AMERICAN CONSULTING ENGINEERS COUNCIL'S

AFFILIATE

HEAVY MOVABLE STRUCTURES, INC.

4TH BIENNIAL SYMPOSIUM

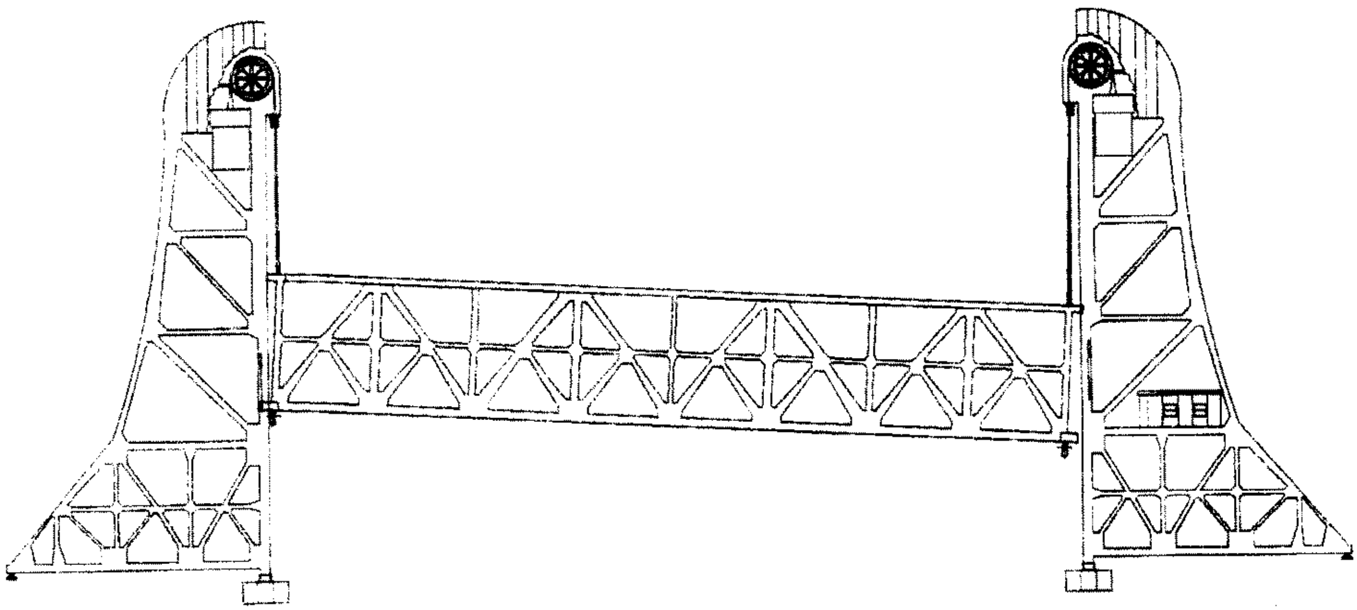
NOVEMBER 10TH - 12TH, 1992

SHERATON DESIGN CENTER
FT. LAUDERDALE, FLORIDA

SESSION
WORKSHOP NOTES

#03 Author: Hassan Eldessoky
NYC Dept. of Transportation
"Failure of Automatic Skew Correction System"

