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# 3.6 ELECTRICAL SYSTEMS

## 3.6.1 Introduction

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

1. Power Distribution Equipment
2. Electrical Machinery
3. Control System
4. Lighting Systems

## 3.6.2 Electrical Inspection Tools and Instruments

Several tools that are necessary for an electrical inspection are a megohmmeter, a voltmeter, a live power indicator, an ammeter, a thermometer, and a receptacle tester. 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 megohmmeter is a cable voltage insulation tester used to inspect bridge wiring, cables, and specialty cables.

The inspector should note all equipment on the bridge and the state of the equipment. Even if a piece of equipment is new and operating properly, that still has to be noted. 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 Transportation and Highway Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual and the National Electric Code (NEC). This inspection manual is intended to augment the inspector's prior knowledge of the NEC by providing bridge specific equipment information.

## 3.6.3 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. Typical three-phase electric service voltages are 120/240-volt, four-wire systems (usually found on older bridges) and 277/480-volt, four-wire systems. Some bridges may be furnished with ungrounded three-wire 480-volt electric services.

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 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.

In lieu of a second utility service, a secondary source of electric power may be provided by an engine generator set. An engine generator set utilizes a combustion engine (usually a diesel engine) as a prime mover to operate an electric generator. The generator generates an electric supply with characteristics similar to the utility electric service. An engine generator set may be located permanently at the bridge site or it may be a mobile unit that is brought to the site when needed.

A transfer switch is utilized to select between the primary electric service and the secondary electric service. Typically, this switch automatically starts the engine generator set upon failure of the primary electric service and connects the generator to the bridge electrical system.

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 Panelboards, 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 panelboard 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 panelboards and motor control centers, circuit breakers, fuses, motor starters, motor controllers, and other motor control equipment may be installed on an enclosed panel. Enclosed panels are of custom construction.

Depending on the electric service at a particular bridge, 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 panelboards, 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.

## 3.6.4 Electrical Machinery

Electrical Machinery refers to electro-mechanical devices that operate the movable span and auxiliary devices such as locks, wedges, and traffic control equipment.

### 3.6.4.1 Span Motors

The movable span is provided with one or more span motors that serve as the prime mover for the span. Span motors may be of the alternating current (AC) type or direct current (DC) type. Depending on the type 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 a span drive (electrical part of complete span drive).

The movable span is provided with 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.

### 3.6.4.2 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 are called auxiliary motors and 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 a simple 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 (either manually or electrically) to connect the auxiliary motor.

### 3.6.4.3 Locks and Wedges

The different types of locks and wedges are described in detail in Section 3.5.3. The electrical equipment is very 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 lock and wedge motors are typically simple across-the-line contactors.

### 3.6.4.4 Warning Gates and Barrier Gates

In order to provide protection to vehicular traffic during a bridge operation, gates are used to warn approaching cars and also provide physical protection when required.

Warning gates provide the function of alerting the traffic that they must stop and indicating beyond which point no vehicle may proceed. The gates are usually equipped with flashing lights that also warn the traffic. Traffic signals, or red flashing lights, are used to initially stop the traffic at a pavement traffic line. Once the traffic has come to a complete stop, the warning gates are lowered to indicate that no vehicles may enter.

Some bridges are equipped with resistance gates or barriers that can physically stop a vehicle that is either out of control or whose driver failed to realize the bridge was opening. Resistance gates are rated for a certain size of car traveling at a certain speed. They may be equipped with flashing lights. Resistance gates are needed for bridges whose moveable spans when open do not provide a barrier to prevent vehicles from falling into the waterway. Because they provide a critical safety function, the integrity of their system when deployed is important.

#### 3.6.4.5 Gongs or Horns

Gongs (bells) or horns are used to alert the vehicular traffic traveling on the bridge to be alert to traffic signals. They are intended to operate at the beginning and end of a bridge operation. The traveling public expects the bridge to be in the closed position. In order to prevent sudden and unexpected stops, the gongs aid in making the traveling public aware that the traffic conditions are changing. They are used in tandem with flashing lights and warning signs.

