Table of Contents

CHAPTER 1  GENERAL ................................................................................................................. 2
SECTION 1.1  INTRODUCTION ......................................................................................................... 2
SECTION 1.2  INSPECTION DETAILS ................................................................................................ 3
  Subsection 1.2.1  Inspector Qualifications ................................................................................ 3
  Subsection 1.2.2  Operating and Maintenance Manual ......................................................... 4
  Subsection 1.2.3  Precision ........................................................................................................ 4
  Subsection 1.2.4  Frequency ...................................................................................................... 4
  Subsection 1.2.5  Bridges Closed to Traffic ......................................................................... 5
SECTION 1.3  INSPECTION SAFETY .............................................................................................. 7
SECTION 1.4  EMERGENCY NOTIFICATION .............................................................................. 10

Table of Figures

Figure 5:1-1: Movable Bridge Gearing .......................................................................................... 5
Figure 5:1-2: Rolling Lift Gears .................................................................................................. 6
Figure 5:1-3: Franklin Street Bridge in Partially Open Position ............................................... 7
Figure 5:1-4: Movable Bridge Span Accessible From the Bank ............................................. 8
Figure 5:1-5: Franklin Street Bridge ......................................................................................... 9
A movable bridge is a bridge across a navigable waterway that has at least one span which can be temporarily moved in order to increase the vertical clearance for vessels in the channel. Such a bridge is built where site conditions preclude constructing a fixed-span bridge with an acceptable vertical profile.

In the second half of the 19th century, the U.S. Congress prohibited the construction of bridges or other obstructions over navigable waterways. Only bridges authorized by an act of Congress could be constructed over a navigable waterway, and these had to be movable or have sufficient height to allow the passage of vessels. To this day, water traffic has the primary right of way at intersections of land and water traffic. Although an act of Congress is no longer required for the construction of a bridge, a rigorous permitting process is in place.

As of 2010, there are three movable highway bridges in the state of Indiana. Two are in East Chicago. The Indianapolis Boulevard Bridge is owned and maintained by the Indiana Department of Transportation (INDOT), and the bridge on Dickey Place is owned and maintained by Lake County. The third bridge, on Franklin Street in Michigan City, is owned and maintained by LaPorte County.

Movable bridges should receive the same inspections mandated for fixed bridges, including applicable specialized inspections such as Fracture Critical, Special, and Underwater Inspections. In addition, the operating systems need to be inspected on a routine basis. Inspection of the structural components is addressed in Part 4. Part 5 of this manual outlines the requirements for a Moveable Bridge Inspection, which is primarily concerned with the electrical and mechanical machinery for operating and stabilizing the movable span. The interaction between the movable bridge and the machinery will also be addressed here because an understanding of the mechanical/structural interaction is important for adequate inspection and maintenance of the machinery.
SECTION 1.2 INSPECTION DETAILS

Subsection 1.2.1 Inspector Qualifications

Movable bridges are large, complex, pieces of machinery. Each part of a movable bridge has a relationship to, and must interact with, many other parts. All functional systems must be inspected and evaluated by personnel experienced in that line of work.

Inspectors for movable bridges should have experience beyond that required for the inspection of fixed bridges. As with a fixed bridge, the structural members of a movable bridge must safely withstand the stresses imposed by the dead loads, live loads, and other loads typically encountered. In addition, many of the structural members must withstand the stresses imposed by the operating equipment and the movement of the bridge. It takes significant experience on movable bridges and with the applicable codes to adequately understand these relationships, evaluate the conditions of the various components, and recommend appropriate action.

The Inspection Team Leader for a Movable Bridge Inspection should be trained in the inspection of fixed bridges and all of the functional systems. He/she must be a Professional Engineer registered in the state of Indiana with experience in the inspection, design, maintenance, or construction of movable bridges. The Inspection Team Leader's experience must understand the inter-relationships inherent in these bridges.

The inspection team for a Movable Bridge Inspection should include structural, electrical, hydraulic, and mechanical lead inspectors. A single individual may serve as lead inspector in more than one of the areas if he/she has the necessary experience. Each lead inspector should have experience in the inspection, design, maintenance, or construction of movable bridges, including the inspection of at least three such bridges within the last five years. The experience should be in the specific systems for which the individual is leading the inspection. Each lead inspector must supervise and monitor any work performed by anyone assisting in the efforts. All inspectors assisting with the inspection should, as a minimum, have experience in the inspection of fixed bridges.

The Lead Structural Inspector must have completed Fracture Critical Inspection Techniques for Steel Bridges (FHWA-NHI-130078) class and must be a Professional Engineer registered in the state of Indiana.
Subsection 1.2.2  Operating and Maintenance Manual

Every movable bridge should have its own Operation and Maintenance Manual, although these documents may not be readily available at the bridge site. If the Operation and Maintenance Manual is available, the inspection team should review the manual to determine if there are any special conditions that should be addressed at the bridge. A copy of the Operation and Maintenance Manual should be scanned into the Central Database. If there is no Operation and Maintenance Manual, the inspection of a movable bridge must be in accordance with this Bridge Inspection Manual and sound judgment should be used where specific conditions are encountered that are not covered by this manual.

Subsection 1.2.3  Precision

Movable bridges are considered complex structures in Indiana and require a Special Inspection, described in Part 1, Chapter 3 of this manual. The Plan of Action for each inspection required for a movable bridge (Routine, Movable, Fracture Critical, and Special) should be written with enough detail to provide guidance on the frequency and specific requirements for each inspection.

The Plan of Action must include the following:

- A timetable for conducting each inspection
- Personnel requirements for each portion of each inspection
- A list detailing what is required to be inspected under each inspection
- Required access and testing equipment needed for each inspection
- Required traffic control for each inspection
- Required type and level of nondestructive testing (NDT) that may be needed for each inspection

Movable Bridge Inspections typically require that a high level of precision be taken with measurements. Mechanical tolerances should be obtained with feeler gauges. Electrical data is typically obtained with specialized devices. The measurement locations and the precision required should be clearly called out in the Plan of Action.

Subsection 1.2.4  Frequency

Movable bridges are normally inspected prior to the start of the navigation season in the spring so that any problems can be corrected before the bridge returns to normal operations. Annual maintenance functions are generally performed at this time, as well. This is a good time to flush the bridge with high-pressure water to remove the previous year’s accumulation of dirt, road salt, and debris. Cleaning the bridge in this manner makes the inspector’s job easier and makes it more likely that small defects will be found.
Various systems, subsystems, and components are normally inspected on a frequent basis to ensure their continued operation and reliability. Some of these inspections may be performed on a daily basis by the bridge operators, while other inspections may be performed by maintenance personnel as a part of normally scheduled maintenance. Operators should be trained to observe the indicators located on the console during each bridge operation. They should be able to recognize if any of the readings are changing over time and, if so, report the changes to supervisory personnel. Any changes in the way the bridge handles should also be reported. Maintenance personnel should be trained to observe the equipment and recognize basic indicators of wear, misalignment, and malfunctioning equipment.

Movable bridges should be thoroughly cleaned prior to any of the required inspections.

**Subsection 1.2.5  Bridges Closed to Traffic**

If a bridge is closed to traffic, the inspection team shall follow the steps outlined in Part 1, Section 3.3 of this manual.

![Figure 5:1-1: Movable Bridge Gearing](image-url)
Figure 5:1-2: Rolling Lift Gears
SECTION 1.3  INSPECTION SAFETY

Nothing is more important during a bridge inspection than the safety of the public, the bridge operating and maintenance staff, and the bridge inspection team. The inspectors need to be alert and aware of the safety issues in the work environment. They should not rely solely upon bridge operating and maintenance staff to create a safe environment. The Inspection Team Leader should take an active role in arranging pedestrian and vehicular traffic control and de-energizing electrical equipment. For basic safety requirements, refer to Part 1, Chapter 4. Potential personnel and public safety hazards are also discussed in Chapter 1.3 of the American Association of State Highway and Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual.

The traveling public must be prevented from accessing any movable bridge that is not in a stable, closed position. All warning devices must be operating. Ensure that no one can access the moving parts during the inspection.

Perform a test opening before beginning the bridge inspection to determine if the movable span is operable and if there are any serious defects which need special consideration, or that would preclude a safe inspection. Such issues should be resolved with the bridge maintenance and design groups if possible.
Following the test lift, the inspection team should:

- Meet with the bridge operation crew to ascertain any scheduled opening times and to establish direct communications with the operating staff.

- Tag and lockout the electrical service to the lift motors. If it is not possible to tag and lockout the electrical service, one member of the inspection crew should remain with the operator and have direct communication with the inspectors working on the bridge to ensure that all inspection crew members are clear of any movable parts prior to initiating a bridge opening.

- Upon completion of the inspection, meet again with the bridge operation crew to inform them that all inspection crew members are in the clear and that bridge operations may resume without interruption. If electrical tags and lockouts have been placed, the person placing the tag and lockout shall remove the tag and lockout and restore the power to the lift motors.

Inspectors must be cognizant of the mechanisms which are intended to move and stabilize the movable span. Do not disconnect any components that would create an unsafe condition. After completion of the inspection, the Inspection Team Leader should check the operating equipment to make certain that it is energized and ready for operation. A test opening should then be made to verify that the bridge condition has not been compromised.

Figure 5:1-4: Movable Bridge Span Accessible From the Bank

The inspector should verify that a panel or device is not powered from a second utility source or standby generator. Under this circumstance, removing power from a single source may be insufficient to de-energize a panel. An inspector should always test the equipment with a voltmeter or similar power detector to determine whether the equipment is safe to inspect.
Give special attention to all rotating or moving machinery. Portions of the inspection will require the inspector to observe the machinery and equipment while in operation. Be very careful not to come into contact with the machinery or let hair or loose clothing be caught in the machinery. Strict notification and communication procedures between the person performing the inspection and the bridge operation staff should be implemented to ensure that inspectors are in the clear when bridge operations are observed.

The inspection of a bridge should not be destructive and the inspector should always take care to seal all panels and equipment properly to prevent later damage. Before attempting to open any panel, the inspector should determine if the panel is warped or damaged. If the equipment is damaged, do not inspect it unless there is a maintenance crew readily available to repair or replace the damaged equipment. Otherwise, the inspector should note in his/her report that the equipment is inaccessible due to damage. Open or cracked panels can expose the bridge wiring to corrosion or damage and expose people to electrical contact. This could lead to permanent injury, disability, or death.

Inspectors should not attempt to repair or modify any bridge equipment. Accurately recording any deficiencies and notifying the appropriate maintenance authority immediately will enable the repairs to be made in a documented and orderly manner.

