Heavy Movable Structures, Inc.

SEVENTH BIENNIAL SYMPOSIUM November 4 - 6, 1998

Grosvenor Resort Walt Disney World Village Lake Buena Vista, Florida

"Better Electrical Documents Allow Quicker Construction and Fewer Claims"

by

Robert Tannor, S.N. Tannor, Inc.

BETTER ELECTRICAL DOCUMENTS ALLOW QUICKER CONSTRUCTION AND FEWER CLAIMS

By Rob Tannor, P.E.

of

S.N. Tannor Engineering Corporation, P.C. 222-02 Merrick Boulevard Springfield Gardens, New York 11413 718-276-6985

> 7TH Biannual Symposium of Heavy Movable Structures Orlando, Florida

> > November 4-6,1998

INTRODUCTION

Drawings are becoming less detailed while specifications for movable bridges are getting thicker. Plans and specifications are becoming performance specifications and drawings that are conceptual are leaving too much to the Contractor, Control System Integrator and too much to chance. Construction schedules are compromised and claims increase.

Plans and specifications are written with the assumption that Contractors have engineering design experience in movable bridges. This flies in the face of low-bid reality where the only experience required is demonstrated ability to get a Bid bond and the low bid on bid day.

Performance Bond Insurance Companies indicate that the Construction of Movable Bridges is one of the highest risks that they underwrite, because of the high rate of bankruptcies of Construction firms attempting their completion.

Department of Transportation's don't usually have the luxury of prequalifying bidders or selecting the winning contractor in a "QBS-Quality Based Selection" contracting method similar to Engineering procurement.

Construction delays are caused by unseen work or conditions discovered during construction or unanticipated work caused by an interpretation of the specifications, and if the unanticipated work is not in the contractor's estimate for the work, a claim is sure to follow.

To properly provide constructable contract Plans and specifications, more information needs to be included in the bid documents.

MINIMUM STANDARDS FOR ELECTRICAL SPECIFICATIONS

The specifications for both Magnetic Relay controlled movable bridges and Programmable Logic controlled movable bridges have common elements that need to be clearly addressed.

A detailed explanation of how the control system works and its key features are a basic requirement. A typical bid cycle is only three to six weeks and this is not enough time to allow an experienced, qualified bidder to review, in detail, the control system functions.

The specifications should provide general electrical requirements and general electrical components to be used. For specified materials, provide the name, catalog number and manufacturer's phone number. Provide similar information for equal products also.

For example, the general electrical specifications would list the type of wire, conduit, junction boxes, engine generator sets, transfer switches, circuit breakers, disconnect switches, lighting, heating, recepticles, light switches, wire tagging methods and means, and grounding methods. Also construction details such as supports, hangers, expansion joint fittings, boxes and terminal cabinets should be provided.

The general electrical requirements are important and can influence the installed electrical cost. For example, the selection of Nema 4X stainless steel junction boxes instead of Cast Iron has a dramatic impact on cost and spacing of conduit supports has a noticeable affect on the final constructed cost and time to deliver the project. Read the 1996 HMS Symposium paper entitled: "A Comparison of the 1988 AASHTO Electrical Requirements and the National Electrical Code" for cost saving ideas.

The Machinery Brake subsystem should be described and highlighting any products and specification requirement that is not provided by the specified manufacturers part number with clear warnings that the specification requires the contractor to take the manufacturer's specified product and modify it to meet the detailed written specifications. For example the covers on some brakes may not be available from the manufacturer in specified Stainless Covers, heating elements may not be available from the specified manufacturer for brake thrusters.

The machinery drawings should clearly indicate the specified equipment that the dimensional layouts were developed from.

Barrier gate and Warning Gate Subsystem should be described by similarly highlighting items that are not standard to the specified manufacturer's Part number or product. For instance, putting the motor starters or drive in a location which differs from standard product, or if the control circuitry would be different from the manufacturer's standard product, the required gate control circuits should be provided in the contract drawings.

The spanlock subsystem should be specified in the mechanical section but close coordination with the electrical specifications and drawings is necessary to properly integrate the electrical requirements for the span locks into the control system. Information such as horsepower, voltage, current of the motors should be given along with the specific limit switch information.

For motor drives of any design, it is not good enough to merely specify the drive, but the drive must be described and its control must be clearly indicated. For example, all of the external drive input's must be described such as a tachometer with a 0-100VDC signal, speed/torque control inputs, and of course the drive power outputs. The adjustment points must be described fully and the specification written to highlight any customization of a drive to meet the specifications. If a motor drive must be modified for the specific application, it should be stated in the specifications.