### 3.6.5 Control Systems

#### 3.6.5.1 Control Desk

The control desk is where the bridge operator controls the operation of the bridge and its associated equipment. There are pushbuttons, control switches, indicating lights, meters and indicators on the desk and often a foot pedal switch mounted on the floor at the control desk.

#### 3.6.5.2 Motor Controllers

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. Once the motor is connected to the current it will operate, once 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.

There are many specialty controllers, called motor drives that 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.

#### 3.6.5.3 Drum Controllers

A very common method of motor control, especially on older bridges, is the use of drum controllers. There are primary drum controllers used with DC motors and secondary drum controllers used with alternating current (AC) wound rotor motors.

The rotation of the drum controller handle changes the motors speed and direction. The drum controller is usually mounted on the control desk. It can either control the motor directly, or use a system of motor secondary resistors to control the motor speed.

#### 3.6.5.4 Limit Switches

Limit switches are devices that determine the limit of travel for machinery and provide an electrical signal to stop or change operation. There are several types of limit switches, lever arm, plunger type, rotary, and proximity.

#### 3.6.5.5 Relays

Relays are low current switching devices that provide logical control of a bridge. They can be used independently or concurrently with a programmable logic controller (PLC) system. In order to provide control for an entire bridge, multiple relays are required. The relays are generally located in a panel or enclosure.

When relays are used with a PLC control system, they are generally interposing relays. These relays are located between the PLC outputs and the equipment being controlled. They serve as a means of isolation between the PLC outputs and any electrical faults.

Relays are also used as part of auxiliary systems, such as traffic gates, for control of local equipment.

Machine tool 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 mounted by being plugged into a mounting strip. Wires to electrical equipment are terminated on the mounting strip.

#### 3.6.5.6 Programmable Logic Controllers (PLC)

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

The processors replace the relay logic network with a programmable logical control of the bridge equipment. 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 PLC processors with the state of equipment and provide the necessary interlocks for the processors to start and stop the bridge equipment.

## 3.6.6 Lighting Systems

### 3.6.6.1 Roadway Lighting

Many bridges are equipped with roadway lighting to illuminate the roadway for vehicular traffic. Illumination levels of the roadway vary depending upon the speed of traffic and local standards. Roadway lights are mostly pole mounted fixtures that are offset with a mast arm to overhang the roadway. On most bridges, the roadway lighting is owned, operated, and maintained by a local agency. Inspection of roadway lighting is not normally included as a part of the bridge inspection. However, if a bridge inspector observes a defect in the roadway lighting system it would be advisable to report it to the appropriate agency.

### 3.6.6.2 Service Lighting and Receptacles

Service lighting and receptacles are provided throughout the structure to enable work and inspection in dark areas or at night. Lighting fixtures have various types of bulbs. Receptacles that are exposed to the elements should be provided with covers.

The goal of service lighting and receptacles is not to illuminate the entire structure, but to provide light and power to specific areas and equipment.

### 3.6.6.3 Navigation Lighting and Signals

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 to pass through. Alternating red and green lights mounted on the span notify the boat operator that the span is either not fully open (when the light is red) or is fully open and it is safe to proceed (when the light is green). Lights are installed in accordance with Coast Guard standards and guidelines. Proper maintenance of the navigation 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. It is sounded before opening the bridge.

## 3.6.7 Inspection of Power Distribution Equipment

### 3.6.7.1 Electric Service

Locate all points of electrical service. Most bridges will only have one point of service, while others may have utility service provided to both sides of the bridge. Some bridges may have separate service for special equipment (such as roadway lighting).

Before performing any inspection of the electric service 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 utility 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. All equipment should be firmly mounted. Check the line jacks to verify that none of them have blown.

Electric service will be terminated to a main incoming protection and disconnect panel. Usually this will consist of a service disconnect switch and fuse or a circuit breaker. Inspect the panels for damage, rust, debris or fluid build up. Check the wiring and terminations as described in Section 3.6.7.9. Schedule the insulation resistance inspection 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. If the grounding at the utility is not acceptable, then a thorough inspection of the bridge grounding system should be performed.

