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NAVY YARD, WASHINGTON, D.C.

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TURRET DISPLACEMENT MEASUREMENTS
U. S. S. NASHVILLE

BY E. E. JOHNSON

EXPERIMENTAL MODEL BASIN
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BUREAU OF
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U.S.S. NASHVILLE

by

E. E. Johnson

U.S. Experimental Model Basin
Navy Yard, Washington, D.C.

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FOREWORD

This report describes one phase of the extensive investigation of turrets and their supporting structures which originated in the development of the contract plans for Battleships 55 and 56. The test was planned by the Research and Information Section of the Bureau of Construction and Repair. The Experimental Model Basin was charged with designing the necessary gages, conducting the experiment, obtaining and analyzing the data, and the preparation of the report.

TURRET DISPLACEMENT MEASUREMENTS

U.S.S. NASHVILLE

Summary

Maximum displacements of the turret, lower roller track, and turret foundation were measured during the structural gun-firing trials of turret No. 1 of the U.S.S. NASHVILLE. This report describes the development and calibration of the gages and discusses the displacements measured by them. The report also includes a comparison of these measurements with data obtained during special firing trials of the U.S.S. CALIFORNIA, and with those obtained from tests of a static model of the turret designed for Battleships 55 and 56. A more comprehensive tabulation will be possible when static model data are available for the turret foundations of the NASHVILLE class.

This work was authorized by Bureau of Construction and Repair letter S72-1, CL/S72-1 of 18 July 1938, and a preliminary report was furnished by the Experimental Model Basin on 9 December 1938 (file CL43/S72-1).

Introduction

The measurements reported herein were made as part of an extensive investigation of various types of turret supporting structures. These tests are expected to furnish some information concerning the extent to which static model tests may be used to predict full-scale dynamic performance of turret foundations.

Static tests of a model representing the turret foundations of Battleships 55 and 56 have been made and are extensively discussed in Experimental Model Basin Report No. 458 (1).* Full-scale displacements during firing have been measured and reported for turret No. 3 of the U.S.S. CALIFORNIA (2). Static tests are scheduled for models of the turrets and foundations of the NASHVILLE and CALIFORNIA classes. When these tests have been completed, both static and dynamic test data will be available for two types of turrets, and they should make possible more definite conclusions concerning the value of static model tests in forecasting full-scale performance of turret supporting structures.

Since test data such as those obtained for the NASHVILLE are readily obtainable and are likely to prove of considerable value, it is suggested that similar data be taken on other turret structures. Consequently it is considered desirable to include in this report a rather extensive discussion of the gages, describing their design, installation, and calibration.

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*Numbers in parentheses correspond to the references listed at the end of the report.

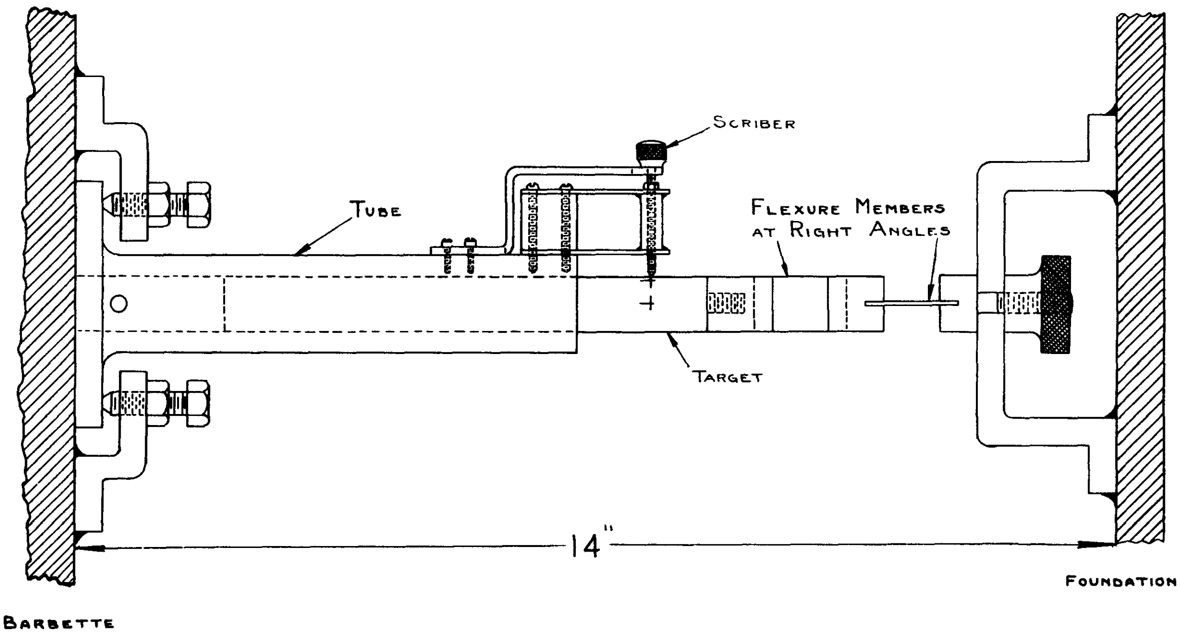

Fig. 1. Longitudinal Gage.
As Mounted Between Foundation and Barbette.

