FULL SCALE TESTS
of
TURRET FOUNDATIONS

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RESUME OF STUDIES OF TURRET FOUNDATIONS SINCE 1925

Effort was made to reduce the elaborate theoretical and experimental results of Hovgaard and the Bureau of Standards to a form suitable for direct application in design. But Hovgaard's theory turned out to require such drastic modification of constants to make it fit the CALIFORNIA tests that the validity of the analysis seemed questionable. A simplified analysis was carried out in which the ring and the cylindrical bulkhead were regarded as separate elements of a flanged-tube cantilever. The intent was to get the main features of the action correctly described, leaving secondary actions to be covered by adjustment of constants on a frankly empirical basis. Such a "theory", though admitted to be deficient as a full explanation of all the details of the action would nevertheless serve the requirements of practical design and even from the purely theoretical point of view can hardly be objected to when regarded as a means of comparison between similar designs.

A formula for the effect of idealized loads of the ring was worked out, and tests on models confirmed its approximate correctness.

Interactions between the ring and tube were explored in a series of small models in which the mode of failure was also observed. The results are contained in the paper on "Short Flanged-Tube Cantilevers under Concentrated Radial Load".

Actual details of loading and construction were somewhat more closely simulated in 3 models on a diameter of 60 inches. Failures of the ring and of the plating were obtained, giving data on the stress at which wrinkling might be expected. Details of these tests are given in Model Basin Report 206 and application of the data to design was illustrated by examples worked out in EMB Report 207.

Finally, measurements of deflection on a full scale foundation under 8 inch mounts in proof and application of the analysis to data obtained from the CALIFORNIA showed that the procedure suggested for design left large margins of strength in these cases due to the support of structure not taken into account, in particular that of the rotating parts which act to stiffen the ring.

The tests indicate that when the ring is stiff enough it greatly assists the plating of the tube, so that longitudinal stiffeners are unnecessary. This is fortunate because without special construction they are of little effect in resisting the type of failure actually occurring. A more suitable reinforcement consists in local increase of plating thickness.

FULL SCALE TESTS OF TURRET FOUNDATIONS

As no model ever simulates all details of structure and loading, model studies of turret foundations were followed by measurements of deflection made on the foundation at the Proving Ground under recoil of the 8 inch triple mounts for Light Cruisers. This consisted of a circular bulkhead 40 inches high, secured to a heavy concrete base. As at first constructed and shown in Figure 1, it was very heavily stiffened by 38 channels which connected it with a second similar bulkhead inside the first. The deflections of this built-up structure were so small that it was found possible to remove the channels altogether, and the significant data were obtained from the foundation consisting only of the outer bulkhead plate. The faying flanges of the channels, which were left in place, were of negligible effect.

In order to make the ring of stiffness equivalent to that designed for the PENSACOLA, additions were made to the section to compensate for those parts of the ship structure not otherwise represented in the proof structure. These consisted of a horizontal plate, with two angles and a face plate at its outer edge, all forming a continuous rim extending right around the circle.

The resulting foundation cantilever was thus shorter than that in the ship, and buckling stresses are therefore correspondingly less. But shear stresses are similar to those in a higher cantilever, and in particular the action of the ring is very similar to that in the ship, as it receives almost no support from the plating at the rear point, where the direct load is applied radially.

The data show that the ring deflections are about half those expected from model tests. This is due to the support received by the fixed ring from the rotating ring which moves within it; the unexpectedly large amount of this support is the main feature developed by the tests.

The fixed ring was reduced in section progressively with the intention of ascertaining the influence of the stiffness of this ring on deflections. Such reductions extended to the twelfth triple mount proved, 113, after which the ring was restored to its original scantlings. The internal bulkhead and stiffeners were, however, not restored. All subsequent data were taken from this restored structure which for the 13th mount, 122, and all those subsequent, remained unchanged.

Figure 2 shows deflections for Proof Salvos at 0 degrees elevation and Service Salvos at 15 degrees elevation as follows: Radial deflection at rear point, transverse diametral deflection of outer ring, transverse diametral deflection of inner ring, all plotted in chronological order of tests.

Up to mount 113, the data show only slight changes in deflections, much smaller than if proportional to the diminishing ring stiffness. This also indicates that support is received from structure not reckoned with in the calculations.

