TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 189

TORSIONAL STRENGTH OF NICKEL STEEL AND DURALUMIN TUBING AS AFFECTED BY THE RATIO OF DIAMETER TO GAGE THICKNESS.

By N. S. Otey,
U.S. Naval Aircraft Factory.

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TORSIONAL STRENGTH OF NICKEL STEEL AND DURALUMIN TUBING AS AFFECTED BY THE RATIO OF DIAMETER TO GAGE THICKNESS.*

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Introduction.

This investigation was made at the request of the Bureau of Aeronautics. Since the ordinary torsion formula is based on elastic resistance to deformation, it is inaccurate for determination of ultimate stresses in thin wall tubing subjected to torsional loads. It has been found that the torsional modulus of rupture varies with the ratio of diameter to gage thickness and the object of these tests was to determine the extent of these variations for subject materials. This is somewhat of a prorogation of work** done by the Army Air Service at McCook Field.

Conclusions.

1. The torsional modulus of rupture of nickel steel (2330) and duralumin tubing varies with the ratio of diameter to gage thickness (D/t) as follows:

(a) Nickel steel heat-treated for 125,000 Psi ultimate tensile strength.

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* Originally prepared as Report No. 6T23-5, U. S. Naval Aircraft Factory.

** Air Service Information Circular No. 263, Volume III, dated July 20, 1921.

Modulus of rupture (M) = $\frac{135,500}{\sqrt[5]{D/t}}$

(b) Duralumin treated for 55,000 Psi. ultimate tensile strength.

Modulus of rupture (M) $\frac{127,500}{\sqrt{D/t}}$.

Materials.

2. The steel tubing used in this investigation was taken from stock having the following specified analysis:

Steel No.	% C.	% Mn.	% P.	% S.	% Ni.
2330	.25-.35	.40-.80	.40 Max.	.045 Max.	3.25-3.75

The heat treatment given this tubing was that of quenching in oil at 1525° F. and drawing at 800 to 1100° F. depending on the brinell hardness after quenching.

3. The duralumin tubing was standard stock material and since it had been heat-treated by the manufacturer, no further treatment was given. The specified chemical analysis is:

% Al.	% Cu.	% Mg.	% Mn.	% Fe.	% Si.	% Ca.
92 Min.	3.5-5.0	.2-.75	.4-1.0	.6 Max.	.4 Max.	.4 Max.

Procedure.

4. Twelve steel and ten duralumin tubes of diameters and gages shown in Table I were supplied in 60-inch lengths. From each of these a 12-inch specimen was cut for tensile tests and the 48-inch lengths used for torsion tests. In the case of steel, the tensile specimens had to be cut before heat treatment due to size of furnace available, which, through heat treatment, resulted in variations in physical properties of the tensile and torsion specimens as will be shown later. The torsion specimens were tested in an Olsen torsion machine at Drexel Institute. The set-up used is shown in photographs (Figures 1 and 2).

Data.

5. Complete results of these tests are shown in Table I and Figures 8 to 15 inclusive.

6. The curves in Figures 5 and 6 show graphically the changes in moduli of rupture as affected by the D/t ratio. These curves were plotted under the following procedure:

(a) Average curves were drawn through the empirical points for convenience in obtaining the final curves.

(b) Values taken from these average curves were plotted to log scale as shown in Figure 7, from which the slope of the average curves was determined.

(c) Using the slopes thus determined, equations were found from which the final curves shown on Figures 5 and 6 were plotted. These final curves were found to agree very favorably with the original average curves.

7. In Figures 8 to 15 inclusive, the torsional load/deformation data is plotted. Curve G1, (Fig. 13), shows irregularities in the region of the yield point which is characteristic of duralumin.

8. Photographs (Figures 3 and 4) show torsion specimens after test. It will be noted that in all cases but three, failure occurred by buckling or collapsing rather than shear.

Discussion.

9. In the case of the steel tubing, it will be noted that the empirical values are erratic as shown in Figure 5. This may be due to two causes:

(a) Variations in physical properties of the material.

(b) Failure by crinkling or collapsing rather than shear.

