CITY OF VICTORIA

JOHNSON STREET BRIDGE

ELECTRICAL/MECHANICAL CONDITION REPORT

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March 1990
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1.0 BACKGROUND

1.1 Johnson Street Bridge consists of a dual-span (road and rail) bascule bridge. The bridge was originally designed and constructed in 1921/1922 and has served the City of Victoria since that time. During the peak harbour activity periods of the 1960s and 1970s, the bridge was reportedly utilized as often as 50 to 75 cycles (raised/lowered) per day. However, in recent years, usage has dwindled to perhaps an average of 3 to 5 cycles per day.

The bridge operating systems are essentially identical to those installed in 1921/1922. Electrical control equipment in the operator's booth was upgraded to more modern standards in the early 1970s. Additional safety interlocking with traffic signals was added at this time. The mechanical equipment and configuration are essentially as installed in 1922.

The bridge underwent an extensive structural investigation and upgrade in the late 1970s.

1.2 The City of Victoria requested Robert Freundlich & Associates Ltd. to conduct an investigation into the electrical and mechanical condition of the bridge. Scope of work included review of available drawings and background data on operational history of the bridge, review of safety interlocking and overall bridge operating procedures, visual inspection of accessible electrical and mechanical equipment with a view to present condition and immediate and long-term repair or upgrade requirements, and a general observation of overall operation under various conditions.

1.3 Numerous site investigations were conducted in late 1989 and early 1990. This report highlights the findings of those investigations, makes recommendations for maintenance and repair of existing facilities, and provides comments on various factors associated with bridge operations.

1.4 This report consists of a summary of recommendations (Section 2.0) followed by detailed discussion of findings and expanded details of recommendations (Sections 3.0 through 6.0).
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2.0 SUMMARY OF RECOMMENDATIONS

The following is a summary of the recommendations for improvements and upgrades of the safety, mechanical, and electrical systems for the bridge.

2.1 Safety:

1. Upgrade safety railings, platforms, and ladders to current standards with particular emphasis on operator access requirements for inspections, lubrication, and maintenance.

2. Thoroughly clean machinery rooms, equipment, and storage areas. Revise engine fuel systems. Establish an enforced policy on storage of flammables. Prohibit smoking in machinery rooms. Consider improvements to machinery room ventilation.

3. Provide safety equipment, including life jackets, hard hats, vests, and safety belts consistent with operation and maintenance requirements.

4. Revise lubrication point manifolding to ease operator access during lubrication.

5. Install personnel guards over exposed gearing which is in operation during engine-driven raising of the rail bridge. Upgrade machinery room walkways/railings. Add additional protective railing in road bridge machinery room.

6. Train and enforce operator safety procedures with particular emphasis on inspection and lubrication requirements.

2.2 Mechanical Systems:

1. Investigate and repair, as required, the engine for auxiliary operation of the road span bridge. This work must precede Item .2.

2. Further investigate nature of bent shaft and damaged bearing on main drive mechanism of road span. These investigations will define the requirement for: repair of existing shafting or manufacture of a new shaft; manufacture of a new bearing shell; and related removals/installation. We consider this work to be urgent and that it must be carried out as soon as possible.
2.0 SUMMARY OF RECOMMENDATIONS (cont.)

2.2 Mechanical Systems (cont.):

.3 Carry out immediate mechanical systems maintenance in the following areas:
   - Tighten all fastenings.
   - Inspect all bearings, record all bearing clearances, and record condition of bearing shell.
   - Adjust all brakes, and tighten all brake fastenings. Clean and install new oil in all brake dashpots. Repack dashpot seals as required. Ensure smooth, proper operation of brake mechanisms.

.4 Thoroughly clean all accumulated grease, grit, and dirt from all gears, brakes, shafts, keyways, and bearings. Following this, a thorough cleaning of the machinery room floors and wall spaces adjacent to machinery should also be conducted. Following clean-up, thoroughly inspect all teeth, gears, hubs, shafts, keyways, etc. for potential damage. (Note: Thorough inspections could not be carried out during investigations due to heavy coat of thick grease/oil blocking visual access to all mechanical machinery.)

