAIR. Armor Rods may be used to restore full conductance and strength to ACSR and aluminum conductors where damage does not exceed approximately 50 percent of the outer strand layer. Consult Factory for repair capability of specific strandings.

For standard catalog numbers damage should be located at the “point of support” or within the “midspan area.” For damage 6" to 36" (152 to 914 mm) from the support point contact PLP for recommendations.

NOTE: When Armor Rods are used to repair damaged aluminum-based conductors, the following application steps are required for optimum **electrical** repair:

Step 1: Thoroughly wire-brush damaged conductor for the full length of the Armor Rods to be applied.

Step 2: Apply a gritted inhibitor to the full length of this area before applying the Armor Rods.



Armor Rods

GENERAL RECOMMENDATIONS CONTD.

TAPPING. Tapping over applied aluminum *Armor Rods* is permissible. Where it is known that tapping clamps will be installed over *Armor Rods*, it is recommended that the conductor be thoroughly wire brushed clean, then an inhibitor be applied.

APPLICATION-INSPECTION. After application of the correct number of rods per set, a slight gap between rods should be present. Consult the General Information Section for detailed explanation.

Apply no more than one-half the number of rods per set at a time on smaller sizes. On conductors 4/0 and larger, do not attempt to apply more than 4 rods at a time. The alignment of the ends of the rods should be maintained within 2 inches for voltages of 230 KV and lower.

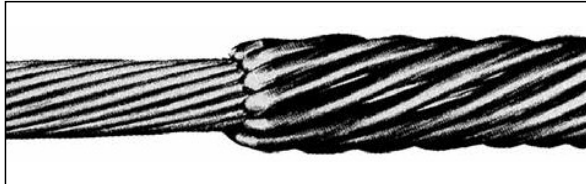
MATERIAL SELECTION. For copper or Copperweld® conductor, Copperweld® or Phosphor Bronze, *Armor Rods* are recommended when electrical requirements such as tapping or repair are not involved.

SAFETY CONSIDERATIONS

1. This product is intended for a single (one-time) use and for the specified application. CAUTION: DO NOT REUSE OR MODIFY THIS PRODUCT UNDER ANY CIRCUMSTANCES.
2. This product is intended for use by trained craftspeople only. This product SHOULD NOT BE USED by anyone who is not familiar with and trained in the use of it.
3. When working in the area of energized lines with this product, EXTRA CARE should be taken to prevent accidental electrical contact.
4. For PROPER PERFORMANCE AND PERSONAL SAFETY be sure to select the proper size PREFORMED™ *Armor Rods* before application.
5. PREFORMED *Armor Rods* are precision devices. To insure proper performance, they should be stored in cartons under cover and handled carefully.

DESIGN MODIFICATION

Armor Rods: PARROT-BILL® Ends



To meet the corona onset and RIV requirements for most extra-high-voltage applications, PARROT-BILL® Ends are to be used instead of the standard ball-end rods. Consult the Factory for an engineering recommendation.

O.D. CALCULATIONS

Applied overall diameter computed as follows:

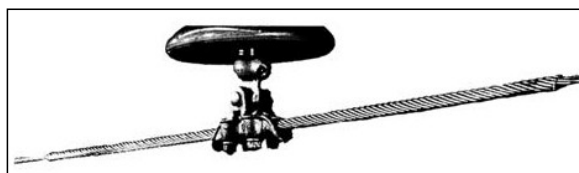
The rod diameter can be obtained from the catalog page tables. Conductor/Strand O.D. can be found in the Conductor Chart, General Information Section.

Rod Diam.,	.167" x 2 = .334"
Conductor Diam.	+ .398"
Total Applied O.D.	.732"

Armor Rods: Aluminum

For use on:

**ACSR, Compacted ACSR,
Aluminum Alloy All-Aluminum,
AWAC® Compacted All-Aluminum,
ACAR, ACSS (AW & TW)**



Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/Lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
AR-0106 AR-0306	.194	.207	#6, 7W Alum. Alloy #6, 6/1	100 100	35 45	40(S) 52(D)	.121	7	Blue
AR-0107 AR-0307	.208	.219	#4, 7W, Comp.	100 100	35 45	40(S) 52(D)	.121	7	Black
AR-0108 AR-0308	.220	.228	#5, 3-7W Alum. Alloy #5, 6/1	100 100	40 51	40(S) 52(D)	.121	8	White
AR-0109 AR-0309	.229	.243	#4, 7W All-Alum. #4, 6/1-7/1 Comp.	100 100	40 51	40(S) 52(D)	.121	8	Brown
AR-0110 AR-0310	.244	.259	#4, 6/1, 7/1 #4, 7W, Alum. Alloy	50 50	25 32	40(S) 52(D)	.146	7	Orange
AR-0111 AR-0311	.260	.273	#3, 7W All-Alum. #2, 7W Comp.	50 50	26 34	42(S) 54(D)	.146	7	Green
AR-0112 AR-0312	.274	.289	#3, 7W, Alum. Alloy	50 50	30 38	42(S) 54(D)	.146	8	Yellow
AR-0113 AR-0313	.290	.308	#2, 7W All-Alum. #2, 6/1 Comp.	50 50	30 38	42(S) 54(D)	.146	8	Purple
AR-0114 AR-0314	.309	.326	#2, 6/1, 7/1 #2, 7W Alum. Alloy	50 50	32 40	44(S) 56(D)	.136	9	Red
AR-0115 AR-0315	.327	.346	#1, 7W All-Alum. #1/0, 7W-19W Comp.	50 50	38 46	46(S) 58(D)	.146	9	Blue
AR-0116 AR-0316	.347	.366	#1, 6/1 #1, 7W Alum. Alloy	50 50	40 49	48(S) 60(D)	.146	9	Green
AR-0117 AR-0317	.367	.389	1/0, 7W All-Alum. 2/0, 7W Comp.	50 50	45 55	50(S) 62(D)	.146	10	Black
AR-0118 AR-0318	.390	.413	1/0, 6/1 1/0, 7W Alum. Alloy	50 50	55 67	52(S) 64(D)	.167	9	Yellow
AR-0119 AR-0319	.414	.436	2/0, 7W-19W All-Alum. 3/0, 7W Comp.	50 50	48 58	52(S) 64(D)	.146	10	Brown
AR-0120 AR-0320	.437	.463	2/0, 6/1 3/0, 6/1 Comp.	50 50	64 76	54(S) 66(D)	.167	10	Blue
AR-0121 AR-0321	.464	.490	3/0, 7W-19W All Alum.	50 50	64 76	54(S) 66(D)	.167	10	Green
AR-0122 AR-0322	.491	.521	3/0, 6/1 3/0, 7W Alum. Alloy 4/0, 6/1 Comp.	25 25	37 46	56(S) 68(D)	.167	11	Orange
AR-0123 AR-0323	.522	.551	4/0, 7W-19W All-Alum.	25 25	38 46	58(S) 70(D)	.167	11	Black

Right-hand lay standard

(Continued on next page)

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Reference O.D. Calculations for: APPLIED O.D. Calculations.
- (4) AWAC is a registered trademark of the Copperweld Co.



Armor Rods: Aluminum

Catalog Number	EHV Armor Rod Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/Lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
		Min	Max		Per Carton					
AR-0124		.552	.585	4/0, 6/1	25	46	60(S)	.182	11	Red
AR-0324					25	55	72(D)			
AR-0125		.586	.606	266.8 kcmil, 19W	25	52	62(S)	.182	12	Black
AR-0325					25	61	74(D)			
AR-0126		.607	.630	266.8 kcmil, 18/1	25	54	64(S)	.182	12	Purple
AR-0326					25	63	76(D)			
AR-0127		.631	.655	266.8 kcmil, 26/7	25	54	64(S)	.182	12	Yellow
AR-0327					25	63	76(D)			
AR-0128		.656	.679	336.4 kcmil, 19W	18	43	66(S)	.182	13	Brown
AR-0328					18	51	78(D)			
AR-0129		.680	.703	300 kcmil, 26/7	18	52	68(S)	.204	12	Blue
AR-0329					18	60	80(D)			
AR-0130		.704	.740	336.4 kcmil, 26/7	18	54	72(S)	.204	12	Green
AR-0342					18	64	84(D)			
AR-0131		.741	.782	397.5 kcmil, 18/1	18	59	72	.204	13	Orange
AR-0132		.783	.814	397.5 kcmil, 26/7	15	66	76	.250	11	Purple
AR-0133		.815	.845	636 kcmil, 19W Comp.	15	66	76	.250	11	Red
AR-0134		.846	.907	477 kcmil, 26/7	15	74	78	.250	12	Blue
AR-0135		.908	.929	636 kcmil, 37W	12	66	80	.250	13	Green
AR-0136		.930	.976	605 kcmil, 26/7	12	72	88	.250	13	White
AR-0137	AR-0500	.977	1.016	636 kcmil, 26/7	9	50	92	.310	11	Yellow
AR-0138	AR-0501	1.017	1.035	795 kcmil, 37-61W	6	55	94	.310	12	Brown
AR-0139	AR-0502	1.036	1.064	715.5 kcmil, 26/7	6	56	96	.310	12	Blue
AR-0140	AR-0503	1.065	1.098	795 kcmil, 24/7	6	56	96	.310	12	Green
AR-0141	AR-0504	1.099	1.139	795 kcmil, 26/7	6	62	100	.310	12	Orange
AR-0142	AR-0505	1.140	1.161	954 kcmil, 36/1	6	63	100	.310	13	Purple
AR-0143	AR-0506	1.162	1.208	954 kcmil, 45/7	6	69	100	.310	13	Red
				954 kcmil, 54/7						
				1033.5 kcmil, 37-61W						
AR-0144	AR-0507	1.209	1.269	1113 kcmil, 45/7	6	81	100	.365	12	Black
AR-0145	AR-0508	1.270	1.327	1192.5 kcmil, 45/7	6	81	100	.365	12	White
AR-0146	AR-0509	1.328	1.390	1272 kcmil, 45/7	3	45	100	.365	13	Yellow
AR-0147	AR-0510	1.391	1.440	1431 kcmil, 45/7	3	54	100	.436	11	Brown
AR-0163	AR-0511	1.441	1.508	1590 kcmil, 45/7	3	58	100	.436	12	Blue
AR-0164	AR-0512	1.509	1.578	1590 kcmil, 54/19	3	58	100	.436	12	Green
AR-0165	AR-0513	1.579	1.651	1780 kcmil, 84/19	3	60	100	.436	13	Orange
AR-0166	AR-0514	1.652	1.728	2000 kcmil, 9/W	3	60	100	.436	13	Purple
AR-0167	AR-0516	1.729	1.809	2156 kcmil, 84/19	3	64	100	.436	14	Red
AR-0168	AR-0517	1.810	1.898	2500 kcmil, 91W	3	64	100	.436	14	Black
AR-0169	AR-0518	1.899	1.991		3	68	100	.436	15	White
AR-0170	AR-0519	1.992	2.090	3500 kcmil, 127W	3	68	100	.436	15	Yellow
AR-0171	AR-0520	2.091	2.193	3500 kcmil, 127W	3	80	100	.468	15	Brown

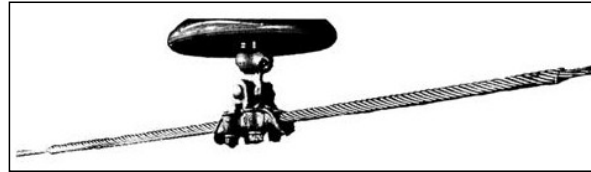
Right-hand lay standard

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Reference O.D. Calculations for: APPLIED O.D. Calculations.
- (4) AWAC is a registered trademark of the Copperweld Co.

Armor Rods: Aluminum-Clad Steel

For use on:
Aluminum-Clad Steel Strands



Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/Lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
AR-2113 AR-2313	.169"	.178"	3#12 AW	50 50	32 40	40(S) 52(D)	.102	7	Orange
AR-2116 AR-2316	.196"	.207"	3#11 AW	50 50	32 40	40(S) 52(D)	.102	7	Black
AR-2118 AR-2318	.218"	.225"	3#10 AW 4-M AW	50 50	36 46	40(S) 52(D)	.102	8	Green
AR-2120 AR-2320	.237"	.249"	1/4", 7#12AW 6-M, AW, 3#9 AW	50 50	40 51	40(S) 52(D)	.102	9	Yellow
AR-2122 AR-2322	.264"	.277"	9/32", 7#11 AW 8-M, AW, 3#8 AW	25 25	28 35	42(S) 54(D)	.114	9	Blue
AR-2124 AR-2324	.296"	.314"	5/16", 7#10 AW 10-M, AW, 3#7 AW	25 25	30 37	46(S) 58(D)	.114	9	Black
AR-2126 AR-2326	.334"	.352"	11/32", 7#9 AW 12.5-M, AW, 3#6 AW	25 25	35 44	50(S) 62(D)	.114	10	Yellow
AR-2128 AR-2328	.373"	.392"	3/8", 7#8 AW 16-M, AW, 3#5 AW	25 25	44 54	50(S) 62(D)	.128	10	Orange
AR-2130 AR-2330	.409"	.425"	18-M AW	25 25	51 62	54(S) 66(D)	.128	11	Black
AR-2131 AR-2331	.426"	.450"	7/16" AW 7#7 AW 20M, AW	25 25	58 70	56(S) 68(D)	.128	12	Green
AR-2133 AR-2333	.477"	.504"	1/2" AW 7#6 AW	20 20	54 65	56(S) 68(D)	.144	11	Blue
AR-2135 AR-2335	.535"	.565"	9/16" AW 7#5 AW	10 10	40 48	60(S) 72(D)	.162	12	Yellow
AR-2137 AR-2337	.593"	.625"	5/8" AW 7#4 AW	10 10	46 56	60(S) 72(D)	.183	11	Black

Left-hand lay standard

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Reference O.D. Calculations for: APPLIED O.D. Calculations.



Armor Rods: Copperweld®

For use on:
Copperweld Strand, Copper
Copperweld®/Copper Composite

Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/Lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
AR-5100 AR-5300	.160	.168	#6 Solid Cu	50 50	35 46	38(S) 50(D)	.102	7	Green
AR-5101 AR-5301	.169	.178	3 #12 Cu	50 50	37 48	40(S) 52(D)	.102	7	Red
AR-5102 AR-5302	.179	.188	#5 Solid Cu	50 50	37 48	40(S) 52(D)	.102	7	Black
AR-5104 AR-5304	.196	.207	3 #11 Cw 8A Cw/Cu	50 50	56 72	40(S) 52(D)	.102	7	Gray
AR-5106 AR-5306	.218	.225	3 #10 Cw	50 50	44 56	40(S) 52(D)	.102	8	Red
AR-5107 AR-5307	.226	.236	6A Cw/Cu #4, 7W Cu	50 50	44 56	40(S) 52(D)	.102	8	Black
AR-5108 AR-5308	.237	.249	6M Cu 7 #12 Cw	50 50	49 64	42(S) 54(D)	.102	9	Blue
AR-5109 AR-5309	.250	.263	#3, 7W Cu 6M Cw 3W	50 50	50 64	42(S) 54(D)	.102	9	Gray
AR-5110 AR-5310	.264	.277	8M, Cw 7 #11 Cw	50 50	57 65	42(S) 54(D)	.102	9	Green
AR-5111 AR-5311	.278	.295	#2, 7W Cu 4A Cw/Cu	50 50	56 72	42(S) 54(D)	.102	10	Red
AR-5112 AR-5312	.296	.314	10M Cw 7 #10 Cw	25 25	35 44	44(S) 56(D)	.114	9	Black
AR-5113 AR-5313	.315	.333	#1, 7W-19W Cu	25 25	44 55	46(S) 58(D)	.128	9	Blue
AR-5114 AR-5314	.334	.352	12.5M Cw 7 #9 Cw	25 25	46 58	48(S) 60(D)	.128	9	Gray
AR-5115 AR-5315	.353	.372	14M Cw 2A Cw/Cu	25 25	54 66	50(S) 62(D)	.128	10	Green
AR-5116 AR-5316	.373	.392	7#8 Cw 16M Cw, 3 #5 Cw	25 25	62 76	52(S) 64(D)	.144	9	Red
AR-5118 AR-5318	.409	.425	18M Cw 2/0, 7W-19W Cu	15 15	44 54	54(S) 66(D)	.144	10	Blue
AR-5119 AR-5319	.426	.450	7 #7 Cw 20M Cw	15 15	55 66	54(S) 66(D)	.162	10	Gray
AR-5120 AR-5320	.451	.476	1/0 K, Cw/Cu 3/0, 7W-19W Cu	15 15	57 69	56(S) 68(D)	.162	10	Green
AR-5121 AR-5321	.477	.504	7 #6Cw 3/0, 12W Cu	15 15	62 75	56(S) 68(D)	.162	11	Red
AR-5122 AR-5322	.505	.534	19 #10 Cw 25M Cw	15 15	64 78	58(S) 70(D)	.162	11	Black
AR-5123 AR-5323	.535	.565	7 #5 Cw 4/0, 12W Cu	10 10	48 58	58(S) 70(D)	.162	12	Blue
AR-5124 AR-5324	.566	.592	19 #9 Cw 250M, 19-37W	10 10	49 59	60(S) 72(D)	.162	12	Gray
AR-5125 AR-5325	.593	.625	7 #4 Cw 250M, 12W Cu	10 10	53 63	60(S) 72(D)	.162	13	Green

Left-hand lay standard

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Reference O.D. Calculations for: APPLIED O.D. Calculations.
- (4) Copperweld is a registered trademark of the Copperweld Co.

Armor Rods: Phosphor Bronze

For use on:

Copper

Copperweld®/Copper Composite

Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
ARB-1103 ARB-1303	.160	.168	#6, Solid Cu	75 75	54 70	38(S) 50(D)	.099	7	Green
ARB-1104 ARB-1304	.169	.178	9 1/2 D Cw/Cu	75 75	56 72	40(S) 52(D)	.099	7	Red
ARB-1105 ARB-1305	.179	.188	#6, 7W Cu 8C, Cw/Cu	75 75	56 72	40(S) 52(D)	.099	7	Black
ARB-1107 ARB-1307	.196	.207	#8A Cw/Cu #4, Solid Cu	50 50	44 56	40(S) 52(D)	.099	8	Gray
ARB-1109 ARB-1309	.218	.225	#8D Cw/Cu #7A Cw/Cu	50 50	44 56	40(S) 52(D)	.099	8	Red
ARB-1110 ARB-1310	.226	.236	#6A Cw/Cu #4, 7W Cu	50 50	44 56	40(S) 52(D)	.099	8	Black
ARB-1111 ARB-1311	.237	.249	#7D Cw/Cu	50 50	52 65	42(S) 54(D)	.099	9	Blue
ARB-1112 ARB-1312	.250	.263	#3, 7W Cu #2 Solid Cu	50 50	52 65	42(S) 54(D)	.099	9	Gray
ARB-1113 ARB-1313	.264	.277	#6D Cw/Cu	50 50	52 65	42(S) 54(D)	.099	9	Green
ARB-1114 ARB-1314	.278	.295	#4A Cw/Cu #2, 7W Cu	50 50	56 72	42(S) 54(D)	.099	10	Red
ARB-1115 ARB-1315	.296	.314	#2F Cw/Cu #5D, Cw/Cu	50 50	68 86	44(S) 56(D)	.111	9	Black

Left-hand lay standard

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Reference O.D. Calculations section, for: APPLIED O.D. Calculations.
- (4) Refer to General Recommendations for material selection.
- (5) Copperweld is a registered trademark of the Copperweld Co.



Armor Rods: Galvanized Steel

For use on:
Steel Reinforced Copper Conductors with
Right-Hand Lay

Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
AR-1154 AR-1354	.244	.259	6/1 #4-7/1	50 50	38 48	40 (S) 52 (D)	.070	12	Orange
AR-1158 AR-1358	.309	.326	6/1 #2-7/1	50 50	60 75	44 (S) 56 (D)	.086	12	Red
AR-1160 AR-1360	.347	.373	#1-6/1	50 50	70 88	48 (S) 60 (D)	.086	13	Black
AR-1162 AR-1362	.390	.413	1/0-6/1	25 25	50 62	52 (S) 64 (D)	.100	13	Yellow
AR-1164 AR-1364	.437	.463	2/0-6/1	25 25	70 84	54 (S) 66 (D)	.119	12	Blue
AR-1166 AR-1366	.491	.521	3/0-6/1	20 20	62 75	56 (S) 68 (D)	.119	13	Orange
AR-1168 AR-1368	.552	.585	4/0-6/1	15 15	66 80	60 (S) 72 (D)	.138	13	Red

Right-hand lay standard

For use on:
Galvanized Steel Strand
with Left-Hand Lay

Catalog Number	Diameter Range (Inches)		Nominal Conductor Size	Units	Wt/lbs	Length (Inches)	Rod Diameter (Inches)	Rods Per Set	Color Code
	Min.	Max.		Per Carton					
AR-1123	.229	.243	1/4-7W	50	37	40	.086	10	Black
AR-1124	.244	.259	1/4-3W	50	37	40	.086	10	Yellow
AR-1128	.309	.326	5/16-3W 5/16-7W HS, & EHS	50	60	44	.100	11	Black
AR-1130	.347	.373	3W 3/8-7W	50	70	48	.100	12	Orange
AR-1133	.414	.436	7/16-7W	20	52	52	.119	12	Green
AR-3139	.491	.521	1/2-7W 19W	20	62	56	.138	12	Blue

Left-hand lay standard

EXPLANATORY NOTES:

- (1) Nominal Conductor size indicates one of various conductors within each range.
- (2) Single Support Length (S) and Double Support Length (D) are described on the first page of the Armor Rod section.
- (3) Galvanized Steel Armor Rods may be suitable for application on materials other than Galvanized Steel. Consult the Factory for specific information.

Rev1. Sep. 2024
Page 19 of 27

APPENDIX E – AAB REPORT

	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

TECHNICAL MEMORANDUM

L7005 CANSO CAUEWAY AIR-FLOW SPOILER AND
DAMPERS MODELLING IN PLS-CADD



0	2024-08-10	Issued for Use	B. Bilkhu	B. Bilkhu
REVISION	DATE	DESCRIPTION	PREPARED BY	APPROVED BY

	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

DISCLAIMER

This document was prepared by AAB Engineering Inc for the sole and exclusive use of Nova Scotia Power. This document must not be used for any other purpose without prior written approval from AAB Engineering Inc.

This document contains AAB Engineering Inc. opinion using its professional judgement and reasonable care based on the information available at the time of preparation.

AAB Engineering Inc. does not accept any liability of any kind arising in any way out of any third party's use of or reliance upon any information disclosed in this document, for purposes other than that for which the report was prepared.

	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

TABLE OF CONTENTS

DISCLAIMER

1. PROJECT DESCRIPTION AND SCOPE
2. DESIGN CRITERIA & MODELLING
3. ASSUMPTIONS AND EXCLUSIONS
4. RESULTS
5. RECOMMENDATIONS
6. KEY PROJECT CONTACTS
7. APPENDIX A

	Client:	NSPI
	Project:	L7005 Canso Causeway
	Date	August 10, 2024
		

PROJECT DESCRIPTION AND SCOPE

The Canso Strait, located between high lands and near both the Atlantic Ocean and the Saint Lawrence River estuary, experiences severe weather conditions, including strong winds and winter storms. These conditions cause significant vibration and oscillation of power line conductors crossing the strait.

The first power line, a 345 kV double circuit line designated L8004, was constructed in 1983 using self-damping conductors. In 1984, severe galloping led to conductor damage and flashovers. This issue was resolved by adding air flow spoilers to the conductors, which prevented further galloping and maintained the span's stability against aeolian vibrations.

This success established the older crossing as a reference point for modelling, future monitoring and comparison. Figure 1 shows the strait in a "Google Earth" view.



Figure 1 Google Earth view of the Strait of Canso with the location of the L7005 345 kV crossing between the Nova Scotia Mainland and Cape Breton Island.

	Client:	NSPI
	Project:	L7005 Canso Causeway
	Date	August 10, 2024
		

A second 345 kV crossing, designated L7005, was built in 2017 to connect hydroelectric power from Labrador to Nova Scotia, necessitating high reliability. Despite being equipped with vibration dampers, this new line also suffered conductor damage. In 2021, recommendations were made to replace the existing dampers with more robust PLP-Helix dampers and to add air flow spoilers. These remedial actions, delayed until late 2022, were not fully implemented immediately due to manufacturing and delivery constraints. Interim measures included installing available Salvi vibration dampers. This situation highlights the ongoing challenge of managing wind-induced vibrations in the strait to ensure the reliability of power transmission.

AAB Engineering have undertaken the task to model the air flow spoilers and Dampers on the Suspension Canso strait 1445m long crossing span on L7005 transmission Line to understand the affects of placing additional weight in terms of Airflow Spoilers and New dampers.

This technical memo lays out assumptions, exclusions, results and recommendations based on PLS CADD Modelling of Airflow spoilers & new dampers and study of existing information from original design by Hatch.

DESIGN CRITERIA & MODEL

As built PLS CADD model was provided by NS Power Transmission Engineering team, this model is used to carry out the addition of AFS and Dampers to develop conceptual model representation effects of additional weight.

No changes were made to the PLS-CADD models regarding the original design criteria.

ASSUMPTIONS AND EXCLUSIONS

1. The weight of the airflow spoilers was determined based on a 60mm Maximum Radial Ice load, consistent with the original crossing design. The weight of the dampers was sourced from the PLP specification sheet.
2. PLS-CADD imposes a restriction of 60 on the maximum number of concentrated weights that can be applied to a single span.
3. The number of airflow spoilers that can be accommodated on the 1445m suspension span was recalculated according to the layout data provided by PLP. These calculations are included in this memorandum for reference.
4. PLP initially specified the installation of 95 airflow spoilers on the 1445m suspension crossing span. However, calculations based on the layout and distances provided by PLP indicate that only 91 airflow spoilers can be installed. This finding should be confirmed with PLP.
5. To simulate the effect of installing 91 airflow spoilers, the total weight was distributed across 38 airflow spoilers modeled on the 1445m suspension span.

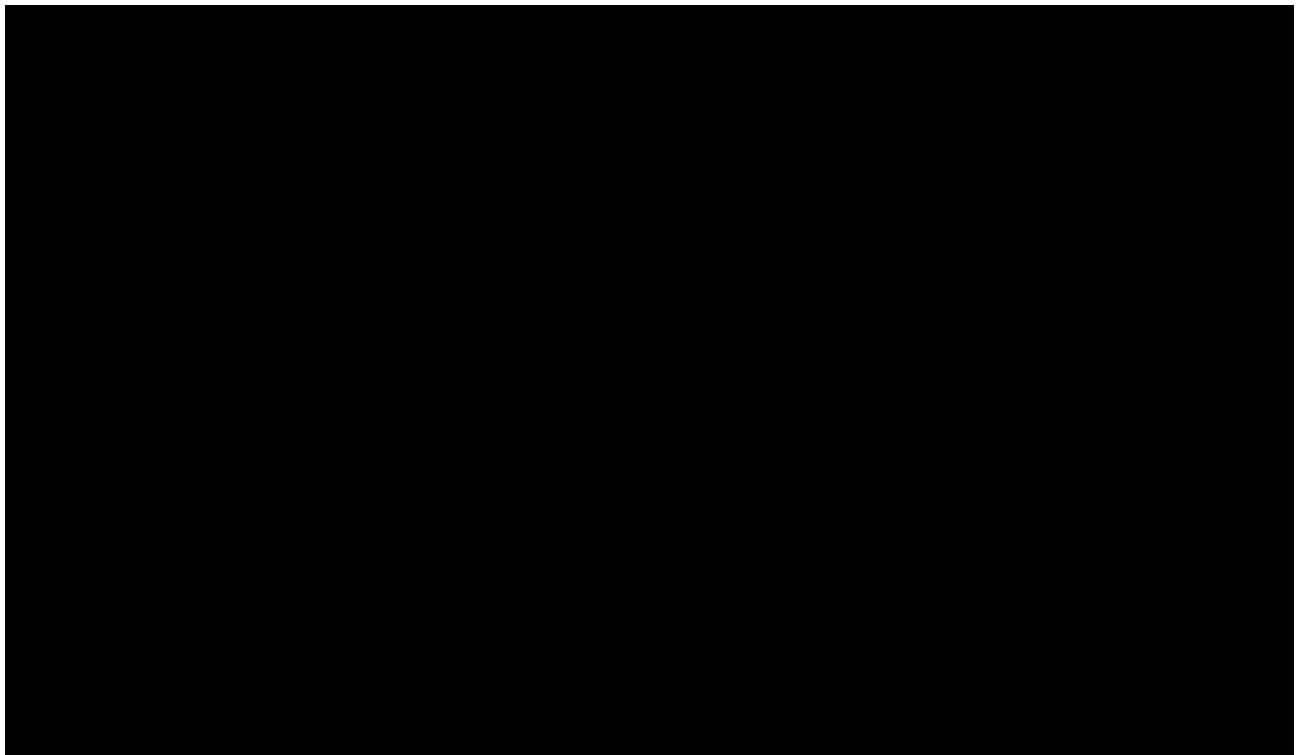
	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

6. A total of 22 dampers were modeled on the 1445m suspension span, strategically distributed to best align with the layout provided by PLP.
7. The combined 38 airflow spoilers and 22 damper concentrated loads account for the maximum allowable 60 concentrated loads on this suspension span.

Notes:

- Tower and foundation analyses or evaluations are not included within the scope of this study.
- This study does not account for any assessment of conductor condition or potential deterioration.

RESULTS

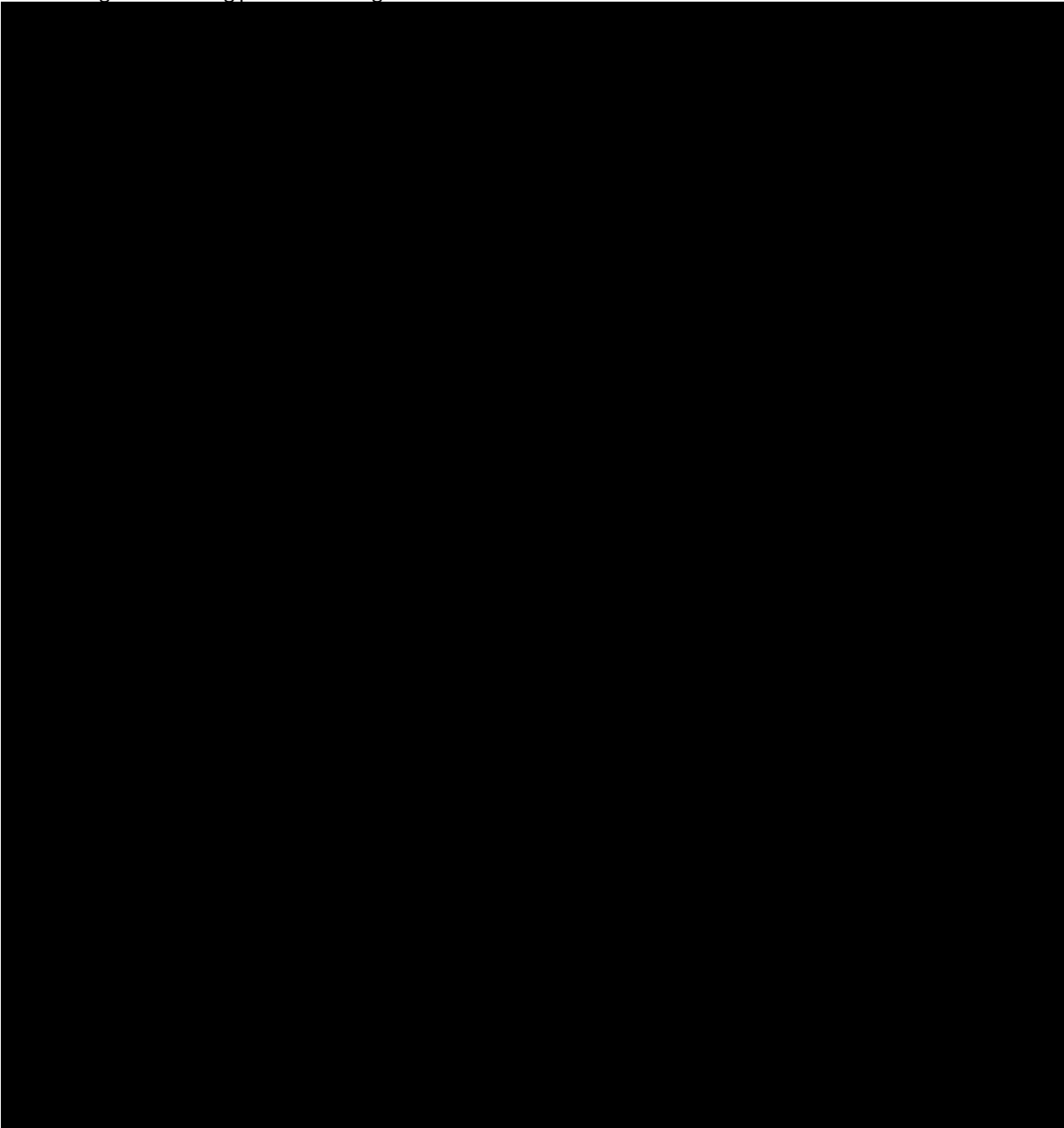


A clearance comparison was conducted with and without the addition of airflow spoilers (AFS) and dampers. The resulting clearance, measured from the centerline after installing the AFS and dampers, is presented in the table below. The reduction in clearance due to the additional weight is estimated to be approximately 6.67 meters.