Inspectors should always use appropriate personal protective equipment while performing the inspection. This includes, at a minimum, the use of a hard hat, safety glasses, safety reflecting vest, appropriate footwear, and clothing that is not loose. Life vests and safety harnesses shall be used when inspecting over the water or areas with a fall hazard, as required by the Occupational Safety and Health Administration (OSHA) and U.S. Coast Guard regulations. Each inspector is responsible for his/her own safety and should take all necessary actions required to minimize risk.

Figure 5:1-5: Franklin Street Bridge
SECTION 1.4 EMERGENCY NOTIFICATION

Structural deficiencies may lead to localized failures or collapse of a bridge. Similarly, mechanical and electrical defects can cause a movable span to become unstable in the closed position, the open position, or both. In Part 1, Chapter 7, procedures are detailed for reporting serious structural defects and the actions to be taken to limit traffic or temporarily close the bridge.

The lead inspector must immediately report any defects of the span drive or stabilizing machinery that would render the operation of the bridge unsafe or leave the bridge in an unsafe condition for motor traffic or pedestrian use. If necessary, the lead inspector shall take all such actions as is necessary to prevent the operation of the bridge until emergency repairs are made. Such defects include cracked or damaged drive gears and pinion shafts, loose or missing keys, improperly operating tail locks, and improper balance. A movable span may be unstable in any position due to defects in the span drive or stabilizing machinery. Much depends on the type of bridge and the redundancy of the overall system. Because of the variations in movable bridge design, the lead inspector must rely on his/her experience when assessing the suitability of the bridge for continued operation.
Table of Contents

CHAPTER 2  BASCULE BRIDGES ................................................................. 2
  SECTION 2.1  INTRODUCTION................................................................. 2
  SECTION 2.2  ROLLING LIFT BASCULES – SCHERZER-TYPE ................. 4
  SECTION 2.3  BRIDGE WATERWAY PROTECTION ................................... 6

Table of Figures

Figure 5:2-1: Franklin Street Rolling Lift Bridge .................................................. 3
Figure 5:2-2: Rolling Lift Bridge Teeth .................................................................. 3
Figure 5:2-3: Motion of Rolling Lift Bridge ........................................................... 5
Figure 5:2-4: Dickey Road Pier Protection Cell .................................................... 6
CHAPTER 2  BASCULE BRIDGES

SECTION 2.1  INTRODUCTION

Bascule bridges are modern versions of the medieval draw bridge. These medieval draw bridges had no counterweights so their size and utility was limited. Modern bascule bridge design can be traced to about 1893 with the construction of the Van Buren Street Bridge in Chicago, a rolling lift bascule, and the Tower Bridge in London, a roller-bearing trunnion bascule.

Bascules are often selected for narrow to moderately wide channels where unlimited vertical clearance is required for navigation. They have been built in many configurations. Usually, a bascule leaf is comprised of two longitudinal bascule girders, or trusses, which support the roadway deck framing. A wide leaf may be supported by multiple girders.

A bascule leaf is usually nominally balanced by a counterweight, which is fixed to the girders and located below the roadway. Counterweights reduce the size of the mechanical systems required to operate the bridge and provide an increased margin of safety in the event that a control system failure leads to a runaway condition.

Bascule bridges can be constructed with one or two leaves spanning the channel. Indiana's three highway bridges all have two leaves. A bridge with two leaves is called a double-leaf bascule. The two leaves usually meet at the center of the navigation channel. A span drive and stabilizing machinery is required for the moving of each leaf. A shear transfer device is provided between the leaves of the bridge to allow both leaves to share live load.

On a deck bascule bridge, the deck is located above the girders or trusses. Indiana's bridges are all deck bascules.

All movable spans utilize a combination of rotation and translation. Rolling lift bridges utilize rotation about a horizontal axis with simultaneous translation. Indiana's three highway bridges were all designed using the concepts in patents granted to William and Albert Scherzer starting in 1893. The Franklin Street Rolling Lift Bridge in LaPorte County, a double-leaf rolling lift bridge, is shown in Figure 5:2-1 below.
Figure 5:2-1: Franklin Street Rolling Lift Bridge

Figure 5:2-2: Rolling Lift Bridge Teeth
SECTION 2.2 ROLLING LIFT BASCULES – SCHERZER-TYPE

Scherzer-type bascules are characterized by cylindrically curved parts of the bascule girders or trusses at the ends over the bascule piers. Because of their large size, the girders or trusses of the early Scherzer bridges were assembled from segments and the girders were called segmental girders. Each segmental girder may be viewed as a segment of a wheel, rigidly attached to the bascule leaf. As the wheels roll along the tracks, the bascule leaf rotates to open or close the bridge.

Figure 5:2-3 depicts this movement for a double-rolling leaf deck type Scherzer bascule. As the curved ends of the girders roll away from the channel, the leaf tilts open to clear the channel. Slippage between the segmental girder treads and the tracks on which they ride is prevented by lugs or teeth that mechanically engage sockets. Typically, the protruding lugs are located on the track and the receiving holes or notches are in the segmental girder treads. Treads and tracks are described in more detail in Part 5, Chapter 3, Section 3.3. The rack is shown located above the pinion, as is common on many newer Scherzers, and is found on all of Indiana’s rolling lift bridges. The tracks on which the bascule leaf rolls may be mounted directly on the substructures, as is the case for the Indiana movable bridges, or they may be mounted on flanking spans. Span locks (also called center locks) are required to transfer vertical shear between the two leaves of a double-leaf bridge and to assure proper lateral and vertical alignment. Span locks are discussed in Part 5, Chapter 3, Section 3.3.
Figure 5:2-3: Motion of Rolling Lift Bridge
SECTION 2.3 BRIDGE WATERWAY PROTECTION

As with all bridges over navigable waters, the movable bridge structure must be protected from water traffic. The movable bridge piers are protected with a combination of protection cells, typically referred to as dolphins, and fenders. The protection cells are located immediately outside of the navigable channel and protect the bridge from direct hits by vessels. Along the face of the bridge piers, fenders are typically installed. The fenders protect the bridge from vessels as they pass through the bridge draw.

Navigation lights are provided on the movable leaf. These indicated whether the bridge is open or closed. The protection cells will also have lights installed to delineate the limits of the navigable channel. Properly operating navigation lights are critical to the safety of the water traffic.

The protection systems must be inspected as part of a Moveable Bridge Inspection.
Table of Contents

CHAPTER 3 FUNCTIONAL SYSTEMS ............................................................................................... 2
SECTION 3.1 INTRODUCTION .................................................................................................... 2
SECTION 3.2 SPAN DRIVE MACHINERY ................................................................................... 3
  Subsection 3.2.1 Type 1 Span Drives ........................................................................................... 3
  Subsection 3.2.2 Type 2 Span Drives ........................................................................................... 5
SECTION 3.3 STABILIZING MACHINERY .................................................................................. 8

Table of Figures

Figure 5:3-1: Type 1 Span Drive With Two Low-Speed, High-Torque Final Outputs ................. 4
Figure 5:3-2: Type 1-AD Span Drive ............................................................................................ 4
Figure 5:3-3: Type 2 Span Drive .................................................................................................. 5
Figure 5:3-4: Hydraulic Drive Motor ............................................................................................ 6
Figure 5:3-5: General Gearing Arrangement With Brake ........................................................... 6
Figure 5:3-6: Hydraulic Pump, Reservoir, and Span Drive Brake ................................................ 7
Figure 5:3-7: Segmental Girder and Track .................................................................................. 8
Figure 5:3-8: Live Load Bearing at Rear of Counterweight ......................................................... 9
Figure 5:3-9: Span Lock .............................................................................................................. 10
Figure 5:3-10: Span Lock Jaw .................................................................................................... 11
Figure 5:3-11: Detail of Mid-Span Shear Lock .......................................................................... 11
Figure 5:3-12: Lever Tail Lock .................................................................................................. 12
CHAPTER 3  FUNCTIONAL SYSTEMS

SECTION 3.1  INTRODUCTION

The functional systems of a movable bridge are classified as span drive machinery and span-stabilizing machinery. Span drives are the machinery needed to move the span. They also serve to stabilize the span when it is not in the fully closed position. Span drive machinery varies little with movable bridge types because the objective is the same: to convert the low-torque rotation of a motor (electric or hydraulic) to the high-torque or force required to move the span. In electro-mechanical drives and hydraulic drives, gearing is used to convert the low-torque, high-speed rotation of the motor to high-torque, low-speed rotation required to move the span.

Stabilizing machinery consists of the electro-mechanical and hydraulic components that support and restrain the span when it is in motion and when it is at rest. Some stabilizing components may be used to decelerate the span under certain conditions, but they do not accelerate the span.

This chapter describes the span drive and stabilizing machinery arrangements utilized on Indiana’s rolling lift bascule bridges.
SECTION 3.2 SPAN DRIVE MACHINERY

The span drive is the combination of electrical or hydraulic motors and mechanical components used to open and close a movable bridge. This can be accomplished in many ways. In this section, we describe the electro-mechanical or hydraulic-mechanical drives found on the Indiana rolling lift bascule bridges.

Subsection 3.2.1 Type 1 Span Drives

Span drives in which the motor outputs are connected mechanically to the drive gear are denoted as Type 1 Span Drives. Indiana’s Franklin Street Bridge span drive is designated as a Type 1 Active Differential (AD) span drive and is described in greater detail below. In all Type 1 arrangements, a motor is connected directly to the primary speed reduction gearing, usually through a shaft with a slip clutch to prevent damage to the gearing. On this bridge, all gearing is fully open. Power from the motor is distributed from the primary reduction gearing to two or more sets of secondary reduction gearing located at the sides or ends of the movable span. Through a series of progressively fewer gear teeth, the mechanical leverage is provided to move the span. The point of interface between the drive gears and the bridge is at the rack which is mounted to the bridge girder.

An active differential span drive is designated as Type 1 AD. On the Franklin Street Bridge, the motor drives a main gear from which planetary gears are driven. The arrangement is similar to that of the rear axle differential of a car. The arrangement of the planetary gears around the main drive gear from the motor permits the output shafts to rotate at slightly different speeds, but transmit equal torques. The active differential is located at the center of the machinery room of the Franklin Street Bridge. The active differential is shown on Figure 5:3-2.