The changes in deflection are not in all cases in the direction which would be expected from the nature of the alterations to the structure. Omitting the isolated spot on mount 107, the drift in the first five cases is toward diminished deflections in spite of small reductions in ring stiffness. The larger reductions in ring stiffness which followed may be said to have checked this tendency toward reduced deflections and even led at first to moderate increase in deflection. The natural effect of restored stiffness in the ring is to strongly reduce transverse diametral deflections. The accompanying increase in radial deflection at the rear point is not so easy to account for. Leaving this last effect aside for the moment, the general progress of the deflections may be described as consisting of partial response to the structural alterations, superposed on a gradual hardening, but the whole confused by a high degree of variability in the data.

The progressive hardening is not surprising in view of the repeated application of high impact loads on the same angle of train. Hammering always does something like this, but on a ship the benefit would be lost through reversal on opposite angles of train.

The variability leads to some speculation as to its cause. It is noted that deflections under proof and service salvos shift in close parallelism throughout, indicating that the variable factor is in the mount itself.

The most striking feature of the data in Figure 2 is the great reduction in diametral deflection after the restoration of ring-section. This may be due to the combined effect of the increased section and the progressive hardening of the structure. But the accompanying increase in rear deflection suggests another influence as well.

As a cause of the irregularities, variation in radial clearance between rings is suggested. Although very careful machining was done to reduce this clearance and make it uniform, temperature and elastic effects could easily lead to rather large variations compared with the nominal figure of .03 to .01 inch on a diameter of 240 inches.

A consideration of the effects of such clearance shows that deflections would be rather sensitive to slight variations through their influence on the interactions between the fixed and turning rings. During the course of the test changes in the design of this bearing occurred, but the details of these changes are not known to me. It is understood that these changes occurred about the same time as the restoration of the ring-section, and that their effect was to reduce the clearance between the rings. This would have the effect of increasing the support along the transverse diameter afforded by the inner ring, to the outer, and thus further reducing the transverse diametral deflection.

The radial deflection at the rear point due to bending would naturally be diminished by the reduced clearance between the rings; the well marked increase in total deflection there is not directly accounted for in the same way as the effects mentioned above. Other possibilities are discussed further below but no wholly satisfactory explanation of the increased deflection at the rear point has been found.

DETAILS OF THE TESTS

The successive changes made in the foundation structure are indicated in the table below:

TEST	ASSEMBLY Number	DATE	STIFFENERS	RING	SECTION MODULUS
1	Twin 104		38	Whole	773 in.^{3}
2	108		38	Whole	773
3	101	20 Sept.'27	38	Whole	773
4	105	11 Nov. '27	24	Whole	773
1	Triple 102	6 Feb. '28	16	Whole	773
2	103	17 Mar. '28	8	Whole	773
3	106	5 May '28	0	Whole	773
4	107	21 May '28	0	2"cut from flange	719
5	111	24 July '28	0	Second 2" cut	665
6	114	21 Aug. '28	0	Face Plate removed	512
7	123	3 Oct. '28	0	No change	
8	109	14 Nov. '28	0	" "	
9	112	13 Dec. '28	0	Angles removed	284
10	121	22 Jan. '29		"	
11	110	20 Feb. '29		"	
12	113	18 Mar. '29		"	
13	122	18 April'29	0	Restored	773
14	116	1 July '29	0	"	773
15	119	24 July '29	0	"	773
16	115	26 Aug. '29	0	"	773
17	17-1	3 Oct. '29	0	"	773
18	18-2	6 Nov. '29	0	"	773
19	120	26 Dec. '29	0	"	773
20	20-3	27 Jan. '30	0	"	773
21	21-1	1 Mar. '30	0	"	773
22	22-2	3 Apr. '30	0	"	773

After preliminary work, and beginning with the triple mounts, the aim was to obtain deflections at six points, corresponding to those in the models, as follows:

Radial, At ends of longitudinal diameter, designated Front and Rear.

Radial, At ends of transverse diameter, designated Right and Left Radial.

Tangential, At ends of transverse diameter, designated Right and Left Tangential.

