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THE DAVID W. TAYLOR MODEL BASIN

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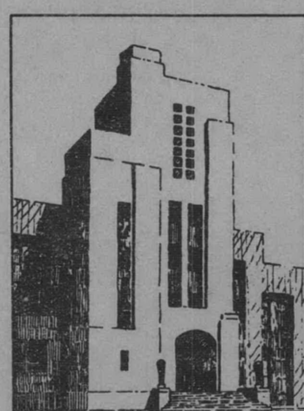
THE ELASTIC BEHAVIOR OF THE CA139-CLASS PILOT TURRET WITH GUNFIRE LOADING

by

L.M. DeLand



October 1950

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THE ELASTIC BEHAVIOR OF THE CA139-CLASS PILOT TURRET WITH GUNFIRE LOADING

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FOREWORD

The new main-battery turret for the CA139-Class cruisers incorporated many novel structural and mechanical features which rendered it capable of firing its three 8-inch 55-caliber guns more rapidly than any of its predecessors. To check its operation, perhaps the most extensive structural investigation ever conducted on turrets was performed. A 1/10-scale structural model was fabricated and tested at the David Taylor Model Basin, and a full-scale pilot turret was tested at the Naval Proving Ground. The results have subsequently been checked by structural firing trials conducted on the USS DES MOINES (CA134), the first naval vessel to carry these new turrets. As its part of the over-all program, the David Taylor Model Basin was given the responsibility of measuring (a) the performance of the turret structure and roller track, (b) the behavior of the recoil-counterrecoil system, (c) the operation of the training buffer, and (d) the motion of the guns and turret during elevating and training exercises.

Apart from the primary objective of confirming the safety and the satisfactory performance of the new turret in advance of construction of the ships themselves, secondary objectives were established to derive experimentally information which could be employed to confirm or invalidate design criteria for guns and turrets, and for structural assemblies which are similarly loaded.

The results of the test of the pilot turret under dynamic load are given in this report. The other results are given in additional reports and memoranda, as follows:

1. "Description of Test of Hydraulic Training Buffer of CA139-Class Pilot Turret," TMB RESTRICTED Report C-38, February 1948.

2. "An Elastic-Tube Gage for Measuring Static and Dynamic Pressures," TMB Report 627, May 1948.

3. "Description of Instruments Employed in the Operational Tests of the Gun-Elevating Systems of the CA139-Class Pilot Turret," TMB RESTRICTED Report C-29, October 1947.

4. "The Measurement of Performance of the Gun-Elevating System of the 8-Inch 55-Caliber Pilot Turret," TMB RESTRICTED Report C-163 (in preparation).

5. "The Measurement of Performance of the Training System of the 8-Inch 55-Caliber Pilot Turret," TMB RESTRICTED Report C-164, May 1950.

6. "Experimental Analysis of the Recoil System of the 8-Inch 55-Caliber Guns Mark 20, Mod 1," TMB RESTRICTED Report C-165, March 1950.

7. "The Elastic Behavior of the Rotating Structure of the CA139-Class Pilot Turret under Static Loading," TMB RESTRICTED Report C-166, March 1950.

8. "The Dynamical Behavior of Turret Structures with Particular Reference to the 8-Inch 55-Caliber Size," TMB RESTRICTED Report C-81, June 1950.

9. "Structural Design Studies of a 1/10-Scale Model of the 8-Inch Gun Girder on the CA139-Class Cruisers," Thesis, Department of Naval Architecture and Marine Engineering, Massachusetts Institute of Technology, 1949.

10. "Schedule of Measurements to be Made by the David Taylor Model Basin during Tests of the CA139 Pilot Turret," TMB Memo 2, CA139 Class/S72-1 of 13 November 1945 (revised 25 April 1947).

11. "Experimental Analysis of Stress and Deformation of a 1/10-Scale Model 8-Inch Gun Turret for the CA139-Class Cruisers," TMB RESTRICTED Report 571, February 1948.

12. "The TMB Tension Dynamometer," TMB Report 605 (in preparation).

13. "Natural Frequencies Measured on the CA139-Class Pilot Turret," TMB RESTRICTED Report C-82, December 1948.

Whereas the experimental and theoretical analyses were conducted for this turret investigation to obtain specific data regarding performance, a vast amount of general information was obtained pertaining to the behavior of hydraulic energy-absorbing systems and to the elastic behavior of complex structures subjected to dynamic loading. It is now planned to present these more general results in two separate reports:

1. Considerations for the Design of Complex Structures Subjected to Dynamic Loads, as Derived from Experimental Analysis.
2. New Considerations for the Design of Hydraulic Buffers as Derived from Experimental Analysis.

TABLE OF CONTENTS

ABSTRACT

Strains were measured in the trusses of the 8-inch 55-caliber pilot turret at the Naval Proving Ground during structural firing tests of the two wing guns to determine the stress distribution throughout the turret, the variation of behavior with different roller-track positions, and the effect of gun elevation on the structural response.

From these dynamic tests it is concluded that the structure as designed is safe but uneconomical; the maximum stress developed with discharge of two guns was only about 8600 psi. It is estimated that 13,000 psi would be developed with all guns firing. The position of the turret on the roller track did not influence structural response, and the effect of gun elevation on measured maximum strains was a random one. Also, the application of the principle of superposition for multiple gunfire was confirmed.

The dynamic load factor derived from comparison with results of tests with static loading was as high as 2.8 ±0.8 and as low as 0.4 ±0.3 depending on the gage station; the average was approximately 1.4. The large variation in load factor was attributed to the low magnitude of stress so that the masking effect of experimental error reduced exactness of the comparison of static and dynamic behavior.

INTRODUCTION

Cruisers of the CA139 Class differ from the earlier CA68 Class primarily in the use of gun turrets which incorporate rapid-firing guns capable of being loaded at any elevation, either with the guns stationary or moving to follow targets. This novel feature involved mechanical equipment which required more space than existed on earlier turrets, but the increase in size was limited by the design hull displacement. Such a limitation necessitated the use of unique structural arrangements which appeared to be accompanied by a reduction in strength and stiffness. It was believed that the acceptability of the new design could best be determined by full-scale tests. Thus it was deemed necessary to construct and test a pilot turret to determine the performance well in advance of the actual construction of naval vessels.[1,2] At the same time, it was considered essential that information be collected which might be of value in the design of other similar turrets.

A pilot turret was subsequently built and tested with both static and gunfire loads at the Naval Proving Ground, Dahlgren, Virginia. Results of the static tests have been published;[3] this report gives the results of the dynamic tests. It includes a brief description of the structural design (a

[1]References are listed on page 28.

more detailed discussion is given in the report on the static tests[3]), a short description of the instruments employed, and a comparison of the results with those of the static tests.

The objectives of these structural firing tests were:

1. To determine the stress distribution throughout the turret, the safety of the structure, and the degree of redundancy.

2. To determine whether the laws of superposition were applicable to the turret structure.

3. To ascertain the variation of behavior with different roller-track positions.

4. To determine the dynamic load factor.

5. To determine the effect of gun elevation on the structural response.

DESCRIPTION OF ROTATING STRUCTURE

The general arrangement of the 8-inch 55-caliber turret is shown in Figure 1. As with earlier designs, it consists of a structural system which supports the guns and which rotates on a roller-track system about a vertical axis, and a cylindrical foundation which supports the roller track. The results obtained in this test pertain primarily to that portion of the turret above the roller-track level, usually referred to as the rotating structure or the turret weldment.

The rotating structure comprises a cylindrical bulkhead bounded at the top by the shelf plate and at the bottom by the pan plate and containing four girders disposed to support the three gun trunnions. The center of the trunnions lies several feet above the shelf plate so that the trunnions themselves are supported by extensions of the girders acting as cantilevers.

In the rapid-fire 8-inch turret, the inboard gun girders are formed of open trusses made up of rolled H-sections. The outboard girders are formed as stiffened plate girders. The construction of the gun girders is shown in Figure 2.

The primary change in structural arrangement of this turret with respect to earlier turrets was the use of the open truss in lieu of heavy double-plate girders, and it was around the performance of these trusses that the structural investigation was planned.

The center gun of the normal three-gun battery was never installed in the pilot turret, primarily to speed the construction and testing but also to save space and material and to provide better access to the various parts

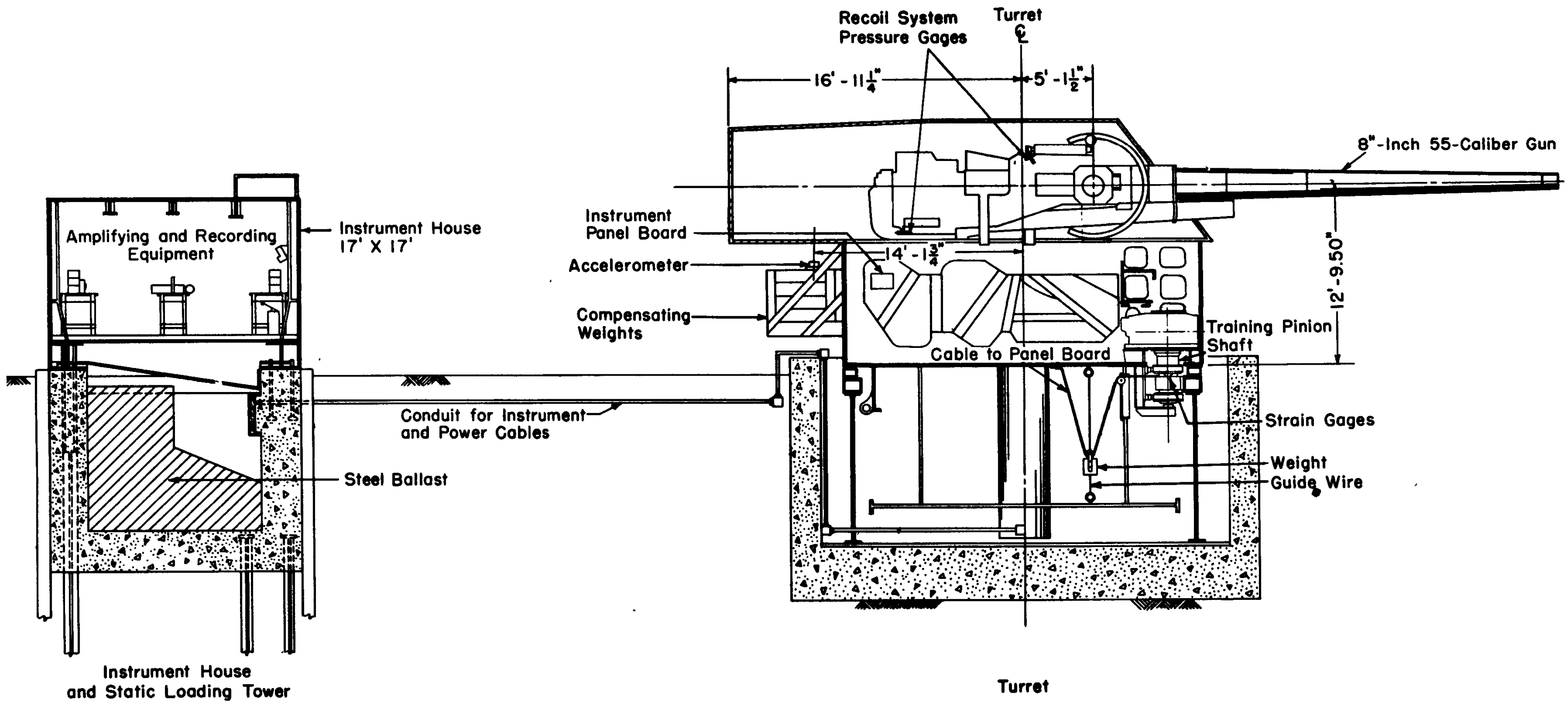

Figure 1 - General Arrangement of the Turret

of the turret. It is felt that the accuracy of the test was not influenced by the omission.

TEST PROGRAM

Dynamic loading of the structure was accomplished by firing the guns. In order to achieve the stated objectives, the test was run so that strains usually were measured on each strain gage at least twice for each condition of gunfire. Strains were measured at stations on the left truss when the left gun was fired at 0° and 40° elevation, when the right gun was fired at 0° and 40°, and when both guns were fired at 0° and 40°. Similar measurements of strains were made in the right truss.

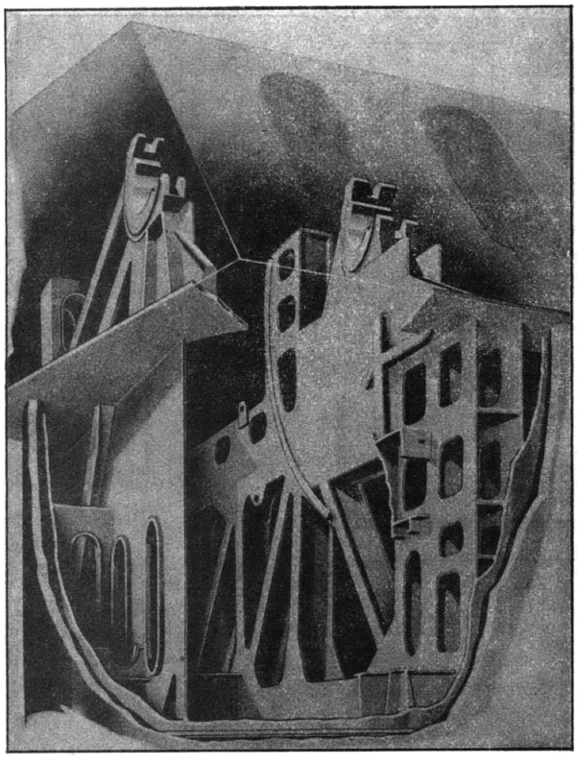

Figure 2 - Construction of the Gun Girders

Strains in the left truss were also measured when the left gun was fired at angles of 5°, 10°, 15°, 20°, 25°, 30°, and 35°. Strains in the right truss were measured when the right gun was fired at 10°, 20°, and 30°.