SPECIFICATION AND DRAWING REQUIREMENTS FOR A <u>MAGNETIC</u> RELAY LOGIC CONTROLLED BRIDGE

All limit switches should be listed and their specific function should be described. Four things need to be described or listed for each device 1) function, i.e. what it specifically should do (each contact or position), 2) manufacturer, 3) part number, and 4) Manufacturers telephone number. For example, a "Fully seated limit switch" could be described that it detects in the closed position (it is normally open), the bridge has

reached it's fully seated position, along with the previously described Manufacturers, part numbers, and telephone numbers. Other similarly described limit switches may be ones for span locks, brake limit switches, barrier gate and warning gate limit switches, and Bridge Position Rotary Cam type limit switches.

The Rotary Cam limit switch's functional description is one of the most important on the movable bridge and the specification should address it carefully and completely. Each cam's contact should be described as to it's function and again, the Manufacturers, part numbers, and telephone numbers should be provided.

Detailed sequence of operation with cross references to the Contract Drawing's magnetic ladder logic must be provided. Special features, special interlocks, special external tie in's should be elaborated on in great detail. For example, external instantaneous output of the electrical control system provides an input to the Closed Circuit TV system control system to send cameras to preset positions.

Ladder Logic should be provided with relay contacts cross referenced. The ladder logic should indicate in which relay cabinet each relay should be placed and the ladder logic should be able to be built without changes from the provided ladder logic.

The drawings should provide a schematic wiring block diagram. The schematic wiring block diagram should indicate each electrical and electrical/mechanical device with the size of the conduit and number of wires necessary to serve the equipment/device. See Attachment 1.

The contract drawings should also include detail point to point wiring diagrams showing each wire from the control panel to the electrical device or electrical/mechanical device, Attachment 2. This will allow the contractor to care about the routing of the conduits and wires which is a standard requirement, and not have to engineer the point to point wiring diagrams to make the electrical control system work. There are software programs that also provide generation of point to point wiring diagrams from relay logic diagrams.

SPECIFICATION AND DRAWING REQUIREMENTS FOR A PROGRAMMABLE LOGIC CONTROLLED BRIDGE

All of the items listed in the magnetic controlled bridge should be provided plus more. It is common practice on a PLC controlled bridge to merely provide a sequence of operation and a schematic drawing showing interconnection of control system devices with a one line diagram. Such diagrams are too general and leave too much detail engineering to the Contractor to ensure timely delivery.

Again, all limit switches should be listed as described above.

Ladder Logic should be provided with relay contacts cross referenced. The ladder logic should indicate in which relay cabinet each relay should be placed and the ladder logic should be able to be built without changes from the provided ladder logic. There are

software programs that allow debugging of ladder logic without building the physical equipment.

The ladder logic however, is not enough. The Programmable Logic Controller movable bridge requires signals, in a "star" configuration connected to a black box:



Showing all of the external devices schematically connected to the PLC does not provide the most critical part of the PLC controlled movable bridge...the PLC logic.

The PLC Logic should be provided as part of the detail design engineering to ensure that the design and operational philosophy of the owner is carried through the design and construction into the finished product.

In magnetic logic controlled bridges, the complete ladder logic should be shown in the drawings. Likewise, in the PLC controlled bridge, the relay logic along with the black box (PLC) logic should be shown.

Arguments could be made about each PLC offered by different manufacturers are different and the ladder logic representation for each is different. However, movable bridges are designed around specific equipment such as motors and brakes with specific dimensional details. Likewise, when the PLC ladder logic shown is provided from a specific manufacturer, then if the Programmable Logic Controller is changed to another manufacturer, then the responsibility and cost of providing the ladder logic on another manufacturer's PLC would be the responsibility of the contractor the same way as if the contractor would choose to provide a different brake assembly than shown on the mechanical drawings.

The Owner will have three available resources to draw upon for changes to a Programmable Logic Controlled bridge. The Owner can do it in house provided that they were furnished with copies of the PLC ladder logic program by the Contractor, the owner can call upon the Control System Integrator that provided the PLC control system to make the changes, or the Owner could call the Design Engineer to make the changes to the control system.

FACTORY TESTING

Factory test requirements are too vague and leave too much for interpretation by others. Clear and concise language must be provided to ensure simulation of the electrical control system for a bridge. The factory test must be approved before shipment of the control system and if necessary, a factory re-test should be done before shipment of the control system to verify, by the engineer, that the control system meets the contract requirements and there are no inherent safety flaws.