Each side of the active differential has a drive shaft that extends to the gear train on each half of the bridge leaf. The shaft drives are attached to a large gear, which in turn drives a smaller gear with fewer teeth, which in turn drives another large gear, which in turn drives a smaller gear with fewer teeth than the first small gear, etc. This is the gear that engages the rack and provides the torque to raise and lower the bridge. Figure 5:3-1 illustrates the general arrangement of a Type 1 span drive system.
Figure 5:3-1: Type 1 Span Drive With Two Low-Speed, High-Torque Final Outputs

1. RACK
2. PINION SHAFT
3. BEARING
4. GEAR COUPLING
5. SECONDARY GEAR SPEED REDUCTION
6. MACHINERY BRAKE
7. FLOATING SHAFT
8. PRIMARY SPEED REDUCTION
   TYPE 1 - NO DRIVE: NO DIFFERENTIAL
   TYPE 1 - AD DRIVE: ACTIVE DIFFERENTIAL
   TYPE 1 - LD DRIVE: LOCKABLE DIFFERENTIAL
9. MOTOR BRAKE (WITH FLEXIBLE COUPLINGS)
10. MOTOR
11. FLEXIBLE COUPLINGS
12. TACH GENERATOR

Figure 5:3-2: Type 1-AD Span Drive
Subsection 3.2.2  Type 2 Span Drives

When each drive pinion gear is separately powered on a bascule bridge, the span drive is called Type 2. The Indianapolis Boulevard and Dickey Place rolling lift bascule bridges have Type 2 span drives. In the case of these bridges, hydraulic motors are directly connected to the various gears that drive each half of the leaf. The motors are connected to a small gear, which in turn drives a large gear, which drives a small gear, etc. With each transfer there are fewer teeth on the gears. This creates the mechanical leverage needed to move the bridge. The Indianapolis Boulevard and Dickey Place bridges also have a shaft that connects the two gear trains. This shaft is used to apply braking forces to control the up and down speed of the bridge. Figure 5:3-3 illustrates the general arrangement of a Type 2 span drive system. Figures 5:3-4, 5:3-5, and 5:3-6 illustrate the motor, gearing, and brakes used on these bridges. Also illustrated is the hydraulic pump used to drive the hydraulic motors.

Figure 5:3-3: Type 2 Span Drive
Hydraulic Motor

Figure 5:3-4: Hydraulic Drive Motor

Hydraulic Span Drive Brake

Brake Shaft Clutch

Figure 5:3-5: General Gearing Arrangement With Brake
Figure 5:3-6: Hydraulic Pump, Reservoir, and Span Drive Brake
Stabilizing machinery supports the span when it is in motion and at rest. The machinery components and assemblies are usually mechanical, but fluid power (air and liquid) components are also utilized. Stabilizing components on rolling lift bascule bridges include treads mounted on segmental girders, tracks, live load bearings, tail locks, mid-span locks, centering devices, and buffers. Components found on Indiana rolling lift bridges are explained below. Additional details are discussed in Chapter 4, Electrical Systems, and Chapter 5, Mechanical Systems. Stabilizing machinery includes the following:

- **Tracks and Treads**: Each rolling lift bridge segmental girder rolls on a track which has upward projecting lugs equivalent to gear teeth. The lugs are usually rectangular protrusions of the steel casting, spaced from about 10 to 25 inches apart, depending on the radius of roll. Lugs are staggered in two lines along the edges of the track. Figure 5:3-7 depicts the lugs on the edges of a track of a rolling lift bridge. The gear segments are then bolted to the sides of the tread. The tracks and treads guide the segmental girder as it rolls forward and backward, closing and opening respectively.

![Figure 5:3-7: Segmental Girder and Track](image)

(a) Tread  
(b) Socket  
(c) Joint Between Segmental Tread Castings  
(d) Track  
(e) Lug
• **Live Load Bearings:** The live load bearing supports the live load, a positive dead load from a desired span heavy imbalance, and the force due to residual torque in the span drive machinery. The live load bearings are found at the tail of the movable span and engage the roadway overhead. The live load bearings prevent the rolling lift span from literally “falling into” the draw. The live load bearings prevent excess force in the gear train from the vehicular loads on the bridge. When properly adjusted, the live load bearings should be nearly touching the reaction bearing of the overhead roadway.

![Figure 5:3-8: Live Load Bearing at Rear of Counterweight](image)

• **Span or Shear Lock (also called Center Lock):** This lock is intended to maintain the toes of both leaves at the mid-span of the bridge, at the same elevation, and in proper lateral alignment when the bridge is in the closed position and subjected to live load. In order to accomplish this, the shear lock must transfer live load shear between the leaves. All Indiana rolling lift bridges employ a jaw-type lock. As the bridge closes, the jaw, shown in Figure 5:3-9, enters between the diaphragm side plates and the diaphragm casting is engaged between the upper and lower jaws. With time, the top and bottom edges of the sliding surfaces of the jaw strike plates wear. The rate
of wear depends on the number of bridge openings and the amount of traffic passing over the bridge. Shims are provided under the jaw plates in order to permit adjustment. Figure 5:3-11 is a detailed drawing of the mid-span lock parts shown in Figure 5:3-9 and Figure 5:3-10. In order to inspect the mid-span shear locks, the bridge must be in the partially open position. Special care is needed to be able to access the locks for full inspection.

Figure 5:3-9: Span Lock
Figure 5:3-10: Span Lock Jaw

Figure 5:3-11: Detail of Mid-Span Shear Lock
Tail Locks: Tail locks provide for the upward reaction that occurs when the live load is located between the center-of-roll and the rear floor break. The tail lock must be retractable to accommodate the motion of the leaf. All Indiana rolling bascules have tail locks, although they do not appear to be used at the present time.

Indiana bridges use a retractable lock bar for the tail lock. The tail lock is mechanically withdrawn prior to the start of the opening sequence of the bridge. It is mechanically inserted under the counterweight at the end of the closing sequence of the bridge. Tail locks reduce wear on the gears of the movable bridge by preventing movement of the leaf under live loads.

Figure 5:3-12: Lever Tail Lock

(a) Tail Lock Post in Driven Position
(b) Actuator (Hidden by Enclosure)
(c) Live Load (Uplift)

Anchor (right)
# Table of Contents

| SECTION 4.1  | INTRODUCTION .................................................................................................... 2 |
| SECTION 4.2  | INSPECTION TOOLS AND INSTRUMENTS ........................................................ 3 |
| SECTION 4.3  | POWER DISTRIBUTION EQUIPMENT ................................................................ 4 |
| SECTION 4.4  | ELECTRICAL MACHINERY .................................................................................. 6 |
| Subsection 4.4.1 | Span Motors........................................................................................................... 6 |
| Subsection 4.4.2 | Auxiliary Motors...................................................................................................... 6 |
| Subsection 4.4.3 | Locks...................................................................................................................... 6 |
| Subsection 4.4.4 | Warning Gates and Barrier Gates........................................................................... 7 |
| Subsection 4.4.5 | Gongs, Horns, Bells, or Sirens............................................................................... 7 |
| SECTION 4.5  | CONTROL SYSTEMS ........................................................................................... 8 |
| SECTION 4.6  | LIGHTING SYSTEMS .......................................................................................... 11 |
| SECTION 4.7  | INSPECTION OF POWER DISTRIBUTION EQUIPMENT ......................................... 12 |
| SECTION 4.8  | INSPECTION OF ELECTRICAL MACHINERY ..................................................... 18 |
| SECTION 4.9  | INSPECTION OF CONTROL SYSTEMS ............................................................. 21 |
| SECTION 4.10 | INSPECTION OF LIGHTING SYSTEMS................................................................. 26 |

## Table of Figures

- Figure 5:4-1: Dickey Road Panel Board ....................................................................................................... 5
- Figure 5:4-2: Franklin Avenue Control Desk.................................................................................................. 8
- Figure 5:4-3: Control Relay Labeling on Dickey Road Panel Board................................................................. 10
CHAPTER 4    ELECTRICAL SYSTEMS

SECTION 4.1    INTRODUCTION

All Indiana rolling lift bascules have relatively modern electrical equipment. These electrical systems are also in generally good condition, although some functionality has been lost, including the tail locks which are no longer operating.

A typical electrical system for a movable bridge includes four major groups of equipment:

- Power Distribution Equipment
- Electrical Machinery
- Control System
- Lighting Systems

Conduits, flexible cables, junction boxes, electrical cabinets, and other components common to electrical systems are found on these bridges. An indispensable tool for the inspection of the bridge electrical system is the wiring or circuit diagram. These diagrams allow the inspector to determine the function of various components and what circuits control which functions. Common electrical systems and the tools unique to these inspections are discussed in this chapter.
SECTION 4.2 INSPECTION TOOLS AND INSTRUMENTS

Tools that are necessary for an electrical inspection include a megohmmeter, a voltmeter, a live power indicator, an ammeter, a thermometer, and a receptacle tester. The megohmmeter is a cable voltage insulation tester used to inspect bridge wiring, cables, and specialty cables. A voltmeter can be used to check the voltage on equipment and help verify equipment is de-energized. An ammeter can be used to verify the current and direction of phasing to motors, and verify desk indicators.

The inspector should note all equipment on the bridge and the state of the equipment. Each piece of equipment should have a unique identifier. This name should be used to track the status of the equipment from inspection to inspection.

An Electrical Inspection should be done in accordance with the recommendations listed in this manual, the American Association of State Highway and Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual and the National Electric Code (NEC). Part 5 of the Indiana Bridge Inspection Manual is intended to augment the inspector’s prior knowledge of the NEC by providing bridge-specific equipment information.
SECTION 4.3  POWER DISTRIBUTION EQUIPMENT

The power distribution equipment consists of electric power sources, protective devices, and distribution equipment.

The primary power source for movable bridges is a three-phase electric service from a local utility company. The typical three-phase electric service voltage used on the Indiana rolling lift bridges is a 277/480-volt, four-wire system.

The electric service from the utility company is delivered from pole-mounted or pad-mounted transformers typically owned and maintained by the utility. Feeders from the transformers extend to the service disconnect. The service disconnect is a circuit breaker or fused switch, owned and maintained by the bridge owner, which provides overload and short-circuit protection of the bridge electrical system. A utility energy consumption meter is located in the vicinity of the service disconnect or at the utility transformers.

A movable bridge electrical system may be provided with a secondary source of electric power should the primary electric source fail. To provide this redundancy in electric supply, a second electric service derived from a utility source independent of the primary electric service may be provided. The second electric service will be furnished with its own service disconnect and utility meter.

Electric power is supplied to the various motors and electrical equipment through protective devices, namely fuses and circuit breakers. Fuses and circuit breakers provide overload and short circuit protection to the electrical equipment they serve. These protective devices are typically housed in panel boards, motor control centers, and/or enclosed panels. Typically, fuses are cylindrical devices that prevent fault currents by melting and preventing any current flow. They are single use items and must be replaced when they have been used. Circuit breakers are used to protect the electrical equipment from a fault condition. Circuit breakers have elements that sense the current and are set to open the breaker if a certain limit is reached. Once tripped, the circuit breaker can be reset and used again.

A panel board contains a group of circuit breakers to distribute power to various electrical devices. Motor control centers house circuit breakers, fuses, motor starters, motor controllers, and other equipment required to control and distribute power to motors and other equipment. Motor control centers are modular in construction. In lieu of panel boards and motor control centers, circuit breakers, fuses, motor starters, motor controllers, and other motor control equipment may be installed on an enclosed, custom-built panel.

