Failure Analysis
of
High Strength Bolt's
Loss of Tension
on
Two Movable Bridges

by

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1 Summary

This forensic analysis attempts to identify a "cause" for the loss in bolt tension in structural joints on two movable bridges in Florida's Movable Bridge Rehabilitation Program.

Laboratory test data could...NOT... establish a reason for the loss of tension. No single or combined ...laboratory result... from the component and simulated assembly tests supported any mode of failure.

Lack of supporting test data suggests additional parameters or conditions must be involved. Although the analysis and laboratory tests involved simulating a structural joint and employing current industry procedures for installation, nothing in the results reflected a loss of tension (relaxation) greater then 3.7% for the sample tested.

Implicit from the data and observations in the field, it may be hypothesized that the physical configuration and dynamics of the structure generate an unaccounted-for loads not included in the original design criteria which could cause this loss of tension phenomenon. Additional analysis and...field testing... will be required to fully answer this hypothesis and questions related to high strength bolts in general and as found on these two movable bridges.

Based upon the laboratory test results, it is recommended the Department utilize ASTM A325, type I, plain steel bolts, with appropriate nut and flat washer on all movable bridge span's structural joints requiring high strength bolts. The latest construction installation procedures should be followed.

A research effort should be initiated to investigate the characteristics of bolted structural steel joints applicable to movable bridges spans.

There was...NO evidence...of counterfeit material in the limited bolt sample drawn from the PGA Blvd. bridge.

2 Introduction

This report describes, integrates and compiles the data related to the loss in bolt tension in high strength bolts (A325) utilized on two bridges in the 4th District's Movable Bridge Rehabilitation Program. Various tests were designed and conducted to answer specific field anomalies attributed to high strength bolts (ASTM A325) utilized in structural joints on movable bridge spans. This analysis includes all laboratory support testing performed by Law Engineering Testing Co, Atlanta, Ga.

The two movable bridges involved are; ...Hobe Sound on State Road (SR-707) in Martin County; a double leaf bascule structure over the Inter - Coastal Waterway replacing an old bridge located just south of the new site, and ...PGA Blvd. (SR-786) in Palm Beach County; a four leaf bascule structure over the Inter-Coastal Waterway. The southern spans were constructed in the 1960 era consisting of two lanes with sidewalks on each side. In 1974, the traffic load required six lanes. To accomplish this economically and with a minimum impact on traffic, a composite design was conceived which consisted of converting the north sidewalk of the southern span to a half a traffic lane and cantilever another half lane and a median onto the northern span's three new traffic lanes. The design therefore, integrated the northern spans with the southern spans. The construction commenced in the late 1970's and was completed in the early 1980's.

3 Purpose

3.1 General

Implicit in failure analysis technology is an assumption that if a system does...NOT...perform properly to a set of criteria or specifications, the first task is to validate the indicated mode of failure or the non-compliance measurement.

In this case, inspection, during rehabilitation, found a number of bolts on floor beam connections which were only finger tight. Further checks determined approximately 80% of the bolts in this structure were 40-60% below an established job torque.

The second task is to align collected facts with either design or material phases. Implicit in this dichotomy then is;

(1)..the engineering is correct and the physical assembly, components or the installation procedures are defective (i.e., bolts, nuts, washers, clip angles, etc.) ....or

(2)..the components or assembly meets specifications and the engineering contains a deficiency.

The probability the former being correct is more likely since it encompasses all the separate quality control processes in the various procurement, installation and inspection procedures. The physical configuration should be dissected first. The engineering phase, involves greater dissection, a larger scale of testing and more time to develop facts (Ref.2,pg.229) sufficient to establish an engineering discrepancy. The more susceptible and least cost to investigate are the physical components. All components and the processes of assembly are suspect.

3.2 Hypothesis

An applicable research hypothesis then states,"...the high strength bolt (ASTM A325) as used in these structural connections on these two bridges do..NOT..meet specification in either material, or processing standards per American Institute of Steel Construction (AISC), as employed on either PGA Blvd. or Hobe Sound bridges."

3.3 Background

The subject of high strength bolts in structural joints on movable bridges, has been highlighted in the past and of some concern to the Department. In the past ten years, various stories and incidents have occurred. The more recent occured while conducting a structural test on the PGA Blvd bridge (figure 1 & 2,). These facts and the hearsay information related to foreign counterfeit bolts, created an atmosphere in which all high strength bolts installed in movable bridges these past 15 years are suspect. As a follow-up, a check for loose bolts was made on the new Hobe Sound structure. A number were found to be below the minimum torque/tension required (i.e., as determined using a Skidmore-Wilheilm Model M bolt tension calibrator).

For a proper engineering disposition, the structural Engineer needed data to establish a positive method of installing structural high strength bolts. The main concern being those structural joints identified as critical to public safety in order to safely open the bridge to traffic on-time. Testing was also required to support recommendations for a permanent policy concerning structural connections in movable bridges. The policy was to encompass the selection, protection, utilization and installation procedures for high strength bolts. Law Engineering Testing Co. in Atlanta, Ga. was the facilities selected to meet the testing demands.

4 Scope

Establish and determine the validity of the ...indicated... mode of failure or non-compliance with specifications. If valid, determine a mode of failure and possible resolution(s).

A testing "scope of services" meeting was conducted on November 20, 1986 at the Law Engineering Testing facilities in Atlanta, Ga. for designing and implementing a test program.

From all indications, assume the bolt is the most susceptible component in the assembly. Therefore, analyze and test the high strength bolt for possible contributory cause. The testing was to determine the material specifications used, environmental coating employed, affects of method of installation and inspection.

The testing was divided into phase (1) basic data collection and (2) field conditions, as follows;

4.1 Phase 1. Basic Data

a) Determine basic mechanical, chemical and metallurgical properties of various size and length of high strength bolts ASTM (A325), type I (encompassing plain, mechanically galvanized and electro deposited galvanized, with and without dichromate) and type III (weathering steel).

b) Establish a calibration reference between bolt tension and strain data for interpreting torque vs. tension loadings.

4.2 Phase 2. Field Conditions

Establish test configurations for simulating field conditions as follows;

(1) Determine sequential "pattern of tightening" bolts in structural connections: does it make any difference between a spiral pattern or any other pattern ?

(2) Determine the "scatter of bolt tension" for the different methods and tools available to a contractor and whether "tension relaxation, (Ref. 2, pg.374)" occurs in a typical structural connection with time.

(3) Investigate the current "procedures" of controlling bolt tension via torque, as applied to structural high strength bolt connections, and the methods of quality control and inspection.

(4) "Snugging" is the initial take-up of the structural connection with all of its plates and/or angles, etc.

a) Determine the amount of scatter in bolt tension resulting from utilizing the AISC criteria for turn-of-the-nut method.
b) Determine the characteristics related to the re-use of high strength bolts in structural connections per AISC.

5 Method or General Approach

The primary objective is to provide a mode of failure which caused the non-complaince or out-of-spec conditions based upon facts, notes and observations.

To accomplish this, required answers to various questions via a literature search, a search of records and a test program. The test program was initiated with two major phases planned:

(1) develop ASTM data on new and used (i.e., used on one of

the two bridges) A325 high strength bolts encompassing chemical, mechanical and metallurgical properties.

(2) design a laboratory test fixtures to study physical installation properties of high strength bolt in field conditions via strain gage instrumentation of the bolt's shank. Fixture must allow for clearance of lead wires to recorders (Figures 3 through 8 & 11).

6 Results

6.1 Literature Search

Since 1951, a number of changes have occurred in the AISC specifications (Ref. 5) on the use and procedures covering high strength bolts. Bolting technology has become an emerging area of interest (Ref. 1 & 2), both in the mechanical and structural engineering disciplines. Implicit from the literature search was the indication of a general lack of data on vibration and prying loads where high strength bolts are used (i.e., in a friction type connection) in structural joints.

6.2 Construction Records

PGA Blvd. - A review of the daily construction logs during the period PGA bridge's north spans were being constructed indicates various procedures were possibly employed in the installation of high strength bolts. Accuracy and consistency of controls over the quality of the operation could not be established from these records.

Hobe Sound - Daily construction logs did not clearly identify high strength bolt installation data. A site inspection of the bolt installation on Hobe Sound revealed some bolts were longer than required, some shorter, and not all of them were at the required job torque.

At the time of the inspection, Hobe Sound bridge was being operated via temporary pneumatic system in order to complete alignment and construction of the spans. The trunnion shaft installations were incomplete and binding. Also, due to improper installation of the trunnion pedestals, the spans were misaligned. These conditions subjected all bolted joints to unknown loads. Therefore, it was not possible to attribute the loss of tension to either installation procedures or operations.

6.3 Field Testing

In mid-August, 1986, the Department in its rehabilitation program attempted to determine the cause of excessive vibration which could be observed at center span on PGA Blvd. bridge. The structural testing was instituted to calibrate a consultant's model. It was during preparation for this testing when the "loss in bolt tension" problem was encountered.

Before testing could begin, all bolted joints had to be re-tensioned. A job torque was established and all bolts on the channel side of the trunnion bearings of the northeast span were torqued to a minimum tension level for the size of bolt.

The structural tests produced data for both static and dynamic conditions. The static data did provide sufficient correlation to accept the model's results.

The dynamic data collected was generated by a truck driven over specific lanes of the north span at a specified speed. The bridge was closed to public vehicular traffic. The bridge was instrumented with two relative displacement probes between the spans at the center of the channel and six strain gages mounted along the main girders on the top and bottom flanges of the northeast span.

6.4 Laboratory Testing

The following test identities are arranged chronologically for each of the objectives and field questions sought to be answered. Law Engineering reports are summarized below to assist in explaining the overall test program. All testing adhered to ASTM specifications wherever possible.