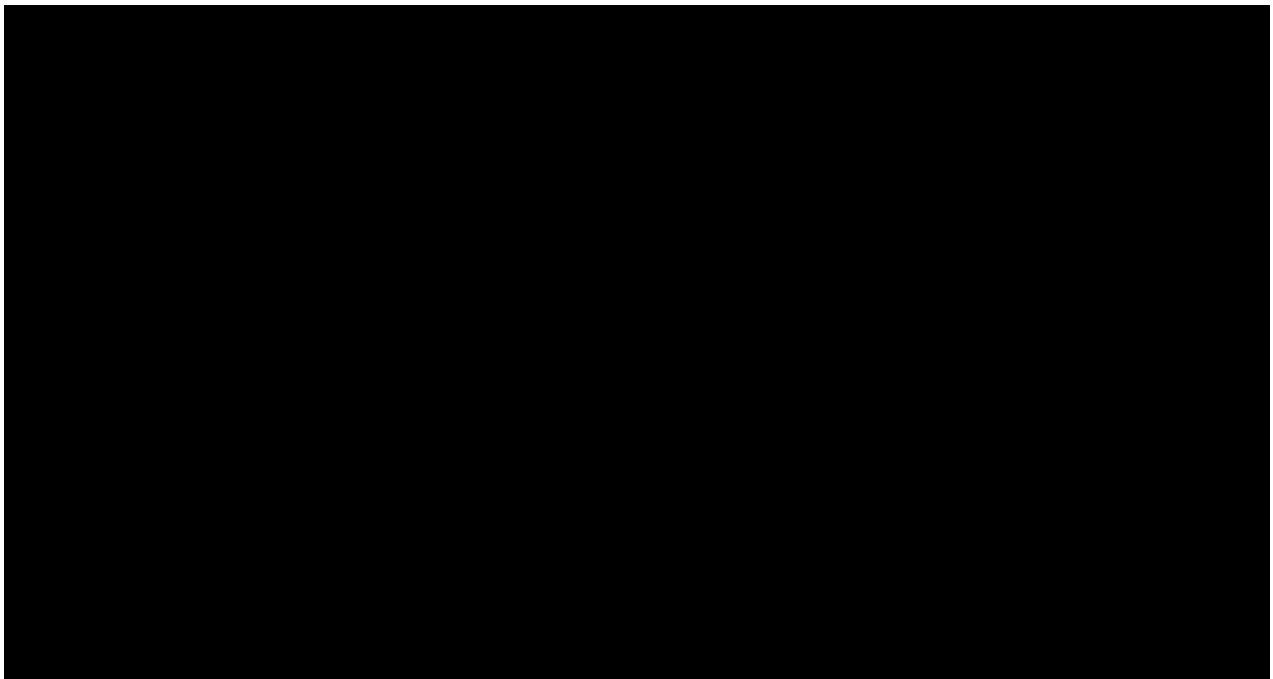
An inconsistency was observed between the clearance measurements obtained from the "As-built" PLS-CADD model provided by NSPI, without the additional AFS weight, and the Original

	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

Crossing permit drawing. It is recommended to consult with the Permit Specialist to determine whether the design drawing or an as-built design drawing was used to measure clearance in the Original Crossing permit drawing.



	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	



RECOMMENDATIONS

- It is recommended that a detailed analysis of the towers and foundations be conducted following the installation (if possible, prior to installation) of the airflow spoilers (AFS) and dampers, accounting for the additional weight these components introduce.
- The original crossing permit drawing indicates that this crossing was designed for a maximum operating temperature of 80°C, which does not align with NSPI's standard practices. Further investigation by NSPI is necessary to fully understand the original design's thermal rating for the L7005 crossing span. This can create major revenue losses for NSPI.
- Airflow spoilers were previously installed on the adjacent L8004 crossing span, resulting in a significant improvement in performance under vibration and galloping conditions, with no adverse impact observed on the structural integrity of the towers. Similar positive outcomes can be reasonably expected following the installation of AFS and dampers on the L7005 crossing span.

	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

KEY PROJECT CONTACTS

Names

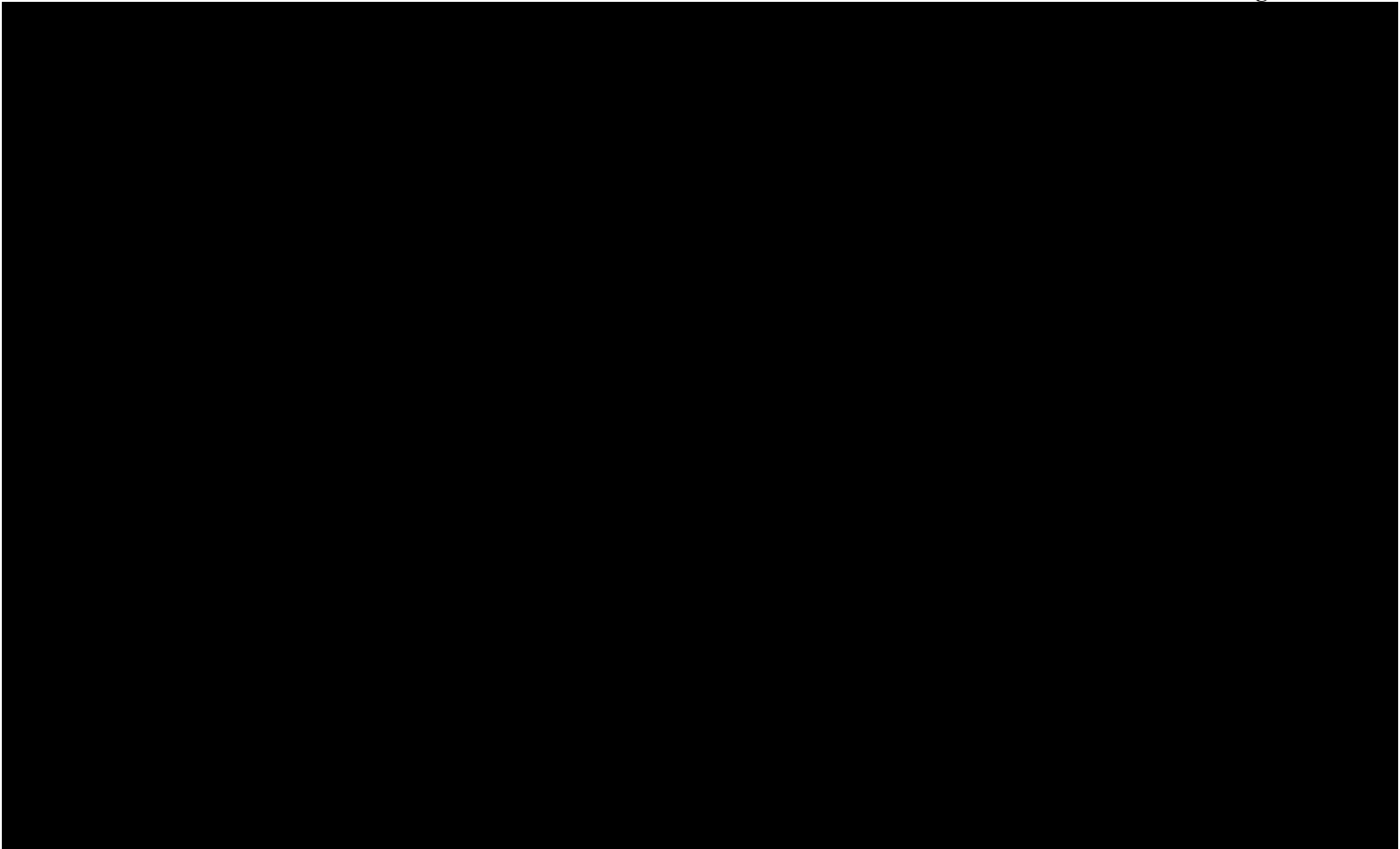
Krutikkumar Trivedi – Transmission Engineering Lead
 Sriram Iyer - Transmission Engineer
 Lance Taylor – Sr. Manager Technical Services
 Balraj Bilkhu – Design Engineer, AAB Engineering Inc.

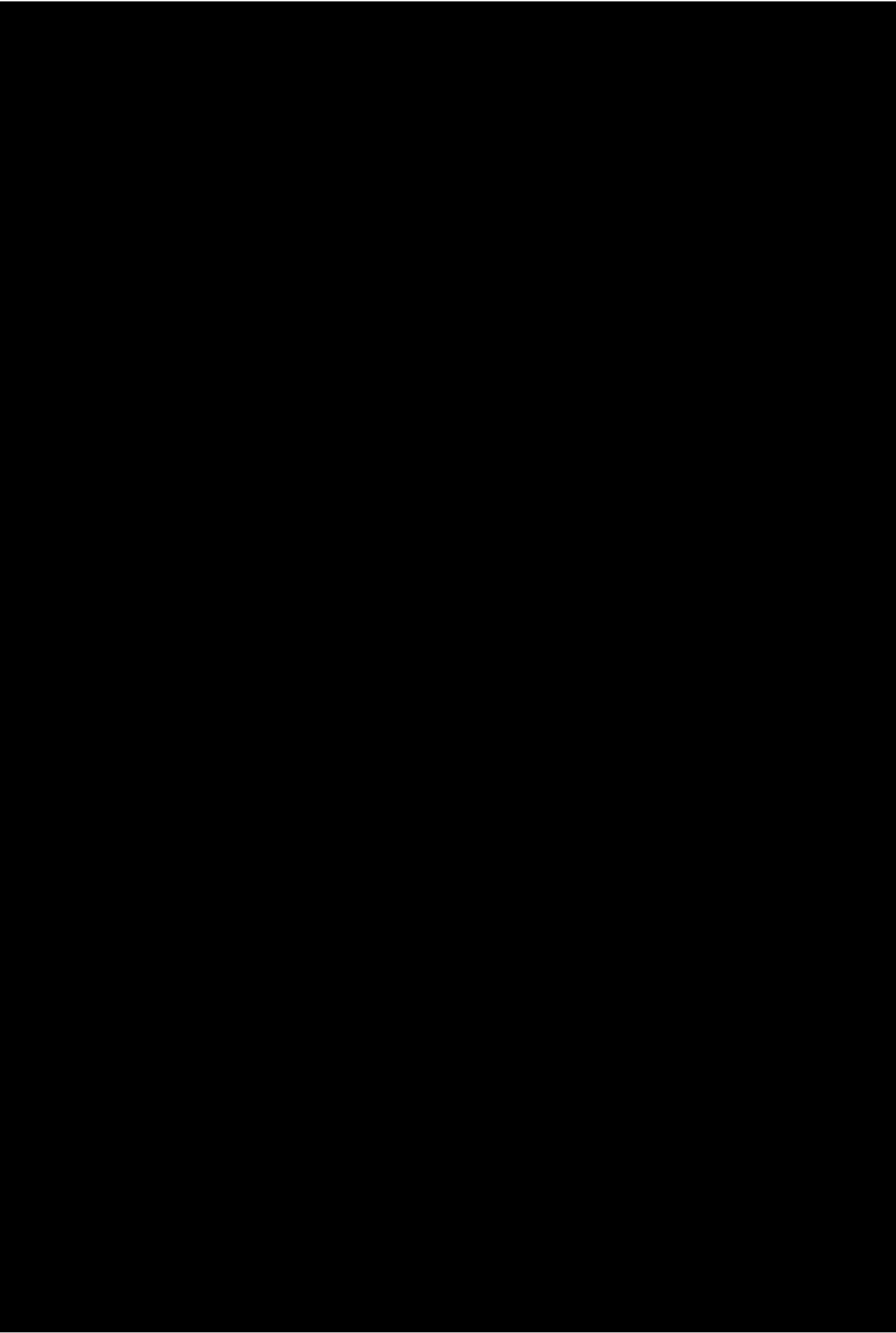
Phone Numbers

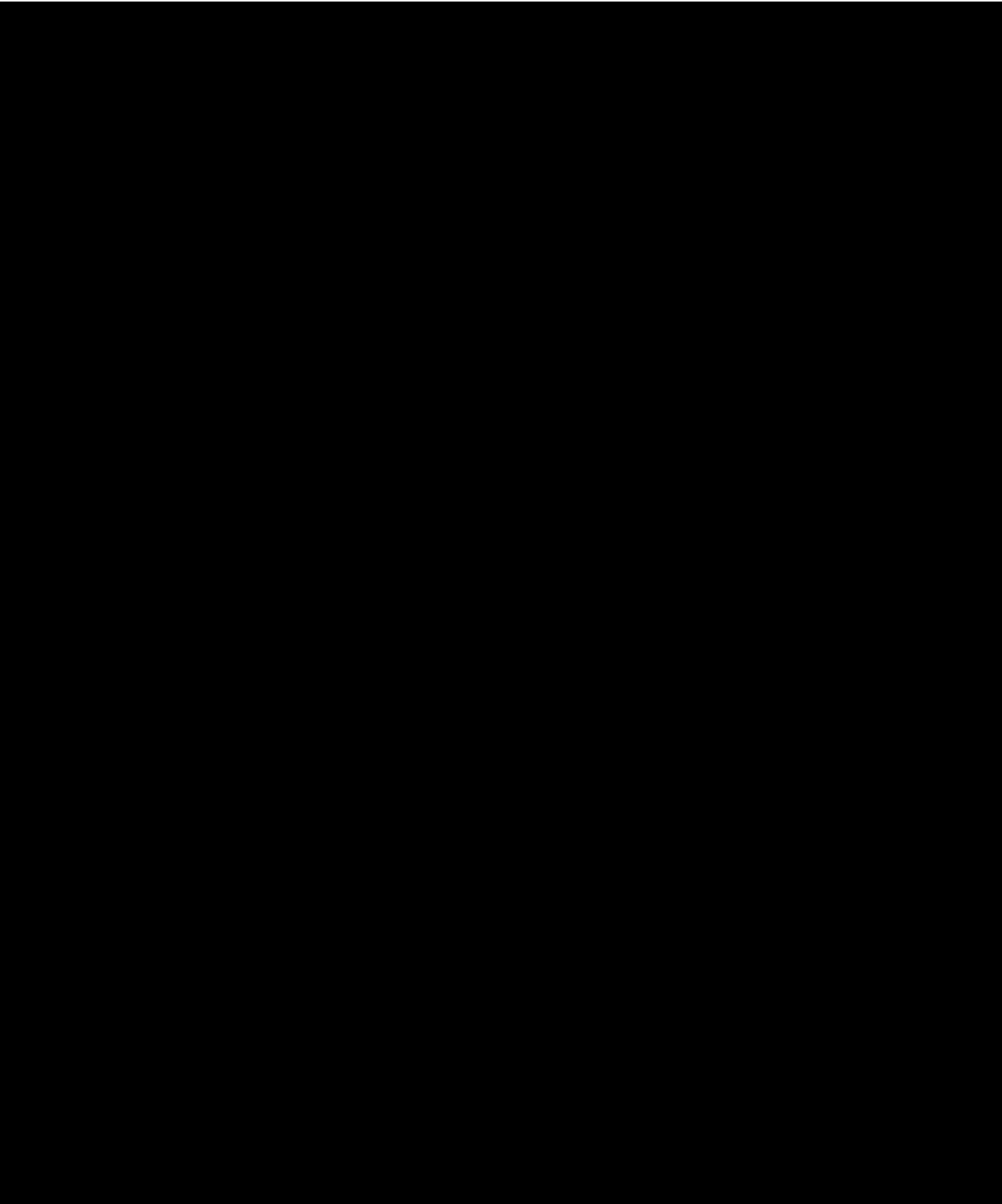
902-223-2284
 902-237-0819
 902-478-0747
 902-441-7406

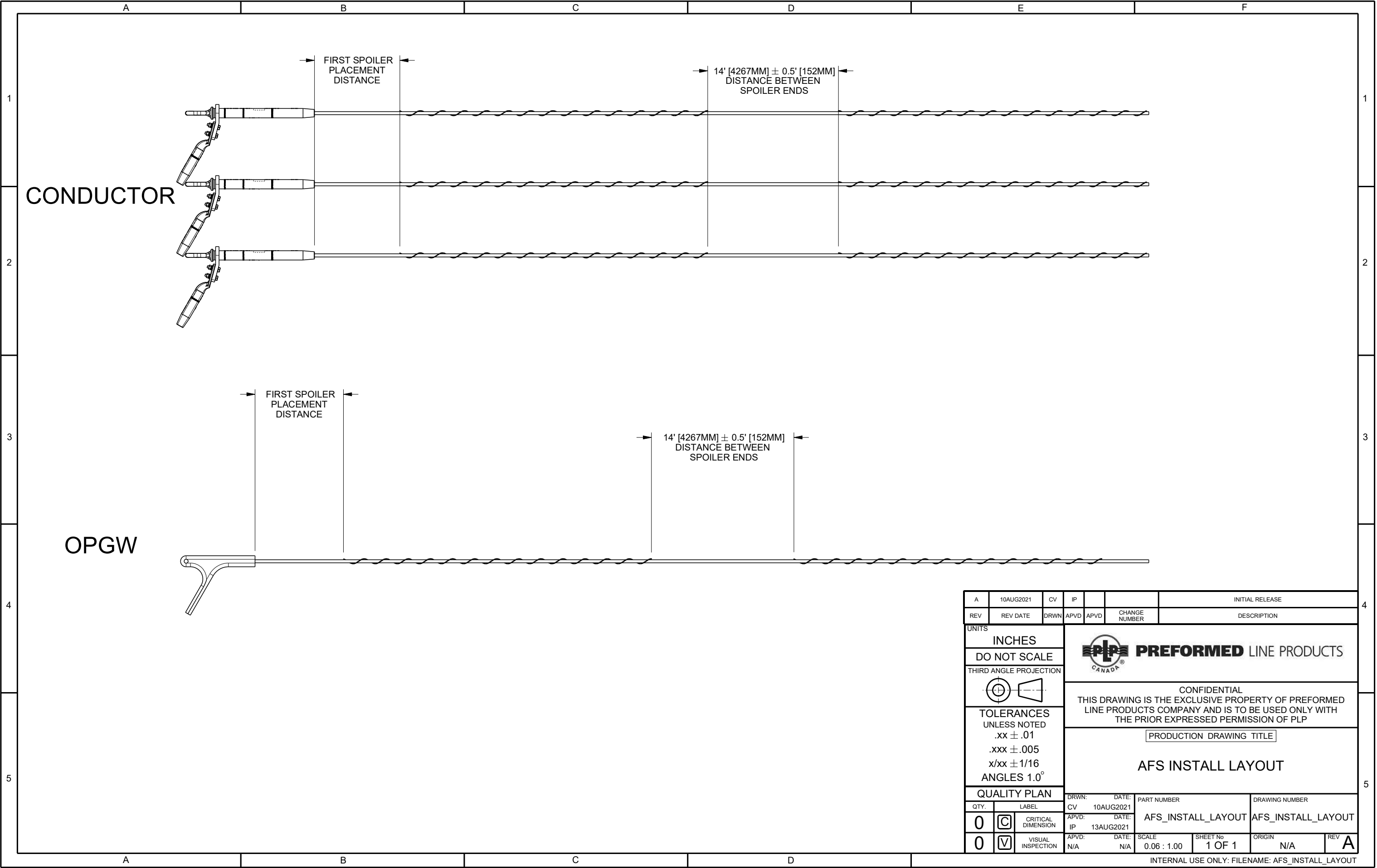
	Client:	NSPI	
	Project:	L7005 Canso Causeway	
	Date	August 10, 2024	

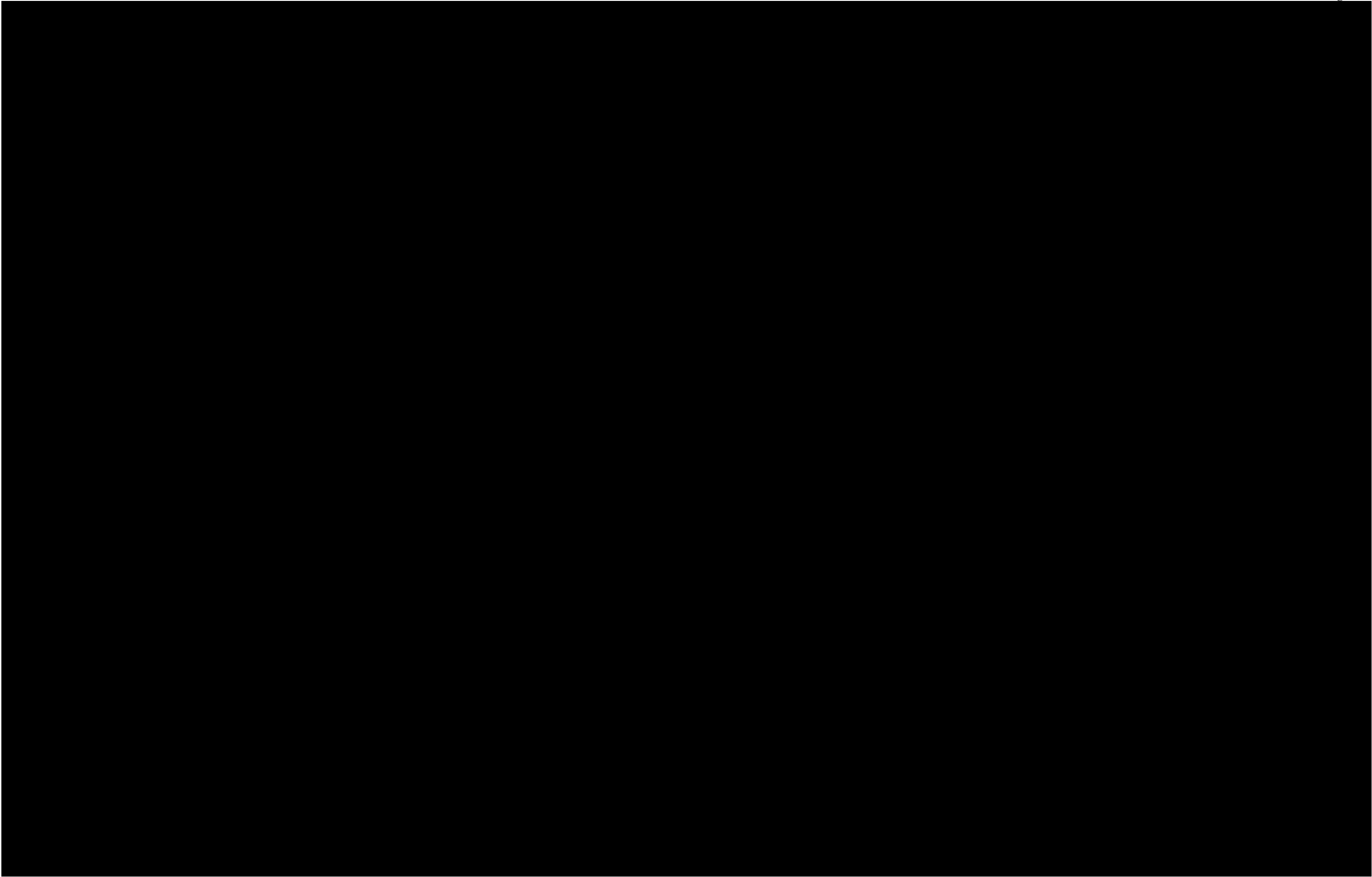
APPENDIX A











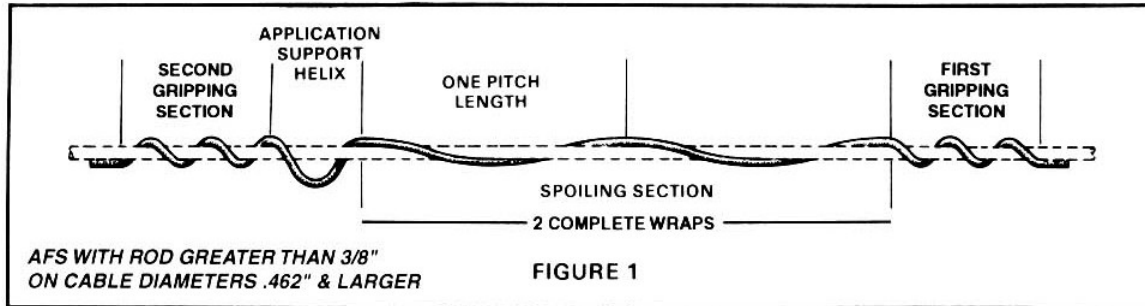
APPLICATION PROCEDURE & SAFETY CONSIDERATIONS **PREFORMED LINE PRODUCTS**

AIR FLOW SPOILER



DECEMBER 1996

Completely read and understand this procedure before applying product. Special attention should be given to the Safety Considerations located on the last page. We advise the reader to review those considerations now, and then again during the general review of this procedure.



NOMENCLATURE

GRIPPING SECTION: Grips cable. Consists of several pitches (360° wraps around the cable) and holds the Air Flow Spoiler firmly in position.

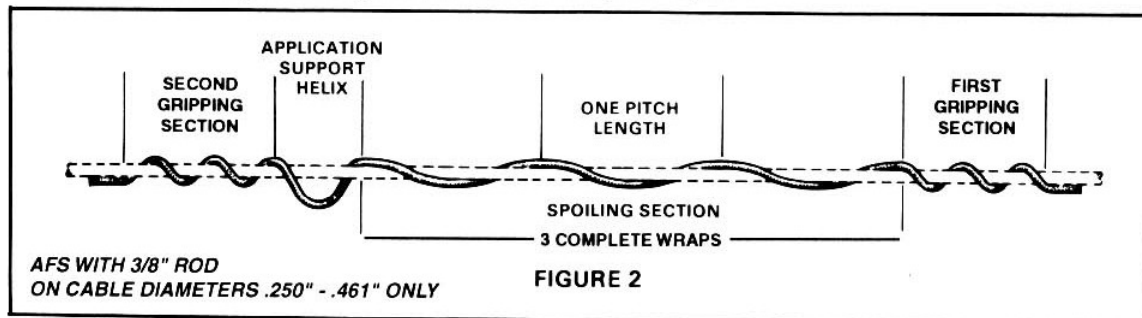
SPOILING SECTION: Disturbs aerodynamic lift. The spoiling section is wrapped around the cable in a manner which presents a constantly changing profile to wind flow and helps reduce lift forces which cause galloping. The spoiling section is wrapped around the cable either two times (FIGURE 1) or three times (FIGURE 2), depending on cable diameter.

APPLICATION SUPPORT HELIX: Supports Spoiler. Air Flow Spoilers range in length from 14 to 16 feet. The Application Support Helix on one end keeps the Air Flow Spoiler from hanging down, while the gripping section on the opposite end is applied.

APPLICATION

1. Once the location for installation of the Air Flow Spoiler has been chosen, wrap the Application Support Helix around the cable and slide the Air Flow Spoiler away from you until the first gripping section is in its correct location. The Application Support Helix prevents the Air Flow Spoiler from hanging down while the first gripping section is wrapped on.
2. Wrap on the first gripping section.
3. Now move to the opposite end of the Air Flow Spoiler where the Application Support Helix is located and wrap the spoiling section around the cable **two times** in a **right-hand** lay direction. See Figure 1.

NOTE: For small diameter cables which use the Air Flow Spoiler made from 3/8" diameter rod, wrap the spoiling section around the cable three times in a right-hand lay direction. (This will limit excessive drooping of the small diameter Air Flow Spoiler during hot weather conditions.) See Figure 2.



4. Install the second gripping section by wrapping it around the cable and snap the end of the gripping section in place.

TIPS ON INSTALLATION

To assist the installer in determining how many times the Air Flow Spoiler is wrapped around the cable, the following will be helpful:

1. For small cable diameters (.250" - .461") where the AFS rod diameter is 3/8", wrap the spoiling section in a right-hand lay direction three times around the cable.
2. For all cable diameters .462" and larger where the AFS rod diameter is larger than 3/8", wrap the spoiling section in a right-hand lay direction two times around the cable.

GENERAL NOTES

1. Several Air Flow Spoilers are required in each span to offset the aerodynamic lift forces which cause galloping.
2. The number and placement of Air Flow Spoilers in each span are determined by a computer program which considers the results of on going field and laboratory research.
3. An Air Flow Spoiler Placement Request form should be completed and returned to Preformed Line Products Company prior to installation of Air Flow Spoilers. A placement scheme will be returned to determine placement of Air Flow Spoilers in each span.
4. Please advise whether the cables contain optical fibers. This may influence Air Flow Spoiler selection.

FIGURE 8 & LASHED MESSENGER CABLES

Figure 8 and lashed messenger cables are special applications for short span construction. Air Flow Spoilers may be located in accordance with the table below.

Span Length in feet	Air Flow Spoilers per cable	Air Flow Spoiler placements start from first structure. Distances are measured from same end of Air Flow Spoiler, accumulated distances in ().		
100-130	2	33.3 (33.3)	28.8 (62.0)	48.0 (110.0)
130-160	3	33.9 (33.9) 48.6 (140.0)	28.8 (62.6)	28.8 (91.4)
160-190	3	48.9 (48.9) 63.6 (170.0)	28.8 (77.6)	28.8 (106.4)
190-220	4	44.5 (44.5) 28.8 (130.8)	28.8 (73.3)	28.8 (102.0)

Please contact the factory for recommendations on longer spans. Figure 8 and lashed messenger cables are more difficult to determine correct Air Flow Spoiler size. Please provide complete dimensions of the cable so correct size may be established.

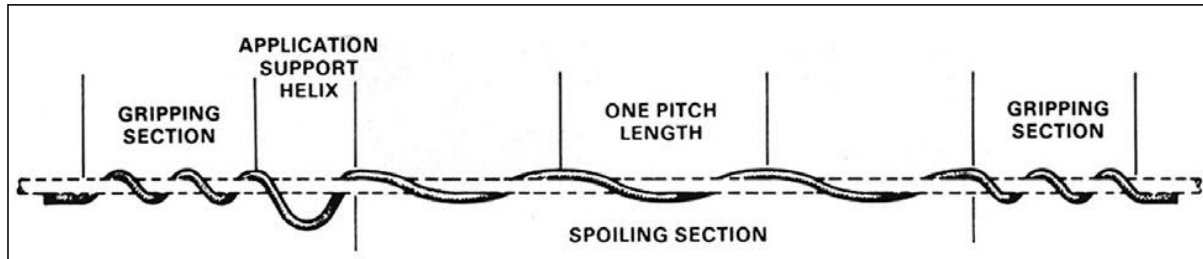
SAFETY CONSIDERATIONS

1. This application procedure is not intended to supersede any company construction or safety standards. This procedure is offered only to illustrate safe application for the individual. **CAUTION: FAILURE TO FOLLOW THESE PROCEDURES AND RESTRICTIONS MAY RESULT IN PERSONAL INJURY OR DEATH.**
2. This product is intended for the specified application. **CAUTION: DO NOT MODIFY THIS PRODUCT UNDER ANY CIRCUMSTANCES.**
3. This product is intended for use by trained craftspeople only. This product **SHOULD NOT BE USED** by anyone who is not familiar with and trained in the use of it.
4. When working in the area of energized lines with this product, **EXTRA CARE** should be taken to prevent accidental electrical contact.
5. For **PROPER PERFORMANCE AND PERSONAL SAFETY** be sure to select the proper size **PREFORMED** product before application.
6. **PREFORMED** products are precision devices. To insure proper performance, they should be stored in cartons under cover and handled carefully.

PREFORMED LINE PRODUCTS 

P.O. Box 91129, Cleveland, Ohio 44101 • 440.461.5200 • www.preformed.com • e-mail: inquiries@preformed.com

Air Flow Spoiler



Thermal Rating (Continuous) 125°C

NOMENCLATURE

Gripping Section: Grips cable. Consists of several pitches (360° wraps around the cable) and holds the Air Flow Spoiler firmly in position.

Spoiling Section: Disrupts aerodynamic lift. The spoiling section is wrapped around the cable in a manner which presents a constantly changing profile to wind flow and cancels lift forces which cause galloping. The spoiling section is wrapped around the cable either two or three times, depending on cable diameter.

Application Support Helix: Supports Spoiler. Air Flow Spoilers range in length from 14 to 16 feet. The Application Support Helix on one end keeps the Air Flow Spoiler from hanging down, while the gripping section on the opposite end is applied.

Air Flow Spoilers for EHV applications have a co-extruded semi-conductive outer layer of material which resists the surface effects of high electrical gradients and minimizes the possible generation of radio interference (RI).

GENERAL RECOMMENDATIONS

Several Air Flow Spoilers are required in each span to offset the aerodynamic lift forces which cause galloping. Each cable, conductor or phase, and neutral need to be treated in each span.

The number and placement of Air Flow Spoilers in each span can be determined by using the General Placement guidelines that follow or by submitting the Air Flow Spoiler Placement Request form. The information submitted on this form is input into a computer program for the determination of the exact placement of the Air Flow Spoilers in each span. The program also supplies the increased wind loading on each span as a percentage increase.

When using the Air Flow Spoiler Placement Request form, the information should be completed and returned to Preformed Line Products prior to installation of Air Flow Spoilers. The placement scheme will be returned giving the placement of Air Flow Spoilers in each span.

Please advise whether the cables contain optical fibers or if the Air Flow Spoilers are to be installed on Figure 8/ Lashed Messenger cables. This may influence the Air Flow Spoiler selection and/or quantity.

GENERAL PLACEMENT GUIDELINES

Extensive laboratory and field research has shown that Air Flow Spoilers are most effective when they are placed on 25% of the span length (based on the 12' spoiling section). For example, a 600' span would require 13 Air Flow Spoilers $[(.25 \times 600) / 12]$. The Air Flow Spoilers are grouped in the middle 50% of the span by leaving a blank space equal to an Air Flow Spoiler length between adjacent units.



Air Flow Spoiler



Catalog Number	EHV Catalog Number	Diameter Range (Inches)		Length (Feet)	Wt./Unit Lbs.	Color Code
		Min.	Max.			
5058100	N/A	0.250	0.326	13-1/2	1.00	Red
5058101	N/A	0.327	0.461	13-1/2	1.00	White
5058102	N/A	0.462	0.563	14	2.25	Orange
5058103	N/A	0.564	0.76	14-1/2	2.40	Yellow
5058104	N/A	0.761	0.926	15	4.25	Blue
5058105	5058200	0.927	1.019	15-1/4	4.50	Black
5058106	5058201	1.020	1.165	15-3/4	5.50	Purple
5058107	5058202	1.166	1.469	16	5.75	Brown
5058108	5058203	1.470	1.602	17	9.50	Green
5058109	5058204	1.603	1.762	17-1/2	9.75	Pink
5058110	5058205	1.763	1.922	18	10.50	Red

EXPLANATORY NOTES:

- (1) For installation on Figure 8 and Lashed Messenger cables, consult PLP®.
- (2) Obtain the Air Flow Spoiler Placement Request form from your local PLP® representative or direct from PLP®.

