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"A Proposed Scope for Movable Highway Bridge Machinery Inspection",Charles Birnstiel, Consult'g Engr, New York

A PROPOSED SCOPE FOR MOVABLE HIGHWAY BRIDGE MACHINERY INSPECTION

by

CHARLES BIRNSTIEL
Consulting Engineer, Forest Hills, NY 11375

ABSTRACT

A scope-of-work description for the inspection of movable bridge machinery and controls is proposed in this paper in response to a perceived need for greater uniformity of such inspections and concomitant reports. The level of inspection described is characterized as intermediate. The proposed inspection is consistent with the intent of the FHWA Bridge Inspector's Manual for Movable Bridges, but less machinery disassembly and simpler field data reporting is advocated. It is considered suitable for the biennial bridge inspection program.

In addition to the scope-of-work, general checklists covering most types of movable bridges are included. They are presented under the following headings: Preparation for Inspection, Bridge Operation, Span Drive Machinery Inspection, Movable Span Stabilizing System Inspection, Electrical System Inspection, and Traffic Control Devices. A recommended format for the report is presented together with broad definitions for rating equipment.

INTRODUCTION

The trend to engage engineering subconsultants for movable bridge machinery inspection primarily on the basis of cost proposals has created a need for development of a standardized scope of work, especially for the inspections performed as part of the national biennial bridge inspection program. Some states do not have a standard specification for inspecting the mechanical and electrical machinery and in other states very brief requirements are distributed with the requests for proposal. This situation is in marked contrast to the State requirements for superstructure and underwater inspections which are often very detailed. The loose requirements for machinery inspection could lead to unfairness in subconsultant selection.

Lack of standardization in field inspection and report preparation also reduces the effectiveness of the inspection programs, particularly the biennial bridge inspection program. The administrative procedures in the agencies charged with supervising inspections have changed significantly during the past two decades. Now the inspection reports are reviewed and decisions are made about a movable bridge by administrators who may have only a cursory knowledge of the bridge. For this reason more extensive reporting of the field inspection actually performed is being required and pressure has developed for standardized rating of individual mechanical and

electrical components of movable bridges. Apparently, the ratings are considered necessary for the systematic allocation of maintenance and rehabilitation funds.

In this paper a proposed scope of work for an intermediate level machinery inspection is presented. It is intended for use in the biennial bridge inspection program for highway bridges but could readily be adapted to railway bridges. The scope is based primarily on experience with movable bridges in the New York City metropolitan area, and is being incorporated by Iffland Kavangh Waterbury, P.C. in a specification for inspection service procurement for New York State.

Because the mechanical and electrical machinery as installed differs so much from bridge to bridge the scope cannot simultaneously be completely general and all inclusive. It is offered here as a focus for discussion by engineers, Department of Transportation officials, and equipment suppliers and installers. The intent is that it should serve as a draft from which a standard scope for machinery inspection and reports could be developed.

SCOPE OF WORK - GENERAL MOVABLE HIGHWAY BRIDGE MACHINERY INSPECTION

The proposed scope of work definition will be presented in two parts; a scope statement that briefly describes the tasks to be accomplished and checklists that define the extent of the effort in more detail. The matters of rating equipment and reporting will be discussed after the checklists. The proposed scope statement follows immediately.

Scope of Work Statement

The mechanical machinery and electrical equipment associated with operation of the movable spans will receive a thorough visual inspection with measurements. Included in the inspection are the mechanical or hydraulic span drive, the movable span stabilizing system, the vehicular traffic and navigation control devices, and the electrical controls for this equipment. In addition to visual inspection, measurements of specific mechanical components and certain electrical characteristics will be made.

The inspection will be in consistent with the intent of the Bridge Inspector's Manual for Movable Bridges published by the Federal Highway Administration (hereinafter termed the Manual). The overall scope will be as implied in the Manual, but less machinery disassembly and measurements will be required and the field data will be presented more concisely. On the other hand, electrical measurements and tests that are not described in the Manual, but which have been found valuable in assessing movable bridge behavior, are included.

The thorough visual inspection of the mechanical and electrical systems includes the following tasks:

- Task A. Preparation for Inspection. Prior to actual field inspection the team leader will visit the bridge in order to become familiar with the machinery and assess inspection difficulties. The available mechanical and electrical drawings for the bridge will be reviewed in order to determine the probable layout of the machinery,

installed dimensions of the gear teeth, and the electrical schematics. The dates of inspection will be coordinated with the Owner so that arrangements can be made to have bridge operators available for test openings and maintenance personnel available for disassembling mechanical and electrical components.