6.4.1 Basic Test-Reference-New Plain Bolts

These tests, performed on ASTM A325 7/8 - 9 UNC, plain steel high strength bolts of different lengths, was to establish information to aid the decision and direction required for applications. The tests provided basic data related to chemical, metallurgical and mechanical characteristics. The chemical analysis indicated all bolts met the ASTM A 325 requirement for type I material. The microhardness data reflected a slight softness near the skin (i.e., thread area) on most of the bolts; a loss, due possibly to decarburization of the surface. According to the load-deflection and load-strain curve data, all bolts met the ASTM tensile and proof load requirements (i.e., 55,450 and 39,250 pounds, respectively).

6.4.2 Basic Test-Samples-PGA Blvd Bridge

These tests were implemented to establish a cause for the mode of failure; loss of tension. Utilizing ten A325 bolts selected at random from the PGA Blvd bridge, Law Engineering proceeded to develop data to substantiate the mode of failure and/or the possibility of counterfeit material. The tests consisted of chemical, hardness and load deflection curve generation.

The results were in accordance ASTM A325 high strength bolt specifications and there was no indication of counterfeit material in this sample. The lack of a desirable metallurgical structure in the "skin" area (i.e., softening of the thread area) was attributed to possible effects from the original heat treatment.

6.4.3 Comparison Test - Types of Galvanizing

The results of these tests checking into the effects of 4galvanizing on the bolt's shank and thread areas for loss in stress/strain capability indicated no abnormalities were observed.

6.4.4 Installation/Relaxation Test-Plain

Tests numbers 1 through 8 were conducted for the purpose of determining affects of a sequential pattern on snugging and final torquing of high strength bolts in a structural joints. Four test fixtures were used simulating a structural joint. Documentation on each consists of a sequence pattern, tabulated data and a line graph. The graph represent tension versus time in days. Each bolt is annotated at the bottom of the graph. Tests No. 5 reflects the most desirable results with the narrowest band of tension. The sequential pattern suggested by these tests indicates a zig-zag pattern from top to bottom was the best for the least scatter in tension and relaxation. There appears to be no significant loss in tension.

6.4.5 Installation/Relaxation Test-Galvanized

Tests were intended to reflect any possible effect of the difference galvanizing processes have on the tension over a 38 day period of time (i.e., relaxation due to "creep or flow"). The average amount of lost bolt tension for the installation procedure utilized was approximately 3.7% for mechanical galvanizing and 2.2% for electroplating. This is not a large amount of tension, but does reflect a slight difference in the two processes.

Tests (11 through 18) represent attempts at improving the AISC turn-of-the-nut method for installing high strength bolts (Phase 2, questions 2, 3, & 6). The specific point being the variance in the initial take-up of bolts in the connection to "snug tight". The human consistency of the manual approach (i.e., spud wrench) throughout a days operation without the aid of a tool is questionable. These tests reflect the effects of four individuals, utilizing an impact tool in obtaining "snug tight" conditions and its corresponding tension. AISC also indicates re-use is possible at the option of the Engineer . The re-tensioning of a bolt appears to require less torque for the same tension. Therefore, care must be taken when exercising this option.

6.5 Field Tests-Static & Dynamic

This data was obtained from the conducted on PGA Blvd. in August, 1986 and reported in the "Functional Improvements..." dated November 24, 1986 from Kunde, Sprecher and Yaskin and Assoc.,Inc. The data reflects the instrumentation traces from displacement probes between the northern set of spans and strain gages mounted on the northeast's main girders upper and lower flanges. These traces were generated by a tare weight (i.e., 72,000 lbs. truck full of sand) being driven onto the bridge for both static and dynamic effect. The dynamic test required the truck to be driven over the bridge at a set speed (45 MPH), running in an east or westerly direction on a specific lane. The positive micro-strains represent members in tension and negative are compression. The DC coupled displacement probe data reflects the relationship between the east and west spans (i.e., span locks driven) in inches (1 mil=0.001). Deflections observed were approximately 1.0 to 1.25 inches, depending upon the lane used.

7 Conclusions

7.1 Installed Bolts

Applicable data does not support the research hypothesis which stated,"...the high strength bolt (ASTM A325) as used...... do..NOT..meet specification.

Other than a slight softening of the threads due to processing, no basic test result (Phase 1) provided evidence which would support a contributory cause for loss of bolt tension. All bolts tested met ASTM specifications. No evidence of any counterfeit material was found in the ten bolts removed from the PGA bridge.

No single or combined laboratory result from the component and simulated assembly tests (Phase 2) could be attributed to the mode of failure in ASTM A325 bolts.

Lack of supporting data suggests additional parameters or conditions must be involved. Although the analysis and laboratory tests involved a simulated structural assembly, nothing reflected a loss of tension (relaxation) greater then 3.7% for the sample tested for the time tested.

Loss of bolt tension (i.e., approx. 80 %) in structural connections on one of these two movable bridges is...."real". The deficiency is NOT considered a safety item due to the size of the design factors involved. The condition of less tension will cause an increase in maintenance expenditure and down-time.

The "cause" for this loss in tension is a major concern. Bolt replacement or adjustment at this time would be a gamble without determining the cause of the loss.

7.2 Structural Joints

Implicit in the field test data is the possibility of unaccounted for loads; loads the initial analysis did not encompass in the design of the structural connections or improper alignment and/or adjustments in the structural configuration.

Such loading could result in "relaxation" or an axial deformation too slight to measure without special devices, but sufficient to cause some "loss" in bolt tension (Ref.2,pg. 282). This is especially true if the loads are cyclic and/or vibratory in nature.

It is, therefore, hypothesized (#2)that a combination of "factors and operating conditions" contributed to this loss in bolt tension. Specifically, unexplained loads due to any initial bridge alignment during construction and/or operating sequence play heavily in this concept.

It should be pointed out there may be a specific set of conditions which (i.e., peculiar to each of these two bridges) manifest itself in the high strength bolt's loss in tension.

For example, on PGA bridge, the half-lane with its median in the compound cantilevered north structure lends itself to generating a wrenching or torsional action in addition to the normal live load. No other bridge maintained by the Department has such a cantilevered amplification of the live load. In addition, it was observed the ...live load... contact was lost when the span locks are driven; adding to the strumming of the structural members.

Considering the span deflection at the center of the channel on PGA of 1200 mils (1.2 inches) generated by a single vehicle and its present ADT (average daily traffic) of approximately 45,000, this bridge is taking a..... pounding; loading possibly beyond design limits.

In regard to the Hobe Sound bridge, the deficiencies developed during the construction process (i.e., four trunnion bearings binding, misalign main girders and spans) placed an additional wrenching loads on the high strength bolts which may have been excessive. In addition, some of the bolts were installed improperly and without adequated inspection.

In summary, based upon all the test data presently available from both bridges, the opening and closing operating sequence generates a wrenching action on the structural connection NOT considered in the original design. Design assumes perfect alignment of the main girders during construction. The live load shoes are shimmed to align and maintain main girder contact. If these conditions are met, the shimming will still NOT take care of the rack/pinion teeth synchronization between the main girder racks. This will always result in some torsional, wrenching or prying action in the cantilevered structural connections (e.g., between main girder and front floor beam). The live load dynamics and an apparent amplification via total wrap-up (figure 9) are the type of unexplained loads imparted to the these connections.

8 Recommendations

8.1 High Strength Bolts

MATERIALS RECOMMENDATIONS - Based upon the laboratory test results obtained from Law Engineering Co., it is recommended that the Department utilize ASTM A325, type I, plain steel bolts, with appropriate nut and flat washer in all movable bridge projects.

QUALITY CONTROL - PROCESSING - Tests results also indicate any lack of quality control in the galvanizing process may result in a softening of the thread area. The purpose of galvanizing should be reconsidered. A loss of hardness could contribute to a relaxation of the bolt tension over time, especially if prying or heavy vibration is involved. In movable bridge structures, this condition is always present.

QUALITY CONTROL - INSTALLATION - Laboratory test results also indicated present AISC methods of installation could result in wide variations in bolt tension. Bolt tension on the initial take-up in a structural connection varied, whether via "snugging" with a spud wrench or utilizing a pneumatic impact tool. The pneumatic tool provided the narrowest band of tension. Temporary limits should be placed on the initial take-up process and/or tools employed until additional testing can produce more data and better quality control procedures in this area.

For now, installation should be a four step process. There is (1) the initial take-up of the connection and marking or etching of nut and bolt, (2) inspection, (3) final tensioning and (4) final inspection and/or verification.

The initial step (1) is the most difficult to control. For the narrowest variation of final tension, use a pneumatic tool for snugging. The tool should be sized to deliver a bolt tension (i.e., via job torque) not to exceed 15-20% of ultimate strength. After spray painting, marking/etching and inspection, the final tension, step (3), should be applied via a precision hydraulic torque wrench (e.g., Hytorc of Alabama) and step (4) as the calibrated wrench.

STORAGE AND PROTECTION - If the shipping container for plain black bolts has been properly sealed, no attempt should be made to wipe or clean the bolts/nuts prior to installation. Bolts should be maintained in their shipping containers as long as possible. No bolts should be returned to the original shipping container once removed. A separate container will be necessary for protecting the surface condition of the bolts until they are used.

After installation, a good temporary protective paint should be applied to the exposed bolt ends at the completion of step (1), initial take-up prior to marking or etching. This also provides for a media to assist inspection procedures. If turn-of-the-nut method is used, fresh paint will assist in scribing the bolt/nut relationship prior to and after setting final tension. A temporary aerosol paint would also assist in visually statusing, from a distance, each structural connection during erection of the spans. This assumes the entire structure must be cleaned prior to the final painting.

