HEAVY MOVABLE STRUCTURES, INC.

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Grosvenor Resort
Walt Disney World Village
Lake Buena Visa, Florida

"Factors to Consider when Developing an Electrical System Design Philosophy for a Movable Bridge Project"

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Abstract:
Movable bridge electrical system design defies an off the shelf approach and must generally be custom tailored to the specific client's needs. Factors to explore and consider in developing the philosophy of design for a particular movable bridge project include not only technical factors such as specific equipment and/or technology selection but include non-technical factors such as costs and local comfort, and legal and political concerns as well. Overall client satisfaction is dependant on basing the electrical design on an adequate assessment of the client's needs and assuring that the client understands how the proposed electrical design approach best meets those needs.

Introduction:
While making decisions on technical issues is a basic part of the movable bridge design process, these decisions are influenced by a number of other factors. These factors are often interrelated; the direction of an influence in one area will redirect the decisions process in other areas. This paper seeks to provide a broad overview of a number of these factors without attempting a deep exploration of any single factor.

In beginning the design process, it is of foremost importance to identify the Client's objectives and the factors which will influence the course of the design. The Engineer should develop a sufficient understanding of the Clients wishes to be able to prioritize the Client's "Wish List." Where necessary, the Engineer should endeavor to provide adequate education to the Client on the available technical options, the advantages and disadvantages of each, the effect of various factors which will influence the design and the feasibility of implementing a particular system for the Client's bridge. This allows the Engineer to optimize the process of tailoring the design to the client's needs and objectives while making compromises necessitated by the various influencing factors.

The factors to consider include:

- System Components and Configuration.
- Financial Factors.
- Standards and Regulations.
- Maintenance and Operation.
- Physical Factors.
- Local Factors.

It is important to provide enough information to the Client so that the Client can be in full agreement with the proposed design concepts for his project prior to the start of the design. By tailoring the design to the Client's needs and objectives, the design can move in the right direction for the right reason and backtracking and redesign may be minimized or avoided.

System Components and Configuration:

This section will describe the available options to consider when selecting materials and equipment for a movable bridge electrical power and control system as well as the configuration of that system. Sections which follow will describe how each of the other factors listed in the Introduction influence the selection of Materials and Equipment and system configuration.

System power is a primary consideration. Typically, a single utility service is provided along with a backup source of power. The backup source of power may be an additional utility electric service or may be a gas or diesel engine driven generator or alternator. Power system options include the ability to install equipment which can be remotely monitored and/or controlled.

The movable span can be driven by a variety of drive systems. Some of the most common types of span drive systems available include:

- AC wound rotor motors with speed control provided by external resistors or thyristor drives.
- AC squirrel cage motors with speed control provided by AC Flux Vector drives.
- Single speed or two speed squirrel cage motors.
- DC motors with speed control provided by SCR drives.
- Hydraulic motors or cylinders with speed control provided by manually or electronically controlled valves.
- Gas or diesel fueled engine directly coupled to the span drive gear system.

Traffic Gates are typically the vertical type while barrier gates are typically horizontal or vertical.

Motor starters can be provided as part of a Motor Control Center or can be individually mounted in a standard or customized electrical cabinet.

The bridge control system can be based on the use of relays, one or more programmable logic controllers (PLC) or one or more personal computers (PC). Control system options include the ability to remotely monitor or control various parts of the control system. Monitored information can also be displayed with a variety of devices which include liquid crystal displays (LCD), cathode ray tube monitors (computer monitor type CRT), or annunciators or window boxes. PLC's can also provide the option for remote diagnostics via computer modem and a telephone line interface.

Financial Factors:

Funding for construction of the new movable bridge electrical system may come from a variety of sources which include the Client, the Coast Guard or a Federal Government program. The source, amount and timing of availability of funding will dictate compromises to be made in meeting the Client's objectives.

Maintenance costs are also an important consideration although it is typical that more emphasis is put on obtaining construction funding rather than maintenance funding. This factor influences compromises in materials and equipment; the material and equipment costs must be kept within the construction budget but the materials and equipment must be of sufficient quality so as to keep maintenance costs within the maintenance budget (which is often severely limited).

Where construction funding is limited but the need to improve the electrical power and control system is great, improvements may be staged to coincide with the availability of funding and existing equipment which may still have useful service life may be temporarily reused in the improved system and replaced at a later time.