In number 9, mount 112 and subsequent tests diametral deflection of inside ring was taken on an electric gage giving a time record. In number 10, mount 121, and subsequent tests tangential and front radial gages were omitted.

Detailed results obtained are exhibited in Figures 2, 3, and 4.

Gross deflection at the rear point is due to cantilever deflection combined with bending of the ring. Taking the data from the tangential gages to represent cantilever deflection and deducting, a net value is obtained which may be compared with the calculated nominal value (concentrated load, proof salvo) of .18 inch. This is based on a trunnion pressure of 570,000 pounds, radius 120 inches, moment of inertia 13477 in.^{4}.

$$.0367 \frac{2 \times 570{,}000 \text{ lb} \times 120^3}{30 \times 10^6 \times 13477} = .18 \text{ inch}$$

For comparison it is noted that a corresponding value measured in the CALIFORNIA was 0.12 inch, the calculated nominal value being 0.22 inch (divided load, see EMB Report 207).

The sum of the two transverse radial deflections gives the transverse dimetral deflections. This is a direct measure of ring stiffness, nominal value being 0.25 inch. The corresponding figure in the CALIFORNIA is .085 maximum, and with load divided between front and rear the nominal value is 0.16 inch.

Although a good check would be obtained if trunnion pressures were not doubled in computing nominal deflections, it is believed the true explanation of the discrepancy between observed and nominal values lies rather in the conservative estimates of stiffness of the structure.

The significant fact, however, is that, all circumstances being what they are, actual deflections are only half nominal. Whether this is due to actual load being smaller than nominal, or actual stiffness being greater than nominal, is a question that would acquire importance only in case of a radical departure in type of structure.

At the front, doubt exists as to the direction of the deflection in direct recoil. On one mount only (102) an electric gage was placed at this point and in this case the initial net deflection was to the rear, but less in magnitude than the side tangentials. This would leave a small net forward ring deflection at the front point in direct recoil. The larger gross forward deflections shown by the optical gage are almost certainly those which occur on counter recoil. In any case front deflections are small and in later work were not ascertained.

The measurements of inside diametral deflection were undertaken for the purpose of determining whether the support given the outer ring led to undue stresses in the inner ring. Observed deflections are all small, as shown in Figure 1, thus providing assurance on that point. The electric gage used indicated time relations as well and uncovered the rather surprising fact that the initial deflection of the inner ring consists of an <u>increase</u> in the transverse diameter which occurs about 1/100 second before the decrease in diameter of the outer ring. There is thus an appreciable interval both in time and space before the two rings come into close contact and thus afford to each other the support which holds deflections down to the observed values. Although the nominal clearance in the bearing between the two rings is .03 inch or less the gages show relative motion of .08 to .19 inch. This suggests that the amount of this clearance under service conditions is considerably larger than as finished in the shop. In view of the dependence of the two rings upon each other for support, variation in the clearance between them of the order indicated by the gage measurements seems quite enough to account for the variability of the observed deflections.

INSTRUMENTS

The electric gages used were of the step-by-step type used in previous ballistic work, operating with oscillographs and reading to .01 inch. Optical gages were of a simple rotating mirror type, which worked very consistently and satisfactorily, readings being taken with telescope and scale to obtain maximum deflection in one direction only without reference to time. Supports for both types of gages were built up from the concrete base of heavy angles welded so as to obtain rigidity sufficient to give a natural period of vibration in the support probably much less than .01 second.