.5 Establish and enforce a mechanical preventive maintenance procedure. This must include logging of maintenance investigations and results.

2.3 Electrical Systems:

.1 Adjust the brakes to reduce the amount of travel as per item 2.2.3. Coordinate adjustment of the motor brake interlock switches to ensure that they operate correctly. Verify interlocking with motor controls. (Road span interlocks do not function properly.)

.2 Add interlock switches on the emergency brakes to prevent the possibility of attempting to run the motors with the brakes engaged.

.3 Carry out immediate maintenance of all aircraft warning hazard lights installed on the bridge.

.4 Install protective covers on exposed limit switch terminals on brake solenoids.

.5 Replace old 2-wire ungrounded receptacles in both machine rooms with grounded receptacles.
2.0 SUMMARY OF RECOMMENDATIONS (cont.)

2.3 Electrical Systems (cont.):

.6 Clean, inspect, and test windings of main drive motors and locking pin motors. Log results. Clean/renew and adjust brushes, brush holders, and slip rings as required. Overhaul motors if necessary. Alternatively, establish preventive maintenance program for motors.

.7 Renew cabtire flexible connection on the junction box above the machinery room.

.8 Repair the broken conduit on the southeast pier below the operator's cab.

.9 Provide instruction label on the ground fault lights in the operator's cab and instruct the operators on the purpose of these indicator lights.

.10 Reconnect the ground conductor on the south motor of the road bridge.

.11 Investigate source of intermittent fault on rail span motor (limits operation to low speed). Probable cause is out-of-adjustment limit switch or general grease/grime on contacts and brushes/slip rings.

.12 Establish and enforce an overall electrical preventive maintenance program. This must include logging of maintenance investigations and results.

2.4 General Observations

.1 We noted several "water/dirt traps" throughout the bridge structure. These traps, some of which are growing vegetation (or ??), contribute to accelerated deterioration of the structural steel. We suggest cleaning as a minimum, and possibly the addition of drain holes to prevent water accumulation.

.2 At several locations where bolts are installed to replace rivets, we noted rusting and indications of bolt movement. Again - all bolts, whether machinery or structure, should be checked for tightness.
3.0 EXTENT OF INVESTIGATIONS

3.1 Mechanical system investigations were confined to reasonably accessible equipment which could be observed by routine access to machinery rooms or along maintenance ladders and pathways. Machinery observations were confined to visually observable equipment with the exception of several bearing caps being removed for condition assessment. All equipment in the mechanical rooms is heavily coated with grease, oil, dirt, and grit. This prevents reasonable inspection of gear teeth and ends of bearing shells. Selected bearings and selected gear teeth were cleaned up to permit detailed inspection of certain items. However, an overall clean-up and inspection for obvious defects should be carried out as part of on-going routine maintenance.

3.2 As part of our mechanical investigations, we requested and received permission to bring in an outside consultant for a one-day overview of the bridge machinery. Mr. Dan Campbell of Crippen & Associates in Vancouver provided his experienced overview and comment on any major items which he observed or felt required further investigations. Mr. Campbell carried out a one-day inspection of the bridge in conjunction with our Mr. Barry Wright. A copy of the resulting Crippen report, along with our comments on Crippen observations/recommendations, is included as an appendix to this report.

3.3 Electrical investigation included visual inspections of all accessible electrical equipment, cable routing, conduit runs, flexible joints, controls, etc. The insulation resistance of the four motors was measured by Alliance Power, who were engaged in brake repairs at the time. Feeder insulation resistance was measured by the City electrical department who also assisted in the examination of brushes and slip rings on the motors.

Operators were interviewed and their comments noted with regard to problems with the operation of the bridge.

There were no items tested which could be defined as being faulty and requiring immediate attention. However, some of the test results were marginal, particularly in the case of motors, and our recommendations include cleaning of these devices followed by further testing to determine condition. Investigations included functional testing of existing operational and safety equipment which interfaces with the overall electrical control system.
3.0 **EXTENT OF INVESTIGATIONS** (cont.)