Transformers are commonly installed on movable bridges. Transformers convert voltage from one level to another, usually to serve lighting loads or to isolate electrical noise in the electrical system.
Electrical circuits are carried from panel boards, motor control centers, enclosed panels, and transformers to the electrical devices they supply power to through a raceway system. A raceway system typically consists of rigid, metal conduit and junction boxes. Electrical wires, or conductors, carry electrical current and are installed inside the conduit and boxes that make up the raceway system.

Figure 5:4-1: Dickey Road Panel Board
SECTION 4.4 ELECTRICAL MACHINERY

Electrical machinery refers to electro-mechanical devices that operate the movable span and auxiliary devices such as locks and traffic control equipment. For the Indiana rolling lift bridges, the electrical systems are designed with interlocks that prevent bridge operation without completing a pre-programmed sequence of operation. This fact must be kept in mind when inspecting the electrical systems for these bridges.

Subsection 4.4.1 Span Motors

The movable span is provided with one or more span motors that serve either as the prime mover for the span or provide the power to operate hydraulic pumps that are used to move the span. Span motors are the alternating current (AC) type on all Indiana bridges. Depending on the type of motor control equipment employed, the operating speed of the span motors is governed by the bridge operator or by a motor controller. A motor controller provides controlled motor speed and torque to ensure smooth movement of the movable span. The span motor and motor controller combination is commonly referred to as the electrical part of a span drive.

In an electro-mechanical drive system, the movable span is provided with electrically actuated span brakes to stop and hold the movable span. With modern motor controllers, the majority of braking during operation is accomplished by the span motor and motor controller. Thus, span brakes are typically utilized for holding the movable span and stopping it during emergency conditions.

Subsection 4.4.2 Auxiliary Motors

Some movable spans are equipped with a back-up motor for operation in the event the span motors fail or are out-of-service. These motors, called auxiliary motors, are generally smaller motors that take longer to open or close the span because of additional speed reduction gearing. The motor controller for an auxiliary motor is typically an across-the-line contactor.

The auxiliary motor will either be directly coupled to the main span machinery, or separated by a clutch. The auxiliary motor will either be selected by the operator at the control desk, or operated locally. The clutch, if present, will then be operated manually or electrically to connect the auxiliary motor.

Subsection 4.4.3 Locks

Locks are described in detail in Chapter 3, Section 3.3, Stabilizing Machinery. The electrical equipment is similar in each type, consisting of a motor directly coupled to the machinery and a series of limit switches to monitor the machinery. The motor controllers for locks are typically across-the-line contactors.
Subsection 4.4.4  Warning Gates and Barrier Gates

Traffic signals, lights, and gates are used to warn approaching cars and pedestrians and to provide physical protection, when required. Traffic signals, or red flashing lights, are used to initially stop the traffic. Once the traffic has come to a complete stop, the warning gates are lowered to indicate that no vehicles may enter. Gates are usually equipped with flashing lights.

Subsection 4.4.5  Gongs, Horns, Bells, or Sirens

Gongs, horns, bells, or sirens are used to alert traffic to changing conditions. They are sounded at the beginning and end of any bridge operation and used in tandem with flashing lights and warning signs.
The control desk is where the bridge operator controls the operation of the bridge and its associated equipment. There are push buttons, control switches, indicating lights, meters, and indicators on the desk, and often a foot pedal switch mounted on the floor at the control desk. Mirrors, cameras, and binoculars are used to help the operator see motor, pedestrian, and water traffic.

There are many types of motor controllers, ranging from simple contactors to motor drives. The equipment may be installed in a panel or motor control center.

A standard motor controller consists of a motor protector, a contactor, and a motor overload device. A motor circuit protector is either a circuit breaker or a fuse that has a trip setting to protect the motor controller and motor. Contactors are devices that make or break current to the motor. When the motor is connected to the current, it will operate, and when the current is removed, it will stop. Contactors can operate the motor in a single direction, or forward and reverse directions. An overload device is a sensitive, quick-acting device that will sense when the motor is drawing too much current and open the contactor to stop the motor. Motor overloads are intended to be faster in reacting to a motor fault than a circuit breaker or fuse, and more sensitive to minor faults that would not trip a circuit breaker.

Many specialty controllers, called motor drives, provide the same functions listed above, as well as speed, torque, and/or counter torque control of the motor. Motor drives use circuit boards and capacitors to generate a specific current amplitude and/or frequency to control the motor.
Limit switches provide an electrical signal to stop or change operation. There are several types of limit switches: lever arm, plunger-type, rotary, and proximity.

Relays are low-current switching devices that provide logical control of a bridge. They can be used independently or with a programmable logic controller (PLC). In order to provide control for an entire bridge, multiple relays are required. They are generally located in a panel or enclosure. When relays are used with a PLC, they are generally interposing relays. These relays are located between the PLC outputs and the equipment being controlled and serve as a means of isolation. Relays are also used as part of auxiliary systems, such as traffic gates, or control of local equipment.

Machine relays are larger relays that can be repaired and modified for various logical configurations. They are bolted to panel back plates and the terminals of the relay accept wire. "Ice cube"-style, plug-in relays are smaller relays covered with a clear plastic cover. They cannot be modified or repaired and must be replaced when damaged. They are plugged into a mounting strip and wires to the electrical equipment are terminated on the mounting strip.

Check all contact surfaces for signs of pitting or flashing. Contacts should not make any sounds.

PLCs are computers that provide the logical control of the bridge. They are generally rack-mounted in cabinets in the control room. There may be multiple PLCs in the cabinet and multiple input/output (I/O) cards in the rack. There may be multiple remote I/O drops. A remote I/O drop will consist of I/O cards and communication cards rack-mounted in a panel. PLCs processors can use communication networks to transmit information from a remote drop to the main processors.

The PLC generates electrical control signals through the PLC output cards. These output signals interface with the motor electrical controllers and equipment to control bridge equipment. PLC input cards supply the PLCs with information on the state of the equipment and provide the necessary interlocks for the processors to start and stop the bridge equipment.
Figure 5:4-3: Control Relay Labeling on Dickey Road Panel Board
SECTION 4.6 LIGHTING SYSTEMS

Service lighting and receptacles are provided throughout the bridge to enable work and inspection in dark areas or at night. Check that receptacles exposed to the elements are provided with covers and have ground fault circuit interrupters (GFCIs) as part of the outlet.

Navigation lighting and signals are provided to guide and alert the channel water traffic. Red lights mounted on the piers or fenders mark the channel for the boats. Alternating red and green lights mounted on the span notify the boat operator of the status of the bridge opening. When the light is red, the span is not fully open. When the light is green, the span is fully open. Navigation lights are installed in accordance with U.S. Coast Guard standards and guidelines. Proper maintenance of these lights is essential for the safety of the waterway traffic.

An air horn or similar audible device is used to warn the water traffic that a bridge operation is about to start.
SECTION 4.7 INSPECTION OF POWER DISTRIBUTION EQUIPMENT

Inspection of the electrical service should include the following:

- Locate all points of electrical service. Some bridges may have separate points of service on each side of the bridge, or separate services for special equipment such as roadway lighting.
- Contact the utility and arrange for power to be disconnected. Have the utility verify, in the presence of the inspector, that electric power is removed.
- Perform a visual inspection of the incoming feeders. If the feeders are from overhead transmission lines, they can be easily viewed. Underground feeders will not be visible except at the point of entry.
- Check for damaged wires and missing or broken supports.
- Verify that all equipment is firmly mounted.
- Check for blown line jacks.
- Inspect the panels where service is terminated for damage, rust, debris, or fluid build up.
- Check the wiring and terminations.
- Check the insulation resistance of the cables while they are de-energized.
- Look for any scorch marks or evidence of faults in the panel.
- Inspect the main ground terminal. Request that the utility take a measurement of the resistance to ground to verify that the incoming service is solidly grounded.
- Inspect the bridge grounding system thoroughly if the grounding at the utility is not acceptable.

Inspection of the transformers should include the following:

- Inspect the exteriors for damage, corrosion, lost paint, or scratches.
- Verify that the hinges and latches of panel doors or bolt on covers operate properly, are sufficiently lubricated, and make a tight seal when the doors/covers are sealed.
- Verify there is a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch. Note if the gasket is brittle, permanently deformed, or missing in areas.
- Verify that the panel mount is secure and vibration-resistant. The panel may be free-standing and bolted to the floor, wall-mounted and bolted to the wall, or wall-mounted and mounted to a metal strut support.
• Note any loose bolts or other deficiencies.

• Listen to the transformer for any unusual noises during bridge operations. Transformers normally have a low, quiet, buzzing sound.

• Take the temperature of the transformer and compare it to the specified normal range. Record the operating temperature.

• Inspect oil-filled transformers for leakage.

• Test older transformers for polychlorinated biphenyls (PCBs).

Motor control centers (MCCs) are cabinets where electrical power is controlled and distributed to end devices. Equipment is arrayed in units called buckets. Each bucket will contain one or more of the following: an overcurrent protection device, a motor controller, an overload relay, or metering equipment. Inspect the panel, motor controllers, circuit breakers, fuses, and wiring.

Panel boards are panels with distribution circuit breakers and, on older bridges, relays. Inspection of the panels should include the following:

• Inspect the panel, circuit breakers, and wiring.

• Inspect the exterior of all panels for damage, corrosion, lost paint, or scratches. Inspect panel doors or bolt-on covers to verify that the hinges and latches are properly lubricated and make a tight seal when the door or cover is sealed.

• Verify there is a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch.

• Note if the gasket is brittle, permanently deformed, or missing in areas.

• Verify the panel mount is secure and vibration-resistant. The panel may be free-standing and bolted to the floor, wall-mounted and bolted to the wall, or wall-mounted and mounted to a metal strut support. Note any loose bolts.

• Determine if any temperature control equipment, such as a heater, ventilation grate, and/or fan is operating properly. Verify that the ventilation grate filter is clean and free of dust and debris.

• Check that each panel is solidly grounded by a conduit fitting or ground bar located in the panel.