Air Flow Spoiler

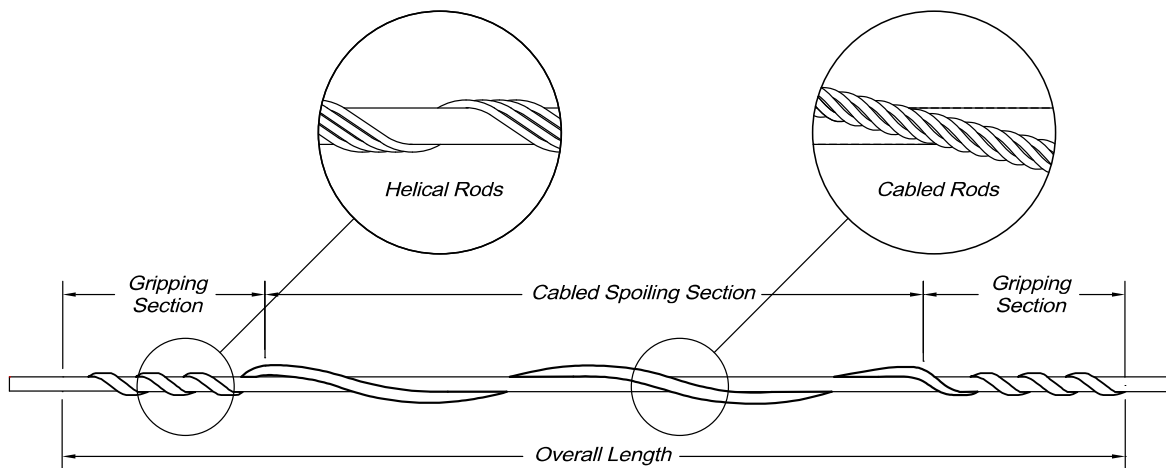
High Temperature Air Flow Spoilers

GENERAL INFORMATION

The high temperature Air Flow Spoiler is constructed of aluminum alloy wires that enable the product to handle temperatures up to 250°C. By subsetting multiple helical rods and cabling (twisting) the center section, the high temperature Air Flow Spoiler functions in the same manner as the standard Air Flow Spoiler.

Thermal Rating (Continuous) 250°C

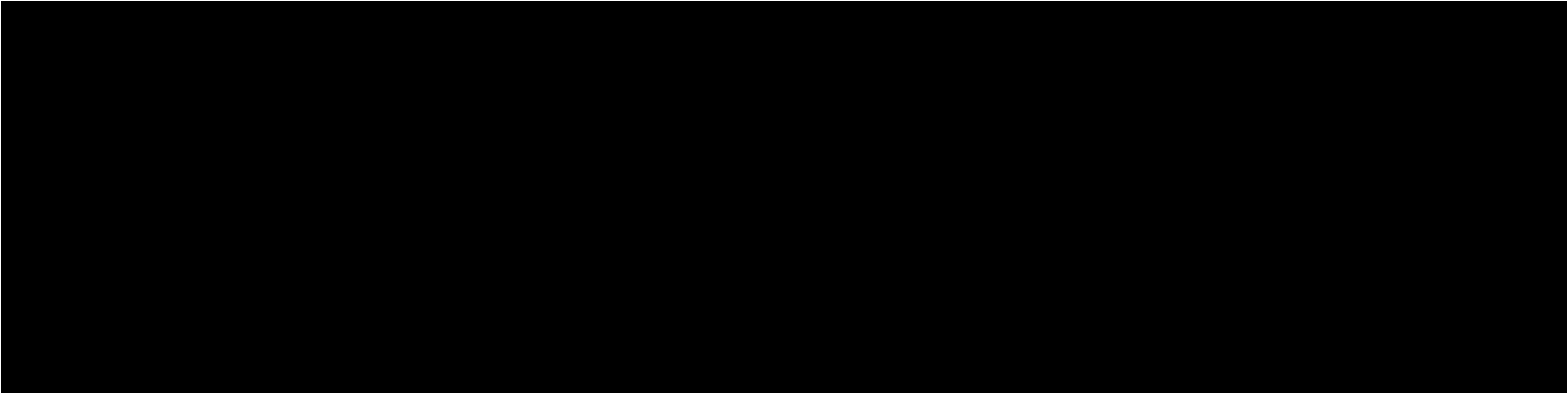
Contact PLP for details regarding applications above 230KV.

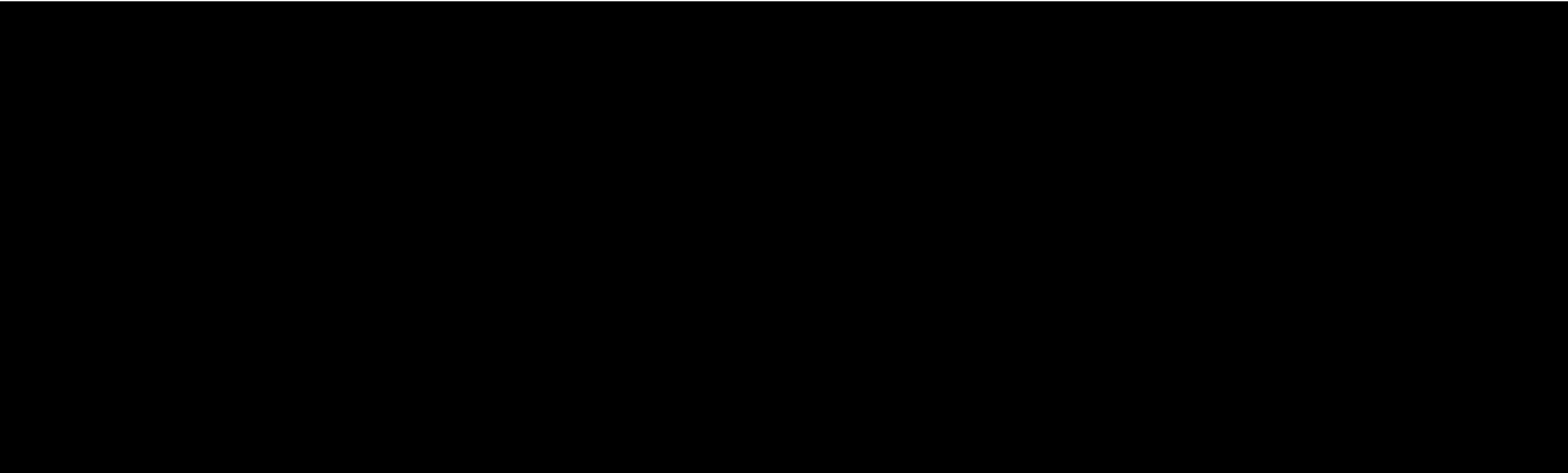


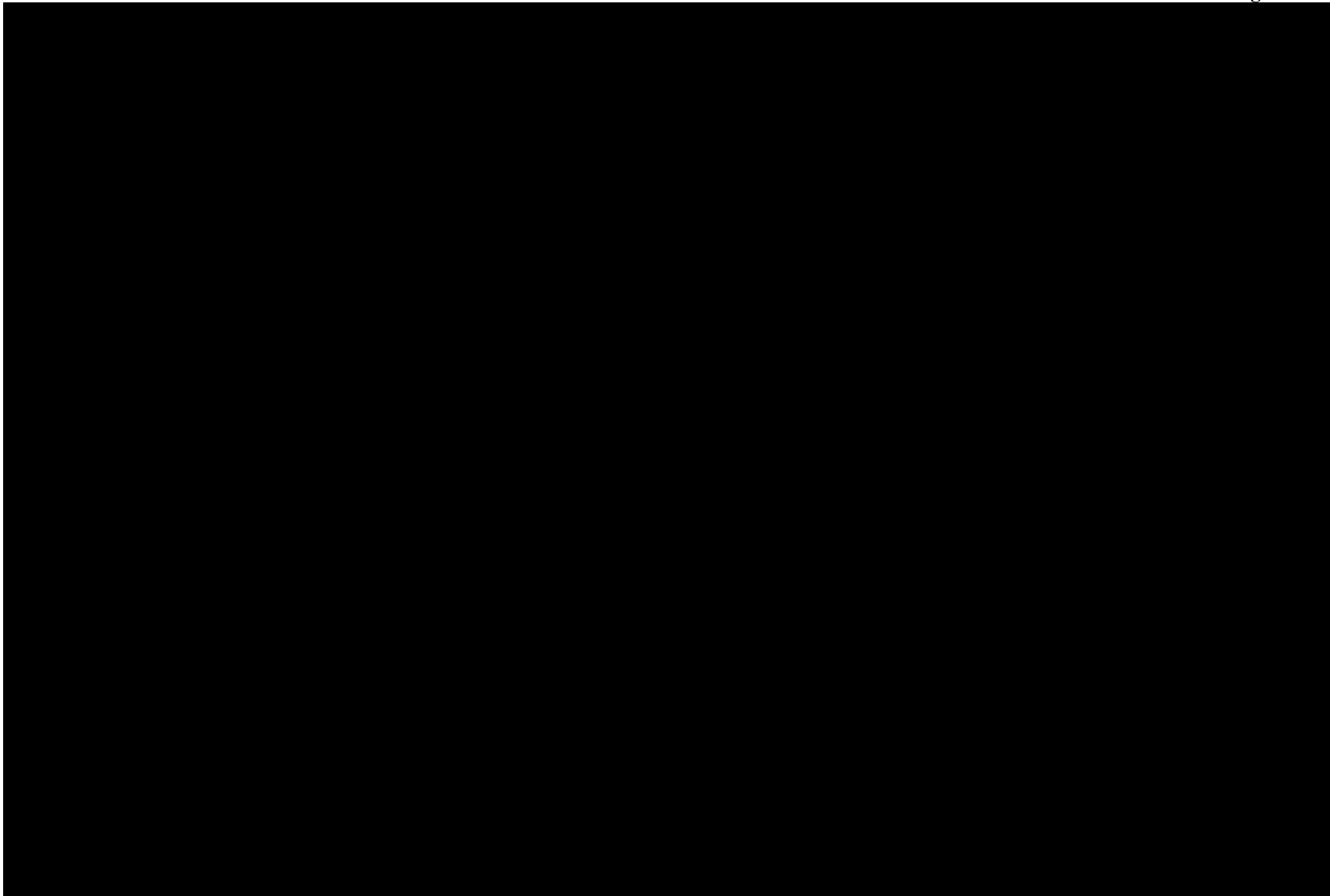
Catalog Number	Diameter Range (Inches)		Length (Feet)	Wt./Unit Lbs.	Color Code
	Min.	Max.			
5059017	0.761	0.808	15-1/2	5.66	Brown
5059018	0.809	0.856	16	5.81	Purple
5059019	0.857	0.907	16	5.81	Orange
5059020	0.908	0.962	16	5.87	Black
5059021	0.963	1.019	16	5.93	Red
5059022	1.020	1.078	16-3/4	10.93	Blue
5059023	1.079	1.138	16-3/4	11.03	Yellow
5059024	1.139	1.199	16-3/4	11.25	Green
5059025	1.200	1.263	17-1/2	11.48	Pink
5059026	1.264	1.330	17-3/4	11.68	Brown
5059027	1.331	1.399	18-1/2	12.18	Purple
5059028	1.400	1.469	19-1/4	12.61	Orange
5059029	1.470	1.549	21-1/2	20.22	Black
5059030	1.550	1.629	22	20.86	Red
5059031	1.630	1.714	22-1/2	21.17	Blue
5059032	1.715	1.805	23-1/2	22.03	Yellow

EXPLANATORY NOTES:

(1) Obtain the Air Flow Spoiler Placement Request form from your local PLP® representative or direct from PLP®.







2013 PLS-CADD Advanced Training and User Group meeting
July 16-18, 2013
Monona Terrace Convention Center, Madison, WI

What's New in PLS-CADD

Interface

- 1) Added the Quick Search Toolbar which can be used to search the menus, help, technical notes and videos. Also acts as a calculator (try typing " $=10*\sin(45)$ ").
- 2) Added support for up to 4 custom toolbars. Toolbars now support both text and icon buttons (over 100 icons added).
- 3) File dialogs now show the PLS-CADD project, structure and cable directories in the Places List (Windows 7) or Favorite Links (Windows Vista) and File/Open has a "Read-Only" option.
- 4) File/Preferences now allows selection of a project specific SMA file.
- 5) Use of gray vs black text to indicate items that have been customized or changed from defaults (File/Preferences/Settings, View/Edit Customizations)
- 6) Feature code multiple select list boxes now draw unused feature codes in gray so can tell them apart from feature codes that are being used.
- 7) Status bar now right justifies text which is too long to fit in it.
- 8 Added "View this location in Bing Maps" option to the "view" menu that appears when middle clicking or pressing Enter in Entity Info mode.
- 9) Added "Lines/Edit Project notes" for project related notes. These are printed in the "Lines/Reports/Summary".
- 10) Tables now highlight the row number and column title for active cell and emulate Excel keyboard commands Control-Apostrophe to copy cell above and F2 to toggle between edit and cursor move mode.
- 11) Message boxes for numerous recurring error messages can be redirected to an "Error Log" window so only have to ok them once per session.

Drafting

- 1) Annotation polygons can now be drawn with a "cloud" line style (for revision cloud).
- 2) Annotation can now be line specific.
- 3) Annotation now supports "%R" keyword for display of lines of text from project notes (similar to the "%C" keyword for criteria notes).
- 4) "Terrain/Alignment/Display options for PI, Alignment & Right of Way" now lets you define ROW width for each segment and provides control over color for each segments PI symbol, ROW lines and alignment line.
- 5) Custom symbols can now be drawn at Structure Center, Pole Bases, Tower Leg Bases and Guy Anchor locations. Different sets of symbols can be used in the Plan, Profile, 3D, Sheet Plan, Sheet Profile and Sheet Inset views. Symbols are selected in the new "Structure" tab within the "Sections/Display Options" dialog box.

- 6) "Drafting/Text Size, Line Width, Style, Color and Layer" modified for more control over alignment, PI and structure symbols (now have separate entries for structures, structure labels, alignment, pi symbols...).
- 7) "Drafting/Structure & Section Labeling" dialog replaces and greatly expands upon capability formerly in "View/Display options/Profile View Structure & Section Labels".
 - a) Program now maintains different settings for plan, profile, sheet profile, and sheet plan views.
 - b) Order in which items (station, offset, structure number...) are displayed is now user controllable.
 - c) Prefix and Suffix associated with each item can be changed by double clicking on the item. One can for example revise the default "Sta=" prefix on station labels or remove the default newline suffix to get multiple items on a single line.
 - d) Wind and weight spans, including left and right side contributions, can now be labeled. This is done by right clicking in the Prefix or Suffix edit boxes and selecting the option to be labeled from the pop up menu (warning: display of wind or weight spans may cause noticeable redraw delays if using FE sag-tension).
 - e) "Inset View" tab has check boxes for "Draw structure geometry" (Geometry defined in PLS-POLE or TOWER) and "Draw Structure Imagery" (photos attached to PLS-POLE or TOWER structures).
- 8) Drafting/Structure Text Position commands now allow editing of position of structure labels in plan part of P&P sheet.
- 9) Context menu has "Structure Label" submenu when snapping to structures which provides options for showing/hiding individual labels and changing text orientation in plan view.
- 10) "Drafting/Plan & Profile Sheet Configuration/Scales" has two new long axis plot settings to let you control if PI and structure labels are shown on one side of the long axis gap or both sides of the gap.
- 11) 'Drafting/Plan & Profile Sheet Configuration/Scales' now has 'Angle Labels' radio buttons with options for "Deg Min Sec", "Decimal deg. 2 digits after decimal" and "Decimal deg. 4 digits after decimal".
- 12) Lots of tweaks for structure and PI labeling for better looking drawing, elimination of long axis duplicates and drawing of stuff that was missing.
- 13) "View/Edit customizations/Schema Report Strings" now lets you customize the plan & profile sheet text like "Horiz. Scale", "Vert. Scale" and some custom long axis text.
- 14) "Edit/Copy" of graphics view now gives option of saving the image as a .TIFF or .BMP. Plan view images saved from PLS-CADD will contain georeferencing information.
- 15) Modified DXF read routine to be more memory efficient and to solve error in some recent versions that could cause out of memory errors on files that used to be readable.
- 16) Tweaked background image memory management to reduce odds of running out of memory on 32 bit machines and to use extra memory if available on x64 machines.
- 17) Switched to new ECW/JPEG 2000 image library that is more tolerant of corrupt images, loads images 2-7 times faster and provides more reliable JPEG2000 support.
- 18) Upgraded to new version of TIFF library and added support for JPEG compressed TIFF files.
- 19) Drafting/Attachments/Attachment Manager now works with images in JPEG format. You can do anything with a ".jpg" file that you could with a ".tif" file. See updated photos technical note for details:
<http://www.powline.com/products/photos.html>
- 20) "Structure/Modify" dialog box "View" button and middle click context menu equivalent now provide access to images attached to PLS-POLE and TOWER structure files in addition to those in structure comments.
- 21 Imagery/DXF attached to PLS-POLE and TOWER structure files can be displayed in profile and sheet profile views ("Drafting/Structure and Section Labeling/Inset Views")

22) Added "F1/Display Features/Toggle display of structure view attachments (DXF+SHP+imagery)" allowing display of GPS camera imagery in the 3D view. Images viewed in the 3D view are visible when viewed from the front but displayed as a rectangular outline when viewed from behind.

23) "Drafting/Attachments/Associate Structure Photos" reads GPS coordinates out of "*.jpg" files and place a reference to that JPG in a structure comment for the closest structure.

24) "Drafting/Attachments/Attachment Manager" now supports a "Plan view vertical plane" image attachment mode for locating GPS camera images in the plan coordinate system. Program will automatically extract image coordinates and azimuth angle from GPS camera (including iPhone) EXIF data when present.

25) "Drafting/Attachments/Attachment Manager" dialog box "Options" button now allows batch application of settings across multiple images. This is especially useful when attaching many GPS camera photos.

Reports / XML / KML

1) Complete overhaul of "Lines/Reports/Construction Staking Report":

- a) Better control over reference hubs to display (centerline, structure, foundation joints, guy anchors, PI)
- b) Option to include graphic views (plan, transverse, longitudinal and isometric views) with user control over hubs, display of wires, set/phase labels, imagery...
- c) Option to include separate "PI Staking Report", "Staking Data by Structure Report" and "Material List".
- d) Optional column showing connection and property information (change required structure file format change and property information only available if structure file saved in PLS-POLE or TOWER 12.18 or newer).
- e) Above settings are now saved to PPS file.

2) "Terrain/Alignment/Display Options..." and PI report now have columns showing "Closest Structure" and "Stationing to Closest Structure" to help situate the PI relative to structures and facilitate location of structures that aren't at PIs.

3) "Terrain/Alignment/PI Report" now has optional columns for line angle, bearing, longitude and latitude displayed in degrees, minutes and seconds.

4) Lines/Reports/Summary "Structure Attachment Coordinates" now reports slack, horizontal projection and vertical projection columns (use View/Edit Customizations/Tables to enable display of these optional columns).

5) Lines/Reports/Summary now gives details for concentrated loads, namely horizontal distance to next marker ball or from wire attachment, as well as corresponding distances along wire.

6) "Lines/Reports/Thermal Rating Report" settings now saved to CRI file and a new control is provided for selection of desired feature codes (earlier versions did all feature codes)

7) All 20+ reports that support KML export now also support ESRI Shapefile (.SHP) export.

8) Added F1/Custom / Under Development/"Multiple Project XML Export..." command.

9) KML export link to PLS-CADD project modified to make it work with new syntax Google changed to for local file references.

10) XML output now includes a version attribute for the table tag which can be used to detect changes in the schema of that table.

11) Now line <rowtext> and <titledetail> tags up with other columns output in XML table in effort to make them more human readable.

12) Added File/Preferences/Settings "Include full path name of files in XML export and when copying tables" that defaults to off in order to match output from 11.00 (turn it on to get full file paths).

13) XML output now includes a <rowtext> tag with any text that was printed before or after the row. This is often a "NG " after the row when usage exceeds 100%.

Structures

- 1) "Structure/Customize Structure/Move Attachment Point/Snap to Survey Point & Freehand" now lets you toggle snapping between the wire attachment point ("W" key) and the insulator attachment point ("I" key).
- 2) Added Structures/Customize Structure/Move Pole/Lean to fit Survey Point command which can be used to match surveyed position of pole tip.
- 3) Structure interaction diagrams and wind and weight span strength definitions can now have limit on percent of maximum wind span, percent of maximum weight span and minimum weight span from a single side. Single side limits are accessible "Edit Single Side Limits" in the dialog boxes used to set wind and weight span limits and interaction diagrams.
- 4) "Lines/Reports/Wind-Weight Span Report" has a new "Wind / Weight Spans By Side" section that shows the total weight span and the portion of that coming from the back and ahead sides.
- 5) Added "Structures/Available Structure List/Batch Modify of Single Side Wind & Weight Span Limits" function to allow rapid application of single side limits to existing structures.
- 6) Structures/Automatic Spotting/Optimum Spotting dialog now has a "Vertical clearance buffer" input. Also added a "Show Advanced and Exotic options" control to hide rarely used options. Language in reports also fine tuned to make it more clear what went wrong when unable to produce a working design due to span, swing, clearance or prohibited zone constraints.
- 7) Optimum spotting "Show Advanced and Exotic Options" displays option that allows the optimizer to consider a range of different insulator hold down weights when solving swing problems.
- 8) Structure weight spans are now adjusted to account for insulator counter weights. Impacts weight spans displayed in "Lines/Reports/Structure Usage" and "Lines/Reports/Wind & Weight Span Report" both of which now have additional comment column that will alert you when a counter weight impacts the weight span.
- 9) Added 'F1/Custom+Under Development/Compatibility Options/Include insulator counterweight in weight span (version 12.10 and earlier did not)...' for customers who do not want counterweights to impact weight span.
- 10) New Structure Groups feature that allows application of load cases to a specific set of structures. This replaces and extends what could be done with the earlier "Struct. Types on Which To Apply" feature. Groups are defined by hitting the "Structure Groups" button in the Criteria/Structure Loads dialog and load cases are applied to groups using the "Structure Groups On Which To Apply" button. A group can be either manual or automatic. For a structure to be part of a manual group you need to make it part of that group using the "Structure Groups" buttons in Structure/Modify or Lines/Reports/Staking Table. Structures become members of automatic groups automatically if they meet the rule for inclusion in the group. This rule can include a combination of structure type, attachment type, line angle, station, height, elevation...
- 11) Increased maximum number of load cases from 256 to 1000.
- 12) "Criteria/Structure Loads/Wind Direction" now has a "MAX: Global wind direction producing maximum structure usage for M4 structures and maximum base moment for M1/M2/M3 structures". Requires use of new PLS-POLE and TOWER 12.22 for M4 structures.
- 13) Structure specific material dialog box now display structure weights (wood, steel, concrete).
- 14) Added a notes input field in each tab of the Project Estimator.
- 15) "Structures/Material/Parts & Assemblies File/Setup" now has a "Define Custom Units" button allowing you to set up your own units of measure (boxes, crates, reels, pints, packages...)

Wires

- 1) Added surveyed temperature for each span feature accessible in "Sections/Modify". It is also set automatically when using "Sections/Thermal Calculations./Batch Thermal Calculator". "Section/Modify", "Sections/Global Display" and "Sections/Table" allow selection of "**** Surveyed Wire Temp. ***" as the display WC to display sections at their surveyed wire temperatures. "**** Surveyed Wire Temp. ***" weather case is also supported by "Sections/Sag-Tension", "Lines/Reports/Summary/Structure Attachment Coordinates", and "Sections/Graphical Sag" (both via menu and Sections/Table). Surveyed temperature can be displayed on drawings using "Drafting/Structure & Section Labels/Wire Labels/Label wires with their surveyed temperature".
- 2) "Sections/Table" now has "Clear length adjust" (clear unstressed length adjustment for all spans in section), "Merge length adjust" (merge unstressed length adjustment into unstressed length), "Set Surveyed Temp." (Set surveyed temperature for all spans in section to temperature for 'Display Weather Case') and "Find Surveyed Temp." (Set surveyed temperature for each span in section to temperature extracted from XYZ points) commands.
- 3) "Sections/Cables & Concentrated Loads/Edit Cable Data" now has a default color and "Sections/Display Options" Section tab has a "Draw each section with the color specified in cable file" option.
- 4) "Sections/Cables & Concentrated Loads/Edit Cable Data" dialog has new options for deriving a creep polynomial from test results.
- 5) "Sections/Thermal Calculations" now supports IEEE Standard 738-2012 which can result in core strand temperature hotter than outer strands. It also allows optional override of emissivity and absorptivity values from cable file. Resistance calculations for IEEE 738-2012 and CIGRE now provide for input of radial thermal coefficient and use average of core and outer strand temperatures when calculating resistance.
- 6) "File/Preferences" setting "Weather cases with input of different temperatures for core and outer wire strands" lets one experiment with different core and outer strand temperatures. It causes "Criteria/Weather Cases" table to show separate "Core Strands Wire Temp." and "Outer Strands Wire Temp." columns instead of a single "Wire Temp." column. (this feature defaults to off as we anticipate most clients will not use it).
- 7) "File/Preferences/Enable Pretensioning of sections" makes sag-tension of pretensioned conductor easy (no more tricks with dummy ice and after load). Causes "Pretension" input to appear in "Sections/Table", "Sections/Modify" and PLS-CADD/Lite "Line/Setup".
- 8) New "Include chained insulators in L2 and L3 models" option under "Criteria/SAPS Finite Element Sag-Tension" allows modeling of insulators supported by other insulators. Earlier versions only included the insulators supporting wires in the L2-L3 FE model. Modeling the supporting insulators allows more accurate modeling of situations involving swing brackets modeled as 2-part insulators and floating dead-ends (strain on end of a suspension or 2-part). Changes to the information passed back and forth between PLS-CADD, PLS-POLE and TOWER require the use of PLS-POLE and TOWER 12.16 or later.
- 9) Can now put concentrated loads at start of span (partial span icing can start at beginning of span instead of some small bit ahead of that). Also increased maximum number of marker balls per span from 20 to 60.
- 10) "Lines/Reports/Structure Longitude, Latitude and Height" now has an option to flag structures exceeding a certain height above ground.
- 11) Added "Sections/Concentrated Loads Automatic Placement" feature for reporting on wires exceeding a specified height above ground or automatically placing marker balls on them. Options are provided to control spacing, staggering between different wires, alternating between different colors...
- 12) New codes: AS/NZS 7000:2010, NESC 2012 (spacer cable choice, warnings if don't use ANSI 05.1 2008 for wood pole checks), EN50341-1:2012 (Cenelec), REE Spain RD 223/2008, IS 802 1995 (India), CSA C22.3 No. 60826-10 (variation on IEC for Canada), IEC option for wind on structure ice, EN 50341-3-9 UKNNA corrigenda
- 13) PLS-CADD/Lite "Lines/Setup" dialog ruling span column now supports calculation of ruling span from entered span lengths. Use "=RSC(HorizProj1,HorizProj2...)" for the classical ruling span formula or "=RSI(HorizProj1,Chord1,HorizProj2,Chord2...)" for one more accurate with unequal end elevations.

14) PLS-CADD/Lite now has a voltage column to support "IS 802 1995" and "CSA" code provisions that single out ground wires for special drag coefficient and ice treatment.

Terrain

- 1) "Terrain/Edit/Delete, Deactivate, or Export Survey Points" commands can now operate on either "selected" or "unselected" (can operate on points outside a fence).
- 2) "Terrain/Edit/Merge Points from External File/Create XYZ or PFL points from DXF attachment" now has an option to create survey points at regular intervals along DXF edges and across planar surfaces. Includes new option to recurse through entities in blocks.
- 3) Reports that can be exported to KML or SHP now have a "Import in Project as XYZ Points" right click menu option. Use of this feature causes creation of an XYZ point with a feature code of your choosing for each row in the report.
- 4) "Terrain/Survey Data Report" maximum length for point descriptor increased from 20 to 256 characters.
- 5) "Terrain/TIN/Display Options" now has "Color by Slope" and "Color by Averaged Slope" to make it easier to visualize slope of ground.
- 6) "Terrain/TIN/Display Options" now has opacity setting so can control translucency of TIN surface.
- 7) "Terrain/TIN/Display Options" now has a "Z value adjustment" allowing one to shift the TIN up or down. Shifting the TIN up can provide a graphical way to determine areas where wires exceed a certain height above ground and may need marker balls.

Web

- 1) Web site now has a "User Contributed" sub-section in the Videos section of the news page. First video is from Norconsult with beautiful fjord crossings. We encourage submission of additional videos.
- 2) Posted "Wind Loading: Uncertainties and Honesty Suggest Simplification" paper on Web site at http://www.powline.com/files/Peyrot_Wind.pdf
- 3) Uploaded new video "Introduction to the QuickSearch Toolbar" (<http://youtu.be/DwYgf5e9IOk>) to our Web site.
- 4) Criteria Files Web page updated to include new NESC 2012 criteria files (<http://www.powline.com/files/criteria.html>).
- 5) "Importing and Exporting Data to and from PLS Software" technote updated with new information concerning JPEG, TIFF attachments and SHP, KML report export (<http://www.powline.com/products/data.html>).

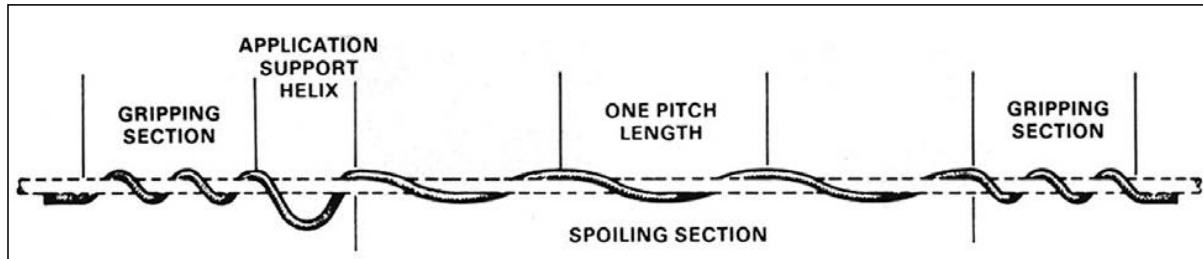
Current Projects

- 1) Improved alignment editing including rubber band lines to show what alignment will look like after PI add/move/delete is done. Also added option to heave ahead/back structures should stay anchored to current position or move with alignment.
- 2) Improved structure integration. Working on more sophisticated method of communicating between PLS-CADD and PLS-POLE or TOWER that enables much faster and intelligent integration.
- 3) Structure spotting and wire stringing without alignment or station constraints.

Rev1. Sep. 2024
Page 20 of 27

APPENDIX F – PLP AIR FLOW SPOILER & DAMPER

Air Flow Spoiler



Thermal Rating (Continuous) 125°C

NOMENCLATURE

Gripping Section: Grips cable. Consists of several pitches (360° wraps around the cable) and holds the Air Flow Spoiler firmly in position.

Spoiling Section: Disrupts aerodynamic lift. The spoiling section is wrapped around the cable in a manner which presents a constantly changing profile to wind flow and cancels lift forces which cause galloping. The spoiling section is wrapped around the cable either two or three times, depending on cable diameter.

Application Support Helix: Supports Spoiler. Air Flow Spoilers range in length from 14 to 16 feet. The Application Support Helix on one end keeps the Air Flow Spoiler from hanging down, while the gripping section on the opposite end is applied.

Air Flow Spoilers for EHV applications have a co-extruded semi-conductive outer layer of material which resists the surface effects of high electrical gradients and minimizes the possible generation of radio interference (RI).

GENERAL RECOMMENDATIONS

Several Air Flow Spoilers are required in each span to offset the aerodynamic lift forces which cause galloping. Each cable, conductor or phase, and neutral need to be treated in each span.

The number and placement of Air Flow Spoilers in each span can be determined by using the General Placement guidelines that follow or by submitting the Air Flow Spoiler Placement Request form. The information submitted on this form is input into a computer program for the determination of the exact placement of the Air Flow Spoilers in each span. The program also supplies the increased wind loading on each span as a percentage increase.

When using the Air Flow Spoiler Placement Request form, the information should be completed and returned to Preformed Line Products prior to installation of Air Flow Spoilers. The placement scheme will be returned giving the placement of Air Flow Spoilers in each span.

Please advise whether the cables contain optical fibers or if the Air Flow Spoilers are to be installed on Figure 8/ Lashed Messenger cables. This may influence the Air Flow Spoiler selection and/or quantity.

GENERAL PLACEMENT GUIDELINES

Extensive laboratory and field research has shown that Air Flow Spoilers are most effective when they are placed on 25% of the span length (based on the 12' spoiling section). For example, a 600' span would require 13 Air Flow Spoilers $[(.25 \times 600) / 12]$. The Air Flow Spoilers are grouped in the middle 50% of the span by leaving a blank space equal to an Air Flow Spoiler length between adjacent units.



