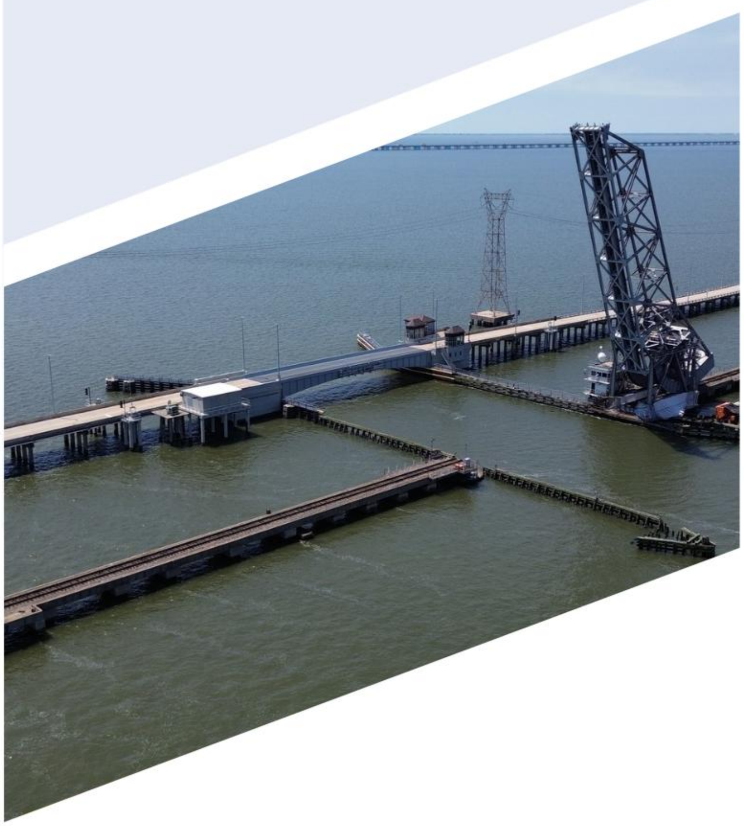
Louisiana Department of Transportation and Development

MOVABLE BRIDGE INSPECTION MANUAL



DOTD

LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

Louisiana Department of Transportation and Development

Section 51 – Bridge Maintenance

Movable Bridge Inspection Manual

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Prepared by

Forward

The primary goal of the Louisiana Department of Transportation and Development (DOTD) Movable Bridge Inspection Program is to ensure the safety of the traveling public. This manual outlines the procedures for inspecting publicly owned, operated, or maintained movable bridges carrying public traffic, as mandated by Louisiana Revised Statute 48:35 and 23 CFR 650.301 of the *National Bridge Inspection Standards* (NBIS). Additionally, it aligns with Section 1111 of the Moving Ahead for Progress in the 21st Century Act (MAP-21), requiring states to report bridge element-level data to the Federal Highway Administration (FHWA) for all highway bridges on the National Highway System (NHS).

This document provides a clear, sequential guide for inspectors, emphasizing consistency across intergovernmental agencies, the bridge engineering community, and bridge owners. It replaces the *LADOTD Movable Bridge Inspectors Program* and complements the following references:

- LADOTD *Bridge Inspection Manual* 2024 Edition (LADOTD BIM)
- LADOTD *Coding and Field Guide*
- LADOTD *Policies and Guidelines for Bridge Rating and Evaluation*
- FHWA *23 Metrics for the Oversight of the NBIP*
- FHWA *Bridge Inspector's Reference Manual*
- FHWA *Specifications for the National Bridge Inventory* (SNBI)
- FHWA *Federal Aid Off-System Highway Bridge Program Guidelines*
- All relevant EDSMs and other references outlined in this document
- AASHTO *Movable Bridge Inspection, Evaluation, and Maintenance Manual, 2nd Edition* (AASHTO MBI)
- AASHTO *The Manual for Bridge Evaluation, 3rd Edition* (AASHTO MBE)
- NFPA 70 *National Electrical Code* (NEC)

Table of Contents

List of Tables

List of Figures

Chapter 1
Bridge Inspection Principles and Overview

1.1 INTRODUCTION

This manual outlines the organization, administration, and operational procedures of DOTD Movable Bridge Inspections. It provides a systematic approach to inspecting movable bridge structures on, under, or over public highways, streets, and waterways, prioritizing public safety and infrastructure preservation. Inspecting movable bridges requires more preparation than fixed bridges, as it involves evaluating structural, mechanical, electrical, and architectural components.

1.2 ACRONYMS

The following is an alphabetically ordered list of acronyms used in this manual:

AC	Alternating Current
ADE	Agency Defined Elements
AGMA	American Gear Manufacturers Association
ANSI	American National Standard Institute
ATS	Automatic Transfer Switch
BIM	LADOTD *Bridge Inspection Manual*
BIRM	FHWA *Bridge Inspector's Reference Manual*
BITC	Bridge Inspection Team Coordinator
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations
CPU	Central Processing Unit
CS	Condition State
DC	Direct Current
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
FRP	Fiber Reinforced Polymer
GFCI	Ground Fault Circuit Interrupter
GRC	Galvanized Rigid Conduit
HID	High Intensity Discharge
HPS	High Pressure Sodium
HPU	Hydraulic Power Unit
HVAC	Heating, Ventilation, and Air Conditioning
I.D.	Inner Diameter

ISO	International Organization for Standardization
LED	Light Emitting Diode
LFMC	Liquid Tight Flexible Metallic Conduit
LPS	Low Pressure Sodium
LRFD	Load and Resistance Factor Design
MBE	AASHTO *Manual for Bridge Evaluation*
MBI	AASHTO *Movable Bridge Inspection Manual*
MCC	Motor Control Center
MH	Metal Halide
MTS	Manual Transfer Switch or Maintenance Testing Specifications (for Electrical Power Equipment and Systems)
MUTCD	FHWA *Manual on Uniform Traffic Control Devices for Streets and Highways*
MV	Mercury Vapor
NCHRP	National Cooperative Highway Research Program
NDE	Non-Destructive Evaluation
NEC	National Electric Code (NFPA 70)
NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
NHI	National Highway Institute
NOAA	National Oceanic and Atmospheric Administration
NSTM	Non-Redundant Steel Tension Member (formerly fracture critical member)
O.D.	Outer Diameter
PCB	Printed Circuit Board
PFD	Personal Flotation Device
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PSC	Pre-Stressed Concrete
PTFE	Polytetrafluorethylene
PVC	Poly Vinyl Chloride
RAC	Rigid Aluminum Conduit
RC	Reinforced Concrete
RC#	Running and Sliding Fit (where the number dictates fit tolerance)
RMS	Root Mean Square
SNBI	Specifications for the National Bridge Inventory
SPD	Surge Protective Device
TAN	Total Acid Number
TEFC	Totally Enclosed Fan Cooled
TENV	Totally Enclosed Non Ventilated
UPS	Uninterruptable Power Supply
USCG	United States Coast Guard

UT	Ultrasonic Testing
VFD	Variable Frequency Drive

1.3 PROCEDURES AND REQUIREMENTS

1.3.1 Types of Inspections

The primary inspection types for movable bridges are routine, in-depth, and NSTM, each with varying intensity. Initial inspections of new or rehabilitated movable bridges should be conducted at an in-depth level due to potential adjustment or break-in issues. See Chapter 4 of the LADOTD BIM for further information on the various inspection types and their requirements.

1.3.2 Qualifications

Movable bridge inspections require a coordinated team of structural, mechanical, hydraulic, and electrical inspectors, each meeting 23 CFR 650, AASHTO MBE, and AASHTO MBI requirements. The inspection team leader must have at least three years of movable bridge design, inspection, or maintenance experience. Lead inspectors for mechanical, hydraulic, and electrical disciplines require similar experience within their expertise. See LADOTD BIM Section 1.6 for structural inspector qualifications.

If qualifications are experience-based rather than engineering certification, inspectors must complete a comprehensive training course covering AASHTO MBE, MUTCD, and AASHTO MBI. A National Fluid Power Association certification may substitute for four years of hydraulic engineering experience. Inspectors covering multiple disciplines must have at least two years of movable bridge-specific experience per discipline.

1.3.3 Safety

Safety protocols for movable bridge inspections address three levels:

- Regulatory Compliance: Adhere to rules ensuring a safe workplace.
- Hazard Assessment: Identify and mitigate risks specific to each structure.
- Emergency Preparedness: Train personnel and establish response capabilities to minimize impacts should an accident or unplanned event occur.

Mechanical Safety

Mechanical inspections pose unique risks. Components, spans, and nearby machinery must be locked and tagged out during inspection (see Sections 1.3.4 and 4.5). Access to mechanical elements may require specialized equipment and training. Inspectors must develop an access and safety plan, stay clear of rotating machinery, pinch points, and falling objects, and establish clear communication protocols with bridge operators.

Electrical Safety

In addition to following standards dictated by NFPA 70E, ANSI, and OSHA, there are some basic, general safety practices that inspectors can undertake to prevent accidents due to human error. The following are some practices you can do when around electrical components.

- Be aware of your surroundings. Observe all points of contact around you and maintain proper clearances to prevent accidental contact.
- Enclosures may have multiple conductors, each with their own power source coming from separate places. Disabling power from one point in the circuit may not disable all power in an enclosure that receives power from multiple sources.
- Always stay focused when inspecting or servicing components. You may find other personnel want to engage in conversation or do other actions that distract you from your task at hand. Losing focus can make you become complacent and forget safety procedures. At the very least it can cause you to make simple mistakes like forgetting to flip a disconnect switch back on after turning it off to inspect it.
- If you're unsure if a component is de-energized, always verify. Non-contact voltage testers are an easy, cheap, and convenient way to tell you if a circuit is energized. Always test non-contact voltage testers by placing them near a receptacle or energized wire and confirming the audible/visual indication before checking a presumably deenergized circuit.

Electrical hazards can come in different forms. The basic forms of electrical hazards include electrical shocks, fires, and arc flashes. Electrical systems are designed to control the flow of electrical energy in an intended path: from the source through conductors, protective devices, and switching devices and then ultimately to the load where the energy is used. When electricity does not flow through the intended path, it will present a risk of injury or death to personnel and costly damage to equipment. Contributing factors to this danger are faulty wiring, corrosion, insulation damage, loose connections, missing or damaged grounding conductor, water, and actions of untrained personnel, e.g., contact of personnel with energized conductors, terminals, or busbars.

Skin burns may occur even from properly loaded and properly operating circuits. Conductors and terminals are commonly designed to allow for electrical heating up to 75°C (167°F). According to the ASTM C1055-20 "Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries" or high temperature metal surfaces, third degree burning of the skin may occur instantaneously upon contact with the surface.

Shock

An electric shock is a source of possible injury or damage to health associated with current through the body caused by contact or approach to exposed energized electrical conductors or circuit parts. The more current in an electric shock, the more likely it is lethal to personnel. Currents as low as 30 mA can cause ventricular fibrillation and death; these currents are readily available even on the smallest 120V circuits.

Shock protection consists of rubber insulating gloves with leather protectors and should be worn where there is a danger of hand injury from electric shock due to contact with energized electrical conductors or circuit parts. Rubber insulating gloves must be rated for the voltage for which the gloves will be exposed. Shock protection approach boundaries and further information can be found in NFPA 70E 130.4.

To reduce the hazard of injury, NEC (NFPA 70 110.26) requires electrical enclosures to have a minimum clear workspace around electrical enclosures. In the most common installations encountered on Louisiana bridges, 42 to 48 inches in front of the enclosure should be free of any obstructions or stored items. Any installation that does not meet this requirement should be noted as a deficiency.

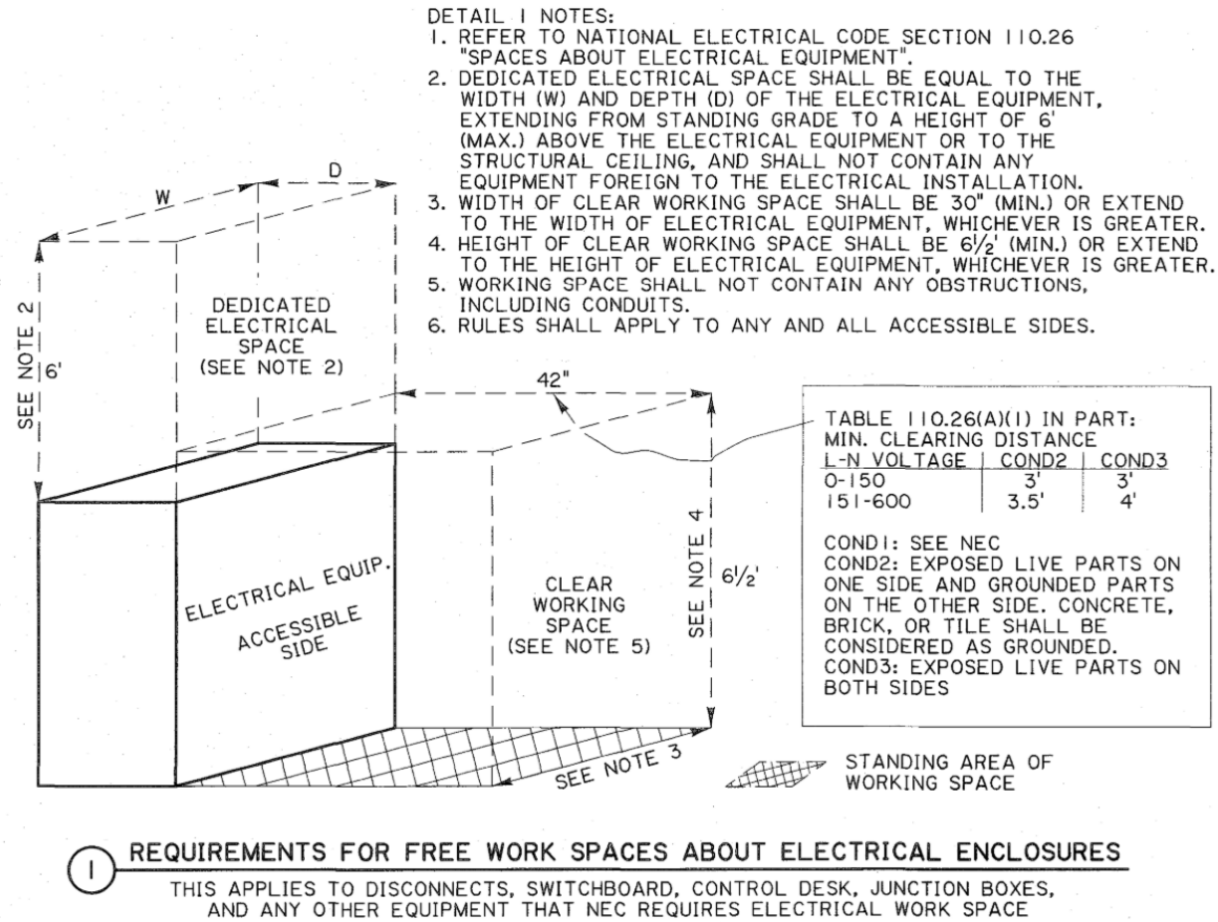

Figure 1-1: NEC Workspace around electrical enclosures.

Fire can be caused by overloaded components, faulty wiring, or poorly maintained, deteriorating, and improperly installed electrical components. Anywhere a fault occurs, an electrical fire can happen, especially around flammable materials. Evidence of fire includes burn and scorch marks, and damaged wiring and components.

Fire will cause failure of barriers and insulators in electrical systems and lead to the complete failure of the system. Fire can also produce hazards to personnel including heat and smoke. Hazards to personnel may exist after the fire is no longer burning; some examples include weakening of the floor, walls, ceiling, or ladder and access structures.

Figure 1-2: Evidence of a fire inside a traffic barrier gate, note the scorch marks and melted components.

Arc Flash

Electrical safety mandated by OSHA requires arc flash assessments in accordance with NFPA 70E 130.5 to be updated every five years or upon major modifications.

An arc flash is the light and heat produced as part of an arc fault, a type of electrical explosion or discharge that results from a low-resistance connection through air to ground or another voltage phase in an electrical system. In the event of an arc flash, the amount of thermal energy impressed on a surface at a certain distance from the source is called incident energy and is typically expressed in calories per square centimeter (cal/cm^2). Following the heat and light of an arc flash is an arc blast. The pressure wave of an arc blast can knock a person to the ground and turn equipment, tools, machinery, and debris into shrapnel which can cause additional damage or injury. Molten or vaporized metal can also be part of the arc blast explosion.

The probability of an arc flash event occurring is increased by:

- Performing “hot” (energized) work, failing to deenergize power to equipment
- Disregarding lockout tagout procedures
- Insufficient qualifications and training of the personnel doing work
- Age and condition of equipment

- Lack of proper tools and PPE

Touching a probe or tool to the wrong point, loose connections, insulation failure, dust, corrosion, all can set the foundation for an arc flash incident. Arc flashes can even occur while opening doors to enclosures. Loose, unsecure equipment may be disturbed by opening a door, causing metal objects to fall onto bus bars, unsecured and uninsulated wires contact each other, or some other unforeseen incident.

An arc flash assessment is performed to calculate arc flash information about an electrical system and its components. NFPA 70E 130.5(D) requires specific information on the level of arc flash hazard to be marked on the equipment when an arc flash hazard analysis has been performed. At a minimum, the label needs to include at least three items:

1. Nominal System voltage
2. Arc flash boundary
3. At least one of the following:
    a. Available incident energy and the corresponding working distance, or the arc flash PPE category in NEC 70E Table 130.7(C)(15)(A)(b) or Table 130.7(C)(15)(B) for the equipment (but not both).
    b. Minimum arc rating of clothing
    c. Site-specific level of PPE

Below is an example of an arc flash label:

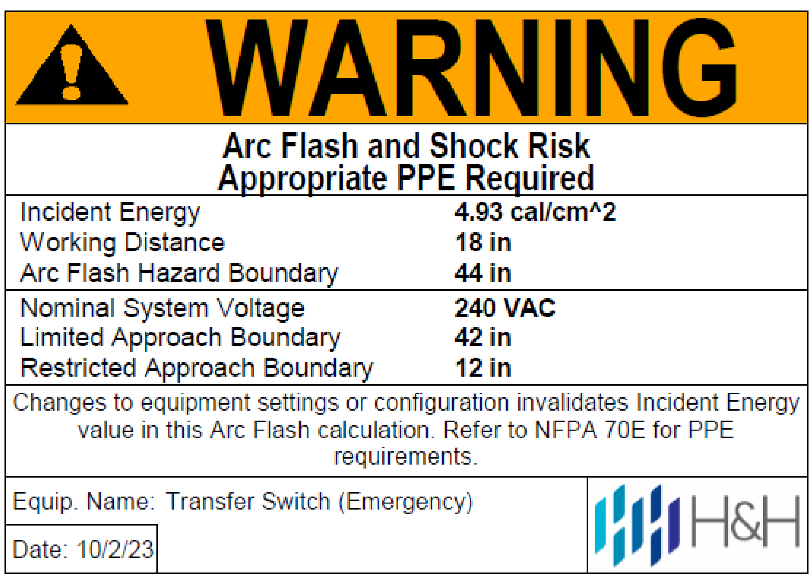

Figure 1-3: Arc flash label

- Incident Energy: The amount of thermal energy impressed on a surface at a certain distance from the source and is typically expressed in calories per square centimeter (cal/cm^2). *NFPA 70E Article 100 Definitions*
- Working Distance: The set value within the arc flash calculation from which the incident energy and boundary values are calculated.
- Arc Flash Hazard Boundary: Describes a distance from a prospective arc source within which a person could receive a second-degree burn were an arc flash to occur. *NFPA 70E Article 100 Definitions*
- Nominal System Voltage: The nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class. *NFPA 70E Article 100 Definitions*
- Limited Approach Boundary: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists. *NFPA 70E Article 100 Definitions*
- Restricted Approach Boundary: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part. *NFPA 70E Article 100 Definitions*
- Equipment Name: The piece of equipment that the label is designated for, this can be a disconnect switch, junction box, or other places where electrical equipment is found.
- Date: The date that the arc flash calculation was performed.

An arc flash label present on the exterior of an enclosure represents a potential danger to personnel. Any work done inside of an enclosure with an arc flash label should have that associated component disabled and isolated from upstream power if possible. Refer to Section 4.3 Isolating Equipment Isolating Equipment for the process of isolating equipment. Working on live components that are at risk of arc flash incidents requires PPE. Refer to below PPE section and associated NFPA 70E for PPE standards.

If no arc flash label is present, the electrical box may not be opened. Deenergize all sources and follow lockout tagout procedures before attempting work.

Personal Protective Equipment (PPE)

Inspectors must wear PPE, including hard hats, ANSI Class II/III high-visibility vests, safety boots, eye protection, hearing protection, gloves, respirators, personal flotation devices, and fall protection, as required.

Personal protective equipment (PPE) are protective articles of clothing worn to protect the wearer from electric shocks and arc flash hazards. Arc flash labeling on components informs personnel of the PPE required to work on a live component. Electrical inspectors require additional PPE per NFPA 70E Table 130.7(C)(15)(c), including:

- ASTM D120 Rubber Gloves.
- Electrical hazard ASTM safety toe boots.
- Arc Flash face shield where an Arc Flash danger exists.

- Long sleeve/pants made from natural non-melting fibers such as cotton should be worn. When there is an arc flash danger, arc flash rated outer layers must be worn. Cotton is not inherently flame resistant, but it is a better choice than polyester and nylon which can melt to the skin.

1.3.4 Lockout/Tagout

Guidance for proper lockout/tagout procedures is found in NFPA 70E 120.2.

The purpose of lockout-tagout procedures is to establish an electrically safe work condition by clearly identifying and documenting the act of de-energizing components while maintenance is performed. The process of lockout-tagout procedures involves safely shutting off components and preventing their re-enabling until work is completed. The procedure makes a portion of an electrical system safe for work through switching off an upstream device (deenergizing) and placing a lock on an operating handle with a tag indicating that work is being performed. This will prevent another individual from turning the device on while personnel are working on the system. Electrical boxes and devices may have multiple sources of power which need to be identified and locked out tagged out.

Figure 1-4: Lockout-tagout device on electrical equipment

1.3.5 Records

Movable bridge records, per AASHTO MBI 2.7.1, mirror those for fixed bridges. See Chapter 2 of the LADOTD BIM for further information.

Keeping accurate records of all maintenance activities is crucial to a successful preventative maintenance program. Records should document the date of maintenance, and any corrective measures taken. Maintenance forms should take the form of checklists designed for specific structural, mechanical, and electrical components. However, sketches, diagrams, and photographs as required should be incorporated to adequately describe the conditions found. In doing so, a history of maintenance problems can be established for the bridge. This will show adverse condition progression over time by comparing past and present records. The numbering and terminology used in completing the forms should be consistent with the bridge plans, inspection reports, and previous maintenance records.

Maintenance records should be concise while describing thoroughly the condition and work performed. When complex repairs or major rehabilitations are performed, the record plan set should be updated to reflect the repairs either by revision to the plan, including identifying the revision number and date in the title block and a brief note where the revision occurs in the plans, or by use of supplemental sheets.

1.3.6 Numbering

Assign identifying numbers or letters to components during inspections, maintaining consistency with bridge plans and prior reports. See Section 4.1.3 of the LADOTD BIM for further information.

1.3.7 Rating System

Bridge element condition ratings guide replacement priorities, maintenance planning, and structural evaluations. Per the SNBI, components (e.g., deck, superstructure, substructure) receive ratings from 0 (failed) to 9 (excellent). Elements (e.g., girders, truss members) are rated in Condition States (CS1–CS4), with CS1 indicating good condition and CS4 requiring structural review. Document CS3/CS4 elements with photographs, measurements, and locations.

Table 1-1 shows the codes, conditions, and description from SNBI for component condition rating. A complete list of components to be rated can be found in SNBI Section 7.1. A complete list of bridge elements to be rated can be found in SNBI 7.2. Bridge elements are identified by element numbers that can be found in FHWA –NHI Publication No. 16-039.

Mechanical and Electrical items will be coded under the appropriate Movable Bridge Elements (MBEs) which are Agency Defined Elements (ADEs). The full list of MBEs can be found in Appendix A. Movable bridge elements may overlap disciplines (e.g., motors inspected by mechanical and electrical inspectors), necessitating multi-disciplinary evaluations.

Table 1-1: SNBI Table 20- Codes and descriptions for component condition ratings.

Code	Condition	Description
N	NOT APPLICABLE	Component does not exist.
9	EXCELLENT	Isolated inherent defects.
8	VERY GOOD	Some inherent defects.
7	GOOD	Some minor defects.
6	SATISFACTORY	Widespread minor or isolated moderate defects.
5	FAIR	Some moderate defects; strength and performance of the component are not affected.
4	POOR	Widespread moderate or isolated major defects; strength and/or performance of component is affected.
3	SERIOUS	Major defects; strength and/performance of the component is seriously affected. Condition typically necessitates more frequent monitoring, load restrictions, and/or corrective actions.
2	CRITICAL	Major defects; component is severely compromised. Condition typically necessitates frequent monitoring, significant load restrictions, and/or corrective actions in order to keep the bridge open.
1	IMMINENT FAILURE	Bridge is closed to traffic due to component condition. Repair or rehabilitation may return the bridge to service.
0	FAILED	Bridge is closed due to component condition, and is beyond corrective action. Replacement is required to restore service.

1.3.8 Reports

The purpose of an inspection report is to record and present in a consistent and logical fashion the findings resulting from field work necessary to:

- Evaluate the physical condition of the structure and its components.
- Evaluate the performance of the bridge functional systems.
- Prioritize maintenance and repair needs for distributing budgeted funds and personnel.
- Monitor the condition and performance of components over time.

See AASHTO MBI 2.7.3 and 2.7.4 for an example list of contents for a movable bridge inspection report. See Appendix B for an example inspection report. See LADOTD BIM Chapter 3 for reporting procedures.

Chapter 2
Movable Bridge Overview

2.1 INTRODUCTION

Movable bridges facilitate traffic over navigable waterways, balancing vehicular and marine needs. Their failure disrupts daily routines, causes traffic delays, and impacts businesses. Regular inspections and maintenance ensure reliable operation and minimize unscheduled interruptions.

2.2 PURPOSE OF INSPECTION

Inspections identify issues affecting structural, mechanical, and electrical systems, enabling proactive maintenance to prevent service disruptions. A thorough inspection has four important uses, in order of importance:

- To ensure the safety of the public, workers on the bridge, and vessels navigating through the bridge.
- To point out areas that need immediate attention to keep the bridge in service
- To provide properly gathered data that will be helpful during future inspections and become part of the documentation of the bridge
- To supply inspection documentation that can be used as an asset management tool to prioritize bridge repairs, rehabilitations, and replacement projects.

A well-maintained movable bridge provides years of reliable service despite exposure to harsh environments (e.g., dirt, corrosion, wind, and thermal variations).

Inspectors must be thorough, patient, and analytical, documenting all components and identifying defect causes with evidence. They recommend immediate repairs, replacements, or long-term maintenance. Effective inspections require dedication, understanding of bridge operation, and curiosity. Inspectors contribute to public safety and infrastructure reliability.

2.3 INSPECTION PROCESS

Inspections involve thorough field observations compared against original specifications and as-built conditions. Experienced inspectors evaluate findings, assign element ratings, and recommend maintenance or repairs. Inspections serve three purposes:

- Identify immediate repair needs to maintain service.
- Document conditions for future reference.

- Develop periodic maintenance programs.

It is good inspection practice to clean selected areas to allow close inspection for corrosion, damage, deterioration, or hidden defects. Debris, vegetation, marine growth, and other items can accumulate and obscure problem areas. If the obstruction exceeds the inspection team's capabilities, the District Bridge Engineer should be notified so the issue can be addressed prior to the inspection whenever feasible.

Movable bridges may also have grease buildup near moving elements. It is important to clean areas covered in grease in order to inspect the elements. Grease used to lubricate rubbing surfaces is very thick and sticky. It may require solvents to thoroughly clean the area. Relubricate any elements requiring grease/lubricant after cleaning and prior to operation.

2.4 MOVABLE BRIDGE FUNCTIONAL SYSTEMS

Movable bridge operation is separated into seven distinct functional systems defined within AASHTO MBI. These systems are defined as support, balance, drive, control, interlocking, navigation guidance, and traffic control. These systems include mechanical, electrical, and structural elements, and as such should be familiar to inspectors across disciplines. Inspectors should understand the purpose of these functional systems and evaluate their operation and individual components within that context.

This section introduces the systems and element components typical of swing, vertical lift, and bascule bridges. Chapters 3, 4, and 5 detail the mechanical, electrical, and structural elements and the components that make up these systems and methods of their inspection. Below, each bridge functional system is introduced along with some of their typical elements and components.

2.4.1 Support System

The support system is comprised of the substructure and superstructure components that ensure span stability in all positions. These include elements such as:

- Piers, abutments, trusses, girders, and bearings.
- Rolling tracks, segmental girders, and tread plates.
- Main trunnions, trunnion supports, and trunnion bearings.
- Bascule heel stops and shear locks.
- Lift-span towers and cables.
- Swing-span balance wheels, center bearings, end lifts, end wedges, center wedges, and live load shoes.

2.4.2 Balance System

The balance system maintains stability during motion using counterweights, balance blocks, or ballast systems to minimize drive system loads.

2.4.3 Drive System

The drive system powers span movement, relying on support and balance systems. Components include motors, hydraulic pumps, gears, shafts, and brakes.

2.4.4 Control System

The control system governs the operation of the movable span and serves as the command interface between operator and the movable bridge machinery, allowing the operator to direct the bridge through its operational cycle. The control system directs bridge operation via manual, semi-automatic, or automatic interfaces, ranging from push buttons to programmable logic controllers (PLCs).

Manual controls do not have automatic sequencing and may have little interlocking protections to prevent operator error. If the operator does not activate controls in the proper sequence, damage to the machinery and unsafe conditions may result.

Semi-automatic and automatic controls have increasing degrees of automation typically with corresponding increased logic and interlocking devices which prevent certain types of operator error. Semi-automatic controls are typical on Louisiana movable bridges.

2.4.5 Interlocking System

Interlocking systems are made up of electromechanical and/or hydraulic components, logic devices, and circuitry that regulate operation to prevent out-of-sequence actions that may be hazardous to public safety, damage operating machinery, and structure, or both. Interlocking system elements and components include:

- Limit switches, relays, detectors, sensors, and wiring that indicate the position or operational data of moving parts.
- Cams, levers, plungers, and other mechanical trip mechanisms.
- Internal position detectors in hydraulic pistons.
- Software and hardware in PLC's dedicated to the sequence of operations control.

2.4.6 Navigational Guidance System

The navigation guidance system facilitates safe vessel passage (AASHTO MBI 1.4.7).

Some elements and components include:

- Marine radio communication, and NOAA navigation charts.
- Lights, retroreflective panels, fog signals, white/red flags, whistles, and horns.
- Navigation lighting, under clearance and tide gauges, fendering and other pier protection devices.

2.4.7 Traffic Control System

The traffic control system manages vehicle flow using signals, signs, gates, and barriers, ensuring safe operation during bridge openings.

2.5 MOVABLE BRIDGE DESIGN AND OPERATION

Numerous factors determine movable bridge design, and many distinct types of movable bridges have evolved to fit specific needs. Movable bridges are classified into swing span, vertical lift, bascule, and pontoon types. Louisiana also has some unique adaptations of the traditional movable bridge types.

Bridges are categorized as On-System (state-maintained highways) or Off-System (non-state highways, possibly on the NHS). The table below lists the total on-system and off-system movable bridges in Louisiana.

Table 2-1: On and off system bridges in Louisiana, as of 2025.

	ON-SYSTEM	OFF-SYSTEM
BASCULE	7	7
PONTOON	8	4
SWING	48	17
VERTICAL LIFT	35	9
TOTAL	98	37

2.6 SWING SPAN BRIDGE OVERVIEW

See AASHTO MBI 1.3.2.

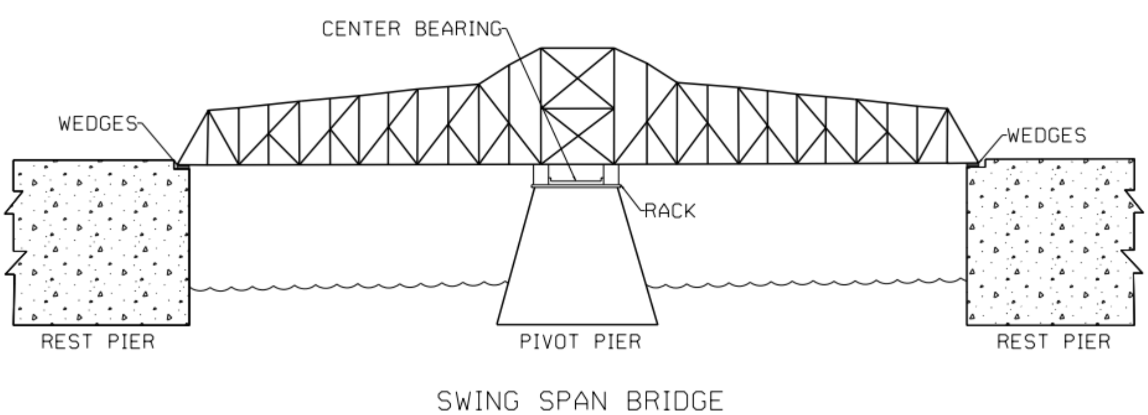

Figure 2-1: Swing span bridge in closed position showing piers and location for operating components.

Figure 2-2: Swing bridge in Madisonville over the Tchefuncte River.

Swing span bridges open by rotating the movable span about a vertical axis so that the span is parallel with the navigation channels. When in a closed position (closed to marine traffic), the span is supported by three piers. The pivot pier supports the dead weight of the swing span itself. When the span is not completely closed, its entire weight rests on the pivot pier. The rest piers stabilize the span and along with the pivot pier, support the live load (the weight of vehicular traffic) as it passes over the bridge.

The machinery used to rotate a swing span is located on the movable span and on the pivot pier. In mechanical operation, the final reduction pinion (rack pinion) engages a curved rack rigidly attached to the pivot pier. As the pinion rotates, it carries the swing span around the curved rack.

Swing span bridges can be made with different structural systems, such as steel plate girder, cable stay or steel truss. Swing spans can be operated by mechanical, hydraulic drives.

Figure 2-3: Symmetrical truss span swing bridge.

2.6.1 Symmetrical Swing Span

Most swing spans are symmetrical about the center (equal distance from center support to each end) of the span (axis of rotation).

Figure 2-4: Symmetrical swing span bridge.

2.6.2 Bob-Tailed Swing Span

Non-symmetrical bob-tailed swing spans are used in space-constrained areas, such as bayous.

Figure 2-5: Bob-tailed swing span bridge.

2.6.3 Cable Stayed Swing Span

Cable-stayed swing spans require careful inspection of the cables and the cable stays.

Figure 2-6: Cable stayed swing bridge.

2.6.4 Design and Operation

Swing spans are either center bearing (using a bronze spherical thrust bearing) or rim bearing (using tapered rollers). Center bearing designs are simpler and more common, with balance wheels preventing tipping. All hydraulic swings are center bearing. Rim bearing designs distribute weight via rollers on a pivot pier track.

When closed, wedges stabilize the span and transfer live loads to piers. To open, traffic is stopped, wedges are withdrawn, and the span rotates via a rack-and-pinion system driven by motors or hydraulic cylinders. Brakes or valves hold the span in position.

Although the center of gravity is normally located over the center bearing, the gear tooth reaction between the rack and pinion, as well as loading from wind, snow, ice and rain, can provide enough imbalance to tilt the span.

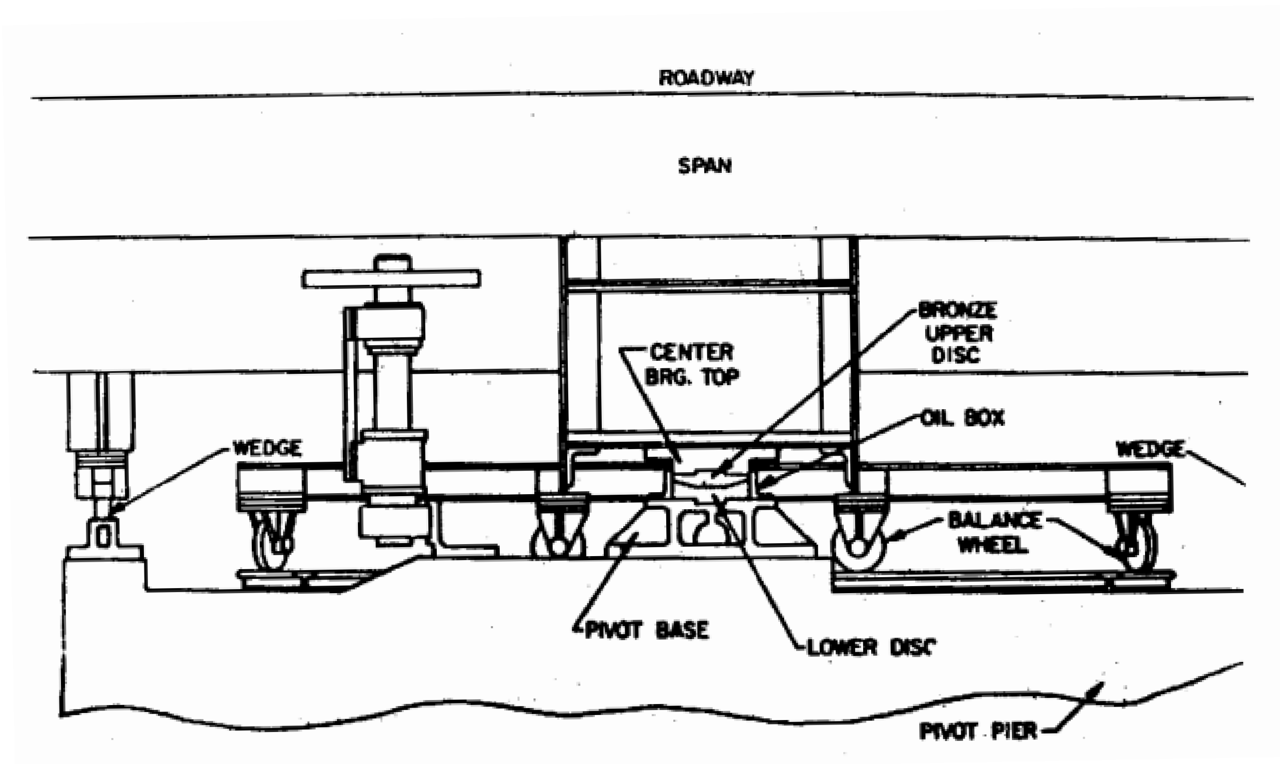

Figure 2-7: Center bearing drawing.

Mechanical Machinery Arrangements

Several mechanical machinery arrangements are found on swing span bridges to rotate the spans, but they are all similar. Drive systems typically use one or two motors connected to speed reducers via flexible couplings. Differentials ensure load sharing between opinions. Hydraulic drives use cylinders for rotation, controlled electrically or mechanically.

The machinery below has one motor and two rack pinions in mesh with the curved rack. The reducer has a differential built into it, to provide load sharing between the two rack pinions. This ensures even loading of all machinery driving the movable span. On some smaller swing spans, there is a single rack pinion. Then, there is no load sharing problem and no need for a differential reducer.

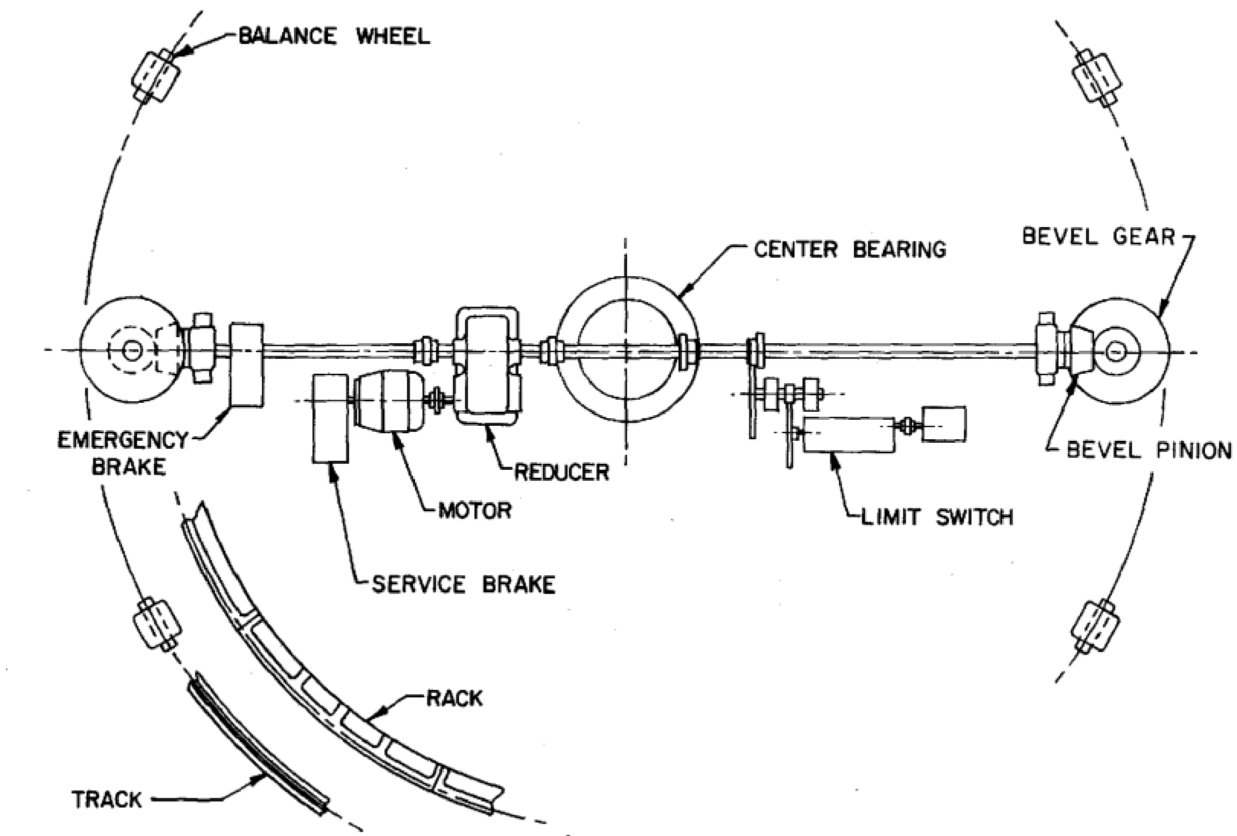

Figure 2-8: Typical drive machinery layout on a swing bridge.

Stabilizing Components

Wedges, end lifts, centering latches, and buffer cylinders stabilize the span. Wedges slide or roll into position, driven mechanically or hydraulically, to align and support the span. Centering latches and buffer cylinders reduce shock during closure.

The figure below shows the various components of a mechanically driven wedge. The crank is mounted on a shaft supported by bearings attached to the bottom of the span. When the wedge is to be withdrawn, the shaft rotates in the direction that will pull the wedge towards the crank.

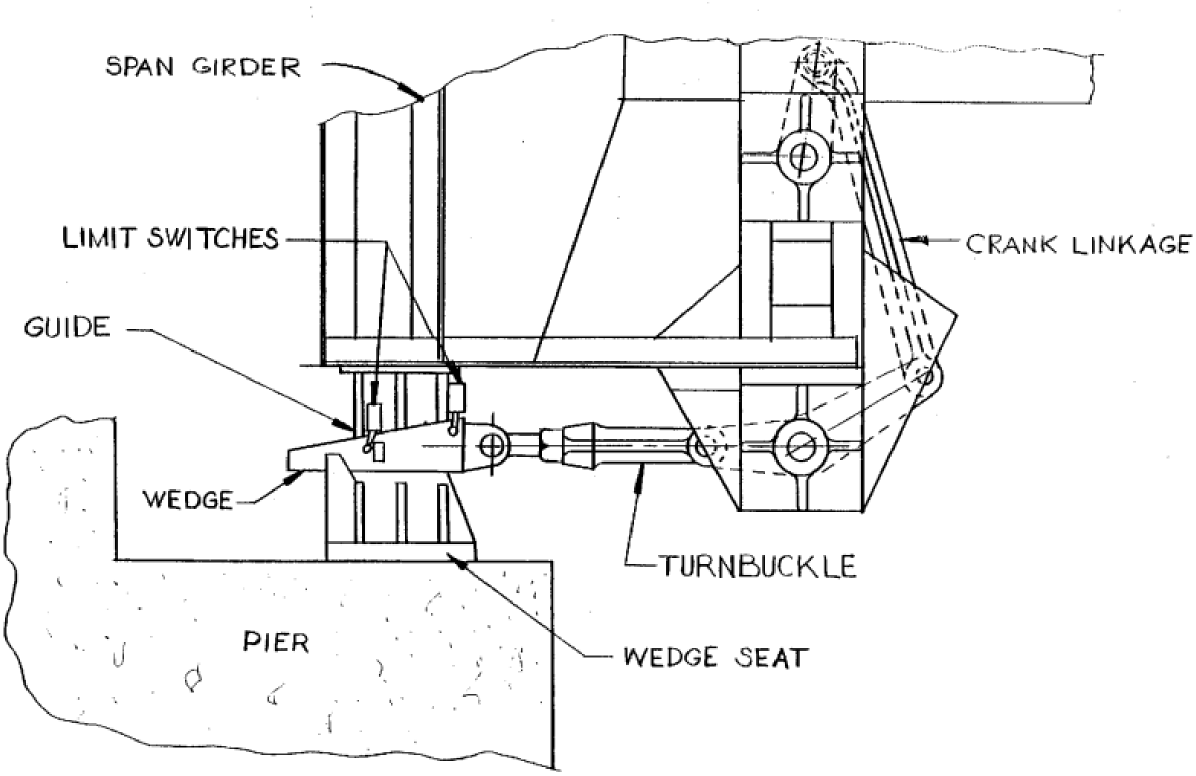

Figure 2-9: Wedge drive with crank and linkage arrangement.

The connecting rod that extends from the crank arm to the wedge has a turnbuckle incorporated in its design. The turnbuckle adjusts the length of the connecting rod to properly position the wedge in the driven position. Lock nuts at each end of the turnbuckle lock it in place after it has been properly adjusted.

In the figure above, that they are trying to manipulate the wedge to raise the span. The turnbuckle has turned to the point where incomplete thread engagement has resulted. Also, only a part of the wedge is in contact, increasing the unit pressure on the small area of contact and increasing wear.

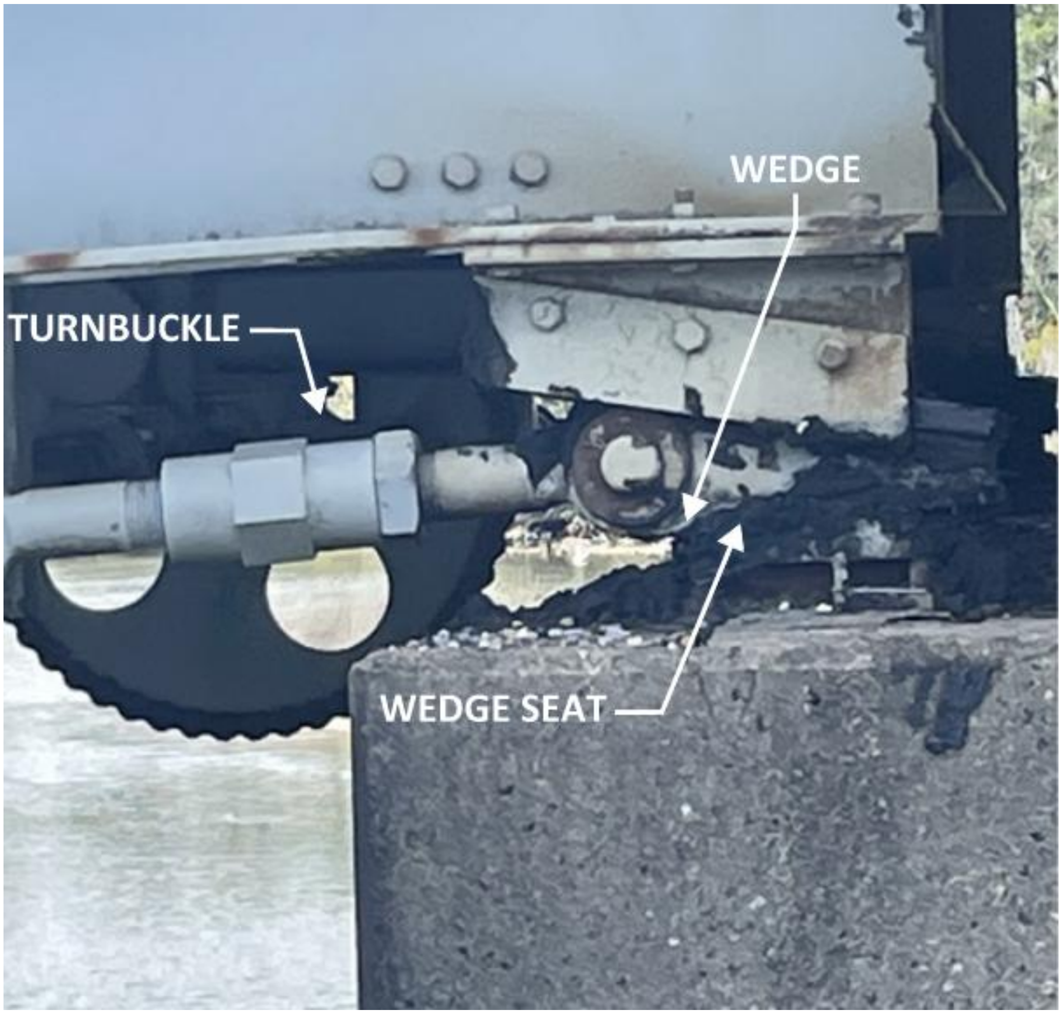

Figure 2-10: Mechanical wedge and wedge seat.

In the schematic shown below, a single motor operates all six wedges. The motor drives through a primary reducer. The two output shaft extensions of the primary reducer are coupled to longitudinal shafts that extend from one end of the span to the other. One worm gear reducer is located at the center of the span to operate the two center wedges. There are two more worm gear reducers, one located at each end of the span. Each of the three worm gear reducers have two output shaft extensions that are coupled to transverse shafts. The transverse shafts will typically drive through one or more gear reductions. The final gear reduction drives the crank shaft that actuates the wedge.

Figure of the wedge drive machinery below only shows the machinery at the center of the span and at one end. The machinery at the opposite end of the span is identical to the end of the machinery shown.