• Inspect other equipment located within the panel.
The raceway system consists of conduits, conduit fittings, junction boxes, and terminal boxes. Conduit is used to protect wire and route it from one location to another. Typically these are 10- or 20-foot sections of rigid galvanized steel (RGS) conduit, polyvinyl chloride- (PVC-) coated RGS conduit, and PVC nonmetallic conduit. Inspection of the raceway system should include the following:

- Ensure raceways are properly coupled and supported.
- Ensure all conduit is tightly connected. If a coupling becomes loose, the conduit sections may separate, and the wires inside may become damaged.
- Verify that required supports are present and securely mounted. Check each support for loose screws or bolts. RGS conduit should have secure support at intervals not exceeding 10 feet. Nonmetallic conduit should have a support every three to seven feet.
- Check the wall-mounted conduit runs for dirt and debris between the conduit and the walls. Dirt and debris should not be allowed to build up on any conduit runs.
- Note any areas that require cleaning.
- Check that conduit fittings are in good condition. Conduit fittings are in-line enclosures in conduit that provide bends or taps in conduit runs. Check the gaskets for a tight seal. Check the conduit fitting for any debris or fluid.
- Check that junction and terminal boxes (enclosures for the routing of wires) are in good condition. The boxes will be rated by the National Electrical Manufacturers Association (NEMA) for various exposure conditions, including watertight, dust-proof, and corrosion-proof. For all junction and terminal boxes:
  - Inspect the wires and terminals.
  - Verify that that seals around the access panels provide a watertight seal.
  - Check the boxes for debris or fluids.
  - Check that the drain and breather valves are operational.
  - Check the exterior of the boxes for rust or chipped paint.
  - Check the conduit bushing and fittings to verify a solid and tight fit.
  - Verify that any grounding fittings are properly installed and the ground wire is bonded to the fitting.
Bridge wires are copper conductors that carry electrical power and control to the electrical devices. Occasionally, aluminum is used in lieu of copper. Wires are either solid cylindrical shapes, or composed of several strands. Conductor sizes are based upon the amount of electrical current, or ampacity, of the load device. The more current required, the larger the conductor. The wire is covered with insulation, rated for electrical voltage, and jacketed to protect the wire. A cable contains several insulated wires within the same outer jacket. The insulation and jacket are selected based upon the electrical voltage of the system and the environmental conditions to which the wire/cable will be exposed. Inspection of the wire and cable should include the following:

- Confirm that the bridge is wired in accordance with the as-built documents of the electrical system. Each wire should be designated with a wire number that is referenced on the as-built drawings.
- De-energize high- and medium-voltage cables before inspecting. Only personnel trained on such equipment should perform the inspection.
- Check for insulation failure when the jacket and insulation of the conductor wears away, causing electrical faults or wire failure. Failure may be caused by overloading, physical wear and tear, exposure to water or corrosive materials, or age.
- Note any signs of abrasion or cracking over the entire length of the cable.
- Note any signs of discoloration and overheating.
- Note any signs of excessive bends or kinks in the wire.
- Note any signs of water or other moisture on the cables.

Wires and cables are usually installed in conduits. The conduits provide additional protection for the cables. When the cable is inside conduit, it cannot be visually inspected for the entire run. The wire and cable should then be inspected at accessible points, such as conduit fittings, terminal and junction boxes, and equipment panels.

Wires and cables are terminated at terminal strips in panels and lugs on equipment. There are three types of terminations to terminal strips: compression, fork-tongue, and ring-tongue. A compression terminal is simply a screw that presses onto the bare wire to make a contact. A fork-tongue or ring-tongue terminal is compression-clamped onto the wire. The screw in the terminal strip will compress onto the tongue portion. Vibrations that occur on a bridge will cause the terminals to loosen over time. Compression terminals traditionally have the least resistance to vibration and the wires may become loose. Ring-tongue terminals provide the best resistance to vibration, as the compression screw travels through the ring on the cable. If the screw becomes loose, the ring will still maintain contact.
The inspector should examine the terminations and note:

- Loose terminals.
- Any wires not tagged with a wire number.
- Any wiring not in accordance with the as-built drawings.
- Terminals not marked with the wire number of the terminated wires.
- Any movement or vibration between the panel and wires.
- Corrosion or rust on the terminals.
- That the exposed copper conductor will not come into contact with exposed metal.
- That the wire is isolated from power and sensitive equipment and perform an insulation megohm resistance to ground test on each individual wire. Record the wire number and the phase-to-ground resistance, and a phase-to-phase resistance with an adjacent disconnected wire in a table. If the resistance value is below one kilo-ohm, the wire is close to failing. If the resistance is zero, the wire has failed. Compare the results to previous results to determine if there are trends in the insulation resistance or the cable test results. This may indicate a problem in the run of wire.

Specialty cables, including flexible cables and submarine cables, are installed in areas that cannot be serviced by wire in conduit. Flexible cables are cables routed between fixed portions and movable portions of the bridge, such as cables from the rest pier to the bascule leaves. Flexibility comes at the cost of reduced jacket protection. In order for the cables to bend and move with the bridge, the jacket must be softer and more flexible. This means that they may wear more quickly from rubbing and abrasion.

Submarine cables are cables that are routed into the channel through the water from one side of the bridge to the other. The cables are usually trenched into the riverbed. They are exposed to a much harsher environment than regular cables. The portions of the cables that remain continually underwater, or continually out of the water, usually remain undamaged. The portions of the cables that are exposed to fluctuations in water level due to wet and dry periods, and the wear and tear of moving in response to the changing water level, require the closest inspection. Submarine cable is typically manufactured with a steel armor wire wrapping and polyethylene covering to protect it from the harsh conditions. Submarine cables are usually terminated in panels where the wiring is transitioned to normal wire and conduit.
The inspection of specialty cables should include the following:

- Check that the armor is terminated and grounded at the submarine cable terminal panels in special fittings.
- Verify the range of motion of flexible cables during an operation of the bridge. Cables should swing freely and move freely during the entire operation of the bridge.
- Check for sharp bends or kinks in the cables during operation.
- Note any cables that snag or rub against the structure or equipment.
- Test the insulation of the individual wires of the flexible cables using a megohm meter and record the values.
- Note the effects of wind on the cables during operation.
- Check the cable grips and supports at each end of the cables. They must have a firm grip on the cables and be solidly attached to the structure.
- Inspect submarine cables during low-water conditions if possible.
- Note any deterioration of the cables.
- Verify panel terminations and cable supports.
- Inspect the clamps of armored cable to make sure the cable is supported and grounded.
- Use a megohm resistance test to check the insulation of the individual wires of the submarine cables and record these values.
SECTION 4.8 INSPECTION OF ELECTRICAL MACHINERY

The inspection of all motors should include the following:

- Verify that the motor shaft is free from oil and grease from the bearings. Leaking oil can indicate a poor seal or misalignment of the shaft.
- Verify all keys, bolts, and pins are in their proper positions. Check all bolts along the motor housing for proper tightness.
- Check any space heaters for proper operation by touching the motor to determine if it is warm before operation.
- Check all surfaces for signs of corrosion.
- Observe the operation of each motor during opening.
- Check motor shafts for normal end play.
- Verify that all motors are smooth-running and free from vibration.
- Check motors and bearings for overheating.
- Note any unusual noises heard during operation. If the motor is fan-cooled, check for proper operation of the fan and that the motor is being properly cooled.
- Check that each motor is wired in accordance with the NEC.
- Verify there is a disconnect switch within sight of each motor.
- Check the internal equipment after disconnecting the motor from its power supply.
- Check electrical connections on the motor for proper attachment.
- Test insulation resistance values on all motors using a megohm meter. Megohm measurements should be taken from phase-to-ground and between phases for all AC, three-phase motors.
- Take megohm measurements at the collector rings to detect cracked or otherwise defective bushings. Readings should be taken using a 500-volt direct current (DC) hand crank or battery-operated megger. Record the results of the megohm meter tests and compare these to prior inspection findings. Any large changes may indicate motor deterioration.
- Recommend overhauling a motor when megohm values for phase-to-ground values are projected to reach 2.0 or less before the next scheduled inspection.
- Recommend that the motor be overhauled as soon as possible if the megohm values are 1.0 or less.
• Check the phase currents in motors under loaded conditions with a clamp-on ammeter for motors of one horsepower or larger. Record the results and compare them to the nameplate data and prior inspection results.

• With the power disconnected, open the inspector ports of the motor to check the interior of the motor. Check that collector rings (slip-rings) are free of carbon, metal dust, discoloration, and deformation. The wearing surface of the collector rings should be smooth, highly polished, and free of dirt, oil, grease, and moisture. Try to determine the source of any detrimental conditions.

• Wound rotor AC motors and synchronous AC motors use brushes to carry current to rotating parts of the motor. For all AC motors:
  o Check that all brushes have free movement within their holders. Each brush holder should be set so the face of the holder is approximately 1/8 inch from the collector ring. Each brush must be reinserted into its original holder and in its original orientation after inspection. It may be helpful to scratch a mark on one side of the brush when removing it to indicate its proper location and alignment.
  o Inspect all brushes for wear. If the remaining portion of any brush within its holder is 1/4 inch or less, the inspector should recommend that all brushes on the motor be replaced.
  o Verify that the entire surface of the brush that rides on the collector ring displays a polished finish, indicating full-surface contact. If a brush is not making full contact over its entire surface, recommend that the brush be re-seated.
  o Inspect the springs that push the brushes against the collector rings. All brushes should be held firmly on the collector ring with approximately the same pressure. Improper spring pressure may lead to collector ring wear or excessive sparking. Recommend that the springs be replaced if this is found.
  o Look for evidence of excessive heat, such as annealed brush springs.

The inspection of electrical span brakes should include the following:

• Check that span brakes are equipped with covers to prevent debris or grease from affecting brake operation.

• Check the mounting and location of limit switches on the brake. Generally, a brake will have a set switch, a release switch, and a hand-released limit switch. Follow the inspection methods listed in Section 4.9.

• Check the wiring in the limit switches.
• Manually operate the hand-release arm to verify that the linkages work properly.
• Check the clearances between the brake shoes and the drum when the brake is released.
• Observe the drum to note the wear pattern. The entire drum should be shiny if it is wearing evenly. Note any uneven wear.
• Make sure no grease, oil, water, or dirt is on the brake drum, as this will reduce braking capacity.
• Check the length of time it takes for the brake to fully release and the brake to set.
• Monitor the brake shoe and drum during operation. If the shoe and drum are not aligned, they will come into contact during operation. This contact could produce smoke and damage the brake.
• Test the insulation of the brake motor with a megohmeter and record the results.

The inspection of warning and barrier gates should include the following:

• Check the exterior of the gate housing for any damage.
• Check the access panels for proper operation.
• Open the housing and inspect for fluid or debris accumulation.
• Closely inspect conduits entering the base of the housing. Oil leaks may flow into the conduits and damage the wiring and environment.
• Inspect the internal equipment.
• Observe the gate arm or barrier during an operation.
• Verify that the flashing lights blink for the duration of the arm's movement. The lights should operate from the time the locks are engaged until the gates are raised.
• Observe the cables powering the flashing lights on the arms.
• Verify the cable is not rubbing against or catching on the gate housing during movement.
• Check the arm for any frayed wire or exposed terminal on the flashing lights. This could pose a danger to a pedestrian.