Air Flow Spoiler



Catalog Number	EHV Catalog Number	Diameter Range (Inches)		Length (Feet)	Wt./Unit Lbs.	Color Code
		Min.	Max.			
5058100	N/A	0.250	0.326	13-1/2	1.00	Red
5058101	N/A	0.327	0.461	13-1/2	1.00	White
5058102	N/A	0.462	0.563	14	2.25	Orange
5058103	N/A	0.564	0.76	14-1/2	2.40	Yellow
5058104	N/A	0.761	0.926	15	4.25	Blue
5058105	5058200	0.927	1.019	15-1/4	4.50	Black
5058106	5058201	1.020	1.165	15-3/4	5.50	Purple
5058107	5058202	1.166	1.469	16	5.75	Brown
5058108	5058203	1.470	1.602	17	9.50	Green
5058109	5058204	1.603	1.762	17-1/2	9.75	Pink
5058110	5058205	1.763	1.922	18	10.50	Red

EXPLANATORY NOTES:

- (1) For installation on Figure 8 and Lashed Messenger cables, consult PLP®.
- (2) Obtain the Air Flow Spoiler Placement Request form from your local PLP® representative or direct from PLP®.

Air Flow Spoiler

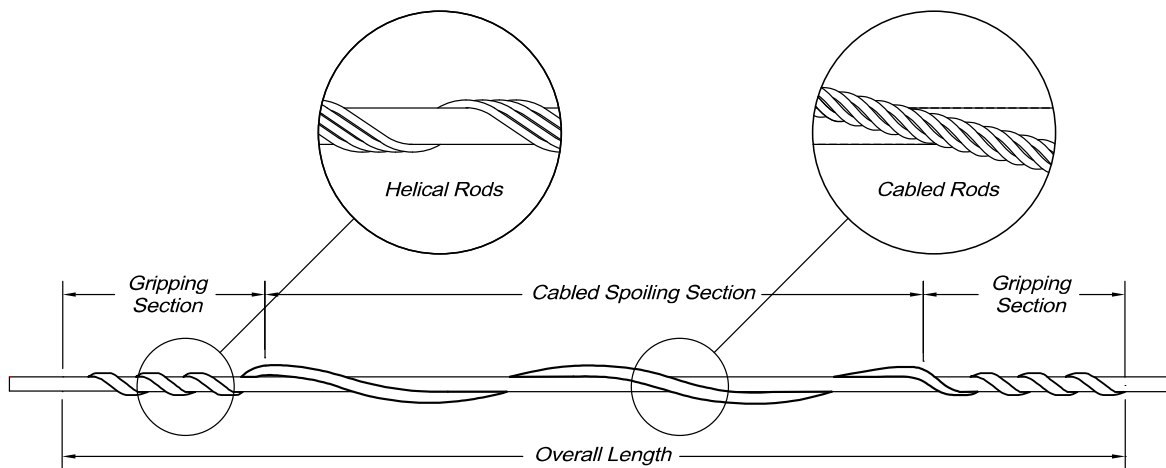
High Temperature Air Flow Spoilers

GENERAL INFORMATION

The high temperature Air Flow Spoiler is constructed of aluminum alloy wires that enable the product to handle temperatures up to 250°C. By subsetting multiple helical rods and cabling (twisting) the center section, the high temperature Air Flow Spoiler functions in the same manner as the standard Air Flow Spoiler.

Thermal Rating (Continuous) 250°C

Contact PLP for details regarding applications above 230KV.



Catalog Number	Diameter Range (Inches)		Length (Feet)	Wt./Unit Lbs.	Color Code
	Min.	Max.			
5059017	0.761	0.808	15-1/2	5.66	Brown
5059018	0.809	0.856	16	5.81	Purple
5059019	0.857	0.907	16	5.81	Orange
5059020	0.908	0.962	16	5.87	Black
5059021	0.963	1.019	16	5.93	Red
5059022	1.020	1.078	16-3/4	10.93	Blue
5059023	1.079	1.138	16-3/4	11.03	Yellow
5059024	1.139	1.199	16-3/4	11.25	Green
5059025	1.200	1.263	17-1/2	11.48	Pink
5059026	1.264	1.330	17-3/4	11.68	Brown
5059027	1.331	1.399	18-1/2	12.18	Purple
5059028	1.400	1.469	19-1/4	12.61	Orange
5059029	1.470	1.549	21-1/2	20.22	Black
5059030	1.550	1.629	22	20.86	Red
5059031	1.630	1.714	22-1/2	21.17	Blue
5059032	1.715	1.805	23-1/2	22.03	Yellow

EXPLANATORY NOTES:

(1) Obtain the Air Flow Spoiler Placement Request form from your local PLP® representative or direct from PLP®.

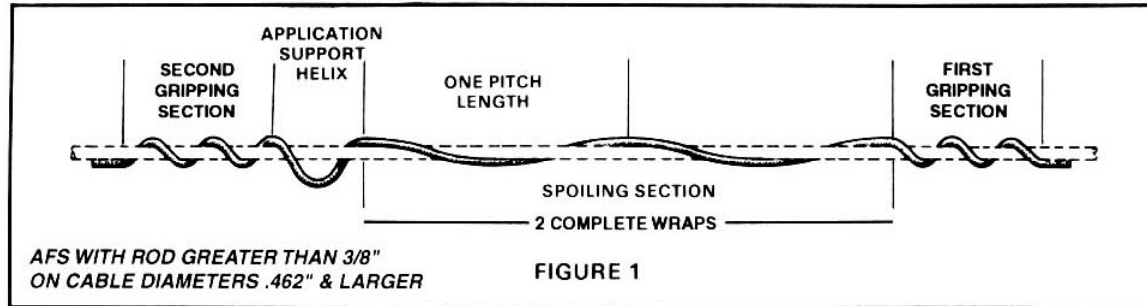
APPLICATION PROCEDURE & SAFETY CONSIDERATIONS **PREFORMED LINE PRODUCTS**

AIR FLOW SPOILER



DECEMBER 1996

Completely read and understand this procedure before applying product. Special attention should be given to the Safety Considerations located on the last page. We advise the reader to review those considerations now, and then again during the general review of this procedure.



NOMENCLATURE

GRIPPING SECTION: Grips cable. Consists of several pitches (360° wraps around the cable) and holds the Air Flow Spoiler firmly in position.

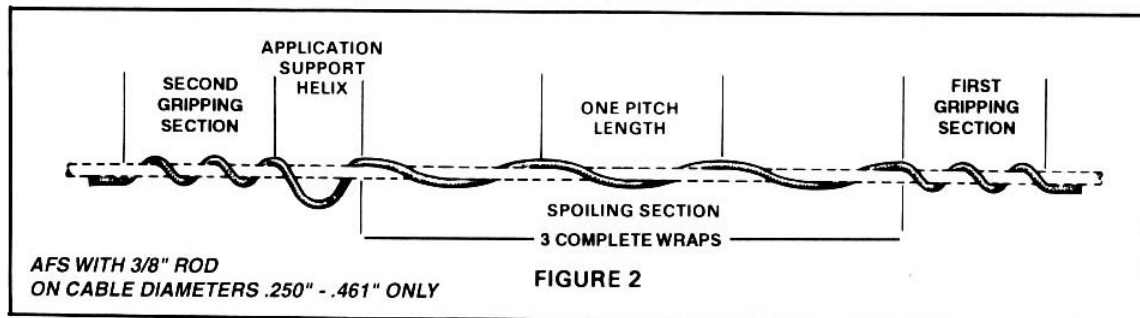
SPOILING SECTION: Disturbs aerodynamic lift. The spoiling section is wrapped around the cable in a manner which presents a constantly changing profile to wind flow and helps reduce lift forces which cause galloping. The spoiling section is wrapped around the cable either two times (FIGURE 1) or three times (FIGURE 2), depending on cable diameter.

APPLICATION SUPPORT HELIX: Supports Spoiler. Air Flow Spoilers range in length from 14 to 16 feet. The Application Support Helix on one end keeps the Air Flow Spoiler from hanging down, while the gripping section on the opposite end is applied.

APPLICATION

1. Once the location for installation of the Air Flow Spoiler has been chosen, wrap the Application Support Helix around the cable and slide the Air Flow Spoiler away from you until the first gripping section is in its correct location. The Application Support Helix prevents the Air Flow Spoiler from hanging down while the first gripping section is wrapped on.
2. Wrap on the first gripping section.
3. Now move to the opposite end of the Air Flow Spoiler where the Application Support Helix is located and wrap the spoiling section around the cable **two times** in a **right-hand** lay direction. See Figure 1.

NOTE: For small diameter cables which use the Air Flow Spoiler made from 3/8" diameter rod, wrap the spoiling section around the cable three times in a right-hand lay direction. (This will limit excessive drooping of the small diameter Air Flow Spoiler during hot weather conditions.) See Figure 2.



4. Install the second gripping section by wrapping it around the cable and snap the end of the gripping section in place.

TIPS ON INSTALLATION

To assist the installer in determining how many times the Air Flow Spoiler is wrapped around the cable, the following will be helpful:

1. For small cable diameters (.250" - .461") where the AFS rod diameter is 3/8", wrap the spoiling section in a right-hand lay direction three times around the cable.
2. For all cable diameters .462" and larger where the AFS rod diameter is larger than 3/8", wrap the spoiling section in a right-hand lay direction two times around the cable.

GENERAL NOTES

1. Several Air Flow Spoilers are required in each span to offset the aerodynamic lift forces which cause galloping.
2. The number and placement of Air Flow Spoilers in each span are determined by a computer program which considers the results of on going field and laboratory research.
3. An Air Flow Spoiler Placement Request form should be completed and returned to Preformed Line Products Company prior to installation of Air Flow Spoilers. A placement scheme will be returned to determine placement of Air Flow Spoilers in each span.
4. Please advise whether the cables contain optical fibers. This may influence Air Flow Spoiler selection.

FIGURE 8 & LASHED MESSENGER CABLES

Figure 8 and lashed messenger cables are special applications for short span construction. Air Flow Spoilers may be located in accordance with the table below.

Span Length in feet	Air Flow Spoilers per cable	Air Flow Spoiler placements start from first structure. Distances are measured from same end of Air Flow Spoiler, accumulated distances in ().		
100-130	2	33.3 (33.3)	28.8 (62.0)	48.0 (110.0)
130-160	3	33.9 (33.9) 48.6 (140.0)	28.8 (62.6)	28.8 (91.4)
160-190	3	48.9 (48.9) 63.6 (170.0)	28.8 (77.6)	28.8 (106.4)
190-220	4	44.5 (44.5) 28.8 (130.8)	28.8 (73.3)	28.8 (102.0)

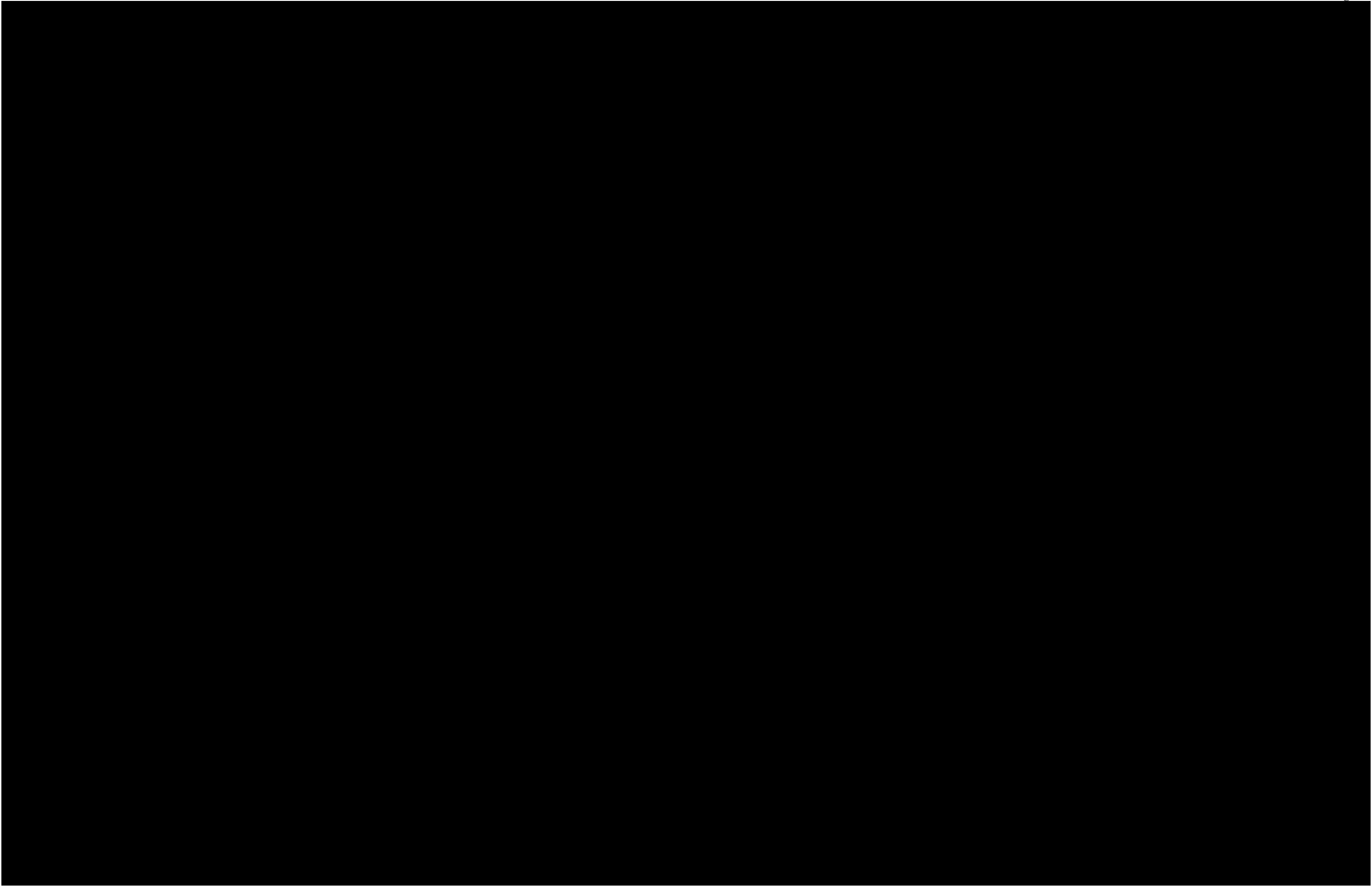
Please contact the factory for recommendations on longer spans. Figure 8 and lashed messenger cables are more difficult to determine correct Air Flow Spoiler size. Please provide complete dimensions of the cable so correct size may be established.

SAFETY CONSIDERATIONS

1. This application procedure is not intended to supersede any company construction or safety standards. This procedure is offered only to illustrate safe application for the individual. **CAUTION: FAILURE TO FOLLOW THESE PROCEDURES AND RESTRICTIONS MAY RESULT IN PERSONAL INJURY OR DEATH.**
2. This product is intended for the specified application. **CAUTION: DO NOT MODIFY THIS PRODUCT UNDER ANY CIRCUMSTANCES.**
3. This product is intended for use by trained craftspeople only. This product **SHOULD NOT BE USED** by anyone who is not familiar with and trained in the use of it.
4. When working in the area of energized lines with this product, **EXTRA CARE** should be taken to prevent accidental electrical contact.
5. For **PROPER PERFORMANCE AND PERSONAL SAFETY** be sure to select the proper size **PREFORMED** product before application.
6. **PREFORMED** products are precision devices. To insure proper performance, they should be stored in cartons under cover and handled carefully.

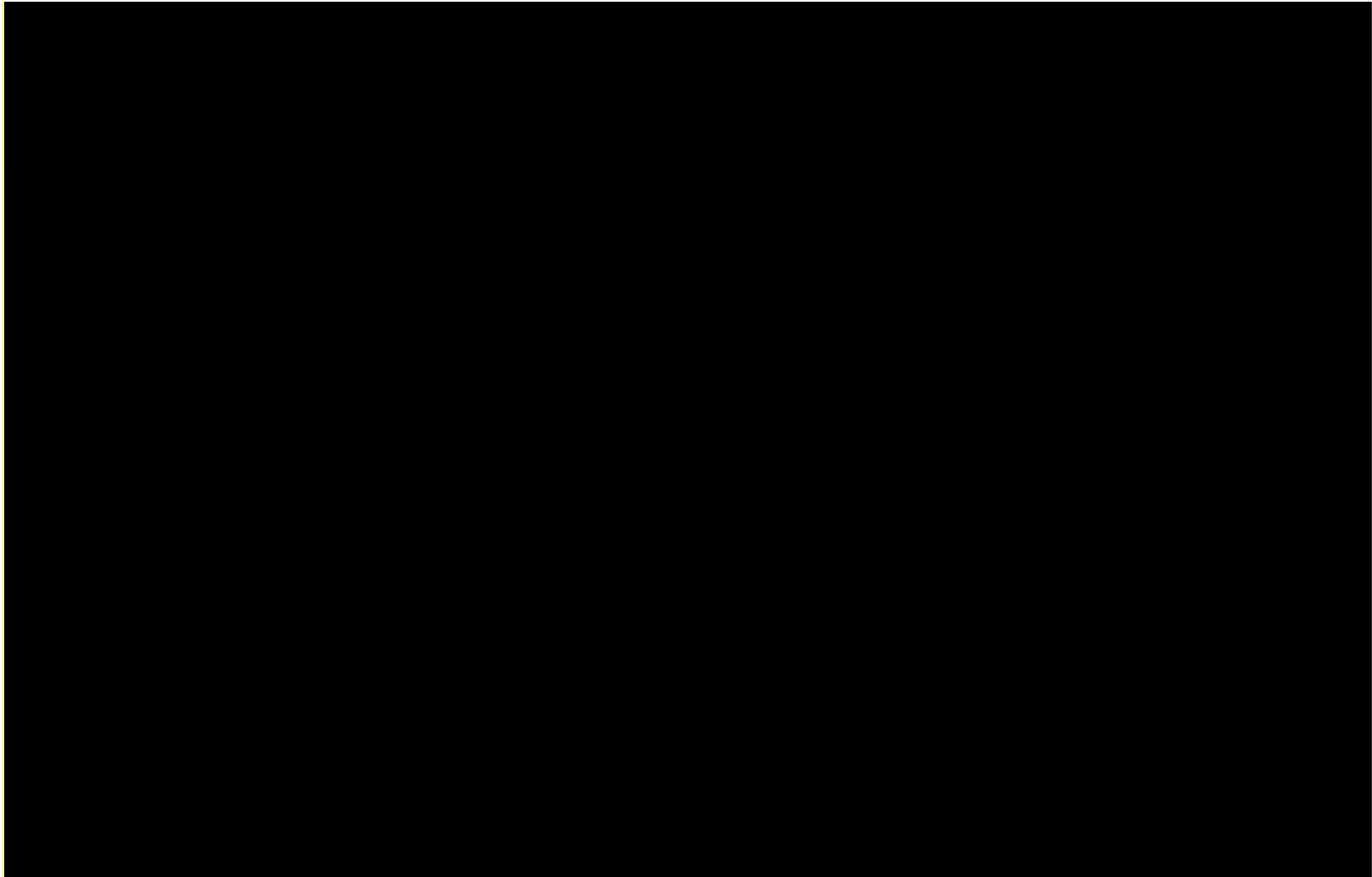
PREFORMED LINE PRODUCTS 

P.O. Box 91129, Cleveland, Ohio 44101 • 440.461.5200 • www.preformed.com • e-mail: inquiries@preformed.com



**Rev1. Sep. 2024
Page 21 of 27**

APPENDIX G – CANSO CROSSING PERMIT DRAWING (CURRENT VS ESTIMATED)



8

7

6

5

4

3

1

**Rev1. Sep. 2024
Page 22 of 27**

APPENDIX H – L7005 TOWER CLIMBING INSPECTION SUMMARY



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

Connect Atlantic Utility Services

L7005 Tower Inspections

Summary Document

Canso Crossing



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing



Inspection completed July, 2024



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

Contents

Scope.....	3
Foundations	3
Block pattern cracking.....	3
Torque and Assembled Steel	5
Str 729A upper platform, middle section.	5
Str 730, SW foundation.	7
Str 731, NE Foundation	7
Str 732, SW Foundation	8
Str 732A, upper platform, middle section	9
Hardware/Connections.....	10
Conductor.....	10
Jumpers on str 729.	10
 Figure 1 - Str 730, NW foundation, cracking in square pattern	4
Figure 2 - Str 731, NE foundation, cracking in square pattern	5
Figure 3 - Str 729A bent piece of steel webbing.....	6
Figure 4 - Str 729A bolt showing signs of rust.....	6
Figure 5 - Str 730, bolts requiring retorquing behind door panel.....	7
Figure 6 - Str 731, plate on NE leg that required retorquing.....	8
Figure 7 - Str 732 damaged piece of steel	9
Figure 8 - Str 732A upper platform, middle section	9
Figure 9 - Str 731 conductor.....	10
Figure 10 - Str 729 jumpers	11



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

Scope

Inspection of towers 729, 729A, 730, 731, 732 and 732A was completed during July 2024. The inspection followed the direction of document “Engineering Work Package – L7005 Inspection Document” which was supplied by NSPI.

The inspection was divided into two categories:

1. Visual inspection.
2. Climbing inspection.

The intent of the inspection was to identify any defects in the structures and assign a maintenance priority rating to the finding.

The following is a high-level summary of the findings. Detailed inspections sheets and pictures will also be provided to the client as a turnover package.

Foundations

All foundations showed signs of deterioration and/or cracking. Also, most foundations had slight separation of grout from concrete. But no serious deficiency was discovered. After saying this the foundations should be added to a maintenance program that would include, as a minimum, sealing the foundation.

All foundations were revealed during the inspections. This consisted of hand excavating an 18-inch hole alongside the foundation and doing a visual inspection of the surface. No issues identified at any location.

Block pattern cracking

The main issue identified during the inspections was that several foundations had cracking and concave patterns, which looked to be in the shape of the installed rebar. This pattern was more evident in certain foundations and most foundations did not show any pattern. This should not be a new issue and should have been identified previously.



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing



Figure 1 - Str 730, NW foundation, cracking in square pattern



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing



Figure 2 - Str 731, NE foundation, cracking in square pattern

Torque and Assembled Steel

As an average very few bolts moved during retorquing. Overall, no major issue was identified. Of the six towers inspected these are the minor issues identified.

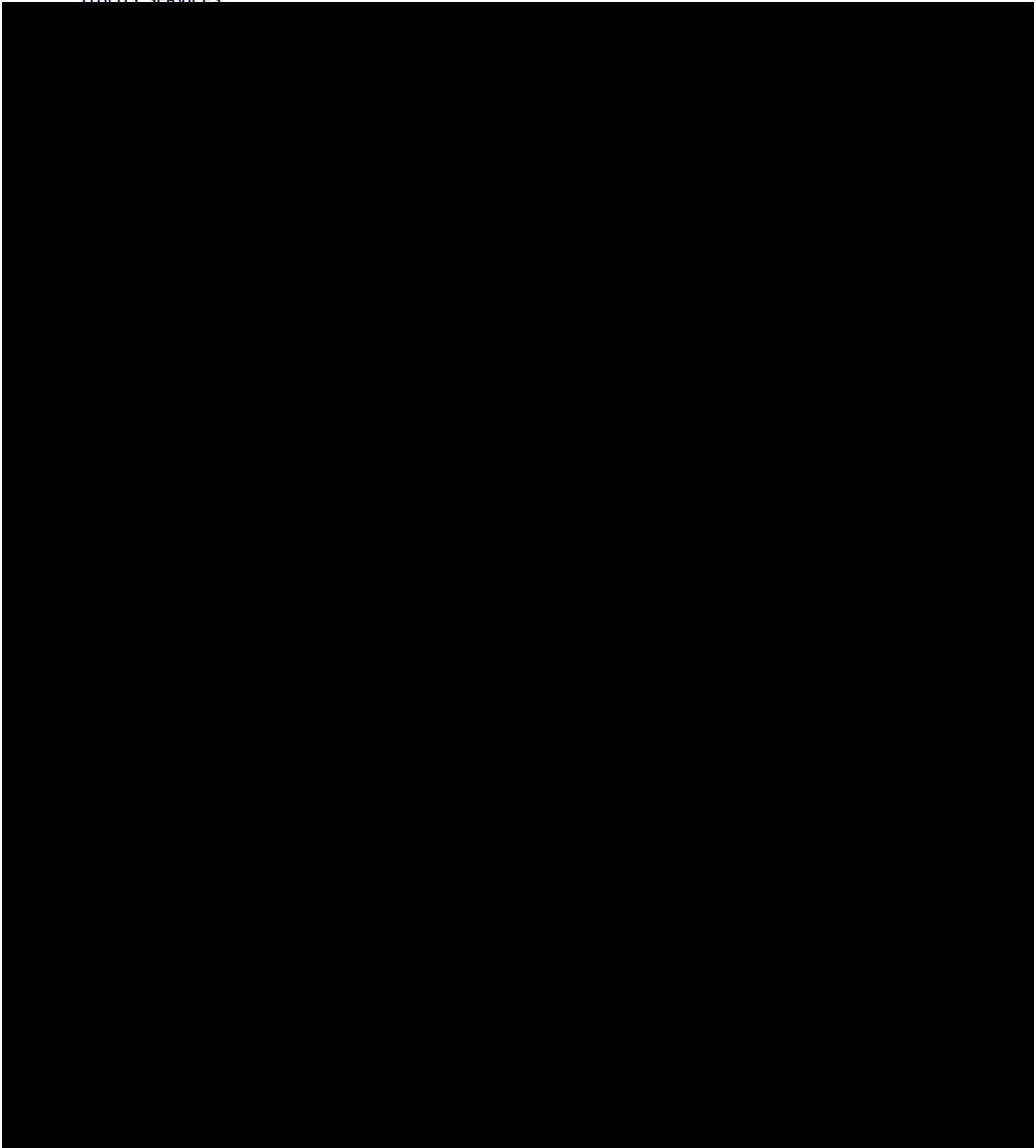
Str 729A upper platform, middle section.

One piece of webbing was bent. One of two main bolts that connect the main support assembly to the platform showed minor signs of rust.



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing





Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

Str 730, SW foundation.

A section of bolts on the SW corner of the leg, located behind the ladder assembly cover covering the access point, were not torqued. They were difficult to reach due to the ladder cover causing a obstruction. Approx. 20 7/8" bolts needed to be torqued. A section of bolts located on the NE corner of the leg also needed to be torqued. Approx 10 7/8" bolts.



Figure 5 - Str 730, bolts requiring retorquing behind door panel

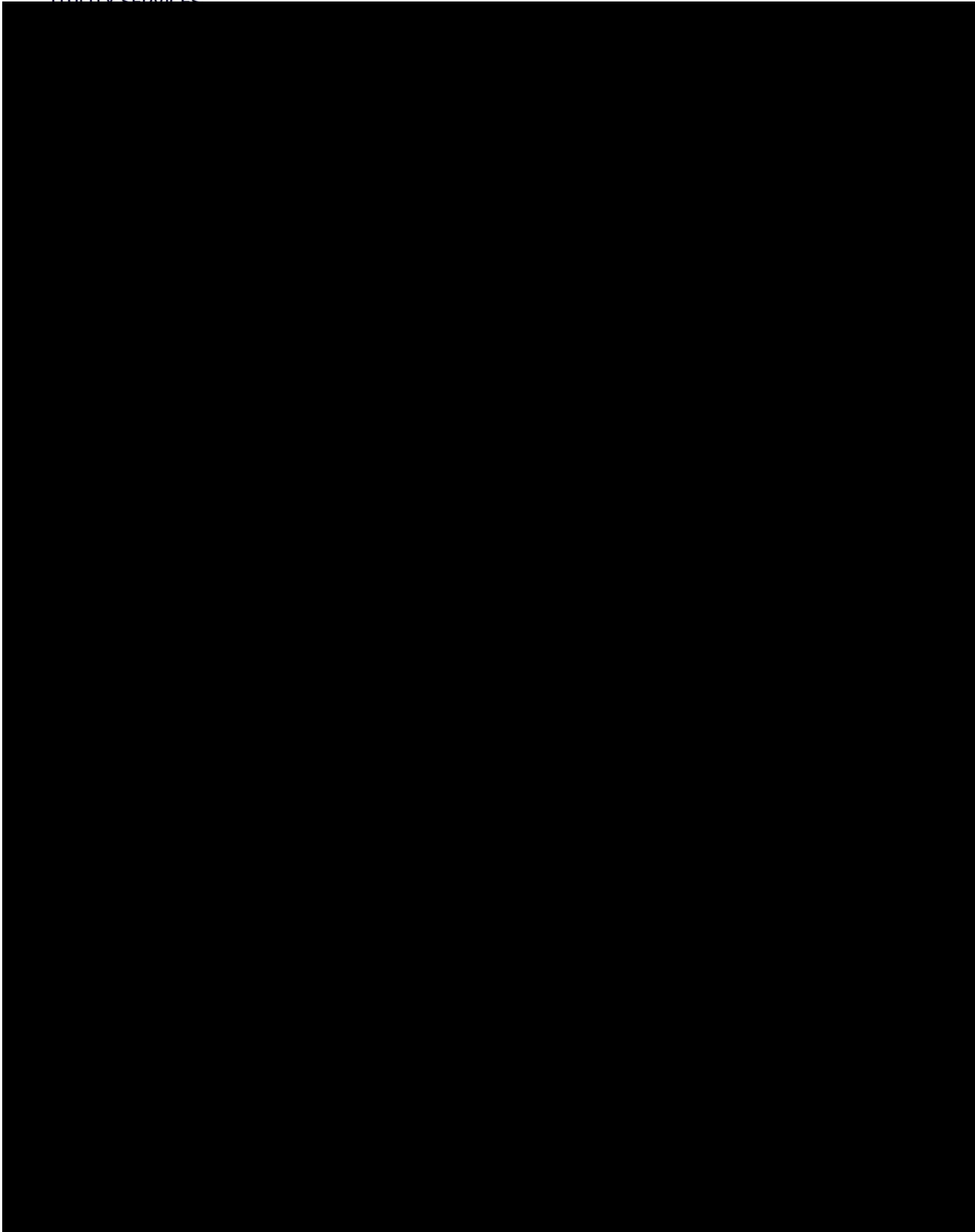
Str 731, NE Foundation

The majority of nuts on one plate needed to be torqued. Plate located on angled steel support which points towards the SE corner of the str. Picture attached. Approx a third of the remaining bolts also moved. It should be noted that this foundation was also showing signs of the most wear.



CONNECT ATLANTIC
UTILITY SERVICES

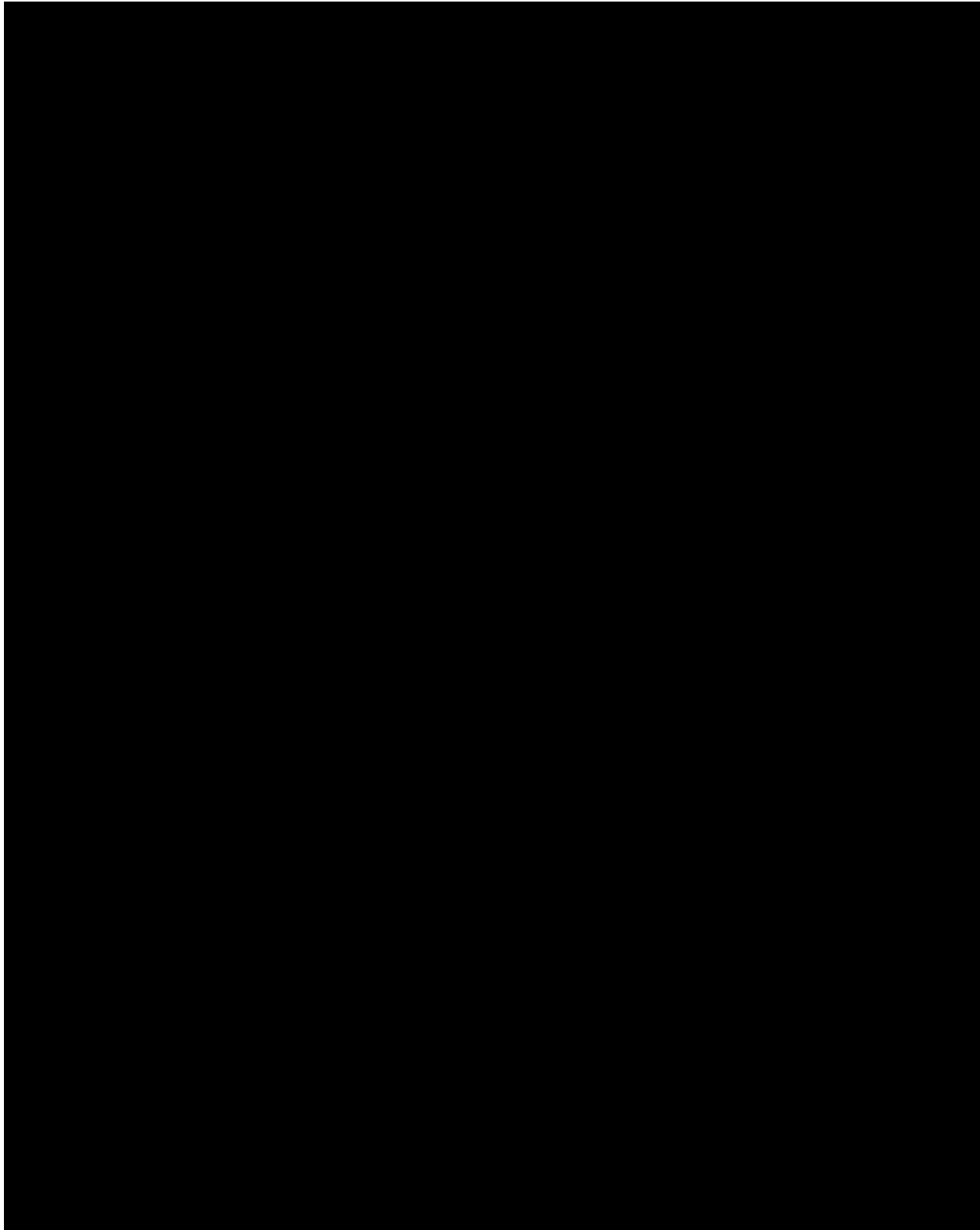
Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing





CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

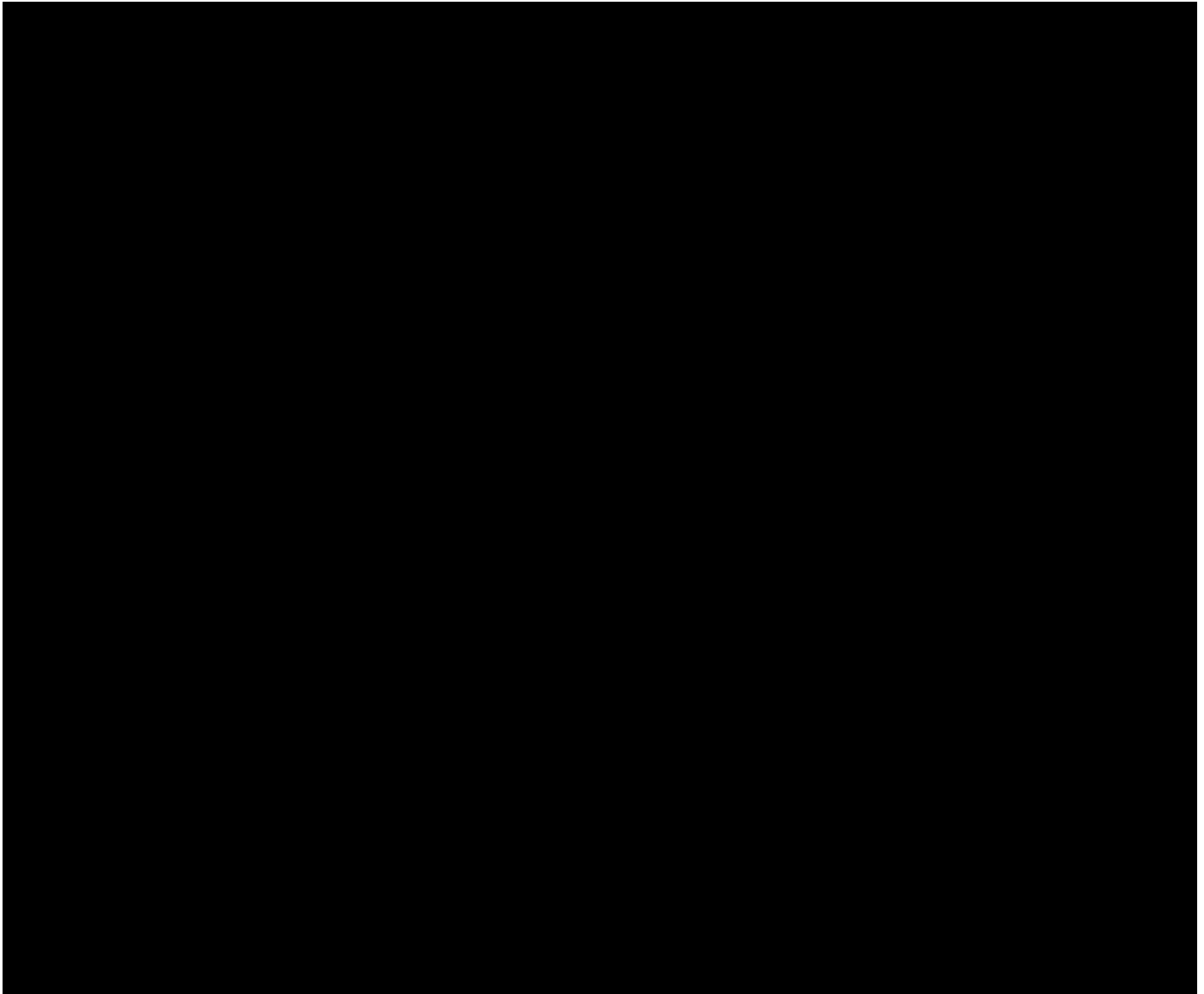




CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing

Hardware/Connections



Jumpers on str 729.