Standards and Regulations:

National and local standards and regulations will have a direct influence on material and equipment selection, electrical system costs and maintenance concerns. National standards typically cited in movable bridge electrical system work include:

- AASHTO American Association Of State Highway And Transportation Officials
- ANSI American National Standards Institute, Inc.
- ASME American Society Of Mechanical Engineers
- AWG American Wire Gauge
- ASTM American Society For Testing And Materials
- EPA Environmental Protection Agency Of The United States Government
- FHWA Federal Highway Administration
- IES Illuminating Engineering Society
- ICEA Insulated Cable Engineer's Association
- IMSA International Municipal Signal Association
- IPCEA International Power Cable Council Engineers Association
- JIC Joint Industrial Council
- NEC National Electric Code
- NEMA National Electric Manufacturers Association
- NFPA National Fire Protection Association
- MUTCD Manual On Uniform Traffic Control Devices
- OSHA Occupational Safety And Health Administration
- UL Underwriters' Laboratories, Inc.

Regulatory agencies include the United State Coast Guard and local traffic control agencies. The Coast Guard has strict requirements regarding the accessibility of waterways to water craft. The Contractor must comply with the Coast Guard's permit process to arrange any temporary disruption to waterway accessibility. Such waterway interruption is usually very limited in duration. Sometimes multiple waterway interruptions are allowed with each interruption limited in duration. This often affects the staging of construction and the type of electrical system configuration possible.

The local traffic agencies may regulate the duration of disruption of roadway traffic and will also require a detailed plan for the interruption of roadway traffic. An interface between the bridge control system and the local traffic signal control system is often required as well.

Maintenance and Operation:

The experience and level of competency of the bridge operators and bridge maintenance personnel is an important factor to consider in movable bridge electrical system design. Operation and maintenance personnel may wish to maintain some similarities between the new electrical system and other bridges that they maintain and operate. These similarities are generally in the area of equipment selection and layout of the control console.

The maintenance staff may be resistant to change in technology or may be responsible for a number of bridges and may wish to maintain a common parts inventory. New technology, such as a PLC based control system rather than a relay based control system, may be totally unfamiliar to maintenance personnel and may require significant education which the maintenance personnel may not be interested in participating in. Standardization of parts for a number of bridges can allow for a smaller parts inventory requiring less capital investment.

If future rehabilitation of other bridges is planned and/or the maintenance staff is open minded to new technology, the new technology can provide improvements in the areas of practicality, ease of repair, reliability, longevity and performance. It is important to choose components which are likely to remain available well into the future. Considering that, despite the consideration of component obsolescence, various components will become unavailable in the future. The design should allow for future retrofitting or component substitution so that the integrity of the electrical system may be adequately maintained as long as possible. Use of a PLC system also allows for remote diagnostic ability using a modem and telephone line. PLC program security may be maintained with such a system simply by unplugging the modem from a telephone jack upon completion of a remote troubleshooting session.

The bridge operators may be operating several bridges and may become confused if the new system is laid out in a significantly different manner from the other existing bridge systems. If plans include the rehabilitation of the other bridges in the future, however, the new design process provides the opportunity to provide for greater ease of operation.

Bridge safety is directly related to the design of the electrical power and control system. The local history of movable bridge accidents and the sensitivity of the local people to the issue of movable bridge related tragedies should be considered in the design of a new system. There have been many incidents of accidents related to movable bridge operation. These accidents have resulted in injury and death as well as damage to property. The safety of pedestrians must be considered as well as the safety of motorists and boaters.

The AASHTO movable bridge specification suggests that interlocking be provided between steps in a control sequence which optimizes safety. In the event of partial system failure, Bypass switches are typically provided to allow the operator to ignore the limitations of a failed component. The manner in which the Bypass function is implemented and executed can vary. The attempt is to attempt to make the control system foolproof to a certain degree. The specific circumstances of each bridge must be carefully considered. There will be a practical limit to how safe a system can be. The operator must also exercise good judgement in bypassing equipment suspected to have failed. The bypass switches can be locked and the key may be stored in an enclosure secured with a combination lock. In this case, the operator would need to notify maintenance personnel of the suspected component failure before the combination for the key enclosure could be obtained.

Another issue for consideration is that of remote bridge operation rather than local operation. During remote bridge operation, the bridge operator relies on closed circuit television and feedback from sensors in the control system when making operating decisions. This method has been employed on remotely located railway bridges. Much consideration to safety and liability issues must be considered if applied to a highway bridge; especially a bridge with great pedestrian traffic.