- Task B. Bridge Operation. Bridge operation will be observed in the normal operating mode to check for smoothness of operation, excessive vibration, seating impact, interference between movable and stationary parts of the bridge, controllability of the moving span, and the effectiveness of stabilizing machinery and traffic control devices. During bridge operation observers will monitor the machinery for abnormal noises and vibration. The sequence of operation at the control desk will be observed.

  The power and current drawn by the span drive motors will be measured and recorded on a strip chart during at least one opening/closing cycle. The position of the leaf corresponding to the measured current and power will be automatically recorded on the chart paper at intervals. The objective of these tests will be to detect excessive imbalance of the moving leaves, control deficiencies, severe binding of machinery, and electrical problems.

  A checklist which defines this task in more detail is presented in this paper.

- Task C. Span Drive Machinery Inspection. Every moving and stationary component of the span drive will be visually inspected. The type of components inspected depend on the type of movable bridge but, generally, the inspection will include brakes, speed reducers, open gearing, drive shafts and couplings, bearings, mounting bolts, sheaves, wire ropes, and hydraulic equipment. Typical components will be opened and cleaned by the Owner's maintenance personnel (as recommended by the Subconsultant) in order to enable the Subconsultant to measure the thickness of gear teeth, gearset backlash, gearset clearance, bearing clearance, and observe the condition of wearing surfaces. However, no shafts will be removed from their bearings nor will couplings be opened which would require major items of machinery to be moved in order to gain sufficient axial clearance for separation of coupling halves. Samples of the oil in speed reducers will be taken for spectrographic analysis. Lubrication patterns on the gearing will be observed to assist in assessing imbalance and misalignment.

  The following measurements will be made as part of this task:
  1. Gear teeth thickness at pitch line (chordal or span measurements).
  2. One measurement of backlash and clearance for each accessible gearset.
  3. Diametral clearance of sleeve bearings.

  The mechanical linkages and operation of the brakes will be inspected as will the brakewheels. Wheel/shoe clearances will be measured with the brakes hand-released and set. Spring lengths will be measured with the brakes set.

  Shafts will be visually inspected for cracks at keyways and for movement between coupling hubs and shafts. Alignment of shaft couplings will be observed.

  All parts will be inspected for loss of section due to corrosion and wear, and signs of distress or pending problems.

  A checklist which further defines this task is presented in this paper.

- Task D. Movable Span Stabilizing System Inspection. The mechanical components that stabilizes the movable span when it is in motion and at rest will be inspected. Depending on the type of movable bridge, these include treads and tracks, span locks, and centering devices, buffers and live load reactions, trunnion, wheels and axles, center and end lifts, span guides, and counterweight wire ropes, sheaves, and adjusting devices. As with the drive system, typical components will be opened by Owner's maintenance personnel to enable the Subconsultant to inspect the internals and make measurements.

  As part of the stabilizing machinery inspection the following measurements will be made:
  1. Live load shoe clearances of bascule spans with the span in the fully closed position (if accessible without the use of scaffolding).
  2. Relative movements of the leaves under traffic at midspan of double-leaf bascule bridges.
  3. Movements at, or guide/socket clearance of, tail locks.
  4. For vertical lift bridges, movements of the lift span with respect to the towers when the bridge is in the closed position after a normal cycle of opening and closing.

  The trunnions of vertical lift bridges which support counterweight sheaves will be inspected visually and by means of ultrasonic testing instruments. Ultrasonic testing will be performed by a recognized testing laboratory experienced in this work.

  A checklist which defines this task in more detail is presented in this paper.

- Task E. Electrical System Inspection. The major electrical components on the load side of the service disconnect will be visually inspected. Span drive motors will be observed while running to check bearings and for excessive vibration. The motors will be meggered. Brushes, commutators, and slip rings will be inspected. The installation and components of contactors, circuit breakers, overload, and drum switches will be examined. The brakes will be inspected for thrustor or solenoid operation, limit switch operation, and deterioration of wiring. Navigation lights and traffic control devices will be inspected.

  Operability of accessible limit switches will be determined and interlock limit switches will be subjected to a simulated test where appropriate. The control desk will be examined to assess operability of control switches, meters, dials, indicating lights, and safety with respect to misoperation and unauthorized operation.

  The exposed portion of the submarine cable will be inspected for corroded armor wires and other damage. The electrical insulation resistance of submarine cable conductors will be measured.

  A checklist which defines this task in more detail is presented in this paper.

- Task F. Traffic Control Devices. Traffic lights, warning gates, and resistance gates will be inspected for structural condition, operation, and effectiveness in stopping vehicular traffic. Layout of traffic control devices will be recorded for comparison with the USDOT Manual of Uniform Traffic Control Devices, or the corresponding State manual.