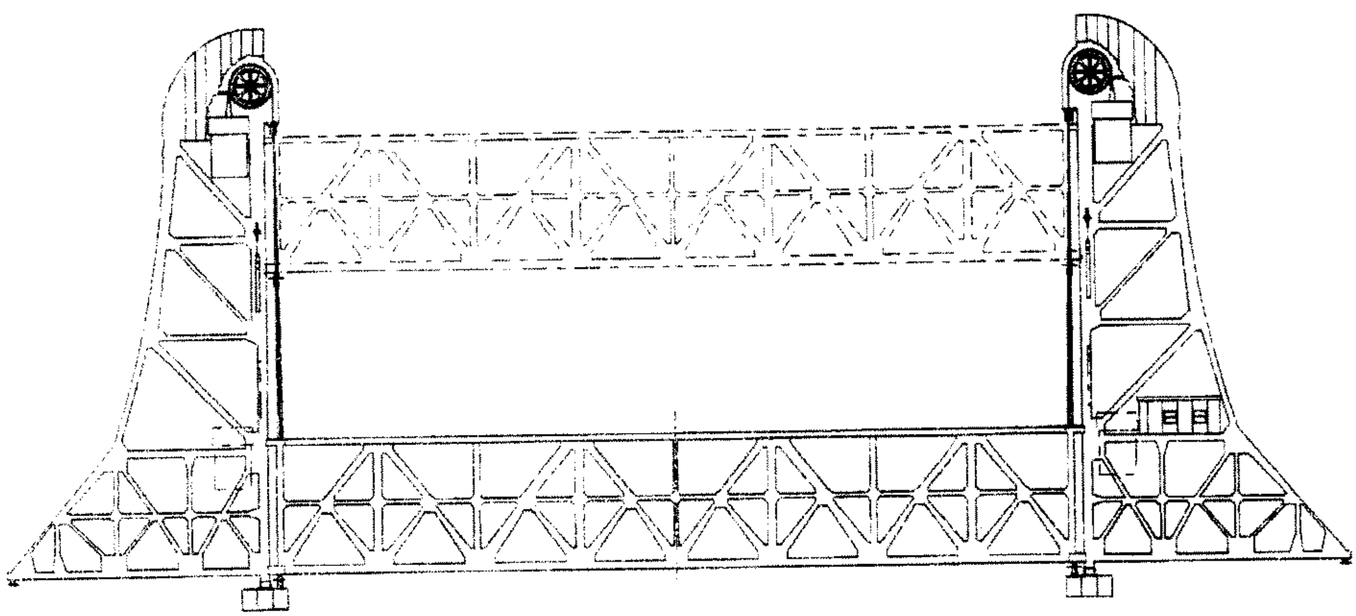
NEW YORK CITY
DEPARTMENT OF TRANSPORTATION
BUREAU OF BRIDGES



BROADWAY BRIDGE
FAILURE OF AUTOMATIC SKEW CORRECTION SYSTEM

HASSAN ELDESSOKY, P.E.
ADMIN. ENGINEER/H.R.B
SEPT. 1992

NEW YORK CITY
DEPARTMENT OF TRANSPORTATION
BUREAU OF BRIDGES



BROADWAY BRIDGE
FAILURE OF AUTOMATIC SKEW CORRECTION SYSTEM

HASSAN ELDESSOKY, P.E.
ADMIN. ENGINEER/H.R.B
SEPT. 1992

CONTENTS

I. GENERAL DESCRIPTION OF BROADWAY BRIDGE

Broadway Bridge was constructed in 1962 as a Tower Drive lift bridge that stands 24 ft. above mean high water. The 304ft lift span comprises two decks, the lower deck supports two 34ft wide roadways (one between each of the two outer trusses and central truss) for vehiclar traffic and two 8ft wide sidewalks outside of the exterior trusses. The upper deck supports three railroad tracks which are used by the IRT Rapid Transit line. The span weighs 5,000,000.00 lbs. and is carried by 96 main cables, each 2-3/8" in diameter and 177 ft. long. There are 8 sheaves altogether, 2 at each corner and each carries 12 cables. Refer to figure 1 for an elevation view of the bridge.

The span is balanced by two main counterweights, one on each end, tied to the other end of the main cables. Four auxiliary counterweights, one at each corner, are used to compensate for the weight of the main cables when they travel over the main sheaves to the main counterweight side. Each auxiliary counterweight weighs 30,000.00 lbs. and is carried by two 1-1/4" cables (Figure 2).

Broadway Bridge is the largest moveable bridge owned by New York City. It carries six lanes of roadway and 3 tracks of the elevated IRT subway line. The input power to the bridge is 208/120V, 60 C, 3 phase, 4 wires. One set of transformers was used to raise the voltage to 2300 V for the operation of the main motor/generator set. Another for the operation of the auxiliary motors and control circuits. Two identical D.C. motors, 520 HP, 550 rpm are used to operate the span on the main systems and two 150 HP., 138 rpm motors are for the emergency systems.