### 3.6.7.2 Engine Generator Set

Test the generator by operating the bridge under generator power. Record the voltage of the generator while lightly loaded and when fully loaded. A full-load test should be conducted every three to five years. Observe the generator vibration during operation and compare the amplitude to the manufacturer’s specifications. Inspect the airflow in the generator room and verify that the generator exhaust evacuates the room quickly and safely. Verify that the airflow in the generator area is sufficient for cooling the machinery.

Inspect the generator housing for damage, rust and corrosion. Pay close attention to the generator fuel tank and batteries for any leakage or corrosion. Inspect the generator wiring as described in Section 3.6.7.9.

### 3.6.7.3 Transfer Switch

There are two types of transfer switches, automatic and manual. The automatic transfer switch (ATS) should be operated by simulating the loss of normal power for an automatic switch. Upon sensing the loss of power the ATS should energize the back-up power system and transfer to that source.

The manual transfer switch should be tested in accordance with the bridge operations manual. In a manual system there will be a series of steps required to supply back-up power and operate the switch. Follow the approved procedure and verify the switch operates.

Inspect the panel and wiring as described in those sections.

### 3.6.7.4 Transformers

All transformers should have their exteriors inspected for damage, corrosion, lost paint or scratches. Panel doors or bolt-on covers should be closely inspected to determine whether the hinges and latches operate properly, are sufficiently lubricated, and make a tight seal when the doors/covers are sealed. There should be a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch. If the gasket is brittle, permanently deformed, or missing in areas, the condition should be noted.

The inspector should determine if the transformer is mounted securely. 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. The panel mount must be secure and vibration resistant. Loose bolts or other deficiencies should be noted.

The inspector should listen to the transformer for any unusually noises. This should be done during bridge operations when it is most heavily loaded. Transformers normally have a low, quiet, buzzing sound. The temperature of the transformer should be taken and compared to the specified normal range. A record of the transformer's operating temperatures should be kept.

Oil-filled transformers should be inspected for leakage. Older transformers should be tested for polychlorinated biphenyls (PCBs).

#### 3.6.7.5 Motor Control Centers

Motor Control Centers (MCCs) are cabinets where electrical power is distributed to end devices, and where controls for the end devices are located. 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 as described in those sections.

#### 3.6.7.6 Panelboards

Panelboards are panels with only distribution circuit breakers and on older bridges, relays. Inspect the panel, circuit breakers, and wiring as described in those sections.

#### 3.6.7.7 Enclosed Panels

All panels should have their exteriors inspected for damage, corrosion, lost paint, or scratches. Panel doors or bolt-on covers should be closely inspected to verify that the hinges and latches operate properly, are sufficiently lubricated, and make a tight seal when the doors/covers are sealed. There should be a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch. If the gasket is brittle, permanently deformed, or missing in areas note the damage.

Verify that the panel is mounted securely. 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. The panel mount must be secure and vibration resistant. Any loose bolts should be tightened and the deficiencies noted.

The panel may be equipped with temperature control equipment, such as a heater, ventilation grate, and/or fan. The equipment should be operated so that the inspector can determine if it is operating properly. The ventilation grate filter should be clean and free of dust and debris.

Each panel should be solidly grounded by a conduit fitting or ground bar located in the panel. Verify that the panel is solidly grounded.

Other equipment located within the panel should be inspected as described in their respective sections.

### 3.6.7.8 Raceway System

The raceway system consists of conduits, conduit fittings, junction boxes and terminal boxes.

Conduits typically used on movable bridges are rigid galvanized steel (RGS) conduit, PVC coated RGS conduit and PVC nonmetallic conduit. Conduit is used to protect wire and route it from one location to another. Conduit must be supported regularly. Conduits consist of 10-foot or 20-foot sections coupled together.

The couplings in a conduit run should be checked to determine if the conduit is tightly connected. If a coupling becomes loose, the conduit sections may separate and the wires inside may become damaged.

The rigid galvanized steel conduit should have secure support at intervals not exceeding 10 feet. Nonmetallic conduit should have a support every 3 to 7 feet in accordance with the National Electric Code. Inspectors should determine if all the required supports are present and securely mounted. Each support should be inspected to determine if there are any loose screws or bolts.