  A checklist which further defines this task is presented in this paper.

Not within the scope of this inspection are bridge house and roadway lighting, house heating, plumbing, HVAC, and architectural and structural features. Electrical feeders from the utility service point to the service switch and utility owned transformers are also not included in the inspection.

Checklist - Bridge Operation

A. Visual and Audible Observations

Observe one or more cycles of bridge operation, when run in the normal manner, and note the following:

- o Unusual noises indicative of interference between the moving and fixed parts of the bridge.
- o Smoothness of motion and controllability of the movable span.
- o Abnormal noises or excessive vibration of the span drive machinery.
- o The angle of opening for each leaf of bascule bridge. Measure maximum angle as bridge is normally opened. Compare this value with reading of the position indicator on the control desk.
- o Effectiveness of traffic control devices.
- o Sequence of operation at control desk. (See also electrical system inspection checklist.)

B. Performance Tests

During one or more operating cycles measure the single phase power and the current drawn by each normal span drive motor. Record both power and current on a strip chart and instrument such that paper position is automatically related to opening angle of leaf or draw.

Checklist - Span Drive Mechanical Machinery

A. Span Drive Diagram

Show all components of main and emergency drive train. Designate all open gearing, shafts and couplings, bearings, enclosed speed reducers, wire rope drums and sheaves, clutches, brakes, and motors.

B. Brakes

Observe the following and enter findings on specific field data sheet:

- o Shoe/brakewheel clearances when brake is hand released and when set.
- o Brakewheel surface condition.
- o Axial alignment of shoes and brakewheel.
- o Condition of key and keyway. Is hub tight on shaft?
- o Brake lining thickness.
- o Condition of brake linkage.
- o Spring extension when brake is set (measure).
- o Brake cover.
- o Space heater.
- o Mounting bolts.

C. Speed Reducers

Remove inspection covers and inspect:

- o Inside of housing; cleanness, corrosion and other damage.
- o Lubricant level if oil lubricated box. Take samples of oil for laboratory analysis.

- o Troughs, in splash lubrication systems.
- o Gears; for wear and corrosion.
- o Effectiveness of location and fastening of any internal pressure lubrication piping.

Replace inspection covers using gasket compound and inspect:

- o *Housing mounting bolts.*
- o Inspect bearing caps and seal covers and note bearings which leak lubricant.
- o Measure diametral clearance of sleeve bearings as described under "Bearings".
- o Pump and lubrication piping, inspect for leaks.

D. Open Gearing

Remove inspection covers, or permanent covers if necessary, and inspect:

- o Gears. Note lubrication, gear wear, and percentage of face width contact. Look for cracks in rim, spokes, and hub of gear. If split gear, inspect bolts connecting gear halves. Measure tooth thickness at pitch line (span measurements).
- o Gearsets. Note amount of axial misalignment and measure backlash and clearance.
- o Keyways in shafts. Are gears tight on shafts?
- o Bearings of open gearsets in frames. Measure plain bearing clearances as described under "Bearings". Remove seal covers as necessary.

E. Rack and Pinions of Bascule Bridges

Inspect as for open gearing just described but in addition:

- o Pay special attention to rack and pinion teeth that are in contact when the bridge is closed. Measure the thickness of these teeth by the chordal method.
- o From the lubrication pattern on rack teeth, note whether leaf is span-heavy or counterweight-heavy and for what range of opening.

F. Bearings

Determine whether plain or antifriction bearing. Inspect:

- o Cap and base castings for cracks.
- o Mounting and cap bolts.
- o Structural members supporting bearing base.
- o Lubrication fittings.
- o Seals.
- o Measure diametrical clearance of plain bearings.

G. Shafts

Inspect shafts for the following:

- o Cracks at keyways and at areas adjacent to hubs of gears and couplings.
- o Other damage which could act as stress raisers.
- o Excessive vibration when running.

H. Couplings

Determine type of coupling; flexible grid, gear, jaw or spline, rigid, or other. For all types inspect hubs, keyways, keys and setscrews. In addition:

For flexible grid couplings:

- o Inspect overall noting condition of cover, bolts, and seal leakage.
- o Remove cover (cover may be flanged or have horizontal split).
- o Examine lubrication seals. Note amount of lubrication present on grid.
- o Check alignment of adjacent hubs.
- o Inspect grid for breaks or cracks. With finger lightly stroke exposed edge of grid wire to feel for defects which may not be visible due to presence of lubricant.
- o Add lubricant if necessary.

- o Replace cover.