The first cause is not considered entirely responsible as examination of brinell hardness and moduli of rupture of the torsion specimens indicate more uniform physical properties than the tensile values shown in Table I, would suggest. Although the tensile and torsion specimens were heat-treated in the same furnace and at the same time, their differences in size likely caused considerable variations in physical properties. With due consideration for these erratic results and their causes, the curve is considered sufficiently accurate for reliable design data.

Much credit is due Drexel Institute for courtesies extended in permitting the use of their torsion testing equipment and for generous aid in conducting these tests.

Table I.

STEEL TUBING

Tensile Properties.

No.	Size	Y.P. Stress	Ult. Stress Psi	% Elong. 2"
A1	1.000" x .032"Ga.	-	-	-
A2	1.000 x .032	-	129000	11.5
B1	1.250 x .049	-	136800	15.0
B2	1.250 x .052	146800	150500	12.5
C1	1.410 x .065	121300	124300	18.5
C2	1.410 x .066	109000	112200	21.0
D1	1.500 x .192	-	-	-
D2	1.500 x .192	140700	149200	10.0
E1	2.250 x .065	132200	138300	10.0
E2	2.250 x .065	113600	128700	10.3
F1	2.620 x .084	108700	129600	10.8
F2	2.620 x .082	-	-	-

DURALUMIN TUBING

No.	Size	Y.P. Stress	Ult. Stress Psi	% Elong. 2"
G1	0.751 x .057	39300	66700	27.5
G2	0.749 x .057	38450	59700	27.5
H1	0.998 x .057	36800	57100	17.0
H2	0.995 x .057	39900	61700	27.0
I1	1.375 x .040	31000	51100	16.0
I2	1.370 x .039	38900	59300	20.5
J1	1.495 x .042	36700	58600	24.0
J2	1.490 x .040	37000	58200	26.0
K1	1.500 x .057	38500	62000	25.0
K2	1.500 x .059	38200	61500	26.5

Notes:
1. J = polar moment of inertia.
2. c = distance from polar axis to extreme fiber or D/2.
3. Load P. limit is torque in inch pounds.
4. Ult. load is torque in inch pounds to rupture.
5. Torsion formula is $S \times J/C = P_p$ where P_p = torque in inch pounds.

Table I (Contd.)

STEEL TUBING

Torsional Properties.

No.	Brinall Hardness	D/t	J	C	J/C
A1	314	31.25	.0228	0.500	.0456
A2	239	31.25	.0228	0.500	.0456
B1	266	25.50	.0667	0.625	.1067
B2	239	24.05	.0703	0.625	.1124
C1	248	21.70	.1245	0.705	.1766
C2	239	21.35	.1261	0.705	.1788
D1	248	7.81	.3445	0.750	.4593
D2	236	7.81	.3445	0.750	.4593
E1	256	34.62	.5330	1.125	.4737
E2	289	34.62	.5330	1.125	.4737
F1	222	31.20	1.0766	1.310	.8218
F2	239	31.95	1.0521	1.310	.8031
	Shore Hardness	DURALUMIN TUBING			
G1	30.0	13.17	.0151	0.375	.0403
G2	28.5	13.13	.0149	0.374	.0398
H1	27.5	17.52	.0374	0.499	.0749
H2	28.5	17.46	.0370	0.497	.0744
I1	24.5	34.35	.0748	0.687	.1088
I2	24.5	35.15	.0723	0.685	.1055
J1	25.5	35.60	.1034	0.747	.1384
J2	24.5	37.25	.0957	0.745	.1284
K1	25.0	26.30	.1347	0.750	.1786
K2	27.0	25.45	.1389	0.750	.1852

Table I (Cont.)

STEEL TUBING				
Torsional Properties.				
No.	Load at P. Limit	Load at Rupture	Modulus of Rupture P. Lim.	Modulus of Rupture at Ult.
A1	3125	3340	68500	73200
A2	3225	3350	70750	73400
B1	7800	8200	73100	77000
B2	8150	8490	73200	75500
C1	11200	11500	63400	65100
C2	11100	11700	62100	65500
D1	-	41800	-	91000
D2	35600	42800	77500	93200
E1	-	33700	-	71300
E2	3360	34355	71000	72500
F1	3800	49800	46200	60600
F2	5040	52400	62750	65250
DURALUMIN TUBING				
G1	880	1615	21800	40100
G2	855	1220	21500	30600
H1	1400	2310	18700	30850
H2	1450	2455	19500	33000
I1	1700	2375	15600	21800
I2	1690	2420	16000	22900
J1	2500	3000	18050	21550
J2	2500	2950	19450	22950
K1	3250	4600	18200	25750
K2	3200	4550	17250	24550