Deflections of the turret were also measured. Due to lack of personnel, however, these data were not reduced but are filed at the Taylor Model Basin.

Recoil loads were measured during each shot, but because of scatter and lack of consistency of the data, they are not reported. Instead the values obtained in the recoil tests[4] are used when load values are necessary. These were 200 kips for gunfire at 0° elevation and 220 kips for gunfire at 40° elevation from either right or left gun. The use of this recoil data is believed justified because of the reproducibility of gunfire loading observed during the recoil investigation.

Strains in the left truss were also recorded with the turret jacked forward and with it jacked aft, to determine if structural response was influenced by position of the turret on the roller track.

INSTRUMENTATION

The strain gages employed were the wire-resistance gages used during the static tests of the turret:[3] Baldwin-Southwark SR-4 gages of 120-ohm resistance. The location of the gages is shown in Figure 3. Recording of the strains was accomplished by means of TMB Type-1A strain indicators, whose output was recorded on string oscillographs (Figures 4 and 5). The frequency response of the recording system was flat from 0 to 200 cps.

As can be seen from Figure 3, there were 51 gages located on the left truss. The positions of these gages had been selected primarily to measure strains at stations which were (a) believed to have high strains and so constitute regions closest to failure or (b) believed to have low strains and thus constitute elements where material could safely be removed if the belief should be confirmed. A more complete discussion of gage position is given in Reference 3.

Nineteen gages were located on the right truss, mainly to check the results obtained on the left truss and to test whether the law of superposition held for this structure.

Deflections were recorded by means of Schaevitz transformer-type gages, which can be used to measure deflections up to 1/2 inch. TMB-built transformer driving units were employed with the gages. Gage output was recorded directly on the string oscillograph without amplification. The data taken with these gages have not been reduced. Figure 6 shows a schematic diagram of the deflection gage and recording system and a photograph of an actual installation.

TEST RESULTS

The maximum strains recorded as a result of gunfire are tabulated in Table 1 for the gages located in the left truss. Values are usually the average of two or more runs.

Table 2 similarly summarizes the strain data obtained with the gages on the right truss.

In Table 3 are compared data obtained with symmetrically located gages. For example, Gage 1 on the left truss and Gage 101 on the right truss were symmetrically located; therefore the strain recorded by Gage 1 when the left gun was fired should be equal to the strain recorded by Gage 101 when the right gun was fired, etc.

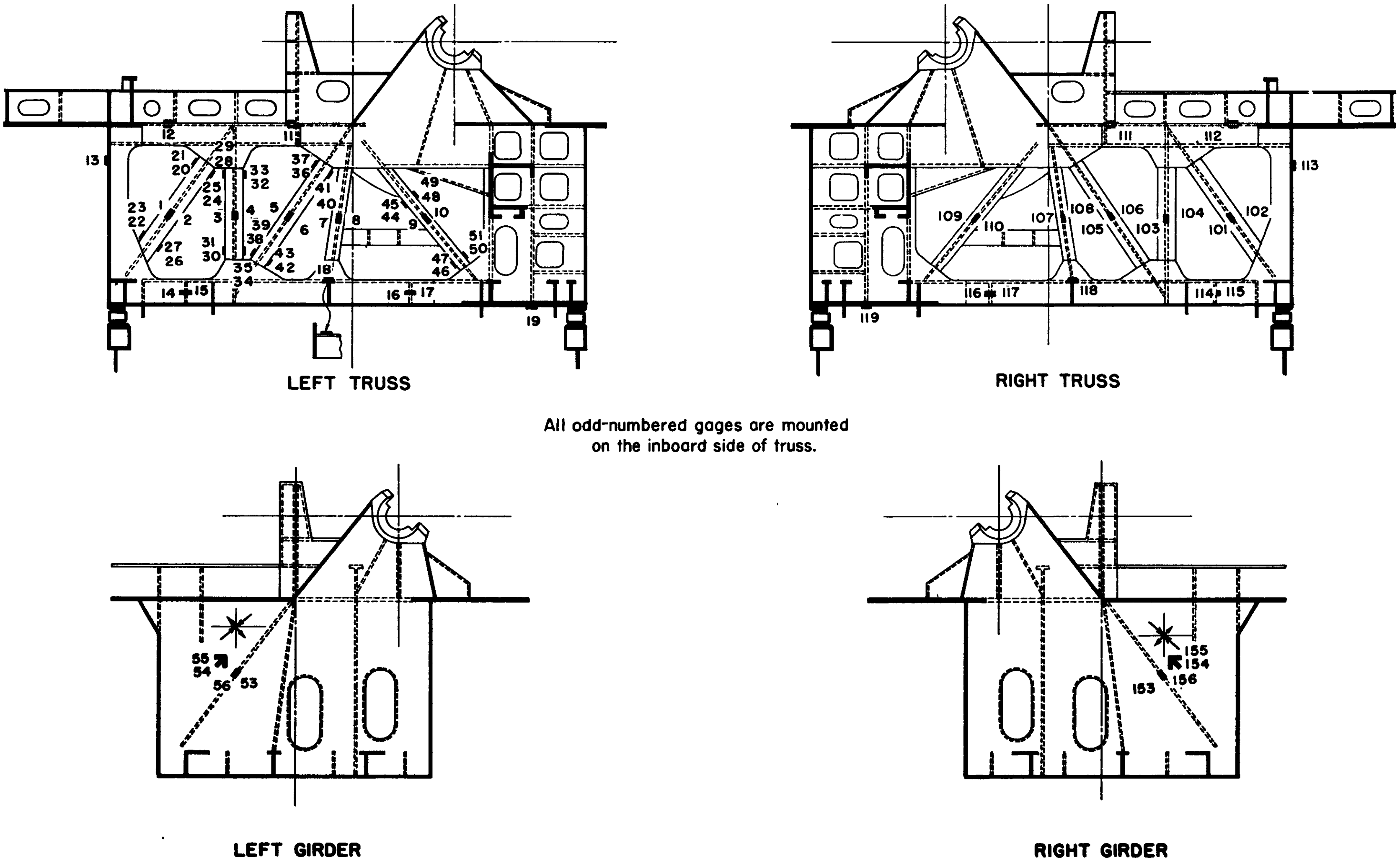

Figure 3 - Location of Strain Gages on the Rotating Structures

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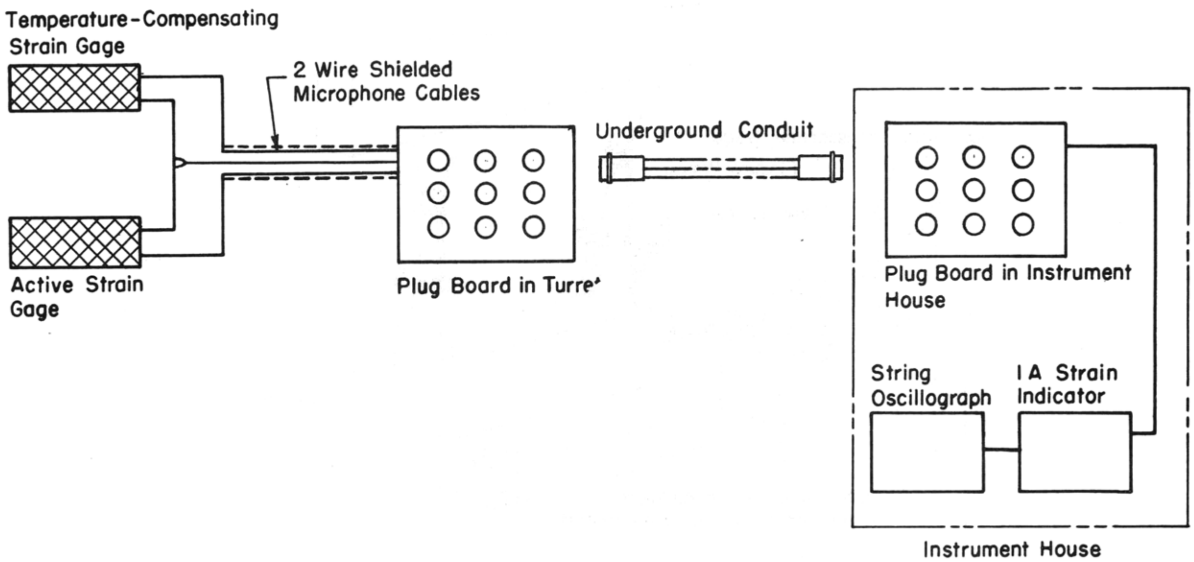