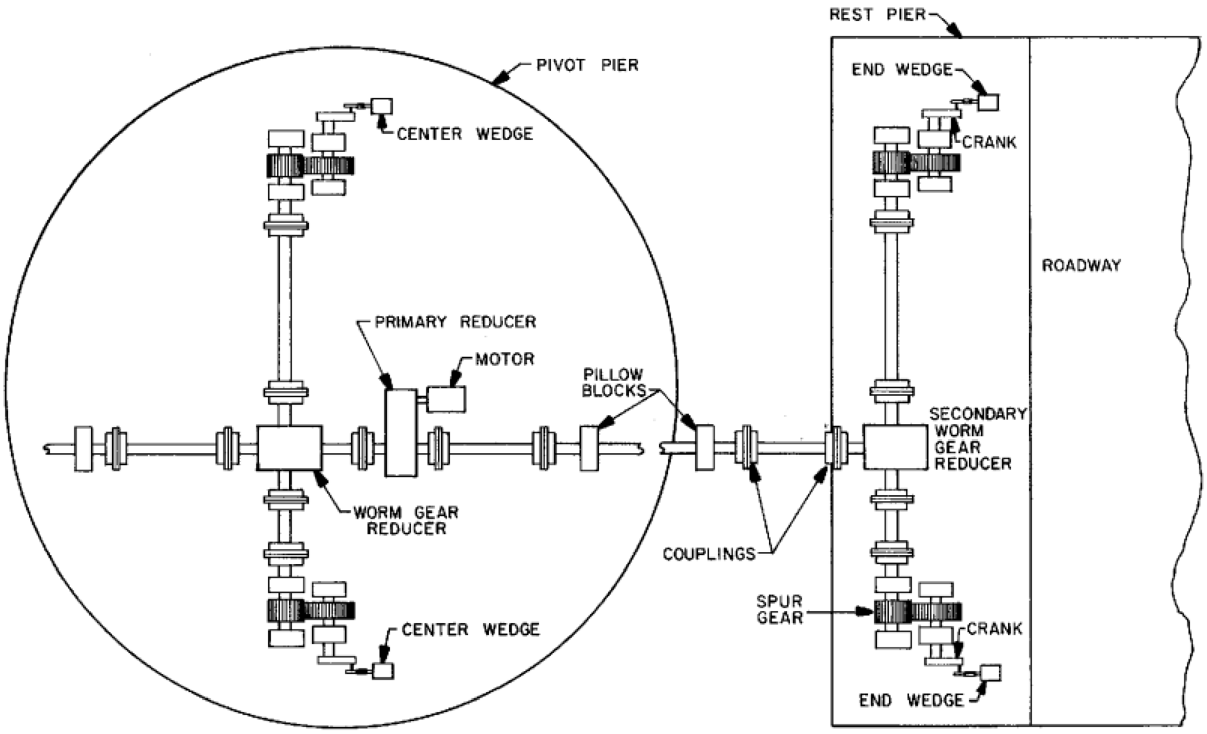

Figure 2-11: Wedge drive machinery.

In some cases, rocker type live load shoes that require no operating machinery have been used instead of wedges.

For very wide bridges that require more than two wedges at each end, additional wedges are added. These added lifts are driven from the same transverse shaft. The turnbuckles in the connecting rods are adjusted to assume uniform motion and loading of the multiple wedges at each end of the span.

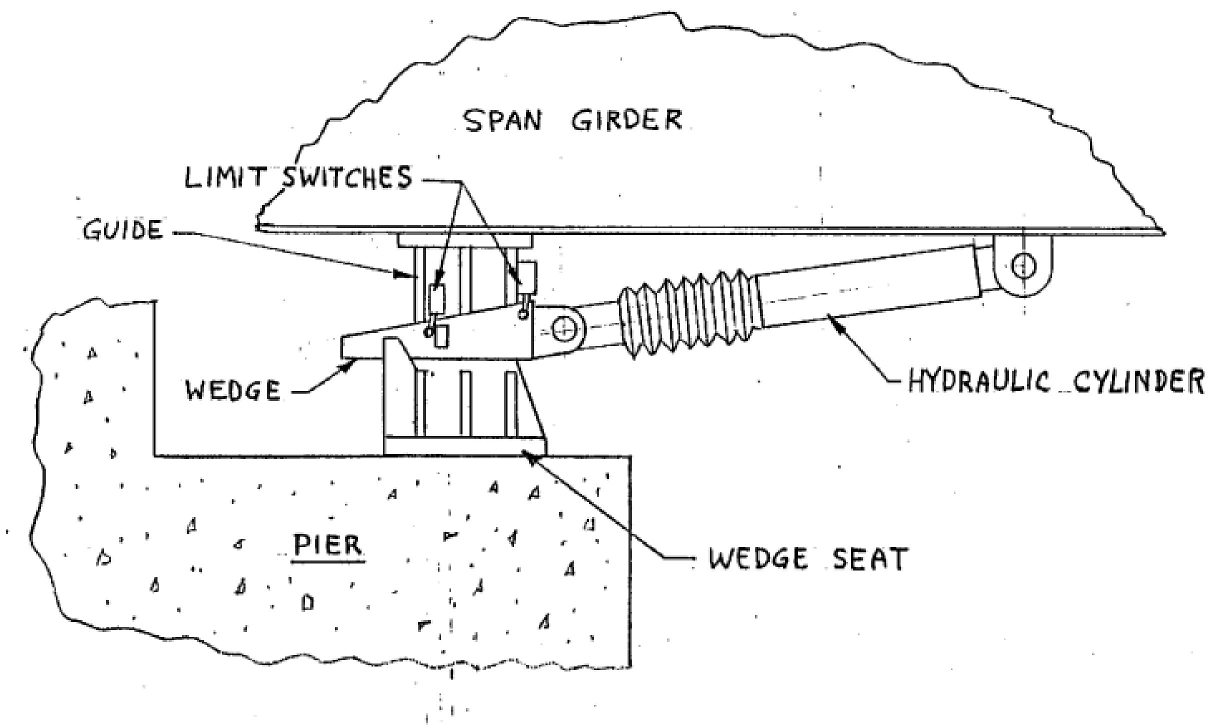

Figure 2-12: Wedge with hydraulic cylinder drive.

Many swing spans in Louisiana have hydraulic driven wedges. These consist of a hydraulic cylinder with its piston rod directly pinned to the wedge. Supply of hydraulic fluid to the cylinder is achieved by means of a motor and pump usually mounted on the movable span in the vicinity of the pivot pier with distribution lines to the various cylinders.

This system offers advantages over the complicated link systems often required on mechanical systems—and the disadvantage of possibly backing out under live loads due to seepage of hydraulic fluid and resultant loss of pressure.

The figure below shows an end roller device utilized on some swing bridges in Louisiana. End rollers perform the same function as wedges; however, they operate in a slightly different manner, rolling into place rather than sliding.

Figure 2-13: Hydraulic roller wedge.

When a swing span closes, the span alignment with the approach span is obtained by two centering latches (except on most hydraulic swing spans), one at each end of the span. Figure below shows the span in the closed position. The centering latch has a roller on the bottom end. The latch is mounted on the span and can slide up and down between two guides on the span. It is counterweighted to reduce the effort required to raise it. The latch pocket is mounted on the rest pier.

When the centering latch is in the fully lowered position, the wheel rests in the latch pocket. The latch pocket prevents the centering latch from moving in either direction. Since the centering latch is attached to the span, it also prevents the span from moving.

When the bridge must be opened, a drive that usually is included in the wedge or live load shoe drive system raises the centering latch just enough so that the wheel is clear of the pocket. This will allow the span to rotate. The end of the span below must move to the left. When the span moves to the left, the roller rolls up the short ramp, over the hump and down the long ramp. As the span is rotated back to the fully closed position, the roller rolls up the long ramp, down the short ramp and drops into the pocket. This prevents the span from rotating any farther. The speed for rotation is extremely low at this point; otherwise, some high shock loads will be generated in all the centering latch components, as well as the structural steel and concrete, on which they are mounted.

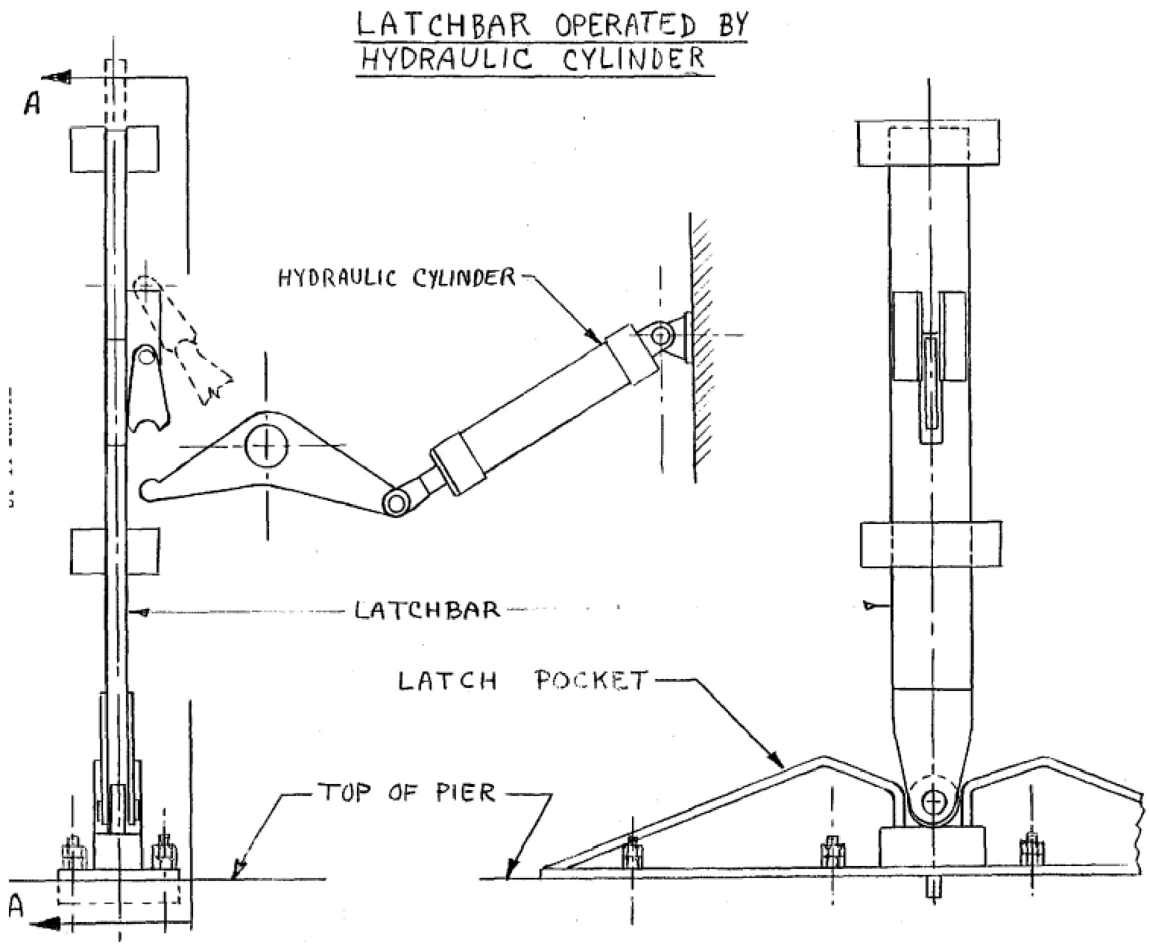

Figure 2-14: Latchbar operated by hydraulic cylinder.

Bridges with modern electrical controls have automatic slowdowns programmed to prevent the operation from closing at too great of a speed. Some of the older bridges do not and are completely dependent upon the operators' judgement. This frequently causes problems, and the centering devices can be damaged.

One additional safety measure on swing spans to reduce the shock when closing is to mount two horizontal buffer cylinders at each end of the span, as shown below. The buffer cylinder is simply a pneumatic shock absorber that will help slow the span down when closed at too great of a speed. Since the buffer cylinders are mounted to act on the side of the span, their use eliminates the possibility of rotating the span in one direction.

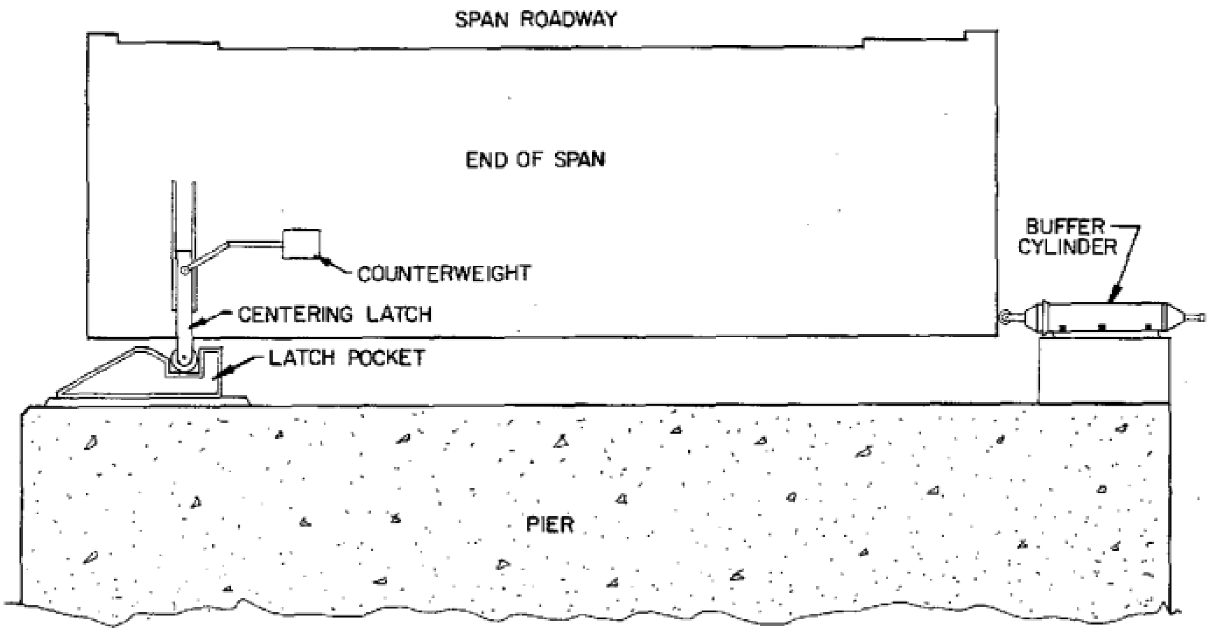

Figure 2-15: End elevation of span showing location of centering latch and buffer cylinder.

Emergency Hand Drive

Emergency hand drives allow manual operation during power or motor failures, requiring multiple personnel to operate. Inspectors must verify operability, as corrosion can render these systems inoperable.

The figure below illustrates a typical hand drive found on swing spans. There are two such drives: one to operate the wedge machinery and one to operate the main drive machinery to rotate the span. The T-bar shown below is at road level. Normally, two or more people are required to turn the T-bar.

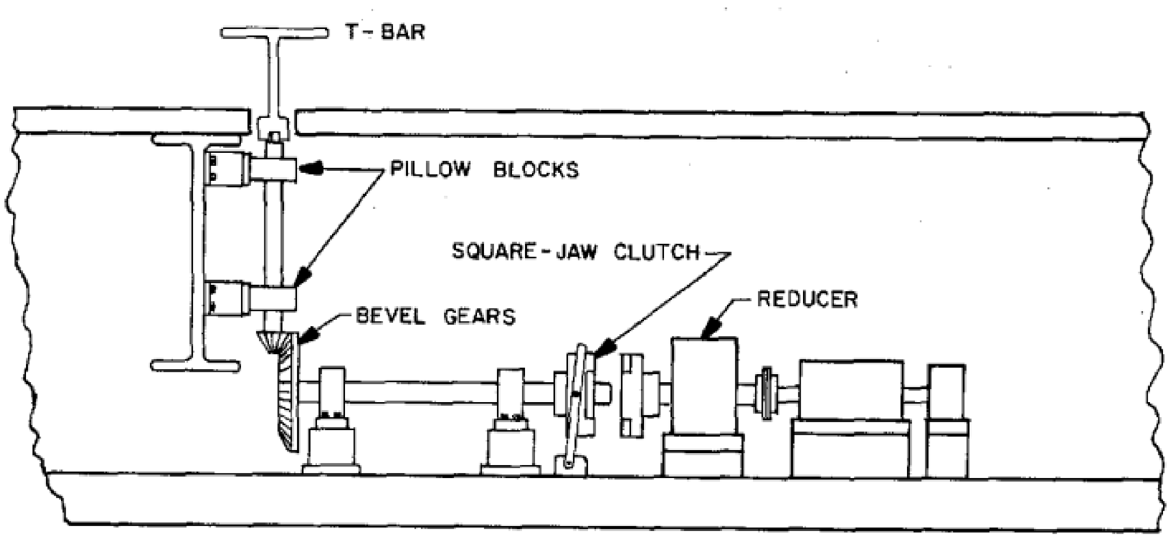

Figure 2-16: Elevation of manual drive components

2.7 VERTICAL LIFT BRIDGE OVERVIEW

Vertical lift bridges raise a horizontal span between two towers, remaining level throughout operation (AASHTO MBI 1.3.3). They are either tower drive (machinery at tower tops) or span drive (machinery on the span).

Figure 2-17: Tower drive vertical lift with concrete towers and steel plate girders, with two sets of drive machinery.

2.7.1 Design and Operation

Mechanical Machinery Arrangements

Counterweight ropes connect the span to counterweights via sheaves, balancing the system. The span is designed to be slightly heavy to ensure closure during power failures. Drive machinery rotates sheaves to raise or lower the span, with electrical synchronization maintaining level operation.

Figure below shows a general arrangement to depict how the span is attached to the counterweights. The heavy lines show the position of the span when closed or fully lowered.

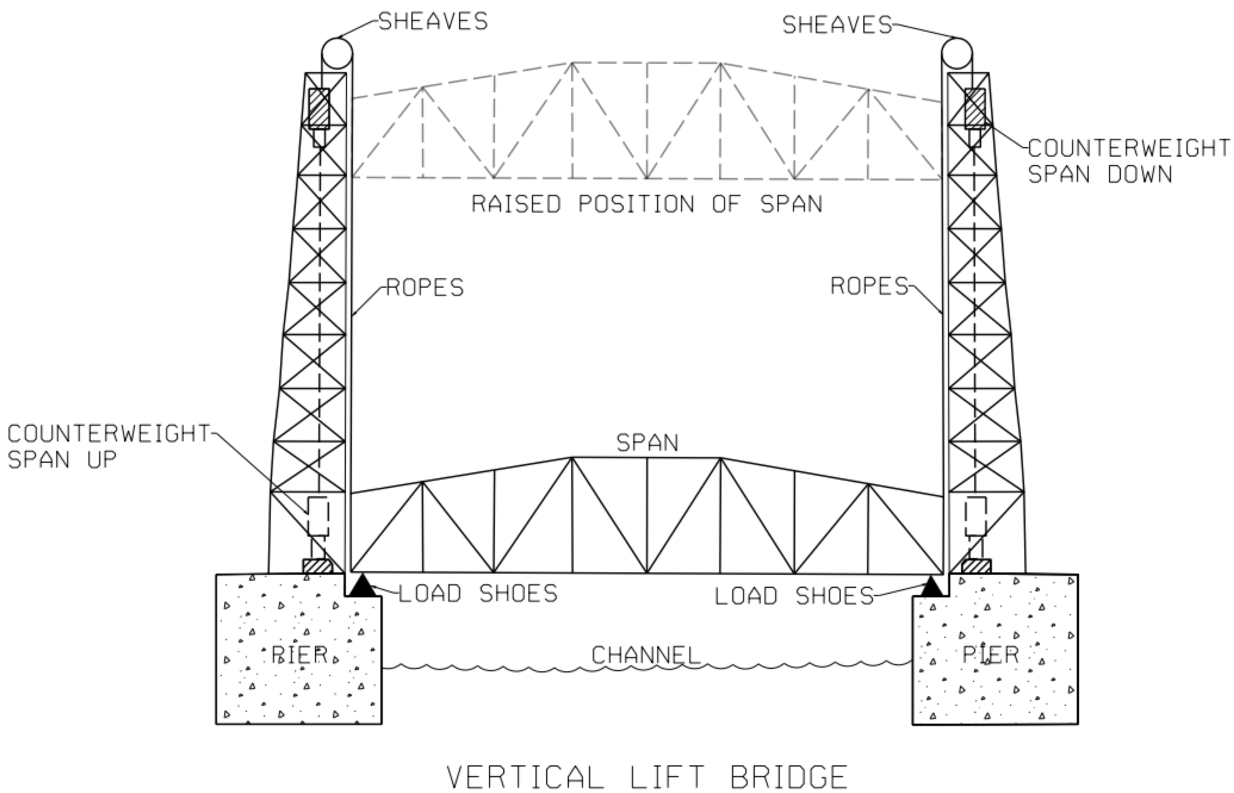

Figure 2-18: Diagram of tower drive vertical lift components.

The figure below shows a typical machinery arrangement for a tower drive. One set of machinery, as shown, is located at each tower. The drives on the two towers are coordinated electrically to keep the span level during operation.

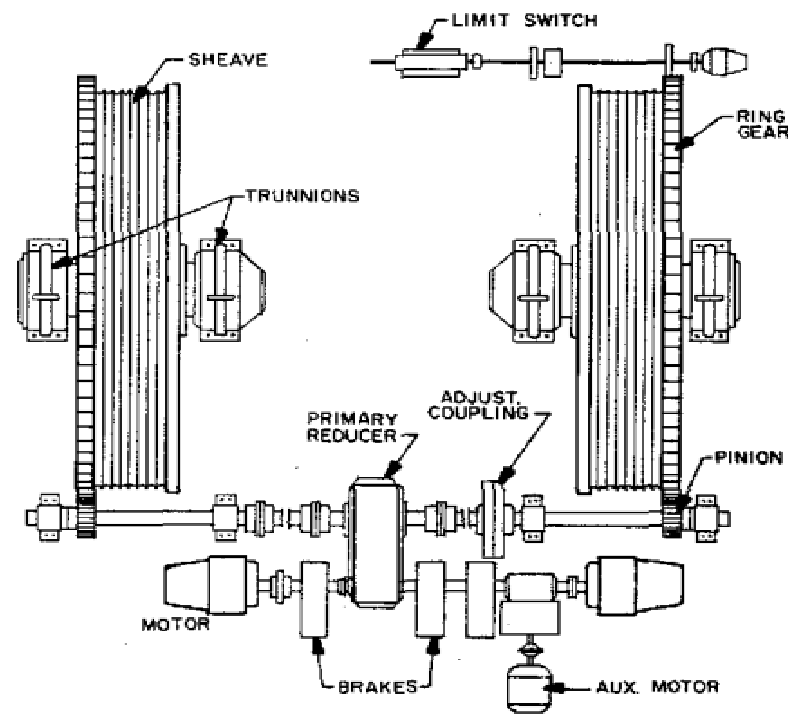

Figure 2-19: Diagram of operating machinery for a tower-drive bridge.

Another common type of vertical lift bridge that is used in Louisiana has a fixed span between the tops of the two towers called tower span. The machinery may be located on the tower span with longitudinal shafts extending to the right-angle reducers on the towers. The output shafts of the reducers connect to transverse shafts, which rotate the rack pinion, thus rotating the tower sheaves.

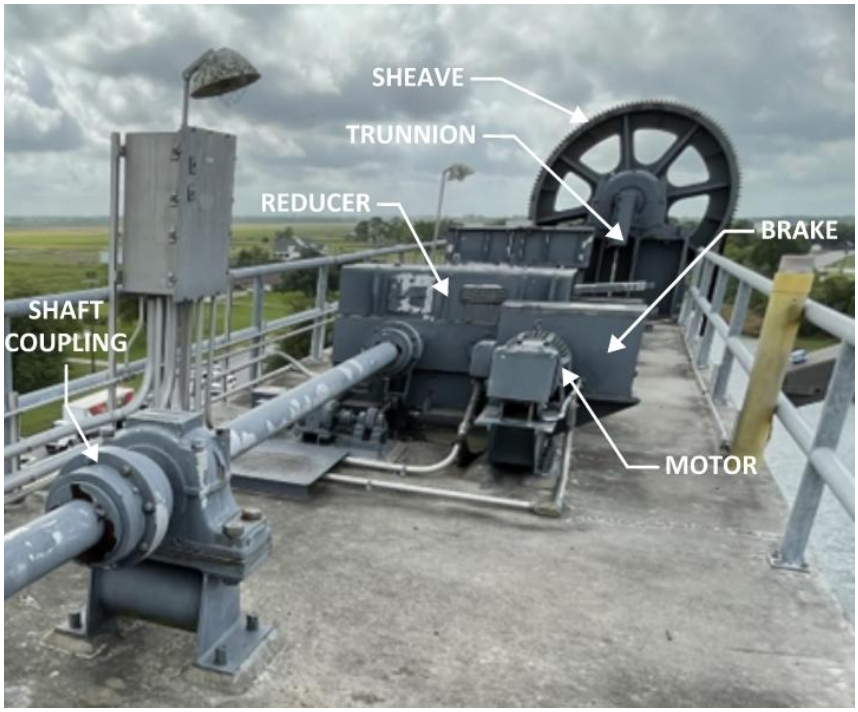

Figure 2-20: Tower drive vertical lift bridge operating machinery layout.

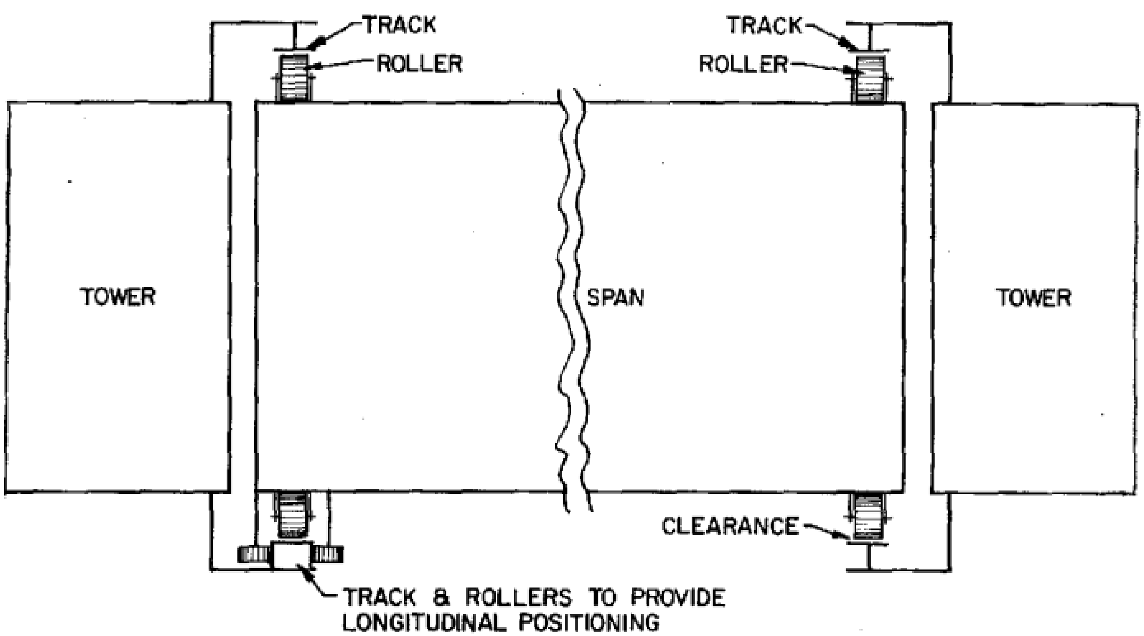

Figure 2-21: Guide rollers schematic.

Guides are provided to prevent the span from excessive swaying during operation. One method of guiding is to have guide rollers attached to the span opposed by tracks attached to the towers at all four corners of the span. Usually on one end of the bridge, at the lower chords, the guides restrict longitudinal and transverse movement. At the other end of the lower chord, as well as at both ends on the upper chord, only transverse movement is restricted. This prevents undesirable movements of the span but allows for thermal expansion of the structure as seen below.

Some vertical lift bridges are guided by guide shoes instead of rollers. The shoes slide along the tracks rather than roll. The shoes must be lubricated to prevent wear from heavy frictional loads during operation. There should be a small amount of space between the guide shoes, or guide rollers, and the tracks during operation under no wind conditions, but a small amount of wind pressure will cause the guides to contact the tracks.

Figure 2-22: Tracks and guide rollers.

Locking Devices

Lockbars or end latches secure the span when closed, engaging sockets on the fixed structure. Centering devices ensure alignment, and buffer cylinders reduce shock.

Vertical lift bridges will have at least two locking devices, one at each end of the span. Sometimes, there will be two at each end of the span to lock it in the closed position. One design used in Louisiana incorporates both the live load shoes and centering device. Image below shows a popular type of lock, or end latch, used in Louisiana.

Figure 2-23: Vertical lift end latch.

Buffer cylinders may be found at each corner of the movable span. The buffers reduce the shock loads generated at both ends of travel during operation of the span.

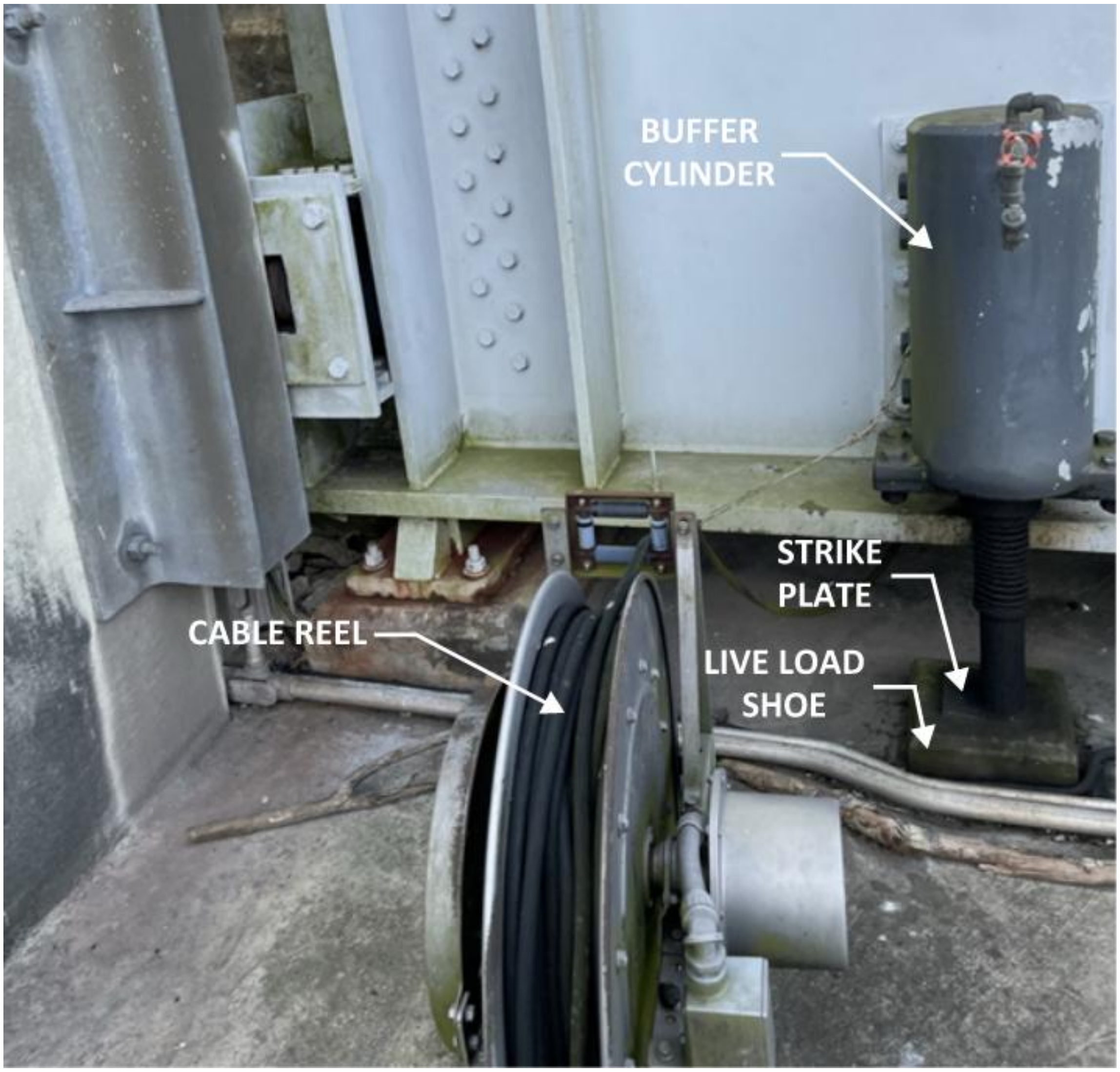

Figure 2-24: Buffer cylinder and live load shoe.

Balance Chains

Balance chains compensate for rope weight shifts during operation, maintaining slight span-heavy balance.

In the figure below the span is raised to the full, open position (shown in the left image.) In this position, most of the chain's weight is carried by the tower. As the span descends and the counterweight rises, the counterweight ropes pass over the sheaves, removing their weight from the counterweight side and adding their weight to the span side. To compensate for this, the counterweight picks up more of the weight of the balance chain until, when the counterweight is in the fully raised position, nearly the entire weight of the balance chain has been added to the counterweight, and the span is lowered (shown in the right image.)

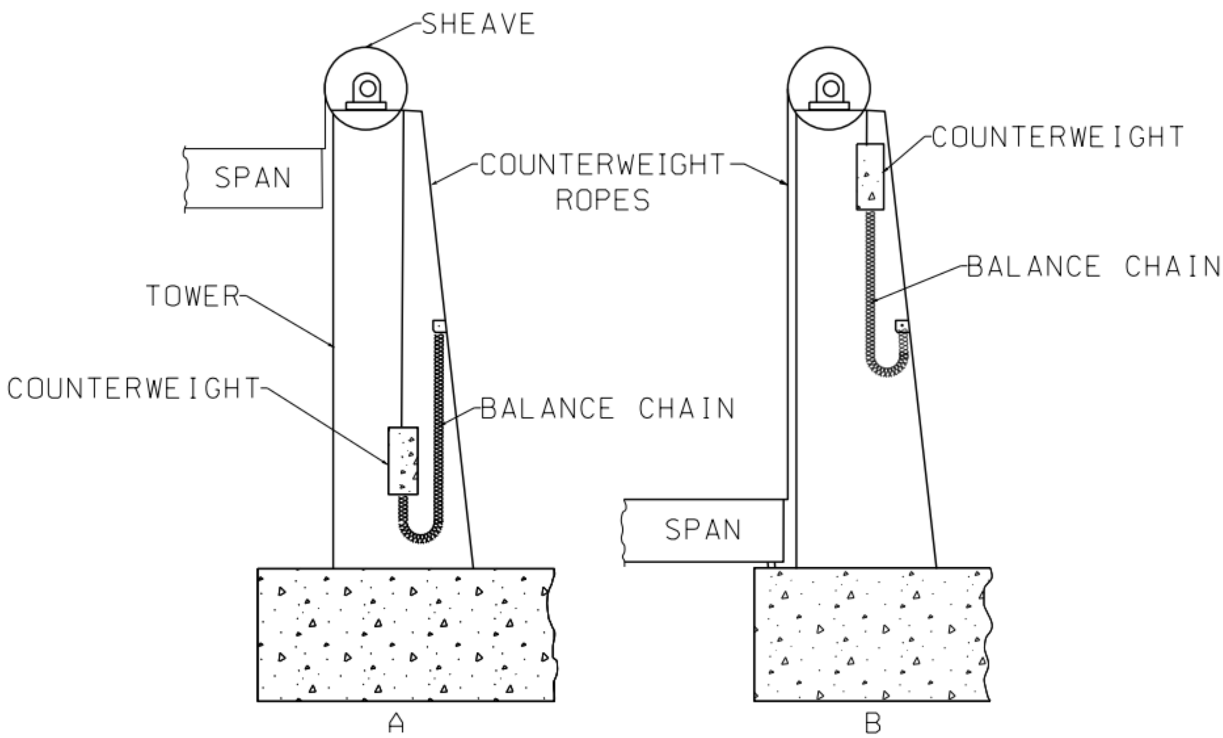

Figure 2-25: Diagram of vertical lift balance chains.

2.8 BASCULE BRIDGE OVERVIEW

Bascule bridges rotate to provide unlimited vertical clearance (AASHTO MBI 1.3.1.1). Types include trunnion, rolling lift, and heel trunnion.

Figure 2-26: Double-leaf bascule bridge.

2.8.1 Trunnion Bascule

Trunnion bascules rotate on horizontal trunnion shafts, with single or double leaves. Counterweights balance the span, and live load shoes transfer loads to piers. Drive systems use rack-and-pinion mechanisms, with differentials ensuring load sharing.

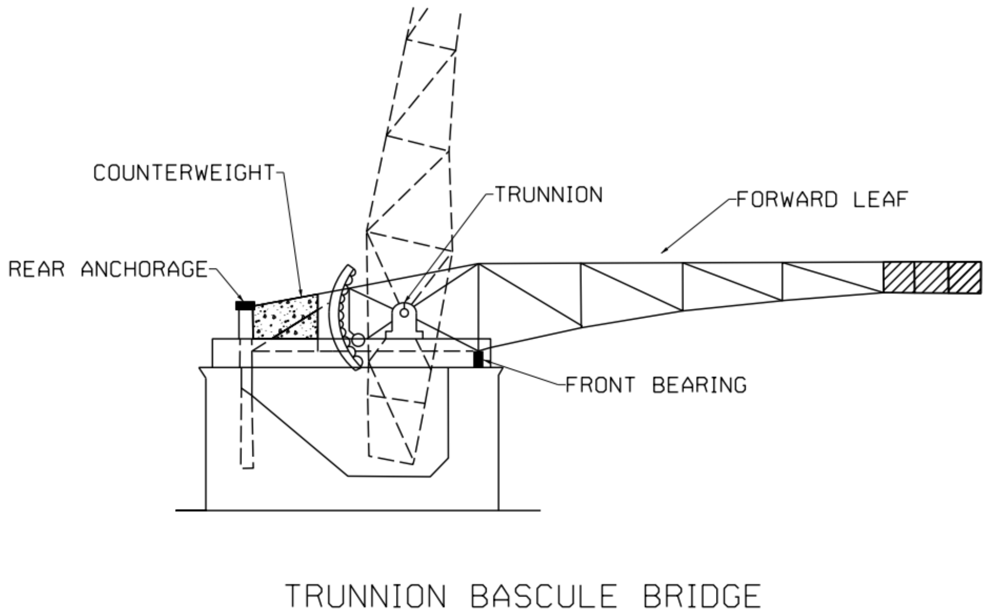

Figure 2-27: Trunnion bascule bridge.

The dashed lines in diagram below indicate the outline of the fixed roadway on an approach. The heavy lines outline the bascule span, its supports, and some of the operating machinery. Locks are provided at the interface between the forward ends of the two bascule leaves and also between the counterweights and the fixed structure to provide additional stability.

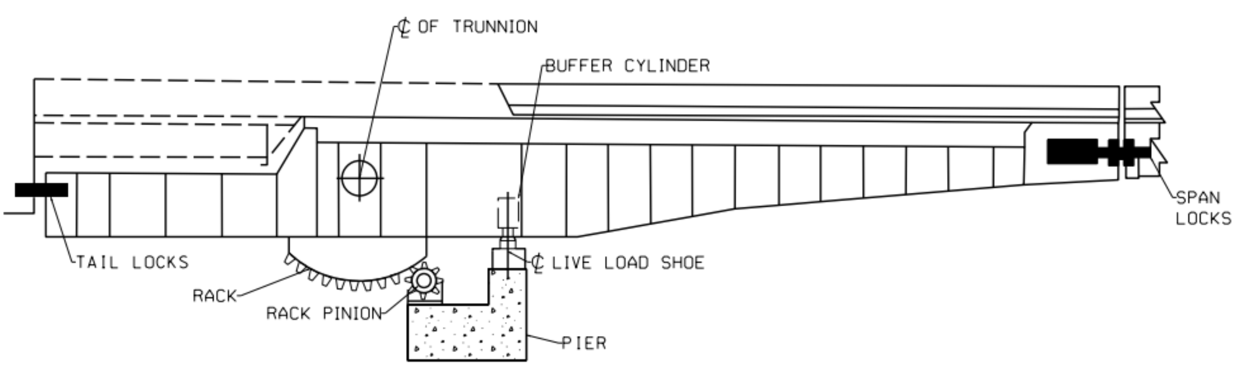

Figure 2-28: Operating components of a double-leaf bascule bridge.

The counterweight is constructed to place the center of gravity of the entire span virtually at the axis of rotation—i.e., the center of trunnion shafts. The power required to operate the bridge then must overcome friction in the system and imbalance caused by wind, ice, snow etc.

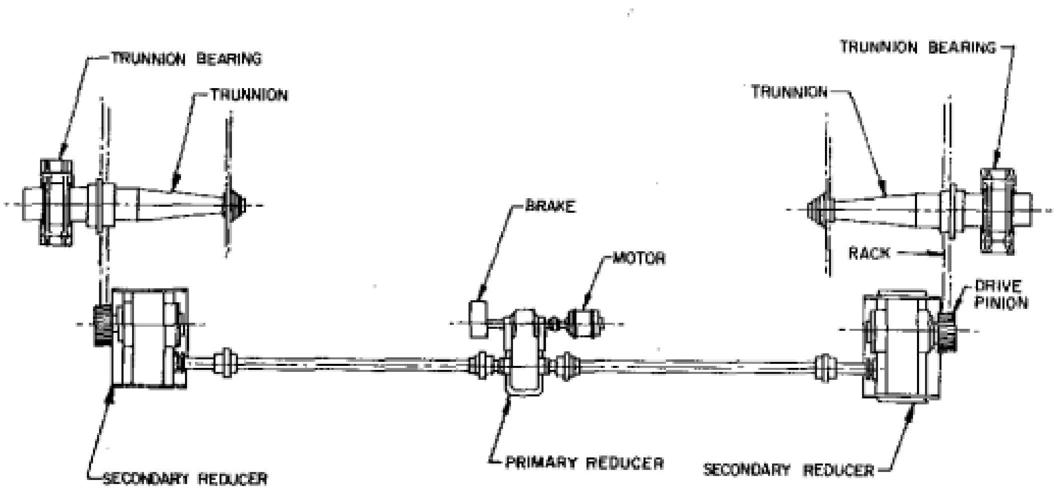

Figure 2-29: Diagram of enclosed drive system.

The support for the bascule span is especially important. The trunnions that support a trunnion bascule are mounted in the main girders on each side of the span, frequently referred to as the bascule girders. The entire weight of the span, including the counterweight, is transmitted from bascule girders through trunnions, then through the trunnion bearings to the pier. It is imperative that the two trunnions be aligned.

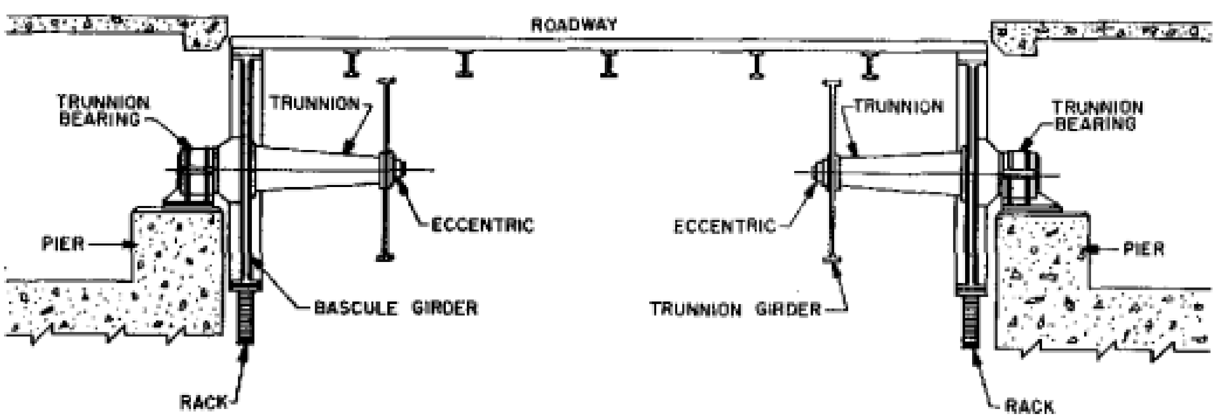

Figure 2-30: Diagram of trunnion assemblies.

2.8.2 Rolling Lift Bascule

Rolling lift bascules roll on curved tracks, with machinery on the span engaging fixed racks. Counterweights maintain horizontal center of gravity movement. Hydraulic versions eliminate rack-and-pinion issues.

Figure 2-31: Rolling lift bascule bridge.

The curved tracks support the entire span. As the pinions rotate in one direction, they provide a horizontal force on the span that rolls the span back away from the navigation channel and raises the toe end of the span to provide clearance.

Counterweights are attached to the movable span to locate the center of gravity at the center of the rack pinions – also the center of the curvature of the curved tracks. This results in the center of gravity moving only in a horizontal direction so that the only power required is to overcome friction plus the imbalance due to wind, rain, and ice.

Rolling lift bascules can be single or double leaf.

The image below illustrates how hydraulic cylinders can be installed on a rolling lift bridge. Notice that no rack or rack pinion is required, thus eliminating the problem of poor tooth mesh as the track plates wear. Further, cylinders have self-aligning rod end bearings that can ease installation and operation difficulties.

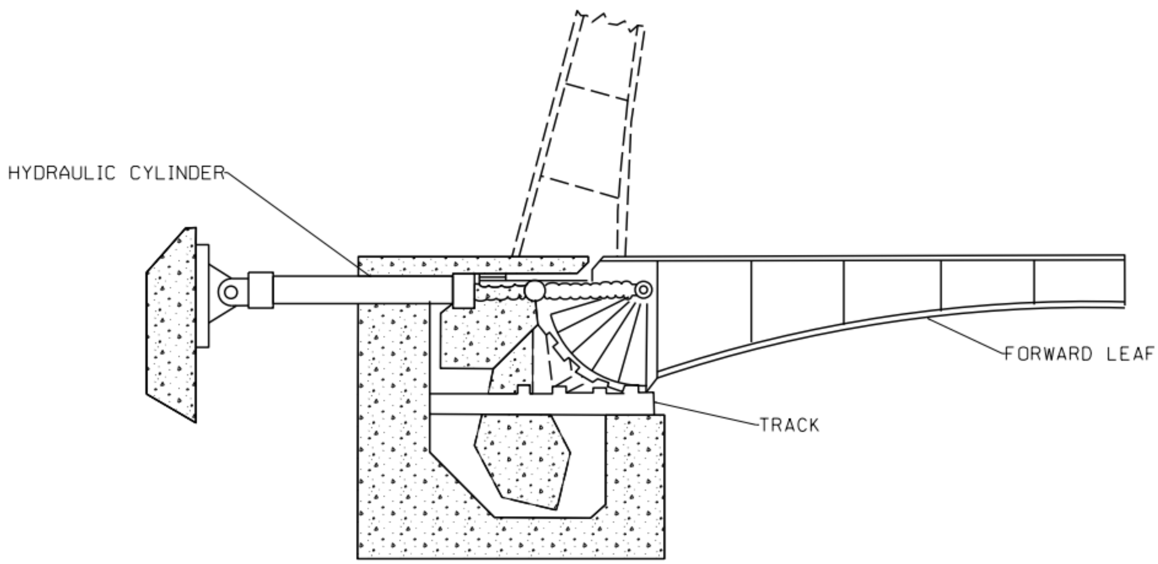

Figure 2-32: Hydraulically operated rolling lift bascule bridge.

2.8.3 Heel Trunnion Bascule

Heel trunnion bascules separate the span and counterweight, rotating on distinct trunnions. Drive machinery engages racks on operating legs to open or close the span.

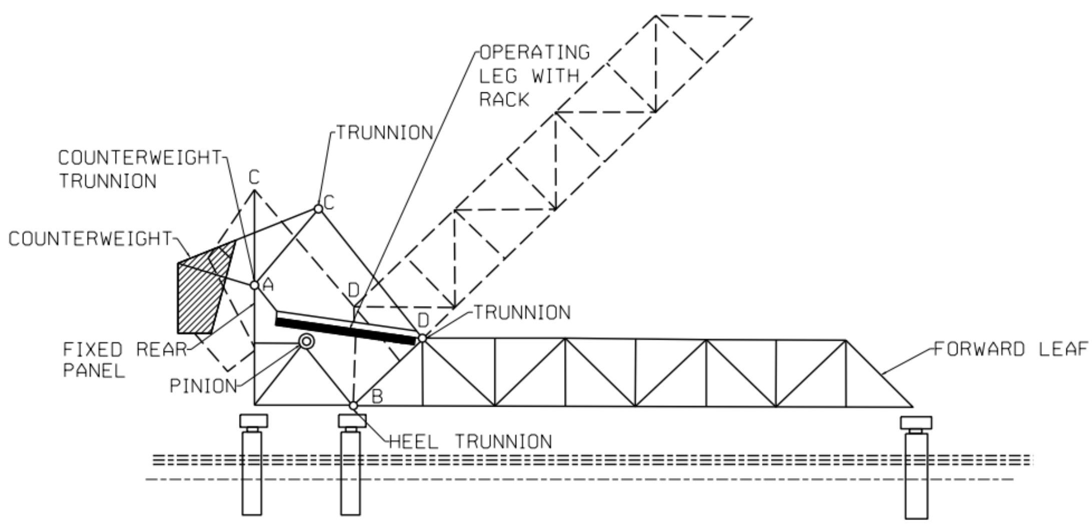

Figure 2-33: A heel-trunnion bridge has two fixed trunnions, A and B. The leaf rotates about B, and the counterweight rotates around A. Trunnions C and D move as the leaf is raised.

The drive machinery is located in the same tower that supports the counterweight. A pinion is mounted on each side of the structure, and pinions engage straight racks. In this case, the straight racks are mounted on operating legs that are pin connected to each side of the movable span. When the pinions rotate in one direction, they produce a pull through the racks to the operating legs, and, in turn, to the movable span. This pulls the movable span to an open position. Reversing the direction of rotation of the pinions develops a pushing force through the racks to the operating legs, pushing the span closed.

2.8.4 Stabilizing Components

Buffer cylinders, live load shoes, span locks, and centering devices stabilize bascule spans, ensuring alignment and reducing shock.

The figure below shows a typical mounting arrangement. The strike plates are attached to the rest pier.

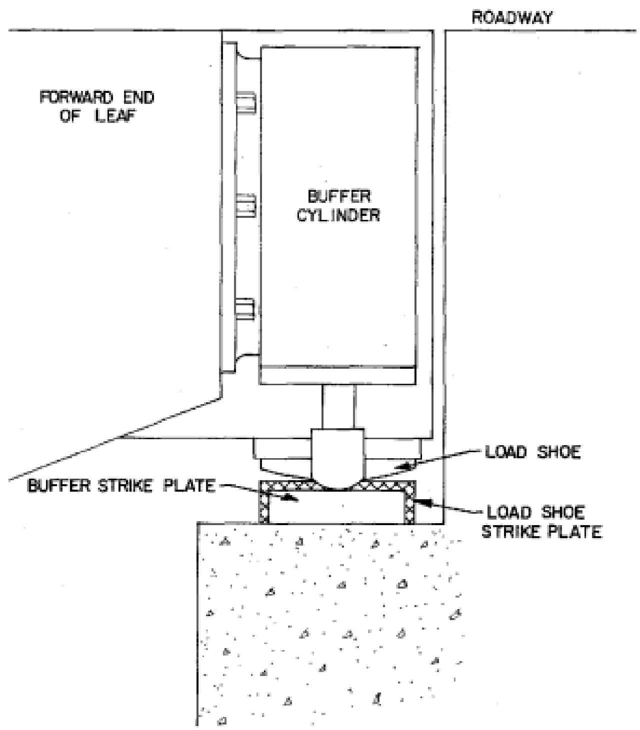

Figure 2-34: Buffer cylinders on a single leaf bascule.

