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2017 Comprehensive Detailed Inspection

BURLINGTON CANAL LIFT BRIDGE

Contract No. EQ754-181509/001/PWL

Project No. R.089504.040

Burlington Canal Lift Bridge

Revised March 29, 2018

(Rev .00)

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March 29, 2018 Project No: R.089504.040

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Dear Sir,

RE: Burlington Canal Lift Bridge
2017 Comprehensive Detailed Annual Inspection
Final Report

We are pleased to submit the final report for the 2017 Annual Inspection for the Burlington Canal Lift Bridge for your records. An electronic version has been uploaded to our FTP server.

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EXECUTIVE SUMMARY

The 2017 Annual Comprehensive Detailed Inspection (CDI) of the Burlington Canal Lift Bridge, including structural/civil, mechanical, and electrical components, has been undertaken in accordance with the requirements of Public Works and Governments Services Canada (PWGSC) Bridge Inspection Manual (BIM), December 2010 version. This report represents the key findings of the 2017 Comprehensive Detailed Annual Inspection.

The structure is a tower-driven vertical lift bridge constructed in 1958, with an overall lift span of 116 meters. The bridge is located in Hamilton, Ontario and carries 4 lanes of Eastport Drive traffic over the Burlington Canal, with a posted speed limit of 50 km/hr. The bridge is normally only in service during the navigable season from mid-March to the end of December. Advantage is taken of the winter shutdown of the bridge to perform annual maintenance and repairs.

The movable span is a tower drive vertical lift span with independent span drive machinery located at the top of each tower. The span drive machinery in each tower is driven by two electric motors which power a drivetrain that consists of shafts, bearings, and gearing, culminating with pinions that mate with ring gears attached to the counterweight sheaves. Motor rotation results in rotation of the counterweight sheaves, enabling the lift span to be raised and the counterweight lowered as the wire ropes pass over the sheaves.

The motors are driven and controlled by state-of-the-art variable frequency drives. The bridge is operated using a single motor in each tower with the second motor used as back up. In addition to the normal span drive machinery, each tower is provided with an auxiliary drive that is capable of operating the bridge in the event of normal span drive failure. The bridge control system consists of redundant programmable logic controllers that provide semi-automatic operation of the bridge and also control of skew of the moving span.

The vertical lift span is balanced by two counterweights located at opposite ends of the span. The ropes extend vertically from the fixed terminations at the lift span, up and over the counterweight sheaves and terminate in connections on top of the counterweight. The ropes transmit the entire dead weight of the lift span and counterweights to the structural tower through the main counterweight sheaves and trunnion bearings.

Each counterweight is equipped with an auxiliary balance system to offset the weight transfer of the unsupported length of the main counterweight ropes during span operation.

Other provided systems include: guides to control the position of the lift span and both counterweights during operation, live load supports to transmit imbalance load and traffic loads to the rest piers, span locks that hold the bridge in the seated position, and tower and span air buffers that are intended to absorb the energy of the lift span should it approach the fully raised or fully lowered position without proper control.

STRUCTURAL

The structural components of the bridge were inspected as per the Scope of Work listed in PWSGC's Terms of Reference, Section 3. The overall structural condition of the bridge members range from **Poor (3) to Good (5)** condition. Extensive severe significant defects were noted on several primary elements below the bridge deck at the approach and tower spans. The severe defects included severe corrosion on the structural steel stringers, diaphragms, towers' floor beams, towers' column anchorages, severe delamination and spalling of the concrete deck slabs and numerous cracks on the open steel deck grating at lift spans. There are a few isolated small areas of light to medium defects on the bridge structure above the deck, including the steel trusses, steel plates, bolts, etc. for the towers and the lift span.

The primary causes of the severe defects on the bridge components at and below the decks were evidently due to water leakage through the deck expansion joints and the concrete bridge decks at the approach and tower spans and the inadequate carrying capacity of the existing deck grating at the lift span as noted in the structural evaluation completed as part of the emergency replacement of a failed deck panel in 2014. The increase in volume of traffic, particularly heavy trucks, on the bridge due to frequent closures of the adjacent QEW highway bridges (Burlington Skyway Bridges), has likely accelerated the deterioration rate on the Burlington Canal Lift Bridge lift span.

The existing compression seal expansion joint system in the concrete deck slabs between the approach and the tower spans is considered redundant or in-appropriate. The steel stringers on the approach and the tower spans were found bolt-connected on the same floor beam and diaphragm below the joint. The connection between the stringers effectively eliminates any differential or relative movement of the structural steel and concrete bridge decks, thus, rendering any useful function of the deck expansion joint system.

It is evident that significant deterioration on the structural steel at the lift span has been stabilized as a result of the 2010 and 2011 recoating contracts. The re-painted areas on the lift span steel, including all below deck steel stringers, floor beams, bracing, and truss members below and within the splash zone areas of the deck are in **Good (5)** condition.

The need to stabilize the structural deteriorations resulting from the development of corrosion and local, severe rust jacking at key locations still remains. There is an increasing need to re-coat the other remaining areas of the bridge, including the upper section of the lift span, the steel towers and the approach spans, particularly the steel below the bridge deck. The re-coating will alleviate the more extensive failures of the painting system and subsequent development of corrosion at critical locations.

It should be noted that the previous report, Inspection Report and Concept Repair Design, Project # R.081864.001, dated April 2017, indicated that the structural evaluation completed as part of the urgent replacement of a failed deck panel in 2014 reported that the existing lift span gratings have insufficient flexural capacity when compared against the CL625 ONT truck loading. However, provided that the ongoing repairs to the lift span grating continually occurs, the deck grating at the lift span should be sufficient in carrying current traffic loads.

All observed significant defects on the bridge elements including recommendations and cost estimates for the recommended remedial measures are presented in details in the ensuing sections of this report.

Overall Structural Condition Rating

The overall structural condition rating, which reflects a structures material condition and performance relative to current standards/codes and is given as per requirements of the Public Works and Governments Services Canada (PWGSC) Bridge Inspection Manual (BIM), December 2010 version, which allows a degree of engineering judgment in addition to consideration of the lowest rating of individual components.

The overall structural condition rating is **Poor (3)**, which represents the condition of the steel deck grating on the lift span and several primary elements on the approach and tower spans, including the structural steel stringers, diaphragms, towers' floor beams, towers' column anchorages, concrete deck slabs, and deck expansion joints. This rating is based on the section loss measurements and significant defects on the deck grating, tower bases, and approach spans from the 2017 comprehensive detailed inspection.

Overall Bridge Functional Rating

The overall bridge functional rating, which reflects a structures material condition and performance relative to functional standards and is given as per requirements of the Public Works and Governments Services Canada (PWGSC) Bridge Inspection Manual (BIM), December 2010 version,

The overall bridge functional rating is **Fair (4)**. This rating is based on the fact that the bridge elements are still able to perform its intended function as per BIM standards, except for the expansion joint seals at the expansion joint between the approach and tower spans, which are leaking.

MECHANICAL

The mechanical machinery on the Burlington Canal Lift Bridge was inspected per the scope of inspection outlined in this report. Note that, since 2016, the high-speed machinery was replaced with new components that include new floating shaft couplings, enclosed reducers, motors, motor brakes, and previously used machinery brakes with new machinery brakewheel couplings. This is the first inspection of these new components.

During the current inspection the mechanical machinery was found to be in fair condition and there were no conditions that are currently resulting in operational problems. The majority of the deficiencies found during the inspection are relatively minor and can be corrected by the capable PWGSC maintenance staff. Minor paint deterioration and corrosion was common in spots at all of the machinery systems. Many of the new components for the span drive machinery were unpainted and were starting to corrode. Unpainted and corroded components should be painted for future protection. Apart from the inadequate paint, the span drive machinery components were found in good condition with only minor issues noted within the body of this report.

The counterweight sheave trunnions and trunnion bearings were in fair condition externally however, based on vibration testing, SKF noted potential issues at the outboard bearing for the SE-IB trunnion (bearing #3), the outboard bearing for the SW-OB trunnion (bearing #8), and the inboard and outboard bearings for the NW-IB trunnion (bearings #5 and #6). Note that analysis at the south tower bearing #8 were consistent with 2015 and 2016 analysis, and have not increased in severity. The other indications are new. SKF recommends a visual inspection of the bearing raceways for the south tower bearings as the impacts are consistent with damage to the raceway. This should be performed during a shutdown period. At the north tower bearings, the noted impact frequencies are unrelated to the bearing design. For these bearings, additional periodic vibration testing and/or troubleshooting is recommended on a yearly basis. This effort should be prioritized as the trunnion bearings are critical components for the reliable operation of the bridge.

The span air buffers have required significant maintenance attention since infiltration during span painting years ago. These were flushed with oil since the 2016 inspection and are performing reliable at this time. The tower air buffers remain functional. Failure of the span buffers could result in hinder the operation of the span near the fully seated position. Given the new control system, it failure of the buffers does not present a risk of damage to the systems from an out of control span. Consideration may be given to removing the span and tower air buffers in their entirety.

As in previous inspections, the lubrication of the main counterweight ropes and sheave grooves were found to be light at the time of the inspection. The main counterweight ropes exhibit areas along the length of the ropes where the lubricant has been displaced by contact with the sheave, but to a lesser extent than in 2016, indicating that the ropes have been lubricated. However, based on the conditions observed during the inspection, the frequency of lubrication remains inadequate. Wear measurements show that the ropes have only experienced a light reduction in capacity, though it can be expected that the wire ropes will corrode and wear at an accelerated rate if they are not properly lubricated. The wire ropes are critical components for the operation of the bridge. It is strongly suggested that they be lubricated periodically to mitigate wear.

Accumulated old lubricant at the north auxiliary ropes and sheaves should be removed. The south auxiliary ropes and sheaves were not lubricated and there is fretting and noise during operation. Without proper lubrication practice of these ropes, accelerated wear is expected. Wear flat measurements at the north auxiliary ropes represent an approximate capacity reduction of 17%. An in-depth inspection of the auxiliary counterweight ropes should be included in the next inspection. As a minimum, consideration should be given to replacing these ropes within the next five years, though this may be adjusted based on the results of the in-depth inspection.

Overall, the mechanical machinery systems are expected to be serviceable in the long term provided that the noted deficiencies, which primarily include lubrication and corrosion issues, are addressed. The largest risk to the reliable operation of the bridge is possible damage at the main counterweight trunnion bearings, which was noted by SKF from their vibration testing. The trunnion bearings should be provided with the recommended internal inspection and additional vibration testing. Strong consideration should be given to re-lubricating the bearings at the time of their internal inspection.

ELECTRICAL

An electrical inspection of the Burlington Canal Bridge was performed as part of the annual inspection cycle for the bridge. The electrical inspection was performed in accordance with the scope of work but also included an evaluation of the recent rehabilitation which included a replacement of a major part of the electrical power and control system for the bridge over a three-year period, concluding in 2017. This inspection included an evaluation of the replaced systems and an assessment of their reliability and appropriateness for their imposed duty. The inspection was in sufficient depth to determine the status of the bridge electrical operating systems and the adequacy of these systems to perform their intended function.

The present bridge electrical systems consist of a combination of electric power service and distribution equipment that was installed some 25 years ago with later modifications and newly designed and installed replacement and upgraded bridge operating drives and control systems.

The electric service and distribution equipment consists of a main electric service provided by the local utility, two (2) standby diesel generators used to provide backup power for the bridge and electric power distribution equipment. The electric service and distribution equipment, although mostly over 25-years old, remain in good serviceable and operating condition, have been well maintained, and provide reliable sources of power to the bridge. A number of deficiencies were noted and are itemized as follows:

- There are no alarm devices in the main transformer to alarm of potential failure.
- The main transformer is an outdoor oil filled transformer without any type oil containment to protect against an environmental spill of oil.
- There is no interlock in place to prevent an attempt being made to parallel the electric utility service with the standby generator. If this were to occur, it could lead to a catastrophic failure and injury to personnel. It is strongly recommended that both mechanical and electrical interlocks be provided between the main and the generator breakers in Switchboard #1.
- Proper phase loss and phase failure relays are not provided for the incoming main and generator breaker.
- Environmental protection or relocation of the battery chargers and alarm equipment in the generator room should be provided to avoid water damage.

The newly installed replacement and upgraded bridge operating drives and control systems consist of a replacement PLC bridge control system, operator control devices, tower Motor Control Centres (MCC’s), main drive motors and variable frequency drives (VFD’s) and associated instrumentation, brakes, auxiliary drive motors, bridge operating, alarm and monitoring field devices, new bridge power and control cable installation, replacement aerial cables and bridge vehicular/pedestrian and marine traffic control systems. The newly installed electrical replacement and upgrades bridge systems have been commissioned and the bridge has been returned to service.

Although the newly installed systems are operational, effectively control, protect and monitor the bridge status, they are still deficient is a number of areas as described below:

- The main drive motor nameplates are misleading and should be changed to reflect the actual design parameters of the motors. This would enable tuning of the motor drives to be performed in a time effective manner.
- A spare main motor has been furnished but it only conforms to two of the four installed motors. An additional spare motor should be procured to provide complete spares coverage for the main motors.
- The electrical upgrade scope included being able to operate the auxiliary motors located in each tower from one location. Presently this functionality is incomplete and requires input from PWGSC Engineer of Record.
- The electrical upgrade scope included providing a system that would self correct for span skew. Although the bridge control system does control skew, it does not eliminate a control deficiency when the span is seating and this deficiency causes a cumulative affect in creating a skew condition that presently has to be manually re-zeroed by bridge personnel every 2 to 3 weeks. The bridge control system should be modified to correct this deficiency.
- The designed and specified primary span skew monitoring device is unable to monitor skew with any accuracy and has been disconnected from the control system. A workable solution to this problem should be provided to ensure the bridge has a reliable and redundant form of skew monitoring.
- A leak exists in the south tower machinery space roof that could be a cause of system failure in the future. This leak should be repaired as soon as possible to protect the electrical equipment in the tower.
- Minor failures to the traffic control system were found and reported in the inspection report. These were all of a minor nature and should all be addressed in the near term.
- The replaced aerial cable installation design did not account for environmental loads and experienced some damage from wind. Repairs to the aerial cable damage and the installation of a spacer and wind damping system, designed by the electrical replacement and upgrade project contractor and their Engineer, was in process at the time of the inspection. To ensure that these mitigation measures solve the instability issues, consideration should be given to monitoring the installed aerial cable system over an extended period. Note that it is important for auditing purposes that PWGSC are provided with signed and sealed drawings and documents for the work performed.

Based on the findings of this electrical inspection, assuming that the above deficiencies are satisfactorily addressed, and with appropriate regular maintenance, it is expected that the bridge electrical systems will provide reliable service in the long term.

1.0 INTRODUCTION

Morrison Hershfield (MH) has been retained by Public Works and Government Services Canada (PWGSC) to provide engineering services for the 2017 Annual Comprehensive Detailed Inspection (CDI) for the Burlington Canal Lift Bridge. The engineering services include inspections of the structural, mechanical, and electrical systems. This work is performed under relevant section of the Standing Offer No. EQ754-161278/001/PWL for Bridge Engineering Services relating to the Burlington Canal Lift Bridge in Hamilton, Ontario.

This report covers the inspection of components (structural, mechanical, and electrical) for the Burlington Canal Lift Bridge as required in the PWGSC's Terms of Reference entitled "Burlington Canal Lift Bridge – 2017 Annual Comprehensive Detailed Inspection". The mechanical and electrical inspections were undertaken for MH by Stafford Bandlow Engineering Inc. (SBE).

1.1 DESCRIPTION OF STRUCTURE

Constructed circa 1958 to carry a railway track and 2 traffic lanes roadway, the BLB is a tower-driven vertical lift bridge fabricated from built-up steel sections. In 1982, the railway track was removed and the bridge was modified to carry a 4 traffic lanes roadway bridge (2 NB and 2 SB lanes of Eastport Drive traffic) over the navigation channel linking Hamilton Harbour with Lake Ontario.

The bridge, a 161.2m total length, consists of 2 short spans (approximately 22.6m long) at each end and a 115.9m long central lift span over the water channel. The bridge decks at the north and south sides of the main lift span are reinforced concrete slabs on steel stringers that are supported by conventional concrete abutments and steel floor beams at the tower sections. The main span bridge deck is an open steel deck grating on a two-sided Warren Truss with built-up steel members of plate and rolled steel sections.

1.2 SCOPE OF ANNUAL INSPECTION

The 2017 Comprehensive Detailed Inspection was performed in accordance with the PWGSC Bridge Inspection Manual (BIM, 2010 edition), AASHTO Moveable Bridge

Inspection Manual (2017 edition), the Ontario Structure Inspection Manual (OSIM, 2008 edition), and the MTO Structure Rehabilitation Manual (2007 revision).

As specified in the PWGSC's Terms of Reference entitled "Burlington Canal Lift Bridge – 2017 Annual Comprehensive Detailed Inspection", field inspections of the bridge included the following:

Structural Components

- Structural steel (approach spans, tower spans, towers, lift span);
- Deck grating;
- Bearings;
- Expansion joints;
- Sidewalk;
- Visible concrete substructures;
- Approach roadways;
- Asphalt wearing surface;
- Concrete bridge deck (soffit);
- Fall arrest.

Mechanical Components

Perform an inspection of the machinery systems in accordance with the established scope of inspection. Inspect every component of the mechanical system for adequacy of lubrication/lubricant, leakage, cracks, unusual noise, corrosion and wear. All components shall have mounting bolts, machinery supports and anchorages inspected. Inspection of the drive system will include, but will not necessarily be limited to, the items listed in the following table.

MECHANICAL INSPECTION TABLE

ITEM	*DESCRIPTION OF INSPECTION*
Open Gearing	Visually observe; lubrication and wear patterns, backlash, and clearance. Listen for any unusual or excessive noises. Gear tooth thicknesses using either span or chordal tooth measurements were taken.

Enclosed Gearing (Reducer)	Perform visual inspection through the inspection port(s). Listen for any unusual or excessive noises. Oil samples were obtained and submitted for analysis.
Brakes	Inspection shall include verifying smooth operation, condition of brakewheels, rotors, pads, thrusters, hand releases, linkages, and spring length settings.
Shafts	Inspect for cracks and distortion with particular attention paid to keyway areas.
Couplings	Observe leakage and condition of seals for all gear-type and grid-type couplings. Visually observe alignment. Couplings were not opened for inspection.
Journal (Sleeve) Bearings	Visually and audibly observe bushings and housings during operation. For detailed inspections, obtain clearance measurements for all that are accessible. Bearings were not opened for inspection.
Anti-Friction Bearings	Perform visual inspection and closely monitor for noise during operation. Bearing vibration measurements were obtained as part of this inspection.
Trunnion and Trunnion Bearings	Perform visual inspection and closely monitor for noise during operation. Bearing vibration measurements were obtained as part of this inspection.
Brakes	Inspection shall include verifying smooth operation, condition of brakewheels, rotors, pads, thrusters, hand releases, linkages, and spring length settings.
Traffic Gates and Traffic Barriers	Inspect warning and barrier gates for smooth operation. Check reducers for proper oil levels where accessible. Check integrity of brakes, anchor bolts, and gate arm hardware.
Wire Ropes and Sheaves	Visually inspect wire ropes, rope sockets, and rope sheaves for proper lubrication and signs of wear or damage.
Auxiliary Drive	Visually inspect components. Test drive for proper engagement for use.
Generators	Visually inspect components.

The mechanical components that stabilize the movable span when it is in motion and at rest will be visually inspected. In general, the components to be inspected include but are not limited to: span locks and drives, counterweight and span guides, centering devices, live load supports, trunnions and trunnion bearings, strike plates, and buffer cylinders.

Electrical Components

Every component of the electrical system will be visually inspected for condition and adequacy to perform its intended function. The following table describes the extent of the proposed electrical inspection services.

ELECTRICAL INSPECTION TABLE

ITEM	*DESCRIPTION OF INSPECTION*
Traffic Signals, Gates & Barriers	Visually observe operation. Check for: proper sequencing, all lamps lighted, physical condition of enclosures, gate arms, hardware, wiring, conduits, mounting bolts, internal dirt & debris, corrosion, etc.
Navigational Lights	Visually observe operation. Check for: all lamps lighted, physical condition of housings, lenses, conduit & wiring, attachment bolts & hardware, corrosion.
Conduit, Wiring, Junction Boxes and Enclosures	Visually check for: corrosion, adequacy of mounting/attachments, bolts and hardware, spare conductors, weathering of cable jackets and insulation, grounding, water-tightness, etc.
Drive Motors (both AC & DC)	Visually check: mounting bolts, frame movement, noise & vibration, shaft end play during operation, coupling/pulley/sprocket bolts, ventilation openings, dirt & debris build-up, cable connections, brushes, commutators/slip rings, load measurements. The drive motor current, voltage and power parameters will be monitored and recorded during operation.
General Purpose Motors	Visually check: mounting bolts, frame movement, noise & vibration, shaft end play during operation, coupling/pulley/sprocket bolts, ventilation openings, dirt & debris build-up, cable connections (when visible).
Brakes	Visually check: overall operation, noise & vibration, wiring, limit switches, corrosion and dirt/debris build-up on electrical components, mounting hardware.
Locks	Visually check: overall operation, noise & vibration, wiring, limit switches, corrosion and dirt/debris build-up on electrical components, mounting hardware. The lock motor current, voltage and power parameters will be monitored and recorded during operation.
Limit Switches	Visually check: overall operation, free movement of lever arms & plungers, wiring, sprockets/chains/gears/couplings, corrosion, mounting bolts & hardware, condition of contacts (when visible).
Control System (Console, Relay/PLC	Visually check for: condition of enclosures and cabinets, wiring and internal components mountings, dirt debris accumulation, noise, heat, safety (exposed terminals, etc.), grounding, functioning of indicator lights, switches, pushbuttons, and metering. Control System interlocking shall be tested.

Cabinets, Speed Controls)	
Aerial Cables between Towers	Visual inspection with binoculars will be undertaken from either the ground or the towers. If more detailed inspection information is available then that will be placed into the report.
Bridge Operation	Visually observe: proper bridge operation, acceleration & deceleration, braking, drive motor current draw during operation, seating.
Main Electrical Service	Visually check for service equipment conditions including equipment for standby power. Record phase to phase and phase to ground voltages under no-load condition to determine the stability of the utility service.

1.2.1 Inspection Personnel

Field inspections on various components of the bridge structure were performed on various dates over the months of November and December, 2017.

Structural

Inspection of the bridge's structural component was performed by a team of four persons led by Scott Quach, P.Eng. of Morrison Hershfield on November 20 to 22 and December 21, 2017.

Mechanical

The detailed mechanical inspection was completed by Ralph Giernacky, P.E. and Michael Denis-Rohr, P.E. of Stafford Bandlow Engineering (SBE) on November 8th, 9th, and 10th, 2017. Assistance to the mechanical inspection was provided by PWGSC bridge operating and maintenance staff.

Christopher Ramos, Service Technician of SKF performed vibration measurements under the supervision of SBE on November 9th and 10th, 2017.

Electrical

The detailed electrical inspection was completed by Gareth Rees, P.Eng., Lin Xu, P.E. and Jeff Koscil of Stafford Bandlow Engineering (SBE) on November 8th and 9th, 2017.

1.2.2 Background Information

Information on the bridge structure was obtained from the available previous inspection report and drawings. The following provided information forms the base for this 2017 Detailed Comprehensive Annual Inspection of the structure:

- 2016 Comprehensive Detailed Annual Inspection by Parsons;
- 2014 drawings for replacement of controls, drives and overhead cables;
- 2013 drawings for replacement of one bridge deck grating panel, Morrison Hershfield Limited;
- 2013 drawings for replacement of controls, drive and overhead cables, Parsons Brinckerhoff;
- 1999 New Deck Grating drawing, PWGSC;
- 1982 Framing Plane-Lift Span drawing, C.C. Parker Consultants Limited;
- 1980 drawings for modication of bridge deck, Parker Consultants;
- 1958 construction shop drawings for Burlington Canal Lift Bridge, Bridge & Tank Company of Canada Limited;
- Operation and Maintenance Manual.

As identified in the 2016 Comprehensive Detailed Annual Inspection Report, a number of remedial repairs were completed on the bridge in 2015 and 2016. These included:

- Lubrication of the main counterweight ropes;
- Freeing the north live load support rockers;
- Replace the aerial cables as part of the current rehabilitation contract;
- Patch repair holes on the roof membrane at the North Tower;

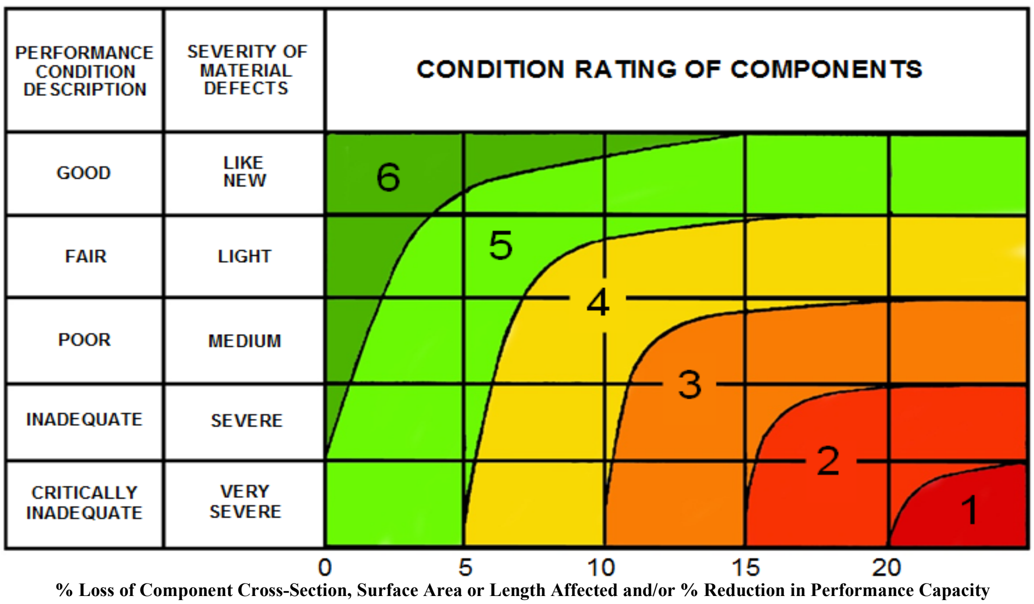
It is understood that the current rehabilitation contract (Project # R.012641.001) to repair and upgrade the security, mechanical and electrical control systems is in its final phase at the time of this report. The rehabilitation work included the replacement of the aerial cables, the bridge control and drive systems, the high speed machinery, the auxiliary drive system, and the warning and barrier gates.

Welding repairs of the deck grating at the lift span have also been recently completed as part of an on-going general maintenance for the bridge.

1.2.3 Component Condition Ratings

The inspection was performed in accordance with the PWGSC Bridge Inspection Manual (BIM), 2010 edition. Material and performance condition ratings for all accessible components were updated using the results of the 2016 Detailed Comprehensive Annual Inspection. Ratings were compiled based on the observed defects criteria specified in the BIM. Results of the inspection were summarized in the standard forms enclosed in Appendices “A3” to “A5”.

The overall general condition rating for the structure is derived from the ratings of individual components as presented in the BIM. The condition ratings for each component are based on the BIM scale from 1 to 6 as shown below:



The priority code assigned to each component is in accordance with Section 2.3 of the BIM:

Code	Description
U	Urgent, requires immediate attention and remedial measures to ensure public safety
M	Required work to be done as part of routine annual maintenance
S	Further study/investigations required prior to initiating repair programme
A	Repair and/or replacement to be done in less than 1 year
B	Repair and/or replacement to be done in less than 3 year
C	Repair and/or replacement to be done in less than 5 year
D	**Condition to be re-assessed at the next inspection**

2.0 STRUCTURAL INSPECTION

2.1 GENERAL

Detailed visual inspections were performed in accordance with element and condition classifications as prescribed in the BIM. Non-destructive means were used to establish the scale of deterioration (e.g. by sounding), where possible. For those components where drawings were available, site measurements were also performed to verify whether the structure was built in accordance with the existing available information.

For consistency and simplicity, a key plan showing identification number on various components of the bridge, similar to the previous report, are shown on Figure 1 in Appendix “A1”. General views and close-ups of defects on the inspected components are presented in the site photographs enclosed in Appendix “A2” of this report. A summary of field observations, as well as the condition ratings and repair priority codes for the individual components of the bridge are included on the inspection form in Appendices “A3” and “A4”. Individual component field observations, material and performance condition rating are included on the MCR/PCR Forms in Appendix “A5”.

2.2 NORTH AND SOUTH APPROACH AND TOWER SPANS

The approach and tower spans at the north and south ends of the bridge, are made up of a reinforced concrete slab on eight steel stringers; the stringers are identified from east to west as Stringer 1 to Stringer 8 as shown a Figure 1 in Appendix “A1”. The concrete bridge decks and stringers are supported on a conventional concrete abutments and on steel floor beams at the tower sections for the central lift span bridge deck. A concrete curtain wall, constructed as part of the concrete bases for the bridge towers, is present below the south and north side of the north and south approach spans, respectively. General views of the bridge and the approach/tower spans are shown on Photos 1 to 5 in Appendix “A2”.

2.2.1 Concrete Abutments and Ballast Walls

The north and south concrete abutments are generally in **Fair (4)** to **Good (5)** condition. Significant defects, observed on the concrete abutments, are shown on Sketch SK-1 in Appendix “A1”. The abutment walls are lightly wet stained and with several large areas of anti-graffiti paint (Photos 6 and 7). There are large accumulation of sediment, concrete, and rust scales debris on the top bearing seat surface of the concrete abutments (Photo 19). There are several large areas of concrete patches and a few isolated medium and wide vertical cracks on the north abutment wall (Photos 8 to 10). Hammer sounding on the north abutment wall identified a few local areas of concrete delamination on the upper interior section of the concrete wall (Photo 11). The south concrete abutment exhibits a few large concrete patches and several medium and wide vertical cracks (Photos 15 and 16). A crack showing wet and rust stains and delaminated areas was noted on the east section of the south abutment wall (Photo 17). There is a wide diagonal crack with wet (seepage of water) and efflorescence stains at the top west corner area of the south wall (Photo 18).

The concrete ballast walls at the north and south abutments are largely wet stained with several narrow cracks and a few medium vertical cracks. Heavy rust stains, cracks, and small spalled areas were also evident on the interior section of the ballast walls (Photos 12 and 19). A severely corroded steel bar was noted in a local spalled area adjacent to a vertical expansion joint near mid-section of the north ballast wall (Photo 13). A small area of concrete patch with spalls and an active wet area was noted at the top of the north ballast wall, near the location of the west stringer (Stringer 8, Photo 14). There is a large delamination area on the south ballast wall near Stringer 7 (Photo 20).

2.2.2 Abutment Bearings

Bearings under the east Stringers 1 to 3 were reported to have been installed in 1982 as part of the deck modification from the original railway track to vehicular traffic. The west bearings under stringers 4 to 8 at both north and south abutments were subsequently replaced in 1998.

All bearings observed at the north and south abutments are elastomeric laminated bearing type (Photos 21 and 22). The bearings are in good condition with no significant defects, except for some light bulging on the rubber surface of the east bearings under Stringers 1 to 3 at the south abutment (Photo 23). It should be noted that oversized shoe plate, approximately 571.5mm wide x 647.7mm long x 8mm thick plate, was typically noted on the underside of the west stringers (Stringers 4 to 8) over the bearings at both abutments (Photo 24). It is likely that the shoe plates, typically galvanized steel finish, were installed on the stringers as part of the bearing replacement in 1998. The steel shoe plate typically act as a direct contact surface for the bearing as well as help stiffen the bottom flange for better and uniform load transfer distributed to the bottom surface to the bearing.

Bearing under Stringer 4 at the south abutment was reported to have tilted eastward. Tilting of the bearing was reported to be approximately 4mm in the previous 2007 to 2011 annual inspection reports and then increased to 6mm in 2012. The most recent inspection in 2016 reported the tilt to have increased to 8mm. As part of the on-going monitoring of the reported tilting of the bearing at the south end of Stringer 4, the bearing height was measure on both west and east side of Stringer 4 as part of this 2017 inspection. A height different between the measured values between the base grout pad and the shoe plate appeared to indicate an eastward tilting of the bearing at approximately 8mm which is similar to that reported in the 2016 inspection; this tilt value is within tolerance for bearings. There were no signs of distress or significant defects evident on the bearing surface (Photo 25).

2.2.3 Concrete Curtain Walls

The concrete curtain walls under the north and south approach spans are in good condition (Photos 26 to 29). There are a few isolated narrow and medium cracks on the concrete walls (Photos 30 and 32). A medium horizontal crack was noted on the bottom west face of the north wall at construction joint with the concrete pier for the north tower base (Photo 31).

2.2.4 Concrete Retaining Walls

The concrete retaining walls at each corner of north and south abutments are in good condition (Photos 33 to 36). The northeast and southeast retaining walls appeared to have been reconstructed under the current rehabilitation contract (Project # R.012641.001) with cantilever slab for new gate barrier (Photos 34, 36, and 37). Local areas of significant defects were found at a few isolated locations on the concrete retaining walls. Narrow-to-medium cracks with efflorescence stains were noted on the top south corner of the northwest retaining wall (Photo 38). There is a medium-to-wide vertical crack near the upper mid-section of the northeast wall (Photo 40). A medium vertical crack and few small areas of concrete patches were noted near mid-section of the southwest retaining wall (Photo 39).

2.2.5 Bridge Deck Wearing Surface

The deck asphalt surface on the concrete bridge decks at the approaches and tower spans are generally in good condition. Asphalt pavement on the concrete bridge deck was reported to have been repaved in 2011. There are a few localized areas of unsealed pattern cracks on the asphalt surface. The cracks were found mainly in areas adjacent to the deck expansion joints between the approach and the tower spans, particularly at the joint between the north approach and the north tower sections of the bridge (Photos 41 to 45). A small shallow pothole was noted at centerline of the roadway adjacent to the finger plate expansion joint the north end of the lift span (Photo 47). Small areas of asphalt patches and a few minor cracks on the asphalt were noted adjacent to the concrete end-dams for the deck expansion joint between the south approach and south tower spans (Photo 49).

2.2.6 Expansion Joints

<u>Abutment Joints</u>

Deck expansion joints at the north and south abutments are paved-over joint type (Photos 50 and 51). The joints were reported to have been installed as part of the deck asphalt re-surfacing in 2011. There were severe pattern unsealed cracks on the south approach road surface near the south abutment joint (Photo 56). Active wet areas on the concrete and severe corrosion structural steel were evident at areas below the north and south abutment joints (Photos 12 to 14, 19, 20, 84 to 88, 101, 102, and 110 to 113), indicating severe leakage through the paved-over abutment joints.

<u>Expansion Joints between Approach and Tower Spans</u>

A compression seal deck expansion joint system with concrete end-dams and steel angles is present at the joint between the north and south approach and tower spans of the bridge (Photos 52 and 53). The concrete end-dams typically exhibit light to medium scaling. Localized small areas of shallow spalls and few patch-repairs, previous concrete patches and recent asphalt patches, were noted on the concrete end-dam surface (Photos 46, 49, 52, 53, 60, and 61). Abrasion marks from plow blades were generally noted on the top surface of the joint steel angles. Severe abrasions and dents were noted on the west section of the north steel angle for the expansion joint between the north approach and north tower spans (Photo 57). A section of the angle near the west curb was found dislodged from the concrete end-dam (Photo 58); loose expansion joint seal was also noted at dislodged angle location (Photo 59). Previous repairs with welded sections were also noted in places on the joint steel angles (Photos 46 and 57). Active wet areas and severe defects on the concrete and structural steel noted below the deck expansion joints (Photos 67, 93 to 96, and 104 to 106) indicate severe leakage through the deck expansion joints. It should be noted that the steel stringers below the joints were effectively found to be continuous over the joint gap in the concrete bridge deck; the bottom flange of the stringers for the approach span and the tower span were found rigidly bolted to the same rear floor beam for the tower and the stringers' webs appear to have been bolt-connected through a single steel channel diaphragm (same channel for both spans stringers, (Photos 117 and 118). These connections effectively eliminated any differential or relative movement of the structural steel and the concrete bridge decks between the spans, thus, rendering any intent useful function of the deck expansion joint system.

Expansion Joints between Tower and Lift Spans

Open gap steel finger plate and open gap with steel end armour angles are noted at joints between the north tower and the south tower with the main span lift section, respectively (Photos 54 and 55). The open gap steel joints were found in good condition with no evidence of any significant defects, except for some abrasion marks from plow blades on the top surface of the armour plate at east section of the joint between the south tower and the lift span (Photo 62). The open gap was measured to be approximately 112mm for the north finger plate joint and approximately 35mm on the south armour plate joint; there were no evident of any impeding or rubbing steel at the joint locations.

2.2.7 Deck Underside and Stringers

There are eight steel stringers supporting the concrete bridge deck below the roadway traffic at the north and south approach and the tower spans; a ninth stringer with steel cross-framing for the support of a cantilever pedestrian sidewalk is present along the west side of the concrete bridge deck. The stringers are identified from east to west as Stringer 1 to Stringer 8 as shown a Figure 1 in Appendix "A1". General views of the deck underside at the spans are shown on Photos 63 to 83 in Appendix "A2".

It is understood that a detailed condition survey of the concrete bridge decks (approach and tower spans) was completed in 2004. The condition survey indicated that a high percentage of the concrete deck slabs are in active corrosion category areas and the concrete was also found to be highly chloride-contaminated.

Concrete Deck Soffit

Significant defects, observed on the concrete deck soffit at the approach and tower spans, are shown on Sketches SK-2 and SK-3 in Appendix "A1". The underside surface of the concrete deck slab at the north and south approach and tower spans is generally in fair condition. The concrete deck soffit is typically wet stained at areas below the deck expansion joints at the abutments, joints between the deck spans and local areas in the interior section of the deck. The end soffit at the north and south abutments were typically found to be sloping towards the stringers and the end diaphragms causing water leakage through the deck abutment joints to run towards the structural steel (Photos 84 and 85); heavy corrosions were typically noted at the stringers' ends and the back face of the end diaphragms (Photos 86 and 87). Local areas of concrete delamination and spalls with exposed rusted rebars were also noted on the south end soffit between Stringers 4 and 7 at the south approach span (Photos 87and 88).

The concrete soffit on the north approach and north tower spans are generally wet stained at areas below the deck expansion joints (Photos 84 to 88, 90, and 93 to 95, and 104 to 107). Large wet staining areas were also noted on the interior soffit at areas between Stringers 4 to 6 (Photo 89). A delaminated area was noted on the thickened soffit over the north end-diaphragm near Stringer 6 (Photo 90). There are a few medium diagonal cracks with efflorescence and wet stains on the eastern soffit section of the north approach span (Photos 91 and 92). Active wet areas were noted on the soffit in the vicinity of the deck expansion joint between the north approach and the north tower spans (Photos 93 to 96); spalls and delamination areas were also evident in the wet areas on the soffit between Stringers 7 and 8 at the north side of the joint (Photo 94) and between Stringers 3 and 4 at the south side of the joint (Photo 96). A wet area with efflorescent stained cracks was also noted on the interior soffit area near Stringer 4 at the north tower span (Photo 97). The south overhang soffit below the open gap finger joint between the north tower and the central lift span section is typically lightly wet stained (Photo 98).

On the south approach span, there are several narrow to medium stained cracks on the southeastern section of the deck; wet stains and delamination on the soffit were generally noted at the cracked areas (Photos 100 and 101). There are several large wet and delaminated areas on the interior central section of the south approach span soffit (Photos 102 and 103). Large wet areas and few stained cracks were noted on the north section of the south approach span soffit at areas adjacent to the deck expansion joint with the south tower span. The north and south end sections of the south tower span soffit, at areas near the open gap joint with the lift span and the joint with the south approach span (Photos 104 to 109), are largely wet stained particularly on the southeast section of the tower span between Stringers 1 to 4 (Photos 106 and 107).

Steel Stringers and Diaphragms

The structural steel on the underside of the bridge decks at the approach and tower spans is in **Poor (3) to Fair (4)** condition. Overall, the paint coating on the steel has lightly faded and peeled in places exposing a light surface corrosion on the structural steel. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints, particularly at the north and south abutment ends.

General views of the structural steel below the approach and the tower spans are shown on Photos 64 to 66, 68 to 76, and Photos 78 to 82 in Appendix "A2". Significant defects on the structural steel under the bridge deck at the north and south approaches and tower spans were mainly found at areas below the deck expansion joints and along the top and bottom of Stringer 8. The most severe corrosion, up to 45% section lost, was noted on stringer 8 and diaphragms below the north and south abutment joints, particularly on the back side and bottom surface of the diaphragms and the stringers (Photos 84 to 87 and 110 to 112). The gusset plates for the connection of the diaphragms and stringers at the abutments were generally found severely corroded and perforated (Photos 112 and 113). Local severe corrosion was also noted on the top flange of Stringer 8 below bent steel plate for west curb and brackets for the cantilever west sidewalk; up to 21% section lost was noted on the top flange of Stringer 8 and approximately 50% on the bracket near mid section of the north approach span (Photos 114 and 115).

Local medium to severe corrosion (up to 20% section loss) was evident on the stringers and diaphragms below the expansion joints between the approach and the tower spans (Photos 67, 93 to 96, and 104 to 107). As noted in Section 2.2.6 under Expansion Joint between Approach and Tower Spans, the bottom flange of the stringers for the approach span and the tower span were found rigidly bolted to the same rear floor beam for the tower with the web sections being bolt-connected through a steel channel diaphragm (common channel for the stringers in both spans, Photos 117 and 118).

Light to medium corrosion, up to 10% section loss, was generally noted on the stringers, steel armour plates, and diaphragm below the expansion joint between the tower and the lift spans (Photos 71, 72, 81, 82, 98, 99, 108, 109, and 116). The corrosion was found mainly on the top and bottom flange areas of the stringers.

2.2.8 Concrete Pier Bases for Towers

The concrete pier bases at the bottom of the north and south towers are generally in **Fair (4) to Good (5)** condition (Photos 119 and 120). Asphalt paving was typically noted on the pier surface at the location of the front tower columns. There are a few wide vertical cracks on the concrete piers walls surrounding the front column locations of the towers. Wide vertical cracks and small areas of concrete delamination with shallow spalls were noted near the southwest corner of the north pier and the northeast corner of the south pier (Photo 121).

As noted in the 2016 Detailed Comprehensive Annual Inspection Report, there are two equalization water tanks in areas between the tower columns at each of the tower piers. Internal inspection of the tanks are required every four years cycle. The tanks were last inspected in 2016 (refer to the 2016 report for the interior condition of the tank).

2.2.9 North and South Steel Towers

The north and south steel towers, extending approximately 58.4m high from the concrete pier foundation to the equipment housing roof, consist of built-up steel truss members for the columns, horizontal, diagonal cross bracing, and sheave girders at the top. Each tower is equipped with an enclosed elevator steel shaft (Photo 179), an access ladder (Photo 182), a large concrete counter weight unit (Photos 163 and 176), upper catwalk with access hatches from the sheave room atop of the towers (Photos 164 to

167, and 194); an enclosed housing for the equipment and sheave rooms is present at the top of each tower (Photo 141). For identification, the towers are assigned as six panel heights starting with Panel 1 at deck level to Panel 6 at the top section below the equipment/sheave rooms as shown in Figure 1 in Appendix “A1”. General views of the towers are shown on Photos 1 to 3 and 141 to 144 in Appendix “A2”.

Below Deck Section

The steel towers at the bottom below deck section are in **Poor (3) to Fair (4)** condition. The tower section comprises of four built-up steel columns with anchorage assemblies (Photos 122 and 123), one front and one rear floor beams, two jacking girders spanning the front and rear columns (Photos 66, 71, 72, 76, 81, 119), and lateral bracing members (Photos 68 to 70 and 78 to 80). An original steel pedestal bearing is present on the eastern section of the rear and front floor beams at both towers (Photo 124); the pedestals are typically located below the original railway track (removed in 1982 contract) on the deck. Significant defects on the tower members below the concrete bridge deck were primarily noted on the anchorage assembly for the tower columns and the rear floor beams. Local areas of light to medium corrosion, up to 10% section loss, was typically noted on the interior surface of the anchorage assembly at the bottom of the rear columns of the towers. More severe corrosion, over 10% section loss, was found on the interior section of the assembly at the northwest column of the north tower and the southwest column of the south tower (Photos 125 and 126). Medium to severe rusted anchor bolts were noted at the front northwest column anchorage at the south tower (Photo 127). Sediment and roadway debris was noted on the top of the anchorage assembly at the base of the south tower (Photo 128).

Light surface corrosion was generally noted on the bottom surface of the steel columns near the anchorage assembly areas. A thick layer of sediment build-up was noted on the bottom internal plate in the northeast column of the south tower (Photo 129, 136 and 147); light to medium corrosion was noted on internal surface of the column at the sediment build-up area.

The rear floor beams at the north and south towers, located below the deck expansion joint between the approach and tower spans bridge decks, exhibit large areas of light to medium corrosion. Large areas of severe corrosion, up to 20% section loss, were also noted in places on the flanges and the web areas of the beams, particularly on the lower west section of the beams at the north and south towers (Photos 130 to 133). This is an increase in section loss, compared to the 10-15% section loss observed in 2016. Medium to severe corrosion was also noted on the lateral bracing at areas in close proximity of the rear floor beams (Photos 131 to 134).

The front floor beam of the towers, located below open gap expansion joint in the deck between the tower and the lift spans, typically exhibits light corrosion areas on the top and bottom flanges. The beam bottom flange, facing the joint in decks, are mostly covered with a thick layer of sediment (Photo 135); light corrosion was general noted on the beam surface at the sediment areas. Local medium corrosion area, up to 10% section loss, was evident on the on the web section of the south tower beam near the bottom of the northeast column of the tower (Photo 128).

The jacking girders, spanning between the front and rear columns of the towers, typically exhibit light fading of the paint coating on the steel surface and few isolated small areas of light surface corrosion. General views of the girders are shown on Photos 119, 137, and 138. Light to medium rust jacking was generally noted on the lower north and south section of the girders (Photo 139). Remains of bird nests and guano were noted on the interior of the east girder at the south tower span (Photo 140).

Above Deck Sections (Panels 1 to 6)

Above the deck, the steel towers are generally in good condition. General views of the towers at sections above the deck are shown on Photos 3 and 141 to 146 in Appendix "A2". Bird droppings and local small areas of light corrosion were noted on north and south steel towers (Photos 146, 149, and 150). Debris accumulation was noted on the internal horizontal plate in the west columns of the towers near the sidewalk level (Photo 148). There are three missing rivets on the upper built-up connection the west Horizontal No. 4 near mid face section of the south tower (Photo 151); the missing rivets were also found on the opposite upper connection of the member, totaling six missing rivets on the horizontal member. The same missing rivets condition was also evident on the east Horizontal No. 4 of the tower, resulting in a total of twelve missing rivets on the south tower. Light to medium rust jacking was typically noted at the missing rivet locations (Photo 152). The missing rivets on the built-up horizontal member at the south tower were reported in the 2016 inspection; the report indicated that the corrosion has visibly increased since the 1999 inspection.

The structural steel at the top of the towers is in **Good (5)** condition (Photos 153 to 158). Bird guano was typically noted on the bottom flange area of the front transverse sheave girder at the towers (Photo 154). Paint failure exposing a light surface corrosion on the structural steel was noted in places on the lower section of the interior sheave girders and lateral bracing on the underside of the housing atop of the towers (Photos 159 and 160). Localized medium to severe rust jacking was typically noted on the bottom north end of 3rd sheave girder from west in the south tower and on the bottom south end of 3rd sheave girder from west in the north tower (Photos 153 and 161). An improperly installed rivet was noted at the top angle connection for the top flange of the 6th longitudinal sheave girder from west over a transverse floor beam for the equipment room in the north tower (Photo 162).

The counter weight at each tower is located below the sheave girders during the lift span in the down position. General views of the main counter weights are shown on Photos 163 to 167 in Appendix "A2". Both north and south counter weights generally exhibit localized paint failure with light corrosion spots. There are a few narrow and medium cracks on the top surface of the concrete caps on the main counter weights (Photos 167 and 168). Paint failure showing light corrosion was typically noted on the steel pin at the top of the service hanger plates for the counter weights (Photo 169). A section of the guide-bar angles was found removed from the top section of the west guiderail for the north counter weight (Photos 170 and 171); the missing guide-bar appeared to be at the top section of the guiderail above the normal travel/stop position of the counter weight. Paint failure showing light corrosion were generally noted on the lower sections of the counter weight guiderails (Photos 172 and 173). Paint coating on the perimeter pipe handrails and the central safety rail has largely faded and peeled exposing a light surface rust on the steel railing surfaces (Photo 167). A loose anchor bolt was noted on the central post for the safety rail atop of the south counter weight (Photo 174). A bent top rail was noted on the perimeter railing near the northeast corner of the north counter weight (Photo 175). There were no apparent of significant defects on the auxiliary counter weights at front face of the towers' front columns (Photos 176 and 177).

The enclosed elevator shaft and steel framing supports are in good condition (Photos 178 and 179). There were no evidence of any significant defects, except for some minor localized areas of light surface rust on some of the framing members at the bottom sections of the shafts.

The stairwell, ladders, and platforms on the towers generally exhibit localized areas of light corrosion. General views of the stairs, ladders, and access hatches are shown on Photos 180 to 185 and 192 to 195 in Appendix “A2”. More severe corrosion and rust jacking was noted on the bottom perimeter of the south access platform and posts (Photos 189 and 190) as well as the stand-off brackets for the supports of the stairs and platforms on the north and south towers (Photo 191). A disused climbing ladder was noted on the outside face near the southwest and northwest corners of the north and south towers, respectively (Photos 186 and 187); the ladders appeared to have been cut-off at the Panel Point 2 near the bottom of the towers (Photo 186). Uncoated steel angles were typically found installed on the upper catwalk’s railing blocking access to the disused ladder (Photo 188).

Fall arrest system was typically noted at all the access hatches to the ladders in the machinery rooms and on all ladder flights at the interior of the north and south towers (Photos 182, 183, 185, and 192 to 195). There were no signs of defects on the fall arrest systems in the towers.

Both towers were being furnished with new aerial cables as part of the current upgrading contract at the time of the site inspection (Photos 196 and 197). Light to medium corrosion was typically noted on the old rigid conduits attached to the beams and girders below the equipment housing (Photos 198 and 199).

<u>Equipment/Sheave Rooms</u>

The equipment and sheave rooms at the top of both north and south towers are in good condition. General views of the rooms are shown on Photos 200 to 205 in Appendix “A2”. All structural members in the rooms, including the walls, roofs, and steel framing are typically covered with a white colour paint. A grey colour paint coating was noted on the concrete floor surface. Failure of the paint coating layers were generally noted in the rooms, particularly on the east wall in the north tower’s equipment room and on the walls and roof panels in the sheave room at both towers (Photo 205 to 207). There were no observable significant defects on the top and the bottom surfaces of the concrete floor slabs in the equipment room at both the towers, except for some localized peeled coating layers on the floor surface and localized areas of light surface rust on the steel framing (Photos 158, 200, 208, and 209).

A layer of PVC roofing membrane was typically noted on the top roof surface of the towers (Photo 210). An access hatch with aluminum pipe railing, aluminum perimeter safety fence, and a penthouse are noted on the north and south tower roofs (Photos 210 to 212). A non-slip rubber mat was found glued to the roof membrane from the access hatch to the penthouse door (Photos 211 to 213). There were no observable significant defects on the roof membrane, aluminum perimeter fence, and the roof access hatch; the access hatch and pipe railing are in new condition.

2.3 LIFT SPAN

The lift span section of the bridge is a steel through truss with open steel grating deck structure. The lift span, approximately 115.9m long, extends over the navigation water channel at the Burlington Canal. The steel through truss, including floor beams, upper and lower lateral bracing, sway and portal bracing, and traction bracing at the lower level, is made up of built-up members from plate and rolled steel sections. Open steel deck grating is supported by twelve (12) steel stringers (WF section) which in turn connect to thirteen (13) steel floor beams.

The original east stringers supporting the railway track were partially removed as part of the deck modification to a four lanes roadway in 1982; some end connections still remain on the floor beams (Photo 230). The lower section of the lift span (below the splash zone) was sandblasted to bare metal and re-coated during the winter shutdown period in 2010 and 2011.

For identification, the lift span is assigned as twelve panel length starting with Panel 1 at north end (section between north two floor beams) to Panel 12 at the south end (section between south two floor beams). The lift span panels are shown in Figure 1 in Appendix “A1”. General views of the lift span are shown on Photos 1, 2, 214, 215, 224, and 243 in Appendix “A2”.

2.3.1 Deck Grating

The lift span bridge deck is comprised of ninety-eight (98) open steel grating panels that were installed in 2000. Each panel is oriented transversely over the longitudinal stringers; a total of forty-nine (49) are used for the two northbound traffic lanes and forty-nine (49) on the two southbound lanes. General views of the deck grating are shown on Photos 216 and 217 in Appendix "A2". Following an extensive cracking on the hold-down weld between the grating panel and the stringers and welds at the intersection of bearing bars, a deck grating panel near the northwest corner of the lift span was completely replaced in 2014 (Photo 222). The replaced panel was intent to serve as a Test Panel for the possibility for similar future replacement of the remaining panels.

The deck grating at the lift span is in **Poor (3) to Fair (4)** condition with numerous cracks, primarily at and near the factory plug weld area. The deck grating has been continually inspected and repaired over the last several years (Photo 218). The most recent inspection and remedial repairs of the grating were being completed during the time of this annual inspection. The steel grating was failing under traffic load in several modes including grating to stringer weld failures, button weld cracks and cracks in bearing bars. The grating inspection indicated that there were as many as 3800 cracked locations on the steel grating surface (Photos 218 to 220). The majority of cracks were found mainly on the outer lanes in both traffic direction. Welding repairs are ongoing and have been completed at 930 locations considered as more critical cracks (Photo 221).

Cracked or broken grating, particularly on the outer traffic lanes, is likely due to heavy wheel loads from truck vehicles. An evaluation completed as part of the urgent replacement of a failed deck panel in 2014 indicated that the spacing of the supporting bars that connect to the stringers were inadequate to carry the wheel loads.

The replaced sample test panel near the northwest corner of the lift span was found in good condition with no evidence of cracks or other significant defects. The new panel with main bars bearing on the stringers at every gridline (double that of the original panel, Photo 223) is evidently performing well on the lift span bridge deck.

2.3.2 Structural Steel below Deck

The steel stringers, floor beams, lateral bracing, and the bottom chords of the trusses are in **Good (5)** condition. Significant defects on the structural steel below the bridge deck were not apparent, except for some localized areas of light surface rust at the time of this inspection. All steel surfaces, including interior surface of the truss bottom chords, were found covered in a thick layer of paint coating; as previously noted, all structural steel at the lower section of the lift span was sandblasted to bare metal and re-coated during the winter shutdown in 2010 and 2011. General views of the structural steel below the deck are shown on Photos 224 to 232 in Appendix “A2”.

Light surface rust on the new coating layer was noted in places on the top flange surface of the stringers below the deck grating at Lift Span Panels 2 to 11 and on the bottom flange areas of the floor beams and the bottom chords at the end panels, Panels 1 and 12. There are a few isolated small areas of light surface rust on the bottom corner connection, the interior surface of truss bottom chords, and the gusset plate for lateral bracing near the tower ends (Photos 233 to 235). The interior surface of the bottom chords at the north and south panels of the lift span was found covered with bird guano throughout (Photo 236). A missing bolt was noted on the north connecting plate for the centering shoe at the bottom north side of the north floor beam (Photos 237 and 238). The shoe plate for the original railway live load support was found removed from bottom flange at the north and south floor beams; light surface rust was typically noted on the bottom flange surface and the rivet holes at the removed shoe plate areas (Photos 239 and 240). There is an enclosed lower guide roller assembly at the bottom each corner of the lift span (Photo 241); severe corrosion was noted on the bottom of a railing post at the north end of the southeast assembly (Photo 242). It should be noted that there was no evidence of the tack weld that was noted in the 2016 inspection report on the bottom flange surface of the north floor beam.

2.3.3 Structural Steel above Deck

The steel trusses and bracing above the deck are generally in **Good (5)** condition. General views of the lift span structure above the deck are shown on Photos 214, 215, and 243 to 250 in Appendix “A2”. The lower section of the truss members, including verticals and diagonals appeared to have been recoated as part of the recoating contracts on the steel below deck in 2010 and 2011. Re-painting spots were also noted on the top surface of the truss members (Photos 251 and 264). The original paint coating has largely faded with several localized failures; light rust stains and spots of light corrosion on the steel were generally noted at the failed coating areas (Photos 252 to 258). Several localized areas of light to medium corrosion were found in places on the upper truss members and connection areas (Photos 259 to 262). Localized medium rust jacking was also noted on the bottom corners of the southwest guide roller assembly (Photo 263).

Dry greases and bird droppings were generally found on the top surface (north and south ends) of the trusses and the lifting girders (Photos 264 and 268). Several bird nests and a few areas with large accumulation of bird guano were noted on the upper members of the trusses, particularly in areas near the north and south towers (Photos 265 and 266).

Safety railing with fall arrest system is typically present along the top perimeter of the lift span (Photos 267 and 268). The system was in good working order with no signs of defects on the fall arrest devices.

2.3.4 Lift Span Bearings

There are two steel bearings at the north and south ends of the lift span bridge structure (Photos 269 and 270). All bearings are in good condition with few local areas of minor defects.

The bearing at the north end is typically a pinned rocker type (Photos 271); the rocker bearing is connected to a large pivot pin with steel bracket that attached to the underside corner of the truss bottom chord and the end floor beam; an air cushion unit was typically noted at the inside corner of the truss and the beam near the rocker bearing (Photo 272). A steel base plate anchored into the north concrete pier serves as the base for the steel rocker and the air cushion unit. There were no significant defects evident on the rocker bearing assembly, except for some peeled paint and grease staining on the steel rocker surface.

Steel saddle bearings are present on the bottom southeast and southwest corners of the lift span (Photo 273). Similar to the north end, an air cushion unit is also located at the corner areas of the lift span near the bearings (Photo 274). A cast steel base assembly anchored onto the south concrete pier is noted below the saddle bearing. All anchor bolts on the steel base assembly are secured onto the concrete pier with an additional locking nuts. There were no observable significant defects on the bearings, except for a few minor loose bolts on the southeast saddle bearing (Photo 275 and 276).

2.4 Bridge Components

2.4.1 Bridge Railings

The east and west railings for the traffic at the bridge include a single steel beam guiderail at the approach spans, a steel beam guiderail and two hollow structural steel rails at the towers, and three steel hollow structural steel rails at the lift span. Steel channels, in addition to the single steel beam guiderail, was typically noted on the guiderail at west side of the north and south approach spans. The bridge railings are typically mounted on steel posts. General views of the railings for the traffic are shown on Photos 277 to 281 in Appendix “A2”. All bridge railings for the traffic were found in good condition with no significant defects. A section of the railing in area below the counterweight guiderail was typically found covered in grease (Photo 282).

Pedestrian railing on the west sidewalk includes a horizontal handrail above the traffic in the lift span and an aluminum railing system along the west edge of the bridge. The east handrail, galvanized hollow steel section, is attached along the east face of the truss members above the west traffic railing at the lift span (Photo 283). A short galvanized steel pipe railing is present on the sidewalk at the north and south openings between the north and south towers’ column and the lift span (Photo 284). The aluminum railing on the west side of the bridge was reported to have been installed in 2007 (Photos 285 and 286). The pedestrian railings on the west side of the bridge are generally in good condition, except for a few localized defects on the aluminum railing. A spindle on the railing was found broken-off at the bottom rail on the lift span at Panel 9 (Photo 288). A missing nut was noted on a splice bolt for the top handrail and post in the lift span Panel 7 (Photo 289). There are loose anchor bolts on three of the aluminum railing posts: one post at the south abutment joint, one at the north abutment joint, and one near the north end of the railing (Photos 290 and 291).

2.4.2 Sidewalks and Curbs

As indicated in the 2016 report, the west sidewalk on the bridge, extending from the north approach to the south approach over the towers and lift spans, was reconstructed in 2007. The sidewalk, consisting of a concrete filled steel grate, is supported transversely by inverted steel tee sections embedded in concrete. A steel cover plate is typically present on the sidewalk surface over the expansion joint gap between the towers and the lift spans (Photos 294 and 295). A galvanized steel deck sheet is present on the underside surface of the sidewalk (Photos 63, 73, 137, and 227). General views of the sidewalk on the deck surface are shown on Photos 285, 292, and 293 in Appendix “A2”. The concrete sidewalk is in good condition with few isolated narrow to medium cracks. Local small areas of light surface corrosion were noted at few locations on the steel deck sheet below the sidewalk at the approach and tower spans (Photo 63). At the lift span, the steel sheet under the sidewalk was completely covered with a layer of paint coating (Photo 227).

A bent steel curb plate is present on the east and west sides of the traffic lanes at the north and south approach and tower spans (Photos 277, 279, and 296). The steel curb plate is generally in fair condition with light surface corrosion and localized medium corrosion on the top surface (Photo 297). Local severe corrosion with perforation holes were noted on the underside surface of the bent curb plate in areas near the deck expansion joints at the abutments and the joints between the approach and the tower spans (Photo 298).

2.4.3 Approach Roadways, Sidewalks, and Curbs

The north and south approach roads are in good condition with few isolated light pattern unsealed cracks. As noted in the previous report, the roadways were repaved in 2011. A single steel beam guiderail is typically present on the approach roads in the vicinity of the bridge. The northwest and southwest guiderails adjacent to the southbound roadway are equipped with an extruder end treatment (Photos 299 and 300); there is no hazard marker or paint marking on the northwest extruder facing the on-coming traffic. Minor dents and leaning posts from vehicular impacts were noted on the south approach guiderail near the southwest barrier gate (Photo 301).

The approach sidewalks are generally in fair to good condition. The concrete sidewalk is generally lightly scaled with a few isolated narrow and medium cracks. Wide fracture cracks were noted on the south approach sidewalk in the vicinity of the impact damaged guiderail posts (Photo 301).

2.4.4 Approach Walkways and Stairs

A concrete staircase, linking the sidewalk at the street level to pathway below the approach spans of the bridge, is present at the northwest and southwest approaches (Photos 302 and 303). There are galvanized steel railings and bike trays on the stairs. A concrete retaining wall is present on the lower section of the southwest stairs (north and south sides, Photo 304). The concrete stairs and the retaining walls are in fair to good condition. There are a few small areas of spalled concrete on the concrete stairs (Photo 305). There were no significant defects noted on the steel railings and bike trays at both stairs. Isolated wide cracks with leakage was noted on the concrete wall below the lower section of the southwest concrete stairs (Photo 306).

2.5 FALL ARREST SYSTEMS

All inspectors at the time of inspection had completed the "Working at Heights Training" requirement as per the Occupational Health and Safety Awareness and Training Regulation.

All fall protection system items (harnesses and lanyards) were inspected prior to use and were found to be in good working conditions. The fall arrest system which consists of Lad-Saf systems on the tower ladders, safety gates in the towers, D-Plate anchorages at each ladder access, horizontal (Sur Rail) systems across the bridge, and self-retracting lifelines were visually inspected prior to use. The fall arrest system was found to be in good working condition with no evidence of cracks or fatigue failure.

Appendix A6, included in the appendices has been provided by PWGSC, as per request.

3.0 MECHANICAL INSPECTION

3.1 INSPECTION FINDINGS

The following sections of this report provide: identification of the primary machinery systems and an explanation of the scope of work at each system, a brief description of each mechanical system, documentation and discussion of the conditions found at each system, conclusions summarizing the current condition of the mechanical systems and recommendations for repairs.

Figures of the span drive machinery and span lock machinery are presented in Appendix B1.

Span drive bearing and gear measurement tables are presented in Appendix B2

Color photographs were taken of mechanical conditions of interest during the inspection. Color copies of the photographs with detailed captions are presented in Appendix B3.

A SKF report summarizing vibration testing at the main counterweight support bearings is presented in Appendix B4.

Oil samples were taken from several enclosed reducers to be analyzed for indications of wear or contaminants. Oil analysis reports are included in Appendix B5.

Where appropriate, inspection findings shall be referenced to the Canadian Highway Bridge Design Code CAN/CSA-S6-14, Section 13, which shall hereafter be designated CHBDC.

3.1.1 Span Drive Machinery

The movable span is a tower drive vertical lift span with independent span drive machinery located at the top of each tower. The machinery at each tower is the same with the exception of specific electrical control equipment that is only located at the south tower.

The span drive machinery in each tower is driven by two electric motors. Each motor is coupled to an input shaft of the enclosed gear reducer via brake wheel couplings that are provided for the machinery brake mounted between each motor and reducer input. A motor brake wheel is mounted on the non-driven end of each motor for a total of four brakes associated with each span drive. The output shafts of the reducer are coupled to transverse shafts that extend east and west to second reduction open gearsets that contain open bevel gear differentials. At each corner the differential provides load sharing between the two pinions that engage spur ring gears that are mounted to each of two counterweight sheaves. Rotation of the motor causes the sheaves to rotate and results in the bridge raising or lowering. Skew control is provided electrically.

Auxiliary span drive machinery is provided in the event of a failure of the high speed main span drive machinery. The auxiliary span drive machinery is comprised of an electric motor face mounted directly to a single input shaft at the opposite end of each reducer. A spline coupling internal to the reducer is used to engage the auxiliary drive.

Figures 1 and 2, Appendix B1 are schematics of the span drive machinery. Figure 3, Appendix B1 is a schematic of the span lock machinery. The nomenclature used in this report is consistent with the component identification used in Figures 1, 2, and 3.

3.1.1.1 Bearings

The span drive machinery at each tower has 12 bearings, not including the bearings that are associated with the differential and the drives for the electrical control equipment. All of the bearings are sleeve type pillow block type bearings with bronze bushings. All of the bearings are grease lubricated.

Clearances were measured at 8 of the 12 bearings in each tower. The four B2 bearings were not accessible for clearance measurements. Measuring clearance is used to identify and track bearing bushing wear. Excessive or unusual wear are signs of machinery being overloaded or not operating as designed. Prior to taking clearance measurements, the brakes were released in an attempt to remove residual torque in the system. Ideal alignment criterion is for uniform clearance across the width of the bearing at the location of maximum clearance. Table 1, Appendix B2 documents the bearing clearance measurements that were taken during this inspection.

The bearing clearances were used to evaluate wear and to compare to the maximum clearances for an RC6 and an RC9 fit (per CSA Standard B97.3). An RC6 fit is the specified fit for a new bearing installation per CHBDC section 13.7.5. An RC9 fit is the threshold clearance that is our basis for adjusting bearing clearances by removing liners to compensate for wear or replacing the worn bushings. The clearance at 6 of the 16 measured bearings is within the limits of an RC6 fit. All of the remaining measured bearing clearances are well within the limits of an RC9 fit. The current clearance measurements were compared to previous measurements recorded by SBE, dating back to 2004. There were no significant increases in the measured clearances indicating that minimal wear has occurred over the past 14 years. There are multiple bearings which had reduced clearances compared to prior measurements. These may be attributable to different loading in the shafts or changes to the bearing cap bolt tensions and are not indicative of a problem.

Bearing alignment was determined through the use of feeler gage measurements. The alignment measured is generally good. Bearing alignment is commonly specified to be within 0.0005”/inch for a new installation. The alignment at 12 of the 16 measured bearings is within this limit and is considered good. A maximum taper of 0.0007”/inch was found at bearing B4-SE. While 4 of the 24 measured bearings exhibit misalignment that are at or exceed our recommended installation limit, the taper is not large enough to warrant corrective action.

All of the bearings were in good external condition. Lubrication at each of the bearings was found to be recent and adequate.

Each bearing mounting bolt and bushing flange bolt was checked and found to be tight.

As has been historically noted, there is typically a poor fit between the sides of the bearing caps and the bases. In some cases, whole or partial shims have been installed in the gaps. Each of the bearings was inspected closely for evidence of relative movement between the bearing cap and the base. Where accessible, the bearings were also checked during operation for movement. There was no evidence of movement at any of the bearings.

3.1.1.2 Brakes

There are four brakes for the span drive machinery in each tower, including two previously used machinery brakes and two new motor brakes. The motor brakes have been installed as part of the recent motor and control upgrades and the machinery brakes are relatively new but have been in service for at least ten years. All of the brake assemblies are in as-new condition. The brake wheel for each machinery brake is installed as part of a brake wheel coupling at the driven end of each motor. See Photo M1, Appendix B3. The brake wheel for each motor brake is mounted on the non-driven end of a span drive motor. See Photo M2, Appendix B3. See Figures 1 and 2 in Appendix B3.

All brakes are thrustor released, spring set, shoe-type brakes. The motor brakes are 15 inch diameter and set to provide 475 ft. lb. of torque. The machinery brakes are 19 inch diameter and are set to provide 950 ft. lb. of torque. The brakes are released when power is applied to the thrustor and spring set when power is removed from the thrustor.

The brakes were inspected to verify proper functionality of the thrustor and release mechanism, the condition of the brake wheel and shoes, and proper contact between the shoes and wheel to provide braking torque. All of the brakes were found in good condition. The oil level was acceptable in all thrustors, all thrustors had sufficient reserve stroke to allow for lining wear, linings were 3/8 inch thick at all brakes (for reference, new lining thickness is 3/8 inch), all hand release mechanisms were functional, all limit switches were mechanically functional and the assemblies were in good condition with no significant corrosion. In addition, the time delays for machinery and motor brake setting are appropriately staggered to minimize impact loads on the machinery during brake setting. The friction surfaces of the brake wheels were generally well polished with the exception of the SE and SW motor brake wheels, which had areas of paint. See Photo M3, Appendix B3. The friction surface should remain unpainted to allow the brake shoes to provide proper braking torque. The paint condition for each brake assembly was fair with areas that were poor and starting to corroded or unpainted. The brake wheel hubs and mounting bolts were unpainted for the all brakes. See Photo M2, Appendix B3.

With the brakes released, clearance was verified between the shoes and brake wheel. With the brakes set, contact was evaluated between the shoes and brake wheel. There are intermittent gaps between the brake shoes and the brake wheels, though the contact was greater than the minimum 60% recommended by the brake wheel manufacturer.

3.1.1.3 Couplings

Each span drive assembly includes six couplings, excluding those associated with the drives for the electrical control equipment. The motor shafts are coupled to the reducer input shafts using grid type brake wheel couplings (C3) that also support the machinery brake wheels. The two output shafts of the reducer are coupled to floating shafts using single engagement gear couplings (C2). These floating shafts are then coupled to the P2 pinion shafts using another set of single engagement gear couplings (C1). See Figures 1 and2, Appendix B1.

All of the couplings were inspected externally for lubrication leakage or signs of distress. All flange bolts were checked for looseness, which is critical since the bolts are responsible for transmitting torque. None of the couplings were opened for internal inspection. There is no significant lubricant leakage at any of the couplings. The external condition of the couplings was fair. All coupling assemblies were unpainted. Light corrosion was forming on all C1 and C2 couplings. Photo M4, Appendix B3. The coupling assemblies should be painted to prevent corrosion. See Photo M1, Appendix B3.

3.1.1.4 Motors

There are three motors associated with each span drive. A new auxiliary drive motor and two new span drive motors were installed as part of the recent rehabilitation. The auxiliary motor is face mounted to the auxiliary drive shaft of the reducer. The auxiliary motors were not operated during the inspection.

The motors appeared to be in good mechanical condition. All of the mounting bolts were checked for tightness and the span drive motors were observed during operation with no issues noted. The paint condition was poor. The mounting bolts and support anchor bolts were unpainted and there was light corrosion forming. The shims and top of the support for the south motors were also unpainted with light corrosion. See Photo M5, Appendix B3.

3.1.1.5 Open Gearing

There are six open spur gearsets associated with each span drive. Each G2 gear is provided with an open bevel differential (equalizer) that is not included in the gearset count. In the recent rehabilitation, the G3 high speed gearsets were replaced with enclosed reducers.

Several teeth from each gear were cleaned to bare to inspect the condition of each gear. The selected teeth on all open gearsets were in the accelerating zone where the highest loading is experienced during operation. Gear teeth thickness measurements were also taken at this location to record the level of wear at each gear. Tables 2 and 3, Appendix B2, document the gear tooth measurements performed as part of this inspection. See Photo M6, Appendix B3. Each open gearset was witnessed during operation, with no abnormal noises noted.

Measured tooth thickness was subtracted from the theoretical tooth thickness to determine wear. The wear on the measured teeth varied from a maximum of 4.6% of the theoretical maximum original tooth thickness at gears G2-NE and R1-NW-IB, to 1.5% at three different gears. This amount of wear is small and indicates that the teeth are properly sized for the imposed load. As expected based on the wear measurements, there was only light plastic flow on the gear teeth. The current tooth thickness measurements were compared to previous measurements recorded by SBE. There were no significant changes in the measured tooth thicknesses indicating that negligible wear has occurred in the 13-year span over which the measurements were taken.

Based on the cleaned surfaces of the gear teeth and the contact patterns in the gear lubrication, the gear tooth contact was generally good on the opening face of the inspected gear teeth. The contact on the closing face of the gear teeth varied from good to poor. The poor contact on the closing face is primarily due to the fact that the inspected gear teeth are lightly loaded during closing and have experienced negligible wear. This is typical for vertical lift bridges that are maintained in a span heavy condition. Light abrasive wear was present on the majority of gear teeth and is typical for open gearing.

The 2003 inspection report documented a problem with debris entrapment in the G1/P1 gearsets for the north tower stemming from power tool cleaning of the sheave grooves circa February 2003. Removal of the metal wires was an ongoing issue for years following the contamination, however no wires were found in the gear mesh during this inspection. All areas of prior gear tooth damage due to wire intrusion appeared to be wearing in and decreasing in significance. See Photo M7, Appendix B3.

The previously noted damage at the tip of the G1/P1-SE-OB gearset has been repaired by removing damaged areas of the tooth. The repair to the teeth has mitigated rough edges, effectively correcting the damaged areas, and does not negatively impact gear operation.

The differential gears were in good condition with good contact and minimal wear. There was corrosion on some differential gear teeth due to inadequate lubrication. See Photo M8, Appendix B3. The thrust clearance at the differential gearsets are similar at all locations and no movement of the bearings for the differential pinions was noted during the current inspection. However, many of the components are not accessible for inspection. No corrective action is required at this time to maintain the integrity of the components, however in-depth inspection should be considered to evaluate the internal components for condition and wear based on long term planning for the structure. There is not timeframe recommended for the in-depth inspection consideration.