8.2 Applications - Bolted Structural Joints

Bascule Bridge Operational Sequence Adjustment - In the closing cycle of the each span, the drive motor(s) torque should be removed prior to, or at the point of main girder contact with the live load shoes. If the structure has air buffer cylinders, the span should be allowed to seat itself due to the weight of the span. After a reasonable time delay, the span locks may be driven. Once these are seated, then set the brakes. This removes all torsional wind-up or wrap-up in the gearing system which causes an amplification of the live load on the structure (ref.3). This will also remove considerable vibration from the structure which contributes to joint slip and fatigue (Ref. 2, pgs.288 & 313).

8.3 Structural Connections

A research effort into the characteristics of bolted structural connections, applicable to movable bridges, should be investigated.

The characteristics of bolted structural joints are still being developed (Ref. 4, pg. 254). Some of the problems encountered in this forensic effort point to a lack of experimental data supporting empirical equations encompassing dynamic loads (i.e., traffic vibrations and prying actions via span opening & closing cycles) encountered on movable bridge spans.

From the data collected, it is recommended the structural joints employed in the design of a movable span's connection of the main girders and their floor beams (figures 1 & 2) should be reviewed and its engineering configuration tested in a laboratory environment...at a minimum.

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3. Poche', Glenn M., "The Application of Current Transducer Technology on Movable Bridges - A Computerized Preventative Maintenance Program", The First Movable Bridge Symposium, November 4 & 5th, 1985, Tallahassee, Fl.

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5. American Institute of Steel Construction, Inc. "Allow Stress Design Specifications for Structural Joints Using ASTM A325 or A490 Bolts", November 13, 1985.

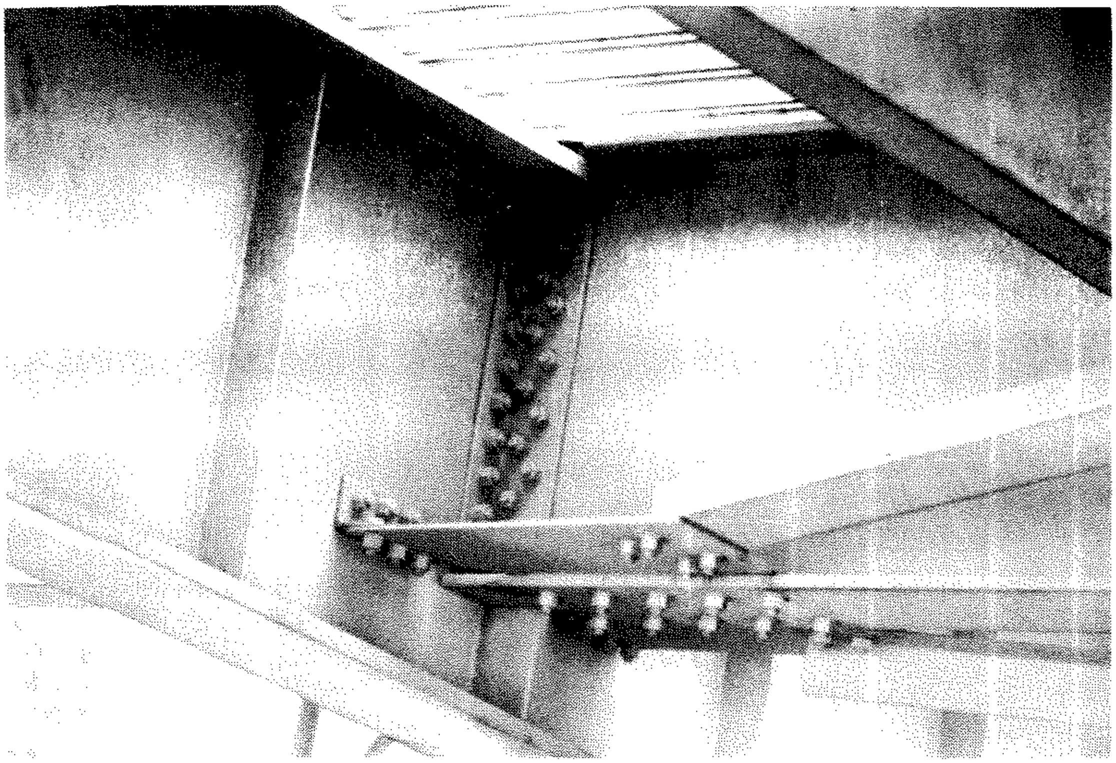


FIGURE 1. FRICTION CONNECTION OF FLOOR BEAM AND MAIN GIRDER
(PGA BLVD. BRIDGE - NORTHEAST SPAN)

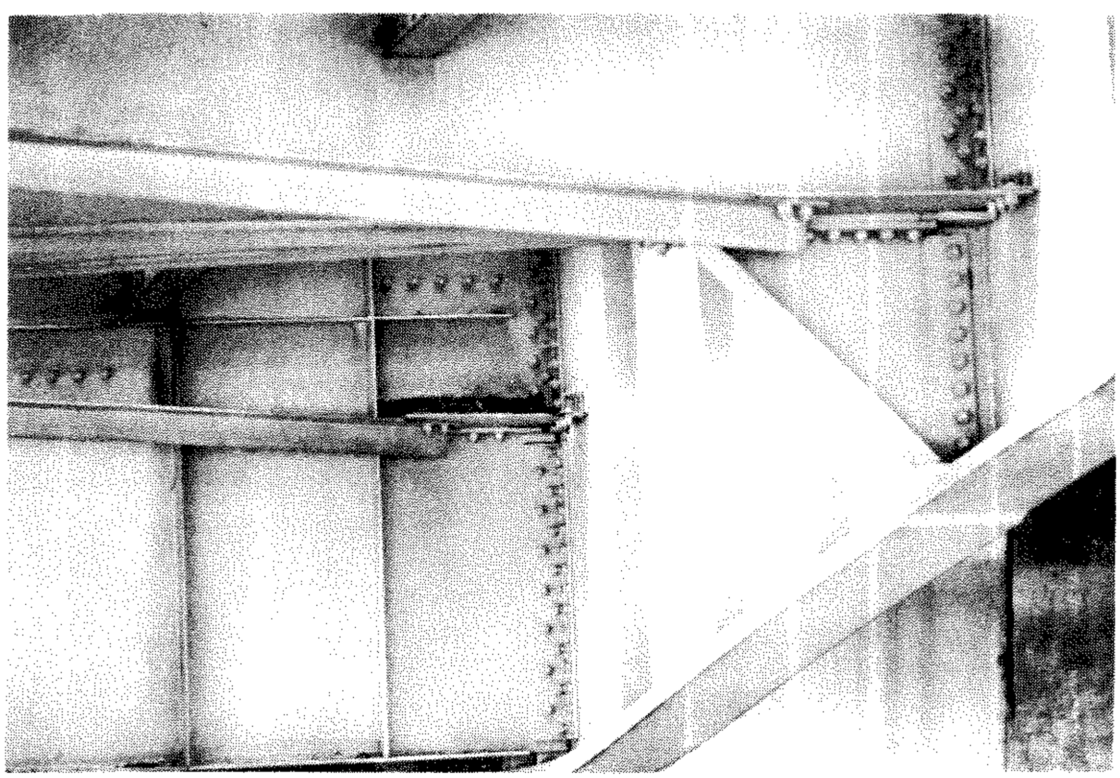


FIGURE 2. FRICTION CONNECTION OF FLOOR BEAM AND MAIN GIRDER
(PGA BLVD. BRIDGE - N.E. SPAN SHOWING WIND BRACING)

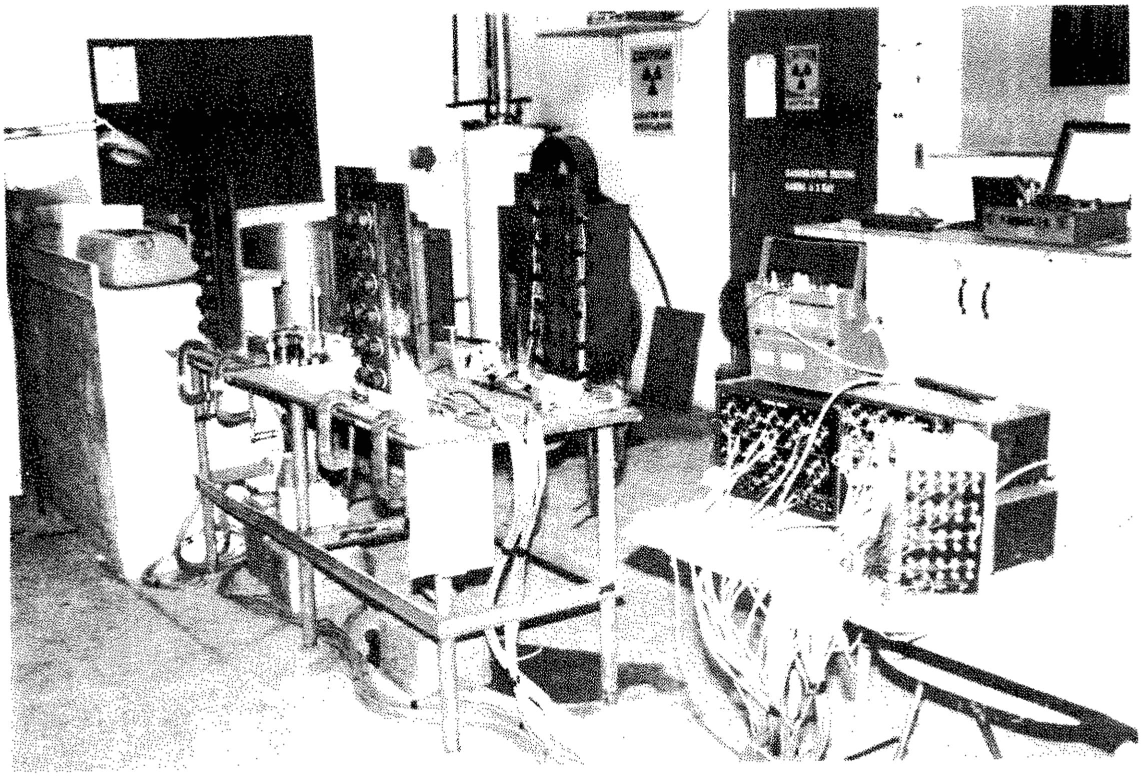


FIGURE 3.