Frequently, limit switches are positioned in the vicinity of buffer cylinders and live load shoes. In this location, a direct signal may be obtained that assures the bridge tender the span is seated. See below.

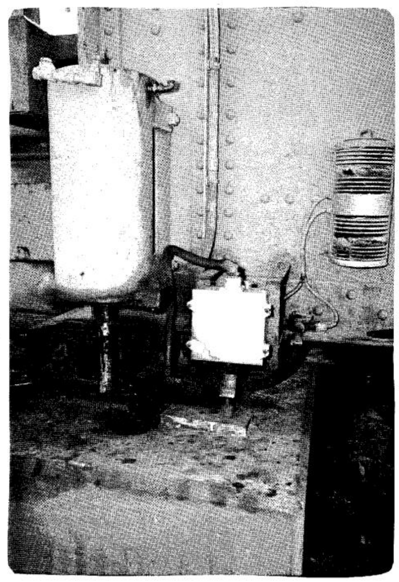

Figure 2-35: Buffer cylinder and limit switch.

2.9 PONTOON BRIDGE OVERVIEW

Pontoon bridges use a floating span pivoted by winches and wire ropes (LADOTD MBI II-41). Ballast pumps adjust span height, and apron ramps facilitate vehicle access. Wire ropes may pose navigation hazards if not properly managed.

Figure 2-36: Pontoon bridge.

The pontoon span should be equipped with ballast pumps. Their purpose is adjustment of the rough span height relative to the roadway with changing seasonal waterline/channel depths, when the apron ramps can no longer accommodate the difference between roadway and floating pontoon span height. The pontoon is caused to rotate by means of electric or hydraulic winches. Their operational wire ropes are strung through snatch block anchorages on both sides of the navigable channel and affixed to both sides of the pontoon. A small number of pontoon bridges in Louisiana utilize wire ropes routed across the navigational channel; these wire ropes must be dropped to the channel bed to permit passage of marine traffic. Properly routed these cables will largely remain clear of the navigational channel, but may still cause a hazard, when unsecured or in place just below the water surface.

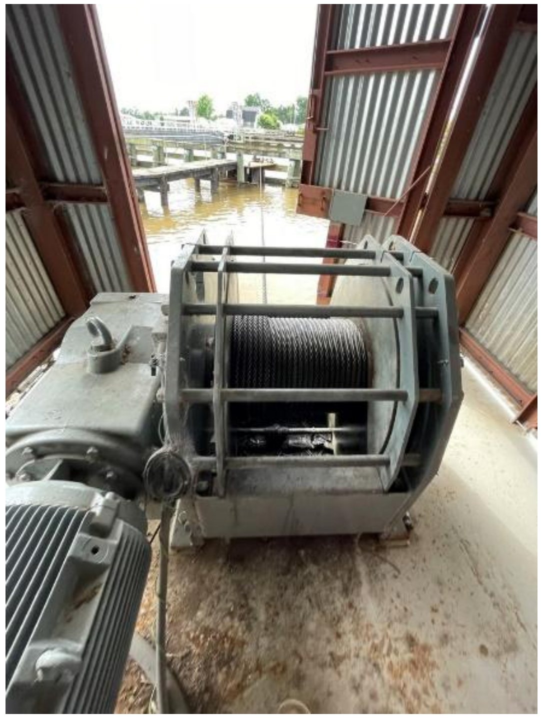

Figure 2-37: Electric operational winch of a pontoon bridge.

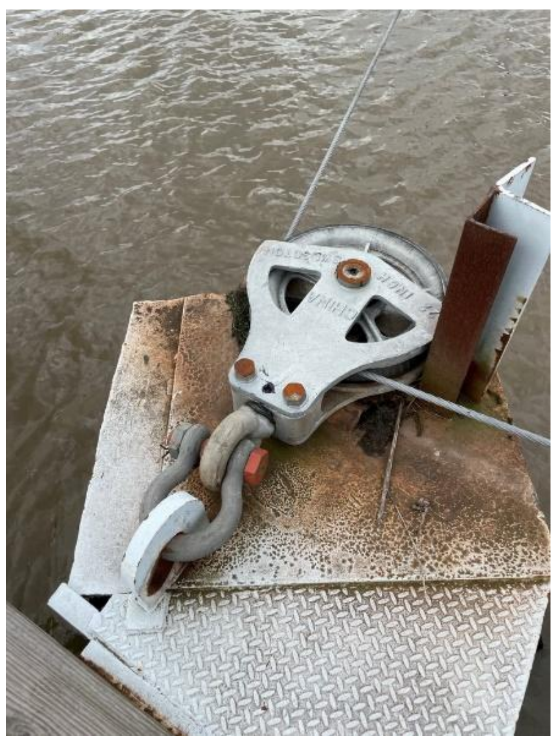

Figure 2-38: Snatch block and anchorage routing the wire rope cables of a pontoon bridge.

2.9.1 Ramps for Pontoons and Ferries

Counterweighted ramps, raised and lowered by wire ropes, connect pontoon spans or ferries to approach spans, aligning with mating pockets for vehicle access.

Figure 2-39: Pontoon bridge apron ramp and machinery towers during operation.

Vehicular traffic enters and leaves floating pontoon spans by means of these ramps located on the approach spans. When a pontoon bridge is to be opened to marine traffic, the ramps are raised, and the pontoon may then be pivoted about the pivot pier to open the navigable channel to marine traffic. After the pontoon is pivoted back into position and properly aligned, the ramps are then lowered and their ends fit into a mating pocket of the pontoon to allow the passage of vehicular traffic.

Similarly, vehicular traffic enters and leaves ferries by means of these ramps located on the approach spans. When the ferry is safely loaded and prepared to depart the ramp is raised, and the ferry may depart. After the ferry is moored and in the proper position, the landing ramp is lowered, and its end fit into a mating pocket of the ferry to allow vehicles to unload.

Chapter 3
Mechanical Inspection of Movable Bridges (Machinery)

3.1 OVERVIEW

The following section attempts to provide the inspector with a description of the mechanical elements typical to movable bridges found in Louisiana, and methods of their inspection. The inspector should recognize that these descriptions and methods will often need to be supplemented with resources specific to the mechanical element, and bridge being inspected. Thus, it is the responsibility of the inspector to seek out and add to tooling, documentation, expertise, training, and additional resources in preparation for a successful mechanical inspection.

3.2 LUBRICATION FITTINGS

To reduce wear and ensure proper operation of moving components lubrication is required. Many mechanical elements on a movable bridge are equipped with fittings so that maintenance personnel can properly lubricate them.

Lubrication fittings are incidental to many Movable Bridge Elements as such they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. Lubrication fittings should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of the lubrication fittings should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have lubrication fittings.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	865	Trunnion-Straight/Curved Rack
843	Shaft Bearings and Shaft Couplings	881	Bridge Specific Equipment (Lift)
844	Brakes	882	Bridge Specific Equipment (Swing)
845	Emergency Drive and Back-Up Power Systems	883	Bridge Specific Equipment (Pontoon)
847	Hydraulic Power Units	884	Bridge Specific Equipment (Bascule)
849	Hydraulic Cylinders /Motors/Rotary Actuators	885	Barriers - Movable Bridges
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	886	Traffic Warning Gates - Movable Bridges
861	Live Load Shoes /Wedges/Strike Plates/Buffer Cylinders		

Grease fittings such as Zerks or button heads are provided on machinery requiring grease. A grease gun is used by maintenance personnel, the grease gun mates solidly with the grease fitting and delivers grease through lubrication lines, and channeling in the mechanical element to deliver fresh grease to the appropriate area between moving machinery surfaces. Relief vents are often installed in these systems such that excess grease can be automatically expelled from the machinery, and to prevent seal damage.

Figure 3-1 : Button head and Zerk style grease fittings.

Oil lubricants are typically delivered using oil reservoirs or cups, that deliver the oil through lubrication lines, and internal channeling to their desired location.

Routine Inspection of Machinery with Lubrication Fittings:

- Oil reservoirs and cups should be filled appropriately.
- When maintenance personnel use grease fittings such as Zerks and button heads, the grease gun will often leave behind a small amount of grease on the fitting. "Dry" grease fittings, or those where the grease is hardened or degraded is a sign that the regular lubrication schedule was not maintained.

Coding Recommendations for Machinery with Lubrication fittings:

- Mechanical elements with lubrication fittings that are broken, missing, or damaged should be automatically coded CS3 "poor," due to lubrication defect.

3.3 BEARINGS

Bearings are machinery components that provide the interface between rotating and non-rotating parts. In most movable bridge applications, the shaft rotates while the bearing and its housing remain stationary.

Bearings can be unique Movable Bridge Elements, and they can be incidental to many Movable Bridge Elements.

Bearings used to provide the interface between rotating Movable Bridge Elements, and non-rotating parts, are themselves unique Movable Bridge Elements in such cases they are given a unique ADE designation number, and each bearing is given an independent Condition State (CS) Rating. These bearings should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
843	Shaft Bearings and Shaft Couplings

Bearings are incidental to many Movable Bridge Elements, in such cases they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. These bearings should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of these bearings should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have bearings.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	881	Bridge Specific Equipment (Lift)
845	Emergency Drive and Back-Up Power Systems	882	Bridge Specific Equipment (Swing)
847	Hydraulic Power Units	883	Bridge Specific Equipment (Pontoon)
849	Hydraulic Cylinders /Motors/Rotary Actuators	884	Bridge Specific Equipment (Bascule)
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	885	Barriers - Movable Bridges
865	Trunnion-Straight/Curved Rack	886	Traffic Warning Gates - Movable Bridges

Two kinds of bearings are typically used on movable bridges: sleeve bearings and anti-friction or rolling element bearings.

3.3.1 Sleeve Bearings

A sleeve bearing is a cylindrical metal sleeve that fits with a slight clearance over its associated shaft, commonly called the journal. A clearance is provided between the sleeve bearing and shaft for lubricant and transfer of heat generated by the friction as the shaft rotates within the bearing.

Figure 3-2: Example of a split block sleeve bearing.

Proper radial clearance is important in a sleeve bearing, and it must be sufficient to provide space for the lubricant but not so much as to permit excess movement. To determine the original design clearance, it is necessary to check the As-Built drawings and specifications. If drawings or specifications are not available, a rule of thumb of .001 to .002 inches per inch of shaft diameter is acceptable for shafts up to a range of 12" diameter. Thus, for a 4" diameter shaft a clearance of .004 to .008 would be normal.

Routine Sleeve Bearing Inspection

- Inspect bearing assembly for dirt, foreign material, paint loss, corrosion, and excessive lubricant.
- Inspect bearing pedestal, support, and entire housing exterior for cracking or signs of stress.
- Inspect fasteners, foundation bolts, and nuts for signs of deterioration due to rusting or fatigue, note any loose fasteners.
- Inspect bearing for proper lubrication and fittings, note any missing or malfunctioning lubrication components.
- Inspect the bearing sleeve to determine if it is damaged and that it is secure in the housing. Check the ends for scoring or signs of damage and wear. Also check the shaft where it emerges from the bearing for signs of damage and wear.
- Observe the bearing during operation. Note any unusual vibration or noises.
- After an operational cycle and the shaft has stopped rotating, feel the shaft immediately adjacent to the bearing. If excessive heat is noted, measure operating temperature with a surface pyrometer, thermal imaging camera, or other similar gauge.
- If accessible, use feeler gauges to measure the clearance between the shaft and bearing, this is called the journal clearance. Prior to use of feeler gauges, clean this intersection to ensure that the tool is not pushing dirt, or foreign material into the gap. Use feeler gages to record journal clearance and compare with the original design. Move the feelers around the circumference of the shaft to record the point with maximum clearance. The point of maximum wear may not be at the top of the bearing in all cases. This should be performed at both ends of the bearing if possible.

Sleeve Bearing Coding Recommendations

- Radial clearances over .050” should be coded CS4 “severe,” due to wear defect.
- Metal sleeves that are cracked or loose should also be coded CS4 “severe,” due to damage defect.

3.3.2 Anti-Friction Bearings

On many newer bridges, self-aligning ball or roller bearings are now being used. These units contain replaceable lubricant seals, as such excess lubrication around where the shaft enters the pillow block may be a sign of seal damage or failure.

Figure 3-3: A pillow block spherical bearing.

Anti-friction bearings may have one piece or split housings. Internal clearance measurements are not generally taken by inspectors to determine the amount of wear, as very little wear typically occurs with the units. Their seals help to prevent the entry of foreign materials and make measurement impractical.

Routine Anti-Friction Bearing Inspection

- Inspect bearing assembly for dirt, foreign material, paint loss, corrosion, and excessive lubricant.
- Inspect bearing pedestal, support, and entire housing exterior for cracking or signs of stress.
- Inspect fasteners, foundation bolts, and nuts for signs of deterioration due to rusting or fatigue, note any loose fasteners.
- Inspect bearing for proper lubrication and fittings, note any missing or malfunctioning lubrication components.
- Carefully inspect the seals. Be sure they are in place and functioning properly. Excess lubrication passing the seal may indicate seal failure.
- Observe the bearing during operation and note unusual vibration or noises. Any loud noises could be a warning of distress and trouble, as anti-friction bearings normally run with little discernible noise.
- After an operational cycle and the shaft has stopped rotating, feel the shaft immediately adjacent to the bearing, if excessive heat is noted measure operating temperature with a surface pyrometer, thermal imaging camera, or other similar gauge.

Anti-Friction Bearing Coding Recommendations

- Frictionless bearings that show signs of excessive wear, vibrate excessively, make grinding noises should be coded CS4 “severe,” due to wear defect.

- Individual rollers or ball bearings that are not free to roll, where bearing faces are scored or loose, or where the bearings running temperature exceeds 200 degrees Fahrenheit should be coded CS4 "severe," due to operation defect.

3.3.3 Trunnion Bearings

Trunnion bearings are used in many types of bascule and vertical-lift bridges, they may be sleeve or anti-friction type bearings and are usually housed in large split type pillow blocks. The trunnion bearing shaft diameters are large typically from 10 to 30 inches depending upon the size of the bridge.

Figure 3-4: Excessive contaminated lubricant of the trunnion bearing of a bascule bridge. Coded CS3 "poor," due to lubrication defect as the lubricants exhibit moderate contamination.

Routine Trunnion Bearing Inspection

Disassembly is not recommended during routine inspection.

- Inspect bearing assembly for dirt, foreign material, paint loss, corrosion, and excessive lubricant.
- Inspect bearing pedestal, support, and entire housing exterior for cracking or signs of stress. Particular attention should be given to areas of high stress concentration such as fillets and bolt holes.
- Inspect fasteners, foundation bolts, and nuts for signs of deterioration due to rusting or fatigue, note any loose fasteners.
- Inspect bearing for proper lubrication and fittings, note any missing or malfunctioning lubrication components.
- Remove lubrication purge plugs and check for moisture and grease condition.
- Observe the bearing during operation. Note any unusual vibration or noises.

- After an operational cycle and the shaft has stopped rotating, feel the shaft immediately adjacent to the bearing, if excessive heat is noted measure operating temperature with a surface pyrometer, thermal imaging camera, or other similar gauge.

Trunnion Bearing Coding Recommendations

- Noises of trunnion bearings during operation should be coded CS3 "poor" or CS4 "severe" depending on the inspector's interpretation of the cause of the noise.
- Trunnion bearings that "knock, thump or bang" should be coded CS4 "severe," and this should be reported to the District Bridge Engineer at the time of the finding. The trunnion bearings scheduled for follow up engineering investigation.
- Lack of lubrication, and lubrication passages that are blocked with hardened lubricant or debris should be coded CS4 "severe," and this should be reported to the District Bridge Engineer at the time of the finding.
- Contaminated lubricant should be coded CS3 "poor" to CS4 "severe" depending on the severity of contamination.
- Signs of misalignment, support structure distress, excessive deflections of support structures, or settlement or movement of bearing supports should be coded CS4 "severe," and this should be reported to the District Bridge Engineer at the time of the finding. The trunnion bearings should be recommended for additional specialty inspection.

3.4 SHAFTS

Shafts transmit torque from one part to another.

Shafts can be unique Movable Bridge Elements, and they can be incidental to many Movable Bridge Elements.

Shafts used to transmit torque between movable bridge elements, are themselves unique Movable Bridge Elements in such cases they are given a unique ADE designation number, and each shaft is given an independent Condition State (CS) Rating. These shafts should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
842	Shafts

Shafts are incidental to many Movable Bridge Elements; in such cases, they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. These shafts should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of these shafts should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have shafts.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	881	Bridge Specific Equipment (Lift)
844	Brakes	882	Bridge Specific Equipment (Swing)
845	Emergency Drive and Back-Up Power Systems	883	Bridge Specific Equipment (Pontoon)
847	Hydraulic Power Units	884	Bridge Specific Equipment (Bascule)
849	Hydraulic Cylinders /Motors/Rotary Actuators	885	Barriers - Movable Bridges
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	886	Traffic Warning Gates - Movable Bridges
886	Traffic Warning Gates - Movable Bridges		

Figure 3-5: Paint failure and corrosion of a machinery shaft, should be coded CS3 "poor" due to moderate corrosion defect.

Properly designed shafts have few problems; however, cracking is the most common defect, and the primary cause of shaft failures.

Figure 3-6: Corrosion and paint failure at intersection of shaft keyway shoulder and key. Shaft coded CS3 "poor" due to moderate corrosion defect.

Figure 3-7: Shaft keyway with sharp corners, these areas act as stress concentration points and should be closely inspected for defects.

Routine Shaft Inspection

- Clean and inspect the shaft carefully. Inspect localized areas of high stress such as shoulders and keyways. Document cracks, damage, paint loss, and surface corrosion.
- Cracks should be directly measured, documented, and compared to any available previous documentation to track propagation rates. Separation of the paint from the shaft along strain lines is another indicator for close visual inspection for cracks in those affected areas.
- Thoroughly inspect areas of paint loss, as they can be an indication of underlying areas of high stress, and cracking.
- Closely examine sharp cornered keyways for cracks.
- Closely examine the shaft, keyways, key, and connected elements for signs of stress, deformation, cracks, damage, or deficiencies.
- Inspect shaft for signs of distortion or twisting. This condition should warrant a CS3 "poor," or CS4 "severe" condition rating and closer visual examination for cracks.
- Observe shaft during operation, note any shaft wobble, or visible malfunction.
- Suspected cracks should be documented and recommended for further investigation

Shaft Coding Recommendations

- Visible shaft wobble should be coded CS3 "poor," until run out can be determined to be within limits detailed in the As-Built documentation.
- All cracked shafts should be coded and reported as CS4 "severe."
- Any shaft deficiency resulting in a CS4 "severe" rating should be reported to the District Bridge Engineer at the time of the finding. A deficiency report should be made to initiate follow-up testing, assessment, and corrective measures including contingency plans in the event of shaft failure, that remain in place until the shaft is replaced or repaired.

3.5 COUPLINGS

Couplings are used to join shaft ends together for the purpose of transmitting rotary motion and torque from one shaft to the next.

Couplings can be unique Movable Bridge Elements, and they can be unique incidental to many Movable Bridge Elements.

Couplings used to join the ends of Movable Bridge Elements together for the purpose of transmitting rotary motion from one Movable Bridge Element to the next are unique Movable Bridge Elements. In such cases, they are given a unique ADE designation number, and each coupling is given an independent Condition State (CS) Rating. These couplings should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
843	Shaft Bearings and Shaft Couplings

Couplings are incidental to many Movable Bridge Elements; in such cases, they are not given a unique ADE designation number nor an independent Condition State (CS) Rating. These couplings should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of these couplings should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have couplings.

El. No.	Element Name	El. No.	Element Name
845	Emergency Drive and Back-Up Power Systems	882	Bridge Specific Equipment (Swing)
847	Hydraulic Power Units	883	Bridge Specific Equipment (Pontoon)
849	Hydraulic Cylinders /Motors/Rotary Actuators	884	Bridge Specific Equipment (Bascule)
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	885	Barriers - Movable Bridges
881	Bridge Specific Equipment (Lift)	886	Traffic Warning Gates - Movable Bridges

3.5.1 Flexible Couplings

When shafts are installed in the field, there is usually some misalignment, however slight, between the machinery components connected by the shaft. Flexible couplings prevent stress buildup in the shaft and bearings resulting from misalignment. However, the misalignment correction is minimal, and shafts should be aligned as closely as possible when connected with flexible couplings.

There are a variety of flexible couplings available, and it is recommended that the inspector review the manufacturers documentation and maintenance manuals of the couplings in use to review clearance, alignment, maintenance, and lubrication specifications prior to coupling inspection. An overview of the most common flexible coupling types is provided below.

Gear Couplings

These are rugged high torque capacity units and generally used for connecting all shafts after the motor shaft in the span drive system.

A gear coupling consists of two hubs, shrunk and keyed to each of the shafts. The hubs have gear teeth machined on the outer diameter. Two flanged sleeves with internal gear teeth fit over the hubs and bolt together. The gear teeth on the hubs mesh with the internal teeth on the sleeves. A gear coupling is shown in the figure below.

Figure 3-8: Cutaway drawing of a gear coupling.

Chain Couplings

These are used in applications less heavily loaded than those requiring gear couplings.

A chain coupling consists of two sprockets, one mounted on each shaft. A short, continuous length of double width roller chain is mounted over the sprocket teeth. Power is transmitted from one hub to the other through the chain. A chain coupling is shown below in the figure.

Figure 3-9: Chain coupling of a rotary limit switch with no observable defects.

Grid Couplings

These are often used to couple the motors to high-speed shafts in the span drive and span lock systems.

A grid coupling has the same basic components as gear couplings, with both hubs shrunk and keyed onto their shafts. Slots are machined on each hub outer diameter. A spring-type grid is inserted in the slots and carries the entirety of the load. A cover with seals protects the grid and keeps lubrication in the coupling. A grid coupling is shown below in figure below.

Figure 3-10: Grid coupling with a sleeve half removed for internal inspection, coupling coded CS3 "poor" due to inadequate lubrication.

Routine Flexible Coupling Inspection

- Inspect exterior of coupling including all seals and gaskets. Document any paint loss, corrosion, damage, or cracks.
- Remove a grease fitting or purge plug to inspect internal lubricant condition.
- Inspect and document lubrication seeping through mating surfaces of coupling sleeves and flanges. If the coupling has been properly lubricated, the lubricant will only leak between the flanges if the gasket is faulty.
- If misalignment is suspected at a gear coupling, use calipers, machinist ruler, or other measurement means to measure the hub protrusion at 12:00, 3:00, 6:00, and 9:00 positions.
- Inspect flange bolts for tightness and condition, document any missing, loose, corroded, or otherwise damaged hardware.

- Inspect keys and keyways for signs of movement, stress, or cracking. If there are any indications of cracking further investigate using dye penetrant.

Flexible Coupling Recommendations

- The absence of coupling covers should result in a CS3 “poor” condition rating and a recommendation for corrective action.
- Fretting corrosion around bolts, and loose coupling hubs should all be coded CS3 “poor.”
- Couplings outside of manufacturers recommended alignment should be coded CS3 “poor” to CS4 “severe” depending upon the severity of misalignment.
- Signs of distress, lack of proper lubrication, and wear of individual coupling parts should be considered CS3 “poor.”
- Looseness, cracked keyways, or damage that appears likely to result in failure of the coupling should be coded CS4 “severe.”

3.5.2 Rigid Couplings

Rigid couplings transmit power from one shaft to another but have no alignment correction capacity. There are no moving parts in a rigid coupling, and no lubrication is required.

Figure 3-11: Rigid coupling.

Routine Rigid Coupling Inspection

- Visually inspect coupling for paint loss, corrosion, damage, and cracks.
- Inspect bolts on flanged couplings for tightness, corrosion, and damage.
- Inspect keys and keyways for tightness and cracking.
- Observe coupling during operation, note any coupling that shows excessive movement or noise.

Rigid Coupling Coding Recommendations

- The absence of coupling covers should result in a CS3 “poor” condition rating and a recommendation for corrective action.
- Fretting corrosion around bolts, and loose coupling hubs should all be coded CS3 “poor.”
- Couplings outside of manufacturers recommended alignment should be coded CS3 “poor” to CS4 “severe” depending upon the severity of misalignment.
- Signs of distress, lack of proper lubrication, and wear of individual coupling parts should be considered CS3 “poor.”
- Looseness, cracked keyways, or damage that appears likely to result in failure of the coupling should be coded CS4 “severe.”

3.6 REDUCERS

Reducers are enclosed gear sets that are mounted with shafts and bearings in dust proof, oil tight sealed housings. The assembly is generally referred to as a "speed reducer."

Speed reducers are unique Movable Bridge Elements as such they are given a unique ADE designation number, and each speed reducer is given an independent Condition State (CS) Rating. Speed Reducers should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
841	Speed Reducers

Reducers enclose gearing and bearings from debris. Their internal components are lubricated through an oil bath and/or pump system. Reducer bearings supporting the shafts are typically ball or roller type. Older reducers may have sleeve bearings supporting the shafts.

Reducers have provisions for replenishing the lubricant without disassembly of the unit, and sight gauges or dip sticks to allow maintenance and inspection personnel to confirm the lubrication level.

Figure 3-12: Reducer sight glass and dip stick.

Seals are installed around each shaft extension to prevent foreign matter from entering the housing and to prevent oil from leaking out. These seals require some lubricant or grease between the seal and the shaft to avoid rapid seal wear, as such some small amount of lubricant around the shaft/seal interface is normal.

Figure 3-13: Evidence of oil leaking past seals in a primary reducer, should be coded CS3 "poor" due to lubrication defect.

Breathers should be installed to allow clean dry air to move in and out of the housing to prevent a pressure differential between the inside and outside of the housing due to temperature changes caused by operation, and or ambient conditions. Silica desiccant filters are common and should be replaced when the color has changed from blue to pink. Without breathers in place, this pressure differential has the potential to rupture shaft seals.

Figure 3-14: Silica breather filter.

Figure 3-15: Internal gearing of a primary reducer.

Reducers are classified by the type of gearing in the reducer and by shaft orientation. Parallel shaft reducers will have herringbone or helical gears. Right angle reducers will have one worm gear set or one spiral bevel gear set to obtain the right-angle arrangement and may have additional sets of helical gearing if additional gear reduction is required.

A differential reducer is often used where an even distribution of loading between multiple final drive pinions is needed for the bridge span drive system. Usually, this differential reducer is used as the primary reducer and allows for the output shafts to rotate at independent speeds until their load share equalizes.

On vertical lift bridges a differential reducer is often equipped with a leveling clutch which allows the differential to be active/engaged (allowing the output shafts to rotate independently) and disengaged (locking/pairing the output shafts together). In general, for safe operation the differential should only be active with the span fully seated or when the span is just above the seats.

Routine Reducer Inspection

External Inspection

- Inspect the structural supports on which the reducer is mounted for proper bearing, condition, checking for signs of corrosion, cracking, or indications of stress.
- Inspect the reducer mounting hardware, checking for signs of corrosion, fit of the hardware, and tightness.
- Clean and examine the reducer mounting feet and flange fillets for any signs of distortion, corrosion, or stress.
- Inspect the flange bolts holding the housing halves together, as well as all other joints, hardware, and fittings.
- Inspect leveling clutch entry into reducer, if equipped.
- Inspect the shaft seals for fit, and note any dislodged, distorted, damaged leaking or dry seals.
- Inspect the condition of the breather filter.

Operational Inspection

- Ensure that personnel are aware of hazards of rotational equipment prior to operation.
- Observe the reducer through several cycles of operation, check for small movement or deflections of the reducer on its' base, any hardware improperly secured and vibrating.
- Observe the shafts under operation, looking for radial or axial movement of the shafts relative to their bearings.
- Listen for any abnormal noises, as a properly functioning and maintained reducer should run quietly. Unusual metallic sounds, whines, clunks, screeches, or hard knocks indicate problems in the reducer, and should trigger further investigation, and condition downgrade.
- Measure vibration at the bearings of the input and output shafts if safely accessible.
- If equipped, observe leveling clutch during bridge operation, noting the points at which the clutch arm is advanced and withdrawn. Confirm that the differential is being used appropriately, and

active only when fully seated or when the span is just above the seats. Improper operation of the differential during operation should be clearly noted in the inspection report findings.
- If the reducer is equipped with a port for the purpose of collecting an oil sample, an oil sample may be taken and sent to a lab for analysis.

Reducer Coding Recommendations

- Conditions unlikely to cause failure in the near future, such as minor corrosion, signs of moisture in the oil, or minor wear should be coded CS2 “fair.”
- Improper operation of the differential should be coded CS3 “poor,” improper operation of the differential resulting in inappropriate movement of the span should be coded CS4 “severe.”
- Cracked reducer enclosures, loose or broken anchor bolts, significant corrosion, or signs of seal failure should be coded from CS3 “poor” to CS4 “severe” based upon the inspector’s opinion of how imminent failure may be and the urgency of corresponding corrective actions.

3.7 OPEN GEARING

The term open gearing refers to gears that are not enclosed in an oil tight, dust tight housing. Spur and straight bevel gears are the most common open gearing type found in movable bridges.

Open gears are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each open gear is given an independent Condition State (CS) Rating. Open gearing should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
840	Open Gearing

Assembly and alignment of open gears in the field is difficult, with misalignment a common problem. Wear of open gearing is compounded by constant exposure to weather and the presence of abrasive foreign materials that become lodged in the gear mesh.

Open gears should have covers installed to protect anyone working near the gears and to partially protect the gears from dirt and debris entering the gear mesh.

Routine Open Gearing Inspection

- Ensure personnel are safely clear of rotating machinery and observe the gear set in operation. Note unusual noises, or abnormal movement.
- Ensure that the rotating machinery is inoperable during visual inspection and measurement.
- Inspect gears for signs of wear, note lubrication cleanliness, quality, pattern, and any contamination. Gear alignment issues can be noted by abnormal grease patterns, contaminated grease is often indicative of gear wear.

- Inspect the entire gear, check gear hub connection at the shaft, gear spokes, and stiffeners for deterioration and cracking.
- Check the grease contact pattern for percent tooth contact, and for balance assessment.
- Clean several gear teeth with a suitable solvent for further visual inspection, utilizing appropriate PPE.
- Photograph the cleaned teeth. Note any surface quality, wear patterns, damage, cracks, deformation, corrosion, and any other deficiencies.
- Cean and closely inspect the gear teeth at the area of contact with the bridge in the closed position. Vibration can be transmitted through the drive system from traffic load when live load shoes and span locks are in poor condition or misadjusted. This can cause accelerated point wear and destruction of the tooth profiles of the gear faces in contact.
- Investigate any areas of suspected cracks, particularly at the root areas of teeth. Utilize dye penetrant or other non-destructive testing methods where cracks are suspected.
- Proceed with tooth vernier or span measurements. In some cases, teeth will be worn or deteriorated such that meaningful measurements cannot be obtained, in these cases document thoroughly.
- Measure backlash and root to tip clearances at every gear set using feeler or taper gauges.
- Replace lubrication in the cleaned area.
- Compare measurements to data from bridge documentation or previous inspection measurements to assess wear quantitatively for the inspection report.

Vertical lift, and bascule bridges without differentials should be thoroughly inspected to confirm proper load sharing at the driving pinion.

- With the bridge in the firmly seated position, confirm that the driving pinions on opposite sides of the leaf engage the gear or rack at the same position.
- Observe the bridge during operation, and note any inappropriate movement, such as alternating starts and pauses to pinion indicative of improper load sharing.
- Inspect and compare grease contact patterns to assess load sharing.
- A recommendation for strain gauge testing should be made when deficiencies indicate possible improper load sharing.

Open Gearing Coding Recommendations

- Open gearing with excessive wear, cracked teeth, or any signs of potential for tooth failure should be coded CS4 “severe.”
- Defects that have the potential to cause failure of the drive machinery should be recommended for immediate corrective action.
- Lack of gearing covers, lack of lubrication, and any sign of accelerated gear tooth wear should be coded as CS3 “poor.”

3.7.1 Gear Alignment

Proper alignment of gearing is critical to provide a reliable and efficient service life. Correct alignment is defined as the condition where the tooth face of the gear and pinion are parallel with full face contact, and the proper amount of designed backlash is present.

Backlash is the space between adjacent non contacting teeth of the active gear mesh. It is also the freedom of one gear to move while the mating gear is held stationary. All gear sets require backlash.

Figure 3-16: Measurement of gear backlash in the field with a taper gauge.

Cross bearing, or pitch misalignment occurs when shafts are out of parallel. Gear teeth will have loading of one face on one end and on the opposite face of the other end. This condition is apparent with visual observation of the gear set, and wear pattern. It can be confirmed by checking the amount of backlash at each end on both faces of the tooth width.

End bearing, or yaw misalignment is the result of convergent nonparallel alignment. High tooth loads are at the end of both faces at one end of the same tooth. This condition is apparent with visual observation of the gear set, and wear pattern. It can be confirmed by comparing the amount root to tip distance of opposite sides of the gear mesh.

Radial misalignment refers to the center distances between the gear and pinion being incorrect, and the resulting pitch being out of contact or overlapped. Improper tooth contact results in either condition.

If the center distance is too great, parts of the tooth out of contact will not wear and a step will develop in the gear tooth profile between contacting and non-contacting surfaces.

When the center distance is too short, the pitch circles overlap, and backlash and/or root clearance are reduced or eliminated.

Figure 3-17: Measurement of root to tip clearance in gears with overlapping pitch circles in the field.

Axial misalignment is present when the pinion and gear are axially offset from one another such that the gear teeth cannot be fully engaged along the designed width of their full effective face.

3.7.2 Spur Gears

Spur gears transmit power between parallel shafts. They are correctly aligned when their center lines are parallel, pitch circles tangent, and the teeth are in mesh for their entire effective length from just above the fillet to just below the tip of the tooth. Perfect full-face contact is rarely observed in open gearsets; however, it is desirable to have open gearing with no less than 85% full face contact. Bridge machinery gearing is required to transmit loads as the bridge is being opened as well as during closing, as such wear should be present on both sides of the teeth.

3.7.3 Rack Gears

A rack is a flat straight bar that has teeth machined into one side. It is a gear segment with an infinite pitch radius and a resulting infinite involute profile (a straight line) resulting in straight sided teeth.

Figure 3-18: Flat rack gear of a rolling bascule bridge.

Many bridge applications require large radius gear segments, such as swing span bridges and bascule trunnion bridges. The involute tooth profile of such a large gear radius is nearly straight, and to simplify manufacturing years ago, these were fabricated with straight sided teeth and referred to as curved racks.

3.7.4 Bevel Gears

Bevel gears are used to transmit power between intersecting shafts. Usually, the shafts are at 90-degree angle relative to each other.

Figure 3-19: Bevel gears of a swing bridge.

Bevel Gear Alignment

Issues discussed previously in the gear alignment section apply to bevel gears as well. Bevel gears are in proper alignment where the shafts form the designed angle (usually 90-degrees), are engaged to the proper depth, have appropriate backlash, and are aligned on the same plane.

End-Loading will occur when the angle of engagement is greater than or less than the designed angle of engagement. Heel loading where the angle of engagement is greater, and toe loading where the angle is lesser.

Cross bearing results where the shaft centerline's do not intersect and are not on the same plane.

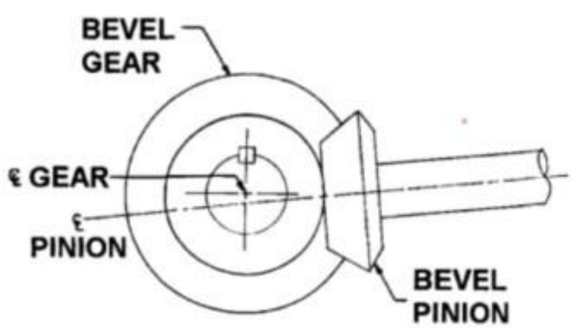

Figure 3-20: Illustration of cross bearing in bevel gears from the AASHTO Movable Bridge Inspection, Evaluation, and Maintenance Manual.

3.7.5 Gear Tooth Wear

Open gearing is subjected to wear from many sources. Issues of corrosion, lubricant contamination, improper lubrication, shock loads, improper installation, alignment, and manufacture are just a few. Inspection of wear patterns and type can provide insight into the origin and cause of wear. Proper identification and remedy before failure can mitigate service interruptions and extend the service life of open gearing. Inspectors should refer to ANSI/AGMA 1010-F14 for an in-depth guide covering the terminology, and appearance of gear teeth wear to supplement the types of gear wear discussed below.

Polishing

A new set of gears will inevitably have some irregularities on the working surfaces. During the initial period of operation asperities (roughness) of contacting surfaces will burnish until a smooth shiny surface develops. This is a normal wearing process, which will continue throughout the life of the gear set. As this continues, a pitch line will become visible as an unbroken line across the full face of the tooth.

Abrasive Wear

Abrasive wear can be caused by insufficient or improper lubrication, abrasive material in the lubricant, and overload. Open gearing is particularly vulnerable to contamination by foreign particles such as dirt, grit, and sand becoming trapped in the lubricant and gear mesh, that commonly causes this type of wear.

Figure 3-21: Abrasive wear of open gearing. Coded CS3 "poor" due to damage defect.

This wear progresses much more rapidly than polishing and will alter the tooth profile between measurements. Once this wear progresses to the point at which the tooth surface profile is destroyed, the wear will accelerate and eventually result in tooth failure.

Radial scratch marks and grooving are typical of abrasive wear. When severe, the grooving can be deep. With even subtle abrasion, the appearance of the tooth face will differ from the smooth surface associated with polishing wear.

Corrosive Wear

The deterioration of the gear tooth by chemical action is referred to as corrosive wear. It is often caused by water in the lubrication attacking the tooth surfaces. Bridge open gearing is regularly exposed to rain, snow, salt spray, and other corrosive products. The resulting oxide from this corrosion then further acts as an abrasive in the gear mesh leading to further abrasive wear such as pockmarks, scratching, and grooving.

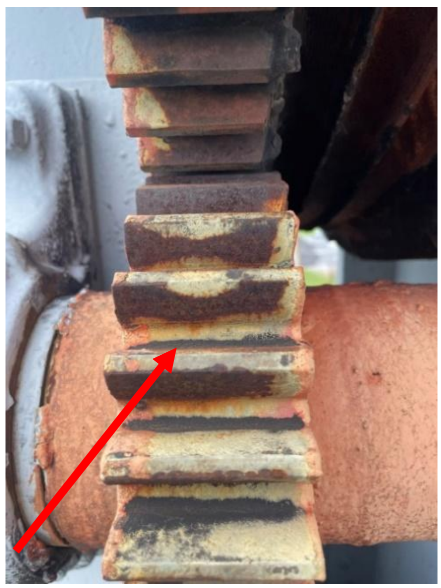

Figure 3-22: Corrosive wear on contacting faces of open gearing. Coded CS4 "severe" due to heavy corrosion defect.

Tip and Root Interference

Where the top of a gear tooth interferes with the root of a gear tooth in mesh, localized scoring, and possible plastic flow of the metal away from the area of interference can occur. As a result, the tips of the pinion gear will show signs of metal removal and have an abraded appearance in addition to tearing damage in the direction of rotation. This condition will typically result in considerable damage if uncorrected. This condition is caused by either improper tooth design/geometry where the gear should have included tip relief, or the meshed gears may be improperly installed with overlapping pitch circles. The resulting tight gear mesh causes heavy tooth loading, breaking down lubricant, and rapid abrasion leading to tooth failure.

Scuffing

Scuffing is the transfer of metal from one surface to another, in the case of open gearing this is caused by an adhesion that occurs when the metal surface of meshed gear teeth under high loads and compressive stress form metallic bonds and are then torn apart. Scuffed areas appear as plastically deformed, rough, and torn areas with radial damage, in the direction of the sliding movement between intermeshed gears. High loads on the gear teeth without proper lubrication can cause high instantaneous pressures and temperatures that result in the momentary welding together of tooth surfaces in contact. As the gears continue to rotate, this bond is broken, and metal is removed from both tooth faces. This scuffing is not a fatigue phenomenon though it is often confused with destructive pitting.

Surface Fatigue

Failure of the tooth surfaces, called surface fatigue, occurs when the fatigue limit of the gear material has been surpassed. Repeated stresses that surpass the limit of the surface gear material will cause surface fatigue and damage. This is often evidenced by small amounts of removed metal, and surface cavities. These start out as small and eventually combine with other deformities as the fatigue continues. Pitting and spalling are examples of surface fatigue.

Pitting

Pitting typically begins as small pits of 0.015-0.030 in diameter in overstressed areas and acts to redistribute the load between meshed gear tooth surfaces, by removing the high spots from the mated surfaces. If the overstress is not excessive, the pitting may stop, and continued operation will polish the contacting surfaces. However, if pitting is widely distributed across substantial portions of the contacting surfaces, the condition tends to progressively deteriorate. Unchecked pits will continue to increase in number and size increasing wear until the tooth profile is destroyed causing very rough and noisy operation. Fatigue cracks and tooth breakage can also result.

Plastic Flow

Plastic flow is the inelastic deformation of tooth surfaces caused by high contact stresses combined with the rolling and sliding actions resulting from the gear mesh. This condition is common to bridge gearing as it is associated with softer gear materials and will be observed on many bridge gears after several years of service. This surface deformation results from yielding of the surface metal under heavy load.

This condition can be recognized by evidence of material flow, where surface material has been worked over the tips and ends of gear teeth giving them a finned appearance. The gear tooth tips may become rounded over, and depressions appear in contact surfaces, and gear tooth faces may appear dented and battered.

Figure 3-23: Open gearing with surface deformation. Coded CS3 "poor" due to damage defect.

Commonly plastic flow in bridge gearing shows plastic flow buildup or ridging of the gear and a corresponding depression or grooving on the pitch line of the pinion. This occurs as the sliding action tends to push or pull material in the direction of sliding. This type of deformation will be very noticeable with large ridges, long before tooth failure occurs.

Tooth Breakage

Tooth failure caused by breakage in bridge machinery is rare. The gearing has usually been conservatively designed with a safety factor such that they should operate for a long time under the most adverse conditions. However, there remain some conditions that can cause abrupt and sudden failure. Extreme overload and shock loads can cause such rapid tooth destruction. Failures of these types normally start with a crack originating at the root section of the tooth and progressing until the whole tooth or a significant portion of it breaks away. Additional probable causes for tooth breakage include bending, fatigue failure, overload fracturing, tooth misalignment, material and manufacturing deficiencies, and foreign objects becoming trapped in the gear mesh.

Figure 3-24: Fractured gear tooth. Coded CS4 “severe” due to damage defect.

3.7.6 Gear Tooth Wear Measurement

Accurate gear wear measurement is an important part of bridge machinery inspection. A record of gear tooth wear will tell how wear is progressing from inspection to inspection. As subsequent measurements are made, it will be possible to determine whether the wear is accelerating or has stabilized. This information is valuable in planning near term and long-term maintenance.

Gear tooth measurement is used in determination of percent wear of the original dimensions of gear teeth. The percentage loss method as described in section 4.1.6.3 of the AASHTO MBI*,* is an important guideline for a mechanical inspector*.* It specifies 15 percent as the “maximum allowable limit beyond which component replacement is recommended.” As such gears with 15 percent or greater wear should be coded as CS4 “severe” condition.

Gear Tooth Measurement Using Gear Tooth Caliper

Gear tooth calipers are costly precision measurement tools requiring calibration, proper handling, maintenance, and training to use properly and record consistent and accurate measurements. Use of a vernier tooth caliper requires that the vernier scale is properly set to the chordal addendum for the gear being measured and measures the chordal thickness of the gear tooth. Chordal addendum and the chordal thickness of gear teeth is ideally found in as-built drawings or previous inspection reports, this information is often omitted or unavailable and will require calculation and confirmation by experienced personnel. Inspectors should refer to the AASHTO MBI section A.4 for methods of calculating gear tooth dimensions. The gear tooth caliper should be set to the proper vertical measurement set to the chordal thickness of the gear tooth, then the caliper is placed squarely on the gear tooth such that the anvil of the tool is tangent to the tooth outside diameter at the tooth midpoint. Measurements of chordal gear tooth thickness should be taken at both ends and midpoints of the gear teeth.

Gear Span Measurement Using Calipers

Another method of gear tooth measurement is through the use of digital, dial, or vernier calipers to take span measurements. However proper span measurement can be difficult, as the ideal number of teeth to be measured should take place between parallel involute profiles. When measured this way, the caliper jaws do not require being on the pitch line. However, this method of measurement does pose multiple potential difficulties.

- Calculation of the number of teeth over which to take this measurement, where the involute profiles are parallel, is complicated, often not included in bridge as-builts or documentation.
- Inspectors should refer to the AASHTO MBI section A.4 for methods of calculating gear tooth dimensions.
- It is not always possible to take this measurement in the field, as there is not an accessible position in which the measurement can be taken properly due to obstructions and gear placement.
- Calipers that can accurately measure over such distances for large gear teeth are costly and impractical for many maintenance personnel to own and maintain for such a specialty purpose.

3.8 BRAKES

Brake systems usually consist of separate devices designed to perform two distinct braking functions.

- Motor brakes are designed to decelerate and stop movement of the span. Normally connected directly to the drive motor shaft.
- Machinery brakes are designed to hold the span in raised or closed position. Normally connected as close to the final machinery output shafts as possible. Machinery brakes are usually set after the motor brakes are applied and the moving span is stationary.

Brakes are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each brake is given an independent Condition State (CS) Rating. Brakes should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
844	Brakes

Generally, brakes are composed of a linkage of moving parts and a friction member. Normal wear of brake shoe linings necessitates frequent adjustment and inspection as changes in brake shoe thickness directly affect the applied braking force.

Brakes regardless of type should be designed such that power is used to release the brake rather than to apply it, such that if power fails the brake will engage to prevent uncontrolled span movement, and the brake is constantly energized in the released position.

Routine Brake Inspection

- Ensure that rotating machinery is inoperable during inspection, and that release of the individual brake will not cause any unintended movement of the span.
- Inspect the structural support pedestal on which the brake is mounted for proper bearing, condition, checking for signs of corrosion, cacking, or indicators of stress.
- Inspect the brake mounting hardware, checking for signs of corrosion, fit of the hardware, and tightness.
- Inspect the brake assembly documenting lubrication condition of pins and moving parts.
- Inspect the brake drum and its connection to shafting, inspecting keyways for tightness and cracking, corrosion, or damage.
- Inspect the brake drum surface, brakes used to slow the span should be clean and smooth, brakes holding the span are often lightly corroded. Note any wear or grooves possibly caused by rivets contacting the face due to overly worn brake shoe liners.
- Inspect brake shoe's alignment with the drum.
- Inspect brake shoe contact with the drum prior to releasing the handbrake. Note any gaps or portions of the brake shoe that are not in contact with the drum using feeler gauges.
- Release the hand brake or otherwise energize the brake one at a time to record time delay for brake release.
- Use feeler gauges to measure and record brake pad clearance of the drum in the released position.
- Inspect the oil level if the brake is thruster type. Record any leaks. Sight glasses and oil level indication marks are typically set with the units on a level base from the factory. Be aware that in the field units may be on a tilted pedestal, and this tilts impact on the oil level line may need to be taken into consideration when evaluating the oil level of this machinery.
- Measure brake shoe pad material thickness and compare with manufacturers specifications.
- Measure and record torque settings of all motor and machinery brakes, compare with As-Built drawings.
- Measure brake reserve thruster stroke and compare with manufacturer specifications.
- Ensuring all personnel are clear of rotating machinery, observe brakes during bridge operation, note any excess heat, smoke, or other indications of improper operation or brake drag.

Brake Coding Recommendations

- Incomplete, misaligned, or improper brake shoe contact should be coded CS3 "poor" to CS4 "severe" depending on the severity of deficiency.
- Brakes that are malfunctioning, inoperable, or fail to provide the required braking force should be coded CS4 "severe," reported to the District Bridge Engineer at the time of the finding, and an immediate deficiency report should be filed.
- Brakes found to have insufficient reserve thruster stroke should similarly be coded CS4 "severe," reported to the District Bridge Engineer at the time of the finding, and an immediate deficiency report should be filed as there is a risk that they could fail to provide braking force.

3.8.1 Thruster Brakes

Thruster brakes are operated by an electric motor and pump that produce hydraulic pressure to extend an actuator. The thruster rod extension releases the brake shoes through linkages in the assembly, allowing the brake drum—mounted on the rotating shaft—to turn freely. When power is removed and the actuator retracts, the shoes are forced against the drum to apply braking torque. Most new motor and machinery brakes are of this type.

Figure 3-25: Top view of thruster brake and drum inside protective machinery cover.

3.8.2 Dual Magnet Clapper and Solenoid Brakes

Dual magnet clapper brakes are operated using dual magnets, called clappers. Each magnet is wound to produce an opposite pole face. When energized the coils attract each other and press against the brake rod on top of the frame which compresses a spring and releases the brake shoes from the brake drum.

A solenoid brake uses an electrically operated solenoid coil to magnetically draw an iron core into the solenoid. The iron core is attached to the operating assembly that releases the spring tension and releases the brake shoes from the brake drum.

These brakes are both “instant on” type which can create heavy braking torques on drive machinery. Systems with this type of brake should be inspected for signs of shaft or gear distress resulting from high braking forces applied quickly.

3.9 SPAN LOCKS

There are many types of devices used to resist rotation and vertical movement of the span and lock the movable spans in closed and or open positions. They are relatively simple devices, and the operation, maintenance, and likely points of wear should be apparent to the inspector after studying the As-Built drawings.

Span locks are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each span lock is given an independent Condition State (CS) Rating. Span locks should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
860	Span Locks/Toe Locks/ Heel Stops/Tail Locks

Excessive clearances at the span locks can allow excess movement and vibration of the span under traffic conditions.

Routine Span Lock Inspection

- Observe the break between adjacent leaves, or the leaf and approach span, measure and record vertical deflection. A dial indicator is useful to accomplish this. Vertical deflection from 1/8 – 1/4 inch should be coded CS3 “poor.” Vertical deflections that exceed ¼ inch should be coded CS4 “severe.”
- Observe the span lock device during its complete operational cycle, note any unusual noises, inappropriate movement, or operational deficiencies.
- Inspect the span lock assemblies, machinery bases, sockets, and hardware, for signs of corrosion, paint failure, stress, and damage.
- Inspect the lubrication system, and component lubrication.
- Inspect all individual components powering the assembly, such as hydraulic cylinders, motor brakes, gears, bushings, shafts, and cranks.
- If the locks have a method for manual operation, the system and all hand cranking tools should be inspected.
- For vertical lift span locks:
  - Perform the same as above. Observation of vertical deflection will occur on both sides of the span at break between the approach spans.
- For conventional and self-contained lock bar systems:
  - Inspect the bronze liners of the socket, for secureness, and wear.
  - Measure the lock bar and guide socket clearance with the use of feeler gauges.

- For intermeshing locks:
  - Inspect the jaws for wear, corrosion, and damage. Access to this area may be difficult and require special equipment and coordination.
  - Measure clearance with feeler gauges if possible. Relative vertical motion under traffic load can be an indication of loose fit and require shimming or maintenance.

Span Lock Coding Recommendations

- Span locks with vertical movement under heavy live loads from 1/8 to 1/4 inch should be coded CS3 "poor."
- If the vertical movement exceeds 1/4 inch, the locks should be coded CS4 "severe" until rating calculations can be performed to evaluate stresses on the primary members, the span lock can then be reevaluated based upon the specific maximum deflection defined in that process.