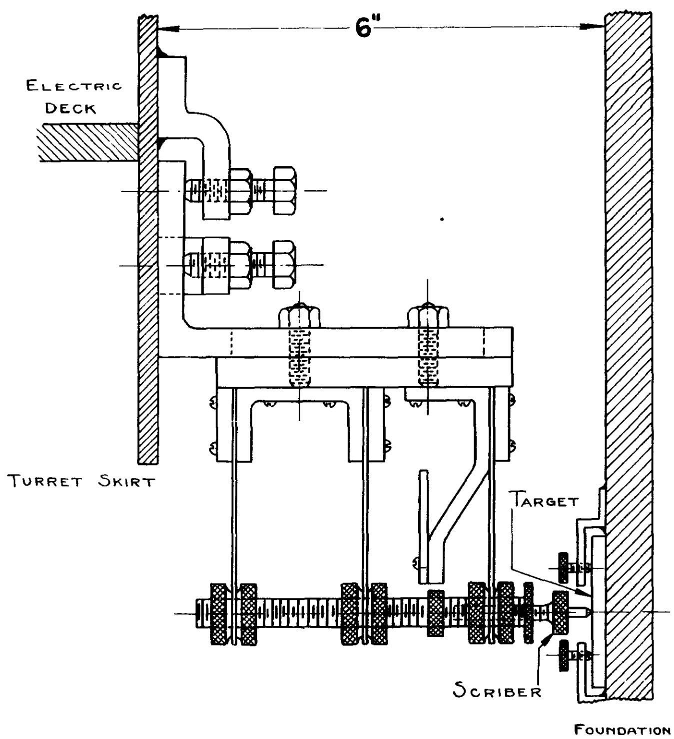

Fig. 2. Lateral Gage.

<u>Description of Gages.</u>

The gages were of the scratch type, in which a hardened steel scriber mounted on parallel suspension springs scratches a record on a black nickel-plated brass target. Two types of gages were designed: a longitudinal gage shown in Figure 1, and a lateral type shown in Figure 2.

In the longitudinal gage, the target is in the form of a plunger which slides in a tube and is scratched by a scriber attached to the tube. With the tube attached to the barbette and the target to the turret or turret foundation, the gage records the component of motion relative to the barbette in the axial direction of the gage. Various tube and plunger lengths are employed to suit the gage locations. By moving the scribing point at right angles to the axis of the gage, or by rotating the target member, it is possible to scribe a short zero reference line.

In the lateral gage, the scriber scratches a flat target. This gage was designed for measuring both lift and rotation of the turret, but for reasons discussed later it was not used on this particular test.

<u>Calibration of Gages.</u>

The gages were tested at the Experimental Model Basin for adaptability and accuracy. Figure 3 shows the apparatus employed. The tube of the gage was

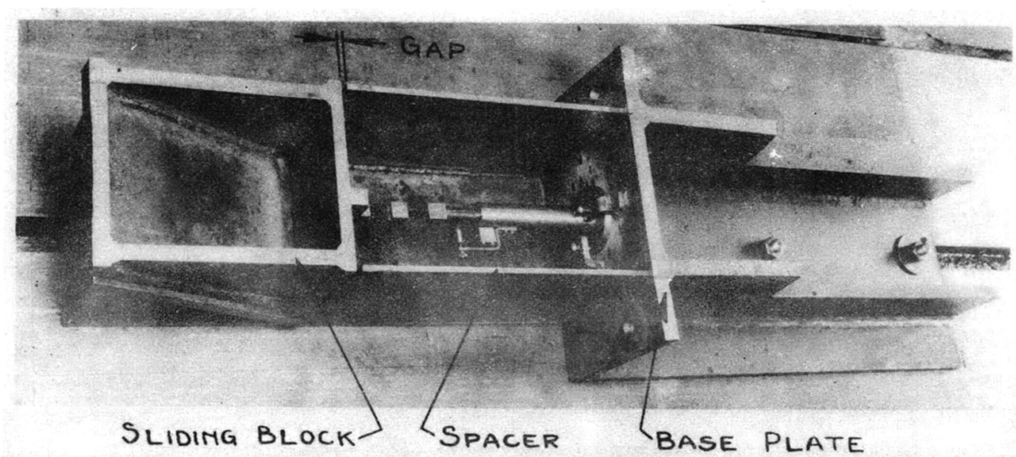

Fig. 3. Gage Calibration Apparatus.

secured in horizontal position to a fixed vertical plate, while the target was connected through its flexure member to a wedge-shaped block sliding on a fixed inclined plane having an angle of thirty degrees. The purpose of the inclined plane was to produce a combination of horizontal and vertical motion of the opposite ends of the gage such as would be experienced with the turret. A U-shaped spacer between the sliding block and the base plate served as a stop for the block. One end of the spacer was set against the base plate while the block was set a

