Heavy Movable Structures, Inc.

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"The Rehabilitation of the Arthur Kill Lift Bridge"

by

John W. McConnell, Jr., P.E., Consoer Townsend Envirodyne Engineers, Inc.

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REHABILITATION OF THE ARTHUR KILL LIFT BRIDGE

By: John W. McConnell, Jr., P.E.

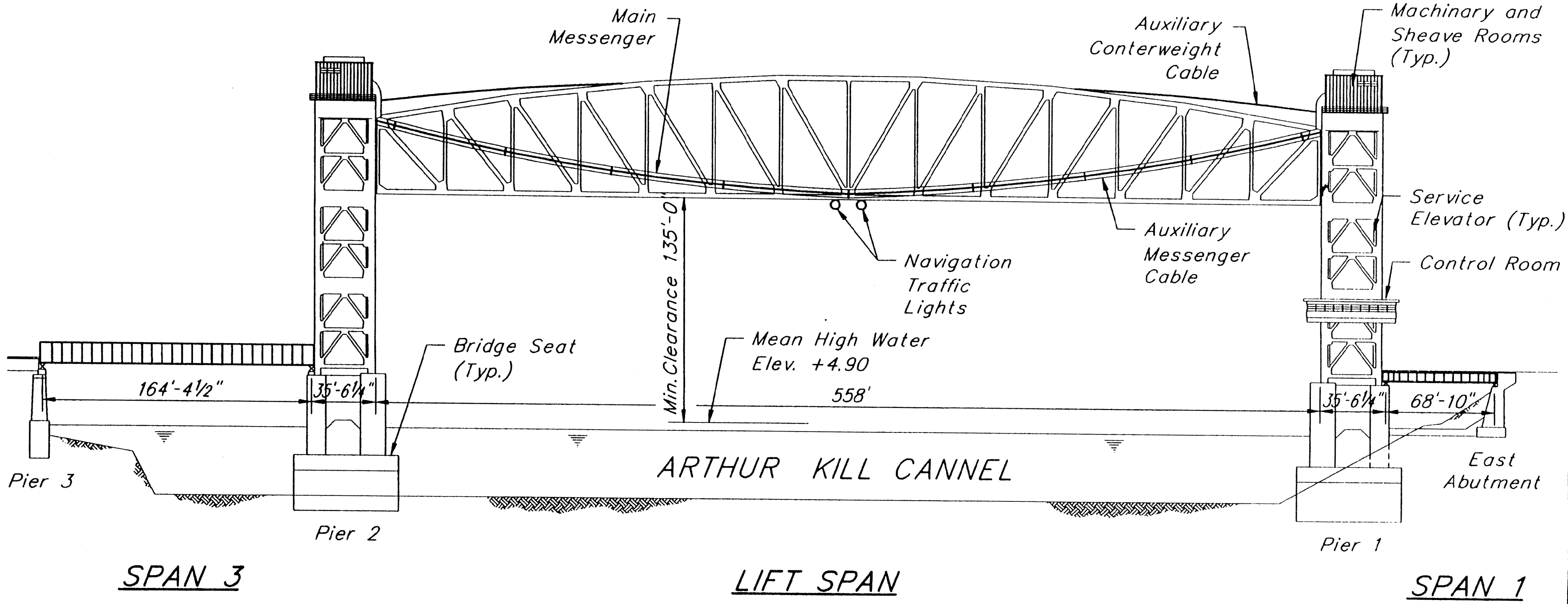
Consoer Townsend Envirodyne Engineers, Inc.
317 Madison Avenue
New York, New York 10017

INTRODUCTION

The Arthur Kill Lift Bridge is a vertical lift structure carrying a single railroad track across the Arthur Kill between Staten Island, New York and Elizabeth New Jersey. The B & O Railroad constructed the bridge in 1958 to replace an aging swing bridge. This replacement structure consists of the lift span, a single approach span on the New York side and an approach span together with an 11 span steel and concrete trestle on the New Jersey side. The lift bridge has a span of 558 feet center to center of bearings, one of the longest vertical lift spans in the world. The lift span is normally kept in the raised position with a clearance of 135 feet over the navigation channel to allow free passage of marine traffic and is only lowered for the passage of trains (See Figure 1).