Gongs are mounted on traffic gates for oncoming traffic. They should be loud. The inspection of gongs should include the following:

• Check that gongs start operating when the warning signals are activated to stop traffic and continue to operate until the locks are released. They should operate again from the time the locks are engaged until the gates are raised.
• Inspect the cables powering the gongs for abrasion or tears.
SECTION 4.9 INSPECTION OF CONTROL SYSTEMS

The inspection of the control desk should include the following:

- Verify that the switches or pushbuttons used to test the indicator lights on the control desk work. Note any light that operates improperly.

- Operate the bridge several times to verify that all pushbuttons, control switches, indicating lights, meters, and indicators operate properly.

- Record all voltmeter, ammeter, and kilowatt meter readings as the bridge is operated. Compare these readings to the records from previous inspections. Dramatic changes in readings may indicate problems and aid with the inspection.

- Interview several of the bridge operators to determine if they have experienced any problems with the controls or other systems.

- Examine the interior of the control desk. Verify that the interior light is working. Check for any loose wires and inspect the wiring. Look for any scorching or discoloration that could indicate a faulty piece of equipment. Inspect all interior equipment.

- Check all relays, especially plug-in types, to verify that they are firmly installed.

- Check for a strip heater and verify that it is operational.

The inspection of the interlocks should include the following:

- Verify that the interlocks in the control system are operating properly with a series of tests. Extreme care must be taken while verifying the interlocks. Vehicular traffic must be stopped by flagmen while testing roadway equipment. River traffic must be made aware of the testing and any potential delays. The testing must be performed in accordance with the AASHTO Movable Bridge Inspection, Evaluation, and Maintenance Manual, as follows:
  - With the bridge in the closed position, perform the following:
    - Attempt to lower the traffic gates prior to sounding the horn or activating the warning lights.
    - With the traffic gate open to vehicular traffic, insert the gate arm hand crank into the traffic gate housing and try to operate the gates from the console. The gate should not operate. Record the results and repeat for all gates.
    - With the locks in place, attempt to operate the bridge span. The span should not operate. Record the results.
During the bridge operation, perform the following:

- For all devices, confirm the motor will not operate if a hand crank is inserted into that device.
- Confirm that the main motors cannot be started prior to the release of the brakes. The main drive motor starters should not engage. Record the results.
- Test the limit switches at fully open.
- Attempt to raise the gates and turn the traffic signals to green before the locks or jacks are fully driven and the bridge span is secure.
- Verify that the traffic signals cannot be changed to green until all gates are raised.

- Note any problems in the interlocking and clearly notify the operators. The operators in control of the bridge must be aware of any issues found in the inspection.

The inspection of the fuses should include the following:

- Verify the fuses are the proper current rating. The fuse ampacity printed on the side of the fuse should match the ampacity on the as-built wiring diagrams.
- If the fuse ratings do not match the as-built documentation, check the load equipment. If the equipment protected by the fuses has changed, the new equipment may require a different fuse size.
- Verify that the fuse ratings are accurately documented. Inspect the fuse terminals for a tight electrical fit.
- Look for corrosion or scorch marks on the fuse blocks.
- Check for wire used to jumper a fuse, leaving the equipment unprotected, but operational. This condition is not acceptable and must be reported. Note any missing fuses.

The inspection of the circuit breakers should include the following:

- Verify that the trip settings on the circuit breakers are accurate. Compare settings to as-built documentation and equipment ratings.
- Molded-case circuit breakers are not accessible due to their plastic cover. Air circuit breakers should have their arc chutes inspected for debris, missing hardware, and damaged chutes. Check the contact surface for corrosion, pitting, and damage. Operate the circuit breaker to determine whether the contacts make and break contact.
- Check the wiring and terminations.
There are many types of motor controllers ranging from simple contactors to motor drives. The equipment may be installed in a panel or motor control center. The inspection of the circuit breakers should include the following:

- Review the manufacturer’s specific written information on the drives on the bridge and follow the inspection recommendations.
- Inspect the motor control panel for any fluid or debris buildup.
- Note any damage to the panel exterior.
- Check the wiring and terminations.
- Inspect the circuit breakers and fuses.
- Inspect the individual contacts for corrosion and scorching.

The inspection of limit switches should include the following:

- Check the wiring and enclosures.
- Note any scratches or damage to the switch exterior.
- Where accessible, open the limit switch and inspect the wiring.
- Inspect the seal of the limit switch and verify that no fluid or debris have accumulated in the housing.
- Check that the limit switches are securely mounted and have little movement or play.
- Lever arm limit switches and plunger-type limit switches have arms that move to trigger the electrical contact. Lever arms rotate around a pivot point in the housing, and plunger-types are pushed into the housing.
  - Inspect the arms for debris, corrosion, and a buildup of dirt.
  - Verify that the arms move freely and do not stick in place. The making and breaking of the limit switch contacts should be audible when testing the arm.
  - Watch the limit switch during a bridge operation.
  - When safe, manually operate the switch to test whether the operation will stop or if the appropriate indicating light energizes.
• Proximity limit switches are generally magnetic sensors that make electrical contact in the presence of a metal trigger.
  
  o Check the limit switch magnetic sensor for a buildup of magnetic filings that may provide a false indication.
  
  o When safe, manually operate the switch to test whether the operation will stop or the appropriate indicating light energizes.

• Open the rotary limit switches and inspect the contacts for any corrosion or scorching. Check the bearings for proper lubrication. The rotary limit switch is coupled to the span drive gearing. Inspect these couplings for proper connection.

• Position indicators, selsyn transmitters, resolvers, and tachometers are all feedback devices that provide position or speed information to the operator or to the motor drives. Inspect the enclosures, wiring, and mountings.

The inspection of relays should include the following:

• Verify that relays, especially plug-ins, are securely mounted.

• Verify that all wires and terminals are tagged and identified.

• Check for any jumper wires that are not part of the logical control system. These wires are added to bypass logical control temporarily and should be removed when the equipment has been repaired.

• Note any wiring without tags or wiring that is not documented on the as-built drawings.

• Determine what equipment the relays with jumpers control, and pay close attention to the interlock testing on the control desk when testing that equipment. Relay identifiers should be on nameplates mounted adjacent to the relays and should match the as-built wiring diagrams.

• Inspect the individual relays for contamination, scorch marks, or discoloration and record any relays with these problems.

• Monitor the relays during a bridge operation to verify proper operation. The inspector will be able to hear a short, sharp, click sound as the relays pull in or become engaged.

• Note chattering relays.

• Use a clock to determine if timing relays are operating properly.
The inspection of PLCs should include the following:

- Review any manufacturer’s manuals for specific maintenance issues with the particular type of PLC installed on the bridge.

- Small switches on the processor and I/O cards, called dip switches, are configured to allow proper operation. Never change these switches.

- Inspect the processors, I/O cards, and remote racks for any dust, dirt, debris, corrosion, or fluid on the equipment.

- Check the PLC diagnostic lights to see if there are any failures in the equipment.

- Inspect all terminals and wires.

- Inspect the cabinet for debris and fluid, and clean air filters on the fans.

- Check the PLC batteries and make sure they are fully charged.

- Check other equipment in the PLC panel, including fuses, circuit breakers, the heater unit, lights, fans, and relays. Verify proper fan, heater, and light operation. Inspect the filter on the fan for an accumulation of dirt and debris. Inspect other equipment as described in this chapter.
SECTION 4.10  INSPECTION OF LIGHTING SYSTEMS

Test the service lighting throughout the bridge. Note any damaged or inoperative light. Check that lights in machinery areas are equipped with guards and globes. Determine whether the fixture or the bulb is inoperative. Carry a typical light bulb during the inspection to test the fixture.

Use a receptacle tester to verify that the lighting receptacles work and are wired properly. Note any damaged receptacles or any exposed receptacles lacking covers.

Navigation lights will be located along the piers or fender system of the bridge and on the span. The fender navigation lights are red fixtures, while the lights on the span may vary between red only and red and green alternating fixtures.

Check each navigation light for damage, broken lenses, loose mounting, corrosion, and functionality. A night inspection may be necessary. Each light should be clearly visible when lit. Note any fixture that is inoperative or damaged. Inspect any rotating lights for proper range of motion.

Navigation signals consist of horns or public address equipment used to alert waterway traffic. Inspect the equipment for any damage, corrosion, or opened enclosures. Inspect the wiring and verify operation. Inspect all signal devices.
# Table of Contents

## CHAPTER 5  HYDRAULIC SYSTEMS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>HYDRAULIC CONTROL SYSTEMS</th>
<th>HYDRAULIC COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION 5.1</td>
<td>INTRODUCTION</td>
<td>2</td>
</tr>
<tr>
<td>SECTION 5.2</td>
<td>HYDRAULIC CONTROL SYSTEMS</td>
<td>3</td>
</tr>
<tr>
<td>Subsection 5.2.1</td>
<td>Constant Horsepower Control</td>
<td>3</td>
</tr>
<tr>
<td>Subsection 5.2.2</td>
<td>Electronic Proportional Control</td>
<td>3</td>
</tr>
<tr>
<td>SECTION 5.3</td>
<td>INTERLOCKS</td>
<td>4</td>
</tr>
<tr>
<td>SECTION 5.4</td>
<td>INSPECTION OF HYDRAULIC COMPONENTS</td>
<td>5</td>
</tr>
<tr>
<td>Subsection 5.4.1</td>
<td>Accumulators</td>
<td>5</td>
</tr>
<tr>
<td>Subsection 5.4.2</td>
<td>Valves</td>
<td>6</td>
</tr>
<tr>
<td>Subsection 5.4.3</td>
<td>Hydraulic Cylinders</td>
<td>7</td>
</tr>
<tr>
<td>Subsection 5.4.4</td>
<td>Pumps</td>
<td>7</td>
</tr>
<tr>
<td>Subsection 5.4.5</td>
<td>Rotary Motors</td>
<td>8</td>
</tr>
<tr>
<td>Subsection 5.4.6</td>
<td>Filters</td>
<td>8</td>
</tr>
<tr>
<td>Subsection 5.4.7</td>
<td>Pipes, Tubing, and Hoses</td>
<td>9</td>
</tr>
<tr>
<td>Subsection 5.4.8</td>
<td>Hydraulic Fluids</td>
<td>9</td>
</tr>
</tbody>
</table>
CHAPTER 5 HYDRAULIC SYSTEMS

SECTION 5.1 INTRODUCTION

The Indianapolis Boulevard and Dickey Place bridges utilize closed-loop hydraulic systems. In a closed-loop circuit design, a single hydraulic pump is used to drive one or more hydraulic motors. The closed-loop circuit is not viable for hydraulic cylinder applications because of the different fluid volume displacements during extension and retraction. The fluid that passes through the actuator is returned directly to the low-pressure side of the pump. For proper operation, the pump must receive the same quantity of oil at its inlet as it is pumping from its outlet.