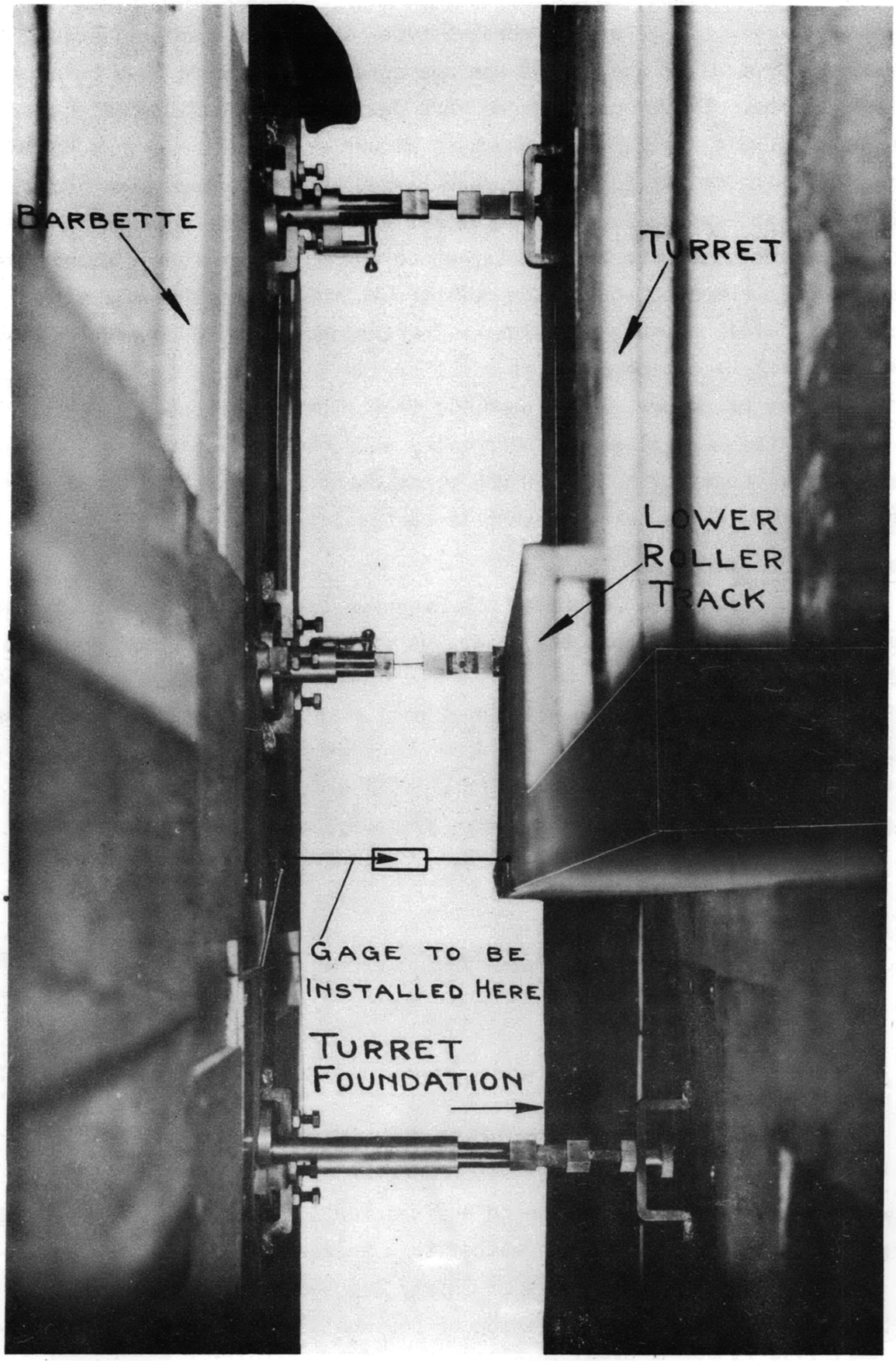

Fig. 4. Laboratory Mockup.

measured horizontal distance from the other end. A sledge hammer blow on the block then drove it up against the spacer. The scratch record checked the measured horizontal distance across the gap within 0.01 inch, showing that no appreciable error was introduced by the vertical component of the motion.

To check the possibility of buckling of the flexure plates during impact, the bolts which held the base structure fixed to the laboratory floor were removed. When the block was then driven against the spacer the impact caused the base structure to slide along the floor away from the block. In this manner it was possible to determine the length of scratch made during the time that the block was moving through the measured horizontal width of the gap to the spacer. As the two measurements checked within 0.01 inch, it was assumed that no buckling of the flexure plates or lag in the gage occurred.

Since the impact of the sledge hammer blow was much more severe on the gage than the anticipated impact during firing of the turret, data of corresponding accuracy could be expected. A similar calibration of the lateral gages showed them to be equally reliable and accurate.

Laboratory Installation Check.