For gear couplings:

- o Listen for noise during operation.
- o Inspect flange bolts.
- o Inspect seals, note leakage.
- o Determine if coupling contains lubricant by removing lubricant fill plugs.
- o If there is evidence of serious misalignment of the coupling, or noise during operation, separate coupling halves and inspect gear teeth on hub and coupling half.

For jaw or spline couplings:

- o Inspect exposed parts of jaws or splines for cracks or excessive deformation.

For rigid couplings:

- o Inspect flange bolts.
- o Inspect joint between flange and shaft; whether hub or one piece forging.

I. Clutches

Determine type of clutch; dry-friction, wet-friction, toothed, etc. Inspect:

- o Hubs, keyways, keys, and setscrews.
- o Listen for unusual noises during operation that may indicate slippage of friction plates or improper engagement of gears.

J. Wire Rope Drives

Make reeving diagram and inspect:

- o Wire ropes around drum or sheave for proper wrapping pattern, rope lubrication, wire breaks, fatigue cracking, and wire corrosion.
- o Wire rope terminations for wire breaks, and corrosion at sockets.
- o Adjusting devices. Check condition of threaded rods and traveling nuts.
- o Drum and sheaves. Look for cracks at juncture between ribs and rim, and rib and hub.
- o Keys and keyways in drum/sheave shaft.

K. Hydraulic Machinery

Obtain manufacturer's maintenance manual for equipment and follow directions for specific component.

Checklist - Movable Span Stabilizing System

A. Stabilizing System Diagram

Prepare diagram of movable span stabilizing system. Designate components. Equipment shown will vary depending on type of movable bridge. Contents of typical diagrams for various bridge types are as follows:

- o Center Bearing Swing Bridges
  - Pivot and rest piers
  - Center bearing
  - Center lifts and drives
  - Balance wheels and track
  - End lifts and drives
  - Centering and latches/mechanisms
  - Buffers
- o Rim Bearing Swing Bridges
  - Pivot and rest piers
  - Cross section showing drum girder, tapered tread plates, tapered wheels,

tapered plate, stool/base casting, rack, live ring, axles, and pivot post.
End lifts and drives
Centering latches/mechanisms
Buffers

- Scherzer Bascule (Rolling Lifts)
  - Tracks and the treads on bascule girders
  - Midspan shear locks and drives
  - Tail locks and drives
  - Live load reactions
  - Buffers
  - Leaf centering device
- Trunnion Bascules with Fixed Counterweight
  - Trunnions and bearings
  - Midspan shear locks and drives
  - Tail locks and drives
  - Front live load reactions
  - Rear live load reactions
  - Buffers
  - Leaf centering device
- Trunnion Bascules with Moving Counterweight (Strauss)
  - Trunnions and bearings
  - Midspan shear locks
  - Tail locks and drives
  - Live load reactions
  - Buffers
  - Leaf centering device
  - Counterweight trunnions and bearings
  - Parallelogram linkage and bearings
- Vertical Lift Bridges
  - Main counterweight with sheaves, trunnions, wire ropes (number, size, and construction).
  - Auxiliary counterweights and ropes, etc.
  - Span locks
  - Buffers (upper and lower)
  - Vertical guide rails, guide shoes, and guide rollers
  - Centering devices

B. Midspan Locks (Bascule Bridges)

Inspect midspan lock drive in a manner similar to span drive machinery inspection. In addition:

- Measure movement between mating leaves at midspan as traffic rolls over bridge.
- Observe movement of lock bar in lock bar guides and sockets. Measure clearance between bar gibs.

C. Live Load Reactions

- Inspect sole plate, strike plate, shims and fasteners.
- Determine if screws of adjustable reactions can be rotated.
- Measure clearance between sole plate or adjusting screw and strike plates with bridge closed and machinery wound up in the normal manner.

D. End Lifts and Center Lifts (Swing Bridges)

Inspect end lift and center lift drives in manner similar to span drives. In addition:

- o Observe condition of wedges and wedging surfaces and lubrication.
- o Measure amount that structure is lifted (record temperature).

E. Center Bearings of Swing Bridges

- o Listen for unusual noises during draw rotation.
- o Check lubrication, take oil sample.
- o Inspect external surfaces looking for signs of distress.

F. Balance Wheels and Tracks of Swing Bridges

- o Measure clearances between balance wheels and track with bridge in closed position and center wedges withdrawn and end lifts retracted.
- o Inspect top of track for damage and misaligned segments.