A charge pump is always used in a closed-loop hydraulic circuit. The charge pump is usually a small, fixed displacement pump with approximately 15 percent of the displacement of the main pump. The charge pump works on the low-pressure leg of the main loop, pumping filtered fluid into the loop. The pressure in the low-pressure leg is maintained between 100 to 300 psi by a relief valve.

During operation, the main pump control can cause the pump's displacement to "go over center." This means that the main pump can pump high-pressure oil from either of its two main ports, causing a clockwise or counterclockwise flow of fluid through the main loop plumbing. This allows the actuator to rotate in either direction.

In closed-loop systems, pressure, flow, and directional control are all achieved by the controlling elements of the pump. Cross-port relief valves are incorporated to protect the actuators from load-induced pressure peaks.

High horsepower, closed-loop systems are compact, operate with a minimum amount of excess fluid storage, and are highly efficient. The pump controls direction, acceleration, deceleration, speed, and torque of the motor actuator so pressure and flow control components are not needed. These systems also provide excellent dynamic braking control, which is highly desirable in most movable bridge applications.
Hydraulic control systems determine how flow and pressure are regulated from the system’s pumps. Three types of hydraulic system controls are commonly used in movable bridge applications: constant horsepower control, electronic proportional control, and hydraulic cylinder control. Each is described below.

Subsection 5.2.1 Constant Horsepower Control

Constant horsepower control, also known as horsepower-limiting control, uses an electric motor connected to the pump and drives the pump at a constant speed. This keeps the pump motor working at a constant horsepower level. To maintain constant horsepower, the mathematical product of flow and pressure must be a constant value. Therefore, if the flow is high, the operating pressure must be low. Since the operating pressure level of a system is dictated by the load conditions, the flow must vary with changes in load-induced pressure to maintain the product of flow and pressure at a constant value.

Constant horsepower controls sense the load-induced pressure and regulate pump flow accordingly. The pump control holds the pump at its maximum displacement until the pressure reaches the point at which regulation or compensation begins. This type of system always uses a system pressure relief valve. Once the end of regulation is achieved, the slightest increase in system pressure will open the relief valve and bypass the minimum pump flow back to the tank.

Subsection 5.2.2 Electronic Proportional Control

Electronic proportional control utilizes a proportional solenoid to vary the pump displacement. The pump varies from minimum to maximum displacement in proportion to the current of a 24-volt direct current (DC) command signal. As DC power is applied to the proportional solenoid, the solenoid pushes the pilot spool with a specific force. When the current, and therefore the force, is high enough, the pump begins stroking and producing flow. Further increases in signal current will increase the pump’s output flow proportionally.
SECTION 5.3  INTERLOCKS

Control systems on movable bridges are provided with interlocking controls that allow the bridge to be operated in a manner that provides safety to the traveling public while protecting the equipment. The requirements for interlocking controls between the hydraulic span drive and other equipment such as span locks, traffic gates, and signals, are discussed in Chapter 4, Subsection 4.9.2, Interlocks.
SECTION 5.4 INSPECTION OF HYDRAULIC COMPONENTS

The inspection of hydraulic equipment requires special precautions due to the use of fluids for the system's operation. Leaks and spills cause slippery areas and special care should be taken when working in the area of the pumps and motors. Frayed or damaged hoses pose hazards since they convey fluids under high pressure. A burst hose can spew hydraulic fluids great distances and possibly cause injury. Hydraulic System Inspections should focus on the following:

- All components should be checked for cleanliness and leakage. Dirt and debris should not be allowed to build up on the components.

- Check the fluid level in the reservoir. Compare actual levels with the recommended levels specified in the bridge's maintenance manual.

- Inspect hoses and pipes for abrasion, kinks, and flattening. Damaged, kinked, or flattened lines restrict fluid flow and may damage pumps.

- Observe and record readings on gauges and compare them to recommended operating pressures found in the bridge's maintenance manual.

- Verify that the reservoir air filter has been cleaned and is free of clogs and contamination.

- Under operation, listen for the occurrence of "water hammering," which is the sudden stoppage of fluid that causes ramming in lines and pipes.

- Under operation, listen for cavitation or a loud rattling in the pump. Cavitation is caused by a lack of fluid passing through the pump and can cause serious damage to the impellers and other parts of the pump.

- Measure the surface temperature of the pumps. Temperatures above 140 degrees Fahrenheit indicate that the fluid may require replacement.

- After checking the temperature of the hydraulic fluid, smell and touch it. If the fluid smells burnt or feels gritty, it is time to change the hydraulic oil.

- Listen and feel for excessive vibration which may cause welds to fail or bolts to become loose.

Subsection 5.4.1 Accumulators

An accumulator stores energy in the form of pressurized hydraulic fluid. Although there are several different types of accumulators, gas-charged accumulators are the most common.
A gas-charged accumulator stores hydraulic fluid under pressure by compressing an inert gas, usually nitrogen. A rubber bladder separates the gas chamber and the oil chamber. Initially, the oil chamber is vented to atmospheric pressure and the gas chamber is pre-charged with nitrogen to a known setting through a gas valve.

Generally, accumulators are maintenance-free. The nitrogen pre-charge should be checked as a part of the inspection as follows:

- Close the isolation valve between the system and the accumulator.
- Slowly vent the accumulator using the venting needle valve.
- Watch the pressure gauge for a gradual decay in pressure as the fluid empties. The moment the accumulator rids itself of all the oil, the needle on the pressure gauge will immediately drop to zero. The pre-charge pressure is the pressure preceding this drop.

If the nitrogen pre-charge is below that value required by the system design, the inspector should recommend that the accumulator be recharged. Recharging an accumulator is dangerous and should only be performed by a qualified technician who is fully trained to properly and safely perform this procedure.

**Subsection 5.4.2 Valves**

Modern hydraulic system valves are very reliable. However, dirty system fluid or unintentional maladjustment could lead to problems with hydraulic valves. The inspector should perform the following for the system valves:

- Verify that pressure settings on all relief valves are correct.
- Check for leaks at the manifold interface.
- Verify that any directional control valve spools move freely.
- Verify that manual override pushbuttons are functional.
- If spools are sticking, disassemble the valve and inspect the internal components for wear, scoring, and fluid debris.
- Check the condition of pilot lines, if applicable.
- Inspect all shut-off valves and their connections to the system pipes for leaks.
- Verify that shut-off valves are fully open or fully closed as required by the system.
Subsection 5.4.3 Hydraulic Cylinders

Hydraulic cylinders are used for span motion or actuation of locking devices. Cylinders should be periodically inspected to ensure proper, safe, and long-term operation. The inspector should:

- Observe the extension and retraction of hydraulic cylinder rods. Span or locking device movement should be smooth.
- Inspect the condition of cylinder rod coating. Look for scoring, nicks, or other surface imperfections that could damage the rod seals.
- Inspect the area around rod seals for fluid leakage. A small amount of fluid is not cause for alarm. If leakage is excessive, recommend the replacement of the rod seals.
- Inspect the cylinder valve manifold blocks and pipe attachments for leaks. Verify that flexible hoses do not scrape anything due to cylinder movement.
- Inspect all connections of the cylinders to the structure or locking device. Verify that all bolted connections are tight. Verify that cylinder end-pin connections have freedom of movement. Verify that cylinder attachments have freedom of movement throughout the entire operating range.

Subsection 5.4.4 Pumps

Inspect system pumps and observe/listen during operation. Operation should be smooth. Verify that pumps equipped with a flow meter provide the required flow. The inspector should:

- Check the pump suction, high-pressure lines, and case drain lines for leaks. Verify that suction shut off valves are fully open, if equipped.
- Check the connections between the bell housing and the pump, and the bell housing and the motor for tightness.
- Check the tightness of the shaft-coupling assemblies.
- Check the tightness of other pump/motor mountings.
- Verify the temperature of the motor under operation. If the temperature is in excess of 140 degrees Fahrenheit, this indicates that the hydraulic fluid should probably be replaced.
- Listen to the pump when in operation. A loud rattling sound is the indication of cavitation, a serious condition which causes permanent damage to the pump.
Subsection 5.4.5  Rotary Motors

Observe and listen to the system’s hydraulic motors during operation. Operation should be smooth. The inspector should:

- Inspect the pressure line and case drain line connections for leaks. If loose, note the condition and recommend they be tightened. Check all housing joints for leaks. Verify that any suction shut-off valves are fully open.
- Check the tightness of the hydraulic motor to its support and mating equipment. Check the tightness of shaft-coupling assemblies, if applicable.

Subsection 5.4.6  Filters

Adequate and proper system filtration is the most important aspect of maintaining a movable bridge hydraulic system. Degradation or catastrophic failure could result from inadequate system filtration.

The abrasiveness of tiny particles wearing the close tolerance surfaces of internal components causes degradation failure. This type of failure spreads throughout the system and is usually not detected until the damage is irreversible. A sluggish system response, the loss of speed adjustment accuracy, the inability of the system to produce full load, and/or overheating, are all indications that degradation failure has occurred.

Catastrophic failure is the immediate failure of a system component and is usually related to large particles causing moving parts to jam or stick. In pumps, dirt can block lubrication passages and cause pump failure. Large debris can collect in orifices which supply oil to components such as the pilot circuit of the pilot-operated relief valve and pressure-compensated flow controls.

In a suction filtration system, the filtering element is located between the reservoir and the pump. The strainer is usually well below the minimum oil level within the reservoir, making servicing inconvenient. It is not unusual for these filters to go unserviced until they starve the pumps and cause cavitation damage.

If the system is equipped with suction filtration access holes, these filters can be serviced without draining the reservoirs.

Pressure filters are commonly used to protect high-pressure components such as directional spool valves and piston-type hydraulic motors. They are contained in a housing that is subjected to the full system pressure and flow. If a clogged pressure filter ruptures in service, a large concentration of contamination could dump directly into the components.

Return-line filtration is based on the assumption that a clean hydraulic system will remain clean if the contamination is filtered out of the fluid soon after it is ingested or created by the system.
Subsection 5.4.7 Pipes, Tubing, and Hoses

Plumbing systems for hydraulic movable bridge machinery often consist of complex arrangements of high-pressure pipes, stainless steel tubing, and hoses. Pipe runs usually contain many bends, elbows, fittings, and mountings due to the complex nature of the bridge structure. Vibration from operation of the equipment, vibrations from vehicular traffic, as well as movement of the equipment itself has the tendency to loosen pipe fittings and pipe supports. Inadequate support can also cause leaks or damage to the plumbing. The inspector should:

- Check for damaged, nicked, or worn hoses, which should be replaced immediately.
- Check all plumbing fittings for signs of leakage.
- Inspect pipe support systems. Check the tightness of hangers and mounting hardware.
- Visually inspect all pump and control valve pilot lines for leakage.
- Visually inspect inlet and outlet plumbing to main pumps.