There is an accumulation of old lubricant within the support frame under each G2 gear. There is a risk of lubricant contamination as the gear passes through the old lubricant during operation. See Photo M9, Appendix B3.

3.1.1.6 Reducer

The new reducer, installed as part of the recent rehabilitation project, has two main input shafts, two output shafts, and a single auxiliary drive input shaft. The gearing and bearings are oil lubricated and the shaft seals are grease lubricated. The span drive machinery drive train is single reduction with a 6.2382:1 ratio. The span drive machinery internal gearing is separated into two independent drive paths. The separate drive paths are normally locked together preventing any differential movement between the east and west halves of the drive train. To index the east and west halves, a spline can be disengaged to rotate the east half of the machinery relative to the west half of the machinery. The auxiliary drive internal gearing is a triple reduction with a 153.007:1 ratio with a singular drive path that can be engaged via a spline inside the reducer housing.

The overall condition of each reducer is good. The inspection covers were removed to inspect the condition of the internal gears. All of the gears were found to be in good condition, with the north tower reducer gears exhibiting full face contact with no evidence of wear or damage. The south reducer gear teeth exhibit full face contact, but some teeth have minor damage that may be from particles passing through the mesh. The visible indications did not have any depth and do not warrant a concern. See Photos M10 and M11, Appendix B3.

Each reducer auxiliary drive engagement lever is secured in position with a threaded positioning bolt. The bolt is threaded through the lever. The south reducer auxiliary drive positioning bolt could not be rotated and the threads through the lever arm appear to be damaged. See Photo M12, Appendix B3. This damage prevented the south auxiliary drive from being engaged. The north reducer auxiliary drive engaged properly.

Both the north and south reducers have multiple inspection cover screws with damaged threads. See Photo M13, Appendix B3.

The mounting bolts and support anchor bolts for both reducers are not painted. See Photo M12, Appendix B3.

The north reducer had evidence of two small oil leaks, one at the drain valve, see Photo M14, Appendix B3 and one at the north index spline lower limit switch plate bolts, see Photo M15, Appendix B3. The leaks were reported to have been addressed since the inspection by contractor personnel as part of the rehabilitation project.

An oil sample was taken from each reducer during the inspection and sent for analysis. The oil sample reports are included in Appendix B5. The south reducer lubricant was found to be in good condition with normal wear particles present. The north reducer was found to have small ferrous rubbing wear particles with wear particles noted as normal and is in good condition.

3.1.1.7 Shafts

There are two transverse shafts associated with each span drive. The shafts were re-used during the recent rehabilitation and are in good condition. No cracks or distortion was noted in the keyway areas.

3.1.1.8 Speed Control and Span Position Indicating Equipment

Two encoders are motor drive shaft driven. The encoders provide feedback for drive speed control and also provide inputs to the PLC for span position control. Span position indicating and skew control equipment is bevel gear driven off the end of the east outboard P1 pinion shaft in each tower.

No mechanical issues were noted at the speed control and span position indicating equipment.

3.1.1.9 Span Drive Operation

The span was operated numerous times throughout the course of the inspection with no operational issues. Maintenance personnel did not report any reliability issues related to the mechanical operating machinery since the previous inspection.

3.1.1.10 Auxiliary Span Drive Machinery

The new auxiliary drive, installed as part of the recent rehabilitation project, consists of a 20hp, 1800rpm motor with an integral solenoid actuated brake mounted to the non-driven end of the motor. The motor is face mounted to each reducer auxiliary drive input shaft. The south auxiliary drive engagement lever was unable to be tested due to a damaged positioning bolt. The north auxiliary drive was engaged with no issues. See Photo M12, Appendix B3. Both auxiliary motor brakes were verified to provide torque when set and were free when released with no issues noted.

3.1.2 Span Support Systems

Each end of the lift span and one of the main counterweights is supported by eight trunnion bearings in each tower. Two trunnion bearings straddle mount each of the main counterweight sheaves. Each main sheave has 10 grooves for the wire ropes used to connect the span to the main counterweight. An auxiliary counterweight system is provided to compensate for the transfer of the weight of the counterweight ropes from the movable span side of the main sheaves to the counterweight side as the span is raised.

When the lift span is seated, the live load and imbalance is carried by the live load supports. There are two rocker supports located at the north end of the span to allow for thermal expansion of the span. Two saddle supports are provided at the south end of the bridge that serve to locate the span longitudinally when the span is seated.

A span air buffer is provided at each corner of the lift span to assist with seating. Two tower air buffers are provided per tower to assist in stopping the span at the full open position.

Guides are provided for the lift span, main counterweights, and auxiliary counterweights.

3.1.2.1 Main and Auxiliary Counterweight Ropes

All main counterweight ropes were replaced circa February 2003. A visual inspection of the main and auxiliary counterweight ropes was performed during the current inspection. This main counterweight rope inspection focused on those areas most prone to wear including those portions of the ropes that are in contact with the sheaves with the bridge in the seated position.

The main counterweight ropes are generally in fair condition with corrosion in spots. The ropes have light wear with the exception of the portions of the ropes that come into contact with lift span splay castings, where moderate wear was noted. During the 2016 inspection, these areas were inspected thoroughly and were found to not have exhibited appreciable wear since the 2009 inspection. There was light fretting evident at the lift span splay castings. See Photo M19, Appendix B3.

The lubrication of the main counterweight ropes was found to be satisfactory at the time of the inspection, with the exception of the crowns of the wires which contact the sheave grooves and isolated areas where the ropes contact the splay castings. See Photo M16, Appendix B3. The contacting crowns of the wires had inadequate lubricant and exhibited surface corrosion on the running length of rope. See Photo M17, Appendix B3. Maintenance personnel indicated in the 2016 inspection that the application of lubricant to the main counterweight ropes remains an on-going concern due to the fact that the established method of applying lubricant results in some degree of environmental contamination, which is prohibited by Canadian law. It can be expected that the wire ropes will corrode and wear at an accelerated rate if they are not properly lubricated.

The main counterweight ropes experience wear on the running length of rope due to contact between the ropes and sheave during operation. The wear is apparent in the form of elliptical flats on the crowns of the wires. See Figure 5, Appendix B1. Typically ropes experience the greatest wear at the portion of rope which contacts the span side tangent point of the sheave when the span is seated. The largest wear flats observed along the running length of the ropes was approximately 5/8”. See Photo M18, Appendix B3. Based on a table taken from the Roebling Wire Rope Handbook, the measured wear equated to a reduction of rope capacity of approximately 5% (95% remaining strength), which is not a significant concern. See Figure 6, Appendix B1.

There is a noted problem with the size and/or location of the splay castings at the lift girder such that the counterweight ropes are generally not well seated in the lift span splay casting grooves. This condition predates the 2003 rope replacement and can likely be attributed to original construction. As a result of this issue, the center pair of ropes do not bear firmly on the splay castings and tend to oscillate under wind load resulting in wear of the ropes. Maintenance has mitigated the oscillation of the center pair of ropes through the installation of a U-bolt to pull the ropes into contact with the splay casting grooves. The other ropes in the group are more securely seated, but the splay casting grooves appear to be offset from the ropes resulting in side loading. The U-bolts were not removed during the current inspection. The U-bolts were removed the 2016 inspection and it was found that the ropes had not deteriorated significantly since the 2009 inspection.

Continued use of the of the U-bolt clamps is recommended to secure the rope against the splay casting and prevent the formation of the elliptical wear flats. However, the area where the clamp contacts the rope prevents wire rope dressing from reaching the rope. Annual removal of the clamps and dressing the ropes underneath the clamps is important to ensure proper lubrication at these locations. Upon assembly of the clamps, ensure that the U-bolt clamp bolts do not contact the outer strands of the wire rope.

At the northwest outboard lift girder splay casting for the main counterweight ropes, the middle nut is not fully seated. See Photo M19, Appendix B3.

It is recommended that a complete in-depth inspection of the main counterweight ropes, including the counterweight and lift span connections, be performed on a five-year cycle.

The auxiliary counterweight ropes were found to be in fair condition with moderate wear and with inadequate lubrication. The north auxiliary ropes have built up old lubricant and should be cleaned and re-lubricated. See Photo M20, Appendix B3. The south auxiliary counterweight ropes and sheaves are devoid of lubricant. The ropes and sheave grooves are corroded and the metal-on-metal contract results in fretting and noise during operation. Without lubrication, the south auxiliary counterweight ropes will wear at an accelerated rate. See Photo M21, Appendix B3.

The south auxiliary counterweight ropes, which have been in service for approximately five years, were found to have minimal damage or wear. At the north auxiliary counterweight ropes, no broken wires were found and the maximum wear flats were measured to be 7/16". See Figure 6, Appendix B1. This amount of wear is an increase from the previous inspection and represents a capacity reduction of approximately 17%. This degree of wear is normal considering the length of time the ropes have been in service (approximately 23 years). Consideration should be given to replacing these ropes within a five-year time frame and an in-depth inspection be performed within two years to evaluate the auxiliary counterweight ropes for deterioration underneath the old lubricant and any further reduction in strength. If the in-depth inspection reveals a deterioration in the condition of the north auxiliary counterweight ropes or broken wires, replacement sooner may be warranted.

3.1.2.2 Main and Auxiliary Counterweight Sheaves

The main counterweight sheaves continuously support the dead weight of the span and counterweights and experience cyclical loading during operation. The inspection of the main counterweight sheaves included a careful visual inspection to evaluate the integrity of the castings and an evaluation of the wire rope grooves.

The main counterweight sheave castings are generally in fair condition with no cracks found, though there is widespread paint deterioration and light corrosion. See Photo M22, Appendix B3. Significant section loss that would compromise the sheaves was not noted, though the deteriorating paint and corrosion may obscure more significant issues such as cracking. It is recommended that the sheaves be cleaned and painted.

The counterweight sheave grooves are devoid of lubricant and exhibit surface corrosion. See Photo M23, Appendix B3. It is recommended that the sheave grooves be lubricated as part of routine maintenance. A small portion of a groove from a representative number of sheaves was cleaned to bare metal to evaluate the condition. The grooves were generally in good condition with light impressions or indentations from the crowns of the wires. The indentations have not increased in severity since 2009 and are not currently problematic, but should be monitored as part of future inspections.

The sheave grooves were spot checked for proper radius with a groove gage. As depicted in Figure 4, Appendix B1, the groove gage should seat in the root of a properly sized groove, whereas clearance between the gage and the root of the groove indicates an undersized and/or worn groove.

The check of the grooves found that the gage did not seat properly in the grooves: contact occurs along the sides of the groove while clearance exists at the root, which is an indication of sheave groove wear. This condition was noted in the 2009 wire rope inspection report and the wear has not significantly increased. The Roebling Wire Rope

Handbook and other respected rope authorities suggest that groove wear in excess of the gage tolerance is basis for replacement or re-machining of sheave grooves on the basis that new ropes operating in undersized grooves will result in accelerated wear due to heightened abrasion of the internal wires and strands which are forced into the smaller grooves. Therefore, a prudent action to maximize rope life is to ensure that the ropes remain well lubricated to mitigate abrasive wear. Additionally, the ropes should continue to be monitored as part of future inspections for wire breakage, accelerated wear, and/or distortion.

The auxiliary counterweight sheaves are in fair condition. As noted during previous inspections, there is a heavy buildup of old lubricant in the north sheaves' rope grooves. See Photo M20, Appendix B3. The lube build-up causes pinching and wear on the sides of the wire ropes. The rope grooves at both north auxiliary counterweight sheaves should be thoroughly cleaned. Minor paint deterioration and corrosion was noted at the south auxiliary counterweight sheaves.

3.1.2.3 Auxiliary Counterweights

The auxiliary counterweights are in fair condition with no issues noted during operation. The assemblies have areas of paint deterioration and light corrosion on the counterweight blocks and the counterweight frames. See Photo M24, Appendix B3. There was corrosion noted on the bolts on the bottom of the SW counterweight. Areas with corrosion should be cleaned and painted.

3.1.2.4 Trunnion and Trunnion Bearings

There are eight trunnion bearings at the top of each tower. The bearings are pillow block mounted roller bearings manufactured by SKF. All of the bearings are grease lubricated.

As in past inspections, NDT of the bearings was performed by SKF. SKF has developed vibration analysis technology for bearings of this type that is non-invasive. According to SKF, it can be used to accurately predict bearing failures by examining the high frequency vibrations and Spectrally Emitted Energy (SEE®) that occur within the bearing during operation. This inspection method is preferable to visual inspection through partial disassembly of the bearing since it eliminates the risk of contamination of the bearing, which is one of the greatest risks to the reliability of roller bearings. SKF's report is presented in Appendix B4.

Periodic impacts, indicative of a possible race fault, were recorded at the SE-IB trunnion, outboard bearing (Bearing #3, South Tower) and the outboard bearing for the SW-OB trunnion (Bearing #8, South Tower). The indications at Bearing #3 were not noted during prior inspections. The findings at Bearing #8 are consistent with the 2015 and 2016 vibration testing. SKF recommends a visual inspection of the bearing raceways to confirm if damage to the raceway exists and to evaluate the severity. Based on these findings, the periodic vibration analysis should be continued and also performed as part of the visual inspection.

In the north tower, at the NW-IB trunnion, inboard and outboard bearings (Bearings #5 and #6, North Tower) impacts were recorded at a frequency that are not related to the bearing, continued periodic non-destructive vibration testing is recommended at these locations to evaluate the impacts recorded.

All of the bearings were found in good condition externally. The bearings are generally well-painted though there are isolated spots of corrosion on some mounting bolts. The level of corrosion is not significant, though consideration should be given to painting the area to prevent further deterioration.

The visible portions of the trunnions are in fair condition with no issues noted. Fatigue cracking at the trunnions is sometimes a concern for vertical lift bridges. Calculations performed as part of the 2012 inspection demonstrated that the trunnions have an infinite fatigue life (i.e., the calculations show that the stresses are low relative to the material endurance limit and that fatigue cracking is not expected). However, given the critical nature of this support, it is important to inspect the high stress fillet areas of the trunnions for cracks. No issues were noted as part of this current inspection.

3.1.2.5 Live Load Supports

All live load supports were in fair condition. The anchor bolts for all live load supports were lightly corroded. There are areas of section loss on some anchor bolts at the both ends of the lift span. See Photo M25, Appendix B3. It is recommended that the assemblies be cleaned and painted. At the time of this inspection both rockers were found to rotate freely. The live load supports were observed under traffic loading for movement. No movement was noted under live loads.

3.1.3 Guides and Centering Devices

The lift span is provided with upper and lower guide rollers at each corner to maintain the position of the span during operation. Both longitudinal and transverse rollers are provided at the south (fixed) end of the span at the lower location. The other six locations only have transverse guide rollers. The rollers engage guide rails mounted to the towers.

Each counterweight has an upper and lower guide at each end (east and west). The main counterweight guides are u-shaped steel castings that travel along guide rails mounted to the tower to prevent the counterweight from swinging during span travel. The auxiliary counterweight guides are grooved wheels located at each corner of each counterweight that travel along guide rails mounted to the towers.

In addition to the span and counterweight guides, span centering devices are provided at each end of the lift span to locate the bridge in the transverse direction when the lift span is in the seated position.

3.1.3.1 Span Guides

The span guides and guide rails were visually inspected and found to be in fair condition. The bearings for the rollers are inaccessible for clearance measurements, though all of the rollers were rotated by hand or were observed to rotate during operation.

There is evidence of previous hard contact at multiple locations, based on wear and fins on the rollers and guide rails. The evidence of hard contact appears to be from an old operating condition as there was no evidence of recent hard contact at the rollers during operation at the time of this inspection.

3.1.3.2 Main and Auxiliary Counterweight Guides

The main counterweight guides and guide rails were visually inspected and found to be in fair condition. The guides and rails were witnessed for contact and wear during operation for the full length of the rail at each location. Contact of the guides with the rail was intermittent throughout operation and the rails and guides did not exhibit excessive wear that would affect the ability of the guides to restrain the counterweight. The main counterweight guide mounting bolts that secure it to the counterweight were covered with lubrication and were inaccessible. The lubrication should be removed to facilitate inspection of the bolts.

All of the auxiliary counterweight guide system components were in good condition. Significant portions of the rails are lightly corroded, though this has not caused operational problems of the guides and no corrective action is recommended.

3.1.3.3 Centering Devices

A span centering device is provided at each end of the lift span. The device consists of a socket mounted on the bridge and a tongue located on the pier. As the bridge approaches the fully seated position the socket engages the tongue and centers the bridge in the transverse direction. Wear plates are provided on the west and east sides of the tongue. Loose fasteners have been noted at these wear plates in past inspections. As a result, maintenance personnel periodically check and tighten the fasteners. At the time of the inspection, several loose fasteners were found; these were tightened at the time of the inspection.

Lubrication at the centering devices was adequate at the time of the inspection. In past inspections, it has been noted that contact at the centering device has shifted the lift span. During the current inspection movement of the span was not noted, though the pattern in the grease provides an indication that there is periodic contact at the centering devices.

There is minor debris accumulation on the support for the centering device tongues which are mounted to the piers. There is also paint deterioration and section loss of the anchor bolts. See Photo M26, Appendix B3. It is recommended that these components be cleaned and painted.

3.1.3.4 Span Air Buffers

The span air buffers are in fair condition overall. The most significant concern regarding the buffers is the possibility of internal damage due to blast intrusion from painting of the splash zone of the lift span during the 2010/2011 winter closures. During the current inspection, all of the buffers descended consistently during span operations. Maintenance has continued the effort to flush oil through the buffers resulting in a more reliable buffer operation over the past year. Continued lubricating efforts are required to maintain operability. Disassembly of the buffers would be recommended to properly clean the interior and inspect for damage however this work may be difficult to accomplish given their removal may require some modifications to the lift span structural steel.

As in past inspections, pressure gages were installed to monitor the pressure developed in each buffer during seating for a normal opening of the span, as a way to determine the effectiveness of the buffers. The recorded pressures are provided in the following table:

Corner ID	Pressure During Seating
SW	20 PSI
SE	20 PSI
NW	12 PSI
NE	10 PSI

The pressures are similar in magnitude to the pressures measured during past inspections. The similarity in operating pressures over several inspections is a good indication that the current maintenance efforts are successfully preserving the functionality of the buffers.

The northwest buffer exhaust valve handle is broken, though it can still be turned with an adjustable wrench or pliers. See Photo M27, Appendix B3.

The lower guide bushing clearances were measured as part of this current inspection. All four bushing clearances were found to be in excess of an ANSI RC9 fit. These bushings should be replaced to restore an RC6 fit if the span buffers are rehabilitated.

Note that the two span buffers at a given end operate independently. It is preferable to install piping to connect the two so that a transverse differential in load provided by the buffers is not possible. The air piping system should include a pressure gage that can be connected via a gate valve to periodically verify the pressure that is developed in the system during seating.

Consideration may be given to Article 13.7.11 of the CHBDC, which notes that a control system that is "capable of performing smooth seating in a positive manner" and "capable of limiting the span lift in a positive manner" may be used in lieu of air buffers. The contract for the replacement of the control system is in progress and the new control system has the capabilities as described in the CHBDC. If desired, consideration may be given to removing the buffers from service following the successful commissioning of the new control system.

If the continued use of air buffers is desired and they are to be retained long term, then consideration should be given to rehabilitating the buffers to ensure that they function as intended. The rehabilitation should include re-boring the buffers, re-bushing them, and piping the two buffers at a given end together to assist in load sharing in the event of their use.

3.1.3.4 Tower Air Buffers

The air buffers that are mounted to the towers are in fair condition externally with minor paint deterioration and corrosion and with some minor debris accumulation. At the northwest buffer, the span side mounting bolts are not painted and are corroded.

Maintenance personnel regularly clean the exposed piston rods, lubricate and rotate the pistons. All buffers functioned satisfactorily during the inspection: the rods descend when lowering from full open and the exhaust and check valves appear to be functional. It is recommended that air filters be installed on the inlet of each tower buffer in order to prevent the ingress of foreign material into the cylinder.

Consideration may be given to Article 13.7.11 of the CHBDC, which notes that a control system that is "capable of performing smooth seating in a positive manner" and "capable of limiting the span lift in a positive manner" may be used in lieu of air buffers. The contract for the replacement of the control system is in progress and the new control system has the capabilities as described in the CHBDC. If desired, consideration may be given to removing the buffers from service following the successful commissioning of the new control system.

If the continued use of air buffers is desired and they are to be retained long term, then consideration should be given to installing piping to connect the two tower buffers at each tower to assist in load sharing in the event of their use.

3.1.4 Span Lock Machinery

A span lock assembly is provided at each end of the bridge. See Figure 3, Appendix B1. Both span locks assemblies are in good condition overall and operated without incident during the inspection.

The painting of the machinery located inside the enclosure for the high-speed end of the lock machinery is incomplete. Several components, including shafts and bolts are not fully painted. There is some minor corrosion in spots, though generally the components are covered with a rust inhibitor. See Photo M28, Appendix B3. No additional corrective action is warranted so long as this coating of rust inhibitor is maintained.

Outside of the enclosure, the components are typically painted, however there were areas were the paint has failed and corrosion was present. The southeast and southwest span lock spring assemblies and bearing B2 mounting bolts were found to have moderate corrosion. See Photo M29, Appendix B3. The north span lock springs, center crank, and bearing B2 mounting bolts were found to have moderate corrosion. All span lock components should be spot-cleaned and painted where corrosion is present.

The lubrication for all of the span lock components, including bearings, gears and reducers, was good with proper lubrication procedures implemented by maintenance personnel. Oil samples were taken from both span lock reducers for analysis. During the 2015 inspection both span lock reducer oil samples analyses were provided with a wear designation as “Watch” given the level of wear particles. The oil sample analysis reports from the 2017 inspection are included in Appendix B5. The analyses from the current inspection show that there are no significant contaminants or wear particles that warrant corrective action. This is consistent with the oil sample analysis conducted in as part of the 2016 inspection. Although the oil analyses do not indicate a problem, the oil in the reducers has not been changed since installation. It is recommended that the oil be flushed and replaced. Consideration should be given to coordinating the oil selection with the selection of the oil for the span drive reducers.

3.1.5 Traffic Gate Machinery

There is a new single barrier gate at each approach to the lift span. There are two warning gates for each approach to the lift span. There are also two pedestrian warning gates, on at each sidewalk approach. All barrier and warning gates were replaced in the recent rehabilitation project.

3.1.5.1 Warning Gates

The warning gates were found in good condition with no significant issues noted.

3.1.5.2 Barrier Gates

The north bearing gate arm counterweights each have a bolt that is not fully seated at the east side of the counterweight. See Photo M30, Appendix B3.

Each barrier gate arm engages a receiver on the west side of the bridge in the lowered position. During operation, when the gate engages the receiver, the gate arm contacts the receiver with an impact that could result in damage to the gate arm. The impact was noted to be worse at the north barrier gate than at the south barrier gate.

3.1.5.3 Pedestrian Warning Gates

The pedestrian warning gates were found in good condition with no significant issues noted.

3.1.6 Generators

There are two generators provided for the facility. One main generator is provided to operate the span in the event of a power failure. A second, smaller facilities generator is provided to operate the facilities buildings in the event of a power failure. The generators were inspected mechanically for oil level, coolant level, leaks and condition of components.

The larger main generator was in good condition with one noted mechanical deficiency. A coolant hose exhibits dry rot and was starting to crack. See Photo M31, Appendix B3.

The smaller facilities generator was in good condition with no noted mechanical deficiencies. The generator fuel storage tanks are relatively new and are inspected and maintained as part of a separate maintenance contract.

3.1.7 Winter Shutdown

The bridge is normally available for opening 24/7 during the navigable channel operating season from mid-March thru December 31 each year. Over the winter shutdown maintenance personnel perform routine maintenance on the mechanical and electrical systems in accordance with existing operating and maintenance manual. During startup of the operational season, maintenance personnel perform routine maintenance tasks to ready the mechanical and electrical systems for the operational season.

4.0 ELECTRICAL INSPECTION

4.1 GENERAL DESCRIPTION

The electrical inspection was performed in accordance with the scope of work. Part of this inspection also included an evaluation of the recent rehabilitation which included a replacement of a major part of the electrical power and control system for the bridge over a three-year period. These replacements were concluded during 2017 and are still under warranty. This inspection included an evaluation of the replaced systems and an assessment of their reliability and appropriateness for their imposed duty.

The inspection consisted of a visual inspection that was sufficient in depth to determine the status of the bridge electrical power and control system and the adequacy of the system to perform its intended function. This included verification of the replacement systems to meet the operating criteria of the bridge and to flag any installed equipment and systems that are found to be deficient.

This inspection is the first independent assessment performed of the replaced electrical systems and their integration into the remaining bridge electrical systems.

The inspection work included:

- Information gathering and the review of gathered information in support of the inspection.
- Planning, scheduling of the inspection work with all parties and participation in a worker safety plan including necessary Health and Safety Plan preparation.
- Inspection of all newly installed control and power equipment associated with the bridge operating and auxiliary systems. This included a determination of the completeness and operating functionality of the newly installed control and power system and the status and life expectancy of the existing electric service equipment, its installation, and the inherent design features that enable the bridge to operate in a safe and reliable manner.
- Testing of the operating electrical systems to determine their condition, operating status and motor loadings with respect to motor ratings and bridge operating duty.
- The inspection was concluded with the submission of this report which defines the findings, provides conclusions, and makes recommendations of any actions necessary to meet operating reliability and safety requirements as well as adherence to all prevailing statutory codes and to ensure that the newly installed bridge electrical control and power system meets the specified design and operating criteria.

The electrical inspection and assessment describes all items of equipment defined in the Terms of Reference Electrical Inspection Table but has been arranged in the order of the inspection that begins with the incoming 13.8 kV electric utility service for the bridge.

4.2 MAIN ELECTRICAL SERVICE

The main electric service for the bridge is comprised of an existing 13.8kV, 3-phase, 60Hz utility service and a 1,000kVA ONAN outdoor transformer with necessary primary and secondary protective and switching devices to provide electric service to the bridge. The 1,000-kVA transformer is of the pad mounted type and forms part of a unit substation that provides 600 volt, 3-phase, Wye connected, 3-wire, solidly grounded service to the bridge. See Photo E2, Appendix C.

The bridge incoming electric service equipment consists of an existing indoor 2,000-amp switchboard. See Photo E3, Appendix C. This 2,000-amp switchboard was modified as part of the recently completed electrical replacements with the addition of:

- North Tower MCC 600-amp Feeder Breaker
- North Tower MCC Back-up 600-amp Feeder Breaker
- South Tower MCC 600-amp Feeder Breaker

A 600-kW emergency diesel generator provides backup standby operational power for the 2,000 Amp indoor switchboard and bridge operation. See Photo E4, Appendix C. The 600-kW generator is provided with an outdoor load bank that is used to exercise the generator under load and maintain its operational and reliable status as an emergency source of electric service for the bridge. Additionally, a 40kW diesel generator is provided in the same room as the 600-kW generator as a backup for bridge essential services. This 40-kW generator is not capable of operating the bridge. The main electric service, generator, load bank, and associated air circuit breakers are described on "As Built" documentation for the bridge as being mechanically and electrically interlocked for safety and capable of being operated from the main control desk (control house 3rd floor). There is no evidence in the switchboard to indicate that these breakers are or had ever been mechanically interlocked and this finding was reported as part of previous inspection reports. A "Kirk Key" interlock between these independent sources of power is an essential element for the safe operation of the bridge and a means of preventing a potentially catastrophic electrical system failure. This item, although included in previous inspection reports has never been addressed and was not included in the scope of the recent electrical rehabilitation work at the bridge.

The electric utility metering for the bridge is derived from the load side of the 2,000 Amp indoor switchboard main breaker and the emergency generators are not provided with any sort of metering to indicate consumption but are provided with an indication of hours run.

Corrective action is required to:

- Kirk key interlocks and electrical interlocks should be added between the Main and Generator circuit breakers to prevent simultaneous closure of these breakers and the possibility of paralleling the electric utility and standby generator.

4.2.1 Electrical Drawings

One-line electrical diagrams have been updated by the electrical contractor responsible for the bridge electrical replacements to reflect the new as-built condition and have been posted on the wall in the electrical room. The one-line diagrams were found at the following locations:

- Second Floor Electrical Room (posted)
- North Tower Machinery Space (ready but not posted)
- South Tower Machinery Space (ready but not posted)

The one-line diagrams indicate useful operational and troubleshooting information regarding the bridge power distribution system and service isolation.

Corrective action is required to:

- Properly affix the one-line diagrams in both North and South tower machinery spaces.

4.2.2 Protective Device Coordination Study Verification

A coordination study was completed as part of the recent control and power system replacements and upgrades at the bridge. This coordination study included the rehabilitated system and also the existing electric service, standby generators, and the existing 2,000 Amp switchboard.

It is considered that the protective relay devices and fuse ratings in the study are appropriate and that the recently prepared coordination study is accurate and a true reflection of the installed system it confirms that the bridge is provided with an appropriately coordinated electrical distribution system.

No corrective action is required at this time.

4.2.3 1,000-kVA Outdoor Transformer

The main transformer which is owned by Ontario Hydro has been in service since 1994. Maintenance and testing, which includes insulating oil testing for both dielectric properties and dissolved gas analysis, has been performed and logged by the Bridge Master on this device annually by the utility with no concerns noted.

The 1,000-kVA transformer is of the pad mounted type and forms part of a unit substation that provides the bridge with its 600-volt, 3-phase, solidly grounded, 3-wire service. The unit substation has been well installed and is considered to be appropriately sized for the prevailing bridge operating duty.

Phase	Phase to Phase Voltage (Volts)	Phase	Phase to Ground Voltage (Volts)
A-B	602V	A-G	346V
B-C	608V	B-G	351V
A-C	607V	C-G	351V

The bridge no-load voltages were recorded during daytime and are within +2% of the nominal system voltage. This is an indication that the bridge electrical service is properly sized and external standing loads are not adversely affecting the electric service to the bridge. It is concluded that the 1,000-kVA transformer tap settings are appropriate for maintaining the 600-volt nominal bridge voltage during times of maximum utility loads.

A previous report recommended taking alarm points to the operator's house to alert of high transformer temperature or low oil level. This recommendation has not been implemented. Given the proximity and criticality of this utility distribution transformer, as was described in the previous inspection report, it is considered that this proposed additional functionality would be beneficial to the reliability of the electric service and as a means of mitigating the possibility of a catastrophic oil spill. Note no oil containment has been provided in the event of a transformer tank rupture.

Corrective action is required to:

- Install high temperature and low oil level alarm devices for the main transformer to alarm at the control house.
- Consideration should be given to providing some form of oil containment to eliminate a potential environmental hazard in the event of a transformer tank rupture or oil spill.

4.2.4 Main Fused Disconnect

The main fused disconnect switch that provides the 600-volt, 3-phase service to the bridge is part of the electric service entrance equipment and located inside the outdoor tamperproof metal-clad 1,000 kVA transformer enclosure. This electric service entrance equipment was reported as receiving regular maintenance on an annual basis. The unit substation enclosure is provided with space heaters and these were verified as being operational during the inspection. The electric service main fused disconnect switch was not inspected due to the electric utility locked enclosure door.

No corrective action is required at this time.

4.2.5 600-KW and 40-KW Emergency Generators

The emergency generator equipment is located in the standby generator and electrical distribution room located in the Control House on the 1st floor. Two (2) diesel driven generators are located in this room:

- A 600-kW, 1800 RPM, 3-phase unit manufactured by Cummins that provides a backup source of power to operate the bridge in the event of electric utility failure. See Photo E4, Appendix C.
- A 40-kW, 1800 RPM, 3-phase unit manufactured by Perkins. This is defined as an auxiliary generator and is used to power facility loads in the event of electric utility failure. See Photo E5, Appendix C.

The Cummins 600-kW emergency generator was installed in 1994 as part of a rehabilitation and upgrade of the main electric service to the bridge. The Perkins 40-kW emergency generator was installed in 1996 and provides the bridge facility with essential back up power but is not capable or able to be connected to operate the bridge drive system.

Records indicate that PWGSC operators test the 600-kW unit on a monthly basis. This testing is performed under load with the use of the provided load bank to comply with CSA-C282-05, this testing as described also complies with CSA-C282-09 as the generator is a life safety item required to keep a building's essential services operational in an emergency. It is understood that monthly testing consists of both load bank testing as well as performing a number of bridge test lifts using the generator. A record of these monthly tests is documented and maintained at the operator's desk. The load bank disconnect switch has been replaced. Both the load bank and its disconnect switch are still in as-new condition. See Photos E8 and E9, Appendix C.

The Perkins 40-kW generator is tested weekly under load and a record is kept of the test results. Testing of both standby generators meets the requirements of CSA 28.2.5. The associated automatic transfer switch is in good serviceable condition. See Photo E6, Appendix C.

Per the operator and electrical maintenance contractor, both generator units are performing well and are both reliable sources of backup power under all bridge and bridge facility operating conditions.

The generator room has been well laid out and contains all necessary equipment and safety features for such a facility in accordance with CSA requirements. These include:

- Appropriate automatic louvers for ventilation and diesel air intake
- Thermostatically controlled ceiling mounted radiant heaters
- Fuel oil alarm panel
- Fuel oil pumps and fuel oil pump controls

- Eye wash station
- Emergency lighting
- Access control system

All generator room equipment is operational and has a record of receiving good and regular routine maintenance which ensures the reliable and safe operation of the generators in the long term with the exceptions noted below. Additionally, a new generator fuel tank and pump system was installed in 2012-2013. This fuel tank and pump system allows automatic refueling of the day tank from the main tank located within the control house compounded area. See Photo E7, Appendix C.

A concern regarding the Cummins 600-kW Diesel Generator, is that the automatic louvers are located over the battery chargers and alarm equipment. This could cause water damage to them when the louvers are opened during conditions of blowing rain.

Corrective action is required to:

- Protect the battery chargers and alarm equipment from adverse weather conditions when the louvers above them are opened.

4.2.6 Main Indoor Switchboard #1 and #2

The Main Indoor 2,000-Amp Switchboard #1 is located in the Control House on the 1st floor in the generator and electric distribution room and was installed in 1994. The switchboard is of the modular construction and provided complete with main and distribution circuit breakers and a ground alarm relay. All protective devices and ratings associated with the switchboard conform to those described in the recently completed coordination study that was part of the bridge power and control replacement project. It was reported by the bridge operators and the electrical maintenance contractor that operation of this switchboard has been continuous and without concern since its installation.

As observed during previous inspections, no phase loss or phase reversal protection is provided for the bridge electric service. A loss of a phase would not only make the bridge inoperable, but if left for a prolonged time could cause damage to the operating electrical equipment. A phase reversal of either the standby generator or the utility would cause motors to operate in reverse and lead to a catastrophic failure of some bridge operating motors. It is strongly recommended that phase loss/reversal protection be added to the main incoming breaker and that this addition be given priority.

Switchboard #2 is located in the Control House 2nd Floor and has been modified to power the new bridge electrical system. Note that additional feeder breakers were added to the switchboard as part of the recently completed bridge control and power replacement and upgrade project. Also note that the original motor feeder breaker which is no longer required has been disabled and locked out. The switchboard is configured as described in the recently completed coordination study that was part of the bridge power and control replacement project. See Photo E10, Appendix C.

Corrective action is required to:

- Add phase loss/phase reversal protective relaying for the incoming main breaker and generator.

4.3 BRIDGE DRIVE AND OPERATING SYSTEM

The originally installed bridge drive system consisted of a combined magnetic amplifier controlled saturable reactor and stepped rotor resistor speed control for the wound rotor drive motors. During 2013 through 2017 this bridge drive system was re-designed and installed as a replacement and upgraded drive system. The new system consists of the replacement of the existing wound rotor motors with squirrel cage induction motors and replacement of the legacy technology magnetic amplifier controlled saturable reactors and stepped rotor resistor speed control with variable frequency flux vector speed and torque-controlled drives.

4.3.1 Main Motors

The main drive motors are of the squirrel cage induction type. There are four main drive motors. See Photo E24, Appendix C. All main drive motors have similar electrical characteristics and only differ in the motor pecker head cable termination arrangement.

Each tower drive is provided with two (2) drive motors coupled in parallel. One main drive motor in each tower is used to operate the bridge with the second being used as back up. The duty and back up motor being an operator selection from the control desk in the operator’s house. The motors were installed during 2016 and 2017 and are part of the recently completed bridge power and control system replacement and upgrade project. The motors are 250 hp at 900 rpm synchronous speed motors at a frequency of 60Hz. The motors are being used, however, at 150 hp and at a maximum speed of 555 rpm. The variable frequency drives (VFD) are used to achieve the desired speed of 555 rpm by reducing the operating frequency to the motors to 37 Hz.

Note that tuning of the drives requires that the original design characteristics of the motor (250hp, 900 rpm, 60 Hz) be understood. It should be noted that the nameplate data on the motors does not truly reflect the characteristics of the motor and this was an impediment to the required tuning of the replacement drive/motor combinations during their commissioning.

Additionally, and due to the specified characteristics of the new motors, the motors have been installed with blowers to dissipate excessive heat generated during their operation.

A disconnect switch is provided for each drive motor in front of each motor for means of disconnecting them locally in accordance with the Canadian Electrical Code. See Photo E23, Appendix C.

All motors and their associated installation are in as-new condition. Note that the nameplate for the northeast motor blower has fallen off and needs to be re-affixed to the blower motor. See Photo E25, Appendix C.

Motor nameplate data was collected and was recorded as follows:

Specification	**Main Span Drive Motor**
Type:	Squirrel cage induction
Manufacturer:	REULAND
S.N.:	N-15-H0117B-1
Type:	A000
Frame:	449TZ
Enclosure:	A-TEFC
Insulation System:	HHH
Phase:	3
Hz:	37
Volts:	600 MAX
Amps:	150
Horsepower:	150
Duty:	30 MIN
Speed:	555 RPM

One new spare new motor provided as part of the replacement project is held at the bridge to be used in the event of a motor failure. Note that two different motor pecker head cable termination configurations have been specified for the newly installed motors and therefore this spare motor can only be used as a replacement motor for two of the four (4) main drive motors installed.

Corrective action is required to:

- Replace the existing motor nameplates with factual data of the motor characteristics based on 60 Hz standard and ensure that this same data is posted in each of the motor drive enclosures and in the O&M Manual for the motors. This data should be obtained from the motor manufacturer and approved by the Engineer of Record for the replacement project.
- Consider procuring an opposite hand spare motor to provide a replacement for each type of motor provided.
- Re-affix the blower nameplate on the northeast blower motor.

4.3.2 Auxiliary Motors

The bridge is provided with an auxiliary drive system. This auxiliary drive system was commissioned in early 2010 and modified as part of the recently replacement and upgrade work at the bridge. The modifications included replacing the auxiliary drive motor, its operating machinery and modify the existing AUX drive control panel so that the operator can operate both AUX drive motor from a single location. The auxiliary drive consists of a squirrel cage motor with a Stearns brake and is coupled to the new main span drive gear reducer. See Photo E26, Appendix C. An auxiliary drive engage/disengage operating lever is provided with control and interlock limit switches to indicate the position of the aux drive lever. The lever operates such that when auxiliary drive is engaged, the main drive system will be disabled. See Photo E27, Appendix C. The auxiliary drive is controlled from a reduced voltage starter mounted in freestanding NEMA1 enclosure and a pendent control station. Note that in the case of the South Tower a second pendent control station has been installed to enable operation of the auxiliary drive motors from this single location. See Photo E28, Appendix C.

Motor nameplate data was collected and was recorded as follows:

Specification	Auxiliary Drive Motor
Type:	Squirrel Cage Induction
Manufacturer:	REULAND
S.N.:	15-0563B-1
Type:	C0S0
Phase:	3
Hz:	60
Volts:	600 MAX
Amps:	18.4
Horsepower:	20
Speed:	1800 RPM

Frame:	284TZC
Style:	ACR

Brake nameplate data was collected and was recorded as follows:

Specification	**Auxiliary Drive Motor Brake**
Manufacturer:	Stearns
S.N.:	97017M001-2
Phase:	1
Hz:	60
Volts:	120
Amps:	1.2
Torque lb-ft:	125 Horizontal
Amp Inrush:	17.6

The auxiliary drive system was not operated as part of the 2017 inspection. Visual inspection yields no signs of significant deficiencies. Both the auxiliary drive controllers and the drive motor appear to be in as-new condition.

The auxiliary drive system can only be operated with independent control in each tower using radio communications between the towers and the bridge control house. The recent design included provisions for operation from a single location, the south tower. However, there are cabling issues with the recent design to the extent that the single location operation is not functional.

Corrective action is required to:

- Resolve the cabling issues and provide auxiliary drive operation from the south tower as per the scope of the rehabilitation design.

4.3.3 Span Brakes

Each tower drive system was provided with two (2) main drive machinery brakes, and two (2) motor brakes.

The new motor brakes and the two (2) existing machinery brakes in each tower are modern electro-hydraulic thrustor brakes. See Photo E24, Appendix C. All four brakes are presently operational and electrically in excellent serviceable condition. The brakes are capable of being hand released for maintenance and troubleshooting purposes and the control system has been configured such that the bridge is allowed to continue to operate with one failed brake in each tower machinery space hand released. The brakes are provided with three limit switches as per code:

- Brake released – permissive with drive controller
- Brake set – status indication
- Brake hand released – Interlock to prevent bridge operation with more than one brake hand released

Motor nameplate data was collected and was recorded as follows:

Specification	**Machinery Brakes**
Manufacturer:	Mondel Engineering
S.N.:	03/582992-4
Size:	19MST/E-ED80/12SH
Supply:	332/575/3/60HZ
Amps:	0.96
Torque:	950 lb-ft
Specification	**Motor Brakes**
Manufacturer:	EMC
S.N.:	393278-00031320
Size:	500 N
Duty:	60 min
Volt:	332/575 +/- 5%
Amps:	0.64/0.37
Frequency:	60
Power:	260 W

No corrective action is required at this time.

4.3.4 Main Motor Drives

As part of the recent replacements and upgrades to the bridge power and control system, the existing legacy technology motor drives (amplidyne/saturable reactor and switched rotor resistors) were replaced with variable frequency flux vector drives of Danfoss manufacture with dynamic braking resistors and encoder feedback. The drive and motor configuration in each tower is such that one drive and its motor combination is used as the duty drive system, while the second is used as back up. The control system is configured such that the duty and standby units can be manually or automatically switched by the bridge operator or PLC system. The drives provide both speed and torque control and utilize encoders connected to the motor shafts for speed feedback and shaft positional data. The drive control system provides both driving and dynamic braking torque over the full range of the bridge operational needs. The drives are configured for safe torque mode operation and, in conjunction with the mechanical brakes, provide torque proving of drive torque output prior to releasing them for bridge operation. See Photos E21 and E22, Appendix C.

The duty drives in each tower are kept synchronized with each other and their rotational position automatically matched through the high-speed counter in the bridge control PLC. This control function eliminates and corrects for span longitudinal skew. The drives are appropriately rated for normal and contingency operating duty of the bridge and accurately control speed and driving and braking torque in accordance with the requirements for bridge operation.

It was reported that during commissioning of the bridge that critical capacitor pre-charge fuses in the drives blew when the incoming 600-volt supply was interrupted and immediately followed by re-energization. This occurred when the main drive feeder breaker to the drives was opened and closed in rapid succession. This event left the bridge immobile for an extended period while the issue was diagnosed and replacement fuses found. This is considered a drive shortcoming and priority should be given to its resolution.

It was noted during the inspection that the south tower has a roof leak. White plastic covers have been placed over the top of the south drives/resistors to protect them. See Photo E73, Appendix C.

Corrective action is required to:

- It is critically important for the reliability of the operating bridge that the capacitor pre-charging fuse blowing issue resolution be given the highest priority. It is recommended that the drive control circuit be modified to provide a time delay in the pre-charge contactor circuit. This time delay to be such that following loss and restoration of power that the contactor is not re-energized immediately but waits until some pre-determined time has elapsed and hence avoid the current inrush that blows the fuses.
- Repair the roof leak in south tower.

4.3.5 Bridge Control System

The bridge control system was replaced as part of the bridge power and control system replacement project. The replacements included a form of PLC distributed control with PLC and remote I/O control panels installed at the following locations:

- Bridge Control House 2nd Floor (CP-2)
- Bridge Control House Operators Location 3rd Floor (HMI)
- South Tower Machinery Room (CP-3)
- North Tower Machinery Room (CP-4)
- South MCC (Ethernet Switch)
- North MCC (Ethernet Switch)

Communications for the distributed control system consists of a redundant fiber optic loop system in a ring configuration that incorporates the above control panels and the new main drive motor VFD's located in each tower machinery space. The communications system has been well installed and provides a redundant network for continued operation of the bridge in the event of a single fiber optic cable failure. It should be noted that although the network is setup in the ring topology and does provide the required redundancy, it does not allow for the possibility of turning off one drive in each tower at the same time, as it will break the ring at two locations. If this occurs, the bridge will not be operational due to this network communication error. Moreover, the bridge will be functional if one drive is powered down but the network will not have the redundancy of the ring setup. In both cases, it will require manual coupling of the network connections within the disabled drive cabinet to and return it to a functional state.

The PLC system consists of redundant CPU's with shared rack mounted I/O's but with no relay logic provided. Relay logic, if installed would provide back-up for operation of the bridge in the event of a PLC or communications failure. See Photo E11, Appendix C.

The replacement control system was designed such that, for the most part, the changes and the additions of the replacement control system would appear transparent to the operator and require a minimal of changes to the bridge operating procedures.

The new system includes maintaining the appearance of existing operator's control desk but with a new operating top panel added to the control desk. The layout of control switches, indication lights and instrumentation have purposely been kept similar to the original control system being replaced to simplify operator transition to the new system. See Photo E14, Appendix C.

The form of control for the bridge and the bridge drive system has been completely revised with additions such as encoders, resolvers and inclinometers that provide inputs into the PLC for enhanced control functionality. These inputs, along with conventional limit switches and position programmable rotary limit switches, are used to provide control for span operation including speed and skew control, seating, end of travel limits as well as bridge operating protection and troubleshooting diagnostic aids. The new system also provides control redundancy for greater operating reliability as well as enhanced protection for the operating system which includes additional monitoring and trip functionality.

The control system for the bridge is provided with a series of emergency stops (e-stops). These e-stops are hard-wired into the bridge PLC control system and were all tested and found to be operational at the time of the inspection.

Two resolvers have been installed in each tower, one single turn resolver and one multi turn resolver. Each resolver functions as designed and specified and is in as-new condition. See Photo E31, Appendix C. The new resolvers are connected to existing gearboxes. The internal condition of the gearboxes is unknown but they are functional and no issues have been reported since the new resolvers were installed. It was noted during the inspection that the single turn resolver differential reading between the north and south were not synchronized. The gear tolerance of the single turn resolver is the cause of this issue. The bridge operator has been instructed to use the readings from the multi turn resolver (bridge height resolvers) for all future bridge position calibrations when the span is seated. As currently designed, the single turn resolvers do not serve a useful purpose.

During the inspection, bridge operating personnel noted that the bridge operating system had an inherent issue of gradually increasing skew indication over time. This cumulative skew condition requires the drive shaft inputs to the resolvers to be adjusted periodically. The adjustment, performed once every two to three weeks, includes uncoupling and zeroing the system with the bridge in the seated position. Following an analysis of the span seated control for the bridge, it was evident that a cause of the problem was a control issue. As configured the operating drive in the tower does not stop when that side of the span seats but continues to drive until the other end of the span seats.

The installed wireless inclinometer was designed and specified as part of the replacement project to provide a measure, indication and control of both longitudinal and transverse skew. It was determined during commissioning of the replacement system that commercially available inclinometers could not achieve the required accuracy to measure the skew due to the very small angular displacements that result in a span skew condition. The inclinometer was moved several times during commissioning of the replacement system as directed by the Engineer of Record and was finally disabled and removed from the bridge control system. See Photos E39 and E40, Appendix C. The use of the inclinometer for longitudinal skew was discarded during commissioning and its intended skew function achieved through the use of the span height resolver feedback to PLC in each tower. The PLC program has now been modified to calculate the differential in counts of the encoder inputs from each tower for drive synchronization and also to adjust for skew condition by adjusting the resolver differentials real time via a PID loop. If either encoder or resolver differential value is excessive, a warning and trip condition will occur. If the bridge operation is tripped by the bridge ultimate skew protection, the control system will be inhibited. The operator will need to use the auxiliary drives to level the bridge before automatic operation via PLC can be re-enabled.

Overspeed protection has also been implemented as part of the control system replacement and upgrade. One overspeed switch has been installed in each tower to monitor the driving shaft speed during the bridge operation. See Photo E34, Appendix C. The control system will stop span operation on high or low over-speed.

Two network switches have been installed inside the south tower aerial cable control termination box to complete the required network loop configuration and fibre network setup. See Photo E32, Appendix C.

Corrective action is required to:

- Implement logic modifications to eliminate the cumulative skew error. These changes should be implemented to alter the control of the drives to eliminate over-travel when seating the span.
- It is recommended that the Engineer of Record for the recent rehabilitation provide an alternative means of skew detection and control.

4.3.6 Motor Control Centres

The Motor Control Centres (MCC's) are located in the North and South Towers. The MCC's were installed as part of the recently completed replacement and upgrade project.

The MCC's are used to power and control the motor and machinery brakes, traffic control warning gates, resistance barriers and pedestrian gates, span drive motor blowers and span locks, heating and lighting in their respective tower machinery spaces, as well as providing feeders for the span drives and auxiliary drive motor starter.

The MCC's are intelligent MCC's and the starters are controlled and monitored from the bridge control system via Ethernet switches located inside the MCC's. The overload devices in each starter are solid state communicating devices and have been fully integrated into the bridge control system.

The MCC's are in as-new condition, have been specified to support the required power, control of all connected devices, and are provided with protective devices that have been set to protect the operating system in accordance with code. Note the South MCC was covered with PVC sheet at the time of inspection to protect it from a roof leak. See Photo E20, Appendix C.

Corrective action is required to:

- Repair the South Tower roof leak.

4.3.7 Motor Control Centre Feeders

The feeders for the tower MCC's are run from the switchboard located on the 2nd Floor of the bridge operator's house. The feeder breakers in the switchboard are adequately sized for the prevailing duties and the breakers have been set in accordance with the latest protective coordination study.

The south tower MCC feeder is directly cabled from the switchboard utilizing cable trough and cable racks running up the tower to the south machinery space. The north MCC feeders consist of duplicate feeders utilizing an aerial cable installation between the south and north towers and an automatic switch transfer located in the north tower machinery space. The duplicate routing of these feeders has been split, one feeder run in each of the two aerial cable bundles which are run on each side of the towers to transition between the two towers, See Photo E63, Appendix C.

An automatic transfer switch (ATS) is installed in the north tower to provide the termination point for the redundant aerial cable power feeds from south tower to north tower. This ATS also automatically transfers from the duty (west side) aerial cable to backup (east side) feeders. The ATS is the break-before-make type with time delay for switching. See Photo E33, Appendix C.

The feeder installation for both towers has been appropriately sized and the duplicate feeders for the north tower MCC provides enhanced redundancy for the north tower operating system.

No corrective action is required at this time.

4.3.8 Span Lock

The span locks consist of two locking devices at each end of the moving structure. Each locking device consists of two lock jaws that are driven by a common span lock motor with associated machinery.

The bridge span lock system was replaced/refurbished approximately five years ago and is in good serviceable condition. The span lock motors were re-wound as part of the replacement and refurbishment project and are in fair condition. See Photo E43, Appendix C. The lock motors are provided with local disconnect switches in accordance with the Canadian Electrical Code. The north disconnect switch cover is moderately corroded. See Photo E44, Appendix C.

The original span lock rotary cam limit switch (RCLS) that is used for control, indication and interlock of the span lock motor has been disabled and replaced with a pair of lever arm limit switches located on the center of the span lock rotary shaft. Additionally, a pair of lock bar engaged and disengaged limit switches are installed at each span lock area near the span lock pocket. These limit switches are wired in series for positive indication and interlock of the bridge control system. See Photos E45 and E46, Appendix C.

Corrective action is required to:

- Replace the north span lock disconnect switch with one with a stainless steel enclosure.

4.3.9 Load Measurement

In an effort to determine the operating characteristics of the main span drive motors, their operating load characteristics were measured and recorded. Each drive output parameters (load current, voltage power, and power factor) were measured during the complete opening and closing operating cycles. Figures documenting the recordings and summary Table E1 are provided below.

	Phase A (Amps) Max./Avg.	Phase B (Amps) Max./Avg.	Phase C (Amps) Max./Avg.	Voltage (V) Max Load	Real Power (kW) Max./Avg.	Horse Power (HP/kW)	Power Factor Max./Avg.
SW Drive Output	150/86	166/87	166/85	627	71/42	150/112	0.64/0.34
NW Drive Output	160/92	153/93	160/92	607	67/41	150/112	0.62/0.32
SE Drive Output	154/88	155/89	140/88	610	62/37	150/112	0.62/0.31
NE Drive Output	160/90	144/90	155/90	607	68/32	150/112	0.64/0.35

SE Drive Output on Gen	145/86	166/86	150/85	609	61/31	150/112	0.61/0.30
NE Drive Output on Gen	148/89	154/90	163/89	606	66/36	150/112	0.63/0.31

Table E1 – Drive Output Parameters.

From the above results, it can be seen that the average load currents of the main span drive motors are within the nameplate rating of the motor (150 Amps). The average real power recorded for the main drive motors are well within the horsepower rating (<50%) from the nameplate data. These are an indication that the rating of the main drive motors and its controllers are correctly sized for the prevailing duty. However, the power factor is low indicating that the motors and the controllers operate at low efficiency due to the low frequency/speed. The span operation under the generator was also tested. The operation characteristic of each drive did not change and the generator is properly sized to operate the bridge.

The auxiliary drive was not tested at the time of inspection.

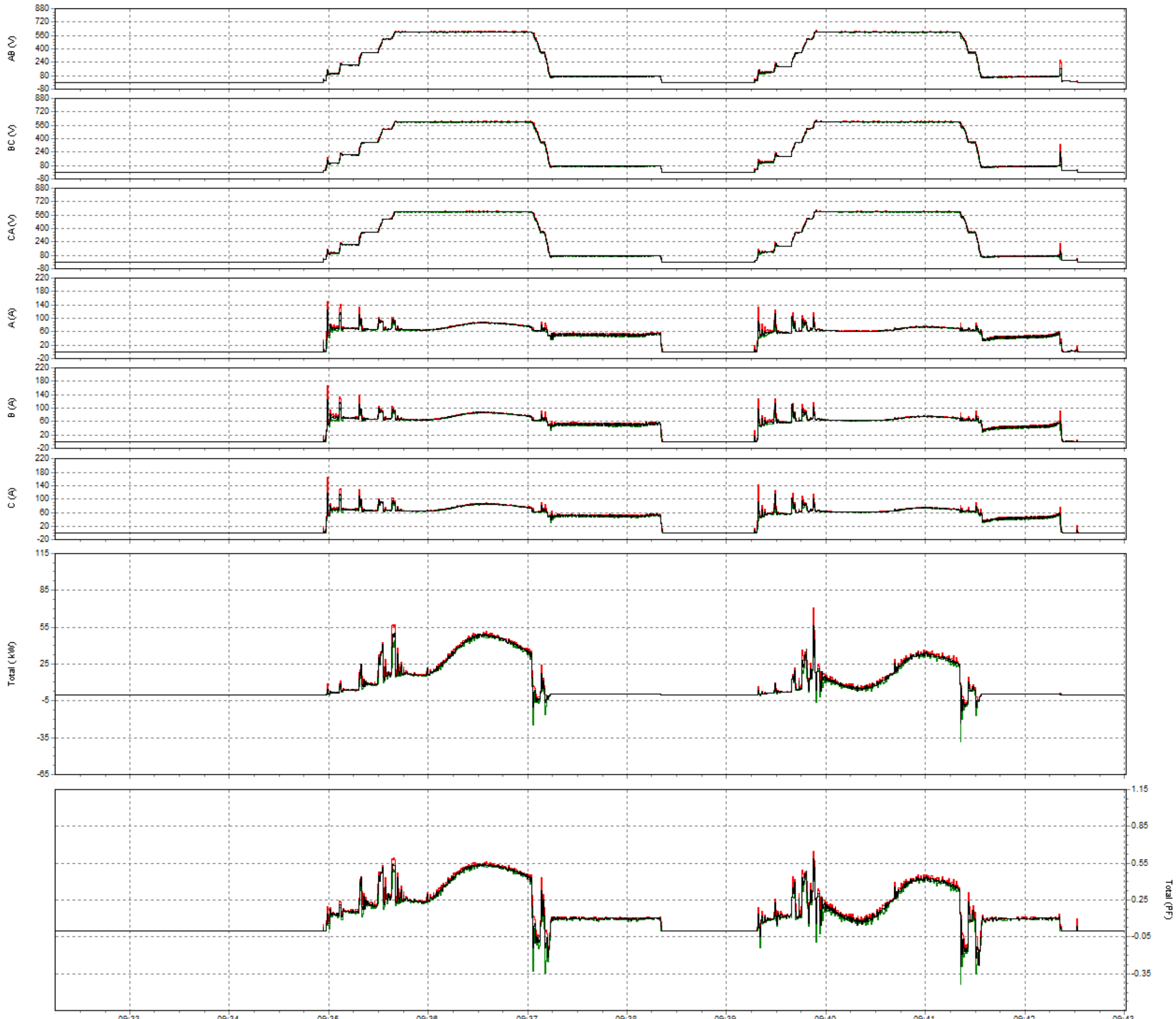


Figure E1: Voltage, Current, and Power Parameters (South Tower West Span Drive Motor – Normal Power)

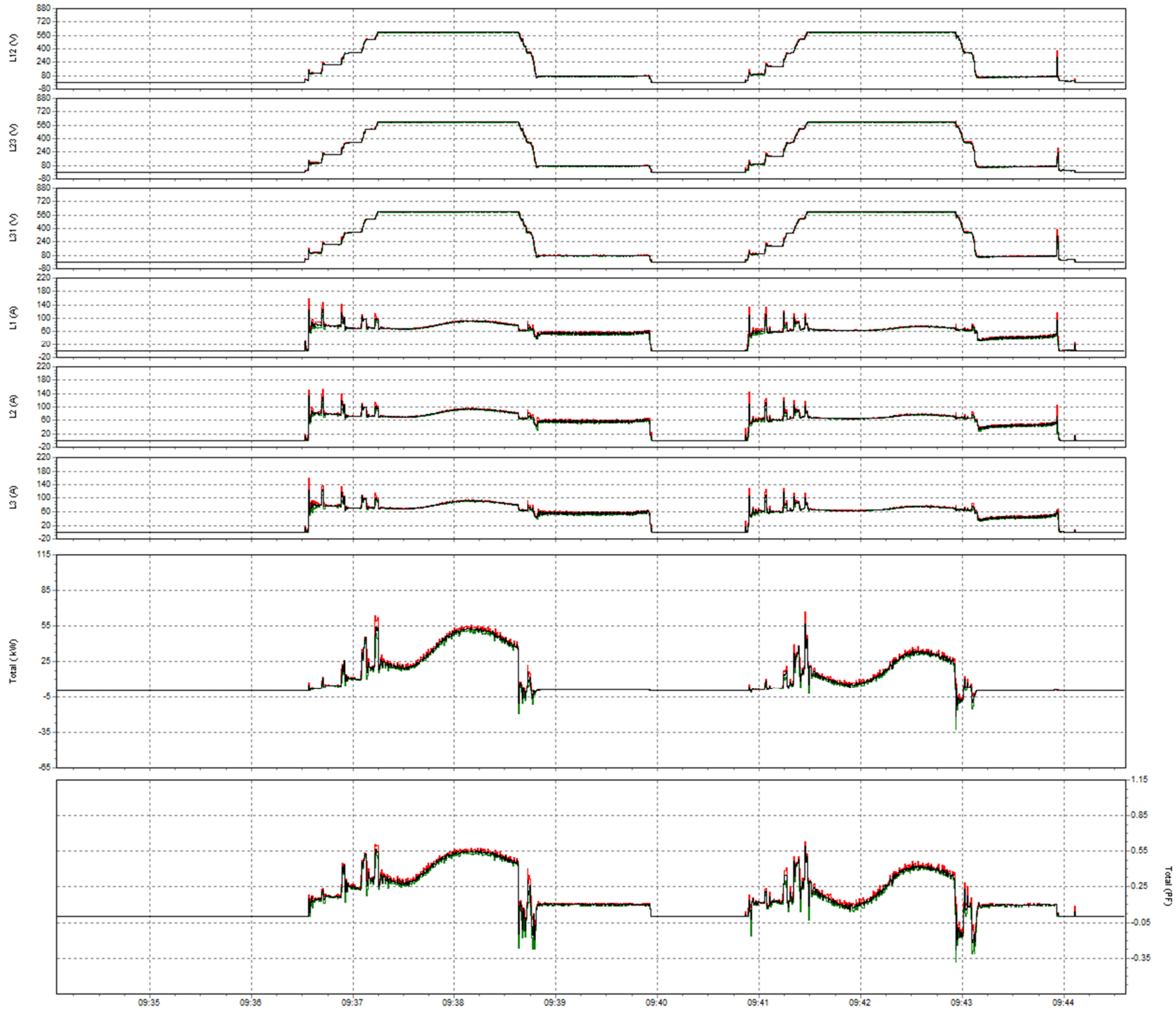


Figure E2: Voltage, Current, and Power Parameters (North Tower West Span Drive Motor – Normal Power).

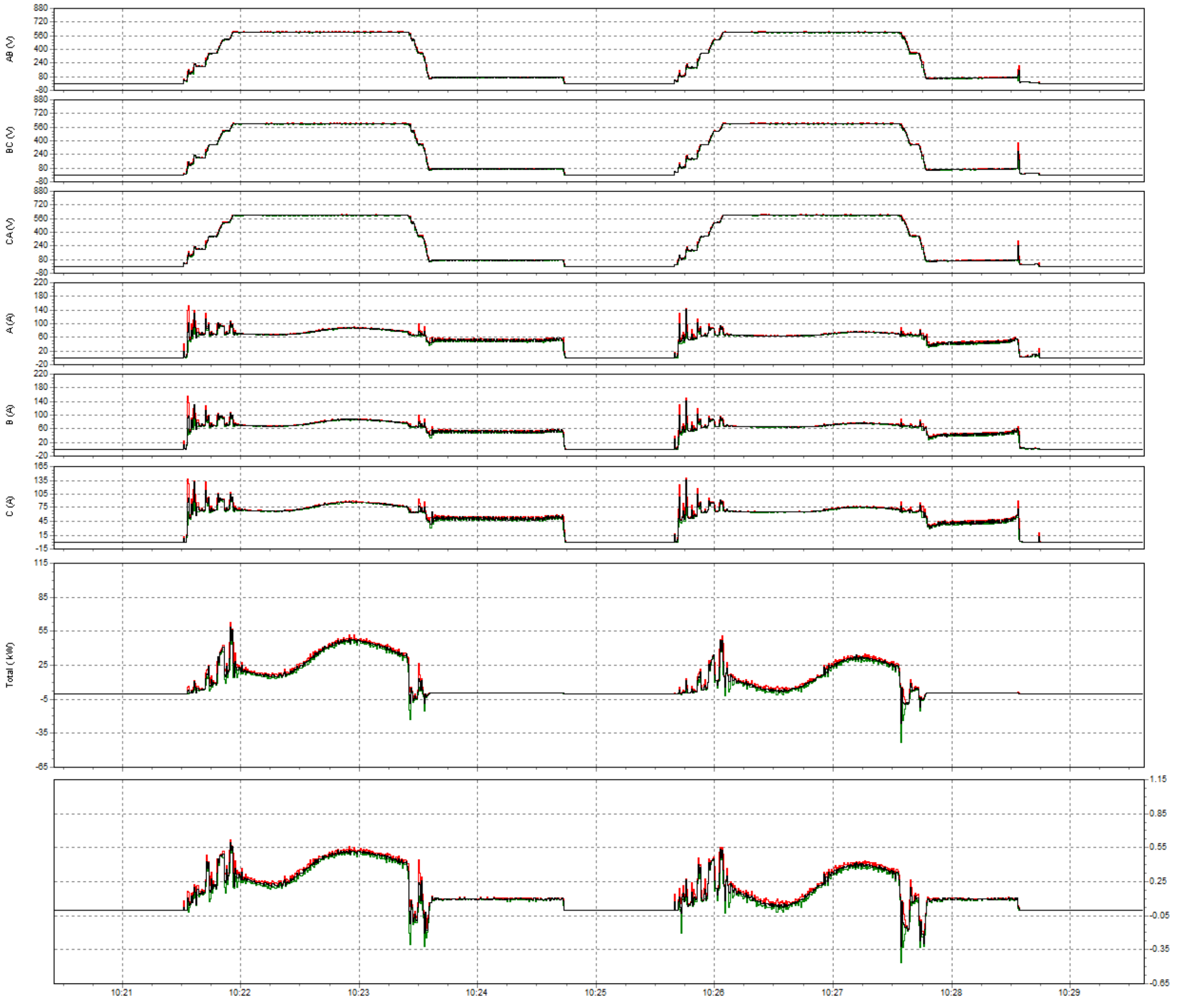


Figure E3: Voltage, Current, and Power Parameters (South Tower East Span Drive Motor – Normal Power)

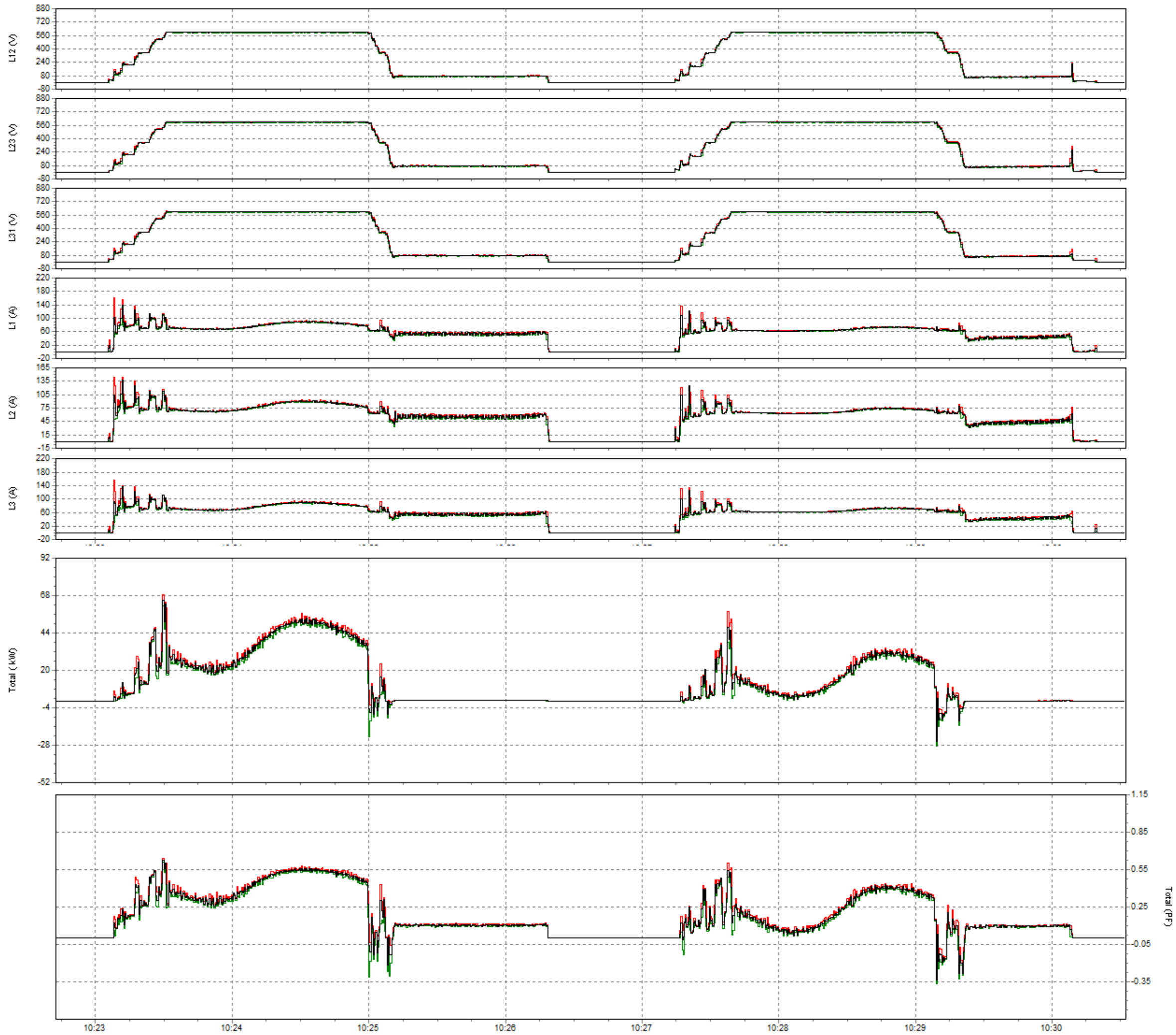


Figure E4: Voltage, Current, and Power Parameters (North Tower East Span Drive Motor – Normal Power).

Further investigation was performed to determine the load characteristic of the main span drive motors under emergency power, which means operating the bridge solely on the emergency diesel generator. Measurements were recorded for a complete operating cycle on the west drive motor on both towers. Measurement data are summarized in Table E1 and in the figures that follow.

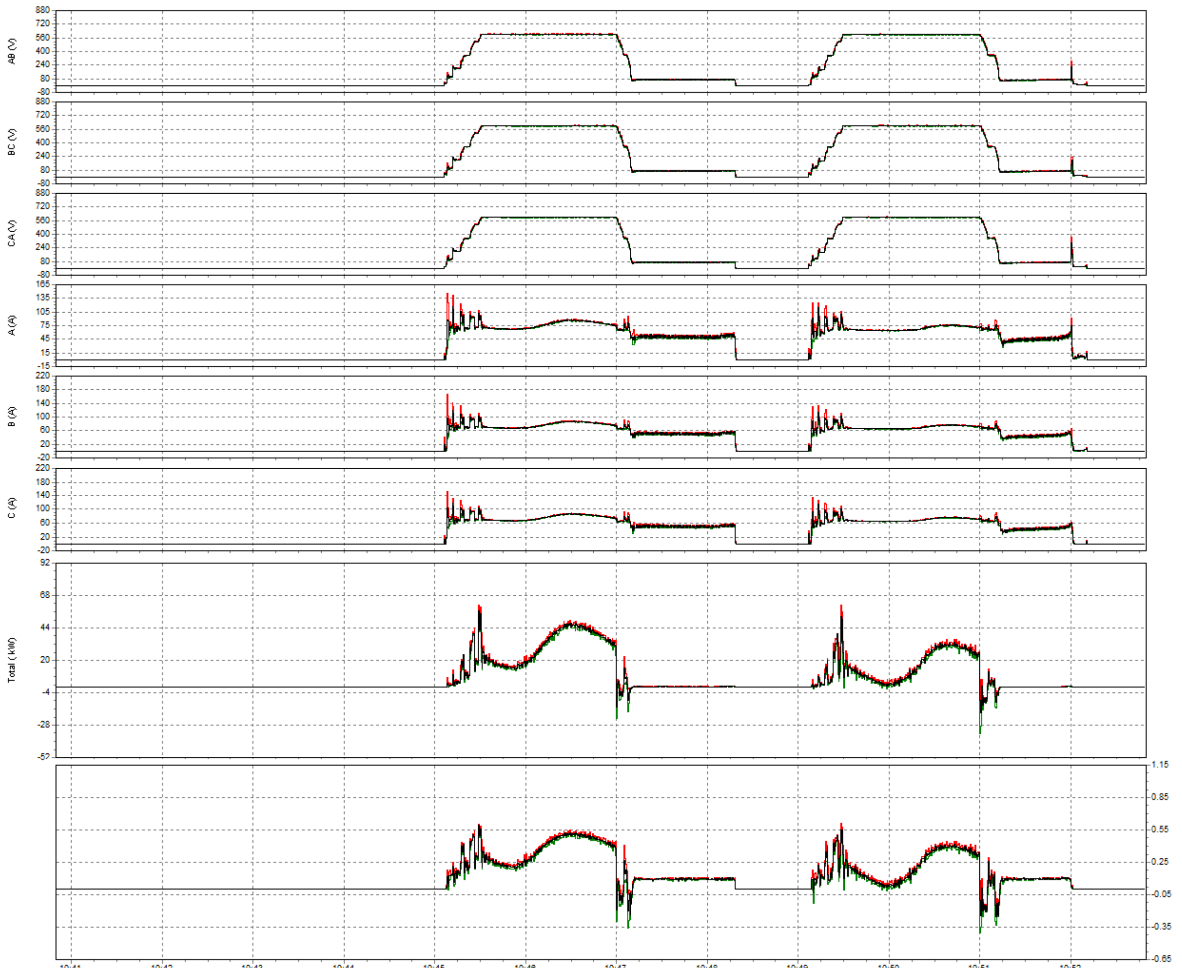


Figure E5: Voltage, Current, and Power Parameters (South Tower East Span Drive Motor on Generator Power)

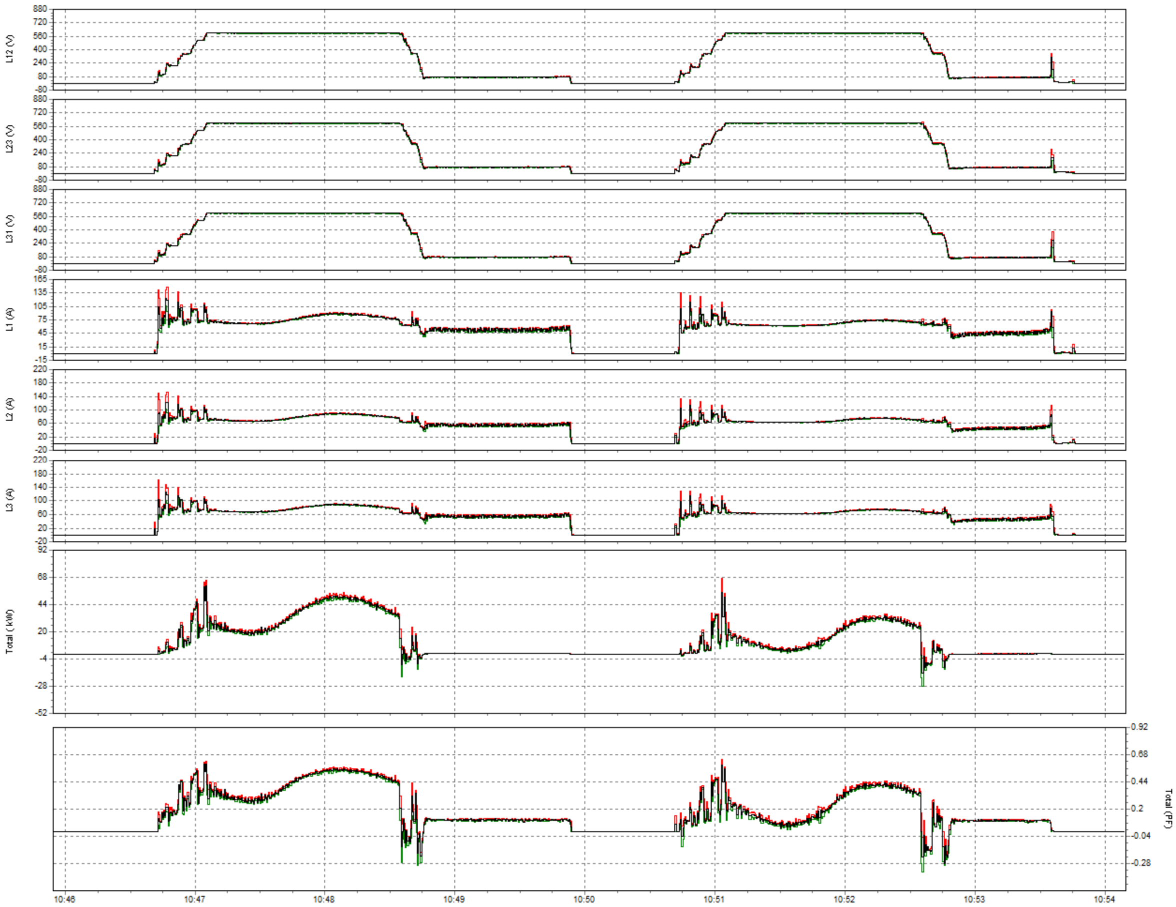


Figure E6: Voltage, Current, and Power Parameters (North Tower East Span Drive Motor on Generator Power).