As the demand for rail freight on Staten Island declined through the eighties, the lift bridge was used less and less until service across the span was suspended in 1991. The bridge went unused and neglected ever since. In 1995 with the reopening of the Howland Hook Marine Terminal on Staten Island and plans for the construction of a paper recycling plant on the west side of Staten Island, rail freight service to Staten Island was again needed. The New York City Economic Development Corporation (NYCEDC) engaged the services of Consoer Townsend Envirodyne Engineers of New York, Inc. (CTE Engineers) to perform a detailed inspection of the bridge and its systems with the intent of rehabilitating the bridge and returning it to service.

The rehabilitation of the Arthur Kill Lift Bridge has involved three distinct phases. The first phase was the detailed inspection rehabilitation of the bridge and its systems. The second phase involved



ELEVATION

LOOKING NORTH

Note:
All Dimensions Are Center To Center Of Bearings

REHABILITATION OF THE
ARTHUR KILL LIFT BRIDGE

the design of the rehabilitation of the structure and its systems while the third phase was actual rehabilitation of the bridge. CTE Engineers performed the inspection of the bridge, prepared the rehabilitation design documents and provided construction inspection and support services. The detailed inspection and rehabilitation of the bridge focused primarily on the following areas: structure, drive system, bridge operating system, span and rail locks, emergency generators, elevators and the signal system. The inspection revealed numerous deficiencies that were detailed in an inspection report to the NYCEDC. Based on the inspection findings, contract documents were prepared for the rehabilitation of the bridge. This paper will present the main findings of the inspection and how the various elements of the structure were rehabilitated.

STRUCTURE

The inspection of the structure revealed that the steel superstructure and the concrete abutment and piers were in very good condition with deficiencies noted in the grating walkways, ladders, railings and stairs. Where deficiencies were noted they were repaired in-kind. Damaged or missing gratings, ladders, railings and stairs were replaced with new materials.

SPAN GUIDE ROLLERS

The alignment of the lift span during movement is maintained by guide rollers at all four corners of the lift span at the top and bottom of the span for eight locations. At six of these locations the rollers are fixed and at two locations the rollers are mounted on a rotating carrier to accommodate skew in the span during movement. During the inspection, the fixed guide rollers were found to be in good condition but the two carrier assemblies were missing. These two carriers had been ripped off the structure during a hurricane in 1985. The mounting points for these carrier assemblies were subsequently replaced but the carrier assemblies were never installed and their location is unknown. The rehabilitation of the fixed rollers involved lubricating the rollers. New carrier assemblies together with their rollers were fabricated from the original design drawings.

DRIVE SYSTEM

The original drive system for the bridge consisted of 135 horsepower variable speed DC motors. DC power for each motor was obtained from a 480-volt AC motor/125 kW DC generator set (Ward-Leonard system). There are two sets of main span drive motors and motor-generator sets in the top of each tower. These motors drive the span through a single gear reducer and two differentials to four 15-foot diameter sheaves. Ten 2¼-inch cables on each sheave are connected to the lift span and counterweights. The main span drive motors were found to be in relatively good condition with only minor damage due to vandalism visible in some motors. This damage consisted primarily of damaged brush holders and wiring. The motor-generator sets consisted of an AC motor and a DC generator. Speed control was accomplished through an amplidyne exciter system. The motor-generator sets and the speed control components were found in generally good condition in the east tower. In the west tower the exciter for System 1 was missing and the casing for the exciter on System 2 was cracked and various connections had been vandalized.

Since the main span drive motors had not been run in a number years and the possibility existed that there may have been damage to the motors that was not visible from the access hatches, the rehabilitation program called for the rehabilitation of the motors. Due to the weight of the motors and the difficulty of removing the motors from the towers, the contractor elected to rehabilitate the motors in place. The contractor engaged the services of a firm specializing in motor rehabilitation to prepare a procedure and perform the rehabilitation of the motors in place. The contractor's procedure for the rehabilitation of the motors involved the dismantling of the motors in place, cleaning, inspection and testing all components, varnishing the windings and installing new bearings, brushes and brush holders. The motors were then run at speed while disconnected from the gear reducer to insure that they run properly.

Since the motor-generator sets were essentially obsolete it was decided that these elements should be replaced with solid state DC drives with isolation transformers. The use of this equipment would easily interface with the proposed programmable logic control system.