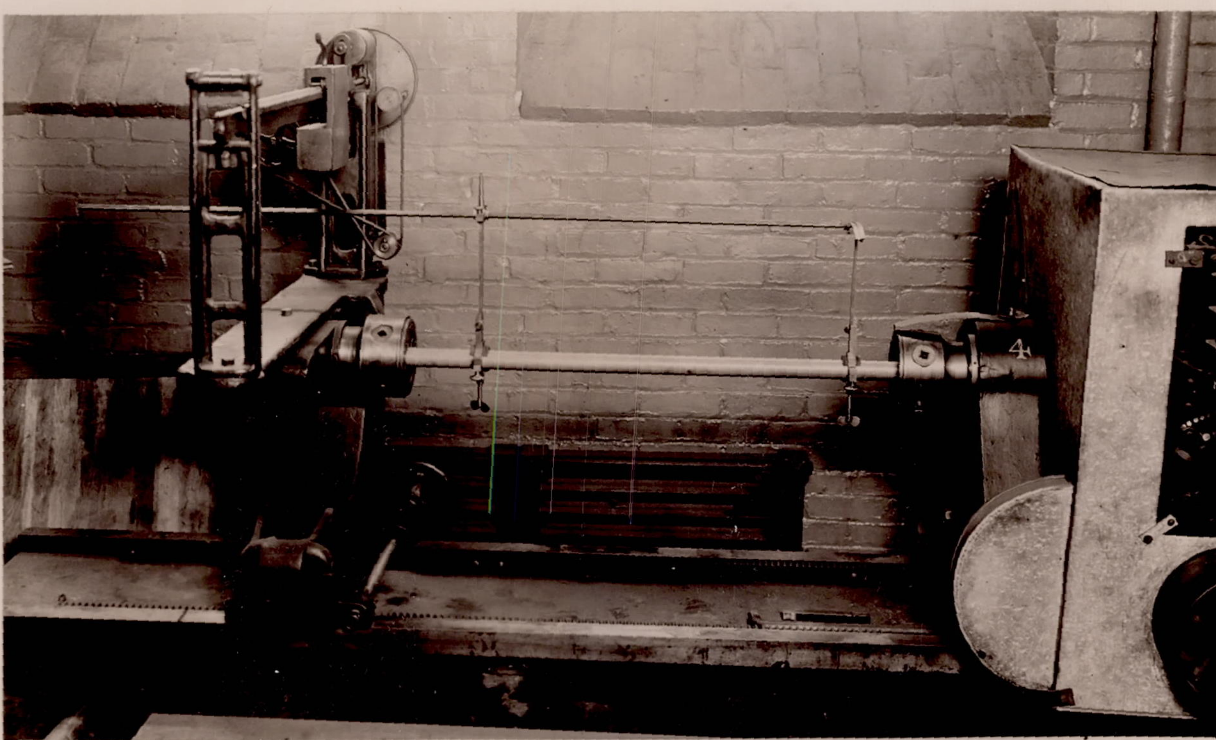

Fig.1.