Comparing these results with the measurements recorded for operations based on the normal utility power, the two sets of data are almost identical. This proves the generator is adequately sized for the duty, and is a stable and reliable source of power for the operation of the bridge.

4.4 BRIDGE CONTROL SYSTEM

4.4.1 Traffic Control Panel

The traffic control panel is a standalone unit that provides traffic control operating and annunciating functionality. The console top along with all operating devices (indicator lights and push buttons) have been upgraded during the recent replacement project. The traffic control panel has been well laid out ergonomically and located in conjunction with the installed CCTV system to optimize the operators sight of roadway and pedestrian traffic. See Photo E15, Appendix C. An additional keyed bypass switch has been installed on the side of the cabinet to switch the traffic control to all relay operation such that it is independent of the PLCs. Note that this "Maintenance" mode of operation does not provide any interlocks and is for maintenance or troubleshooting purposes only.

No corrective action is required at this time.

4.4.2 Navigation Control

The operating devices (indicator lights and push buttons) have been upgraded and are located on the traffic control panel. All specified functions associated with navigation control are operational and the installation is in good serviceable condition. With continued routine maintenance this navigation control should continue to provide reliable operation in the long term. The marine traffic navigation lights located at each end of the pier were found to be in good serviceable condition. See Photo E49, Appendix C.

The lift span is provided with span navigation lights, one light faces each approach of the waterway. See Photo E48, Appendix C. These lights are used to indicate to the marine traffic of the bridge position. The lights will automatically switch to "Green" when the bridge is fully raised. Both span navigation lights were found to be in good serviceable condition at the time of inspection.

Two small craft navigation lights were originally installed, one on each side of the bridge axis on the south pier. Both small craft lights were operational at the time of the inspection but with moderate corrosion on the fixtures and poles. See Photo E50, Appendix C.

Air horns are installed on the control house facing both side the channel to signal the marine traffic. The air horns are of the original installation and exhibit light paint deterioration but were in good operational condition. See Photo E69, Appendix C.

No corrective action is required at this time.

4.4.3 PLC

The bridge logic control was originally relay logic when the bridge was first placed into service in the 1950's. The relays were replaced with a Programmable Logic Controller (PLC) in 1989. The existing PLC was an Allen Bradley Model 5/20, which was powered from a UPS to ensure a conditioned and reliable and uninterruptible source of supply for the PLC. The PLC system was replaced and upgraded during 2016 and 2017 as part of the present replacement and upgrade bridge project. The replacement PLC is of GE manufacture and was provided as a redundant system. See Photo E11, Appendix C. The PLC memory is in the form of an embedded memory module of adequate capacity to satisfy bridge control functionality including all specified enhancements. The PLC and all peripherals have been configured for cold backup redundancy with watchdog detection to automatically switch to the healthy PLC if the running PLC alarms an alarm state. The bridge control logic has been configured to operate the new VFD drives and to automatically switch over the duty drives to back up drives in the event of drive failure. Numerous safety features have been programed into the PLC logic to enhance bridge operational safety including redundant overspeed trips, redundant skew control and trip functions, redundant bridge end of travel, redundant brake failure alarms drive monitoring as well as traffic control system monitoring and alarming a failure.

No corrective action is required at this time.

4.4.4 Control Panels in Tower

There are several control panels installed in each tower to take care the bridge operation and interface needs.

CP-3 (South Tower) and CP-4 (North Tower) are the main interfacing control panels in the towers with HMI's with each control panel. Each control panel and its peripherals consist of:

- PLC remote I/O rack
- PLC network module
- Resolver interfacing module
- PLC encoder interfacing module
- Speed switch module on the door
- Breakers for sub control circuits
- Relays
- Terminals
- Aerial cable transfer switch

Note that the panels appear to be undersized based on their wire fill. See Photos E29 and E30, Appendix C.

4.4.5 Uninterruptible Power Supply

To assure control system and essential communication links are maintained during short duration power outages and that the power supplies are conditioned and free from transients or harmonics, the bridge has been provided with a 10 kVA Uninterruptible Power Supply (UPS). The UPS is located on the second floor next to the main control panel (CP-2) with sub UPS distribution panel. The UPS and its distribution panel was installed as part of the recently completed replacement and upgrade project. The UPS has been provided with status and failure monitoring devices that alarm on the bridge operator's HMI in the event of UPS trouble. Additionally, routine maintenance of the

UPS is being performed by maintenance staff in accordance with the current bridge O&M Manual. See Photo E12, Appendix C. The following critical loads has been connected to the UPS:

- PLC
- Control Power
- Radar
- Marine Radio
- Main Office
- Emergency Receptacles

The UPS is sufficiently sized to maintain the critical devices powered until transferring to the standby generator emergency power.

No corrective action is required at this time.

4.5 OPERATIONAL DEVICES

Operational devices are defined as all electrical devices that contribute and are part of the bridge operating system.

The operational devices group includes the following items:

- Motor Overloads
- Safety Interlocks
- Limit Switches
- Limit Switches
- Resolvers
- Encoders
- Speed Switches

4.5.1 Motor Overloads

The main motor overloads were visually inspected as part of the inspection. The overloads are part of the MCC starter assembly. Two type of motor overloads were inside the MCC: networked solid-state overload and thermal morganatic overload protectors. All thermal overloads are in as-new condition.

No corrective action is required at this time.

4.5.2 Safety Interlocks

The safety interlocks were functionally observed as part of this inspection. The bridge operating sequence state is defined in the bridge operator's manual and the safety interlocks ensure that the bridge operator is prevented from operating the bridge out of sequence. The control circuit interlocks disable and prevents out of sequence operation of the bridge that could potential damage the bridge equipment or harm the public. The interlock functions were observed, tested and adjusted during the bridge commissioning process in early 2017 and verified as part of this inspection. All code required interlocks were found to be incorporated into the bridge control system and perform their intended function.

No corrective action is required at this time.

4.5.3 Limit Switches

Limit switches were inspected as part of the inspection. The following devices were visually inspected and functioned as intended:

- Seated limit switches
- Span position limit switches
- Programmable limit switches (PLS) with resolver
- Span lock safety limit switches
- Auxiliary drive clutch limit switches
- Main spline gear clutch limit switches

All limit switches were in as new operational condition at the time of the inspection and all were operating reliably and as intended.

No corrective action is required at this time.

4.5.3.1 Seated Limit Switches

The bridge is provided with four (4) span seated limit switches, one at each corner of the moving structure. The switches are of the plunger type and detect the presence of the span at the bridge seated position. The switches are new and were installed as part of the bridge control system replacement and upgrade project. The switches are in good operational condition, perform their intended function reliably and have been well installed. See Photo E38, Appendix C.

No corrective action is required at this time.

4.5.3.2 Span Position Limit Switches

Three (3) span position limit switches have been installed on the south tower along the travel path of the south span counter weight. Two limit switches were installed on the lower level of the tower near the staircase for span near open and full open detection and one limit switch installed on the top for the span near seated detection. The switches are in good operational condition, perform their intended function reliably and have been well installed. See Photo E37, Appendix C.

The rotary cam limit switches are programmed to be replaced as part of the electrical power and control system replacement contract.

No corrective action is required at this time.

4.5.3.3 Programmable Rotary Limit Switches (PLS) with Resolvers

One resolver based programmable rotary limit switch was installed in each tower. The triggering parameters were set in the PLS to provide a second mean of span limit switch functionality for the bridge. Each relay output from PLS is arranged in series with the equivalent span position limit switch to provide the failsafe span/drive positional control. The PLS's are installed in CP-8 (south Tower) and CP-9 (North Tower), but only the south tower PLS is in service. The CP-9 South Tower PLS only serves as a display unit in CP-9 and for PLC readout purposes. Note that the PLS resolver signals were also split to provide the PLC with span height and a height readout inside the CP-8. Note that an output from the PLS in south tower is also used to control the span navigation lights.

No corrective action is required at this time.

4.5.3.4 Span Lock Safety Limit Switch

The span lock system is provided with two disengaged limit switches one mounted on the each of the span lock bars for positive indication of the span lock status. These limit switches have been wired in series with the span lock end of travel limit switches at the center of the span lock rotating machinery. These switches are in good operational condition, perform their intended function reliably and have been well installed.

No corrective action is required at this time.

4.5.3.5 Auxiliary Drive Clutch Limit Switch

The auxiliary drive system is provided with two interlock limit switches on the reducer operating lever to prevent powering of the main drive system when the auxiliary drive lever is engaged. These auxiliary drive limit switches are in good operational condition, perform their intended function reliably, and have been well installed. See Photo E27, Appendix C.

No corrective action is required at this time.

4.5.3.6 Main Spline Gear Clutch Limit Switch

The reducer is provided with a main drive clutch lever with two interlock limit switches to prevent powering of the main drive system when the main clutch lever is disengaged. This provides the permissive to enable transverse skew correction to be made and to provide for machinery indexing. The main drive interlock limit switches are in good operational condition, perform their intended function reliably, and have been well installed.

No corrective action is required at this time.

4.5.3.7 Reducer Manual Crank Limit Switch

Two reducer manual crank limit switches have been installed under the manual crank cover on the speed reducer. When the cover is opened, both main and auxiliary drive operation is disabled. The reducer manual crank limit switches are in good operational condition, perform their intended function reliably and have been well installed.

No corrective action is required at this time.

4.6 TRAFFIC CONTROL

The Traffic Control group contains the Traffic Lights, Gates and Pedestrian Control.

4.6.1 Traffic Lights

All the traffic light fixtures have been replaced with LED type luminaries as part of the recently completed replacement and upgrade project. All traffic lights are operational and function in accordance with the prevailing bridge operating control requirements. See Photo E51, Appendix C.

No corrective action is required at this time.

4.6.2 Gates

The warning gates, barrier gates and pedestrian gates were all replaced as part of the recently completed electrical replacement and upgrade project. The warning gates are of B&B Roadway manufacture, are in as new condition and have been well installed. See Photo E55, Appendix C.

Electrically, the gates operate satisfactorily except the NE warning gate gong which did not function at the time of the inspection. See Photo E53, Appendix C. The SE traffic gate arm has a dent which, per bridge personnel, was due to a past accident when the gate was being lowered. See Photo E54, Appendix C.

There are two barrier gates, one on each of the roadway approach. The barrier gates are of B&B Roadway Manufacture and are of their VR-6 type. Each barrier gate is single armed and spans across the width of the roadway. The barrier arm is approximately 55 ft. in length and, although exhibiting little movement in the wind when in its vertical position, it does exert stresses on the machinery. This may result in a fatigue issue in the long term. See Photo E59 Appendix C. A steel receiver pocket has been installed on the opposite of the roadway such that the barrier gate tip end will be locked in the receiver to provide a physical stop for vehicular traffic when the barrier is lowered. It was noted during the inspection that a wooden barrier was installed around the barrier gate's receiver to keep the pedestrians out of range of the gate arm when it is being lowered. See Photo E60, Appendix C. The barrier gates have been well installed and all components inside the gate enclosure were in as-new condition. See Photo E61, Appendix C.

Pedestrian gates were installed on the walkway approach to the bridge span. A small and short armed B&B roadway gate was installed to stop the pedestrian traffic. The gate is in as-new condition inside and outside and has been well installed. See Photos E57 and E58, Appendix C.

All gates come with door limit switches and hand crank limit switches for safe operation of the gates. See E56, Appendix C.

Corrective action is required to:

- Return the NE warning gate gong to normal operation
- Perform an inspection of the barriers and barrier arms on a 6-monthly cycle, concentrating on the barrier gate machinery, bearings and barrier arm fatigue.

4.6.3 Pedestrian Control

Pedestrian control devices have been installed to signal bridge operation to pedestrians. The control consists of indicating lights and a bell at both the North and South sidewalk approaches to the bridge. The north pedestrian bell was not functional during the inspection. But apart from this defect, the pedestrian control system was in almost as-new condition and functioned as intended. See Photo E52, Appendix C.

Corrective action is required to:

- Repair or replace the north pedestrian bell.

4.7 BRIDGE AUXILIARY SUB SYSTEMS

Bridge auxiliary sub systems include the power distribution panelboard, marine radio, radar system, elevator control and lighting.

4.7.1 Bridge Distribution Panel Boards

Most of the distribution panelboards were existing and not part of the recent electrical replacement and upgrade project except for one panelboard in each tower which was recently installed. The new and original panelboards are in good operating condition. The panelboards in the electrical room were modified during the recent replacement and upgrade work with additional circuits and designations added. See Photo E13, Appendix C.

Heater distribution panels in both towers are existing and are in good operating condition. See Photo E35, Appendix C.

One new lighting panel was installed in each tower at the elevator landing. The required additional power is fed from the new MCC's via disconnect switches, step down transformers and 42 circuit panelboards. See Photo E36, Appendix C.

A separate panelboard is located on the north pier at the foot of the north tower together with its lighting transformer, disconnect switch and lighting contactor. The equipment in this area is mostly in good condition exhibiting only minor signs of corrosion. See Photo E47, Appendix C.

No corrective action is required at this time.

4.7.2 Marine Radio

The marine radio is of the long range multi-channel radio system. It is in good condition and is operational. See Photo E19, Appendix C.

No corrective action is required at this time.

4.7.3 Radar System

The radar system was installed some years ago to aid the bridge scheduling and operation. Note that the radar system can also detect and record the wind speed and direction data in real time on the bridge. See Photo E18, Appendix C.

No corrective action is required at this time.

4.7.4 Bridge Elevators

The elevators were part of the bridge original installation. The existing elevator machinery was installed approximately twenty years ago. Although functional, both elevators require periodic maintenance. The elevator controllers have been modified several times and are approaching the end of their service lives. See Photos E41 and E42, Appendix C.

Corrective action is required to:

- Refurbish or upgrade the elevator machinery and controllers.

4.8 CONDUITS, JUNCTION BOXES, CABLE TRAYS AND SUSPENSION CABLES

The outdoor locations contain numerous conduits and junction boxes. Most of the raceway installation are new with PVC coated rigid steel conduits and stainless-steel junction/pull boxes. Only a few of the existing conduits and junction boxes remain after the recent rehabilitation. See Photo E74, Appendix C.

4.8.1 Conduits

The bridge conduit installation consists of a combination of conduits that were installed when the bridge was originally constructed and conduits that have been replaced as part of recent upgrade project. All newly installed outdoor conduits are of PVC coated rigid steel. The conduit installation is generally in good serviceable condition and should provide reliable service in the long term.

No corrective action is required at this time.

4.8.2 Junction Boxes

All of the failed and badly corroded junction boxes were replaced during the recently completed electrical replacement and upgrade project. The junction boxes and their installation are generally in good serviceable condition and should provide reliable service in the long term.

No corrective action is required at this time.

4.8.3 Cable Trays

Cable trays run vertically up each tower and are installed under the tower machinery rooms to feed the equipment in the machinery spaces. Concerns existed with the horizontal runs under each tower machinery rooms accumulating bird waste. Lightweight steel covers have been installed over the trays to alleviate the problem. The overall condition of the bridge cable tray system is in good condition and no major issues were evident during the inspection.

Additional curved cable trays were installed on the tower wings to route the new aerial cables into the machinery room. See Photo E66, Appendix C.

No corrective action is required at this time.

4.8.4 Cable Reel

Cable reels have been installed at the bridge to provide power and control for the electrical equipment located on the movable span such as the span navigation lights and roadway heaters. The cable reels are in serviceable condition and no significant deficiencies at the time of inspection. Note that the north cable reel body exhibits signs of corrosion. See Photo E62, Appendix C. With continued routine maintenance the cable reel should continue to provide reliable service in the long term.

No corrective action is required at this time.

4.8.5 Aerial Cables

Arial suspension cables have been provided to electrically connect the South to the North towers. These cables carry all power feeders and control conductors for the North tower drive system. The cables were replaced and added to as part of the recent electrical replacement and upgrade project. The aerial cables installation has been routed from the wings of the towers to the machinery spaces in cable trays with code compliant bending radii, and terminated in the tower machinery spaces. The aerial suspension cables were visually inspected from the cable support structure. The cables and the installation appear to be in generally good condition but have been damaged by wind loads. The damage to the aerial cable was due to a lack of consideration of the dynamic effects of wind and ice during the design and engineering phase of the project. Note that a repair to the aerial cable damage and the design of a spacer and wind damping system was undertaken by the electrical replacement and upgrade project Contractor and their Engineer.

At time of the inspection, the cable repairs had been completed and the contractor was in the process of installing the newly designed aerial cable spacer assemblies. See Photos E63 through E66, Appendix C. Although the spacers should address the dynamic effects of the wind and ice on the aerial cable system, continued monitoring and inspection of the installation is recommended over the remainder of the winter season to ensure the integrity and performance of the system.

Note also that signed and sealed drawings for the aerial cable spacer system were not available. These should be provided to the PWGSC for future reference.

Corrective action is required to:

- Develop a means of video recording the aerial cable system and use the gathered data to monitor the performance of the installation.
- Ensure that the signed and sealed aerial cable repair and spacer/damper design drawings are provided. In addition, provide a formal design and implementation report for the retrofit summarizing modifications to the aerial cable system. The report should include an evaluation of the effect of the aerial cables on the tower structure and an assessment of the effectiveness of the spacer/damper solution.

4.9 GROUNDING AND BONDING

The inspection included a visual inspection of the bridge grounding and bonding installation. The installation appears to be complete with the structure and the electrical installation grounded and bonded in accordance with Canadian Highway Bridge Design Code and Canadian Electrical Code.

All newly installed raceway, power and control systems are properly grounding and bonded. See Photo E70, Appendix C.

Corrective action is required to:

- Ensure that the ground integrity is maintained throughout the bridge structural steel and electrical system. This should take the form of ground resistance and continuity testing and should be performed annually.

4.9.1 Lightning Protection

In addition to the grounding and bonding improvements made to the bridge, additional surge suppressors have been added to the bridge electrical distribution system. It is considered that, as installed, the surge suppressors provide adequate protection. These combined additions improve the protection of the bridge structure and sensitive electronic equipment from lightning energy discharges.

No corrective action is required at this time.

4.10 ACCESS CONTROL SYSTEM

The bridge is provided with access control system to prevent unauthorized access to the bridge facilities. The access control system was operational at the time of the inspection and provides an effective means of ensuring that only authorized personnel can gain access to the facility. See Photo E67, Appendix C.

No corrective action is required at this time.

4.11 CCTV SYSTEM

The bridge is provided with a CCTV system. The CCTV cameras are strategically located throughout the bridge to monitor the roadway approaches, waterway approaches and main access areas to the bridge. The operator is able to monitor these location from the operator's room via a CCTV monitor. The camera installation was found to provide good visual information and had been well installed and was operating reliably at the time of the inspection. See Photos E17 and E68, Appendix C.

No corrective action is required at this time.

4.12 SAFETY LOCKOUT

Considerable effort has been put forth to install lockable disconnect devices in order to facilitate Lockout and Tagout Procedures. Recently, the following devices have been installed or replaced to provide lockable disconnects:

- Main drive breakers and disconnect (North and South)
- North and south roadway gates or from the MCC starters
- Span lock disconnects (North and South)
- Main drive motors (8 locations in total)
- Second floor lighting panels
- Machinery room lighting panel disconnects (North and South)
- Auxiliary drive control panel disconnects (North and South)
- Brake starter disconnects on MCC (North and South)

- LP-4 local disconnect

No corrective action is required at this time.

4.13 BRIDGE LIGHTING

Bridge lighting is generally in good condition and is sufficient for the workplace. Exit lights installed in varies paths of egress in accordance with the prevailing fire code. Note the exit light cover above the generator room entrance is damaged (split). See Photo E71, Appendix C.

Corrective action is required to:

- Repair the exit light cover above the generator room entrance.

4.14 FIRE ALARM SYSTEM

A fire alarm system has been installed on the bridge and is in serviceable condition. The fire alarm devices consist of the smoke detectors, stokes, speakers, pull stations and annunciator. See Photo E73, Appendix C.

No corrective action is required at this time.

4.15 LOCAL PORTABLE EMERGENCY GENERATOR RECEPTACLES

Portable emergency generators receptacles have been installed at the roadway level of each tower. The receptacles have been installed to provide emergency backup power for the bridge auxiliary drive system and emergency lighting in the tower machinery spaces. The receptacles and disconnect combination units are in good serviceable condition but bridge operating personnel reported that they have never been used to operate the bridge auxiliary drive system. See Photo E72, Appendix C.

Corrective action is required to:

- Consideration should be given to testing this portable means of powering the auxiliary drive motors using generators.

5.0 RECOMMENDATIONS FOR REMEDIAL ACTION

5.1 STRUCTURAL RECOMMENDATIONS

The following recommendations have been categorized according to the time frame within which they should be implemented:

5.1.1 THIS YEAR (2018) – Priority Code (A)

5.1.1.1 Approach Roadways, Sidewalks, Platforms and Curbs

- Repair broken sidewalk railing spindle and tighten loose bolts on rail posts on the sidewalk.

5.1.1.2 North and South Approach & Tower Spans – (Priority Code (S))

- Complete detailed section loss measurements and close-up inspection of the corroded sections of the approach and tower span stringers, jacking girders, rear floor beams, columns and tower anchor assemblies.

5.1.1.3 North and South Tower

- Installing missing toe boards at the bottom of the railings at the upper catwalk and platform below

5.1.2 ROUTINE MAINTENANCE AND REVIEW YEARLY (ONGOING) – Priority Code (M)

5.1.2.1 Lift Span

- Repair broken welds between lift span steel grating and stringers, as well as deck grating butt welds as ongoing maintenance, pending grating replacement.
- Replace missing bolt of the north face of the floor beam at panel point 1, above the west centering device.

5.1.2.2 North and South Towers

Clean and recoat steel members at corroded locations:

- North tower span: jacking girder, column and floor beams.
- North and south tower spans: front and rear floor beam, and gusset plates connecting the lateral bracing to the tower floor beams.

5.1.2.3 Bridge Accessories

Clean and touch-up the paint for steel members at corroded locations:

- North and South sidewalk expansion joint plates.

5.1.2.4 Steel Structural Members (Entire Bridge)

- Clean accessible areas of debris, grease and bird guano.

5.1.2.5 Expansion Joints

- Repair loose steel armouring angle and compression seal at the expansion joint between the north approach and north tower span.

Monitor the condition of:

- Concrete end dam and armouring angle at the north/south expansion joint;
- Rivets on lift span;
- All ladders;
- East side of south tower messenger cable clamps.

5.1.3 1 TO 3 YEARS – Priority Code (B)

5.1.3.1 Abutment and Retaining Walls

- Repair or replace the corroded and perforated stiffener and gusset plates at the south abutment.
- Repair the corroded sole plate and gusset plate at the north abutment.
- Repair the concrete spalls and delamination of the north and south ballast walls and abutments.

5.1.3.4 North and South Approach and Tower Spans

- Replace or repair the concrete decks and expansion joint systems in the north and south approach tower spans.
- Replace or repair steel stringers beneath both north and south approach/tower spans.
- Strengthen the rear/front floor beams and tower anchorage in areas with the most section loss.

5.1.3.5 North and South Towers

- Replace the missing 12 rivets with high strength bolts on the west and east horizontal member at the south tower (6 on the west member and 6 on the east member). Clean and recoat the area.

- Replace improperly installed rivet at the top angle connection for the top flange of the 6th longitudinal sheave girder from west with a high strength bolt.

5.1.4 3 TO 5 YEARS – Priority Code (C)

5.1.4.1 Lift Span

- Detail drilled holes in portal framing members to upturned elements connections for drainage prior to cleaning and painting of the truss.

5.1.5 6 TO 10 YEARS

5.1.5.1 Lift Span

Clean and recoat steel members at corroded locations:

- East and west truss panel members, top/bottom chords, lateral bracing, jacking girders, portal and sway bracing horizontal members, etc.

5.1.5.2 North and South Towers

Clean and recoat steel members:

- North and south tower: horizontal and diagonal members, tower columns, sheave girders, fascia girders, etc.
- North machine room exterior
- North and south counterweights

5.2 MECHANICAL RECOMMENDATIONS

The following recommendations have been categorized according to the time frame within which they should be implemented.

5.2.1 THIS YEAR (2018)

5.2.1.1 Span Drive Bearings

- No corrective action is required.

5.2.1.2 Span Drive Brakes

- All Brake Assemblies – Clean areas of corrosion and paint the unpainted areas on the brake assemblies, included, but not limited to the mounting bolts, brake wheel hubs and top support surfaces.

- SE Motor Brake and SW Motor Brake – remove paint from the brake wheel friction surface.

5.2.1.3 Span Drive Couplings

- All Couplings - clean corrosion from the couplings and paint.

5.2.1.4 Span Drive Motors

- All Motors – clean areas of corrosion from the motor supports and bolts and paint the motor supports and mounting bolts.

5.2.1.5 Span Drive Open Gearing

- All G2/P2 gearsets - remove old lubricant accumulation from under all G2 gears.
- All G2/P2 gearsets - lubricate the G2 differential assembly bevel gears.

5.2.1.6 Reducers

- Restore functionality to the south reducer auxiliary drive lever positioning bolt to enable operation of the south tower auxiliary drive.
- Replace all reducer housing inspection cover bolts. Repair damaged threads in the reducer housings as needed.
- Paint all reducer mounting and base bolts.
- Periodically check the north reducer drain valve and north indexing spline limit switch bolts for oil leakage to verify the leakage has been eliminated.

5.2.1.7 Span Drive Shafts

- No corrective action is required.

5.2.1.8 Speed Control and Span Position Indicating Equipment

- No corrective action is required.

5.2.1.9 Auxiliary Span Drive Machinery

- No corrective action is required.

5.2.1.10 Main and Auxiliary Counterweight Ropes

- Increase the frequency of lubricating the main counterweight wire ropes to a minimum of every 6 months. Consider the use of environmentally friendly lubricants to address environmental concerns.
- NW Outboard Lift Girder Splay Casting – tighten the nut that is not fully seated.
- Clean old rope lubricant from the north auxiliary counterweight ropes and lubricate all auxiliary counterweight ropes. Consider the use of environmentally friendly lubricants to address environmental concerns.

5.2.1.12 Main and Auxiliary Counterweight Sheaves

- Remove excess lubricant from the north auxiliary counterweight sheave grooves.
- Spot clean and paint corroded areas at the main counterweight sheaves.
- Spot clean and paint corroded components at the south auxiliary counterweights sheave assemblies.
- Lubricate the main and auxiliary counterweight sheave grooves.

5.2.1.13 Auxiliary Counterweights

- Clean and paint areas of corrosion on the auxiliary counterweights.

5.2.1.14 Trunnion and Trunnion Bearings

- Schedule an internal visual inspection of trunnion bearings #8, south tower (outboard bearing supporting sheave-SW-OB) and #3, south tower (outboard bearing supporting sheave SE-OB) to evaluate the raceways for damage. Continue to perform vibration testing as part of annual inspections.
- Schedule SKF maintenance at all 16 trunnion bearings in conjunction with the internal inspection recommended at bearings #3 and #8 in the south tower in accordance with SKF recommendations.
- Spot clean and paint corroded mounting bolts.

5.2.1.15 Live Load Supports

- Clean and paint the live load supports and anchor bolts.

5.2.1.16 Span Guides

- No corrective action is required.

5.2.1.17 Main and Auxiliary Counterweight Guides

- Remove excess lubricant and inspect main counterweight guide bolts.

5.2.1.18 Centering Devices

- Clean and paint the centering devices.

5.2.1.19 Span Air Buffers

- Continue to monitor and periodically flush the buffer assemblies to ensure that they operate properly.
- Repair or replace the damaged northwest span buffer valve.

5.2.1.20 Tower Air Buffers

- Clean and paint corroded portions of the tower air buffers.

5.2.1.21 Span Lock Machinery

- Spot clean and paint component areas with corrosion. Components include, but are not limited to, the span lock spring assemblies, Bearing B2 mounting bolts, and the center crank.

5.2.1.22 Warning Gates

- No corrective action is required.

5.2.1.23 Barrier Gates

- North Barrier Gate – Tighten the west counterweight bolts.
- Both Barrier Gates – Adjust gate arm operation to eliminate impact when the gate arm engages the receiver.

5.2.1.24 Main Generator

- Main Generator – Replace the cracked coolant hose.

5.2.2 2 TO 5 YEARS

5.2.2.1 Main and Auxiliary Counterweight Ropes

- Conduct an in-depth inspection of the main counterweight and auxiliary counterweight ropes.
- Replace the north auxiliary counterweight ropes.

5.2.2.2 Span Air Buffers and Tower Air Buffers

- Remove the span air buffers and tower air buffers from service based on a review of the new control system and CHBDC requirements.
- If the span air buffers and tower air buffers are retained, consider rehabilitating the buffers to ensure that they function as intended by installing piping to connect the two buffers at each end of the span and incorporate a pressure gage that can be connected via a gate valve to perform adjustments and periodically verify the pressure that is developed in the system during seating.

5.2.3 6 TO 10 YEARS

- No corrective action is required.

5.3 ELECTRICAL RECOMMENDATIONS

The following electrical recommendations are based on previous bridge inspections and knowledge of the bridge electrical systems including the electrical inspectors' involvement in the recently completed electrical replacement and upgrade project. The recommendations have been prioritized into the following categories.

5.3.1 THIS YEAR (2018)

The following recommendations are considered critical and should be addressed within this year to assure continued safe and reliable operation of the bridge.

5.3.1.2 Main Electric Service

- Complete "As-Built" documentation including the recently completed electrical replacement and upgrade project to be provided at the bridge and key drawings posted at strategic locations on the bridge to aid maintenance and troubleshooting.
- No interlocks presently exist to prevent the electric utility service being paralleled with the standby generator. Priority should be given to installing both a form of mechanical interlock (Kirk Key) and electrical interlocks in the main and generator circuit breakers as is indicated on the existing One Line Diagram.
- Additional protective and alarm devices should be installed in the electric utility transformer to protect the transformer and alarm in the event of trouble or failure conditions.

5.3.1.3 600-kW and 40-kW Emergency Generators

- Provide protection for the battery chargers and alarm equipment exposed to the adverse weather conditions when the air intake louvers for the standby generator are open.

5.3.1.4 Main Indoor Switchboard #1 and #2

- Add phase loss and phase failure relays to Switchboard #1 Main and Generator breakers.

5.3.1.5 Main Motors

- Replace main motor nameplates with nameplates that accurately describe the parameters and rating of the motors and also include this information in the motor O&M Manual.
- Re-affix blower nameplate to the northeast blower motor.

5.3.1.6 Auxiliary Motors

- Fully commission the new bridge auxiliary drive system such that the bridge can be operated from one location using the auxiliary motors.

5.3.1.7 Main Motor Drives

- Modify the drive control logic to ensure that rapid switching of the drive 3-phase power does not blow the capacitor pre-charging circuit fuses.

5.3.1.8 South Tower Machinery Space Roof

- Repair the leak and/or leaks in the South tower machinery space roof.

5.3.1.9 Bridge Control System

- Implement logic changes to the bridge control system to minimize or eliminate the existing cumulative skew condition that presently requires re-zeroing every 2 to 3 weeks. This work should be performed by the drive manufacturer to maintain drive warranty.
- Direct the Engineer of Record for the electrical replacement and upgrade project to provide a form of skew control and skew monitoring that will provide accurate, reliable and useable data.

5.3.1.10 Gates

- The North-East warning gate gong be made operational

- Perform an inspection of the barriers and barrier arms on a 6-monthly cycle concentrating on barrier machinery, bearings and barrier arm fatigue.

5.3.1.11 Pedestrian Control

- Repair or replace the defective North pedestrian bell.

5.3.1.12 Aerial Cables

- Obtain formal “As-Built” drawings and documentation from the Contractor responsible for the repairs and design and installation of the cable spacers and dampers.
- Procure and install a means of video recording of the new aerial cable installation to monitor the performance of the installation.

5.3.1.13 Grounding and Bonding

- Perform ground resistance and continuity testing to prove the integrity of the bridge grounding and bonding system on an annual basis.

5.3.1.14 Bridge Lighting

- Repair the exit light above the generator room entrance door.

5.3.1.15 Fire Alarm System

- No corrective action is required.

5.3.1.16 Local Portable Emergency Generator Receptacles

- Rent portable generators and perform a test to prove that the portable generators can operate the bridge using the existing auxiliary drive motors.

5.3.2 2 to 5 Years

The following recommendations are not considered critical but should be addressed within the next five years.

5.3.2.1 Main Electric Service

- A containment basin to protect the surrounding environment against a transformer tank rupture and subsequent oil spill should be installed.

5.3.2.2 Main Motors

- Procurement of a second spare main motor with opposite hand cable termination is recommended to provide a spare for both hand motors installed.

5.3.2.3 Gates

- Perform an inspection of the barriers and barrier arms on a 6-month cycle concentrating on barrier machinery, bearings and barrier arm fatigue.

5.3.2.4 Span Lock

- Replace the corroded North span lock motor disconnect switch.

5.3.2.5 Bridge Elevators

- Replace the existing bridge elevator motors and controls.

5.3.2.6 Grounding and Bonding

- Perform ground resistance and continuity testing to prove the integrity of the bridge grounding and bonding system on an annual basis.

5.3.3 6 to 10 years

The following recommendations are for inspections that are considered beyond the scope of routine inspections and maintenance required for the bridge electrical systems.

5.3.3.1 Gates

- Perform an inspection of the barriers and barrier arms on a 6-month cycle concentrating on barrier machinery, bearings and barrier arm fatigue.

5.3.3.2 Grounding and Bonding

- Perform ground resistance and continuity testing to prove the integrity of the bridge grounding and bonding system on an annual basis

6.0 COST ESTIMATES

6.1 STRUCTURAL ESTIMATES

Basic construction cost estimates, including engineering and construction administration are presented in Tables 6.1.1 and 6.1.2 below. All dollar values are shown as present value.

TABLE 6.1.1: CONSTRUCTION COSTS WITHIN 5 YEARS (2018-2022)

	STRUCTURAL RECOMMENDATIONS	PRIORITY CODE	ESTIMATED COST (TOTAL)	2018 1	2019 2	2020 3	2021 4	2022 5
1.	**Deck at approach and tower spans.**							
	1a. Concrete deck replacement (including stringers, abutment bearings and expansion joints)	B	**$4,108,000**	***$3,303,000****	--	--	--	--
	1b. Repair steel at tower base (below deck)	B		$400,000	--	--	--	--
	1c. Clean and coat steel at tower base (below deck)	B		$395,000	--	--	--	--
	1d. Repair concrete abutments and piers.	B		$10,000	--	--	--	--
2.	**Deck at Lift Span**							
	2a. Replace steel deck grating on northbound lane.	B	**$15,091,000**	--	**$7,431,000***	--	--	--
	2b. Replace steel deck grating on southbound lane.	B		--	--	**$7,660,000***	--	--
3.	**Miscellaneous Repairs**							
	3a. Replace the missing 12 rivets with high strength bolts on the south tower Horizontal No. 4 (6 on the west member and 6 on the east member), and replace the improperly installed rivet at the top angle connection for the top	B	**$32,000**	$5,000	--	--	--	--

	flange of the 6th longitudinal sheave girder from west with a high strength bolt. Clean and repaint the area.							
	3b. Repair broken spindle on sidewalk railing and tighten the loose bolts on rail posts on the sidewalk.	A		$2,000	--	--	--	--
	3c. Install toe boards on the walkways over the counter weights under the messenger cable beams for both north and south tower.	A		$5,000	--	--	--	--
	3d. Detail drilled holes in portal framing members to upturned element connections for drainage prior to the cleaning and painting of the truss.	C		--	--	--	$20,000	--
TOTAL ESTIMATED COSTS WITHIN NEXT 5 YEARS			**$19,231,000**	**$4,120,000**	**$7,431,000**	**$7,660,000**	**$20,000**	--

TABLE 6.1.1: CONSTRUCTION COSTS WITHIN 5 YEARS (2018-2022)								
STRUCTURAL RECOMMENDATIONS		PRIORITY CODE	ESTIMATED COST (TOTAL)	2023 6	2024 7	2025 8	2026 9	2027 10
4.	**Structural Steel Coatings (Excluding Tower Sections Below Deck)**							
	4a. Clean and recoat main deck truss	N/A	**$4,050,000**	***$2,025,000****	***$2,025,000****	--	--	--
	4b. Clean and recoat tower sections above deck.	N/A	**$6,008,000**	--	--	***$1,998,000****	***1,9980,000****	***1,490,000****
ESTIMATED COSTS FOR YEARS 6-10			**$10,058,000**	**$2,025,000**	**$2,025,000**	**$1,998,000**	**1,998,000**	**2,012,000**

Refer to Appendix "A7" for itemized estimates of the recommended work.

6.2 Mechanical Estimates

MECHANICAL RECOMMENDATION	ESTIMATED COST	2017 0	2018 1	2019 2	2020 3	2021 4	2022 5	2023 6	2024 7	2025 08	2026 09	2027 10
ESTIMATED COSTS FOR THIS YEAR (IMMEDIATE)												
1. All Brake Assemblies – Clean areas of corrosion and paint the unpainted areas on the brake assemblies, included, but not limited to the mounting bolts, brake wheel hubs and top support surfaces.	Maintenance											
2. SE Motor Brake and SW Motor Brake – remove paint from the brake wheel friction surface.	Maintenance											
3. All Couplings - clean corrosion from the couplings and paint.	Maintenance											
4. All Motors – clean areas of corrosion from the motor supports and bolts and paint the motor supports and mounting bolts.	Maintenance											
5. All G2/P2 gearsets - remove old lubricant accumulation from under all G2 gears.	Maintenance											
6. All G2/P2 gearsets - lubricate the G2 differential assembly bevel gears.	Maintenance											
7. Restore functionality to the south reducer auxiliary drive lever positioning bolt to enable operation of the south tower auxiliary drive.	Maintenance											
8. Replace all reducer housing inspection cover bolts. Repair damaged threads in the reducer housings as needed.	Maintenance											
9. Paint all reducer mounting and base bolts.	Maintenance											
10. Periodically check the north reducer drain valve and north indexing spline limit switch bolts for oil leakage to verify the leakage has been eliminated.	Maintenance											
11. Increase the frequency of lubricating the main counterweight wire ropes. Consider the use of environmentally friendly lubricants to address environmental concerns.	Maintenance											

12. NW Outboard Lift Girder Splay Casting – tighten the nut that is not fully seated.	Maintenance											
13. Clean old rope lubricant from the north auxiliary counterweight ropes and lubricate all auxiliary counterweight ropes. Consider the use of environmentally friendly lubricants to address environmental concerns.	Maintenance											
14. Remove excess lubricant from the north auxiliary counterweight sheave grooves.	Maintenance											
15. Spot clean and paint corroded areas at the main counterweight sheaves.	Maintenance											
16. Spot clean and paint corroded components at the south auxiliary counterweights sheave assemblies.	Maintenance											
17. Lubricate the main and auxiliary counterweight sheave grooves.	Maintenance											
18. Clean and paint areas of corrosion on the auxiliary counterweights.	Maintenance											
19. Schedule an internal visual inspection of trunnion bearings #8, south tower (outboard bearing supporting sheave-SW-OB) and #3, south tower (outboard bearing supporting sheave SE-OB) to evaluate the raceways for damage. Continue to perform vibration testing as part of annual inspections. Schedule SKF maintenance at all 16 trunnion bearings in conjunction with the internal inspection recommended at bearings #3 and #8 in the south tower in accordance with SKF recommendations.	$100,000											
20. Spot clean and paint corroded mounting bolts.	Maintenance											
21. Clean and paint the live load supports and anchor bolts.	Maintenance											
22. Remove excess lubricant and inspect main counterweight guide bolts.	$20,000											

23. Clean and paint the centering devices.	Maintenance											
24. Continue to monitor and periodically flush the buffer assemblies to ensure that they operate properly.	Maintenance											
25. Repair or replace the damaged northwest span buffer valve.	Maintenance											
26. Clean and paint corroded portions of the tower air buffers.	Maintenance											
27. Spot clean and paint component areas with corrosion. Components include, but are not limited to, the span lock spring assemblies, Bearing B2 mounting bolts, and the center crank.	Maintenance											
28. No corrective action is required.	Maintenance											
29. North Barrier Gate – Tighten the west counterweight bolts.	Maintenance											
30. Both Barrier Gates – Adjust gate arm operation to eliminate impact when the gate arm engages the receiver.	Maintenance											
31. Main Generator – Replace the cracked coolant hose.	Maintenance											
ESTIMATED COSTS FOR THIS YEAR (IMMEDIATE)	$120,000											
YEARS 2 - 5												
1. Conduct an in-depth inspection of the main counterweight and auxiliary counterweight ropes.	$50,000											
2. Replace the north auxiliary counterweight ropes.	$100,000											
3. Remove the span and tower air buffers from service based on rReview of the new control system and the CHBDC requirements and consider removing the span air buffers and tower air buffers from service. If the span air buffers and tower air buffers are retained, consider rehabilitating the buffers to ensure that they function as intended by installing piping to	$250,000											

connect the two buffers at each end of the span and incorporate a pressure gage that can be connected via a gate valve to perform adjustments and periodically verify the pressure that is developed in the system during seating.													
ESTIMATED COSTS FOR YEARS 2-5	$400,000												
YEARS 6-10													
ESTIMATED COSTS FOR YEARS 6-10													

6.3 ELECTRICAL ESTIMATES

ELECTRICAL RECOMMENDATION	ESTIMATED COST	2017 0	2018 1	2019 2	2020 3	2021 4	2022 5	2023 6	2024 7	2025 08	2026 09	2027 10
ESTIMATED COSTS FOR YEAR 1 (IMMEDIATE)												
1. Develop up to date "AS-Built" electrical drawings for all bridge electrical systems and post key diagrams on bridge.	$15,000											
2. Add mechanical and Electrical interlocks to main and generator breakers in Switchboard #1.	$24,000											
3. Add main transformer protection and alarm monitoring equipment.	$11,000											
4. Provide environmental protection for battery chargers and alarm equipment in bridge generator room.	Maintenance											
5. Add phase loss and phase failure relay to main and generator breaker in Switchboard #1.	$8,000											
6. Replace main motor nameplates with factual nameplate data.	Warranty											
7. Re-affix motor blower nameplate.	Warranty											
8. Fully commission bridge auxiliary drives (single location control).	$9,500											
9. Modify main motor drive capacitor pre-charging contactor logic.	Warranty											
10. Repair south tower machinery space roof.	$5,000											
11. Logic changes to control system to eliminate or minimize cumulative skew.	$7,500											
12. Add a workable form of skew monitoring to replace inclinometer.	$18,000											
13. Perform repairs to traffic and pedestrian gate bells and inspect and monitor condition of traffic barriers.	Maintenance											
14. Obtain formal signed and sealed “As-Built" drawings for aerial cable repairs and retrofit design.	Ongoing Contract											

15. Procure video monitoring of aerial cable installation and inspect installation.	Ongoing Contract											
16. Perform grounding and bonding testing.	Maintenance											
17. Repair cracked lighting cover.	Warranty											
18. Test portable generator operation of bridge auxiliary drives.	Maintenance											
ESTIMATED COSTS FOR THIS YEAR (IMMEDIATE)	$98,000											
YEARS 2 - 5												
1. Install an oil containment basin for the main Electric transformer.	$26,000											
2. Procure a second spare main motor (opposite hand)	$35,000											
3. Perform 6-monthly inspection of barrier gate arms and machinery.	Maintenance											
4. Replace corroded North span lock motor disconnect switch.	$6,600											
5. Replace elevator motors and controls in both towers	$74,000											
6. Perform grounding and bonding testing.	Maintenance											
ESTIMATED COSTS FOR YEARS 2-5	$141,600											
YEARS 6-10												
1. Perform 6-monthly inspection of barrier gate arms and machinery.	Maintenance											
2. Perform grounding and bonding testing.	Maintenance											
ESTIMATED COSTS FOR YEARS 6-10	Maintenance											

7.0 CONCLUSIONS

7.1 STRUCTURAL CONCLUSIONS

Inspection of the Burlington Canal Lift Bridge revealed severe deterioration on the primary structural elements on the reinforced concrete bridge decks at the approach and tower spans, the open steel grating at the lift span deck, the deck expansion joints between the spans, and the structural steel below the bridge deck at the approach and tower spans. Defects in other areas of the bridges were found to range from light to medium and highly localized where present. The primary causes of the severe defects on the bridge components at and below the decks were evidently due to water leakage through the deck expansion joints and the concrete bridge decks at the approach and tower spans as well as the inadequate capacity of the existing deck grating at the lift span. The increase in volume of traffic, particularly heavy trucks, on the bridge due to frequent closures of the adjacent QEW highway bridges (Burlington Skyway Bridges), has likely accelerated the deterioration rate on the Burlington Canal Lift Bridge structure.

Based on the criteria specified in BIM, an overall structural condition rating of **Poor (3)** is assigned to the bridge due to the extensive deteriorations on the structural steel below the bridge deck at the approach and tower spans. Considering the ongoing maintenance and repair program being completed on the bridge, the overall bridge functional rating is **Fair (4)** as all elements, including those exhibiting defects, appeared to adequately function under the current service. Several elements of the bridges, particularly those structural steel members and bridge deck at the approach and tower spans and the deck grating at the lift span, will require major repair or replacement in the near future. In the interim, local temporary repairs such as the welding repairs of cracks in the deck grating panels at the lift span and temporary repair or reinforcing of the severely corroded stringers, will need to be continually completed for the bridge.

The existing compression seal expansion joint system in the concrete deck slabs between the approach and the tower spans is considered redundant or in-appropriate. The steel stringers below the joints were effectively found to be continuous over the joint gap in the concrete bridge deck. The bottom flange of the stringers at the approach and tower span were found rigidly bolted to the same rear floor beam for the tower. The stringers' web appears to have been bolt-connected through a single steel channel diaphragm. Therefore, this effectively eliminates any differential or relative movement of the structural steel and concrete bridge decks, thus, making the existing deck expansion joint system redundant. A proper deck expansion joint system should be determined as part of the bridge deck rehabilitation or replacement.

It is evident that significant deterioration on the structural steel at the lift span has been stabilized as a result of the 2010 and 2011 recoating contracts. The re-painted areas on the lift span steel, including all below deck steel stringers, floor beams, bracing, and truss members below and within the splash zone areas of the deck are in good condition. The need to stabilize the structural deteriorations resulting from the development of corrosion and local severe rust jacking at key locations will always remain. There is an increasing need to re-coat the other remaining areas of the bridges, including the upper section of the lift span, the steel towers and the approach spans, particularly the steel below the bridge deck. The re-coating will alleviate the more extensive failures of the painting system and subsequent development of corrosion at critical locations.

7.2 MECHANICAL CONCLUSIONS

The mechanical machinery on the Burlington Canal Lift Bridge was inspected per the scope of inspection listed in the Scope of Annual Inspection section of this report. The new span drive mechanical machinery provided as part of the recent rehabilitation contract was found to be in good condition. All other mechanical machinery, including the span drive, span guides, sheaves, counterweight guides, traffic gates, and span locks were found to be in fair condition. The majority of the deficiencies found during the inspection are minor issues such as paint deterioration and corrosion and can easily be corrected by the capable PWGSC maintenance staff.

Apart from the inadequate paint, the span drive machinery components were found in good condition with only minor issues. The south reducer auxiliary drive engagement lever was inoperable due to a damaged positioning bolt. Some minor marks were noted on the south reducer gear teeth, though they did not appear to have significant depth and corrective action is not required. These should be monitored during future inspections.

The counterweight sheave trunnions and trunnion bearings were in fair condition externally however, based on vibration testing, SKF noted potential issues at the outboard bearing for the SE-IB trunnion (bearing #3), the outboard bearing for the SW-OB trunnion (bearing #8), and the inboard and outboard bearings for the NW-IB trunnion (bearings #5 and #6). Note that analysis at the south tower bearing #8 were consistent with 2015 and 2016 analysis, and have not increased in severity. The other indications are new. SKF recommends a visual inspection of the bearing raceway for the south tower bearings as the impacts are consistent with damage to the raceway. This should be performed during a shutdown period. At the north tower bearings, the noted impact frequencies are unrelated to the bearing design. For these bearings, additional periodic vibration testing and/or troubleshooting is recommended.

As in previous inspections, the lubrication of the main counterweight ropes and sheave grooves were found to be light at the time of the inspection. The main counterweight ropes exhibit areas along the length of the ropes where the lubricant has been displaced by contact with the sheave, but to a lesser extent than in 2016, indicating that the ropes have been lubricated. However, based on the conditions observed during the inspection, the frequency of lubrication remains inadequate. Wear measurements show that the ropes have only experienced a light reduction in capacity, though it can be expected that the wire ropes will corrode and wear at an accelerated rate if they are not properly lubricated.

Accumulated old lubricant at the north auxiliary ropes and sheaves should be removed. The south auxiliary ropes and sheaves were not lubricated and there is fretting and noise during operation. Without proper lubrication practice of these ropes, accelerated wear is expected. Wear flat measurements at the north auxiliary ropes represent an approximate capacity reduction of 17%. An in-depth inspection of the auxiliary counterweight ropes should be included in the next inspection. As a minimum, consideration should be given to replacing these ropes within the next five years, though this may be adjusted based on the results of the in-depth inspection.

The span air buffers have required significant maintenance attention since infiltration during span painting years ago. These were flushed with oil since the 2016 inspection and are performing reliably at this time. The tower air buffers remain functional. Given that a new modern control system is in place, consideration may be given to removing the span and tower air buffers in their entirety as this acceptable per Article 13.7.11 of the CHBDC which notes that a control system that is “capable of performing smooth seating in a positive manner” and “capable of limiting the span lift in a positive manner” may be used in lieu of air buffers.

If the continued use of air buffers is desired and they are to be retained long term, then consideration should be given to rehabilitating the air buffers to ensure that they function as intended. For both the span and tower buffers, if they are to be maintained long term, it is recommended that the two buffers on a given end be piped together to equalize loads.

Overall, the mechanical machinery systems are expected to be serviceable in the long term provided that the noted deficiencies, which primarily include lubrication and corrosion issues, are addressed. The largest risk to the reliable operation of the bridge is possible damage at the main counterweight trunnion bearings, which was noted by SKF from their vibration testing. The trunnion bearings should be provided with the recommended internal inspection and additional vibration testing. Strong consideration should be given to re-lubricating the bearings at the time of their internal inspection.

7.3 ELECTRICAL CONCLUSIONS

The bridge is provided with a dedicated unit substation which received its feed from the local electric utility. The utility service provides a reliable source of power for the bridge that has been adequately sized to operate the bridge under all normal and contingency conditions. Additionally, two (2) standby diesel generators have been installed at the bridge to provide backup power in the event of electric utility failure. It is considered appropriate that two (2) standby generators have been installed at the bridge. One (1) has been sized to be capable of operating the bridge, while the second is much smaller and only used to provide electric service for the bridge facilities. Normally only the facilities generator is used under electric utility failure with the main generator only used when the bridge is operated. It is concluded that with both the electric utility service and the two (2) standby generators that the bridge is provided with fully redundant electric service.

The electrical power and control systems have undergone major changes over the last three years which were intended to replace the legacy technology control and drive systems for the bridge with modern control and drive systems. The objective was to enhance reliability and longevity of the bridge electrical operating systems and minimize required system maintenance. For the most part, the installed replacement systems achieve these goals but a number of control issues remain that should be resolved to ensure that the goal of providing a reliable operating system is achieved. These issues consist of:

- Complete as-built electrical documentation should be held at the bridge and key drawings posted at strategic locations on the bridge to aid maintenance and troubleshooting.
- No interlocks presently exist to prevent the electric utility service from being paralleled with the standby generator. Priority should be given to installing both a form of mechanical interlock (Kirk Key) and electrical interlocks in the main and generator circuit breakers as is indicated on the existing One Line Diagram.
- Additional protective and alarm devices should be installed in the electric utility transformer to protect the transformer and alarm in the event of trouble or failure conditions.
- The existing electric utility transformer is an oil filled transformer but no oil containment has been installed to prevent a potential environmental hazard. Consideration should be given to the installation of a containment basin to protect the surrounding environment against a transformer tank rupture and subsequent oil spill.
- The battery chargers and alarm equipment associated with the standby generators are presently exposed to adverse weather when the generator is running and the generator room louvers are open for air intake. It is concluded that, due to their criticality, these units should either be moved or some form of environmental protection added to them.
- Neither the main or generator breaker in Switchboard #1 are provided with phase loss and phase failure relays. This is a critical deficiency without this protection, a phase loss or phase failure would go unchecked and potentially could cause catastrophic and costly damage to the bridge operating system.
- The main motors are squirrel cage motors and are oversized motors (250hp) operating at 900 rpm but their nameplate indicates the duty required for the bridge which is 150hp at 555 rpm. This mismatch causes an issue when tuning the drive that operates the motor. To tune the drive the motor operating characteristics must be inputted into the drive. For future reference, and to enable the drives to be re-tuned, the

nameplates should be changed to truly reflect the design parameters of the motors. This updated data should also be included in the O&M Manual for the motors.

- A spare main motor has been furnished at the bridge as part of the electrical and replacement project but it is only able to replace two of the installed motors as two are opposite hand cable terminations. Consideration should be given to procuring a second spare main motor with opposite hand cable termination.

- The present auxiliary drive system requires the auxiliary drive motors in each tower to be operated locally and independently from one another. Consideration should be given to fully implementing the original scope of the electrical replacement and upgrade project by completing the auxiliary drive work to enable both motors to be operated from one location.

- The newly installed main motor drives are presently vulnerable to failure in the event of rapid power switching and the blowing of drive pre-charging fuses. It is considered critical that this deficiency be given priority and rectified as soon as possible to maintain reliable operation of the bridge.

- The South Tower machinery space has a roof leak which potentially will cause damage and failure of the bridge electrical equipment in that area. This roof leak should be repaired as soon as possible to maintain the operating reliability of the bridge.

- The bridge operating system has always had an issue of creating a span skew condition after numerous bridge operating cycles of cumulating skew error. The intent was that the recent electrical replacement and upgrade project would eliminate this issue. This has not been the case and the bridge operating system have to be manually re-zeroed every two to three weeks. It has been concluded that this issue can be reduced and/or completely eliminated with minor control logic changes.

- The recently completed electrical replacement and upgrade project specified an inclinometer to monitor and control span skew. This device is unable to provide the accuracy necessary for the desired function. This device should be replaced with one more suited for the application.

- The north span lock disconnect switch exhibits extensive corrosion and should be replaced in the mid-term.

- The replaced aerial cable installation design did not account for environmental loads and experienced some damage from wind. Repairs to the aerial cable damage and the installation of a spacer and wind damping system, designed by the electrical replacement and upgrade project contractor and their Engineer, was in process at the time of the inspection. To ensure that these mitigation measures solve the instability issues, consideration should be given to monitoring the installed aerial cable system over an extended period. Note that it is important for auditing purposes that PWGSC are provided with signed and sealed drawings and documents for the work performed.

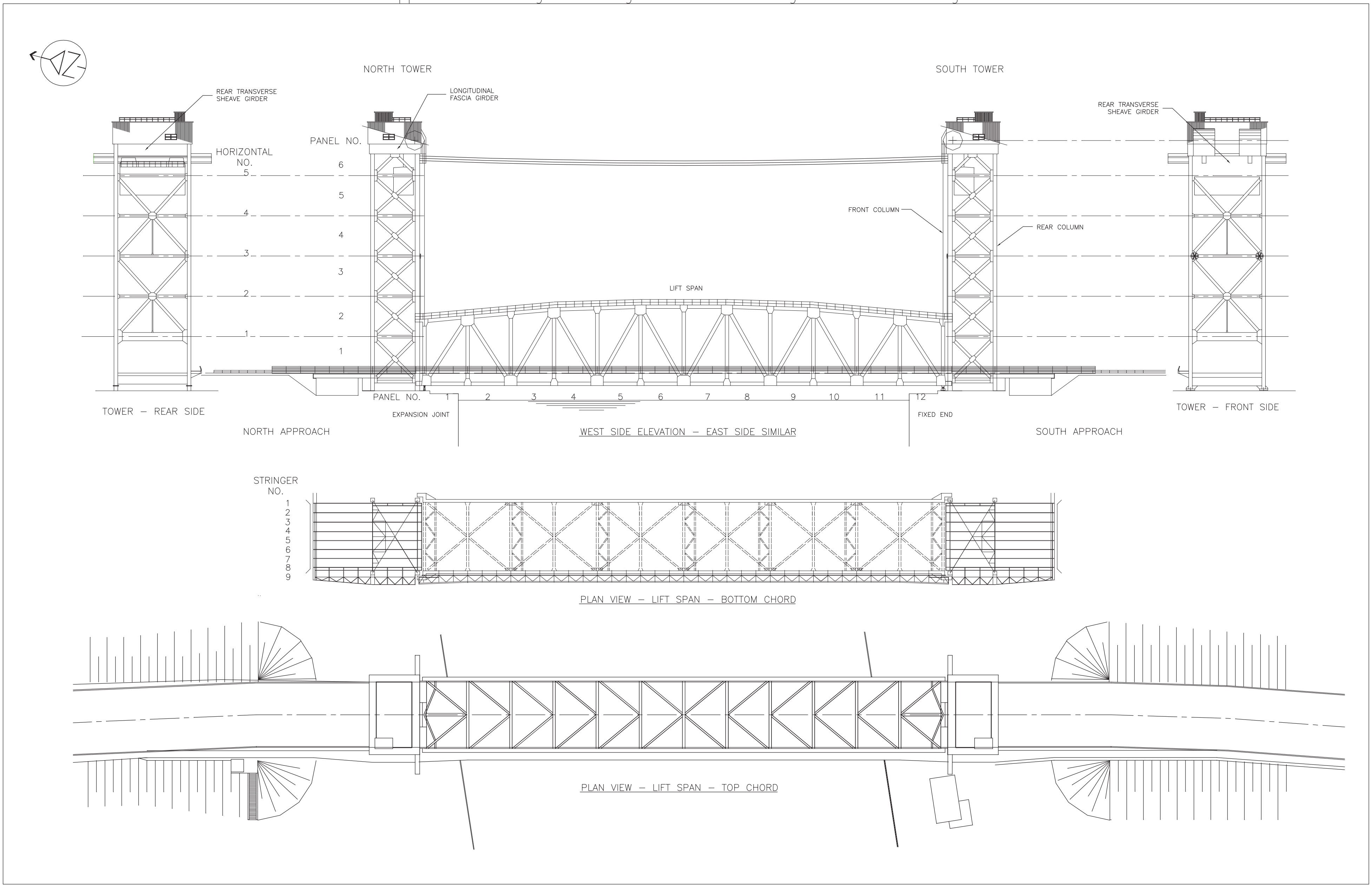
- The traffic control system for the bridge was designed and installed as part of the recent electrical replacement and upgrade project. The traffic control system functions in accordance with code and has been well installed with the exception of the following deficiencies;

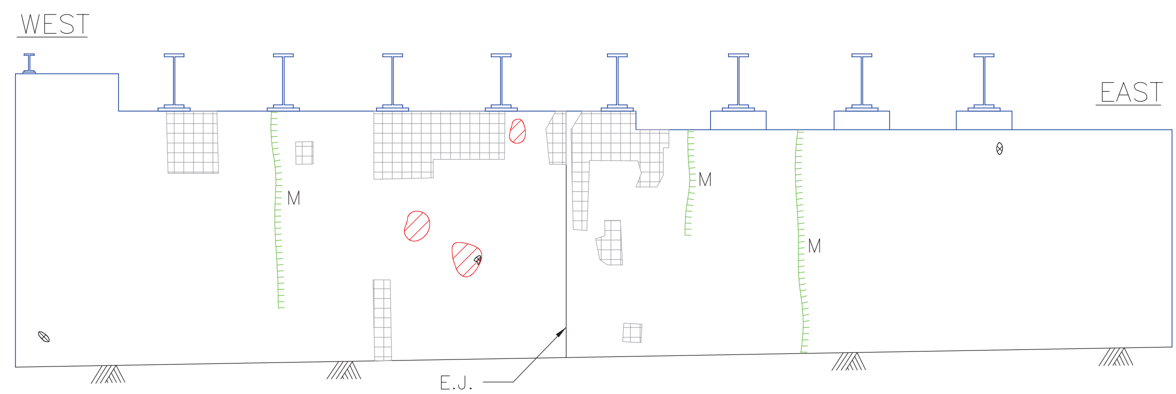
- The NE traffic gate waring gong was not operational at the time of the inspection and should be repaired.
- The defective North pedestrian signal bell should be repaired.
- The barrier arms are over 55’ long and the effect of wind on their integrity is a concern. Consideration should be given to inspecting these barriers and barrier arms on a 6-monthly cycle for machinery and bearing issues as well as barrier arm fatigue.
- The existing bridge tower elevators are prone to failure and consideration should be given to refurbishing their machinery and controls to improve their reliability.

APPENDIX A1

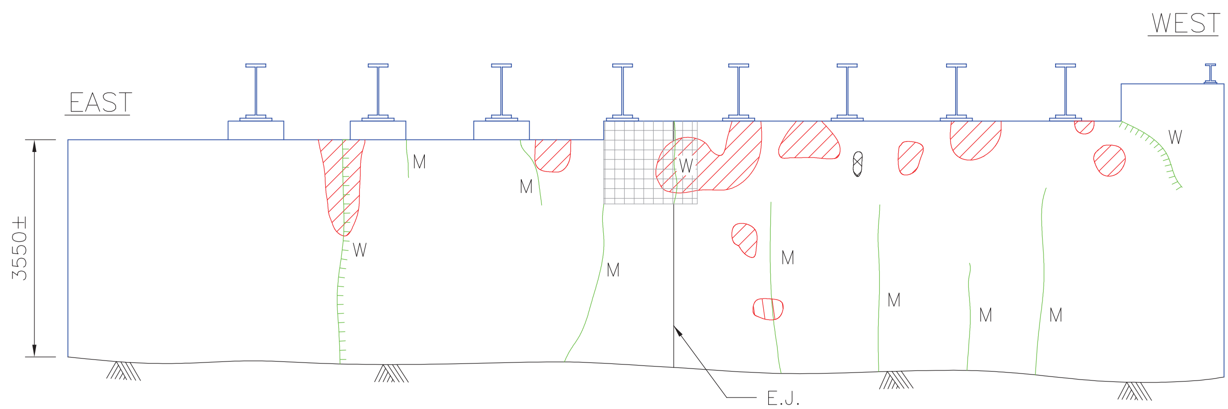
Figures & Sketches

Appendix A1 – Fig. 1 Burlington Canal Lift Bridge – General Arrangement





NORTH ABUTMENT



SOUTH ABUTMENT

LEGEND

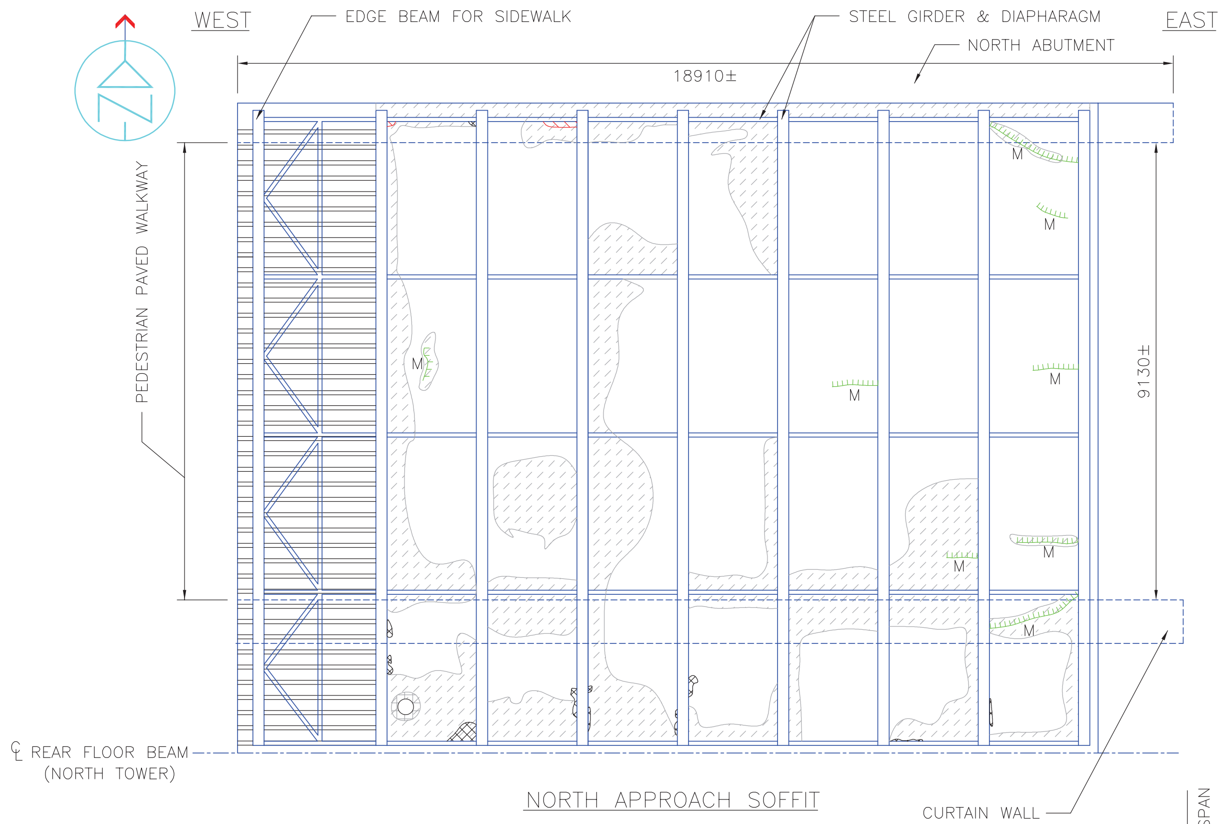
M	MEDIUM CRACK
M	STAINED MEDIUM CRACK
W	WIDE CRACK
	DELAMINATION
	SPALLS
	WET AREAS
	PATCHED AREAS

MORRISON HERSHFIELD

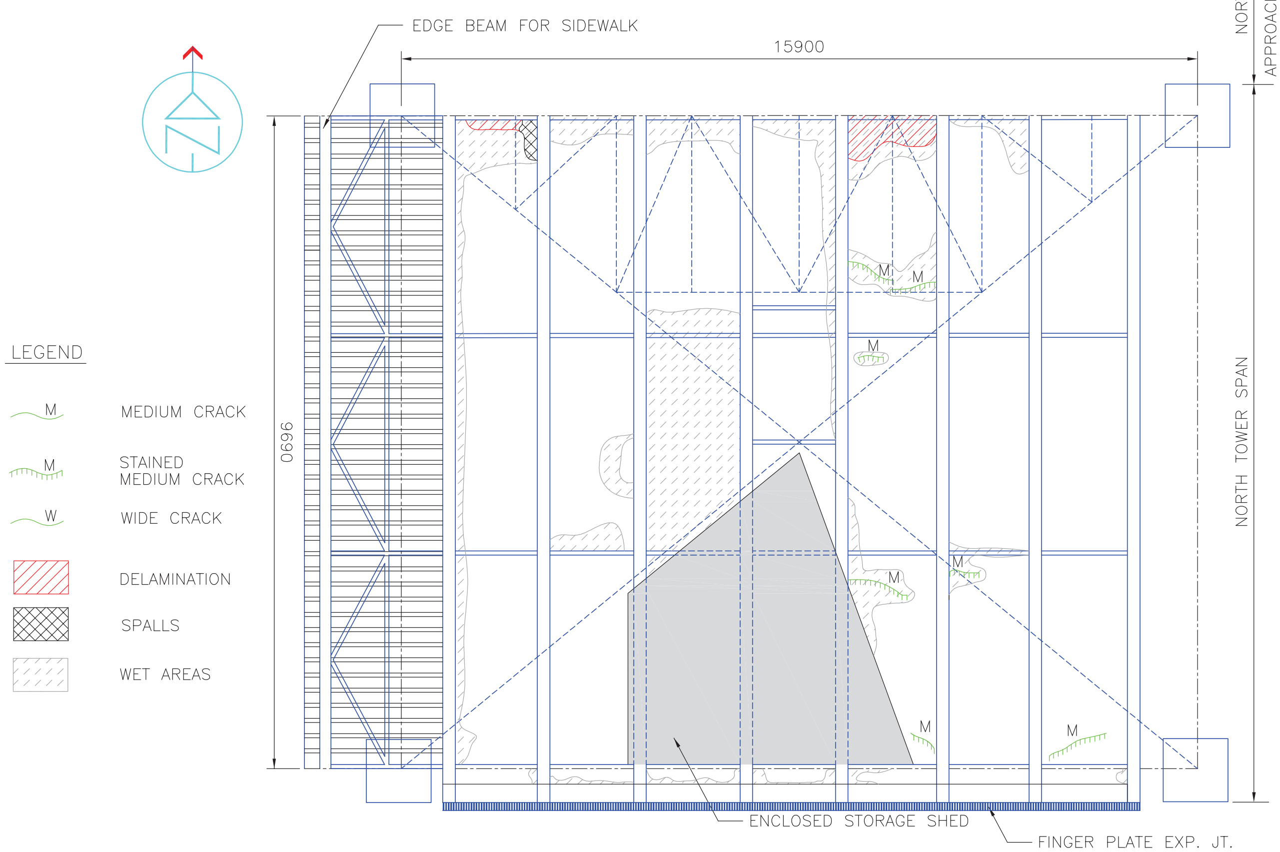
DESIGNED:	S.S.Q.
DRAWN:	P.L.
SKETCH:	SK-1

BURLINGTON LIFT BRIDGE – NORTH & SOUTH APPROACH SPANS

SURFACE DETERIORATION – ABUTMENTS



NORTH APPROACH SOFFIT



NORTH TOWER SPAN SOFFIT

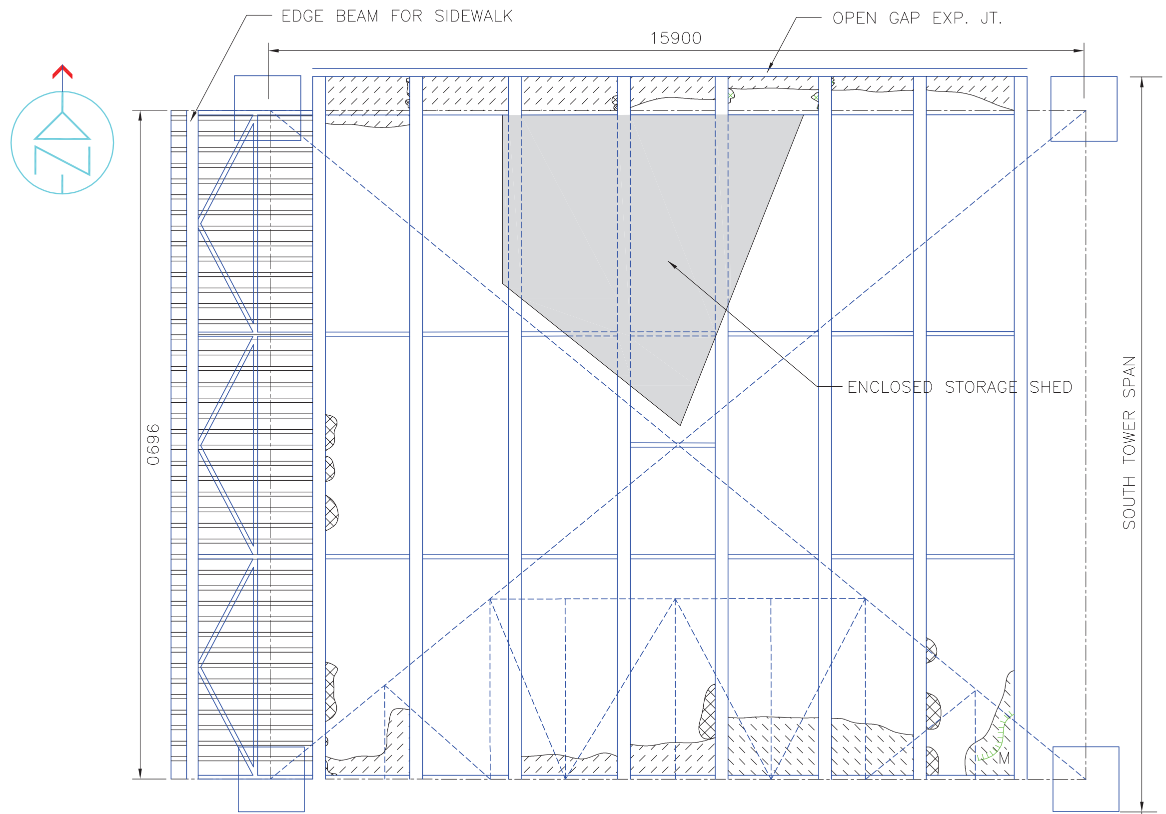
MORRISON HERSHFIELD

DESIGNED:	S.S.Q.
DRAWN:	P.L.