A full-scale mockup of a portion of the inner wall of the barbette and the outer wall of the turret was made to check the practicability of welding in the narrow space available and to study the technique required to install the gages. This mockup, shown in Figure 4, was of wood with steel plating attached where the gages were to be mounted, and was of sufficient length to require the welder to be entirely within the space between turret and barbette walls while welding. Spring loaded jigs, one of which is shown in Figure 5, held the lugs and brackets for the

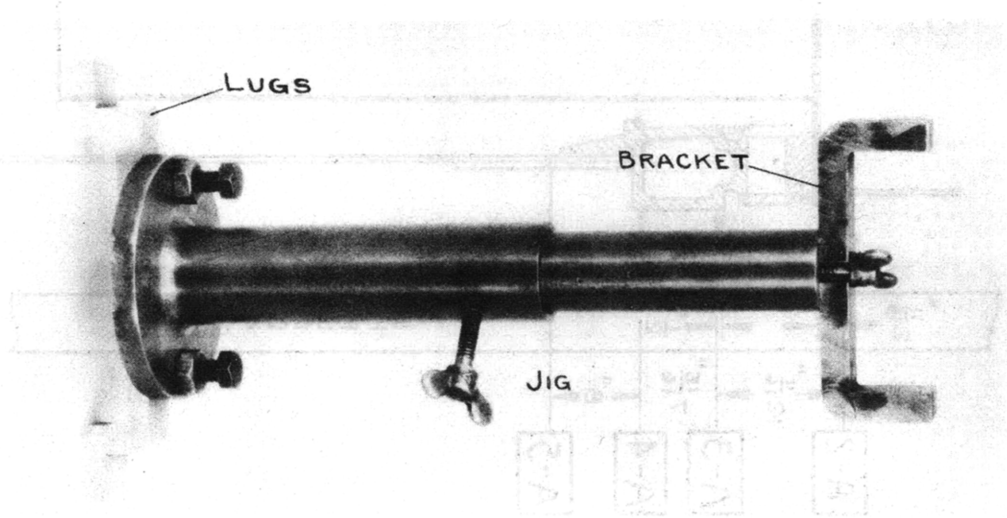

Fig. 5. Spring loaded Welding Jig.

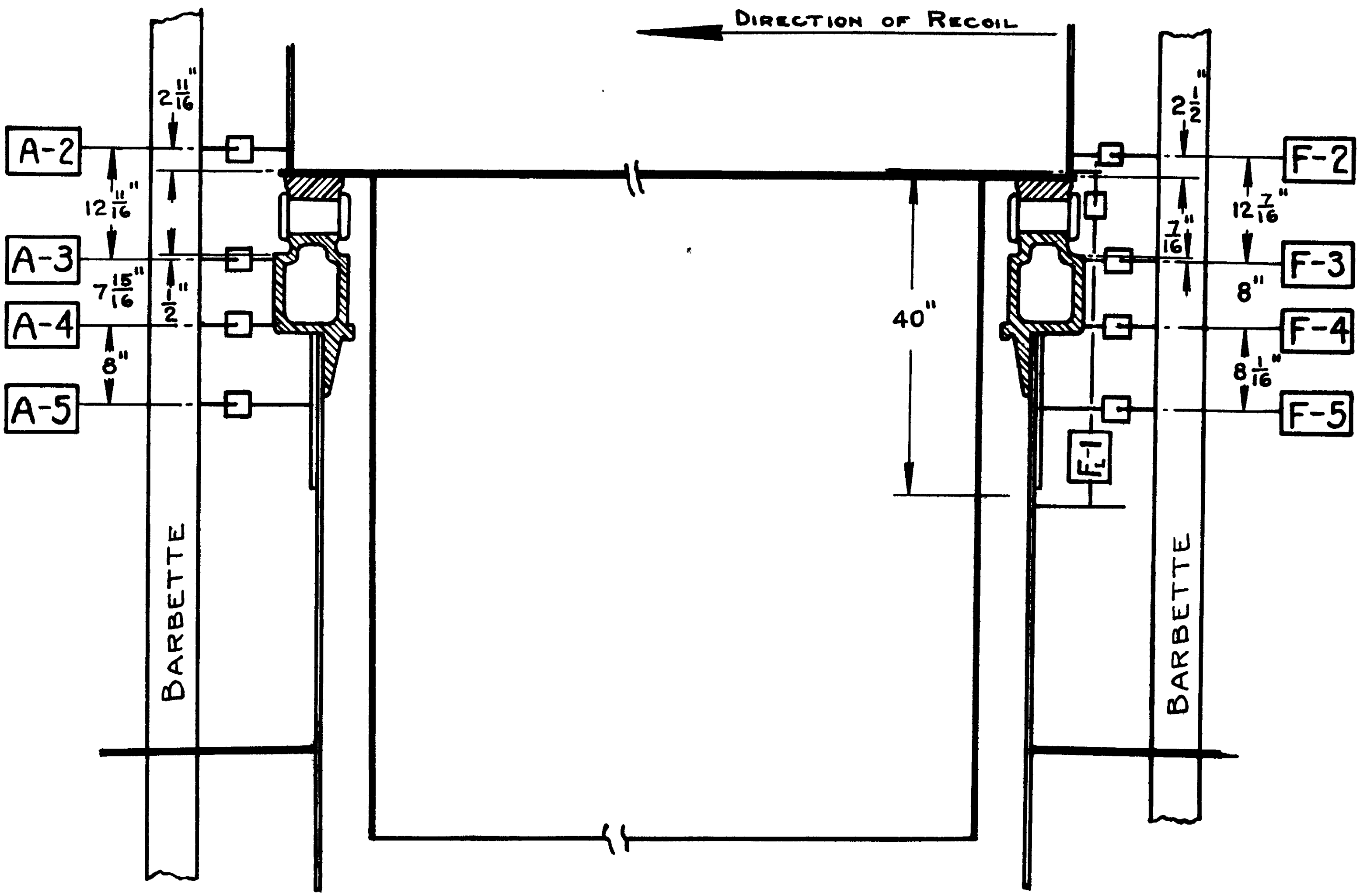

Fig. 6. Location of Gages on Ship.

longitudinal gages in the desired position during welding. The gages were mounted and all necessary operations for conducting the test performed. It might be remarked that the working space between barbette and turret foundation is only 14 inches and that this is reduced to 8½ inches in way of the lower roller track.