The jumper section from the idler arm to the conductor on the west side of the str looks to be encroaching (estimated 3 ft) on the angled support assemblies that attach to upper platform to the SW, NW and Mid-West foundations. May have been caused by ice load that caused the jumper to sag.



CONNECT ATLANTIC
UTILITY SERVICES

Nova Scotia Power Inc.
L7005 Tower Inspections Canso Crossing



Figure 10 - Str 729 jumpers

All remaining hardware and connection points were found to be in excellent condition. No issues identified during visual inspections.



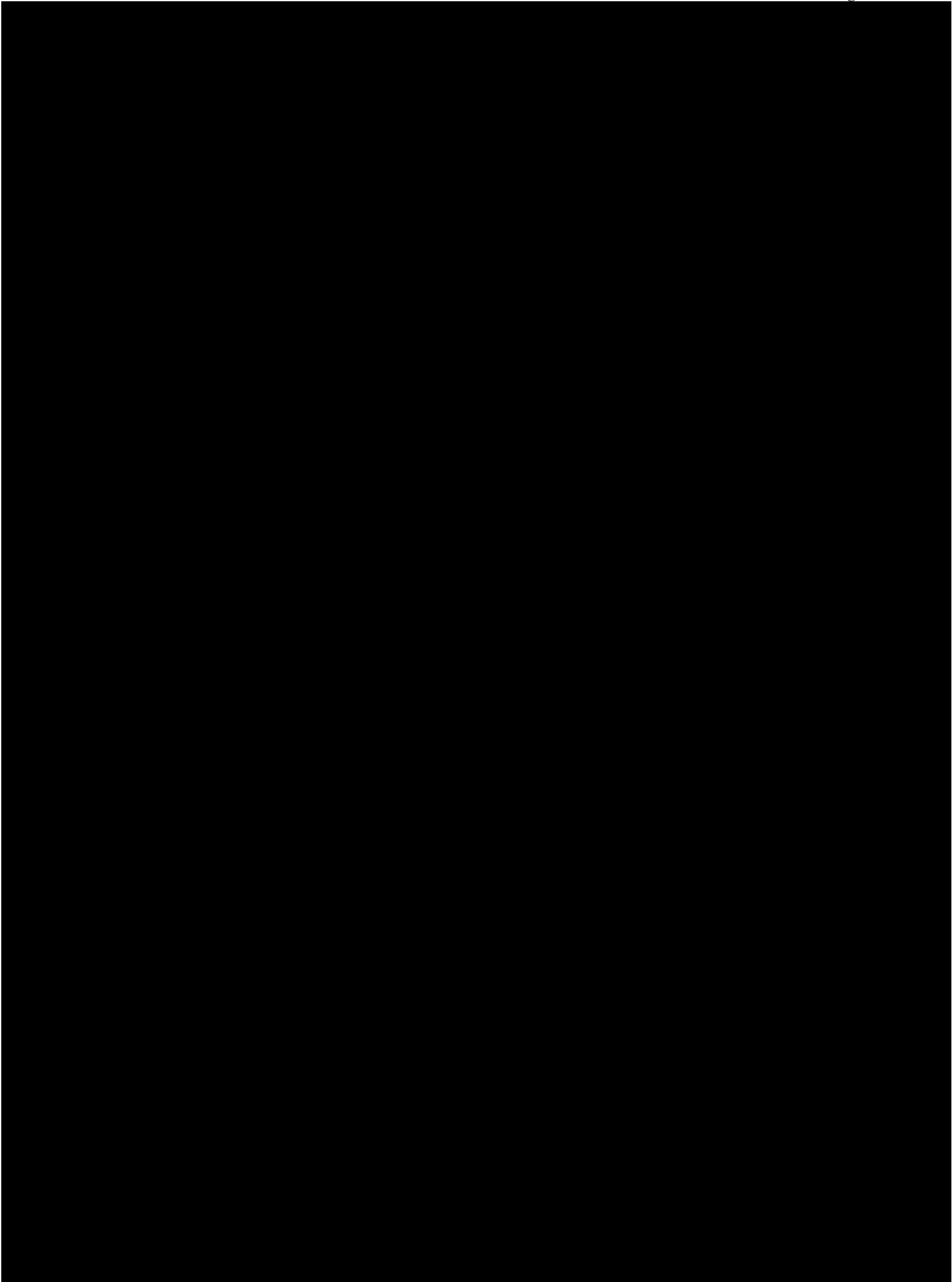
CONNECT ATLANTIC
UTILITY SERVICES

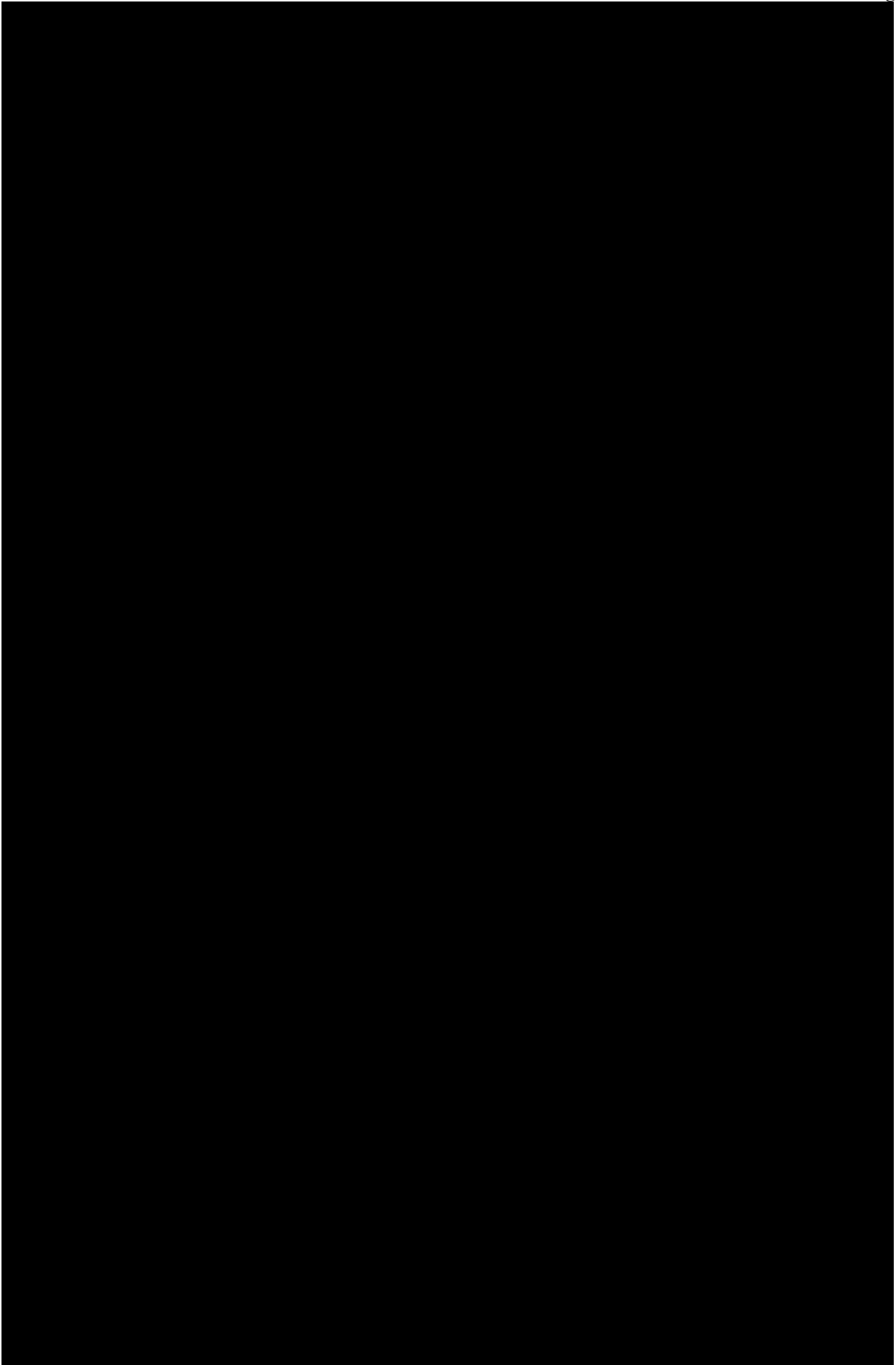
Nova Scotia Power Inc.

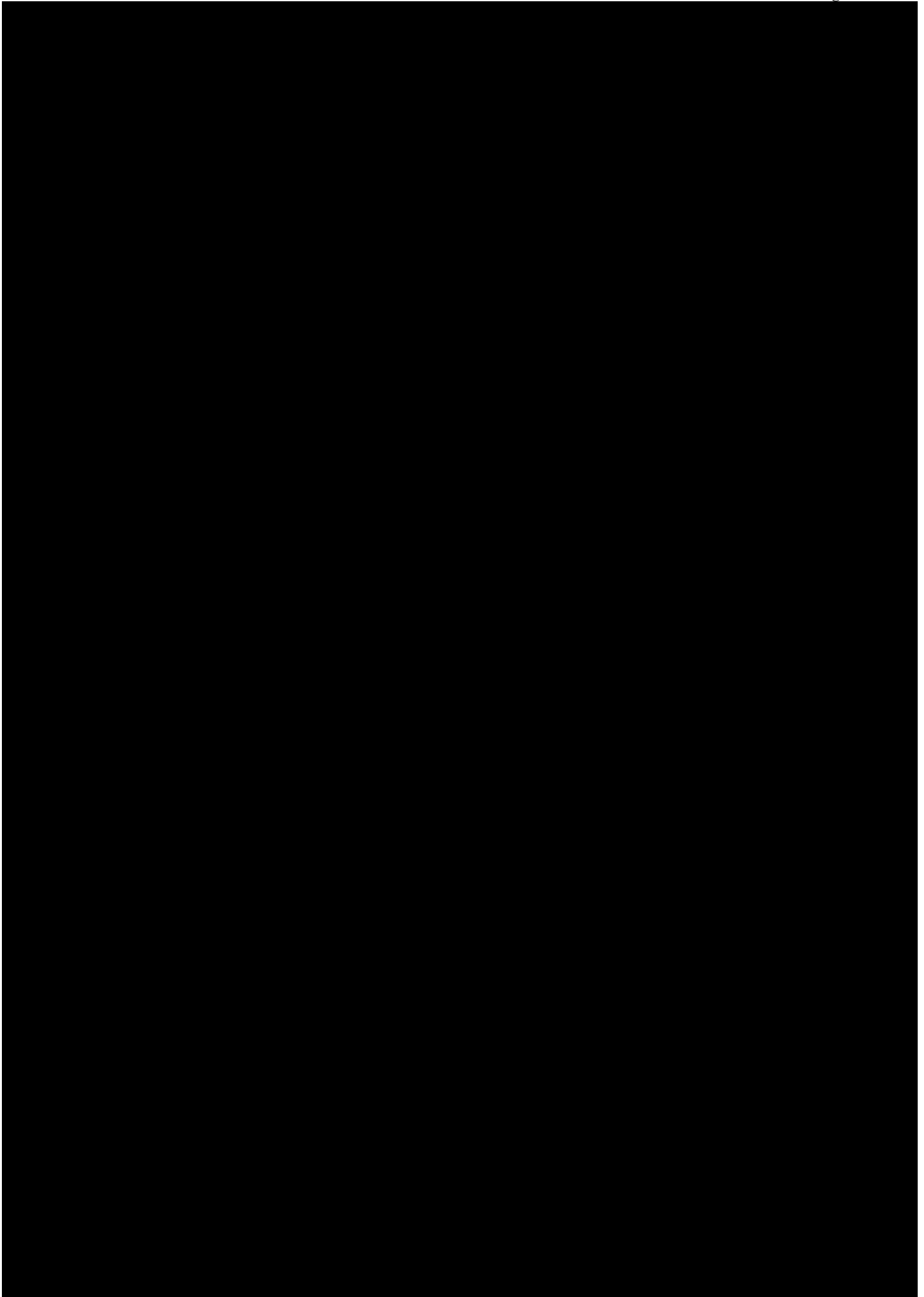
L7005 Tower Inspections Canso Crossing

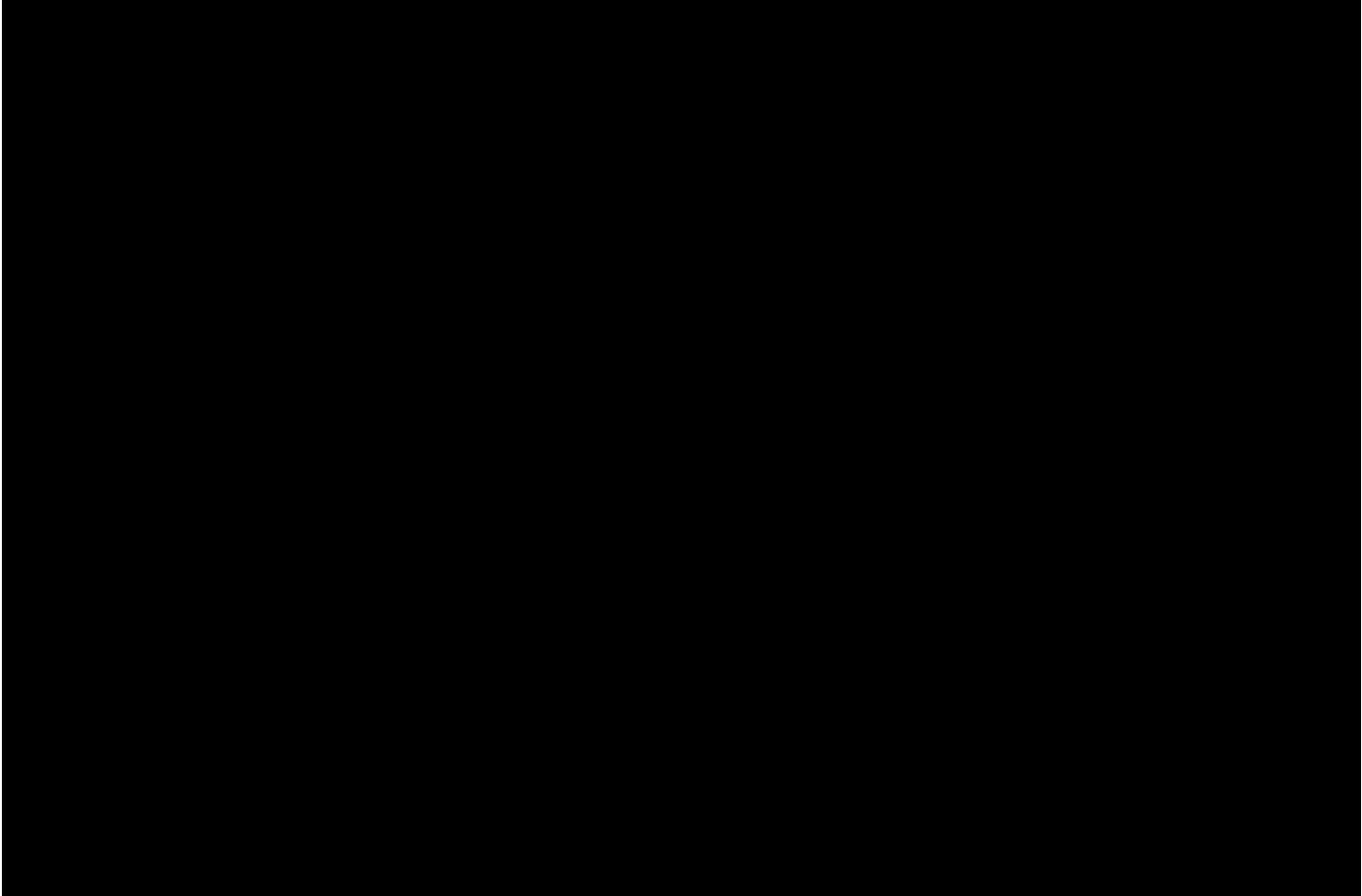
Rev1. Sep. 2024
Page 23 of 27

APPENDIX I – SYSTEM PLANNING INFORMATION



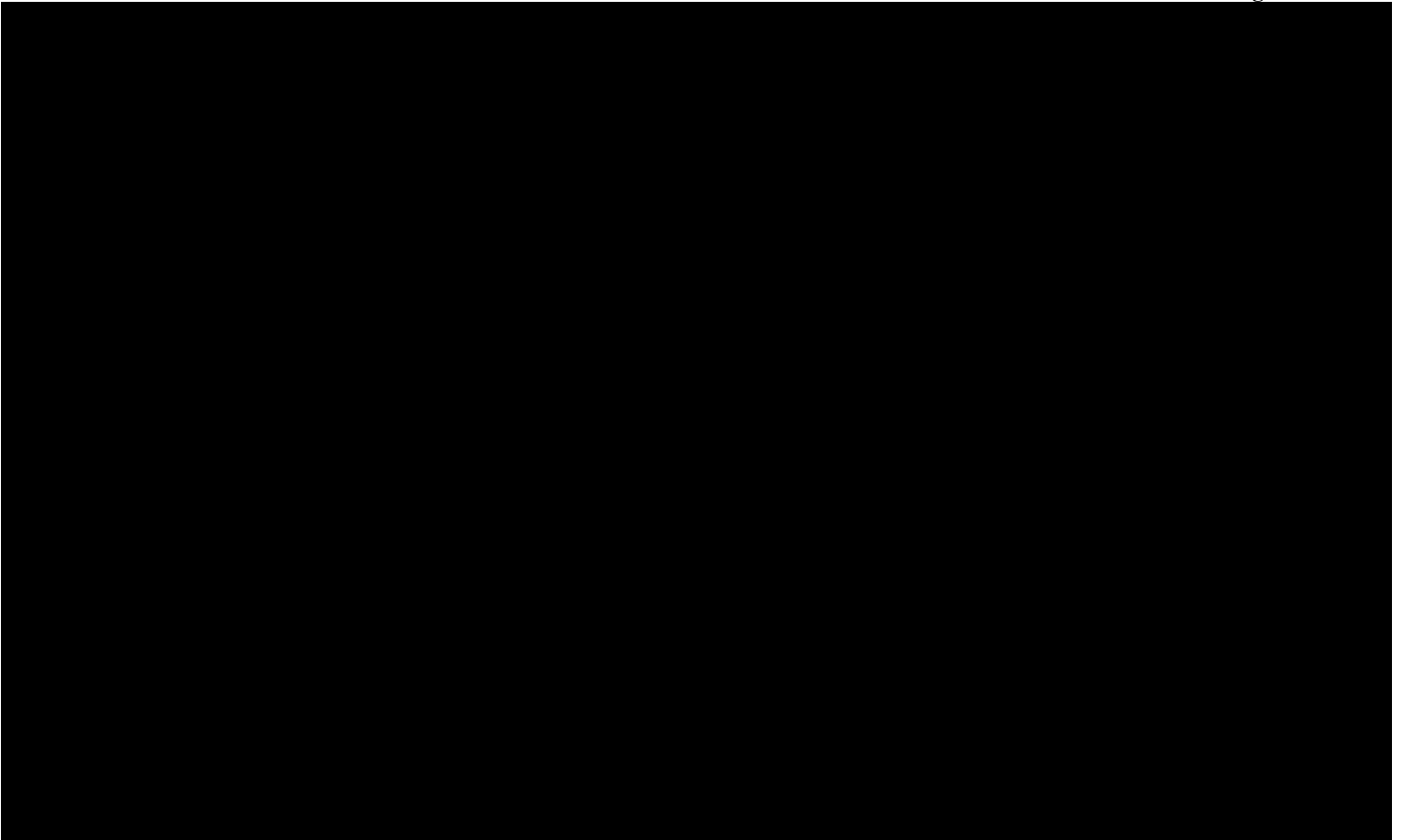






**Rev1. Sep. 2024
Page 24 of 27**

APPENDIX J – AIR FLOW SPOILERS PLACEMENT INFORMATION



**Rev1. Sep. 2024
Page 25 of 27**

APPENDIX K – DAMPER PLACEMENT CHARTS

 PLP Canada Ltd 1600, 46th Avenue Lachine, Qc H8T 3J9 Tel. : 514-828-0057 Fax : 514-828-0070	TECHNICAL NOTICE NT-230424-1 VIBRATION DAMPER PLACEMENT
---	---

Rev.	Description	Date (dd/mm/yy)
1	Initial version	23/04/24
2	Revised span lengths	2/08/24

VIBRATION DAMPER PLACEMENT CHART – NOVA SCOTIA CANSO STRAIT CROSSING L7005

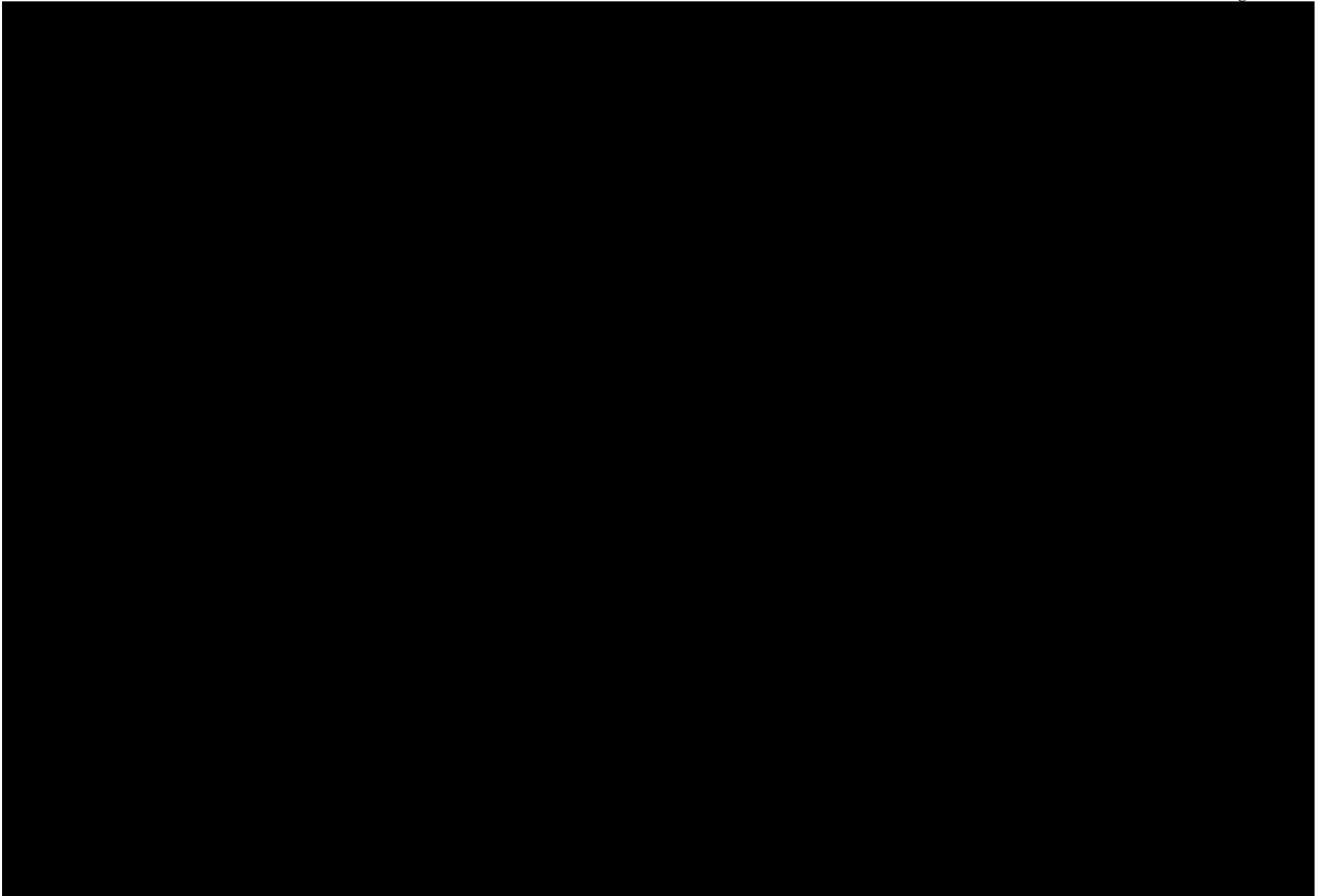
Ref.: 360431 / PLP CANADA QUOTE 302778

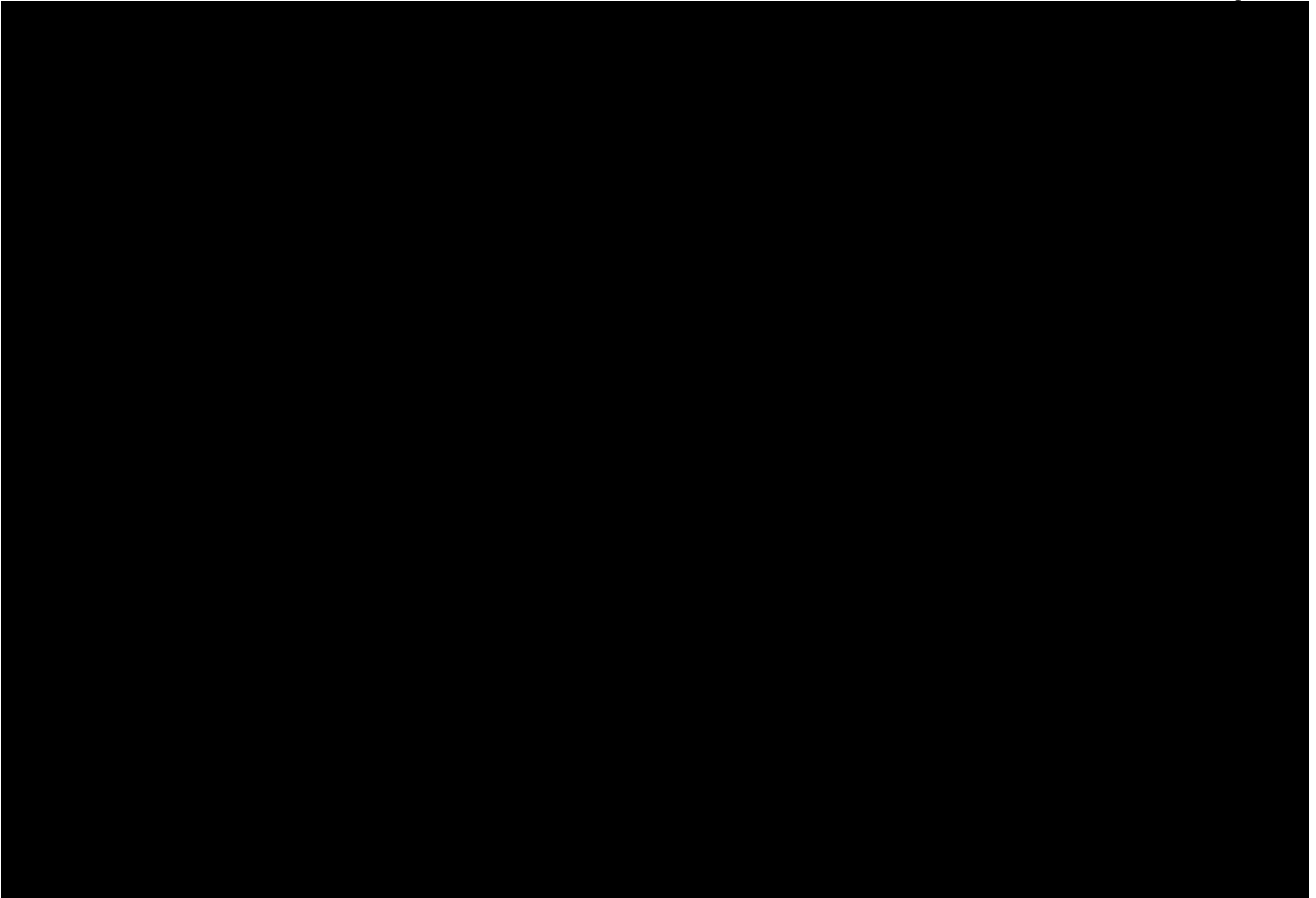
Scope

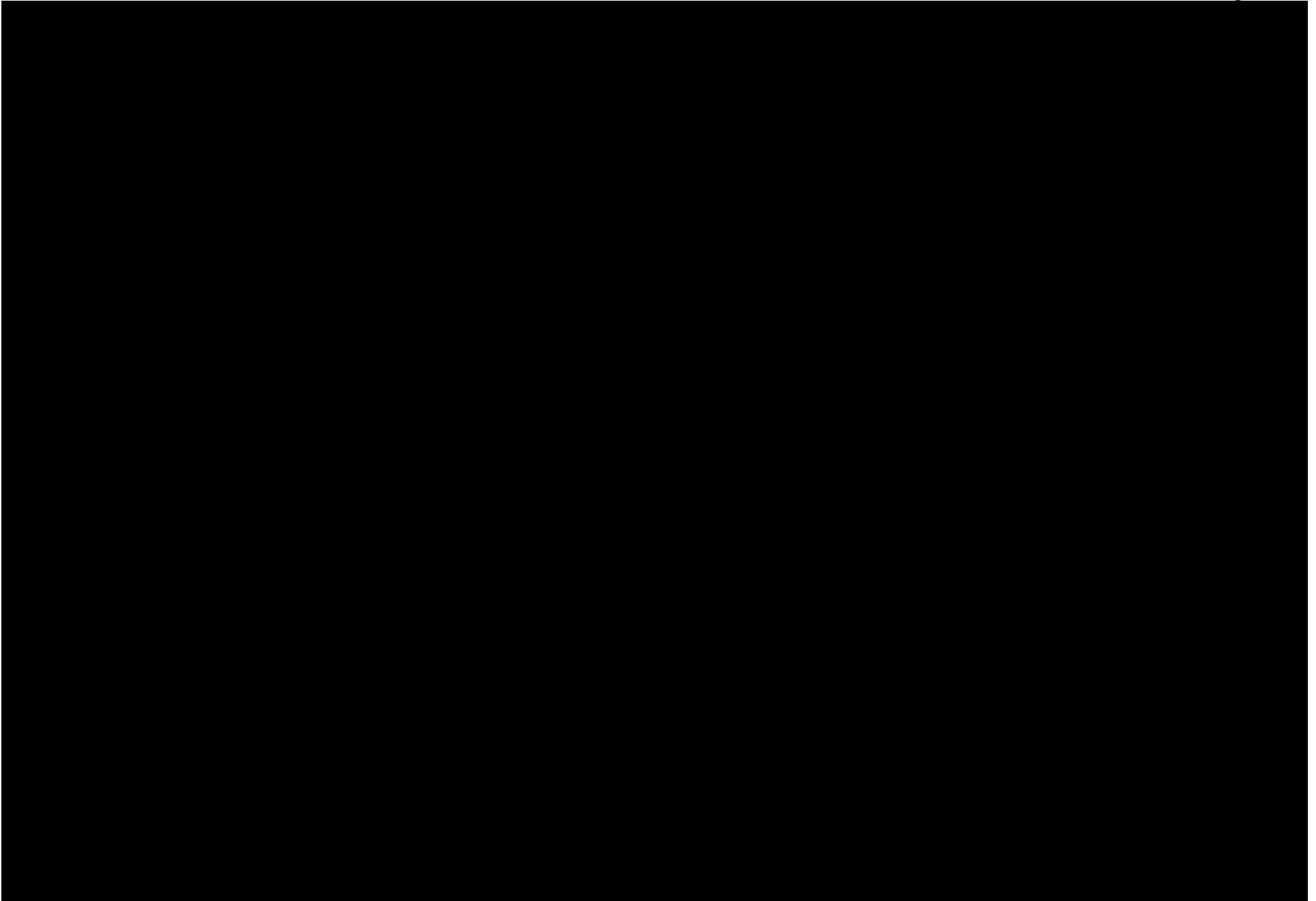
This document presents the proposed vibration damper placement for the replacement of the existing damping system on the Canso crossing.