Wall mounted conduit runs should be inspected for accumulation of 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.

Conduit fittings are in-line enclosures in conduit that provide bends or taps in conduit runs. The fittings have removable plates that are screwed in place and sealed with a gasket. The plates should be removed and the gaskets inspected for a tight seal. The conduit fitting should be inspected for any debris or fluid.

Junction and terminal boxes are enclosures for the routing of wires. The boxes will be rated for various conditions, water tight, dust proof, corrosion proof, etc. The boxes must be opened and inspected. Wire and terminals are to be inspected as directed in Section 3.6.7.9. The seals around the access panels must be inspected to verify that they provide a watertight seal. Check boxes for accumulation of debris or fluid. Check that 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 fight. Verify that any grounding fittings are properly installed and the ground wire is bonded to the fitting.

### 3.6.7.9 Wire and Cable

Bridge wires are copper conductors that carry electrical power and control to the electrical devices. A wire consists of a copper conductor (occasionally aluminum is used in lieu of copper) that is either a solid cylindrical shape 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 copper wire is covered with insulation, rated for electrical voltage, and a jacket 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 the wire/cable will be exposed to. Refer to the National Electric Code for information concerning jacket and insulation types, wire ampacity, and conductor sizing.

The bridge should be 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.

Warning: High and medium voltage cables require special protection and must be de-energized before inspecting. Only personnel trained on such equipment should perform the inspection. See Section 3.1.3.

The primary concern with cable is insulation failure. Insulation failure is when the jacket and insulation of the conductor wears away. The copper conductors in the cable become exposed, and this can cause electrical faults or the wire to fail. Insulation failure may be caused by overloading, physical wear and tear, exposure to water or corrosive materials, or age.

While inspecting electrical cables, the inspector should visually inspect the entire length of cable for the following:

1. signs of abrasion or cracking on the cable
2. discoloration and over-heating
3. excessive bends or kinks in the wire
4. water or other moisture on the cables

Any of these conditions should be noted as they will reduce the useful life of the material.

Wire and cable 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.

Wire and cables are terminated at devices. These terminations are to 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 a device that is compression-clamped onto the wire, and 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 will sometimes become loose and even fall off the terminal strips. 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 inspect the terminations to verify:

1. All terminals are tight and no wires are loose. Note loose terminals and terminals with problems.
2. All wires are tagged with a wire number.
3. Spot check the wiring with the as-built drawings to verify accuracy.

4. All terminals are marked with the wire number of the wires terminated on it.

5. Any movement or vibration between the panel and wires damaging the wires.

6. Corrosion or rust on the terminals.

Loose terminals will cause heating in the wires and reduce the useful life of the equipment.

When a wire is terminated, the insulation is removed from the bare copper. Verify that all wires do not have so much insulation removed that the exposed copper conductor will come into contact with exposed metal.

During each inspection, the insulation of the wiring should be tested. The method to perform the test is to isolate the wire from power and sensitive equipment, and have an insulation megohm resistance to ground test performed on each individual wire. Testing the cables in this manner, or “meggering” the cables will indicate the state of the insulation. A table should be made recording the wire number and the phase to ground resistance, and a phase to phase resistance with an adjacent disconnected wire. If the resistance value is below one kilo-ohm, the wire is close to failing. If the resistance is zero, the wire has failed. The results of the testing should be compared to previous results to determine if there are any trends in the insulation resistance or the cable test results. This may indicate a problem that has not yet been identified in the run of wire.

### 3.6.7.10 Specialty Cables: Flexible and Submarine Cables

Specialty cables are installed in areas that cannot be serviced by wire in conduit. These include flexible cables and submarine cables. All specialty cable should be inspected as described in the above sections and with the following additional inspections:

Flexible cables are cables routed between fixed portions to movable portions of the structure. Examples are cables from the pivot pier to the swing span, cables from the rest pier to the bascule leaves, and cables from the tower to the lift span. Flexible cables are designed to be very flexible. 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 the near side to the far side of the bridge. The cables are usually trenched into the riverbed. These cables 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 armor should be terminated and grounded at the submarine cable terminal panels in special fittings.