Installation of Gages.

The gages were installed on the NASHVILLE at the Navy Yard, Philadelphia, in the locations shown in Figure 6. A special adaptation of the longitudinal gage, spanning the roller track, was used to measure lift of the turret relative to the foundation at the front. The details of this gage and its attachment can be seen in Figure 7.

The lateral gages were to have been placed at the level of the electric deck but their installation had to be abandoned when the unforeseen presence of live shells directly beneath this location prevented welding. The scriber was clamped to the turret and an attempt made to use thick shellac or deKhotinsky cement to fasten the target to the foundation, but this proved unsuccessful.

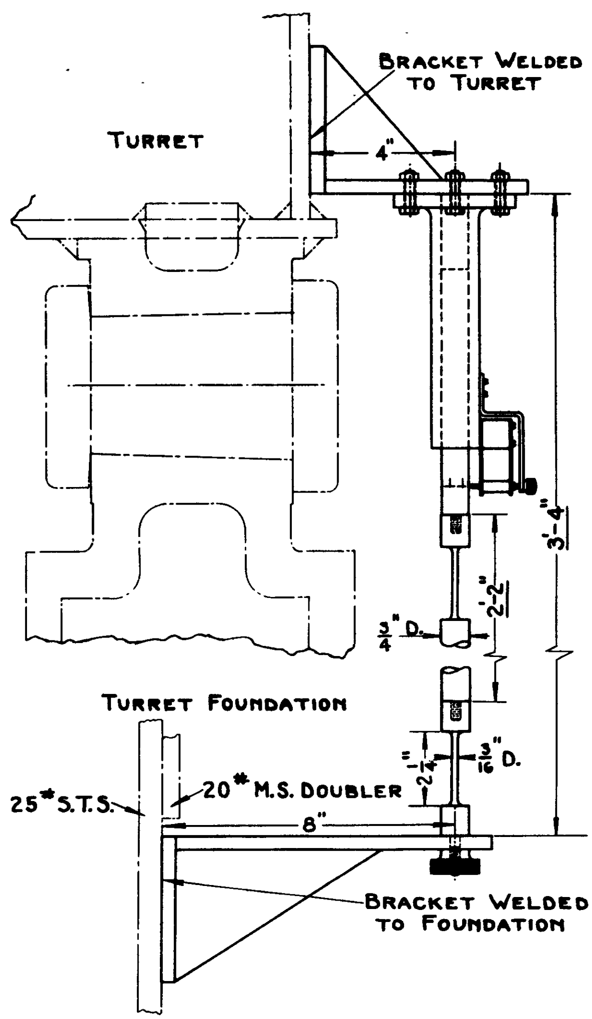

Fig. 7. Lift Gage.

Gage Station Designation.

Gage station symbols, as shown in Figure 8, were chosen to correspond to those of the model representing the turret structure of Battleships 55 and 56. The lift gage at the front (F_L – 1) and gages F–5 and A–5 which measured horizontal displacement of the turret foundation are exceptions. As in the previous model tests, the letters F and A were used to indicate forward and after sides of the turret, the forward side being in the direction of fire.