ACKNOWLEDGMENT

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W. P. Roop

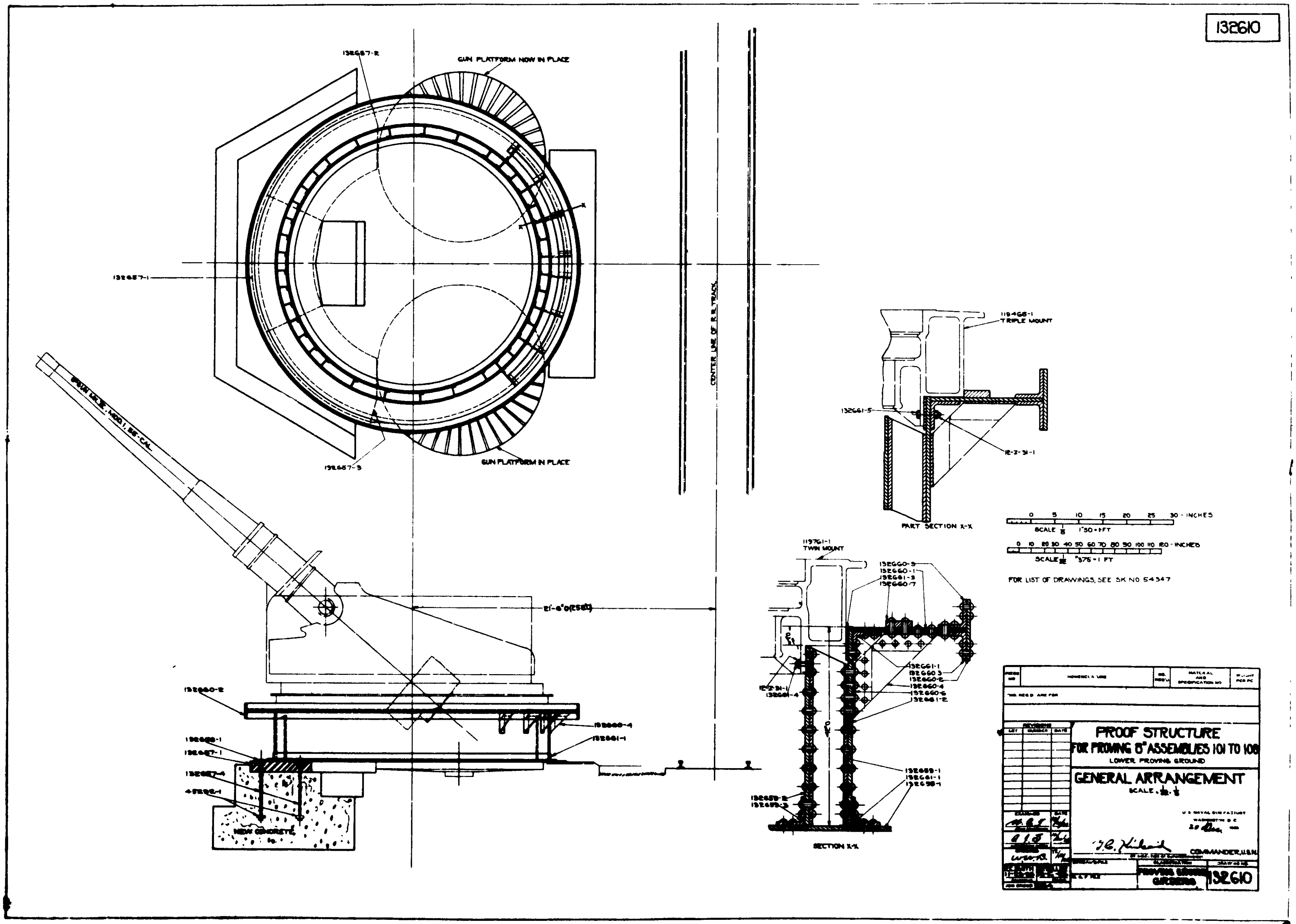

132610
GUN PLATFORM NOW IN PLACE
GUN PLATFORM IN PLACE
CENTER LINE OF R.R. TRACK
119468-1
TRIPLE MOUNT
PART SECTION X-X
119761-1
TWIN MOUNT
SECTION X-X
FOR LIST OF DRAWINGS, SEE SK NO 54347
NEW CONCRETE
PROOF STRUCTURE
FOR PROVING 8" ASSEMBLIES 101 TO 108
LOWER PROVING GROUND
GENERAL ARRANGEMENT
COMMANDER, U.S.N.
132610