NOTES:

- On spans with armour rods installed near the suspension clamp for conductor repair, the placement of the first damper with respect to the suspension clamp needs to be adjusted. If repair rods are installed near the suspension and prevent to install ALL vibration dampers according to this document, **the position of the first damper needs to be measured from the end of the repair rods**. In all cases, the spacing between vibration dampers needs to be according to this document.







**Rev1. Sep. 2024
Page 26 of 27**

APPENDIX L – L7005 TOWER ASSESSMENT REPORT (CIMA+)



Modelling and Analysis of Canso Crossing Lattice Towers

7005 – 315kV Double Circuit – Towers 730-731 Assessment with new dampers

PRELIMINARY

CIMA file number: Z0017482
September 3rd, 2024 – Revision A





Modelling and Analysis of Canso Crossing Lattice Towers

7005 – 315kV Double Circuit – Towers 730-731 Assessment with new dampers

Prepared by:

Cedrik Levesque, P.Eng.
Engineer, Energy
Lines and Substations Structural Engineering
ENS #: 11601
OIQ #: 142530

Verified by:

Mario Robichaud, P. Eng.
Project Director, Energy
Lines and Substations Structural Engineering
ENS #: 20220346
OIQ #: 97719 (Quebec)



900–740, Notre-Dame West, Montreal, Quebec
CANADA H3C 3X6

CIMA file number: Z0017482
September 3rd, 2024 – Revision A

Table of Revision

Register of Issues			
Revision No.	Issued by	Date	Description of the Issue
A	CL	2024-09-03	For client comments

Confidentiality and ownership

Unless CIMA+ and its client have agreed otherwise, the intellectual property rights and all documents delivered by CIMA+, whether in hard or electronic copy, are the property of CIMA+, which reserves copyright therein. It is strictly prohibited to use or reproduce such proprietary rights on any support, even in part, without the authorization of CIMA+.

Table of contents

1.	Scope of Work	1
1.1	Background	1
1.2	Detailed Scope of Work	1
2.	Modelling	2
2.1	Methodology	2
2.2	New loads	2
3.	Results	3
3.1	Original Strength reduction factor	3
3.2	Comparison of the Member/Connection Usage	3
3.3	Foundation reactions	5
4.	Conclusion	6

List of Table

Table 3.1: Comparison table example (refer to Appendix C)	3
Table 3.2: Load increase in main members	4
Table 3.3 : Members with utilization factor above 90% (sorted by the highest load difference).	4
Table 3.4 : Foundation reactions comparison	5

List of Figures

Figure 1 : Canso Crossing plan and profile (H349324-0000-0-012-0001)	1
--	---

List of Appendices

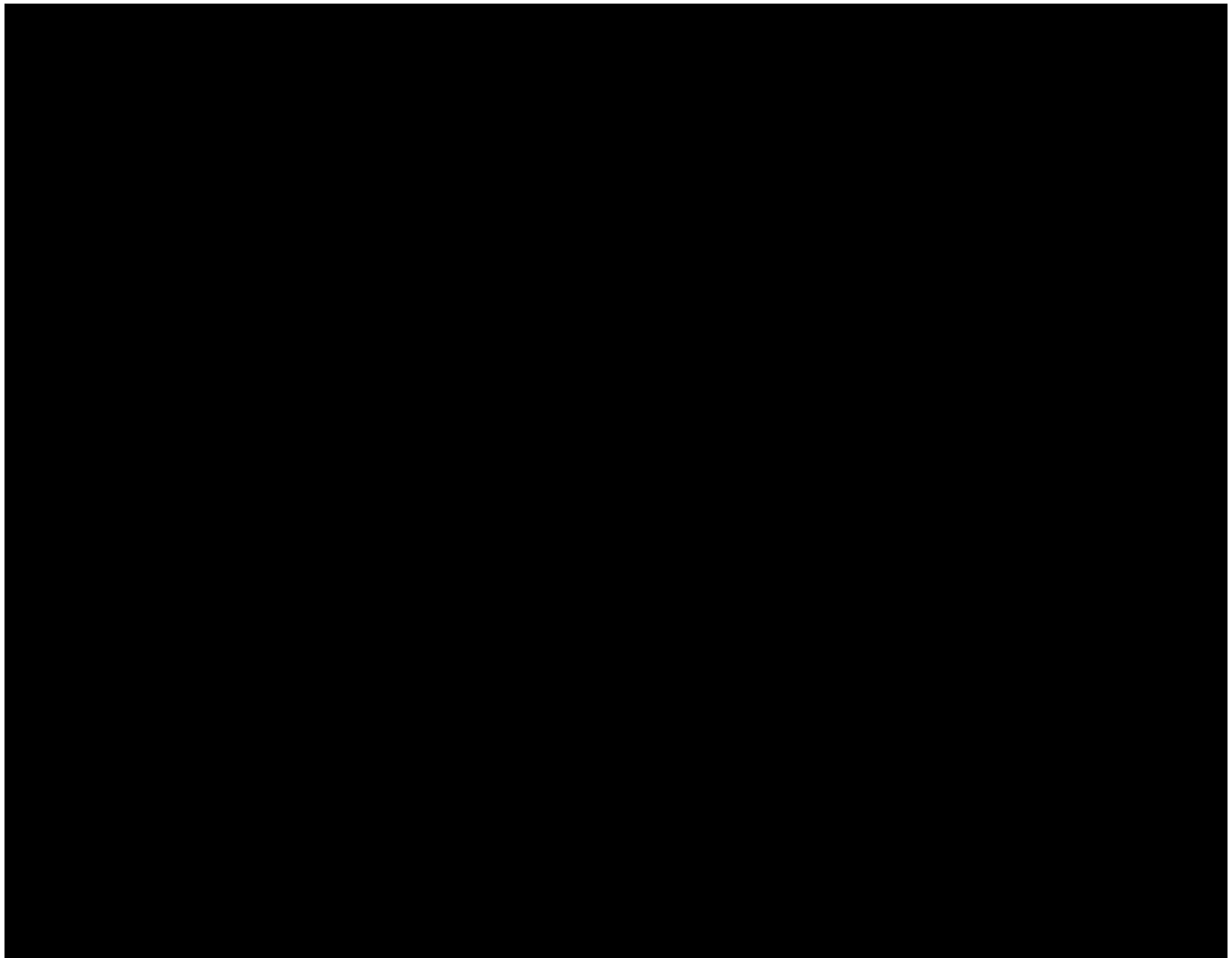
Appendix A Summary of loads and utilization factors - Original Loads
Appendix B Summary of loads and utilization factors - Updated Loads
Appendix C Comparison of loads and utilization factor between original and updated loads
Appendix D Comparison of loads and utilization factor between original and updated loads for members with utilization factor above 90%
Appendix E Foundation loads
Appendix F Outline Drawings

1. Scope of Work

1.1 Background

L7005 is a double circuit 315 kV transmission line owned and operated by Nova Scotia Power Inc. Spanning the Strait of Canso the section from structures 729 to 732 covers approximately 3 km, with a central span of around 1500 m between structures 730 and 731.

Recent modifications to the hardware and dampers have resulted in an increase in vertical loads on the structures, prompting the need for a capacity assessment of towers 730 and 731, which are suspension structures.



2. Modelling

2.1 Methodology

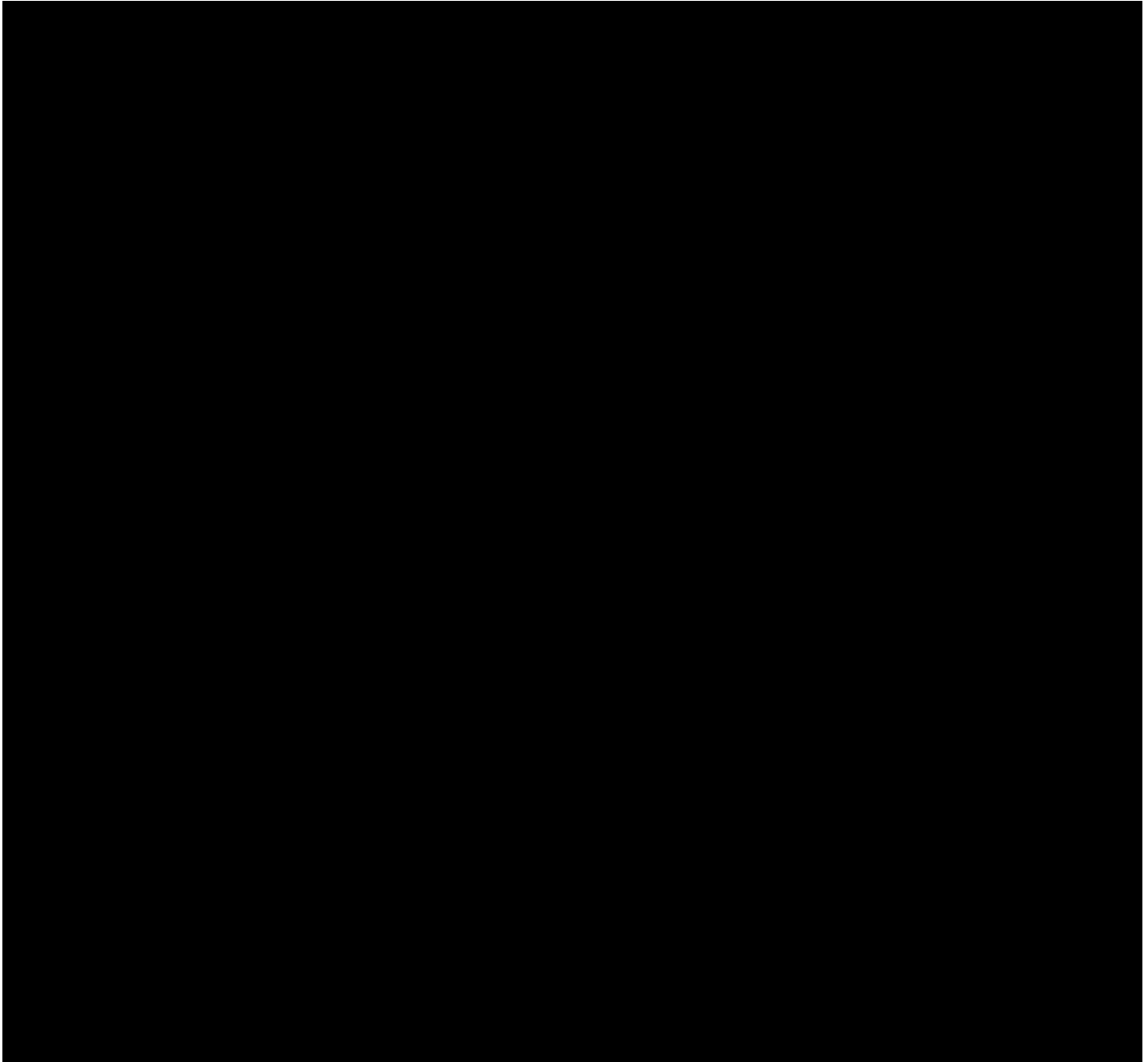
The following methodology was used:

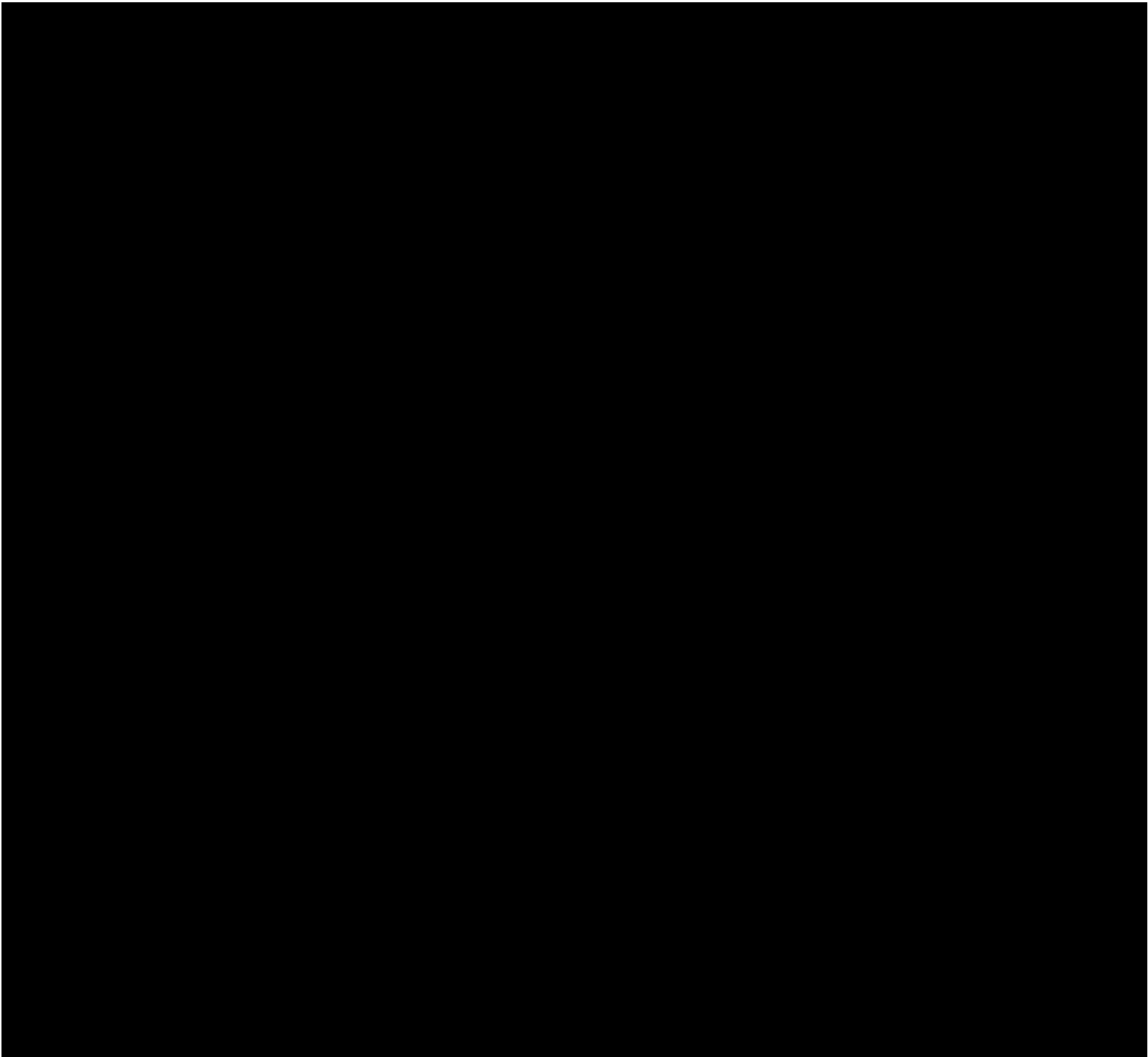
- > Opened the existing PLS-Tower models and verified that the loadings correspond to the original design loads.
- > Cross-referenced the initial calculation notes to ensure consistency with the member loadings and confirmed that the .lca file included in the models reflects the latest calculation notes.
- > Created a new .lca file incorporating the additional vertical loads provided by the client.
- > Performed structural analysis with the updated loads and documented the results within our calculation notes for comparison with the original design.
- > Prepared comparative reports in Excel, detailing the differences in member utilization and foundation loads between the original and updated load scenarios.

We have assumed that the members in the tower models and calculation notes are accurate, as the design and construction were based on them.

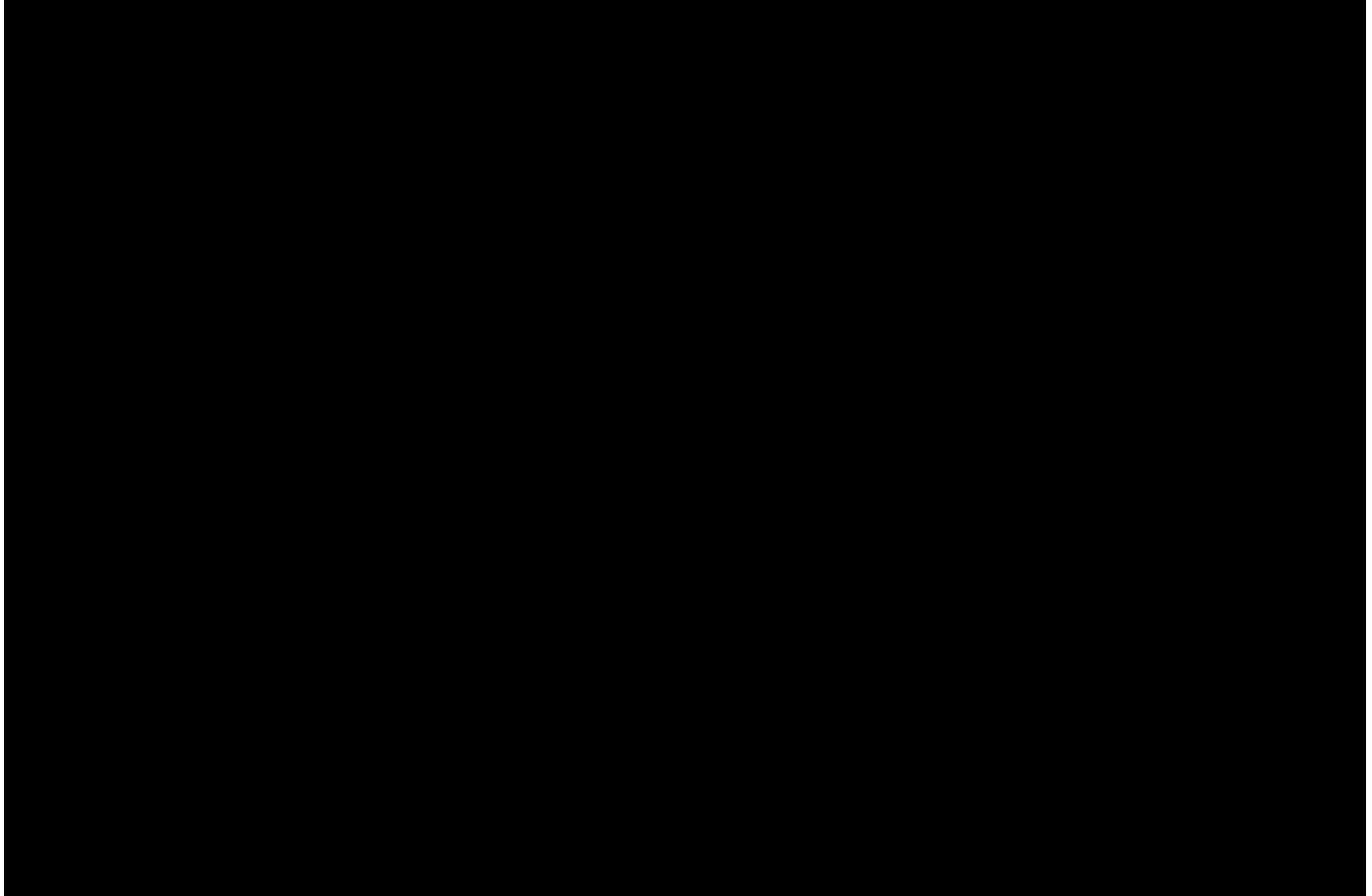
The results refer to structure 3A and 4A instead of 730 and 731 respectively, which is the way they were named at the time of design.