G. Rim Bearings of Swing Bridges

- o Inspect joint between bottom flange of drum girder and tread plate. Check for relative radial movement. Also check fasteners connecting tread to flange inside and outside of drum girder web.
- o Inspect tread plate for cracks.
- o Measure clearance between top of each tapered wheel and tread plate with draw in closed position in order to determine which wheels are not bearing (not taking load).
- o For wheels not bearing in closed position, check to determine if these wheels are also not bearing when the draw is in the open position.
- o Clean and inspect 10 percent of tapered wheels for cracks in rim, ribs, and hub.
- o Inspect axle lubrication hole and plug.
- o Inspect track plate for cracks.
- o Inspect fasteners holding track plate to stool and rack to stool.

H. Live Ring of Rim Bearing Swing Bridges

- o Inspect channels and structural members of live ring paying attention to field connections between segments.
- o Observe clearance between tapered wheels and outer member of live ring. Are wheels rubbing against ring?
- o Inspect nuts at outer ends of radial rods. Are they loose?
- o Inspect all radial rods/axles.

I. Pivot Post

- o At each rotating central plate of live ring measure diametral clearance between plate rubbing surface and post journal (if jacking is not required).
- o Check for lubrication of these bearings.
- o Inspect anchor bolts.
- o Inspect connections between radial members and pivot post and stool.

J. Centering Latch/Mechanisms of Swing Bridges

Determine if device is automatic gravity-operated centering latch or positive centering mechanism. Observe operation during bridge opening and closing. Inspect:

- o Mounting of latch/mechanisms to structure.
- o Socket on rest pier; condition of anchor bolts, shock absorbing spring, and socket mouth.
- o Counterweight lift arm.

K. Tail Locks (Bascule Bridges)

Inspect tail lock drive in manner similar to span drive machinery inspection. In addition:

- o Do guides and sockets have gibs?
- o Measure clearance between lock bar and guide and socket bearing surface.
- o Observe lubrication of guide and sockets. Is there a lubrication station?

L. Span Locks (Vertical Lift Bridge)

Inspect span lock drive in manner similar to span drive inspection. In addition:

- o Is span lock a part of the span centering mechanism?
- o Measure clearance between lock bar and socket.
- o *Observe lubrication of bar.*

M. Buffers

Determine if buffers are air-operated or hydraulic. For air-operated buffers observe:

- o For buffers mounted in the moving span observe if the piston rod descends smoothly as the span is raised. During closing listen for escape of air from cylinder as piston compresses air.
- o For buffers mounted on lift bridge towers, inspect piston rod finish. As lift span reaches end of upward travel listen to escaping compressed air. Are buffers operating uniformly?
- o Observe automatic cylinder lubricator; is it dripping oil at a reasonable rate?
- o Inspect intake air filter.
- o Inspect mounting bolts.
- o Inspect strike plates.

N. Counterweight Sheaves & Trunnions

- o Station observer at each counterweight sheave prior to start of test run. Observer should listen for "cracking" sounds at start of sheave rotation and during rotation.
- o Inspect counterweight ropes; look for lubrication condition, wire wear, and wire breaks.
- o Inspect sheave for cracks in rim, ribs, and hub.
- o Inspect trunnions by ultrasonic means (work by recognized laboratory).

P. Guide Rails, Shoes, and Rollers

Inspect:

- o Guide rails; look for corrosion and condition of fastening to tower.
- o Shoes for wear and lubrication.
- o Excessive guide rail/shoe clearances.
- o Rotation of rollers. Lubrication.

Checklist - Electrical System Inspection

A. Incoming Power and Main Distribution

Examine incoming power source and determine:

- o If alternate utility feeder is provided and is operational and whether alternate feeder is from a second power source.
- o Whether a diesel generator or other emergency or secondary source is provided and operational.
- o If automatic or manual transfer of the primary and secondary source is provided.

Inspect exposed or accessible components of the incoming fused switches, transfer switches and or circuit breakers.
Where incoming power and distribution are provided on a separate panelboard or switchboard, inspect the panelboard or switchboard in a manner similar to the inspection of Control Switchboards, Control Panels and Motor Control Centers.
Observe the adequacy and condition of the system ground conductor, terminals and electrode.
Check that the service equipment, main distribution equipment, span drive electrical equipment, and all metallic structures are adequately bonded.

B. Span Drive Motors

External inspection. Record nameplate data and observe:

- o Condition of frame and motor mounts.
- o Condition of shaft.
- o Electrical wiring to motor and motor auxiliaries.
- o Operation of disconnect switch. Check disconnect switch safety interlocks, contacts, connections, and wiring.
- o Tachometer generator and overspeed switch for thyristor controlled motors.
- o Insulation resistance of stator and rotor windings (measure).
- o Condition and wiring of secondary resistors. (Also check primary resistors for thyristor controlled motors).
- o Noise or vibration during operation, indicating worn or damaged bearings or rotor imbalance.