LAW ENGINEERING LAB.
WITH TEST FIXTURES ON BENCH

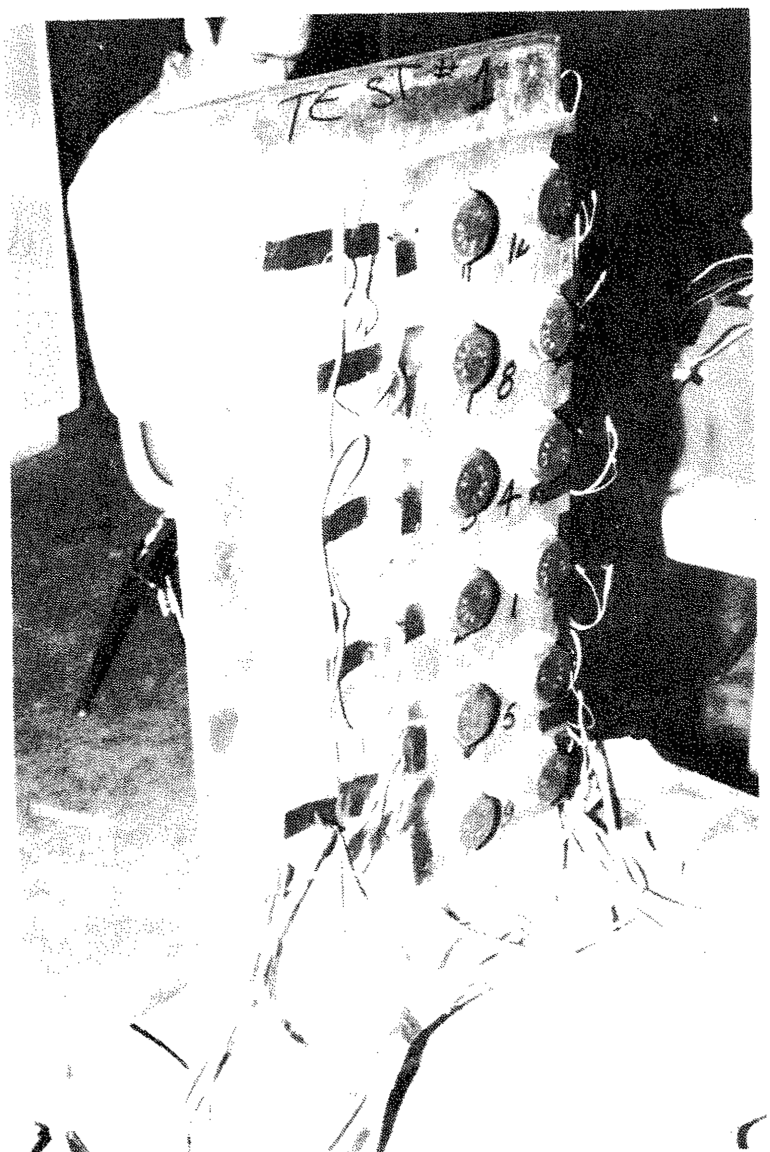
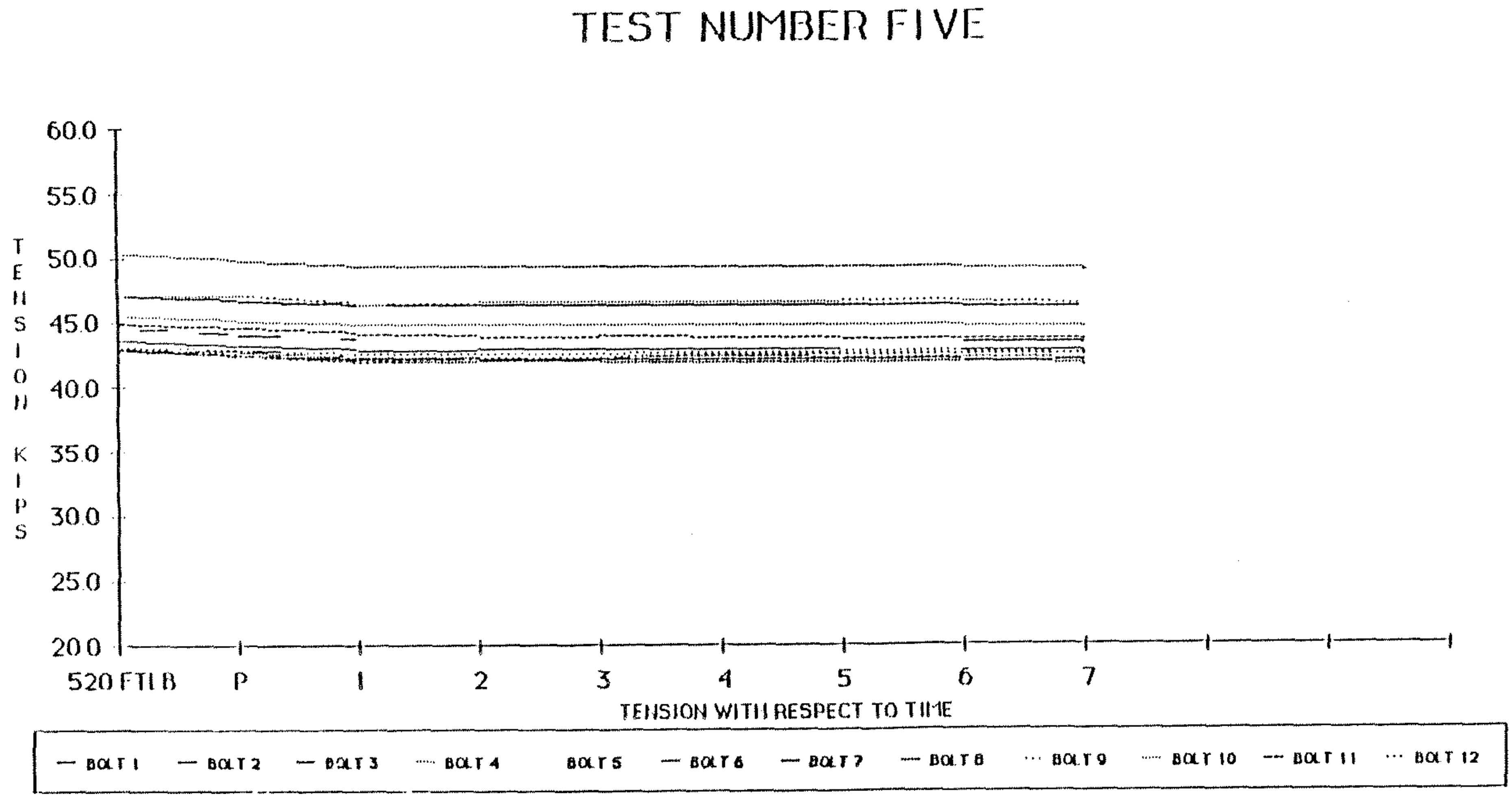


FIGURE 4.

TEST FIXTURE SHOWING
SIMULATED FRICTION CONNECTION
STRAIN GAGED BOLTS IN PLACE.



CONFIGURATION: 7/8" A325 Bolt, hardened washer under nut (Reuse of Test No.4 Bolts)

TIGHTENING SEQUENCE: 12,11,8,7,4,3,1,2,5,6,9,10

TIGHTENING PROCEDURE: Hand tight, 520 ft-lb using Hytorc wrench

Figure 5

LAW ENGINEERING TESTING COMPANY
TABLE OF COMPUTED BOLT TENSION VALUES (1000 LBS)
LETCO JOB NO. AM-10673

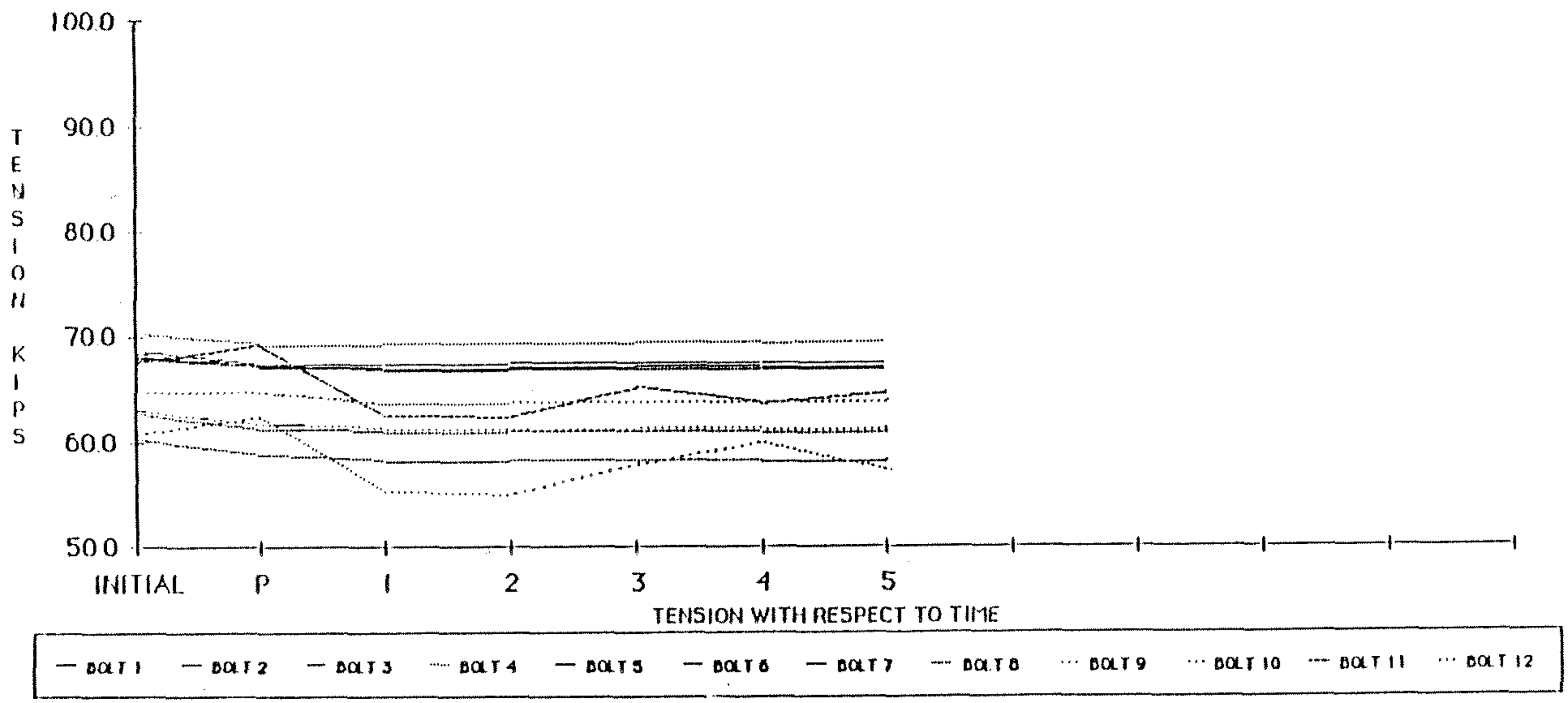
TEST NUMBER FIVE TEST BEGUN ON DEC. 11, 1986