Flexible cables should be inspected during an operation of the bridge to verify their range of motion. The cables should swing freely and move freely during the entire operation of the bridge. There should be no sharp bends or kinks in the cables during operation. If the cables seem to snag on or rub against the structure or equipment, this should be noted. Megohm resistance test the insulation of the individual wires of the flexible cables and record the values.

During the operation, note the effects of wind on the cables. Some installations will be protected from the effects of wind, but in areas where the cables are exposed, consider how the wind will likely blow the cables and assess potential problems.

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.

Submarine cables should be visually inspected, where they are accessible. The inspector should coordinate inspection with low water conditions to see the portion of the cables at the water line. Note any deterioration of the cables. Verify panel terminations and cable supports. When the submarine cable is armored, inspect the armor clamps to make sure the cable is supported and grounded. Megohm resistance test the insulation of the individual wires of the submarine cables and record the values.

## 3.6.8 Inspection of Electrical Machinery

### 3.6.8.1 Motors

Motors have external features and internal features to inspect. Inspection should begin by verifying the motor shaft is free from oil and grease from the bearings. Leaking oil can indicate poor seal or misalignment of the shaft. All keys, bolts, and pins should be inspected to verify they are in their proper position. All bolts along the motor housing should be checked for proper tightness. Where applicable, space heaters should be checked for proper operation. This can be accomplished by touching the motor to determine if it is warm before operation. Painted surfaces should be checked for signs of corrosion.

The operation of each motor should be observed during opening. Motor shafts should be checked to determine if there is normal end play. Motors should be examined to verify that they are smooth running and free from vibration. Motors and bearings should be checked for overheating. Any unusual noises heard during operation should be noted. If the motor is fan cooled, check for proper operation of the fan and that the motor is being properly cooled.

Each motor should be wired in accordance with the National Electric Code (NEC) and there should be a disconnect switch within sight of each motor. If a disconnect switch is not located within sight of each motor, this condition should be noted. After disconnecting the motor from its power supply, check the internal equipment. Electrical connections on the motor should be checked for proper attachment.

A dielectric test should be performed by using a megohm meter test insulation resistance values on all motors. Megohm measurements should be taken from phase to ground and between phases for all AC, three phase motors. Megohm measurements should be taken at collector-rings to detect cracked or otherwise defective bushings and collars for all DC motors; this is done by testing the insulation resistance of ring to shaft and studs (leads) to rings. Readings should be taken using a 500 Volt DC hand crank or battery operated megger. Results of the megohm meter tests should be recorded and compared to prior inspection findings. Any large changes may indicate motor deterioration. The inspector should 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. If the megohm values are 1.0 or less, the inspector should recommend that the motor be overhauled as soon as possible. The inspector should check the phase currents flowing in motors under loaded conditions with a clamp-on ammeter for motors 1 horsepower or larger. The results should be recorded and should be compared to the nameplate data and prior inspection results.

With the power disconnected, the interior of the motor should be inspected by opening the inspection ports of the motor. The collector-rings (slip-rings) should be 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. If any of these detrimental conditions exist, the inspector should try to determine the source(s).

Wound rotor alternating current (AC) motors, synchronous AC motors, and direct current (DC) motors use brushes to carry current to rotating parts of the motor. The brushes should be inspected. The brushes should 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. When removing brushes for inspection, each brush must be reinserted into its original holder and in its original orientation. It may be helpful to scratch a mark on one side of the brush when removing it to indicate its proper location and alignment. All brushes should be inspected for wear. If the remaining portion of any brush within its holder is ¼ inch or less, the inspector should recommend that all brushes on the motor be replaced. The entire surface of the brush that rides on the collector-ring should display a polished finish – this indicates full surface contact. If evidence is observed that indicates that a brush is not making full contact over its entire surface, the inspection report should recommend that the brush be re-seated. The springs that push the brushes against the collector-rings should be inspected. The brushes should be held firmly on the collector-ring and all brushes should be held with approximately the same pressure. Improper spring pressure may lead to collector-ring wear or excessive sparking. If this condition is found the inspector should recommend that the springs be replaced. Excessive heat may anneal brush springs. If this condition is observed, the inspector should try to determine the cause of the overheating.