Internal inspection. Remove inspection covers and inspect:

- o Internal housing, shaft, and rotor iron for corrosion or excessive dirt.
- o Brushes for excessive wear, scoring, chipping or arcing.
- o Brush holders and assemblies for corrosion, carbon or dirt build-up, proper alignment, and brush tension.
- o Collector rings for wear, scoring, carbon or dirt build-up.
- o Brushes and rings with motor running.
- o Bearings and bearing seals.

C. Brakes

Inspect and observe:

- o Thrustor motor or solenoid.
- o Operation, wiring, and contacts of limit switches.
- o Insulation resistance of thrustor motor (measure and record).
- o Condition, operation, wiring, and contacts of disconnect switch.

D. Control Desk

Observe:

- o Desk for cleanliness and corrosion.
- o All control components observing physical condition and identification.
- o By-pass switches. Note status and whether locking devices are provided.
- o Operation of indicating lights and control switches, and operation and accuracy of meters and indicators while bridge is operating.
- o Bridge Operator's handling of controls and sequence of operation with special attention to the seating of bascule or lift spans and the centering of swing spans.

E. Control Switchboards, Control Panels and Motor Control Centers

Observe:

- Condition and mounting of structure or enclosure. Also look for corrosion or dirt build-up.
- For proper personnel clearances and work spaces.
- For installation of rubber mats in front of live-front panels.
- For proper identification of components and their accessibility.
- Condition of bus, wiring, terminals, and connections.
- For freedom of movement of contactors and relays. Manually operate.
- Older contactors and relays that permit disassembling. Remove arc chutes and check for cracking or signs of burning. Check condition of contacts. Check cores or armatures for corrosion. Check condition of coils.
- Physical condition of circuit breakers. Manually operate and observe ease of operation.
- Condition of contacts, arc chutes, and springs of circuit breakers that can be opened.
- Condition and operation of knife switches. Observe ease of operation and condition of contact surfaces.
- *Protective devices such as fuses, overload relays, and circuit breakers and check for proper sizes.*

F. Span Lock Drive Motors

Inspect:

- Frame and motor mounts.
- Electrical wiring to motor and motor auxiliaries such as disconnect switches, brakes, and limit switches.
- Insulation resistance; measure and record.
- Disconnect switches and switch safety interlocks, when provided.
- Limit switches that are easily accessible.

G. Clutch Drive Motors

Inspect motors and auxiliaries in the same manner as the span lock drive motors.

H. Limit Switches

For rotory span control limit switches and position transmitters observe:

- Gear or chain and sprocket drive assemblies.
- Switch and transmitter enclosures and mountings.
- Conduit and cable connections to switch and transmitter.
- Contacts, wiring, and connections and also observe the condition of the interior of limit switch. (Remove cover).

For span seated limit switches check:

- For proper location and position of switch and switch actuator.
- Condition of switch actuator.

I. Conduits, Cables, Boxes and Wiring

- Inspect the physical condition of visible conduits, cables, and boxes.
- Open a representative sample of the terminal and junction boxes and all submarine cable and aerial cable terminal boxes and check the condition of the box interior, wiring, terminals and connections. Check for corrosion, evidence of moisture, and proper identification of wires and terminals.
- Inspect jackets of movable cables (festooned or looped) for abrasions or cracks and proper support.

- o Observe movement of cables during bridge operation. Note any possible obstruction or excessive stress or rubbing.
- o Inspect the visible portions of the submarine or aerial cables for the condition of armor or jacket, cable supports, and entrances to terminal boxes.
- o Measure and record the insulation resistance of the conductors of the submarine cables.

J. Navigation Aids

Observe and check:

- o Physical condition of the navigation lights and air horn and compressor.
- o Devices for proper placement and secureness of mountings.
- o Wiring to navigation aids.
- o Operation of lift mechanism of bascule span lights or mid-span lights (for lift spans).
- o Internal wiring and lamp holders of navigation lights.
- o Operation of navigation lights and air horn.
- o That bascule span lights or midspan lights are switched from red to green when the span is fully open. What is condition for the amount the span is normally opened?

K. Traffic Gates

For all electrically operated warning and resistance gates, open gate housing door, and:

- o Observe the physical condition and mounting of the motor, disconnect switch, and limit switch.
- o Check contacts on limit switch and disconnect switch.
- o Check internal wiring and connections.
- o Check for proper grounding.
- o Check for proper operation of manual operation interlock switch, when provided.
- o Measure and record insulation resistance of gate motor.

L. Obstruction Lights

Observe the physical condition, mounting, wiring, and operation of the obstruction lights.

M. Traffic Signals

Observe the physical condition, mounting, wiring, and operation of the traffic lights, hazard warning beacons, pedestrian bells, and traffic gongs.