3.4 There are certain areas of the electrical and mechanical systems which were not thoroughly inspected for reasons of inaccessibility. There is no reason to doubt that these inaccessible areas are in good operating condition. However, we recommend that the following items be inspected as part of other works or general maintenance:

.1 Connection of rack teeth (bolt/rivet fastenings) to main rack throughout the rack length of both bridge spans. Also inspect rack teeth for damage throughout the rack length. (Requires time to operate bridges in small increments to check/observe.)

.2 Main trunion bearings (requires heavy lift for cap removal and subsequent inspection of shaft and bearing condition).

.3 Electrical drive motors (require internal inspection, cleaning, and bearing condition evaluation by experienced motor repair shop).

3.5 There are several areas where additional observations and checks should be made during and following the various recommendations. In particular, fastener maintenance and general clean-up are required to permit complete observation of shafts, gears/gear teeth, bearing shells, and machinery supports. In general, these on-going observations and condition assessments can be conducted by maintenance personnel unless some special or questionable condition arises.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS

4.1 Maintenance Program:

.1 Existing mechanical systems have had virtually no preventive maintenance in recent years. Equipment condition has deteriorated to the point where increased operating problems should be expected and, in some cases, items have deteriorated to the point of being non-operational or prone to major failure with associated equipment damage. This condition must be corrected immediately, and steps must be taken to prevent ongoing recurrence.

.2 Following equipment upgrade in accordance with other recommendations contained in this report, we strongly recommend that a scheduled preventive maintenance program be established and enforced for the mechanical systems equipment on the Johnson Street Bridge. This program should include a formalized monthly checklist and inspection requirements, a quarterly work program of actual maintenance work to be carried out, and an annual detailed inspection program. The maintenance inspections should be accompanied by a checklist and logging method to maintain a record of current conditions of various critical components. In this manner, a track record can be established and changes in components noted with the passage of time. This will allow scheduling of major repairs.

4.2 Urgent Repairs:

Reference the mechanical equipment schematic drawings which accompany this report.

.1 Road Span Auxiliary Drive Engine. Discussions with operating personnel indicate that the auxiliary engine has not been used to raise the bridge for at least three years, and possibly for as long as eight years. During our investigations, attempts to operate the bridge with the auxiliary engine indicated that there was insufficient engine power to effect the raising or lowering of the bridge. There was no immediately apparent reason for this except for lack of engine power. This problem must be resolved immediately, with initial concentration on the engine itself.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.2 Urgent Repairs (cont.):

.1 Road Span Auxiliary Drive Engine (cont.). Once the engine is in proper running order, if problems still persist, then the engine drive gearing should be investigated for possible binding or excess loading. (There is no obvious problem. The equipment works "normally" on electric drive.)

The second problem with the auxiliary engine is the lack of a speed control governor. This presents a dangerous situation and invites engine overspeeds unless the operator is extremely attentive during attempts to raise and lower the bridge. We recommend that a proper speed governor be added to this engine or, as a minimum alternative, that a spring return-to-idle position be added so that the throttle must be hand-held into the fast position and would automatically return to low speed in the event that the operator released the throttle.

.2 Road Span Shaft S1112 and Bearing B12 (Drawing E-1). Bearing B12 was observed to be oscillating approximately 1/2" on its mount housings. The mount tie bolts were found to be loose, with approximately two turns to bring them up to finger tight. The mating main 6" diameter drive shaft, identified S1112, is suspected of being bent in the area of the final drive pinion or immediately adjacent to bearing B12. As a result, the final pinion to bull gear tooth mesh oscillates severely (once per shaft revolution). Attempts to fully tighten the B12 mounting bolts must be avoided, as this will remove the present strain relief point for the bent shaft. (Further investigations should be carried out to confirm the bent shaft, but these are deferred until the engine problem of 4.2.1 above is resolved.)