The span is kept level during operation by the control of the automatic skew correction systems which consists of two transmitter selsyn motors (one on each tower) and one receiver selsyn motor at the control house to differentiate the two signals from each end. It then creates an error signal to feed back to the amplidyne set to slow down whichever is the faster motor. The maximum skew allowed is 18", at which point, the power shuts off automatically. If the skew exceeds 18" it can be corrected manually by selecting the high end and bringing it down to level the span while holding the lower end in place. When the span is leveled or the skew is brought down below 18", the operator can resume normal operation as long as the skew correction system is working properly. The bridge is equipped with one normal system and one emergency system with separate control components. Both systems share the same mechanical components except for the motors and brakes and the motor/generator sets.

II. FAILURE OF AUTOMATIC SKEW CORRECTION SYSTEM

On Monday June 5, 1989, during a bridge opening using the emergency drive system, the bridge went into skew about 6" (North end high) and did not correct itself. The Bridge Operator in Charge (B.O.I.C) switched to the normal system to correct the skew and to bring the span down but the bridge went into excessive skew due to malfunction of the automatic skew correction system. The B.O.I.C tried to correct the skew manually, but the skew increased until reaching almost ten feet.

The top truss of the South end of the span was jammed against the auxiliary counterweight. Two 1 1/4" cables carrying the Southwest auxiliary counterweight snapped off at the socket ends (Fig. 2) The Southeast cables were also highly stressed. but did not snap. Without the support of its cables, the Southwest auxiliary counterweight had to be secured in place to prevent it from falling down to the roadway before any attempt could be made to move the span.

Inspection revealed that both auxiliary counterweights were jammed between the guide rails and had to be secured to the rails and disconnected from the span in order to lower the span safèly. After requesting a power-outage from the Transit Authority on the third rail of the subway tracks, the ironworkers secured the auxiliary counterweight from the top by tying four 5/8" steel cables to the guide railing with 1" shackles.

Bottom of the counterweight was supported by installing a structural steel 12" channel bolted to the existing guide rails. The two broken cables on the Southwest auxiliary counterweight were removed after it was secured.

The cables for the Southeast auxiliary counterweight were still under tension and had to be removed. To release the tension, the counterweight was secured and the cables removed in the same manner described above for the Southwest counterweight.

Each auxiliary counterweight weighs about 15 tons. They compensate for the unbalanced weight for the main counterweight cables as the cables travel over the sheaves to the main counterweight side. The span weight of 5,000,000 lbs is balanced by the two main counterweights.

In preparation for moving the span, all machinery and control equipment was inspected on both the North and South towers. Due to an overload, one contactor on the selsyn receiver skew indicator micro switch was stuck and this was freed easy. The automatic skew correction system could not be checked properly since it required moving the span and adjusting the selsyn from a zero reference point. We decided not to use the automatic skew correction system to correct the skew. but, instead to correct the skew manually and then bring the span down.

By 8:30 PM Tuesday (6/6) all steel repair and checking was complete and we were ready to lower the span. The manual skew correction was not working properly due to a defective selsyn receiver which activates limit switch 107 (Fig 4). This switch controls the selection of the drive motor. We had to trace the control circuits for each drive motor and bypass various limit switches and relays on the control board to drive the ends alternately and level the span. This meant that the lowering would proceed tediously and would involve trial and error.

First, we slowly lowered the North end of the span in order to clear the interference at the South tower auxiliary counterweights. Six engineers were assigned to observe critical points for binding and interferences during the span lowering. Each observer had a two-way radio to communicate with the operating room. Progress was very slow and there was much difficulty controlling the direction of movement of each end of the bridge.

After many trials and lots of patience, we were able to clear the span from the South tower and level it. The span was, however, displaced about 2" towards the North tower due to the missing auxiliary counterweight cables on the South side: this created physical interferences and prevented normal seating of the bridge. We had to burn some minor steel elements such as apron plates and angles. By slowly inching the span down until we engaged the centering mechanism, we were able to guide the span into place without causing damage to the structure.