Figure 4 - Schematic Diagram of Strain Gage Instrumentation

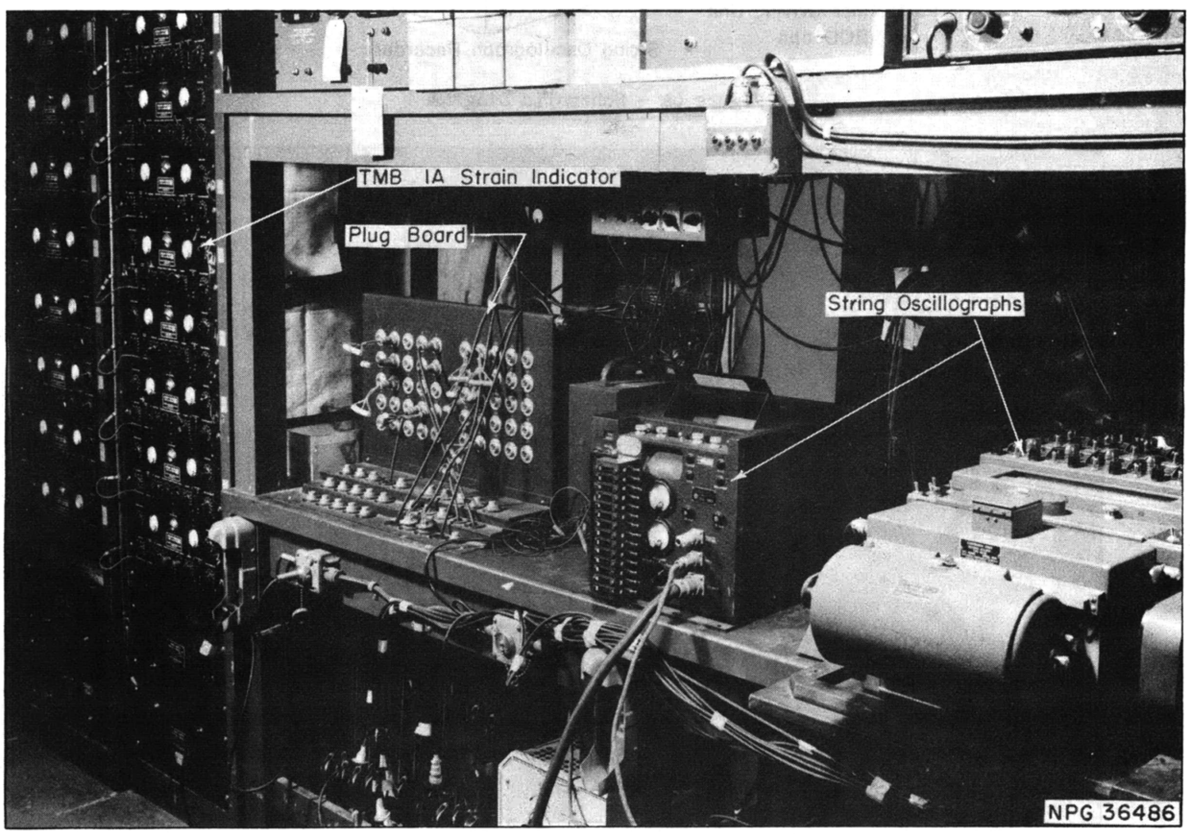

Figure 5 - Strain Gage Recording Equipment

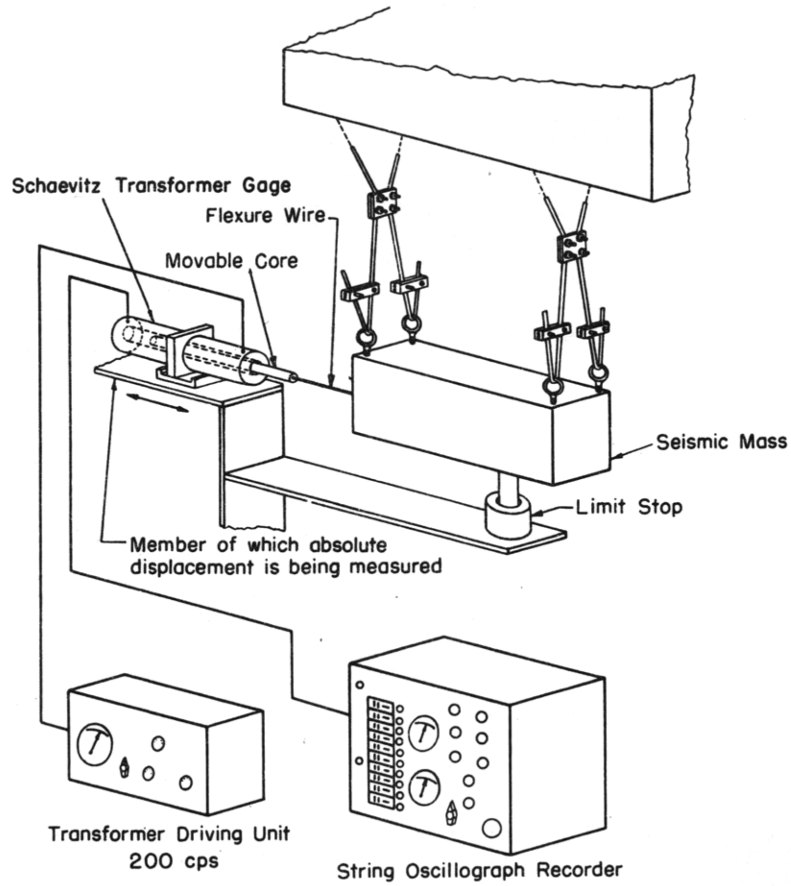

Figure 6a - Schematic Diagram

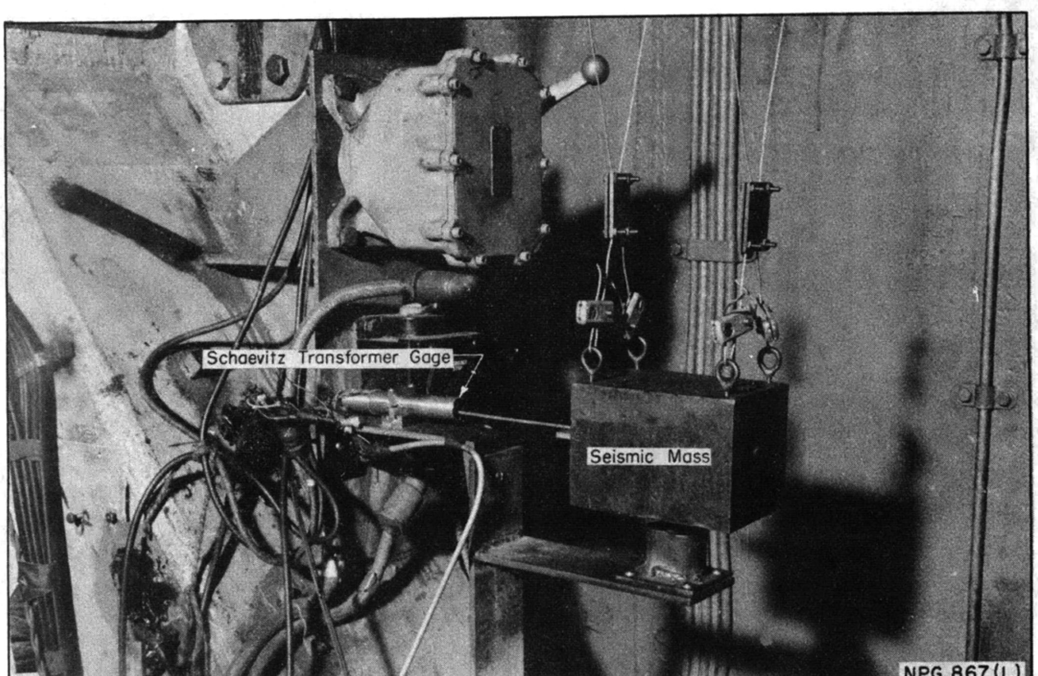

Figure 6b - Installation of Deflection Gage on Trunnion Bearer of Pilot Turret

Figure 6 - Deflection-Gage Instrumentation

TABLE 1

Maximum Strains* in Microinches per Inch Recorded in Left Truss

Gage	0° Elevation			40° Elevation		
	Left Gun Fired	Right Gun Fired	Both Guns Fired	Left Gun Fired	Right Gun Fired	Both Guns Fired
1	-87	-36	-124	-87	-23	-106
2	-71	-41	-104	-81	-20	-97
3	+37	+31	+57	+55	+18	+69
4	+35	+23	+56	+52	+12	+60
5	-86	-34	-104	-75	-17	-98
6	-72	-41	-114	-75	-21	-107
7	-29	+25	-22	-25	+15	-18
8	-	-9	-23	-	-	-
9	+30	+72	+79	+41	+39	+74
10	+59	+67	+102	+50	+41	+92
11	-30	+11	-30	-24	+4	-27
12	-20	+14	-24	-14	+8	-10
13	+10	-10	-25	+15	-8	+11
14	+29	+8	+22	+22	+11	+23
15	+34	+14	+27	+21	+12	+28
16	+33	+15	+18	+26	+14	+24
17	-30	-24	-22	-24	-10	-23
18	-54	+23	-46	-51	+21	-40
19	+10	+14	+20	+14	+8	+10
20	-64	-53	-130	-51	-23	-99
21	-72	-41	-129	-56	-23	-92
22	-71	-27	-72	-81	-19	-89
23	-114	-32	-114	-89	-33	-114
24	-98	-37	-124	-96	-33	-122
25	-126	-39	-152	-116	-34	-146
26	-90	-55	-116	-69	-28	-113
27	-102	-50	-148	-77	-27	-114
28	+123	+61	+161	+120	+42	+165
29	+150	+72	+203	+150	+54	+202
30	-84	-48	-111	-63	-25	-102
31	-90	-32	-117	-70	-17	-96
32	-72	-41	-96	-57	-20	-90
33	-87	-32	-97	-62	-16	-88
34	+135	+69	+179	+127	+48	+178
35	+139	+72	+186	+136	+54	+189
36	-46	-18	-59	-43	-8	-54
37	-56	-14	-48	-43	-16	-50
38	-130	-72	-194	-128	-45	-186
39	-164	-62	-203	-150	-42	-192
40	-109	-64	-165	-116	-39	-171
41	-112	-51	-173	-69	-45	-154
42	-13	-11	-14	-12	-8	-19
43	-27	-7	-24	-27	-9	-24
44	+150	+155	+286	+113	+116	+245
45	+172	+164	+267	+117	+128	+248
46	+60	+66	+100	+32	+49	+91
47	+40	+50	+110	+34	+52	+82
48	-51	-23	-70	-66	-18	-72
49	-34	-16	-56	-54	-15	-65
50	+66	+87	+116	+43	+53	+89
51	+65	+74	+104	+41	+45	+69
83	-	-	-	-	-	-
84	+17	-	+24	+16	+8	+24
85	+34	-	+44	+28	+12	+42
86	-18	-	-32	-26	-12	-29

*Positive strains indicate tension; negative strains, compression.

TABLE 2

Maximum Strains* in Microinches per Inch Recorded in Right Truss

Gage	0° Elevation			40° Elevation		
	Left Gun Fired	Right Gun Fired	Both Guns Fired	Left Gun Fired	Right Gun Fired	Both Guns Fired
101	-36	-84	-120	-28	-70	-102
102	-38	-70	-106	-33	-57	-95
103	+24	+29	+43	+24	+29	+48
104	+14	+25	+44	+14	+32	+50
105	-28	-74	-104	-19	-70	-98
106†	-44	-65	-108	-44	-63	-100
107	-	-36	-31	-	-	+21
108	-19	-32	-28	-20	-27	-27
109	+62	+36	+90	+56	+27	+69
110	+65	+41	+88	+56	+31	+63
111	+11	-20	-30	+9	-24	-26
112	+12	-19	-21	+8	-14	-14
113	-9	+13	-21	-12	+10	-17
114	+14	+22	+22	+11	+19	+21
115	+15	+23	+25	+14	+18	+20
116	+18	+24	+20	+12	+21	+22
117	-19	-28	-26	-9	-23	-20
118	+29	-50	-43	+22	-58	-52
119	+10	+16	+15	+9	+13	+17

*Positive strains indicate tension; negative strains, compression.

†Signs of strain for Gage 106 were inconsistent with those of other similarly located gages. Reversal was attributed to improper electrical connections. The signs for strains in the table were changed to render them consistent.

In Figures 7 through 18 the apparent stresses corresponding to the strains tabulated in Tables 1 and 2 are shown superimposed upon diagrams of the trusses. Apparent stress was obtained by multiplying the strain by an assumed modulus of elasticity of 30×10^6 psi. It is to be noted that these apparent stresses are actual stresses only where the actual stress field is uniaxial and the gage is oriented in the direction of the stress. Usually the gage was oriented in this direction.

TABLE 3

Comparison of Maximum Strains* Measured by Symmetrically Located Gages

Gage	0 Degrees				40 Degrees			
	Left Gun Fired	Right Gun Fired	Both Guns Fired Simultaneously	Sum of Strains for Left and Right Guns Fired Separately	Left Gun Fired	Right Gun Fired	Both Guns Fired Simultaneously	Sum of Strains for Left and Right Guns Fired Separately
1	-87	-36	-124	-123	-87	-23	-106	-110
101	-36	-84	-120	-120	-28	-70	-102	-98
2	-71	-41	-104	-112	-81	-20	-97	-101
102	-38	-70	-106	-108	-33	-57	-95	-90
3	+37	+31	+57	+68	+55	+18	+69	+73
103	+24	+29	+41	+53	+24	+29	+48	+53
4	+35	+23	+56	+58	+52	+12	+60	+64
104	+14	+25	+44	+39	+14	+32	+50	+46
5	-86	-34	-104	-120	-75	-17	-98	-92
105	-28	-74	-104	-112	-19	-70	-98	-89
6	-72	-41	-114	-113	-75	-21	-107	-96
106	-44	-65	-108	-109	-44	-63	-100	-107
7	-29	+25	-22	-4	-25	+15	-18	-10
107	-	-36	-31	-	-	-	-21	-
8	-	-9	-24	-	-	-	-	-
108	-19	-32	-28	-51	-20	-27	-27	-47
9	+30	+72	+79	+102	+41	+39	+74	+80
109	+62	+36	+90	+98	+56	+27	+69	+83
10	+59	+67	+102	+126	+50	+41	+92	+91
110	+65	+41	+88	+109	+56	+31	+63	+87
11	-30	+11	-30	-19	-24	+4	-27	-20
111	+11	-20	-30	-9	+9	-24	-26	-15
12	-20	+14	-24	-6	-14	+8	-10	-6
112	+12	-19	-21	-7	+8	-14	-14	-6
13	+10	-10	-25	0	+15	-8	+11	+7
113	-9	+13	-21	+4	-9	+10	+17	-
14	+29	+8	+22	+37	+22	+11	+23	+33
114	+14	+22	+22	+36	+11	+19	+21	+30
15	+34	+14	+27	+44	+21	+12	+28	+33
115	+15	+23	+25	+38	+14	+18	+20	+32
16	+33	+10	+18	+43	+26	+14	+24	+40
116	+18	+24	+20	+42	+12	+21	+22	-
17	+30	+24	+22	+54	+24	+10	+23	+34
117	+19	+28	+26	+47	+9	+23	+20	+32
18	-54	+23	-46	-31	-51	+21	-40	-30
118	+29	-50	-43	-21	+22	-58	-52	-36
19	+10	+14	+20	+34	+14	+8	+10	+22
119	+10	+16	+15	+26	+9	+13	+17	+22

*Positive strains indicate tension; negative strains, compression.