3.9.1 Bascule Span Locks

Span locks are located at the end of the trunnion bascule leaf and used to hold the span securely closed. On a single leaf bascule, the lock bar operator is mounted to the substructure toe and engages a lock bar on the end of the span. On double leaf bascules the socket is located at the end of the adjacent leaf.

When locks are mounted on the counterweight end of the span, they are called tail locks. These locks are typically located on a bridge when the deck extends behind the centerline of rotation. The tail locks are mounted to the substructure and engage a socket on the movable span.

Figure 3-26: Span lock and sockets of a double leaf bascule.

Loose lock bar fit can often be discovered by measuring deflection of the floor break between adjacent leaves on double bascules, or the leaf and the approach span floor break. Relative vertical motion at the leaf brake will generally indicate loose fit.

Span Lock Machinery – Lock Bar

A lock bar is used to secure the bascule span on many bridges. The lock bar slides through two span-mounted guides and engages a socket mounted to the substructure, tower, or leaf (on a double-leaf bascule).

The lock bar should move freely through the guides and socket, which should have bronze liners with lubrication fittings. If the leaves are properly aligned, a small clearance is provided, top and bottom and slightly more on the sides, for rectangular lock bars.

When the leaves are closed and traffic passes over the bridge, the lock bars are subject to top and bottom loads. With proper clearance little span movement will develop as the traffic passes over.

A limit switch, driven by a gear or line shaft, is interlocked with the operating controls. It prevents over-travel of the lock bar or operation of the bridge before the lock bar is withdrawn.

Hydraulic Actuator Lock Bars

Locks may also be actuated by a hydraulic cylinder.

Figure 3-27: Hydraulically operated lock bar.

With the hydraulic lock bar, the bar is pinned directly to the piston rod of the cylinder. Limit switches can be mounted on the receiving sockets so that a positive indication is given when the bar is fully driven. Flexible, accordion type boots may also be used to protect the piston rod from foreign materials, water, and the environment. The socket and lock bar assemblies otherwise resemble conventional lock bar machinery arrangements.

Self-Contained Lock Bar Operator

The self-contained lock bar operator performs the same function as a conventional span lock bar machinery, but has its own drive motor, brakes, and limit switches integrated into the unit. Torque from the motor is translated to linear force by the gear and acme screw. With proper clearance and alignment little span movement should occur during live load passage over the span.

Intermeshing Span Locks

Many rolling lift double leaf bascules have rigid nonmoving intermeshing jaw and diaphragm type span locks. These rigid locks consist of a tongue and groove where the tongue intermeshes with grooves on the opposite leaf. The bottom groove extends further than the top portion. When the leaves are lowered the leaf with the grooves is lowered first and is stopped short before fully set. The leaf with the tongue is then lowered until it meets the opposite leaf. Once intermeshed the leaves are lowered until both leaves are fully seated.

Access for inspection of this type of span lock system can be difficult and require special equipment, planning, and coordination.

3.9.2 Vertical Lift Span Locks

Vertical lifts utilize span locks to hold the span against vertical movement in the closed position. This is accomplished using jacking mechanism engaging a wedge inserted into a socket and guide assembly that firmly holds the lift span in place to the pier.

Figure 3-28: Vertical lift span locks inoperable in the released position. Fractured gear tooth. Coded CS3 "poor" due to moderate corrosion defect.

Another method is the use of pier mounted actuator engaging a latch that interfaces with a fixture mounted to the span girder.

Figure 3-29: Latch style vertical lift span locks, inoperable in the open position. Coded CS4 "severe" due to operational defect.

3.10 LIVE LOAD SHOES

Live load shoes are simple devices that are vitally important when the movable span is in the closed position. They are used on many vertical lift and bascule bridges. Their function is to carry the weight of the traffic (live loads) and allow vertical positioning of the span in the closed position.

Live load shoes are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each live load shoe is given an independent Condition State (CS) Rating. Live load shoes should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
861	Live Load Shoes/ Wedges/Strike Plates/ Buffer Cylinders

A live load shoe consists of the shoe mounted to the movable span and a strike plate secured to the pier or another portion of the fixed structure. The bottom of the shoe typically incorporates a slight curvature that prevents edge contact due to slight misalignment or leaf deflection. The size of the shoe is determined by the live load it is intended to support.

The shoes are typically mounted on the main girders and the strike plates on piers. The two engage when the leaf is closed. Proper adjustment provides firm contact between the strike plates with the span closed, locks driven, and brakes set under traffic load. Shims are used to adjust and maintain this firm contact. Improper adjustment of the live load shoes can transmit loads into machinery and structural components that can exceed their design loads and can result in failure.

On trunnion type bascule bridges, live load shoes are usually mounted forward (toward the navigational channel) of the trunnion center line.

Figure 3-30: Live load shoes of a bascule bridge, designed to accept a lock bar. The hardware of this live load shoe base is not properly tightened. Coded CS3 “poor” due to connection defect.

On vertical lift bridges, live load bearings are mounted on each end and both sides of the span. They can also serve as centering devices to properly align the span in the closed position.

Figure 3-31: Live load shoe of a vertical lift bridge. Coded CS4 "severe" due to heavy corrosion.

Live load shoes are located on both sides of a leaf and on very wide bridges there may be three or more across the width of the leaf.

On trunnion bascules, a rear live load bearing may be present. When a forward live load bearing is present, the rear live load bearing will have a small clearance.

Live load shoe clearances if any are generally given in the design plans and should be verified. In the absence of this information inspectors should assume that the presence of any gap requires further investigation and engineering evaluation of the stresses resulting from the gap.

Routine Live Load Shoe Inspection

- Inspect shoe and baseplate bearings are flush and in firm contact, note any signs of stress, cracks, or deformation at or near the live load shoe or strike plates. Record any gap with the use of feeler gauges. Shims are provided to adjust the position of the shoe and strike plate. Failure to maintain proper adjustment of the live load shoes can result in damage of the trunnion bearings, span locks, and the live load shoes themselves.
- Inspect fastener hardware and shims for corrosion, section loss, damage, and deficiencies.
- Inspect live load shoe and strike plate for signs of damage, deformation, cracks, paint failure, corrosion, and section loss.

- Inspect the contacting surfaces between the shoe and plate to see that they are not deformed. Particular attention must be given to the shims as they deteriorate rapidly under corrosive action and the repeated application of loads causing slight relative movements resulting in fretting corrosion.
- Observe the live load shoe under traffic load. Vertical deflection that exceeds ¼ inch should be coded CS4 “severe.”

Live Load Shoe Coding Recommendations

- Vertical span movement at the live load shoe under heavy loads should be coded CS3 “poor.”
- Relative movement at the shoes resulting in a vertical gap greater than ¼ inch should be coded CS4 “severe” until rating calculations can be confirmed to determine that the resulting stresses on primary members do not present a hazard.

3.11 BUFFERS

Buffer cylinders, often considered shock absorbers, are typically mounted vertically on bascule and vertical lift bridges and horizontally on swing spans. Their purpose is to cushion the span during closing, eliminating shock loads and permitting secure, controlled seating of the span. Usually buffers are large pneumatic cylinders, although hydraulic devices are occasionally used. Typically, the cylinder contains a piston attached to a piston rod that extends beyond the cylinder body that engages a strike plate. Buffers are typically equipped with a means of lubrication such as an oil cup or reservoir.

Buffer cylinders are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each buffer cylinder is given an independent Condition State (CS) Rating. Buffer cylinders should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
861	Live Load Shoes/ Wedges/Strike Plates/ Buffer Cylinders

On bascule and vertical lift bridges, the buffer is normally mounted vertically on the movable span. As the span opens the piston descends and air is drawn into the cylinder through a check valve and filter. As the leaf descends during closing, the end of the extended piston rod meets the strike plate of the pier and forces the piston into the cylinder. The air is compressed and can only escape through a control valve on the outlet port (the intake port is a check valve, and no air can escape from the cylinder through the intake). Thus, controlled air pressure absorbs shock loads during closing and helps seat the span softly. Proper adjustment of the buffer control valves should be maintained to prevent bouncing during seating and does not impart unnecessary shock loads to the system. The piston is equipped with cast iron rings to minimize air leakage, and a bronze bushing is provided in the cylinder cover plates to center the piston rod.

Figure 3-32: Bascule bridge buffer cylinder.

Occasionally, a bascule bridge will have buffer cylinders mounted in the counterweight pit that engage as the span closes. Vertical lift bridges may mount the buffer cylinders on the tower legs, the counterweight, or both to serve a similar function.

Horizontally mounted buffers have been used on swing spans. Their design must include a means to force the piston rod to extend as the span opens. This is typically done with a spring.

Routine Buffer Inspection

- Check oil level in oiler and verify operation.
- Inspect the buffer cylinder hardware, and machinery bases for signs of distortion, stress, cracking damage, corrosion, section loss, and paint failure.
- Inspect the buffer cylinder and strike plate for signs of distortion, stress, cracking, damage, corrosion, section loss, and paint failure.
- Inspect the cylinder body and seals, note contamination, damaged seals, or excess lubricants.
- Visually observe each buffer cylinder in operation. The piston rod should smoothly extend to its full position during the opening cycle. If the piston rod does not fully extend during opening of the span, it could indicate many things. Among them are improper lubrication, the piston rod binding in the guide bushing, wear and/or foreign material in the cylinder causing the piston to bind, the check valve not opening, or in the case of horizontal cylinders, a broken spring.
- When the bridge is closing, make certain the piston rod contacts the strike plate near its center.

- As the piston is forced in the cylinder, listen to confirm that air is exiting the pressure relief and buffer is operational. Make certain air is not escaping from the inlet pipe. If this occurs the check valve is not operating properly. This is most important because if the inlet valve is not functioning correctly, the buffer will appear to operate properly but no pressure will be built up and shock loads will be permitted.
- Check to make certain an air filter is on the inlet pipe if indicated in bridge documentation or as-built plans.
- If possible, it is desirable to check the pressure developed in the buffer cylinders during operation. One means of doing this is to install air pressure gages between the control valve and the cylinder on the outlet side, or between the check valve and the cylinder on the inlet side. This must be done simultaneously on each buffer on the leaf. Make certain the same amount of air pressure is developed in all cylinders. One person will be required at each location to observe and record the maximum pressure. Adjustment of the air pressure control valves may be required to equalize the pressure in all cylinders on each leaf and to make certain the span does not bounce when the buffers come into action. Note: Some bridges buffers are piped together such that the pressures throughout the system are automatically equalized.
- Note any bouncing of the span during closure. Bouncing can indicate improper valve adjustment.

Buffer Cylinder Coding Recommendations

- Nonfunctional cylinders or those found with piston rod's not fully extending should be coded CS3 "poor."
- Buffers with signs of abrasive wear or causing the span to bounce during closure should be coded CS3 "poor."
- Air escaping from areas of the cylinder other than by design should be coded CS3"poor" or CS4 "severe" depending upon the inspector's evaluation of the potential consequences of cylinder failure.

3.12 CENTERING DEVICES

Centering devices are provided to ensure that the deck, roadway, walkways on movable spans are properly aligned.

Centering devices are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each centering device is given an independent Condition State (CS) Rating. Centering devices should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown in the table below corresponding to the type of bridge the centering device serves.

El. No.	Element Name
881	Bridge Specific Equipment (Lift)
882	Bridge Specific Equipment (Swing)
883	Bridge Specific Equipment (Pontoon)
884	Bridge Specific Equipment (Bascule)

Routine Centering Device Inspection

- Inspect hardware, check fasteners and bolts for tightness, corrosion, section loss, and damage.
- Inspect guide plates, sockets, and equipment. Note damage, deformation, cracks, section loss, corrosion, and paint failure.
- Note any debris build up in sockets, guides, and pockets.
- Inspect for proper lubrication between mating surfaces.
- Inspect contact surfaces between the guide and socket, deformation, polishing, plastic flow, and hard bearing are all potential indicators of bridge misalignment.
- Observe during the complete operational cycle of the device engaging.
- For Swing Span Center Latches:
  - Observe during operation, checking the height of the wheel as it rises out of the pocket. Check the height of the wheel when it is raised out of the recess in the pocket to be sure that it can roll up the ramp properly when the span begins to rotate. Make sure the latch bar pawl disengages the pin and allows the latch bar to drop to the lowered position as the wheel rolls down the ramp.
  - Watch the latch bar operation as the span closes. The span should slow down and nearly stop before the latch bar drops into the pocket. Be sure the latch bar drops completely into the pocket.
  - Inspect for movement of the anchors.
  - Inspect for movement between the pocket and the substructure. Check the bar and the guide for deformation due to over travel as the span closes.
  - Check the system for proper lubrication.

Centering Device Coding Recommendations

- Centering devices that fail to align the span and roadway consistently and appropriately in the closed position should be coded CS4 “severe.”

3.12.1 Bascule Centering Devices

Bascule centering devices are designed and utilized to maintain precise alignment of the deck and roadway and ensure that the span lock bar is properly aligned. Some single leaf bascules include a tapered centering guide on the leaf fits with a pocket on the substructure. On double-leaf bascules the tapered guides on one leaf mesh with tapered slots on the opposite leaf as the bridge spans begins to seat.

Figure 3-33: Centering device of a double leaf bascule bridge, view is from below the centering device. Note that the centering device is in hard contact on one side. Coded CS3 “poor” due to alignment defect.

3.12.2 Vertical Lift Centering Devices

Many vertical lifts are equipped with span centering devices that consist of base plates with tapered guides mounted to the substructure on each corner of the span. These intermesh with a tapered positional guide mounted to the span as the bridge seats. The devices are designed such that they can accommodate thermal expansion of the span by fixing one end of the span and permitting the other end to expand or contract.

Figure 3-34: Vertical lift centering device. The hardware of the base plate at the corner pictured is not properly tightened. Coded CS3 "poor" due to connection defect.

3.12.3 Swing-Span Centering Latches

A centering latch may be used to align the span roadway and walkways on swing spans. The latch bar has a roller attached to its lower end that fits into a centering pocket that is attached rigidly to the substructure. The latch is raised by the drive crank shaft to allow opening of the bridge and drops again when clear of the ramped receiver. When the bridge is closed, the roller on the lower end of the latch rolls up the tapered ramp receiver and sets into the pocket positioning the span.

Figure 3-35: Swing-Span centering latch located below the span of a bob-tail swing-span.

3.13 MACHINERY BASES

Machinery is supported by machinery bases, frames, brackets, pedestals, and structural steel fixtures. All the forces developed must be transmitted through the supports to the piers or the spans on which the machinery is mounted.

Independent machinery bases used to support Movable Bridge Elements, are themselves unique Movable Bridge Elements, in such cases they are given a unique ADE designation number, and each machinery base is given an independent Condition State (CS) Rating. These machinery bases should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
850	Machinery Base

Machinery bases are incidental to many Movable Bridge Elements, in such cases they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. These machinery bases should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of these machinery bases should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have machinery bases.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	861	Live Load Shoes/Wedges/ Strike Plates/ Buffer Cylinders
843	Shaft Bearings and Shaft Couplings	865	Trunnion-Straight/Curved Rack
844	Brakes	881	Bridge Specific Equipment (Lift)
845	Emergency Drive and Back-Up Power Systems	882	Bridge Specific Equipment (Swing)
847	Hydraulic Power Units	883	Bridge Specific Equipment (Pontoon)
848	Hydraulic Piping System	884	Bridge Specific Equipment (Bascule)
849	Hydraulic Cylinders /Motors/Rotary Actuators	885	Barriers - Movable Bridges
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	886	Traffic Warning Gates - Movable Bridges

Gear, bearing, shaft and coupling alignment are all dependent upon the rigidity of the machinery bases. They are subjected to damage, corrosion and cyclical machinery stresses that may cause fatigue failure. Failure has the potential to cause damage to the supported machinery components and can cause significant bridge downtime.

Figure 3-36: Extensive paint failure and corrosion of a vertical lift machinery base. Coded CS4 "severe" due to heavy corrosion defect.

Routine Machinery Base Inspection

- Inspect machinery bases for signs of damage, deformation, cracks, section loss, corrosion, or paint failure.
- Observe bases during operation of the span to see if they deflect or move. Note any movement of machinery on the bases.
- Check all fasteners, including the foundation bolts.
- Note if any bases deflect visibly, and measure deflection.
- Inspect and observe carefully around flanges, welds, and fillets. Cracks may open during operation so that they are more visible. Additional dye penetrant or magnetic particle testing of any cracks uncovered should be scheduled as it is required to determine extent of the flaw.
- Inspect bases partially imbedded in concrete or resting on concrete, these can be subjected to corrosion and section loss at the interface with the concrete.
- Check any associated hardware for the framework such as pins, clevis feet, or a Hopkins frame for movement, cracks, corrosion, wear, or anomalies.

Machinery Base Coding Recommendations

- Cracked or damaged machinery bases should be coded CS3 "poor."

- Deflection of machinery bases during bridge operation greater than 1/16 inch should be coded CS4 “severe.”

3.14 AUXILIARY DRIVES

Gasoline and diesel engines are frequently used to develop emergency electrical power. The auxiliary engines sometimes drive the bridges directly or are used in conjunction with a generator that supplies electric power to either normal drive motors, or smaller, auxiliary motors.

Auxiliary drives are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each auxiliary drive is given an independent Condition State (CS) Rating. Auxiliary drives should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
845	Emergency Drive and Back-Up Power Systems

When using an auxiliary drive all machinery should operate in the usual manner, though most always at a reduced speed. Some owners utilize permanently mounted air drives, gear motors, or hydraulic motors. They may use air motors and electric tools to turn auxiliary manual drives.

Since auxiliary drives are seldom used, they are often overlooked during maintenance. As a result, they are frequently found in poor condition.

Most bridges have provisions for hand operation when all power sources, utilities, and emergency generating equipment fail. Auxiliary hand drives are composed of hand cranks that are connected to the primary gear drive system. In most situations little force is required to turn the machinery, but it does take a long time to manually open or close the bridge.

Figure 3-37: Auxiliary drive shaft of a swing bridge.

Routine Auxiliary Drive Inspection

- Ensure that the normal drive system cannot be activated. Operation of the normal drive while personnel are inspecting or testing auxiliary drive elements represents a serious hazard.
- Inspect auxiliary system, note corrosion, damage, deformation, paint failure, contamination, and deficiencies of system components.
- Inspect each auxiliary drive for proper operation, coordinate with bridge personnel who should know the location of hand cranks, chains, and other removable components of the system.
- Install and inspect removable components fit with the system.
- Coordinate with bridge personnel to start auxiliary systems and operate the bridge. Observe and record bridge cycle. If the auxiliary system has been recently used the inspector may review the operations log in lieu of performing an emergency test operation.

Auxiliary Drive Coding Recommendations

- Auxiliary drives that do not function should be rated CS4 “severe.”
- Drives that function with difficulty or leave doubt of their continued ability to function after testing should be coded CS3 “poor.”

3.15 KEYS AND KEYWAYS

Keys are used on shafts to secure associated rotating elements, such as couplings to join shafts, pinions, sheaves, and brake drums. A keyway is machined into both the shaft, and mated component to accommodate the key which enables the transmission of torque between the shaft and component.

Keys and keyways are incidental to many Movable Bridge Elements as such they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. Keys and keyways should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of the keys and keyways should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have keys and keyways.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	865	Trunnion-Straight/Curved Rack
843	Shaft Bearings and Shaft Couplings	881	Bridge Specific Equipment (Lift)
844	Brakes	882	Bridge Specific Equipment (Swing)
845	Emergency Drive and Back-Up Power Systems	883	Bridge Specific Equipment (Pontoon)
847	Hydraulic Power Units	884	Bridge Specific Equipment (Bascule)
849	Hydraulic Cylinders /Motors/Rotary Actuators	885	Barriers - Movable Bridges
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	886	Traffic Warning Gates - Movable Bridges

Figure 3-38: Key and keyway of a bascule bridge drive shaft. Note excess grease, and contamination of area, and possible fatigue crack of the shaft.

Setscrews are sometimes used along with the key to hold components axially and minimize backlash when the shaft rotates in both directions.

Routine Key and Keyway Inspection

- Inspect the key in keyway, note any missing keys.
- Inspect the key and keyway on the shaft and associated component for corrosion and paint failure. Thoroughly inspect these areas, as they can be an indication of underlying areas of high stress, and cracking.
- It is best practice to machine a radius in to reduce local stress at the otherwise sharp corners of shaft keyways. As such, sharp corner keyways should be closely inspected as fatigue, and cracks are more likely in these areas.
- Inspect the key and keyway on the shaft and associated component for signs of cracking, stress, deformation, and damage. The keyway radius is an area that should be inspected closely due to possible high stress concentrations.
- Inspect the key and keyway on the shaft and associated component, check that the key is properly seated, and tight, note the presence or evidence of any key movement.

Key and Keyway Coding Recommendations

- Loose or improperly seated keys in keyways should be coded CS3 “poor.”
- Cracked keyways and missing keys should be coded CS4 “severe.”

3.16 SWING BRIDGE MECHANICAL SYSTEMS

Swing bridges utilize many of the components covered in sections 3.3 through 3.16, however there are some mechanical systems specific to swing bridges worthy of additional consideration presented in the sections below.

Swing bridge mechanical systems are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and swing bridge mechanical system is given an independent Condition State (CS) Rating. Swing bridge mechanical systems should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
882	Bridge Specific Equipment (Swing)

3.16.1 Center Bearings

The center bearing is the most important wearing part of a swing span bridge. It supports the entire dead load weight of the swing span during bridge operation.

Figure 3-39: Center bearing of a swing bridge.

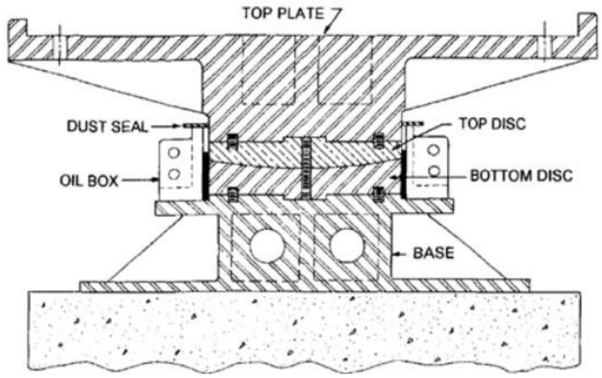

Figure 3-40: Cross sectional diagram of a typical center bearing.

The bearing consists of a top plate that is mounted to the bottom of the swing span pivot girder. The top plate sits on a bronze disc with a spherical bearing surface called the top disc. Dowels or keys are used to prevent the top disc from rotating with respect to the top plate. Dowels are not threaded. A boss on the top disc engages a counter bore in the top plate to locate the pieces and the span. The top disc sits on a hardened steel bottom disc with a mating spherical surface. The bottom disc sits on a steel base that in turn is attached to the pivot pier. The bottom disc has dowels or keys and a boss to locate it and prevent rotation between it and the base in the same manner as the top disc.

The movement between the bridge and support pedestal occurs at the spherical interface between the two discs. The surface must be well lubricated and highly polished to provide a surface that will support the weight of the span during operation. A split oil box is mounted on the base with a small amount of clearance with the discs and top plate. The bottom disc and part of the top disc are submerged in oil. A split dust seal is attached to the top of the oil box on older designs. The dust seal and oil box are both split in a vertical plane so they can be removed for inspection. Oil grooves are machined into the spherical surface of the top disc and the bottom of the bottom disc. There should be an oil drain in the base to permit the changing of oil in the bearing in addition to a sight glass in place to confirm the appropriate oil level.

Some swing bridges utilize a spherical roller bearing as their center pivot. These bearings can be sensitive to debris and flooding.

Disassembly, and internal inspection of center swing bearings is outside the scope of this document, requiring extensive personnel, equipment, training, engineering oversight, and Section 51 Bridge Maintenance supervision.

Routine Center Bearing Inspection

- Observe center bearing during bridge operation, personnel should remain safely clear of pinch and crush points as the span rotates. Listen for noises indicating poor lubrication, damage, or wear.
- Inspect for missing or loose fasteners, note any signs of damage, corrosion, section loss, or other deficiency.
- Inspect the center bearing for contamination, corrosion, paint failure, damage, signs of stress, cracks, and other deficiencies.
- Inspect the center bearing for signs of lubrication maintenance. Check sight glass oil level, oil cups, and any lubrication fittings.
- If the center bearing is equipped with an oil bath lubrication box, an oil sample should be taken and sent for analysis including a check for ISO oil cleanliness.
- If the center bearing is not equipped with an oil bath lubrication box, inspectors should coordinate with bridge maintenance personnel, to observe lubrication procedure, and collect expelled lubrication for analysis.
- During the operational cycle notice any unusual movement or deflection.

Center Bearing Coding Recommendations

- The noises of center bearings during operation should be coded CS3 “poor” or CS4 “severe” depending on the inspector’s interpretation of the cause of the noise.
- Center bearings that “knock, thump or bang” are likely to be experiencing high stresses due to intermittent sticking and slipping due to damaged bearing surfaces, abrasive particles, poor lubrication, and other potentially hazardous causes. Center bearings with these symptoms should be coded CS4 “severe,” reported to the District Bridge Engineer at the time of the finding and an immediate deficiency report should be filed. The center bearings should also be scheduled for follow up engineering investigation.
- Lack of lubrication, and lubrication passages that are blocked with hardened lubricant or debris should be coded CS4 “severe,” and an immediate deficiency report should be filed.
- Signs of misalignment, support structure distress, excessive deflections of support structures, or settlement or movement should be coded CS4 “severe,” and reported to the District Bridge Engineer at the time of the finding. The center bearing should remain in CS4 “severe” condition until engineering study demonstrates that the affected components are serviceable.

3.16.2 Drum Differentials

Some hydraulic swing bridges in Louisiana are equipped with a drum differential. As the swing span rotates, a sliding straight rack connected to the span, passes through the underside of the differential, thus rotating the central shaft of the drum differential. A right-angle bevel gear on the cam shaft drives a selsyn to provide feedback to the control system on bridge position. A control lever for the hydraulic pump is linked to the helix cam, and thus the appropriate hydraulic circuit is selected through the phases of bridge operation. Internal inspection of drum differentials is outside the scope of routine inspection.

Figure 3-41: Drum differential of a swing bridge. Drum differential coded CS2 "fair" due to minor corrosion defect.

Routine Drum Differential Inspection

External Inspection

- Inspect the structural supports on which the drum differential is mounted for proper bearing, condition, checking for signs of corrosion, cracking, or indications of stress.
- Inspect the drum differential mounting hardware, checking for signs of corrosion, fit of the hardware, and tightness.
- Clean and examine the reducer mounting feet and flange fillets for any signs of distortion, corrosion, or stress.
- Inspect the flange bolts holding the housing together, as well as all other joints, hardware, and fittings.

Operational Inspection

- Ensure that personnel are aware of the hazards of rotational equipment prior to operation.
- Observe the drum differential through several cycles of operation, check for small movement or deflections of the drum differential on its' base, any hardware improperly secured and vibrating.
- Observe the shafts under operation, looking for radial or axial movement of the shafts relative to their bearings.
- Listen for any abnormal noises.
- Measure vibration at the bearings of the input and output shafts if safely accessible.
- If accessible note lubrication quality of all observable open gearing.

Drum Differential Coding Recommendations

- Conditions unlikely to cause failure in the near future, such as minor corrosion, minor lubricant contamination, minor wear, and minor pitting of a gear tooth should be coded "fair."
- Cracked drum differential enclosures, loose or broken anchor bolts, or significant corrosion should be coded from CS3 "poor" to CS4 "severe" based upon the inspector's opinion of how imminent failure may be and the urgency of corresponding corrective actions.

3.16.3 Balance Wheels and Tracks

During bridge operation balance wheels provide the span with stability from tipping due to wind, and unbalanced loads. Balance wheels are mounted on the bottom of the span. The balance wheels are paired with a curved track, often rack teeth have been machined into the curved track and operates as an open gearing element of the bridge drive machinery.

Figure 3-42: Balance wheel and track, note corrosion, and surface quality of the balance wheel.

Routine Balance Wheel and Track Inspection

- Inspect balance wheels, track, and hardware, note loose or missing hardware, corrosion, cracks, damage, or deformation.
- Inspect track, ensure that track is of a consistent plane, and free of distortion with the aid of a laser level.
- Inspect the balance wheels and track with the wedges driven. No balance wheel should be in contact with the curved track. Measure and record clearance between wheels and track using feeler or taper gauges. If the drawings do not show what the clearance should be, use 1/16 inch as an appropriate value. Excess clearance can result in the swing span bottoming out on fenders, rest piers, and wedge seats.
- Measure and record clearance between wheels and track using feeler or taper gauges with the wedges pulled.
- Inspect lubrication fittings, and quality of lubrication.
- Rotate wheels, they should rotate freely.
- A dial indicator or feeler gauges can be used in conjunction with a pry bar to raise and lower the wheel to determine bearing and shaft wear.
- If accessible measure bearing clearance.
- Observe balance wheels during bridge operation cycle, ensure that personnel are clear of the rotating span and any pinch/crush points:

- When the wedges are withdrawn, the minimum clearance of the wheels should remain constant with no wheels making hard contact until the rotation begins if there is no wind load on the span. Movement indicates improper balance of the span.
- Observe wheels as the span rotates, note any binding, or hard bearing of wheels on the track.
- Span imbalance is indicated when hard bearing consistently on the same or same set of wheels.

Balance Wheels and Track Coding Recommendations

- Balance wheels that show signs of dragging instead of rolling during operation should be coded CS4 "severe."
- Wheels that squeal or emit other noises such as grinding, snapping, or banging when rolling during operation should be coded CS3 "poor," unless the inspector believes they may seize prior to the next inspection in which case they should be upgraded to CS4 "severe." In either case, a deficiency report should be filed recommending cleaning and lubrication of the components.
- The track should be of a consistent plane and provide a surface that allows the balance wheels to roll freely, otherwise it should be coded CS3 "poor," or CS4 "severe" based upon the inspector's assessment of the observed conditions.

3.16.4 Live Load Supports and Wedges

Support of live loads to the swing span in the closed position are accomplished with the use of live load shoes, wedges, live load bearings, rollers, and jacks. Their design on swing bridges must be such that they disengage prior to bridge operation, or that the bridge's rotation moves the components off their support pedestals, and that they are clear of obstruction throughout the rotation of the span.

Figure 3-43: Live load support of a swing bridge. The element pictured is outboard of the balance wheels on the center pivot pier and utilizes a hydraulic operated wedge.

Center wedges or live load shoes are not intended to support dead load. Located at the center pier, they are designed to stabilize the center of the span to carry traffic and to help relieve a portion of the live load. Before the span is opened, wedges are withdrawn, and live load shoes clear their bearing supports as the span rotates.

End wedges or jacks support a portion of the superstructure dead load sufficiently to prevent movement at the distant span ends under traffic and support live load.

Figure 3-44: Jack style end supports on a swing bridge.

Routine Live Load Support and Wedge Inspection

- Inspect wedges, jacks, shoes, rollers, bearings, and live load devices for deformation, damage, cracking, corrosion, paint failure, debris, contamination, and deficiencies.
- Inspect mounting hardware for tightness, corrosion, paint failure, damage, and section loss.
- Inspect sliding parts such as wedges and moving parts for appropriate lubrication.
- Inspect support clearance, note any gaps, improper bearing, or deflection under traffic loads.
- Observe live load supports components during a complete operational cycle.
    - Document any instances of loud operation of the center machinery during operation.
    - Document deflection when wedges are pulled at each end and at each wedge. Measure joints before and after wedges are pulled.
    - Ensure the center machinery when driven does not provide uplift to the center of the span. Record any measurable deflection because of center machinery being driven, as this is a deficiency and should be coded CS3 “poor” in the resulting inspection report.
    - Observe machinery clearance during operational cycle. Machinery must be appropriately adjusted, and account for potential “sag.” Observe the withdrawn machinery, ensure that it clears sockets, and obstructions during span rotation.
    - Observe end supports during operation. As they are withdrawn, note any asymmetrical span movement as it can be an indication of poor span balance.

- Verify proper roadway alignment, gap, and elevation when live load machinery is driven.

Live Load Support and Wedge Coding Recommendations

- Vertical span movement under live loads should be coded CS3 "poor."
- Relative movement at the inspected component resulting in a vertical gap greater than ¼ inch should be coded CS4 "severe" until rating calculations can be confirmed to determine that the resulting stresses on primary members do not present a hazard.

The AASHTO *Movable Bridge Inspection, Evaluation, and Maintenance Manual* provides guidance in section 2.8.2.11.4.2-1 for coding live load wedge, jack, shoes, and bearings based on area and material surface conditions, and is included below for reference.

Table 3-1: Wedge, jack, and shoe bearing area condition coding guide.

Measure bearing contact area length and width in contact when the wedge, jack or shoe is fully driven. Divide computed actual bearing area by available contact area surface of smaller component. Compute percentage of actual versus available contact area and code condition rating as follows.		
Percentage Bearing	**Condition Coding**	**Comments**
100%	CS1 GOOD	Bearing surface clean – no pitting
90% to 100%	CS2 FAIR	Minor pitting over <10% of actual
75% to 90%	CS3 POOR	Pitting may be present over <20% of actual
<75%	CS4 SEVERE	Pitting over >25% of actual contact area is a separate cause for coding CS4 "severe"

3.16.5 Centering Latches

Centering latches are used to align the road and walkways of the span in the closed position. These latch assemblies are placed on each end of the span.

The latch bar is attached to a lower roller end, mated with a centering pocket attached to the substructure. During operation of the span, the latch is raised by a drive crank shaft and the span can rotate. When the bridge is closed, the latch lowers, and then the roller on the lower end of the latch rolls up the ramps of the centering pocket, and drops into the centering pocket, accurately and repeatably centering the span in the closed position.

Routine Centering Latch Inspection

- Inspect system, note damage, deformation, section loss, corrosion, paint failure, wear, and contamination.
- Inspect for proper lubrication fittings, and maintenance.
- Inspect hardware for tightness, damage, deformation, section loss, and corrosion.

- Observe the latch bar during an operational cycle of the span, ensure personnel are clear of span rotation pinch, and crush points.
    - Observe wheel as it is raised out of pocket, note height of wheel as it raises out of the pocket, and note if the bar drops once clear of pocket and reengages the socket appropriately as the bridge returns to the closed position.
    - Coordinate with the electrical inspection team to confirm inclusion and operation of interlock elements. Without limit switches that provide feedback for latch position, there is a potential for the centering latch to fail to locate the span appropriately, and subsequent operation of machinery to cause damage when operating outside of ideal alignment.

Centering Latch Coding Recommendations

The AASHTO *Movable Bridge Inspection, Evaluation, and Maintenance Manual* provides guidance in section 2.8.2.11.4.2-2 for coding centering latches based on proper operational percentages and is included below for reference.

Table 3-2: Swing span centering latch condition coding guide.

Functioned properly during the stated percentage of opening	Condition Coding
More than 90 percent	CS1 “Good”
Between 75 percent and 90 percent	CS2 “Fair”
Between 60 percent and 75 percent	CS3 “Poor”
Less than 60 percent	CS4 “Severe”

3.17 VERTICAL LIFT BRIDGE MECHANICAL SYSTEMS

Vertical lift bridges utilize many of the components covered in sections 3.3 through 3.16, however there are some mechanical systems specific to vertical lift bridges worthy of additional consideration presented in the sections below.

Vertical bridge mechanical systems are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and vertical bridge mechanical system is given an independent Condition State (CS) Rating. Vertical bridge mechanical systems should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below unless otherwise indicated.

El. No.	Element Name
881	Bridge Specific Equipment (Lift)

3.17.1 Wire Ropes

Wire ropes are used to lift the spans of vertical lift bridges. Wire ropes are fitted with sockets at each end so they can be fitted to the structure and counterweight. The connection to the structure and counterweight is either directly pinned or utilizes eye bolts that permit tension adjustment after installation.

Wire rope (Cables) used in this application are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each wire rope is given an independent Condition State (CS) Rating. Wire ropes should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
880	Cables – Vertical Lift

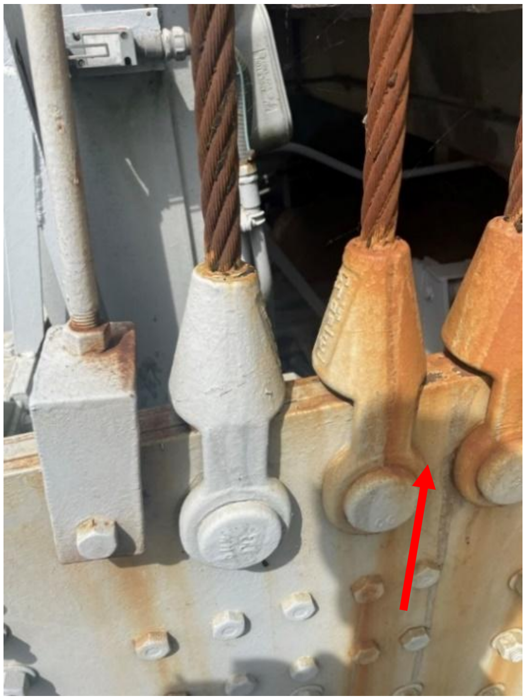

Figure 3-45: Wire rope attachment point to lifting girder of a vertical lift bridge, note corrosion staining.

Common causes for wire rope problems are fatigue, abrasive wear, corrosion, and neglect.

Fatigue presents as small cracks or breaks in individual wires.

Abrasion is identified as locations of flattened area on the outside surface of the wire rope. Abrasion between individual strands within the rope is also common, this type of wear results in abrasive dust and presents as a rusty appearance to the rope, this abrasive wear is usually pronounced in ropes just below the sheaves in the span closed position. Lack of lubrication accelerates abrasive wear.

Wire ropes have high stress areas tangent to operational sheaves and drums. Wear and abrasion will often be concentrated, or most severe in these locations.

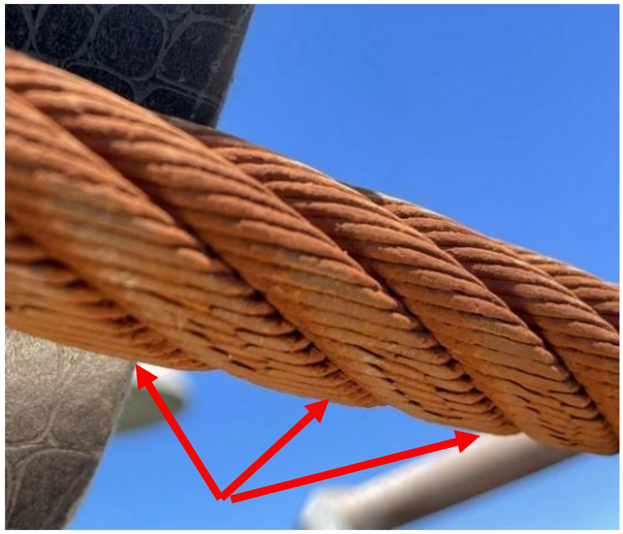

Figure 3-46: Wire ropes suffering from abrasive wear and corrosion. The outer strands of the wire rope have worn flat to such an extent that the outer strands have broken.

Corrosion of the wire rope is seen in the degradation of the steel along all exposed surfaces. Routine lubrication is necessary to protect wire ropes from corrosion.

Abrasion of wire ropes is caused by the presence of foreign matter, improper lubrication, damage from impacts, rubbing, mishandling the rope, and other methods of mechanical damage. This presents as plastic deformation of the steel, kinks, or bends in the rope noticeable when the rope is unloaded, and nicks and cuts to the wire strands.

Inspection of wire rope should occur in conjunction with inspection of sheaves and drums. Evaluations and recommendations for wire rope replacement should be made simultaneously with sheaves and drums.

Routine Wire Rope Inspection

- Thoroughly inspect individual wires for cracks, breakage, damage, kinks, distortion, and deficiency.
- Thoroughly inspect wire rope at tangent points to operational sheaves and drums where high stress may concentrate wear and abrasion.
- If breakage/cracks are found, document number of broken wires in any one rope lay of each strand.
- Inspect the outer individual strands of wire rope for flat areas indicative of abrasive wear. Measure the length of flattened sections, as this is useful data in determining the remaining service life of the wire rope. Note ropes where flattened areas have expanded completely to contact with adjacent strands, as their replacement should be planned.

- Inspect the wire rope lubrication, note it's adequacy, frequency of lubrication, and the inclusion of any foreign particles.
- Inspect the wire rope as it passes over the sheaves, note how it is seated in the sheave groove.
- Check for corrosion of wire rope, fasteners, and end sockets/connections. Note corrosive dust and abrasive particles indicative of wire rope wear.
- Measure the wire rope diameter. Compare to previous inspections and design parameters.
- Evaluate wire rope diameter in conjunction with groove diameter.
- If accessible, wire ropes should be checked for relative tension. There are specialty devices to measure their tension directly. A more practical method is to "shake" the wire ropes and observe and record the wire rope's vibrational frequency to evaluate their relative tension. This data can be useful in engineering calculations based upon wire rope lengths, and diameters can be used to quantify their tension.

Wire Rope Coding Recommendations

- Wire rope that is crushed or flattened should be coded CS4 "severe" and recommended for replacement.
- Wire rope which shows evidence of jammed, high strands or unlaying of strands or wires; bird caging; severe internal corrosion; excessive stretching; core protrusion; heat damage; torch burn; or arc strikes should be coded CS4 "severe" and recommended for replacement.
- Wire rope that has kinks, bulges, gaps or excessive clearance between strands or wire should be coded CS4 "severe" and recommended for replacement.

The Code of federal regulations section 30 CFR § 77.1434 is the most applicable standard for determining when wire ropes should be retired for movable bridges and is a useful additional reference in preparation for inspections and making recommendations in the inspection report.

The AASHTO *Movable Bridge Inspection, Evaluation, and Maintenance Manual* provides further guidance in the conditioning of wire ropes with damaged wires and is provided below for reference.

Table 3-3: Wire rope coding criteria.

	Number of wires broken or damaged in two strand lays			
	In running wire ropes		In standing wire ropes	
	In entire rope	In one strand	In entire rope	In end connection
CS2 "Fair"	2 or less	1 or less	1 or less	N/A
CS3 "Poor"	3, 4, or 5	2	2	1 or less
CS4 "Severe"	6 or more	3 or more	3 or more	2 or more

3.17.2 Sheaves and Drums

Sheaves are large-diameter, annular-grooved drums over which the ropes connecting the span and counterweight pass. Sheaves are mounted on trunnion bearings which usually have a split pillow block with a sleeve bearing or spherical roller bearing.

Figure 3-47: Sheave grooves of a vertical lift, with signs of abrasive wear corresponding to the wire rope lay.

Figure 3-48: Use of a sheave groove gauge to assess wear.

Inspection of sheave grooves should occur in conjunction with inspection of the wire ropes. Evaluations, and recommendations for sheave replacement or machining should be made simultaneously with any rope replacement recommended.

Routine Sheave and Drum Inspection

- Inspect the sheave or drum for signs of stress, damage, distortion, section loss, corrosion, paint failure, and deficiency.
- Inspect rope grooves for corrosion, damage, signs of wear, or the presence of abrasive materials.
- Inspect for indications of rubbing between ropes and grooves.
- Check the condition of the lubrication on the grooves and examine it for foreign matter.
- Compare groove diameters to groove gauges, to make an analysis of groove wear.
- Evaluate groove diameter in conjunction with sheave diameter.

Sheave and Drum Coding Recommendations

- Sheave and drum surfaces with signs of abrasive wear and lack of proper lubrication should be coded CS3 “poor” to CS4 “severe” depending on the severity of those conditions.
- Sheave grooves which fall outside of +2.5% to +10% sheave gauge analysis should be coded CS4 “severe.”

3.17.3 Tension Adjusting Devices

Means are often provided to remove slack and insure uniform tension in the operating ropes. Tensioning devices are located on the tower columns and serve as the anchors for the up-haul and down-haul ropes. There are several designs for adjusting devices, including long, threaded eyebolts with turnbuckles and hand-operated worm wheel mechanisms. Data for proper tension is given in the plans, which should be checked before attempting adjustments.

Routine Tension Adjusting Device Inspection

- Rope sockets, eyebolts, turn-buckles, and worm wheel adjusting devices should be inspected for rust, corrosion, wear, and proper lubrication.

Tension Adjusting Device Coding Recommendations

- Tension adjusting devices that fail to provide appropriate tension should be coded CS4 “severe.”

3.17.4 Span Guides

Span guides keep the span properly centered and restrain it from excessive movement during operation. Guides can be either sliding members or rolling contact types. The guides are located on the four corners of the span and maintain a close clearance (in the range of 1/4 to 5/8 inches) over guide rails located on the tower columns.

Figure 3-49: Vertical lift span guide angle and roller.

Routine Span Guide Inspection

- Have bridge operator raise span a few feet and check clearance at all four corners. Check clearance again with span a foot from the top. Be sure proper clearance is maintained for the entire length of travel of the span.
- On roller-type guides, be sure the rollers rotate freely.
- On sliding guides, be sure tracks are adequately lubricated for their entire length.

Span Guide Coding Recommendations

- Guides with inadequate lubrication or making hard contact during operation should be coded CS3 “poor.”
- Binding of span or rollers in guides should be coded CS4 “severe.”

3.17.5 Balance Chains

During lifting of the span, an unbalanced condition occurs due to the weight of the counterweight ropes as they pass over the sheaves. Balance chains suspended from the counterweight and attached to the tower compensate for this. Balance chains are massive link chains constructed of cast steel or iron links.

Figure 3-50: Balance chains.

Each link is pinned to its adjacent link and should not bind or undergo irregular movement during operation of the bridge. Pins and links should be well lubricated and free from rust, corrosion, and foreign material.

Routine Balance Chain Inspection

- Inspect balance chain during bridge operation, note any abnormal or binding chain movement.
- Inspect balance chain and fasteners to the tower and counterweight, note damage, corrosion section loss, poor lubrication, foreign material, and loose or missing hardware.

Balance Chain Coding Recommendations

- Balance chains with abnormal or binding chain movement should be coded CS3 “poor.”
- Failure of any chain link or connecting hardware should be coded CS4 “severe.”

3.17.6 Counterweights

The purpose of the counterweight is to offset the weight of the span. If the span and counterweights are in the correct balance, the load on drive machinery is minimal. Vertical lift spans should be balanced to have a small positive dead load reaction (i.e., slightly span heavy), at the supports when closed. The counterweights may be paired with a railed guide system.

Figure 3-51: Vertical lift counterweight.

Mechanical inspection of the counterweight should be performed in conjunction with structural personnel.

Routine Counterweight Inspection

- Inspect counterweights, their connecting, restraining hardware, and any guide system for signs of corrosion, section loss, damage, stress, cracking, distortion, and damage.
- Observe counterweight at rest and during operation, note initial alignment, and any changes in counterweight alignment during operation. Uneven tension on ropes, or imbalance of the counterweight can cause the counterweight to shift. Shifting of the counterweight during operation can cause uneven loading on mechanical components. In designs where the counterweight or its assembly is restrained, binding can occur and affect bridge operation.

Counterweight Coding Recommendations

- Shifting of the counterweight during operation should be coded CS3 “poor.”
- Any binding of the counterweight during operation should be coded CS4 “severe.”

3.17.7 Span-Leveling Devices

After prolonged operation or severe conditions of unbalance, slippage between counterweight ropes and sheaves could prevent proper seating of the span. Vertical-lift bridges are equipped with the same kind of machinery to adjust the span if one side seats before the other.

The simplest leveling device is the adjustable coupling. It is usually a single engagement gear coupling with large diameter plates bolted to each coupling half. Removing the bolts and rotating one of the plates very slightly will bring another set of three holes into alignment.

Spring adjustable torque limiting couplings, and keyless rigid couplings are also used to adjust the span. Checking for slippage is critical in these devices.

Some vertical lifts have a locking clutch at each end to level the span. It is often located in a special differential primary reducer. The inspector should visually check the general external condition of the clutch and associated machinery. If practical, have the bridge tender operate the clutch to be sure that it is functioning properly.

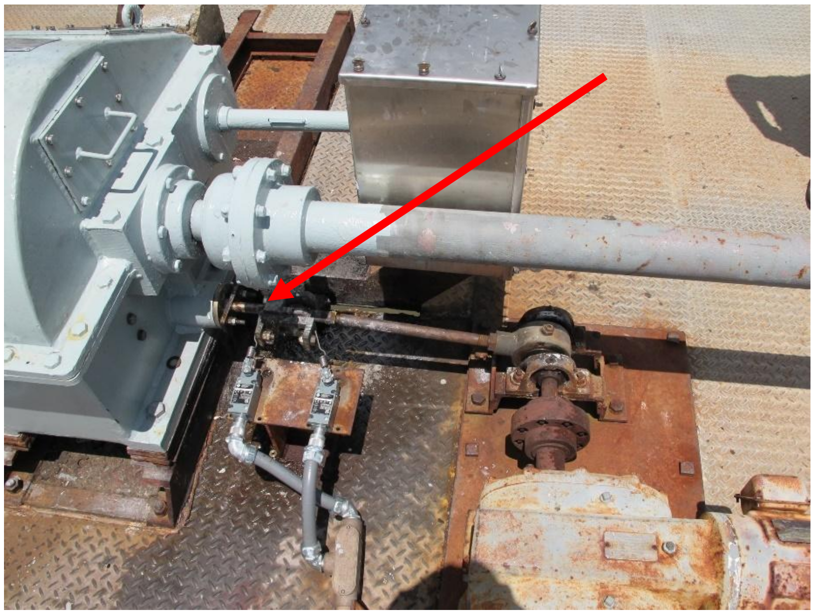

Figure 3-52: Span-leveling clutch of the primary reducer on a vertical lift bridge.

A detailed inspection procedure for locking clutch machinery is beyond the scope of the field inspector. If a leveling clutch is not working, a qualified expert should be consulted.

Routine Span Leveling Device Inspection

- Inspect span leveling device, note any damage, cracks, corrosion, section loss, or deformation.
- Inspect hardware, note any loose, damaged, or missing hardware.
- Inspect couplings used for span leveling for any sign of slippage.
- Observe span leveling device during operation.
    - Confirm proper span leveling device operation.
    - Note any abnormal noises.

Span Leveling Device Coding Recommendations

- Span leveling devices with loose or missing hardware should be coded CS3 “poor” to CS4 “severe” depending upon the severity of the condition.
- Damaged span leveling devices should be coded CS3 “poor.”
- Inoperable leveling devices should be coded CS4 “severe.”

3.18 BASCULE BRIDGE MECHANICAL SYSTEMS

Bascule bridges utilize many of the components covered in sections 3.3 through 3.16, however there are some mechanical systems specific to bascule bridges worthy of additional consideration presented in the sections below.

Bascule bridge mechanical systems are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each bascule bridge mechanical system is given an independent Condition State (CS) Rating. Bascule bridge mechanical systems should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below unless otherwise indicated.

El. No.	Element Name
884	Bridge Specific Equipment (Bascule)

3.18.1 Trunnions

Trunnion shaft assemblies are typically mounted to each side of the bascule leaf. Symmetrical and asymmetrical assemblies are the most common basic types in use. In either case, the weight of the entire bascule leaf is transmitted through the bascule girder to the trunnion shaft and to the trunnion bearings. As a result, trunnion shafts and their bearings are often of large diameter from 10 – 30 inches depending on the size of the bridge.