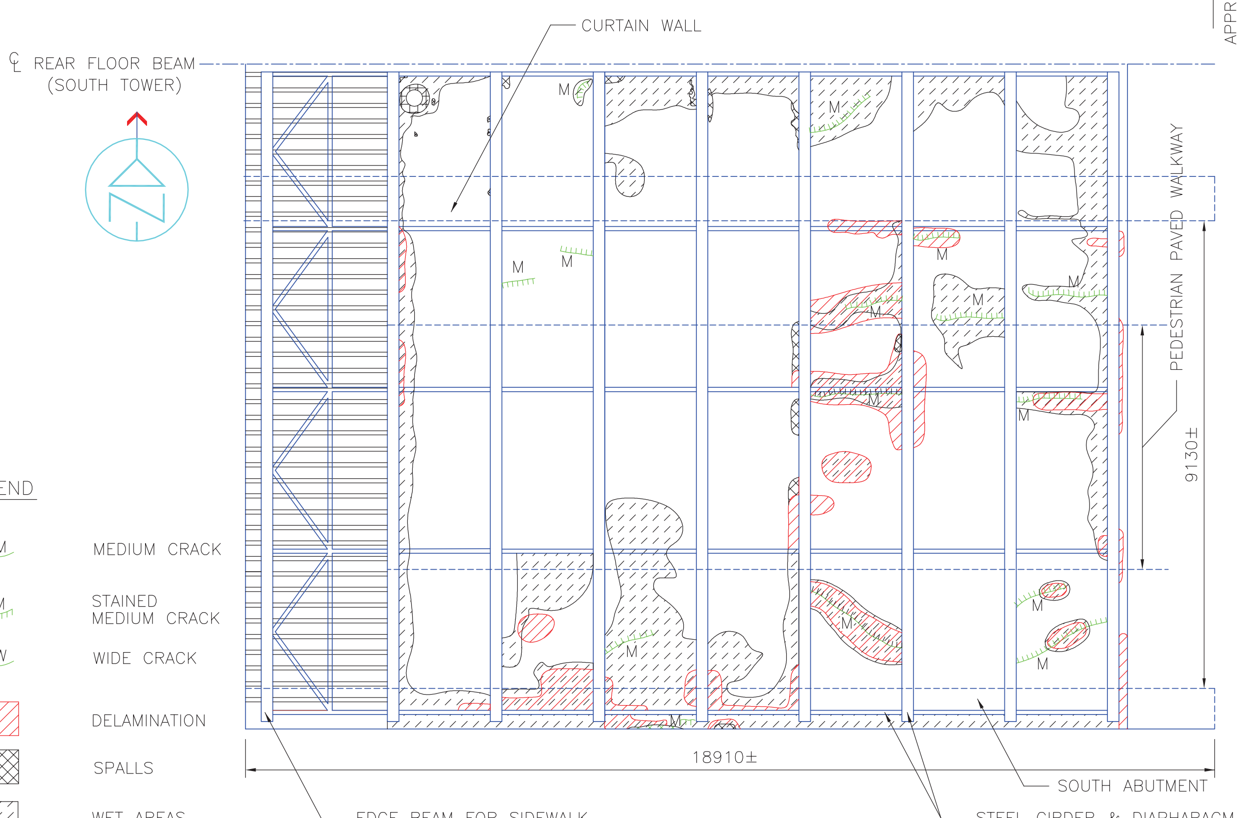
BURLINGTON LIFT BRIDGE – NORTH APPROACH & TOWER SPANS

SOFFIT DETERIORATION

DRAWING No.: SK–2



SOUTH TOWER SPAN SOFFIT



SOUTH APPROACH SOFFIT

LEGEND

M	MEDIUM CRACK
M	STAINED MEDIUM CRACK
W	WIDE CRACK
	DELAMINATION
	SPALLS
	WET AREAS

MORRISON HERSHFIELD

DESIGNED:	S.S.Q.
DRAWN:	P.L.
DRAWING No.:	SK-3

BURLINGTON LIFT BRIDGE – SOUTH APPROACH & TOWER SPANS

SOFFIT DETERIORATION

APPENDIX A2

Site Photographs

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10 North Abutment, Typical Stained Vertical Crack on North Abutment Wall, West Section of Wall Shown

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13 North Abutment, Exposed Bar in Spalls @ Central Construction Joint in North Ballast Wall

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19 South Abutment, Typical Concrete Debris on Bearing Seat

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26 North Curtain Wall @ South Section of North Approach Span looking East

27 North Curtain Wall, South Face looking East

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29 South Curtain Wall, North Face looking West

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37 New Cantilever Slab for Swing Gate Support on Northeast & Southeast Retaining Walls, Northeast Wall Shown

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49 Cracks & Asphalt Patches at Exp Joint between South Approach & Tower Span, looking West

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85 Typical Soffit Sloping Towards Structural Steel @ South Abutment, Stringers 3&4 Shown

86 Typical Wet Soffit & Severe Corrosion on Steel below Abutment Joints, South End @ Stringers 5&6 Shown

87 Heavy Wet Area with Large Delamination & Spalls at South Deck End, East of Stringer 5

88 Wet Area & Spalls on South End Soffit between Stringers 6&7

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90 North Approach Span, Local Delam on Soffit atop North End Diaphragm @ Stringer 6

91 North Approach Span, Stained Diagonal Cracks @ Northeast Section

92 North Approach Span, Diagonal Stained Crack with Wet Area on East Soffit near Mid Section of Span

93 Wet Soffit & Heavy Corrosion on Steel below Exp Joint @ North Approach & Tower Spans, looking West

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95 North Tower Span, Wet Areas on Soffit @ Northwest Section of Span

96 Wet Area & Delamination on Soffit between Stringers 3&4 near Exp Jt @ North End of North Tower Span

97 North Tower Span, Stained Crack with Wet Area on Interior Soffit near Mid-Span @ Stringer 4

98 Typical Soffit below North Finger Plate Expansion Joint, looking West

99 Wet Soffit & Heavy Corrosion on Stringer 4 below North Finger Plate Expansion Joint

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101 South Approach Span, Large Wet & Delam on Interior Soffit @ South Abutment

102 South Approach Span, Central Interior Soffit @ South Abutment

103 South Approach Span, Delam on Central Interior Soffit

104 Wet Soffit @ North End of South Approach Span, looking West

105 Wet Soffit @ Stringers 2&3 adjacent to Exp Joint @ North End of South Approach Span

106 Wet Soffit & Heavy Corrosion on Steel below Expansion Joint @ South Approach & Tower Spans, looking SE

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108 Overhang Soffit below Open Gap Expansion Joint @ North End of South Tower Span, looking West

109 Wet Soffit & Heavy Corrosion on East Stringers below Open Gap Exp Joint @ NE corner of South Tower Span

110 Typical Severe Corrosion on Stringers & Diaphragms at Abutment End, Stringer 6 @ South Abutment Shown

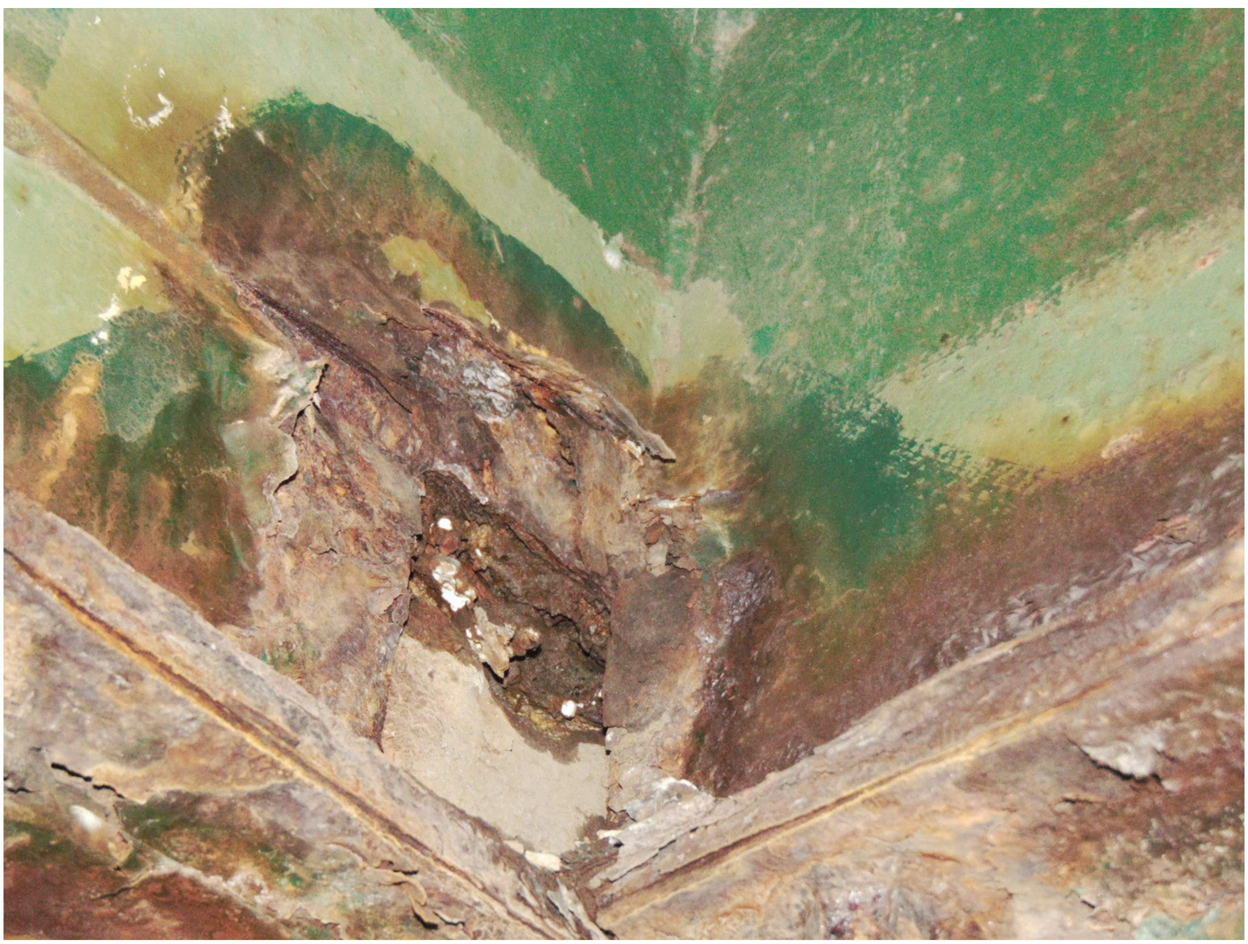
111 North Approach Span, Severe Corrosion on Bottom of Stringer 6 @ North Abutment

112 Typical Heavy Corrosion on Steel Diaphragm-Gusset Plate & Stringer at North Abutment, Stringer 3 Shown

113 Severe Corrosion on Stringer 8 & Perforated Stiffener for Diaphragm @ South Abutment

114 Severe Corrosion on Top Flange of Stringer 8 @ North Approach Span

115 Local Severe Corrosion on Bracket for Cantilevered West Sidewalk @ North Approach Span



116 South Approach Span, Perforated Curb Plate @ South Expansion Joint End

117 Typical Diaphragm & Stringers Connections below Exp Joint @ North Approach & Tower Spans

118 Typical Stringers & Diaphragm Connections below Exp Joint between South Approach & Tower Spans

119 Concrete Pier @ North Tower Base (Lift Span Up), looking West

120 Concrete Pier @ South Tower Base (Lift Span Down), looking East

121 Cracks & Local Severe Scaling on Concrete Base @ North Tower's Southwest Leg

122 Typical Anchorage Assembly @ Front Tower Column, Northwest Column @ South Tower Shown

123 Typical Anchorage Assembly on Rear Tower Column, Northwest Column @ North Tower Shown

124 South Tower Base, Interior Steel Pedestal Bearing under South Floor Beam

125 Local Severe Corrosion on Anchor Assembly for NW Rear Column @ North Tower

126 Severe Corrosion on Anchorage Assembly @ SW Rear Column of South Tower

127 Severe Corrosion on Anchor Bolts for Anchorage Assembly for Front Tower Column, NW Column @ South Tower

128 Sediment on Bottom of Northeast Column @ South Tower (TYP)

129 Sediment Accumulation @ Interior Bottom Plate of Tower Column, Northeast Column @ North Tower Shown

130 North Tower, Heavy Corrosion on North Face of Rear Floor Beam near NW Column

131 North Tower, Medium-Severe Corrosion on South Face of Rear Floor Beam, looking East

132 South Tower, Heavy Corrosion on Lower West Section of Rear Floor Beam (TYP)

133 North Tower, Severe Corrosion on Lower South Face Section of Rear Floor Beam near NW Column

134 Severe Corrosion on Sway Bracing at Rear Floor Beam @ North Tower (TYP)

135 Typical Accumulation of Sediment on Front Floor Beam, South Tower Shown

136 Sediment on Gusset Plate behind Front Tower Column, Northeast Column @ South Tower Shown

137 West Jacking Girder @ North Tower, looking South (3)

138 Typical Underside of Jacking Girder, East Girder @ South Tower Shown

139 Local Medium Rust Jacking on Bottom North Section of West Jacking Girder @ North Tower (TYP)

140 Bird Feather & Debris on Bottom interior of East Jacking Girder @ South Tower (TYP)

141 South Elevation view of North Tower

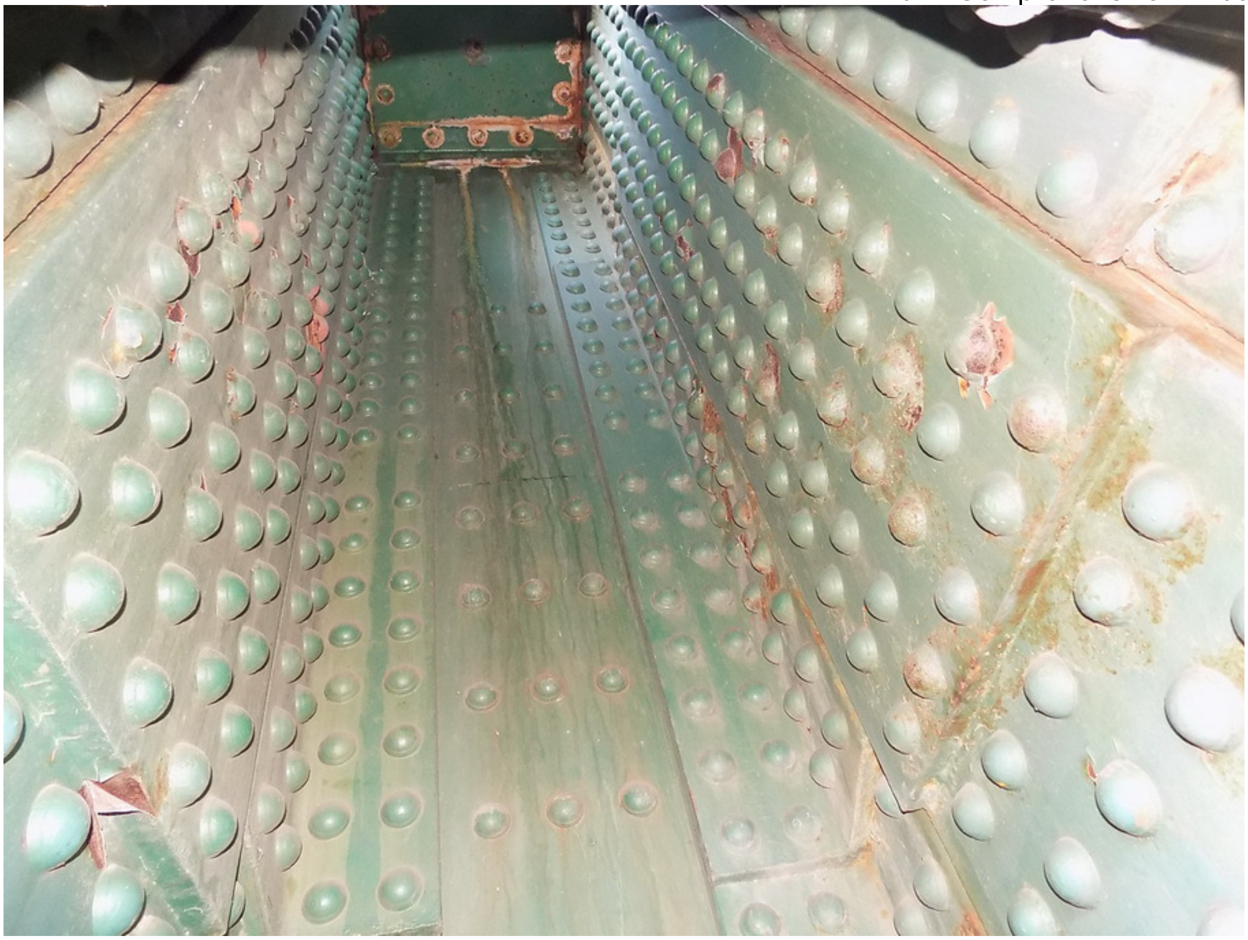
142 Enclosed Housing for Equipment & Sheave Rooms atop of South Tower (TYP)

143 General View of North Tower Interior from NW Corner

144 General View of South Tower Interior

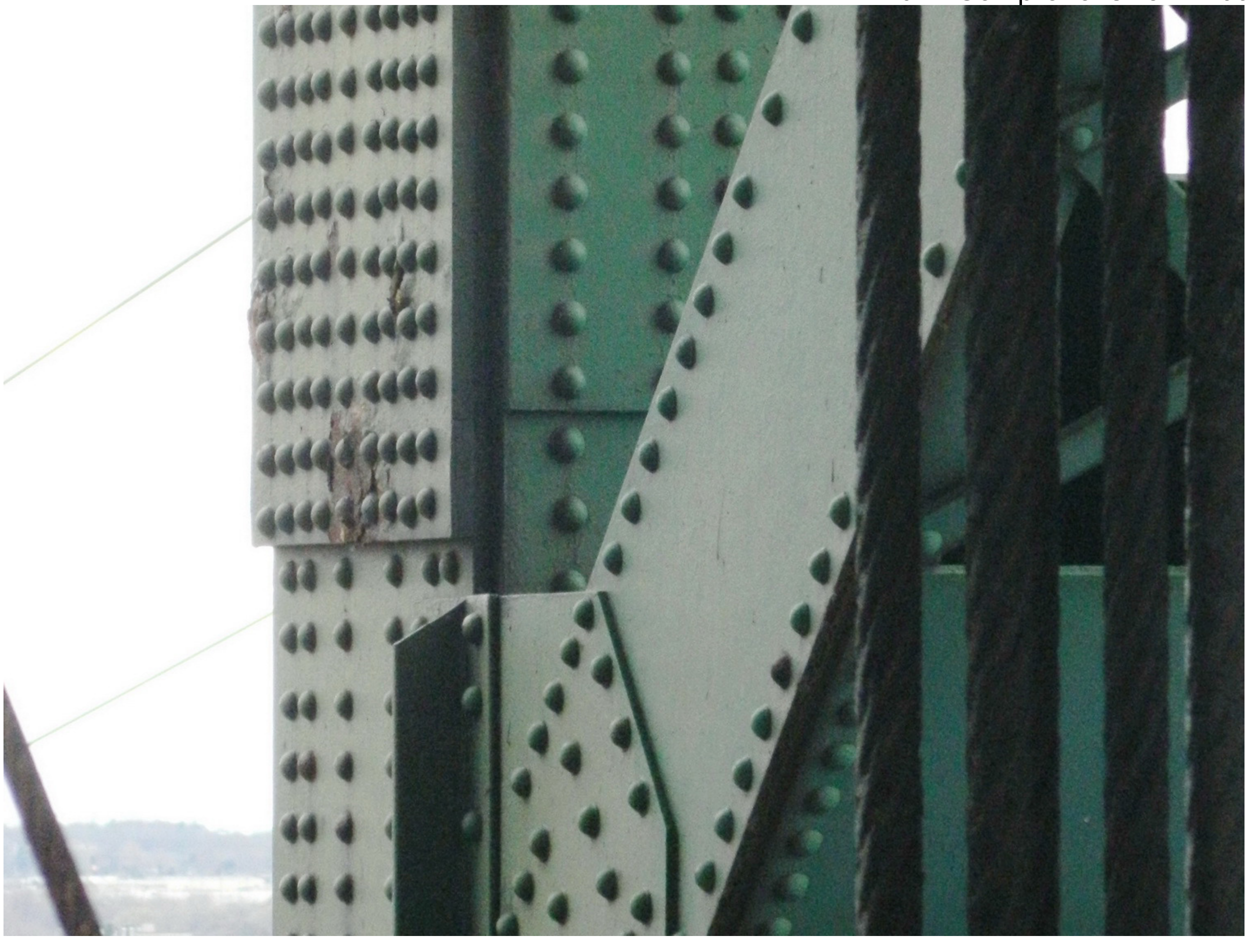
145 North Tower @ Road Level, looking East

146 Typical Bird Dropping on Tower Steel, South Tower Shown



147 Typical Local Peeled Paint & Light Rust on Column Interior, Northeast Column of South Tower Shown

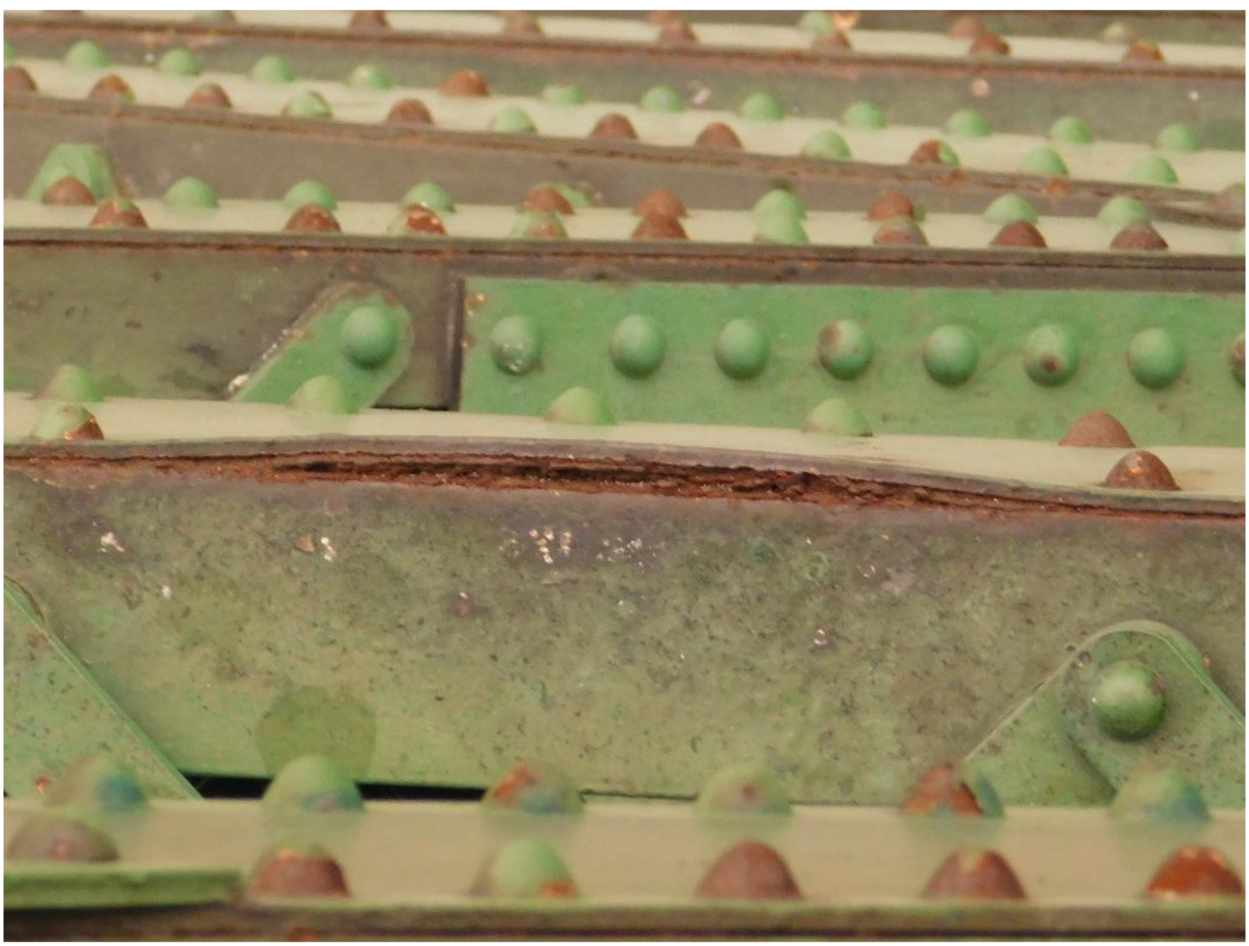
148 Debris on Interior Plate in Northwest Column of North Tower @ Sidewalk Level (TYP)



149 Typical Light Corrosion on Tower Column @ Coating Failure Spots, Southwest Column @ North Tower Shown

150 Typical Rust Spots on Steel Tower, North Tower Shown


151 Missing Rivets on Central West Face of Horizontal Member 4 @ South Tower (TYP)


152 Severe Rust Jacking @ Missing Rivets on Horizontal Member 4 of South Tower (TYP)

153 Typical Front Transverse Sheave Girder at top of Towers, South Girder in North Tower Shown

154 Bird Guano on Bottom Flange of Font Transverse Sheave Girder, South Tower Shown

155 East Fascia Girder & Cladding on Equipment Room Housing atop South Tower (TYP)

156 Typical Sheave Girders on Underside of Equipment Room atop South Tower

157 Typical Sheave Girder below Sheave-Equipment Rooms, 6th Girder from East @ South Tower Shown

158 Typical Underside of Concrete Floor Slab for Equipment Room, South Tower looking South Shown

159 Typical Local Light Surface Rust on Bottom of Sheave Girders, South Tower Shown

160 Typical Light Corrosion on Bottom of Sheave Girders, South Tower Shown

161 Severe Rust Jacking on Bottom North End of 3rd Sheave Girder from West in South Tower

162 Un-Fitted Rivet @Top of 6th Sheave Girder from West above Floor Beam, North Tower

163 Typical Main Counter Weight @ top of Tower, North Tower Shown

164 Typical Catwalk & Main Counterweight below Machine Room @ top of Tower, Nortth Tower Shown

165 Typical Anchorage of Lift Cables @ Top of Counter Weight, East Side in North Tower Shown

166 Typical Sheave for Main Counter Weight, West Sheaves in South Tower Shown

167 Concrete Cap on Main Counter Weight in South Tower, looking East (TYP)

168 Typical Medium Crack on Top Surface of Concrete Counter Weight, North Tower Shown

169 Light Surface Rust on Pin for Counter Weight Hanger Plates @ South Tower (TYP)

170 Typical Counter Weight Guiderail in Tower, Top Section of East Rail in South Tower Shown

171 Missing Guide-Bar Angles @ top Section of West Guiderail for Counter Weight in North Tower

172 Blistered & Peeled Paint on Guiderail for Counter Weight on West Side of South Tower @ Panel 2

173 Peeling of Paint & Light Corrosion on Counter Weight's Guiderail @ Lower Platform in South Tower (TYP)

174 Loose Anchor Bolt on Central Post of Safety Rail atop South Counter Weight

175 Bent Pipe Rail near Northeast Corner of North Counter Weight, looking East

176 Typical Auxiliary Counter Weight and Sheave on Front Column, Southwest Column of North Tower Shown

177 Southeast Column @ Tower Panel Point 3, North Tower @ Auxiliary Counter Weight Sheave Shown

178 Typical Framing Supports @ Bottom of Elevator Shaft, North Tower Shown

179 Elevation Shaft below Equipment Room in North Tower (TYP)

180 Catwalk & Stairs to Elevator in South Tower, looking East

181 Typical Upper Catwalk below Machine Room, South Tower Shown

182 Typical Access Ladder with Cable Arresting System on Tower, Ladder @ South Tower Shown

183 Ladder with Cable Arresting System and Landing Platform in North Tower (TYP)

184 Typical Platform & Caged Ladder from Lower Catwalk to Lift Span Truss, South Tower Shown

185 Caged Ladder with Cable Fall Arrest System & Platform to Monitoring Camera on East Face of South Tower

186 Typical Disconnected Lower Section of Disused Exterior Ladder, South Tower near Northwest Column Shown

187 Typical Disused Exterior Ladder from Top, Southwest Ladder on North Tower Shown

188 Extended railings on Upper Catwalk at Disused Exterior Ladder @ South Tower (TYP)

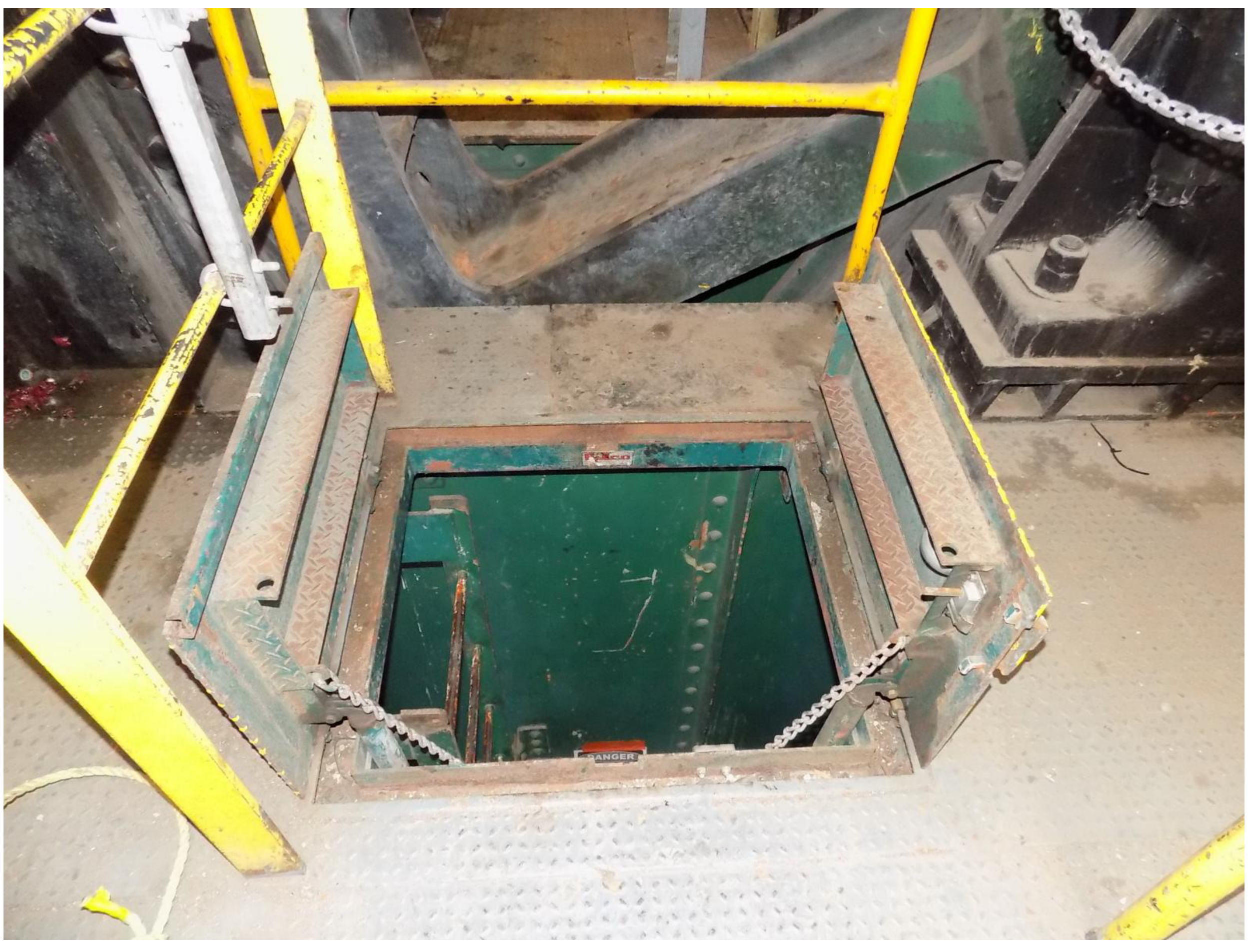
189 Severe Rust Jacking @ Top of Floor Beam for Lower Catwalk of South Tower (TYP)

190 Light-Medium Corrosion on Anchor Plate for Catwalk Railing @ South Tower (TYP)

191 Typical Light-Medium Corrosion on Stand-off Bracket for Lower Platform, North Tower Shown

192 Typical Access Hatch to Climbing Ladder near Machine Room @ Top of Tower, North Tower Shown

193 Typical Cable Arresting System on Access Ladder



194 Typical Access Hatch in Sheave Room to Upper Catwalk, South Tower Shown

195Typical Arresting Hoist Cable Unit for Ladder to Upper Catwalk

196 East Messenger Bracket & Cables under Construction (TYP)

197 New Cable Tray behind Rear Transverse Sheave Girder @ North Tower (TYP)

198 Typical Messenger Cable Beam, West Beam @ North Tower Shown

199 Light Surface Rust on Conduits under Sheave Girder in North Tower (TYP)

200 General View of Equipment Room atop North Tower, looking West (TYP)

201 General view of Sheave Room atop South Tower, looking West (TYP)

202 Stabilizing Weight Concrete Blocks @ South Central Area of Sheave Room in North Tower (TYP)

203 Typical Air Cushion Unit @ Front of Sheave Room, East Side in North Tower Shown

204 Roof Framing & Panels in Equipment Room atop North Tower, looking West

205 Roof Framing & Panels in Sheave Room atop South Tower, looking East

206 Typical Peeled Coating on Walls & Roof Panel in Sheave Room, North Tower Shown

207 Severe Peeling of Paint Coating on East Wall of North Equipment Room

208 Typical Concrete Floor in Equipment Room, North Tower Shown

209 Typical Light Corrosion on Steel Frame, Sheave Room in South Tower Shown

210 Typical Roof Membrane atop of Tower, North Roof looking East Shown

211 Typical Penthouse Equipment Room on Tower's Roof, South Roof Shown

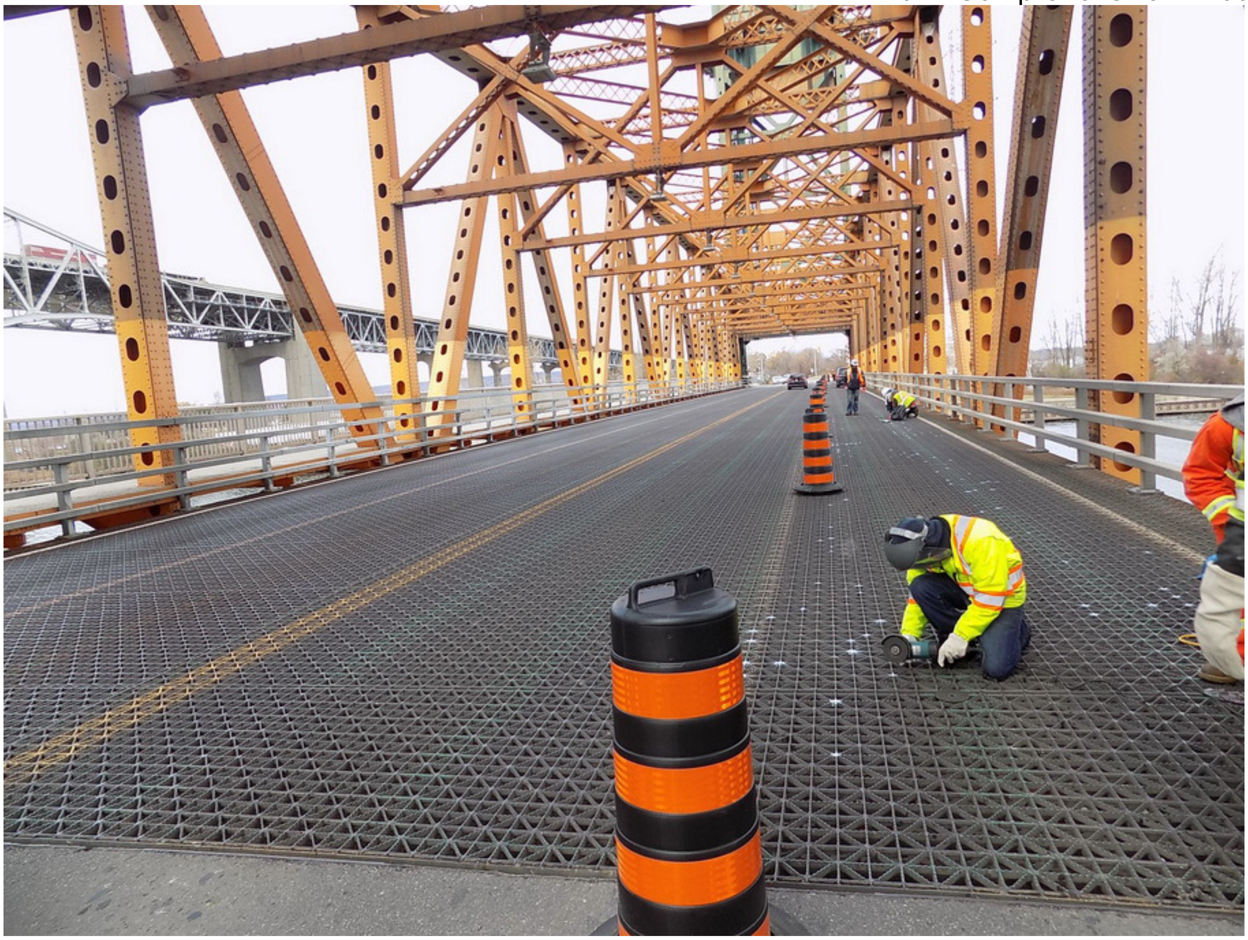
212 Typical Access Hatch with Railing to Roof, South Tower Shown

213 Typical Rubber Mat Walkway on Roof Membrane atop South Tower (TYP)

214 General View of Lift Span from Northeast Corner

215 Lift Span from Southwest Corner

216 Deck Grating @ Lift Span from North



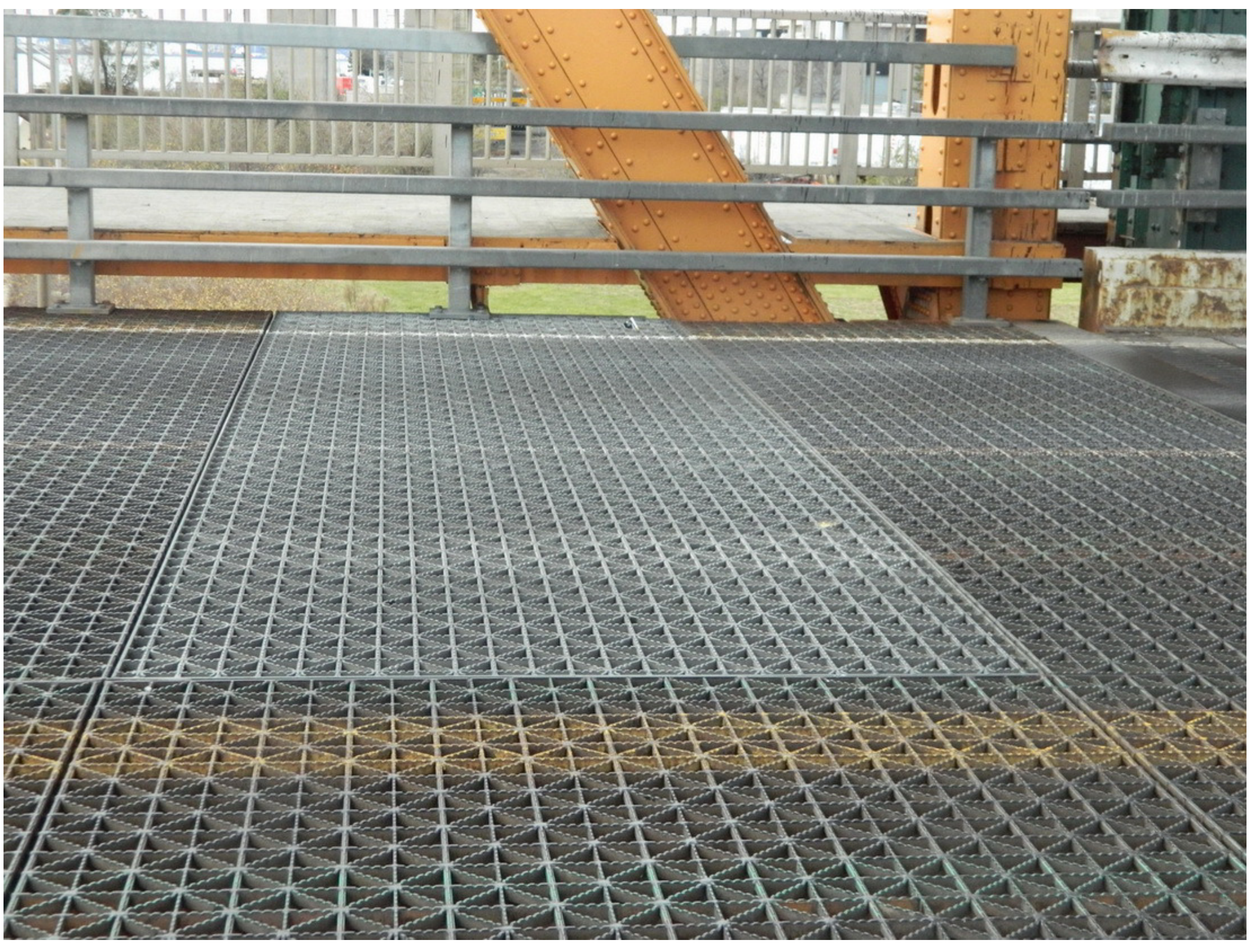
217 Lift Span Deck Grating from South

218 Typical Weld Repaired on Original Deck Grating

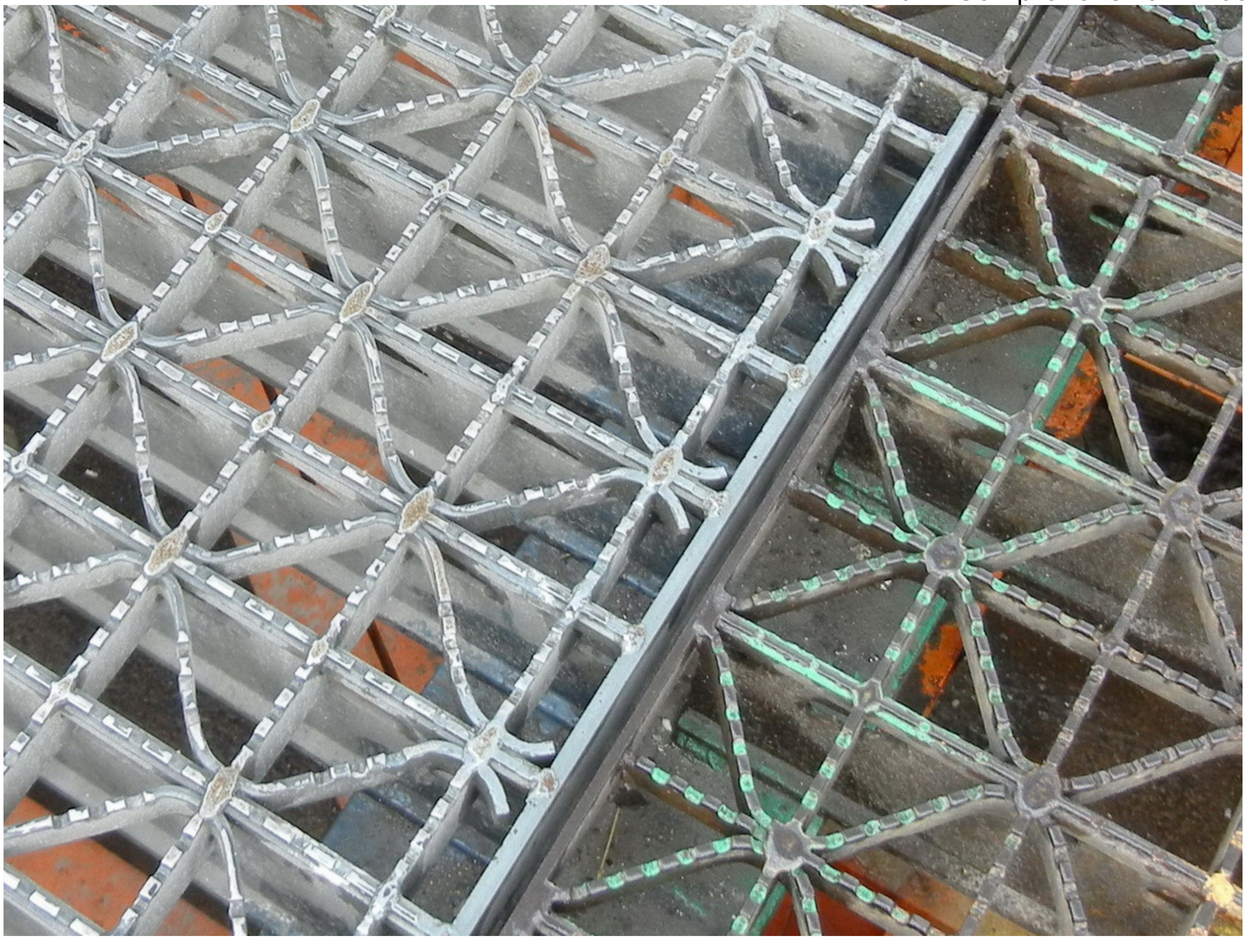
219 Typical Cracked Grating Panel, Central Section of Northbound Lane Shown

220 Broken Bearing Bar on Grating Panel in Central Section of Northbound Traffic Lane

221 Emergency Welding Repairs of Severe Cracks & Broken Deck Grating (TYP)



222 Replaced Deck Grating Panel near Northwest Corner of Lift Span, looking West



223 Close-up View of Replaced & Original Deck Gratings

224 General View of Deck Underside @ Lift Span from Northwest Corner

225 Deck Underside @ Tower End, North End of Lift Span looking West Shown

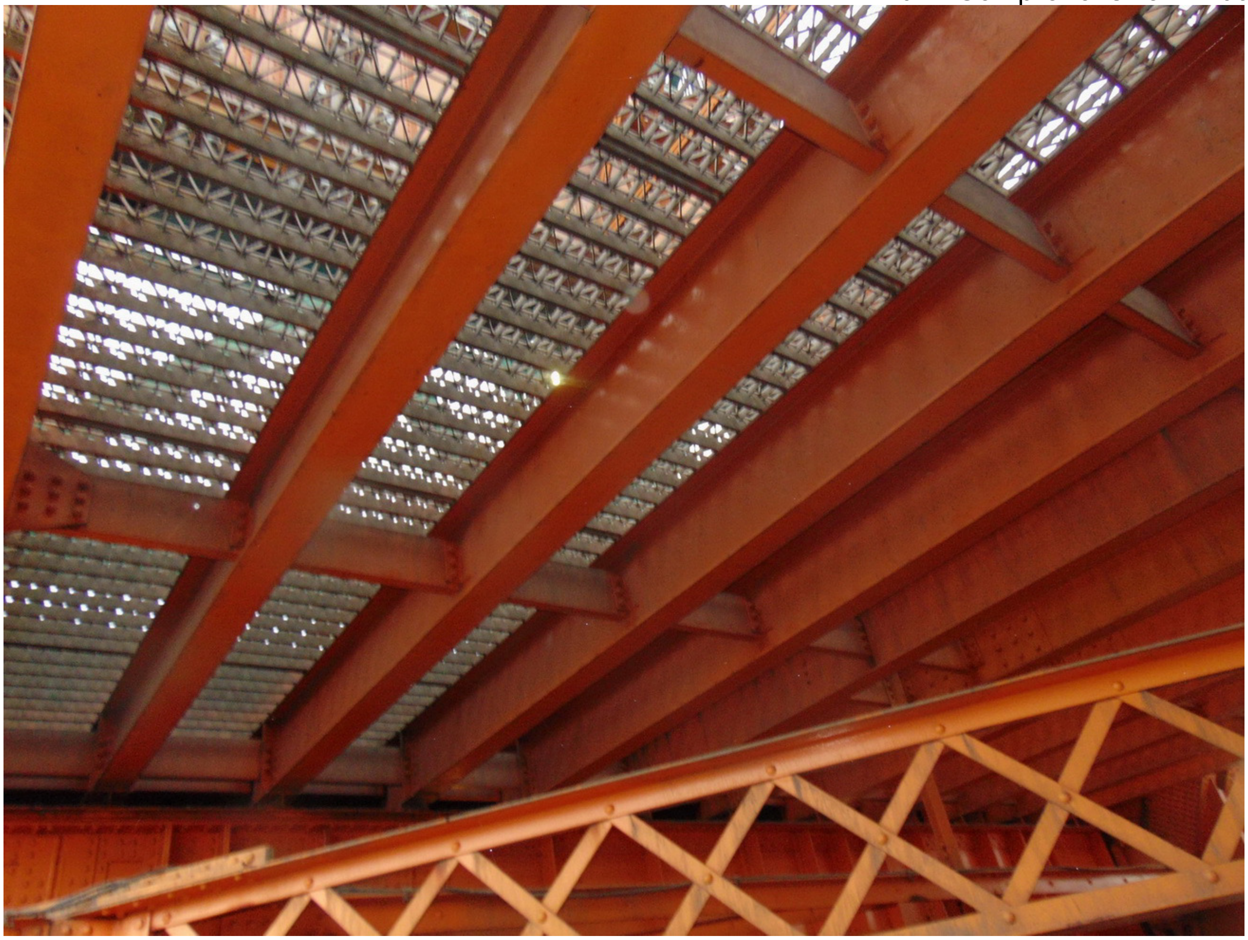
226 Floor Beams & Stringers @ Mid Section of Lift Span, looking South

227 Typical Underside of Lift Span Truss Bottom Chord, West Chord looking South Shown

228 Typical Floor Beam @ Tower End, North End looking West Shown

229 Typical Steel Floor Beam on Underside of Lift Span, North Int Beam looking West Shown

230 Typical Remains of End Connection for Original Stringers under Railway Track



231 Typical Stringers below Deck Grating, North Section looking South Shown

232 Typical Painted-Over Pitted Stringer Surface @ Lift Span

233 Typical Localized Corrosion on Truss Bottom Chord

234 Local Light-Medium Corrosion on Internal Stiffener Plate near South End of East Deck Truss

235 Typical Light Rust Spots on Gusset Plate for Bottom Lateral Bracing

236 Bird Guano in Bottom Chord @ Southeast Corner of Lift Span

237 Typical Painted-Over Pitted Connecting Plate Surface on End Floor for Centering Shoe, North End Shown

238 Missing bolt on North Connecting Plate over Centering Shoe, North End Shown

239 Removed Shoe Plate from Bottom Flange Railway Live Load Support @ South Pier (TYP)

240 Light Rust Stains Bottom Flange & Rivet Holes @ Removed Shoe Plate for Rail Support(TYP)

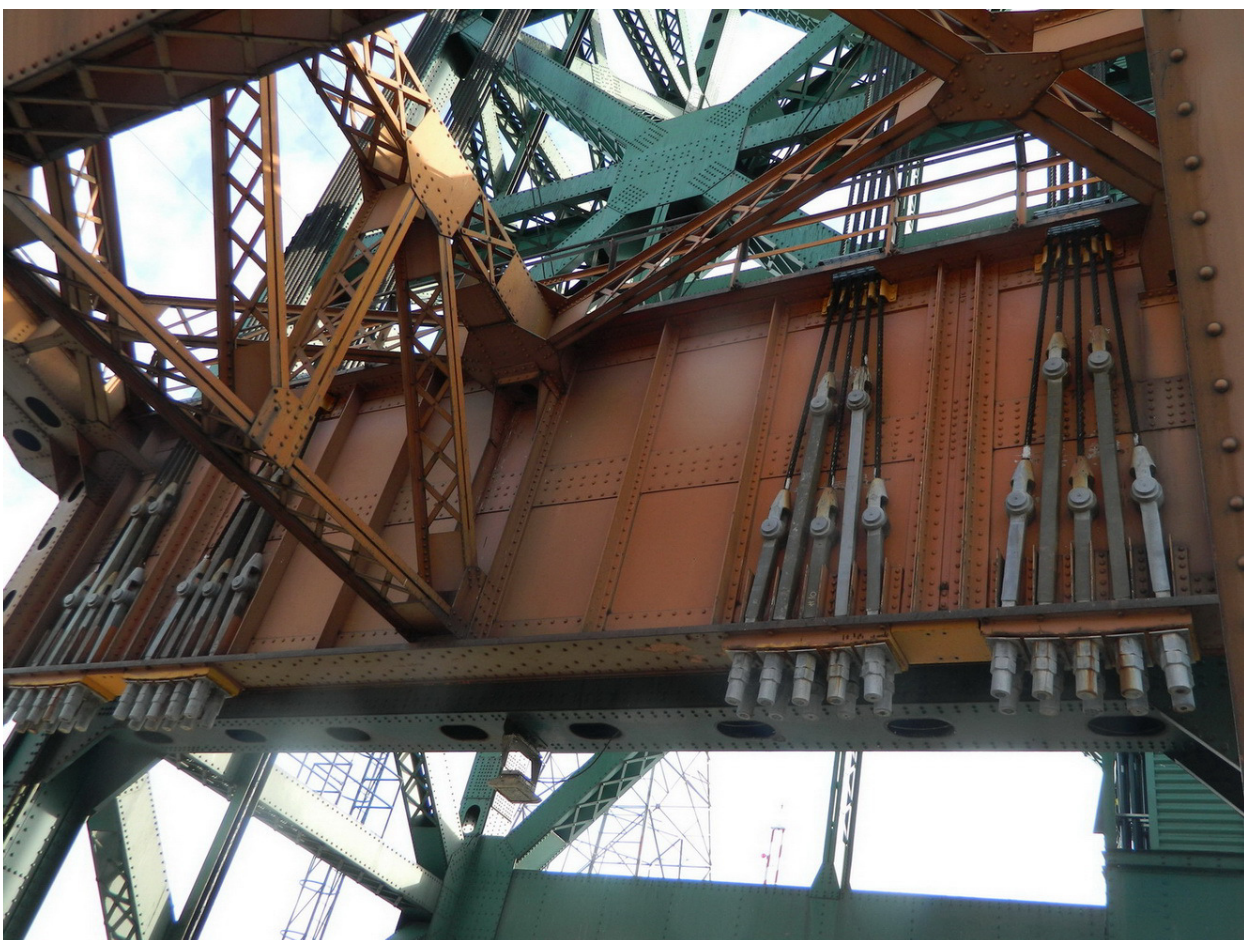
241 Typical Lower Guide Roller Assembly, Southeast Shown

242 Typical Severe Corrosion on Railing Post @ Southeast Lower Guide Bracket

243 General View of Lift Span Truss over bridge Deck from North Tower

244 General View @ Top of Truss from Southwest Corner

245 General View of Steel Truss above Deck, looking North



246 Typical Lifting Girder, South Girder Shown

247 Typical Portal & Sway Bracing on Lift Span Truss, North Portal Shown

248 South Portal Strut & Bracing, looking East (TYP)

249 Typical Light Fixture over Traffic Lanes

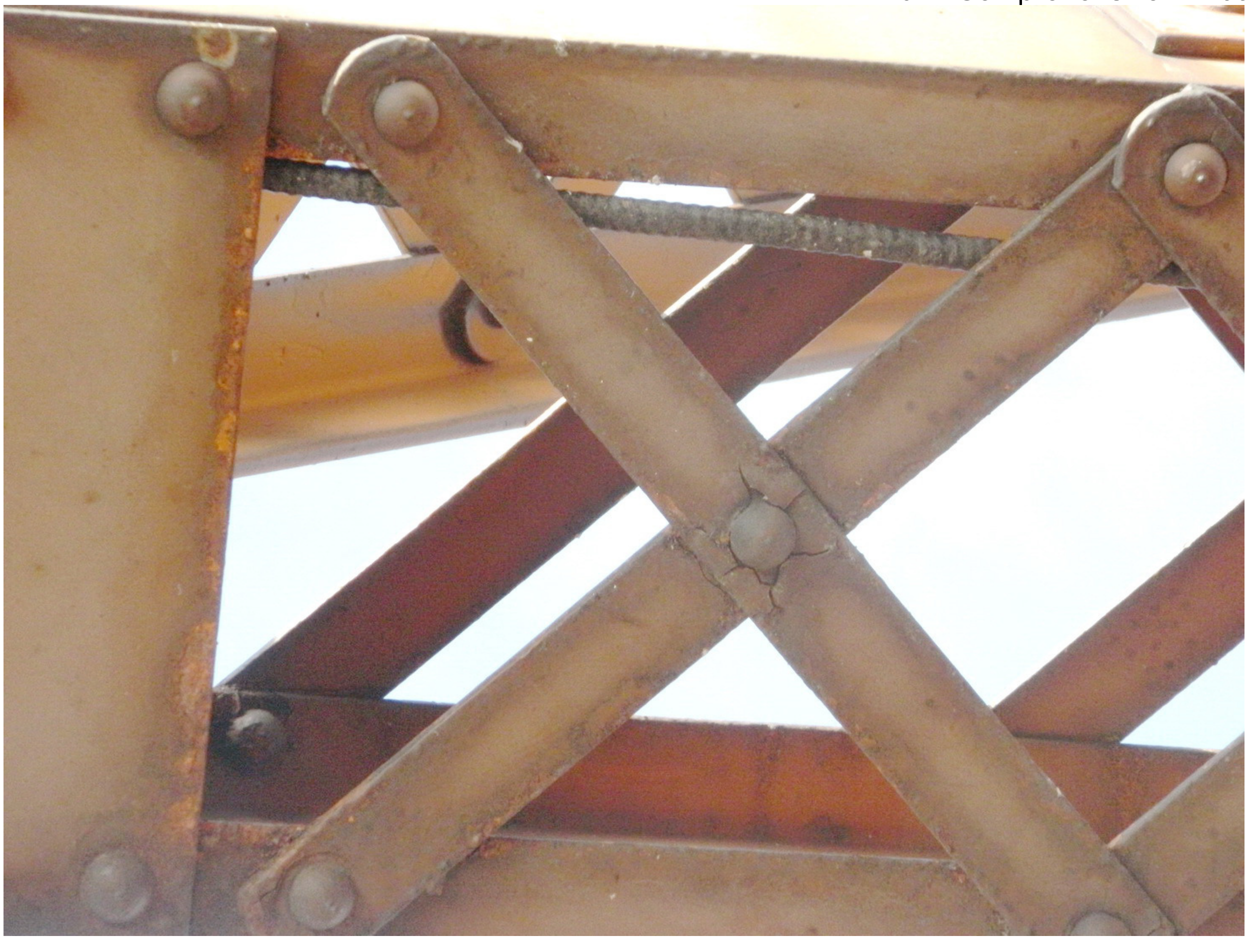
250 Typical Upper Roller Guide Assembly, Southwest Shown

251 Typical Localized Failure of Paint on Top Chord Surface, West Chord @ Panel 3 Shown

252 Typical Light Corrosion Spots on Post Base atop of Truss's Top Chord

253 Typical Faded Coating & Light Surface Rust on Truss, Vertical Member near SW Corner of Lift Span Shown

254 Rust Stain & Light Corrosion on Lower Sway Bracing @ Vertical Chord of Truss (TYP)



255 Typical Localized Paint Failure @ Lattice on Sway Frame Built-up Member

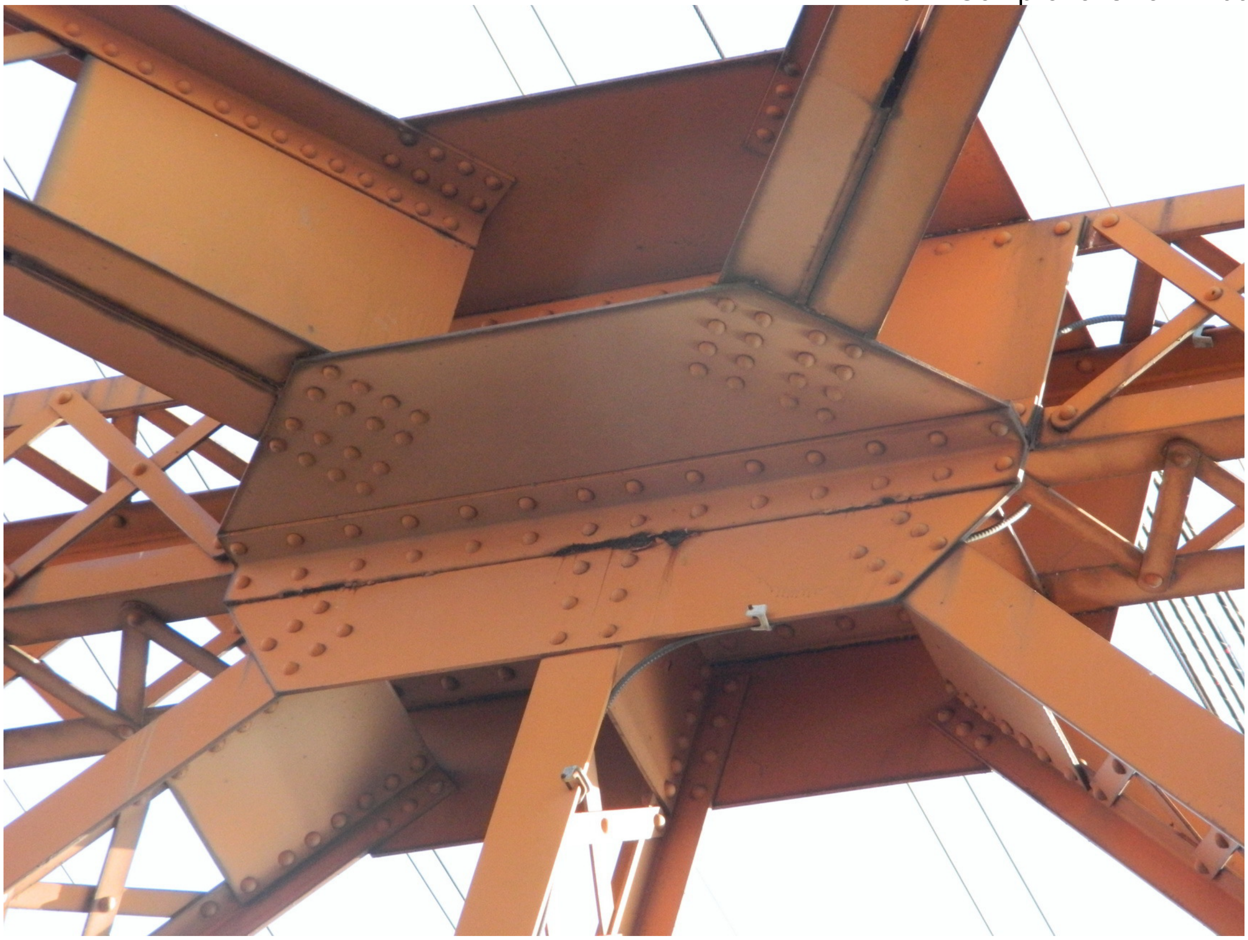
256 Peeled Paint & Light Corrosion on Gusset @ East Corner of North Portal Strut

257 Peeled Paint & Light Corrosion on Gusset Plate @ South Portal Bracing

258 Localized Peeled Paint & Light Corrosion on Gusset Plate at Top East Chord near Mid Span Section

259 Light-Medium Corrosion on top of Portal Bracing Gusset Plate @ West Corner of South Lifting Girder

260 Local Light-Medium Corrosion on Portal Bracing Gusset Plate @ North Lifting Girder



261 Light-Medium Rust Jacking on Gusset Plat @ Mid Section of Upper Horizontal of Sway Bracing @ Panel 5

262 Local Medium Corrosion on Diagonal for Sway Bracing @ Truss Panel 5 (TYP)

263 Light-Medium Rust Jacking on Bottom Corners of Southwest Guide Roller Assembly

264 Typical Grease Stains on Top Corner of Truss, Northwest Corner Shown

265 Bird Nesting in Mid Section of South Portal Strut

266 Large Built-Up of Bird Guano in Vertical Member of West Truss near North Tower

267 Sure-Rail Fall Arrest Device at Top Chord (TYP)

268 Sure-Rail Fall Arrest Device @ South Lifting Girder (TYP)

269 General View of Bearings @ North End of Lift Span, looking West

270 General View of Bearings @ South End of Lift Span, looking East

271 Rocker Bearing @ Northwest Corner of Lift Span

272 Roker Bearing & Air Cushion @ Northeast Corner of Lift Span (TYP)

273 Steel Saddle Bearing @ Southeast Corner of Lift Span

274 Saddle Bearing & Air Cushion @ Southwest Corner of Lift Span (TYP)

275 Bolts on Saddle Shoe Plate @ Southeast Bearing

276 Loose Bolts on front West Side of Southeast Saddle Shoe of Lift Span

277 Steel Beam Guiderail on East Side of South Approach looking North

278 Steel Beam Guiderail and Channel on West Side of North Approach, looking South

279 Typical Traffic Guiderail @ Tower Span, East Side of North Tower Shown

280 Typical Traffic Railing on East Side of Lift Span

281 Typical Traffic Railing on West Side of Lift Span

282 Typical Grease on Railings below Counterweight Guiderail @ Tower Span, East Railing @ North Tower Shown

283 Pedestrian Handrail attached Truss on East Side of Sidewalk at Lift Span

284 Pedestrian Pipe Railing on West Sidewalk @ North Tower Column and Lift Span (TYP)

285 Pedestrian Railing on West Sidewalk from South Approach


286 West Pedestrian Railing @ Lift Span, looking North

287 Grease Stains on Pedestrian Railing near North Tower, looking South

288 Broken Spindle at Bottom Rail on West Pedestrian Railing in Lift Span Panel 9

289 Missing Nut on Splice Bolt for Top Handrail @ Post in Panel 7 of Lift Span

290 Typical Loose Anchor Bolt on West Railing Post adjacent to Abutment Joint, South Abutment Joint Shown

291 Loose Anchor Bolts on Pedestrian Railing Post on 2nd Post North of North Abutment Joint

292 General View of West Sidewalk at Bridge from North Approach

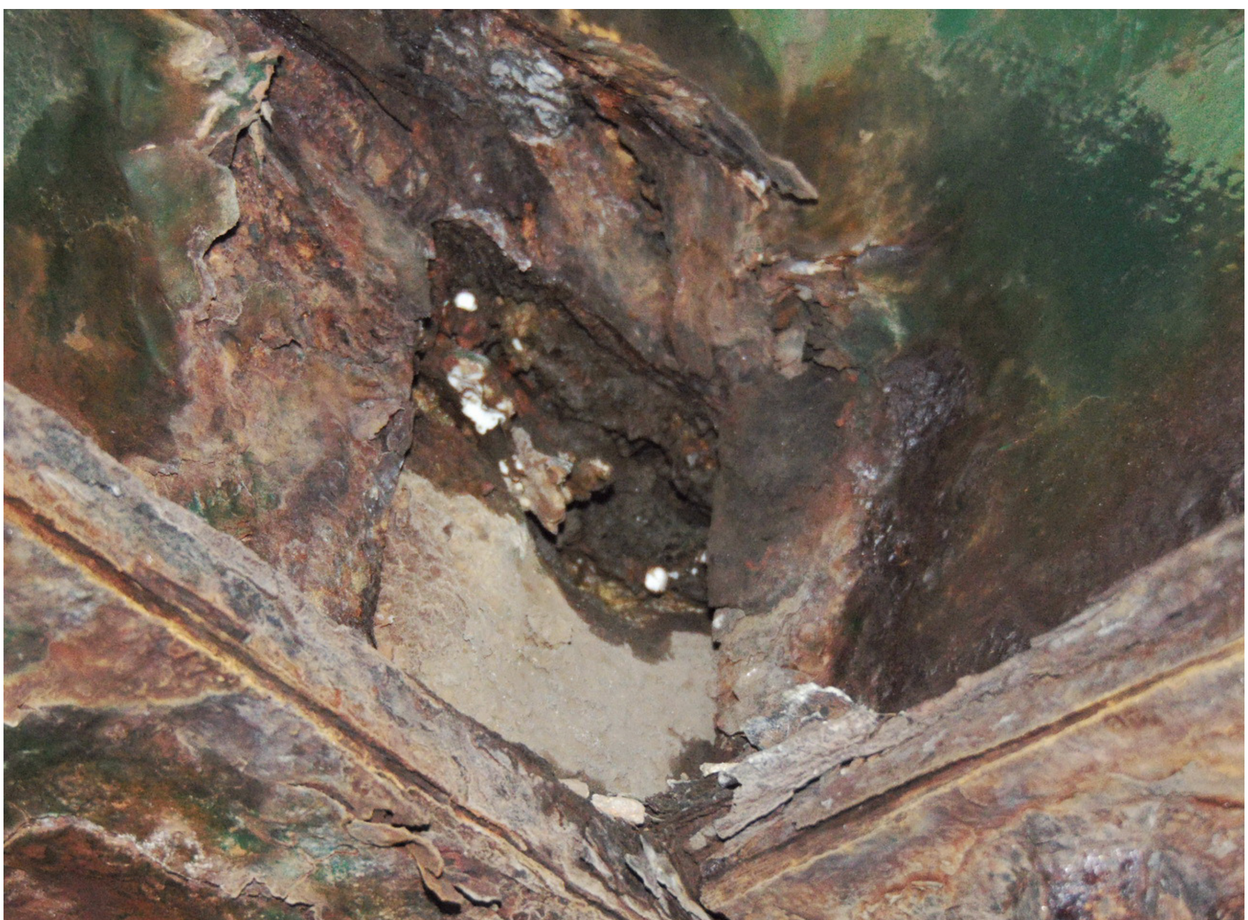
293 West Sidewalk at Lift Span, looking South

294 Steel Cover Plate on Sidewalk @ Joint between North Tower & Lift Span

295 Steel Cover Plate @ Joint between South Tower & Lift Span

296 Typical Steel Curb Plate @ Approach & Tower Spans, North Approach Shown

297 Typical Light with Local Medium Corrosion on Steel Curb Plate



298 Local Severe Corrosion with Perforation Hole on Bent Curb Plate, South Approach Span Shown

299 North Approach Road & Sidewalk, looking South

300 South Approach Road & Sidewalk, looking North

301 Northwest Stairs, looking East

302 Southwest Stairs, looking East

303 Retaining Wall & Stairs @ Southwest Corner of Bridge, looking South

304 Wide Cracks on Sidewalk & Light Impact Damages on Posts @ Southwest Approach

305 Local Shallow Spalls on Northwest Stairs (TYP)

306 Wide Crack with Leakage on Lower Southwest Staircase Section near Retaining Wall

APPENDIX A3

Component Rating Data

APPROACH

No.	I	PREV.		NEW		Component	TYPE
		CR	PC	CR	PC		
NORTH							
1	S	5	D	5	D	Roadway	Four-lane roadway ≃ 3.75 m each
2	S	5	D	5	D	Wearing surface	Asphalt
3	S	NI	N/A	NI	N/A	Approach slab	Concrete
4	S	5	D	5	D	Shoulders	Asphalt
5	A	5	D	5	D	Drainage	Storm sewer
6	A	5	D	5	D	Curb and gutter	Concrete
7	S	5	D	5	D	Sidewalk/curb	Concrete
8	S	5	D	5	D	Guiderail	Steel guiderail connected to wood posts
9	S	5	D	5	D	Railing	Steel posts and rows of rail
SOUTH							
10	S	5	D	5	D	Roadway	Four-lane roadway ≃ 3.75 m each
11	S	5	D	5	D	Wearing surface	Asphalt
12	S	NI	N/A	NI	N/A	Approach slab	Concrete
13	S	5	D	5	D	Shoulders	Asphalt
14	A	5	D	5	D	Drainage	Storm sewer
15	A	5	D	5	D	Curb and gutter	Concrete
16	S	5	D	5	D	Sidewalk/curb	Concrete
17	S	5	D	5	D	Guiderail	Steel guiderail connected to wood/steel posts
18	S	5	D	5	D	Railing	Steel posts and rows of rail

COMPONENT RATING DATA

ABUTMENTS AND RETAINING WALLS

No.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
NORTH							
1	P	NI	N/A	NI	N/A	Foundation	Shallow
2	P	4	D	4	B	Abutment wall	Reinforced concrete
3	S	5	D	5	B	Bearing seat and support pads	Reinforced concrete
4	S	5	D	5	B	Bearings	Elastomeric laminated
5	S	3	B	3	B	Ballast walls	Reinforced concrete
6	S	5	D	4	D	East wingwall	Reinforced concrete
7	S	5	D	4	D	West wingwall	Reinforced concrete
8	S	5	D	5	D	East retaining wall	Reinforced concrete
9	S	5	D	5	D	West retaining wall	Reinforced concrete
SOUTH							
10	P	NI	N/A	NI	N/A	Foundation	Shallow
11	P	4	D	4	B	Abutment wall	Reinforced concrete
12	S	5	D	5	B	Bearing seat and support pads	Reinforced concrete
13	S	4	D	4	B	Bearings	Elastomeric
14	S	3	B	3	B	Ballast walls	Reinforced concrete
15	S	5	D	5	D	East wingwall	Reinforced concrete
16	S	5	D	5	D	West wingwall	Reinforced concrete
17	S	5	D	4	D	East retaining wall	Reinforced concrete
18	S	5	D	5	D	West retaining wall	Reinforced concrete

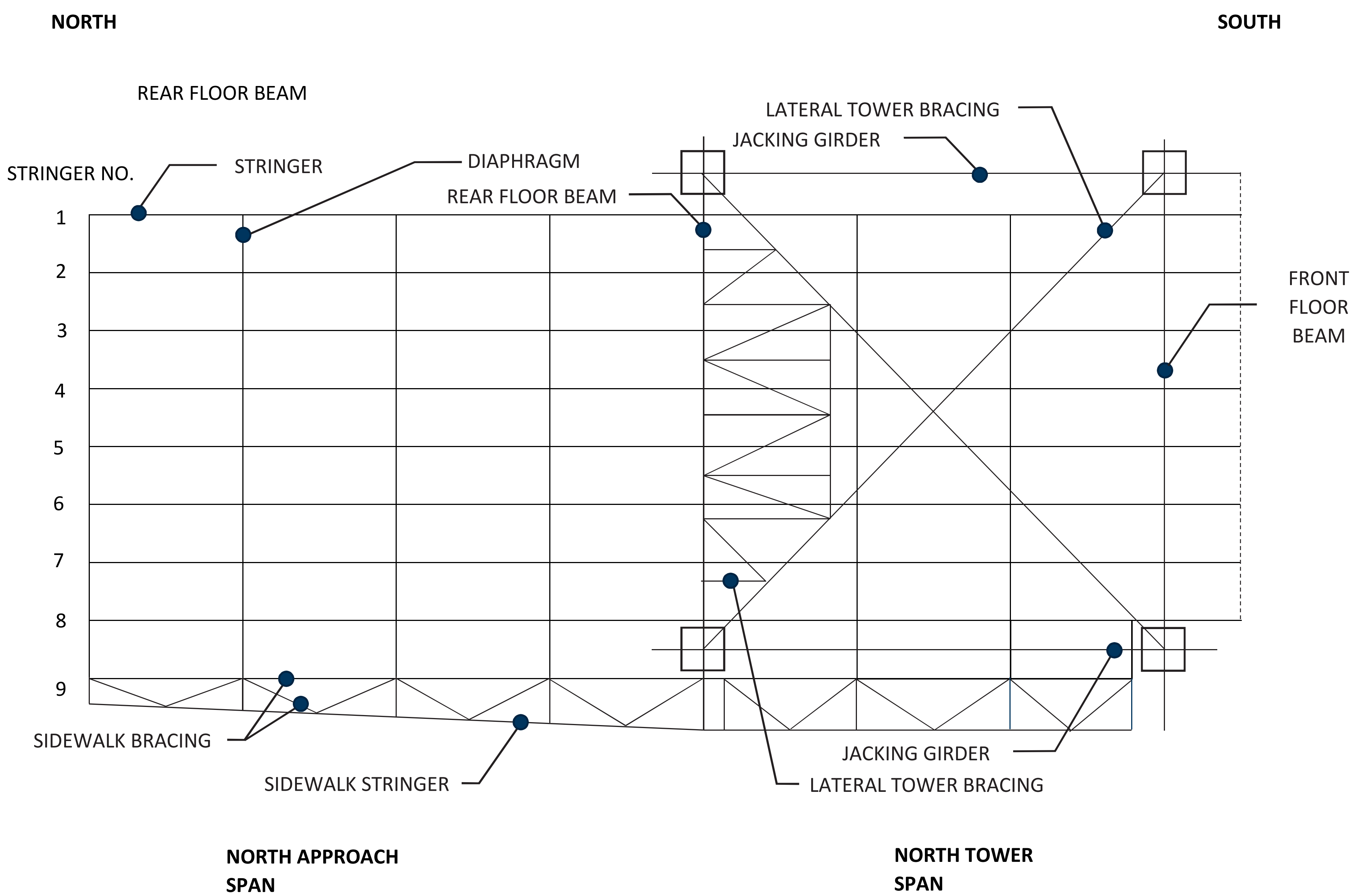
COMPONENT RATING DATA

NORTH APPROACH AND TOWER SPAN

NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
NORTH APPROACH SPAN											
1	P	3	S-A	3	S-A	2	S	2	S	Stringer No.1*	33 WF 130
2	P	3	S-A	3	S-A	2	S	2	S	Stringer No.2*	33 WF 130
3	P	3	S-A	3	S-A	2	S	2	S	Stringer No.3*	33 WF 130
4	P	3	S-A	3	S-A	2	S	2	S	Stringer No.4*	33 WF 130
5	P	3	S-A	3	S-A	2	S	2	S	Stringer No.5*	33 WF 130
6	P	3	S-A	3	S-A	2	S	2	S	Stringer No.6*	33 WF 130
7	P	3	S-A	3	S-A	2	S	2	S	Stringer No.7*	33 WF 130
8	P	3	S-A	2	S-A	2	S	1	S	Stringer No.8*	33 WF 130
9	P	4	D	4	D	3	B	3	B	Sidewalk Stringer No.9	24 WF 76
10	S	2	A	2	A	2	A	2	A	Diaphragms	15 C 33.9
11	S	4	D	4	D	3	B	3	B	Sidewalk bracing	8 I's, 23 T's
NORTH TOWER SPAN											
12	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.1*	27 WF 102
13	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.2*	27 WF 102
14	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.3*	27 WF 102
15	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.4*	27 WF 102
16	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.5*	27 WF 102
17	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.6*	27 WF 102
18	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.7*	27 WF 102
19	P	3	S-A	3	S-A	2	S-A	2	S	Stringer No.8*	27 WF 102
20	P	4	S	4	B	3	S	4	B	Sidewalk Stringer No.9	21 WF 62
21	S	2	A	2	A	1	S-A	1	S	Diaphragms	15 C 33.9
22	S	5	D	4	D	3	B	3	B	Lateral tower bracing	1L, 2L's, 4L's with lacing

* Extensive corrosion at bottom flange of stringers and floor beams at expansion joint locations.