#### 3.6.8.2 Span Brakes

Brakes should be 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, released and a hand released limit switch. Follow the inspection methods listed in Section 3.6.9.7.

**Limit Switches:** Check the wiring in accordance with 0, Section 3.6.7.9.

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. If the drum is wearing evenly, the entire drum should be shiny from the wear. Uneven wear will allow sections of the drum to rust and corrode while other sections do not. Make sure no grease, oil, water, or dirt is on the brake drum, as this will reduce braking capacity.

During a bridge operation, time the length of operation 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.

The insulation of the brake motor should be tested with a megohmmeter and the results recorded.

#### 3.6.8.3 Auxiliary Motors

The auxiliary motor(s) should be inspected in accordance with Section 3.6.8.1 Motors.

Equipment associated with auxiliary motors should be inspected. The main component of the auxiliary equipment is the motor clutch. The clutch should be operated to verify proper electrical control and range of motion. Verify that interlocking limit switches are triggered by clutch operation.

#### 3.6.8.4 Warning and Barrier Gates

Check the exterior gate housing for any damage and 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 per their respective sections; the wire and terminations in accordance with Section 3.6.7.9, the limit switches in accordance with Section 3.6.9.7.

**Limit Switches:** The motors in accordance with Section 3.6.8.1, and other applicable sections.

Observe the gate arm or barrier during an operation. Verify that the gong operates and the flashing lights blink for the duration of the arm's movement. The lights should start operating when the warning signals are activated and operate until the locks, jacks and wedges are released when stopping traffic. They should operate from the time the locks, jacks, and wedges 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. Inspect the arm for any frayed wire or exposed terminal on the flashing lights. This could pose a danger to a pedestrian.

#### 3.6.8.5 Gongs

Gongs are mounted on traffic gates for oncoming traffic. Gongs should be observed during a bridge operation. The gongs should start operating when the warning signals are activated to stop traffic and should continue to operate until the locks, jacks, and wedges are released. They should operate again from the time the locks, jacks, and wedges are engaged until the gates are raised. The gongs should make a loud, audible sound. The cables powering the gongs should be inspected for any abrasion or tears.

## 3.6.9 Inspection of Control Systems

### 3.6.9.1 Control Desk

Usually there is a switch or pushbutton that will test all the indicator lights on the desk. The switch or pushbutton should be activated to test the lights and verify they all work. Any light that operates improperly should be noted in the report.

The bridge should be operated several times to verify that all pushbuttons, control switches, indicating lights, meters, and indicators operate properly. A functional checkout will indicate whether the equipment is working properly. Voltmeter, ammeter, and kilowatt meter readings should be recorded as the bridge is operated. Readings should be compared to the records from previous inspections. Dramatic changes in readings may indicate problems and aid with the inspection.

As part of the inspection, several of the bridge operators should be interviewed to determine if they have experienced any problems with the controls. The operators may also relate any other problems that they have experienced on the bridge that may aid in the overall inspection.

The interior of the control desk should be examined. Verify that the interior light is working, and note if the light is inoperable or missing. Check for any loose wires and tighten terminations, and inspect the wiring in accordance with the section Wire and Cable. Look for any scorching or discoloration that could indicate a faulty piece of equipment. Inspect all interior equipment. Check all relays to verify that they are firmly installed, especially plug-in type relays. Check for a strip heater and verify that it is operational.

### 3.6.9.2 Interlocks

Interlocks are a mechanism that provides protection to both the bridge users and bridge operating equipment by ensuring various elements of bridge operation occur in a specific sequence, order and condition. A series of tests should be made to verify that the interlocks in the control system are operating properly. 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. Testing must be reviewed and made applicable to the particular bridge inspection. The testing shall be performed in accordance with the American Association of State Transportation and Highway Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual, as follows:

With the bridge in the closed position:

1. Prior to sounding the horn or activating the warning lights attempt to lower the traffic gates. The gates should not lower.