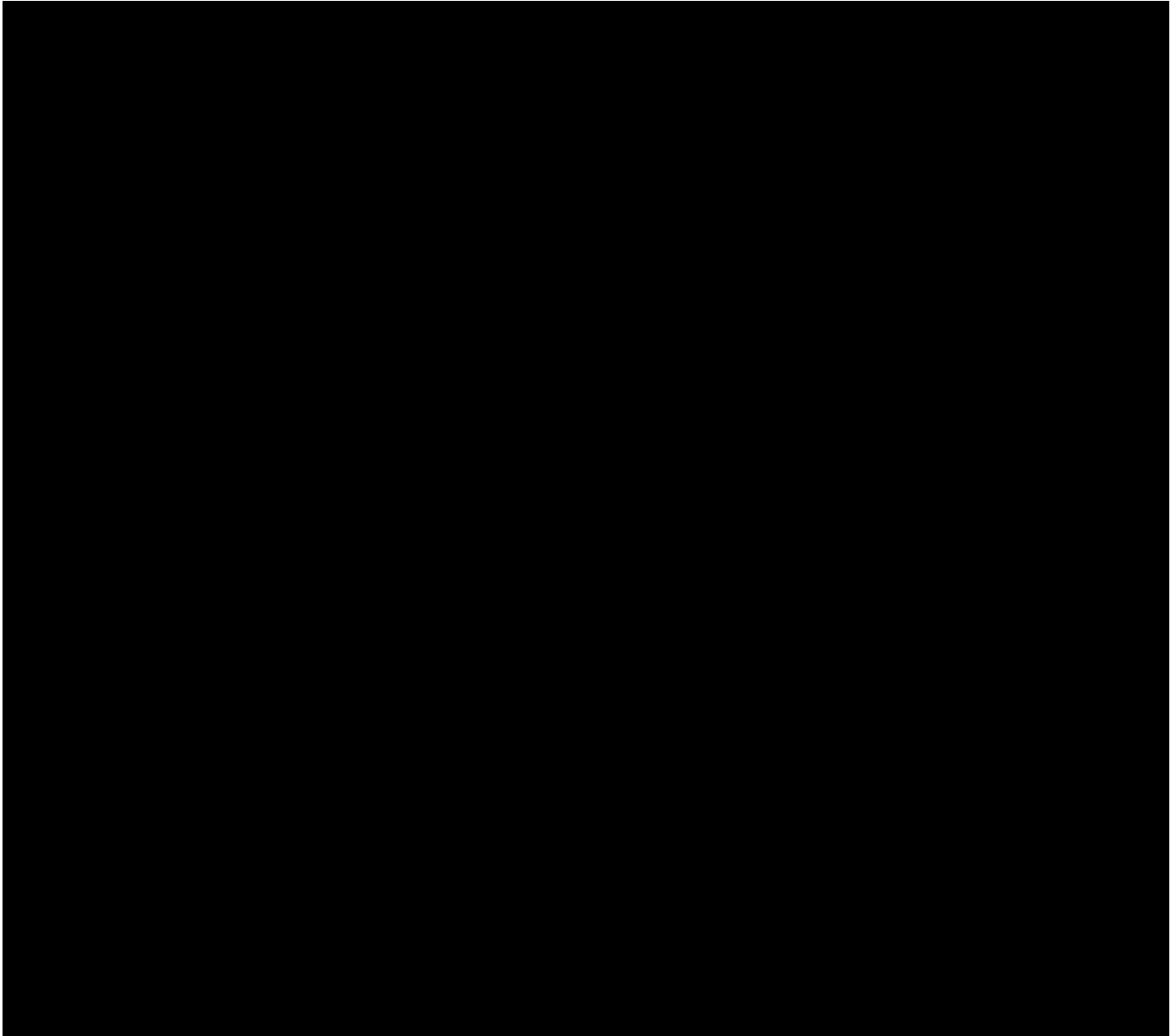
3. Results





3.3 Foundation reactions

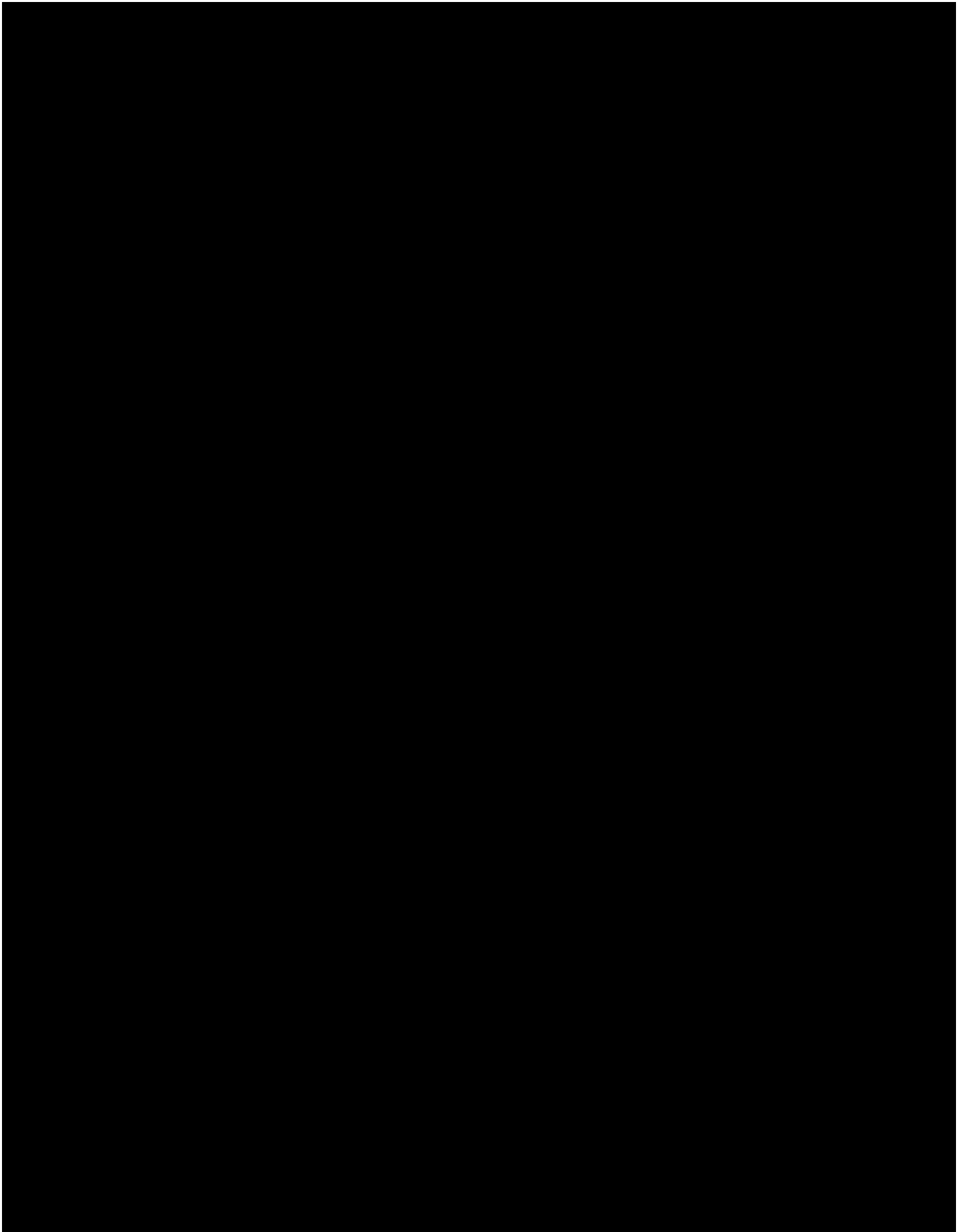


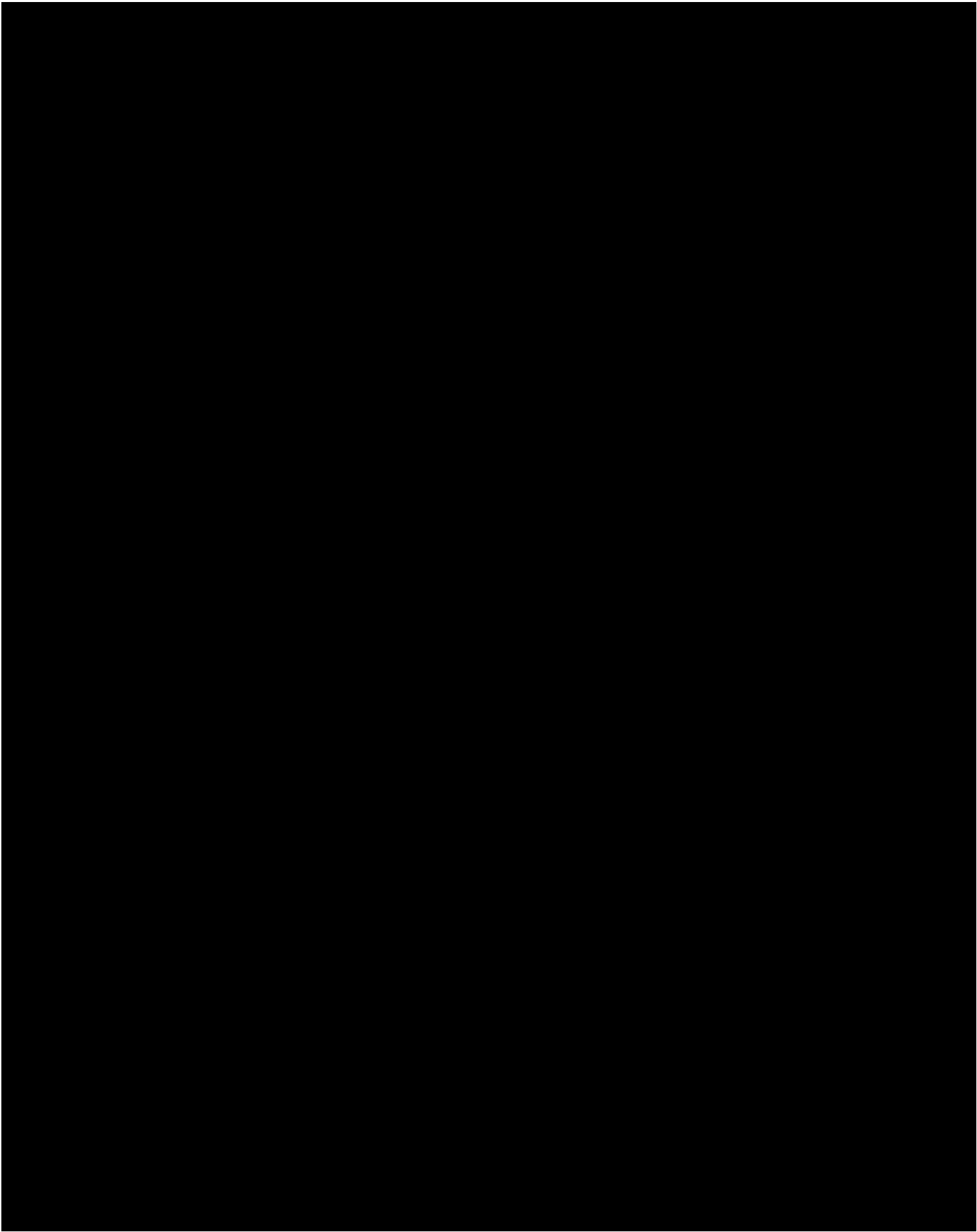


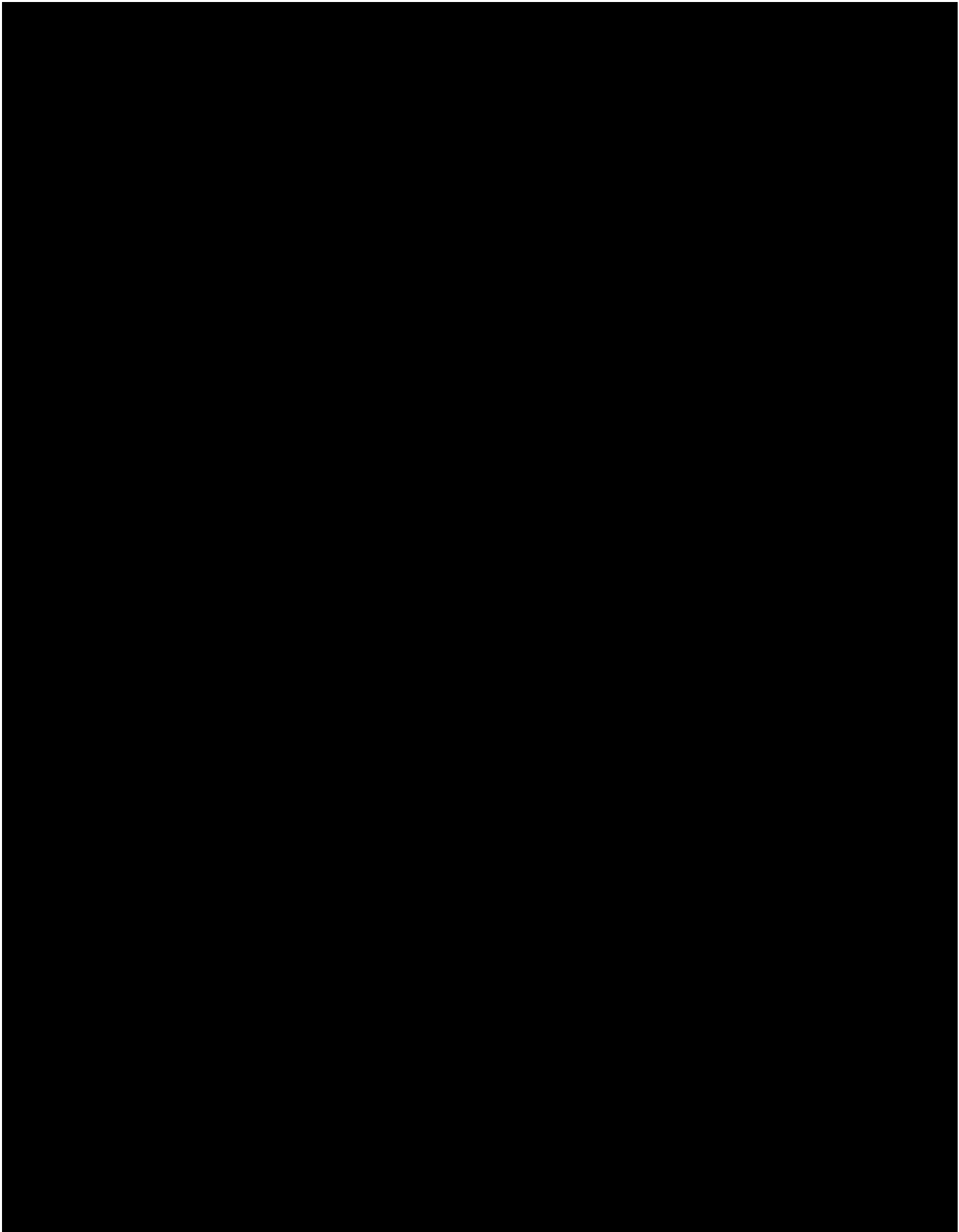
A

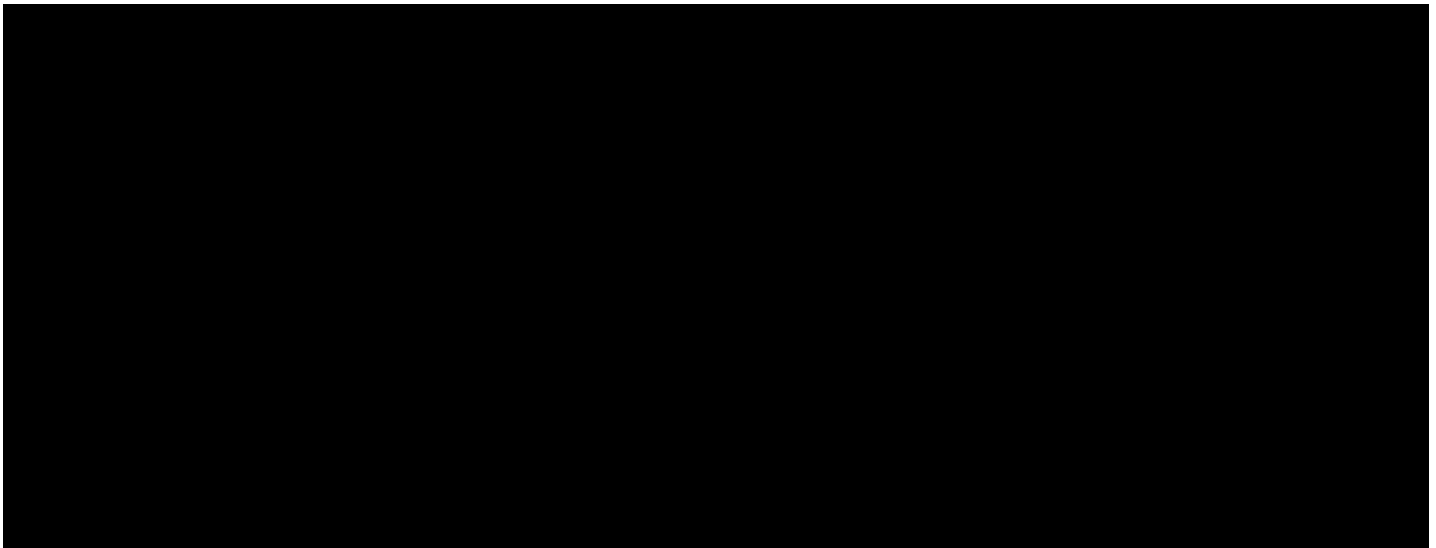
Appendix A

Summary of loads and utilization factors - Original Loads





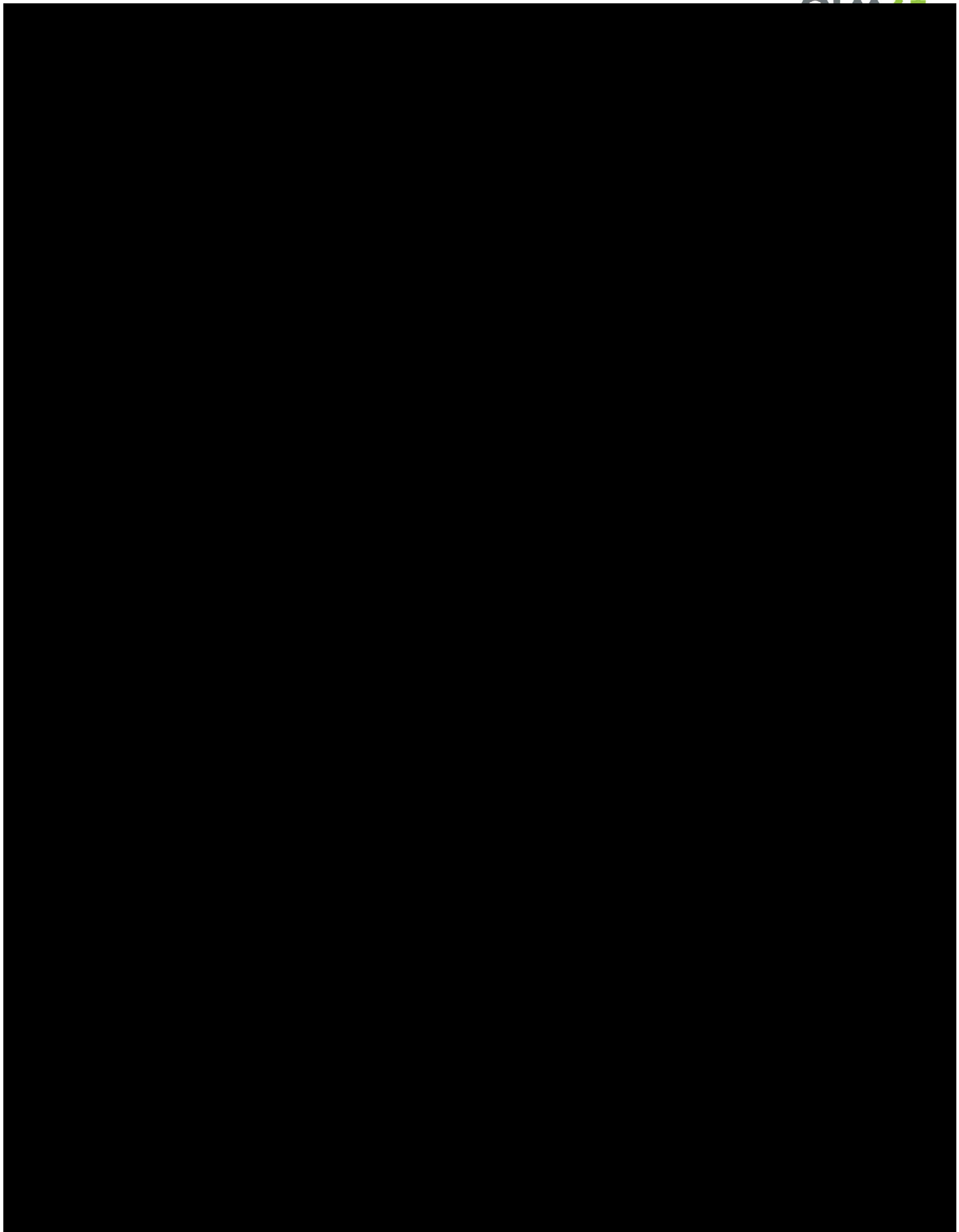




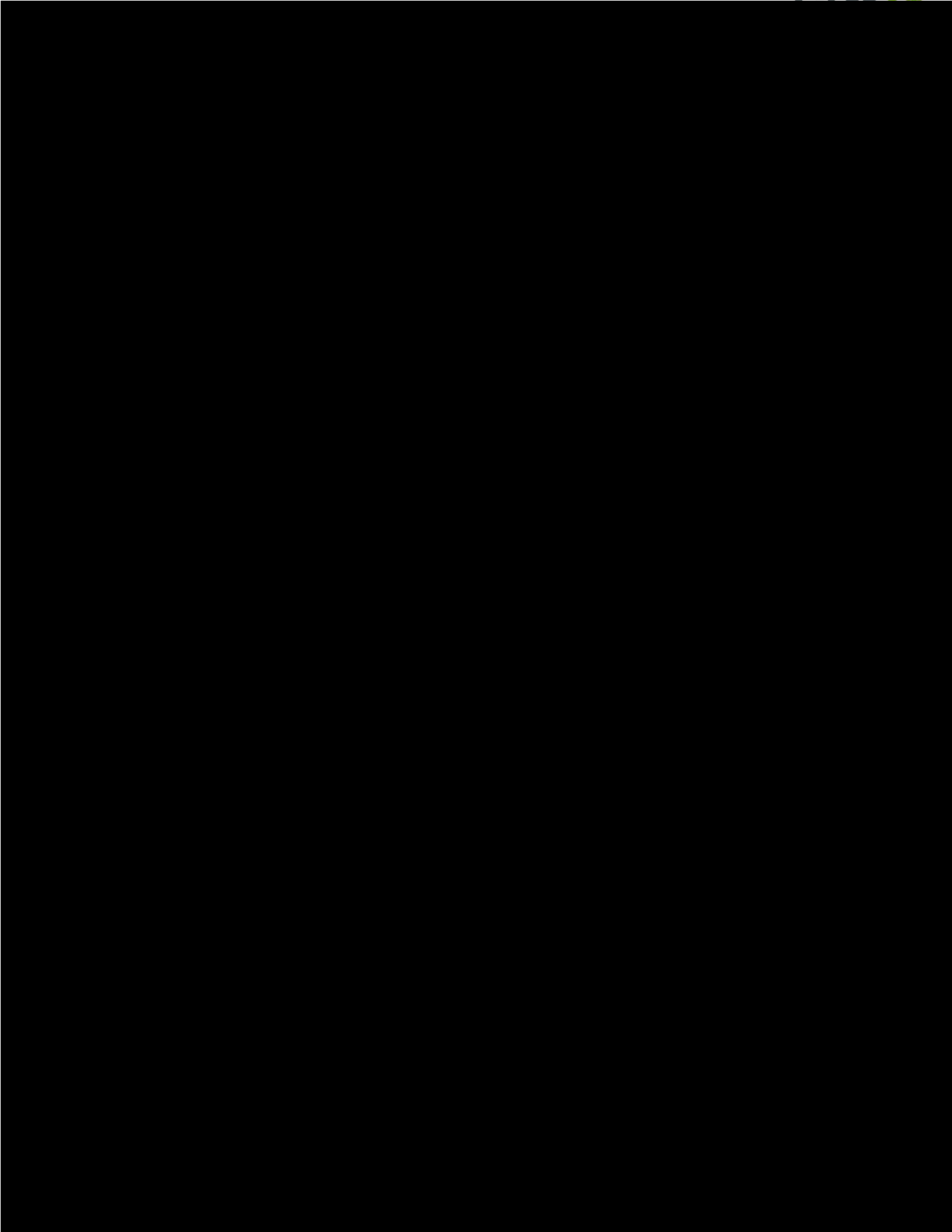
PRELIMINARY

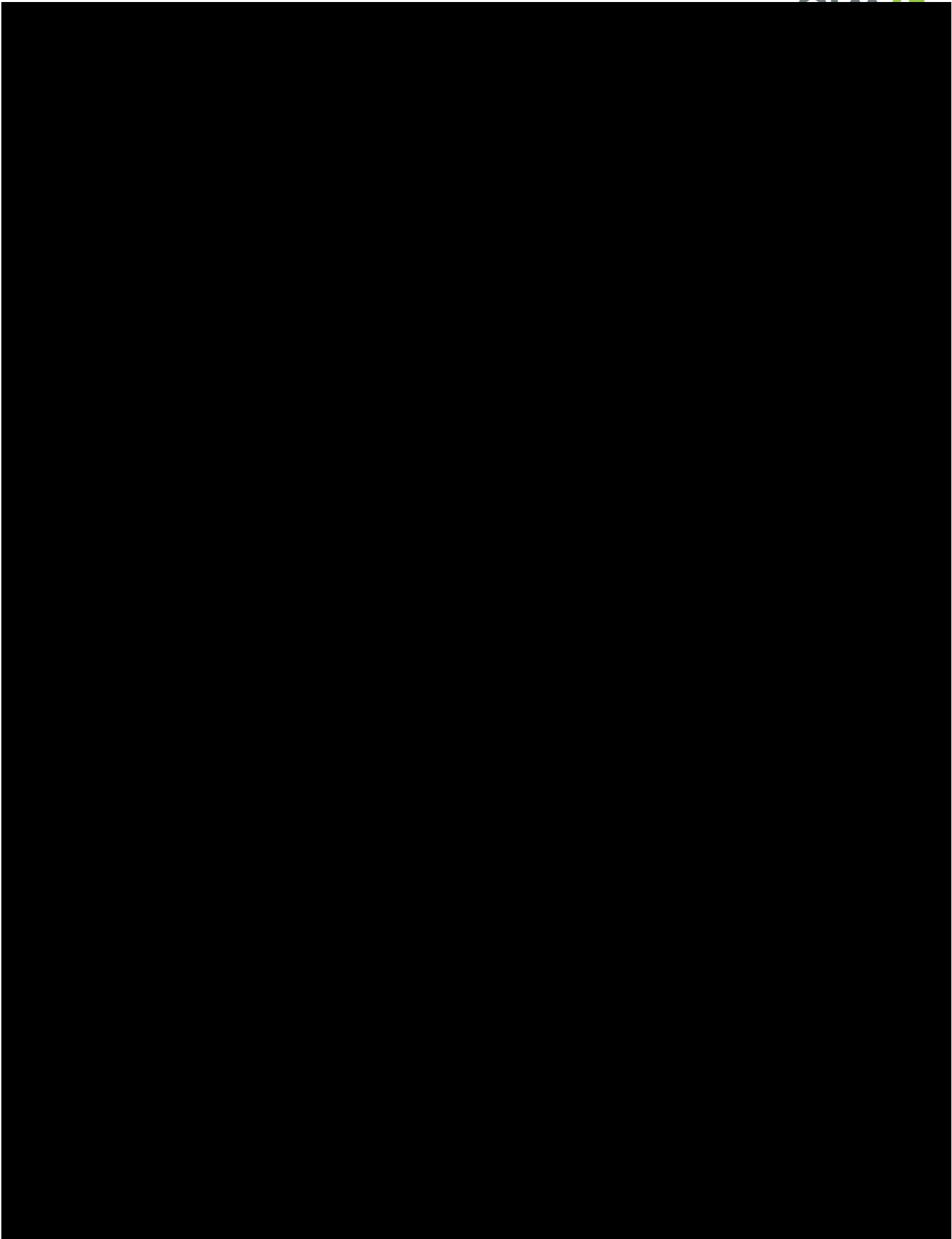
B

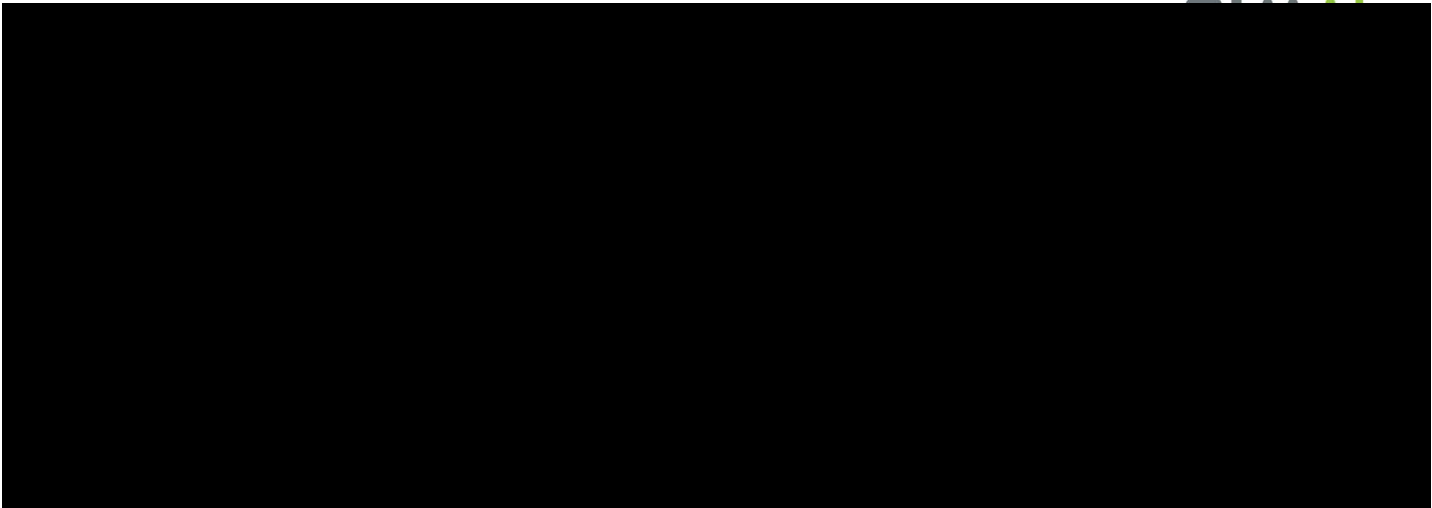
Appendix B Summary of loads and utilization factors - Updated Loads



Prepared by : C. Levesque, P.Eng.
Checked by : M. Robitault, P.Eng (Quebec)







PRELIMINARY

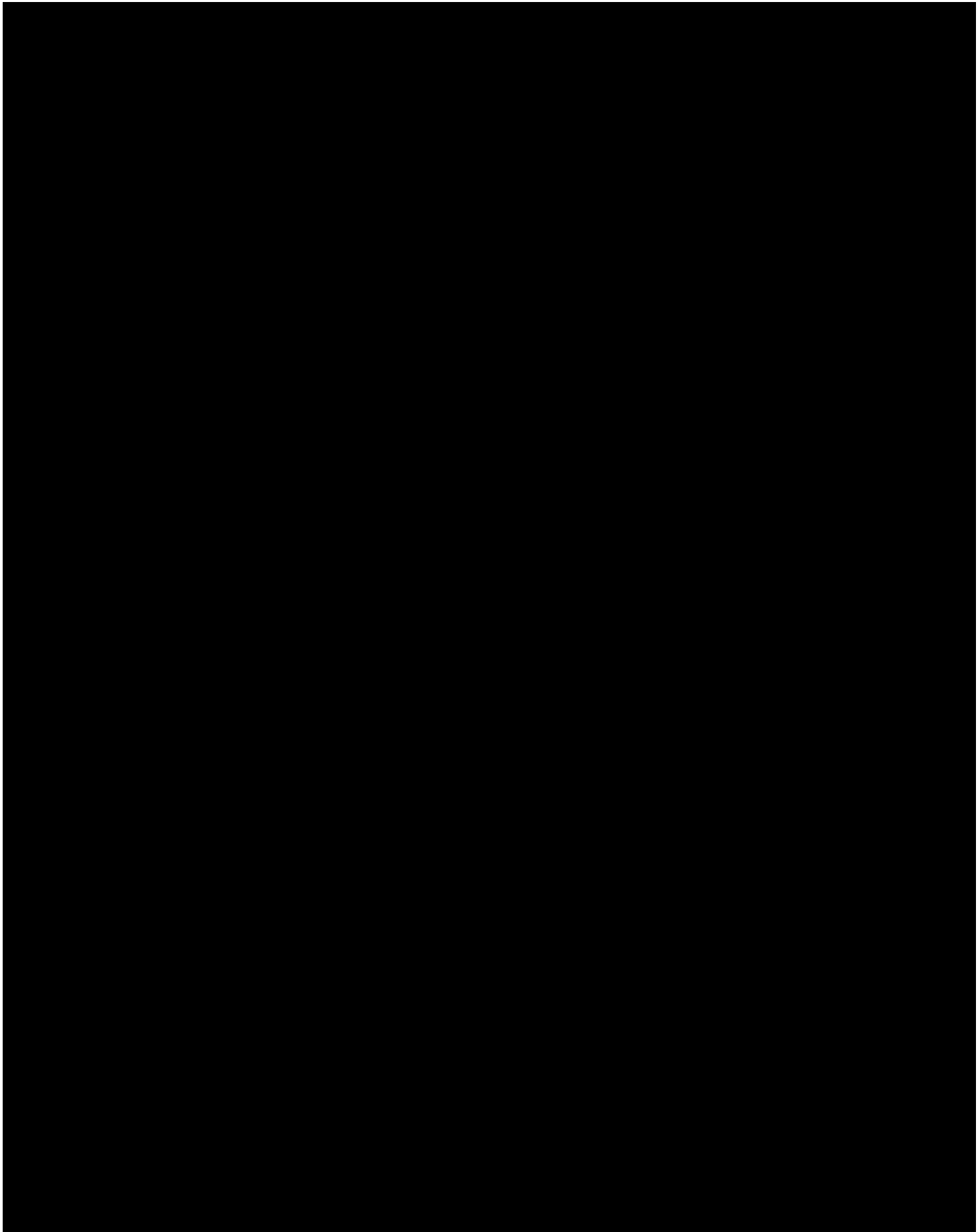
C

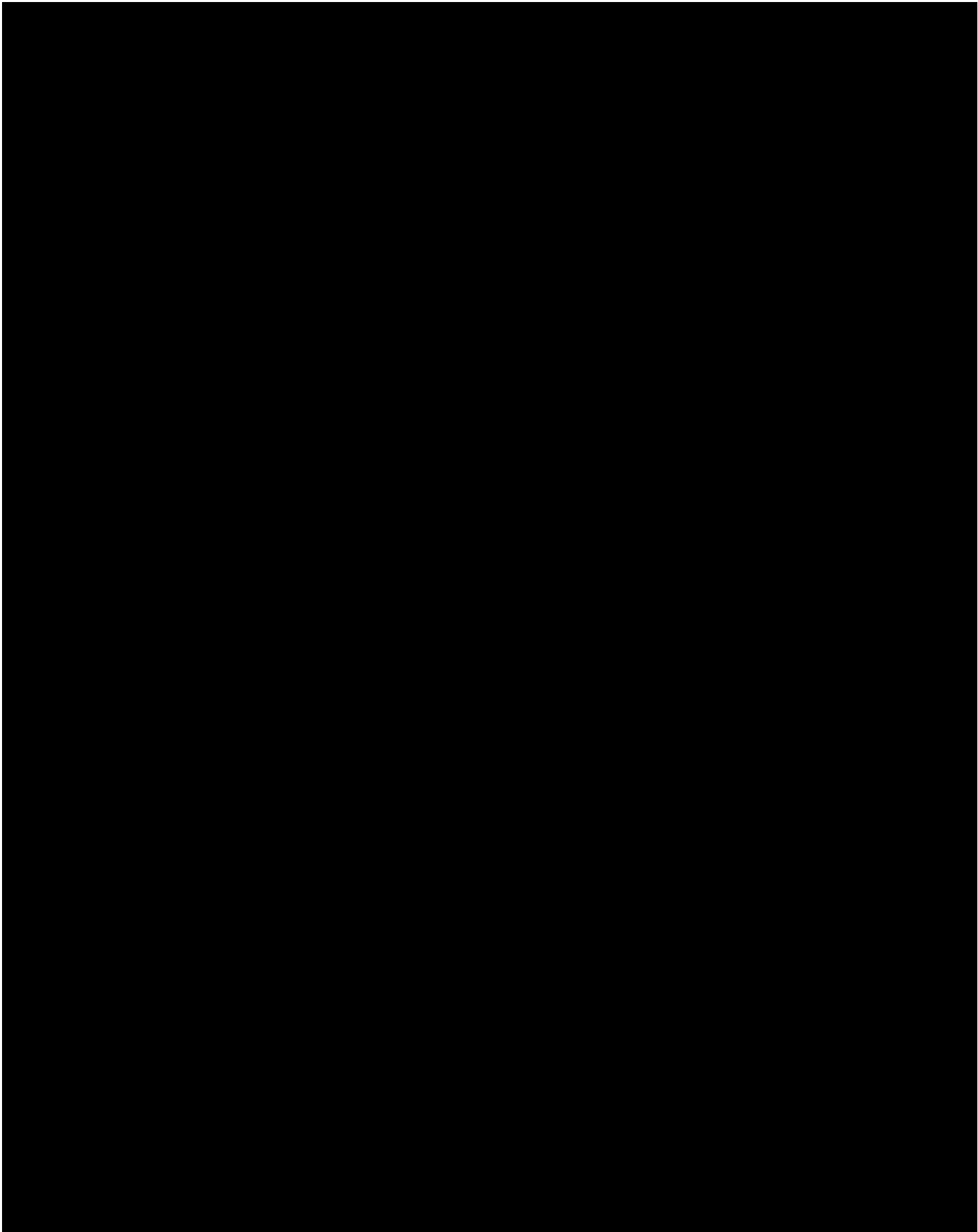
Appendix C

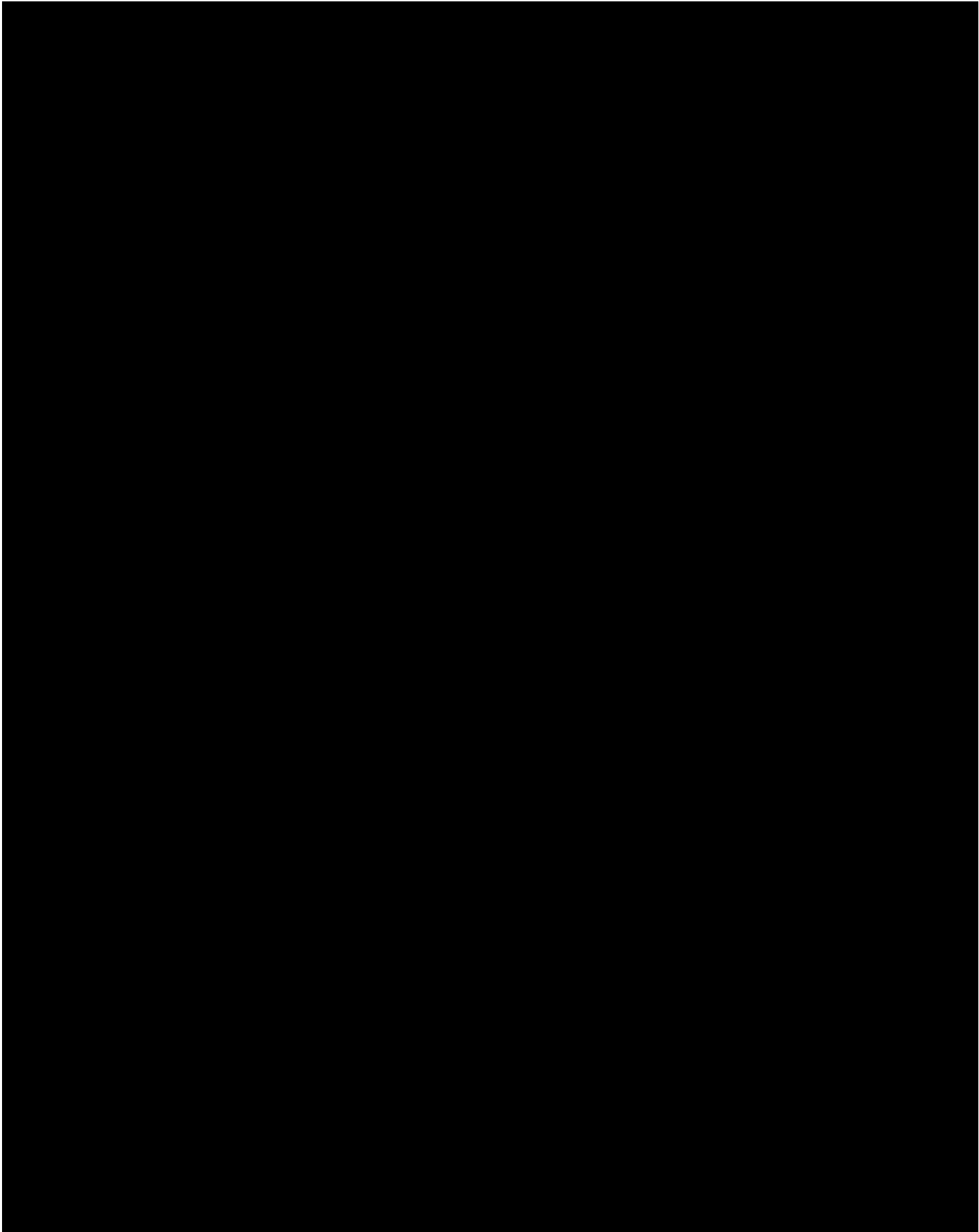
Comparison of loads and utilization factor between original and updated loads