This condition has existed for some considerable time, probably many years. It has probably been brought on by some sort of shock loading at some point in the bridge's past history. The duration of operation in the present mode is unknown. However, our investigations suggest that it has been going on for many years at present rates of bridge operation.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.2 Urgent Repairs (cont.):

.2 Road Span Shaft S1112 and Bearing B12 (cont.). The condition does represent a potential danger to long-term use of the bridge. In the event that the condition is allowed to persist, fatigue failure in the mounts or mount bolts of bearing B12 are a distinct possibility. Alternatively, a failure in the drive shafting is a possibility. Either of these would result in loss of tooth mesh, possible damage to pinion and gear, and additionally a potential for damage to the main bridge structure. While it is tempting to permit the operation to continue under the present conditions and to monitor for any change, we believe that the risk of continued operation under these conditions is too great. We recommend that shaft S1112 be replaced (or repaired if feasible) and that bearing B12 have a new inner shell manufactured.

Replacement of the shaft and bearing will necessitate bridge closure, even with pre-manufacture of major items. The bridge must be locked either down or up, depending on the marine vs. highway conditions. Some of the manufacturing process final machining will have to be conducted after the existing shaft and bearing are removed. Also, the pinion will be removed with the existing shaft, cleaned/inspected, and then reassembled onto the new (or repaired) shaft. This will require several working days (4 to 7 estimated).

We curtailed our detailed investigations of this item due to lack of ability to locally operate the bridge on slow engine drive. Some further investigations should be pursued before detailed planning of the shaft/bearing replacement.

.3 Rail Span South Motor Pinion/Gear Engagement. The motor pinion (G1) to gear (G2) engagement is too tight. This causes: bearing loading on the motor shaft bearings B1 and M1; noticeably accelerated tooth wear; and significant engagement noise during operation. There is an associated problem in that gear G2 has a loose keyway and the gear oscillates on the shaft during operation, contributing to cyclic "growling" noise.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.2 Urgent Repairs (cont.):

.3 Rail Span South Motor Pinion/Gear Engagement. (cont.)
We recommend that gear G2 keyway be replaced with a proper key that will permit tightening of the gear to the shaft. We further recommend that the south motor M1 be repositioned to properly align the pinion G1 to gear G2 and to achieve correct centre to centre distance for proper tooth engagement. During this work, the motor bearings should be thoroughly inspected and the motor cleaned and tested as recommended in Section 5.2.

4.3 General Upgrade and Repairs:
The following are items which are an accumulation of lack of maintenance over the years. These items should be immediately upgraded to the recommended status, and then an on-going preventive maintenance program implemented.

.1 General Clean-Up. There is excess grease and associated grit located at all bearings, all grease points, the sides of all gearing, drive shafts, floor, etc. This accumulation prevents reasonable inspection, invites problems with dirt entering the bearings or gear teeth, and contaminates brake shoes. It also represents a safety hazard from the point of view of potential fire, particularly associated with the brakes. (Brakes engaged (e.g. failed solenoid) during operation get VERY hot.)

We recommend that the entire machinery room and equipment receive a thorough high-pressure wash and steam clean to remove all existing grease build-up that has accumulated over the years. Clean-up would be most effective on a "hot" summer day when grease is soft. Clean-up will probably require extensive hand work along with steam and/or solvent washes. Extreme care must be taken during this clean-up as fire hazard will be high and work area will be very slippery. Catchment of "grunge" must be planned to avoid spillage and waterway pollution. Following this clean-up, a thorough inspection of all gears and bearings should be undertaken and any observations logged in a permanent log record book.

Similar clean-up of lock equipment, major trunion bearings, and rack teeth should also be done.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.3 General Upgrade and Repairs (cont.):

.2 Brakes. During our investigations, we found that virtually all brakes in both the rail and road spans were badly out of adjustment, some to the point of causing imminent failure or actual failure of motor brake solenoids. This condition will undoubtedly lead to premature wear and failure of brake solenoids (e.g., October 1989 solenoid failure). It is also a dangerous condition in that, in some cases, the brake adjustment was so bad that the brakes were relatively useless. For the most part, this condition has been corrected by mechanical personnel during the course of our investigations. All brakes have presently been adjusted to the point of proper operation and reasonable clearances for the solenoids.

Loose and sloppy assembly bolts have been tightened on some brakes, while others still require maintenance attention. Keeping bolts tight requires on-going attention, particularly where solenoid dampers are not functioning. When adjusting/checking solenoids, auxiliary switches must also be checked/adjusted for correct operation.