Physical Factors:

Environmental factors include available space to mount electrical equipment, operator visibility around obstructions and the effects of the environment on the materials and equipment.

Available space is a major consideration in equipment selection. Where space is limited, motor starters can be mounted in standard or custom electrical enclosures rather than mounted in motor control centers (MCC). Where space is adequate to accommodate a motor control center, MCC use affords greater ease of maintenance. Individual motor starters can be located in enclosures of various dimensions. These enclosures have even been covered with counter tops and located below window level in bridge control rooms affording centralized equipment in climate controlled conditions.

Where visibility of gates, roadways and/or sidewalks is sufficiently obstructed to compromise safety, a closed circuit television system may be employed. These systems also allow greater security when cameras are used at the control house door and/or within the control house.

Attention must be given to unique site features. For example, where driveways are located between warning and barrier gates, consideration must be given to the possibility of requiring a traffic gate across the driveway entrance.

Materials should be sufficiently corrosion and impact resistant to provide for a long life. Placement of components also directly influences component life. As an example, steel conduits placed directly on concrete piers subject to much condensation typically corrode faster than conduits spaced away from the concrete surfaces.

Local Factors:

The concerns and political influence of the people who work or live in the vicinity of a movable bridge also exert much influence on the design (and construction) of the bridge electrical system. The combination of the frequency of bridge operation and the speed of operation (drive system performance) have a very direct effect on traffic flow. In areas of great traffic flow, sensitivity to bridge performance is very high (bridge operation has often resulted in rage and subsequent violent actions by motorists). In such circumstances, the extra cost and maintenance associated with the installation of a high performance variable speed AC or DC drive system may be well worth the extra effort.

Noise and/or light from a movable bridge can also cause concern amongst local residents.

Bridge aesthetics and the historical status of some bridge structures is also very important in some areas. Residents living near some movable bridges have banded together to stall movable bridge system design until the proposed design was modified to their satisfaction. In these cases, the placement of conduits and equipment where they can be seen (or heard) by passers-by should be avoided.

Construction and performance of movable bridge electrical systems has contributed much material for local newspapers and radio stations. Where problems with movable bridge systems have become well known, the result has been much pressure on the agencies responsible for the bridge and the designer of the system.

Conclusion:

There are a variety of important factors to consider when developing an electrical system design philosophy for a movable bridge project. These factors can directly or indirectly have great impact on the technical portion of the electrical system design. During the design process, the Engineer must endeavor to fully understand the Client's needs and objectives as well as other influencing factors. The Engineer must provide the Client with the information necessary to attain a consensus of opinion on how the specific electrical design should proceed. This is a highly individualized process and cannot be handled by predetermined assumptions that a specific type of bridge should be equipped with a specific type of system. When adequate effort is used to both, learn from and educate the Client, the opportunity results to optimize Client satisfaction and provide a successful Movable Bridge Electrical System.

Design Consideration Checklist

System Components and Configuration:

- System Power.
- Backup Power.
- Motor and Drive Type.
- PLC vs. Relay vs. PC
- Gates.
- Motor Starters.

Financial Factors:

- Construction Funding.
- Maintenance Costs.
- Stage Project to Available Funds.

Standards and Regulations:

- National.
- State.
- Local.

Maintenance and Operation:

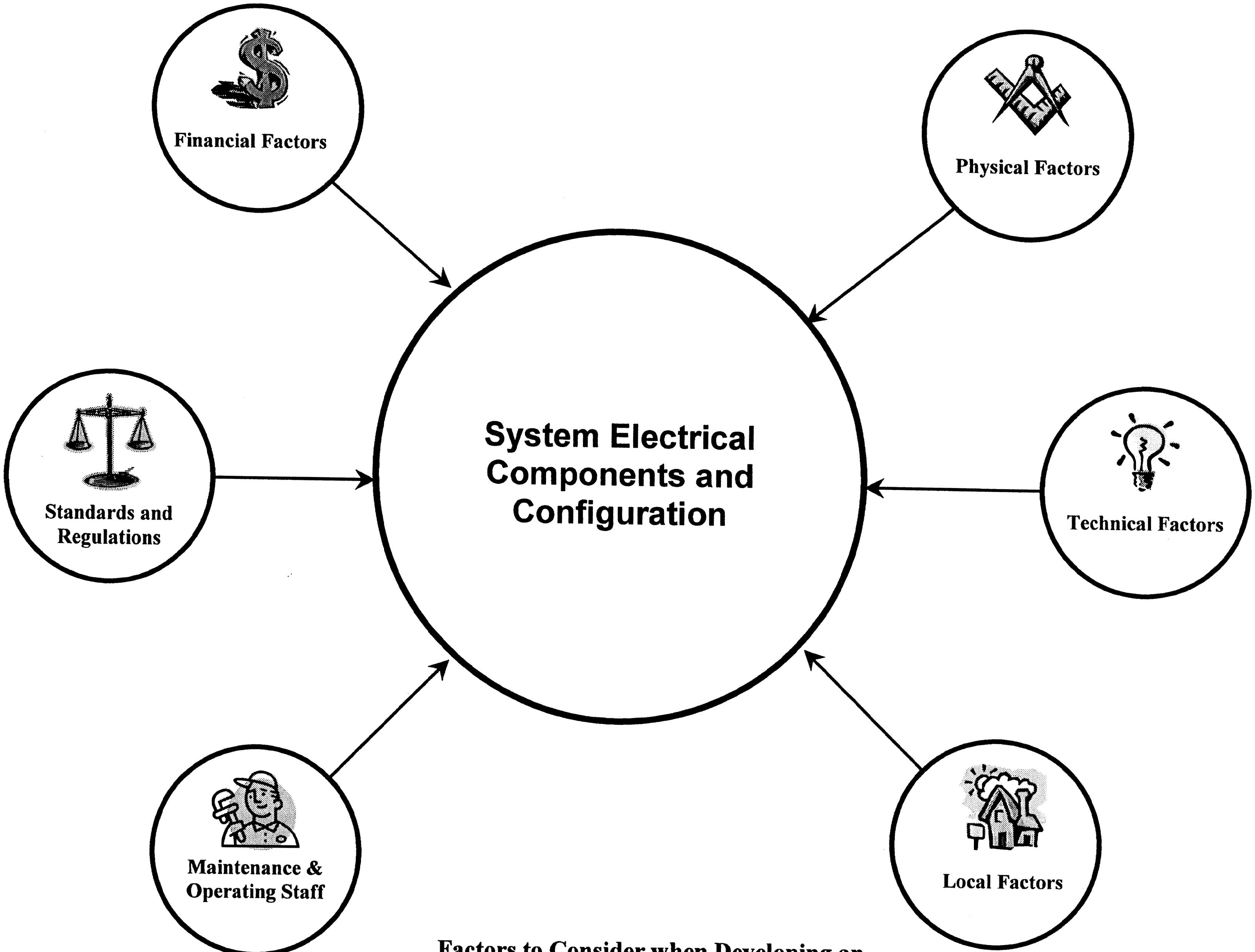
- Concerns about New Technology.
- Experience and Competency Level of Staff.
- Consistency with other Local Bridges.
- Local Movable Bridge Accident History.
- Bypass Operation.
- Remote vs. Local Operation.
- Ease of Control.
- Ease of Repair.
- Remote Diagnostics.

Physical Factors:

- Space.
- Visibility.
- Unique Site Features.
- Environmental Effects on Materials.
- Design Life.

Local Factors:

- Concerns and Political Involvement of Local People.
- Roadway Traffic.
- Aesthetics and Historical Status.
- Noise or Light Pollution.



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"Electrical and Mechanical Rehabilitation of the Conrail Calumet River Vertical Lift Bridge"

by Tim Mander
Aldridge Electric, Inc.

Heavy Moveable Structures
November 2000
Orlando, FL

"CR" Bridge

Electrical and Mechanical Rehabilitation
Consolidated Rail Corporation
Vertical Lift Bridge
Calumet River, Chicago, IL

By Tim Mander
Aldridge Electric, Inc.
Libertyville, IL

Owner / Operator:	Consolidated Rail Corporation Philadelphia, PA
Prime Contractor:	Aldridge Electric, Inc. Libertyville, IL
Consulting Engineers:	Hardesty & Hanover New York, NY

The purpose of this contract...

...was to rehabilitate an 88 year old skewed span, vertical lift, rail bridge. Nicknamed "CR" bridge; it is the only bridge remaining in operation, from a group of 4 bridges built in 1912, at this crossing of the Calumet River, in Chicago, Illinois.