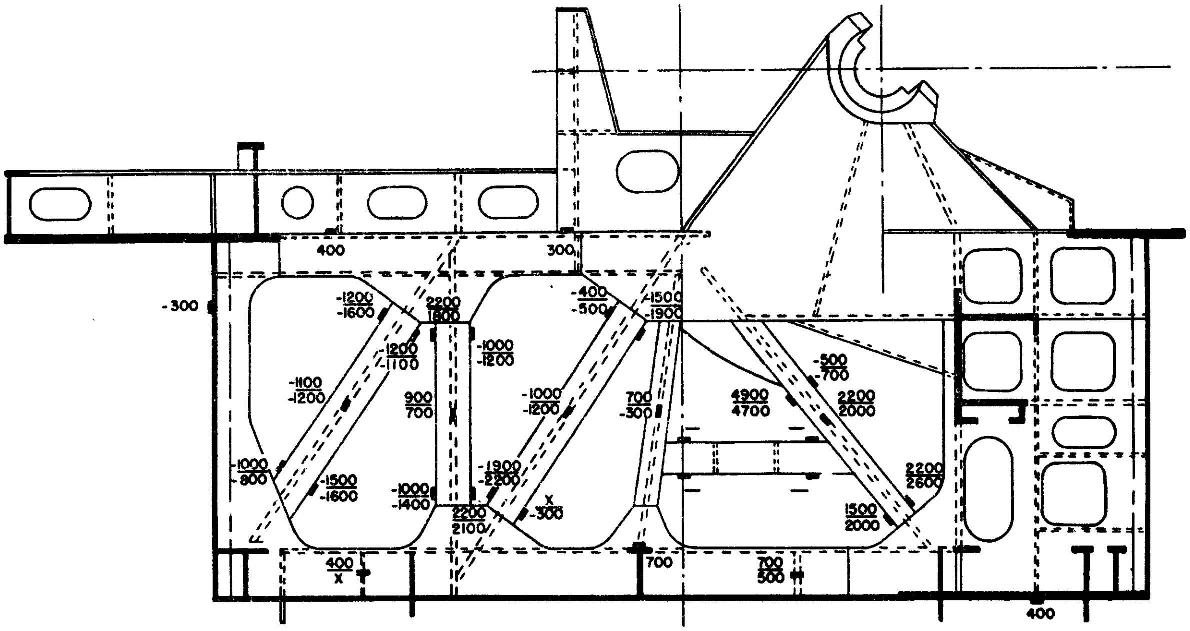

Figure 7 - Stresses in Left Truss when Right Gun was Fired at 0° Elevation

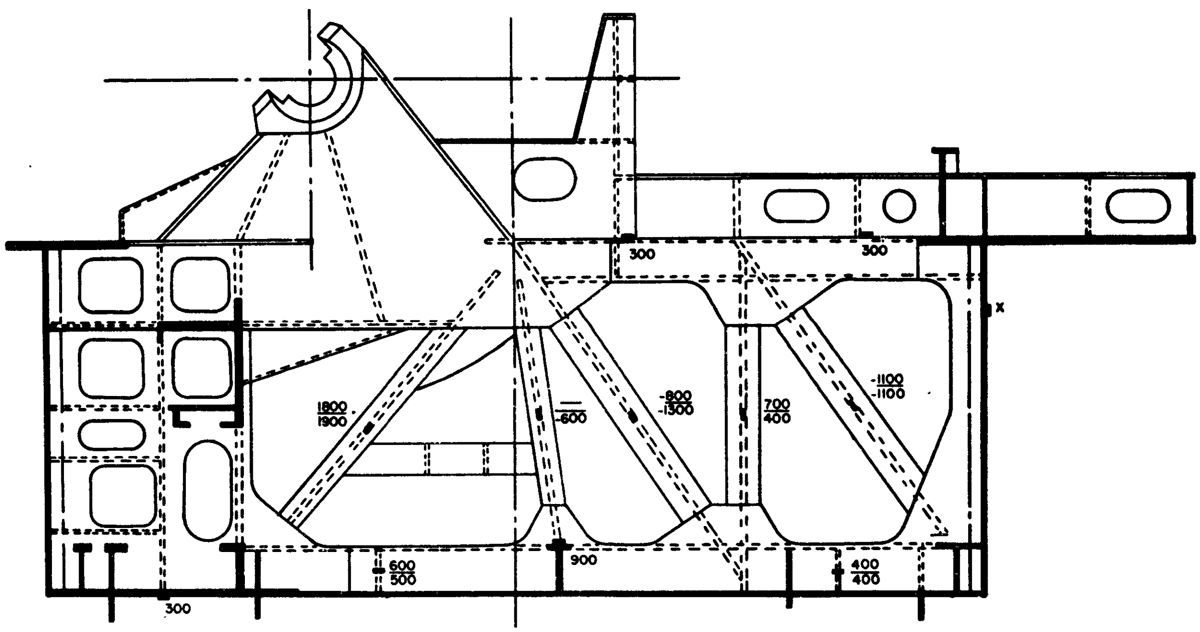

Figure 8 - Stresses in Right Truss when Left Gun was Fired at 0° Elevation

Figure 7 shows the apparent stress developed in the left truss when the right gun was fired at 0° elevation. Figure 8 shows that developed in the right truss when the left gun was fired at 0° elevation. From symmetry, the stresses at similar points in both trusses should be equal.

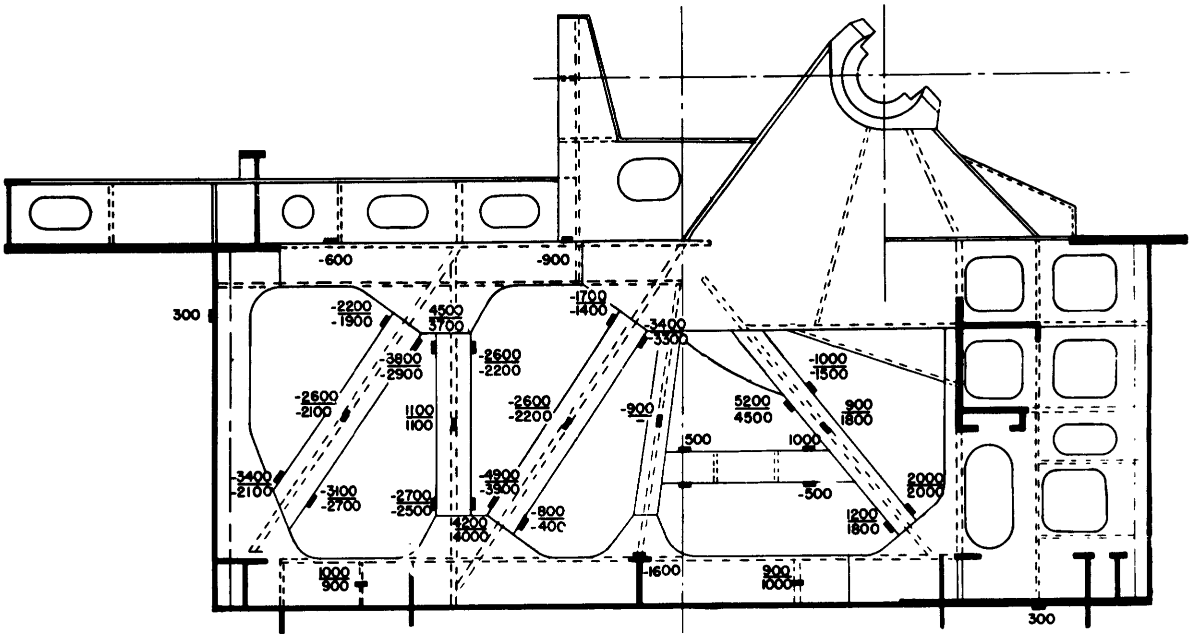

Figure 9 - Stresses in Left Truss when Left Gun was Fired at 0° Elevation

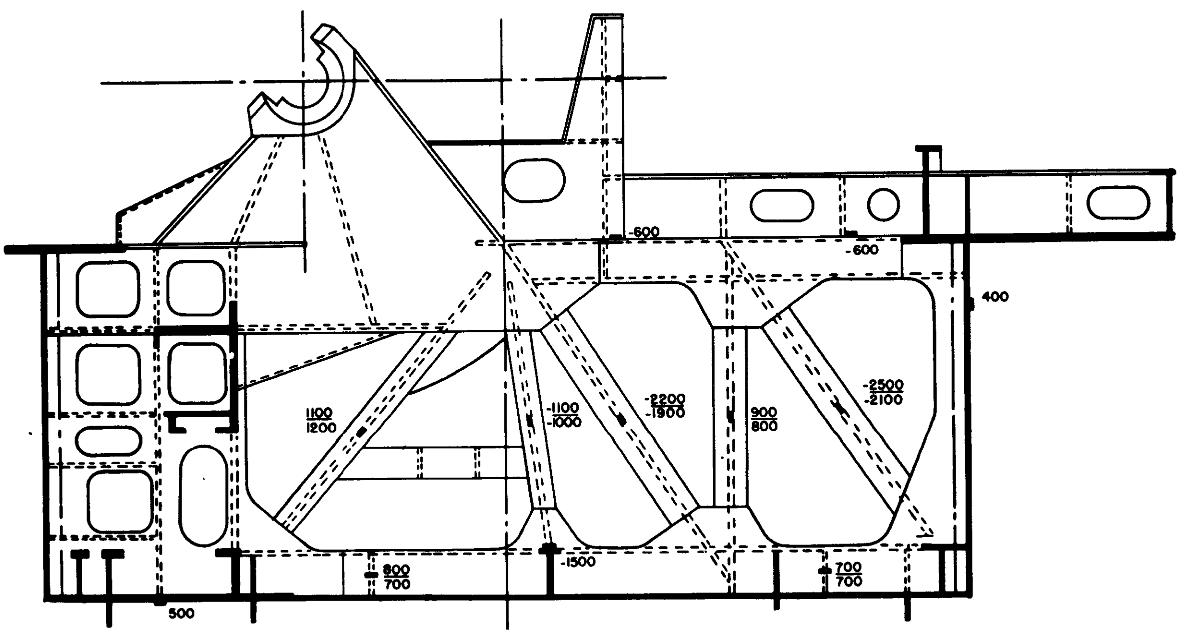

Figure 10 - Stresses in Right Truss when Right Gun was Fired at 0° Elevation

Figures 9 and 10 depict the stresses developed in each truss when the gun above it is fired.

Figures 11 and 12 show the stress in each truss when both guns are fired. From symmetry, the stresses at similar points in the trusses should be equal. From the law of superposition, the stresses in one truss resulting

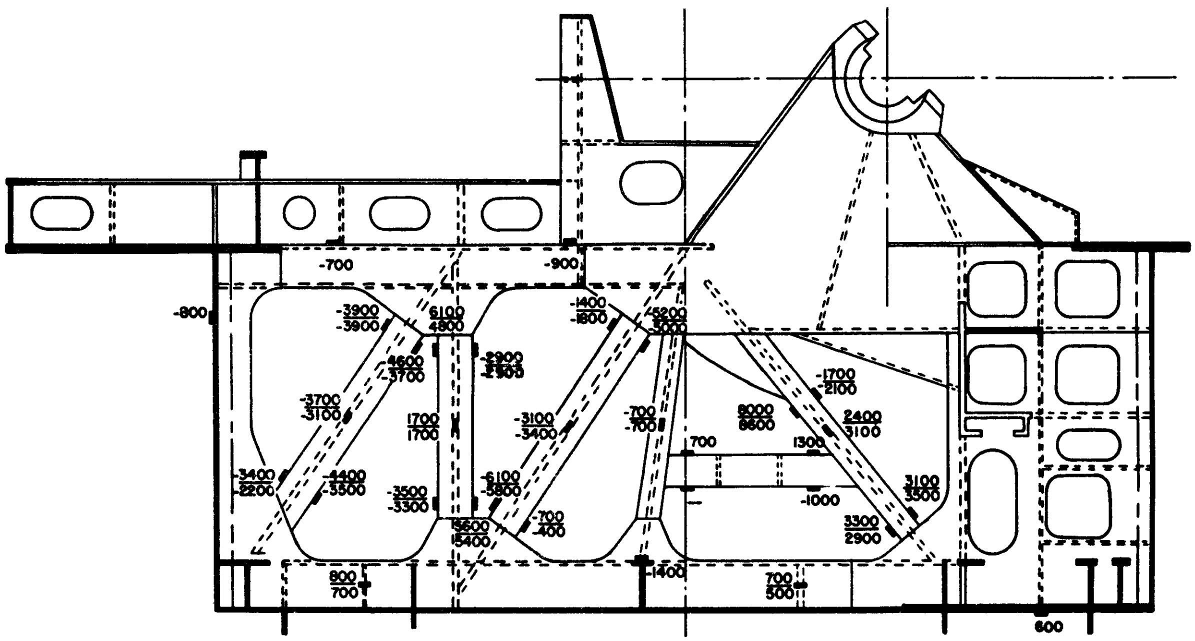

Figure 11 - Stresses in Left Truss when Both Guns were Fired at 0° Elevation

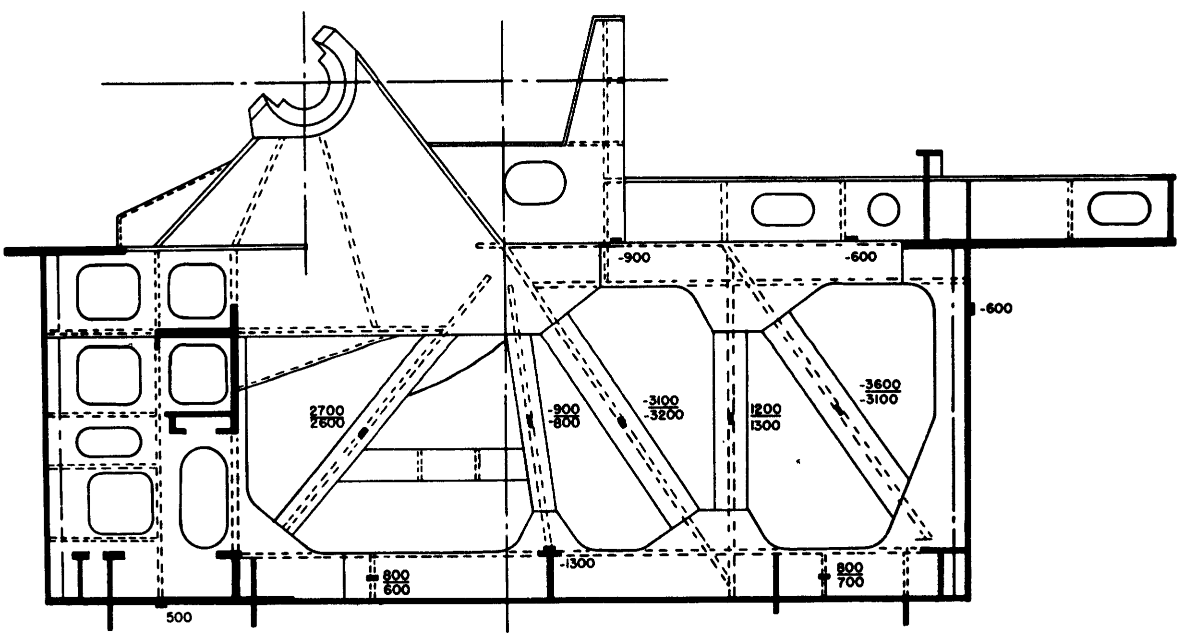

Figure 12 - Stresses in Right Truss when Both Guns were Fired at 0° Elevation

from the simultaneous firing of both guns should be the sum of those resulting from firing each gun separately.