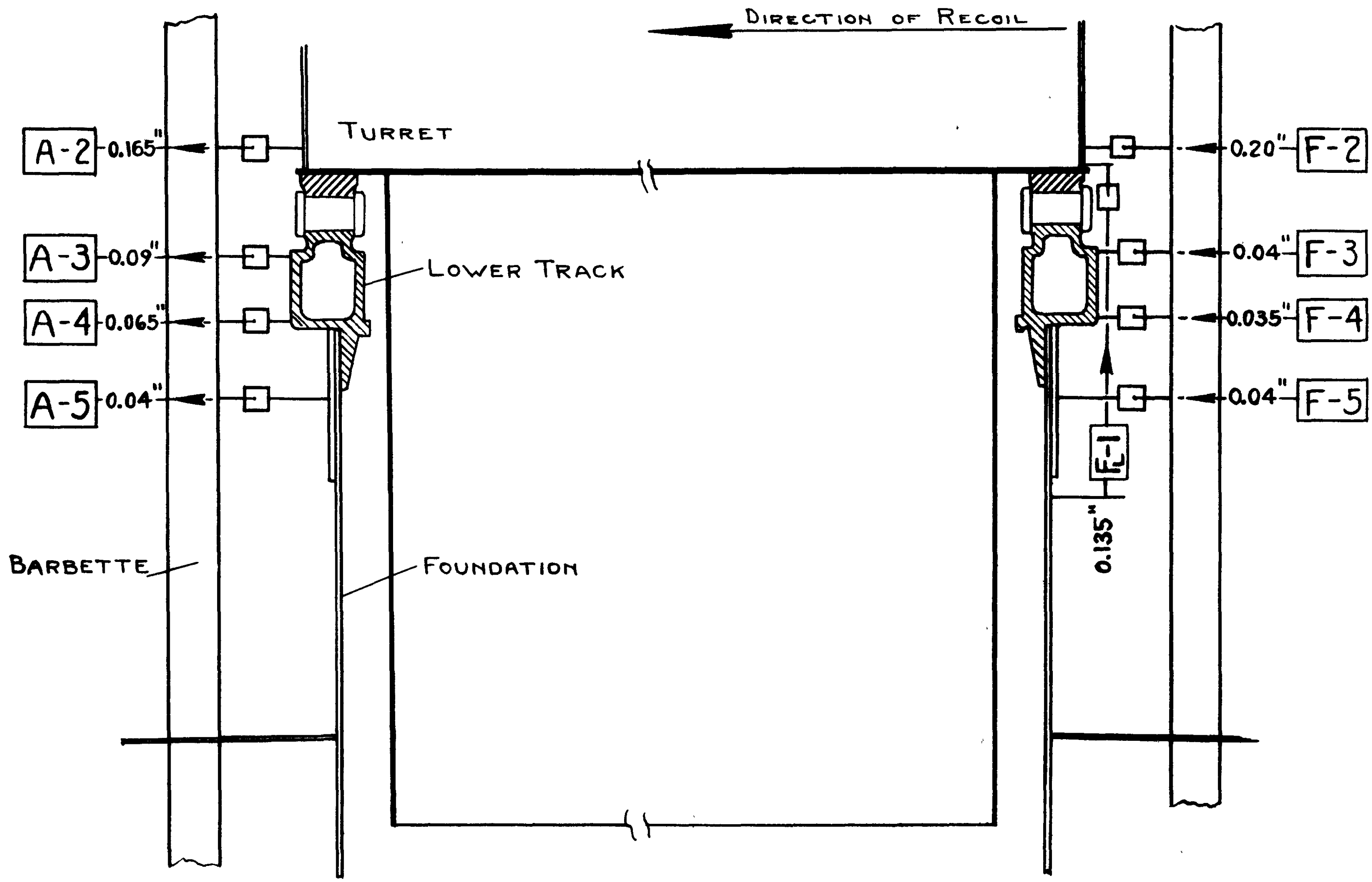

Fig. 8. Displacements of No. 1 Turret and Foundation of U.S.S. NASHVILLE

Average of Two Three-Gun Salvos
Maximum displacements measured from zero position during recoil.
Arrows indicate directions of displacements.

Description of Tests.

The measurements were made on November 27, 1938, during structural gun firing trials of the U.S.S. NASHVILLE. Maximum displacements of the turret and its supporting structure were measured for two three-gun salvos, both with the guns at zero elevation and trained 270 degrees.

The gages, which had been previously mounted, were set for recording after the fourth salvo. The targets, which had been removed from the gages to enable training of the turret, were inserted, the scribers set and the zero marks made. The complete operation required about twenty minutes, or no longer than the usual interval between the structural firing salvos. All guns of all turrets were fired on this fifth salvo. The targets were then rotated to place a fresh area under the scriber, new zero marks were made and a second three-gun salvo for No. 1 turret only was fired. The targets were then removed from the gages and the displacements measured with a steel scale and reading glass.

Data and Results.

The data are summarized in Table 1 and Figure 8. Table 1 includes displacements as measured for the two salvos and shows good agreement between the two sets of readings. The displacements are measured from the zero position and both the maximum displacements during recoil and the maximum counter recoil or kick-back displacements are tabulated. Figure 8 shows the average of the displacement measurements during recoil for each station. These are average maximum displacements from the zero position. A photograph of one of the scribed targets is included as Figure 9.

Since data are not yet available for a geometrically-similar model of this turret, a proper correlation of these readings with existing test results is impossible. However, predicted displacements of the NASHVILLE turret and supporting structure have been computed from data obtained during the experimental firing of the U.S.S. CALIFORNIA and from available curves of load vs. displacement for static test No. 5 of the model for the Battleship 55 and 56 turret. These computed displacements, based on three guns fired at zero elevation, are compared with the actual measured displacements in Table 2. Both computed

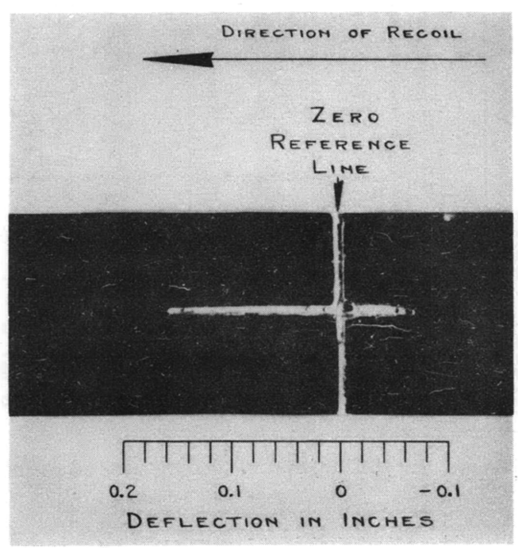

Fig. 9. Sample Record of Turret Deflection
Record for Rear Point A-2, Salvo No. 5
Magnification approximately 5½ diameters.