BOLT NO.	TORQUE APPLIED W/ HYTORC (FT LBS)	INITIAL TENSION	TENSION AFTER ALL BOLTS TIGHTENED	TENSION VALUES AT ONE DAY INTERVALS							TOTAL TENSION CHANGE SINCE COMPLETION OF TIGHTENING SEQUENCE	
				1	2	3	4	5	6	7	(1000 LBS)	PERCENT
1	520	43.5	43.1	42.9	42.9	42.9	42.9	42.9	42.8	42.7	-0.4	-1.0
2	520	47.0	46.6	46.3	46.3	46.3	46.3	46.3	46.2	46.2	-0.4	-0.9
3	520	43.0	42.4	42.2	42.2	42.2	42.2	42.2	42.1	42.0	-0.5	-1.1
4	520	45.4	45.1	44.8	44.8	44.9	44.9	44.8	44.7	44.7	-0.4	-1.0
5	520	44.5	43.9	43.6	43.6	43.6	43.6	43.5	43.5	43.4	-0.5	-1.2
6	520	50.3	49.8	49.4	49.4	49.4	49.3	49.3	49.2	49.1	-0.6	-1.3
7	520	42.9	42.4	42.0	42.0	41.9	42.0	42.0	42.0	41.7	-0.7	-1.6
8	520	42.8	42.7	42.3	42.3	42.4	42.5	42.3	42.3	42.1	-0.6	-1.5
9	520	43.1	42.9	42.6	42.5	42.5	42.7	42.8	42.7	42.5	-0.3	-0.8
10	520	47.0	47.0	46.3	46.6	46.6	46.6	46.7	46.6	46.4	-0.6	-1.4
11	520	44.8	44.5	44.0	43.8	43.9	43.8	43.7	43.7	43.7	-0.8	-1.9
12	520	43.1	42.5	42.0	42.3	42.3	42.6	42.6	42.5	42.4	-0.1	-0.1
	AVERAGE=	44.8	44.4	44.0	44.1	44.1	44.1	44.1	44.0	43.9	-0.5	-1.1
	STD DEV=	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	0.2	0.4

NOTES: SAME SET-UP (BOLTS AND TEST PLATES) AS USED IN TEST NUMBER FOUR
FOR TEST NUMBER FIVE: BOLTS COMPLETELY LOOSENED THEN TIGHTENED WITH THE HYTORC TO 520 FT LBS IN ONE STEP
TIGHTENING SEQUENCE IN A ZIG-ZAG PATTERN STARTING FROM THE TOP LEFT BOLT
BOLTS NUMBERED AS INDICATED ON ATTACHED DRAWING
HYTORC (OWATONNA TOOL CO.) CAT. NO. SST 10, MODEL C, SERIAL NO. 53537