Figures 13 through 18 show the apparent stresses induced in the trusses when the guns were fired at 40° elevation.

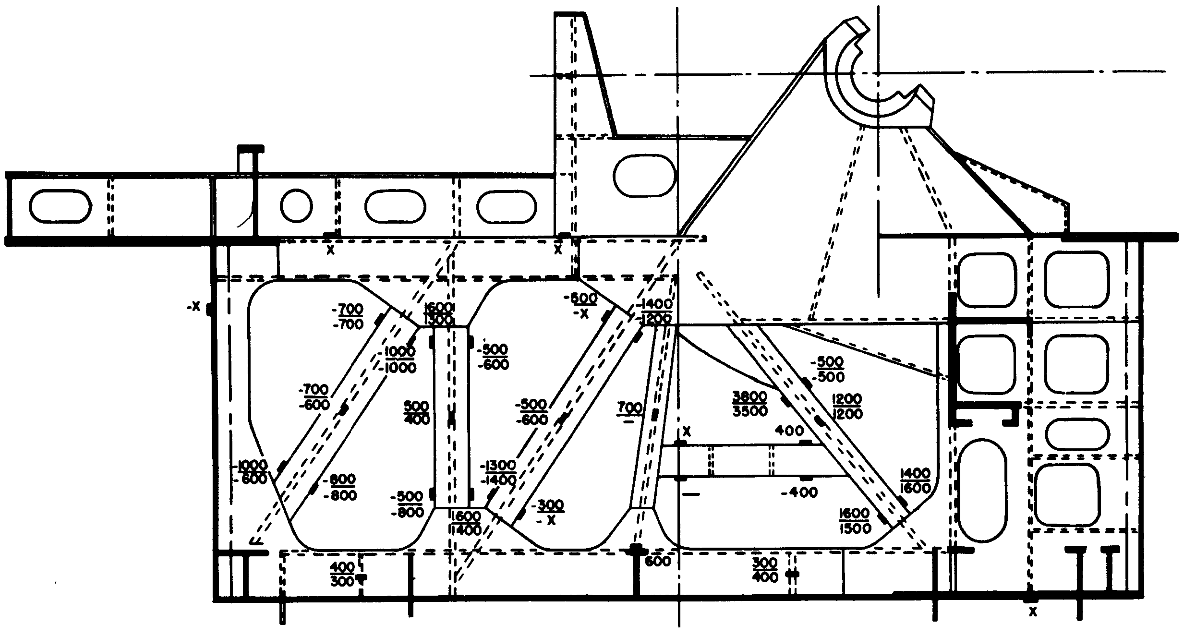

Figure 13 - Stresses in Left Truss when Right Gun was Fired at 40° Elevation

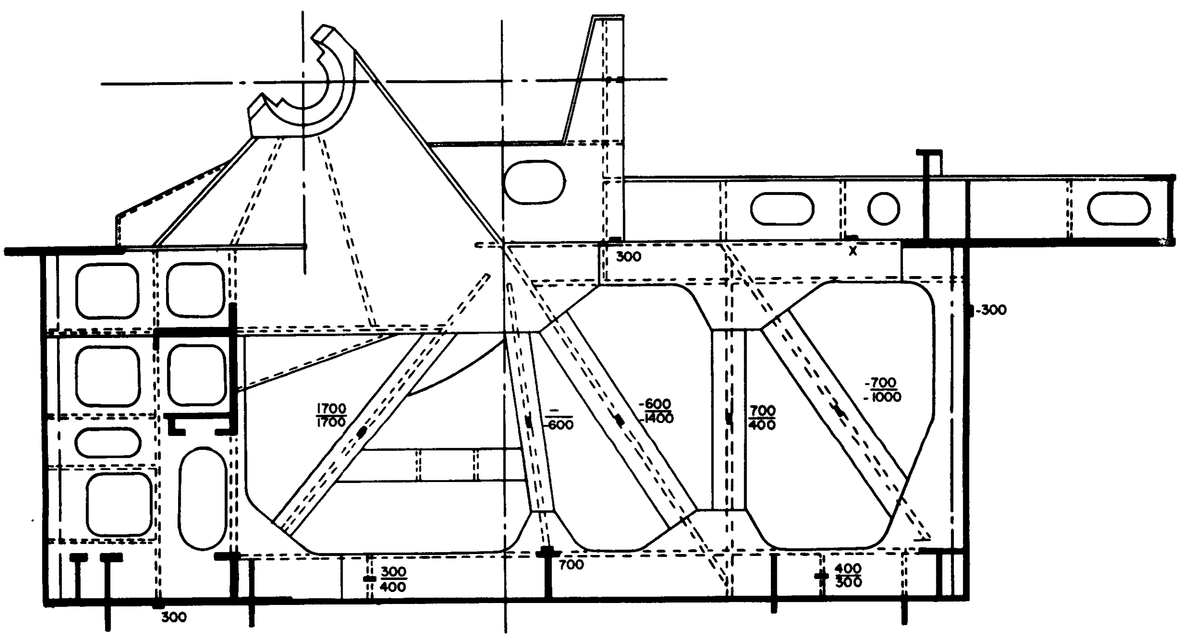

Figure 14 - Stresses in Right Truss when Left Gun was Fired at 40° Elevation

Figures 19 through 22 show the apparent stresses measured when a static load of 200 kips was applied to each gun. These data are taken from Reference 3. Figures 19 and 20 show the stresses in the trusses when the right and left guns were loaded simultaneously. Figures 21 and 22 show the stresses when all three guns were statically loaded.

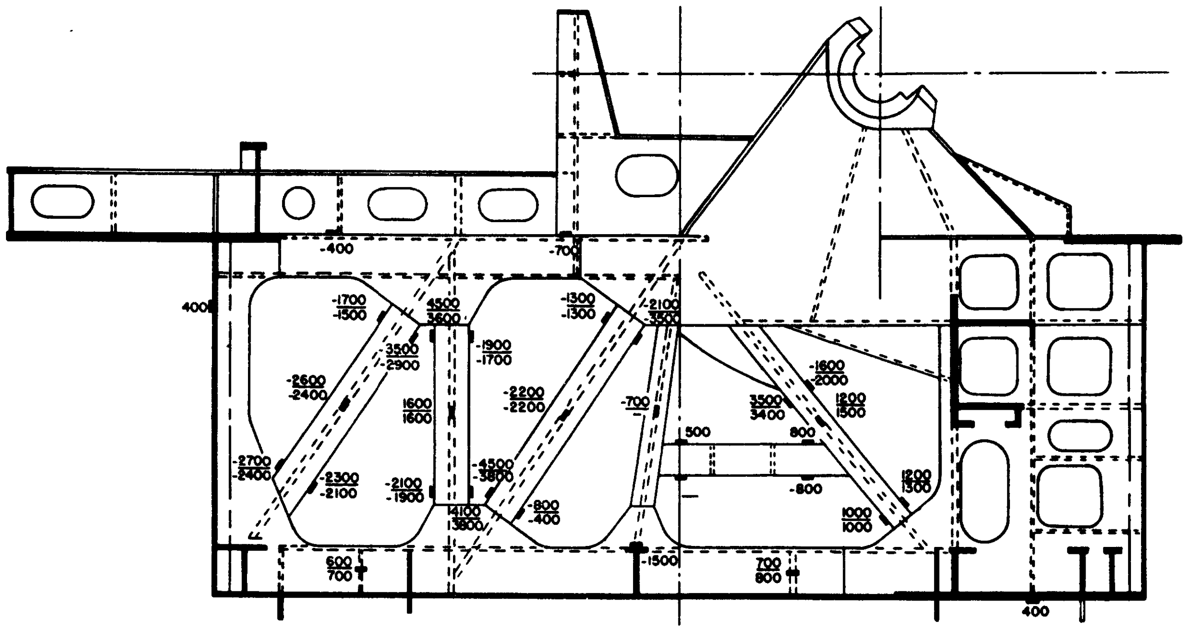

Figure 15 - Stresses in Left Truss when Left Gun was Fired at 40° Elevation

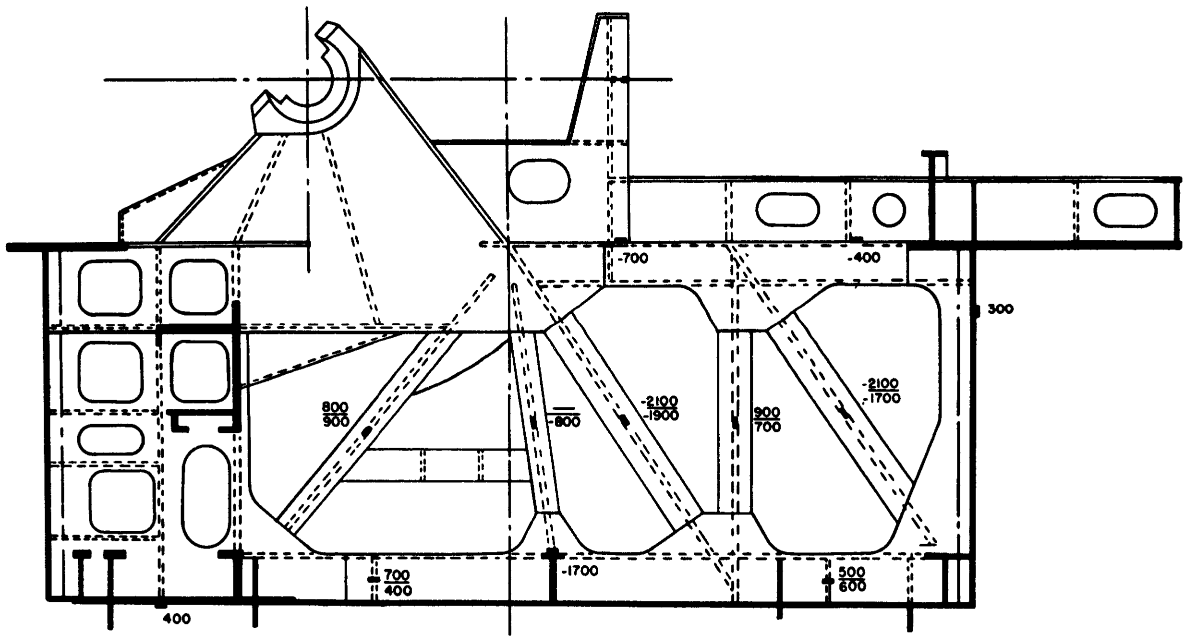

Figure 16 - Stresses in Right Truss when Right Gun was Fired at 40° Elevation

Figures 23 and 24 refer to the dynamic factor at various stations on the truss when two guns are fired. Dynamic factor is here defined as the ratio of the stress produced by a dynamic load to the stress produced by an equal static load. The value of the peak dynamic load when a gun was fired at 0° elevation was found to be 200 kips.[4] The probable error in the dynamic