Since the bridge was not operational during the inspection, it was not possible to do a running test of the gear reducers, differentials and sheaves. A visual inspection revealed that the gearing was in good condition but that a lack of lubrication in the years before the inspection had resulted in extensive surface rust at contact surfaces where there was no lubrication. Grease patterns on the gears indicated good pitch alignment and tooth contact. The rehabilitation for these units involved the dismantling, cleaning and inspection of all bearings, cleaning the dried grease from all gears and re-lubricating all components. During the rehabilitation, two bearings were found damaged by foreign material getting into the bearings and were replaced with new bearings. In one instance, the grease fitting tube had been advanced too far into the bearing and had made contact with the shaft, which then broke off pieces of the grease tube, damaging the bearing.

The inspection of the counterweight cables revealed that the cables were in good condition. The rehabilitation of the counterweight cables involved the removal of all dried grease and lubricating the cables with new grease.

BRIDGE CONTROL SYSTEM

Control of the bridge in its original configuration was largely a manual operation with hardwired relay based interlocking to insure that the individual operations necessary to raise or lower the bridge were performed in the proper sequence and skew (height difference from one end of the bridge to the other). All bridge controls were duplicated in two identical systems for redundancy. A drum switch enabled the operator to switch between the two systems. To insure that the skew and speed of the bridge, during raising and lowering operations, were kept within pre-determined parameters, skew and rotary limit switches were included in the original design. While it was possible to rehabilitate the existing bridge controls, the long term reliability of the rehabilitated system could not be assured. In addition, parts that may be available today may not be available in the future. This system, while functional, is essentially obsolete by today's standards.

The operation of lift bridges such as the Arthur Kill Lift Bridge is very complex and involves many different functions that must be performed in a specific sequence. With the technology available today the operation and control can be automated to a high degree requiring minimal operator input. A Programmable Logic Controller (PLC) system was chosen as the control system for this bridge. To retain the redundancy of the bridge controls, two identical PLC control systems operate through a common push button and electronic display panels in the operator's console in the control room. In addition to operating the bridge from the operator's console, a provision for local operation of the bridge in the machinery rooms was included in the system. Skew and positional input for the PLC system are provided by new absolute encoders and the original rotary limit switches.

LOCKS AND BRAKES

LOWER SPAN LOCKS

At each of the lift span piers there is a lock mechanism to lock the bridge in the down position when seated. Each lock mechanism consists of a 5 horsepower motor operating through a Falk gear reducer to drive two shafts with lock bars through guides to lock the bridge. At the west pier the shafts for the span locks were severely distorted when the locks were once driven when the bridge was not fully seated. Many of the limit switches for the lower span locks were found damaged by vandalism and the operating machinery was found in need of cleaning and lubrication.

The rehabilitation of the lower span locks consisted of a number of elements. These elements included the replacement of the distorted lock bar shafts (reusing the existing shaft end pieces), removal of the gear reducers for shop cleaning and rehabilitation, cleaning and lubrication of the open drive gearing, installation of torque couplings and the removal of the motors for shop rehabilitation. When the motors were removed and disassembled is was found that one motor was damaged internally and could not be rehabilitated. At that time it was decided to replace both motors so that similar motors would be in use on both sides. Since the original motors were equipped with hand crank extensions, the new motors were also equipped with hand crank extensions.

RAIL LOCKS

At each of the lift span piers there is a lock mechanism to lock the rails in the down position when the bridge is seated. Each rail lock mechanism consists of a 3 horsepower motor operating through a Falk gear reducer to drive two lock bars through guides to lock the rails down. The operating machinery for the rail locks was found to be in need of cleaning and lubrication.

The rehabilitation of the rail locks was similar to the rehabilitation of the lower span locks. The rail lock rehabilitation included the removal of the gear reducers for shop cleaning and rehabilitation, cleaning and lubrication of the open drive gearing, installation of torque couplings and the removal of the motors for shop rehabilitation. When the motors were removed and disassembled is was found that one of these motors was also damaged internally and could not be rehabilitated. At that time it was decided to replace both motors so that similar motors would be in use on both sides. Since these original motors were also equipped with hand crank extensions, the new motors were also equipped with hand crank extensions.