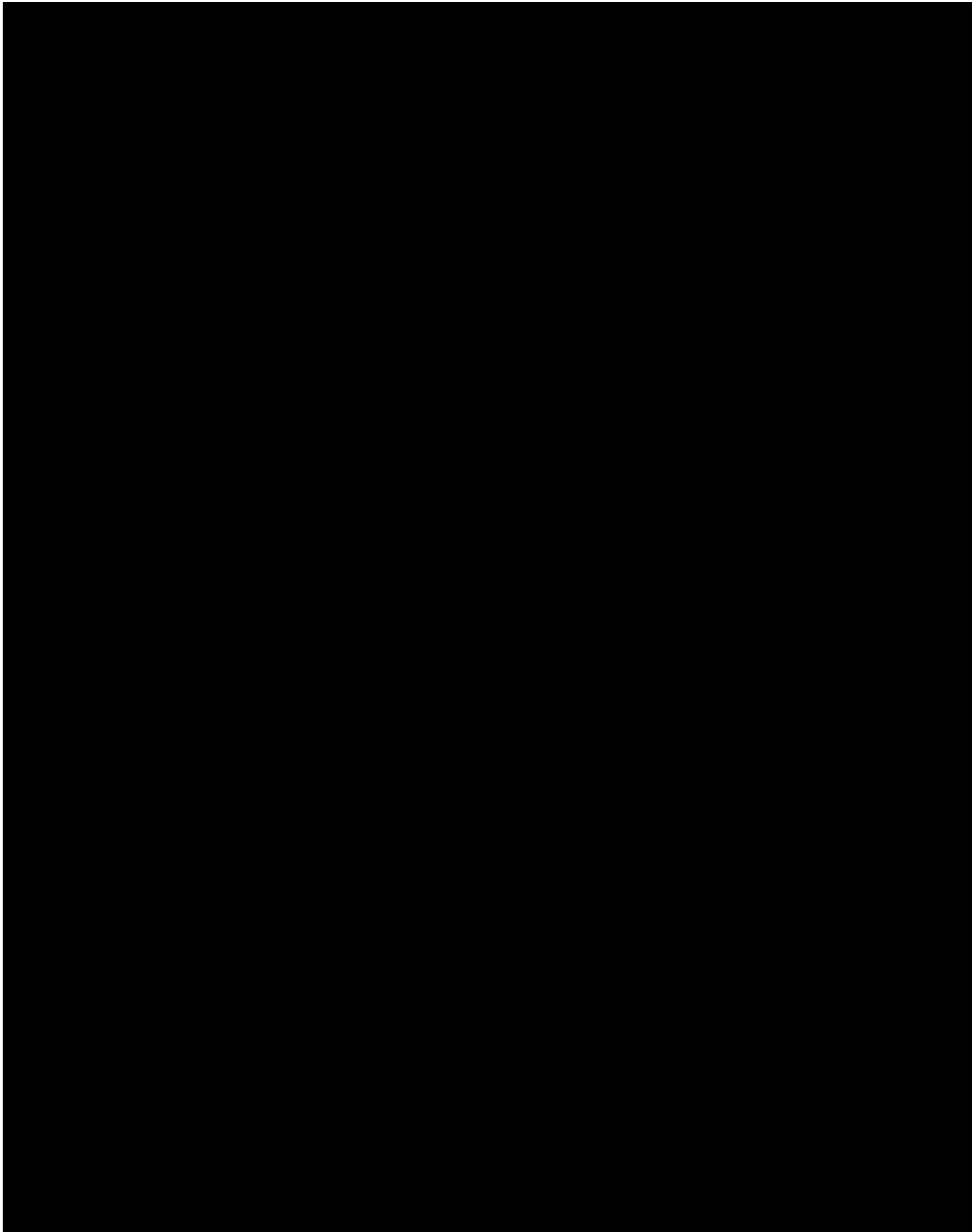
PRELIMINARY

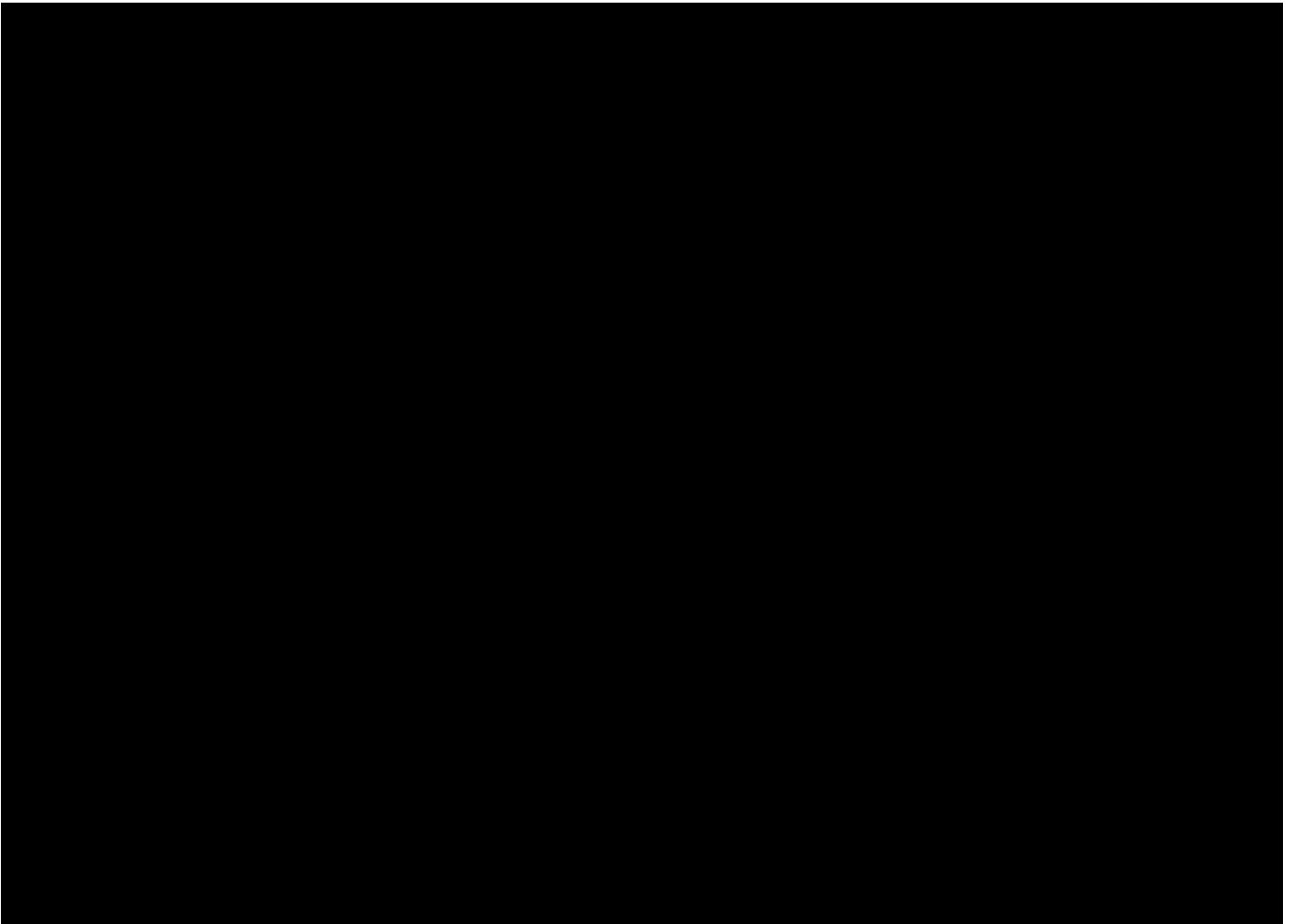










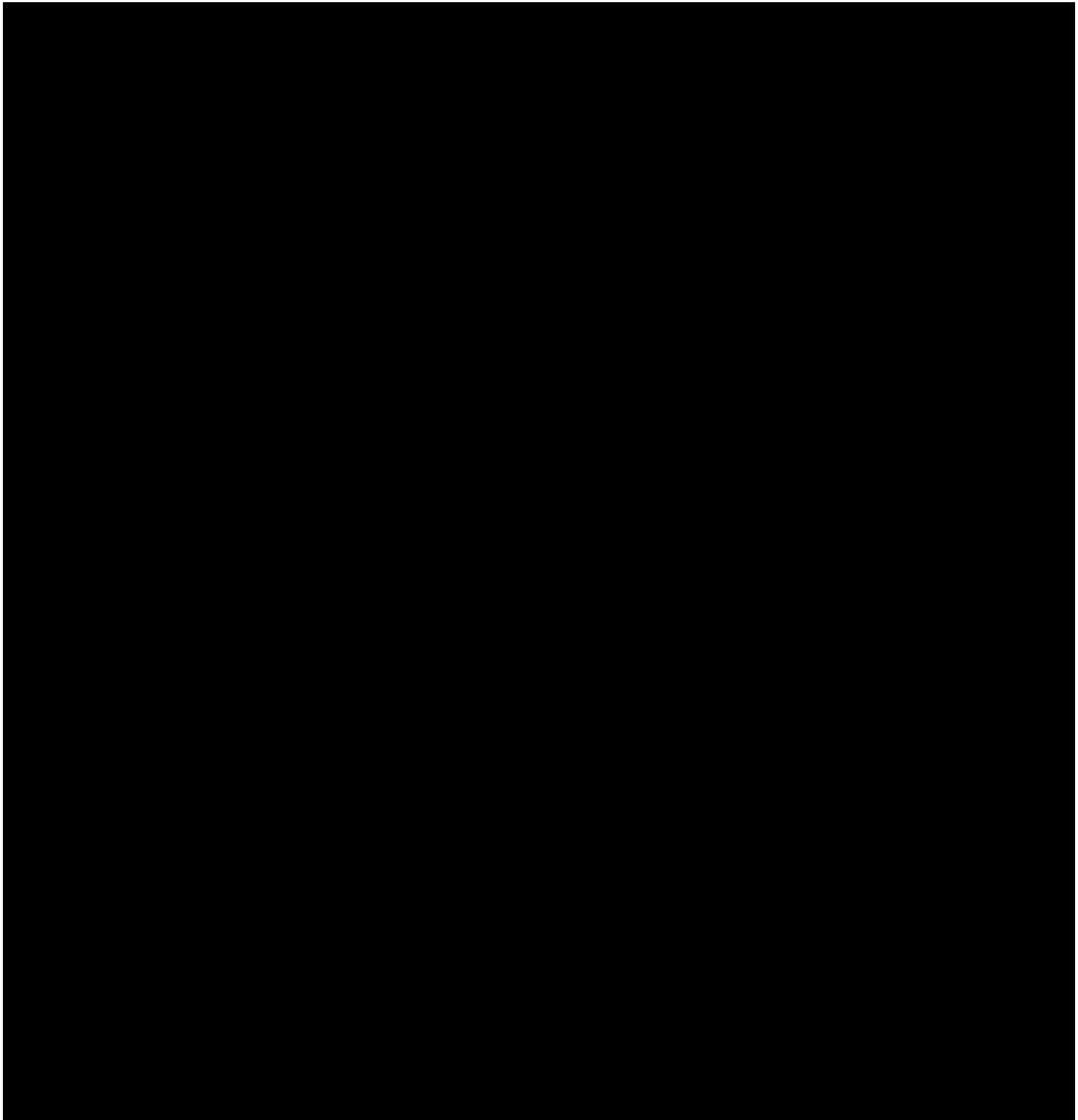


PREL

D

Appendix D

Comparison of loads and utilization factor between original and updated loads for members with utilization factor above 90%



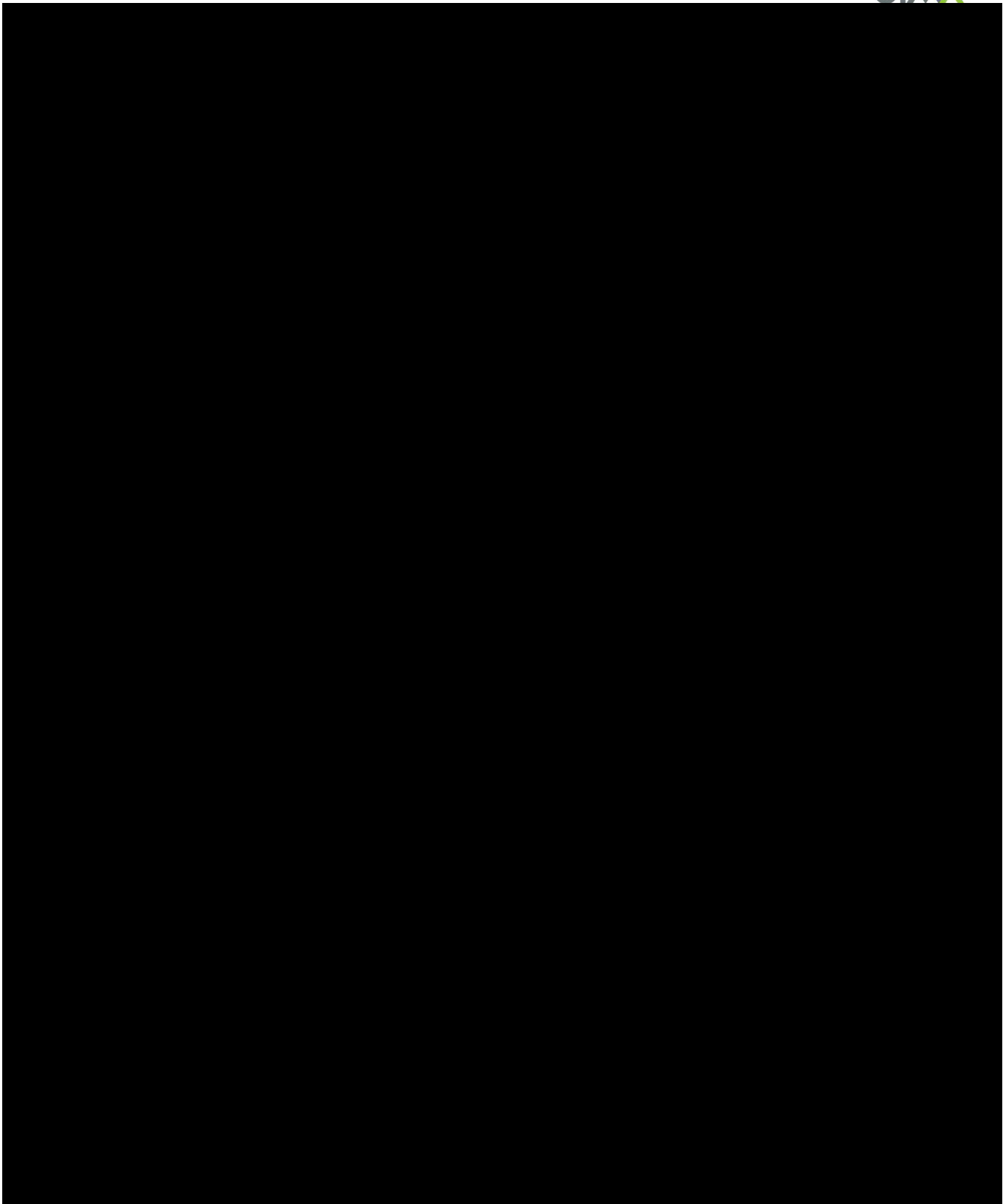
E

Appendix E Foundation loads

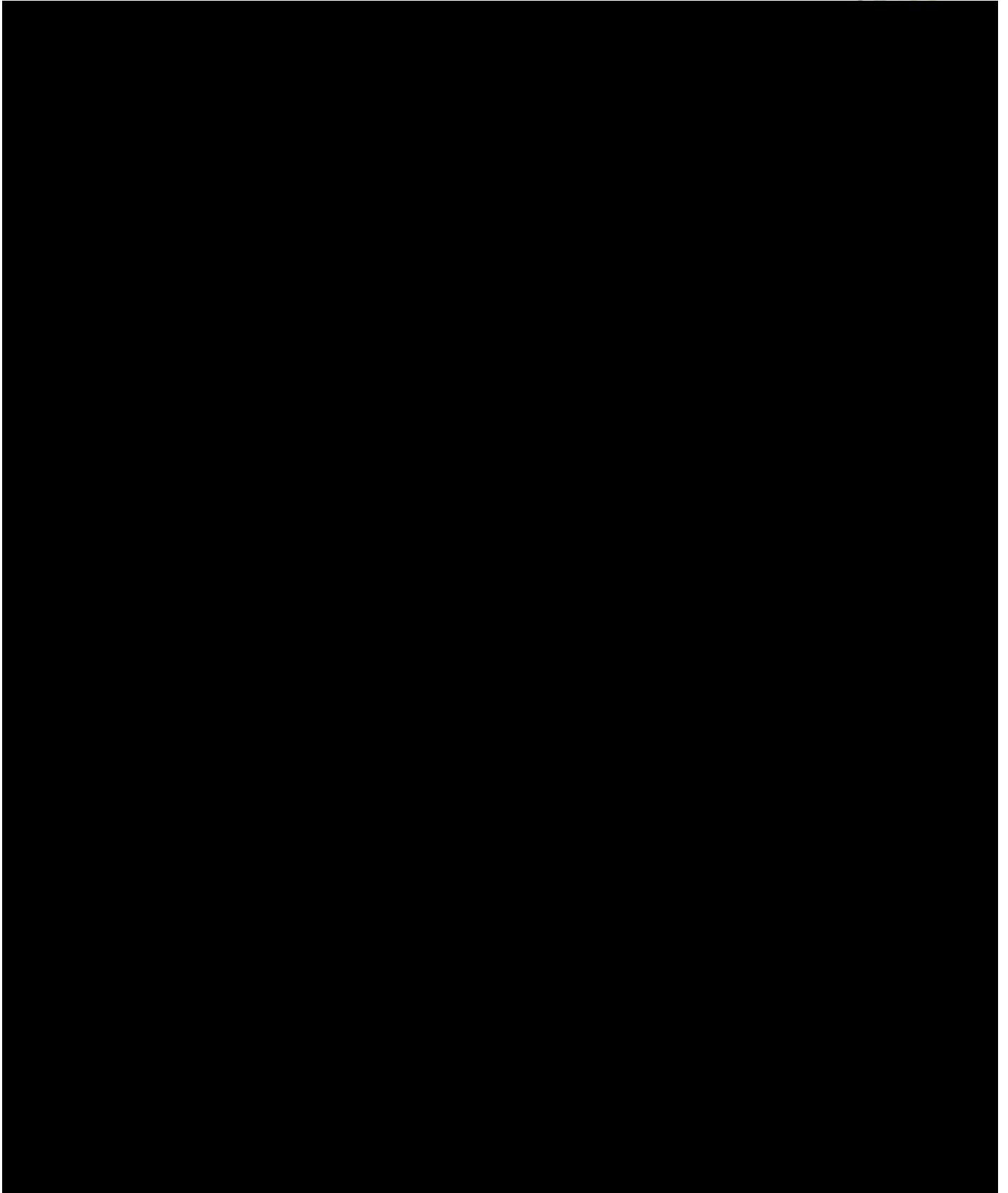
PRELIMINARY



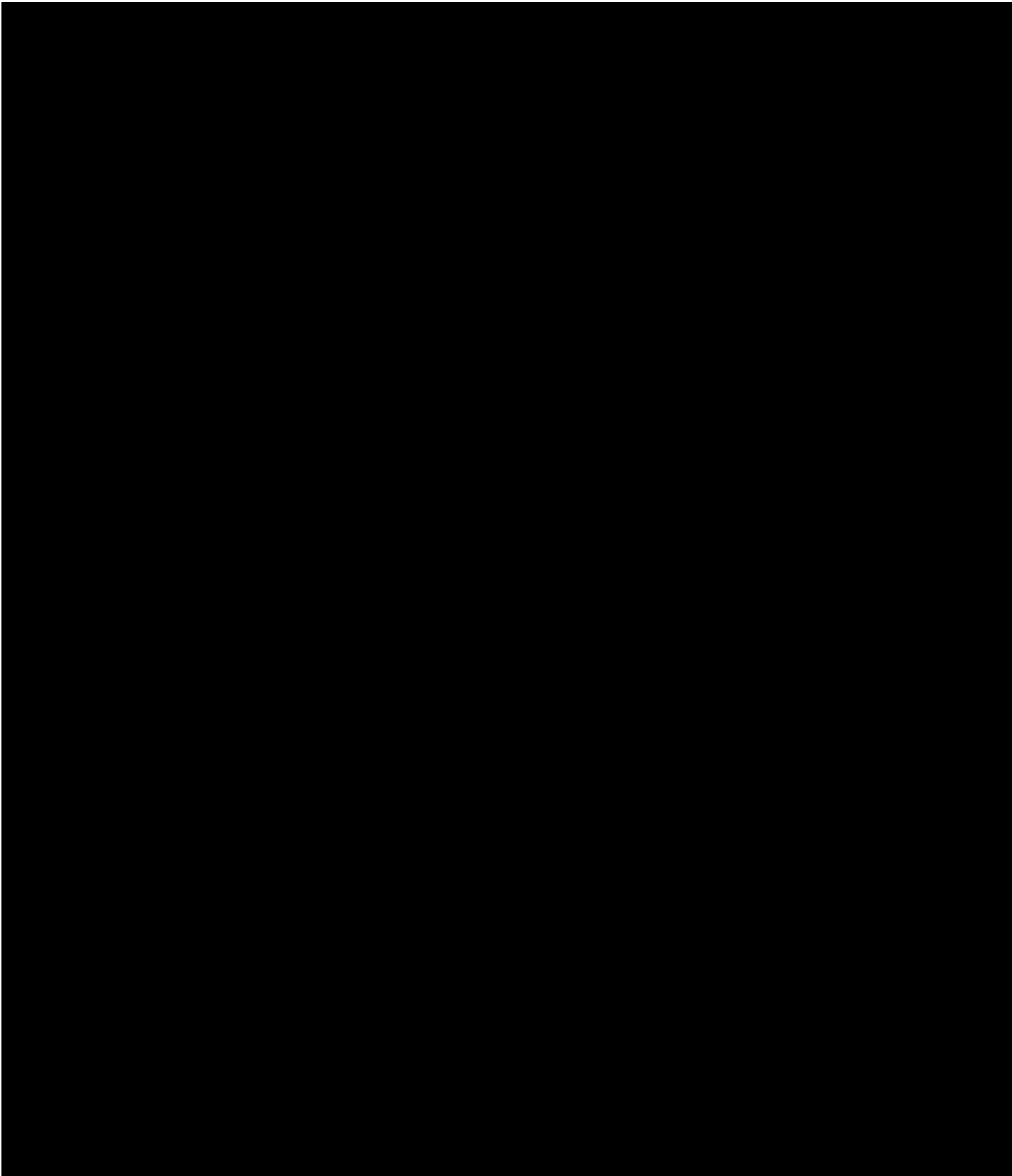
Prepared by : C. Levesque, P.Eng.
Checked by : M. Robichaud, P.Eng.

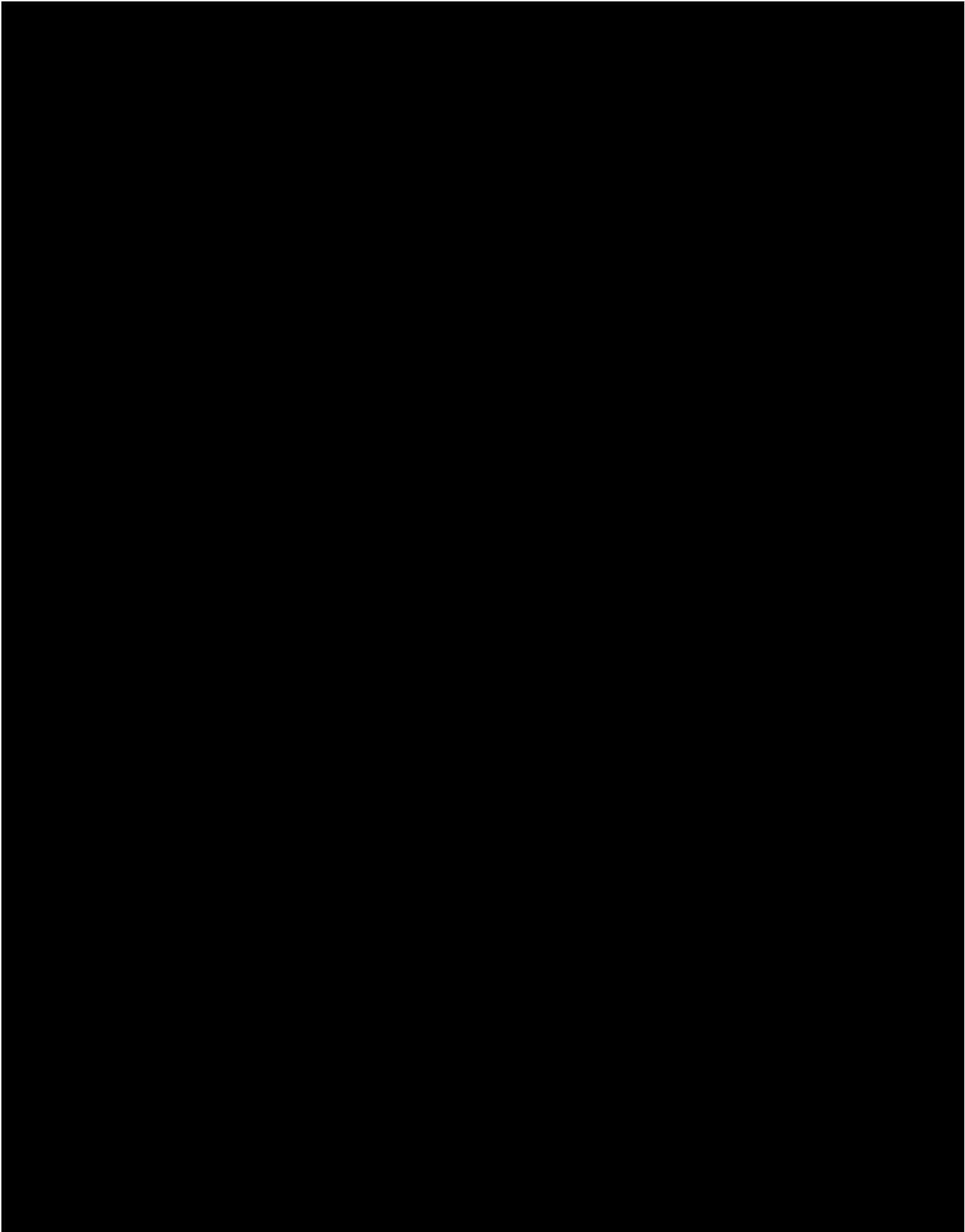


Prepared by : C. Levesque, P.Eng.
Checked by : M. Robichaud, P.Eng.



Prepared by : C. Levesque, P.Eng.
Checked by : M. Robichaud, P.Eng.



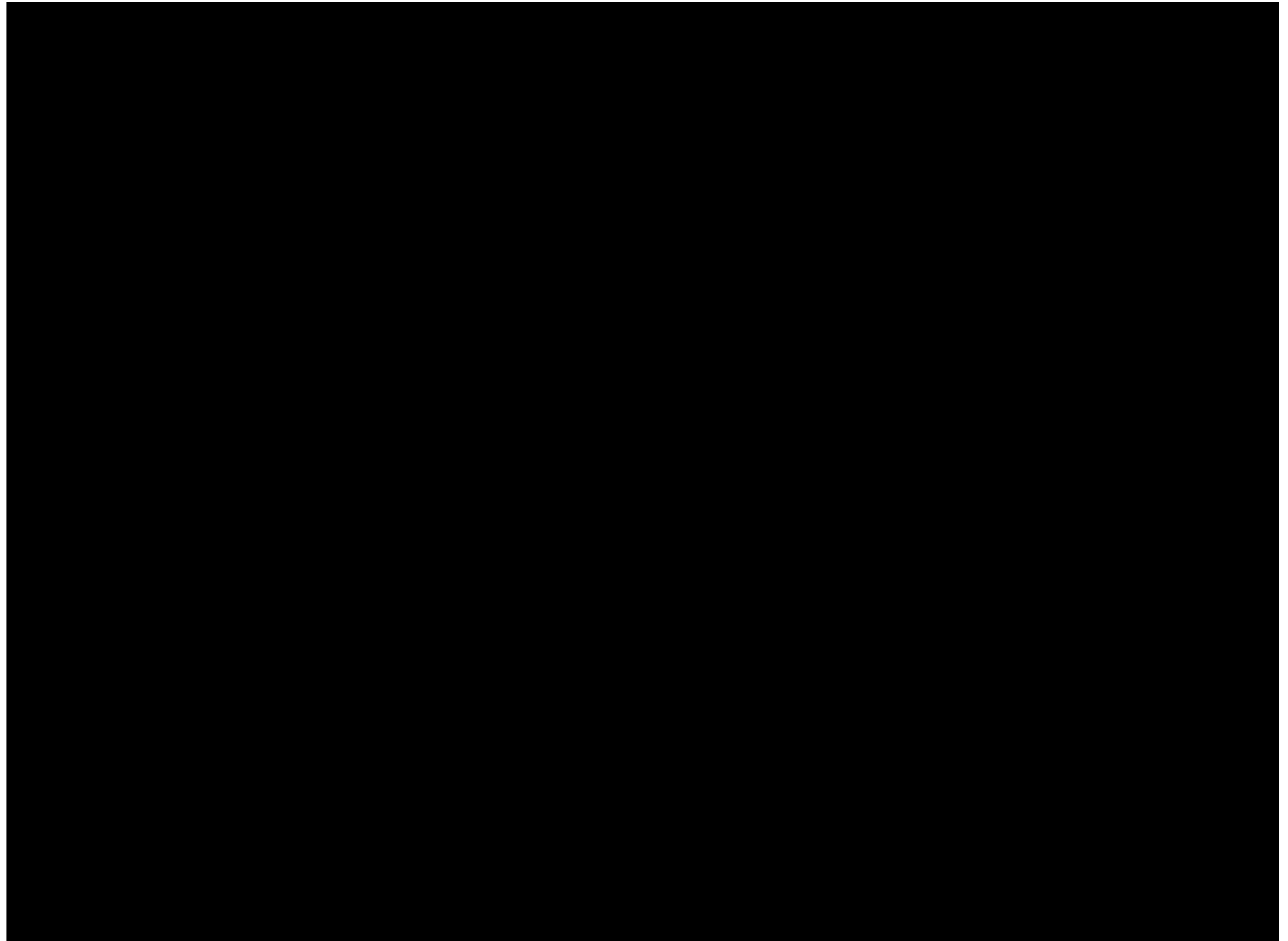


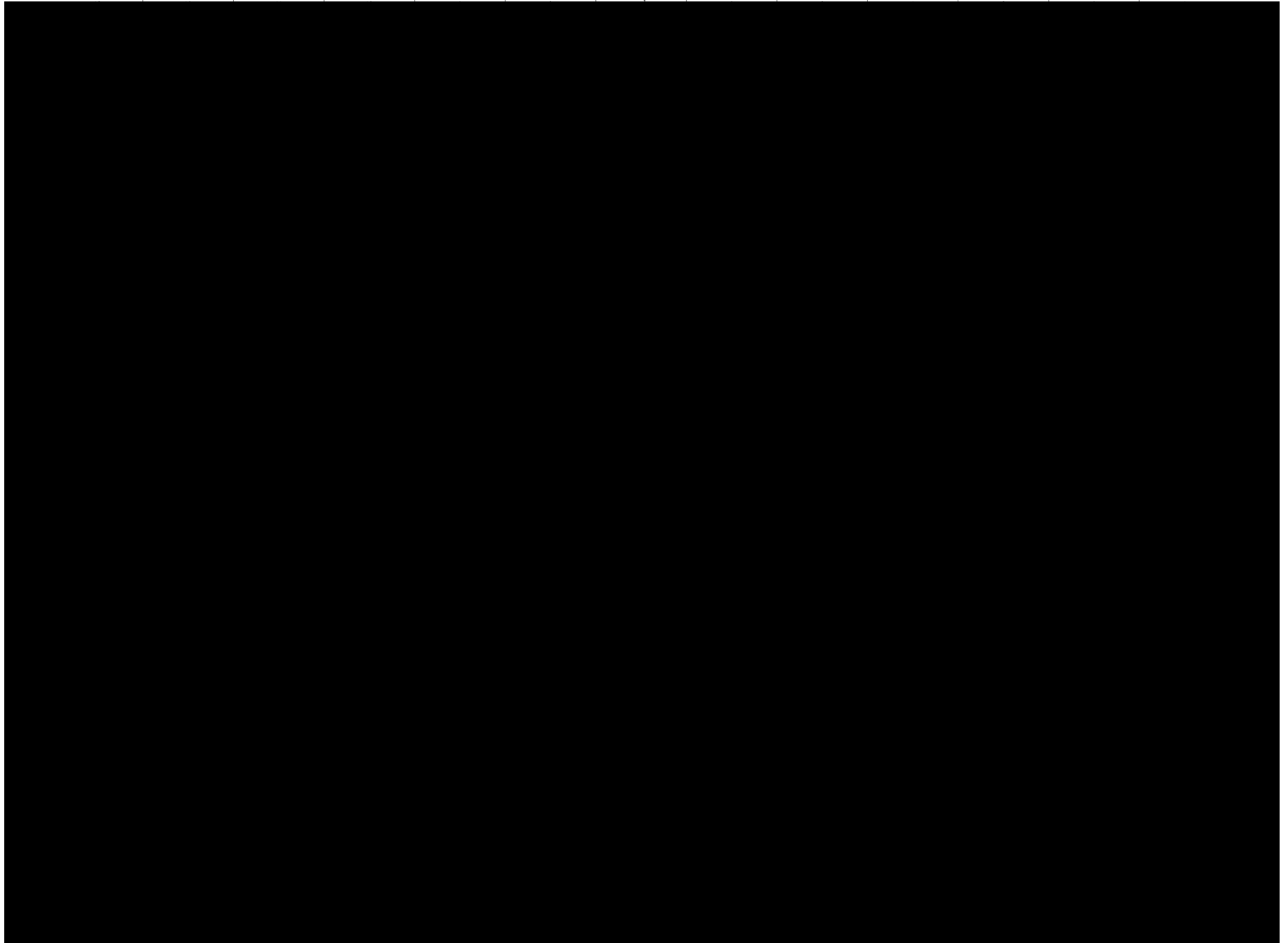
F

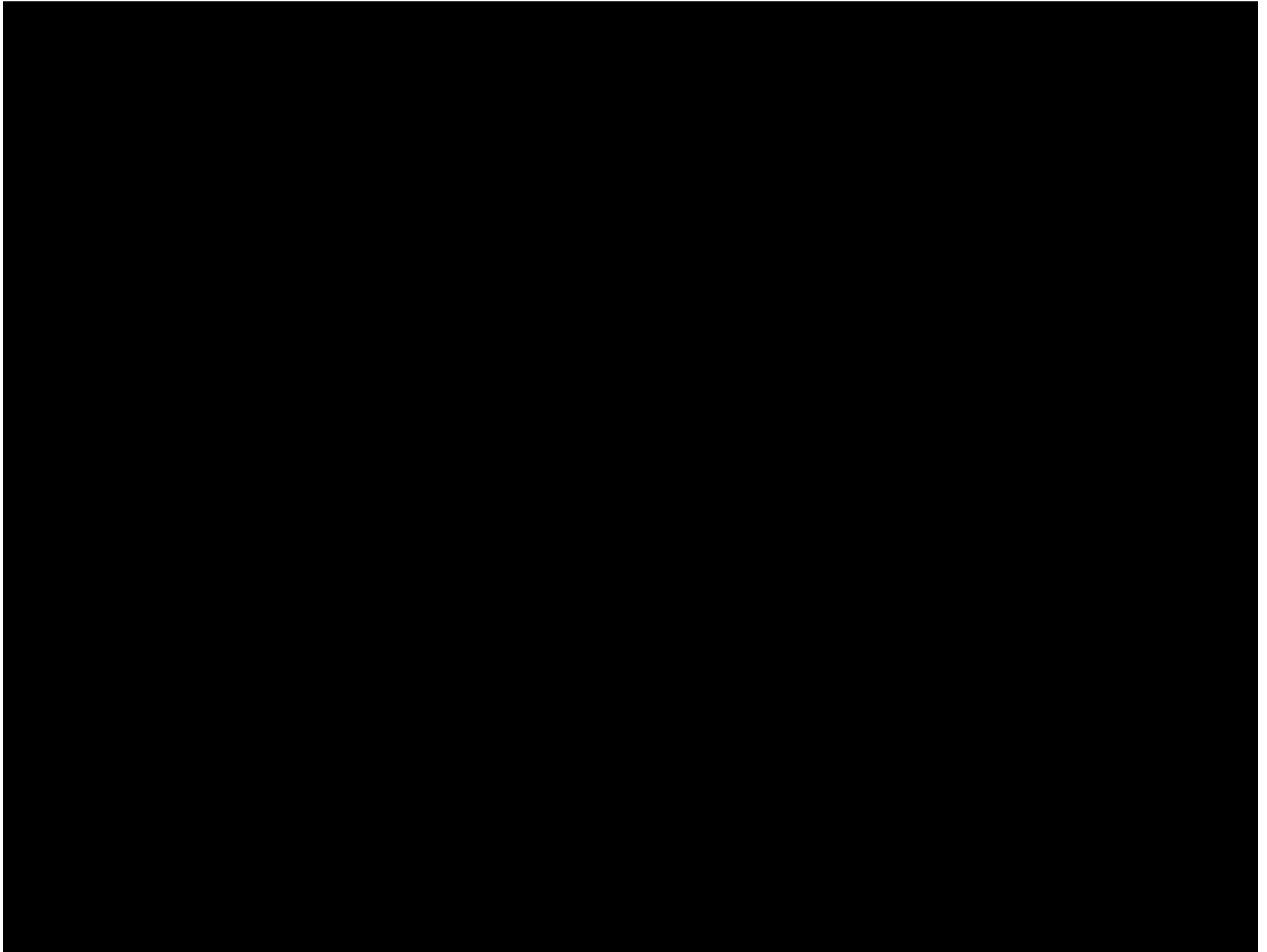
Appendix F Outline Drawings

PRELIMINARY









**Rev1. Sep. 2024
Page 27 of 27**

APPENDIX M – VIBRATION MONITORING OPTIONS COMPARISON