Brake shoes should be removed and thoroughly degreased, particularly where there is evidence of excess grease having gotten onto the brake linings. Grease procedures must be revised to eliminate over-greasing of brake assemblies.

.3 Brake Solenoid Dampers. All brakes are equipped with an oil damper (shock absorber) to prevent sudden application of the brakes when the solenoids are de-energized and to prevent shock loading of the solenoids during energization. All dampers were found to be virtually totally inoperative due to loss of oil over time. The dampers are simple mechanical devices which appear to be highly rugged and quite capable of being maintained in an operational mode. It would appear that the only requirement is a general clean-up. In some cases the shaft packing will require replacement to prevent on-going oil loss. The dampers should then be filled with a multi-grade oil. We recommend initial test operation using grade 10W-30 viscosity to accommodate the temperature changes during the seasons. Subject to testing, other viscosities may provide more suitable operation.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.3 General Upgrade and Repairs (cont.):

.4 Hand Brakes. Of the four brake hand-release devices on the two bridge spans, only one was operational at the commencement of our inspections. One was repaired during our inspections. The other two require attention to put them into operational condition.

.5 Bearing Assessments (Not Including Road Span Bearing B12).

.1 The bridge mechanical machinery includes some 60-odd plain bearings located on the bridge lock pin motor drive assemblies and on the main machinery equipment for raising and lowering the bridges. Our investigations included inspections of about nine of these bearings, with conditions ranging from good to excellent through extremely poor.

.2 Good engineering practice would normally dictate that all bearings that are sub-standard should be repaired or replaced to bring them into good operating condition. For ideal conditions of extended equipment life and optimum reliability, we would normally recommend that this be undertaken. However, we estimate that this will require approximately one-half to two-thirds of the existing bearings be reconditioned or remanufactured. This would be an extremely costly and time-consuming undertaking.

.3 There are indications that several of the badly out-of-tolerance bearings have, in fact, operated in this condition for many years and possibly throughout the life of the bridge. There did not appear to be any serious damage to mating shaft journals or to gear teeth as a result of these deteriorated bearings. Unfortunately there are virtually no track records of bearing replacements or bearing rework during the life of the equipment. It is impossible to tell whether bearing deterioration or out-of-tolerance conditions have developed in recent years or whether the equipment has, in fact, been operating with this condition for extended periods.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.3 General Upgrade and Repairs (cont.):

.5 Bearing Assessments (cont.)

.4 As an option to the optimum recommendation of total upgrade of all substandard bearings, we suggest that condition monitoring of all bearings on an on-going basis should be considered. The City must recognize that there are increased risks associated with continued operation of the equipment with out-of-tolerance bearings. However, we believe that these risks are, in fact, relatively low. Therefore, as a lower cost/moderate risk alternative to total bearing upgrade, we recommend that all bearings be thoroughly inspected and condition/clearances be checked and logged. Any conditions of major deterioration or damage which might progress to associated equipment failure should be repaired immediately.

Following this procedure, the bearings should be inspected on an annual basis, clearances checked, and results again logged. A comparison from year to year would indicate any deterioration occurring in any given bearing, and repairs could then be scheduled when necessary. We believe that, at present operating frequency of the bridge, this procedure could result in 5-15 years of operation without a significant number of bearings requiring repair or replacement. We believe the cost/risk of this procedure to be more viable than total bearing upgrade. However, it is important that the inspections/checks/logging be religiously carried out.

Mechanical maintenance staff should be capable of carrying out and recording these inspections and evaluations and of determining when deterioration warrants repair.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.3 General Upgrade and Repairs (cont.):

.6 Fastenings. Our investigation revealed extensive loose nuts and bolts throughout the machinery equipment. Of the bolts actually checked (approximately 10%), almost all were not properly tightened. This applies to bearing mounts, bearing caps, and equipment mounting bolts. It also is particularly applicable to the various bolts associated with the brake operating solenoids. These bolts work loose very quickly due to hammering of the solenoids, caused partially by the lack of oil in the dampers as previously noted.

It is imperative that all mechanical equipment fastening devices receive immediate attention. This should include inspection of bolts and nuts. Any worn or damaged bolts should be replaced. (Refer to item 4.2.2 for exception to tightening bolts.)