Upper Span Locks

When the bridge is in the fully open position it was designed to be locked in position by locking devices at each corner. Shortly after the bridge was constructed the operators often found it difficult to disengage the locks due to settling of the span and rope stretch. In addition, the two lock fingers at the east pier were found broken off. Due to the difficulty of operating these locks the operators decided to disconnect these locks. These locks consist of rotating fingers that rest against the span below steel angle "stops" to prevent the bridge from dropping. Thruster units operate these fingers through a simple linkage system.

Since the Arthur Kill is a very busy waterway serving ships whose upper most portions come close to the lift span in the open position, it was felt that these locks should be restored to service. The rehabilitation of the upper span locks consisted of the replacement of the damaged lock fingers and the replacement of the four thrusters.

THRUSTER BRAKES

In each tower there are three thruster operated shoe brakes. The thruster brakes in the west tower have been vandalized, one of the motors has been stolen and a number of the limit switches have been destroyed. With the exception of the missing motor the thruster brakes were found to be operational. The rehabilitation of these brakes involved the removal of one complete brake assembly at a time, replacement of the motor and thruster mechanism and the complete disassembly, cleaning, lubrication and reassembly prior to reinstallation. The drums were cleaned and new limit switches installed.

LOCK AND BRAKE MOTOR CONTROLS

The motor controls for the locks and brake motors were originally contained in a motor control center located in the operator's house on the east tower. During the inspection it was found that these motor controls do not meet electrical codes and it was decided that they should be replaced. Since the motor controls were going to be replaced and the PLC interface for these controls were located in the machinery rooms at the top of each tower, the new motor control centers were also located in the machinery rooms.

EMERGENCY GENERATORS

To insure that there was always power for the operation of the bridge and for emergency lighting, there were two generators in a room at the base of the east tower. One generator supplied power for raising the bridge while the second supplied power for emergency lighting. The large generator was found to have been damaged by a fire and is of an obsolete design. An inspection of the large generator by firms specializing in rehabilitating generators revealed that rehabilitation of this generator was not feasible. The rehabilitation of the small generator was determined not to be economical.

Since an emergency generator is required at this bridge by the United States Coast Guard it was decided that a replacement generator was necessary. Following an analysis of the power required to raise the bridge and power the emergency lighting, it was determined that a single 300 kW generator would be sufficient. To insure that the generator will operate properly when only the emergency lighting is drawing power, a load bank was placed on the generator. To keep the costs for the generator in line with the available funding, it was decided to place a new weatherized generator in a fenced enclosure on the New York bank of the Arthur Kill and abandon the original generators in place.

ELEVATORS

There is an elevator in each tower to provide access to the machinery rooms at the tops of the towers. Since these elevators are not in an enclosure and are completely exposed, the original designers had opted to use a radio controlled elevator system. During the inspection it was found that the radio control systems were inoperative due to vandalism and disuse. The rehabilitation of the elevators included the complete replacement of the radio control systems with new radio control systems. It was found that the manufacturer of the original radio control systems was still in business and they supplied the replacement systems. New limit switches were installed and all other components were cleaned, inspected and lubricated as necessary. Emergency communications from the elevator will be by cellular phones since the possibility exists that there may only be one man at the bridge when it is being operated.

SIGNALS

Since this movable bridge will be carrying rail traffic, the Federal Railroad Administration requires a signal system interlocked with the bridge control system. During the inspection of the structure, it was found that the signal system had been previously dismantled and vandalized to the point that there was virtually nothing left to reuse. In addition, the insulation on the aerial signal cables across the Arthur Kill was frayed indicating that the cables needed to be replaced. Since it was not possible to rehabilitate the original signal system, the remaining components were removed completely and replaced with a new system. The aerial signal cables were also removed and replaced with new cables.

OPERATION AND TESTING

On July 28,1998 the bridge was operated for the first time with the new control system and rehabilitated systems and a period of testing the systems followed. On the first day of testing, a mariner overhearing the communications between the bridge tower and the United States Coast Guard, made the comment "That bridge actually works?"

Credits:

Owner:	*New York City Economic Development Corporation*
Designer:	*Consoer Townsend Envirodyne Engineers, Inc.*
General Contractor:	*Mulvihill Electric / Linco Electric Joint Venture*