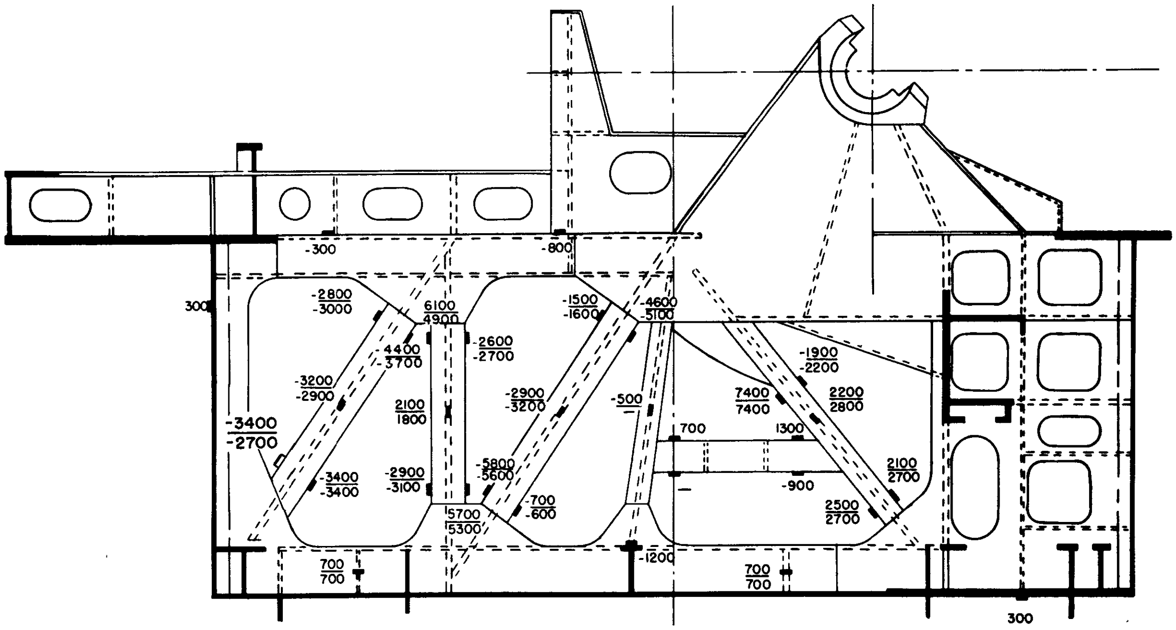

Figure 17 - Stresses in Left Truss when Both Guns were Fired at 40° Elevation

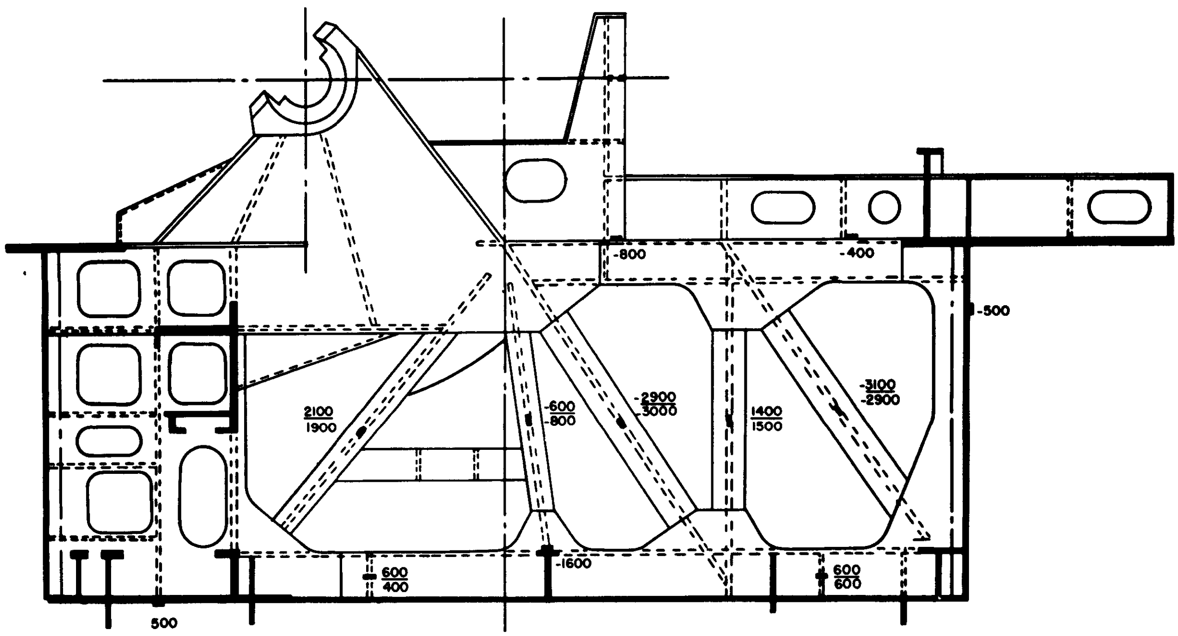

Figure 18 - Stresses in Right Truss when Both Guns were Fired at 40° Elevation

factor is listed after each value in Figures 23 and 24; it was derived by assuming an experimental error of ±10 microinches per inch which corresponds to ±300 psi of stress.

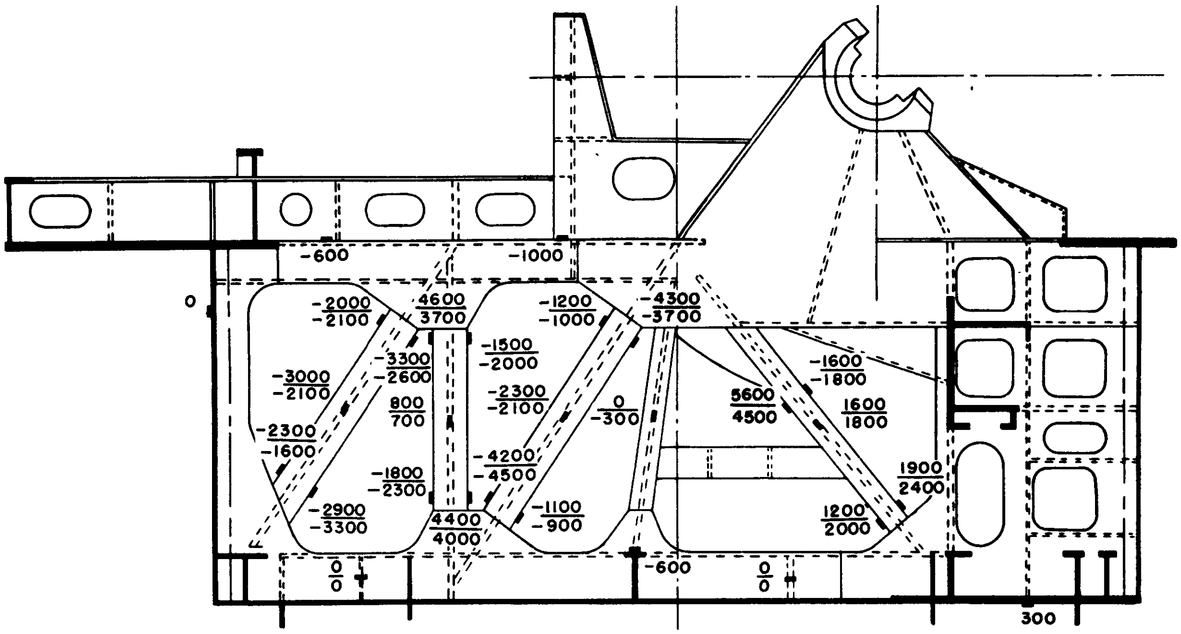

Figure 19 - Stresses in Left Truss when 200-Kip Static Load was Applied to Right and Left Guns at 0° Elevation

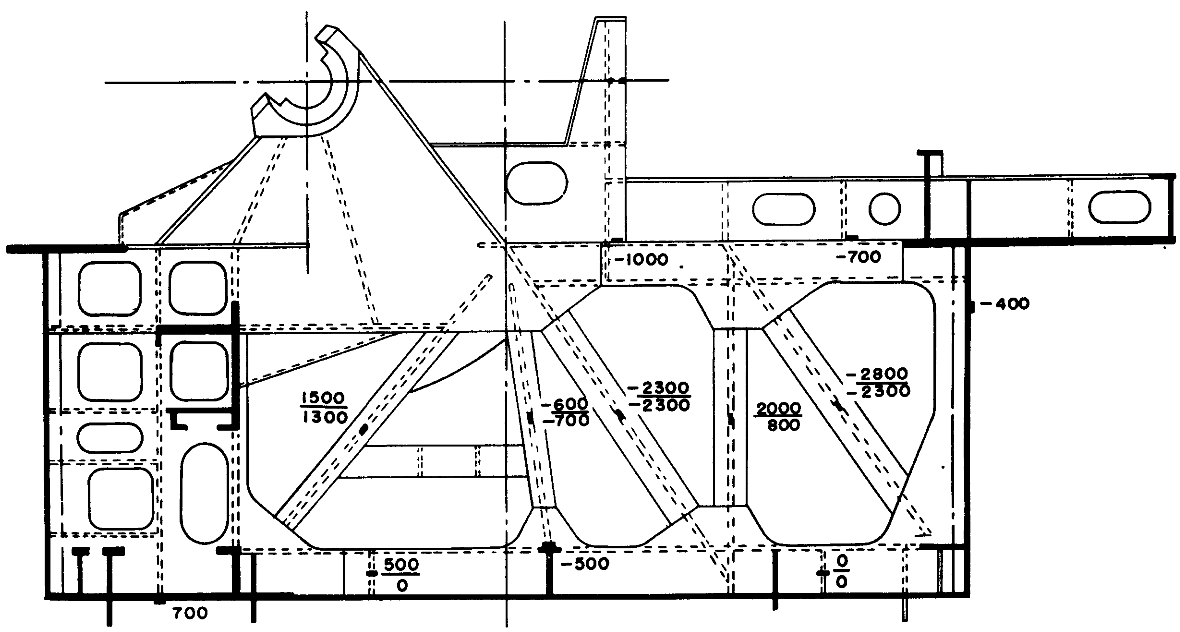

Figure 20 - Stresses in Right Truss when 200-Kip Static Load was Applied to Right and Left Guns at 0° Elevation

Table 4 lists the maximum strains recorded by gages on the left truss when the left gun was fired at elevations from 0° to 40°. One shot was fired at each elevation. In Figure 25 these data are plotted.

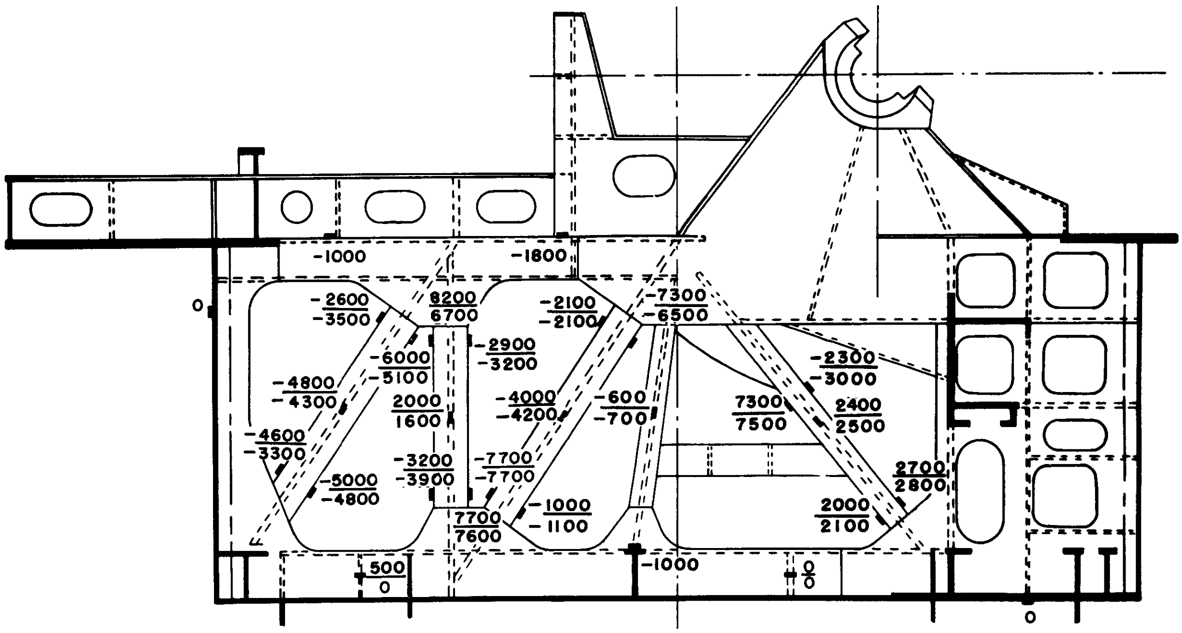

Figure 21 - Stresses in Left Truss when 200-Kip Static Load was Applied to All Guns at 0° Elevation

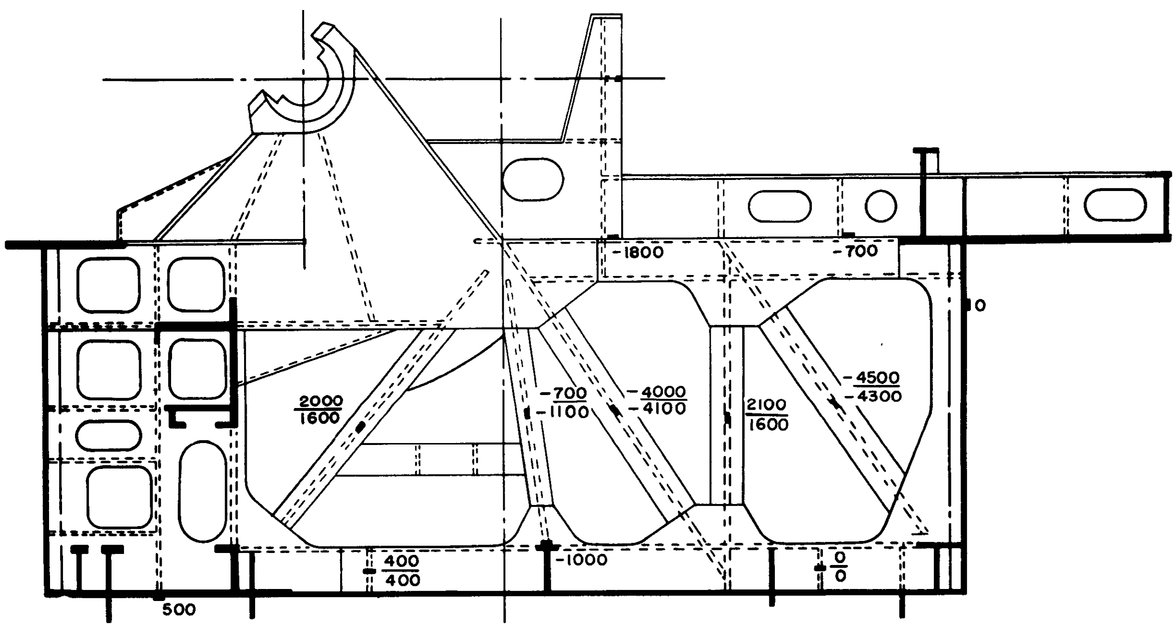

Figure 22 - Stresses in Right Truss when 200-Kip Static Load was Applied to All Guns at 0° Elevation

Table 5 lists the maximum strains recorded by gages on the right truss when the right gun was fired at angles from 0° to 40°. The same data are depicted graphically in Figure 26.