Contract Schedule

Pre-Shutdown Activities:	April 1, 1998 through January 31, 1999
River Traffic Outage:	February 1, through February 23, 1999
Punchlist, Closeout:	February 24 through March 31, 1999

This was a very aggressive schedule, considering the sum total and variety of work required by this contract, combined with the natural conditions of a busy bridge. A bitterly cold and snowy, early winter threatened the scheduled completion of essential structural modifications and other exterior activities. However, human desire overcame the elements and we were blessed with a warm, dry February.

The bridge was successfully operated on February 22, 1999.

Contract Restraints

- *Maintain rail operations throughout the project duration.*

  This requirement was especially difficult since this is the only operating bridge at this crossing of the Calumet River. In times past, there were up to (5) bridges operating at this location. Close coordination with Conrail's on site representative allowed brief, periodic track outages to move equipment on and off the bridge.

  Longer track outages were needed when additional weight was added to the counterweights at the top of each tower.

- *Maintain waterway and bridge operations at all times, through January 31, 1999.*

  Cranes were set on work barges, which were placed on both sides of the bridge to stage and hoist equipment and materials to and from the bridge. The barges had to be moveable within a two-hour period to allow free flow of river traffic.

- *Remove and replace all bridge span operating equipment between February 1, 1999 and February 24, 1999.*

  This all or nothing proposition required months of planning to ensure the success of the project. Once the ropes were cut, there was no turning back. Each relevant activity was identified prior to the shutdown and then reviewed daily for progress during the shutdown. Just-in-time delivery of structural supports and machined equipment left no margin for error and caused a few sleepless nights along the way.

Electrical Elements of the Project

Aldridge Electric self performed replacement of the electrical distribution system, consisting of primary metering equipment, an underground 3760 volt primary feeder, 500 KVA service transformer, 350 KW standby diesel generator, automatic transfer switch, and associated distribution equipment.

Aldridge Electric installed a well designed bridge operating system, manufactured and integrated by Panatrol Corporation, consisting of (2) Flux Vector motor drive controllers, (2) 250 HP drive motors, and a custom built PLC. The bridge is designed for one motor operation. For emergency operations, a 25 HP auxiliary drive motor with gear reduction was installed and coupled to the drive train with a manually operated clutch. Normal and emergency bridge operations are accomplished from a custom built operating console. A new track signal control panel communicates bridge status, from bridge operator to railroad communication and signal personnel, for fail safe operation of the bridge.

After fabrication, all control equipment was staged and temporarily wired at Panatrol Corporation for a full control system test. This was done to ensure we would have no unforeseen problems with the equipment or control logic once the equipment was on site. Once completed, the motor drive equipment was transported to a facility in Milwaukee for a full load test of the motors, motor controllers and associated equipment. Upon successful completion of the test, the equipment was delivered to the job site and immediately installed.

Multi-conductor, "droop cables" were installed to provide power and control wiring to the bridge span. The cables are terminated in termination cabinets, which are attached to custom fabricated platforms, mounted at the middle point of each tower and at corresponding corners of the bridge span. The cables are attached with flexible cable grips and laid over a cable deflector to keep the cables out of the waterway during operation of the bridge.

Miscellaneous electrical work performed as part of this contract included replacement of bridge span lighting fixtures, convenience receptacles and control devices on the tower structures and bridge span. Machinery room electrical equipment was completely replaced as well.

Structural Elements of the Project

Aldridge Electric subcontracted construction of a new bridge operator's building to Illinois Constructor's Corporation. The building contains electrical distribution equipment, motor drive controllers, and bridge control and operating equipment. The building also serves as a work area for a full time bridge operator. The building sits on two pre-existing piers, which previously served as supports for a neighboring bridge.

Illinois Constructor's Corporation changed the design of the operator's building from structural steel to structural concrete, electing to use cast-in-place concrete columns and pre-cast concrete floor support beams. The walls, roof and interior finishes remained unchanged.

A structural steel stair and walkway provide access to the building from the support piers and bridge span. A wood timber fender system was added to the side of the piers to protect the building from passing vessels.

Structural steel platforms, installed on each bridge structure, provide access to the uphaul and downhaul operating rope takeups and droop cable support platforms. Structural steel platforms were also installed on the bridge span to provide access to the secondary deflector sheaves and droop cable support platforms. In addition, modifications were made to the existing grating around the operating drums and machinery areas.