TABLE 1

DEFLECTIONS OF NO. 1 TURRET OF U.S.S. NASHVILLE

Measured during firing trials with three-gun salvos at zero degrees elevation and 270 degrees train.

Gage Station	Direction	Displacements from zero position in inches				
		Maximum displacement during recoil		Direction	Maximum kickback or displacement from turret rebound	
		Salvo 5 all 6-inch guns	Salvo 5-A 3 guns in No. 1 turret only		Salvo 5 all 6-inch guns	Salvo 5-A 3 guns in No. 1 turret only
F_L-1	Vert. up+	0.13	0.14	—	0.00	0.00
F-2	Horiz. to* rear	0.19	0.21	Horiz. to front	0.06	0.05
F-3	"	0.04	0.04	"	0.005	0.00
F-4	"	0.03	0.04	"	0.00	0.01
F-5	"	0.04	0.04	"	0.00	0.00
A-2	"	0.16	0.17	"	0.07	0.07
A-3	"	0.09	0.09	"	0.01	0.01
A-4	"	0.07	0.06	"	0.01	0.02
A-5	"	0.04	0.04	"	0.02	0.01

+Vertical displacements relative to foundation.

*Horizontal displacements relative to barbette.

TABLE 2

COMPARISON OF OBSERVED DISPLACEMENTS ON NASHVILLE WITH PREDICTED DISPLACEMENTS FROM CALIFORNIA TEST AND FROM STATIC TEST OF BATTLESHIP 55 AND 56 MODEL.

Maximum Displacements from Zero Position during Recoil for Three-Gun Salvos with Guns at Zero Elevation.

Part of Structure Displaced.	Direction of Displacement	Displacements in Inches		
		Observed NASHVILLE Displacements	NASHVILLE Displacements. Predicted from CALIFORNIA Data*	NASHVILLE Displacements. Predicted from Static Test of BB55 and 56 Model.+
Displacement of turret relative to top of foundation.				
Horiz. at Front (F-2) - (F-3)	To rear	0.16	0.12	0.06
Horiz. at Rear (A-2) - (A-3)	" "	0.075	0.08	0.04
Vertical lift of turret at front relative to foundation	Vert.up	0.135	0.07	0.04
Horiz. displacements of lower track relative to barbette				
Top at Front	To rear	0.04	0.05	0.03
Top at Rear	" "	0.09	0.08	0.04
Bottom at Front	" "	0.035	—	0.03
Bottom at Rear	" "	0.065	—	0.03
Twist of lower track, minutes of arc.				
At Front	Outward	2.0	—	0.6
At Rear	Outward	10.8	—	12.4

*Computed from CALIFORNIA data using multiplying factor of 0.326 (see text).

+Computed from model test data at a load analogous to actual load measured on CALIFORNIA during firing (see text).

and measured displacements include only the maximum displacement from the neutral position during recoil, and do not include the displacement from the rebound or kickback of the turret structure.

Comparison with CALIFORNIA and BB55 and 56.

To interpret Table 2 properly, consideration must be given to the method of scaling down battleship turret data. It can be shown (4) that, for two geometrically-similar structures, the first being λ times as large as the second, the relation between the loads P and the displacements Δ is

$$\Delta_1 = \lambda \Delta_2 \left(\frac{P_1}{\lambda^2 P_2} \right) \quad (1)$$

where the term in parenthesis may be regarded as a correction for loads that are not corresponding, i.e., $P_1 = \lambda^2 P_2$. The scale ratio, λ, of the turrets was taken as the ratio of the roller track diameters. The actual firing load was measured for the CALIFORNIA but not for the NASHVILLE or for Battleships 55 and 56. Hence it was necessary to make some assumption regarding relative firing loads to correlate the data. It was assumed that the ratio of firing to design load* is the same for all three turrets. Since these loads are not corresponding, the correction term in parenthesis must be included when scaling the battleship data.

For correlation of CALIFORNIA data the following values are used (subscripts C and N denoting CALIFORNIA and NASHVILLE respectively):

P_C = Design load CALIFORNIA = 2090 tons

P_N = Design load NASHVILLE = 375 tons

$$\lambda = \frac{Diam_C}{Diam_N} = \frac{322.25}{177.5} = 1.815$$

From equation (1) rearranged

$$\Delta_N = \Delta_C \frac{375}{2090} \times 1.815 = 0.326 \ \Delta_C$$

The predicted NASHVILLE displacements were determined from the CALIFORNIA data by using the multiplying factor 0.326.

The actual measured firing load on the CALIFORNIA was 1000 tons or 0.48 x design load. The actual firing load for Battleships 55 and 56 is taken as 0.48 x its design load = 1800 tons. From curves of static load vs. deflection the full-scale deflections are determined for this load and then converted to correspond to NASHVILLE measurements by means of equation (1), using the following values (subscripts BB and N denote Battleships 55 and 56 and NASHVILLE respectively):

*Design load = brake load per gun x number of guns x 2.