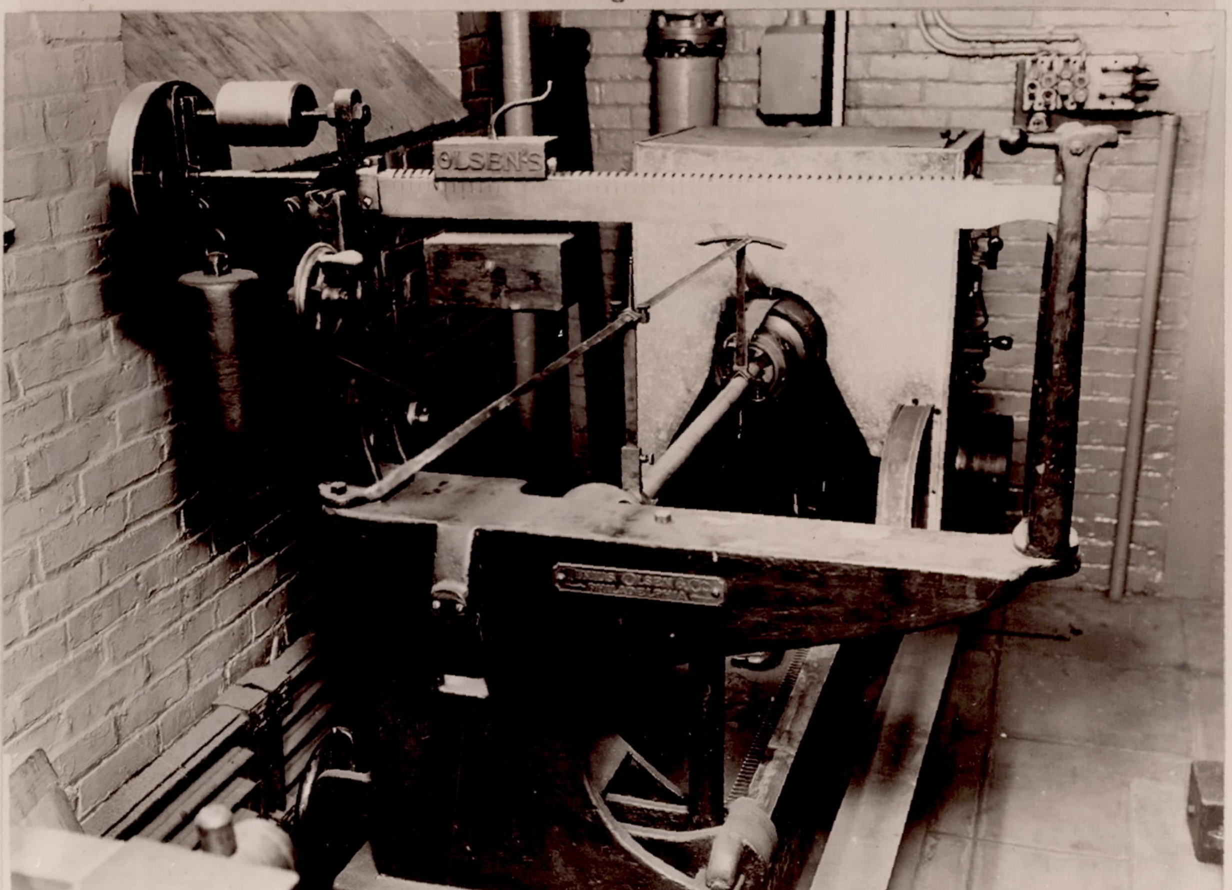

Fig.2. Set-up for test at Drexel Institute.

N.A.C.A.
11425 A.S.