COMPONENT RATING DATA

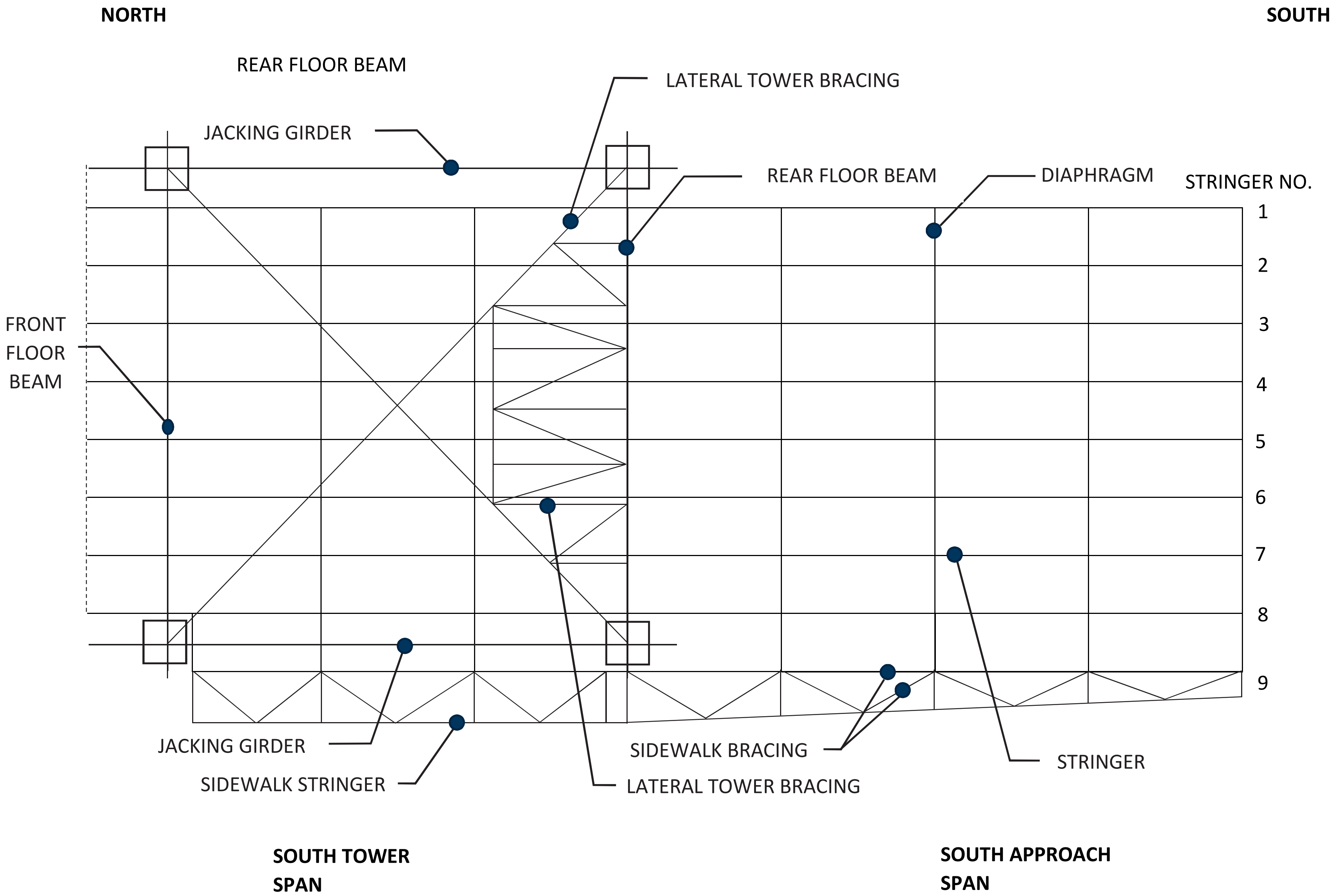


SOUTH APPROACH AND TOWER SPAN

NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
SOUTH APPROACH SPAN											
1	P	3	S-A	3	S-A	2	S	2	S	Stringer No.1	33 WF 130
2	P	3	S-A	3	S-A	2	S	2	S	Stringer No.2	33 WF 130
3	P	3	S-A	3	S-A	2	S	2	S	Stringer No.3	33 WF 130
4	P	3	S-A	3	S-A	2	S	2	S	Stringer No.4	33 WF 130
5	P	3	S-A	3	S-A	2	S	2	S	Stringer No.5	33 WF 130
6	P	3	S-A	3	S-A	2	S	2	S	Stringer No.6	33 WF 130
7	P	3	S-A	3	S-A	2	S	2	S	Stringer No.7	33 WF 130
8	P	3	S-A	3	S-A	2	S	2	S	Stringer No.8	33 WF 130
9	P	4	D	4	D	3	B	3	B	Sidewalk Stringer No.9	24 WF 76
10	S	2	A	2	S-A	2	S	2	S	Diaphragms	15 C 33.9
11	S	4	D	4	D	3	B	3	B	Sidewalk bracing	8 I's, 23 T's
SOUTH TOWER SPAN											
12	P	3	S-A	3	S-A	2	S	2	S	Stringer No.1	27 WF 102
13	P	3	S-A	3	S-A	2	S	2	S	Stringer No.2	27 WF 102
14	P	3	S-A	3	S-A	2	S	2	S	Stringer No.3	27 WF 102
15	P	3	S-A	3	S-A	2	S	2	S	Stringer No.4	27 WF 102
16	P	3	S-A	3	S-A	2	S	2	S	Stringer No.5	27 WF 102
17	P	3	S-A	3	S-A	2	S	2	S	Stringer No.6	27 WF 102
18	P	3	S-A	3	S-A	2	S	2	S	Stringer No.7	27 WF 102
19	P	3	S-A	3	S-A	2	S	2	S	Stringer No.8	27 WF 102
20	P	5	D	4	D	3	B	3	B	Sidewalk Stringer No.9	21 WF 62
21	S	2	A	2	S-A	1	A	1	A	Diaphragms	15 C 33.9
22	S	5	D	4	D	3	B	3	B	Lateral tower bracing	1L, 2L's, 4L's with lacing

* Extensive corrosion at bottom flange of stringers and floor beams at expansion joint locations.

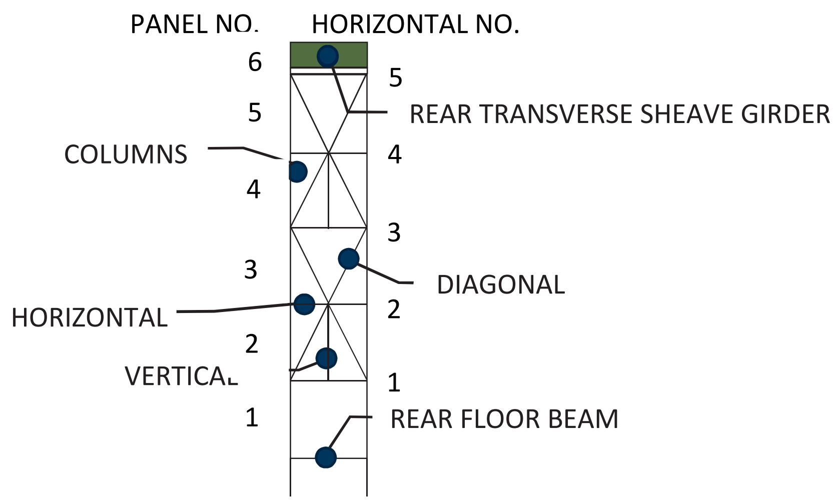
COMPONENT RATING DATA



COMPONENT RATING DATA

NORTH TOWER – REAR SIDE

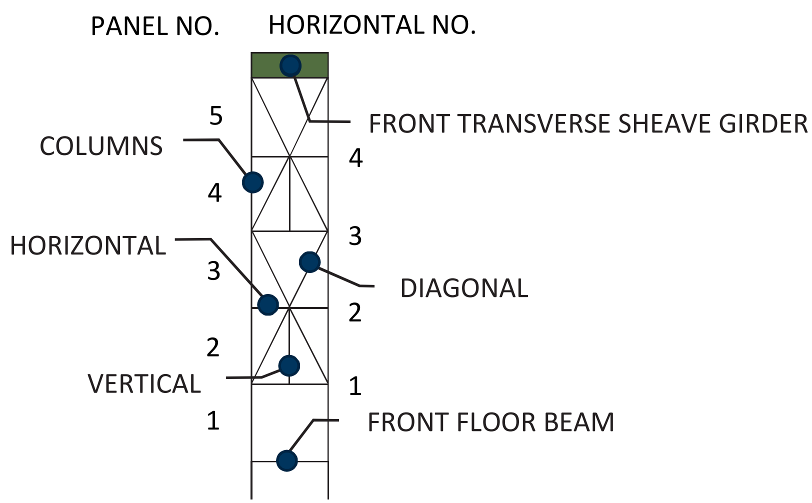
PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	B	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	3	D	3	S	2	B	2	B	Rear floor beam	Built-up I section
2	P	5	D	5	D	4	C	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Vertical	Built-up I section, laced web
3	P	5	D	5	D	4	C	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Vertical	Built-up section, laced web
5	P	5	D	5	D	4	C	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	C	Horizontal #5	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Rear transverse sheave girder	Built-up I section



COMPONENT RATING DATA

NORTH TOWER – FRONT SIDE

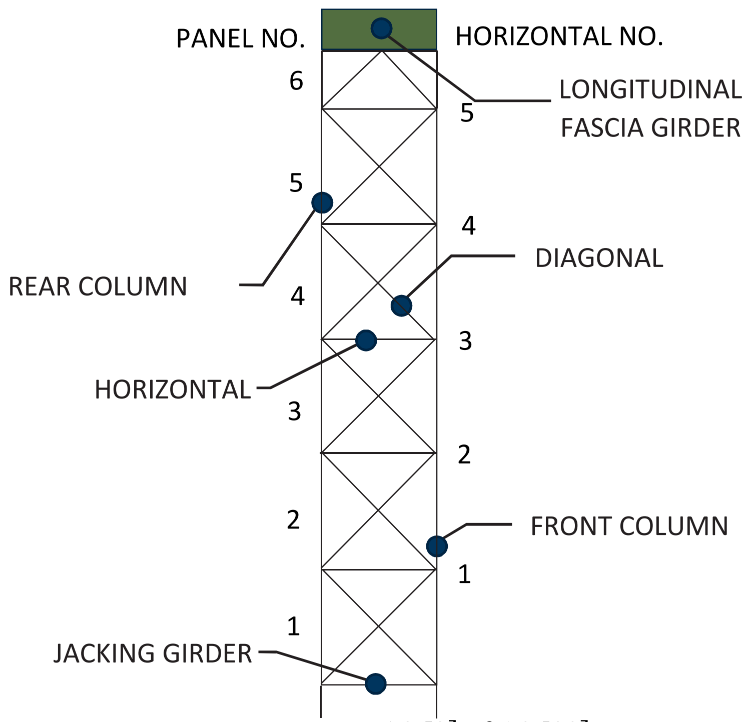
PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	B	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	4	D	3	D	2	B	2	B	Front floor beam	Built-up I section
2	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Vertical	Built-up I section, laced web
3	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Vertical	Built-up section, laced web
5	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Front transverse sheave girder	Built-up section, double lacing



COMPONENT RATING DATA

NORTH TOWER – WEST SIDE

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Jacking Girder	Built-up hollow section
2	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
3	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
5	P	5	D	5	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	C	Horizontal #5	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Longitudinal fascia girder	Built-up double I (deep) girder



COMPONENT RATING DATA

NORTH TOWER – EAST SIDE

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Jacking Girder	Built-up hollow section
2	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
3	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
5	P	5	D	5	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	C	Horizontal #5	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Longitudinal fascia girder	Built-up double I (deep) girder

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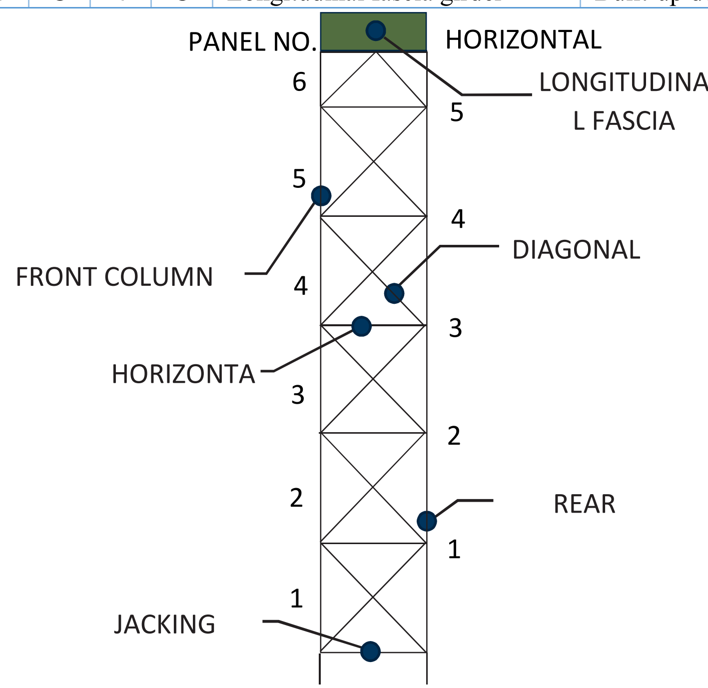
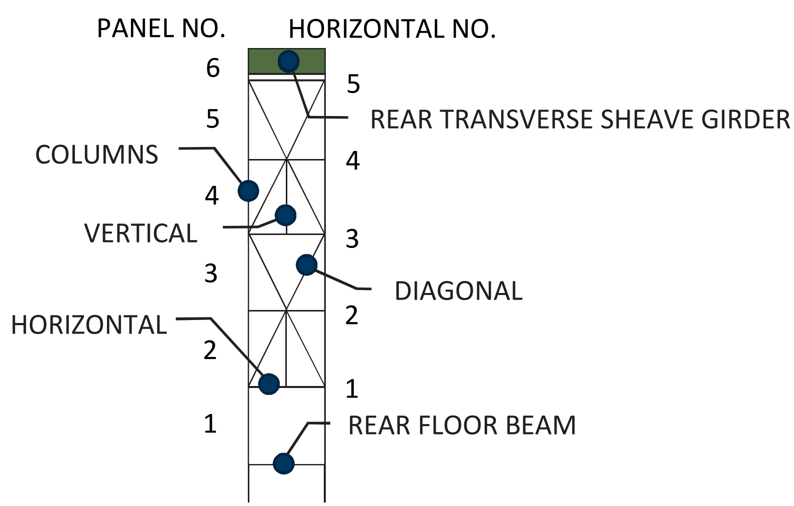


COMPONENT RATING DATA

SOUTH TOWER – REAR SIDE

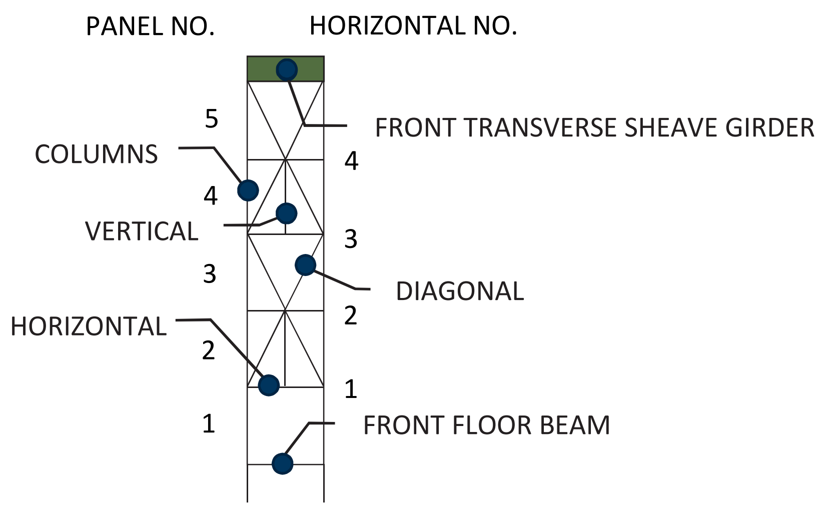
PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	B	4	C	Rear columns	Built-up hollow section, perf. cover plate
	P	3	D	3	D	2	B	2	B	Rear floor beam	Built-up I section
2	P	5	D	5	D	4	C	4	4	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	4	Horizontal #1	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Vertical	Built-up I section, laced web
3	P	5	D	5	D	4	C	4	4	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	4	Horizontal #2	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	4	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	4	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	4	Vertical	Built-up section, laced web
5	P	5	D	5	D	4	C	4	4	Rear columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	4	Horizontal #4	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	4	Horizontal #5	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	4	Rear transverse sheave girder	Built-up I section



COMPONENT RATING DATA

SOUTH TOWER – FRONT SIDE

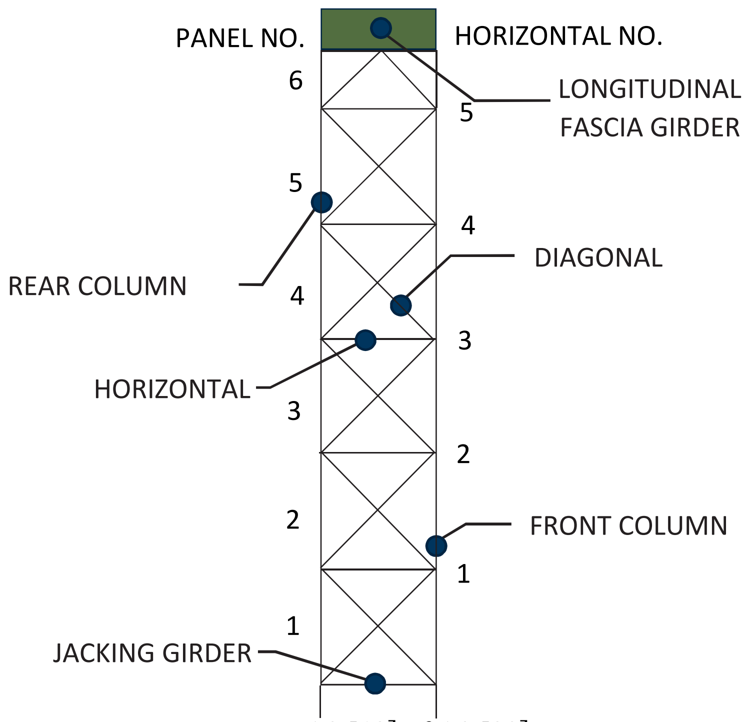
PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	B	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	4	D	3	D	2	B	2	B	Front floor beam	Built-up I section
2	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Vertical	Built-up I section, laced web
3	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Vertical	Built-up section, laced web
5	P	5	D	5	D	4	C	4	C	Front columns	Built-up hollow section, perf. cover plate
	P	5	D	5	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Front transverse sheave girder	Built-up section, double lacing



COMPONENT RATING DATA

SOUTH TOWER – WEST SIDE

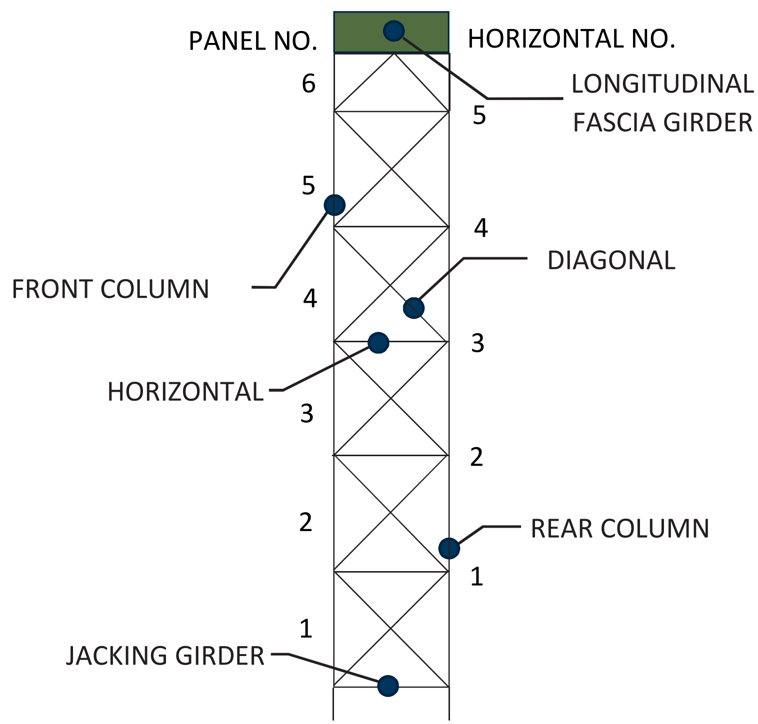
PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Jacking Girder	Built-up hollow section
2	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
3	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
5	P	4	D	4	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	C	Horizontal #5	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Longitudinal fascia girder	Built-up double I (deep) girder



COMPONENT RATING DATA

SOUTH TOWER – EAST SIDE

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Jacking Girder	Built-up hollow section
2	P	5	D	5	D	4	C	4	C	Horizontal #1	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
3	P	5	D	5	D	4	C	4	C	Horizontal #2	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
4	P	5	D	5	D	4	C	4	C	Horizontal #3	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
5	P	4	D	4	D	4	C	4	C	Horizontal #4	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
6	P	5	D	5	D	4	C	4	C	Horizontal #5	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up section, double lacing
	P	5	D	5	D	4	C	4	C	Longitudinal fascia girder	Built-up double I (deep) girder

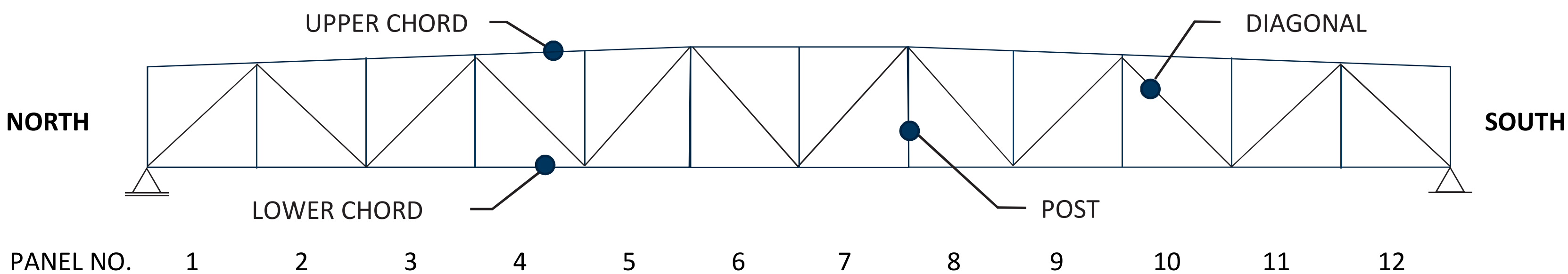


COMPONENT RATING DATA

LIFT SPAN (Warren Truss) - WEST

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1,2, 11,12	P	4	D	4	D	5	D	5	D	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts*	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals*	Built-up hollow section-rectangle
3,4, 9,10	P	4	D	4	D	5	D	5	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts*	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals*	Built-up hollow section-rectangle
5,8	P	4	D	5	D	5	D	5	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	3	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts*	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals*	Built-up hollow section-rectangle
6,7	P	4	D	5	D	5	D	5	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	3	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts*	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals*	Built-up hollow section-rectangle

* Splash zone was previously repainted (up to 2.5m above the roadway and below).

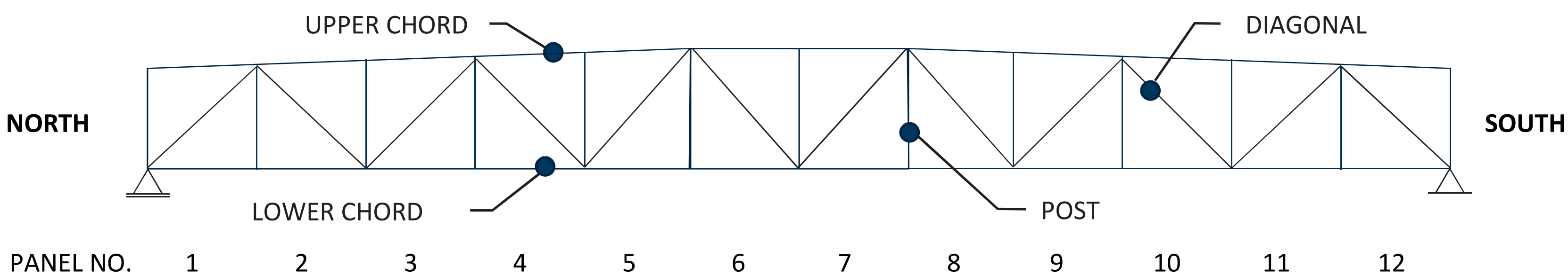


COMPONENT RATING DATA

LIFT SPAN (Warren Truss) - EAST

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1,2, 11,12	P	4	D	4	D	5	D	5	D	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up hollow section-rectangle
3,4, 9,10	P	4	D	4	D	5	D	3	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up hollow section-rectangle
5,8	P	4	D	5	D	5	D	4	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	3	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up hollow section-rectangle
6,7	P	4	D	5	D	5	D	5	C	Lower chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Upper chord	Built-up hollow section-rectangle
	P	5	D	5	D	4	C	4	C	Posts	2-hollow-built-up section-rectangle
	P	5	D	5	D	4	C	4	C	Diagonals	Built-up hollow section-rectangle

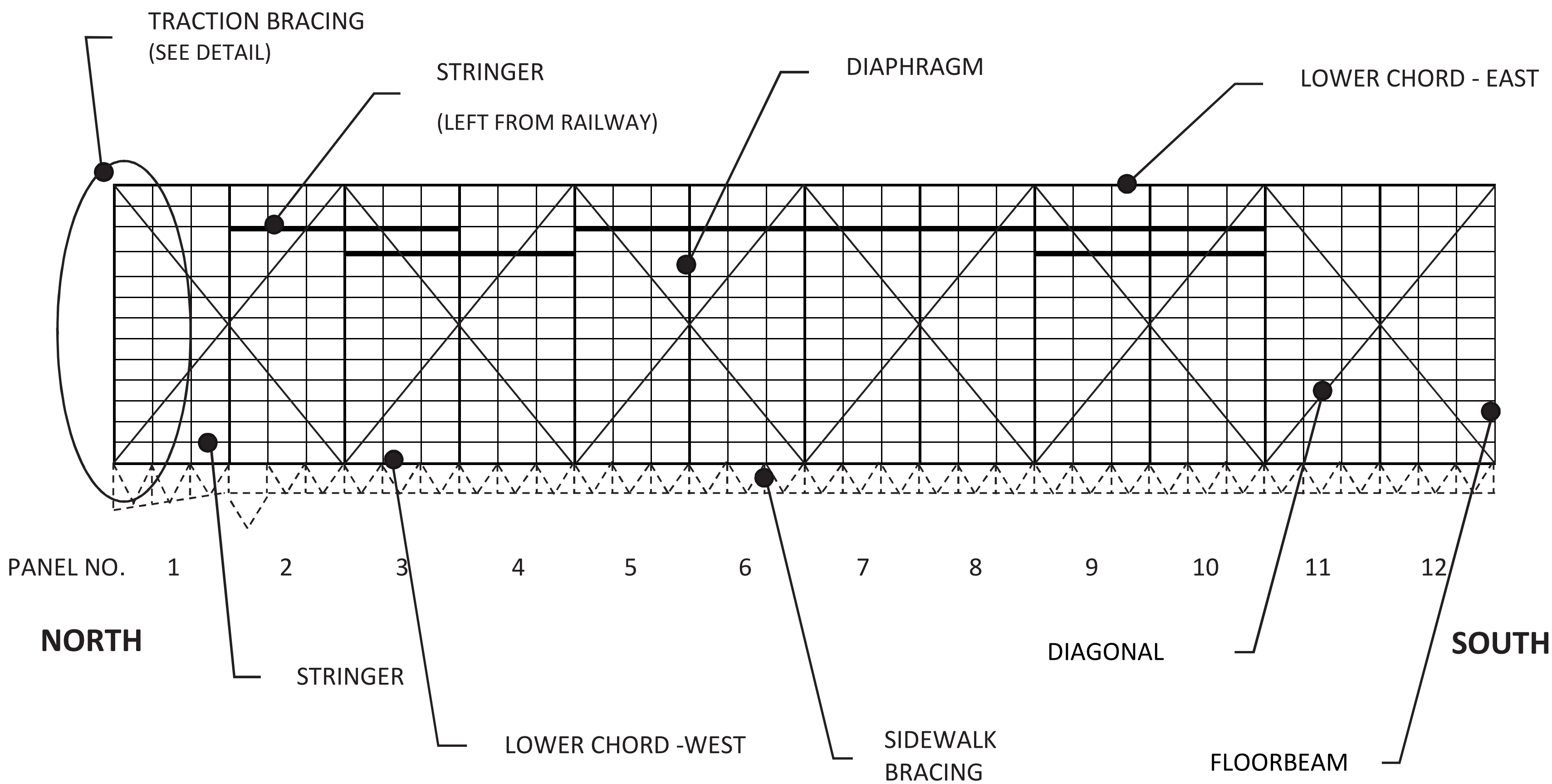
* Splash zone was previously repainted (up to 2.5m above the roadway and below).

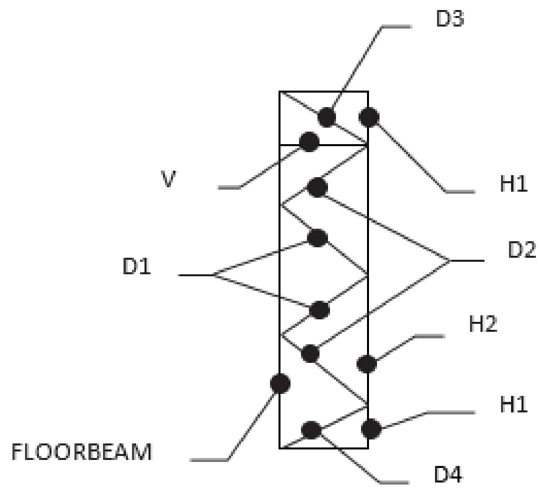


LIFT SPAN – LOWER LATERAL BRACING, TRACTION BRACING AND STRINGERS

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1,12	P	4	D	4	D	5	D	5	D	Floor beams*	Built-up I section
	S	4	D	4	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	4	D	4	D	5	D	5	D	Stringers*	24 WF 84
	S	4	D	4	D	5	D	5	D	Diaphragms*	12 C 20.7
2,11	P	5	D	5	D	5	D	5	D	Floor beams*	Built-up I section
	S	4	D	4	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	4	D	4	D	5	D	5	D	Stringers*	24 WF 84, 36 WF 230 (1 from railway-2nd Panel)
	S	4	D	4	D	5	D	5	D	Diaphragms*	12 C 20.7
3,10	P	5	D	5	D	5	D	5	D	Floor beams*	Built-up I section
	S	5	D	5	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	4	D	4	D	5	D	5	D	Stringers*	24 WF 84, 36 WF 230 (2 from railway)
	S	5	D	5	D	5	D	5	D	Diaphragms*	12 C 20.7
4,9	P	5	D	5	D	5	D	5	D	Floor beams*	Built-up I section
	S	5	D	5	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	4	D	4	D	5	D	5	D	Stringers*	24 WF 84, 36 WF 230 (1 from railway – 4th panel), (2 from railway – 9th panel)
	S	5	D	5	D	5	D	5	D	Diaphragms*	12 C 20.7
5,8	P	5	D	5	D	5	D	5	D	Floor beams*	Built-up I section
	S	5	D	5	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	5	D	5	D	5	D	5	D	Stringers*	24 WF 84, 36 WF 230 (1 from railway)
	S	5	D	5	D	5	D	5	D	Diaphragms*	12 C 20.7
6,7	P	5	D	5	D	5	D	5	D	Floor beams*	Built-up I section
	S	5	D	5	D	5	D	5	D	Diagonals*	4 L's with lacing
	P	5	D	5	D	5	D	5	D	Stringers*	24 WF 84, 36 WF 230 (1 from railway)
	S	5	D	5	D	5	D	5	D	Diaphragms*	12 C 20.7
1-12	S	5	D	5	D	5	D	5	D	Sidewalk bracing*	8 I 23, T's
TRACTION BRACING											
1,3,5 7,8 10, 12	S	5	D	5	D	5	D	5	D	Diagonals D1*	2 L's with equal legs
	S	5	D	5	D	5	D	5	D	Diagonals D2*	2 L's with equal legs
	S	5	D	5	D	5	D	5	D	Diagonals D3*	2 L's with unequal legs
	S	5	D	5	D	5	D	5	D	Diagonals D4*	2 L's with equal legs
	S	5	D	5	D	5	D	5	D	Horizontal H1*	2 L's with equal legs
	S	5	D	5	D	5	D	5	D	Horizontal H2*	2 L's with equal legs
	S	5	D	5	D	5	D	5	D	Vertical V*	2 L's with equal legs

COMPONENT RATING DATA



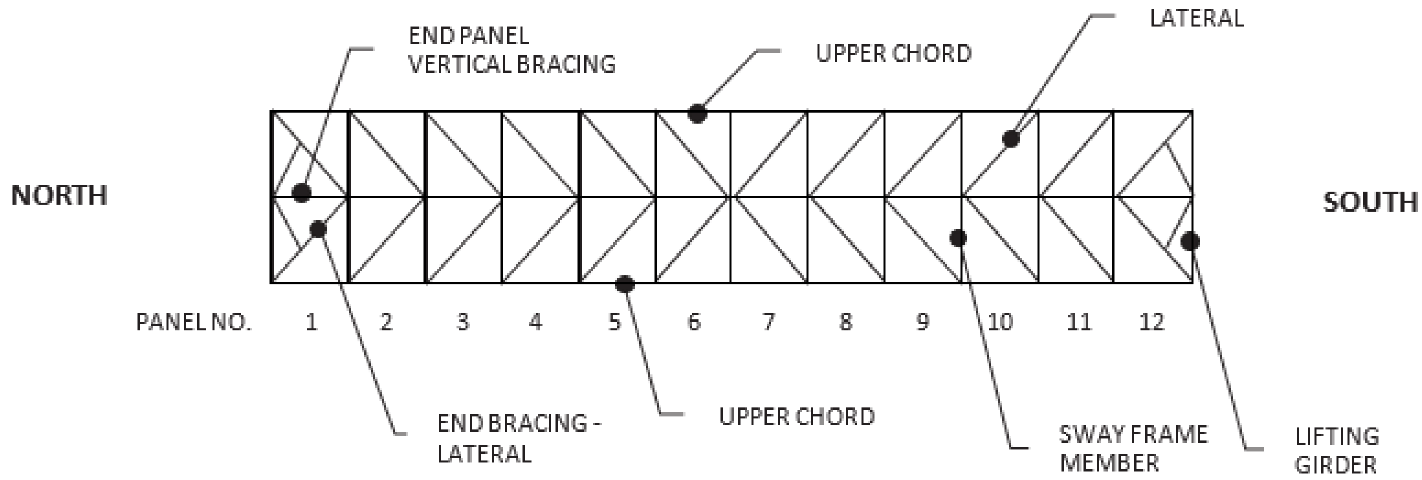


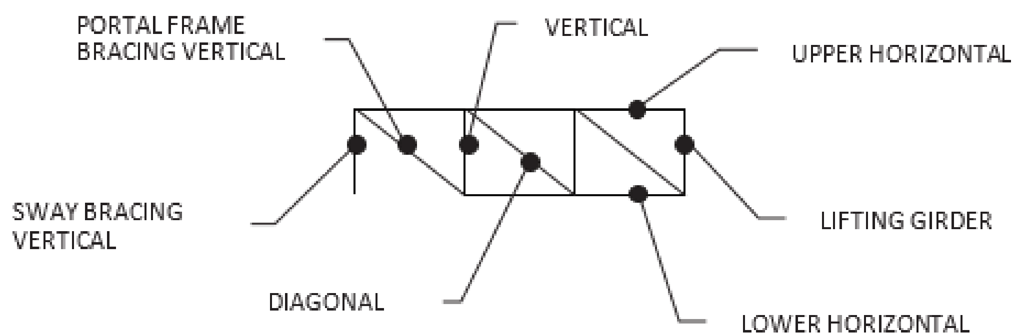
TRACTION BRACING

LIFT SPAN – UPPER LATERAL BRACING

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
1,12	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
	S	5	D	5	D	4	C	4	C	End bracing-laterals	4 L's with lacing
2,11	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
3,10	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
4,9	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
5,8	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
6,7	S	5	D	5	D	4	C	4	C	Sway frame member	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Laterals	4 L's with lacing
END PANEL VERTICAL BRACING											
1,12	S	5	D	5	D	3	C	3	C	Upper horizontal	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Lower horizontal	4 L's with lacing
	S	5	D	5	D	4	C	4	C	Portal frame bracing vertical	4 L's with lacing at each side
	S	5	D	5	D	4	C	4	C	Diagonals	4 L's with lacing
	P	5	D	5	D	4	C	4	C	Lifting girder	Built-up I section

COMPONENT RATING DATA





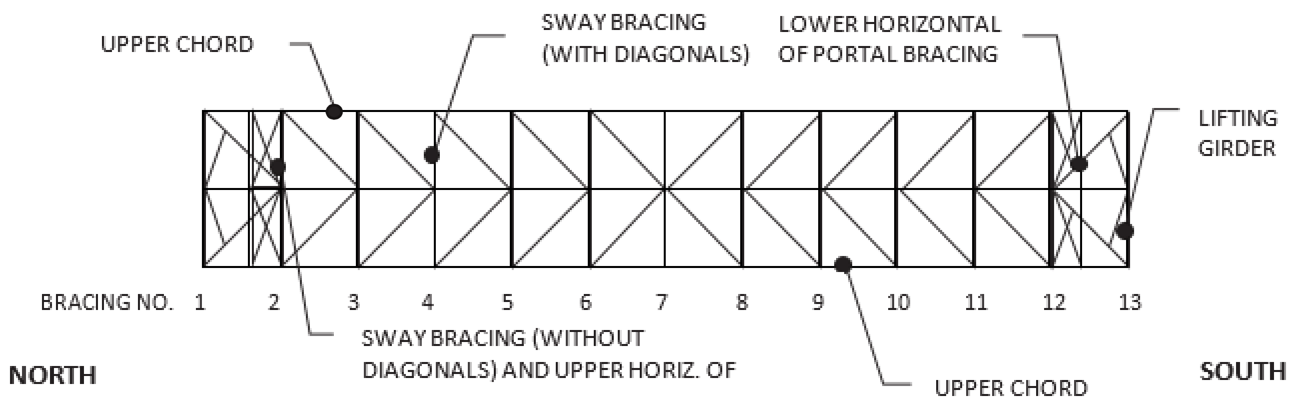
END PANEL VERTICAL BRACING

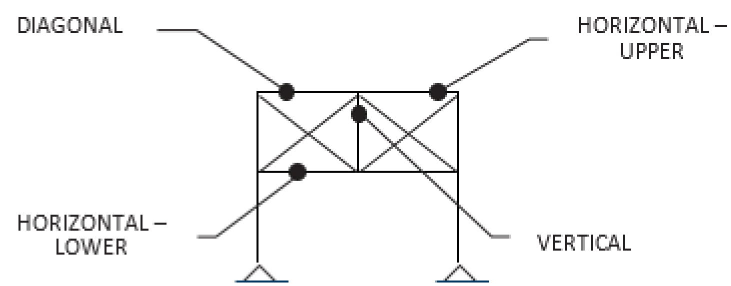
COMPONENT RATING DATA

LIFT SPAN – SWAY AND PORTAL BRACING

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
PORTAL BRACING											
1,13	P	4	D	4	D	4	C	4	C	Horizontal-upper	4L's with lacing, each side
	P	4	D	4	D	4	C	4	C	Horizontal-lower	Two 12 C 25 with lacing
	S	4	D	4	D	4	C	4	C	Diagonals	Two WT4 x 24 with lacing
	S	4	D	4	D	4	C	4	C	Vertical	4L's with lacing, each side
SWAY BRACING WITHOUT DIAGONALS											
2,12	S	4	D	4	D	4	C	4	C	Horizontal-upper	4L's with lacing, each side
	S	4	D	4	D	4	C	4	C	Horizontal-lower	Two 12 C 25 with lacing
	S	4	D	4	D	4	C	4	C	Vertical	Two WT4 x 20 with lacing
SWAY BRACING WITH DIAGONALS											
3,4,5	S	5	D	5	D	4	C	4	C	Horizontal-upper	4L's with lacing, each side
5,6,7	S	5	D	5	D	4	C	4	C	Horizontal-lower	Two 12 C 25 with lacing
7,8,9	S	5	D	5	D	4	C	4	C	Diagonals	Two WT4 x 20 with lacing
10,11	S	5	D	5	D	4	C	4	C	Vertical	Two WT4 x 20 with lacing

COMPONENT RATING DATA





PORTAL AND SWAY BRACING WITH DIAGONALS

EXPANSION JOINTS - NORTH

PANEL NO.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
BALLAST WALL (ABUTMENT) –APPROACH SPAN							
1	S	1	A	1	A	Seal/Sealants	Bituminous filler and PVC water stop
2	S	5	D	3	B	Expansion devices	Poured bituminous
3	S	NE	-	NE	-	Clamping/Retaining devices	-
4	S	NE	-	NE	-	Armoring/Anchorage	-
5	S	NE	-	NE	-	End dam	-
6	S	NE	-	NE	-	Cover plates	-
APPROACH SPAN - TOWER SPAN							
7	S	1	A	1	A	Seal/Sealants	Molded rubber joint seal
8	S	NE	-	NE	-	Expansion devices	-
9	S	NE	-	NE	-	Clamping/Retaining devices	-
10	S	5	C	4	M	Armoring/Anchorage	2 L's 150x100x10 and 15 mm Ø studs
11	S	3	C	3	B	End dam	Concrete
12	S	NE	-	NE	-	Cover plates	-
TOWER SPAN – LIFT SPAN (EXPANSION END)							
13	S	NE	-	NE	-	Seal/Sealants	-
14	S	5	D	5	D	Expansion devices	Finger steel expansion joint.
15	S	NE	-	NE	-	Clamping/Retaining devices	
16	S	4	D	4	D	Armoring/Anchorage	12 mm steel plate, hook anchored to concrete
17	S	4	D	4	D	End dam	Steel plates with fingers
18	S	NE	-	NE	-	Cover plates	-

EXPANSION JOINTS - SOUTH

PANEL NO.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
LIFT SPAN – TOWER SPAN (FIXED END)							
1	S	NE	-	NE	-	Seal/Sealants	32 mm gap SB lane, 32 mm gap NB lane
2	S	3	C	3	C	Expansion devices	Open gap joint
3	S	NE	-	NE	-	Clamping/Retaining devices	-
4	S	4	D	4	D	Armoring/Anchorage	12 mm steel plates, 630x10 mm anchors (to the concrete), L 150x100x13 mm
5	S	NE	-	NE	-	End dam	-
6	S	NE	-	NE	-	Cover plates	-
TOWER SPAN – APPROACH SPAN							
7	S	1	A	1	A	Seal/Sealants	Molded rubber joint seal
8	S	NE	-	NE	-	Expansion devices	-
9	S	NE	-	NE	-	Clamping/Retaining devices	-
10	S	4	C	4	C	Armoring/Anchorage	2 L’s 150x100x10 and 15 mm Ø studs
11	S	3	C	2	C	End dam	Concrete
12	S	NE	-	NE	-	Cover plates	-
APPROACH SPAN – BALLAST WALL (ABUTMENT)							
13	S	1	A	1	A	Seal/Sealants	Bituminous filler and PVC water stop
14	S	5	D	3	B	Expansion devices	Poured bituminous
15	S	NE	-	NE	-	Clamping/Retaining devices	-
16	S	NE	-	NE	-	Armoring/Anchorage	-
17	S	NE	-	NE	-	End dam	-
18	S	NE	-	NE	-	Cover plates	-

DECK AND GRATING

PANEL NO.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
NORTH APPROACH AND TOWER SPAN - DECK							
1	P	5	D	5	D	Wearing surface	Asphalt
2	A	5	D	5	D	Transverse deck drainage	Transverse
3	A	5	D	5	D	Longitudinal deck drainage	Gutter lane
4	A	NE	-	NE	-	East exterior face	-
5	A	NE	-	NE	-	West exterior face	-
6	P	3	D	3	B	Abutment end soffit	Reinforced concrete
7	P	3	D	3	B	Middle soffit – approach span	Reinforced concrete
8	P	3	D	3	B	Approach – tower span end soffit	Reinforced concrete
9	P	3	D	3	B	Middle soffit – tower span	Reinforced concrete
10	P	3	D	3	B	Lift span end soffit	Reinforced concrete
LIFT SPAN - GRATING							
11	P	4	M	3	M-B	Wearing surface	Weathering steel grating
SOUTH APPROACH AND TOWER SPAN – DECK							
12	P	5	D	5	D	Wearing surface	Asphalt
13	A	5	D	5	D	Transverse deck drainage	Transverse slope
14	A	5	D	5	D	Longitudinal deck drainage	Gutter lane
15	A	NE	-	NE	-	East exterior face	-
16	A	NE	-	NE	-	West exterior face	-
17	P	3	C	3	B	Abutment end soffit	Reinforced concrete
18	P	3	C	3	B	Middle soffit – approach span	Reinforced concrete
19	P	3	C	3	B	Approach – tower span end soffit	Reinforced concrete
20	P	3	C	3	B	Middle soffit – tower span	Reinforced concrete
21	P	3	C	3	B	Lift span end soffit	Reinforced concrete

COMPONENT RATING DATA

SIDEWALK AND CURBS

PANEL NO.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
WEST							
1	S	5	D	5	D	Sidewalk	51mm – T's filled with concrete
2	S	NE	-	NE	-	Curb face and top of the curb	Steel Plates
EAST							
3	S	NE	-	NE	-	Curb face and top of the curb	Steel plates

RAILING SYSTEMS

PANEL NO.	I	PREV.		NEW		COATINGS				COMPONENT	TYPE
						PREV.		NEW			
		CR	PC	CR	PC	CR	PC	CR	PC		
NORTH											
1	S	5	D	5	D	4	C	4	C	Handrail (top)	Steel tube
2	S	5	D	5	D	4	C	4	C	Median rails	Four steel tube rails
3	S	4	A	4	A	4	C	4	C	Posts	Curved steel posts
4	S	5	D	5	D	4	D	4	D	Guiderails	Steel guiderails connected to tower members or I steel posts
5	S	5	D	5	D	5	D	5	D	Guiderails	Steel HSS rails connected to steel HSS posts on lift span
SOUTH											
6	S	5	D	5	D	4	D	4	D	Guiderails	Steel guiderails connected to tower members or I steel posts
7	S	5	D	5	D	5	D	5	D	Guiderails	Steel HSS rails connected to steel HSS posts on lift span

GATES AND SIGNS

No.	PREV.		NEW		TYPE	REQUIRED	EXIST	LOCATION
	CR	PC	CR	PC				
NORTH								
1	NI	N/A	NI	N/A	Lights	Yes	Yes	North Approach
2	NI	N/A	NI	N/A	Barrier gate	Yes	Yes	North Approach
3	NI	N/A	NI	N/A	Traffic gate	Yes	Yes	North Approach
4	NE	-	NE	-	Load limit signs	No	No	-
5	NE	-	NE	-	Hazard marker signs	No	No	-
6	NE	-	NE	-	Narrow bridge signs	No	No	-
7	NE	-	NE	-	Clearance sign	No	No	-
8	5	N/A	5	N/A	Other signs	Yes	Yes	-
SOUTH								
9	NI	N/A	NI	N/A	Lights	Yes	Yes	North Approach
10	NI	N/A	NI	N/A	Barrier gate	Yes	Yes	North Approach
11	NI	N/A	NI	N/A	Traffic gate	Yes	Yes	North Approach
12	NE	-	NE	-	Load limit signs	No	No	-
13	NE	-	NE	-	Hazard marker signs	No	No	-
14	NE	-	NE	-	Narrow bridge signs	No	No	-
15	NE	-	NE	-	Clearance sign	No	No	-
16	5	N/A	5	N/A	Other signs	Yes	Yes	-

CANAL AND RETAINING WALLS

Clearance under the bridge (down): 10 feet (min)

Clearance under the bridge (up): 120 feet

Clearance above highway: 20 feet

PANEL NO.	I	PREV.		NEW		COMPONENT	TYPE
		CR	PC	CR	PC		
1	S	4	D	4	D	North retaining wall	Concrete wall
2	S	4	D	4	D	South retaining wall	Concrete wall

APPENDIX A4

Inspection Forms

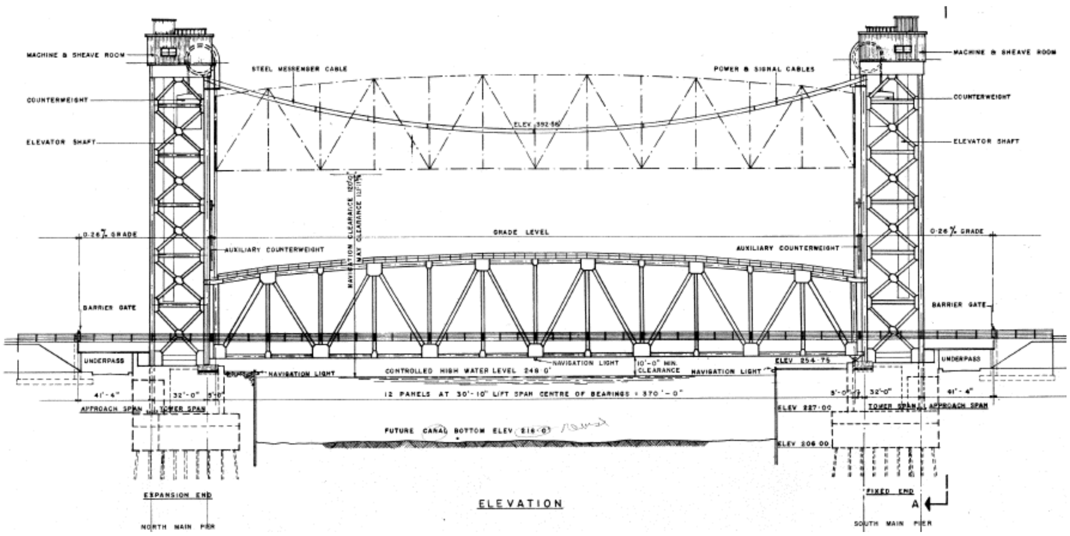
Appendix A4 **INSPECTION FORM**

NAME: Burlington Canal Lift Bridge:

LOCATION: Burlington, Ontario

YEAR CONSTRUCTED: Construction Commenced in 1958 and opened for service in 1962:

WEST ELEVATION



WEST ELEVATION

NAME:	Burlington Canal Lift Bridge:
LOCATION:	Burlington, Ontario
YEAR CONSTRUCTED:	Construction Commenced in 1958 and opened for service in 1962:
TYPE OF INSPECTION:	Comprehensive Detailed Annual Inspection:

Original Design:	1958
Drawings Available:	Yes
Previous Inspection Report Date:	November 2016 (Burlington Canal Lift Bridge 2015 Inspection Final Report).
Author:	Morrison Hershfield
Current Inspection Date:	Structural: November 20-22, & December 21, 2017 Mechanical: Electrical:
Inspectors:	Morrison Hershfield: *Scott Quach, P.Eng., Paul Locham, Tien Nguyen, and Neru Sivanesan* SBE: *Ralph Giernacky, P.E., Michael Denis-Rohr, P.E., Gareth Rees, P.Eng, Lin Xu, P.E., and Jeff Koscil* SKF: *Christopher Ramos*
Temperature:	Variable: *around 2°C*
Weather:	Variable: *partially cloudy*.
Special Access Equipment:	None

Previous Overall Rating: Structural:	4	Current Overall Rating: Structural:	3
(Approach and Tower Spans:	3)	(Approach and Tower Spans:	3)
Previous Overall Rating: Functional:	4	Current Overall Rating: Functional:	4

INSPECTION FORM

ELEMENT	OBSERVATION	CR	PR
Primary Components			
Waterway	No evidence of flooding or overflow of Burlington Canal was observed.	5	D
Embankments	Embankments on each side of the North and South Abutment Wingwalls were observed to be in good condition.	5	D
North Abutment	The north abutment exhibited some areas of wet stains and few isolated medium to wide vertical cracks. There are a few delaminated and large areas of concrete patches on the north abutment wall; delamination on the north abutment wall was found at the lower end between stringer 5 & 6 and at the upper end directly below stringer 5. Wet stains and light spalls on the ballast wall indicates leakage through the expansion joint. Priority B due to a few concrete delaminated areas and few spalled areas on the abutment walls and ballast walls that requires concrete repairs (Photos: # 11, 12-14).	4	B
South Abutment	The south abutment exhibited multiple medium to wide vertical cracks, multiple areas of delamination, few areas of spalls and one large concrete patch. The delaminated areas were found along the top sections of the abutment wall. A crack showing heavy wet with rust stains and delaminated areas was noted on the east section of the south abutment wall. There is a wide diagonal crack with wet and efflorescence stains at the top west corner area of the south wall. Wet stains and local delamination on the ballast wall indicates leakage through the expansion joint. Priority B due to a few concrete delaminated areas and few spalled areas on the abutment walls and ballast walls that requires concrete repairs (Photos: # 17, 19-20).	4	B
North Tower	The tower members below the concrete bridge deck exhibited significant defects primarily on the anchorage assembly for the tower columns and the rear floor beams. Local areas of light to medium corrosion, up to 10% section loss, was mostly noted on the interior surface of the anchorage assembly at the bottom of the rear columns of the towers. More severe corrosion, over 10% section loss, were found on the interior section of the assembly at the northwest column. The rear floor beams exhibits large areas of light to medium corrosion. Large areas of severe corrosion, up to 20% section loss, were also noted in places on the flanges and the web areas of the beams, particularly on the lower west section of the beams. Medium to severe corrosion was also noted on the lateral bracing at areas in close proximity of the rear floor beams. Above the deck, paint failure exposing a light surface corrosion on the structural steel was noted in places on the lower section of the interior sheave girders and on the underside lateral bracing. Localized medium to severe rust jacking was noted on the bottom south end of the 3rd sheave girder from west. An improperly installed rivet was noted at the top angle connection for the top flange of the 6th longitudinal sheave girder from west over a transverse floor beam for the equipment room in the There are a few narrow and medium cracks on the top surface of the concrete caps on the main counterweight. A section of the guide-bar angles was found removed from the top section of the west guiderail for the counterweight.	3	M-A-B

	Priority A due to section loss in the steel requires detailed section loss measurements and close-up inspection of the corroded sections of the jacking girder, rear floor beams, columns, and tower anchorage assemblies as well as installing missing toe boards at the bottom railing at the upper catwalk and platform. Priority M due to cleaning and painting corroded section of the jacking girder, columns, floor beams, and gusset plates connecting to the lateral bracing. Priority B due to more severe section loss in the rear/floor beams and tower anchorages requires strengthening as well as the improperly installed rivet requires to be replaced (Photos: # 123, 125, 127, 130-131, 133-134, 137, 139, and 162).		
South Tower	The tower members below the concrete bridge deck exhibited significant defects primarily on the anchorage assembly for the tower columns and the rear floor beams. Local areas of light to medium corrosion, up to 10% section loss, was particularly noted on the interior surface of the anchorage assembly at the bottom of the rear columns of the towers. More severe corrosion, over 10% section loss, were found on the interior section of the assembly at the southwest column of the south tower. Medium to severe rusted anchor bolts were noted at the front northwest column anchorage at the south tower. The rear floor beams exhibit large areas of light to medium corrosion. Large areas of severe corrosion, up to 20% section loss, were also noted in places on the flanges and the web areas of the beams. Medium to severe corrosion was also noted on the lateral bracing at areas in close proximity of the rear floor beams. The front floor beam exhibited local medium corrosion, up to 10% section loss on the web section near the bottom of the northeast column of the tower. Above the deck, paint failure exposing a light surface corrosion on the structural steel was noted in places on the lower section of the interior sheave girders and lateral bracing on the underside. There are three missing rivets on both faces of the upper built-up connection of both the east and west horizontal number 4 near mid face section, totaling 12 missing rivets. Light to medium rust jacking was noted at these missing rivet locations. Localized medium to severe rust jacking was noted on the bottom north end of the 3rd sheave girder from west. There are a few narrow and medium cracks on the top surface of the concrete caps on the main counterweight. A loose anchor bolt was noted on the central post for the safety rail atop of the counterweight. Priority A due to section loss in the steel requires detailed section loss measurements and close-up inspection of the corroded sections of the jacking girder, rear floor beams, columns, and tower anchorage assemblies as well as installing missing toe boards at the bottom railing at the upper catwalk and platform. . Priority M due to cleaning and painting corroded section of the floor beams, and gusset plates connecting to the lateral bracing. Priority B due to more severe section loss in the rear/floor beams and tower anchorages requires strengthening and replacing missing rivets is also, required (Photos: # 122, 126, 132, 138, 161, and 174).	3	M-A-B
Warren Truss – Lift Span	It was observed that the members along with the lower chords and bottom 2m of the diagonals and posts were blast cleaned and painted over and found in good condition. It was evident the re-coating is continuing to fail on the surfaces of the diagonals, posts, and chords with light to medium corrosion. The top surfaces of the portal and sway bracing horizontal members at the connections exhibit some light to medium corrosion. Priority C due to the cleaning and painting of the truss, detail drilled holes are required in the portal framing members to upturned elements connections for drainage.	4	C-D

Floor System – Lift Span	The structural steel members beneath the deck are directly exposed to water, road salt and all other airborne contaminants. The steel stringers, floor beams, lateral bracing, and the bottom chords of the truss are in good condition. Light surface rust on the new coating layer was noted in places on the top flange surface of the stringers below the deck grating at Lift Span Panels 2 to 11 and on the bottom flange areas of the floor beams and the bottom chords at the end panels, Panels 1 and 12. There are a few isolated small areas of light surface rust on the bottom corner connection, the interior surface of truss bottom chords, and the gusset plate for lateral bracing near the tower ends. The north face of the floor beam has one missing bolt at Panel point 1 just above the west centering device. Priority M due to missing bolt at north face of floor beam at Panel point 1 requires to be replaced (Photo#: 238).	5	M-D
Grating – Lift Span	The grating inspection in November 2017, indicated that there as many as 3800 cracked locations on the steel grating surface. The majority of cracks were found mainly on the outer lanes in both traffic directions. Welding repairs were completed at 930 locations, in November 2017, considered as more critical cracks on the grating; it is not known when the remaining cracks will be repaired. The broken welds were widespread throughout the span and approximately 10% more cracks were found than the inspection from 2016. Most of the critical failures, along the button welds, were found on the NB outer lane. The replacement panel grating is in good condition with no evidence of cracks or other significant defects. Priority B due to broken welds between lift span steel grating and supporting beams as well as deck grating butt welds requires deck replacement. Priority M due to broken welds in the deck gratings and the grating panels replacement is yet to be decided; ongoing weld repairs are recommended as part of maintenance (Photos: # 216-223).	3	M-B
Stringers – North Tower Span	The stringers are in poor to fair condition. The paint coating on the steel has lightly faded and peeled in places exposing a light surface corrosion on the structural steel. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. Light to medium corrosion, up to 10% section loss, was noted on the stringers, and diaphragm below the expansion joint between the tower and the lift spans. The corrosion was found mainly on the top and bottom flange areas of the stringers. Priority A due to the corroded sections and section loss in the structural steel requires detailed section loss measurements and close-up inspection of the corroded sections. Priority B due to corroded sections requires replacing or repairing steel stringers (Photos: # 67-72).	3	S-A-B
Stringers – South Tower Span	The stringers are in poor to fair condition. The paint coating on the steel has lightly faded and peeled in places exposing a light surface corrosion on the structural steel. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. Light to medium corrosion, up to 10% section loss, was noted on the stringers, and diaphragm below the expansion joint between the tower and the lift spans. The corrosion was found mainly on the top and bottom flange areas of the stringers. Priority A due to the corroded sections and section loss in the structural steel requires detailed section loss measurements and close-up inspection of the corroded section. Priority B due to corroded sections requires replacing or repairing steel stringers (Photos: # 77-82).	3	S-A-B

Stringers – North Approach Span	The stringers are in poor to fair condition. The paint coating on the steel has lightly faded and peeled in places exposing a light surface corrosion on the structural steel. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. The most severe corrosion, up to 45% section lost, was noted on the stringers and diaphragms below the abutment joints, particularly on the back side and bottom surface of the diaphragms and the stringers. The gusset plates for the connection of the diaphragms and stringers at the abutments were found severely corroded and perforated. Local severe corrosion was also noted on the top flange of Stringer 8 below bent steel plate for west curb and brackets for the cantilever west sidewalk; up to 21% section lost was noted on the top flange of Stringer 8 and approximately 50% on the bracket for cantilevered west side walk near midsection of the north approach span. Priority A due to the corroded sections and section loss in the structural steel requires detailed section loss measurements and close-up inspection of the corroded section. Priority B due to corroded sections requires replacing or repairing steel stringers (Photos: # 63-66, 89-94, 111-112,114-115, and 117).	3	S-A-B
Stringers – South Approach Span	The stringers are in poor to fair condition. The paint coating on the steel has lightly faded and peeled in places exposing a light surface corrosion on the structural steel. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. The most severe corrosion, up to 45% section lost, was noted on the stringers and diaphragms below the abutment joints, particularly on the back side and bottom surface of the diaphragms and the stringers. The gusset plates for the connection of the diaphragms and stringers at the abutments were found severely corroded and perforated. Priority A due to the corroded sections and section loss in the structural steel requires detailed section loss measurements and close-up inspection of the corroded section. Priority B due to corroded sections requires replacing or repairing steel stringers, and the perforated stiffener and gusset plates at the south abutment (Photos: # 73-76, 85-87, 104-107,109-110,113, and 116).	3	S-A-B
Deck – North Approach and Tower Spans	The underside surface of the concrete deck slab approach and tower spans is in fair condition. The concrete deck soffit is wet stained at areas below the deck expansion joints at the abutments, the joints between the deck spans, and at areas between Stringers 4 to 6. The end soffit at the abutment was found to be sloping towards the stringers and the end diaphragms causing water leakage through the deck abutment joint to run towards the structural steel. A local delaminated area was noted on the thickened soffit over the north end-diaphragm near Stringer 6. There are a few medium diagonal cracks with efflorescence and wet stains on the eastern soffit section of the north approach span. Active wet areas were noted on the soffit in the vicinity of the deck expansion joint between the north approach and the north tower spans; spalls and delamination areas were also evident in the wet areas on the soffit between Stringers 7 and 8 at the north side of the joint and between Stringers 3 and 4 at the south side of the joint. Priority B due to the few concrete delaminated areas and few spalled areas requires concrete repairs (Photos: # 91-92, 94, and 96-97).	4	B
Deck - South Approach and Tower Spans	The underside surface of the concrete deck slab approach and tower spans is in fair condition. The concrete deck soffit is wet stained at areas below the deck expansion joints at the abutments and the joints between the deck spans. The end soffit at the abutment was found to be sloping towards the stringers and the end diaphragms causing water leakage through the deck abutment joint to run towards the structural steel. Local areas of concrete delamination and spalls with	4	B

	exposed rusted rebars were also noted on the south end soffit between Stringers 4 and 7. On the approach span, there are several narrow to medium stained cracks on the southeastern section of the deck; wet and delaminated areas on the soffit were noted at the cracked areas. There are several large wet and delaminated areas on the interior central section of the approach span soffit. The north and south end sections of the south tower span soffit, at areas near the open gap joint with the lift span and the joint with the south approach span are largely wet stained particularly on the southeast section of the tower span between Stringers 1 to 4. Priority B due to the few concrete delaminated areas and few spalled areas requires concrete repairs (Photos: # 85-88, and 100-104).		
Secondary Components			
Retaining Walls	Local areas of significant defects were found at a few isolated locations on the concrete retaining walls. Narrow-to-medium cracks with efflorescence stains were noted on the top south corner of the northwest retaining wall. There is a medium-to-wide vertical crack near the upper midsection of the northeast wall. A medium vertical crack and few small areas of concrete patches were noted near midsection of the southwest retaining wall	5	D
Canal Retaining Walls – North Side	The wall was observed to be in fair condition due to the cracks, and strips of spalls with exposed reinforcing steel.	4	D
Canal Retaining Walls – South Side	Retaining walls were in good condition. Few hairline to narrow vertical cracks where observed on retaining walls.	5	D
Wingwalls	The wingwalls from the North and South abutment exhibit light to medium defects. On the Northwest wingwall, a small shallow spall with exposed reinforcing steel and light rust stains was observed.	4	D
Bearings – Lift Span	All bearings are in good condition. There were no observable significant defects on the bearings, except for a few minor loose bolts on the southeast saddle bearing.	5	D
Bearing – Abutment Bearings	The north and south abutment bearings were observed to be in good condition with the exception of light bulging on the rubber surface of the east bearings under stringers 1 to 3 for both abutments. The previous inspection report have noted a progressive tilting of the bearing under stringer 4 on the south abutment wall. In the 2017 inspection, it was found there was approximately an 8mm eastward tilt, which was similar to the 2016 inspection; this tilt value is considered within the allowable tolerance for bearings.	5	D
Deck Joints: Lift Span – North Tower Span	The open gap steel joints were found in good condition with no evidence of any significant defects.	5	D
Deck Joints: Lift Span – South Tower Span	The open gap steel joints were found in good condition with no evidence of any significant defects, except for some abrasion marks from plows on the top surface of the armour plate at east section of the joint.	5	D
Deck Joints: Tower Span – Approach Span	The concrete end-dams exhibit light to medium scaling. Localized small areas of shallow spalls and few patch-repairs, previous concrete patches and recent asphalt patches, were noted on the concrete end-dam surface. Abrasion marks from plow blades were noted on the top surface of the joint steel angles. Severe abrasions and dents were noted on the west section of the north steel angle for the expansion joint between the north approach and north tower spans. A section of the angle near the west curb was found dislodged from the concrete end-dam; loose expansion joint seal was also noted	3	M-B

	at dislodged angle location. Previous repairs with welded sections were noted in places on the joint steel angles. Active wet areas and severe significant defects on the concrete and structural steel noted below the deck expansion joints indicate severe leakage through the deck expansion joints. It should be noted that the steel stringers below the joints were effectively found to be continuous over the joint gap in the concrete bridge deck; the bottom flange of the stringers for the approach span and the tower span were found rigidly bolted to the same rear floor beam for the tower and the stringers' webs appear to have been bolt-connected through a single steel channel diaphragm (same channel for both spans stringers). These connections effectively eliminated any differential or relative movement of the structural steel and the concrete bridge decks between the spans, thus, rendering any intent useful function of the deck expansion joint system. Priority M due to the loose steel armouring angle and compression seal at the expansion between the north approach and tower span requires to be repaired and the corroded section on the north and south expansion joint plates requires to be painted and cleaned. Priority B due to the concrete delaminated areas and few spalled areas requires concrete repairs as well as the severe leakage through the deck joints requires the expansion joints to be replaced (Photos: #: 45-49, 57-62, 93-94, and 106-107).		
Joints: Approach Span – Ballast Wall	The paved-over joints at both approach spans are observed to be in poor condition. The asphalt wearing surface along the north joint was found in good condition. Unsealed pattern cracks were noted on the asphalt wearing surface along the east section of the paved-over expansion joint. Active wet areas on the concrete and structural steel were evident at areas below the north and south abutment joints indicating severe leakage through the paved-over abutment joints. Priority B due to the severe leakage through the paved-over joints requires to be replaced (Photos: # 84-88).	3	B
Sidewalks – Lift Span	The sidewalk was found to in good condition. An isolated narrow to medium crack was observed at the edge of the southeast side of the sidewalk. One expansion joint cover plate at the south end was found not to be checkered. This may create a potential slip hazard to pedestrians crossing the bridge.	5	D
Sidewalks – Tower Span and Approach Span	The sidewalk on both sides are found to be in good condition. The approach sidewalks are in fair to good condition. The concrete sidewalk is lightly scaled with a few isolated narrow and medium cracks. Wide fracture cracks were noted on the south approach sidewalk in the vicinity of the impact damaged guiderail posts.	4	D
Curb and gutter	The curbs on the tower spans and approach spans were found to be in fair to good condition. The steel plates exhibited light surface corrosion and localized medium corrosion on the top surface. Local severe corrosion with perforation holes were noted on the underside surface of the bent curb plate in areas near the deck expansion joints at the abutments and the joints between the approach and the tower spans.	4	D
Railings – Lift Span	The railings on the east and west side of the bridge were found in good condition. All bridge railings for the traffic were found in good condition with no significant defects. A section of the railing in area below the counterweight guiderail was found covered in grease. On the west side at the pedestrian sidewalk railing, a spindle on the railing was found broken-off at the bottom rail on the lift span at Panel 9. There are loose anchor bolts on three of the aluminum railing posts: one post at the south abutment joint, one at the north abutment joint, and one near the north end of the railing. Priority A due to the broken spindle, and loose bolts on the sidewalk railing requires to be repaired (Photos: # 288-291).	5	D (A-for one section on the pedestrian railing)
Approaches	The north and south approach roads are in good condition with few isolated light pattern unsealed cracks. Minor dents and leant posts from vehicular impacts were noted on the south approach guiderail near the southwest barrier gate.	5	D

Auxiliary Component			
Slope Protection	Not applicable.	N/A	N/A
Coatings	The splash zone in the lift span was found to be in good condition. The coating for the rest of the structural components were found to be in poor to fair condition, with localized paint failure over most of the structure.	3	D
Deck Drains	No deck drains are provided on the deck of the lift span.	N/A	N/A
Approach Drains	The approach drains on both the north and south approach spans were found to be free of debris.	5	D
Approach Catch Basins	The catch basins were observed to be in good condition. Minor road debris was observed at the north and south catch basins.	5	D
Utilities	The conduits mounted on the front face of both abutment walls were found to be removed after, the 2016 inspection. The new conduits mounted at the top of the north and south abutments exhibit no significant defects.	NI	N/A
Signage	Signs were observed to be in good condition.	5	D

APPENDIX A5

MCR – PCR Forms

ELEMENT	Previous		New		Comments
	MCR	PCR	MCR	PCR	
Primary Components					
Streams	N/A	N/A	N/A	5	No evidence of flooding or overflow of Burlington Canal was observed.
Embankments	5	5	5	5	Embankments on each side of the north and south abutment wingwalls were observed to be in good condition.
Foundations	NI	NI	NI	NI	Not inspected as not accessible.
North Abutment	4	4	4	4	The north abutment exhibited wet stains and few isolated medium to wide vertical cracks. There are a few delaminated areas and large areas of concrete patches on the north abutment wall; delamination on the north abutment wall was found at the lower end between stringer 5 & 6 and at the upper end directly below stringer 5. Wet stains and light spalls on the ballast wall indicate leakage through the expansion joints.
South Abutment	3	4	3	4	The south abutment exhibited multiple medium to wide vertical cracks. There are multiple areas of delamination, few areas of spalls and one large concrete patch. Delaminated areas were found along the top sections of the abutment wall. There is a wide diagonal crack with wet and efflorescence stains at the top west corner area of the south wall. Wet stains and local delamination on the ballast wall indicate leakage through the expansion joints.
North Tower	5	4	3	3	The front floor beam exhibits localized light to medium corrosion at the west end, top, and bottom flange. While, the rear floor beam exhibits painting failure and medium-to-severe corrosion on the webs, bottom, and top flange. Large areas of severe corrosion, up to 20% section loss, were noted in places on the flanges and the web areas of the beams, particularly on the lower west section of the beams. The gusset plates connecting the lateral bracing to the floor beams were observed to have localized areas of light to medium corrosion on most of its upper surfaces. Local areas of light to medium corrosion, up to 10% section loss, was noted on the interior surface of the anchorage assembly at the bottom of the rear columns of the towers. More severe corrosion, over 10% section loss, were found on the interior section of the assembly at the northwest column. The connections of built-up section members, gusset plates, splices, rivets, and joints exhibit localized light to medium corrosion. Paint failure exposing a light surface corrosion on the structural steel was noted in places on the lower section of the interior sheave girders and lateral bracing on the underside. No missing rivets or loose connections were observed. The drop in rating is mostly due to the areas of medium to severe corrosion on the flanges, and web of the rear floor beam, and severe corrosion on the anchorage assembly.