Figure 6

TEST NUMBER SIX

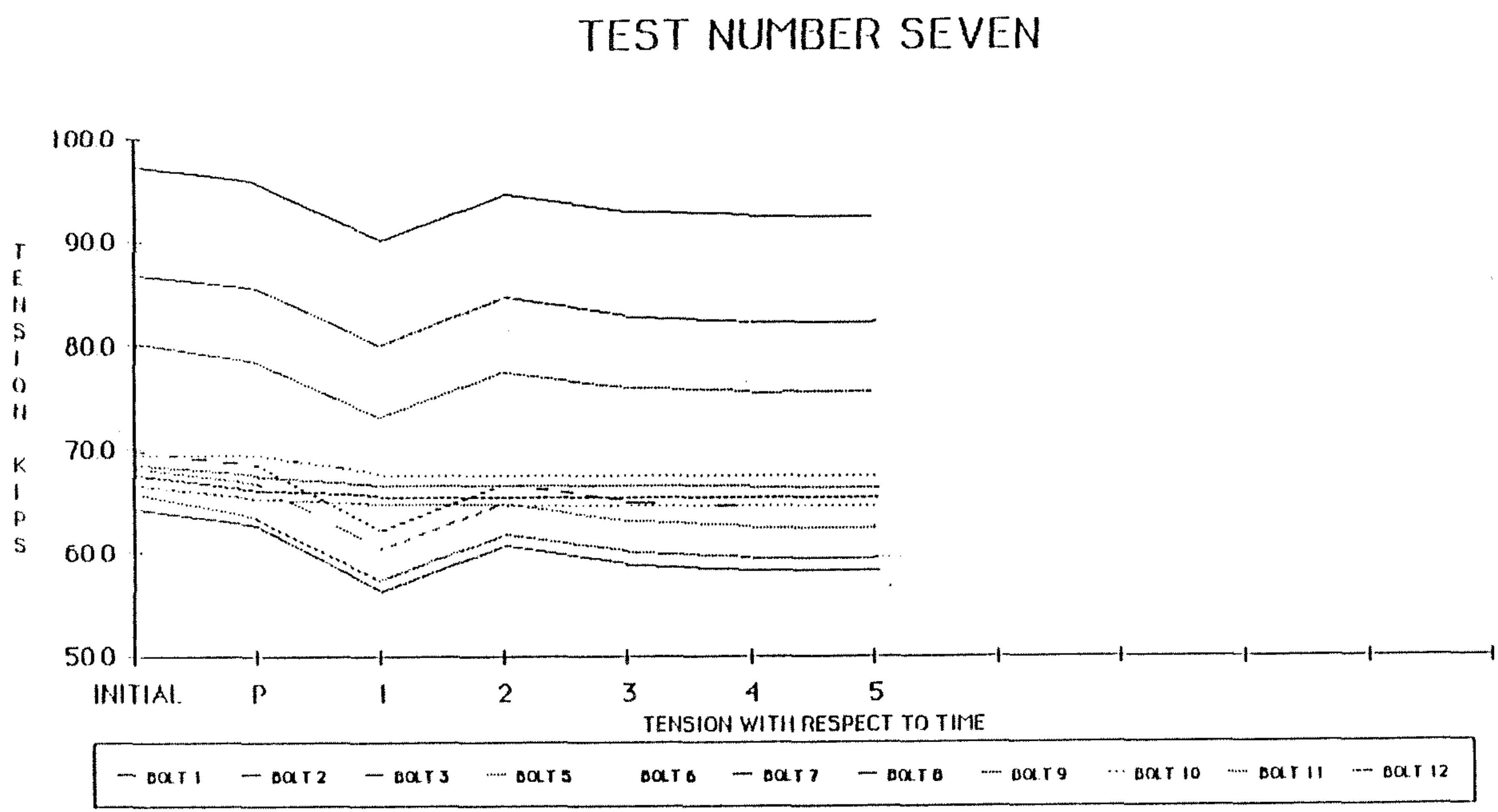


CONFIGURATION: 7/8" A325 Bolt, hardened washer under nut

TIGHTENING SEQUENCE: 12,11,8,7,4,3,1,2,5,6,9,10

TIGHTENING PROCEDURE: "Snug tight," turn-of-nut (1/3 turn) per AISC

Figure 7



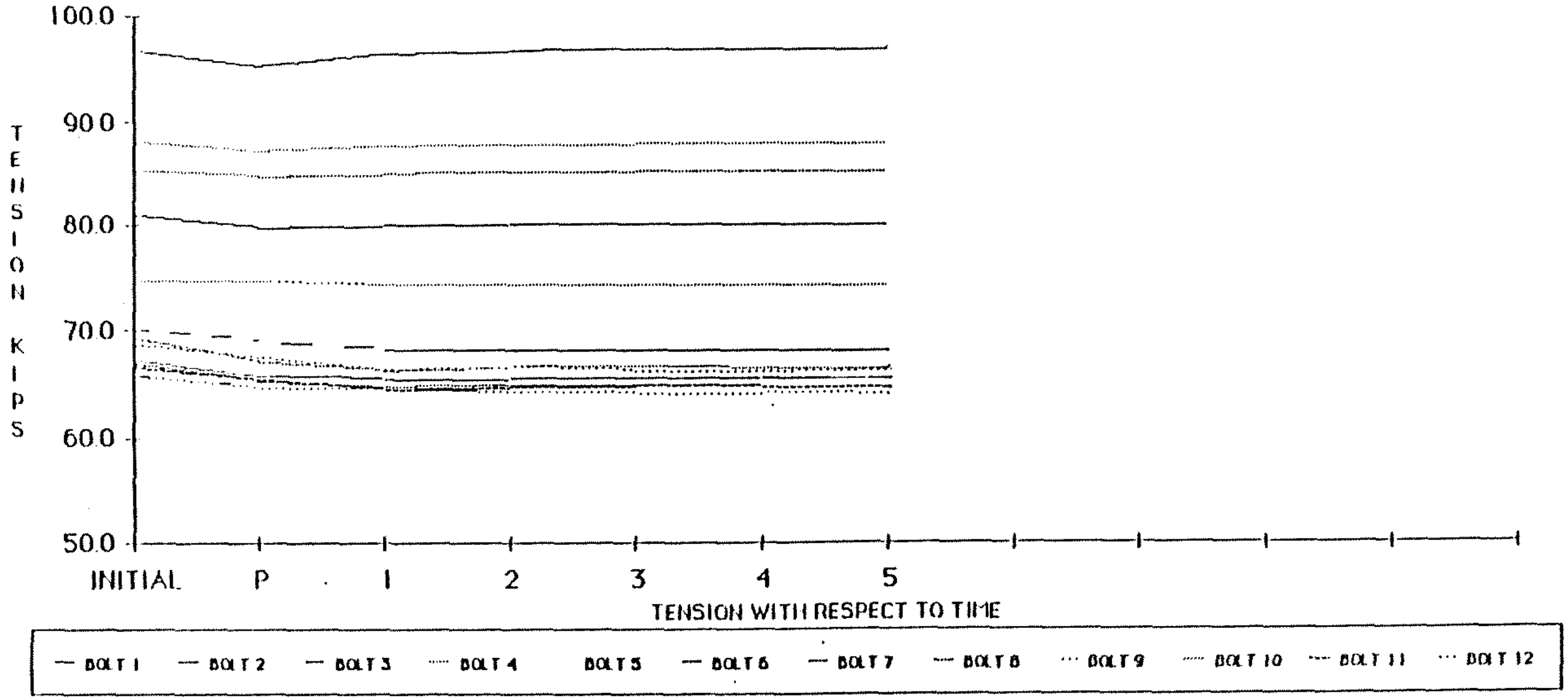
CONFIGURATION: 7/8" A325 Bolt, hardened washer under nut (Reuse of Test No.3 Bolts)

TIGHTENING SEQUENCE: 12,11,8,7,4,3,1,2,5,6,9,10

TIGHTENING PROCEDURE: "Snug tight," turn-of-nut (1/3 turn) per AISC

Figure 8

TEST NUMBER EIGHT

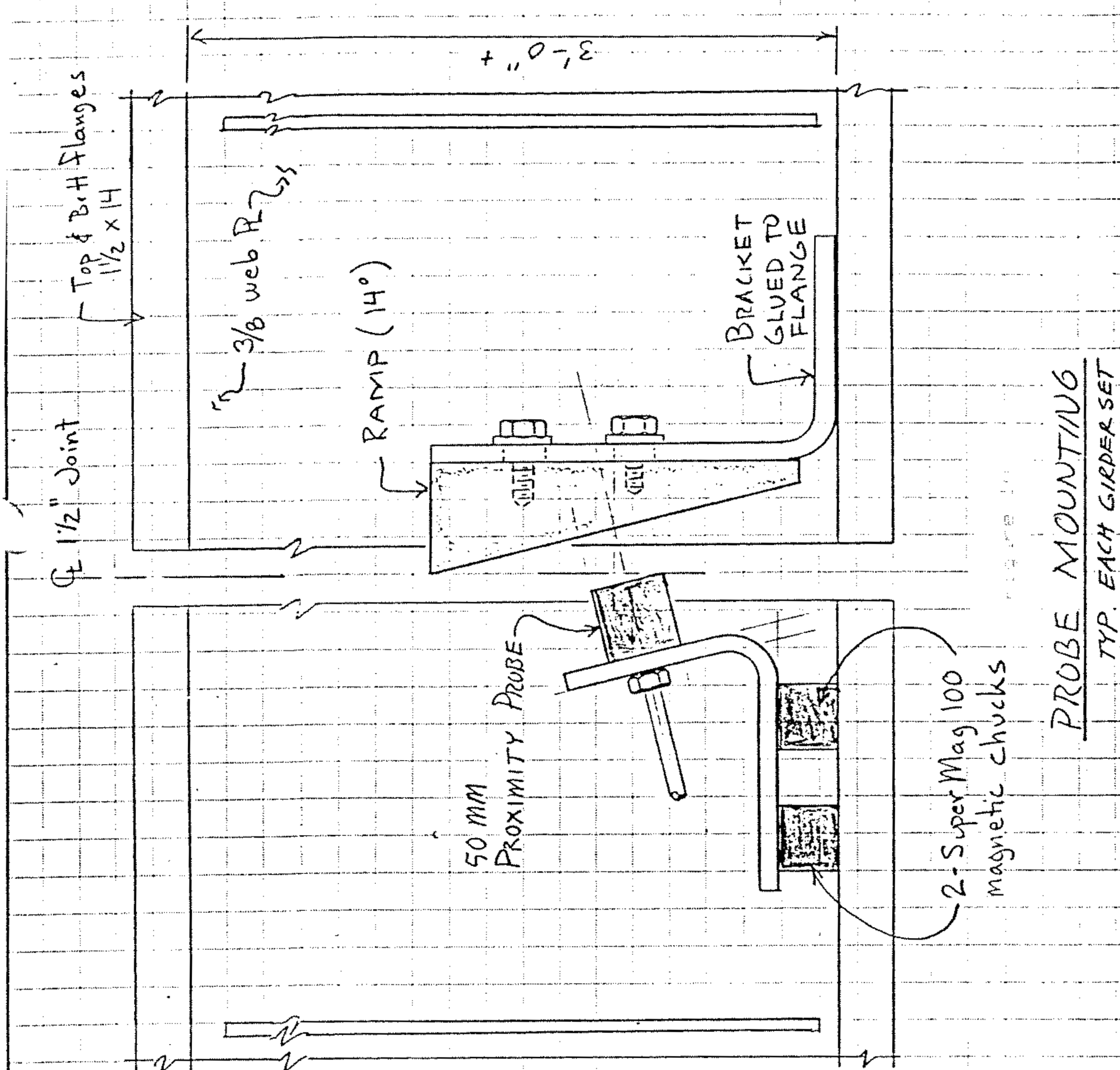


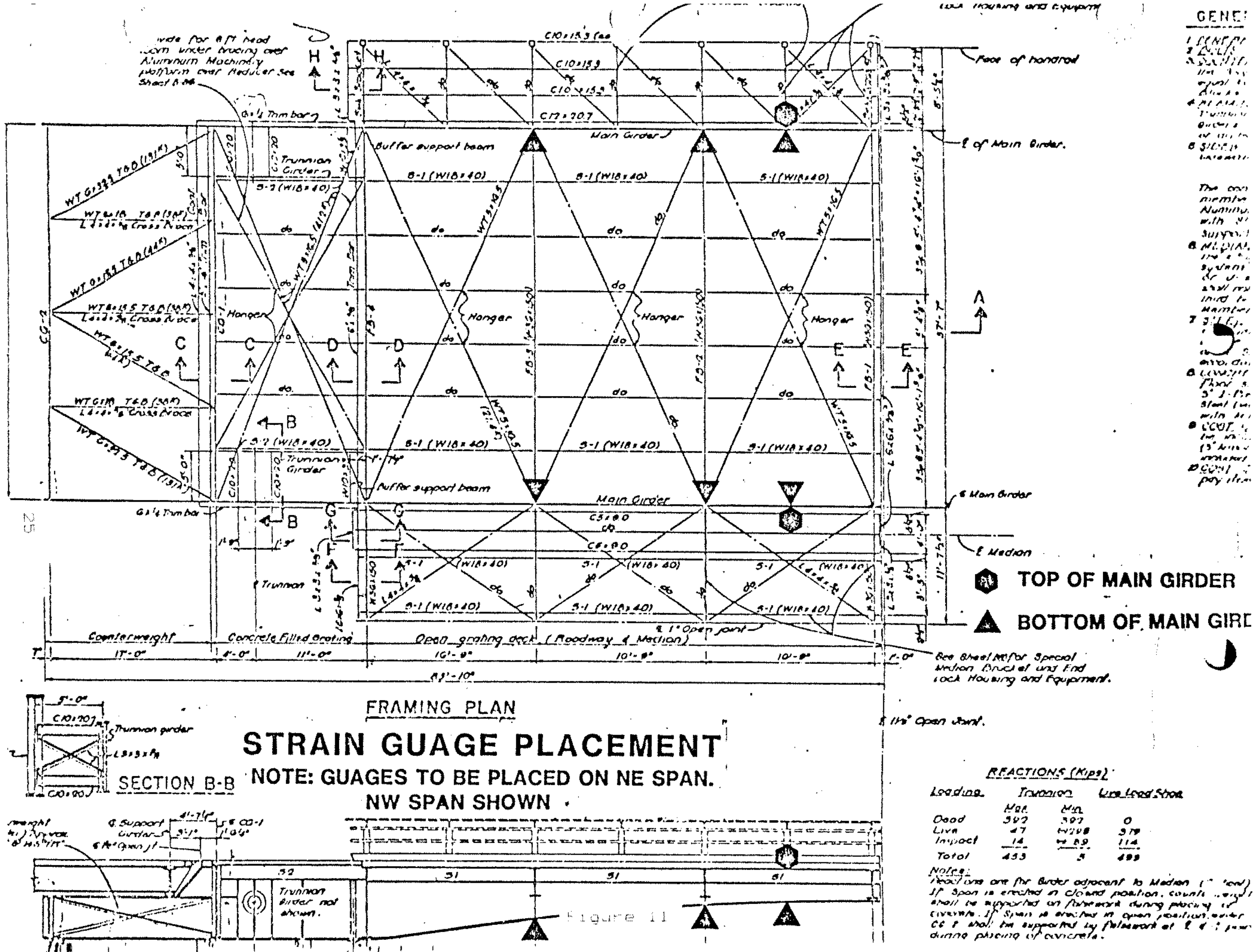
CONFIGURATION: 7/8" A325 Bolt, hardened washer under nut (Reuse of Test No. 4 & 5 Bolts)