Proper maintenance tools should be permanently located in the machinery rooms.

.7 Lock Stands. Guides and rollers on lock stands require on-going inspections for wear, with particular attention to the road span. Road span pin engagement is presently somewhat sloppy, and guides and rollers should be shimmed to ensure tight engagement. All components should be inspected on an annual basis and kept in tight working order. Worn guides and rollers should be repaired or replaced. Check bent signal actuator arm on rail span and monitor for further deterioration.

.8 Travel Limits. There is a large discrepancy between the upward travel electrical limit switches and the mechanical stops of both bridge spans. In fact, the mechanical stop position would result in damage to walkways and guard rails in the event that the bridge was operated to the point of contacting the mechanical stops. While there is good merit to some overtravel between the electrical limit switch and the mechanical stop (to allow deceleration and manual stopping of the bridge, if possible), we question the amount of this overtravel. There may be some unknown (to us) reason for the present set-up. We recommend that this subject be reviewed and, in the absence of other factors, the mechanical stops should be repositioned to perhaps 4 to 6 feet beyond the electrical limit switches.
4.0 MECHANICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

4.3 General Upgrade and Repairs (cont.):

.8 Travel Limits (cont.). One of the mechanical stops is noted to be loose and ineffective. This requires immediate attention.

.9 Main Structure Bearings. The various main structure trunion bearings, rack mount ends, and pivot points that are located throughout the bridge structure (external to machinery rooms and lock pin drives) were generally examined for signs of obvious distress or problems. There were no apparent defects or observations which result in major concerns. However, all of these devices should have fastenings tightened and all excess grease, grit, and grime removed from the exteriors of the bearing shells. On-going annual preventive maintenance should include visual inspection of operation and clearance checks of the bearings at each of these points.

4.4 Lubrication Considerations:

.1 The present lubricating practices are apparently effective in that there is no obvious equipment deterioration due to lack of lubrication. Brush oiling of the machinery gears is highly effective as evidenced by limited wear, even where tooth mismatch is evident. However, this procedure requires good access to gearing and contributes to grit/grime and related need for clean-up maintenance.

.2 The rack teeth do not get lubricated properly throughout their length. We believe there are effective spray lubricants which could be simple to apply and effective for extended periods on rack teeth.

.3 We recommend that the lubrication methods/materials be reviewed by a lubrication specialist (consultant or manufacturer's representative). There may be improved methods or materials which would be more suited to the application and would result in less lubricant "mess" in the machinery spaces. This subject is beyond our area of expertise.

.4 The present procedures result in needless overgreasing of the brakes. This contributes to grease accumulation on the linings and also constitutes a fire hazard if brakes overheat. Brake greasing intervals should be reduced and accompanied by clean-up of excess grease.

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5.0 ELECTRICAL SYSTEM COMMENTS AND RECOMMENDATIONS

5.1 Maintenance Program:

.1 Electrical system maintenance does not seem to have been neglected to the same degree as mechanical systems. However, there is ample evidence of maintenance requirements which should be receiving routine attention.

.2 We strongly recommend implementation of a scheduled preventive maintenance program as referenced under Mechanical System, Items 4.1.2 and .3. This program should include electrical systems procedures, checks, tests, inspections, and record-keeping.

5.2 Drive Motors:

Resistance tests carried out during the course of our investigations indicate some concerns with some of the drive motors, although results are still within acceptable levels. We suspect that low resistance readings may result from the generally dirty and greasy condition of all of the motors.

We recommend that all motors receive a thorough cleaning and an evaluation by an independent motor repair shop. Evaluations should include bearing condition, winding condition, and brush condition. During this evaluation, there may be merit to authorizing minor repair or in-place upgrades during the course of the investigations (e.g. brush replacement or spring replacement). Following this procedure, resistance tests should again be taken. If abnormally low results are indicated for any given motor, the motor should be scheduled for removal and rewind.