As a minimum, the control panels and starter panels, control desk, and rotary cam limit switches should be used at the factory test. Also, the motor drives and motors, if provided by a "bridge control system vendor" should be tested at the factory.

If the electrical control system equipment has defects, a punchlist should be generated within a day of the factory test, the punch list should be addressed, and another factory test must be scheduled. Equipment may be shipped only when it receives final approval from the Design Engineer.

FIELD TESTING AND TEST RESULTS

The Owner and Engineer must properly address the "window of time" necessary for checkout of field wiring and field integration of the control system. If the project is a rehabilitation, blocks of time are needed for the field integration of the control system work.

Field test requirements need to be project specific and electrical control specific so as not to delay testing and clearly define the test requirements.

Final field testing should be broken down by subsystems such as Gates, locks, brakes, and motors. Each subsystem should be checked without required interlocks to check discrete functionality. Upon subsystem checkout, interlock checkout of sequence of operation must be ensured. The Engineer should furnish the detailed job specific interlocking checkout as part of the specifications.

If strip charts are desired, the engineer must clearly specify the desired information on each x-y axis. The Electrical Engineer should verify the information to be recorded with the Mechanical Engineer.

The strip chart recordings should be done by an experienced testing company similar to requirements for strain gauge testing and similar to requirements for bridge control system integrators.

Final field integration and final testing takes time. Basic required testing ensuring proper interlocking of electrical devices is the minimum acceptable criteria for testing.

MANUALS

The Operations & Maintenance Manual requirements and vagueness, cause disputes, anguish, and must be resubmitted too many times.

The contents of the manuals should contain the as-built information and drawings used to construct the bridge. Added requirements beyond the scope of previously required submissions delays the entire process of manual preparation, since new drawings and information are being requested and being reviewed.

Manuals are being filled with information that is unnecessary for the need to operate and maintain the bridge. Teaching electrical maintenance is beyond the scope of manuals. Presenting useful information to operate and maintain the bridge is required.

An option available to the Owner is preparation of the Operations & Maintenance Manual by the Design Consultant. The Design Engineer can include the as-built drawings including the as-built control system drawings and vendor information. Furthermore, the Engineer should be familiar with the expectations of the Owner for the manuals.

CONCLUSIONS

The Electrical Contractor is the last contractor to complete work on a movable bridge project. Quicker construction of movable bridges can be achieved by better and more complete specifications and drawings. Plans and specifications must be written by Engineers with the specific knowledge that Construction Contractors are not usually Engineers, but are tradesmen that have gone into business to provide Construction Services for others, not Engineering Services.

Construction delays are caused by "unseen" work or unanticipated work caused by an interpretation of the specifications. The unanticipated work, not in the contractor's estimate for the work, will result in a claim. Providing necessary information to build a bridge will provide for construction on time, on budget, and without construction disputes.

CHECKLIST FOR ELECTRICAL DOCUMENTS

COMMON REQUIREMENTS

Detailed review of control system functions Specify components with detailed function, catalog number, phone number Detail required modifications to manufacturer's standard products Limit switch function for each contact Motor drive input and output signals Detailed job specific sequence of operations Job specific factory test requirement Field integration of control system "window of time" to allow problem solving Job specific field test requirements Operation and Maintenance Manual contents to contain useful information

No "If X, then provide Y" specification requirements (See Page 9)

MAGNETIC RELAY LOGIC	PLC LOGIC	
Detailed working ladder logic	Detailed working ladder logic	
Control Desk and Control Panel layouts	Control Desk and Control Panel layouts	
Working and Verified Relay Ladder logic	Working and Verified Relay Ladder logic	
with cross referenced relay contacts	with cross referenced relay contacts	
shown and annotated ladder rungs	shown and annotated ladder rungs	
Schematic block wiring diagram with	Schematic block wiring diagram with	
conduit size and wire contents to each	conduit size and wire contents to each	
device	device	
Wiring diagram showing each device with	Wiring diagram showing each device with	
wiring given	wiring given	
Factory test accepted by Engineer	Factory test accepted by Engineer	
	Verified Programmable Logic Controller	
	Ladder Logic cross referenced with relay	
	contacts and comments on rungs	

SAMPLES TO AVOID

General

"The exact extent of the work and resultant quantities cannot always be accurately determined prior to the commencement of work. These contract documents have been prepared based upon field inspection and other information available from existing shop drawings. Actual field conditions may require modifications in construction details in accordance with field conditions. In order to make the electrical and ventilation systems operable, the contractor may be required to furnish and install additional material. The cost of additional work and material shall be deemed to be included in the unit price of the respective items unless otherwise permitted by the Engineer."