The span was finally seated and locked in place at about 5 a.m. Wednesday. The T.A. was then notified to check the alignment of the tracks to prepare for re-energizing the third rail and resumption of train service. With the cooperation and dedication of all city personnel, we were able to resolve this serious situation in less than 48 hours.

III. OUTLINE OF REPAIR PROCEDURES

The following plan was prepared for the repairs to the Bridge:

(1) Purchase of:

a) four 1-1/4" cables, 6 X 25, 126,000 lbs plow steel, fiber core with end sockets each 102' 3" (Fig. 3).

b) 60 ft of steel angle (6 x 6 x 3/8) for guide railing

(2) After the roadway closing and T.A. outage one engineer will be standing at each corner of the bridge to monitor the height and inform the operating room with any unusual condition.

(3) 2 electricians will be located in each machine room and 2 at the control room.

(4) Use spiders to hook up new cables to top of counterweight (C.W.).

(5) Raise the span through normal procedures to a level where iron workers are able to hook the Auxiliary cable to the hitches on the span and to hook the cable reflectors.

(6) Lower the span to get some tension in the cable to support the Auxiliary (C.W.)

(7) Free the C.W. and clear the railing to allow the C.W. to travel upward (some work will be done in advance prior to the night of the opening).

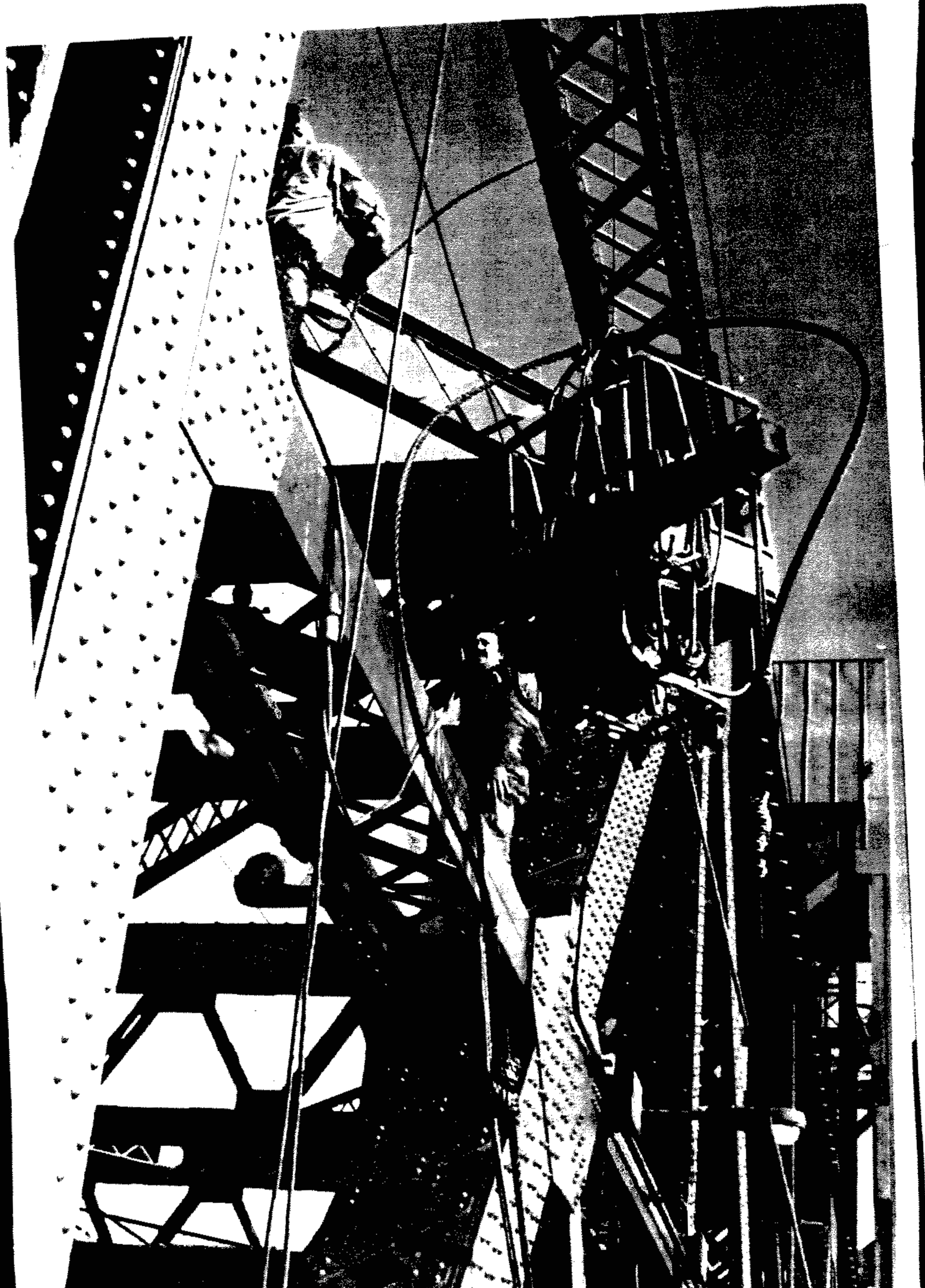
(8) Lower the span and seat it properly as per normal procedures.