South Tower	5	4	3	3	The top flange of the front and rear floor beams and their bracing components exhibit light to medium corrosion at midspan. Local area of medium to severe corrosion was observed on the bottom flange of the rear floor beam near the west end and on the gusset plates. The jacking girders were found to be in good condition and exhibited local areas of light corrosion. . Local areas of light to medium corrosion, up to 10% section loss, was noted on the interior surface of the anchorage assembly at the bottom of the rear columns of the towers. More severe corrosion, over 10% section loss, were found on the interior section of the assembly at the southwest column of the south tower. Localized areas of paint failure and light to medium corrosion were observed at connections of built-up section members, gusset plates, splices and rivets. Six rivets were found missing on both horizontal member #4 (total of12); three along the top at midspan on both east and west faces. The drop in rating is mostly due to the areas of medium to severe corrosion on the bottom flange of the rear floor beam and gusset plates, and severe corrosion on the anchorage assembly.
Warren Truss – Lift Span	4	4	4	4	The condition of the truss members in the Lift Span are in good condition with defects including section loss from corrosion and paint failure. Light defects with few local areas of light corrosion on the interior face of the top chords were observed. The top surfaces of the portal and sway bracing horizontal members at the connections exhibit some light to medium corrosion; localized light corrosion with pitting was found on the bottom faces of some members. The recent repainting program mitigated the deterioration.
Floor Beams – Lift Span (Floor System)	4	4	5	5	The structural steel members beneath the deck are directly exposed to water, road salt and all other airborne contaminants. Significant defects on the structural steel below the bridge deck were not apparent, except for some localized areas of light surface rust at the time of this inspection. The structural steel floor beams were observed to be in good condition after the repainting program.
Stringers – Lift Span (Floor System)	4	4	5	5	The structural steel members beneath the deck are directly exposed to water, road salt and all other airborne contaminants. Significant defects on the structural steel below the bridge deck were not apparent, except for some localized areas of light surface rust at the time of this inspection. The structural steel stringers were observed to be in good condition after the recent repainting program.
Diagonals – Lift Span (Floor System)	4	4	5	5	The structural steel members beneath the deck are directly exposed to water, road salt and all other airborne contaminants. Significant defects on the structural steel below the bridge deck were not apparent, except for some localized areas of light surface rust at the time of this inspection. The structural steel floor diagonals were observed to be in good condition after the recent repainting program.
Traction Bracings – Lift Span (Floor System)	4	4	5	5	The structural steel members beneath the deck are directly exposed to water, road salt, and all other airborne contaminants. Significant defects on the structural steel below the bridge deck were not apparent, except for some localized areas of light surface rust at the time of this

					inspection. The structural steel bracings were observed to be in good condition after the recent repainting program.
Grating – Lift Span	4	4	3	3	It was observed that the welds connecting to the floor stringers to the grating and within the grating panels themselves, were found broken as many as 3800 cracked locations on the steel grating. The broken welds were widespread throughout the span and approximately 10% more cracks were found than the inspection from 2016. Most of the critical failures, along the button welds, were found on the NB outer lane. The drop in rating is attributed to the approximate 10% increase in the number of cracks at the grating panels than in the 2016 inspection.
Stringers – North Tower Span	3	3	3	3	The stringers exhibited light to medium corrosion and paint failure at the end of the span and light to medium corrosion along the span. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. Light to medium corrosion, up to 10% section loss, was noted on the stringers, and diaphragm below the expansion joint between the tower and the lift spans. The corrosion was found mainly on the top and bottom flange areas of the stringers.
Stringers – South Tower Span	3	3	3	3	The stringers exhibit areas of localized light to medium corrosion at the end of the span and light to medium corrosion along the span. The coating was found largely peeled from steel stringers and diaphragms at areas below the deck expansion joints. Light to medium corrosion, up to 10% section loss, was noted on the stringers, and diaphragm below the expansion joint between the tower and the lift spans. The corrosion was found mainly on the top and bottom flange areas of the stringers.
Stringers – North Approach Span	3	3	3	3	The stringers exhibited localized medium to severe corrosion and paint failure at the end of the span. Most of the stringers exhibit light corrosion along the span with the exception of stringer 8, which exhibited light to medium corrosion along the span. The most severe corrosion, up to 45% section lost, was noted on the stringers and diaphragms below the abutment joints, particularly on the back side and bottom flange of the diaphragms and the stringers. The gusset plates for the connection of the diaphragms and stringers at the abutments were found severely corroded and perforated. Local severe corrosion was also noted on the top flange of Stringer 8 below bent steel plate for west curb and brackets for the cantilever west sidewalk.
Stringers – South Approach Span	3	3	3	3	The stringers exhibit localized medium to severe corrosion and painting failure at the end of the span. Most of the stringers exhibit light corrosion along the span with the exception of stringer 8, which exhibited light to medium corrosion along the span. The most severe corrosion, up to 45% section lost, was noted on the stringers and diaphragms below the abutment joints, particularly on the back side and bottom flange of the diaphragms and the stringers. The gusset plates for the connection of the diaphragms and stringers at the abutments were found severely corroded and perforated.
Load Bearing Diaphragms	1	2	3	3	Due to the leaking expansion joint on the north and south abutment, the end diaphragms exhibit medium to severe paint failure and medium corrosion on the top and bottom flanges and at the

					connections with the stringers. Small local bend on bottom flange of diaphragm 7 (between Stringer 7 and 8) on the south abutment. Section has been observed on the diaphragms.
Connections of Primary Components	3	3	3	3	On the south abutment, the gusset plate at the diaphragm connection on the east side of Stringer 8 exhibits perforation in the plate and severe corrosion on the diaphragm, and the bottom flange.
Deck – North Approach and Tower Spans	3	3	4	4	The concrete deck exhibited light to medium defects, which include light to medium spalls and delamination, narrow to medium efflorescence stained cracks rust stains and wet areas. The end soffit at the abutment was found to be sloping towards the stringers and the end diaphragms causing water leakage through the deck abutment joint to run towards the structural steel.
Deck – South Approach and Tower Spans	3	3	4	4	The concrete deck exhibited light to medium defects, which include delamination, narrow efflorescence stained cracks, rust stains, and wet areas. The end soffit at the abutment was found to be sloping towards the stringers and the end diaphragms causing water leakage through the deck abutment joint to run towards the structural steel.
Wearing Surface	4	4	5	5	The approach was in good condition. Few isolated light transverse and longitudinal cracks were observed near the expansion joint between the south approach and south tower span. Few light edge cracks were observed at the expansion joint between the north approach and tower span.
Sidewalks Accessible to Traffic – Lift Span	5	5	5	5	The sidewalk was found to be in good condition. An isolated narrow to medium crack was observed at the edge of the southeast side of the sidewalk. One expansion joint cover plate at the south end was found to not be checked. This may create a potential slip hazard to pedestrians crossing the bridge.
Sidewalks Accessible to Traffic – Tower Span and Approach Span	5	5	5	4	The sidewalk was found to be in good condition. The approach sidewalks was found in fair to good condition. Wide fracture cracks were noted on the south approach sidewalk in the vicinity of the impact damaged guiderail posts. The drop in rating for PCR is attributed to the wide fracture cracks on the south approach sidewalk in the vicinity of the impact damaged guiderail posts.
Structural Steel Coatings on Primary Components	3	3	2	3	The structural steel coating on primary components were found to be in fair to good condition on the lift span and poor to fair on the approach/tower spans. The coating within the splash zone, on the lift span, was recently repainted and found to be in good condition. Local areas of paint peeling/failure was observed at the top chord at rivet locations. The coatings on the structural steel stringers and the front/rear floor beams exhibited the worst conditions. Multiple areas of paint failure were observed at corroded areas. The drop in rating for MCR is attributed to the paint failure on the structural steel stringers, the front and rear floor beams, and on multiple corroded areas..
Secondary Components					
Embankment	N/A	N/A	N/A	N/A	Not Applicable.
Ballast Walls	3	3	3	3	The north ballast wall exhibited multiple wet areas, small spalls, several narrow cracks and a few medium vertical cracks. A small area of concrete patch with spalls and an active wet area was

					noted at the top of the north ballast wall. Local wet stains were also observed on the north abutment bearing seat. This indicates that the north expansion joint may be leaking. Wet stains, spalls, delaminated areas, several narrow cracks and a few medium vertical cracks were observed on the south ballast wall. Local wet stains were also observed on the south abutment bearing seat. This indicates that the south expansion joint may be leaking.
Wingwalls	5	5	4	4	The wingwalls from the North and South abutment exhibit light to medium defects. On the Northwest wingwall, a small shallow spall with exposed reinforcing steel and light rust stains was observed.
Retaining Walls	5	5	4	5	Retaining walls were in good condition. Narrow-to-medium cracks with efflorescence stains were noted on the top south corner of the northwest retaining wall. There is a medium-to-wide vertical crack near the upper midsection of the northeast wall. A medium vertical crack and few small areas of concrete patches were noted near midsection of the southwest retaining wall. The drop in rating for MCR is attributed to the medium-to-wide vertical crack at the northeast wall, medium crack at the southwest wall, and narrow-to-medium cracks at the northwest wall.
Canal Retaining Wall – North Side	4	4	4	4	Retaining walls were in fair condition. Few strips of spalls with exposed reinforcing steel and
Canal Retaining Wall – South Side	4	4	5	5	Retaining walls were in good condition. Few hairline to narrow vertical cracks where observed on retaining walls.
Bearing Seats	5	5	5	5	The top surface of the north and south abutments and concrete pedestals were observed to be filled with debris.
Bearing – Lift Span	4	5	5	5	All bearings are in good condition. There were observable significant defects on the bearings, except for a few minor loose bolts on the southeast saddle bearing.
Bearings – Abutments Bearings	5	4	5	4	It was observed that there was light bulging on the rubber surface of the east bearings under Stringers 1 to 3. At the south abutment, the bearing under Stringer 4 has approximately 8mm eastward tilt.
Deck Joints: Lift Span – North Tower Span	4	4	5	5	The open gap steel joints were found in good condition with no evidence of any significant defects.
Deck Joints: Lift Span – South Tower Span	4	3	5	4	The open gap steel joints were found in good condition with no evidence of any significant defects, except for some abrasion marks from plows on the top surface of the armour plate at east section of the joint.
Deck Joints: Tower Span – Approach Span	3	3	3	3	The concrete end-dams exhibit light to medium scaling. Localized small areas of shallow spalls and few patch-repairs, previous concrete patches and recent asphalt patches, were noted on the concrete end-dam surface. Abrasion marks from plow blades were noted on the top surface of the joint steel angles. Severe abrasions and dents were noted on the west section of the north steel angle for the expansion joint between the north approach and north tower spans. The concrete end dam and steel armouring angle at the south expansion joint was observed to be in fair condition. The rubber seal was observed to be filled with debris. The previously repaired

					steel armouring section appears to be in good condition. The concrete end dam exhibits light to medium scaling and a few narrow to medium cracks.
Joints: Approach Spans – Ballast Walls	5	5	5	5	The paved-over joint were found in good condition with the exception of leakage found at the joints and a few crack on the south joint at the NBL.
Non-Load Bearing Diaphragms – Lift Span	4	4	4	4	The diaphragms on the lift span were observed to be in good condition after the recent repainting program.
Non-Load Bearing Diaphragms – North Tower Span	3	4	4	4	The intermediate diaphragms were observed to be in good condition. Local areas of light paint peeling were observed on all intermediate diaphragms.
Non-Load Bearing Diaphragms – South Tower Span	3	4	4	4	The intermediate diaphragms were observed to be in good condition. Local areas of light paint peeling were observed on all intermediate diaphragms.
Non-Load Bearing Diaphragms – North and South Approach Spans	3	4	4	4	The intermediate diaphragms were observed to be in good condition. Local areas of light paint peeling were observed on all intermediate diaphragms.
Bracings – Lateral North and South Tower Bracings	4	5	4	5	The lateral bracings were observed to be in good condition. No observable performance deficiencies were observed. Localized areas of light to medium corrosion and paint peeling was observed.
Connection of Secondary Components	4	4	4	4	The connections of the secondary components were observed to be in good condition. No observable performance deficiencies were observed. Localized areas of light corrosion and paint peeling was observed.
Curb and gutter	4	5	4	5	The curbs on the tower spans and approach spans were found to be in fair to good condition. The steel plates exhibited light corrosion with local areas of light to medium corrosion. A majority of the paint exhibits light to medium rust.
Sidewalks not Accessible to Traffic	N/A	N/A	N/A	N/A	Not Accessible.
Approaches	5	5	4	5	The approach was in good condition. Few isolated light transverse and longitudinal cracks were observed near the expansion joint between the south approach and south tower span. Unsealed severe pattern cracks and small pothole were observed at the expansion joint between the north approach and north tower span.
Approach Slabs	N/A	N/A	N/A	N/A	Not Applicable.
Guide rails – Tower Spans	4	5	4	5	The guide rails exhibited light defects with minor paint loss and minor impact damage on east side of the south tower span.
Guide rails – Approach Spans	5	5	5	5	The guide rails on the approach spans were found in good condition.

Railings – Lift Span	4	5	4	5	The pedestal sidewalk railing was found to be in good condition with the exception of two missing bolts at railing posts 19 and 20, one spindle held together with duct tape, and another rattling between railing posts 14 and15.
Structural Steel Coatings on Secondary Components	4	4	4	4	The coating was found to be in fair condition, with local areas of light to medium corrosion and localized paint failure.
Auxiliary Component					
Slope Protection	N/A	N/A	N/A	N/A	Not Applicable.
Deck Drains	N/A	N/A	N/A	N/A	Not Applicable.
Approach Drains	5	5	5	5	The approach drains on both the north and south approach spans were found to be free of debris.
Approach Catch Basins	5	4	5	5	The catch basins were observed to be in good condition. Minor road debris was observed at the north and south catch basins.
Signs	5	4	5	5	Signs were observed to be in good condition.
Utilities	NI	NI	NI	NI	The conduits mounted on the front face of both abutment walls were found to be removed after, the 2016 inspection. The conduits mounted at the top of the north and south abutments exhibit few defects.

APPENDIX A6

Fall Arrest Inspection Report (As Provided By PWGSC)

level in all tanks has been observed to be slightly above the lake level. Continued monitoring of water levels in the tanks is recommended as part of the annual inspection; if any significant difference appears, a more detailed inspection using divers may be warranted. The current equalization tanks inspection frequency of once every four years is considered acceptable.

2.14 Fall Arrest System Inspection

The fall protection system was inspected in October 2016 prior to the structural and mechanical inspections. The scope of the inspection includes DBI Sala Lad-Saf systems on the tower ladders; D-Plate anchors at each ladder access; 2 TS Rail systems across the bridge; 2 Sure-Rail systems at ends of bridge; safety gates in the towers; and soft goods including harnesses and lanyards. It also includes the inspection and re-certification by SRL manufacturer for the self-retracting lifelines on the bridge.

All fall protection system items passed the inspection except two (2) harnesses, four (4) 12" Lanyards, four (4) 6" Lanyards, two (2) 6" DBL Lanyards and one (1) 1 ¾" SRL. The details of the inspection findings are included in Appendix 1E.

capital

260 Export Blvd., Mississauga, ON, Canada L5S 1Y9, 1-800-387-7484 (905)795-9333 Fax (905)795-0977 www.capitalsafety.ca

Certification

We hereby certify the following items to meet or exceed the appropriate CSA requirements or manufacturer's specifications as applicable to the products serviced.

COMPANY	MODEL NUMBER(S)	SERIAL NUMBER(S)
W.S. SAFETY TECHNOLOGIES 221 LAWRENCE AVENUE ORILLIA, ON L3V 5N3	**3400115C**	**097866**
	3403402C	**099992, 099440, 099332, 099512, 099442**
	3504430C	**17415, 17377, 17408**
	3103208C	**22044, 22019**

NOTE: ANNUAL INSPECTION IS RECOMMENDED BY AN AUTHORIZED SERVICE CENTRE. EXTREME WORKING CONDITIONS MAY INDICATE THE NECESSITY TO INCREASE ANNUAL SERVICE. CONSULT YOUR OWNERS MANUAL FOR ADDITIONAL INFORMATION.

All certifications apply to new (or serviced) products. Certification void if manufacturer's instructions for use, care and maintenance are not followed. Alterations or misuse of this product will also void all certification.

Certificate Number **BR48530**

Peter Kotyra - Technical Services Supervisor   Date: November 2016

Fall Protection System Inspection Report

W.S. Safety Technologies
623619 Ontario Inc.
221 Lawrence Ave, Orillia
Ontario, Canada
L3V 5M3

Ph: 855-227-5787
Email: mail@wssafety.com

Company:	**PARSONS – BURLINGTON LIFT-BRIDGE**
Attn:	**KAREN LIU**
Date:	**OCTOBER 2016**
Inspector:	**WARREN BENNETT**
Reviewed:	**PATRICK MICHELS**

NOTES:

This inspection certificate is a random indication on the date of the inspection. User and supervisor have to inspect and maintain the equipment prior to each use following standards and manufacturers manuals.

The results of this P.P.E. Visual Inspection are provided to you subject to the condition that the components to be inspected do not come into any falls, modifications, local pressure force or blow and are not used longer than the manufacturer described, any of which would require the rejection of the component.

This inspection report is no longer valid when the product has been subjected to any fall forces, has been used for other purposes than described in the user manual, has been used in combination with other components than described in the user manual, has been stored and/or maintained in a different way than described in the user manual.

Please note, the date for your next inspection is either one year from the date of completion for this inspection or sooner if an incident was to occur on the system.

Fall Protection System Inspection Report

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Email: mail@wssafety.com

COMPANY SITE: BURLINGTON LIFT BRIDGE		SITE CONTACT: KAREN LIU
ADDRESS: Canal Road		PHONE: FAX:
CITY: BURLINGTON	PROV./STATE: ONTARIO	INSPECTOR: WARREN BENNETT
INSPECTION DATE: October 24, 25, 2016	TEMPERATURE: (deg. C)	SYSTEM LOCATION;
System MFR: 10 DBI Sala Lad-Saf systems AND 10 DBI Sala Anchor points at each access location, NORTH Tower		☒Pass ☐Pass w/Conditions ☐Fail (See Conditions)
Conditions (if any)/Comments: All systems were inspected and passed inspection, inspection tags were installed.		
Recommendations:		

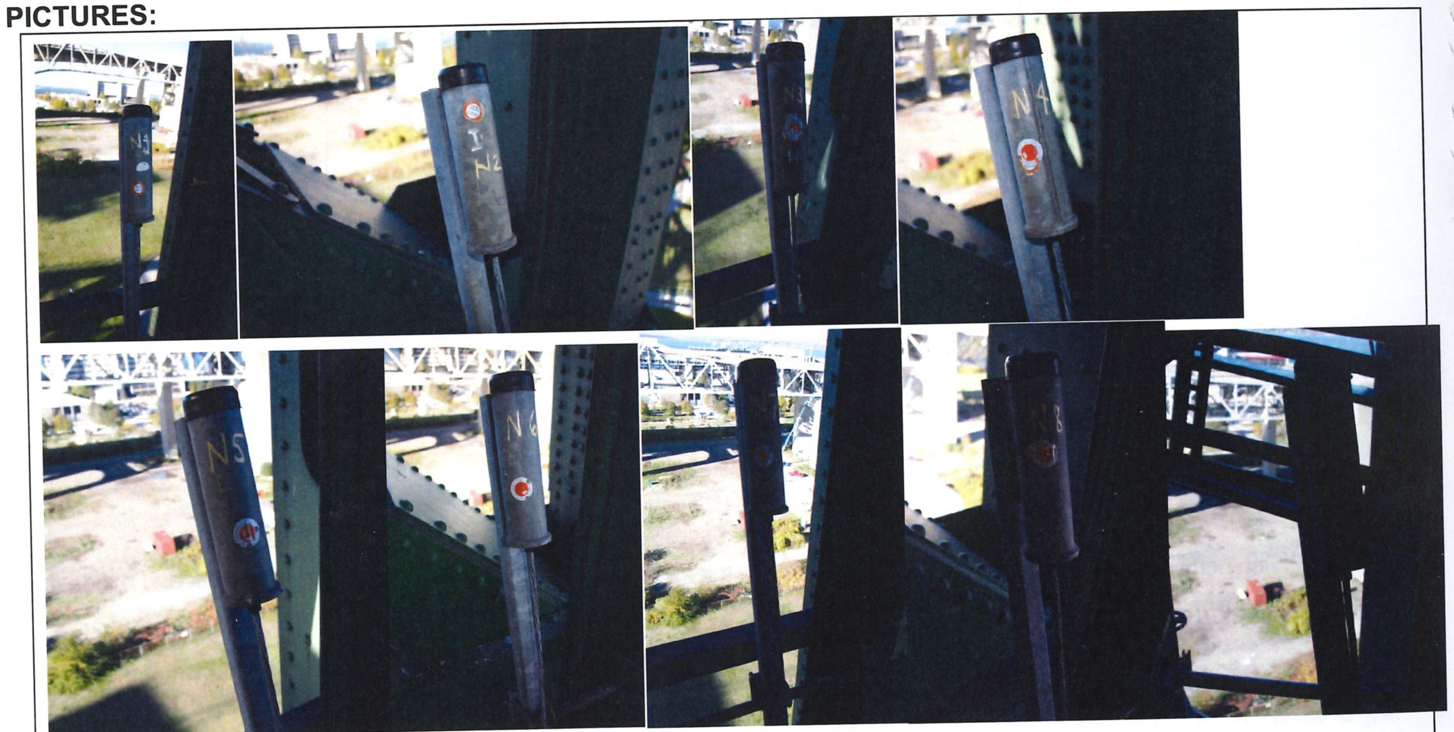
SYSTEM TYPE

☐Horizontal Rigid Rail ☐Horizontal Cable ☒ Vertical Cable ☒ Anchor Point

ANCHOR POINT & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:



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ADDRESS: Canal Road		PHONE: FAX:
CITY: BURLINGTON	PROV./STATE: ONTARIO	INSPECTOR: WARREN BENNETT
INSPECTION DATE: October 24, 25, 2016	TEMPERATURE: (deg. C)	SYSTEM LOCATION;
System MFR: 10 DBI Sala Lad-Saf systems AND 10 DBI Sala Anchor points at each access location, SOUTH Tower. Also includes 1 system on antenna tower.		☒Pass ☐Pass w/Conditions ☐Fail (See Conditions)
Conditions (if any)/Comments:		
Recommendations:		

SYSTEM TYPE

☐Horizontal Rigid Rail ☐Horizontal Cable ☒ Vertical Cable ☒ Anchor Point

ANCHOR POINT INSPECTION & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:

Fall Protection System Inspection Report

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COMPANY SITE: BURLINGTON LIFT BRIDGE	SITE CONTACT: KAREN LIU
ADDRESS: Canal Road	PHONE: FAX:
CITY: BURLINGTON / PROV./STATE: ONTARIO	INSPECTOR: WARREN BENNETT
INSPECTION DATE: October 24, 25, 2016 / TEMPERATURE: (deg. C)	SYSTEM LOCATION;
System MFR: Sure-Rail systems, 2 systems, on bridge span, north and south ends.	☒Pass ☐Pass w/Conditions ☐Fail (See Conditions)
Conditions (if any)/Comments: Trolleys function as required.	
Recommendations:	

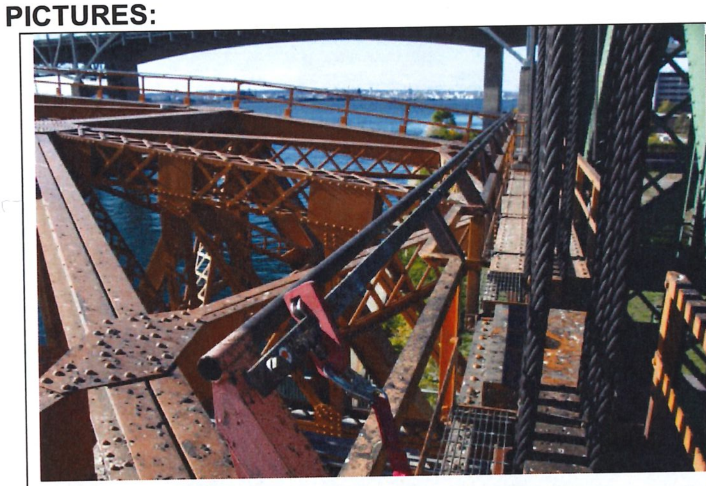
SYSTEM TYPE

☒Horizontal Rigid Rail ☐Horizontal Cable ☐ Vertical Cable ☐ Anchor Point

ANCHOR POINT INSPECTION & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:



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ADDRESS: Canal Road	PHONE: FAX:
CITY: BURLINGTON / PROV./STATE: ONTARIO	INSPECTOR: WARREN BENNETT
INSPECTION DATE: October 24, 25, 2016 / TEMPERATURE: (deg. C)	SYSTEM LOCATION;
System MFR: TS Rail systems, 2 systems, on bridge span, east and west ends.	☒Pass ☐Pass w/Conditions ☐Fail (See Conditions)
Conditions (if any)/Comments: Trolleys function as required.	
Recommendations:	

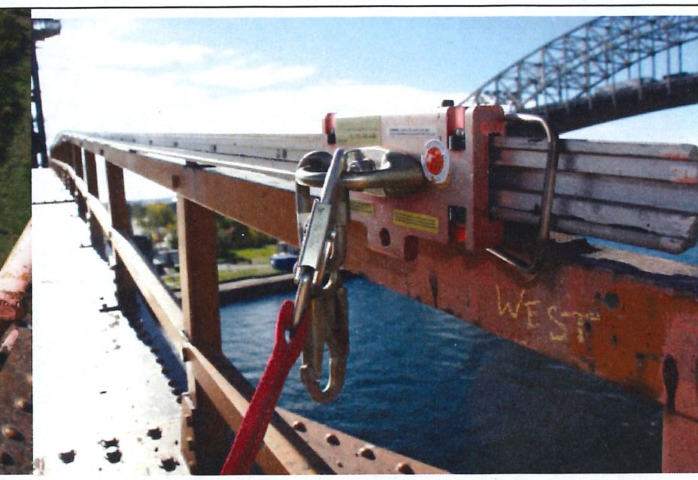
SYSTEM TYPE

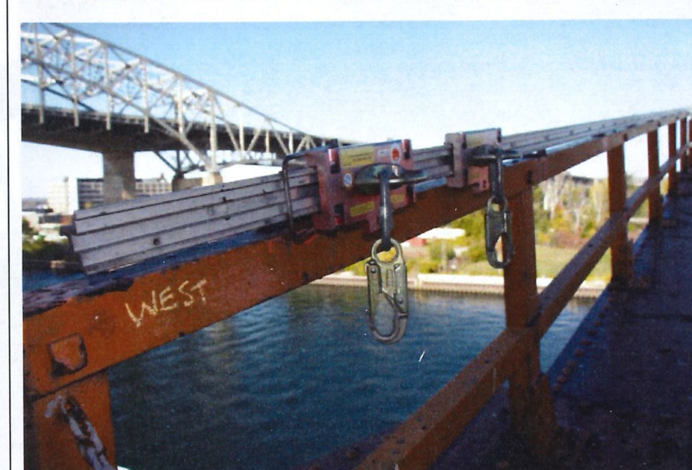
☒Horizontal Rigid Rail ☐Horizontal Cable ☐ Vertical Cable ☐ Anchor Point

ANCHOR POINT INSPECTION & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:





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ADDRESS: **Canal Road**	PHONE: FAX:
CITY: **BURLINGTON** / PROV./STATE: **ONTARIO**	INSPECTOR: **WARREN BENNETT**
INSPECTION DATE: **October 24, 25, 2016** / TEMPERATURE: **(deg. C)**	SYSTEM LOCATION:
System MFR: 6 FabEnCo safety gates in North and South towers	☒Pass ☐Pass w/Conditions
Conditions (if any)/Comments: Gates function as required.	☐Fail (See Conditions)
Recommendations:	

SYSTEM TYPE

☐Horizontal Rigid Rail ☐Horizontal Cable ☐ Vertical Cable ☐ Anchor Point

ANCHOR POINT INSPECTION & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:

Fall Protection System Inspection Report

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ADDRESS: **Canal Road**	PHONE: FAX:
CITY: **BURLINGTON** / PROV./STATE: **ONTARIO**	INSPECTOR: **WARREN BENNETT**
INSPECTION DATE: **October 24, 25, 2016** / TEMPERATURE: **(deg. C)**	SYSTEM LOCATION:
System MFR: 6 Anchor Points in Towers for SRLS	☒Pass ☐Pass w/Conditions
Conditions (if any)/Comments:	☐Fail (See Conditions)
Recommendations:	

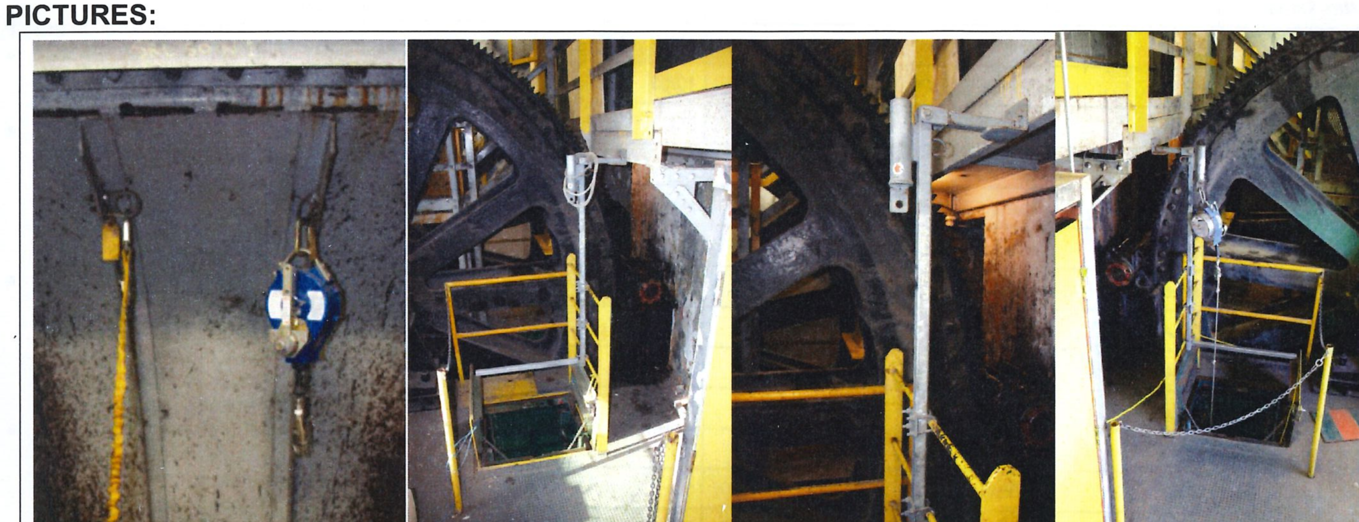
SYSTEM TYPE

☐Horizontal Rigid Rail ☐Horizontal Cable ☐ Vertical Cable ☒ Anchor Point

ANCHOR POINT INSPECTION & FALL ARREST SYSTEM INSPECTION

☒ fasteners ☒ support structure ☒ end and intermediate supports

PICTURES:



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Softgoods Inspection

Item	Make	Model	Serial #	Mo/Yr Date	Pass/Fail
Harness	MSA	SSH 80920350	Q908824	2/15	P
Harness	MSA	SSH 80922300	10533803	10/08	P
Harness	MSA	SSH 80922300	1053381	10/08	P
DBL Lanyard	MSA	10035965	_	6/5	P
Harness	MSA	SH 80920300	_	4/5	P
DBL Lanyard	MSA	10035965	_	6/5	P
Lanyard	MSA	WL 2268805LS	_	2/5	P
5' Wire Rope	Protect	AJ400G 5	_	5/3	P
Harness	MSA	SSH 80920300	1050087	9/8	P
DBL Lanyard	MSA	10035965	-	6/5	P
Lanyard	MSA	WL226880SLS	_	2/5	P
6' Wire Rope	_	_	_	_	P
Harness	MSA	SH 8920300	_	1/5	P
Harness	MSA	SH 80920300	_	10/03	F
6' Lanyard	SALA	1220256	2259988	2/3	F
12" Lanyard	SALA	1201117	2281625	5/3	F
same	same	same	2281626	same	F
same	same	same	2281629	same	F
same	same	same	2281666	same	F
6' DBL Lanyard	SALA	1226700	1840189	3/1	F
same	same	same	1840188	same	F
6' Lanyard	SALA	1220256	2259967	2/3	F
same	same	1226300	1844201	3/1	F
1 3/4" SRL	MSA	PF6902002	85348	5/3	F
6' Lanyard	SALA	1226300	1844206	3/1	F
Harness	MSA	SH 80920300	_	4/5	P
Harness	MSA	SH 80920300	_	2/5	F
DBL Lanyard	MSA	10035965	_	6/5	P

Failed items were marked 'failed' directly on the items, and left with personnel at maintenance shed to dispose of.

Fall Protection System Inspection Report

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TYPICAL RIGID RAIL INSPECTION

- Complete visual and physical inspection of entire rail system
  - tab anchors
  - splice bars
  - anchorage bolts and spacers
  - endstop/entry devices
- Inspect Rail Tab Anchors
  - for cracking or deformation of anchor plates/connections that would indicate that a fall or near miss may have taken place
  - check torque of anchor bolts and other fall protection components
- Inspect Rail System
  - for track warping, alignment, and gap spacing
  - check dimensions of rail to evaluate the amount of acceptable wear against the original mill specifications.
  - check all Rail Tab Anchors welds
  - check anchorage bolt torque
  - check trolley motion on rail
- Inspect Personal Protective Equipment and Secondary Components
  - trolley/shuttle
    - bearings
    - cracking { indicates that a fall (or near miss) may have taken place}
    - rolling motion on the Rigid Rail system
  - carabiners/connecting devices
  - self-retracting lifelines
  - full body harnesses & softgoods

TYPICAL CABLE INSPECTION

- Complete visual and physical inspection of entire cable system -end anchors
  - intermediate connections
  - cable (kinks, damage)
- Inspect End Anchors
  - for cracking or deformation of anchor plates/connections that would indicate that a fall or near miss may have taken place
  - pull test to design specifications
  - check torque of anchor bolts and other fall protection components
  - retention cable to design specifications
  - check turnbuckles, swaged ends, shackles, bolts, and pins
- Inspect Cable System
  - cable tension
  - for cable fraying
  - check all intermediates and pull test if necessary
  - retention cable to design specifications
  - inspect energy absorber
- Inspect Personal Protective Equipment and Secondary Components
  - trolley/shuttle
  - carabiners/shackles
  - self-retracting lifelines
  - full body harnesses

APPENDIX A7

Itemized Estimates for Recommended Major Work

Improvement	Unit	Unit Cost	Qty	2018	2019	2020		2023	2024	2025	2026	2027	TOTAL
1a. Concrete Deck Replacement (Deck at Approach and Tower Spans)													
Removal of Existing Deck and Stringers	LS	$365,000	1	$365,000									$365,000
New Concrete Deck on New Steel Stringers (included Expansion Joints, Bearings)	m^2	$2,710	700	$1,897,000									$1,897,000
Access & Protection (incl. Traffic Controls)	LS	$185,000	1	$185,000									$185,000
Subtotal:				**$2,447,000**									**$2,447,000**
Engineering & Contract Administration (20%)				$489,400									$489,400
Contingency (15%)				$367,050									$367,050
Total				**$3,303,000**									**$3,303,000**
2a. Replace Deck Grating on SB Lane (Lift Span- SB Deck, 48 Panels total)													
Traffic Controls	LS	$400,000	1		$400,000								$400,000
Access Platforms & Environmental Protection	LS	$670,000	1		$670,000								$670,000
Removal of Existing Grating Panels	LS	$700,000	1		$700,000								$700,000
Clean & Coat Structural Steel Subsrate for New Grating	m^2	$1,300	155		$201,500								$201,500
Supply & Install New Deck Grating (48 Panels)	t	$23,000	154		$3,532,800								$3,532,800
Subtotal:					**$5,504,300**								**$5,504,300**
Engineering & Contract Administration (20%)					$1,100,860								$1,100,860
Contingency (15%)					$825,645								$825,645
Total					**$7,431,000**								**$7,431,000**
2b. Replace Deck Grating on SB Lane (Lift Span- NB Deck, 49 Panels total)													
Traffic Controls	LS	$400,000	1			$400,000							$400,000
Access Platforms & Environmental Protection	LS	$680,000	1			$680,000							$680,000
Removal of Existing Grating Panels	LS	$780,000	1			$780,000							$780,000
Clean & Coat Structural Steel for New Grating	m^2	$1,300	160			$208,000							$208,000
Supply & Install New Deck Grating (49 Panels)	t	$23,000	157			$3,606,400							$3,606,400
Subtotal:						**$5,674,400**							**$5,674,400**
Engineering & Contract Administration (20%)						$1,134,880							$1,134,880
Contingency (15%)						$851,160							$851,160
Total						**$7,660,000**							**$7,660,000**
												TOTAL (2a & 2b)	**$15,091,000**
4a. Structural Steel Coating, Lift Span above Deck													
Traffic Controls	LS	$180,000	1					$90,000	$90,000				$180,000
Clean & Coat Structural Steel Truss in Lift Span (including access & environmental Protection)	LS	$2,820,000	1					$1,410,000	$1,410,000				$2,820,000
Subtotal:								**$1,500,000**	**$1,500,000**				**$3,000,000**
Engineering & Contract Administration (20%)								$300,000	$300,000				$600,000
Contingency (15%)								$225,000	$225,000				$450,000
Total								**$2,025,000**	**$2,025,000**				**$4,050,000**
4b. Structural Steel Coating, Towers (Section above Deck)													
Traffic Controls	LS	$210,000	1							$70,000	$70,000	$70,000	$210,000
Clean & Coat Structural Steel Towers above Deck (including access & environmental Protection)	LS	$4,240,000	1							$1,410,000	$1,410,000	$1,420,000	$4,240,000
Subtotal:										**$1,480,000**	**$1,480,000**	**$1,490,000**	**$4,450,000**
Engineering & Contract Administration (20%)										$296,000	$296,000	$298,000	$890,000
Contingency (15%)										$222,000	$222,000	$223,500	$667,500
Total										**$1,998,000**	**$1,998,000**	**$2,012,000**	**$6,008,000**
												TOTAL (4a & 4b)	**$10,058,000**

*Includes Traffic Control and Engineering

APPENDIX B

MECHANICAL INSPECTION DATA

APPENDIX B Mechanical Inspection Data

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APPENDIX B1

Figures

APPENDIX B1 Figures

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Figure 6 Estimate of Remaining Rope Area, Main Counterweight Ropes B7

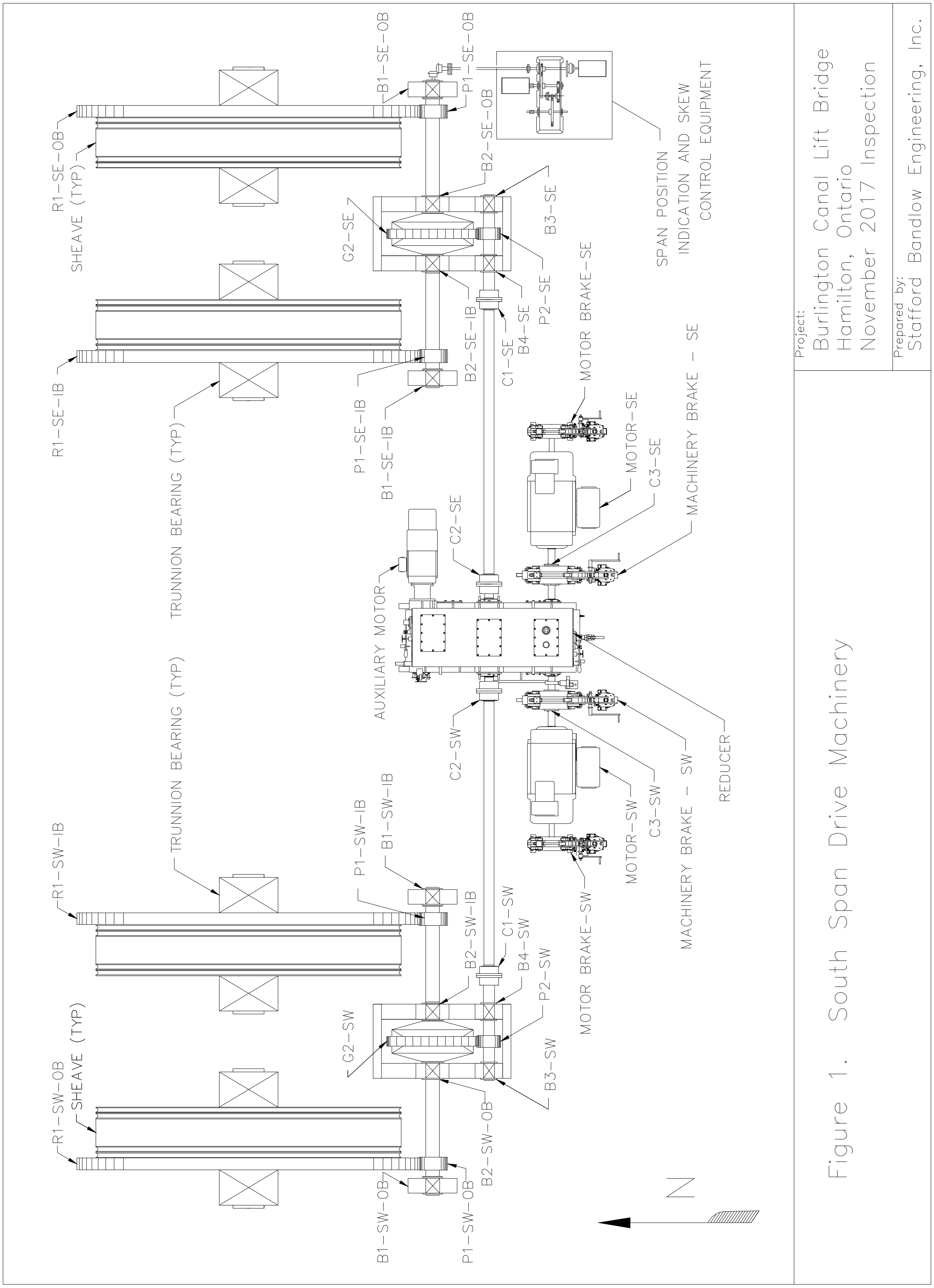

Figure 1. South Span Drive Machinery

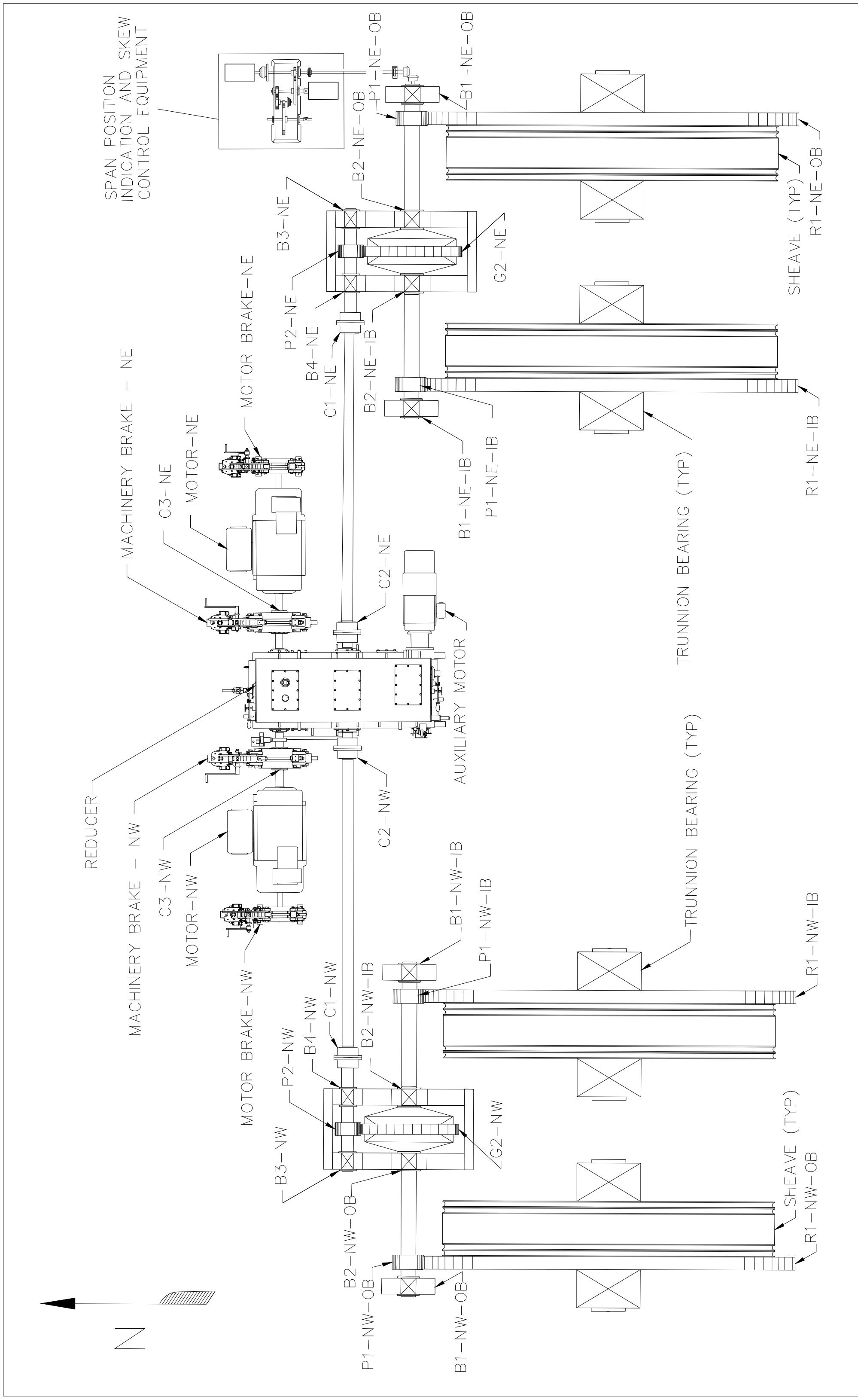

Figure 2. North Span Drive Machinery

Project:
Burlington Canal Lift Bridge
Hamilton, Ontario
November 2017 Inspection

Prepared by:
Stafford Bandlow Engineering, Inc.

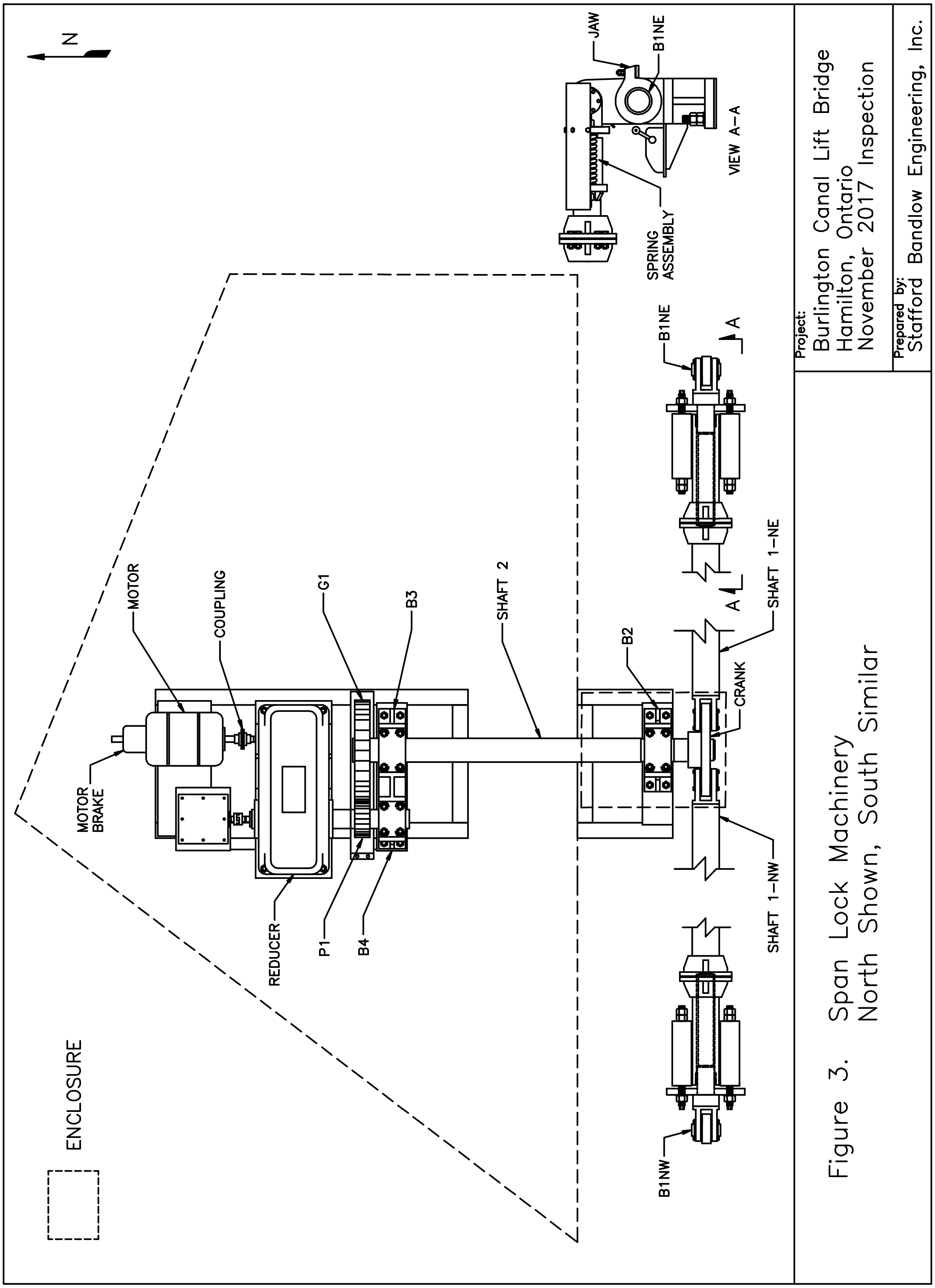

Figure 3. Span Lock Machinery
North Shown, South Similar

Nominal Rope Dia. (in)	Allowable Rope oversize (in)	1/2 Allowable Rope Oversize (in)
0 - 3/4	+ 1/32	+ 1/64
13/16 - 1-1/8	+3/64	+3/128
1-3/16 - 1-1/2	+ 1/16	+ 1/32
1-9/16 - 2-1/4	+3/32	+ 3/64
2-5/16 - and larger	+1/8	+1/16

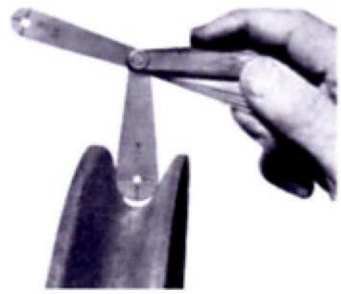

Photo shows new gauge and worn sheave. This new gauge is designed with one-half the allowable oversize (see table). Using the new gauge, when you do not see light, the sheave is okay. When you do see light under the new gauge, the sheave should be replaced.

FIGURE 4 – Illustration of Sheave Groove Wear

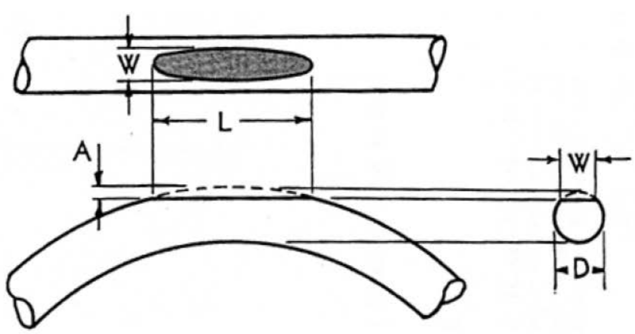

FIGURE 5 – Illustration of Elliptical Wear Area

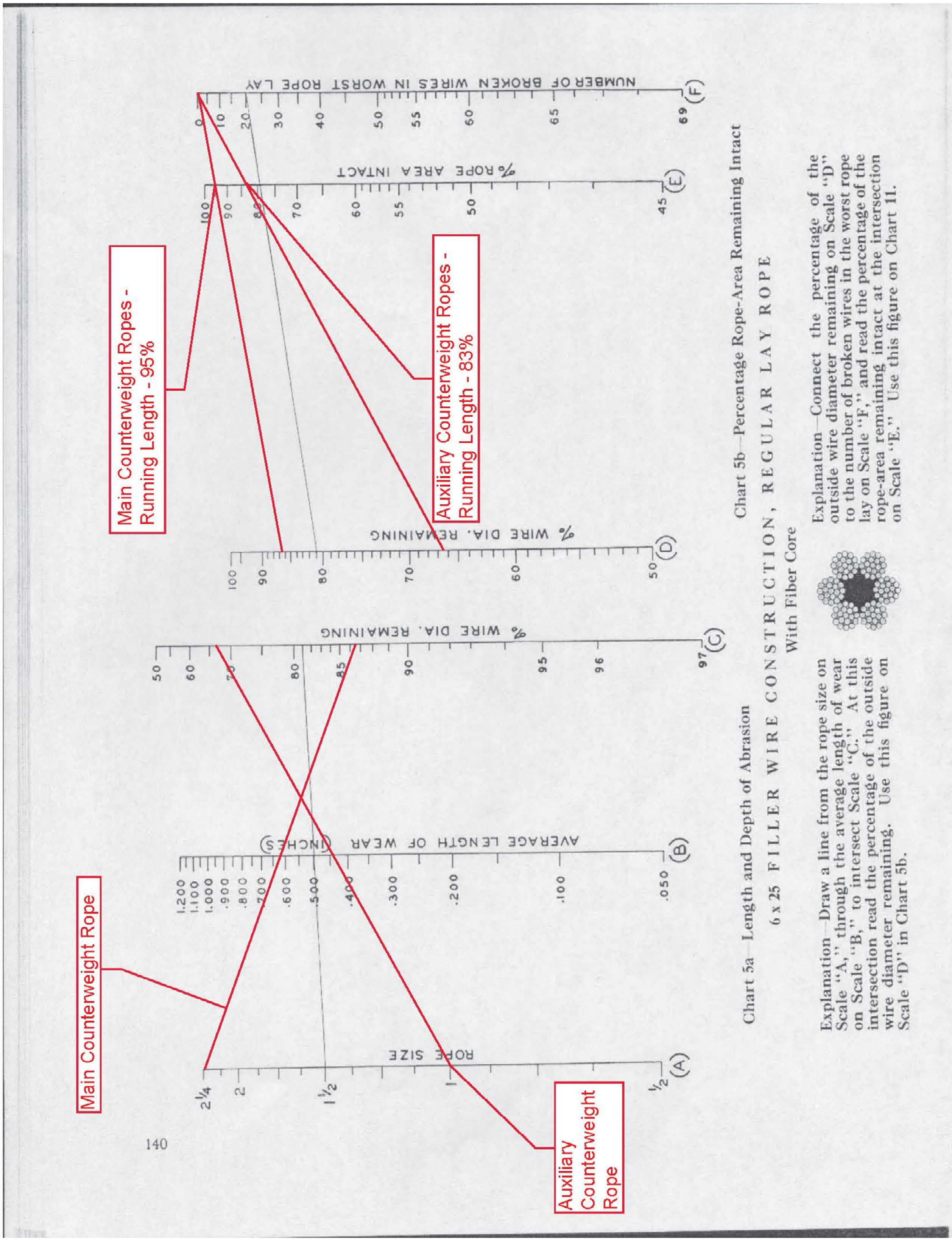

FIGURE 6. Estimate of Remaining Rope Area, Main Counterweight Ropes

APPENDIX B2

Bearing and Gear Measurement Tables

APPENDIX B2 Bearing and Gear Measurement Tables

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Table 1
Burlington Canal Lift Bridge
Span Drive Machinery Bearing Clearance Measurements
November 2017 Inspection

BEARING IDENTIFICATION	BEARING CLEARANCE (in inches)							WEAR (in inches)	REMARKS
	RC6	RC9	2004	2009	2012	2015	2017		
South Tower									
B1-SW-OB	.010	.028	.014	.012	.011	.011	.016	.006	0.006 inches taper across bearing
B1-SW-IB	.010	.028	.012	.012	.010	.009	.010	Nil	0.002 inches taper across bearing
B2-SW-OB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B2-SW-IB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B3-SW	.010	.028	.009	.008	.007	.008	.011	.001	0.004 inches taper across bearing
B4-SW	.010	.028	.011	.009	.009	.008	.010	Nil	0.002 inches taper across bearing
B1-SE-OB	.010	.028	.014	.014	.014	.014	.014	.004	0.004 inches taper across bearing
B1-SE-IB	.010	.028	.015	.015	.015	.015	.014	.004	0.004 inches taper across bearing
B2-SE-OB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B2-SE-IB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B3-SE	.010	.028	.009	.009	.009	.008	.011	.001	0.005 inches taper across bearing
B4-SE	.010	.028	.012	.012	.012	.011	.015	.005	0.007 inches taper across bearing
North Tower									
B1-NW-OB	.010	.028	.015	.015	.015	.012	.014	.004	0.004 inches taper across bearing
B1-NW-IB	.010	.028	.017	.015	.015	.016	.016	.006	0.004 inches taper across bearing
B2-NW-OB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B2-NW-IB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B3-NW	.010	.028	.012	.007	.007	.011	.010	Nil	0.004 inches taper across bearing
B4-NW	.010	.028	.009	.010	.010	.011	.012	.002	0.004 inches taper across bearing
B1-NE-OB	.010	.028	.011	.011	.011	.011	.010	Nil	0.003 inches taper across bearing
B1-NE-IB	.010	.028	.011	.010	.010	.010	.010	Nil	0.003 inches taper across bearing
B2-NE-OB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B2-NE-IB	.010	.028	IA	IA	IA	IA	IA	NA	Inaccessible for measurement due to step in shaft.
B3-NE	.010	.028	.012	.010	.010	.008	.009	Nil	0.003 inches taper across bearing
B4-NE	.010	.028	.015	.012	.011	.011	.012	.002	0.006 inches taper across bearing

Notes:
1. The indicated RC6 value is the maximum clearance for a RC6 fit. The indicated RC9 value is the maximum clearance for a RC9 fit.
2. The original bearing clearances were not available. Wear is calculated by comparing the measured clearance to the maximum clearance for an RC6 fit. A RC6 fit is the specified clearance for bearings of this type per the CHBDC.
3. Clearance in excess of an RC9 fit is suitable basis for rehabilitating or replacing worn bushings.

Table 2
Burlington Canal Lift Bridge
Span Drive Machinery Gear Measurements
South Tower
November 2017 Inspection

GEAR DATA					GEAR TOOTH MEASUREMENTS									WEAR		BACKLASH *See note 1							
	Pitch Circular (CP) or Diametral (DP)		Number of Teeth in Gear	Pressure Angle In Degrees	Type of Measurement Span or Chordal	Number of Teeth Measured Over	Chordal Addendum (Inches)	MEASUREMENTS (Inches)							Percent Of Original Tooth Thickness	MEASUREMENTS (Inches)						Gear wear since 2004	Change in BL since 2004
Gear								"As-Built"	2004	2009	2012	2015	2017	Inches		"Original"	2004	2009	2012	2015	2017		
R1-SW-OB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.093	1.081	1.081	1.081	1.091	.034	3.0	.080 - .110	.103	.099	.097	.106	.103	0.002	0.000
P1-SW-OB	2 1/4	CP	19	20	Span	3		5.476	5.453	5.453	5.453	5.449	5.449	.027	2.4							0.004	
R1-SW-IB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.112	1.107	1.105	1.107	1.108	.017	1.5	.080 - .110	.042	.065	.050	.061	.055	0.004	0.013
P1-SW-IB	2 1/4	CP	19	20	Span	3		5.476	5.455	5.459	5.459	5.456	5.455	.021	1.9							Nil	
G2-SW	1 3/4	CP	80	20	Span	10		16.247	16.224	16.240	16.226	16.226	16.218	.029	3.3	.030 - .050	.044	.039	.039	.040	.055	0.006	0.011
P2-SW	1 3/4	CP	19	20	Span	3		4.259	4.237	4.239	4.240	4.241	4.240	.019	2.2							Nil	
R1-SE-OB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.099	1.095	1.089	1.090	1.090	.035	3.1	.080 - .110	.071	.064	.051	.064	.065	0.009	-0.006
P1-SE-OB	2 1/4	CP	19	20	Span	3		5.476	5.459	5.462	5.460	5.455	5.458	.018	1.6							0.001	
R1-SE-IB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.102	1.099	1.094	1.091	1.104	.021	1.9	.080 - .110	.096	.099	.094	.102	.100	Nil	0.004
P1-SE-IB	2 1/4	CP	19	20	Span	3		5.476	5.461	5.459	5.455	5.453	5.458	.018	1.6							0.003	
G2-SE	1 3/4	CP	80	20	Span	10		16.247	16.230	16.230	16.228	16.207	16.222	.025	2.8	.030 - .050	.043	.042	.041	.047	.050	0.008	0.007
P2-SE	1 3/4	CP	19	20	Span	3		4.259	4.245	4.238	4.237	4.236	4.237	.022	2.6							0.008	

Notes:
1. The original backlash values are not available. The backlash range indicated is the typical range of backlash for new gears of the same size and type.

Table 3
Burlington Canal Lift Bridge
Span Drive Machinery Gear Measurements
North Tower
November 2017 Inspection

GEAR DATA					GEAR TOOTH MEASUREMENTS									WEAR		BACKLASH *See note 1							
								MEASUREMENTS (Inches)								MEASUREMENTS (Inches)							
Gear	Pitch Circular (CP) or Diametral (DP)		Number of Teeth in Gear	Pressure Angle In Degrees	Type of Measurement Span or Chordal	Number of Teeth Measured Over	Chordal Addendum (Inches)	"As-Built"	2004	2009	2012	2015	2017	Inches	Percent Of Original Tooth Thickness	"Original"	2004	2009	2012	2015	2017	Gear wear since 2004	Change in BL since 2004
R1-NW-OB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.105	1.098	1.095	1.085	1.096	.029	2.6	.080 - .110	.069	.056	.062	.069	.075	0.009	0.006
P1-NW-OB	2 1/4	CP	19	20	Span	3		5.476	5.453	5.455	5.454	5.450	5.455	.026	2.3							Nil	
R1-NW-IB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.080	1.082	1.081	1.073	1.076	.052	4.6	.080 - .110	.030	.034	.038	.038	.045	0.004	0.015
P1-NW-IB	2 1/4	CP	19	20	Span	3		5.476	5.460	5.458	5.455	5.455	5.458	.021	1.9							0.002	
G2-NW	1 3/4	CP	80	20	Span	10		16.247	16.232	16.228	16.229	16.228	16.218	.019	2.1	.030 - .050	.058	.072	.071	.060	.065	0.014	0.007
P2-NW	1 3/4	CP	19	20	Span	3		4.259	4.241	4.237	4.232	4.232	4.234	.027	3.1							0.007	
R1-NE-OB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.111	1.104	1.104	1.093	1.100	.032	2.8	.080 - .110	.045	.055	.054	.050	.055	0.011	0.010
P1-NE-OB	2 1/4	CP	19	20	Span	3		5.476	5.460	5.463	5.458	5.459	5.459	.017	1.5							0.001	
R1-NE-IB	2 1/4	CP	280	20	Chordal	1	0.718	1.125	1.110	1.116	1.105	1.096	1.101	.029	2.6	.080 - .110	.034	.032	.026	.026	.035	0.009	0.001
P1-NE-IB	2 1/4	CP	19	20	Span	3		5.476	5.459	5.460	5.460	5.459	5.461	.017	1.5							Nil	
G2-NE	1 3/4	CP	80	20	Span	10		16.247	16.221	16.239	16.222	16.206	16.222	.041	4.6	.030 - .050	.086	.073	.051	.084	.085	Nil	-0.001
P2-NE	1 3/4	CP	19	20	Span	3		4.259	4.233	4.228	4.224	4.226	4.229	.033	3.8							0.004	

Notes:
1. The original backlash values are not available. The backlash range indicated is the typical range of backlash for new gears of the same size and type.

APPENDIX B3

Mechanical Inspection Photographs

APPENDIX B3 Mechanical Inspection Photographs

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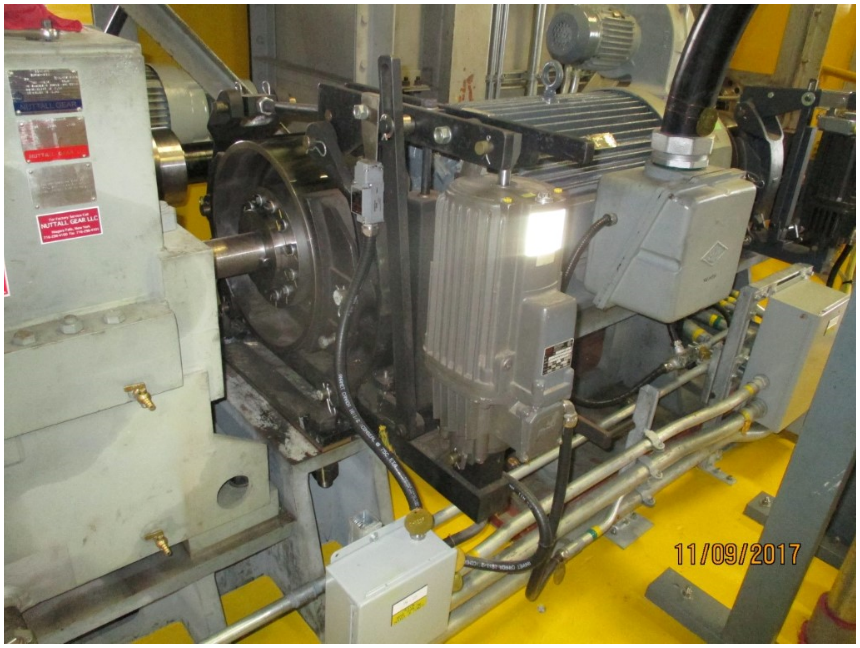

Photo M1 Machinery Brake - SE and Brake Wheel Coupling C3-SE. General view of the machinery brake assembly. Note the unpainted brake wheel coupling bolts.

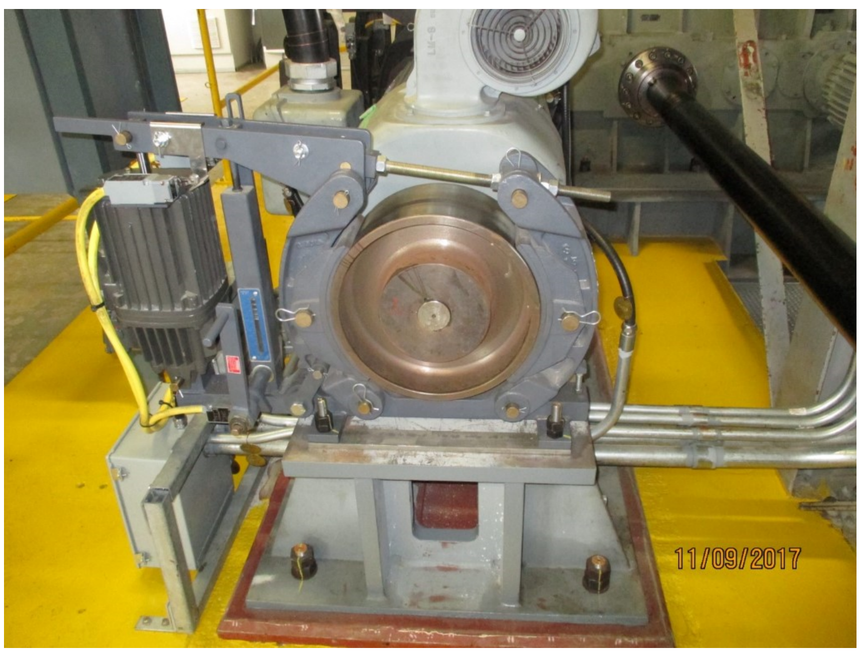

Photo M2 Motor Brake-SE. General view of a typical motor brake assembly. The brake assembly, including the brake wheel hubs and fasteners are unpainted.

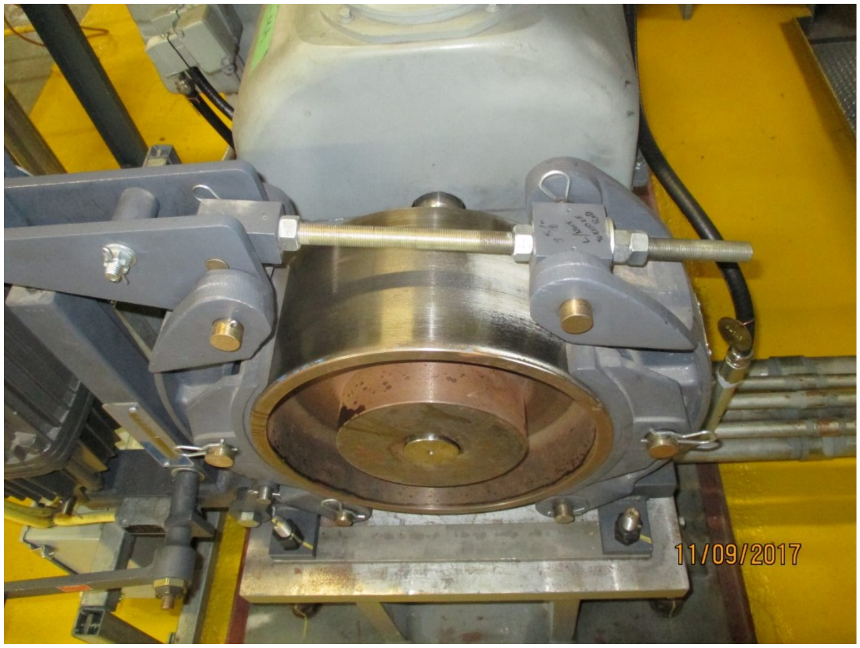

Photo M3 Motor Brake-SE. Areas of paint were found on the friction surface of the brake wheel.

Photo M4 Coupling C1-SE. There was light corrosion on the hub. Corrosion was noted at all C1 and C2 couplings.

Photo M5 Motor-SW. The motor mounting bolts and support anchor bolts are unpainted with light corrosion forming. The shims and the top of the support are also unpainted.

Photo M6 Pinion P1-SW-OB. The gear teeth in the acceleration zone were cleaned to bare metal for inspection. Gear tooth thickness measurements were taken at all gears.

Photo M7 G1-SW-OB. Damage to the gear tooth caused by wire intrusion is wearing in.

Photo M8 Gearset G2/P2-SE, Differential Gear. There was corrosion on some of the differential gear teeth due to inadequate lubricant

Photo M9 G2/P2-SE, Support Frame. There was an accumulation of old grease within the support frame under the G2 gear.