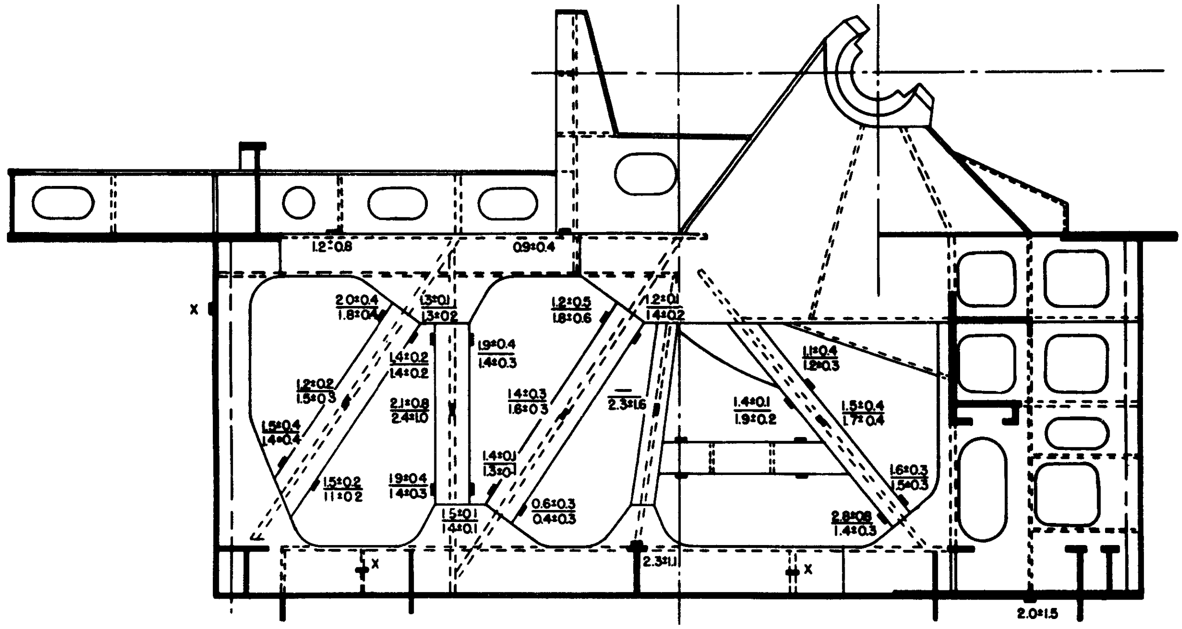

Figure 23 - Dynamic Factors for Left Truss when Left and Right Guns were Fired at 0° Elevation

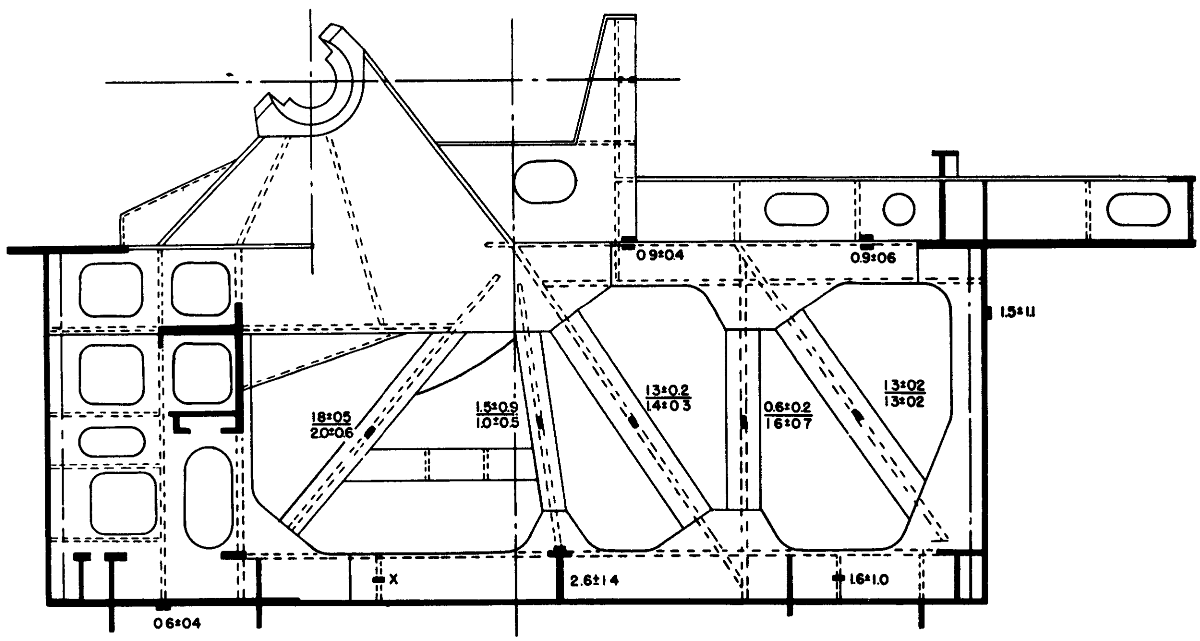

Figure 24 - Dynamic Factors for Right Truss when Left and Right Guns were Fired at 0° Elevation

In Figure 27 the predominate frequencies which appeared on the strain-gage records are shown at the gage positions.

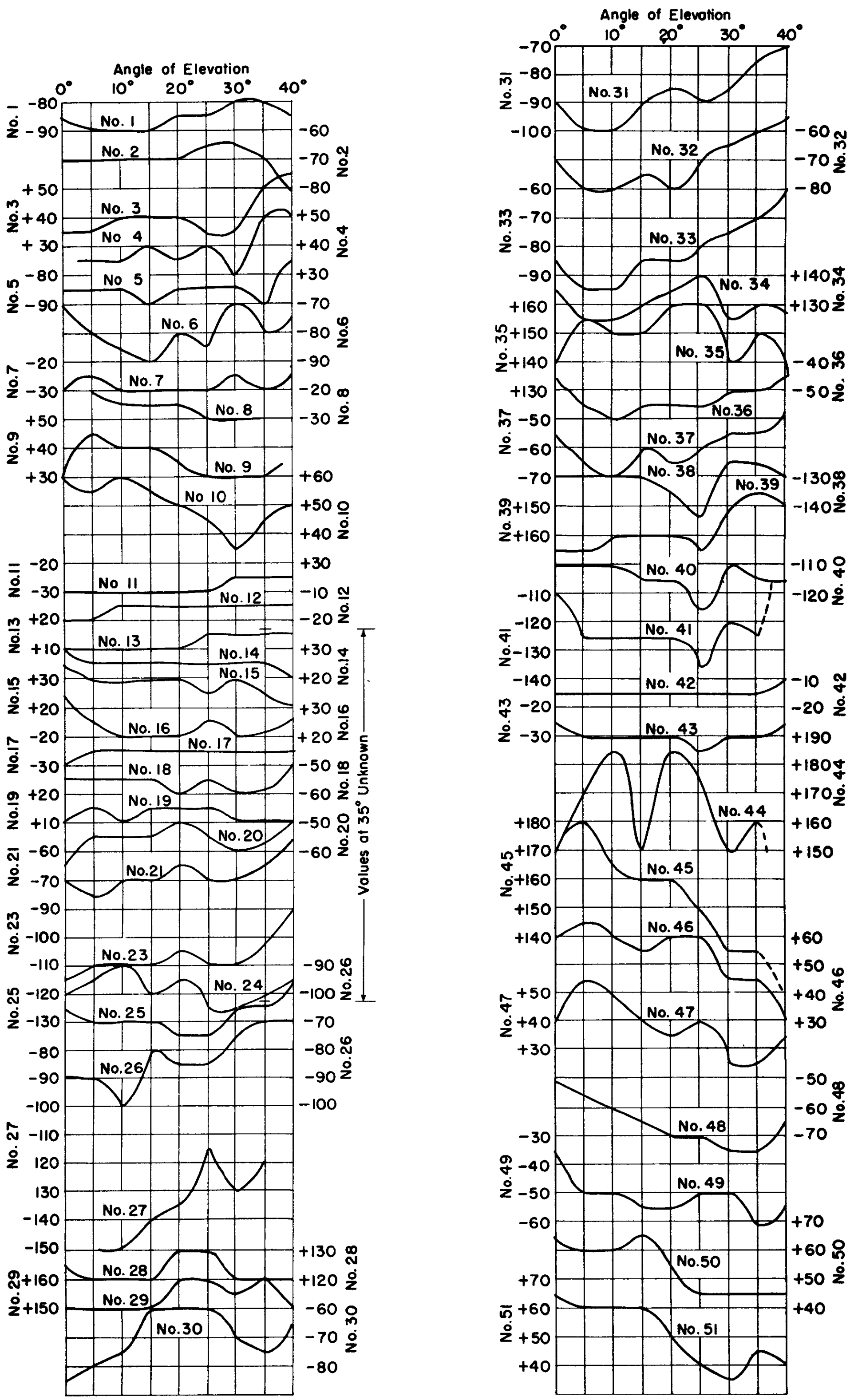

Figure 25 - Strains in Left Truss as Angle of Elevation of Left Guns is Varied

Ordinates are strains in microinches per inch.

TABLE 4

Strains in Microinches per Inch in Left Truss When Left Gun Was Fired at Various Angles of Elevation

Strain Gage	Angle of Elevation								
	0°	5°	10°	15°	20°	25°	30°	35°	40°
1	-87	-88	-89	-92	-86	-85	-81	-80	-87
2	-71	-72	-70	-72	-68	-67	-64	-69	-81
3	+37	+37	+38	+41	+40	+34	+37	+49	+55
4	+35	+34	+34	+38	+36	+39	+30	+48	+52
5	-86	-85	-87	-88	-87	-87	-83	-92	-75
6	-72	-80	-87	-90	-82	-85	-71	-79	-75
7	-29	-27	-28	-30	-28	-28	-26	-32	-25
8	-	-22	-24	-24	-27	-28	-28	-30	-
9	+30	+45	+42	+42	+36	+31	+29	+28	+41
10	+59	+54	+60	+54	+52	+46	+35	+47	+50
11	-30	-31	-31	-31	-30	-29	-26	-26	-24
12	-20	-18	-17	-17	-16	-16	-15	-15	-14
13	+10	+9	+9	+9	+9	+13	+13	-	+15
14	+29	+23	+23	+23	+25	+25	+25	-	+22
15	+34	+31	+32	+30	+32	+27	+28	-	+21
16	+33	+23	+21	+22	+22	+23	+22	-	+26
17	-30	-25	-24	-25	-25	-25	-26	-	-24
18	-54	-55	-54	-54	-58	-53	-58	-	-51
19	+10	+16	+12	+13	+13	+15	+12	-	+9
20	-64	-57	-56	-57	-48	-57	-60	-	-51
21	-72	-76	-71	-71	-65	-70	-70	-	-56
22	-71	-	-	-	-	-	-	-	-81
23	-114	-110	-108	-112	-105	-108	-108	-	-89
24	-98	-95	-91	-99	-97	-105	-105	-	-96
25	-126	-132	-132	-128	-134	-137	-127	-125	-116
26	-90	-91	-98	-81	-87	-85	-74	-69	-69
27	-102	-148	-148	-138	-136	-114	-131	-118	-77
28	+123	+122	+121	+118	+131	+128	+118	+121	+120
29	+150	+148	+151	+151	+158	+159	+156	+162	+150
30	-84	-78	-76	-61	-61	-60	-70	-76	-63
31	-91	-99	-99	-90	-85	-88	-86	-76	-70
32	-72	-81	-82	-75	-82	-70	-63	-60	-57
33	-87	-95	-95	-84	-87	-81	-77	-70	-62
34	+135	+127	+127	+130	+136	+139	+125	+128	+127
35	+139	+156	+150	+150	+159	+162	+142	+148	+136
36	-46	-56	-58	-54	-56	-56	-49	-49	-43
37	-56	-66	-69	-60	-66	-59	-55	-53	-43
38	-130	-130	-128	-128	-135	-143	-125	-127	-128
39	-164	-165	-161	-158	-159	-163	-148	-146	-150
40	-109	-108	-112	-113	-117	-124	-111	-114	-116
41	-112	-123	-124	-124	-127	-135	-121	-124	-
42	-13	-17	-15	-15	-15	-15	-15	-13	-12
43	-27	-31	-29	-29	-31	-33	-28	-32	-27
44	+150	+171	+186	+152	+186	+175	+149	+160	+113
45	+172	+180	+165	+160	+160	+148	+137	+137	+117
46	+60	+64	+61	+56	+61	+60	+43	+43	+32
47	+40	+53	+49	+39	+35	+41	+27	+25	+34
48	-51	-55	-60	-64	-69	-72	-76	-75	-66
49	-34	-48	-48	-54	-56	-51	-51	-61	-54
50	+66	+58	+59	+66	+57	+47	+43	+46	+43
51	+65	+60	+58	+58	+52	+42	+37	+46	+41