Figure 1

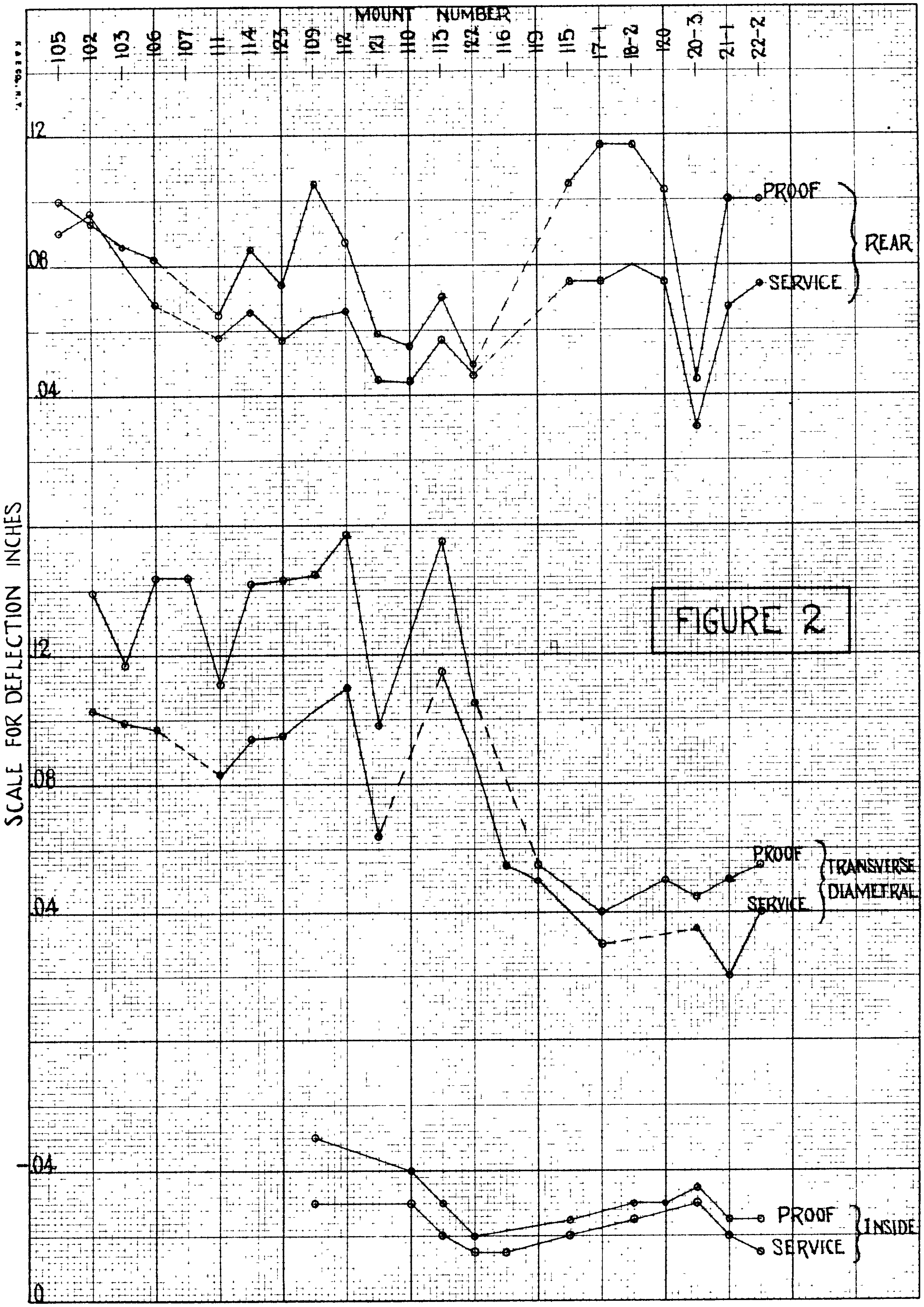