2. With the traffic gate and barrier/resistance gate arms open to vehicular traffic, insert gate arm hand crank into the traffic gate housing and try to operate the gates from the console. The gate should not operate. Record results and repeat for all gates.

3. With the traffic gates open to roadway traffic, attempt to operate the barrier/resistance gates. The barrier/resistance gate should not operate if the associated traffic gate(s) are not closed to traffic. Repeat for all gates.

4. With resistance gates open to roadway traffic, attempt to disengage locks, jacks, and/or wedges. They should not operate. Repeat for all locks, jacks, and/or wedges.

5. With locks, jacks, and/or wedges in place, attempt to operate the bridge span. The span should not operate, record the results.

At the appropriate point in bridge operation:

1. Confirm that if a hand crank is inserted into any device (lock, jack, wedge, etc.) the motor for that device will not operate.

2. 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.

3. Test limit switches at fully open.

Additional recommended tests are:

1. Attempt to raise the gates and turn the traffic signals to green before the locks, jacks, and/or wedges are fully driven and the bridge span secure.

2. 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 of the problems. The operators must be aware of any issues in control of the bridge.

#### 3.6.9.3 Fuses

Inspect fuses by verifying the fuses are the proper current rating. The fuse ampacity should be printed on the side of the fuse and the correct ampacity of the system should be documented on the as-built wiring diagrams. If the fuse ratings are different from 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 and good electrical fit. Look for corrosion or scorch marks on the fuse blocks. Occasionally a fuse will blow and no replacement fuse is available. The inspector may find that a piece of wire has been used to jumper a fuse, leaving the equipment unprotected but operational. This condition is not acceptable and must be reported. Note any missing fuses. It would be good practice for the bridge owner to maintain a supply of extra fuses.

#### 3.6.9.4 Circuit Breakers

Verify that the trip settings on the 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, 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 wiring and terminations in accordance with 0, Section 3.6.7.9.

### 3.6.9.5 Motor Controllers

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.

There are many specialty controllers, called motor drives that provide the same functions listed above as well as speed, torque, and/or counter torque control of the motor. Given the diversity of this equipment and the varied manufacturers that supply motor drives, the inspector should review manufacturer's specific written information on the drives on the specific bridge and follow their inspection recommendations.

The inspector should first inspect the panel that the motor controls are mounted on for any fluid or debris build up. Any scratches or damage to the panel exterior should be noted.

The wiring and terminations should be checked as described in Section 3.6.7.9. The circuit breakers and fuses should be inspected as described in their respective sections.

Motor contactors should have their wiring inspected as described in Section 3.6.7.9. The individual contacts should be inspected for corrosion and scorching.

### 3.6.9.6 Drum Controllers

The drum switch should be inspected for any corrosion or debris. The wires and terminations should also be inspected as described in Section 3.6.7.9. Inspect the drum switch contacts for good solid contact while being operated and any scorching or corrosion.

### 3.6.9.7 Limit Switches

All limit switches should have their wiring and enclosures inspected. Note any scratches or damage to the switch exterior. Where accessible, open the limit switch and inspect the wiring as describe in Section 3.6.7.9. (Some limit switches are factory sealed and should not be opened.) Inspect the seal of the limit switch and verify that no fluid or debris have accumulated in the housing. The limit switches should all be 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 type 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. While testing the arm, the making and breaking of the limit switch contacts should be audible. During a bridge operation watch the limit switch. When safe, manually operate the switch to test whether the operation will stop or the appropriate indicating light energizes.

Proximity limit switches are generally magnetic sensors that make electrical contact in the presence of a metal trigger. The limit switch magnetic sensor should be inspected for a buildup of magnetic filings that may provide a false indication. When safe, manually operate the switch to test whether the operation will stop or the appropriate indicating light energizes.

Rotary limit switches should be opened and the contacts inspected. Any corrosion or scorching should be noted. Bearings should be checked for proper lubrication. The rotary limit switch is coupled to the span drive gearing and these couplings should be inspected 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. The enclosures, wiring, and mounting should be inspected as described above.