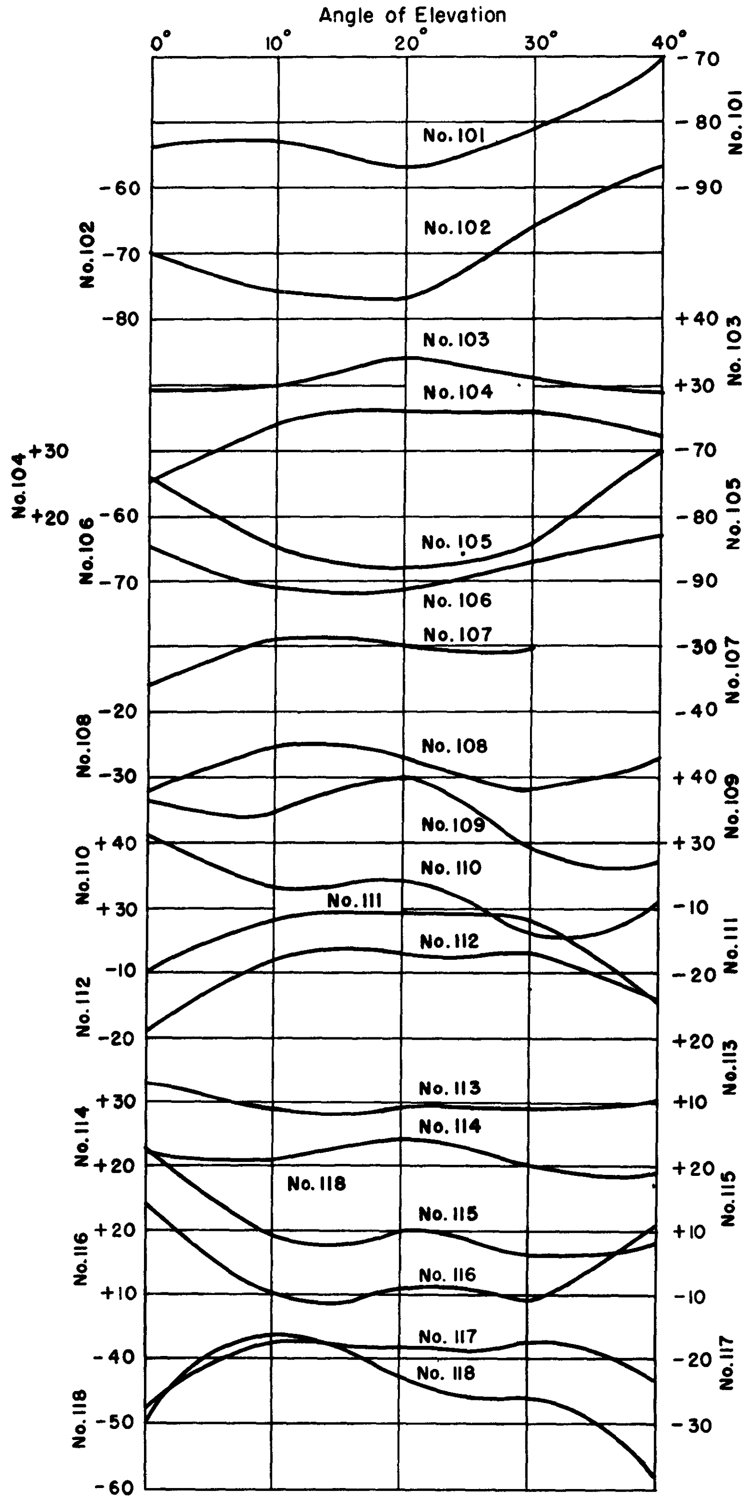

Figure 26 - Strains in Right Truss as Angle of Elevation of Right Gun is Varied

Ordinates are strains in microinches per inch.

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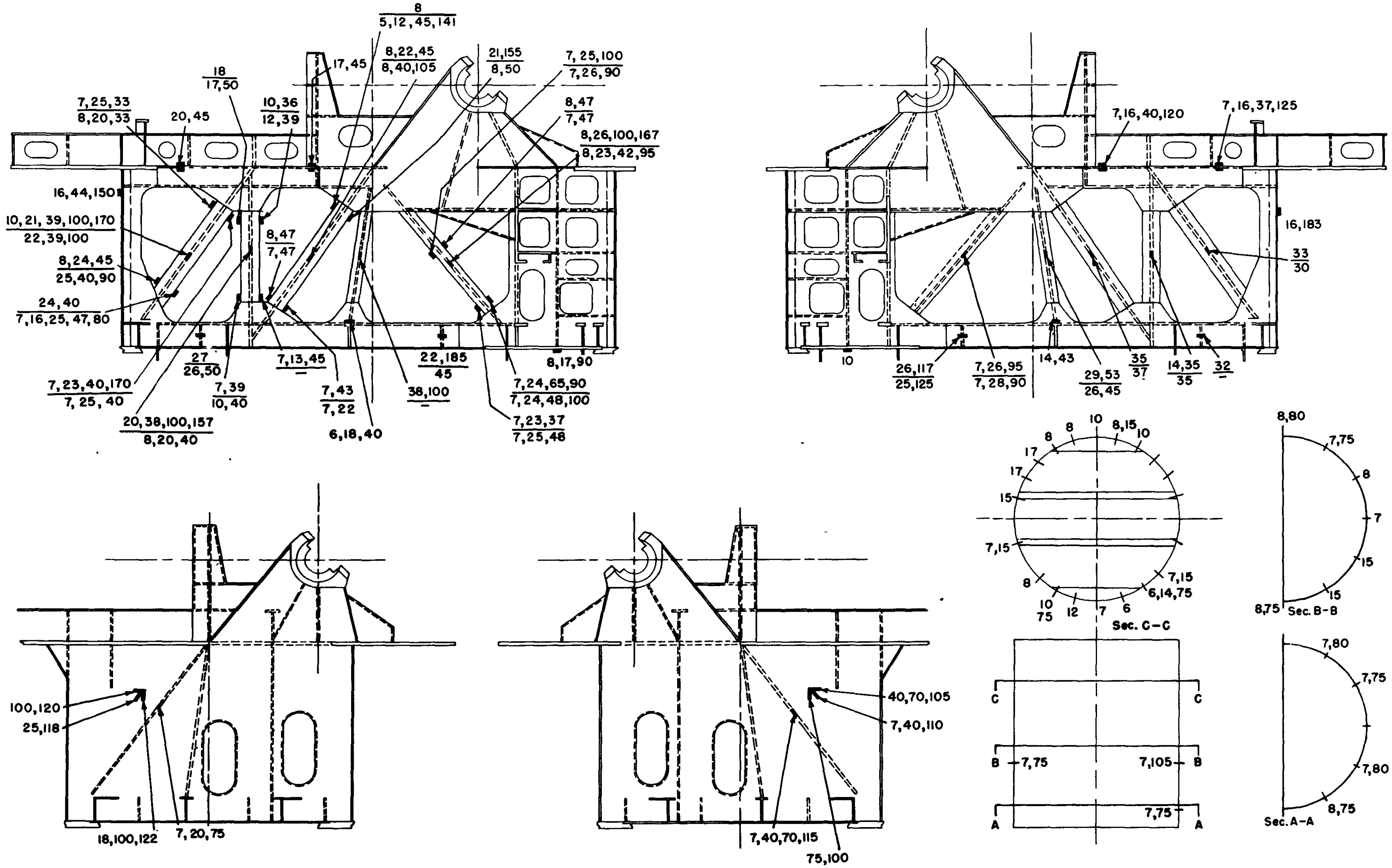

Figure 27 - Frequencies in Cycles per Second of Strain Variation Observed during Firing Trials

TABLE 5

Strains in Microinches per Inch in Right Truss when Right Gun was Fired at Various Angles of Elevation

Strain Gage	Angle of Elevation				
	0°	10°	20°	30°	40°
101	-84	-83	-87	-81	-70
102	-70	-76	-77	-66	-57
103	+29	+30	+34	+31	+29
104	+25	+34	+36	+36	+32
105	-74	-85	-88	-84	-70
106	-65	-71	-71	-67	-63
107	-36	-29	-30	-30	-
108	-32	-25	-27	-32	-27
109	+36	+35	+40	+29	+27
110	+41	+33	+34	+26	+31
111	-20	-12	-11	-12	-24
112	-19	-8	-7	-7	-14
113	+13	+9	+9	+9	+10
114	+22	+21	+24	+20	+19
115	+23	+9	+10	+6	+18
116	+24	+10	+11	+9	+21
117	-28	-17	-18	-17	-23
118	-50	-36	-43	-46	-58
119	+16	-	-	-	+13

DISCUSSION

The strain measurements cited in Tables 1 and 2 and pictured in Figures 7 through 22, show that the safety of the structure is more than adequate. The maximum observed stress was 8600 psi; this value was recorded when both guns were fired at 0° elevation. If all three guns of a turret were fired, the maximum stress expected would be about 13,000 psi, which is considerably less than the 20,000 psi permitted in design. The value of 13,000 psi is obtained by adding the stress measured when the left gun alone was fired to that measured when both guns were fired. It seems evident that, from the standpoint of strength, the structure is more than adequate; therefore, redesign of the truss should permit more economical use of structural material without sacrifice of safety.

Study of Table 3 shows that the principle of superposition held for the truss under study here, i.e., within the limits of experimental error the sum of the maximum strains produced in the left truss, as a result of firing the left and right guns separately, equaled the maximum strains produced by firing the guns simultaneously. The same table shows identical results for the right truss. Study of the static-test data revealed a similar conclusion.

Figures 23 and 24 show the variation of dynamic factor with respect to gage location in the truss. Dynamic factor is seen to range from 2.8 ±0.8 to 0.4 ±0.3 depending on gage station. This is not in agreement with the simple theory which assumed that the structure was a one-degree-of-freedom system, and thus that the dynamic factor would be the same for the entire truss.

The variation of strain with respect to the angle of gun elevation is not a systematic function, as can be seen from Tables 4 and 5 and from Figures 25 and 26. The occurrence of a maximum strain at 0° or at 40° was random, but in all cases the variation was not great. It has always been assumed that the turret structure has been so much stiffer in a vertical direction as compared to the horizontal that strains due to vertical components of recoil loading could be neglected. Thus, strains could be expected to be lower with greater angles of elevation. Previous tests of turret models,[5] however, have produced data which show that strains do not vary greatly with change in direction of load. In view of the increase in recoil load with increased angles of elevation, effects may compensate so that the observed small random variation in strain with angle of elevation can be attributed entirely to experimental errors.

EXPERIMENTAL ERRORS

The good agreement between results when the shots were repeated indicates a low level of error in the measurements. The agreement between symmetrically positioned gages on the left and right trusses, as shown by Table 3, is evidence not only of the symmetry of the test structure and applicability of the law of superposition but also of the excellent quality of the measurements.

A reasonable estimate of the magnitude of the error in the strain readings would be about 10 microinches per inch, regardless of the magnitude of strain. This is about the same error estimated for the results of the static tests.[3] This accuracy is considered adequate; although in evaluating results where the strains are small, which frequently occurred because of the massiveness of structure, the percentage error is large.

CONCLUSIONS

It is believed that the objectives of the structural firing test of the pilot turret have been successfully accomplished. Accuracy and consistency of results have permitted:

1. The determination of the stress distribution throughout the trusses. (The degree of understressing and the degree of redundancy of structure follow from this study.)

2. Comparison of the data obtained here with that of previous tests on reduced-scale models of this turret and with that of the full-scale static tests of the turret.

3. Confirmation of the principle of superposition for this structure.

4. Determination of the strain distribution with respect to angle of gunfire; no significant change was found as the angle was varied.

5. Determination of the dynamic load factor; it varied from as high as 2.8 to as low as 0.4 for different parts of the truss and averaged 1.4. The relatively large variation is attributed to the inherently low stresses such that precision of comparison of static and dynamic results is masked by experimental errors.

6. With the applied techniques, the accuracy of strain measurement with dynamic loading was of a high order; errors were less than 10 microinches per inch.

ACKNOWLEDGMENTS

These tests were planned and conducted under the direction of Dr. E. Wenk, Jr. Assistance during the test was provided by V.J. Mildenberg, J.F. Rhodes, and M. Dean. Assistance in writing this report was given by E.T. Habib.

The tests were conducted at the Naval Proving Ground and were made possible by the enthusiastic cooperation of personnel from that activity.

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2. "Schedule of Measurements to be Made by the David Taylor Model Basin during Tests of the CA139 Pilot Turret," TMB Memo 2, CA139 Class/S72-1 of 13 November 1945 (revised 25 April 1947).

3. Wenk, Edward, Jr., and Wagley, Charles A., "The Elastic Behavior of the Rotating Structure of the CA139-Class Pilot Turret under Static Loading," TMB RESTRICTED Report C-166, March 1950.

4. Habib, E.T., "Experimental Analysis of the Recoil System of the 8-Inch 55-Caliber Guns Mark 20, Mod 1," TMB RESTRICTED Report C-165, March 1950.

5. Wenk, E., Jr., "Measurements of Strains and Deflections of a 1/8-Scale Model of the Turret Stool for Cruisers of the CL144 Class," TMB RESTRICTED Report 562, September 1947.