Subsection 5.4.8 Hydraulic Fluids

Modern movable bridge hydraulic systems utilize either standard mineral oil or synthetic oil as their working fluid. The useful life of these fluids is not infinite. Several factors influence the expected life of hydraulic fluid including usage, operating temperature, system cleanliness, and water intrusion. Synthetic oils tend to oxidize after several years and require replacement. The inspector should touch and smell the hydraulic fluid. If the fluid smells burnt or feels gritty, the fluid should be replaced.
# Table of Contents

**CHAPTER 6**  MECHANICAL SYSTEMS .......................... 2

**SECTION 6.1**  INTRODUCTION......................................................... 2

**SECTION 6.2**  OPEN GEARING ..................................................... 3
  **Subsection 6.2.1**  Gear Alignment .................................................. 3
  **Subsection 6.2.2**  Gear Wear ......................................................... 3

**SECTION 6.3**  BEARINGS ............................................................... 4
  **Subsection 6.3.1**  Sleeve Bearings ............................................... 4
  **Subsection 6.3.2**  Anti-Friction Bearings ................................. 5

**SECTION 6.4**  SHAFTS AND COUPLINGS ........................................ 6

**SECTION 6.5**  LIVE LOAD BEARINGS ............................................. 7

**SECTION 6.6**  SPAN LOCKS .............................................................. 8

**SECTION 6.7**  TREADS AND TRACKS .......................................... 9
CHAPTER 6    MECHANICAL SYSTEMS

SECTION 6.1    INTRODUCTION

This chapter discusses the basic inspection of mechanical components. All machinery components are related to, and function as, a system with the electrical and structural components. A deficiency found at one item would most likely affect other elements. Special care must be taken when inspecting mechanical components. Inspectors must make certain that the power is disconnected to motors and other drive mechanisms to prevent accidentally engaging the motor. Serious injury can result from clothing getting caught in the gears. The gears usually have a liberal application of grease to minimize wear. The grease is difficult to remove from hands and clothing and can cause skin irritation. Gloves should be worn when working around the gears and disposed of after use. Rags or paper towels are invaluable when cleaning gear teeth to obtain tooth wear.
SECTION 6.2 OPEN GEARING

Open gearing refers to gears that are not contained in a sealed housing. The gears are supported by shafting and bearings that are mounted onto fabricated or cast metal structural supports or framing. Distortion of the supports, deterioration of the fasteners, or deterioration of the shims may result in an abnormal alignment and/or wear of open gears. Wear of open gearing is compounded by the constant exposure to weather and the presence of abrasive, foreign materials that lodge in the gear mesh. The most common type of open gearing found on movable bridges is spur gearing. Spur gears transmit power and regulate the speeds of parallel shafts.

Subsection 6.2.1 Gear Alignment

Gears may be misaligned due to incorrect installation or deterioration of the supports. Misalignment may result in accelerated wear and undue stress on the gear teeth.

Inspection for gear alignment should include the following:

- View the grease patterns left behind during operation for even contact across the full tooth width at the pitch line. If the pattern is heavier on one edge of the tooth, or the pattern is not along the pitch line, the shafts are not parallel.
- Determine the amount of misalignment, indicated by grease patterns, by measuring the backlash between the mating gears. Backlash is the space between adjacent noncontacting teeth. Measure backlash to ± 0.003 inch using feeler gauges.
- Check the alignment of the bevel gears. Misalignment can show as heavier contact at the heel portion or the toe portion of the tooth.

Subsection 6.2.2 Gear Wear

Detailed examples of types of wear are described and pictured in the American Association of State Highway Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual.

Inspection for gear wear should include the following:

- Verify the tooth surface is smooth at the contact area. Scoring or deep gouges are evidence of deterioration of the tooth surface.
- Inspect the tooth roots for cracks. This is the area of highest bending stress.
- Inspect each tooth for fins that may form due to plastic flow of the steel.
- Verify that the teeth of one gear properly mesh with the teeth of the other gear and are properly aligned.
SECTION 6.3 BEARINGS

Two types of bearings are used on the movable bridges in Indiana: sleeve bearings and anti-friction bearings. These are discussed below.

Subsection 6.3.1 Sleeve Bearings

A sleeve bearing is a fixed cylinder in which a shaft journal rotates. The sleeve is usually made of bronze and is held to a fixed point within a steel housing. Housings are usually split in order to remove the shaft for repairs. The top half is bolted down to the base, and the base is bolted to the steel structure. Often, the sleeve bearing is provided with a flange that acts as a thrust surface to hold the shaft in the horizontal position.

A sleeve bearing requires lubrication between the sliding surfaces of the journal and bushing. Normally, one or more grease fittings are located at the top of the housing. A path is drilled through the housing and bushing and meets with grooves machined into the surface of the bushing. The groove is usually in a spiral pattern, which helps to lubricate the entire surface of the journal.

Inspection of sleeve bearings should include the following items:

- Inspect bearing supports, mounting bolts, and grout pads for cracks, damage, and deterioration.
- Inspect mounting bolts and cap bolts for tightness.
- Inspect bearing housing for cracks and damage.
- Inspect bushing and flange for cracks and damage.
- Confirm that old grease exits from the space between the journal and bushing during lubrication.
- During operation, note any movement of the bearing or support. This will indicate damage to the system that may need repair.
- During operation, note any movement of the shaft within the bushing. Any excessive radial movement indicates wear to the bushing. If excessive movement is found, other parts of the system may be adversely affected.
- Measure and record the clearance between the shaft and the bushing, using feeler gauges.
- Feel the exterior housing of the bearing after operation. The bearing should remain cool to the touch. Any heat generation may indicate improper lubrication or damage to the bearing.
Subsection 6.3.2 Anti-Friction Bearings

Anti-friction bearings include roller bearings and ball bearings. Typically, heavy-duty, spherical roller bearings are used to transmit power. Lighter-duty ball bearings are commonly used for instrumentation that drives electrical control feedback devices. In general, the clearances of the bearing are set during installation, and the unit is sealed for operation. Little wear occurs at these bearings, so wear measurements are not required. Overheating, unusual noises, and shaft or bearing vibration are indications of potential problems or the failure of an anti-friction bearing. Too much or inadequate lubrication, dirt, rust, or foreign materials in the bearing; a faulty ball or roller; seal failure; and loss of clearance or preloading can contribute to a failure.

Inspection of the anti-friction bearings should include the following:

- Examine bearing supports, mounting bolts, and grout pads for cracks, damage, and deterioration.
- Check the mounting bolts and cap bolts for tightness.
- Inspect bearing housing for cracks and damage.
- Note any movement of the bearing or support during operation.
- Listen to each bearing for any unusual noises during operation. Anti-friction bearings should operate smoothly and quietly.
- Inspect the seals for damage and proper sealing. Excessive lubricant may indicate a problem.
- Feel the exterior housing of the bearing after operation. The bearing should remain cool to the touch. Any heat generation may indicate improper lubrication or damage to the bearing.
- If possible, open the housing and visually inspect accessible portions of rollers and races. Check for internal contamination.
SECTION 6.4 SHAFTS AND COUPLINGS

Shafts transmit torque from one rotating part to another. Shafts ends are usually connected by couplings, which are secured to the shaft by an interference fit and key.

Inspection of shafts should include the following items:

- Inspect the keyways and shoulders for cracks.
- Check suspect cracks using nondestructive testing (NDT) methods.
- Inspect shafts for excessive radial movements and vibration during operation.

Couplings can be rigid, flexible, or adjustable. Rigid couplings are commonly found on older bridges, and are used to clamp shaft ends together. Flexible-type couplings are designed with internal elements that allow for misalignment during operation due to distortion of the bridge structure. The intent is to avoid bending the shafts. They also simplify shaft installation by allowing slight misalignment at the joints. Adjustable couplings are used when an angular adjustment, over time, is needed, or to monitor electrical control devices.

Inspection of couplings should include the following:

- Inspect the keyways for cracks.
- Look for corrosive deterioration and cracks.
- Check the flange bolts for tightness.
- Check for adequate lubrication of flexible couplings.
- Inspect all seals and gaskets of flexible couplings for leakage of lubricant.
- Make sure couplings rotate smoothly and are free of noise during operation. Noise indicates inadequate lubrication or misalignment of the shafts greater than the tolerances of the coupling.
- Disassemble the housings or covers. Inspect the internal flex grids and coupling hub teeth.
SECTION 6.5  LIVE LOAD BEARINGS

Live load bearings transfer vehicular live load from the span to the pier or approach span when the span is in the closed position. The bearings also prevent the span from rolling into the water in the closed position. The assembly consists of a shoe with a rounded surface (mounted to the span) and a flat strike plate mounted to the pier or other fixed structure. Both are secured with mounting bolts and are provided with shims for adjustment of the span position.

Inspection of the live load bearings should include the following:

- Determine if the mounting bolts are tight.
- Inspect the bolts and shims for deterioration.
- Check the contact surfaces of the shoe and the strike plate for deformations and wear.
- Confirm that firm contact exists between the shoe and the strike plate. If a gap exists, measure with feeler gauges and recommend re-shimming.
SECTION 6.6 SPAN LOCKS

A centering device called a span lock is located at the toe of each span to ensure roadway alignment of a rolling lift bridge. The two-part device consists of a tapered male upper and lower jaw and female diaphragm that gradually align the span horizontally during seating. The span locks also serve to transmit the live load shear between the two movable spans. The male jaws are faced with hardened steel shims that can be adjusted to nearly eliminate all movement between the spans under load.

Inspection of the span locks should include the following items:

- Inspect for adequate lubrication.
- Inspect for uneven wear that may indicate span misalignment.
- Inspect fasteners for tightness and deterioration.
- Inspect housing for cracks and damage.
- Observe the device during operation. Under normal conditions, the device should not encounter much sideward force.
On rolling lift bridges, the weight of the leaf during operation is transferred from the curved segmental girders to the flat tracks through the treads. The treads are constructed with sockets that engage mating pintles or lugs on the tracks as the leaf rolls. These serve to position the span during operation and provide resistance against wind forces.

Inspection of the tread plates should include the following items:

- Inspect the mounting bolts that attach the treads to the girder.
- Inspect the contact surfaces for even wear across the width of the tread and track.
- Inspect the treads and tracks for cracks or surface deformation.
- Inspect the lugs, pintles, and sockets for wear and interference.
- Check the girders for cracks. Pay particular attention to the angles between web and flange.