Trunnions used in this application are unique Movable Bridge Elements and as such they are given a unique ADE designation number, and each trunnion is given an independent Condition State (CS) Rating. Trunnions should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
865	Trunnion – Straight/Curved Rack

Trunnion shafts are installed in the same horizontal and vertical planes at the bridge construction. Throughout the life of the bridge, changes to this alignment may occur. If the alignment changes enough, the asymmetrical loading on the bearing and supports may cause the bridge to operate improperly. The inspections should identify when this condition may be occurring to determine when additional inspection or evaluation is needed.

Figure 3-53: Trunnion of a bascule bridge, bolted to the trunnion girder.

Symmetric trunnion alignment is accomplished during initial bridge construction. Asymmetric trunnion shafts allow for the adjustment of this alignment by rotating the relative inner and outer eccentric collars to achieve precise trunnion alignment.

Routine Trunnion Inspection

- Inspect trunnion bearings as described in section 3.3.3.
- Inspect bolts, hubs, rings, collars, and fasteners, that connect the trunnion shaft to the bascule girder. Note section loss, damage, deformation, stress, cracking, paint failure, corrosion, and deficiencies. Ensure all hardware is in place and tightened securely to prevent undesired movement of components during operation.
- Observe during operational cycle, note any noise, or undesired movement or deficiencies.

Trunnion Coding Recommendations

- Noises of trunnion bearings during operation should be coded CS3 “poor” or CS4 “severe” depending on the inspector’s interpretation of the cause of the noise.
- Trunnion bearings that “knock, thump or bang” should be coded CS4 “severe,” and this should be reported to the District Bridge Engineer at the time of the finding. The trunnion bearings scheduled for follow up engineering investigation.
- Lack of lubrication, and lubrication passages that are blocked with hardened lubricant or debris should be coded CS4 “severe,” and this should be reported to the District Bridge Engineer at the time of the finding.

- Contaminated lubricant should be coded CS3 "poor" to CS4 "severe" depending on the severity of contamination.
- Signs of misalignment, support structure distress, excessive deflections of support structures, or settlement or movement of bearing supports should be coded CS4 "severe," and this should be reported to the District Bridge Engineer at the time of the finding. The trunnion bearings should be recommended for additional specialty inspection.

3.18.2 Segmental Girders and Tread Plates

On rolling-lift bascules, curved tracks with pockets are mounted on the leaf and roll along straight tracks with lugs attached to the pier. If the span is properly installed, the lugs fit into the pockets as the span rolls back.

Figure 3-54: Lugged track and pocketed tread plate fastened to segmental girder of a rolling bascule bridge.

The purpose of the tracks is to permit the leaf to roll to its open or closed position. These members support the full dead load of the span when open as well as carrying some of the dead load together with some of the live load when the span is closed. They are vital to the operation and integrity of the span. Normally they should not be lubricated and thus are susceptible to rust and corrosion.

Routine Segmental Girder and Tread Plate Inspection

- Inspect and note corrosion, paint failure, damage, distortion, section loss, and contamination of the girder and track plate.
- Inspect hardware, note damage, loose, sheared, or otherwise deficient hardware.
- Inspect the pockets and lugs for evidence of wear or plastic flow. Shiny polished surfaces, abrasion dust, or metal shavings found at the lugs and pockets are indicators of possible span misalignment.
- Inspect for fatigue cracks near base of lugs and corner of pockets.
- Inspect the tread plate for signs of plastic flow or cracking.
- Inspect the bottom fillet of the bottom flange angle of the segmental girder for signs of distortion, stress, and cracking.
- Inspect segmental girder, track girder, and tread plate surfaces for squareness. The tread plate should be completely horizontal, a laser level can be used to confirm this.
- Ensure personnel are clear of rotating machinery pinch, and crush points during operational inspection.
- Inspect the track girder and tread plate during bridge operation, confirm uniform between components. Note loud noises, or abnormal operation, note movement or inappropriate relative motion of lugs and tread plate.

Segmental Girder and Tread Plate Coding Recommendations

- Cracking, signs of severe wear or plastic flow, deformation, fastener breakage, and any defect that indicates overstress should be coded CS4 “severe” unless an engineering study has determined that the condition does not adversely affect short term serviceability.
- After an engineering study has been performed and the deficiencies determined to not pose an immediate hazard, distressed components may be coded CS3 “poor” while awaiting long-term solutions which typically involve rehabilitating the structure and replacing the plates.

3.19 HYDRAULIC MACHINERY

Some movable bridges utilize hydraulic systems and components to create controlled appropriate motion.

Hydraulic machinery systems and components can be unique Movable Bridge Elements, and they can be incidental to many Movable Bridge Elements.

Many hydraulic machinery systems and components are unique Movable Bridge Elements and in such cases they are given a unique ADE designation number, and each hydraulic machinery system or component is given an independent Condition State (CS) Rating. Hydraulic machinery systems and components should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown in the table below corresponding to the type of system or component being inspected unless otherwise indicated.

El. No.	Element Name
847	Hydraulic Power Units
848	Hydraulic Piping System
849	Hydraulic Cylinders/ Motors/ Rotary Actuators

Hydraulic machinery is incidental to many Movable Bridge Elements, in such cases they are not given a unique ADE designation number, nor an independent Condition State (CS) Rating. This hydraulic machinery should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE number that they serve. Deficiencies of this hydraulic machinery should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have hydraulic machinery.

El. No.	Element Name	El. No.	Element Name
844	Brakes	881	Bridge Specific Equipment (Lift)
845	Emergency Drive and Back-Up Power Systems	882	Bridge Specific Equipment (Swing)
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	883	Bridge Specific Equipment (Pontoon)
		884	Bridge Specific Equipment (Bascule)

The inspection of these systems and components requires special training, and qualifications. Leaks in the high-pressure systems encountered during inspection can be potentially hazardous to personnel. Eye protection is always required, and inspectors should not check for leaks in high pressure systems with bare fingers or hands. High pressure oils can cause severe injury and fluid injections into the body if a leak develops. Use of a tool should be used to verify the location of any leaks that could produce a high-pressure jet of hydraulic fluid. Disassembly of hydraulic system components requires additional consideration and qualification, as the disassembly of hydraulic components represents additional hazards.

Many types of hydraulic systems and components are available. It is not feasible to provide specific data covering the disassembly and troubleshooting of hydraulic components due to the wide variety of types, individual brands, and system configurations that the inspector will encounter in the field. It is critical that inspectors should seek manufacturers data along with As-Built bridge plans, and documentation prior to the inspection of any given hydraulic system or component. Some basic components are detailed below to provide a description of the components the inspector should be familiar with and prepared to inspect.

Predicted Hydraulic Component Life

It is often difficult to make condition evaluations of hydraulic components based solely on visual inspection. Hydraulic elements are frequently in sealed units that require significant engineering expertise, time, testing, and disassembly to accurately evaluate their condition. The AASHTO MBI Table 2.9.2-1 provides useful guidelines for establishing hydraulic component conditions based upon years of service life, and bridge usage shown in Table 3-4 below. It should be noted that individual well maintained hydraulic components in ideal environments may surpass these predicted lifespans.

Table 3-4: Predicted hydraulic component life table.

COMPONENT TYPE	PREDICTED LIFE FOR STATED CONDITIONS (IN YEARS)					
	LOW USAGE Fewer than 400 openings per year		**AVERAGE USAGE** 400 to 4,000 openings per year		**HIGH USAGE** More than 4,000 openings per year	
	W/O Fluid Testing	**With Fluid Testing**	**W/O Fluid Testing**	**With Fluid Testing**	**W/O Fluid Testing**	**With Fluid Testing**
Accumulators and Reservoirs[1]	28	42	36	55	24	36
Pumps and Motors or Rotary Actuators[1]	24	36	30	45	20	30
Cylinders[1]	16	24	20	30	12	18
Operating Valves and Hydraulic System Sensors other than Electromechanical Limit Switches[1]	20	30	25	38	16	24
Welded Pipe or Flanged Pipe With O-Rings[2]	36	55	36	55	24	36
Tubing (except Flare Fittings)[2]	15	22	15	22	10	15
Flexible Hoses[1,2]	5	7	5	7	3	5

[1] If systems have history of contamination or overheating, a 50 percent reduction in the tabulated values should be assumed for components subject to accelerated wear of seals, O-rings, and other soft parts which can be easily damaged by grit or varnish accumulation.

[2] Pipe, tubing, and flexible hoses do not experience an increase in deterioration due to infrequent use.

A numeric condition grading can then be applied to the hydraulic element being inspected based upon its service history based on the guidance below.

- CS1 “good”: 65 Percent or more of predicted life remains.
- CS2 “fair”: 65 to 35 percent of predicted life remains.
- CS3 “poor”: 35 to 15 percent of predicted life remains.
- CS4 “severe”: Less 15 percent of predicted life remains.

Routine Inspection of Hydraulic Components

Routine inspection of Hydraulic components should not include the disassembly of hydraulic components.

- Visually inspect hydraulic systems and components, note corrosion, paint failure, section loss, damage, deformation, cracking, and deficiencies.
- Visually inspect hardware of the hydraulic components such as clevises, machinery bases, drip pans, hose clamps, and fasteners. Note paint failure, section loss, deformation, corrosion, or other deficiencies.
- Visually inspect the hydraulic system for signs of historic leaking. A leak that could be hard to detect during operation, will often leave evidence such as oil pooling or contamination from leak nearby.
- Inspect valves for leakage, and check wire and terminal connection condition of solenoid valves.
- Inspect hydraulic hoses, note hoses that are overbent with tight radius, signs of cracking, abrasion, and interference with neighboring hoses or obstructions.
- Inspect HPU reservoirs for proper filter/breathers, temperature, and fluid gauges.
- Obtain a hydraulic fluid sample and send it to lab for analysis.
- Observe the hydraulic components and system throughout the operational cycle.
    - Note any audio/visual deficiencies during the operational cycle.
    - Note any excess vibration of hydraulic pumps/motors. Use dial gauge, or a vibrational meter to quantify vibrational displacement or frequency.
    - During operation, the hydraulic stem and hoses pressurize, and machinery moves through its operational cycle. Note inappropriate movement, and or contact with obstructions.
    - Inspect system for hydraulic leaks during operation.
    - Verify and record hydraulic system operational pressures. Many systems have pressure gauges included in their design. Compare these pressures to documentation.
    - If gauge accuracy is in question, gauges are not in place, or broken, additional attempts should be made to determine operational pressures. This will require additional tooling and appropriate training to utilize a portable hydraulic test kit, and system test ports.
    - Check cylinders after multiple operational cycles, feel for heat. If excess heat is noted, assess heat zones with a thermal handheld camera.

3.19.1 Valves

There are three basic types of valves utilized in hydraulic systems, pressure control, directional control, and flow control valves. Inspectors should obtain documentation specific to the valve being inspected to understand their design features and recognize potential internal defects common to them.

Valve Coding Recommendations

- Valves that do not operate reliably and give signs of sticking open or closed should be coded CS3 "poor," and CS4 "severe" when heavy leakage results.
- Solenoid valves with signs of melting or burning insulation should be coded CS4 "severe."

3.19.2 Cylinders

Hydraulic cylinders convert hydraulic energy into mechanical movement in the form of linear motion. They are often used to drive span locks and are the driving machinery responsible for span movement in some bascule and swing bridges.

Cylinders should include rod boots when the cylinder is normally left in the open position. These boots protect the cylinder from contaminants and damage that can mar the surface of the rod and degrade the seal.

Cylinders rod and clevis ends may use a simple pinned connection or use spherical bearings.

Four factors are the most likely to reduce cylinder life: cylinder misalignment, high working pressures, temperature extremes, and contamination of the fluid or seals.

Figure 3-55: A horizontally mounted cylinder on a hydraulically operated swing bridge.

Side loads due to cylinder misalignment cause rapid wear of bearings and cylinder bores. Misalignment is most likely in fixed type side mounts, pivot and standard construction clevis pin mount arrangements are less likely to suffer misalignment.

Pressure should be maintained within the manufacturers' recommended limits and confirmed by inspection.

Fluid temperatures should be checked during operation. Temperatures above 200 or below 44 degrees Fahrenheit are not acceptable unless otherwise specified by design. Extreme heat and cold can cause valves to malfunction, seals to fail, and inconsistencies of operational pressure.

Abrasive grit and contamination in the fluid and around seals can score polished surfaces of the cylinder and destroy the seals.

Cylinder Coding Recommendations

- Overheating cylinders should be coded CS3 "poor" and those with leaking and signs of contamination as well should be coded CS4 "severe."
- Misalignment, loose hardware, or excessive clearances should be rated CS3 "poor" unless the inspector believes that failure is imminent, in which case a coding of CS4 "severe" is appropriate.
- Cylinders with damaged or missing boot covers should be coded CS3 "poor."

3.19.3 Pumps

Pumps for hydraulic systems are available in three basic types, these include vane, gear, and piston pumps. The biggest issue affecting pump performance and longevity is cavitation. Cavitation can occur in any fluid when the pump suction causes an area of low pressure that heats and eventually boils the hydraulic fluid. Fluids boil at increasingly lower temperatures as fluid pressure drops. Suction at the inlet or interior of the pump is likely to cause cavitation if the fluid is already warm, and the pressure drops due to high suction. Bubbles will form and collapse in the cavitation area causing exceedingly high localized pressure spikes, damaging the internal materials of the hydraulic system in that area.

Pump Coding Recommendations

- Pumps failing to provide necessary system pressure without running constantly should be coded CS4 "severe."

3.19.4 Filters

Filters should generally be of the bypass type where system failure due to a clogged filter is unacceptable and should be checked to see if the flow is acceptable. Filters that are bypassed by hydraulic fluid due to clogs should be recommended for corrective action and reported via deficiency.

Figure 3-56: Cartridge style filter in place on the primary hydraulic system of a hydraulically operated swing bridge.

Hydraulic system failure is most often the result of damage caused by system contamination. Thus, properly designed, installed, and maintained filters are a critical preventive measure to remove damaging contamination from the hydraulic system to ensure system longevity.

Filter Coding Recommendations

Clogged filters on systems with signs of heavy particulate contamination should be coded CS4 "severe" as such a filter is close to failing and allowing particulates to pass through the filter. Filters with a history of frequent replacement may be inadequate for their installed use and should be reevaluated by a qualified fluid power engineer.

3.19.5 Hoses, Piping, and Tubing

Hydraulic hose, rigid piping, and tubing transfer hydraulic fluid to, from, and between hydraulic pumps and hydraulic machinery. Proper routing, clearance, maintenance, and sizing are all critical in their longevity.

Figure 3-57: Overbent hydraulic hose, with cracking of the outer elastomer.

Hose, Piping, and Tubing Coding Recommendations

- Hoses with damaged elastomers should be coded CS3 “poor.”
- Hoses with excessive movement at fittings, hose leakage, or damage should be coded CS4 “severe.”
- Piping or tubing that is leaking should be coded CS3 “poor.”
- Cracks, or any observation suggesting imminent failure should be coded CS4 “severe.”

3.19.6 Reservoirs

Hydraulic reservoirs are the storage vessels for hydraulic fluid that is to be pumped to and from the cylinders or motors during machinery operation. These should be fitted with a filter/breather unit and have some means to check fluid level and temperature without opening the unit.

Reservoir Coding Recommendations

- Reservoirs without filter/breather units or means to check the fluid level and temperature without opening the unit should be coded CS3 “poor.”

3.19.7 Hydraulic Fluid

Hydraulic fluid should be clean, and of the type specified for the hydraulic system in the original design. Hydraulic fluid contamination is the primary cause of hydraulic system failure. Sampling and testing fluids is a reliable method to monitor system performance and provide timely detection of problems resulting from contamination. It is recommended that hydraulic fluid samples be evaluated for particle counts, viscosity, ISO cleanliness, and Total Acid Number (TAN).

ISO 4406 details methods for analysis and recommendations for hydraulic fluid power. Hydraulic fluid with ISO particle counts of 16/14/12 or greater should be recommended for fluid replacement or offline filtration and additional analysis of the hydraulic components and filters for methods of wear, and contamination.

TAN or Total Acid Number is a measure of corrosive acids in the hydraulic fluid and will increase over time along with viscosity as an indication of deterioration of the hydraulic fluid due to oxidation. Oxidation is initiated by heat, and impurities in the fluid, and is such a useful metric in determining hydraulic fluid quality, and remaining life. Hydraulic fluid with an increase of more than 2.0 mg KOH/g between hydraulic sampling should be recommended for replacement.

Hydraulic Fluid Coding Recommendations

- Fluid that has overheated or shows signs of particulate or chemical contaminants should be coded CS3 “poor” to CS4 “severe” based on the severity of the contamination.

3.20 SPAN BALANCE

Span balance is a particularly important consideration on movable bridges. The span must be sufficiently well balanced so that the load on the drive machinery is within the limits for which the bridge was designed. Adjustment of the spans balance is accomplished by placement and removal of counterweight blocks. If the bridge is extremely unbalanced, the machinery can be overloaded, wear out prematurely, and cause operating problems. This balance can change over time due to dirt, debris, deterioration, component wear, and alterations to the structure.

Span balance is a condition impacted by many Movable Bridge Elements but is not itself a movable bridge element. As such it does not have a unique ADE designation number. Issues of span balance are often notated under Movable Bridge Element ADE 863 – Counterweight, as adjustments to the counterweight are the primary method to adjust span balance. However, issues of span balance can impact other Movable Bridge Elements and span balance notes should also be included under the element that the span balance has impacted.

Span balance in this context refers to bascule and vertical lift bridges that are balanced by a counterweight system. Theories of the best balance condition varies among owners and should be established during bridge design and construction.

Span balance of swing spans does not generally affect drive system loads, drift tests are not possible due to their design, and methods of confirming or adjusting span balance of swing spans are beyond the scope of this document.

Routine Span Balance Inspection

- If bridge schedule permits, and with coordination of bridge personnel, and under the supervision of properly qualified and experienced personnel a drift test should be performed:
- Do not perform drift test in conditions of strong wind, snow, rain, or icing.
- Open the span to the 1/3 and 2/3 open position and slowly release the brakes. On vertical lifts release brakes in tandem and stop the drift test if span skew approaches the maximum allowable.
- The drift test qualitatively establishes whether the system is span or counterweight heavy.
- In conjunction with the electrical inspection team, record span motor currents during the complete bridge operational cycle.

Span Balance Coding Recommendations

- Span balance conditions outside of the bridge design specifications provided in As-Built documentation should be coded CS4 “severe.”
- Strain gauge testing should be recommended if any work has been performed that would impact balance, or if the drift test, and/or span motor currents indicate an abnormal imbalance:
    - Strain gauge testing requires extensive coordination, specialty equipment, and qualified personnel.
    - Balance adjustments through the placement or removal of counterweight blocks should only be made with district/engineering oversight based on the results of and subsequently verified by strain gauge testing.

Chapter 4
Electrical Inspection of Movable Bridges

4.1 OVERVIEW

The following section attempts to provide the inspector with a description of methods to inspect typical electrical elements of movable bridges found in Louisiana. The inspector should recognize that these descriptions and methods will often need to be supplemented with resources specific to electrical equipment and the bridge being inspected. Thus, it is the responsibility of the inspector to seek out and add to tooling, documentation, expertise, training, and additional resources in preparation for a successful electrical inspection.

4.2 MEASUREMENT TYPES AND PROCEDURES

In addition to visual inspection, measurements can be taken of electrical components to evaluate their physical and operational status.

Always wear appropriate PPE when working on live circuits. Properly rated gloves, clothing, safety glasses, and other forms of PPE may be needed. Refer to NFPA 70E 130.7(C) for more information on PPE. Measurements should only be attempted by trained and qualified personnel.

4.2.1 Voltage and Current

The voltage levels typically found on Louisiana bridges range from 120 to 480 volts, and the current levels are in the tens to hundreds of amperes. All conductors and enclosed electrical components present a risk of injury or death. In general, larger electrical enclosures and conductors are associated with a greater level of electrical hazard. The types of measurements used by electricians or other qualified personnel to measure voltage and current are beyond the scope of this manual.

4.2.2 Insulation Resistance

Insulation resistance describes the ability of electrical insulation to resist current flow. Insulation is designed to eliminate or reduce the risk of shock, fire, energy loss, and equipment failure. Age, exposure to environmental contamination, and weather reduces the effectiveness of the insulation over time. Insulation Resistance (megger) testing is beyond the scope of this manual and should only be performed by and electrician or other qualified personnel.

Additional information on insulation resistance testing may be found in AASHTO MBI 2.10.9, ANSI/NETA MTS, and IEEE 43.

4.2.3 Temperature

Temperatures of motors, motor starters, variable frequency drives, motor controllers, and other electrical equipment should be monitored during operation for signs of overheating. Temperature can be measured using a thermocouple thermometer, an infrared temperature gun, or a thermal imaging camera. Refer to the electrical equipment manufacturer's documentation for normal operating temperatures.

4.2.4 Tools and Equipment

Electrical inspections may require tools to inspect the broad range of components that make up bridge electrical systems.

The following tools are typically used inspections:

- Screwdriver: Philips head and flat head, used for opening enclosures and disconnect switches.
- Adjustable wrench: Used for opening enclosures.
- GFCI Receptacle Tester: Used to verify that receptacles are energized and checks the outlet for proper wiring. A button on the device tests the ground fault protection on GFCI receptacles.
- Non-contact Voltage Tester: Used for detecting AC voltage in wires or electrical outlets without touching the conductor.
- PPE: Personal protective equipment that is used while inspecting energized components, refer to section 1.3.3 Electrical Safety PPE and associated NEC references for further information and specifics.

Figure 4-1: GFCI receptacle tester plugged into a receptacle. The two yellow lights on the tester are illuminated while the bottom light is not, indicating the receptacle is functioning- energized and correctly wired.

Figure 4-2: Non-contact voltage tester.

Figure 4-3: Insulation tester with multimeter capabilities.

The following tools are typically used for in-depth inspections performed by qualified personnel and are not required for routine inspections described in this manual:

- Multimeter: Used for measuring voltage, continuity, and resistance.
- Clamping Ammeter: Refers to a contactless, clamping ammeter used for measuring current. These meters may also have multimeter capabilities like measuring voltage, continuity, and resistance.
- Insulation Resistance Tester: Refers to a DC, portable insulation resistance tester, used for measuring insulation resistance of motors and conductors.

4.3 ISOLATING EQUIPMENT

Disconnecting, isolating, and locking out equipment is a vital aspect of safety for performing inspection or maintenance. Isolating equipment involves turning off power to a device located downstream of a disconnecting device, this includes local disconnect switches and circuit breakers located upstream of the device.

To isolate a component, identify through the as-built plans how the device is connected to an upstream disconnecting device. Disable that disconnecting device and verify that the component is disconnected from power.

Refer to Section 1.3.3 Electrical Safety for safety considerations and Section 1.3.4 Lockout-Tagout for lockout tagout information.

4.4 BASIC CONTROLS

The control system governs the operation of the movable span. The control system serves as the command interface between operator and machine, allowing the operator to direct the bridge to open and close.

Drum controllers (or a rotary actuated selector switch) and relay logic provides for interlocking and sequencing to prevent out of order operation that may cause danger to the public or damage to the bridge.

4.4.1 Limit Switches and Rotary Cams

Limit switches are devices that function to stop the span/machinery at the limits of travel or provide position indication. The four most common types of limit switches found on movable bridges are the lever, plunger, proximity, and rotary cam.

Limit switches are incidental to many Movable Bridge Elements; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Limit switches should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the limit switches should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below is a table of Movable Bridge Element ADE's that often have limit switches.

El. No.	Element Name	El. No.	Element Name
841	Speed Reducers	881	Bridge Specific Equipment (Lift)
844	Brakes	882	Bridge Specific Equipment (Swing)
845	Emergency Drive and Back-Up Power Systems	883	Bridge Specific Equipment (Pontoon)
847	Hydraulic Power Units	884	Bridge Specific Equipment (Bascule)
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	885	Barriers - Movable Bridges
874	Control Console	886	Traffic Warning Gates - Movable Bridges

Lever Arm Limit Switches

Lever arm limit switches are often attached to bridge and actuate when the bridge is at the limits of travel such as fully open, fully seated, overtravel, etc. Lever arms are also used in shoe brake operating linkages to indicate when the brake is set and released, and on the span locks and wedges to indicate their position. A roller is usually provided at the end of the limit switch lever arm.

Plunger Switches

Plunger type limit switches are typically used to indicate when the movable span is seated, fully open, or fully closed. The switch housing is attached to either the movable or fixed part of the bridge and the plunger is depressed upon contact by a strike plate mounted to the span.

Proximity Switches

Proximity type limit switches are often attached to the bridge structure to indicate the movable span position, such as fully closed or fully open. Proximity switches open or close an electric circuit when they within a certain distance of ferrous metal or a magnetic target. Proximity switches do not have exposed moving parts.

Rotary Cams

Rotating cam limit switches are connected to the span drive machinery through a shaft and typically are used to indicate critical points of span travel, such as the “nearly closed” and “nearly opened” positions. Cams mounted on the shaft, within the housing, rotate with the shaft and open or close spring-loaded contacts.

Routine Inspection of Limit Switches:

- Examine the operation of the switches to make sure they are operating normally, confirm the limit switch is active in the control circuit.
- Check lever arm rollers to make sure they are free to rotate and make sure the limit switch housing is properly aligned with the strike plate. Spring should return the lever arm.

- Check for excessive looseness of lever arm assembly.
- Wiring should be checked for looseness or deterioration, look for any missing covers on the switch.
- Check for corrosion and section loss of lever arms.
- Check for secure mounting of the limit switch and the strike plate.
- Inspect the striker plate for any damage or deterioration.
- Check for corrosion and deterioration of plunger mechanisms.
- Check that the spring returns the plunger to the extended position.
- Check contact surfaces of movable and stationary surfaces for corrosion, metal filings, grease, and other debris.
- Check enclosure gasket and for moisture or corrosion inside switch enclosure.
- Check rotary cams for deterioration, general dirt/debris.
- Check terminations and terminals for tightness and corrosion.
- If present, check barriers between the terminals for deterioration.
- Check shaft seal integrity, breath and drain operation (if equipped).

Limit Switch Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the limit switch CS3 "poor."
- Failure of the gasket/seals or moderate corrosion of the limit switch housing, wire terminals, supports or support hardware should be coded CS3 "poor." Severe corrosion or holes in the housing/enclosure should rate the limit switch CS4 "severe."
- If the limit switch or its supports or strike plate show damage or loose connections, it should be coded CS3 "poor" or CS4 "severe."
- If the limit switch does not function, it should be coded CS4 "severe."

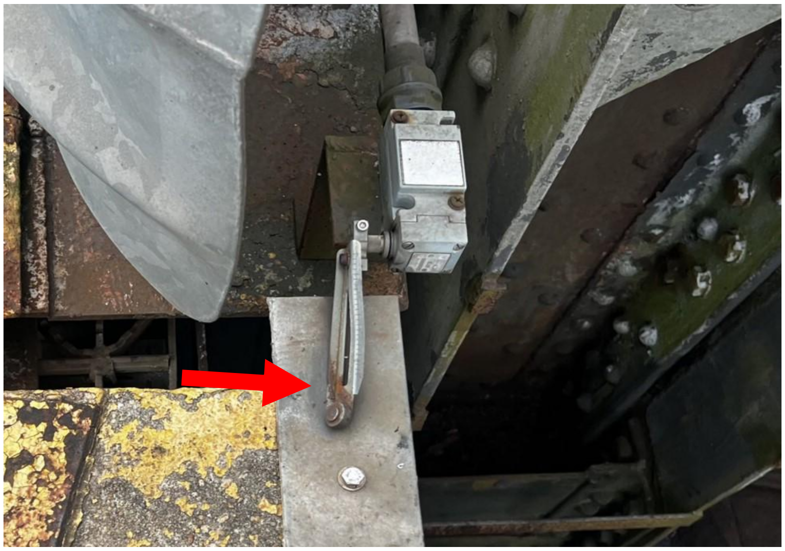

Figure 4-4: Lever arm limit switch. Note that the lever arm is bent, the roller is not making proper contact with the strike plate, and there is rust on the lever arm.

Figure 4-5: Lever arm limit switches used on a vertical lift bridge. Each switch is placed to activate at a different point during opening. Moderate corrosion is present on the entirety of the limit switches.

Figure 4-6: Plunger limit switch on a swing-span bridge. Note the dirt and dust buildup.

Figure 4-7: Two proximity limit switches on a bascule bridge. Note the minor rust around the mounting plate for the switch, the label is deteriorating, and the conduit connection is loose.

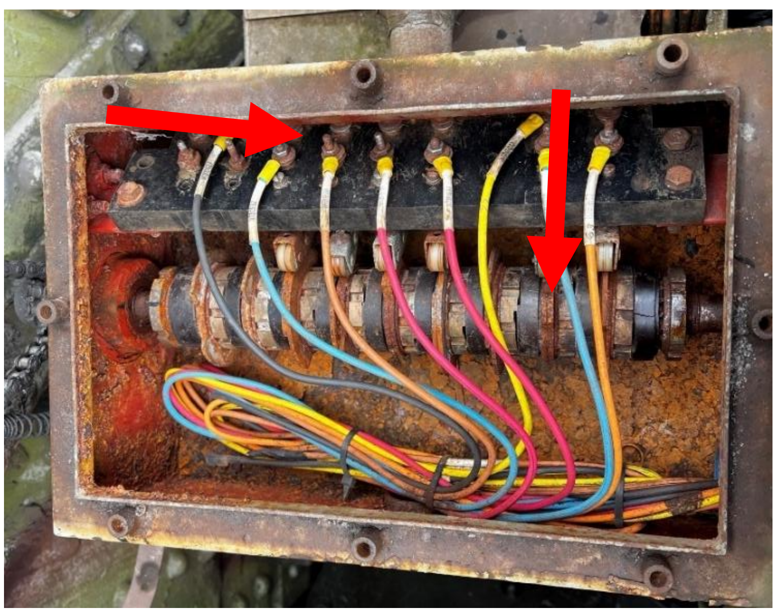

Figure 4-8: Rotary cam limit switch inside enclosure. Note the rust on the rotary cams, wire terminal hardware, and the back of the enclosure. The heavy corrosion suggests water intrusion and a failed gasket.

Figure 4-9: Rotary cam limit switch inside enclosure. No notable deficiencies.

4.4.2 Encoders

Motor encoders are rotary positional transducers but are designed to interface with modern solid-state controls such as drives, programmable controllers, and digital panel meters. Encoders are employed to provide motor feedback or bridge and/or machinery position. Motor encoders are used to send motor shaft position and rotation speed and direction (velocity) information to the control system. Position encoders are typically used to transmit span position and span skew information.

Encoders are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Encoders should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the encoders should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No.	Element Name
874	Control Console

Routine Inspection of Encoders:

- Examine the operation of the encoder to make sure they are operating normally, confirm the motor speed is shown on the control desk or drive/panel meter.
- Check for secure mounting and misalignment.
- Check exterior for deterioration and corrosion/damage.
- Check wires for looseness and deterioration.

Encoder Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the encoder CS3 "poor."
- Failure of the gasket/seals or moderate corrosion of the housing, wire terminals, supports or support hardware should be coded CS3 "poor." Severe corrosion or holes in the housing/enclosure should rate the limit switch CS4 "severe."
- If the supports show damage or loose connections, it should be coded CS3 "poor" or CS4 "severe."
- If the encoder does not function, it should be coded CS4 "severe."

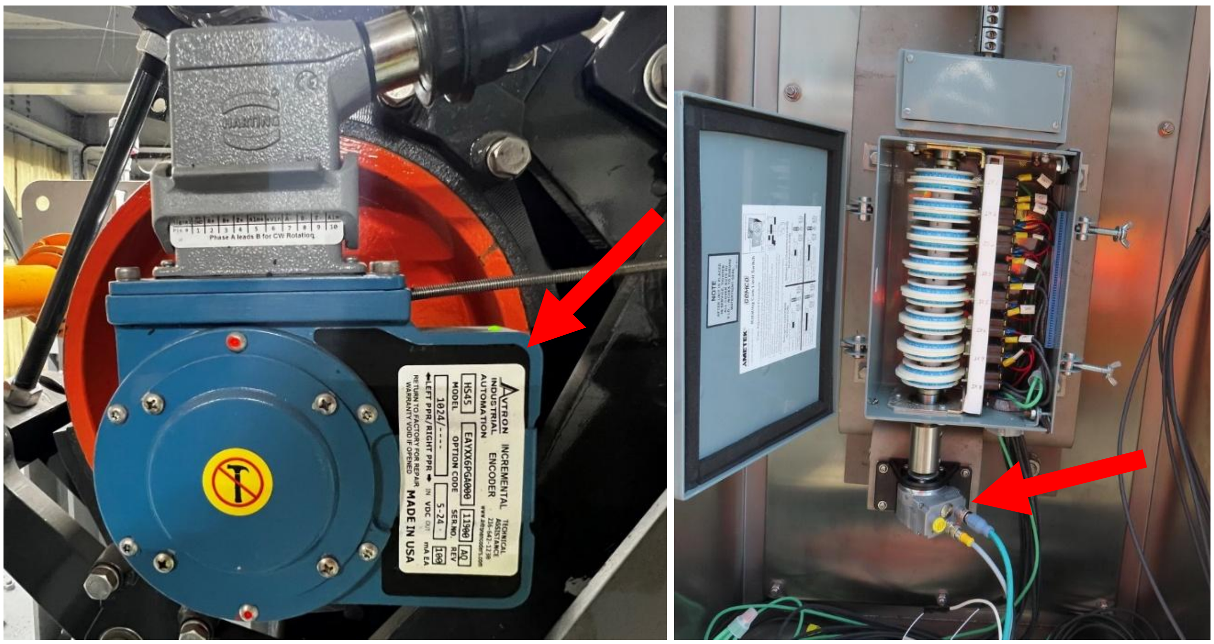

Figure 4-10: Encoder mounted to a span motor shaft(left) and mounted to a span skew rotary cam limit switch shaft(right).

4.4.3 Relays

Relays are control circuit devices that operate as an electrically controlled switch. Control power will energize a coil which magnetically attracts an armature to open or close the relay contacts. The relay may be operated by a button or a switch on the control desk or by limit switches on the span or machinery.

Relays are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Relays should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the relays should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No.	Element Name
874	Control Console

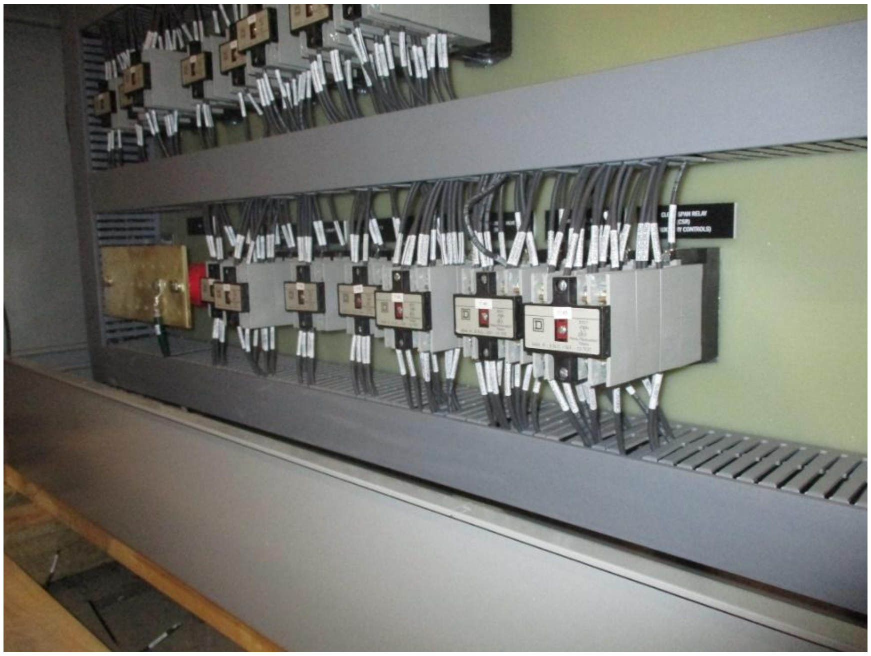

Figure 4-11: Relays mounted in a cabinet enclosure.

Timing Relays

Timing relays use timers that automatically switch the relay on/off after receiving power. These timers can be electro-mechanical or solid-state and are typically adjustable to suit the needs of the control circuit.

Latching Relays

Latching relays stay in place when triggered, as opposed to traditional relays that require a constant flow of current to remain switched.

Contactors

Contactors are used for higher power applications usually used for roadway lighting and outdoor lighting.

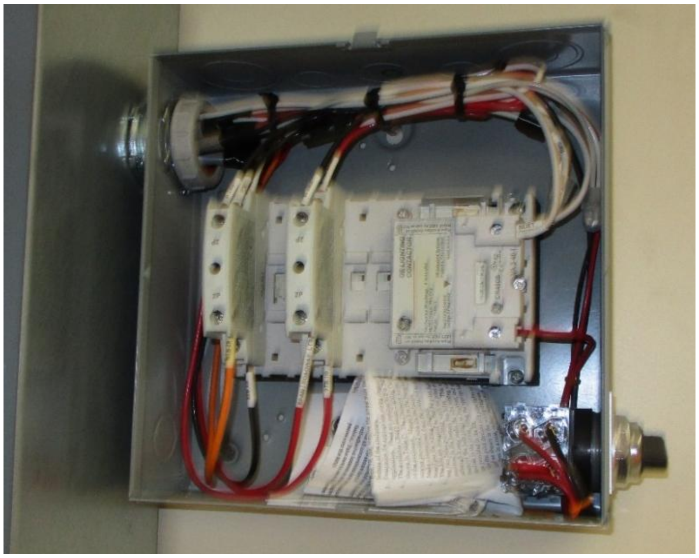

Figure 4-12: Lighting Contactor; note the Auto/Manual Switch on the right side of the box.

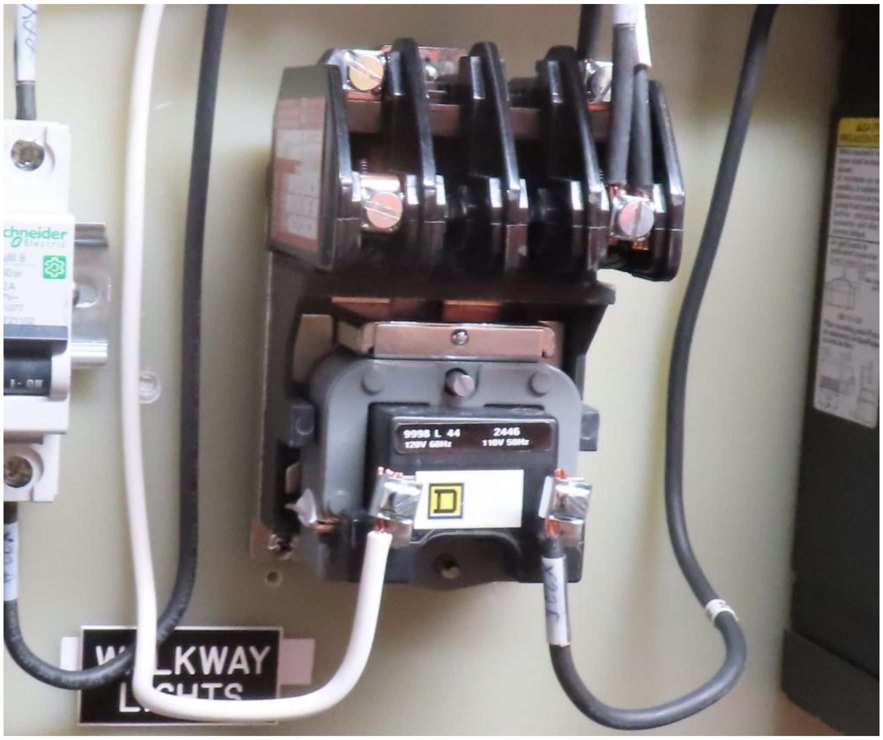

Figure 4-13: Lighting Contactor mounted within a switchboard.

Routine Inspection of Relays:

The following are general guidelines for inspecting any relay logic system.

- Check for burning around device and contacts, as well as contamination of relay if exposed to the elements.
- If exposed to the elements, check for corrosion around wire terminals.
- Inspect the cabinet/enclosure for debris, fluid, and clean air filters on the fans. Cabinet should not be used for storage.
- Check for wire jumpers in the control circuits. The use of a jumper can eliminate the overload protection or interlocking incorporated into the circuit. Jumpers should be used for temporary repair to allow operation and not be utilized for long-term operation of the bridge.
- Verify that devices are functioning properly as per original design parameters. Refer to manufacturer literature for the particular type of relay.

Contactors should be inspected with the above considerations. Additionally, check the following.

- Check for signs of burning or contamination if contactors are easily accessible.
- Check terminals for loose wires and corrosion.
- Check wiring for burned or degrading insulation.
- Check for dirt and debris.
- Check for loose wires and connections.

Relay Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the relay CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the relay CS3 “poor.”
- Buildup of dirt and debris should code the relay CS3 “poor.”
- Messy wiring, many missing or unreadable wire/relay labels, or use of jumper wires should code the relay CS3 “poor.”
- If the relay does not function, it should be coded CS4 “severe.”

4.4.4 Programmable Logic Controller (PLC)

A programmable logic controller (PLC) is a general-purpose industrial microprocessor-based control system. A PLC uses input/output cards or modules which are wired to field devices, relays, and motor starters to control or monitor the bridge control system and provide information to a control desk display.

PLCs have a unique ADE designation number, and each PLC is given an Independent Condition State (CS) Rating. PLCs should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No.	Element Name
873	Programmable Logic Controller

Routine Inspection of PLCs:

- Check PLCs for proper wiring and labeling. Inspect HMI (human machine interface) display PLC thrown errors and alerts.
- Check the status of diagnostic indicator lights located on the CPU and I/O modules, these lights will indicate equipment malfunction if present.
- Check air filters of PLC enclosures for cleanliness.
- Check for dirt and dust accumulation of PLC components.
- Check wiring connections for tightness and overall condition of wiring.
- Inspect batteries, these usually have audible alarms that become activated when battery power becomes low.
- Check for loose articles stored within PLC enclosures.

PLC Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the PLC CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the PLC CS3 “poor.”
- Buildup of dirt and debris, as well as missing air filters should code the PLC CS3 “poor.”
- Messy wiring, many missing or unreadable wire/relay labels, or use of jumper wires should code the PLC CS3 “poor.”
- Malfunctioning lights on the controller should result in coding the PLC CS3 “poor.”
- If the PLC does not function and/or the diagnostic display or bridge tender indicate malfunctions, it should be coded CS4 “severe.”

Figure 4-14: PLC system installed in a control cabinet
(From left to right, the top row has a PLC followed by input/output modules. The bottom row has a communications switch, power supply, terminal blocks, circuit breakers, and an electrical receptacle.)

4.4.5 Control Desk Devices

The bridge is operated from a control console panel with switches that operate the traffic control devices and bridge machinery. Indicator lights provide feedback to the operator about the position of the traffic gates, barriers, span, and other bridge machinery. Other instrumentation on the control desk may include meters for voltage, current, power, span height/angle, and PLC readout screens.

Control Desk Devices are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Control Desk Devices should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the devices should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No.	Element Name
874	Control Console

Routine Inspection of Control Desk:

Exterior

- Note the location of the control desk for visibility of all directions.
- Check for indicator lights for various positions of the bridge, especially fully closed, fully open, nearly closed, nearly open positions, lights indicating closed and open positions of traffic gates, bridge locks, span brakes, and end lifting devices should be present.
- Check overall console condition, rust, corrosion, peeling paint, objects on the console that interfere with bridge operation.
- Check that bypass switches are locked and sealed to prevent inadvertent operation.
- Check for burnt out pilot lights, missing or broken lamp lenses.
- Check voltmeters, ammeters, and position indicators for proper operation as the span is operating. Record voltmeter and ammeter readings during bridge operation.
- Check that each device is properly labeled.
- Check metering equipment on control desk for loose connections, corrosion of metal parts, cracks or broken cases on cover glass, and collection of dirt and grease.

Interior

- Check for internal temperature (between 32F and 104F)
- Check for cleanliness of enclosure, loose articles stored at bottom of enclosure, neatness of internal wiring.
- Check that plug-in relays are firmly secured.
- Check for heater and light operation, if equipped.
- Visually check connections for any loose wires and terminations.

Control Desk Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the control desk CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the control desk CS3 “poor.”
- Buildup of dirt and debris should code the control desk CS3 “poor.”
- Messy wiring, many missing or unreadable wire/control desk device labels, or use of jumper wires should code the control desk CS3 “poor.”
- If switches or indicators on the control desk do not function, it should be coded CS4 “severe.”

Figure 4-15: Control desk inside of an operator's house used on a Strauss-trunnion bridge. Note the excessive clutter on the desk, cups are used to cover up buttons, and some lights and switches are obscured by loose articles.

Figure 4-16: Control desk inside of an operator house on a bascule bridge. No notable deficiencies. Note that the dials used to relay information about the bridge are old, and personnel should verify that the dials are functional during operation, as equipment of that age tends to fail over time.

4.4.6 Overall System Safety Interlocks

Interlocking must be tested to assess the suitability of the control interlocking system. Interlock testing is beyond the scope of a routine inspections as defined in the manual. However, inspectors shall identify any bypasses in effect at the time of inspection or as recorded in the bridge logs.

Interlocks should be considered when evaluating the Control Console element and should be recorded underneath that element.

El. No.	Element Name
874	Control Console

Routine Inspection of Safety Interlocks:

- Inspect the desk and note any bypass switches that are in use. Record each active bypass switch.
- Observe a bridge complete bridge operation and record any bypass switches activated by the bridge operator during the sequence.

Safety Interlock Coding Recommendations:

- Use of bypass switches should code the control console CS4 "severe."

4.5 MOTORS AND MOTOR CONTROLS

4.5.1 Motors

The common types of motors found on movable bridges are AC (alternating current) induction motors and DC (direct current) motors. Most span lock, rear lock, traffic gate, barrier (resistance) gate, pump, and fan motors are AC induction motors with "across the line" full voltage starters. Most span motors are one of two types of AC induction motors- wound rotor or squirrel cage. Frames for the span motors are typically totally enclosed nonventilated (TENV) motors or totally enclosed fan cooled (TEFC); the coils and internal parts are not accessible without tools. The fan cooled motors will have a fan and a cover with vent screen; the vent should be free from debris and intact to protect personnel from harm and the fan from damage. Older motors may be drip-proof open frame. Wound rotor induction motors and DC motors have covers that need to be removed to inspect the slip rings, brushes, and commutators; this should only be performed by trained and qualified personnel.

Span motors are incidental to their parent element, the Bridge Specific Equipment elements (881-884): as such, they are not given a unique ADE designation number but are quantified by each item and each given a Condition State (CS) rating. Any notes including deficiencies should be recorded underneath the parent Movable Bridge Element ADE number that they serve according to the bridge type.

El. No.	Element Name
881	Bridge Specific Equipment (Lift)
882	Bridge Specific Equipment (Swing)
883	Bridge Specific Equipment (Pontoon)
884	Bridge Specific Equipment (Bascule)

All other motors are incidental to many Movable Bridge Elements; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Motors should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the motors should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have motors.

El. No	Element Name	El. No	Element Name
841	Speed Reducers	860	Span Locks
844	Brakes	885	Barriers
845	Emergency Drive and Back-up Power Systems	886	Traffic Warning Gates
847	Hydraulic Power Units		

Routine Inspection of Motors:

Routine inspections of motors are purely external and should be performed with the motor running. The following routine inspection items apply to all motor types:

- Listen to motor for abnormal squealing or grinding sounds. Observe the motor for excessive vibration.
- Listen to the motor; check to determine if the bearings emit a squealing or grinding sound.
- Feel the motor casing for excessive vibration.
- Feel the motor in the bearing locations. If it is unusually hot to the touch, bearing trouble is indicated.
- Check to make sure all components are tight, and all bolts are in place.
- Check bearing seals for signs of lubricant leakage.
- Check the exterior for corrosion, paint/coating failure, and deterioration.

- Observe and record motor amperage during test operations; record the value when the bridge is at rest, when it is opening, and when the bridge is closing.

Motor Coding Recommendations:

- Abnormal squealing or grinding sounds, excessive vibration, excessive heat, dry lubrication ports should rate the motor CS3 “poor.”
- Heavy corrosion of the motor frame or mounting hardware should rate the motor CS3 “poor” or CS4 “severe.”
- Loose mounts, cracks in the motor frame, or missing mounting hardware should rate the motor CS4 “severe.”

4.5.2 Brushes

Brushes are usually rectangular, spring-loaded carbon conductors that contact a commutator or slip ring and carry current from the brush terminal to the rotating conductor of a motor. These are found in wound-rotor motors and DC motors.

Brushes are incidental to and inspected as part of the motor and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that the motor is part of.

Routine Inspection of Brushes:

- Check slip ring surface for smoothness and free of grooves.
- Check brush holders for equal clearance. Refer to manufacturer recommended procedures for proper brush installation, settings, and spring pressure. In general, an approximate spring pressure of 2.5 lbs. (11 N) could be used in the absence of manufacturer information.

Motor Brush Coding Recommendations:

- If a brush is not contacting the slip ring or has damage to the wires, the motor should be coded CS4 “severe.”
- Excessive dirt or grease buildup on the brush should code the motor CS3 “poor.”

Figure 4-17: Slip rings on a wound rotor motor. Note the "striation" line that indicates dirt and uneven color where the brush contacts indicating possible moisture or contaminants.

4.5.3 Starters

Starters are used to start, stop, and often reverse the direction of motor rotation. A motor starter acts as a large relay with a power contactor. Reversing starters have two contactors side by side.

Starters are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Starters should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the starters should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Routine Inspection of Starters:

- Motor starters should be inspected for loose wires, missing or loose hardware, burned coil or wire insulation, worn and pitted contacts, and the presence of dust and debris.
- The inspector should listen to motor starters during operation and note any unusual noises.
- Check for burning around device and contacts, as well as contamination of relay if accessible.

- Check for corrosion around wire terminals.
- Inspect the cabinet/enclosure for debris, fluid, and clean air filters on the fans. Cabinet should not be used for storage.
- Check for wire jumpers in the control circuits. The use of a jumper can eliminate the overload protection or interlocking incorporated into the circuit. Jumpers should be used for temporary repair to allow operation and not be utilized for long-term operation of the bridge.
- Check terminals for loose wires and corrosion.
- Check wiring for burned or degrading insulation.
- Check for dirt and debris.

Starter Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the relay CS3 "poor."
- Loose connections, signs of overheating wires or contacts, pitting, or moderate corrosion of the terminals should code the starter CS3 "poor."
- Buildup of dirt and debris should code the starter CS3 "poor."
- Buzzing or loud humming during operation should code the starter CS3 "poor."
- Messy wiring, many missing or unreadable wire/relay labels, or use of jumper wires should code the starter CS3 "poor."
- If the starter does not function, it should be coded CS4 "severe."