(9) Adjust the tension in the C.W. through the take up turn buckles.

(10 Adjust and calibrate all selsyn transmitters and receiver between North and South towers and operating room to determine the 0" skew level for the span.

(11) Test openings for final adjustment. (1 day)

Note: All work will be coordinated with the T.A., especially that which might require a train and/or roadway power outage.



IV. RECOMMENDATIONS TO IMPROVE BRIDGE OPERATION AND MAINTENANCE

A) Excessive Skew Alarm

It was suggested to incorporate an audio alarm signal to the skew correction circuit to alert the operator when the skew reaches 18" in case the automatic skew correction system fails to function properly. A buzzer circuit could be added to micro switch 106 (see Fig. 4) of the selsyn receiver motor for the skew indicator between wires 1102, 1106 and C1 to accomplish this.

Micro switch #2 or #4 will activate the buzzer circuit when either end of the bridge leads the other 18" and will stay on until the skew is corrected. Using a buzzer system in the circuit will add one more safety feature to the system since visual determination of the amount of skew is difficult if the skew indicator fails to function for any reason while the automatic skew correction is defective. All modification on the control circuit will be done in-house by our electricians. A wiring diagram for the new control circuit will be prepared to show the modification.

(B) Inspection and Testing of Main Cables

The Main cables are in need of a thorough, in depth inspection. These cables now almost 30 years old and have never been inspected. Bridge Design has prepared the scope of work which would include complete cleaning of all cables and removal of the entire cable for sampling and destructive testing. It is most desirable that this work be done in the near future.

Present automatic skew correction system which relies on the selsyn transmitters to generate the error signal are all coupled to the main drive shaft, rather than getting a direct indication from the lift span itself. Thus the existing system has to be monitored and continually adjusted to compensate for cable stretch and slippage on the sheaves.

The new system we added will monitor the leveling of the span during travel and will give direct indication from the span on the amount of skew. It will shut down the system if the amount of skew exceeds 1/2 degree, and will also give an alarm, but will not correct the skew. By the use of an inclinometer, direct current operated gravity reference tilt sensors, we will be able to create a signal depending on the skew angle to activate a buzzer and drop out the under voltage relay to stop the drive motor immediately. The new application will prevent going into excessive skew, but will not correct the skew. The skew will still be corrected through the amplidyne to slow down the faster motor, which is dependent on the error signal generated by the selsyn motor.

WHAT CAUSED THE AUTOMATIC SKEW CORRECTION TO FAIL?

Device 106 in normal system and 506 in emergency system is the selsyn receiver that is supposed to receive both signal from N & S. towers and differentiate it to develope an error signal to activate the Amplidyne to slow down the faster motor. During operation testing on the emergency system device 506 failed to operate at all and all micro L.S. on the device were set improperly causing relay 118, 121, 122, to stay engaged all times which by passed the ultimate skew L.S. for both S & N tower and never dropped out relay 117 (Undervoltage relay) to shut down power and stop the span.