P_{BB} = Design load, Battleships 55 and 56 = 3771 tons

P_N = Design load, NASHVILLE = 375 tons

$$\lambda = \frac{Diam_{BB}}{Diam_N} = \frac{395.5}{177.5} = 2.23$$

$$\Delta_N = \Delta_{BB} \frac{375}{3771} 2.23 = 0.222 \Delta_{BB}$$

Full scale displacements determined from curves for static model test No. 5 were multiplied by factor 0.222.

Consider first the scaled-down CALIFORNIA displacements in Table 2, second column. An exact check with measured NASHVILLE displacements should not be expected since the structures are not geometrically similar, but the displacements should check within reasonable limits. Ignoring weight and height considerations, a fair agreement is not to be regarded as purely accidental, but rather as an indication of structures of equal stiffness. Displacements of the top of the lower roller track relative to barbette (average of front and rear) check exactly. This might be attributed to: foundations of equal stiffness, proportional relation between firing and design load, and equal accuracy of measurement for the two tests. However, it is likely that errors from the foregoing assumptions have canceled one another to bring about agreement in the results. Lift of the front of the turret is considerably greater on the NASHVILLE than the corresponding lift measured on the CALIFORNIA. The holding-down clip clearance is 1/32 inch on the former and 1/10 inch on the latter ship, or proportionately greater on the CALIFORNIA. The smaller lift on the CALIFORNIA is not surprising, however, since an outside clip is installed on this turret whereas the NASHVILLE has an inside clip of less effective leverage.

This relative weakness of the NASHVILLE clip is also substantiated by the horizontal displacements of the two turrets and their lower roller tracks. A weaker clip would allow greater tilting of the rollers at the front with an accompanying shift to the rear of some of the horizontal load carried at the front of the turret foundation. This increased load at the rear would cause greater elongation of the longitudinal lower roller track diameter and greater contraction of the longitudinal turret diameter. Since these diametral changes are greater on the NASHVILLE than on the CALIFORNIA (computed from the data of Table 2), the horizontal displacements confirm the vertical motions in indicating a weaker clip on the NASHVILLE.

The displacements predicted for the NASHVILLE on the basis of the tests of the Battleship 55 and 56 model, are very much less than those measured. Considering first the horizontal displacements of the top of the lower roller track relative to barbette (average of front and rear), the predicted displacements are about one-half those measured. This discrepancy very likely results from the lack of geometrical similitude of the structures. The model turret foundation, besides differing in shape and lower track design, is cut off at the level of the second deck and welded to a very rigid test frame. The full scale foundation extends through the second deck to the decks below, and while it is supported by the decks, these supports are considerably more elastic than the model foundation support. As discussed in reference (3), strain in the decks between the turret foundation and barbette allows a tilting of the foundation which may account for a considerable portion of the measured full-scale displacements, and deflections of the foundation itself below the second deck also contribute to these measurements. Consequently, it is not surprising that (even neglecting dynamic effects) the displacements of the relatively short model foundation are less than those of the longer and differently supported full-scale foundation.

The motions of the rotating part of the turret predicted from the static model test show even greater disagreement with those measured. The more rigid holding-down clip on the model is probably responsible for most of the discrepancy in vertical motions and it undoubtedly influences the horizontal displacements. Furthermore, the horizontal displacements of the static model were measured after roller flange clearances had been taken up, whereas, the dynamic measurements include the double roller flange clearance since, as discussed in reference (3), the initial position of the turret as regards roller clearance is at the extreme front. The double roller flange clearance is 0.03 inch on the NASHVILLE.

Conclusions.

1. The high degree of accuracy of the gages, as shown by calibration, and the good agreement between readings for the two salvos in the NASHVILLE test, indicate that reliable measurements of turret displacement can be made with this type of gage.

2. The measurements compare reasonably well with those obtained on the U.S.S. CALIFORNIA.

3. Static displacements of the Battleship 55 and 56 model at a load corresponding to the measured load on the CALIFORNIA are much less than the corresponding full-scale displacements measured on either the NASHVILLE or the CALIFORNIA. These discrepancies doubtless result from sources of dissimilitude inherent in the static method of testing.

Acknowledgments.

The gages were designed and calibrated by Mr. R. T. McGoldrick; the tests were conducted by Mr. R. T. McGoldrick and Mr. E. E. Johnson; and the work was supervised by Lieutenants R. D. Conrad, (CC), U.S.N. and J. M. Farrin, (CC), U.S.N. Administrative arrangements and correlation of activities concerned were handled by Lieutenant W. E. Howard, (CC), U.S.N. of the Bureau of Construction and Repair.

LIST of REFERENCES

(1) "Tests of a One-Eighth Scale Model Turret Foundation for Battleships 55 and 56," Experimental Model Basin Report No. 458, December, 1938.

(2) "Motions and Deflections of a Three Gun Turret," A Report by the Bureau of Standards of the Experimental Firing on the U.S.S. CALIFORNIA, November, 1921.

(3) "Memorandum of Turret Stresses as Deduced from the Measurements Made by the Bureau of Standards on the CALIFORNIA," by Captain E. F. Eggert, (CC), U.S.N., Turret Foundations, Vol. II.

(4) "Structural Models, Part I: Theory," C. & R. Bulletin No. 13, by Lieutenant R. D. Conrad, (CC), U.S.N.