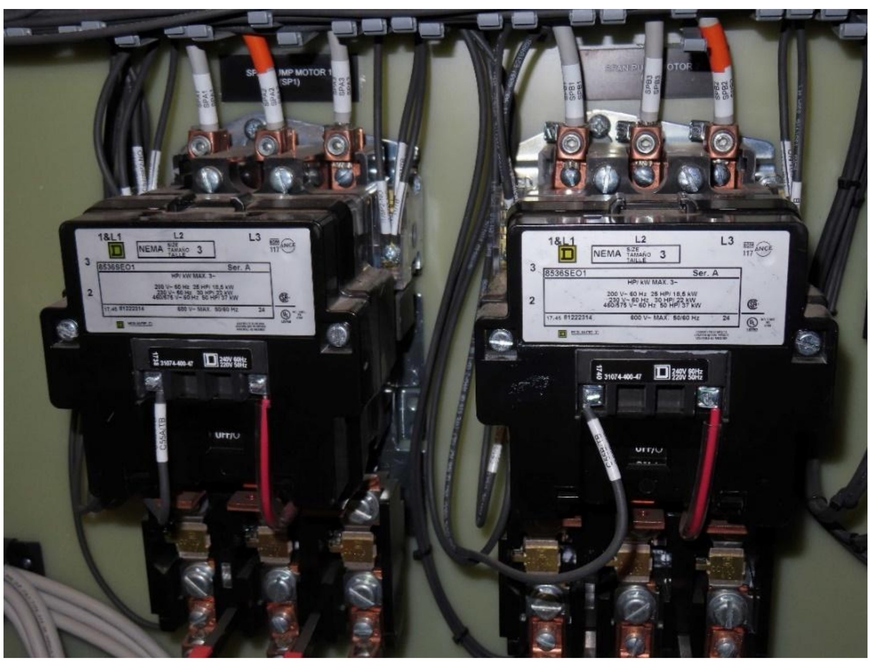

Figure 4-18: Two motor starters mounted in a switchboard enclosure.

4.5.4 Motor Overload Circuit Protectors

Motor overload circuit protection usually comes built-in to motor starters in the form of overload relays but can occasionally be used as a stand-alone relay. These overload relays are comprised of a current sensing device, typically a thermal heating element. An overload current triggers the relay contacts to break the connection by melting or bending the thermal element.

The motor overload circuit protector is inspected along with the relay starter it is attached to; follow the inspection procedure in the starter section above.

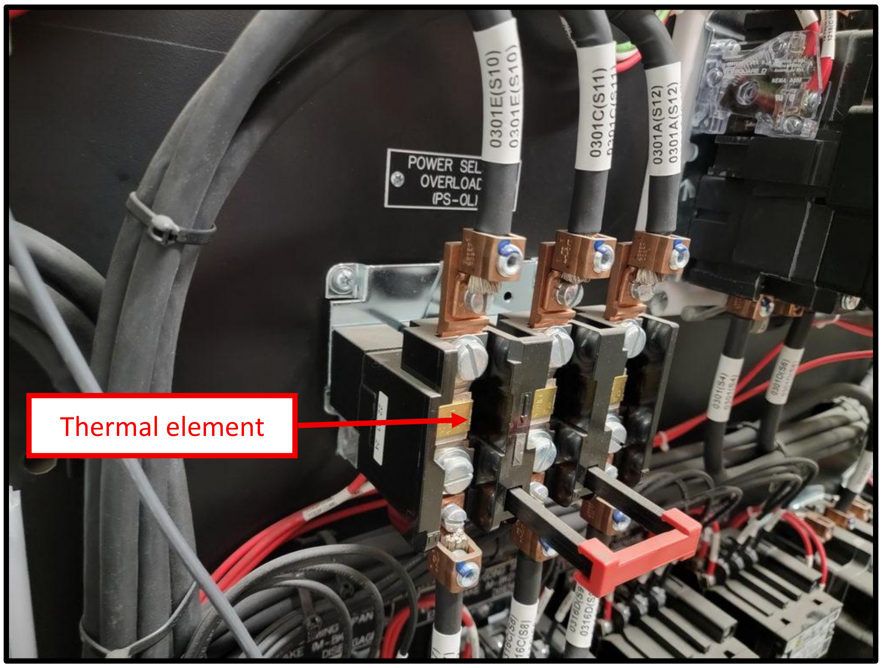

Figure 4-19: Stand-alone overload relay.

4.5.5 Motor Control Center/Switchboards

Motor controls are grouped together in a custom fabricated switchboard or a modular motor control center (MCC). An MCC is an assembly of multiple cabinet sections subdivided into bucket compartments. Each compartment has individual doors that may be opened for maintenance or inspection.

On many Louisiana bridges, switchboards are more common than motor control centers. These are large panel housings that have larger compartments usually divided into power distribution, motor starters, and control relay sections. Devices are mounted on interior panels and the power bus may be a combination of bus bars and lugged wiring. Extra care must be taken inside of switchboards because the power bus is exposed in some areas.

Motor Control Centers/Switchboards are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Motor

Control Centers/Switchboards should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the Motor Control Centers/Switchboards should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Routine Inspection of Switchboards:

- Look inside each compartment for signs of rust and corrosion, dust, debris, and broken parts that may have fallen from equipment housed within the compartment.
- Wiring should be visually checked for deteriorating insulation and terminal connections should be tight.
- All wires should be properly tagged in accordance with the as-built drawings.
- The exterior of the motor control center should be checked for rust and corrosion.
- Check for appropriate NEC workspace clearance in front of MCC or switchboard.
- Look for any new, temporary conductors or wire nuts that stand out from original equipment.
- Electrical enclosures should not be used for storage.

Switchboard Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the switchboard CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the switchboard CS3 “poor.”
- Buildup of dirt and debris should code the switchboard CS3 “poor.”
- Messy wiring, many missing or unreadable wire/ switchboard device labels, or use of jumper wires should code the switchboard CS3 “poor.”
- If switches or indicators on the switchboard do not function, it should be coded CS4 “severe.”

Figure 4-20: Motor control center used for a rolling bascule bridge.

Figure 4-21: Switchboard for a swing-span bridge has warning labels; however, NFPA 70E Arc Flash labels are not present.

4.5.6 Resistors and Associated Controls

Resistors and associated controls are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Resistors and associated controls should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the resistors and associated controls should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Resistors

Routine Inspection of Resistors:

- Check for discoloration from overheating, broken resistors, or discoloration that could indicate overheating or atmospheric corrosion of the metals. Discoloration around a break point would be apparent.
- Check wires and terminals for corrosion, deterioration, and general dirt/debris.
- Check for any loose wires and terminations.
- Check for signs of discoloration and broken resistors/insulators.

Resistors Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the Resistors CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the Resistors CS3 “poor.”
- Buildup of dirt and debris should code the Resistors CS3 “poor.”

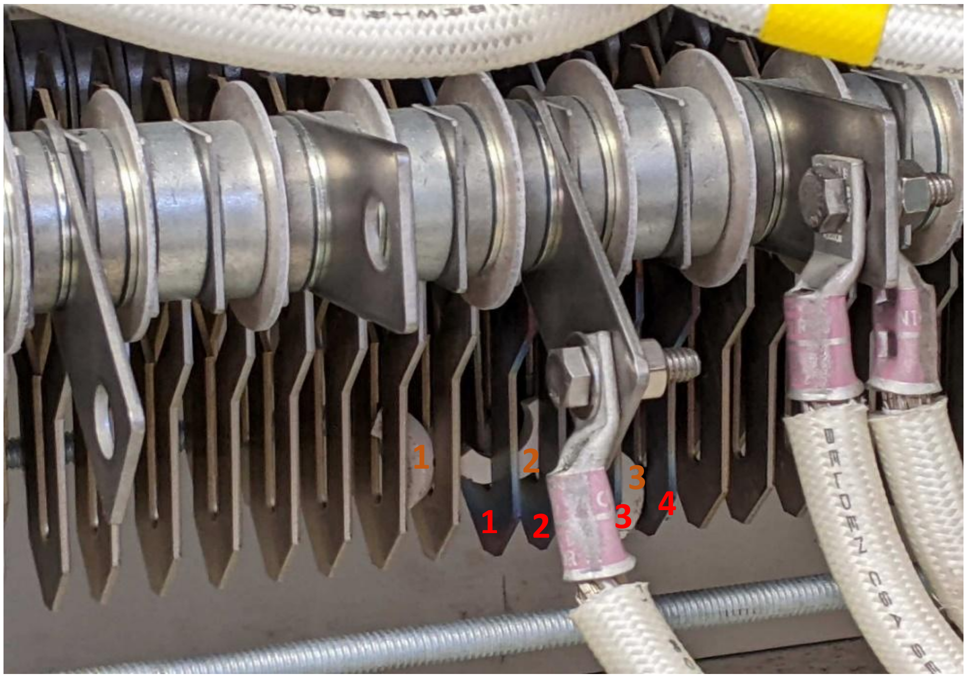

Figure 4-22: Close-up of a resistor bank. Note the blue-like discoloration on the resistor indicating overheating, and the broken ceramic insulator lodged in between plates of the resistor (Four discolored resistor elements and three broken ceramic pieces are visible).

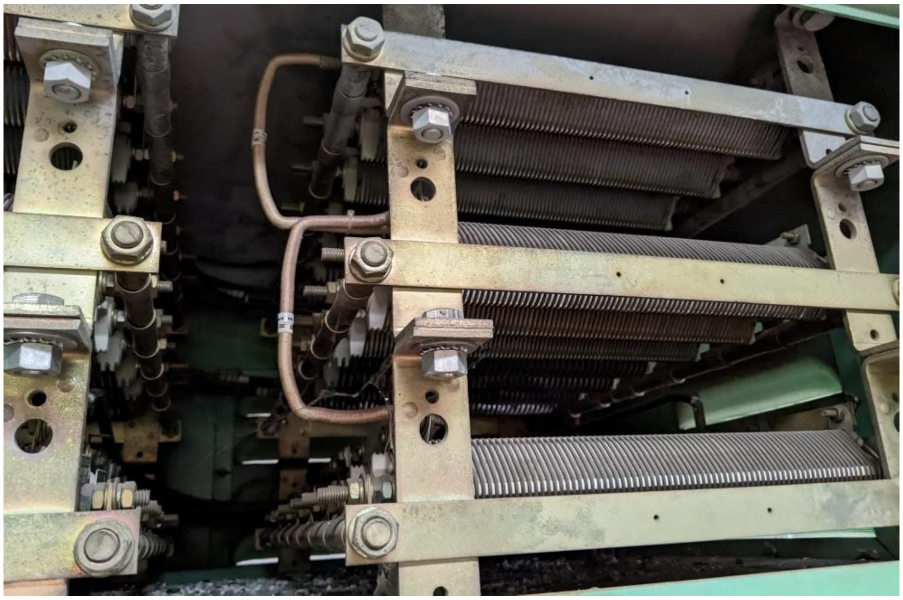

Figure 4-23: Resistor bank used on a bascule bridge.

Secondary Controller

The secondary controller is a group of motor contactors that switch the wound rotor motor external resistors in and out of the motor circuit. These contactors are the same size as the motor starter and will be similar in appearance.

Routine Inspection of Secondary Controller Contactors:

- Observe the secondary controller during motor operation. The contactors should not chatter or bounce on their contacts. No sustained arcing should occur during any part of the control operation. Make certain the controller sequence is correct and that all components function properly. A schematic diagram of the controller will be required to perform this check.
- Visually check the controller components for wire and cable conditions. Cable connections should be tight. Look for broken conductors and signs of terminal cracking. Partially broken connectors can accelerate an insulation failure due to overheating.
- Contactors should be inspected for loose wires, missing or loose hardware, burned coil or wire insulation, worn and pitted contacts, and the presence of dust and debris.
- The inspector should listen to contactors during operation and note any unusual noises.
- Check for burning around device and contacts, as well as contamination of contactors if accessible.
- Check for corrosion around wire terminals.
- Check for wire jumpers in the control circuits. The use of a jumper can eliminate the overload protection or interlocking incorporated into the circuit. Jumpers should be used for temporary repair to allow operation and not be utilized for long-term operation of the bridge.
- Check wiring for burned or degrading insulation.
- Check for dirt and debris.

Contactor Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the contactor CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, pitting, or moderate corrosion of the terminals should code the contactor CS3 “poor.”
- Buildup of dirt and debris should code the contactor CS3 “poor.”
- Buzzing or loud humming during operation should code the contactor CS3 “poor.”
- Messy wiring, many missing or unreadable wire/relay labels, or use of jumper wires should code the contactor CS3 “poor.”
- If the contactor does not function, it should be coded CS4 “severe.”

Drum Controls

Drum controllers are stand alone or mounted enclosed rotary switches used to start, stop, change the direction, and change the speed of reversible AC and DC motors. The switch contacts are heavy duty and may directly switch motor currents without contactors; they may also switch secondary resistance for wound rotor motors. The drums are furnished with rotary operating handles. The drum contacts are usually hard drawn copper and are renewable. The contact fingers are mounted on finger boards. They are formed hard drawn copper with flexible shunts and are easily replaced. Contact pressure is maintained by means of special coiled compression springs. In modern relay or PLC control system designs, the controls signal switching current is lower, so a smaller rotary actuated selector switch is used in place of a drum controller.

Routine Inspection of Drum Switches:

- Inspect the condition of the contactors and cams or contact segments, contacts should be clean and tight.
- Check wiring for cleanliness, insulation in good condition.
- Check for loose wires or terminations.
- Inspect the contacts, terminations, and controller enclosure for corrosion.
- Check for any loose wires and terminations.

Drum Switch Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the contactor CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, pitting, or moderate corrosion of the terminals should code the contactor CS3 “poor.”
- Buildup of dirt and debris should code the contactor CS3 “poor.”
- Messy wiring, many missing or unreadable wire/relay labels, or use of jumper wires should code the contactor CS3 “poor.”
- If the switch does not function, it should be coded CS4 “severe.”

Figure 4-24: Interior of a drum controller.

Timers

Timer relays are devices commonly found in control systems which delay opening and closing of contacts for a set amount of time.

Routine Inspection of Timer Relay:

- Observe operation to check the time setting is correct.
- Follow guidelines given for section 4.4.3 Relays.

4.5.7 Speed Switches

Speed switches (plugging switches) are mounted to the motor shaft and have contacts that will open or close motor control circuits to use the motor for braking. The motor braking is accomplished by “plugging” - momentarily reversing the voltage to the motor. The speed switch can be adjusted to prevent machinery overspeed in an overhauling condition and/or to bring the motor to a stop.

Speed switches are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Speed switches should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the speed switches should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Routine Inspection of Speed Switches:

- Observe and verify proper operation of the speed switch.
- Check the condition of the wiring on the switch for tightness and degradation.
- Check for tightness of the support and mounting.
- Check the condition of the coupling to the motor shaft.
- Check for corrosion on any parts of the housing and mounting.

Speed Switch Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the switch CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the speed switch CS3 “poor.”
- If the switch does not function, it should be coded CS4 “severe.”

4.5.8 Foot Switches

Foot switches may be found at the operator console or near local motor operation equipment and are used as a safety mechanism to prevent accidental unintended operation of the bridge. They are typically wired so that they must be continuously pressed down to open and close the span. Lifting off of the foot switch would temporarily disable bridge operation through the console until the switch was activated again. It's not uncommon to see these switches with heavy objects (like bricks) placed on them to relieve the operator from needing to depress the foot switch. This behavior defeats the purpose of the foot switch and is unacceptable.

Foot switches are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Foot switches should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the foot switches should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Routine Inspection of Foot Switches:

- Check for operation of foot-operated switches and correct functionality with the control system wiring.
- Check for build-up dirt/debris within the foot switch that may hinder operation.
- Check for objects placed on the foot switches and remove them if applicable.
- Check wiring coming from foot switch for deterioration or damage to insulation sleeve.

Foot Switch Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the foot switch CS3 "poor."
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the foot switch CS3 "poor."
- If the switch does not function, it should be coded CS4 "severe."

Figure 4-25: Foot switch used for manual control of an auxiliary winch motor on a pontoon bridge. The switch has heavy corrosion with paint failure and dirt/dust debris build-up, rendering the switch is inoperable.

4.5.9 Variable Frequency Drives

Variable frequency drives (VFD) are typically used to control the speed of AC induction squirrel-cage motors. VFDs provide information to an operator desk mounted HMI (human machine interface) monitor display. The display will typically show voltage, current, motor speed, and position information for the bridge.

VFDs are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. VFDs should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the VFDs should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
874	Control Console

Routine Inspection of VFDs:

- Check contacts around VFD for discoloration.
- Check exterior for dust buildup, as VFDs can get hot during operation.
- Verify that information display panels are functional if present on the exterior or interior of the VFD enclosure.
- Check the interior of the cabinet or MCC section as well as any screens and filters for dust and dirt.
- Check the data sticker for the date of manufacture. If it is close to ten years old, it is nearing the end of its design life.

VFD Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the VFD CS3 "poor."
- Loose connections, signs of overheating wires or contacts, or moderate corrosion of the terminals should code the VFD CS3 "poor."
- If the VFD is more than 10 years old, it should be coded CS3 "poor."

Figure 4-26: Variable frequency drive used to control an AC induction motor, located in an MCC enclosure.

4.6 TRAFFIC CONTROL SYSTEMS

The traffic control system serves to manage and control the traffic flow through a movable bridge span and to stop and store the vehicles safely during bridge openings. Traffic control electrical systems operate traffic signals, traffic gates, advance warning signs with flashing lights and message boards, and resistance or energy absorbing barriers located on bridge approaches open to the waterway crossing.

4.6.1 Traffic, Pedestrian, and Barrier Gates

Traffic gates on movable bridges are installed on the approaches for each span to prevent vehicles and pedestrians from driving onto the span during bridge operation.

Barrier gates are installed closer to the span to act as a physical barrier for vehicles and pedestrians and are typically found on vertical lift and swing-span bridges.

Traffic Gates are themselves unique Movable Bridge Elements; as such, they are given a unique ADE designation number, and each traffic gate is given an Independent Condition State (CS) Rating. These traffic gates should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
886	Traffic Warning Gates

Barrier gates are themselves unique Movable Bridge Elements; as such, they are given a unique ADE designation number, and each barrier is given an Independent Condition State (CS) Rating. These barrier gates should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
885	Barriers

Routine Inspection of Traffic and Barrier Gates:

- Check for traffic gate smoothness of operation and proper lubrication of gearing and linkages. Check for excess grease.
- Check that the gates are seated parallel to the roadway when lowered. Gate arms should sit approximately 4 ft above the payment. (MUTCD "Design and Location of Movable Bridge Signals and Gates")
- Check exterior of traffic gate for corroded or damaged hardware and support hardware.
- Check gate access door hardware for damage, proper fit and operation, and check for proper sealing of door gasket.
- Check support cables for tautness, cables should have 3 wire clips at each connection point.

- Check gate arm for faded or failed reflective striping.
- Check that gate arm is attached using breakaway shear bolts.
- Check warning light exterior flex cable for cracked, deteriorated, or damaged insulation.
- Check for gate and barrier brake operation. Brakes are typically motor mounted (Stearns type), but shoe brakes are not uncommon on barriers.
- Check interior electrical connections for tightness and signs of corrosion on terminals. Check wires for damaged or deteriorating insulation. Check for temporary wiring, jumpers, and wire nuts.
- Check the interior (or exterior depending on design) limit switches for proper operation. Rotary Cam limit switches are common for gate position and doors and manual operation safeties have plunger limit switches.
- Check all warning lights are operating properly and their associated wiring is in good condition. Check cable jacket for cracking and environmental degradation.
- Check for presence of a hand crank and/or drill attachment for manual operation.
- Check the interior for build-up of dirt/debris, evidence of vermin, and general corrosion build-up on electrical and machinery components.

Traffic and Barrier Gate Coding Recommendations:

- Failure or cracks of the wire jacket/insulation, loose connections, signs of overheating wires, or moderate corrosion of the terminals should code the gate CS3 “poor.”
- Buildup of dirt and debris should code the gate CS3 “poor.”
- Dry chains/grease ports or excessive grease on the interior components should code the gate CS3 “poor.”
- If multiple warning lights on the same gate arm are inoperable, the gate should be coded CS3 “poor.”
- If the traffic gate arms do not stop parallel to and about 4 ft from the roadway, the traffic gate should be coded CS3 “poor.”

Figure 4-27: Barrier gate in the lowered position, used on a swing-span bridge.

Figure 4-28: Traffic gates in the lowered position.

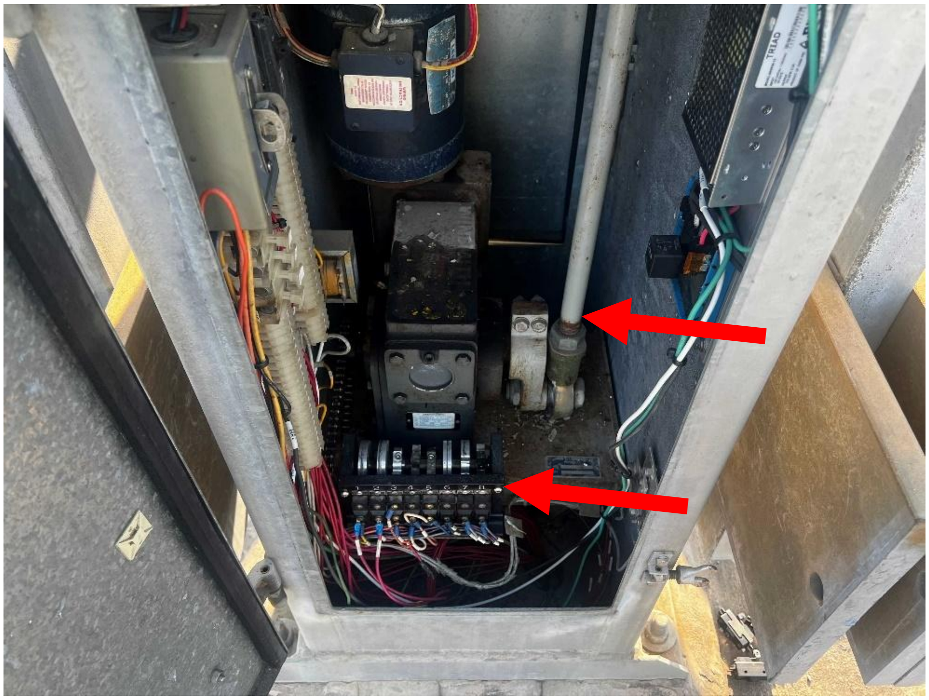

Figure 4-29: Interior of a traffic gate. Note the rotary cam limit switch at the bottom of the enclosure is missing its cover and minor corrosion spots that does not affect operation is on the linkages.

Figure 4-30: Machinery for a traffic barrier. The equipment has been painted, but areas with moderate corrosion remain (not clearly visible in this photo).

4.6.2 Traffic Signals and Flashers

Traffic signals are used to alert oncoming vehicles to a bridge opening/closing, as well as halt traffic so that the traffic gates can be lowered. Advance warning lights are placed further away from the span to alert vehicles to a bridge opening, and tri-color or flashing red traffic signals are placed further up the approach to halt traffic.

Traffic signals and flashers are themselves unique Movable Bridge Elements; as such, they are given a unique ADE designation number, and each traffic signal and flasher is given an Independent Condition State (CS) Rating. These items should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
890	Traffic Signals

Routine Inspection of Traffic Signals:

- Check the traffic signals for proper electrical connections, corrosion of any metal parts and mounting hardware, damage, missing visors, or slanted mounting.
- Check for non-functioning lights or burnt-out bulbs.
- Verify that the traffic flashers alternate between both lights if two are present. Tri-color signals should have the green light illuminated at all times while the bridge is open to vehicular traffic and should transition to a yellow light before turning red. Refer to MUTCD Traffic Control for Movable Bridges for further information on traffic signals and gates.
- Check that the traffic signals are monitored at the control desk, and that the lights are integrated into the interlocking sequence of the bridge.

Traffic Signal Coding Recommendations:

- Missing covers for light maintenance handholes and/or exposed wiring should code the traffic signal CS3 “poor.”
- Signals with burned out or nonfunctioning lamps should be coded CS3 “poor.”
- Tri-color signals should switch from green to yellow to red. If the signal does not have a yellow interval, the signal should be coded CS4 “severe.”
- If the signal has loose mounting at the signal head or the anchor bolts, it should be coded CS4 “severe.”

Figure 4-31: Tri-color traffic signals. Note the missing visor on the left green light.

4.7 NAVIGATION GUIDANCE

4.7.1 Navigation and Obstruction Lighting

Bridge lighting and signals requirements are regulated by Federal Code (33 CFR 118). The navigation guidance system channels the travel path of an approaching vessel from the open channel through the bridge opening.

Navigation and obstruction lighting is composed of marine navigation lights and occasionally aerial lights. These lights line the pier fender system and are present on the sides of the bridge spans, facing the channel.

Navigation and obstruction lighting are themselves unique Movable Bridge Elements; as such, they are given a unique ADE designation number, and each traffic signal is given an Independent Condition State (CS) Rating. Navigation and obstruction lighting should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
891	Navigational Light System

Routine Inspection of Navigation Lighting:

- Verify that navigation lights are present and operating properly. Inoperative navigation lights should be reported immediately and recommended for immediate repair.
- Check for corrosion and damage on fixtures, lenses, gaskets, conduits, mounting brackets, or other components.
- Check span-mounted navigation lights for correct functionality during bridge openings. These lights should turn green when the bridge is at the fully open position and revert back to red when the bridge begins closing.
- Verify that clearance gauge lights are present and operating properly.
- Inspect the condition of aerial lights/strobes and verify that they are operational.

Navigation Light System Coding Recommendations:

- Multiple burned out lights or broken lenses should code the navigation lighting CS3 "poor."
- Moderate to heavy corrosion of the lights and supports should code the navigation lights CS3 "poor."
- Broken supports on multiple lights should code the navigation lights CS3 "poor."
- If the lights are not operational, the navigation light system should be coded CS4 "severe."

Figure 4-32: Fender navigation light with photocell attached.

Figure 4-33: Span navigation lights on a bascule bridge.

4.7.2 Other Navigational Aids

Other than obstruction and navigation lights, the most common navigational aids include signal horn, marine radio, fog lights, channel floodlight, and signage.

Other navigational aids are incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Navigational aids should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of these items should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
891	Navigation Light System

Routine Inspection of Navigation Aids:

- Check the operation of the horn; this is typically controlled by a button on the control desk.
- Check the marine radio for functionality and any accessories, e.g., batteries, chargers, antennas, etc.
- Check the operation of channel fog and/or flood lights and verify they are oriented properly.
- Check the condition of and retroreflective panels or channel signage.

Navigation Aids Coding Recommendations:

- A non-operational marine radio or navigation horn should rate the system CS3 “poor.” If both the radio and the navigation horn do not work, the system should be coded CS4 “severe.”

4.8 LIGHTING AND RECEPTACLES

General lighting is found in the control house, machinery spaces, and bridge roadway, as well as flood and spotlighting.

Lighting is not part of a Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Lighting should be inspected and any notes including deficiencies should be recorded under general notes for the bridge.

4.8.1 Roadway and Parking Lot Lighting

Roadway and parking lot lighting usually consists of pole mounted HID or LED luminaires. Lighting requirements vary by area, amount of traffic, and environmental conditions. Lights may have individual photocells for automatic operation at night or be controlled by a singular photocell usually located at the operator house. Lighting contactors are also commonly found in the electrical or control room for exterior lighting and roadway lighting. Photocells for these lighting contactors are commonly found on exterior walls.

Routine Inspection of Lighting:

- Check for burnt bulbs and damaged fixtures, as well as blinking or inconsistent functionality.
- Check photocells for damage or incorrect mounting that may alter the operation of the lights. If accessible, test the photocell by covering it with black tape or with something opaque- the light should come on.
- Check for corrosion.
- Check for exposed wiring or damaged/missing handhole covers on mounting pole.
- Check that the light is aimed at the roadway or parking lot and that the fixture has not been rotated out of place.
- Check the operation of the Hand-Off-Auto switch on the control desk or panel.

Figure 4-34: LED roadway luminaire.

4.8.2 Control House, Machinery, and Maintenance Area Lighting

Check these areas and inspect the lighting of the operating machinery, machinery platforms and decks, barrier gate platforms, and areas where electrical panels are located.

Routine Inspection of Lighting:

- Check for burnt bulbs and damaged fixtures.
- Check for corrosion on the fixtures and the weatherproofing, if applicable.
- Check light switches for smooth operation.
- Verify that adequate lighting is present throughout the interior of the bridge structure.
- Check emergency light and emergency exit light operation and each backup battery by pushing the “test” button or turning off the lighting circuit breaker.

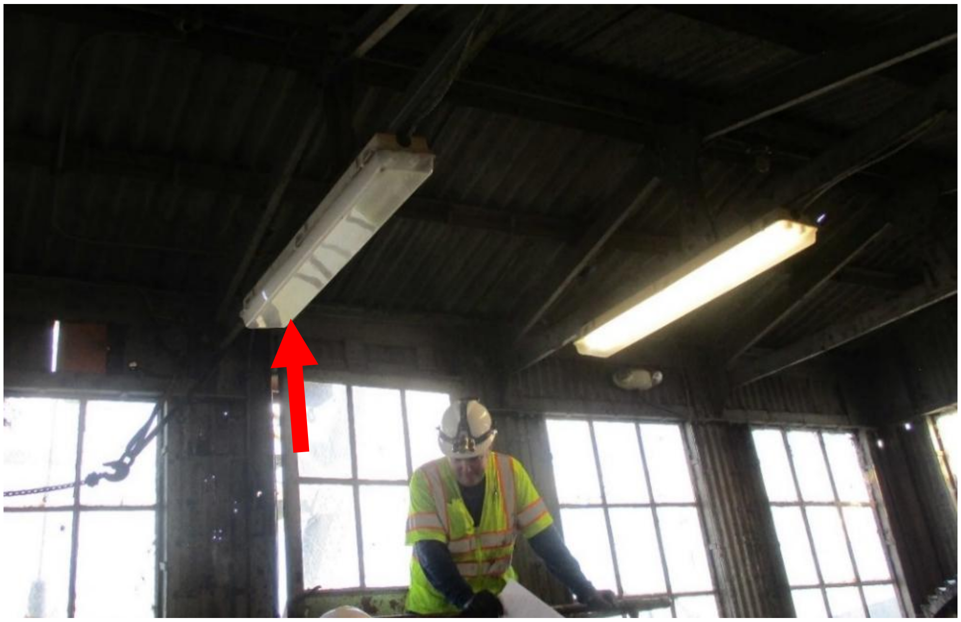

Figure 4-35: Fluorescent fixtures in a machinery room. Note that one of them is not functioning.

4.8.3 Receptacles

Ground fault circuit interrupter (GFCI) receptacles are a type of receptacle that can interrupt a circuit by detecting ground faults. These receptacles have two buttons, one to test the receptacle and one to reset the receptacle.

Receptacles are not part of a Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Lighting should be inspected and any notes including deficiencies should be recorded under general notes for the bridge.

Routine Inspection of Receptacles:

- Check receptacles for availability of power and correct wiring.
- Use a GFCI receptacle tester to verify that the GFCI receptacles are functional.

4.9 POWER DISTRIBUTION

4.9.1 Typical Power Distribution Layout

The general power distribution layout of a bridge is designed to give personnel the ability to safely disconnect and isolate downstream devices. The following power distribution devices are listed in order of furthest upstream, to furthest downstream:

- Utility Service
- Service Disconnect Switch
- Transfer Switch
- Standby Generator
- Distribution Panels
- Lighting and Control Power Transformer
- Load Devices

Below is a diagram outlining the typical power distribution layout for a movable bridge.

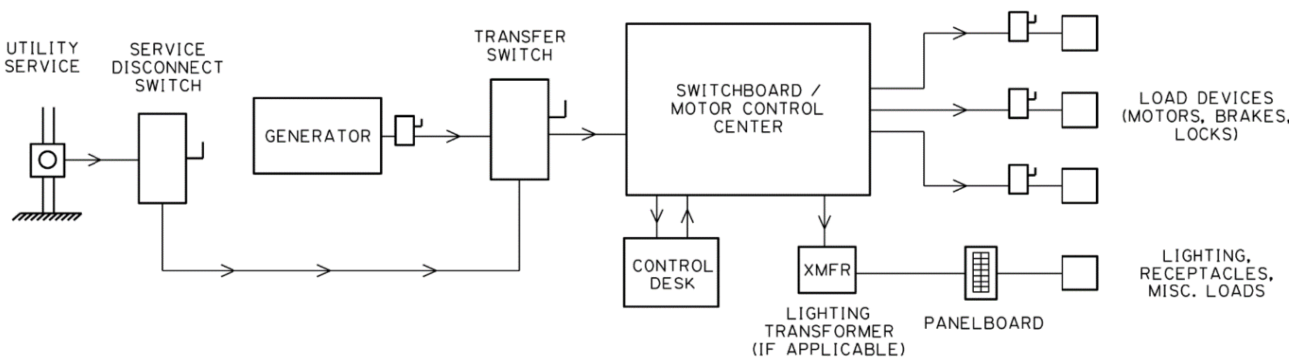

Figure 4-36: Diagram outlining typical power distribution layout for a movable bridge.

4.9.2 Utility Service and Service Disconnect Switch

The incoming power from the utility company that services the bridge typically comes from overhead power lines through a pole-mounted transformer or underground cables through a pad-mounted transformer. The service disconnect switch is located directly after the utility service that enables personnel to turn off power to the bridge. This is typically located right next to the service meter and may be in the form of a fused disconnect or a circuit breaker.

Utility service equipment is incidental to a parent Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Utility service equipment should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the utility service equipment should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
872	Conduit and Junction Boxes

Routine Inspection of Utility Service:

- Check for a drip loop, which is a u-shaped bend in the wires which prevents water from entering into the weather head. Wires should exit the weather head on a downward angle.
- Overhead service conductors will be mechanically supported by a wire rope "messenger" wire attached to a galvanized eyebolt on the power pole. Inspect the eye bolt and wire for corrosion.
- Inspect the power pole for loose or broken hardware and note the condition of the meter and the service disconnect. Check that the outdoor service equipment is weather tight with secured doors and no penetrations allowing water or insects/pests inside.

Utility Service Coding Recommendations:

- Heavy corrosion, failed supports or missing fastener hardware, or exposed wiring should code the conduit and junction boxes as CS3 "poor." If the service disconnect switch is inoperable, the conduit and junction boxes should be coded CS4 "severe."

Figure 4-37: Weather head and cable drip loop for utility service.

Figure 4-38: Service disconnect switch and service meter.

4.9.3 Transfer Switch

A device that can switch between electrical sources to an electrical load. These devices can be manual or automatic and are typically used to switch between utility and generator power. Inspection procedures for generators are found in the section 4.11 Emergency Power Generator System.

4.9.4 Standby Generator

A combustion engine driven system that runs off of fuel that can supply power to the bridge in the event of utility failure and allow the bridge to operate for an extended period of time. These are connected to the transfer switch and have their own circuit breaker. Inspection procedures for generators are found in the section 4.11 Emergency Power Generator System.

4.9.5 Distribution Panels

Device distribution is accomplished by a central panel or enclosure that contains circuit breakers for each load device and provides a safe and convenient way to de-energize and isolate loads. These enclosures are typically of the following: switchboard, motor control center (MCC), both of which are covered in previous sections, and/or panelboards.

Panelboards are not part of a Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Panelboards should be inspected and any notes including deficiencies should be recorded under general notes for the bridge.

4.9.6 Panelboards

Panelboards are collections of circuit breakers that provide power to downstream devices, housed in an upright manufactured panel that may be flush with the wall. These panels are often used to distribute power for 120/240V single-phase devices such as lighting, receptacles, and control power.

An electrical panelboard contains a group of circuit breakers housed in an enclosed panel, in order to distribute power to various electrical devices and loads. These devices are typically used to distribute 120/240V power to downstream devices, such as lighting, receptacles, and various house loads.

Routine Inspection of Panelboards:

- Inspect exteriors of panels for damage, corrosion, lost paint, or scratches.
- Check that the front covers are securely fastened and in place.
- Check for any tripped or turned off breakers.
- Verify that circuit breakers are properly labelled with a schedule and are up to date.

Figure 4-39: Panelboard inside an operator house. Note the moderate corrosion at the bottom of the panel.

4.9.7 Transformers

The transformer's function is to transform, or change, AC power from one voltage and frequency to another voltage at the same frequency. Transformers are typically used at movable bridges to step-down voltage from 480V to 120/240V for lighting and control circuits. Larger transformers may be freestanding on the floor, and smaller transformers will often be mounted to a wall or to another electrical cabinet.

Transformers are themselves a unique Movable Bridge Element, as such it is given a unique ADE designation number and Independent Condition State (CS) Rating. Transformers should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
870	Transformers and Thyristors

Routine Inspection of Transformers:

- Check transformers for overheating and correct environmental conditions.
- Note any unusually loud humming that could indicate loose fasteners or laminations.
- Note any paper, boxes, or combustible materials stored on or near transformer.
- Check the transformer nameplate and check that the installation meets the ventilation clearance indicated and 6 inches at the minimum.
- Check that the transformer mounting is secure.

Transformer and Thyristors Coding Recommendations:

- Moderate corrosion, oil leakage, or signs of overheating should code the system CS3 “poor.”
- Heavy corrosion, damage, or major oil leakage may rate the system CS4 “severe.”

Figure 4-40: Lighting transformer inside an operator house. Articles are on top of the transformer.

Figure 4-41: Lighting transformer inside an operator house. Articles are stored in front of and on top of the transformer.

4.9.8 Enclosures, Junction Boxes, Conduits, Wire, and Cables

Enclosures refer to any housing or box that contains electrical equipment such as conductors, terminal blocks, control system devices, and other miscellaneous components. These enclosures are typically made of stainless steel, aluminum, or plastic, and use rubber gaskets to protect internal components from the elements.

Wires refer to any type of insulated electrical conductor that connects electrical components together. There are many types and classes of wire and cable available. Wires are connected together using terminal blocks or strips. These are manufactured items that use screws or lugs to clamp down wires and connect them to other wires.

Flexible cables are used to connect power and controls from the fixed span to electrical equipment on the moving part of the span; cable grips support cables called “droop” cables. Refer to section 4.13.1 Droop Cables for further information on droop cables. Flexible cables are also sometimes used for limit switches.

Enclosures, Junction Boxes, Conduits, Wire, and Cables are all part of the Conduit and Junction Boxes Movable Bridge Element, as such it is given a unique ADE designation number and Independent Condition State (CS) Rating as a system. Enclosures should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
872	Conduit and Junction Boxes

Routine Inspection of Enclosures, Junction Boxes, Conduits, Wire, and Cables:

- Check enclosures for dirt, corrosion, sealed and intact door gaskets, proper bonding to ground, and proper labeling. Check the interior for evidence of vermin.
- Enclosures with door mounted switches or indicators must have a green bonding jumper wire connecting the door to the enclosure.
- Inspect the terminals and conductors for corrosion, discoloration due to overheating, and proper labeling. Also, verify that the terminal blocks are securely mounted.
- Visually inspect the wiring for damage, overheating, and failing insulation. Check the wiring to door mounted devices for wire and insulation damage in the bending area.
- Inspect the door/cover for missing, failed, or broken latches and hardware.
- Check for evidence of water intrusion and adequate breathers and drains at low points of the system.
- Check for any unplugged holes and loose or failing connections to the conduit system.
- Check the enclosure supports for damage, corrosion, and that they are securely mounted to the structure.
- Inspect conduits for corrosion, damage, and insecure mounting. Make note of unplugged conduit penetrations in enclosures.
- Check conduit bodies for similar deficiencies along with housing gaskets for wear.

- Check that conduit is supported at intervals not exceeding 10 feet and supported within 3 feet of a termination or box.
- Check that flexible (metallic) conduit lengths do not exceed three feet and includes a bonding wire jumper.
- Wearing of insulation from rubbing or abrasion.
- Repeated or severe bending of wires.
- Deterioration of insulation from age or atmospheric conditions.
- Overheating (insulation discoloration)
- Cable insulation shows signs of "sweating", a condition that results from temperature differences between two areas that a wire runs through.
- Check that wires are not exposed to the elements, this is usually the result of damage or corrosion to conduits, enclosures, or housings.
- Check to make sure that the cables are supported at both ends of the loop. A loop is provided so that the movement of one end, during raising and lowering of the span, does not cause the cable to bend too sharply or twist while moving.
- Check to see if cable supports are provided. If not, cables may drag along the floor. This can cause a short circuit.
- Check for severe (short radius) bending. This can cause the wires to break at these points.
- Check for cracking or wearing of the insulation and jacket at stress locations.
- Check for signs of overheated joints, charred insulation, and discolored terminals.
- Check wire connections to make sure wires terminals are properly tightened and secured.
- Check for use of multiple wires under the same lug. Putting two wires under a lug is not allowed for power cabling but is allowed for control wiring.

Enclosures, Junction Boxes, Conduits, Wire, and Cables Coding Recommendations:

- Moderate to severe corrosion, broken supports, broken conduit, loose or corroded connections, damaged or burned wire or cable insulation, poor gaskets, or missing door hardware affecting 10 to 25% of the system should be rated CS3 "poor."
- Moderate to severe corrosion, broken supports, broken conduit, loose or corroded connections, damaged or burned wire or cable insulation, poor gaskets, or missing door hardware affecting more than 25% of the system should be rated CS4 "severe."

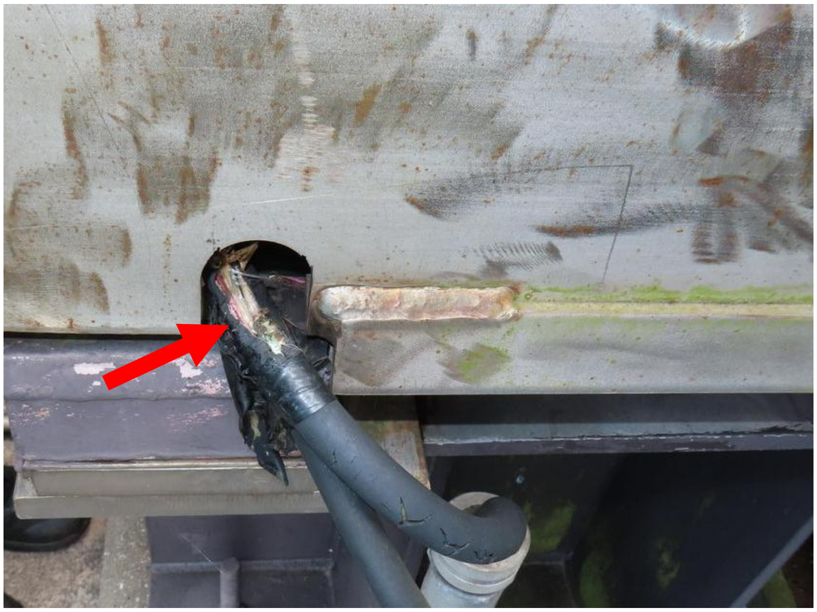

Figure 4-42: Damaged flexible cable jacket with interior wiring showing.

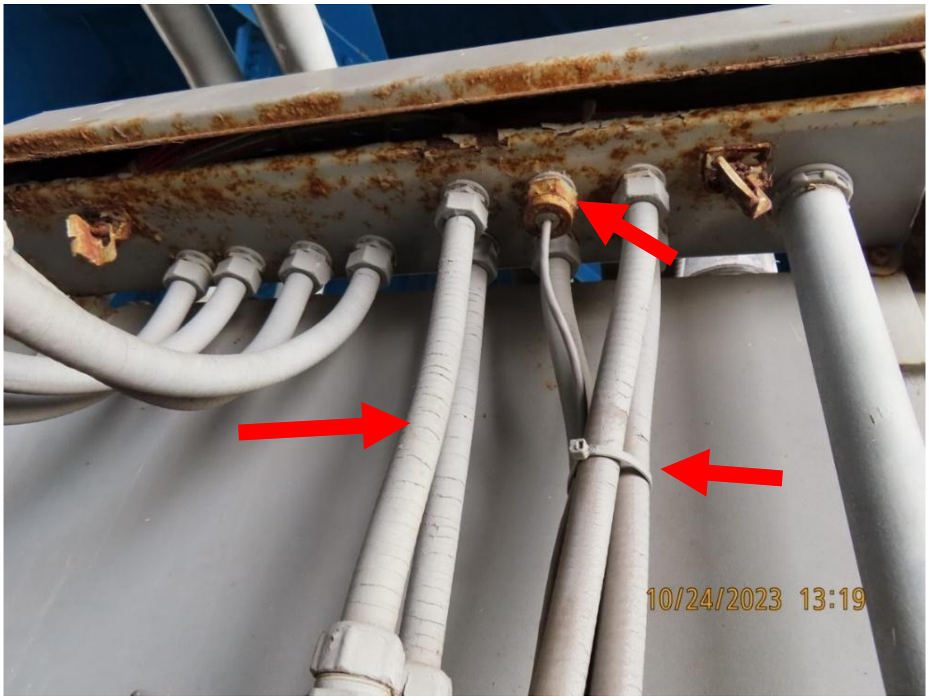

Figure 4-43: Flex conduit exiting a wire enclosure. Note the cracking and deterioration on the conduit, the use of zip ties to group/support conduit together, and corrosion and paint failure of the cable gland (connector).

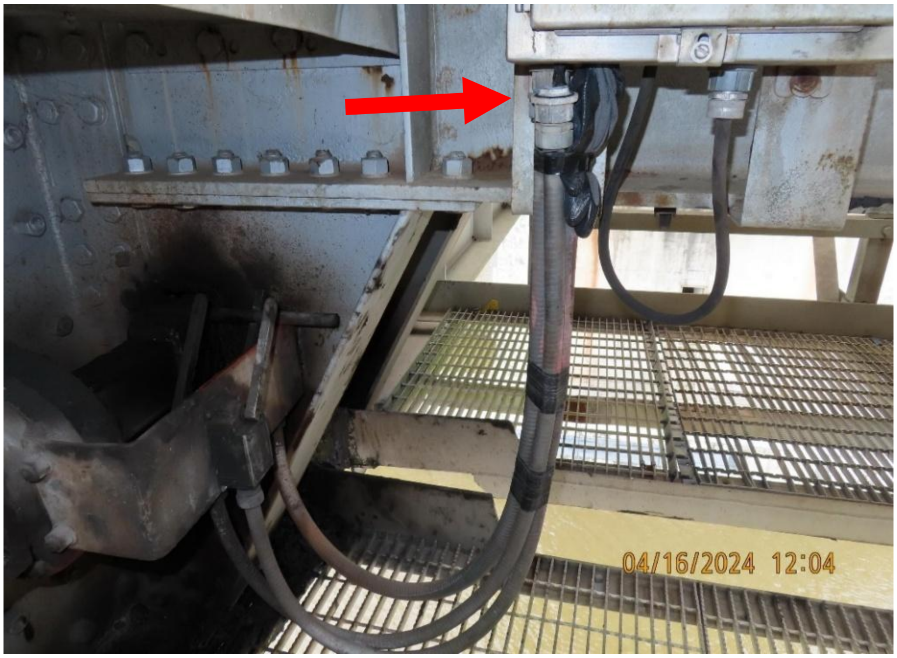

Figure 4-44: Flex conduit and a flex cable exiting an enclosure. Note broken coupling and tape used to provide support.

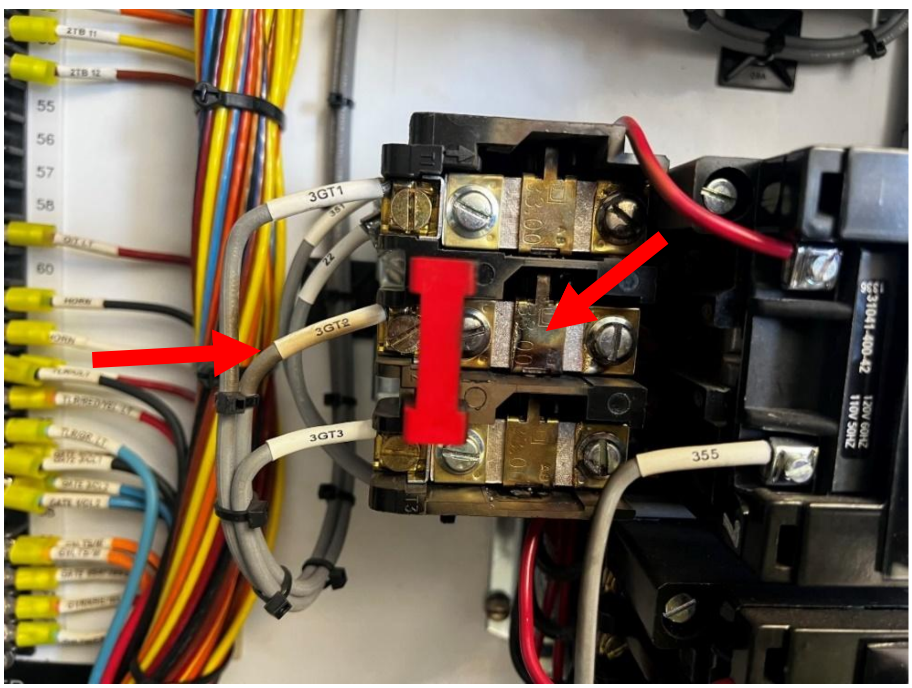

Figure 4-45: Terminal connections on a motor starter overload. Note the discoloration on the thermal element and connecting wire, indicating overheating. The I-shaped red bar is pushed to reset the starter overload after a fault.

4.9.9 Submarine Cables

Submarine cables are used to route wiring from one side of the channel to the other. These cables may be in the form of a custom-made armored cable that has a collection of individual conductors of various sizes, or a cable duct made out of HDPE or PVC.

Submarine cables are part of a unique Movable Bridge Element, as such is given a unique ADE designation number and each an Independent Condition State (CS) Rating. Submarine cables should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
871	Submarine Cable

Routine Inspection of Submarine Cables:

- Check if submarine cables are under tension, meaning the cable is stressed with no supporting hardware attached.
- Check for deterioration and damage of cables and support hardware.
- Check for damage to outer jacket, exposing armor strands.
- If ducts are present, check visible portions for damage and deterioration, along with support hardware.
- Note support as deficient if the cable has less than 3 supports, or the supports are more than 3 ft apart.

Submarine Cable Coding Recommendations:

- If the cable or duct is not firmly attached to the pier, has multiple loose connections, damage to the jacket that exposes the armor or wiring, or if the terminals are loose or have moderate to severe corrosion, the submarine cable should be coded CS3 “poor.”
- If there is significant deterioration to the outer protective coating, the cable isn’t functioning properly, or if minimal spare wires are available, the submarine cable should be coded CS4 “severe”.

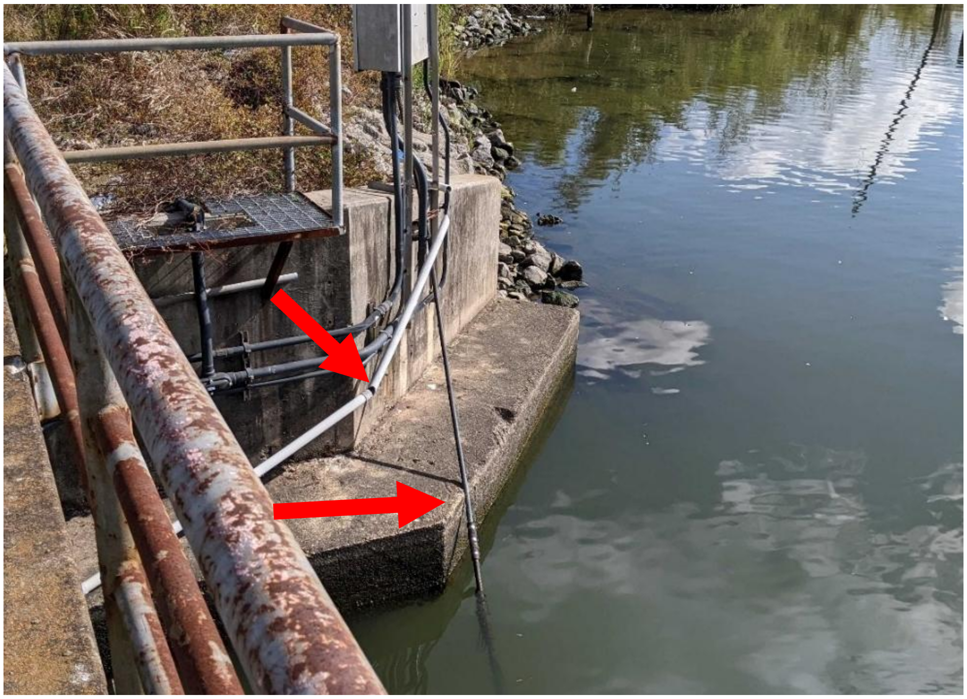

Figure 4-46: Submarine cable entering a channel. The submarine cable is under tension, insufficiently supported, and subject to abrasion on the concrete. In addition, conduits are broken around the area.