TECHNICAL DATA

Normal Operation System

Span Drive Motors:
2 - 360 HP, 380 rpm, 230 v, 3 Ph, D.C.
with 72 v field, seperately excited with
340 v to develope 520 HP at 550 rpm

Motor/Generator Set

2 - 6 pole, 600 HP, 2300 v, 60 c, 3 Ph
Induction Motor

2 - 400 KW, 60 pole, 350 v, 1145 A
shunt wound D C Generator, capable
of commutating a momentary peak
of 200%

2 - 7 1/2 kw, 4 pole, 125v, compound
wound D C exciter for both drive motor
fields and D.C. control circuit

Amplidyne M/G Set

Motor 3HP, 220/440, 60c 3Ph induction motor gen.
2kw, 1750rpm, 250v, 8A generator with 9 fields.

EMERGENCY OPERATION SYSTEM

Drive Motor
2 - 130HP, 138rpm, 90v

Motor/Generator Set
2 - 150HP, 4pole, 2300v, A/c induction motor
2 - 100kw, 1750rpm, 125v, 800A D/C generator
2 - 9kw, 1750rpm, 125v, 72A D/C exciter

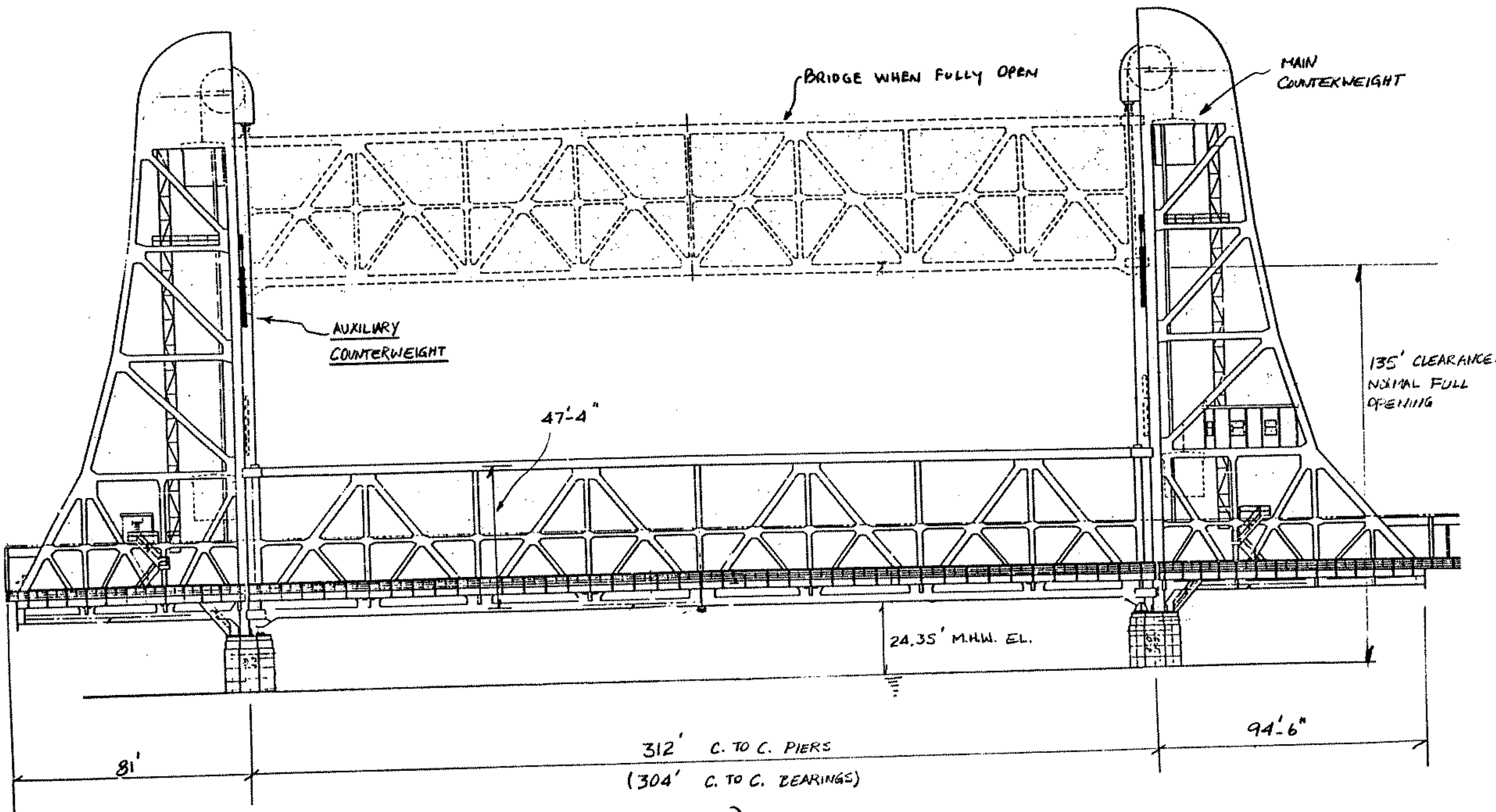
Amplidyne Set
- Motor 3HP, 1725rpm, 220/440, 60c 3Ph
induction motor
Generator 1 1/2kw, 1725rpm, 250v gen.