Checklist - Traffic Control Devices

A. Traffic Control Device Layout

Measure widths of roadways, medians, sidewalks to nearest foot and record on sketch. Locate all traffic control devices with respect to movable span floor breaks (to nearest 5 feet). Sketch should show movable span, floor breaks, piers supporting movable span, channel, north arrow, direction of vehicular traffic flow, and the following traffic control devices (if present):

- o DRAWBRIDGE warning signs, and hazard warning beacons.
- o Traffic signals, stop signs, white stop lines, Stop-Here-On-Red signs, and gongs.
- o Warning gates.
- o Resistance gates.

B. Signals

Inspect, photograph, and record condition of:

- o DRAWBRIDGE signs.

- o Hazard warning beacons.
- o Traffic signal heads, standards, and bridges. Note size and number of lenses, operating condition, and exposed wiring.
- o Stop-Here-On-Red signs and white stop lines.
- o Gongs.

C. Warning Gates

Inspect, photograph, and record condition of:

- o Roadway and sidewalk arms. Arm material? Are arms level when closed; vertical when open? Height of arm above roadway? Color of coating on arms? Type of coating?
- o Housing and mounting bolts. Clearance between curb and housing? Color of housing?
- o Obstruction lights. Operational? Are there steady red lights at roadway arm tips?

D. Resistance Gates

Inspect, photograph, and record condition of resistance gates.

- o Are resistance gates normally used during bridge openings?
- o Type of gate (pintel, semaphore, drop) and whether motorized or manual.
- o Structural and mechanical condition of gate.
- o Is there a lock on free end? Lock condition when open and closed?
- o Are there obstruction markers on side of gate facing traffic?
- o Color of gate and housing?
- o Distance of gate/housing from curb when gate is open?

MECHANICAL AND ELECTRICAL EQUIPMENT RATINGS

As stated previously, condition ratings of the individual mechanical and electrical components and subsystems, and overall ratings for the movable leaf machinery, are desired by some States. The objective of these requirements is to make the reporting for the mechanical and electrical equipment consistent with that presented for the superstructure and the underwater inspections, especially that part entered into a computer data bank.

In order to obtain consistency in reporting by various inspectors, it has been proposed by others that very specific criteria be published for the rating of the individual mechanical and electrical components likely to be found on movable bridges. The argument is that it has been done for superstructure and underwater diving inspections -why not for machinery. However, because of the wide variety of mechanical components and electrical devices on existing bridges the development of such criteria is, in the author's opinion, a formidable task. Many mechanical, hydraulic, and electrical devices are much more complex than structural elements and correlating the many possible defects to a numerical rating system does not appear practicable. The author suggests that the rating of the individual components be left to the judgement of the inspector, team leader, and project engineer. In New York State the system used by some subconsultants is:

Rating No.	Condition Description
1.	Potentially Hazardous.
2.	Used to shade between a Rate of 1 and 3.
3.	Serious deterioration, or not functioning as originally designed or device missing.

4. Used to shade between a Rate of 3 and 5.
5. Minor deterioration and is functioning as originally designed.
6. Used to shade between a Rate of 5 and 7.
7. New Condition.
8. Not Applicable.
9. Unknown.

The ratings for individual components are utilized by some DOT's in their maintenance program. They should also be utilized in deciding on the overall movable bridge machinery rating.

The overall movable bridge machinery rating is the most valuable rating from an administrative viewpoint, and hence the consistency of this rating from bridge to bridge is important. The following tentative descriptions are offered as guidelines for selecting the overall rating numbers:

- **Rating 1 - Potentially Hazardous.** Deterioration or damage to span drive or stabilizing machinery which could cause movable span to become imminently unstable in any position. Malfunction or deterioration of electrical system which could cause loss of control of the moving span. Deficiency in electrical system design, maintenance, or operational procedure which could cause loss of control of moving span. Inoperable vehicular traffic control device. Also, extreme cases of defects listed under higher rating numbers. Bridge may not be opened to marine traffic. If problem is with stabilizing machinery in the closed position, temporary shoring or supports may be necessary to permit safe vehicular traffic over the closed bridge at reduced speed or rating. However, if problem, is with counterweight components of vertical lift bridge stabilizing machinery, bridge may be closed to all traffic until shored or repaired.