Attachment of structural supports to the structure by welding was prohibited. The original riveted connections were replaced, where required, by bolted connections. Additional holes were drilled through the structure, and reamed as required, to provide connection points for each new structural component. To expedite delivery, many structural components were field drilled due to the difficult or impractical task of field measuring connection locations prior to shipment.

A local steel fabricator was contracted to final design, fabricate and deliver all structural components for the project.

Mechanical Elements of the Project

Rehabilitation of the bridge operating machinery was by far the most challenging aspect of this project. Aldridge Electric subcontracted procurement, coordination and installation of machinery, machinery supports and all related items to Illinois Constructor's Corporation.

Prior to removal or installation of equipment on the bridge span, the balance condition of the bridge was calculated using "strain gage" testing procedures. The weight of the span was increased by this project and equal weight was added to the main counterweights during the shutdown. A post construction strain gage test was conducted and found the bridge to be span heavy by an acceptable amount of 34,000 pounds.

Auxiliary balance chains (12) were found to have worn link pins. The chains were detached from the bridge and hoisted down to the ground, where the pins were replaced. An extra chain was found on site, reworked and rotated with the first chain removed, to expedite the process and maintain balance at all times.

Every effort was made to reduce the amount of work to be done in January and February. Items were prioritized and expedited based on where they were located on the bridge and if we could install them prior to the shutdown. Much of the work on the structures and span was related to the operating rope supports and tensioners. Sheave assemblies were pre-assembled and hoisted onto the span in one piece. Supports for the uphaul rope deflectors and take up supports were installed at the top of each tower. Reinforcement of the structure and span for connection of new machinery supports was also completed prior to the shutdown.

The operating drums presented a number of challenges. Floating shafts, between the drum shaft and drive train, were removed, re-machined and returned to the job in a matter of days. The drums themselves are so large, only one source could be found to make them. The drum support bases required extensive reinforcement of the span and all of the drum work had to be done during the shutdown. As soon as the drums were set in place and made ready, the process of reeving (4) 1" pre-stressed ropes per drum was begun.

In the machinery room, only the open gearing would remain. All other equipment was removed, weighed, and scraped. The pinion shaft was promptly removed and sent out for re-machining. Parts of the floor were removed to gain access to the floor beams, which were then reinforced to support the motor and gear box support structures. Everything was hoisted from the barges through holes cut into of the sides of the room. The old operator's coop was cut apart and reduced to become a simple platform below the machinery room.

Once the pinion shaft was returned and the supports were in place, the gear reducers, brakes and motors were set, coupled and aligned. Prior to the shutdown, the major components were pre-fitted at Illinois Constructor's shop to ensure that all of the various parts were correct and on hand. Other than the electric clutch for the auxiliary motor, which subsequently was changed to a manual clutch coupling, everything went together as it was designed.

Addressing the Safety Issue

A brief safety meeting was held each morning with everyone on the job to discuss the day's activities and reinforce the importance of safety on the project. The objective was to create a sense of importance about safety. Everyone was reminded that at any given time, one missed step could cause a serious injury to themselves or a fellow worker. One moment of distraction by one person could spell disaster for many.

To ensure a safe work environment, safety department representatives from the owner, contractors, and their insurance companies, frequently conducted safety inspections. A hazard analysis of all major activities was completed and used to evaluate specific safety requirements and procedures. Everyone on site understood their responsibility for safety and was encouraged to report unsafe conditions.

The owner provided full time flagmen to control access to the structure, warn the construction crew of approaching trains, and report any unsafe conditions. By constantly monitoring rail traffic and worker access to the bridge, workers were able to walk on and off the structure, move and stage equipment, and perform construction tasks, without interfering with rail traffic or risking their safety.

There was no property damage and there were no injuries for the duration of the project.

As always, it is the human element that makes a project successful.

Many thanks to Ken Aldridge, Lee Bennett, Don Chesny, Dean Chrones, Mike Connolly, Ron Davis, John Gimblette, Michael Goich, Vandana Gogate, Steve Harlacker, Jerry Johnston, Brad Kopping, Mark Lustig, Rob Moses, Abbas Pourbohloul, Jim Quinlan, Roy Rasmussen, James Richter, Steve Rivi, Pete Roody, Bob Schless, Doug Setmeyer, Paul Skelton, Terry Southard, Chris Svara, Gerry Weitzel, Debbie Wolff, Charles Yordy, and Frank Zetthe.

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