TIGHTENING SEQUENCE: 12,11,8,7,4,3,1,2,5,6,9,10

TIGHTENING PROCEDURE: "Snug tight," *turn-of-nut (1/3 turn)* per AISC

Figure 9


3'-0" ±
Top & Bott Flanges
1½ x 14
3/8 web PL
RAMP (14°)
BRACKET
GLUED TO
FLANGE
℄ 1½" Joint
50 MM
PROXIMITY PROBE
2-Super Mag 100
magnetic chucks
PROBE MOUNTING
TYP. EACH GIRDER SET


FRAMING PLAN
STRAIN GUAGE PLACEMENT
NOTE: GUAGES TO BE PLACED ON NE SPAN.
NW SPAN SHOWN
TOP OF MAIN GIRDER
BOTTOM OF MAIN GIRD
SECTION B-B
Face of handrail
℄ of Main Girder
℄ Main Girder
℄ Median
Main Girder
Buffer support beam
Trunnion Girder
Hanger
Counterweight
Concrete Filled Grating
Open grating deck (Roadway & Median)
17'-0"
4'-0"
11'-0"
10'-9"
1'-0"
83'-10"
37'-7"
See Sheet for Special Median Bracket and End Lock Housing and Equipment.
1/8" Open Joint
1" Open joint
REACTIONS (Kips)
Loading | Trunnion Max. | Trunnion Min. | Live Load Shoe
Dead | 392 | 392 | 0
Live | 47 | -298 | 379
Impact | 14 | -89 | 114
Total | 453 | 5 | 493
Notes:
Figure 11

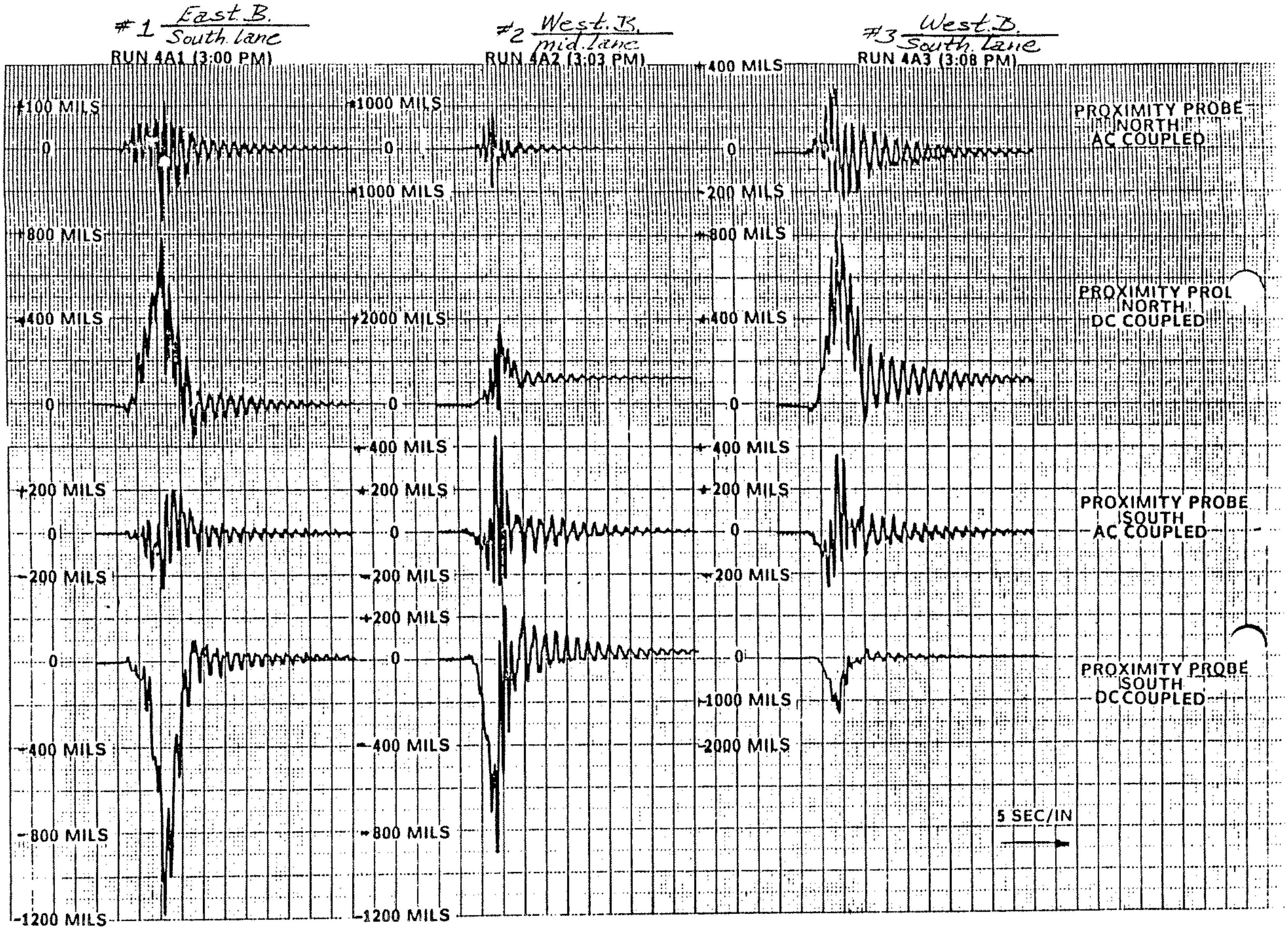
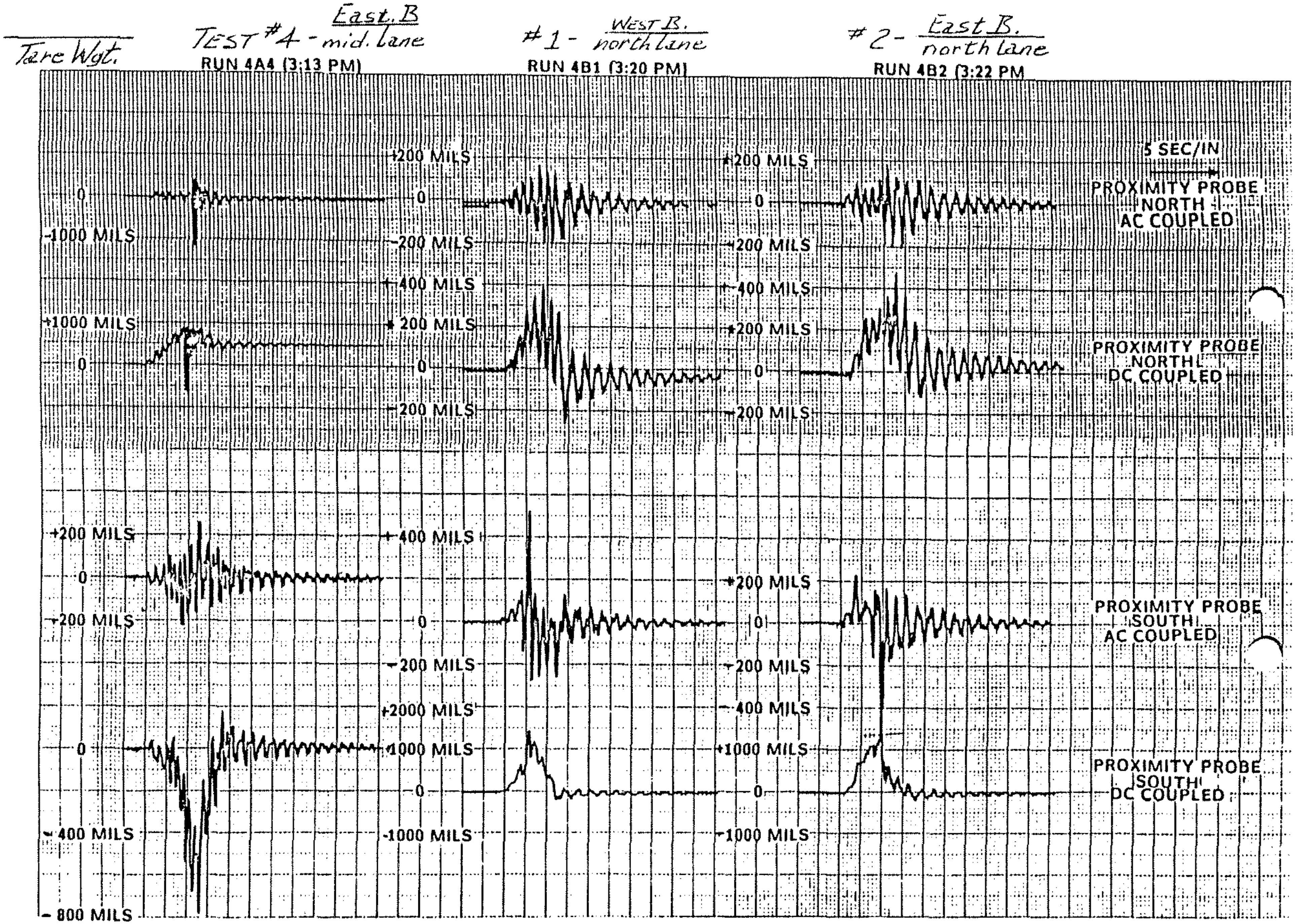