The bearing condition evaluation may precipitate requirement for removal and repair. At the present time there is no indication that the condition of motor bearings requires immediate attention, although the thrust bearing in the south rail motor is somewhat suspect. As noted under mechanical conditions, there is some rectification work to be carried out in this area, and the condition of this thrust bearing should be evaluated again following this mechanical adjustment work.
5.0 ELECTRICAL SYSTEM COMMENTS AND RECOMMENDATIONS (cont.)

5.3 Observations disclosed a number of minor electrical items which require maintenance or minor upgrading for safety/code reasons. These are identified in Section 2, Summary of Recommendations.

5.4 Operators have reported an intermittent fault on the rail span which results in limiting motor operation to minimum speed. This may have been caused by out-of-adjustment brakes which made limit switches intermittent. (Rail span brakes/switches were adjusted during our February investigations.) Cause could also be general oil/grease contamination of motor brushes/slip rings.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS

6.1 Access:

Our observations of the bridge lubrication procedure indicates a major safety concern. Lubrication of the various machine elements requires access throughout the bridge structure on a weekly basis. This is presently carried out by one experienced operator, who has been conducting this procedure for many years and who has developed a well-established technique to access the various points. However, the ladders, platforms, and guard railings which exist along the lubrication route do not comply with good safety practices. Also, the location of the various lubrication points requires some considerable degree of skill and agility (under less-than-ideal conditions) to access the lubrication connection points.

We strongly recommend an overall safety upgrade be implemented, with particular attention paid to the following points:
- Add safety hoops to all ladders.
- Add kick rails to all walkways and platforms.
- Add/improve safety guards at lock machinery.
- Re-manifold all lubrication points so that grease fittings can be accessed from service platforms in a normal standing position.
- Establish a safe routing to each lubrication or inspection point. Document the routes and lubrications/observations.
- Install safety lock-outs at all machinery locations.
- Ensure that a minimum of two operating personnel and two mechanical maintenance personnel are well trained and thoroughly familiar with lubrication and inspection procedures and access routes at all times.

6.2 Safety Equipment:

Operators should be equipped with safety belts, life jackets, hard hats, and portable communication equipment under all conditions of movement on the bridge structure. Additionally, the bridge itself should be equipped with life buoys and throwing rings.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS (cont.)

6.3 Fuel Storage:

Both the road and rail span machinery rooms include gasoline-powered engines for auxiliary lift. Gasoline is stored in small storage tanks elevated above the individual engines. Replenishment of fuel must be done by hand from hand jerry cans, which are carried up the access ladders and then poured into the fuel tanks. This whole situation is an inherently dangerous condition and invites potential disaster.

We recommend as follows:

.1 Remove engine fuel tanks from within the machinery room and relocate them outside the enclosure. Ensure tank vents are routed away from accessible areas. Provide convenient filling method, including consideration of manual transfer pump to conveniently fill tanks in a safe manner. Install manual shut-off valves at each tank outlet, followed by a fusible-link fire valve.

.2 Install new piping from fuel tanks to engine location. This piping should be copper tubing run within flexible conduit for protection. Conduit should be identified as fuel pipe.

.3 Install new flex hose connection between end of copper tube and engine fuel inlet. This hose to be single- or double-braided and fire rated hose approved for gasoline fuel delivery.

.4 Permanently eliminate the storage of gasoline (and equivalent low-flash-point fluids) within the machinery rooms.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS (cont.)

6.4 General Storage:

The machinery rooms are used for storage of fuel (noted above) and lubricants, as well as related maintenance equipment. This includes rags, cleaning materials, open pots of gear lubricant, lubricating brushes, grease guns, etc. Again, this is an inherently dangerous condition in the event of fire, and it is imperative that steps be taken to minimize the possible risk. There is no question that materials must be stored someplace and, due to the nature or location of the machinery rooms, it is impractical to consider storage in another location. There will always be inherently a need for some degree of petroleum products to be stored within the machinery rooms. However, the present storage procedures must be upgraded to reduce the risk of disaster.

We recommend that an oil- and dust-tight, heavy gauge metal cabinet be installed for storage of petroleum products, including greases and oils. This cabinet must be permanently vented to the exterior of the room.