4.9.10 Disconnect Switches

Disconnect switches are used to disconnect electrical devices safely and rapidly. Per NEC, motor disconnects must be placed within sight of the device it serves.

Disconnect switches are incidental to many Movable Bridge Elements as such they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Disconnect switches should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of the disconnect switches should be taken into consideration when determining the Condition State (CS) Rating of their parent element. Below a table is provided of Movable Bridge Element ADE's that often have disconnect switches.

El. No	Element Name	El. No	Element Name
841	Speed Reducers	886	Traffic Warning Gates
844	Brakes	881	Bridge Specific Equipment (Lift)
845	Emergency Drive and Back-up Power Systems	882	Bridge Specific Equipment (Swing)
847	Hydraulic Power Units	883	Bridge Specific Equipment (Pontoon)
860	Span Locks	884	Bridge Specific Equipment (Bascule)
885	Barriers		

Routine Inspection of Disconnect Switches:

- Check enclosures for dirt, corrosion, sealed and intact door gaskets, and proper bonding to ground.
- Inspect the terminals and conductors therein for corrosion, discoloration due to overheating, and proper labeling.

Disconnect Switch Coding Recommendations:

- Failure or cracks of the wire jacket/insulation should code the disconnect switch parent element CS3 “poor.”
- Loose connections, signs of overheating wires or contacts, or moderate to severe corrosion of the terminals or contacts should code the disconnect switch parent element CS3 “poor.”
- If the switch is not operable and unable to be switched, the disconnect switch parent element should be coded CS3 “poor.”

Figure 4-47: Disconnect switch for a motor.

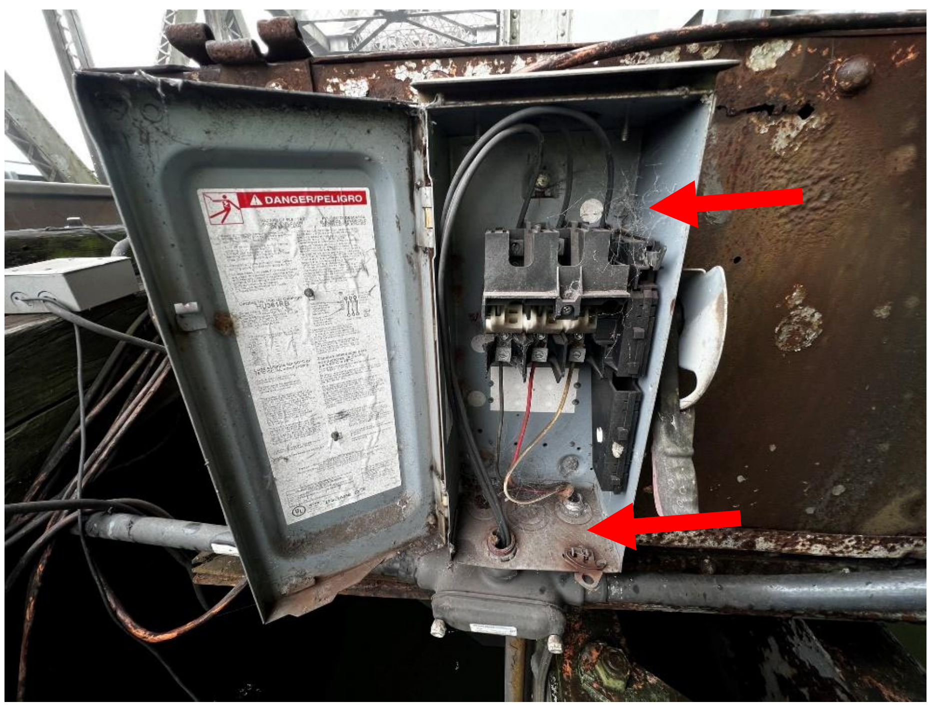

Figure 4-48: Disconnect switch for a motor. Note the corrosion on the conduit entries and door hardware, bug debris (spiderwebs), and lack of wire labels.

Figure 4-49: Disconnect switch used for a motor. Note the lack of labeling indicating what motor it's for and no arc flash labeling.

Figure 4-50: Two small disconnect switches used for motor and machinery brakes. The switches have minor corrosion, and the levers are difficult to operate due to the corrosion.

4.9.11 Overcurrent Protective Devices

Overcurrent protective devices include fuses and circuit breakers that are found within disconnect switches, switchboards, MCCs, or panelboards. Fuses are condition rated along with their parent element.

Fuses

A fuse is a protective device to prevent overcurrent conditions that could potentially damage equipment or cause fires. Once blown, fuses need to be replaced by new ones of the same properties.

Routine Inspection of Fuses:

- Observe fuses to verify they are properly secured and in-tact. Blown fuses may have a broken metal strip or visual blown indicator.
- Check fuses for corrosion.

Fuse Coding Recommendations:

- Fuses that have heavy corrosion or evidence of overheating should be coded CS3 “poor.”
- Blown fuses should code the system CS4 “severe.”

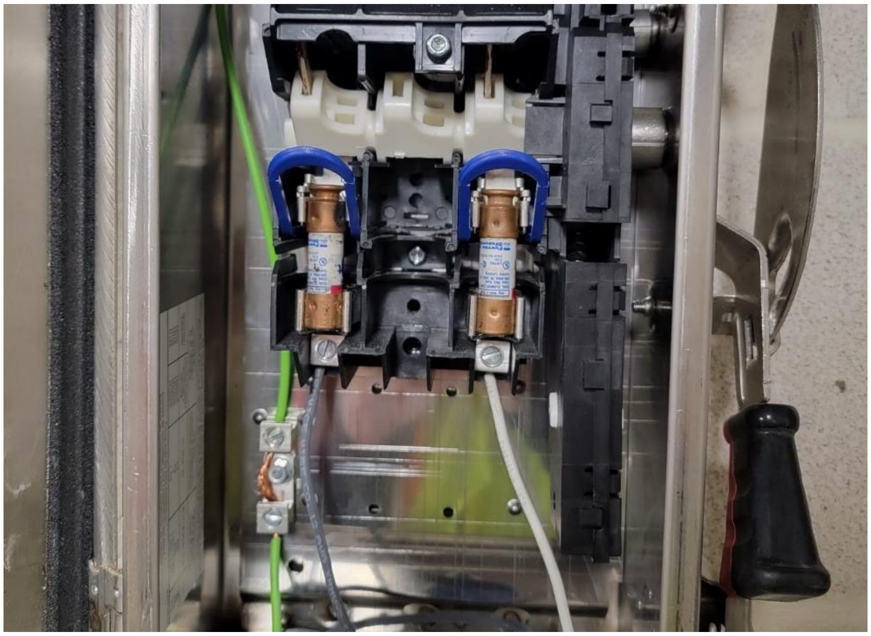

Figure 4-51: Two fuses inside a disconnect switch.

Circuit Breakers

Circuit breakers are used both as protective devices and for switching electrical power. Fuses are condition rated along with their parent element: e.g., switchboards, MCC, or panelboard.

Routine Inspection of Circuit Breakers:

- Check connection points to verify that overheating has not occurred, and cable connections are tight.
- Check temperatures with an infrared thermometer for excessive heat during use.
- Check trip settings on the front of the breaker to verify that correct trip settings are in use according to as-built plans.

Circuit Breaker Coding Recommendations:

- Circuit breakers that have heavy corrosion or evidence of overheating should be coded CS3 “poor.”
- Tripped circuit breakers that do not reset should code the system CS4 “severe.”

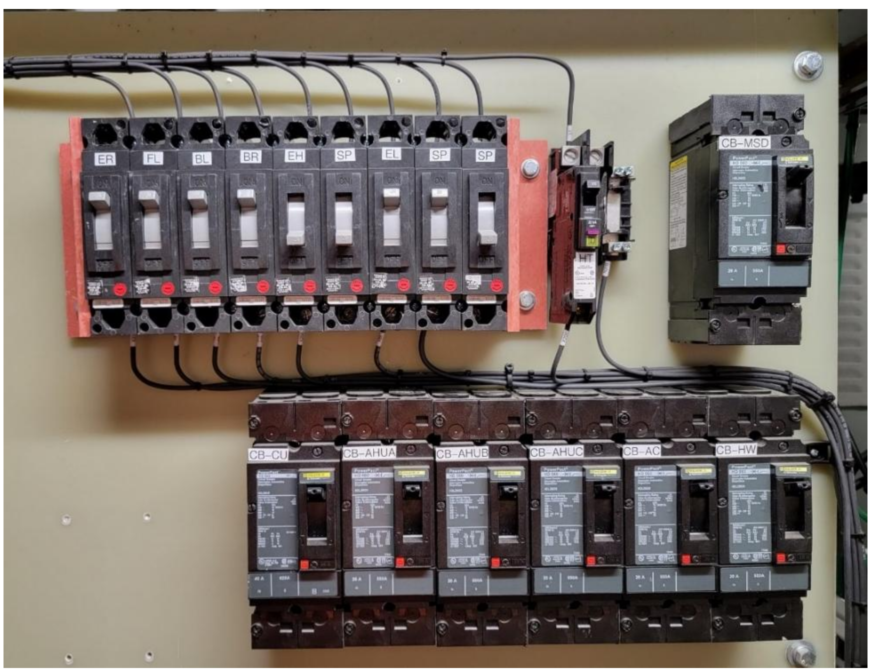

Figure 4-52: Collection of circuit breakers inside a switchboard.

4.10 SURGE PROTECTION

Surge protection is used to protect solid-state devices within bridge control systems.

Surge protection is incidental to a parent Movable Bridge Element, as such it is not given a unique ADE designation number, nor an independent condition State (CS) Rating. Surge protection should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of this should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
872	Conduit and Junction Boxes

Routine Inspection of Surge Protectors:

- Check that electrical and system grounds are bonded together.
- Verify whether or not the main electrical service panel is equipped with a surge protector.
- Verify if surge suppression is present on incoming electric service panel and record the finding.
- Check the indicator lights for the surge protective device. A properly connected and functioning SPD typically has a green "OK" LED indicator. A red LED indicates a malfunction, and no lights indicate that it is disconnected or faulty.

Surge Protection Coding Guidelines:

- If the SPD "OK" LED indicator is not lit or if no indicator lights are lit, the surge protection parent element conduit and junction boxes should be coded CS3 "poor."

4.11 EMERGENCY POWER GENERATOR SYSTEM

The standby generator and associated systems are all part of the Emergency Drive and Back-Up Power Systems Movable Bridge Element; as such, the system is given a unique ADE designation number and Independent Condition State (CS) Rating. The standby generator should be inspected and any notes including deficiencies should be recorded underneath the Movable Bridge Element ADE Number shown below.

El. No	Element Name
845	Emergency Drive and Back-Up Power Systems

4.11.1 Generators

Where provided, a backup standby generator maintains continued electric service for the movable bridge in the event of utility service failure. Generators should be tested on a regular schedule according to NFPA 110 and manufacturer recommendations.

Generators use internal combustion engines running on fuel, typically diesel or natural gas. Diesel or gasoline fuel is stored in special tanks that may be mounted under the generator skid (subbase fuel tank), or they may be located remotely with fuel line pipes to the generator.

Generator engine radiators are typically mounted to the opposite side of the controls. Ambient air is taken in by the cooling fan and vented through ducts outside the building or the generator enclosure. The room will have louvers to allow fresh outside air into the room which may be gravity actuated or motor actuated.

The alternator is connected to the generator engine and generates AC power from mechanical energy.

Generator controllers are typically found in the operator house and is typically installed on the generator itself; a separate remote panel installed on a wall or near the operator console may be provided. Additionally, some controls are often found on the automatic transfer switch. Testing of generators is typically done by dedicated maintenance personnel.

Occasionally, generators may have a resistor load bank used for keeping the generator under a continuous electrical load and for generator testing purposes.

Routine Inspection of Generators:

- Check generator for functionality using a full bridge opening at minimum once a month.
- Check that the battery is charged to a reasonable fraction of its rated capacity, about 80 percent. Check the battery terminals for corrosion and note the date of installation.
- Check the battery charger is connected and operational.
- Observe fluid levels and visually inspect for any leaks.
- Record voltage when generator is both loaded and unloaded.
- Perform a full bridge operation under generator power to test that the generator and automatic transfer switch (if applicable) function as intended. This is typically performed by cutting power to the bridge, either at the service disconnect switch or by manually running a generator test through the ATS or generator control panel. Monitor supplied power through associated panels or instrumentation to verify that the generator is supplying the correct voltage and appropriate amps.
- The engine should be checked for exterior corrosion, loose articles present on top of the engine, and general dirt/debris.
- If the generator is enclosed, check the condition of the door hinges and latches. Note broken hardware or corrosion.
- Check the instrumentation and electrical display for proper function.

- The area around the fuel tank should be checked for leaks.
- Check the fuel level and verify proper operation of fuel gauges.
- Check water filters and strainers.
- Verify operation and visually inspect fuel pumps, recirculation pumps, and heaters.
- Visually inspect vents, fittings, and pipelines.
- Check propane tank gauges, valves, and fittings for generators that run on gaseous fuel.
- Check the radiator for corrosion.
- Visually inspect the hoses for cracking and degradation.
- Check that the level of coolant is adequate and there are no leaks.
- Check for damage, dirt, debris, or obstructions to the fan and vents.
- Check the intake louvers for proper operation and obstructions.
- Check the oil level.
- Observe the alternator for general dirt/debris and corrosion.
- Verify functionality of generator control panels, check for any logged alerts or errors that may indicate an operational issue with the generator system.
- is in operation.

Generator Coding Recommendations:

- Heavy corrosion, major fluid leaks, non-functional intake louvers, damage or disconnected ductwork, damage or breaks in the exhaust piping should rate the system CS3 “poor.”
- 0If the generator does not start, or if the bridge cannot complete a bridge operation under generator power, the system should be coded CS4 “severe.”

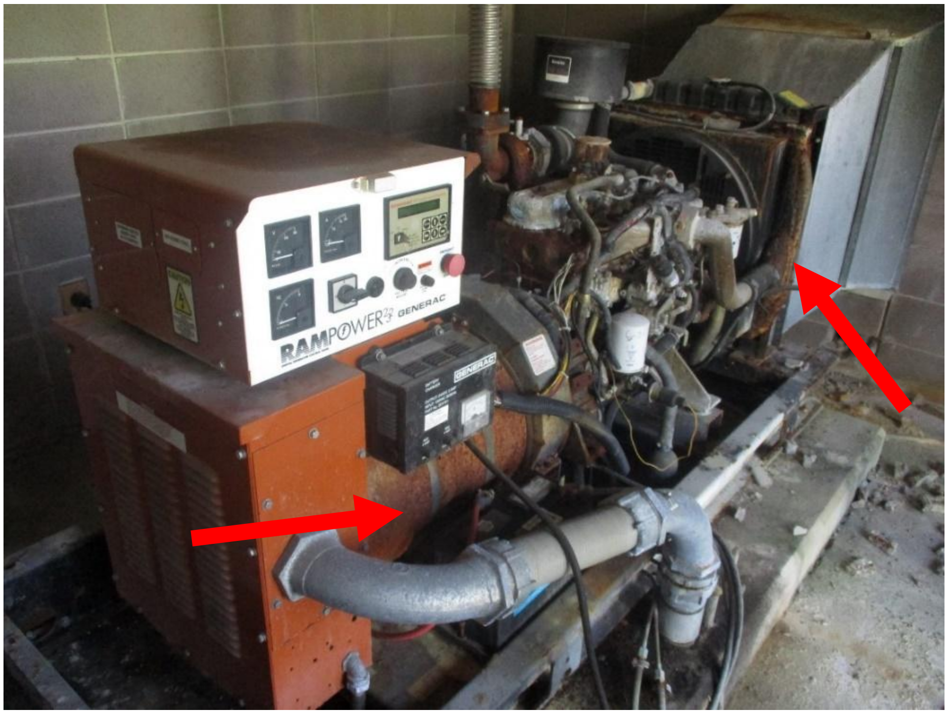

Figure 4-53: Generator sitting inside a machinery room. There is some corrosion and deterioration on the components.

Figure 4-54: Generator inside an operator house.

4.11.2 Transfer Switches

Transfer switches are used to safely switch between utility service and emergency power.

Transfer switches are incidental to a parent Movable Bridge Element, as such they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. Transfer switches should be inspected as part of their parent element and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of transfer switches should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
845	Emergency Drive and Back-Up Power Systems

Automatic transfer switches (ATS) are transfer switches that automatically transfer power between the utility service and the emergency power, usually a standby generator. Manual transfer switches are transfer switches that require personnel to manually switch between utility service and emergency power.

Routine Inspection of Transfer Switches:

- Check automatic transfer switch for functionality.
- Inspect the exterior and interior as any other enclosure.
- Inspect manual transfer switches as if they were regular disconnect switches.
- Verify that the switches are rated for the amount of power being supplied upstream and downstream. As an example, a switch rated for 400A shouldn’t be feeding into a 450A circuit breaker.

Transfer Switch Coding Recommendations:

- If an automatic transfer switch does not automatically transfer when main power is switched off, but the switch can be manually switched to emergency power, the system should be rated CS3 “poor.”
- 0If the transfer switch fails to transfer to emergency power under any conditions, the system should be coded CS4 “severe.”

Figure 4-55: Generator control panel.

4.12 MISCELLANEOUS

Louisiana movable bridges may be equipped with systems that assist the operator with communication and control, provide control of building access, meet life safety and building code requirements, or used for maintenance. These systems should be visually inspected and checked for proper functionality. Maintenance records, where required, should be verified.

These miscellaneous items are not part of a Movable Bridge Element; as such, they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. These items should be inspected and any notes including deficiencies should be recorded under general notes for the bridge.

- Air Compressors – check that the condensate drain works and is regularly drained, check that the pressure switch operates the compressor.
- Telephone and broadband intranet/internet equipment
- Uninterruptible power supply (UPS) systems
- Fire and security systems
- Public Address (PA) system
- CCTV camera systems
- Weather stations
- Access control for doors and gates
- Ventilation fans and powered louvers
- HVAC

- Water heaters
- Sewerage pumps – check the monitoring/alarm system if equipped.
- Monitoring equipment such as water level alarms, control system monitoring, machinery/structural stress data acquisition, etc.

Routine Inspection of Miscellaneous Electrical Items:

- These systems should be visually inspected and checked for proper functionality. Maintenance records, where required, should be verified.
- For any device with batteries, the batteries should be visually inspected and tested. The date of installation should be noted in inspection notes.

4.13 BRIDGE SPECIFIC ELECTRICAL SYSTEMS

This section includes control system differences like selsyns, skew monitoring, and synchro-tie systems for vertical lifts; electrical system differences like aerial cables on vertical lifts or submarine cables on swings and bascules; and integration (how certain electrical issues can impact the other systems and vice versa).

Bridge Specific Equipment element numbers may be considered a "catch all" for other important bridge elements. Each item given a Condition State (CS) rating shall contain a description of the item and a quantity of 1.

El. No	Element Name
881	Bridge Specific Equipment (Lift)
882	Bridge Specific Equipment (Swing)
883	Bridge Specific Equipment (Pontoon)
884	Bridge Specific Equipment (Bascule)

Span Motors

The span motors that drive the movement of the span do not have a unique ADE designation number; however, defects in motors require a condition state assignment to avoid an unplanned bridge outage due to motor defects or deterioration. Each span motor should be quantified under the Bridge Specific Equipment and assigned a unique condition state rating. Inspection procedures and coding recommendations are given in the Motor section of this manual.

4.13.1 Swing Bridge Electrical Systems

Swing bridges in Louisiana primarily have one of two types of swing operating machinery: rack and pinion or hydraulic cylinder operated. Wedges and lifts are often hydraulically operated but may also be driven with motors through mechanical linkages. A span position rotary cam limit switch assembly may be found on the operating machinery or near the center pivot with its own rack and pinion. Span position discrete lever arm or plunger switches are typically located along the balance wheel track for the nearly and fully open/closed span positions.

Rack and pinion operated bridges have electrically powered motor and machinery brakes that need to be uncovered to inspect; brake set, and release limit switches are internal. Hydraulic cylinder bridges will not have brakes or brake limit switches; however, the HPU control valves typically have rotary cam limit switch assemblies.

An auxiliary control panel for manual operation from the machinery area, when present, shall be inspected. Coordinate an operational test of this auxiliary control station with the bridge operator and the district.

Overview of Typical Interlocking Scheme

Swing bridges follow a typical interlocking scheme outlined below. The following items can only be engaged in the sequential order in which they are listed. The process is the same in reverse order.

- Traffic Signals
- Oncoming Traffic Gates
- Off-going Traffic Gates
- Barrier Gates
- Lifts/Wedges
- Span Open and Close (Motors and Brakes)

Droop Cables

Droop cables are found on the center pivot pier and are used to link the fixed and movable junction boxes between the center pivot pier and the movable span. The droop cables enable power and communications for electrical devices on the movable span such as navigational lighting. Inspect droop cables as flex cables.

Figure 4-56: Droop cabling used on a swing-span bridge.

Alignment at Closing

Modern control system design will automatically slow and stop the span so that it comes to rest with the span in alignment without requirements for the operator to manually line it up. This relies on proper operation and adjustment of the relay control circuits, discrete limit switches, and the drive system. Some swing spans have a buffer and a center lock which prevents overtravel.

4.13.2 Vertical Lift Bridge Electrical Systems

Vertical lift bridges in Louisiana primarily have machinery located on a fixed span between the towers (tower span drive), or at the top of each tower (tower drive). On span drive lifts, motor(s), associated motor and machinery brakes, and clutches may be accessible by climbing a single ladder. On tower drive lifts, a drivetrain is located on each tower.

Discrete span position limit switches are engaged near grade level and often located on the guide rail/track. The nearly and fully closed lever arm limit switches are engaged by the span and the nearly and fully open lever arm limit switches are engaged by the counterweight. Span locks or end latches have limit switches and motor drives that also need to be inspected; these are located under each end of the movable span.

Skew detection and control system may have enclosures within the control house; inspect these enclosures as any other electrical enclosure and verify skew control through observation of span operation. The machinery deck will have a panel that allows the synchro-tied motors to be switched from transmitter to receiver. Coordinate an operational test of this control station with the bridge operator and the district.

Overview of Typical Interlocking Scheme

Vertical lift bridges follow a typical interlocking scheme outlined below. The following items can only be engaged in the sequential order in which they are listed. The process is the same in reverse order.

- Traffic Signals
- Oncoming Traffic Gates
- Off-going Traffic Gates
- Barrier Gates
- Locks/Wedges
- Clutch (if applicable)
- Span Open and Close (Motors and Brakes)

Skew Detection and Prevention

Vertical lift bridges can skew along the transverse (width) or the longitudinal (length) direction. Skew detection and prevention systems are implemented using different methods outlined below.

Synchro (Selsyns)

Synchro transmitters are rotary position sensors designed to convert mechanical input rotation to an electrical signal proportional to the input shaft position. On vertical lifts, synchro transmitters are usually coupled through gearing to each sheave.

Synchro-Tie

These are a type of synchro through which mechanical power is transmitted. The power synchro-tie (or power selsyn) is a wiring and control method that synchronizes two or more three-phase wound rotor motors turn-for-turn. This scheme adds dedicated relays and motor starters in the switchboard.

Routine Inspection of Selsyns:

- Selsyns are inspected externally to detect signs of deterioration, misalignment, the housing should be checked for corrosion and check wiring for looseness and deterioration.
- For wound rotor motors used for synchros, follow the inspection procedure for motors.

Computerized Modules

Bridge systems that utilize PLCs for automated control or for monitoring can use motor encoders for RPM and encoders attached to the sheave rotary cam limit switch for skew monitoring.

Cable Reel

Cable reels often found on Louisiana vertical lifts are used to transmit power to the span mounted navigation lights. Multiconductor cable is laid out under tension as the span is raised. On some bridges, droop cables may be used in place of a cable reel.

Routine Inspection of Cable Reels:

- Visually inspect the housing and hardware for corrosion.
- Check that the reel is securely anchored and mounted.
- Visually inspect the cable support grip mounted to the span.
- Check the cable jacket for signs of wear and degradation.
- Observe the cable under operation; the cable should pay out smoothly and the spring should take up the cable slack.
- Check the terminals and slip rings for dirt, wear, and corrosion.
- Inspect the cover gasket for degradation.

Cable Reel Coding Recommendations:

- Heavy corrosion, loose anchorage, excessive slack in the cable, broken cable jacket that exposed the wiring should rate the system CS3 "poor."
- If the cable is broken or not providing power to the span navigation lights, the system should be coded CS4 "severe."

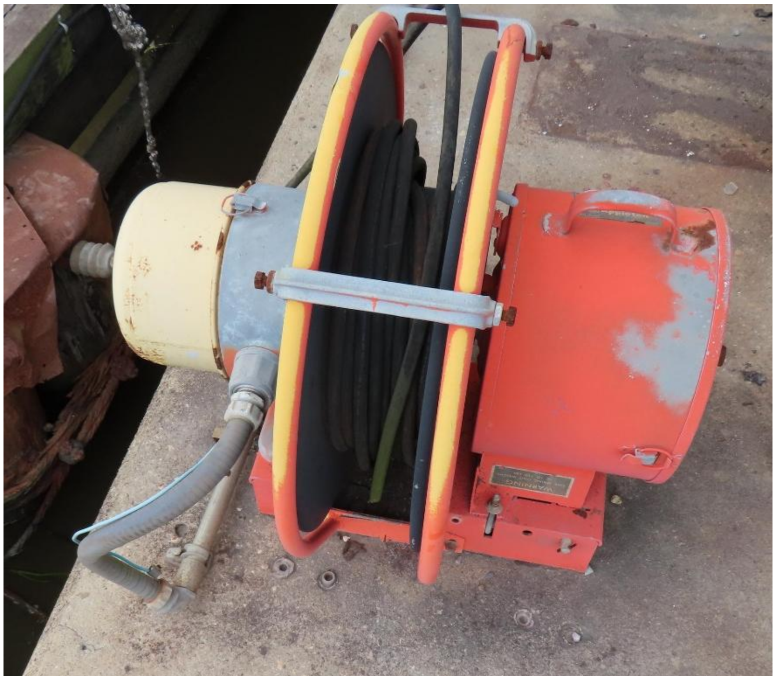

Figure 4-57: Cable reel.

Aerial Cables

Aerial cables are used on vertical lift bridges and connect one end of the fixed structure to the other to route power and communications across the channel. These cables are suspended horizontally in the air between towers and are typically made with steel rope or have a separate steel wire rope for support called a messenger cable.

Routine Inspection of Aerial Cables:

- Check aerial cables for wear, deterioration, and signs of corrosion.
- Check the messenger cable (wire rope) and the hardware at each termination for corrosion or damage.

Aerial Cable Coding Recommendations:

- If the cable is not firmly attached to the messenger cable, the messenger cable is not firmly attached to the bridge, the jacket has damage that exposes the wiring, or connecting hardware has moderate to severe corrosion or wear, the aerial cable should be coded CS3 "poor."

Warping Clutches

Clutches are used in vertical lift machinery to eliminate skew in the transverse direction while seating (difference in elevation of the span in the direction across the same end of a span). This is usually accomplished by a small electric motor which engages a gear that locks or unlocks a differential.

Routine Inspection of Warping Clutches:

- Follow the inspection procedure for motors.

Figure 4-58: Clutch motor used to engage a differential in the gear assembly. Note the heavy corrosion on the motor and clutch assembly.

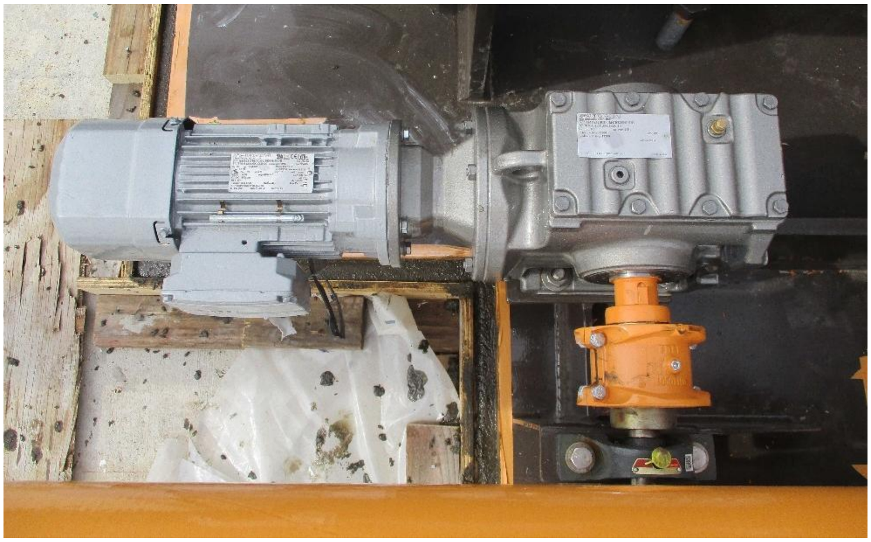

Figure 4-59: Clutch motor used to engage a differential in the gear reducer.

4.13.3 Bascule Bridge Electrical Systems

There are two main types of bascule bridges: trunnion and rolling lift. The electrical and control systems on each are similar in design and operation. Rolling leaf bascules commonly have the drive machinery mounted on the movable span, and the power and controls are transmitted through flexible droop cables connecting the movable and fixed portions of the span.

Motor and machinery brakes have discrete limit switches which are usually under a cover. The drive machinery for each span typically has a rotary cam limit switch on the pinion shaft or the motor shaft through a reduction drive. Discrete lever arm (or proximity) limit switches are found near the trunnion or rolling leaf track; occasionally, fully seated limit switches may be found near the live load bearings. Lever arm or proximity switches will be found on the center or rear locks. Inclinometers are becoming more common and may be found mounted to the movable span usually in a machinery access area.

Overview of Typical Interlocking Scheme

Bascule bridges follow a typical interlocking scheme outlined below. The following items can only be engaged in the sequential order in which they are listed. The process is the same in reverse order.

- Traffic Signals
- Oncoming Traffic Gates
- Off-going Traffic Gates
- Barrier Gates (if applicable)
- Locks
- Span Open and Close (Motors and Brakes)

Droop Cables

Droop cables are flexible cables that are found at the point where the electrical equipment transitions between the fixed and movable sections of the bridge.

Routine Inspection of Droop Cables:

- Check the cables for signs of wear, degradation, or rubbing on surfaces during operation.
- Observe the strain relief for the droop cables on each junction box and verify its integrity.

Droop Cable Coding Recommendations:

- If the cable is not firmly attached to the termination boxes, the jacket has damage that exposes the wiring, or connecting hardware has moderate to severe corrosion or wear, the droop cable should be coded CS3 "poor."

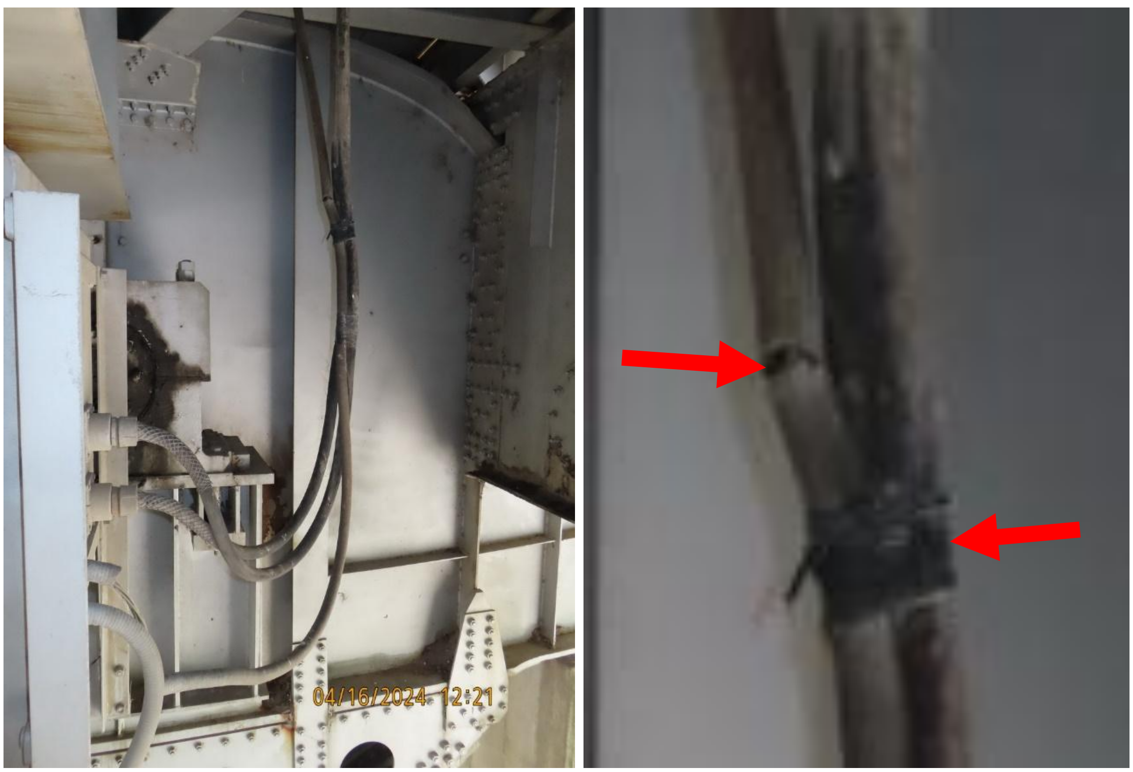

Figure 4-60: Droop cables used on a bascule bridge. Note the cables are cracked, broken, and deteriorating, and the cabling is grouped together using tape (enlarged in photo on the right).

4.13.4 Pontoon Bridge Electrical Systems

A pontoon bridge has the following unique equipment relevant to the electrical inspection. The inspection procedure for each of these items is covered in other sections. Ramps have similar features to barriers and are inspected in an analogous way.

- Droop cables
- Rotary encoder or rotary limit switch at the pivot for span position indication
- Ramps at each end of the span that also serve as barriers
- Winch house with gearmotor that may also have auxiliary manual control stations
- Pontoon pumps to adjust water ballast

Figure 4-61: Rotary Encoder for pontoon span position mounted on the pivot (close up photo on the right).

Overview of Typical Interlocking Scheme

Pontoon bridges follow a typical interlocking scheme outlined below. The following items can only be engaged in the sequential order in which they are listed. The process is the same in reverse order.

- Traffic Signals
- Oncoming Traffic Gates
- Off-going Traffic Gates
- Ramp Motors
- Span Open and Close (Motors and Brakes)

4.13.5 Hydraulic Equipment Electrical Systems

The electric motors for pumps are the main electrical concern in hydraulic systems; however, there are many other components that require inspection and maintenance. These components, electrical terminations, and wiring should be visually inspected, as covered in other sections. Observe the system and the indicators while in operation.

- Hydraulic fluid heaters and heat exchangers
- Hydraulic fluid recirculation pumps
- Solenoid and electrically actuated valves
- Temperature, pressure, and flow sensors
- Fluid level alarms

These items are incidental to two parent Movable Bridge Elements, as such they are not given a unique ADE designation number, nor an independent condition State (CS) Rating. These should be inspected as part of their parent element as a system and any notes including deficiencies should be recorded underneath the Movable Bridge element ADE number that they serve. Deficiencies of these items should be taken into consideration when determining the Condition State (CS) Rating of their parent element shown below.

El. No	Element Name
847	Hydraulic Power Units
849	Hydraulic Cylinders/Motors/Rotary Actuators

Hydraulic Control

A common method of controlling span speed which relates directly to flow in hydraulic operated bridges is through proportional valves. The proportional valve is operated through a linkage to a gearmotor, and a rotary cam limit switch assembly provides the control system with the valve position. Other common methods of flow control are variable displacement pumps utilizing swashplates, and VFD driven variable speed pump motors. Drum differential operated swing bridges have a control motor and a rotary cam limit switch connected to the drum differential. Motor and rotary cam limit switch inspection is covered in the preceding sections.

Solenoid Valves

Solenoid valves are electrically controlled by control units typically located in dedicated control cabinets. The solenoid valves are typically located on the HPU within manifolds.

Routine Inspection of Solenoid Valves:

- Verify proper operation and perform a visual inspection of the electrical connections and wiring.

Solenoid Valves Coding Recommendations:

- Heavy corrosion or damage to the connecting cables that expose wiring should rate the system CS3 “poor.”

Figure 4-62: Solenoid valves and wiring connections on a control valve block.

Amplifier Cards

Amplifier cards are electrical devices that are used for electrical control of valves and are typically found in dedicated control cabinets.

Routine Inspection of Amplifier Cards:

- Verify proper operation and perform a visual inspection of the electrical connections and wiring.
- Ensure the cards are firmly secured in the cabinet/enclosure and check for dirt and debris buildup.

Amplifier Cards Coding Recommendations:

- Loose connections, loose or unsecured cards, heavy dirt or dust buildup should code the system CS3 “poor.”

Figure 4-63: Amplifier Cards in a cabinet.

4.14 CATHODIC PROTECTION

4.14.1 Basic Theory

Cathodic protection uses the galvanic process to minimize the deterioration and damage by corrosion to structural steel and reinforcing steel elements of bridge structures.

4.14.2 Testing

Sacrificial anode cathodic protection systems require special inspection procedures performed by qualified personnel. The system is mostly invisible (underwater) and requires underwater inspection methods. Where cathodic protection systems are employed, bridge maintenance should keep logs of installation, replacement, and testing dates.

4.15 LIGHTNING PROTECTION SYSTEM

To protect electrical components from lighting strikes, conductors connect air terminals at high points on building roofs and run down the walls in at least two places to ground rods. Down conductors are vertical drops that route current from lightning from the air terminals to the grounding system. Often, down conductors are partially run through PVC conduit to discourage theft.

Lightning protection components are incidental to their parent element, the Bridge Specific Equipment elements (881-884), as such they are not given a unique ADE designation number, but the system as a whole is considered an item and given a Condition State (CS) rating. Any notes including deficiencies should be recorded underneath the parent Movable Bridge Element ADE number that they serve according to the bridge type.

El. No	Element Name
881	Bridge Specific Equipment (Lift)
882	Bridge Specific Equipment (Swing)
883	Bridge Specific Equipment (Pontoon)
884	Bridge Specific Equipment (Bascule)

Routine Inspection of Lightning Protection Systems:

- Verify that the metal path is continuous from the ground terminal to the air terminal.
- Check that conductors aren't corroded and are properly secured to the structure (3 ft minimum between supports), and that the connections are secure and tight.
- Visually inspect the accessible bare wire conductors for damage. Any break in the conductors should be noted.

Lightning Protection System Coding Recommendations:

- If half or more of the connections along a down conductor run or along a horizontal run to air terminals are loose hardware or missing, the system should be coded CS3 "poor."
- If an air terminal is broken or missing, or if the wire along a down conductor run or along a horizontal run to air terminals is broken or discontinuous, the system should be coded CS3 "poor" or CS4 "Severe."

Chapter 5
Structural Inspection of Movable Bridges

5.1 OVERVIEW

This chapter supplements the LADOTD *On-System Bridge Inspection Manual*, FHWA *Bridge Inspector's Reference Manual* (BIRM), AASHTO *Movable Bridge Inspection, Evaluation, and Maintenance Manual* (MBI), and AASHTO *Manual for Bridge Evaluation* (MBE) for inspecting structural components of movable bridges. Unlike fixed bridges, movable bridge structural elements (deck, superstructure, substructure, electrical and machinery supports) experience unique loadings during span motion, which may affect span balance and operating systems. Inspectors must observe global span operation, as distress in critical components is often most evident during movement.

Significant differences between as-built and as-inspected conditions may affect span balance and other operating systems.

Any conditions which are considered critical findings (CS4) should be immediately reported to the Bridge Inspection Engineer.

5.1.1 Structural Components Unique to Movable Bridges

- Machinery access ship ladders, walkways, and platforms
- Counterweight and counterweight pits
- Pier protection system and other waterway protective devices
- Operator's house
- Traffic signs and signalization
- Live load shoes and strike plates
- Span locks
- Trunnion support members for bascule bridges
- Towers for vertical-lift bridges

5.2 STRUCTURAL CONDITION RATING SYSTEM

The structural condition ratings largely follow the same process as fixed bridges. Reference the LADOTD *On-System Bridge Inspection Manual* and AASHTO *Manual for Bridge Element Inspection* for guidance on element level defects by material.

5.3 SUBSTRUCTURE

5.3.1 Piers, Abutments, Bents

See AASHTO MBI 2.8.1.1, AASHTO MBE 4.3.5.7.1, and AASHTO MBE 4.3.5.7.3.

An abutment is a retaining wall supporting the ends of a bridge, and in general, retaining or supporting the approach embankment.

A bent is a substructure unit used to support each end of a bridge span; also called a pier. It is made up of two or more columns or column-like members connected to their top most ends by a cap, strut or other member holding them in their correct positions. Typically, bents with one column are referred to as piers.

Figure 5-1: Bascule pier with a pier protection system.

The pier protection system is a major appurtenance of a movable bridge. It serves to protect the bridge structure and its machinery, as well as to facilitate marine vessel passage and minimize damage from potential allision.

The pier protection system should be inspected in a manner similar to that used for inspecting the main substructure elements, including an underwater inspection at the same frequency required for the underwater portions of the bridge structure, as stated by NBIS 23 CFR 650. The overall condition of the system will be coded in accordance with Item B.N.06 *Substructure Navigation Protection* of the SNBI.

Each of these items should be examined and typical sketches provided to show horizontal and vertical dimensions. Comparisons should be made to the "as-built" plans, if possible, to determine changes that may have occurred.

Figure 5-2: Swing bridge pivot pier with pier protection system

Routine Inspection for Pier, Abutment, and Bent:

- Inspect exposed abutment and wingwall surfaces for damage, deterioration, or overstress. The horizontal surfaces of the tops of abutments are particularly vulnerable to attacks from deicing salt effects, causing cracking, spalling, or discoloration.
- Check seismic restraint devices for corrosion, broken strands, missing fasteners, or improper adjustment. Verify no superstructure movement relative to abutments.
- Inspect steel partially encased in concrete at interfaces for corrosion or movement.
- Observe bascule bridge piers/bents during leaf opening for rocking or motion (report immediately).
- Assess abutments for rotation, shifting, or settlement via cracks, joint changes, bearing misalignment, or clearance variations. Re-evaluate post-earthquakes.
- Evaluate substructure for erosion, scour, or structural damage. Document exposed pile heights.
- Verify abutment drain and weep hole function. Note seepage indicating water accumulation.
- Inspect steel piers/bents for corrosion at joints, splices, rivets, and cable connections.
- Check bents and piers for lateral movement, tilt, or settlement post-high water, storms, or earthquakes. Observe under heavy loads.
- Note any material deposited against a bent or pier that was not provided for in the original design, as horizontal instability could result from such loads.
- Inspect timber piles for decay at groundline, waterline, or tidal zones, probing if needed. Examine steel/concrete piles for damage or corrosion, especially in splash zones or near concrete encasements.
- Examine steel and concrete piles throughout their length for physical damage, including in the splash zone and below the water surface, for corrosion and deterioration.
- Inspect all submerged steel piles at waterline (below waterline is for underwater inspection) for deterioration and loss of sections. Special attention should be given to exposed piles in or near salt water. Corrosion of exposed steel piles may be more active at the terminus of concrete encasements on partially encased structural steel members, at the waterline or tide affected zone, and at the mud line. Coastal streams may be brackish for several miles upstream due to tidal effects and are considered a potentially corrosive environment until confirmed otherwise.
- Observe pile caps under heavy loads to detect unusual movement or any excessive deflection. Steel and timber caps should be observed for any rotational movement resulting from eccentric connections. Bracing members must be checked to see that they are adequate, sound, and securely fastened.
- Evaluate pier foundations for structural damage and deterioration.
- Check the braces, bearings, and all housings for cracks, especially where stress risers are present.
- Check for cracks in areas where machinery bearing plates, anchor bolts, or braces are attached. Note the tightness of bolts and the tightness of other fastening devices. Loose anchorages can cause movement of machinery and result in misalignment and abnormal wear.
- Visually survey the spans, including towers, with a plumb bob and/or a spirit level to check both horizontal and vertical alignment. These measurements will help to identify any foundation

movements that may have occurred. Movement or settlement can cause machinery operational problems.
- Check for standing water in the counterweight pit.
- Check if the substructure interferes with full opening of the span. This can restrict the horizontal or vertical clearance in the navigational channel limits.
- Check for debris and water in the counterweight pockets which can add unwanted loads in the counterweight and create imbalances.

5.3.2 Foundation Scour

See FHWA *Evaluating Scour at Bridges* and AASHTO MBI 4.4.2.1.

Scour is the erosive action of flowing water on soil or other material of the waterway bed. The vulnerability of a movable bridge to scour damage should be evaluated on the basis of hydraulic, subsurface, and foundation conditions. The evaluation should include a hydraulic assessment and a foundation assessment.

Movable bridge piers, especially bascule counterweight pit piers and swing-span pivot piers, tend to be wider than common fixed bridges and can create unique scour conditions.

Routine Inspection for Foundation Scour:

- Use wading/probing in shallow, slow-moving water, or diving in aggressive hydraulic conditions.
- Check abutments/piers for scour-induced footing exposure or undermining. Note slope protection instability at spill-through abutments.
- Inspect any exposed piling in undermined areas to determine the number of exposed piles and their exposure heights. The inspector should measure and report the exposed length of pile. Pay particular attention to foundations on spread footings where scour or erosion is more critical than for foundations on piles. Measure and report exposed pile lengths.
- Record scour void volume and location, noting pile/foundation damage.
- Investigate bridge settlement if significant scour is detected.

5.4 SUPERSTRUCTURE

5.4.1 Overview

This section includes routine inspections of superstructure components. In addition to this manual, consult the BIRM, AASHTO MBE, and AASHTO MBI for comprehensive superstructure inspection techniques. Movable bridge superstructures are primarily comprised of steel elements.

5.4.2 Common Deficiencies

Common problems with movable bridge superstructure elements include:

- Corrosion
- Cracking
- Missing bolts or rivets
- Deteriorated coatings
- Deformation due to overload
- Collision damage
- Drainage
- Joints

5.4.3 Non-redundant Steel Tension Members (NSTMs)

NSTMs (formerly Fracture Critical Members) are tension-loaded steel members whose failure could cause partial or full bridge collapse (AASHTO MBE 4.2.3.4, 4.3.7.2). Examples can include 2 girder systems, floor beams, truss members, and anchor span cross girders. Inspection team leaders must be NSTM certified by completing the FHWA-NHI-130078 training.

Fatigue prone details on NSTM elements should be identified prior to inspection and given special attention during inspection. See AASHTO LRFD Table 6.6.1.2.3-1 for more information on identifying fatigue prone details.

See Section 4.4 of the LADOTD BIM for further information on inspecting and documenting NSTMs.

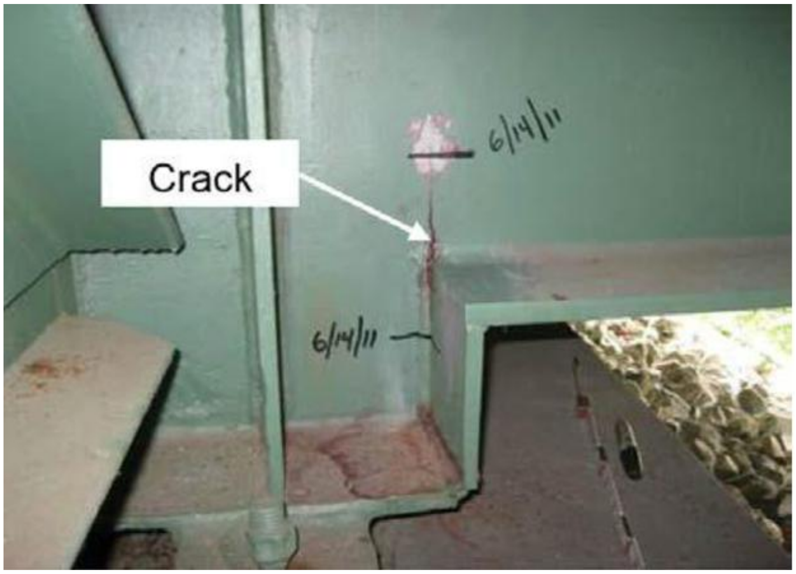

Figure 5-3: Crack in fatigue prone detail.

5.4.4 Bearings

Bearings transfer loads from superstructure to substructure while accommodating movement from temperature changes and applied loads. (AASHTO MBE 4.3.5.6.12; MBI 1.3.2.1).

Routine Inspection for Bearings:

- Verify bearing functionality, noting settlement effects.
- Check for binding or damage in bearings/shear keys on skewed bridges.
- Ensure expansion bearings move freely, are debris-free, and properly lubricated. Verify roller/rocker alignment and position relative to temperature.
- Inspect anchor bolts for corrosion, damage, and to see that nuts are secure. See that the anchor bolt nuts are properly set on expansion bearings to allow normal movement. Missing anchor nuts, sheared anchor bolts, or both should be identified and reported.
- Assess elastomeric pads for flattening, bulging, or splitting. Verify positioning.
- Sharply skewed and curved girder bridges have bearings that permit multi-rotation and adequate movement. Check the substructure in the vicinity of such bearings for possible distress.
- Examine bearings and note any instances of gaps, extruded or deformed elastomer, polyether urethane, or PTFE (polytetrafluorethylene), damaged seals or rings, or cracked steel.
- Observe bearings under heavy loads for rattles or unintended movement, identifying causes.

5.4.5 Towers

Vertical lift bridge towers (steel or concrete) support machinery, sheaves, and cables.

Routine Inspection for Towers:

- Apply standard steel or concrete inspection procedures.
- Observe towers during operation for unusual movement or sounds.

Figure 5-4: Vertical lift bridge with concrete towers supporting bridge machinery, sheaves, and lifting cables.

5.4.6 Rolling Lift Track Girders

Rolling lift bascule bridges use curved segmental girders supported by track girders (AASHTO MBI 2.8.2.11.1.1–2).

Routine Inspection for Rolling Lift Track Girders:

- Check segmental track castings and track girders for wear or cracking in angle fillets.
- Verify uniform contact between segmental and track girder tread plates during operation.
- Inspect for paint deterioration, corrosion, or section loss, especially in water/debris-prone areas.
- Check for cracks near welded stiffeners or floor beam connections.
- Assess bottom flanges for vessel impact damage.
- Inspect connectors for floor beams, sidewalk brackets, bracing, and counterweight girders.