#1 East B. South lane
RUN 4A1 (3:00 PM)
#2 West B. mid lane
RUN 4A2 (3:03 PM)
#3 West B. South lane
RUN 4A3 (3:08 PM)
PROXIMITY PROBE NORTH AC COUPLED
PROXIMITY PROBE NORTH DC COUPLED
PROXIMITY PROBE SOUTH AC COUPLED
PROXIMITY PROBE SOUTH DC COUPLED
+100 MILS
0
+800 MILS
+400 MILS
+200 MILS
-200 MILS
-400 MILS
-800 MILS
-1200 MILS
+1000 MILS
-1000 MILS
+2000 MILS
+400 MILS
-200 MILS
-2000 MILS
5 SEC/IN

Figure 12



Tare Wgt.
TEST #4 - East. B mid. lane
RUN 4A4 (3:13 PM)
#1 - West B. north lane
RUN 4B1 (3:20 PM)
#2 - East B. north lane
RUN 4B2 (3:22 PM
5 SEC/IN
PROXIMITY PROBE NORTH AC COUPLED
PROXIMITY PROBE NORTH DC COUPLED
PROXIMITY PROBE SOUTH AC COUPLED
PROXIMITY PROBE SOUTH DC COUPLED
+200 MILS
0
-200 MILS
+400 MILS
-400 MILS
-1000 MILS
+1000 MILS
+2000 MILS
- 800 MILS

Figure 15

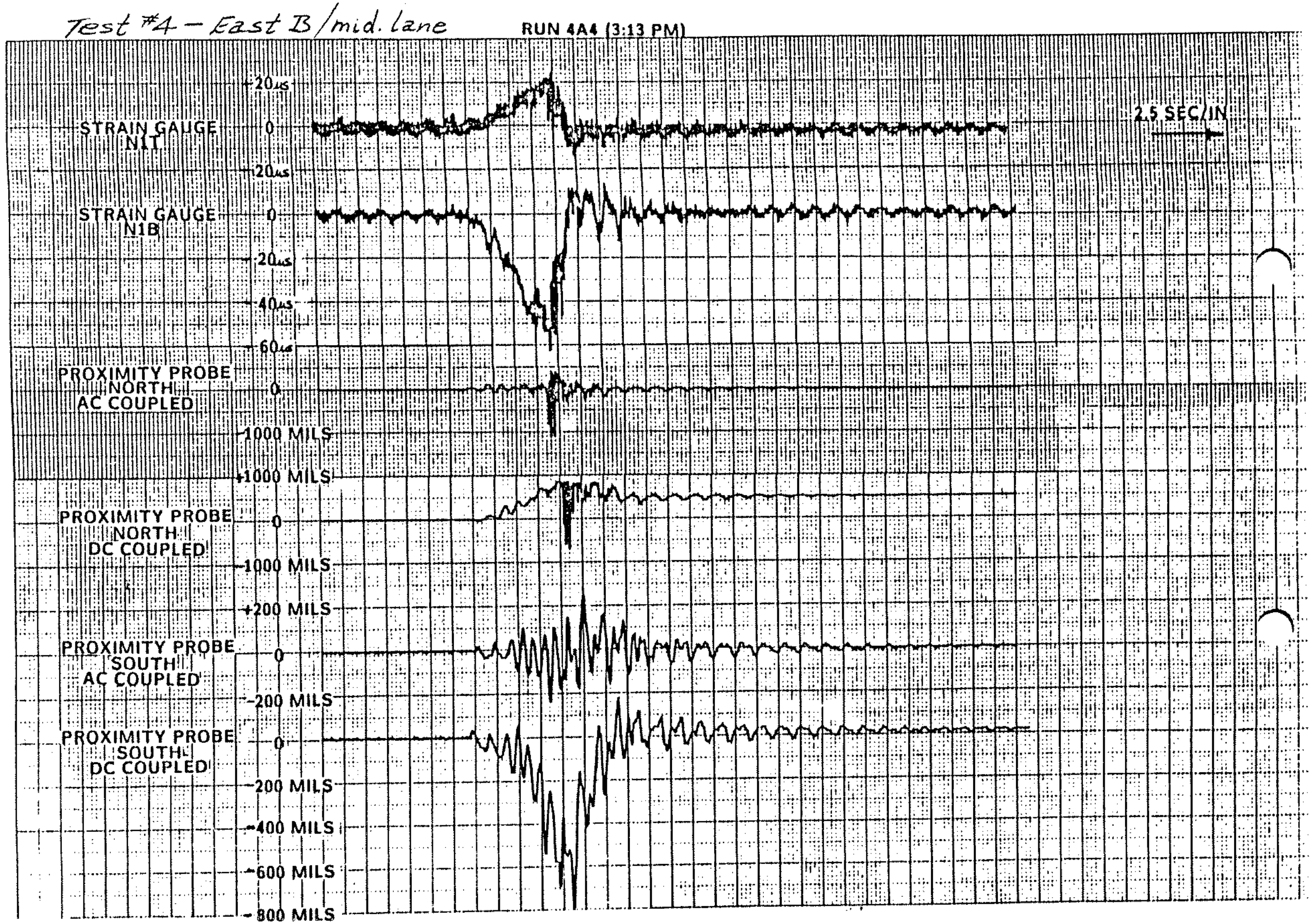

Test #4 – East B/mid. lane
RUN 4A4 (3:13 PM)
2.5 SEC/IN
STRAIN GAUGE N1T
+20µs
0
-20µs
STRAIN GAUGE N1B
0
-20µs
-40µs
-60µs
PROXIMITY PROBE NORTH AC COUPLED
0
-1000 MILS
+1000 MILS
PROXIMITY PROBE NORTH DC COUPLED
0
-1000 MILS
+200 MILS
PROXIMITY PROBE SOUTH AC COUPLED
0
-200 MILS
PROXIMITY PROBE SOUTH DC COUPLED
0
-200 MILS
-400 MILS
-600 MILS
-800 MILS

Figure 14

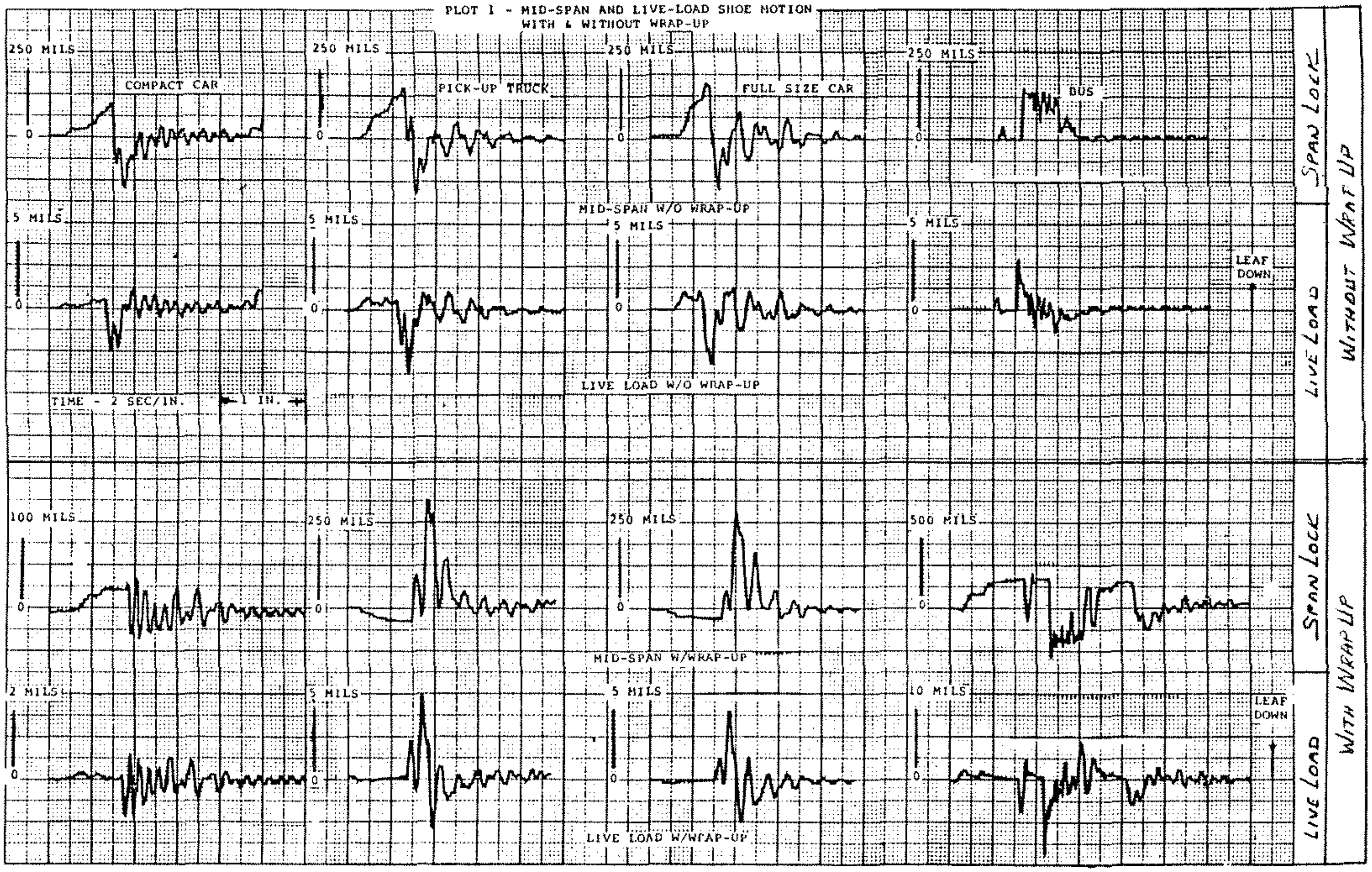


Figure 15 DANIA BLVD. DYNAMIC TEST RESULTS