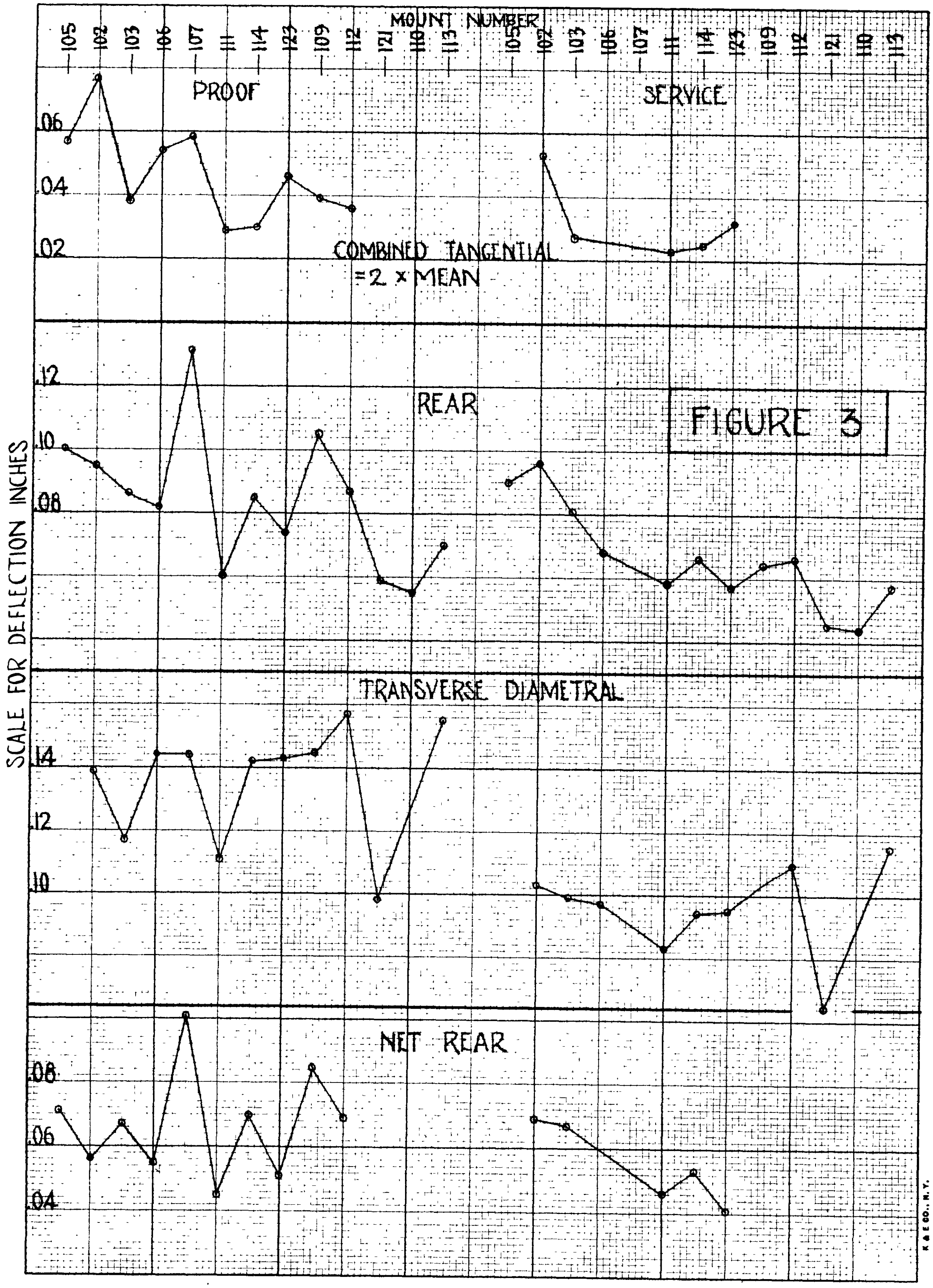
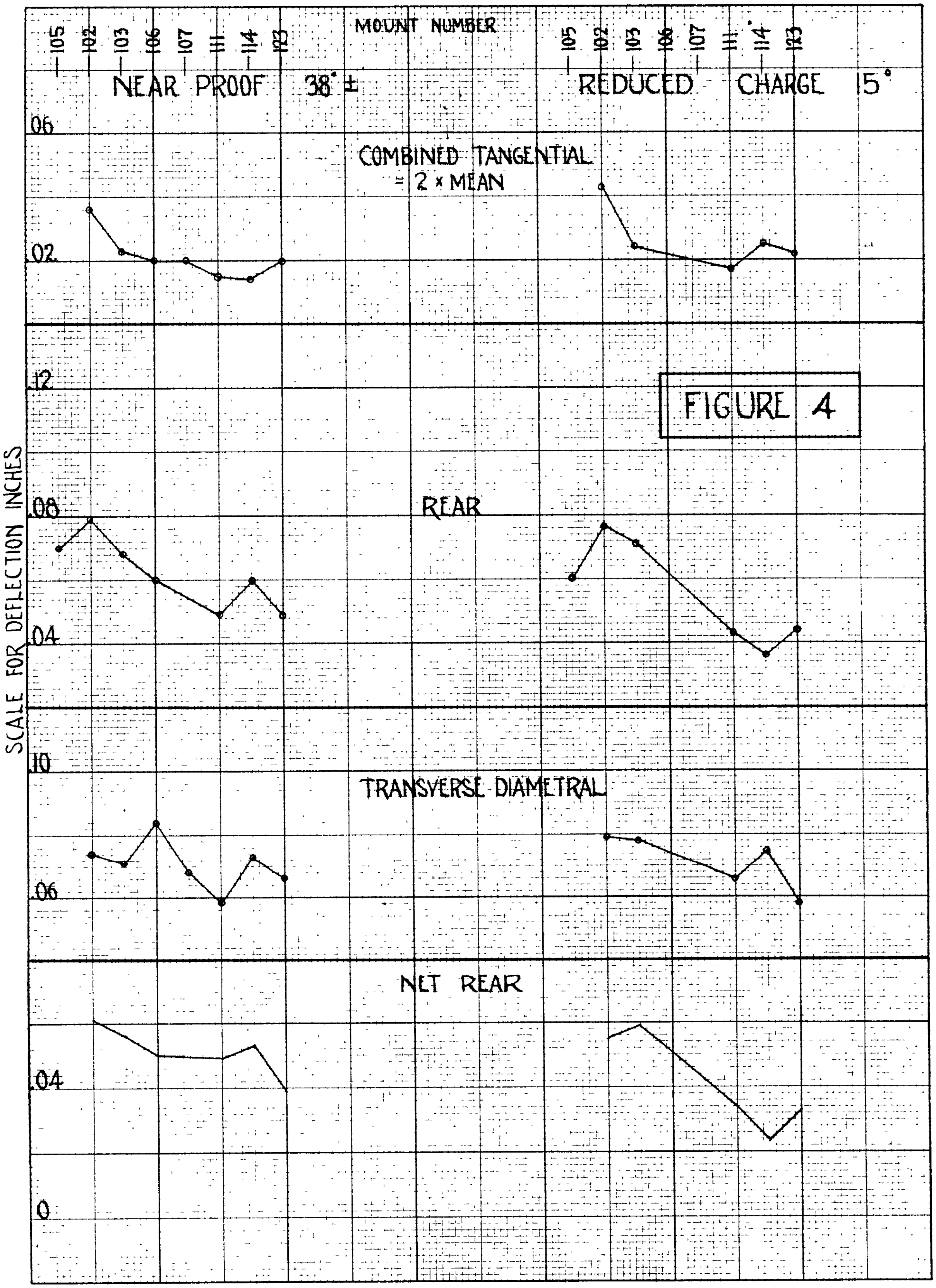