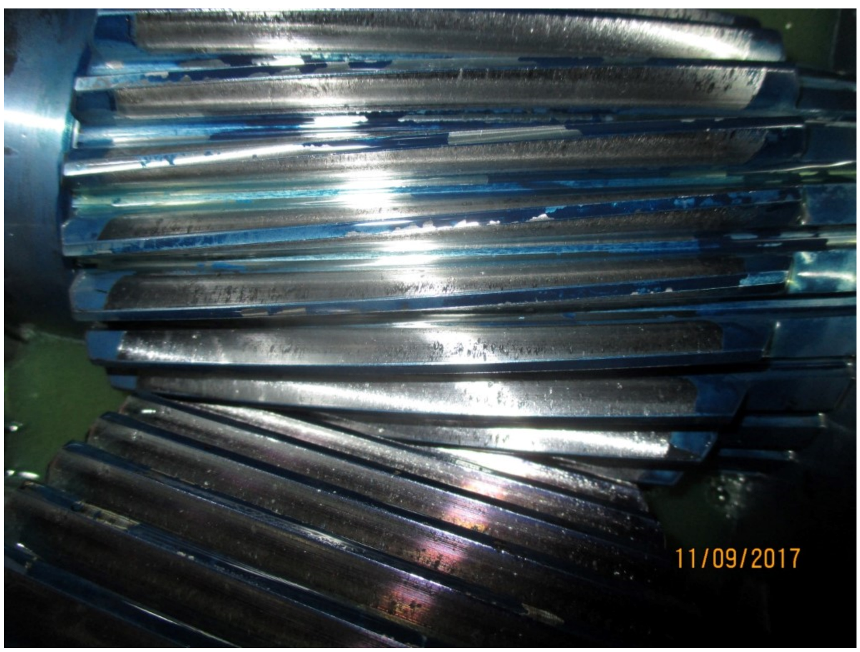

Photo M10 South Span Drive Reducer Auxiliary Gears. The reducer gear teeth have minor damage that may be from particles passing through the mesh.

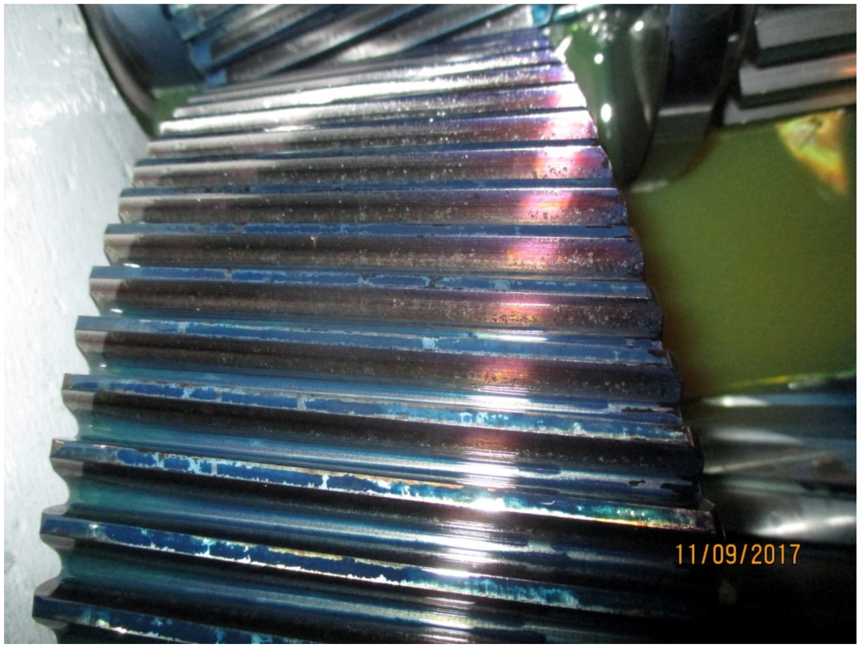

Photo M11 South Span Drive Reducer Auxiliary Gears. The reducer gear teeth have minor damage that may be from particles passing through the mesh.

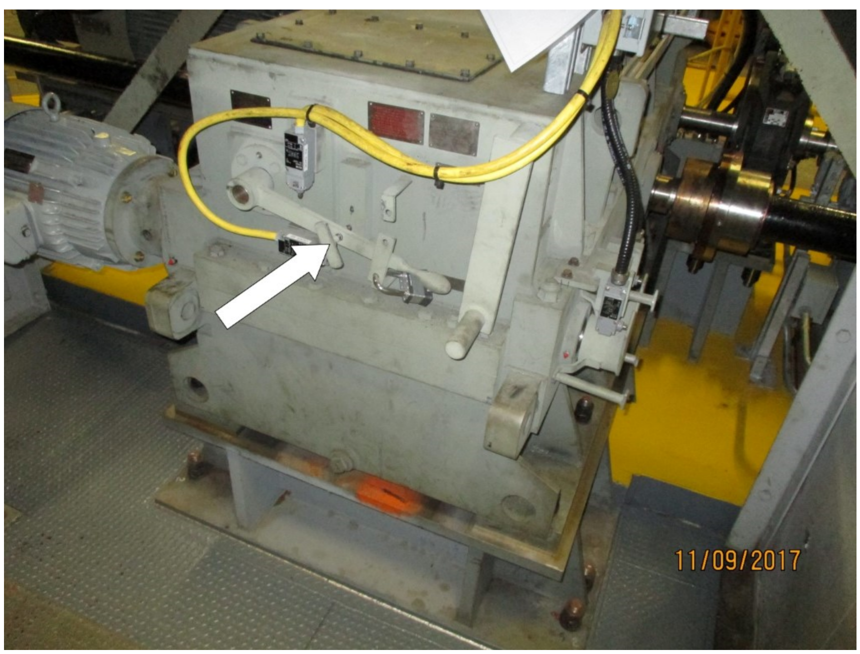

Photo M12 South Span Drive Reducer. The reducer auxiliary drive engagement lever is secured in position with a threaded position bolt (arrow). This bolt could not be rotated to test the south auxiliary drive engagement. Also, note that the reducer mounting bolts and support anchor bolts are unpainted.

Photo M13 North Span Drive Reducer. The inspection cover screws have damaged threads.

Photo M14 North Span Drive Reducer. There is evidence of a small oil leak at the drain valve.

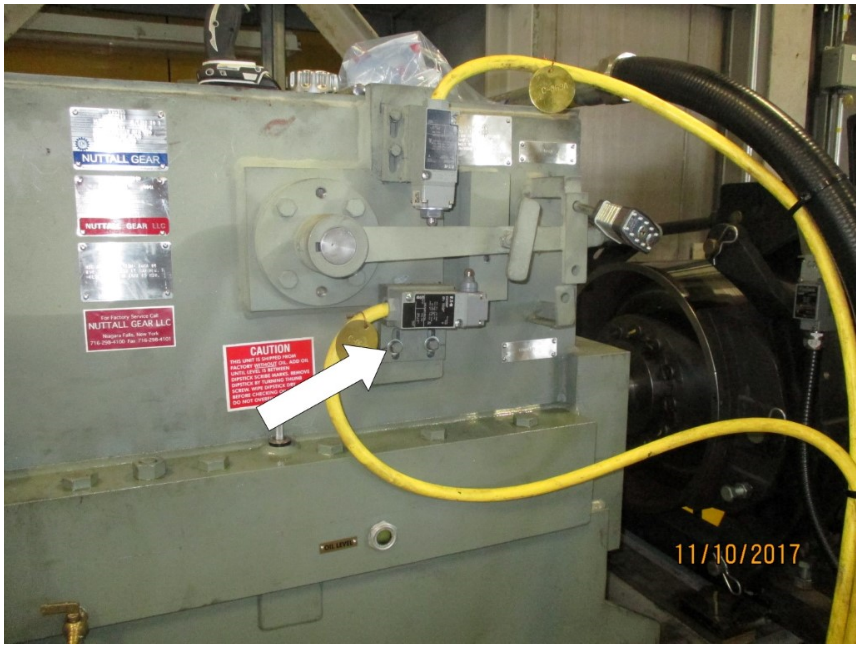

Photo M15 North Span Drive Reducer. There is evidence of a small oil leak at the north index spline lower limit switch plate bolts (arrow).

Photo M16 NW-OB Counterweight Rope Connections. There was fretting where the counterweight ropes rub against the counterweight splay casting. There was also light corrosion in spots due to inadequate lubricant.

Photo M17 SW-IB Counterweight Ropes. View of the section of the ropes that contact the sheave grooves. Note the corrosion due to inadequate lubricant.

Photo M18 NW-IB Counterweight Ropes. The maximum counterweight rope wear flats were measured to be 5/8”.

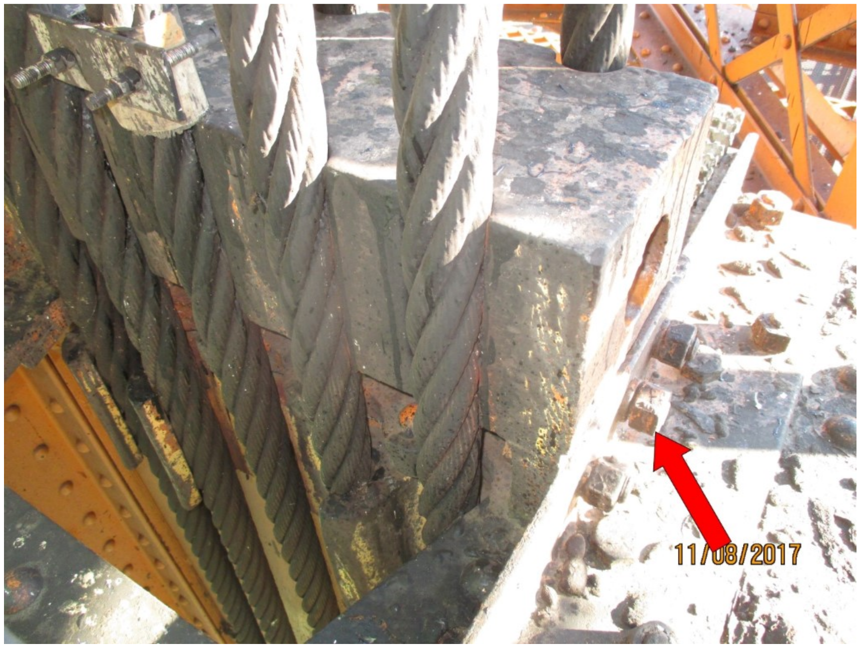

Photo M19 NW-OB Main Lift Girder Splay Casting. The middle nut is not fully seated at this location (arrow). Also note the light fretting at the rope/splay interface.

Photo M20 NW Auxiliary Counterweight Ropes. The auxiliary ropes and sheave have built up old lubricant.

Photo M21 SW Auxiliary Counterweight Ropes. The counterweight ropes and sheave are devoid of lubricant.

Photo M22 SW-OB Counterweight Sheave. There was paint deterioration and light corrosion on the sheave casting.

Photo M23 NW-IB Counterweight Sheave. The counterweight grooves are devoid of lubricant and exhibit surface corrosion.

Photo M24 NE Auxiliary Counterweight. There are areas of light corrosion and paint deterioration on the counterweight blocks and frames.

Photo M25 SW Live Load Support. The anchor bolts were corroded.

Photo M26 North Centering Device. There is minor debris accumulation on the support. The anchor bolts have paint deterioration and section loss.

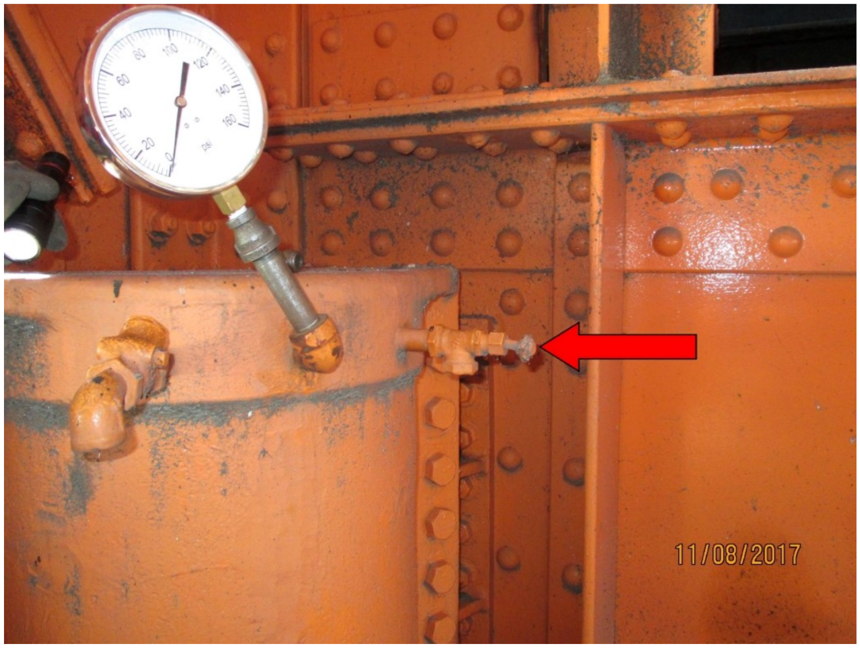

Photo M27 NW Span Air Buffer. The exhaust valve handle (arrow) is broken.

Photo M28 South Span Lock Machinery. Several components including the shaft and bolts are not fully painted. A coating of rust inhibitor limits corrosion.

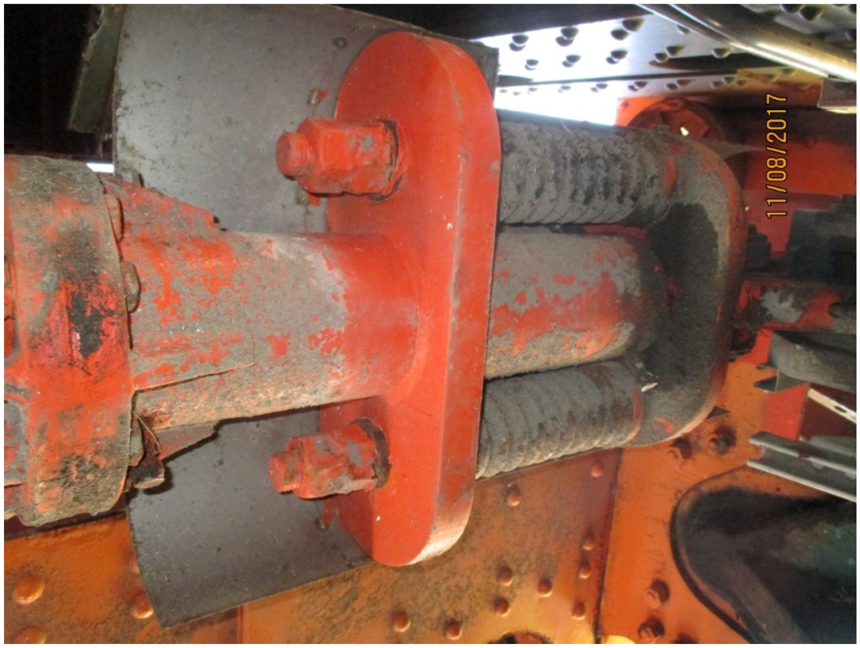

Photo M29 28. The spring and bolts have moderate corrosion.

Photo M30 North Barrier Gate. The gate arm counterweight has a bolt that is not fully seated at the east side of the counterweight.

Photo M31 Main Generator. A coolant hose (arrow) exhibits dry rot and was starting to crack.

APPENDIX B4

SKF Vibration Report

APPENDIX B4 SKF Vibration Report

INDEX pages

Technical Note B30

Technical Note

Customer	Stafford Bandlow Engineering, Inc.	Date	December 7, 2017
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Contact	Ralph Giernacky Clare Lamont	CC	Francky Ramaroson, SKF Lead Reliability Como Specialist
		SR #	

Subject

Vibration Data Analysis/Report for Burlington Canal Lift Bridge

Introduction

Bridge Main Lift Support Bearings (16), Burlington Canal Lift Bridge, Ontario

This report covers the vibration analysis for the 16 main support bearings.

Vibration data were collected on November 9 and 10, 2017 at the bridge site.

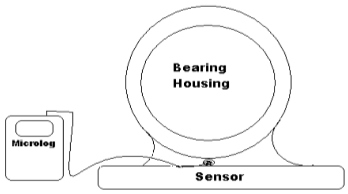
The reliability of the Burlington Canal Lift Bridge is important to surrounding industries and communities; replacing any of the 16 main support bearings would be very difficult and costly. SKF Reliability Systems had the opportunity to take vibration readings on all 16 bearings while in operation to:

1) Evaluate current running conditions from the vibration aspect.
2) Analyze vibration data to identify any existing defect (failure) and possible cause(s) for the defect(s), and to provide solutions.

All the main bearings are SKF 232/530 K.

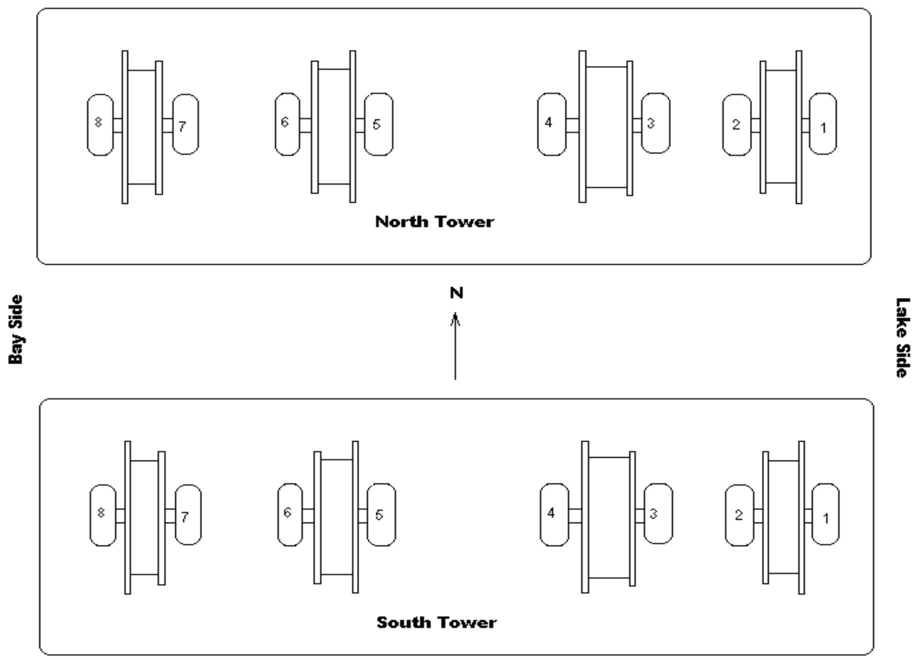
Methodology

The vibration sensors were attached using magnetic bases onto the bearing housing bottom (load zone) Axial (A) locations,



Vibration Measurement Schematics

Bearings are numbered from 1 to 8 as in the following plot.



Measurement types and units are:

Enveloped Acceleration (Env Filter 3), gE
Enveloped Acceleration (Env Filter 4), gE

The purpose of using Enveloped Acceleration technology is focused on detecting bearing defect(s).

Each type of measurement contains separate vibration readings for the bridge moving up and the bridge moving down at full operating speed. Under this operation, the related frequencies are as follows:

Bearing turning speed - about 1.27 RPM (47 seconds interval),
BPFO (outer race defect frequencies) – 10.52 CPM (5.70 seconds interval) and harmonics,
BPFI (inner race defect frequencies) – 13.60 CPM (4.41 seconds interval) and harmonics,
BSF (roller defect frequencies) – 4.76 CPM (12.60 seconds interval) and harmonics,
FTF (cage defect frequencies) - 0.55 CPM (108.33 seconds interval) and harmonics.

Analysis

SOUTH TOWER

Bearing 1.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 2.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 3.
Time waveform shows a symmetrical pattern and appears to closely coincide with the bearing outer race fault frequency. These readings are visible at both lift and lowering cycle of the bridge.

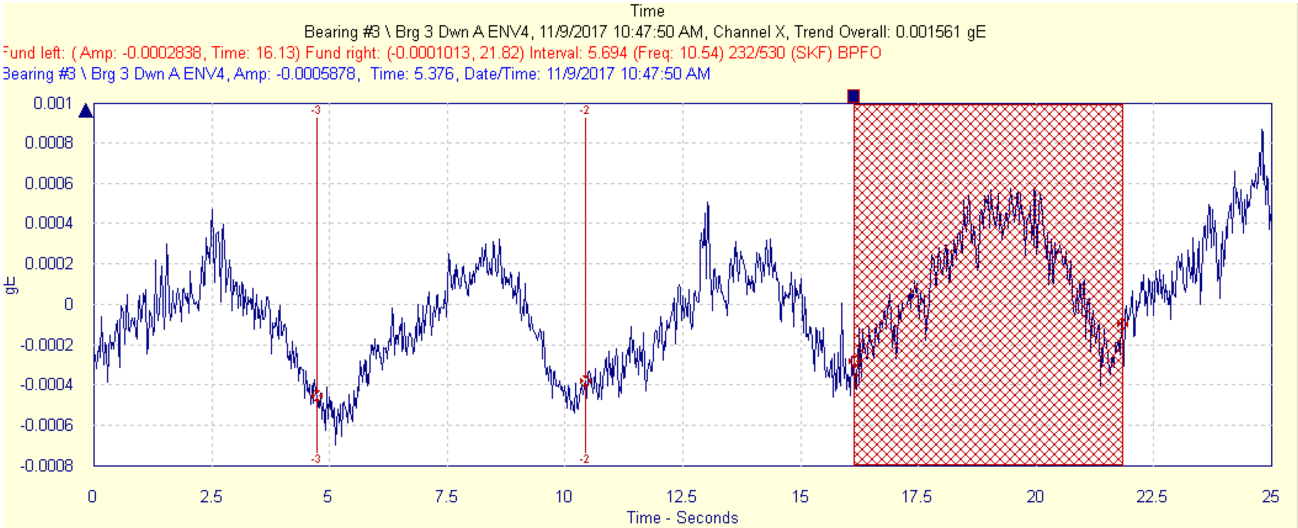
Bearing 4.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 5.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

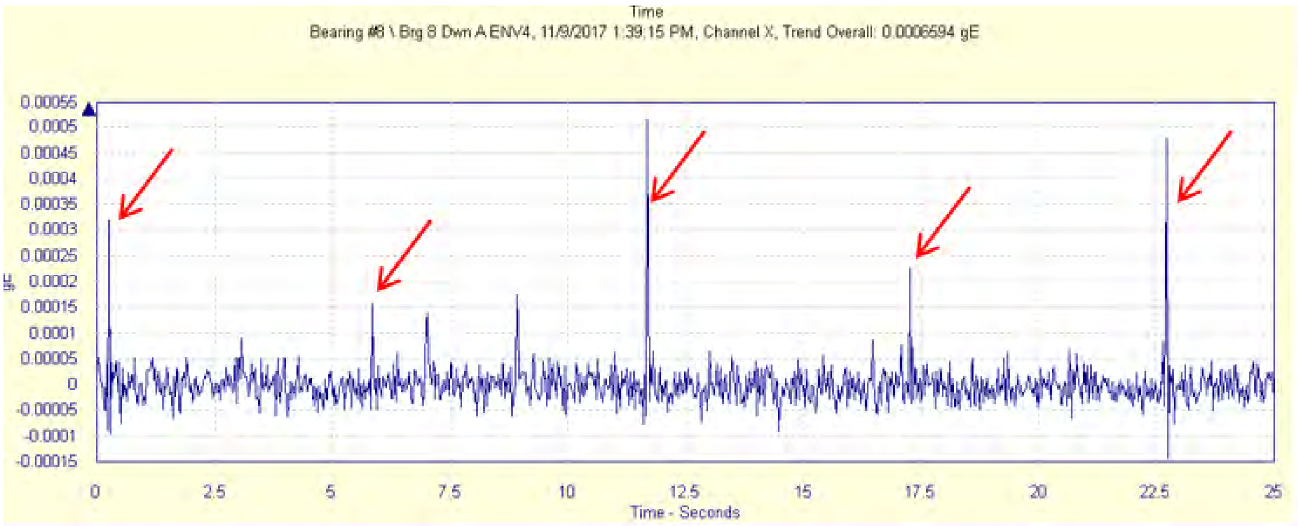
Bearing 6.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 7.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 8.
The time waveform during the bridge lowering cycle shows impacts at 5.7 second intervals **(see plot 1).** These impacts coincide with the fault frequencies of the bearing outer race. These observations do seem very similar to those taken in 2015 and 2016. It is recommended to confirm these findings through visual inspection of the bearing raceway. (See whether the suspected damage exists and if so, evaluate its severity.)



Plot 1.
South tower bearing #3, time domain showing symetrical pattern, the interval appears to coincide with the interval of the bearing outer race frequencies



Plot 2.

- South tower bearing #8, time domain showing impact at 5.7 second interval during lowering cycle.

NORTH TOWER

Bearing 1.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 2.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 3.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

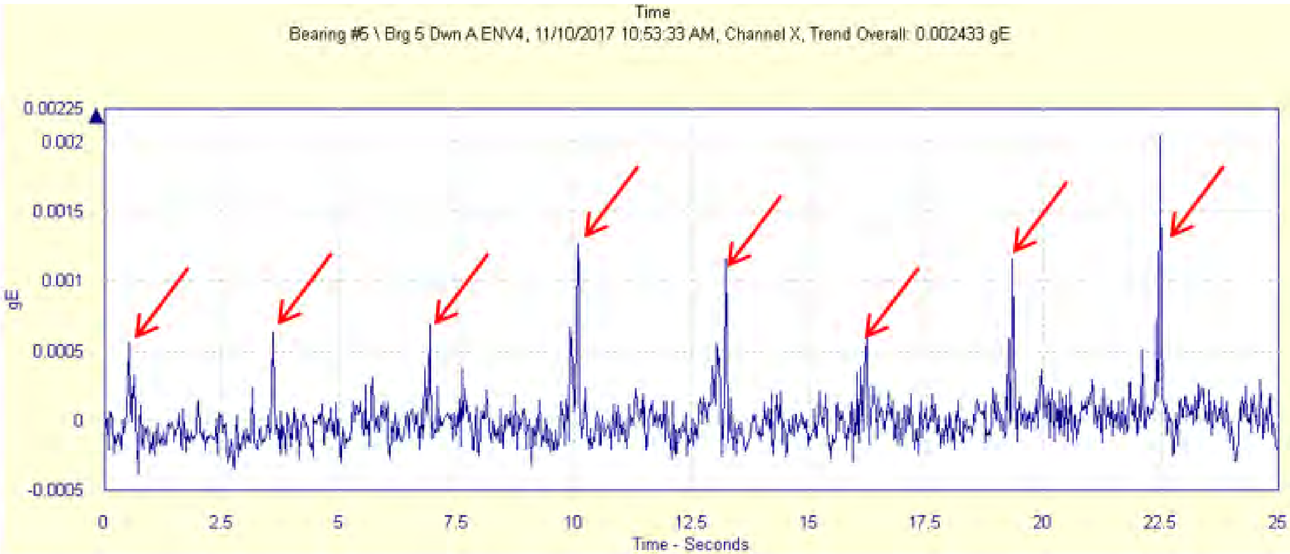
Bearing 4.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 5.
The time domain shows impacts roughly at a 3.1 second interval (19 CPM) during the bridge lowering cycle; see plot 3. These impacts are not related to any of the bearing frequencies. However it is recommended to investigate the source of these impacts to verify whether or not it is an issue.

Bearing 6.
The time domain shows impacts roughly at a 3.1 second interval (19 CPM) during the bridge lowering cycle; see plot 4. These impacts are not related to any of the bearing frequencies. However it is recommended to investigate the source of these impacts to verify whether or not it is an issue.

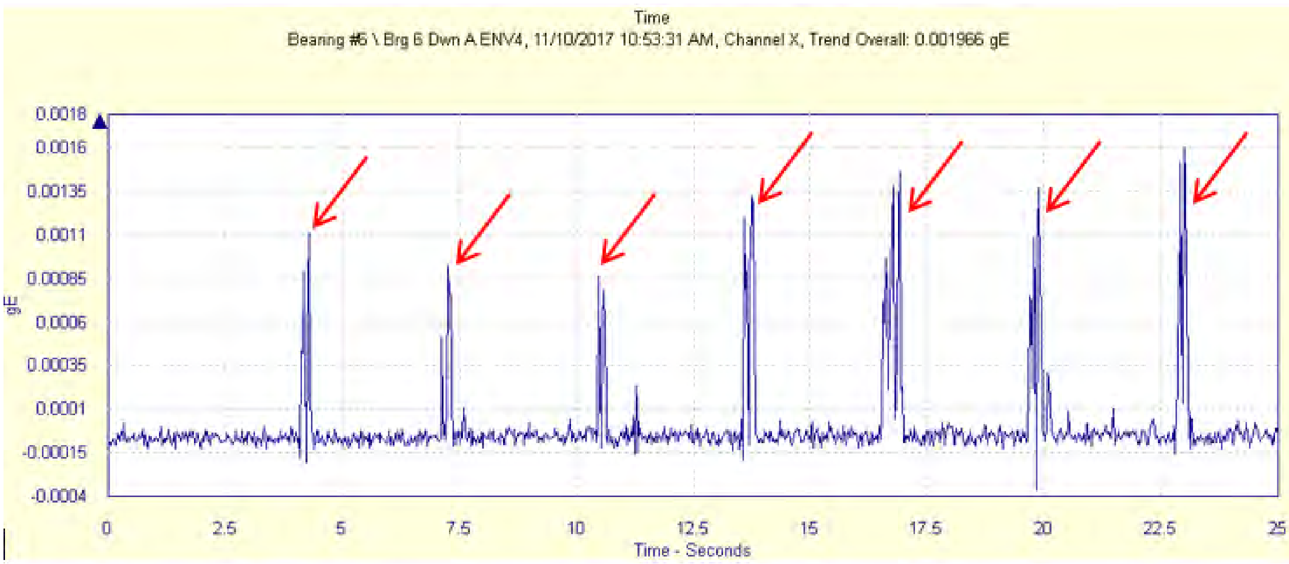
Bearing 7.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.

Bearing 8.
Observed no signs of any impact or anomaly that would relate to the fault frequencies of the bearing. Overall, bearing appears to be in good condition.



Plot 3.

- North Tower bearing #5, time domain shows impact at 3.1 seconds interval during lowering cycle.



Plot 4.

- North Tower bearing #6, time domain shows impact at 3.1 seconds interval during lowering cycle.

Recommendation

- On the next scheduled downtime, perform a visual inspection on the South Tower Main bearing #8 and #3 by opening the bearing housing and carefully inspecting the condition of the bearing inboard and outboard raceway surfaces to correlate with vibration findings and to assess the severity. Care should be taken to prevent contamination from entering the bearing cavity.

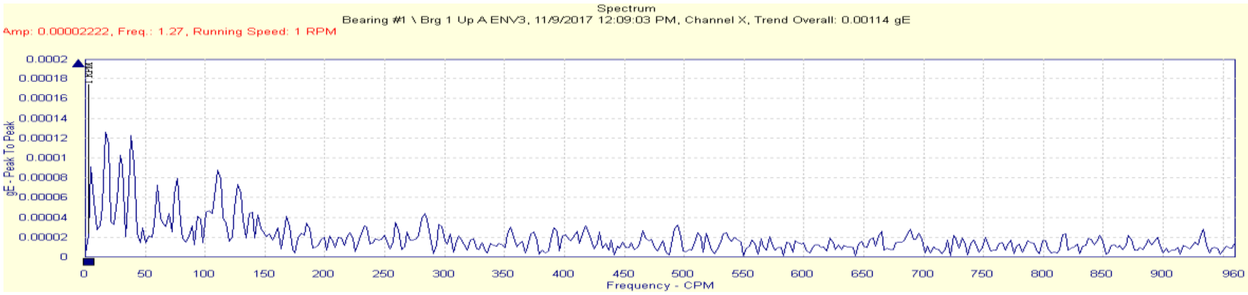
- Investigate the source of 19 CPM impact at the North tower bearing #5 and #6 during lowering cycle; verify if this observed activity is an issue.

- Continue to re-lubricate at scheduled intervals. In addition, while re-lubricating take the opportunity to visually inspect the condition of the bearing running surfaces.

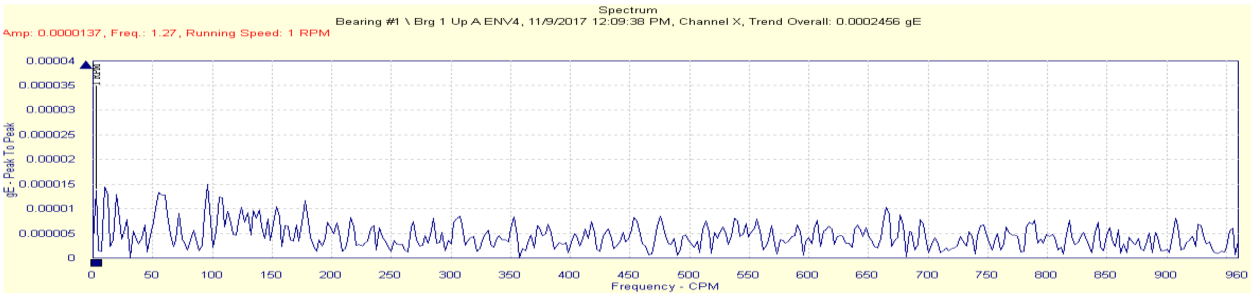
- If needed, contact SKF Application Engineering to verify proper lubrication interval.

- Continue to do periodic vibration analysis measurements.

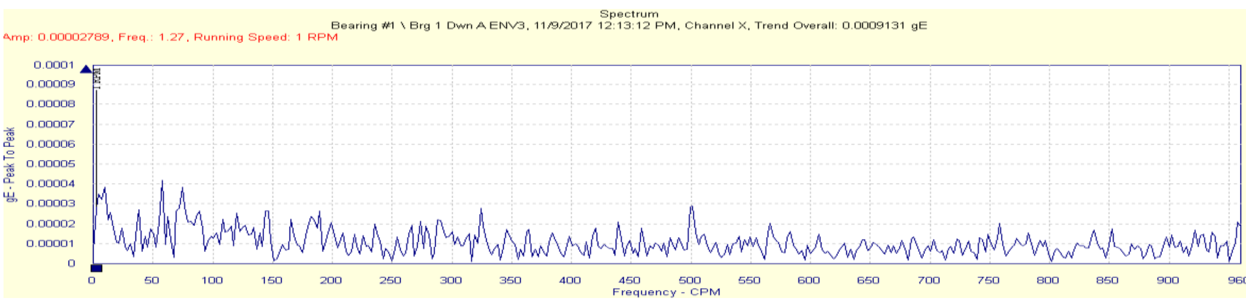
South Main Bearing #1



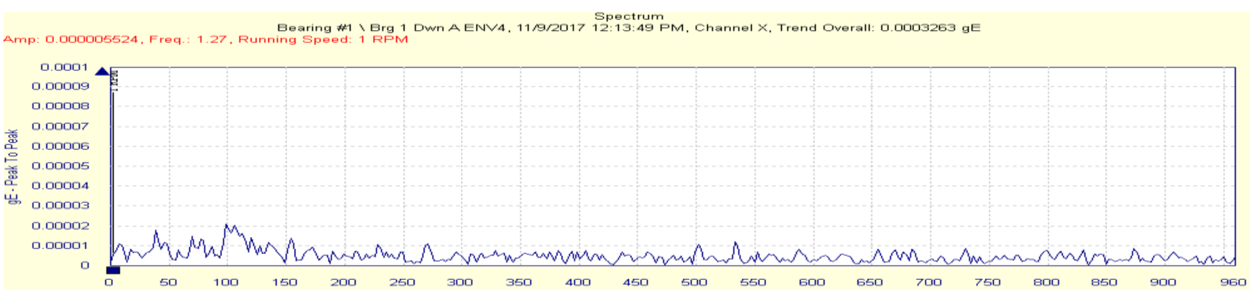
Bearing #1 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #1 – Envelope Acceleration gE4 – Up cycle.



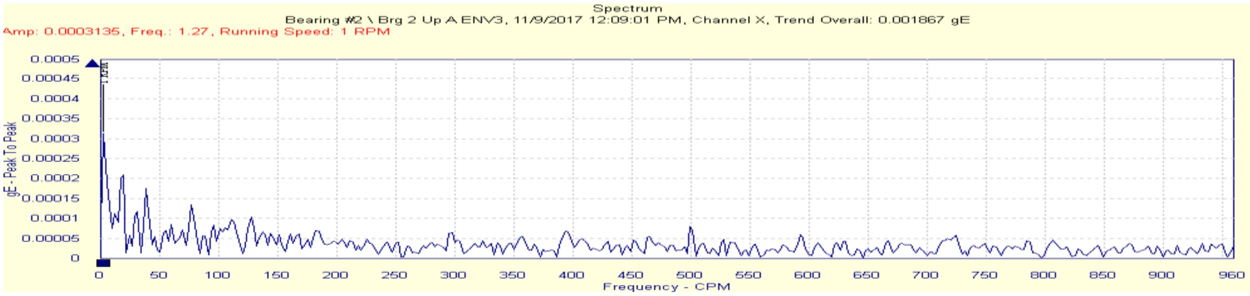
Bearing #1 – Envelope Acceleration gE3 spectrum – Down cycle.



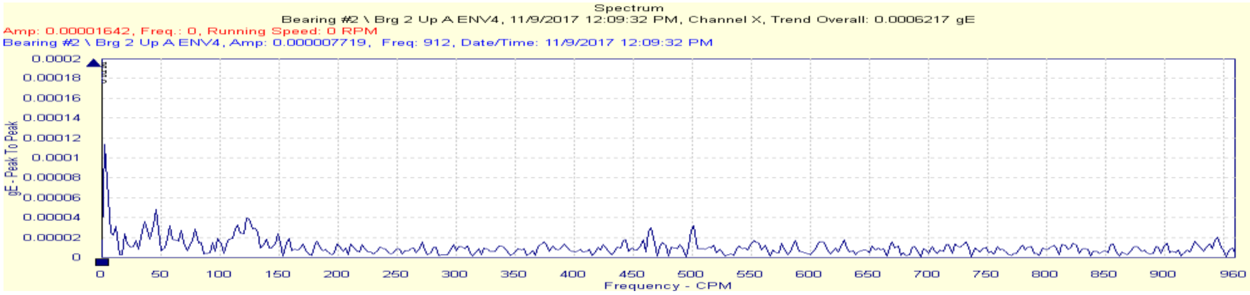
Bearing #1 – Envelope Acceleration gE4 – Down cycle.

SKF

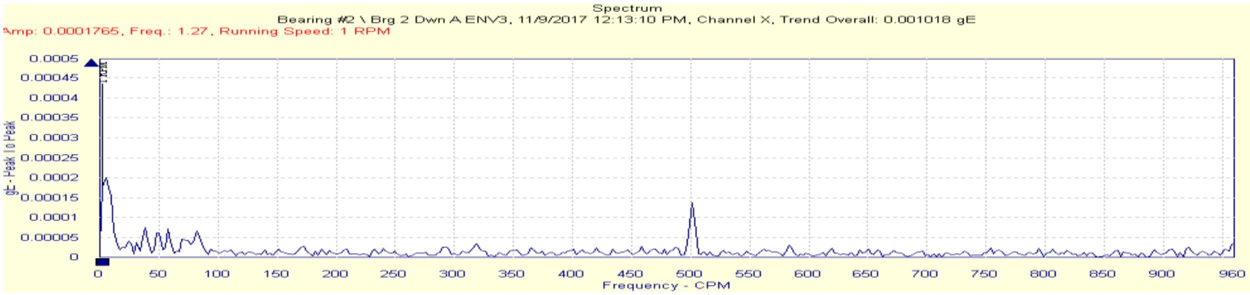
South Main Bearing #2



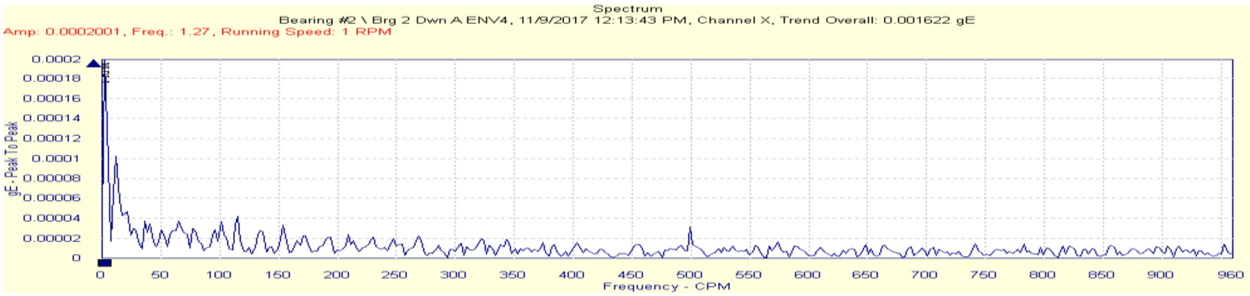
Bearing #2 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #2 – Envelope Acceleration gE4 spectrum – Up cycle.

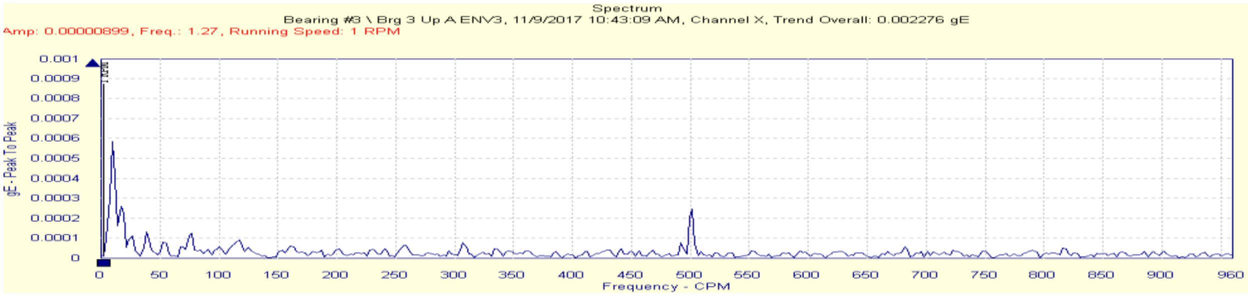


Bearing #2 – Envelope Acceleration gE3 spectrum – Down cycle.

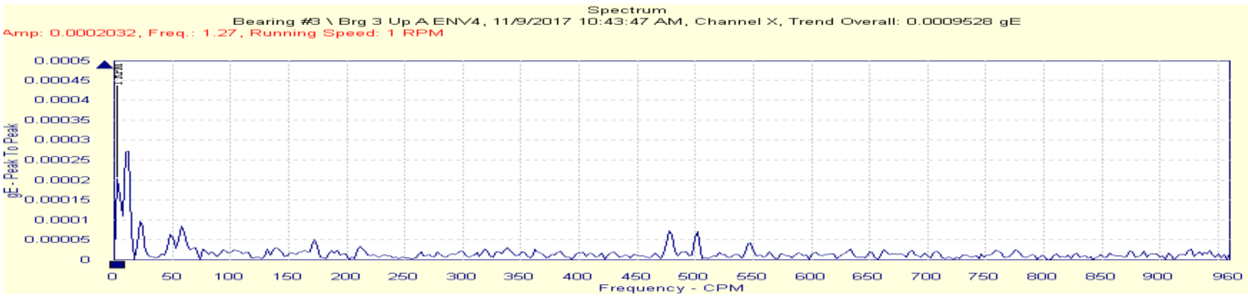


Bearing #2 – Envelope Acceleration gE4 spectrum – Down cycle.

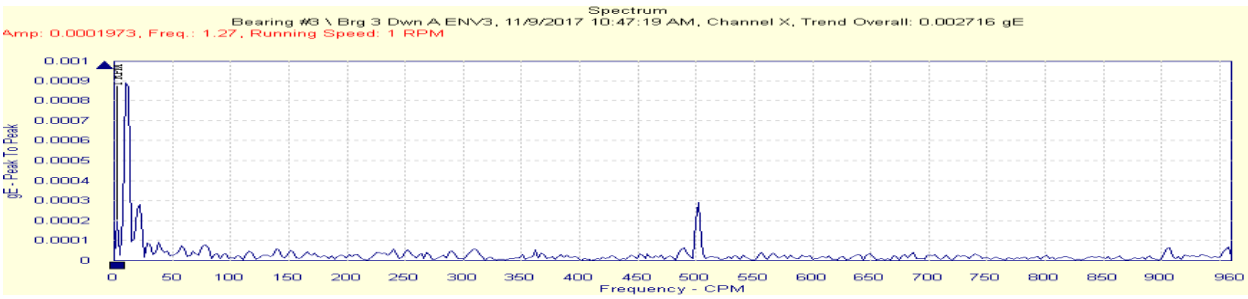
South Main Bearing #3



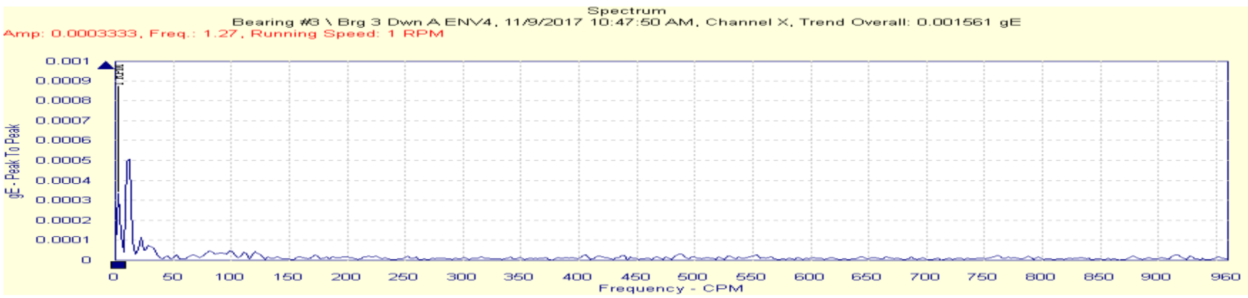
Bearing #3 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #3 – Envelope Acceleration gE4 spectrum – Up cycle.

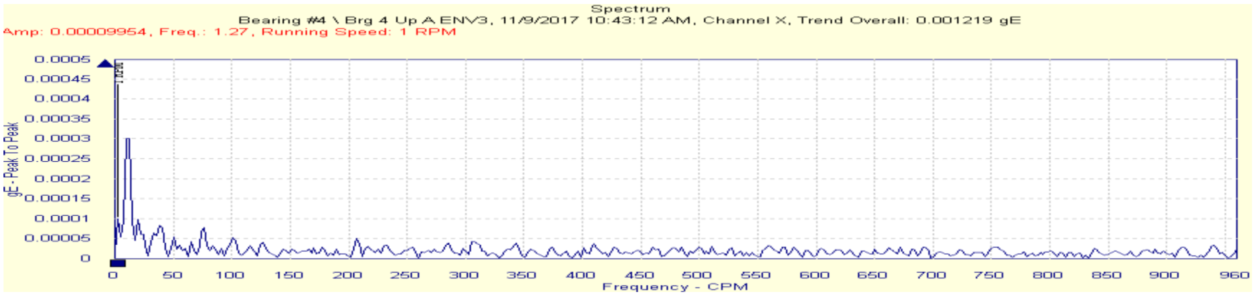


Bearing #3 – Envelope Acceleration gE3 spectrum – Down cycle.

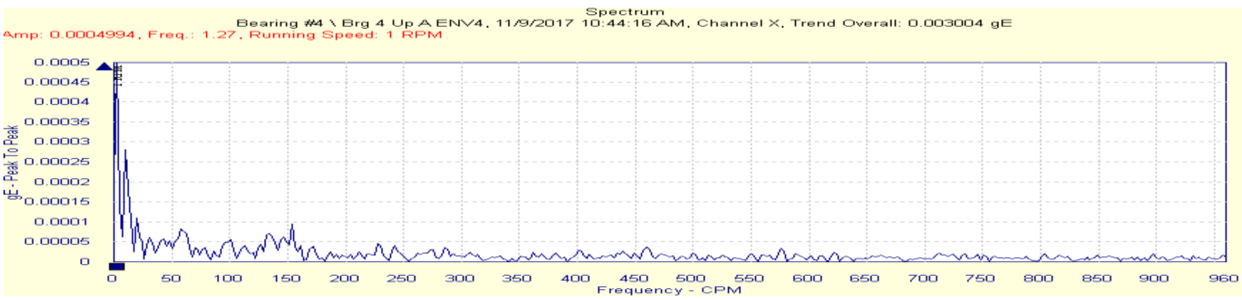


Bearing #3 – Envelope Acceleration gE4 spectrum – Down cycle.

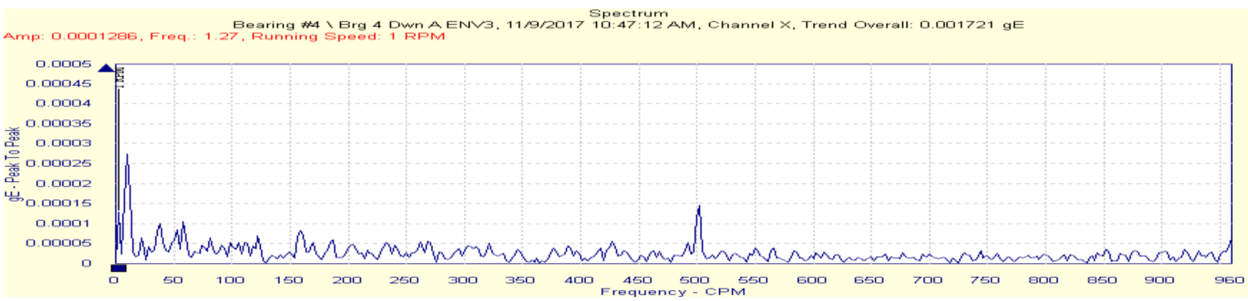
South Main Bearing #4



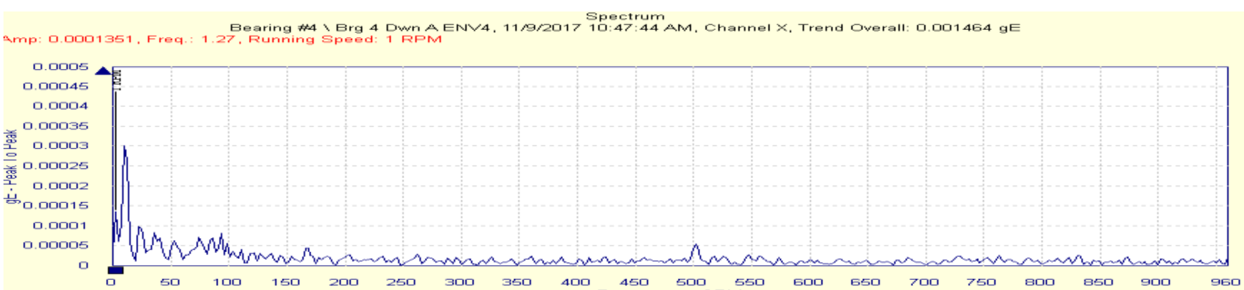
Bearing #4 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #4 – Envelope Acceleration gE4 spectrum – Up cycle.

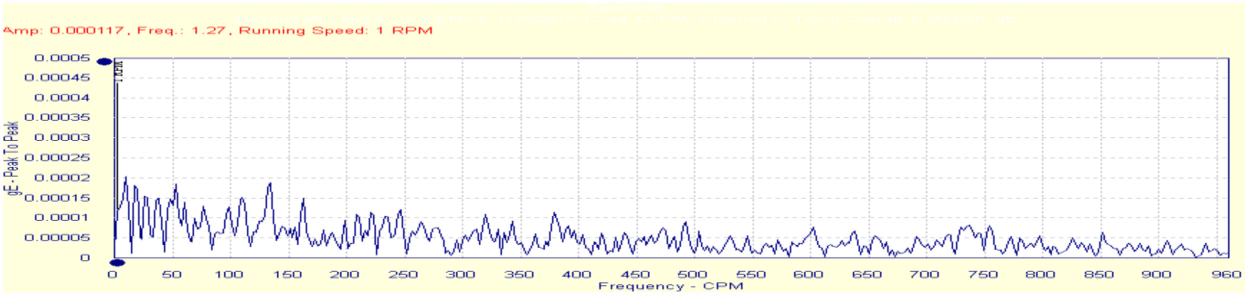


Bearing #4 – Envelope Acceleration gE3 spectrum – Down cycle.

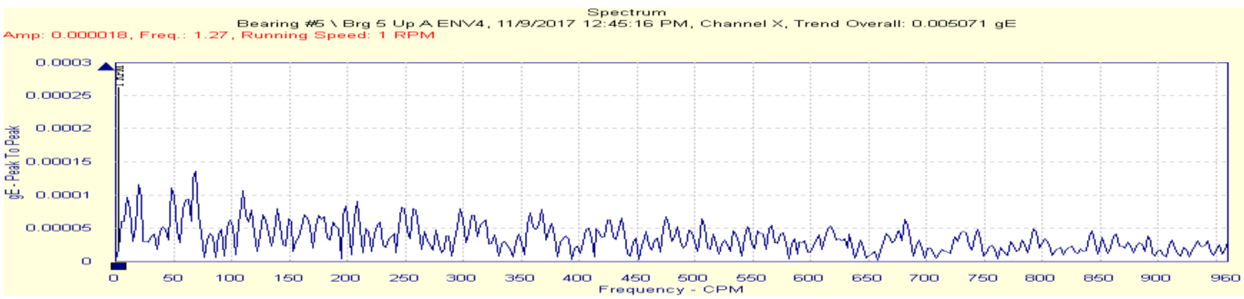


Bearing #4 – Envelope Acceleration gE4 spectrum – Down cycle.

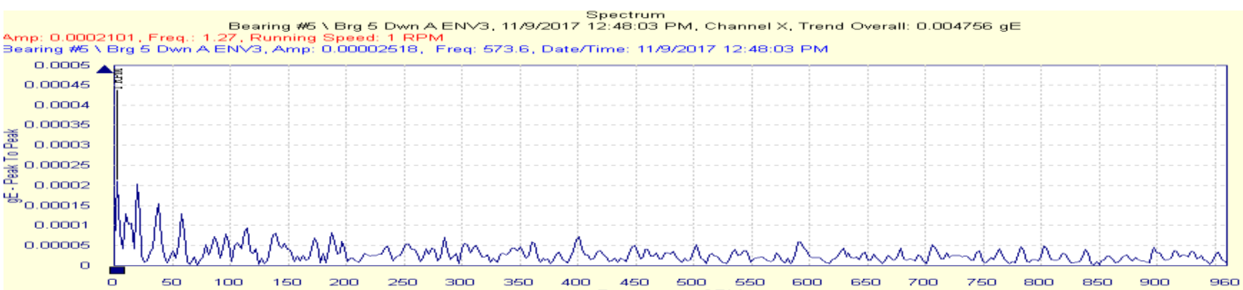
South Main Bearing #5



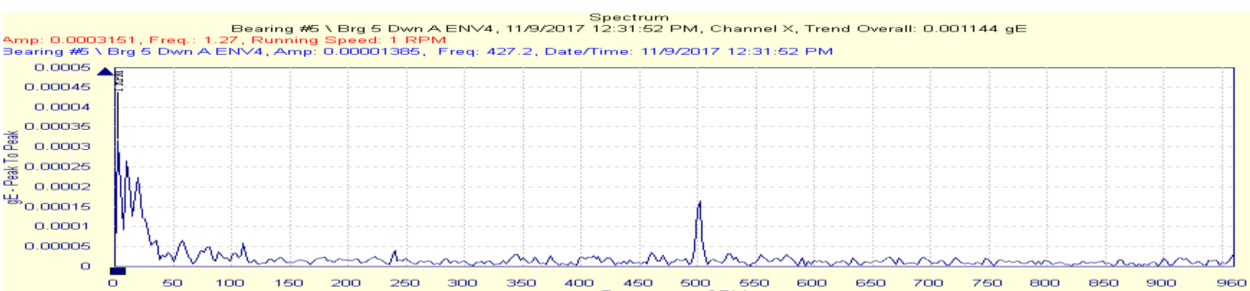
Bearing #5 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #5 – Envelope Acceleration gE4 spectrum – Up cycle.

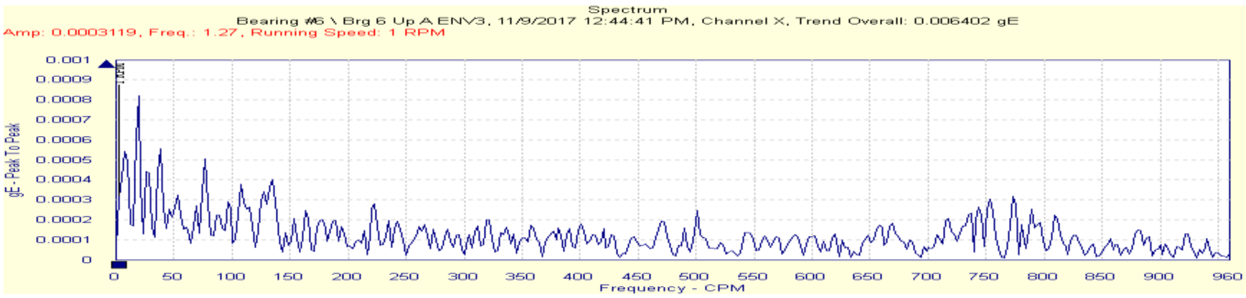


Bearing #5 – Envelope Acceleration gE3 spectrum – Down cycle.

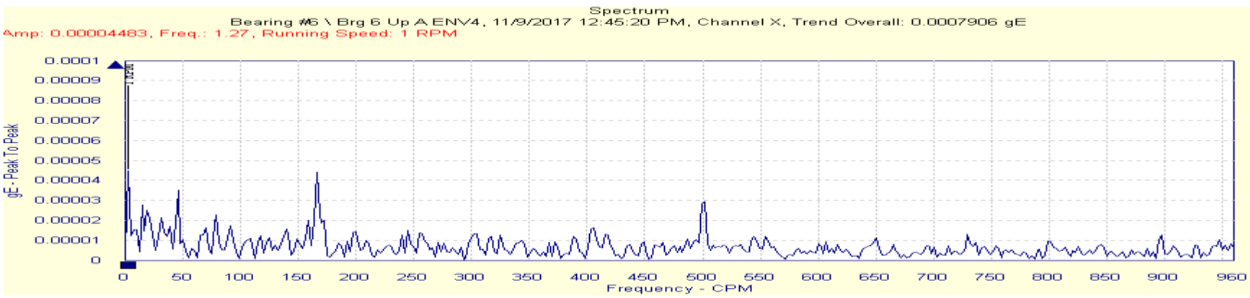


Bearing #5 – Envelope Acceleration gE4 spectrum – Down cycle.

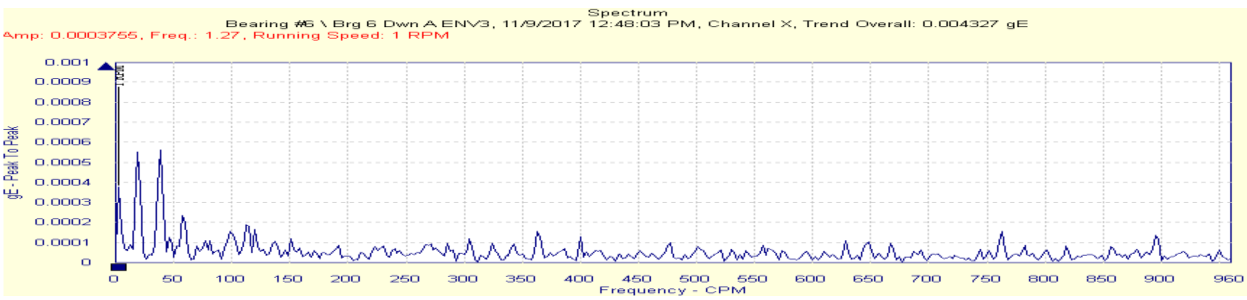
South Main Bearing #6



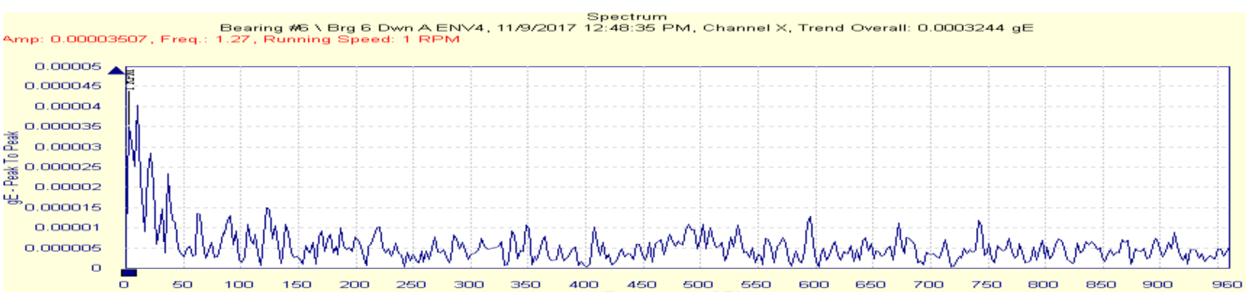
Bearing #6 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #6 – Envelope Acceleration gE4 spectrum – Up cycle.

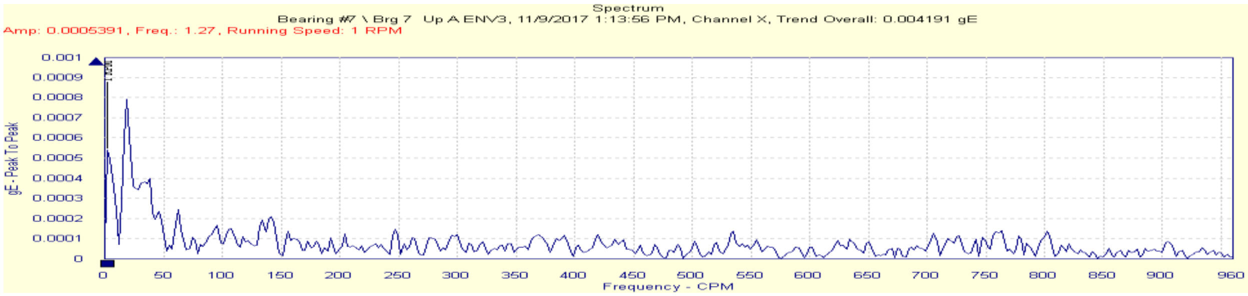


Bearing #6 – Envelope Acceleration gE3 spectrum – Down cycle.

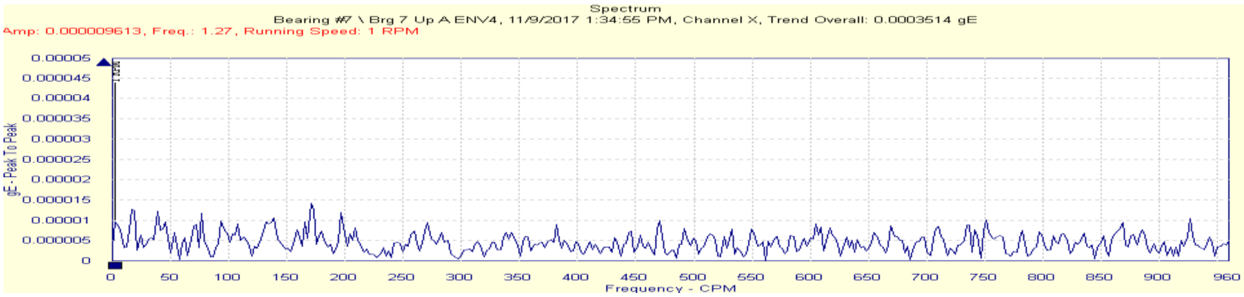


Bearing #6 – Envelope Acceleration gE4 spectrum – Down cycle.

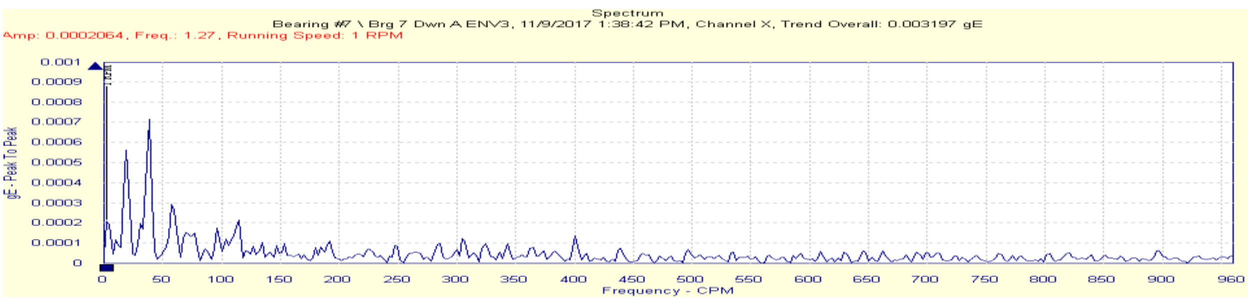
South Main Bearing #7



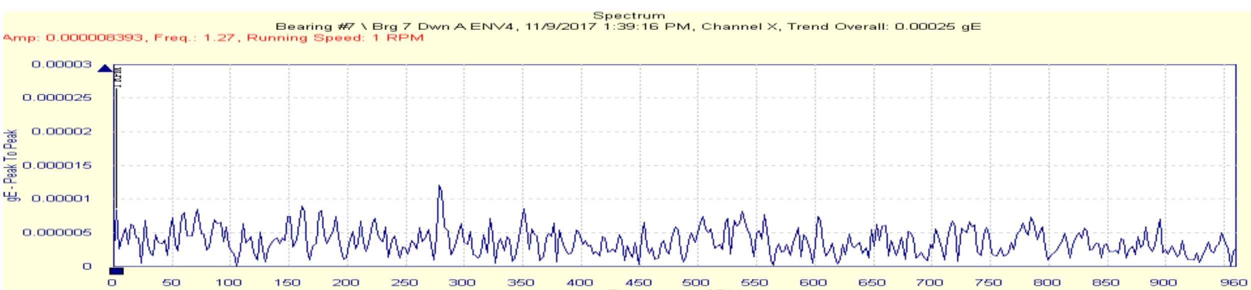
Bearing #7 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #7 – Envelope Acceleration gE4 spectrum – Up cycle.

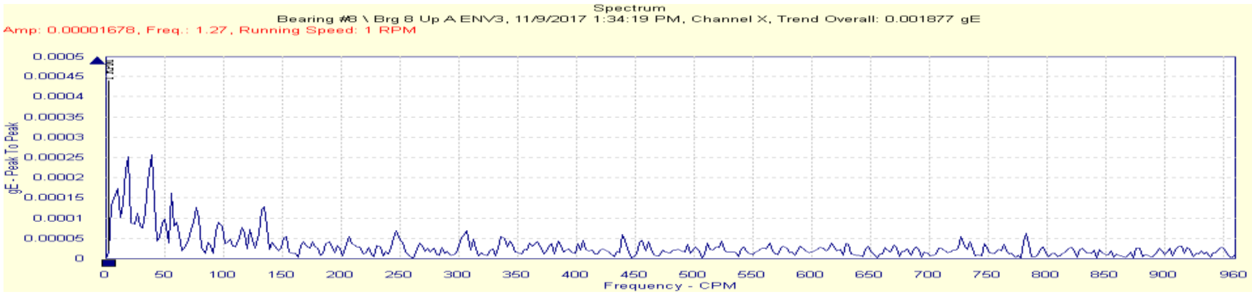


Bearing #7 – Envelope Acceleration gE3 spectrum – Down cycle.

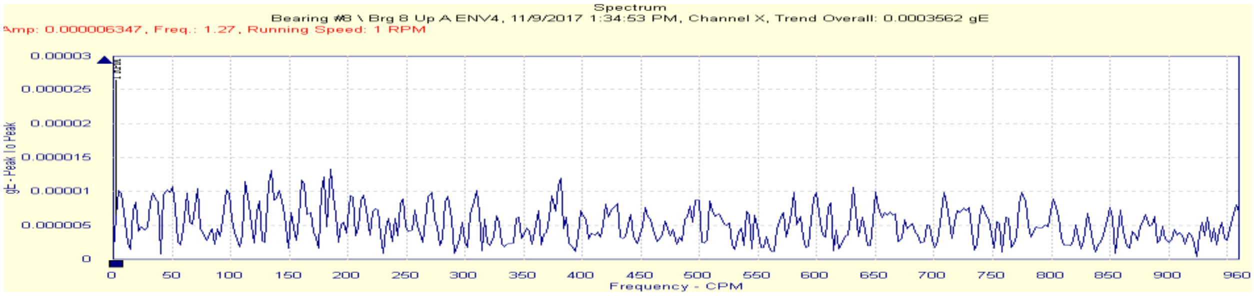


Bearing #7 – Envelope Acceleration gE4 spectrum – Down cycle.

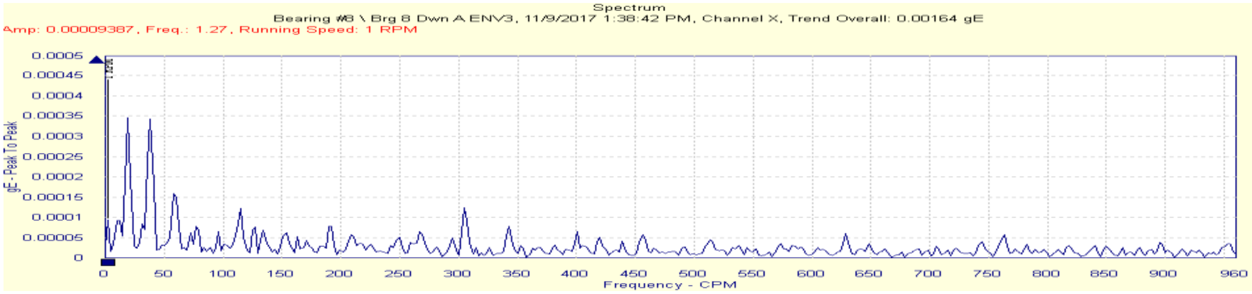
South Main Bearing #8



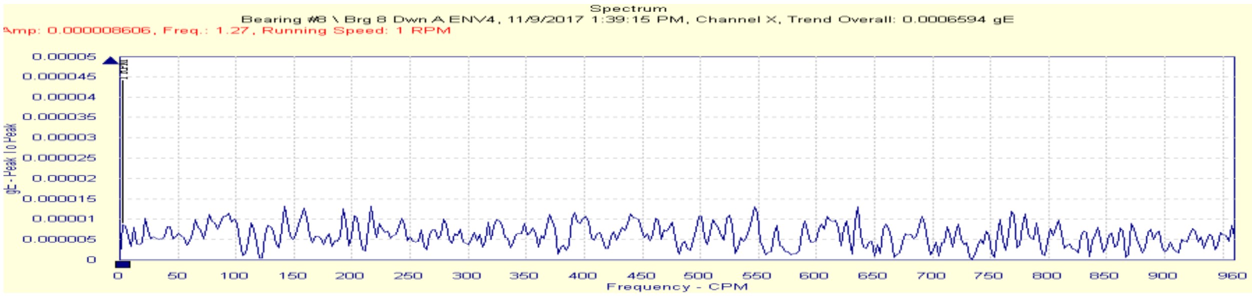
Bearing #8 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #8 – Envelope Acceleration gE4 spectrum – Up cycle.

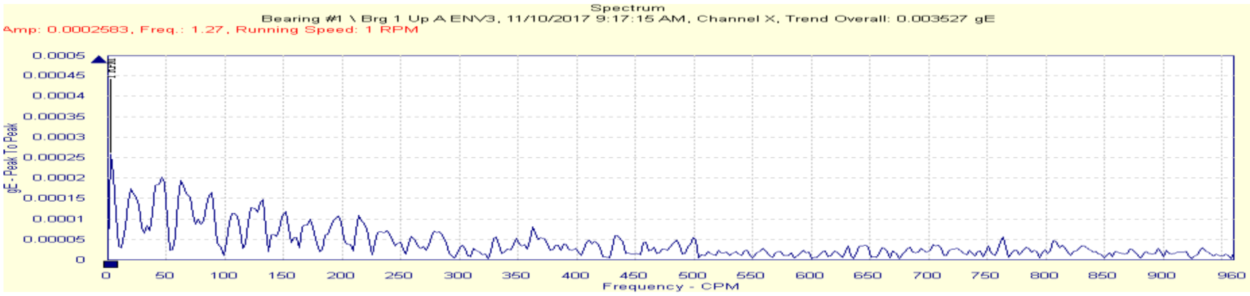


Bearing #8 – Envelope Acceleration gE3 spectrum – Down cycle.

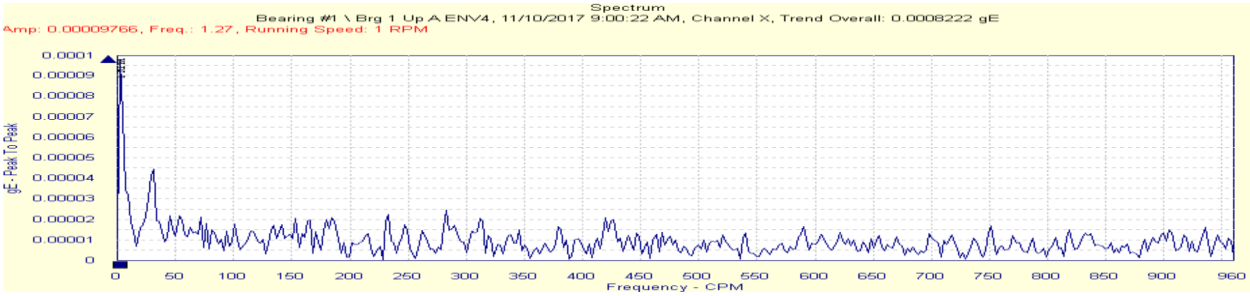


Bearing #8 – Envelope Acceleration gE4 spectrum – Down cycle.