- **Rating 2 - Very Serious Deterioration.** Deterioration or damage to machinery which will not cause imminent instability of a non-redundant span drive but reduces allowable load on drive and may cause future instability if not corrected. Stabilizing machinery damaged, deteriorated, or improperly operated such that movable structure is not properly supported causing structure not to behave as designed and resulting in structural overstress and movements under vehicular traffic that severely affect ride quality. Severe misalignment of stabilizing machinery, resulting in overload of electrical system and consequent overstressing of span drive machinery. Severe interference between moving span and fixed structure due to substructure movements. Deterioration of electrical control system such that many of the safety interlocks are normally by-passed, inconsistent control of moving span, and inoperable or missing traffic control devices. Operation of movable span may be restricted in terms of opening angle, number of openings, and allowable wind velocity. If problem is with stabilizing machinery, shoring may be necessary to permit vehicular traffic.

- **Rating 3 - Serious Deterioration.** Severe wear, deterioration or damage to span drive or stabilizing machinery due to overloading, inadequate maintenance, improper operation, or movement of structure or substructure. Electrical system malfunctions and numerous safety interlocks are by-passed. Results in inconsistent, noisy, and unreliable operation of movable span. Improper closure, affecting structural action and vehicular ride quality. Electrical system has archaic components for which replacements are no longer available and open bus panelboards that are considered unsafe nowadays.

- **Rating 4 - Moderate Deterioration.** Excessive wear, some damage, and deterioration of span drive or stabilizing mechanical machinery. Repairs and replacement of some machinery components required. Bearings may need liner adjustment. Machinery may be

misaligned due to shifting of structure and substructure but not enough to seriously overload span drive: correctable by adjusting machinery component location using shims, etc. Replacement of corroded machinery fasteners required. Moving span usually under control but some indicating and safety devices may be inoperable and by-passed, and span limit switch may need adjustment.

- **Rating 5 - Minor Deterioration.** None of the major mechanical machinery components are worn or damaged to the extent that replacement is now required. Some components of span drive may need to be replaced, such as flex-coupling grids, brake linings, etc. Span stabilizing machinery functioning except that wear may have caused excessive clearances in lockbar guides, etc. Shimming of lockbar guides, replacement of limit switches and adjustments necessary. Machinery needs cleaning, painting, lubrication and adjustment. Electrical system generally functioning as designed. Replacement of some relays, indicating devices, and lights may be required. Traffic control devices need repair maintenance.

- **Rating 6 - Almost New Condition.** No extensive repairs required. Machinery needs cleaning, painting, lubrication, and adjustment. Electrical system functioning as designed; may need replacement of indicating lights and minor switches, cleaning of relay contacts, and housekeeping in panelboard. Traffic control devices functioning but may need replacement of obstruction lamps, object makers, painting of housings, lubrication and adjustment of limit switches.

- **Rating 7 - New Condition.** Virtually no repairs required. Mechanical machinery may need cleaning, touch-up painting, and lubrication. Electrical system and traffic control devices functioning but may need replacement of bulbs and minor housekeeping.

REPORT

As indicted previously, more emphasis seems to be placed on reports and report format in recent years. The new technology for word processing and reproduction has probably contributed to this situation. However, standardization of the report format also aids in the State review process. A suggested report specification follows.

Report Scope

The results of the entire movable bridge inspection effort will be presented in a report. Five copies of the report will be submitted to the State. Each will contain original color prints or color xerox copies. The typical arrangement of the report will be as follows:

1. Cover Sheet
2. Bridge Data and Location Map
3. Rating Summary Sheet
4. Table of Contents, List of Tables, List of Figures
5. Description of the mechanical, electrical, and traffic control systems including diagrams of the span drive machinery, the stabilizing machinery and the traffic control devices.
6. Discussion of the condition of the mechanical and electrical components emphasizing defects and corrective measures.

7. The traffic control devices will be evaluated in accordance with the NYSDOT Manual of Uniform Traffic Control Devices.
8. Recommendations for in-depth inspections of inadequate components where appropriate and a listing of defects and items that require attention.
9. Photographs of the general arrangement of machinery, electrical equipment, and traffic control devices. In addition, photographs of defects will be presented where appropriate.
10. Major components of the mechanical and electrical systems and the traffic control devices will be rated according to the State numerical condition rating system. Guides to selection of the ratings are presented in this paper. The rating will be based solely on the visual observation. No numerical stress analysis will be made.
11. The performance test strip charts will be annotated to illustrate significant features, reproduced at reduced size, and included in the report.
12. Mechanical Machinery Field Inspection Data Sheets.
13. Electrical Field Inspection Data Sheets.
14. Results of Outside Laboratory Analysis (Ultrasonic, spectrographic, etc.).

CONCLUSION

A scope-of-work description for the inspection of the mechanical and electrical components and systems of movable highway bridges has been proposed as a focus for developing a standard scope, especially for the biennial inspection program. The scope statement is supplemented by inspection checklists, report format, and guidelines for numerical rating of the mechanical and electrical equipment.

END