MOUNT NUMBER
105
102
103
106
107
111
114
123
109
112
121
110
113
122
116
119
115
17-1
18-2
120
20-3
21-1
22-2
SCALE FOR DEFLECTION INCHES
.12
.08
.04
0
PROOF
SERVICE
REAR
TRANSVERSE
DIAMETRAL
INSIDE

FIGURE 2


MOUNT NUMBER
105 102 103 106 107 111 114 123 109 112 121 110 113 105 102 103 106 107 111 114 123 109 112 121 110 113
PROOF
SERVICE
.06
.04
.02
COMBINED TANGENTIAL =2 × MEAN
.12
REAR
.10
.08
FIGURE 3
SCALE FOR DEFLECTION INCHES
TRANSVERSE DIAMETRAL
.14
.12
.10
NET REAR
.08
.06
.04
K & E CO., N.Y.


MOUNT NUMBER
105 102 103 106 107 111 114 123
105 102 103 106 107 111 114 123
NEAR PROOF 38° ±
REDUCED CHARGE 15°
SCALE FOR DEFLECTION INCHES
.06
.02
COMBINED TANGENTIAL
= 2 × MEAN
.12
.08
.04
REAR
.10
.06
TRANSVERSE DIAMETRAL
.04
0
NET REAR
FIGURE 4