Transformers
4 - 333/373kva
Single phase, oil immersed, self cooled, outdoor, rated
60/333/2400/4/60Y - 120/240 - W2F with two taps rated
2 1/2% above or below 2400v.

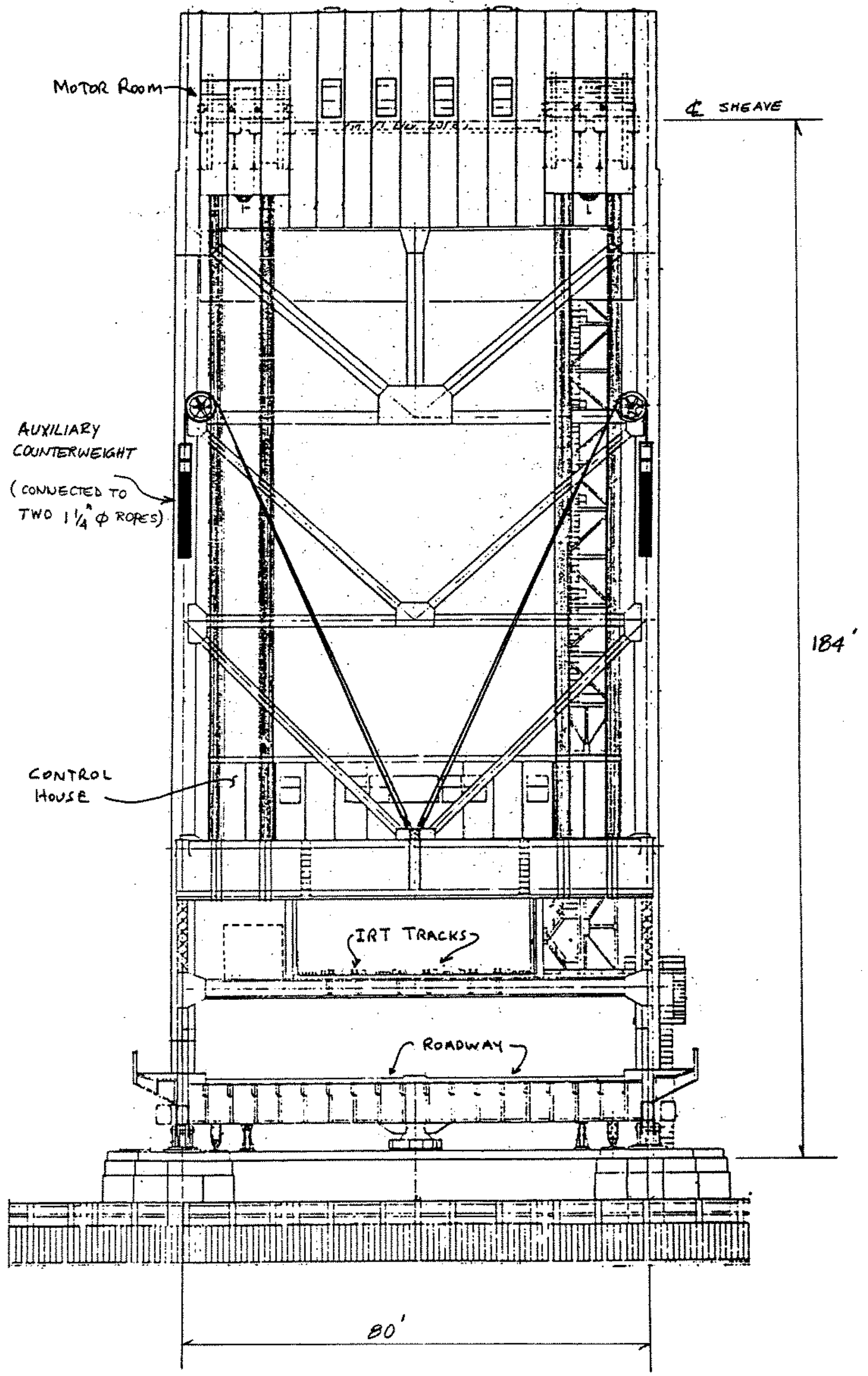
4 - 50/56kva
Single phase, oil immersed, self cooled, outdoor, rated
60/480/120/240 with 2 taps rated 2.5% above or below 480v.