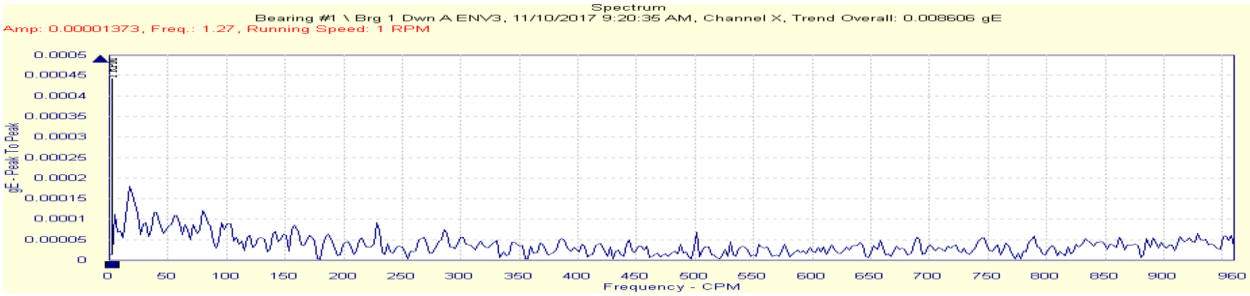
North Main Bearing #1



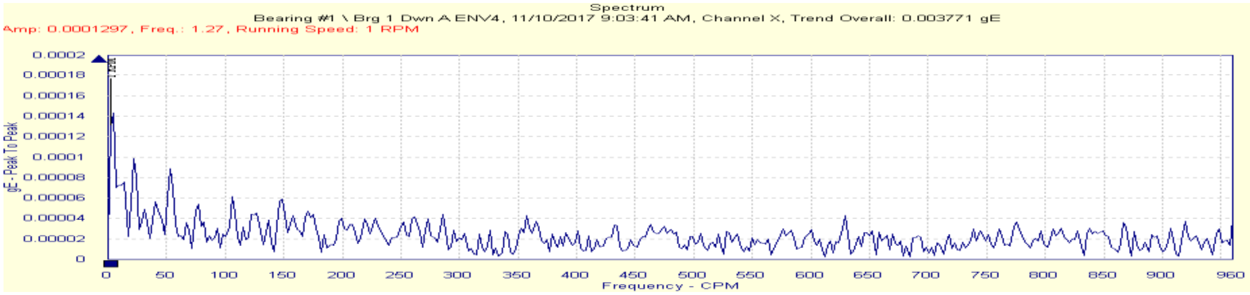
Bearing #1 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #1 – Envelope Acceleration gE4 spectrum – Up cycle.

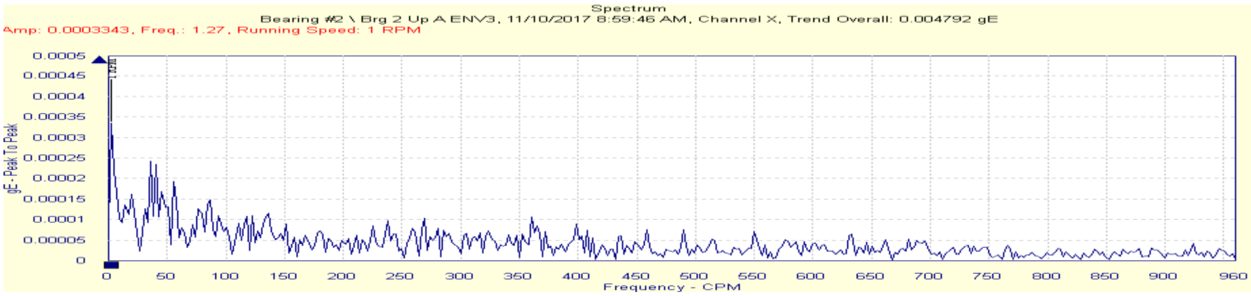


Bearing #1 – Envelope Acceleration gE3 spectrum – Down cycle.

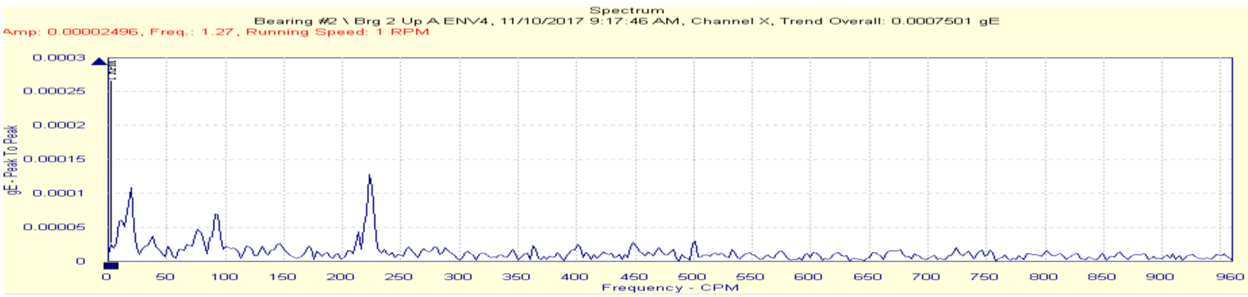


Bearing #1 – Envelope Acceleration gE4 spectrum – Down cycle.

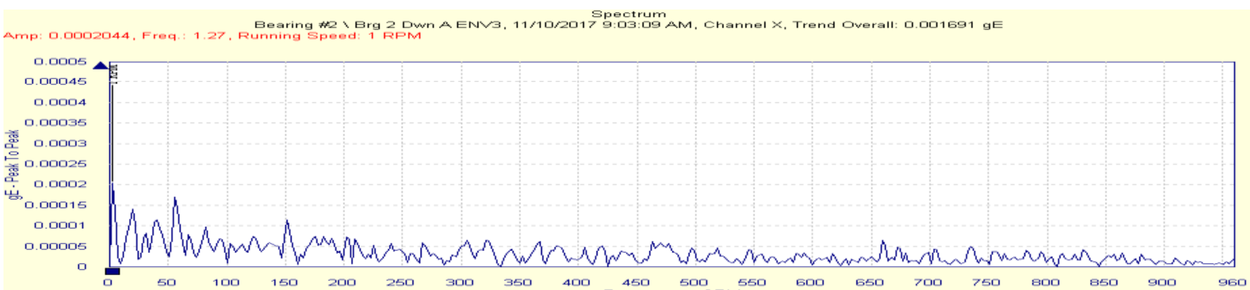
North Main Bearing #2



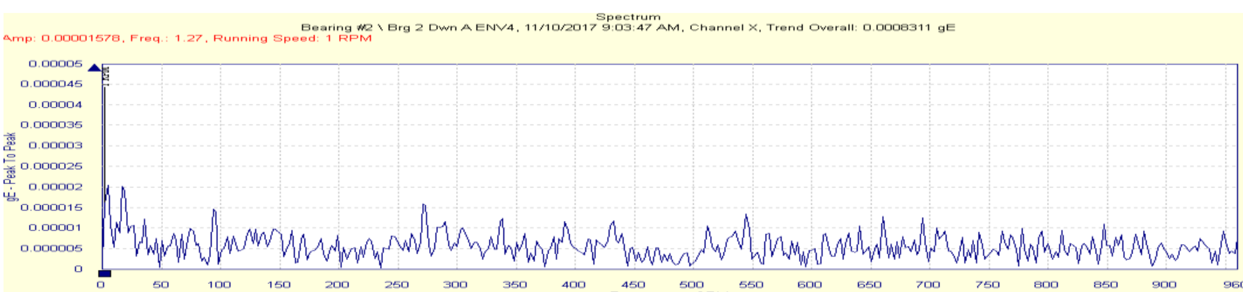
Bearing #2 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #2 – Envelope Acceleration gE4 spectrum – Up cycle.

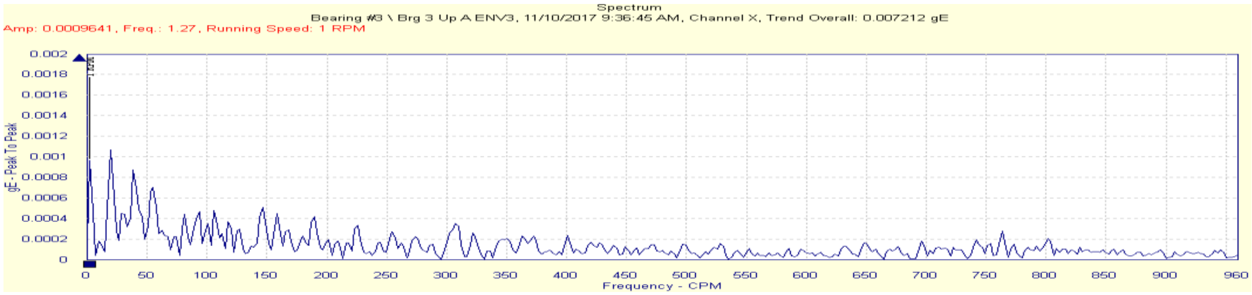


Bearing #2 – Envelope Acceleration gE3 spectrum – Down cycle.

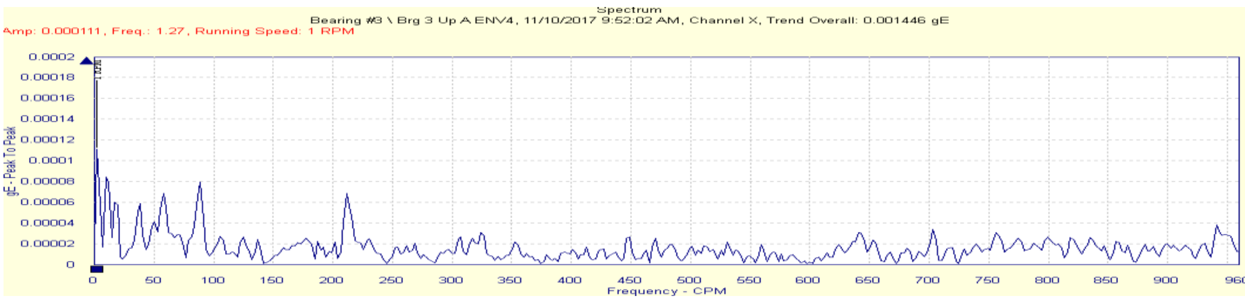


Bearing #2 – Envelope Acceleration gE4 spectrum – Down cycle.

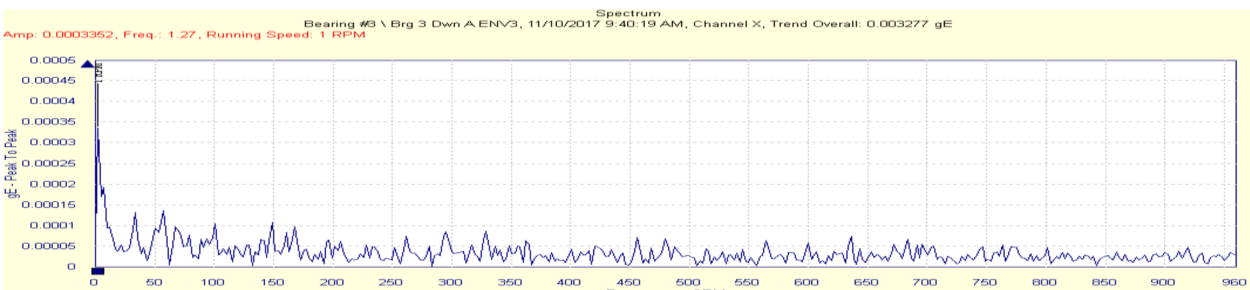
North Main Bearing #3



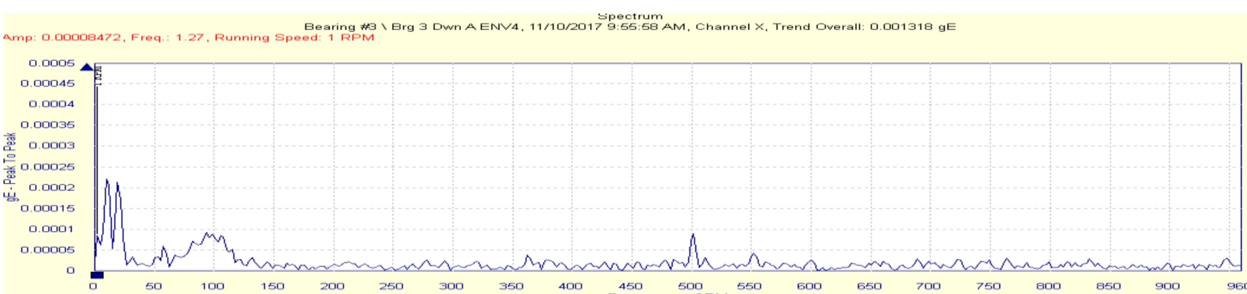
Bearing #3 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #3 – Envelope Acceleration gE4 spectrum – Up cycle.

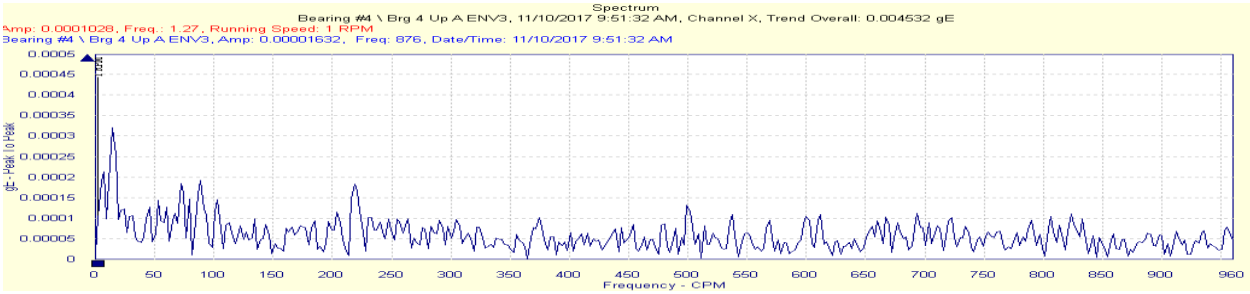


Bearing #3 – Envelope Acceleration gE3 spectrum – Down cycle.

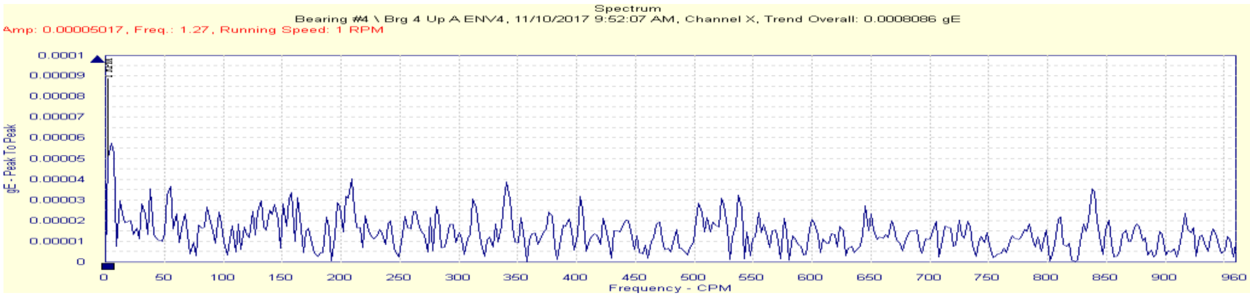


Bearing #3 – Envelope Acceleration gE4 spectrum – Down cycle.

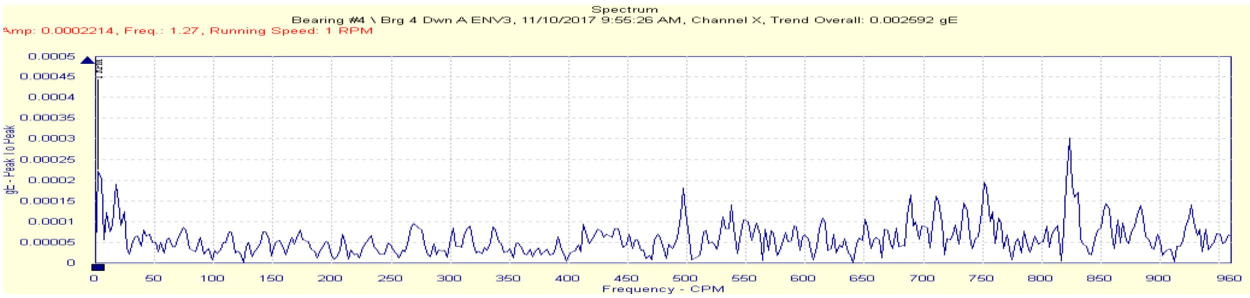
North Main Bearing #4



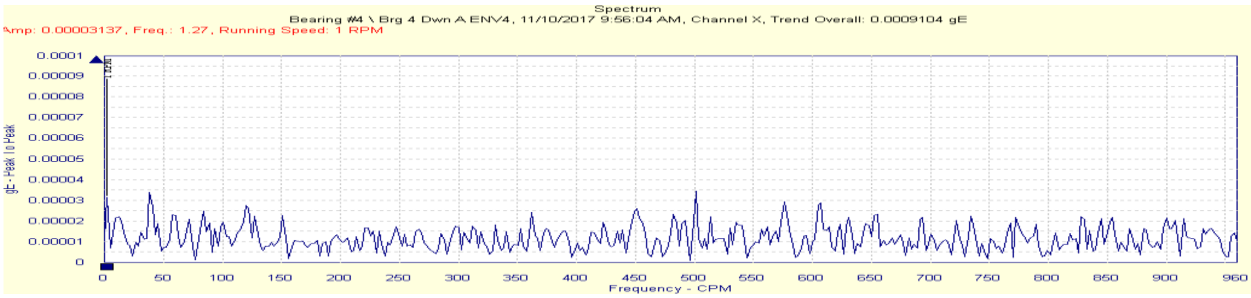
Bearing #4 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #4 – Envelope Acceleration gE3 spectrum – Up cycle.

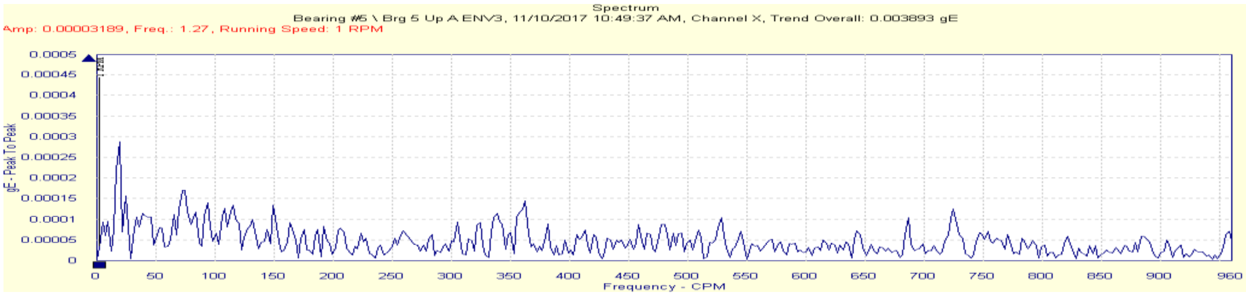


Bearing #4 – Envelope Acceleration gE3 spectrum – Down cycle.

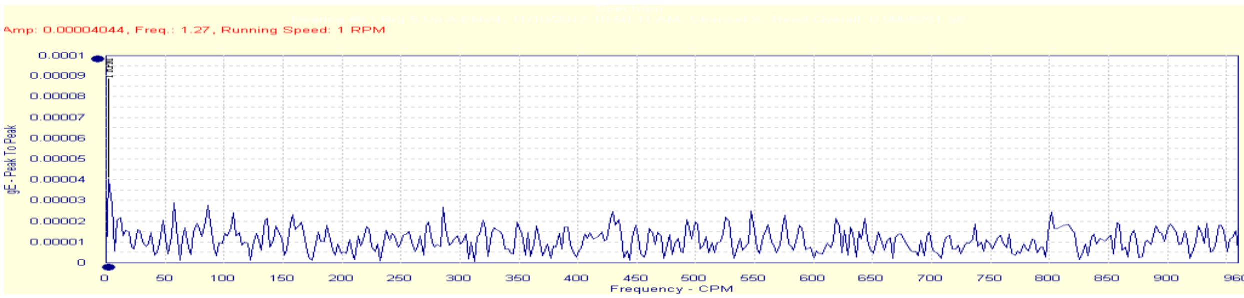


Bearing #4 – Envelope Acceleration gE4 spectrum – Down cycle.

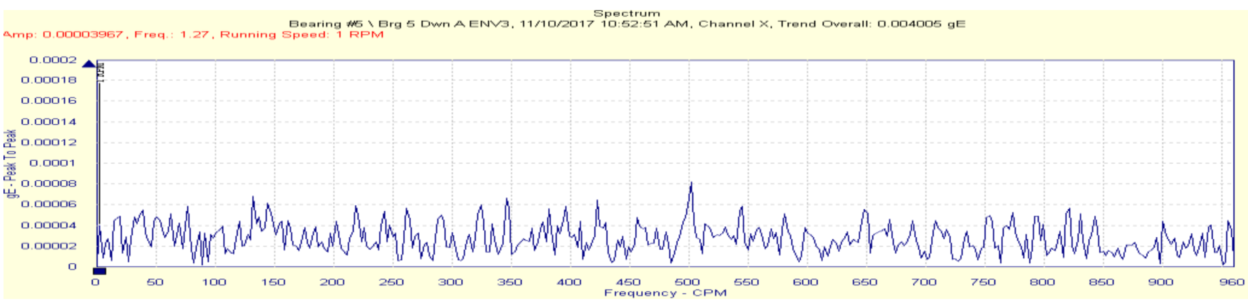
North Main Bearing #5



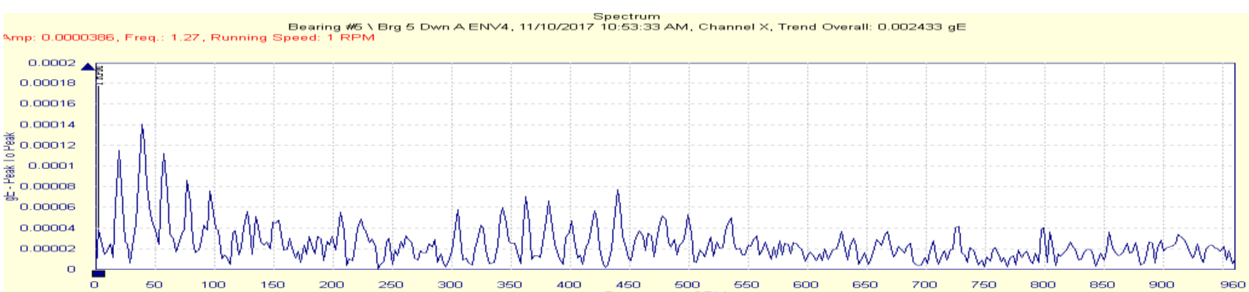
Bearing #5 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #5 – Envelope Acceleration gE4 spectrum – Up cycle.

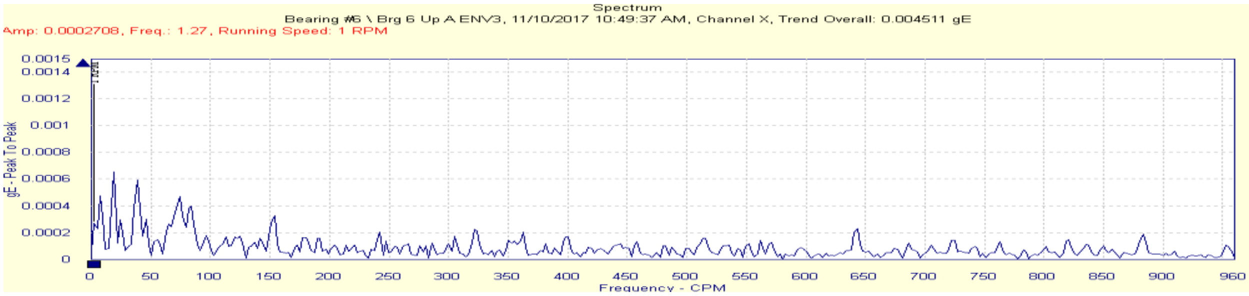


Bearing #5 – Envelope Acceleration gE3 spectrum – Down cycle.

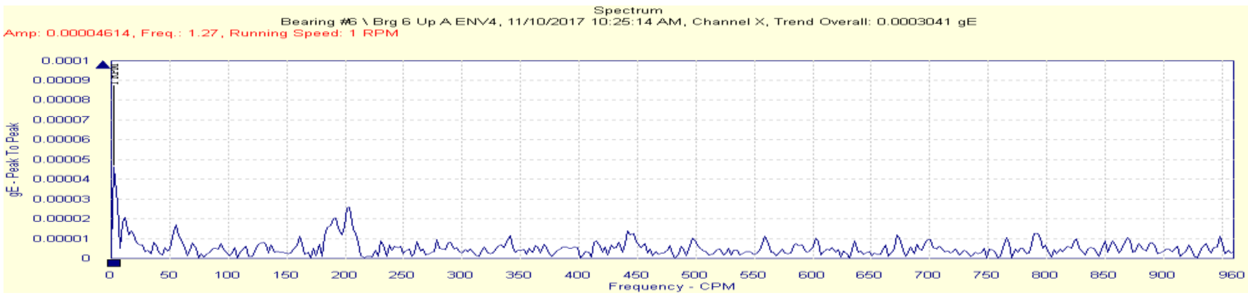


Bearing #5 – Envelope Acceleration gE4 spectrum – Down cycle.

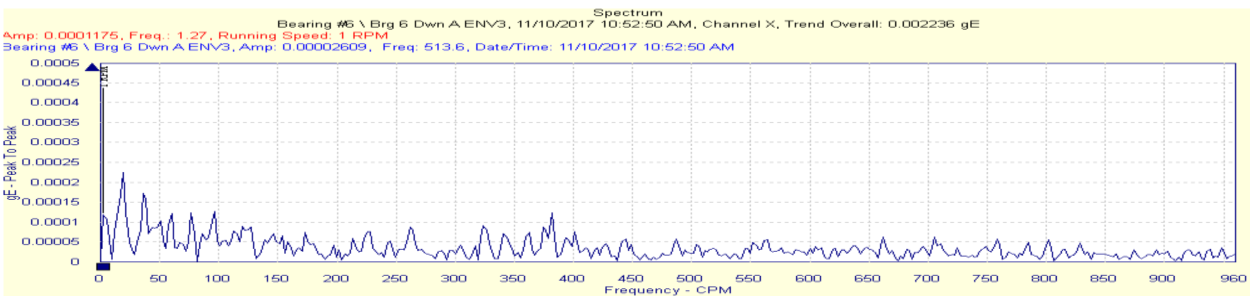
North Main Bearing #6



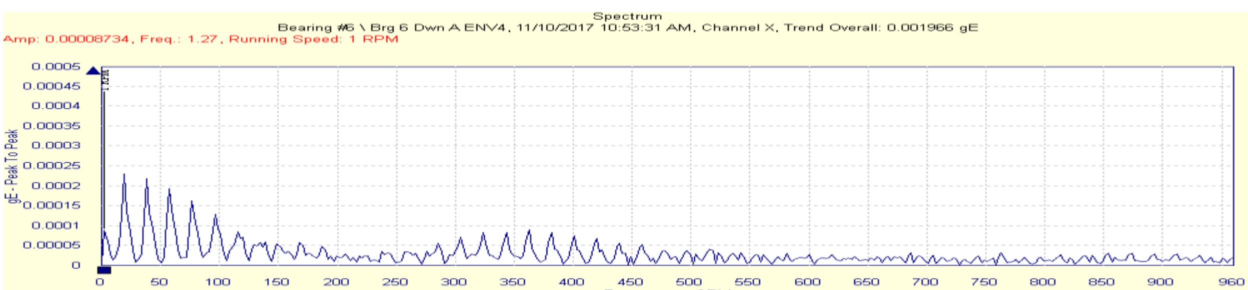
Bearing #6 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #6 – Envelope Acceleration gE4 spectrum – Up cycle.

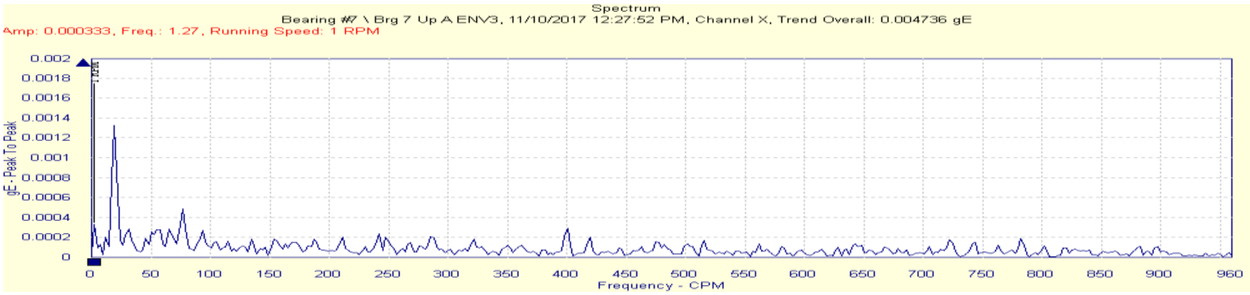


Bearing #6 – Envelope Acceleration gE3 spectrum – Down cycle.

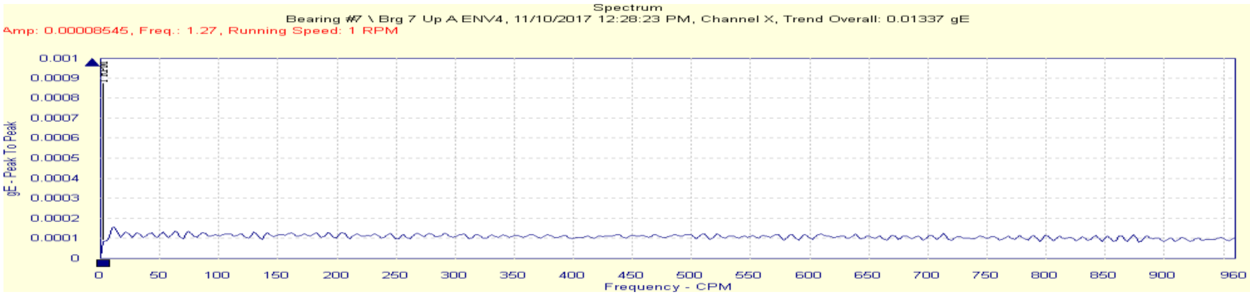


Bearing #6 – Envelope Acceleration gE4 spectrum – Down cycle.

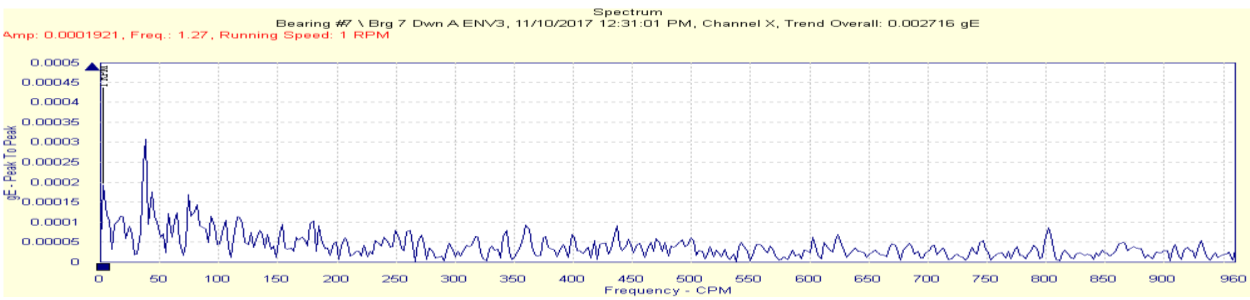
North Main Bearing #7



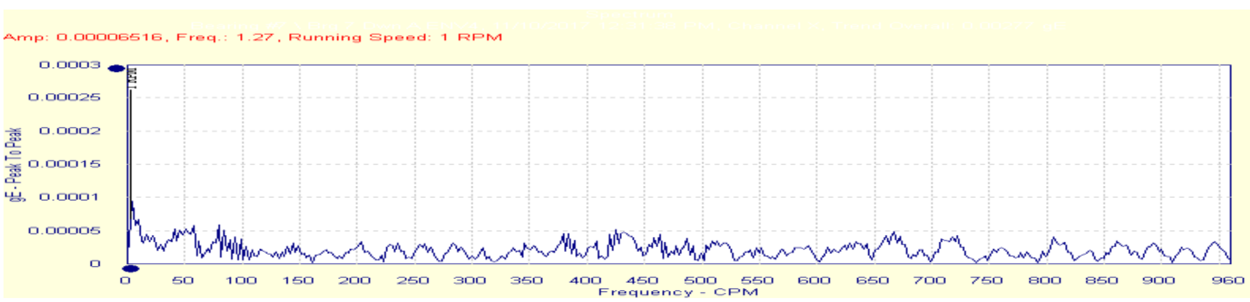
Bearing #7 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #7 – Envelope Acceleration gE4 spectrum – Up cycle.

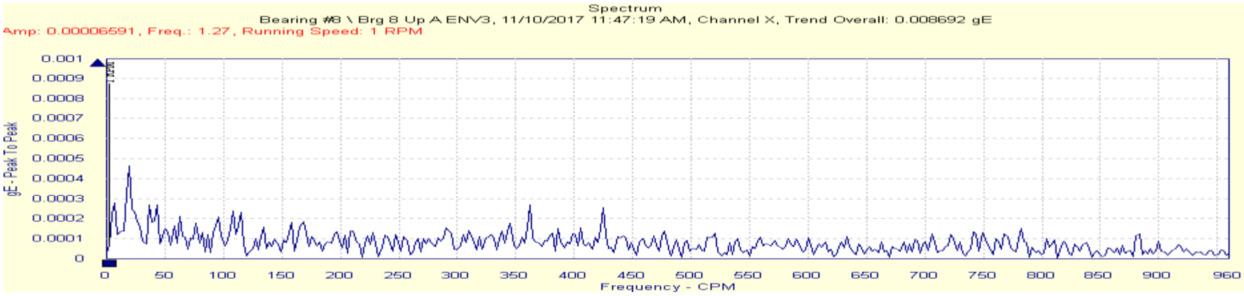


Bearing #7 – Envelope Acceleration gE3 spectrum – Down cycle.

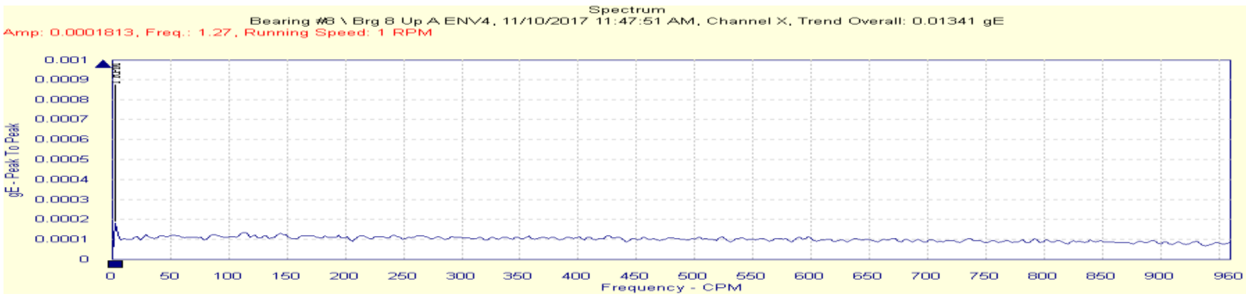


Bearing #7 – Envelope Acceleration gE4 spectrum – Down cycle.

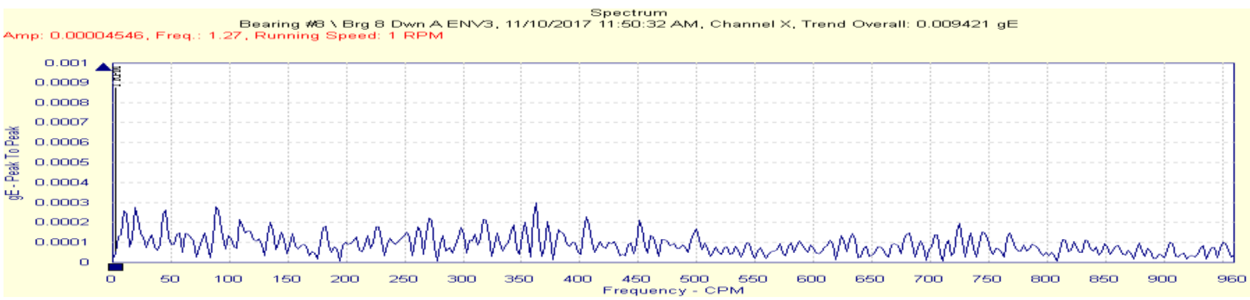
North Main Bearing #8



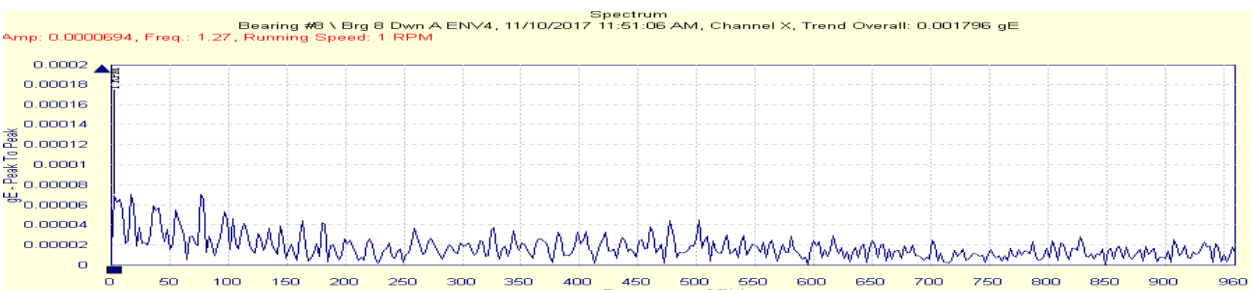
Bearing #8 – Envelope Acceleration gE3 spectrum – Up cycle.



Bearing #8 – Envelope Acceleration gE4 spectrum – Up cycle.



Bearing #8 – Envelope Acceleration gE3 spectrum – Down cycle.



Bearing #8 – Envelope Acceleration gE3 spectrum – Down cycle.

SKF Canada Limited – Toronto
40 Executive Court, Scarborough, ON M1S 4N4 Phone: (416) 299 1220 Web: www.skf.ca

APPENDIX B5

Oil Analysis Reports (Southwest Sprectrochem Lab)

APPENDIX B5 Oil Analysis Reports (Southwest Sprectrochem Lab)

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OVERALL WEAR JUDGEMENT
1-Normal

Analytical Ferrograph Report

SAMPLE INFORMATION			
CUSTOMER #:	234565	LAB SAMPLE #:	K0759
CUSTOMER:	STAFFORD BANDLOW ENG	OIL USED:	UNKNOWN
LOCATION:	BURLINGTON CANAL	TIME ON OIL:	N/A
UNIT:	LIFT BRIDGE	SAMPLE DATE:	11/10/17
DESCRIPTION:	NORTH SPAN DRIVE REDUCER	REPORT DATE:	11/29/17
SERIAL #:	N/A	ANALYST:	PLau
EQUIP NO:	0050		

PARTICLE ANALYSIS

1 - Normal; 2 - Watch; 3 - Alert; 4 - Critical

FERROUS METAL WEAR	SEVERITY
RUBBING	1
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
CHUNKS	1
RED OXIDES	1
DARK OXIDES	
ADHESION WEAR	1
ABRASION WEAR	1
SLIDING	
COPPER/COPPER ALLOY WEAR	**SEVERITY**
RUBBING	
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
FATIGUE CHUNKS	
ABRASION WEAR	
SLIDING	
OTHER NON-MAGNETIC PARTICLES	**SEVERITY**
INORGANIC/BIREFRINGENT	1
WHITE METAL	
MOLYBDENUM DISULFIDE	
OTHER NON-METALLIC PARTICLES	**SEVERITY**
ORGANIC/BIREFRINGENT	1
SILICEOUS	1
FRICTION POLYMER	
FIBERS	1
LACQUER	
AMORPHOUS	
CARBONACEOUS	

METAL CONTENT, ppm by Emission Spectroscopy

NOTE: Particles greater than 10-microns will probably not be measured in the emission spectrometer.

WEAR			
Iron	2	Tin	0
Copper	1	Nickel	0
Aluminum	0	Titanium	0
Chromium	0	Silver	0
Lead	0	Vanadium	0

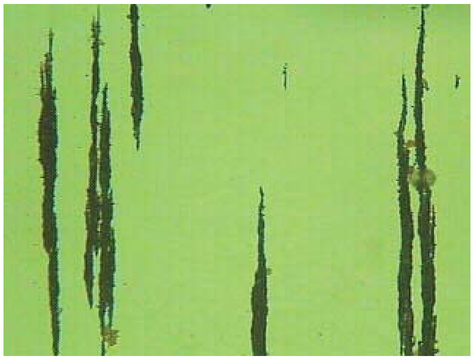
ADDITIVE	
Magnesium	0
Calcium	6
Barium	0
Phosphorous	225
Zinc	17

MULTI-SOURCE	
Molybdenum	0
Antimony	0
Boron	0

CONTAMINANT	
Silicon	0
Sodium	0
Potassium	0

PHYSICAL PROPERTIES		
Ferro D.R, Small	9.3	
Ferro D.R, Large	38.8	
KF Water	50	ppm
TAN	0.47	mg/g

SAMPLE #: K0759



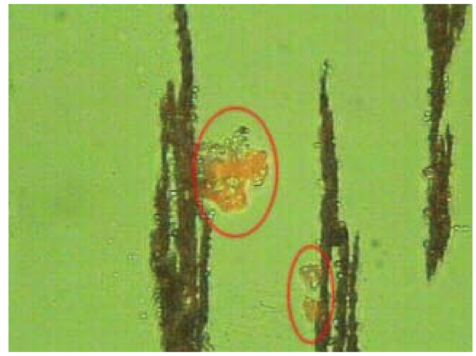
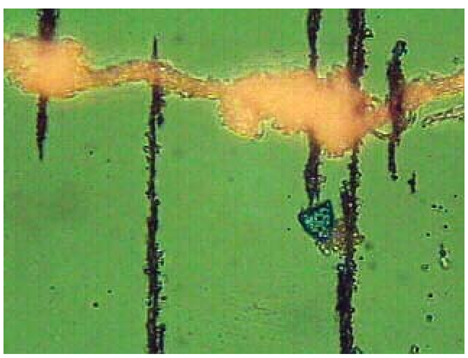


PHOTO-MICROGRAPH A @ 400 X
FINE FERROUS RUBBING WEAR NEAR SLIDE ENTRANCE IS NORMAL.

PHOTO-MICROGRAPH B @ 1000 X
A CLOSER LOOK AT A FEEROUS MAGNETIC BAND; NOTE THE LOOSE RED OXIDES.



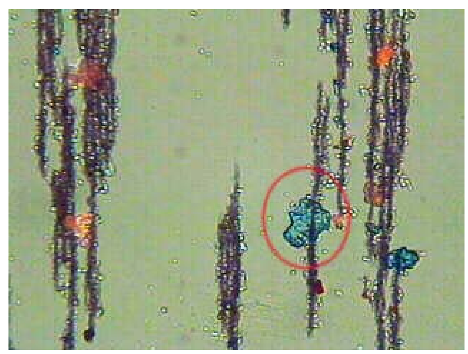


PHOTO-MICROGRAPH C @ 1000 X
APPEARS TO BE A RUST STAINED FIBER OR ORGANIC MASS. THIS STRUCTURE IN EXCESS OF 300 MICRONS LONG.

PHOTO-MICROGRAPH D @ 1000 X
AMONG THE FERRO-MAGNETIC BANDS ARE RED OXIDES AND BLUE PARTICLES.

SUMMARY:

In general, wear is normal: small ferrous rubbing wear comprises the majority of particles. No large fatigue chunks were observed. However, the blue particles seen in photo-micrograph C and D are interesting. These particles could be tempered iron alloy from the gear teeth, but the texture is inconsistent and the size small. It is possible this just a mineral contaminant. A few large fiber like particles were observed; the origin is not clear. The main concern is contamination, but abnormal wear is not indicated.

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OVERALL WEAR JUDGEMENT
1-Normal

Analytical Ferrograph Report

SAMPLE INFORMATION			
CUSTOMER #:	234565	LAB SAMPLE #:	K0758
CUSTOMER:	STAFFORD BANDLOW ENG	OIL USED:	UNKNOWN
LOCATION:	BURLINGTON CANAL	TIME ON OIL:	N/A
UNIT:	LIFT BRIDGE	SAMPLE DATE:	11/09/17
DESCRIPTION:	SOUTH SPAN DRIVE REDUCER	REPORT DATE:	11/29/17
SERIAL #:	N/A	ANALYST:	PLau
EQUIP NO:	0051		

PARTICLE ANALYSIS

1 - Normal; 2 - Watch; 3 - Alert; 4 - Critical

FERROUS METAL WEAR	SEVERITY
RUBBING	1
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
CHUNKS	1
RED OXIDES	1
DARK OXIDES	
ADHESION WEAR	
ABRASION WEAR	1
SLIDING	1
COPPER/COPPER ALLOY WEAR	**SEVERITY**
RUBBING	
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
FATIGUE CHUNKS	
ABRASION WEAR	
SLIDING	
OTHER NON-MAGNETIC PARTICLES	**SEVERITY**
INORGANIC/BIREFRINGENT	
WHITE METAL	
MOLYBDENUM DISULFIDE	
OTHER NON-METALLIC PARTICLES	**SEVERITY**
ORGANIC/BIREFRINGENT	1
SILICEOUS	1
FRICTION POLYMER	
FIBERS	
LACQUER	
AMORPHOUS	
CARBONACEOUS	

METAL CONTENT, ppm by Emission Spectroscopy

NOTE: Particles greater than 10-microns will probably not be measured in the emission spectrometer.

WEAR			
Iron	1	Tin	0
Copper	0	Nickel	0
Aluminum	0	Titanium	0
Chromium	0	Silver	0
Lead	0	Vanadium	0

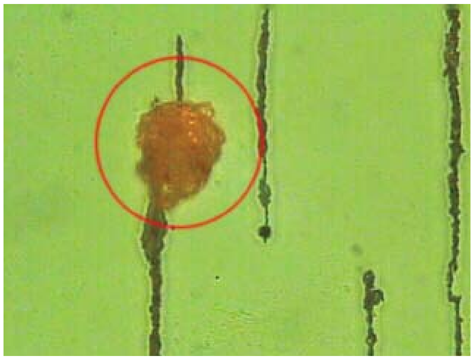
ADDITIVE	
Magnesium	0
Calcium	3
Barium	0
Phosphorous	225
Zinc	6

MULTI-SOURCE	
Molybdenum	0
Antimony	0
Boron	1

CONTAMINANT	
Silicon	0
Sodium	0
Potassium	0

PHYSICAL PROPERTIES		
Ferro D.R, Small	7.0	
Ferro D.R, Large	33.5	
KF Water	46	ppm
TAN	0.47	mg/g

SAMPLE #: K0758



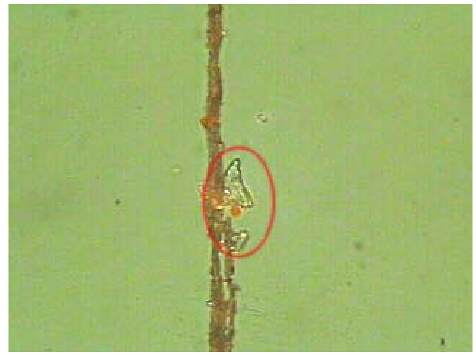


PHOTO-MICROGRAPH A @ 1000 X
FINE FERROUS RUBBING WEAR; NOTE THE RED OXIDE.

PHOTO-MICROGRAPH B @ 1000 X
FERROUS MAGNETIC BAND WITH SOME RED OXIDES; NOTE THE SILICEOUS PARTICLE.

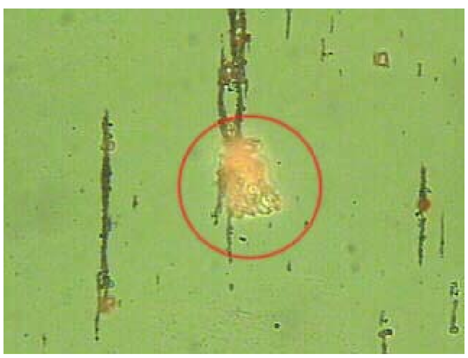


PHOTO-MICROGRAPH C @ 1000 X
MINERAL OR SILICEOUS DEBRIS APPROXIMATELY 10-15 MICRONS.

PHOTO-MICROGRAPH D @ 1000 X
NOTE THE BLUE PARTICLE: COULD BE GEAR TEETH WEAR CAUSE BY SCORING/SCUFFING.

SUMMARY:

Particle density is light. The vast majority of particles are small ferrous rubbing wear aligned in magnetic bands. These bands are fewer relative to the other samples in this set. Most particles are not oxidized, water contamination is not an issue. Contaminant debris including siliceous particles, is present, but fairly light in concentration. In general, elemental, moisture and Ferrographic data suggests the condition of this equipment and lubricant is normal.

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OVERALL WEAR JUDGEMENT
1-Normal

Analytical Ferrograph Report

SAMPLE INFORMATION			
CUSTOMER #:	234565	LAB SAMPLE #:	K0757
CUSTOMER:	STAFFORD BANDLOW ENG	OIL USED:	UNKNOWN
LOCATION:	BURLINGTON CANAL	TIME ON OIL:	N/A
UNIT:	LIFT BRIDGE	SAMPLE DATE:	11/08/17
DESCRIPTION:	SOUTH SPAN LOCK	REPORT DATE:	11/29/17
SERIAL #:	N/A	ANALYST:	PLau
EQUIP NO:	0052		

PARTICLE ANALYSIS

1 - Normal; 2 - Watch; 3 - Alert; 4 - Critical

FERROUS METAL WEAR	SEVERITY
RUBBING	1
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
CHUNKS	1
RED OXIDES	1
DARK OXIDES	1
ADHESION WEAR	1
ABRASION WEAR	
SLIDING	
COPPER/COPPER ALLOY WEAR	**SEVERITY**
RUBBING	
SEVERE WEAR	
CUTTING	
LAMINAR PARTICLES	
SPHERES	
FATIGUE CHUNKS	
ABRASION WEAR	
SLIDING	
OTHER NON-MAGNETIC PARTICLES	**SEVERITY**
INORGANIC/BIREFRINGENT	1
WHITE METAL	
MOLYBDENUM DISULFIDE	
OTHER NON-METALLIC PARTICLES	**SEVERITY**
ORGANIC/BIREFRINGENT	1
SILICEOUS	1
FRICTION POLYMER	
FIBERS	
LACQUER	
AMORPHOUS	
CARBONACEOUS	

METAL CONTENT, ppm by Emission Spectroscopy

NOTE: Particles greater than 10-microns will probably not be measured in the emission spectrometer.

WEAR			
Iron	0	Tin	0
Copper	1	Nickel	0
Aluminum	0	Titanium	0
Chromium	0	Silver	0
Lead	1	Vanadium	0

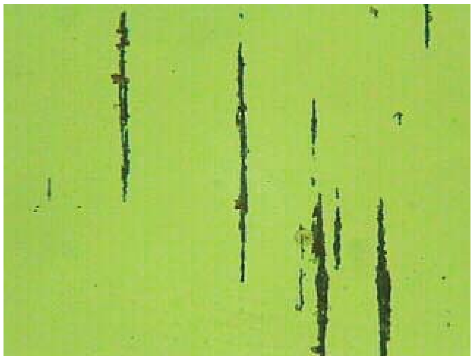
ADDITIVE	
Magnesium	0
Calcium	46
Barium	0
Phosphorous	198
Zinc	16

MULTI-SOURCE	
Molybdenum	0
Antimony	0
Boron	16

CONTAMINANT	
Silicon	0
Sodium	0
Potassium	0

PHYSICAL PROPERTIES		
Ferro D.R, Small	4.1	
Ferro D.R, Large	14.0	
KF Water	180	ppm
TAN	0.49	mg/g

SAMPLE #: K0757



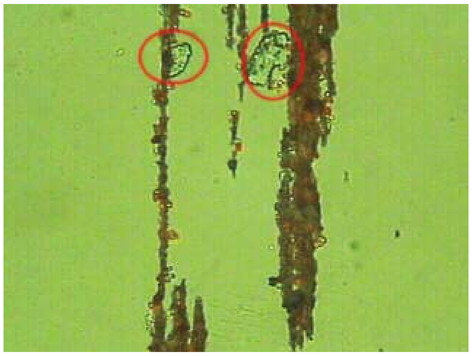


PHOTO-MICROGRAPH A @ 400 X
SMALL FERROUS RUBBING WEAR IS NORMAL.

PHOTO-MICROGRAPH B @ 1000 X
CLOSER VIEW OF A BAND SIMILAR TO "A"; NOTE THE SOFT, TRANSLUCENT PARTICLE.

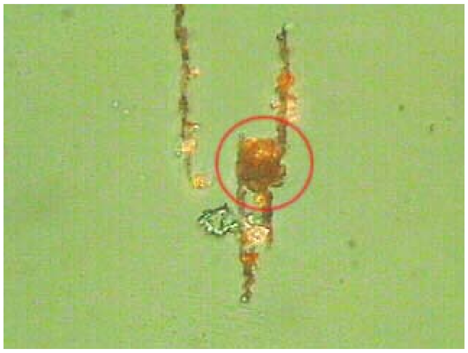


PHOTO-MICROGRAPH C @ 1000 X
FERROUS WEAR: THE LARGEST PARTICLE IS A RED OXIDE.

PHOTO-MICROGRAPH D @ 1000 X
POSSIBLE MINERAL DEBRIS, 20 TO 30 MICRONS.

SUMMARY:

Particle density is fairly light. The vast majority of particles are small ferrous rubbing wear, which are normal. Some ferrous wear has oxidized (red oxides present), but corrosion does not appear to be problematic. Contaminant debris, including amorphous organic particles and siliceous debris, is present, but fairly light in concentration. In general, elemental, moisture and Ferrographic data suggests the condition of this equipment and lubricant is normal.

APPENDIX C

ELECTRICAL INSPECTION DATA

APPENDIX C1

Electrical Inspection Photographs

APPENDIX C Electrical Inspection Photographs

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Photo E1 One Line Diagrams in Electrical Room
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Photo E6 Automatic Transfer Switch (ATS)
Photo E7 Generator Fuel Pump System
Photo E8 Main Standby Generator Load Bank
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Photo E73 General Lighting and Smoke Detectors (South Tower Shown)
Photo E74 Typical Outdoor Raceway Installation.

Photo E1 One Line Diagrams in Electrical Room. Note that the "As Built" one-line diagrams of the recently completed rehabilitation project are poster printed.

Photo E2 1,000KVA Outdoor Pad Mounted Incoming Service Transformer/Unit Substation. Note the primary service to the transformer is 13.8kV from the local utility overhead supply and secondary of the transformer serves the bridge at 575volt, 3-phase, 60 Hz.

Photo E3 Switchboard #1. The switchboard is the original installation and is in good condition. Note that the utility and generator power main breakers are electrically operated and interlocked. There is no mechanical interlock for this manual transfer means.

Photo E4 Main 600kW Standby Generator. Generator is used as an alternative source of power to operate the bridge. The standby generator is well maintained and been tested monthly.

Photo E5 Auxiliary Standby Generator. Note auxiliary standby generator only provide powers the bridge facility and auxiliaries in the event of a utility electric failure but is not used or rated to operate the bridge.

Photo E6 Automatic Transfer Switch (ATS). This ATS is used to automatically start the auxiliary generator to power the bridge facilities in the event of a power failure.

Photo E7 Generator Fuel Pump System. This pump system allows automatic refuelling of the day tank from the main tank located within the control house compounded area. It was previously reported that the main tank status monitoring system has not been properly installed and is currently not operational.

Photo E8 Main Standby Generator Load Bank. This load bank is located outside of the control house and is appropriately sized to exercise the main (600kW) standby generator under load. Note the excellent condition of the load bank enclosure with louver and protective screen.

Photo E9 Load Bank Disconnect Switch. The disconnect switch is wall mounted outside the generator room facing the load bank. Note the as-new condition of the disconnect switch.

Photo E10 Main Switchboard No.2. This is the main distribution switchboard for the bridge electrical system. Note some change has been made to this switchboard since the 2016 inspection due to the recently completed rehab. project. The changes include new breakers, new labels and disabling of the old drive system feeder breaker with a padlock.

Photo E11 New CP-2 Control Panel. New free standing control panel was installed as part of the recent bridge rehabilitation work. The redundant PLC system and control devices are properly installed inside the panel. Note that the wireway cover cannot be mounted due to over saturated wires in the wireway in some area. The new control system has been updated to the newest GE PLC with improved functions and performance.

Photo E12 New UPS and UPS Distribution Panel. The UPS and its distribution panel is located next to the CP-2 and is in as new condition. Note the different type of laminated labels on the UPS distribution panel are used to indicate the purposes of the breakers.

Photo E13 Electrical Room Panelboards. The transformer and the panelboards are of the existing installation. All panels are in good condition with additional circuits been added as part of the recent rehab.

Photo E14 Main Control Desk. New upgraded console top is provided during the recent rehabilitation project. The console is in excellent condition.

Photo E15 Traffic Control Panel. The new traffic control console top was recently installed. The layout and function of the console top is similar to the old console.

Photo E16 Traffic Control Bypass. A keyed selector switch for PLC and Maintenance select has been installed on the side of the console cabinet as part of the new control system function. Note that the relay mode of the traffic control does not have any interlocks per new logic.

Photo E17 CCTV and Intercom Interface. The CCTV and intercom interface units are mounted on the upright corner of the traffic control console. Note that both CCTV and intercom system are original and are functional. Also note that the CCTV monitor is CRT display and is outdated.

Photo E18 Bridge Radar System. The Radar system was installed to aid the bridge operation and schedule for the boat traffic. It also capable of display the wind speed and direction.

Photo E19 Wind Speed Indicator and Marine Radio. Both units are of the existing installation and are in good serviceable condition.

Photo E20 Typical New Motor Control Centre. Note that the white plastic that covers the MCC is the indication of the roof leak.

Photo E21 Typical VFD Drives Enclosure with Braking Resistors. Two new drives with resistors are installed in each tower. Both drives are in as new condition. Note two drives are providing redundancy for the main drive operation. Operator can select drives automatically or manually.

Photo E22 Typical VFD Drive System. The 200HP Danfoss VFD drive, 18 poles transformer and rectifier are well installed inside the drive enclosure.

Photo E23 Typical Drive Motor Disconnect Switches. The drive motor disconnect switch is of the original installation and been reused to serve the new motor.

Photo E24 Typical Drive Machinery Arrangement. The span motors and motor brakes are in as-new condition. The machinery brakes are existing but are provided with a new brake drum.

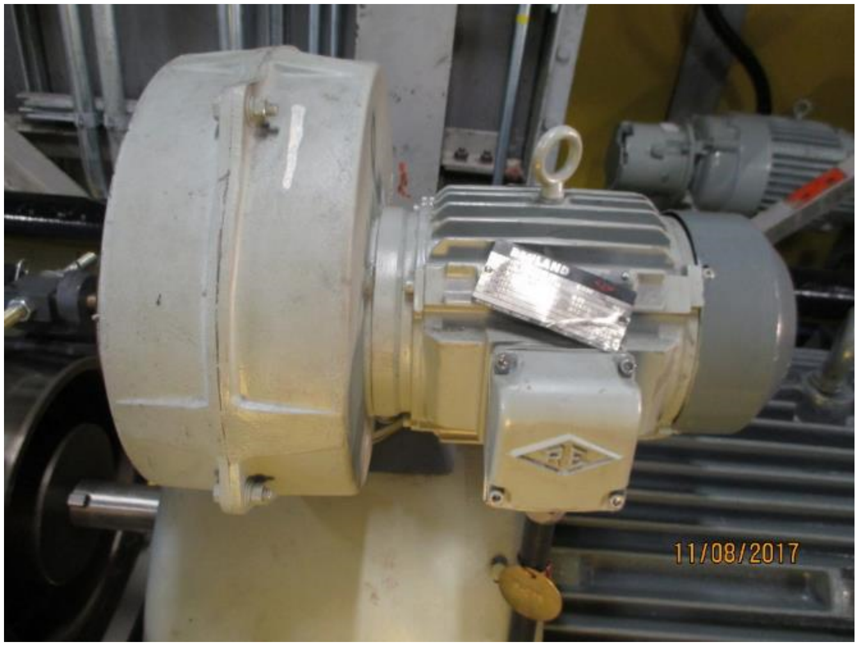

Photo E25 Northeast Motor Blower Nameplate. The blower nameplate was not affixed to the motor at the time of inspection.

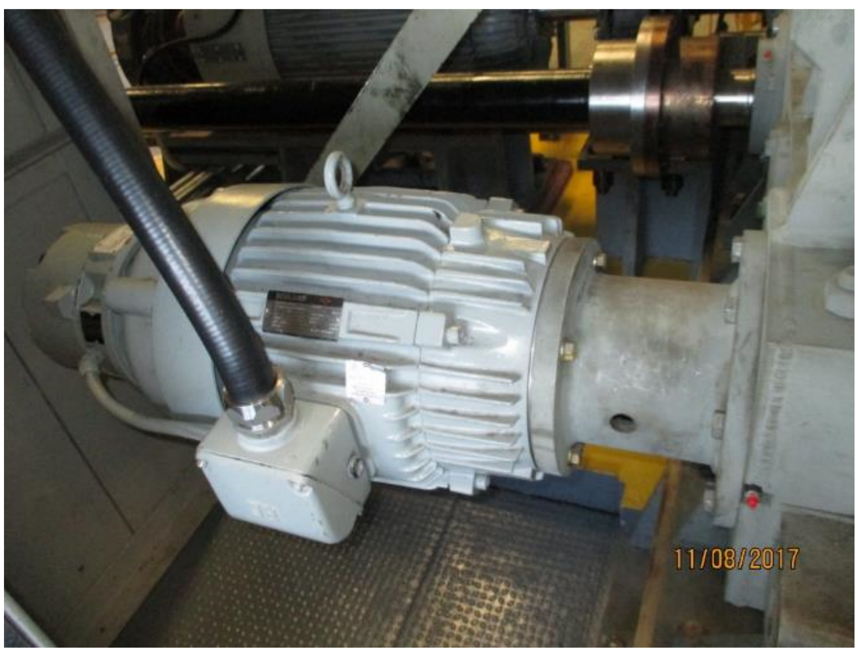

Photo E26 Typical Auxiliary Drive Motor. The new auxiliary motor with integral brake was installed during the recent rehab. Note that the original chain drive aux. has been changed to the direct coupling to the reducer.

Photo E27 Lever Handle and Limit Switches on the Gear Reducer. Two handles are provided, one on each side the reducer for AUX drive operation and transverse skew adjustment. Many limit switches have been installed on the reducer box for the lever position indication and interlock.

Photo E28 South Auxiliary Drive Controller and Span Height Indication Panel. The auxiliary drive was relocated along with the MTS and emergency power panelboard. They are all in good serviceable condition. Note the white plastic sheet cover over the units is the indication of the roof leak in the area. The span height indication is recently installed.

Photo E29 Typical Pull Box and Control Cabinet (CP-3) in South Tower. The control cabinet with PLC display was installed as part of recent rehab. They are in as-new condition.

Photo E30 Inside of Pull Box and CP-3 Cabinet. Although the pull box was installed in addition to the control cabinet, both enclosures are over-congested.

Photo E31 Span Resolvers. One single turn resolver and one multi-turn resolver have been attached to the existing gearbox after removing the old control devices.

Photo E32 South Tower Aerial Cable Control Termination Box. The network switches and fiber patch boxes are also installed inside the box. Note the looped cables are the spare conductors and communication cables. All wires are well trained and installed.

Photo E33 New Aerial Cable ATS in North Tower. The ATS was installed during the recent rehab project. It is used to automatically switch the aerial cable power feed between the east and west. The ATS is well installed.

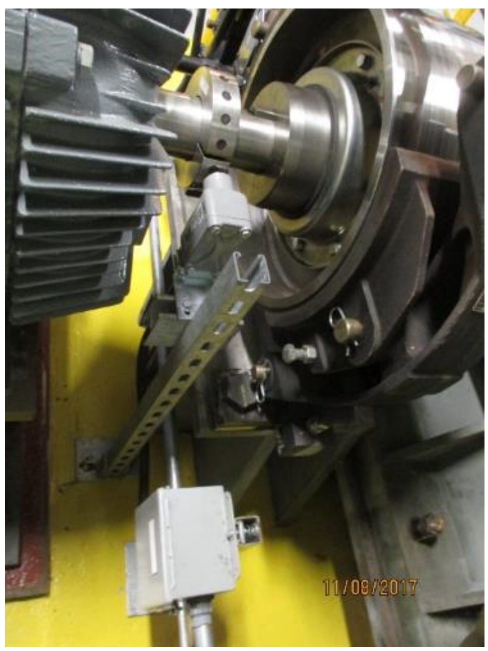

Photo E34 Typical Speed Switch Sensor. The speed switch sensor and pulse wrap are installed between the motor and machinery brake for overspeed protection. The units are well installed.

Photo E35 Typical Tower Heater Distribution Panel. This panel is of the existing installation and is in good operating condition.

Photo E36 Typical New Lighting and Disconnect. A transformer, a disconnect switch and a lighting panel are of part of the new installation during the recent bridge rehabilitation. These components are in an as-new condition.

Photo E37 Typical Span Position Limit Switch. 3 span position limit switches have been installed on the south side along the counter weight traveling path: near seated, near open and full open limit. Note that these switches were configured in series with the programmable limit switch interfacing the span height resolver to create redundant/fail safe operation. However, the bridge operation is not fail safe without the positive indication from the north side of the span.

Photo E38 Typical New Span Seated Limit Switch. The switch is of the plunger type and provides indication that the span is fully seated. Note the switches were newly installed during the recent rehab project.

Photo E39 Span Inclinometer Enclosure. Per the rehab design, the span inclinometer was originally installed in the enclosure and communicated wirelessly with the transmitter located inside the CP-2 enclosure. The inclinometer was to be used for the span skew control but does not function.

Photo E40 Inclinometer Unit. The span inclinometer had been moved several times under the direction of the Engineer during the rehab project. The function of the inclinometer has now been disabled. The multi-turn span height resolvers, one in each tower, are being used in place of the inclinometers. The bridge has no secondary means of skew detection.

Photo E41 Typical Elevator Motor. The elevator motor is of the original installation.

Photo E42 Typical Elevator Control Cabinet. The elevator control is of the original bridge installation. Although still working, it reportedly requires periodic maintenance.

Photo E43 Typical Span Lock Motor. Note the lock motor is of original installation. A limit switch has been installed as part of the hand crank installation and used to prevent electrical operation of the lock motor when the hand crank cover is removed. The hand crank limit switch has been replaced during the recent rehab.

Photo E44 Typical Span Lock Motor Disconnect Switch (North Disconnect Switch Shown). The disconnect switch is rated NEMA 3R and exhibits excessive corrosion.

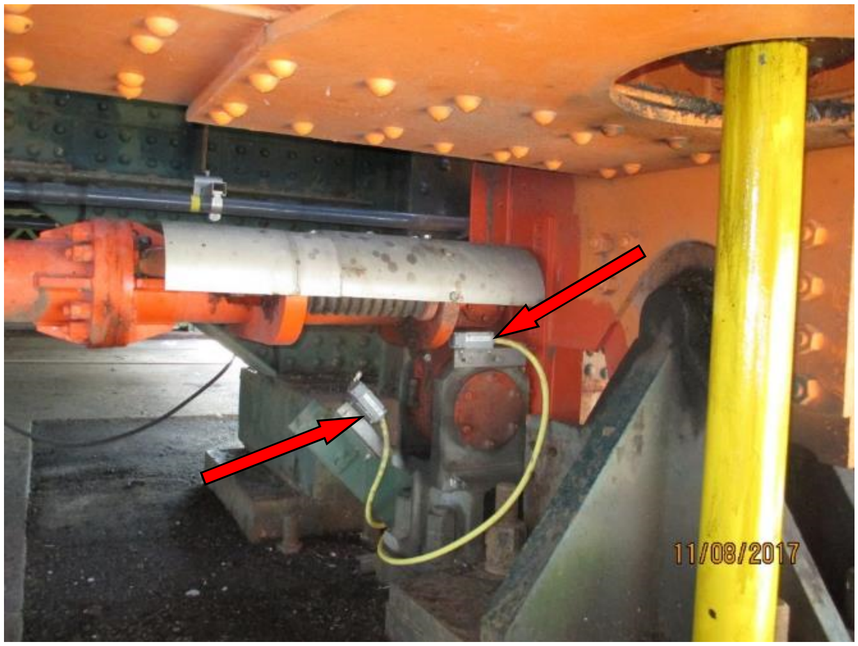

Photo E45 Typical Span Lock Limit Switches at the Lock Bar. These limit switches were installed as part of the recent rehab.

Photo E46 Typical Span Lock Limit Switches at the Center of Lock Machinery. A set of limit switches have been installed at the center of the span lock rotation machinery. These limit switches were installed as part of the recent replacement and upgrade project and are used in place of the original rotary cam limit switch.

Photo E47 Lighting Panel on North Pier (LP-4). The disconnect switch, transformer, lighting panel and the lighting contactor are of the original installation. The lighting contactor has been modified to work with the current control system.

Photo E48 Typical Span Navigation Light. The bridge is provided with two span navigation lights, one facing each approaching navigable channel. These lights were found to be operational at the time of inspection and in good serviceable condition.

Photo E49 Typical Marine Traffic Navigation Light. The marine traffic lights are located at the tip end of the pier for signaling approaching vessels. The lights are operational but lights and poles exhibit minor signs of corrosion.

Photo E50 Small Craft Navigation Light. The small craft navigation lights are installed one on each side of the canal. Note the corrosion on its mounting post.

Photo E51 Traffic Signals. Note the good condition of the signals. The light bulbs are LED which extend the life of the bulbs.

Photo E52 Typical Pedestrian Light and Pedestrian Bell. The pedestrian light is LED type Walk and Halt light. All pedestrian lights functioned properly. The North pedestrian bell (arrow) was out of service and should be fixed.

Photo E53 Typical Traffic Gate with Gong. The traffic gates of the new construction and function as expected. Note that the gong on NE traffic gate did not work at time of the inspection.

Photo E54 Damaged SE Traffic Gate Arm. Note the dent on the gate arm with a red tape is the result of the impact by a vehicle.

Photo E55 Typical Traffic Gate Enclosure. The equipment inside the gate enclosure is in as-new condition.

Photo E56 Typical Traffic Gate Motor and Hand Crank Limit Switch. The components are in as-new condition. Note that the gate is provided with a hand crank limit switch (arrow).

Photo E57 Typical Pedestrian Gate. The pedestrian gate is used to stop pedestrian during the bridge operation. The Pedestrian gates are in as-new condition. Note that the pedestrian gate and signal control are not in the traffic control sequence so that the operator can stop the pedestrian before stopping the traffic.

Photo E58 Typical Pedestrian Gate Enclosure. Note that the length of wires inside the gate is excessive in such a small enclosure. Otherwise the gate is in as-new condition.

Photo E59 Typical Barrier Gate. Note the newly installed barrier gate, including arm light flasher and gong. The gate is in as-new condition.

Photo E60 Barrier Gate Receiver. Note the wooden fencing around the receivers for temporary protection. Note that due to the independent of the pedestrian gate operation, the pedestrian can possibly come close to this receiver while the barrier gate is lowering. The wooden fencing was created after the barrier gate installation during the rehab but permanent railing should be provided to keep the pedestrian away from the receiver pocket.

Photo E61 Typical Barrier Gate Enclosure. The barrier gate is in as-new condition. Note that the hand crank handles and drill adapter are laying on the bottom of the enclosure.

Photo E62 Typical Cable Reel (North Shown). Provides power and control for electrical equipment on the movable span. Note the corrosion throughout the cable reel body.

Photo E63 Typical New Aerial Cables Installation (East Shown). The aerial cables were replaced during the recent rehab project. The new aerial cable is the self-supported type and there has been some damage among the cable assemblies due to movement under the wind loads. The aerial cables have been temporary tied together with ropes to mitigate damage. A solution in the form of the installation of aerial cable spacers was underway at the time of the inspection.

Photo E64 Typical Aerial Cable Spacer Installation (West Shown). The contractor is in the process of installing the aerial cable spacers.

Photo E65 Typical Aerial Suspension Cables Routing. Sufficient bending radius has been created for the aerial cable before routing into the cable tray.

Photo E66 Typical Aerial Suspension Cables on Cable Tray. The aerial cables are well supported and spaced inside the cable tray.

Photo E67 Bridge Access Control System. The bridge is provided with access control system to prevent unauthorized access to the bridge facilities. The access control system was operational at the time of inspection and provides an effective means of ensuring that only authorized personnel can gain access to the facility.

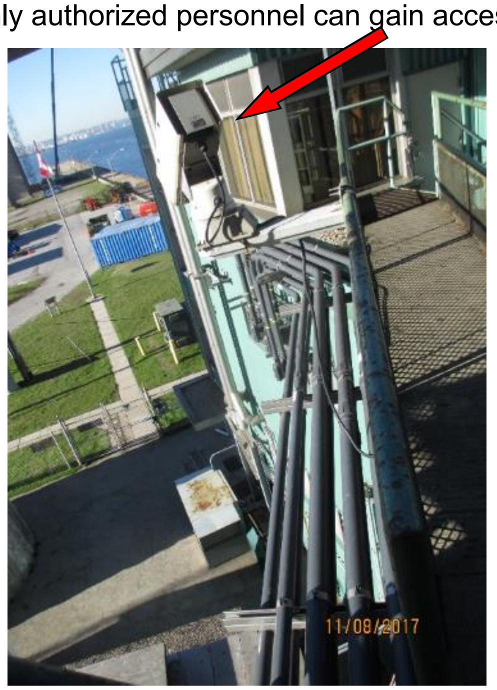

Photo E68 CCTV System. The CCTV cameras are strategically located throughout the bridge to monitor the roadway approaches, waterway approaches and main access areas to the bridge. The operation can monitor all these location from the operator’s room via a CCTV monitor. The camera installation was found to provide good visual information and had been well installed.

Photo E69 Typical Air Horn. The air horn is operational and is in serviceable condition. Note the corrosion on the air horn housing.

Photo E70 Typical Bonding. The raceway system bonding is well installed and conform to the CSA standard.

Photo E71 Exit Light. The casing of the Exit light in the generator room was damaged. Otherwise all exit lights are in working order.

Photo E72 Existing Mobile Generator Disconnect and New Junction Boxes. Note the mobile generator disconnect with receptacle was the original installation. The disconnect switch and generator receptacle have never been used.

Photo E73 General Lighting and Smoke Detectors (South Tower Shown). The space lighting and fire system equipment is the original installation. They are adequately installed to provide safe work place. Note the cover over the top of the south drive/resistors is the indication of the roof leak. Immediate action should be taken to repair the roof leak in order to keep bridge operating reliably.

Photo E74 Typical Outdoor Raceway Installation. The newly installed conduit and stainless steel pull boxes are in as-new condition.