Clean cleaning rags should be stored in a separate elevated wire-mesh container. Used cleaning rags must not be stored within the machinery rooms but must be placed in a separate container and removed from the room immediately following use. Oily and greasy rags must not be allowed to accumulate in the machinery spaces. Likewise with other refuse, e.g. empty grease containers, paper towels, and general working debris. These must be removed from site at all times.

6.5 Smoking:

During our observations, it was apparent that operating and maintenance personnel routinely smoke in the machinery rooms. This should be banned immediately. Signs should be posted and no-smoking rules strictly enforced.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS (cont.)

6.6 Open Gearing

There is extensive open gearing and shafting in both the rail and road span machinery rooms and in the under-bridge lock motors. Access to gearing is required for brush lubrication which is carried out weekly. It is impractical to provide full covers over all gears, as these would necessitate removal on a weekly basis. However, the existing personnel protection is poor. Machinery room platforms should be upgraded to include kick plates and better railings or wire mesh guards. The road span machinery room should include personnel guard rails between the electrical panels area and the adjacent gearing. This area is an excellent observation and work area, but personnel presence in this location during bridge operation is potentially dangerous, and additional protective measures should be incorporated.

During engine operation of the rail span, it is presently necessary for the equipment operator to work immediately adjacent to open gearing while raising and lowering the bridge and while engaging the necessary gearing for engine operation. This open engine gearing urgently requires removable safety covers and guards to prevent personnel contact with operating gearing. Procedures demonstrated during our observations are "an accident waiting to happen."

We recommend that the present practice of having the rail span auxiliary gearing disengaged under normal conditions be continued. However, when engine use is contemplated and gearing is engaged, then it must be protected by guards and covers. Likewise, the open engine flywheel should be equipped with a personnel guard. The engine radiator fans in both machinery rooms do not include safety guards, and these should be added.

Incorporation of the above items will still not provide a totally safe work place within the machinery rooms. The recommended items merely provide upgrading to some reasonable minimum standard. However, danger to operating or inspecting personnel will still be high and is inherent to the nature of effectively working within the gear room. It is imperative that all personnel be aware of these dangers and that appropriate precautions be taken during inspections and observations.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS (cont.)

6.7 Safety Cut-Outs:

Operating and maintenance personnel working within the machinery rooms are presently relying on teamwork/word of mouth for proper safety procedures. Personnel are not knowledgeable in how to de-energize the electric solenoids and motors and, in general, this procedure is not done before working in the equipment spaces. Personnel appear to rely solely on the good memory of the operator in the main control booth. We recommend that a simple overall safety cut-out switch be added, located at the door of each machinery room. This switch should de-energize controls, motors, solenoids, etc. to permit safe operation within the machinery rooms. All personnel should be made aware of the cut-out and its purpose.

6.8 Stored Energy:

During our investigations, we found that there can be a considerable amount of stored mechanical energy in the machinery room gearing after the bridge is locked in the down position. This stored energy is potentially dangerous to personnel conducting investigations or carrying out shaft/bearing/gearing maintenance. It is important that maintenance personnel be aware of this situation and that a proper procedure be established to relieve residual stored energy in the mechanical shafts and gearing. This is done by simultaneously releasing all four brakes to allow the machinery stresses to dissipate. It is imperative that this procedure be done prior to working on equipment.

6.9 Communication:

The lack of communication between the machinery house and the main operator booth is a major handicap to successful operation and maintenance of the bridge. We recommend that a high quality radio communication system be installed immediately. This should include a mobile pack and headset which can be used in the machinery rooms or by the operator when out on lubrication rounds. This will permit direct communication between various points on the bridge and the main operating booth.
6.0 GENERAL AND SAFETY OBSERVATIONS AND RECOMMENDATIONS (cont.)

6.10 Fire Detection:

Fire is one of the greatest disaster threats to the bridge machinery room and equipment. At present we consider the machinery rooms to be at significant risk, and fire damage is likely to extend to adjacent structural damage. Other measures recommended herein should significantly reduce this risk. However, the machinery rooms should probably include some form of fire detection and alarm system. In view of access time and the nature of the rooms, detection alone may be ineffective and should probably be supplemented with an automatic extinguishing system. We recommend this subject be further investigated following implementation of other clean-up and safety improvements.