"Any incidental apparatus, appliance, material or labor not herein specifically mentioned or included that may be found necessary to comply with the requirements of the related documents and referenced standards or codes shall be furnished by the Contractor without additional cost to the Department."

"The Engineer shall be allowed, for the examination of a set of more than five (5) shop drawings or submittals, two (2) working days for each shop drawing or submittal in the set after receipt of the submittal."

"All electrical equipment and its installation shall conform to the requirements of the latest revision of the Standard Specifications for Movable Highway Bridges of the American Association of State Highway and Transportation Officials, except as may be otherwise provided herein...Materials and construction shall conform to the requirements of the current National and New York City Electrical Code..."

"The exact extent of the work and resultant quantities cannot always be accurately determined prior to the commencement of work. These contract documents have been prepared based upon field inspection and other information available from existing shop drawings. Actual field conditions may require modifications in construction details in accordance with field conditions."

"For bidding purposes, the Contractor shall assume the most restrictive (expensive) method will govern and shall prepare his bid proposal to reflect the most restrictive (expensive) method."

"The Contractor shall prepare and submit for review within 90 working days after the award of the contract, working drawings and samples."

Field Wiring

"Based on the preliminary wire count it is estimated that sufficient conduits are available to rewire the existing installation. Should the conduit wire fill percentage exceed the mandated NEC code requirements, the contractor shall run additional conduit to allow proper conduit wire fill. The contractor shall provide access to the conduits at no additional cost and upon inspection and approval of the engineer, an extra work order shall be issued by the engineer to add additional conduits."

"It is the contractor's responsibility to ensure adequate conductors are available for proper and complete installation of the system. Additional conductors if needed shall be furnished, installed and wired at no additional cost."

"The Contractor shall provide conductors of sufficient number and size, including spares as many be required for the installation in accordance with wiring diagrams on his approved drawings."

<u>Gears</u>

"Clean the following of all dirt and debris and relubricate: a) Sheave ring gears and pinions...The following machinery components shall be thoroughly cleaned and relubricated as described below. The contractor shall provide new lubricant which is equal to the type currently being utilized by the department for each particular component. All procedures shall be performed in the presence of the engineer and are subject to his approval...The gears and pinions shall be cleaned of all debris by the use of solvents, rags, and scrapers."

Gates

"Anchor bolts are to be reused with double hexagonal nuts if found in satisfactory condition. If not, they are to be restored or replaced, as ordered by the engineer."

Motor windings

"The Contractor shall arrange for and provide all the necessary field tests, as directed by the Engineer, to demonstrate that entire electrical system is in proper working order and in accordance with the Plans and Specifications. The test shall include, but not be limited to continuity and insulation resistance testing of conductors..."

"All windings shall be checked for damage and repaired or replaced as necessary."

Field Testing

"Measure and record insulation resistance of windings using 1000volt megger...If the measurements continue to be less than ten megohms, the motor windings shall be replaced."

"Under this Section, the Contractor shall schedule and test the various systems and components at the fabricator's shop prior to shipment...A detailed testing procedure and limits of acceptance similar to applicable sections of "Testing Procedures for the Emergency and Normal PLC Control Systems of the Marine Parkway Gil Hodges Bridge will be prepared by the Engineer based on the approved submittals and shop drawings...The number of tests required by the Engineer shall be dependent on the satisfactory shop test results or field test results of the bridge control system and bridge machinery."

"The [motor] testing shall be performed using an appropriate multi channel 3-phase strip chart recorder. Each test shall include scale factors, motor nomenclature, bridge name, time of test, day and date. The recorder shall be capable of changed amplitude and time scale factors to produce a suitable, easily interpret[ed] table chart. The recorder speed shall not be in excess of 1 centimeter per second."

Training

"The training shall be thorough and complete, and if in the opinion of the Engineer, more time is needed than the mandated ten days, the Contractor shall provide such training without additional compensation...The Contractor will prepare a syllabus for the training and it will be reviewed by the Engineer at a future date."

Waterway work

"Upon completion of the bridge work, an inspection of the waterway bottom shall be performed to insure that all bridge construction waste materials have been completely removed from the waterway...The contractor shall remove any bridge related debris, resulting from the current or prior work or occurrences, discovered during this survey."







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ATTACHMENT 2

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