Figure 5-5: Rolling lift track girders on bascule bridge.

5.4.7 Overhead Counterweight Frames/Trusses

Figure 5-6: Counterweight truss.

See AASHTO MBE 4.3.5.6.6.

Routine Inspection of Overhead Counterweight Frames/Trusses:

- Check alignment of trusses carefully for any sags that may indicate partial failure in joints or improper adjustments of the steel verticals or diagonals. Investigate any deviation from the normal alignment fully to determine its cause. Check each of the truss members and their connections.
- Examine steel compression members to see if they are straight with no kinks or bows. Also, check compression member connections; eccentricity in the connecting details has a major influence on the strength of the member and therefore warrants a close check.
- Identify NSTMs. Inspect all NSTMs closely in accordance with the provisions of AASHTO MBE 4.2.5.5 and 4.3.7
- Inspect gusset plate member connections closely in accordance with AASHTO MBE 4.3.5.6. Confirm gusset plate dimensions and connection details match those shown in the bridge record plans and shop drawings. Record any difference found. Field inspections of gusset plates need to focus on corrosion, distortion, and connections.

- Visual inspections may not detect or accurately quantify corrosion on gusset plates. Use of ultrasonic thickness gauges and calipers are recommended for determining any reduced thickness due to section loss. Out-of-plane distortion can be determined by the use of a straight edge. Check for individual broken or loose rivets or bolts. Inspect for slipped surfaces around the individual bolts and rivets and for any cracking in the gusset plate at bolt and rivet holes.
- Evaluate truss and bracing members for impact damage. Portal bracing usually is the most restrictive overhead clearance and consequently is the most susceptible to damage from over-height vehicles.
- Check all upper and lower lateral-bracing members for damage and observe if they are properly adjusted and functioning satisfactorily. In old bridges, an appraisal of the lateral and sway bracing should be made to determine its adequacy. This appraisal will normally be a judgement of the Engineer based on observation of transverse vibration or movement of the structure under traffic.
- Check the conditions of the pins at the connections and verify that the nuts and keys are in place. Also, verify that spacers on the pins are holding eyebars in their proper position. Nondestructive examination of the pins via ultrasonic inspection may be warranted to determine notching (wear) or cracking of the pin.
- Check rivets and bolts to verify none are loose, worn, or sheared.
- All reinforced concrete superstructures should be inspected for cracking. Carefully note the locations of the cracks and their sizes for future reference and comparison. An effort should be made to determine the probable cause of the cracking, such as shrinkage, overstress, settlement of substructure, or possible chemical action.

5.4.8 Counterweights Including Balance Block Pockets and Hatches

See AASHTO MBI 2.8.1.4.

Counterweight is a weight used to balance the weight of a movable member. Counterweights are used to balance a leaf or span so it rotates or lifts with minimum resistance.

Routine Inspection of Counterweights Including Balance Block Pockets and Hatches:

- Verify counterweights are sound and securely attached. Check temporary supports and bumpers.
- Inspect for deterioration, cracks, spalling, or material loss.
- Confirm availability of extra balance weights.
- Check steel members in concrete for corrosion or rust stains. On Strauss bascules, inspect counterweight struts for fatigue cracks near gusset connections when open.
- Ensure counterweight pits are free of water/debris and walls are crack/spall-free. Verify drain functionality.
- Confirm no contact between span/counterweight and other structures during motion.
- Consider cleaning and NDT for deteriorated members during in-depth inspections.

Figure 5-7: Counterweight pocket and balance blocks.

5.4.9 Links- such as those on Strauss bascules

Figure 5-8: Link on Strauss bascule bridge.

Routine Inspection of Links- such as those on Strauss bascules:

- Identify links in the inspection file or plans.
- Conduct hands-on arm's length inspections using visual/NDE techniques.
- Confirm suspected cracks with UT or dye penetrant, documenting size/length.
- Close bridge and follow critical findings procedures for cracks threatening stability.

5.4.10 Fasteners and Connections

AASHTO MBI 5.2.6 states, Fasteners are used to connect structural members; hold machinery elements and supports in place; secure ship ladders, walkways, and platforms; and provide anchorage for bearings. Fasteners come in different forms such as anchor bolts, turned bolts, and rivets. They may stretch from overloads or work loose from vibration or shrinkage of timber members.

Routine Inspection of Fasteners and Connections:

- Check for loose fasteners and connections and broken, sheared, or missing fasteners, or fasteners found with greater than 20 percent section loss. Check for and report missing coatings on replacement fasteners.

5.4.11 Protective Coating Systems

Coatings (e.g., galvanizing, weathering steel, paint) protect steel from corrosion.

Routine Inspection of Protective Coating Systems:

- Check coating failures visually and assign condition state.
- Specialized coating inspectors may be required for detailed testing.

5.5 DECK

5.5.1 Deck Types

Movable bridge decks, primarily open steel grid, support vehicular/pedestrian traffic (AASHTO MBI 2.8.1.2, 5.2.11).

Steel Grid Decks

Types include welded grid, riveted grate, concrete-filled, and exodermic decks. Common issues include weld cracking, rivet/bolt shear, debris accumulation, and vehicle damage. See the figure below.

Routine Inspection of Steel Grid Decks:

- Verify structural weld integrity. Listen for popping/rubbing under live loads, indicating broken welds.
- Assess skid resistance, reporting worn studs/notches. Check roadway evenness and joint clearance.
- For closed grid decks, inspect for corrosion in embedded elements, delamination, or fractured welds.
- Examine riveted grids for loose/broken rivets, replacing deteriorated sections as needed.
- Examine the concrete fill-wearing surface for spalling or scaling, which exposes the grid. Where grid is visible, check for evidence of water ponding.
- Check the underside of the filled grid for evidence of water leakage and corrosion of grid elements.
- Check for adequate drainage along the gutter lines. Ensure that there is no evidence of ponding water and roadway debris.

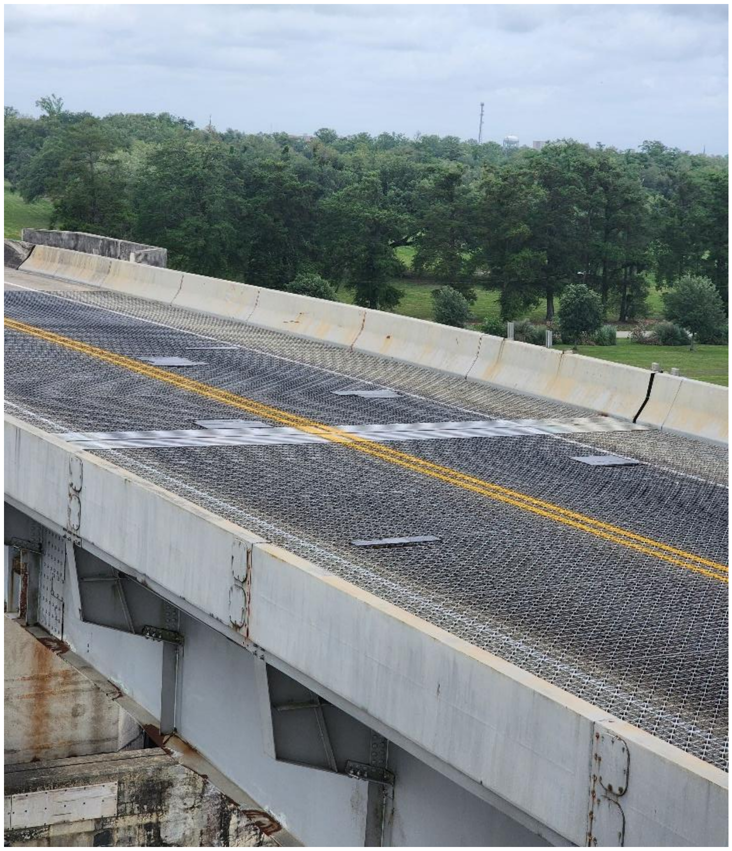

Figure 5-9: Grid deck on bascule bridge with multiple repairs to deck using cover plates.

Other Decks

Other deck types have been utilized on movable bridges including steel orthotropic decks (utilizing concrete or asphalt inlays/overlays), aluminum decks, and fiber reinforced polymer (FRP) decks.

The most common problems with these decks are in debonding of the inlay/overlay, and the development of fatigue cracks in the web elements or connecting welds. Sections can also be damaged by vehicles dropping or dragging items.

Routine Inspection of Other Decks:

- Inspect welds and connections for cracking or looseness.
- Listen for popping/rubbing under live loads.
- Evaluate wearing surface condition.

5.5.2 Bridge Barrier/Railing

Movable bridge railings are typically lightweight hollow steel barriers.

Routine Inspection of Bridge Barrier/Railing:

- Assess structural condition, geometry, and capacity per Bridge Owner and NBI Item 36 requirements.
- Check connections for loose or missing fasteners, cracked welds, fatigue cracks, or other deficiencies.
- Inspect collision damage and deterioration of the various elements, along with post bases for any loss of anchorage hardware. Railing should be smooth and continuous.
- Check for collision damage and gouges.
- Observe the bridge railing during bridge operation and check for any rubbing or unintended contact at the end joints where the steel barrier meets the concrete barrier.
- Check for adequate drainage along the gutter lines. Ensure that there is no evidence of ponding water and roadway debris.

Figure 5-10: Bridge railing transition from concrete to steel

5.5.3 Sidewalks/Bicycle Paths

Movable bridge sidewalks/bicycle paths are primarily comprised of steel grid deck or steel tread plate.

Routine Inspection of Sidewalks/Bicycle Paths:

- Inspect curbline barriers for evidence of impact damage or rotation. Record areas of collision damage or movement.
- Inspect the sidewalk area for structural defects and pedestrian safety items such as tripping hazards or ponding of water or ice. The walking surface should not be slippery in wet weather. Make note of uneven floor breaks and tripping hazard for pedestrians. Check for wide joints that could can cause a loss of control for bicyclists.
- Examine the type, condition, and alignment of the curbs. Check curbs to see they are properly anchored.

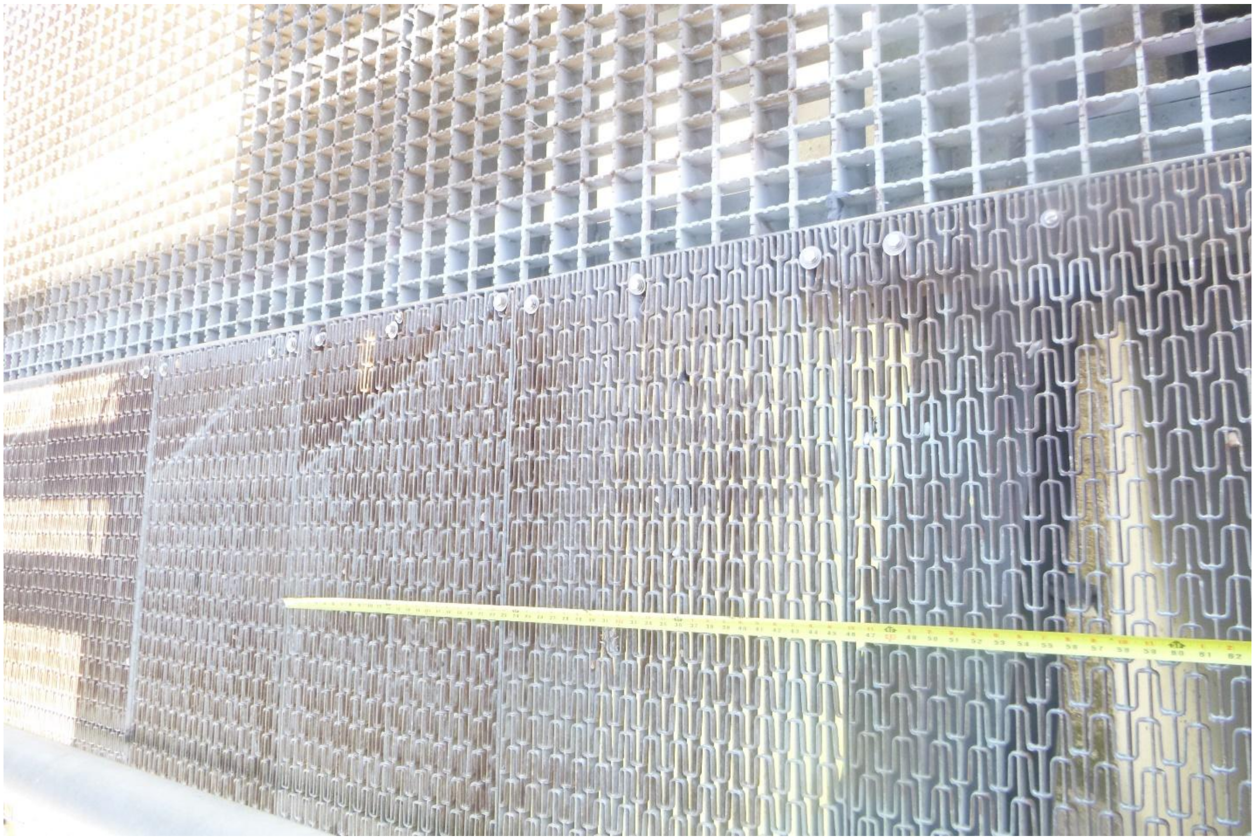

Figure 5-11: Sidewalk on movable bridge comprised of closer spacing open steel grid that is pedestrian and bicyclist friendly.

5.5.4 Ship Ladders, Walkways, and Platforms

Ship ladders, walkways, and platforms are used to provide access to the bridge machinery and structure (AASHTO MBI 2.8.1.3).

Routine and In-Depth Inspection of Ship Ladders, Walkways, and Platforms:

- Inspect connections for loose or missing fasteners, cracked welds, fatigue cracks, or other deficiencies.
- Check stair treads and walkway surfaces for adequate connection to supports.
- Examine bridge structural components supporting ship ladders and/or walkways for evidence of distress or deterioration.
- Ensure roadway/sidewalk hatches are functional and deterioration-free.

5.6 ANCILLARY STRUCTURES

5.6.1 Signage and Lighting

Signs, lights, and signals warn traffic of bridge operations (AASHTO MBI 2.8.1.7, 4.6; MBE 4.3.5.13).

Figure 5-12: Example of broken warning lights and sign.

Routine Inspection of Signage and Lighting:

- Verify signage placement, legibility, and condition, including advance warning signs.
- Photograph load posting signs in accordance with the BIM every inspection.
- Observe devices during operation, checking supports/connections for movement or defects.
- Ensure compliance with AASHTO MBE, MUTCD, and height/weight restriction postings. Note changes, either suspected or confirmed, to either weight or height posting values.
- Inspect sign-framing connections, especially epoxy anchors, for movement or fatigue.
- Confirm navigational signs/lights meet USCG regulations and function correctly.

Figure 5-13: Signage attached to hydraulic swing bridge.

5.6.2 Vehicular Resistance Barriers and Gates

Traffic gates warn motorists, while resistance barriers provide a positive means of stopping a vehicle (AASHTO MBI 2.8.1.7.1).

Routine Inspection of Vehicular Resistance Barries and Gates:

- Observe the traffic gates and resistance barriers during a complete operation cycle. Check structural supports and connections for movement during operation. Check connections between the structural support and its foundation structure for loose or missing fasteners, cracked welds, fatigue cracks, settlement, displacement, or other defects.
- Check members of the structural supports in accordance with the current criteria for the inspection of bridges listed in accordance with AASHTO MBE, MUTCD regulations, and NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features.*
- Perform clearance measurements of the resistance barrier in the lowered position to confirm compliance with MUTCD *Traffic Control for Movable Bridges* and perform clearance measurements in the raised position to confirm the required roadway clearance is adequate.

Figure 5-14: Traffic gate arm lowered.

Figure 5-15: Traffic barrier.

5.7 CHANNEL AND CHANNEL PROTECTION

5.7.1 Channel

See MBE 4.3.5.8 and LADOTD *Bridge Inspection Manual* for monitoring scour and plans of action. The Channel Condition Rating should be coded in accordance with Item B.C.09-Channel Condition Rating in the SNBI.

Routine Inspection of Channel:

- Check channel edges for erosion and slope stability. Note swirling currents near banks.

5.7.2 Channel Protection Devices

Channel protection devices are used to prevent erosion and scour of channel banks. Examples of these devices include concrete riprap, sheet pile walls, concrete revetment, and timber lagging. The Channel Protection Condition Rating should be coded in accordance with Item B.C.10-Channel Protection Condition Rating in the SNBI. This should only be coded if the devices extend beyond the bridge limits.

Routine Inspection of Channel Protection Devices:

- Inspect steel components for corrosion, especially in splash zones, and check for impact damage.
- Examine timber for decay, insect/marine damage, or abrasion. Verify cable/bolt condition.
- Check concrete members for spalling, cracking, corrosion of the reinforcing steel, and damage from abrasion or collisions. For concrete surfaces that have a protective treatment, indicate the condition of the treatment and the need for patching or replacement.

Chapter 6
Operator House

6.1 OVERVIEW

Figure 6-1: Operator house.

The operator house provides shelter and a location for the bridge controls for the bridge operator. The operator's house should be regularly maintained to provide a safe and comfortable environment for the bridge tender. Most tender houses are constructed of reinforced concrete walls and floors, impact resistance doors and windows, roof system, HVAC system, and plumbing fixtures. Electrical components located in the operator house such as bridge controls, CCTV, and lighting are outlined in the electrical section of this report.

6.2 HVAC

Routine Inspection of HVAC:

- Check the air temperature of HVAC registers and look for evidence of refrigerant or condensate leaks.
    - Exercise split system AC and temperature settings.
    - Confirm operation of thermostat/humidistats within range.
    - Report on cleanliness or replace filters.
- Check Back-Up Emergency Generator interface with building dampers and louvers.
    - Verify proper operation including interlocks with vent fans, firestats, smoke detectors, and safety cut-off switches.

6.3 PLUMBING

Routine Inspection of Plumbing:

- Check plumbing fixtures.
    - Lavatory and service sink faucets.
    - Toilet operation and flow.
    - Sanitary DWV Plumbing & Water Service piping supports and coupling corrosion or leaking.
    - Test output temperature of hot water heater.
    - Test all shut-off isolation valves.
    - Test quality of domestic water.

6.4 ARCHITECTURAL

6.4.1 Access (Doors, Stairs, Ladders, Platforms)

Routine Inspection of Access (Doors, Stairs, Ladders, Platforms):

- Check physical elements along Bridge Maintainer's Accessible Route including walking surfaces, guarding devices, railings and access gates for signs of deterioration, misalignment, or functionality.
- Report on ladder rungs and rails and any fall protection devices.
- Check ease of operation of overhead doors.
- Check functionality of fire rated and exterior door closures, adjustable operating speed final engagement.

6.4.2 Roof

Routine Inspection of Roofs:

- Access roof level and inspect roofing system components, gutters or roof drains, fascia and soffit flashing for evidence of delamination, damage, or corrosion.
- Inspect interior ceilings for any signs of water intrusion.

6.4.3 Building (Walls, Floors)

Routine Inspection of Buildings (Walls, Floors):

- Check the interior and exterior of the house for cracks, decay, marine and plant growth, signs of insects/rodents, termites, or other defects.
- Check perimeter seals around windows and doors for water intrusion.
- Check window sash operation/fixed window glazing and impact glazing visibility.
- Check condition of window shade treatment/window insect screening.
- Check on fixed and operable louvers. Check operation of exhaust fan and back-draft damper.
- Report condition of operable window treatments.
- Check exterior walls, windows, and doors for potential corrosion damage to finish or functionality of security hardware functions.
- Check the condition of restroom accessories such as, mirrors, toilet tissue dispensers, paper towel dispensers, soap dispensers, etc.
- Check operation of Fire Alarm Control Panel Fire Alarm system.
- Check for proper installation and function of smoke alarms, fire extinguishers, and firefighting systems; and function and visibility of control systems as required by current federal, state, and local regulations.
- Check intrusion alarm function.
- Check floor finishes for wear and stair nosing's and handrails for strength and security.
- Check ground fault circuit operation trips. Check ground fault circuit interrupter (GFCI) outlet trips by pressing TEST button and pushing RESET button to restore power to GFCI.
- Check bridge machinery controls are adequately secured and supported.
- Report items that clutter or restrict the bridge operator, maintenance personnel, or inspection access to be removed.

6.4.4 Desks, Chairs, Appliances (Refrigerators/Microwaves)

Routine Inspection of Desks, Chairs, Appliances (Refrigerator/Microwave):

- Check and report on condition of kitchenette appliances and built in cabinetry.
- Report on any wear-and-tear of typical office furnishings.

6.4.5 Operator Accessibility and Visibility

The operator's house should be located to permit the operator an uninterrupted view of the navigation channel and approach roadways during all phases of the movable bridge cycle. The house should provide adequate protection for the bridge operator and controls from the environment, traffic, and other detrimental forces. Existing operator's houses that do not have a clear view should be reported for possible corrective action, such as installation of additional windows, closed circuit television, etc. in a deficiency report. The operator's house should have a clear visibility of the waterway and roadway.

Routine Inspection of Operator Accessibility and Visibility:

- Report on window cleaning ease of access, any issues with controls and maintenance frequency.
- Confirm manufacturer's cleaning instructions are prevalently displayed especially where polycarbonate or window films are used.
- Check that emergency numbers and the standard operating procedures for the bridge are clearly posted near the control desk.
- Check that the bridge operator is following SOPs during an opening.

Figure 6-2: Window visibility from operator control panel.

Appendices

APPENDIX A: AGENCY DEFINED ELEMENTS

MOVABLE BRIDGE ELEMENTS (ADEs)			
El. No.	Element Name	Description	Units
840	Open Gearing	Defines all gears that are not enclosed in an oil tight, dust tight housing. Includes the rack or rack pinion. (Each gear and pinion set count as one unit)	Each
841	Speed Reducers	Defines gear sets that are mounted with shafts and bearings in dust proof, oil tight housing.	Each
842	Shafts	Defines the shafts that serve to transmit torque from one part to another.	Each
843	Shaft Bearings and Shaft Couplings	Defines the members that support the shafts or joins shafts together.	Each
844	Brakes	Defines the members including limit switches that are used to stop the span and hold the span in the open/closed positions.	Each
845	Emergency Drive and Back-Up Power Systems	Defines those members that function as a back-up drive and power system in case of failure of the main drive and/or power system.	Each
847	Hydraulic Power Units	Defines the pump, electric motor, valves, filters, oil reservoir, and accessories that make up the Hydraulic Power Unit. Any limit switches which assist in controlling the units are incidental to this item.	Each
848	Hydraulic Piping System	Defines the pipe, tubing, and flexible hose including fittings, manifolds, and piping supports which conduct fluids for a fluid power system.	Each
849	Hydraulic Cylinders /Motors/Rotary Actuators	Defines those components which convert fluid pressure into mechanical force and motion. Any limit switches that assist in controlling this element are incidental to this item.	Each
850	Machinery Base	Defines the independent frame/support that holds the machinery.	Each
860	Span Locks/Toe Locks/Heel Stops/Tail Locks	Defines all locks and motors used to drive the locks present on the structure. Limit switches which control the movement of the locks are incidental to this item.	Each
861	Live Load Shoes /Wedges/Strike Plates/Buffer Cylinders	Defines those elements used to transmit live load from the movable span to the substructure, or to cushion the span while it is being closed.	Each
862	Counterweight Support	Defines the structural steel elements used to support the counterweight and attachments.	Each
863	Counterweight	Defines the counterweight and includes any balance blocks.	Each
864	Access Ladder and Platforms	Defines the members that make up the access ladder and platforms. Each access ladder and platform is counted as one item.	Each
865	Trunnion-Straight/Curved Rack	Defines the trunnions about which the leaf of a bascule bridge rotates, the curved rack mounted on the leaf, and straight rack mounted on the pier for a rolling bascule. Trunnion journals and bearings are incidental to this item.	Each
870	Transformers and Thyristors	Defines the members that step down the voltage of the incoming power to a level compatible with the bridge equipment.	Each
871	Submarine Cable	Defines the cable that is used to carry power and control signals from one pier to the other pier on a bridge.	Each
872	Conduit and Junction Boxes	Defines those members which enclose, support, and protect the power and control wiring. The quantity for this element will only be "1" for the entire bridge.	Each

873	Programmable Logic Controllers	Defines the general-purpose industrial microprocessor-based control systems.	Each
874	Control Console	Defines the console which controls the operation of the movable bridge. This element includes interlocks, span limit switches, and span position indicator devices.	Each
880	Cables - Vertical Lift	Defines only those steel cables on a vertical lift bridge.	Each
881	Bridge Specific Equipment (Lift)	Defines those components found on Lift Bridges but not found on other types of movable bridges such as sheaves, span guides, counterbalance chains, etc. The quantity for this element will be one (1) for each item.	Each
882	Bridge Specific Equipment (Swing)	Defines those components found on Swing Bridges but not found on other types of movable bridges such as balance wheels, tracks, etc. The quantity for this element will be one (1) for each item.	Each
883	Bridge Specific Equipment (Pontoon)	Defines those components found on Pontoon Bridges but not found on other types of movable bridges such as Pontoons, sheaves, open/close cables, winches, etc. The quantity for this element will be one (1) for each item.	Each
884	Bridge Specific Equipment (Bascule)	Defines those components found on Bascule Bridges but not found on other types of movable bridges such as Trunnions, etc. The quantity for this element will be one (1) for each item.	Each
885	Barriers - Movable Bridges	Defines the components that provides a physical barrier to vehicles while the bridge is in the open position and all equipment required to operate the barrier. All limit switches required to operate the barrier are incidental to this item.	Each
886	Traffic Warning Gates - Movable Bridges	Defines the components that alert vehicular traffic to impending bridge operation. This element includes all equipment required to operate the traffic gate. Limit switches that control the operation of the traffic gate are incidental to this item.	Each
890	Traffic Signals	Defines the components that signals vehicular traffic when to stop and start.	Each
891	Navigational Light System	Defines the lights for navigation mounted on the bridge or fender system. This is not limited to lights on movable bridges. This element includes clearance gauge lights and power system. Inspection should include the back-up power system.	Each
892	Fender System/Pier Protection	Defines those wood, steel, or concrete fender systems and/or pier protection systems in or around the bridge elements.	Each

APPENDIX B: MOVABLE BRIDGE ELEMENT GUIDE

840 Open Gearing

Element Number	Description	Unit
840	This element defines all gears that are not enclosed in an oil tight, dust tight housing. This element includes the rack or rack pinion. (Each gear and pinion set count as one unit.)	Each

Condition	Description	Feasible Action
1	Gears are properly aligned and lubricated; minimal wear or corrosion is present.	0 - Do Nothing
2	Minor misalignment, gear teeth pitting, wear, or corrosion is measurable, but operation of drive system not impacted.	0 - Do Nothing 1 - Realign
3	Major misalignment, gear teeth pitting, wear, or corrosion is extensive, operation of drive system may be affected. There may be minor cracking in the casting requiring structural review.	0 - Do Nothing 1 - Realign 2 - Replace Member
4	Major misalignment, gear teeth fractures may be present, operation of drive system threatened.	0 - Notify District Bridge Engineer 1 - Realign 2 - Replace Member

841 Speed Reducers

Element Number	Description	Unit
841	This element defines gear sets that are mounted with shafts and bearings in dust proof, oil tight housings.	Each

Condition	Description	Feasible Action
1	Gears are properly operating, and lubricant level is okay.	0 - Do Nothing
2	Minor backlash or teeth wear has caused minimum noise in the gears. Case cracks have occurred above oil level. Oil has been contaminated.	0 - Do Nothing 1 - Repair Cracks 2 - Replace Member 3 - Replace Oil 4 - Adjust Span Setup (Speed or Balance)
3	Moderate backlash or teeth wear has caused moderate noise in the gears. Case cracks have occurred at or above oil level. Oil has been contaminated.	0 - Do Nothing 1 - Repair Cracks 2 - Replace Member 3 - Replace Oil 4 - Adjust Span Setup (Speed or Balance)
4	Major backlash or teeth wear has caused major noise in the gears. Case cracks occurred below oil level.	0 - Notify District Bridge Engineer 1 - Repair Cracks 2 - Replace Member 3 - Adjust Span Setup (Speed or Balance)

842 Shafts

Element Number	Description	Unit
842	This element defines the shafts that serve to transmit torque from one part to another.	Each

Condition	Description	Feasible Action
1	Shafts/couplings are properly aligned, bearings are properly lubricated, shaft clearance at bearings is appropriate, and no cracks or corrosion are present.	0 - Do Nothing
2	Shafts are not properly aligned, bearings are not lubricated, or shaft clearance at bearings is not uniform. Minor corrosion may be present. Seals and gaskets show evidence of minor leaking.	0 - Do Nothing 1 - Lubricate Bearing
3	Measurable section loss is present. Minor cracks are evident in shaft or bearing supports. Seals and gaskets are not working. Shafts/couplings are not properly aligned.	0 - Do Nothing 1 - Lubricate Bearing 2 - Replace Seals & Gaskets 3 - Align Shafts
4	Significant section loss or major cracking threaten operation of bridge. Shafts/couplings are not properly aligned.	0 - Notify District Bridge Engineer 1 - Replace Member

843 Shaft Bearings and Shaft Couplings

Element Number	Description	Unit
843	This element defines the members that support the shafts or join shafts together.	Each

Condition	Description	Feasible Action
1	Couplings are properly aligned; bearings are properly lubricated; shaft clearance at bearings is appropriate, and no cracks or corrosion are present.	0 - Do Nothing
2	Couplings are not properly aligned, bearings are not lubricated; and shaft clearance at bearings is not uniform. Minor corrosion may be present. Seals and gaskets show evidence of minor leaking.	0 - Do Nothing 1 - Lubricate Bearing
3	Measurable section loss is present. Minor cracks are evident in shaft or bearing supports. Seals and gaskets are not working. Minor slack is evident in coupling.	0 - Do Nothing 1 - Lubricate Bearing 2 - Replace Seals & Gaskets 3 - Align Shafts
4	Significant section loss or major cracking threaten operation of bridge. Major slack is evident in coupling	0 - Notify District Bridge Engineer 1 - Replace Member

844 Brakes

Element Number	Description	Unit
844	This element defines the members including limit switches that are used to stop the span and hold the span in the open/closed positions.	Each

Condition	Description	Feasible Action
1	Clearances are normal, shoes do not show abnormal wear; shoes are clean; no oil or grease is present on shoes; and shoes do not have a glazed appearance. Brake wheel surface is clean and smooth. Brakes operate correctly. Moving parts are properly lubricated.	0 - Do Nothing
2	Brakes are operating properly; moving parts may need lubricating; oil may need to be changed, and minor corrosion or shoe wear may be evident.	0 - Do Nothing 1 - Lubricate and Fill Hydraulic Fluid
3	Brake operation needs improvement; measurable corrosion may be present; and moving parts may be sticking. Excessive shoe wear is evident.	0 - Do Nothing 1 - Lubricate and Fill Hydraulic Fluid 2 - Replace Shoes
4	Brakes are not functioning and require replacement.	0 - Notify District Bridge Engineer 1 - Replace Shoes 2 - Replace Member

845 Emergency Drive and Back Up Power System

Element Number	Description	Unit
845	This element defines those members that function as a back-up drive and power system in case of failure of the main drive and/or power system.	Each

Condition	Description	Feasible Action
1	System is operating properly.	0 - Do Nothing
2	System needs servicing.	0 - Do Nothing 1 - Service Member
3	System needs repair.	0 - Do Nothing 1 - Repair Member
4	System needs replacement.	0 - Notify District Bridge Engineer 1 - Replace Member

847 Hydraulic Power Units

Element Number	Description	Unit
847	This element defines the pump, electric motor, valves, filters, oil reservoir, and accessories that make up the Hydraulic Power Unit. Any limit switches, which assist in controlling the Hydraulic Power Units, are incidental to this element.	Each

Condition	Description	Feasible Action
1	All components are clean, no leakage is present, and there is no build-up of dirt and debris. Fluid level in the reservoir is within the prescribed limits. Fluid conductors are free of abrasion, flattening, or kinking. Gauge readings are within prescribed limits. Filters are clean. Hydraulic Power Unit is operating properly.	0 - Do Nothing
2	Hydraulic Power Unit is operating properly, but there is need for maintenance or servicing. There may be minor leakage of hydraulic fluid.	0 - Do Nothing 1 - Replace Fluids 2 - Repair Member
3	Hydraulic Power Unit is not operating properly; there is evidence that repairs may be needed. There may be moderate leakage of hydraulic fluid.	0 - Do Nothing 1 - Replace Fluids 2 - Repair Member
4	Hydraulic Power Unit is not operating or is operating poorly. Replacement of all or part of the Hydraulic Power Unit may be required.	0 - Notify District Bridge Engineer 1 - Replace Fluids 2 - Repair Member

848 Hydraulic Piping System

Element Number	Description	Unit
848	This element defines the pipe, tubing, and flexible hose including fittings, manifolds, and piping supports, which conduct fluids for a fluid power system.	Each

Condition	Description	Feasible Action
1	Piping system is clean and shows no sign of leakage. Flexible hose is properly installed and aligned. Pipe, tubing and hoses are free of damage, corrosion, and abrasion.	0 - Do Nothing
2	Minor deterioration or corrosion present. There may be minor leakage of hydraulic fluid present. Maintenance may be required.	0 - Do Nothing 1 - Repair Member, Refill Fluids
3	Moderate deterioration or corrosion present. There may be minor to moderate leakage of hydraulic fluid present. Maintenance is required.	0 - Do Nothing 1 - Repair Member, Refill Fluids
4	There is significant leakage present. Repair or replacement required.	0 - Notify District Bridge Engineer 1 - Repair Member, Refill Fluids 2 - Replace Member

849 Hydraulic Cylinders/Motors/Rotary Actuators

Element Number	Description	Unit
849	This element defines those components, which convert fluid pressure into mechanical force and motion. Any limit switches that assist in controlling this element are incidental to this element.	Each

Condition	Description	Feasible Action
1	Units are clean and no signs of excess leakage are present. Cylinder rods are not scored. Cylinder rod boots are connected and not damaged. Cylinder rods operate smoothly and freely. Bushings are not worn and are lubricated.	0 - Do Nothing
2	Units are operating properly, but there is need for maintenance or servicing. There may be minor leakage of hydraulic fluid. Unit anchors are loosening or wearing. Cylinder rod boots loose or damaged.	0 - Do Nothing 1 - Repair Member, Refill Fluids 2 - Service Member
3	Units are not operating properly; there is evidence that repairs may be needed. There may be moderate leakage of hydraulic fluid. Unit anchors are missing/unattached. Cylinder rod boots missing.	0 - Do Nothing 1 - Repair Member, Refill Fluids 2 - Service Member
4	Units are not operating or are operating poorly. Replacement may be required.	0 - Notify District Bridge Engineer 1 - Repair Member, Refill Fluids 2 - Replace Member

850 Machinery Base

Element Number	Description	Unit
850	This element defines the independent frame/support that holds the machinery.	Each

Condition	Description	Feasible Action
1	There is no evidence of active corrosion, and the paint system is sound and functioning as intended to protect the metal surface. Repairs are sound.	0 - Do Nothing
2	Paint system is showing signs of deterioration. Surface corrosion has or is forming. There may be exposed metal, but there is no active corrosion, which is causing loss of section. Unit anchors are loosening or wearing.	0 - Do Nothing 1 - Clean and Recoat 2 - Reattach Member
3	Corrosion may be present, but any section loss due to active corrosion does not yet warrant structural review. Movement of clevis pins may exceed desirable limits. Limited cracking may be present. Unit anchors are missing or unattached.	0 - Do Nothing 1 - Clean and Recoat 2 - Reattach Member 3 - Replace Member
4	Corrosion has caused section loss and is sufficient to warrant structural review to ascertain the impact on the ultimate strength and/or serviceability of the element. Movement of clevis pins may be excessive. Severe cracking may exist.	0 - Notify District Bridge Engineer 1 - Replace Member

860 Span Locks/Toe Locks/Heel Stops/Tail Locks

Element Number	Description	Unit
860	This element defines all locks and motors used to drive the locks present on the structure. Limit switches, which control the movement of the locks, are incidental to this item.	Each

Condition	Description	Feasible Action
1	Locks are operating properly, there are no signs of deterioration, wear, or distress. Clearances may not be within specifications.	0 - Do Nothing
2	Locks are operating properly; there are signs of limited deterioration or wear and clearances may not be within specifications. Lubrication may be needed. Maintenance may be required.	0 - Do Nothing 1 - Lubricate
3	Locks are not operating properly, there are signs of significant deterioration or wear, and clearances may not be within specifications. Repair may be required.	0 - Do Nothing 1 - Lubricate 2 - Reset Locks and Catches
4	Locks are not operating or are operating poorly. There is excessive deterioration or wear. Replacement may be required.	0 - Notify District Bridge Engineer 1 - Reset Locks and Catches 2 - Replace Member

861 Live Load Shoes/Wedges/Strike Plates/Buffer Cylinders

Element Number	Description	Unit
861	This item defines those elements used to transmit live load from the movable span to the substructure, or to cushion the span while it is being closed.	Each

Condition	Description	Feasible Action
1	This element shows little or no deterioration. If a paint system is present, it is sound and functioning as intended to protect the metal. There is minimal corrosion. Vertical and horizontal alignments are within limits. Buffer is operating effectively.	0 - Do Nothing
2	The paint system, if present, may show minor to moderate corrosion with minimal pitting but still functioning as intended. The strike plate may have moved enough to cause minor cracking in the supporting concrete. Alignment of the live load shoe and strike plate is still within limits. Buffer may have lost some of its effectiveness. Shim plates may be loose.	0 - Do Nothing 1 - Clean and Coat
3	The paint system, if present, may show moderate to heavy corrosion with some pitting but still functioning as intended. The strike plate may have moved enough to cause moderate cracking in the supporting concrete. Alignment of the live load shoe and strike plate is still tolerable. There may be no contact with the live load shoe. Buffer has lost most of its effectiveness. Shim plates are loose or missing. Oiler may be empty, and buffer rod is beginning to corrode.	0 - Do Nothing 1 - Clean and Coat 2 - Lubricate
4	Advanced corrosion with section loss. There may be loss of section of the supporting member sufficient to warrant supplemental supports or load restrictions. Misalignment has occurred. Oiler may be empty, and buffer rod is frozen. Bridge is not seated fully or is seating too hard.	0 - Notify District Bridge Engineer 1 - Clean and Coat 2 - Realign Span 3 - Replace Member

862 Counterweight Support

Element Number	Description	Unit
862	This element defines the structural steel elements used to support the counterweight and attachments.	Each

Condition	Description	Feasible Action
1	There is no evidence of active corrosion, and the paint system is sound and functioning as intended to protect the metal surface.	0 - Do Nothing
2	There is little or no active corrosion. Surface corrosion has formed or is forming. The paint system may be chalking, peeling, curling, or showing other early evidence of paint system distress, but there is no exposure of metal.	0 - Do Nothing 1 - Clean and Coat
3	Surface corrosion is prevalent. There may be exposed metal with active corrosion but any section loss due to corrosion does not yet warrant structural review.	0 - Do Nothing 1 - Clean and Coat 2 - Rehab Member
4	Corrosion has caused section loss and is sufficient to warrant structural review to ascertain the impact on the ultimate strength and/or serviceability of the element.	0 - Notify District Bridge Engineer 1 - Rehab Member 2 - Replace Member

863 Counterweight

Element Number	Description	Unit
863	This element defines the counterweight, and includes any balance blocks.	Each

Condition	Description	Feasible Action
1	The element shows little or no deterioration. There may be discoloration, efflorescence, and/or superficial cracking, but without effect on strength and/or serviceability.	0 - Do Nothing
2	Minor cracks and spalls may be present, but there is no exposed reinforcing or surface evidence or rebar corrosion.	0 - Do Nothing 1 - Clean Rebar; Patch/Seal
3	Some delaminations and/or spalls may be present and some reinforcing may be exposed. Corrosion of rebar may be present, but loss of section is incidental and does not significantly affect the strength and/or serviceability of either the element or the bridge.	0 - Do Nothing 1 - Clean Rebar; Patch/Seal 2 - Rehab Member
4	Deterioration is advanced. Corrosion of reinforcement and/or loss of concrete section is sufficient to warrant review to ascertain the effect on the strength and/or serviceability of either the element or the bridge.	0 - Notify District Bridge Engineer 1 - Clean Rebar; Patch/Seal 2 - Rehab Member 3 - Replace Member

864 Access Ladder and Platforms

Element Number	Description	Unit
864	This element defines the members that make up the access ladder and platforms. Each access ladder and platform is counted as one item.	Each

Condition	Description	Feasible Action
1	There is no evidence of active corrosion, and the paint system is sound and functioning as intended to protect the metal surface.	0 - Do Nothing
2	There is little or no active corrosion. Surface corrosion has formed or is forming. The paint system may be chalking, peeling, curling, or showing other early evidence of paint system distress, but there is no exposure of metal.	0 - Do Nothing 1 - Clean and Coat
3	Surface corrosion is prevalent. There may be exposed metal, but there is no active corrosion, which is causing loss of section.	0 - Do Nothing 1 - Clean and Coat 2 - Rehab Member
4	Corrosion has caused section loss and is sufficient to warrant structural review to ascertain the effect on the ultimate strength and/or serviceability of the element. Attachment anchors may be loose, cracked, or missing.	0 - Notify District Bridge Engineer 1 - Rehab Member 2 - Replace Member

865 Trunnion-Straight/Curved Rack

Element Number	Description	Unit
865	This element defines the trunnions about which the leaf of a bascule bridge rotates, the curved rack mounted on the leaf and straight rack mounted on the pier for a rolling bascule. Trunnion journals and bearings are incidental.	Each

Condition	Description	Feasible Action
1	Minimal wear or corrosion is present, alignment and lubrication is good.	0 - Do Nothing
2	Minor misalignment has occurred; lubrication may be needed; teeth wear or corrosion is measurable, but operation is not affected.	0 - Do Nothing 1 - Lubricate
3	Major misalignment has occurred; wear or corrosion is extensive; operation of drive system may be affected.	0 - Do Nothing 1 - Lubricate 2 - Realign
4	Major misalignment has occurred; teeth fractures may be present; operation of drive system is threatened.	0 - Notify District Bridge Engineer 1 - Lubricate 2 - Realign 3 - Replace Member

870 Transformers and Thyristors

Element Number	Description	Unit
870	This element defines the members that step down the voltage of the incoming power to a level compatible with the bridge equipment.	Each

Condition	Description	Feasible Action
1	There are no signs of corrosion, oil leakage, or any deteriorated condition at the transformer. There are no blown fuses at the transformer.	0 - Do Nothing
2	There are minor signs of corrosion and/or oil leakage.	0 - Do Nothing 1 - Clean and Coat
3	There are moderate signs of corrosion and/or oil leakage.	0 - Do Nothing 1 - Clean and Coat 2 - Rehab Member
4	There are major signs of corrosion and/or oil leakage. A fuse at the transformer may be blown.	0 - Notify District Bridge Engineer 1 - Rehab Member 2 - Replace Member

871 Submarine Cable

Element Number	Description	Unit
871	This element defines the cable that is used to carry power and control signals from one pier to the other pier on a bridge.	Each

Condition	Description	Feasible Action
1	The cable is firmly attached to the pier wall and protected. There is no chafing of the outer protective coating. Cable is properly grounded.	0 - Do Nothing
2	The cable has some loose attachments to the pier wall. There is chafing of the outer protective coating.	0 - Do Nothing 1 - Replace Member
3	The cable is not firmly attached to the pier wall. There is moderate deterioration of the outer protective coating. Cable is not properly grounded.	0 - Do Nothing 1 - Replace Member
4	There is significant deterioration to the outer protective coating, or the cable is not functioning properly. Minimal spare wires are available; cable may need replacing.	0 - Notify District Bridge Engineer 1 - Replace Member

872 Conduit and Junction Boxes

Element Number	Description	Unit
872	This element defines those members, which enclose, support and protect the power and control wiring. The quantity for this element will only be one (1) for the entire bridge.	Each

Condition	Description	Feasible Action
1	There is no evidence of corrosion; supports are tight and firmly anchored into concrete or attached to structural steel. Junction box cover gaskets are intact and provide a good seal. Less connections and terminal strips are not tight. Between 2% and 10% of the conduit is in poor condition.	0 - Do Nothing
2	There is major corrosion, supports are broken or missing; junction box is badly deteriorated, and conduit may be broken. Connections and terminal strips are not tight. Between 2% and 10% of the conduit is in poor condition.	0 - Do Nothing 1 - Repair Member 2 - Replace Member
3	There is major corrosion, supports are broken or missing; junction box is badly deteriorated, and conduit may be broken. Between 10% and 25% of the conduit is in poor condition.	0 - Do Nothing 1 - Repair Member 2 - Replace Member
4	There is major corrosion, supports are broken or missing, junction box badly deteriorated, and conduit may be broken. 25% or more of the conduit is in poor condition.	0 - Notify District Bridge Engineer 1 - Rehab Member 2 - Replace Member

873 Programmable Logic Controllers

Element Number	Description	Unit
873	This element defines the general-purpose industrial microprocessor-based control systems.	Each

Condition	Description	Feasible Action
1	Diagnostic display or bridge tender reports do not indicate equipment malfunction; air filters are clean; and there is no accumulation of dirt and dust. Wiring connections are all tight. Controlled item is operating properly through entire range of movement and smoothly ramps and seats.	0 - Do Nothing
2	Air filters are not clean, there is accumulation of dirt and dust, lights on controller may not work.	0 - Do Nothing 1 - Clean Member; Replace Filters
3	Air filters missing, large accumulation of dirt and dust, lights on controller are not working. Wiring connections are not tight. Controlled item may not be operating properly through entire range of movement or may not ramp or seat properly.	0 - Do Nothing 1 - Clean Member; Replace Filters; Tighten Connections
4	The diagnostic display or bridge tender indicate malfunctions, the programmable logic controller is not working. Controlled item may be slamming/not moving.	0 - Notify District Bridge Engineer 1 - Repair Member

874 Control Console

Element Number	Description	Unit
874	This element defines the console, which controls the operation of the movable bridge. This element includes interlocks, span limit switches, and span position indicator devices.	Each

Condition	Description	Feasible Action
1	There is no corrosion or paint failure, the console area is clear of foreign objects, all switches operate properly, all bypass switches are locked or sealed to prevent inadvertent operation, there are no burned out pilot light lamp or missing or broken lamp lenses.	0 - Do Nothing
2	There is some corrosion or paint failure, the console is not clear of foreign objects. Loose/entangled wires or improperly labeled/tagged wires.	0 - Do Nothing 1 - Clean and Paint
3	There is heavy corrosion or paint failure, there are burned out pilot light lamps, missing or broken lamp lenses. Missing electrical covers, broken breakers. Some bypasses are on with remaining bypass switches locked and sealed.	0 - Do Nothing 1 - Clean and Paint 2 - Repair Member
4	The switches/breakers do not operate properly, the bypass switches are not locked or sealed.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

880 Cables - Vertical Lift

Element Number	Description	Unit
880	This element defines only those steel cables on a vertical lift bridge.	Each

Condition	Description	Feasible Action
1	Little or no corrosion. No signs of distress in strand or anchor sockets.	0 - Do Nothing
2	Surface or freckled rust has formed or is forming. No signs of distress in strand or anchor sockets.	0 - Do Nothing 1 - Clean and Lubricate
3	Corrosion may be present, but any section loss is incidental and does not affect the strength or serviceability of element or bridge. Cable strands may be worn. Cable banding/clamps, if any, may show some loosening or slipping. Cable anchor devices may be loosening.	0 - Do Nothing 1 - Clean and Lubricate
4	Corrosion is advanced. Cable strands may be broken or severely abraded. Anchors show signs of slippage. Section loss or other deterioration is sufficient to warrant analysis to determine impact member strength and/or serviceability of both element and bridge.	0 - Notify District Bridge Engineer 1 - Rehab Member; Lubricate 2 - Replace Member

881 Bridge Specific Equipment (Lift)

Element Number	Description	Unit
881	This element defines those components found on Lift Bridges, but not found on other types of movable bridges such as sheaves, span guides, counterbalance chains, etc. The quantity for this element will be one (1) for each item.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

882 Bridge Specific Equipment (Swing)

Element Number	Description	Unit
882	This element defines those components found on Swing Bridges, but not found on other types of movable bridges such as balance wheels and tracks. The quantity for this element will be one (1) for each item.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

883 Bridge Specific Equipment (Pontoon)

Element Number	Description	Unit
883	This element defines those components found on Pontoon Bridges, but not found on other types of movable bridges such as Pontoons, sheaves, open/close cables, winches, etc. The quantity for this element will be one (1) for each item.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

884 Bridge Specific Equipment (Bascule)

Element Number	Description	Unit
884	This element defines those components found on Bascule Bridges, but not found on other types of movable bridges such as Trunnions, etc. The quantity for this element will be one (1) for each item.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

885 Barriers - Moveable Bridges

Element Number	Description	Unit
885	This element defines the component that provides a physical barrier to vehicles, while the bridge is in the open position and all equipment required to operate the barrier. All limit switches required to operate the barrier are incidental to this element.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

886 Traffic Warning Gates - Moveable Bridges

Element Number	Description	Unit
886	This element defines the components that alert vehicular traffic to impending bridge operation. This element includes all equipment required to operate the traffic gate. Limit switches that control the operation of the traffic gate, if present, are incidental to this item.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

890 Traffic Signals

Element Number	Description	Unit
890	This element defines the component that signals vehicular traffic when to stop and start.	Each

Condition	Description	Feasible Action
1	There is no need for any maintenance or repair.	0 - Do Nothing
2	There is need for maintenance.	0 - Do Nothing 1 - Service Member
3	There is need for repair.	0 - Do Nothing 1 - Repair Member
4	There is need for replacement or rehabilitation.	0 - Notify District Bridge Engineer 1 - Repair Member 2 - Replace Member

891 Navigational Light System

Element Number	Description	Unit
891	This element defines the lights for navigation, mounted on the bridge or fender system, and is not limited to lights on movable bridges. This element includes clearance gauge lights and power system. Inspection should include the back-up power system.	Each

Condition	Description	Feasible Action
1	Lights are operational, lenses are clean and not broken, and there is no evidence of corrosion.	0 - Do Nothing
2	There is some evidence of corrosion and some lights may be burned out.	0 - Do Nothing 1 - Replace Bulbs
3	There is evidence of corrosion, several lights may be burned out, some lens and/or fixtures may be damaged or broken.	0 - Do Nothing 1 - Replace Bulbs 2 - Repair Member
4	Lights are not operational.	0 - Notify District Bridge Engineer 1 - Replace Bulbs 2 - Repair Member 3 - Replace Member

892 Fender System/Pier Protection

Element Number	Description	Unit
848	This element defines those wood, steel, or concrete fender systems and/or pier protection systems in or around the bridge elements.	Each

Condition	Description	Feasible Action
1	Fender/pier protection system in place and fully functional.	0 - Do Nothing
2	There is minor damage or deterioration to fender/pier protection system.	0 - Do Nothing 1 - Rehab Member
3	There is moderate damage or deterioration to fender/pier protection system.	0 - Do Nothing 1 - Rehab Member
4	There is major damage or deterioration to fender/pier protection system.	0 - Notify District Bridge Engineer 1 - Rehab Member 2 - Replace Member