#### 3.6.9.8 Relays

When inspecting relays, the inspector should verify that they are securely mounted; especially plug-in relays. All wires and terminals should be 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 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, should cross reference the as-built wiring diagram.

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

The relays should be monitored during a bridge operation to verify proper operation. The inspector will be able to hear the relays “pull in” or become engaged. This should be a short sharp click sound. Chattering relays indicate a faulty relay and the relay should be noted. Use a clock to determine whether timing relays are operating properly.

#### 3.6.9.9 Programmable Logic Controller (PLC)

Care should be taken whenever inspecting a PLC processor. Small switches on the processor and I/O cards called dip switches are configured to allow proper operation. Changing these switches can interfere with proper PLC operation. The inspector should be familiar with the type of processor and not change anything during the inspection. As part of the familiarization process, the inspector should review any manufacturer’s manuals for specific maintenance issues with the particular type of PLC installed on the bridge.

The inspector should inspect the processors, I/O cards, and remote racks for any dust, dirt, debris, corrosion, or fluid on the equipment. The inspector should check the PLC diagnostic lights to see if there are any failures in the equipment. All terminals and wires should be inspected as described in Section 3.6.7.9. Inspect the cabinet for debris, fluid, and clean air filters on the fans. Check the PLC batteries and make sure they are fully charged.

Other equipment in a PLC panel may include fuses, circuit breakers, heater unit, lights, fans, and relays. Verify proper fan, heater, and light operation. Inspect the filter on the fan for accumulation of dirt and debris. Inspect the other equipment as described in their various sections.

## 3.6.10 Inspection of Lighting Systems

### 3.6.10.1 Roadway Lighting

The roadway lighting system may be owned and operated by the owner of the bridge or it may be owned and operated by another agency. If the lighting system is to be inspected as a part of the bridge inspection, the following items should be inspected.

The inspector should inspect the roadway lights at night in order to determine whether the lights operate properly. The inspector should measure and record the intensity of illumination on the roadway at points on a grid.

The inspector should open the roadway light's transformer bases to inspect the wire and cable and the enclosure. The enclosure should be free of debris and fluids. Any damage to the base or pole should be noted.

### 3.6.10.2 Service Lighting and Receptacles

As a part of the bridge inspection, the inspector should test the service lighting throughout the whole structure. Note any damaged or inoperative light. Lights in machinery areas should be equipped with guards and globes. While inspecting, attempt to determine whether the fixture or the bulb is inoperative. A simple method is to carry a typical light bulb during the inspection to test the fixture.

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

### 3.6.10.3 Navigation Lighting and Signals

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.

Each navigation light should be checked for damage, broken lenses, loose mountings, and corrosion. The navigation lights should be tested for functionality. This may require a control switch on the desk be used to activate the lights or a night inspection. Each light should be clearly visible when lit. Note any fixture that is inoperative or damaged. The navigation span lights may rotate along a hinge and this should be inspected for proper range of motion.

Signals consist of horns or public address equipment used to alert waterway traffic. The equipment should be visually inspected for any damages or corrosion, enclosures opened and the wiring inspected as described in Section 3.6.7.9, and subjected to a test to verify operation. Bridges may have multiple signal devices and all must be inspected.

### 3.6.11 Inspection of Remote Operation System

Some of the Moveable Bridges in Wisconsin have been provided with the ability to remotely operate from an operator house located on another nearby moveable bridge. The remote operations provide for a significant savings in operator costs at locations where multiple roadways cross a navigational waterway in near proximity to one another. Remote operation requires US Coast Guard permission. Equipment for these systems include control console at the remote location; camera and camera monitors for providing comprehensive views of the roadway, sidewalks and waterway; bridge–to-bridge communication signals at the bridges for remote operations; and PA systems for communication to bridge users and mariners.

Bridges equipped for remote operation should be operated in all modes from the remote site. Camera monitors should be inspected for providing clear unobstructed views without blind spots. For camera systems with recorders, those devices should be verified for proper recording of camera images. PA systems should be tested to confirm their operation.

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