APPENDIX

ELEVATION

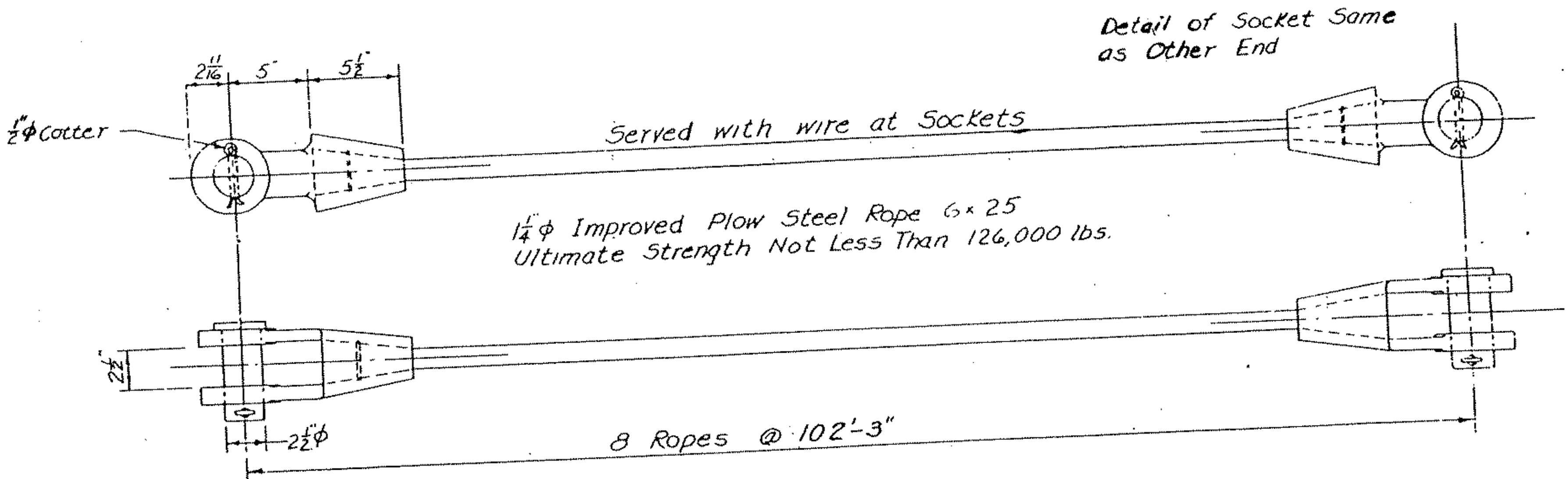


(FIGURE 1)



SOUTH ELEVATION OF NORTH TOWER
(BRIDGE IN CLOSED POSITION)

(FIGURE 2)



AUXILIARY COUNTERWEIGHT ROPES

SCALE 1 1/2 IN. = 1 FT.

(FIGURE 3)