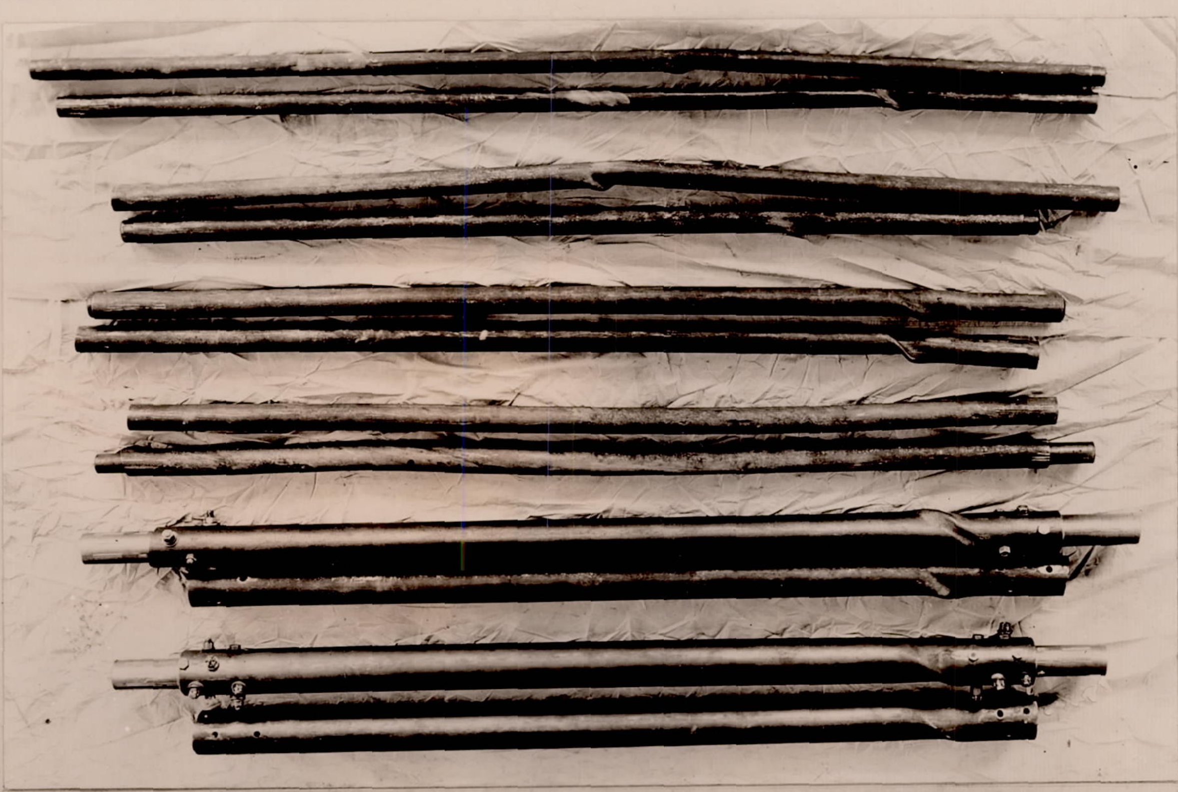

Fig.3. Torsion test on 2330 steel tubing.

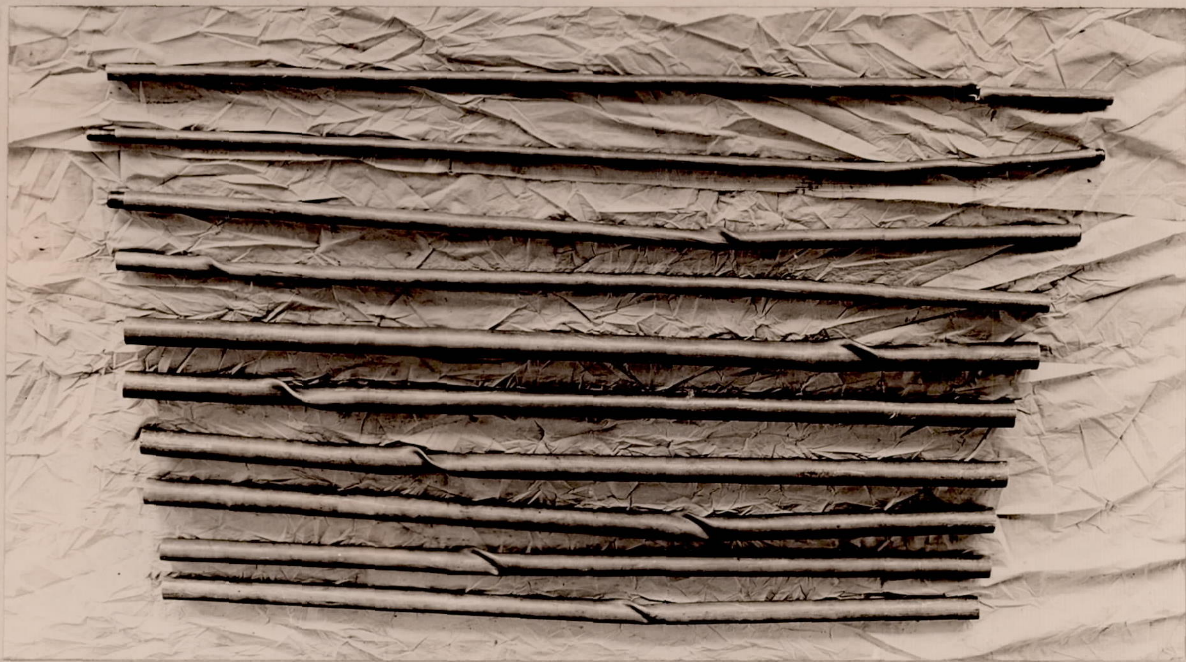

Fig.4. Torsion test on duralumin tubing.

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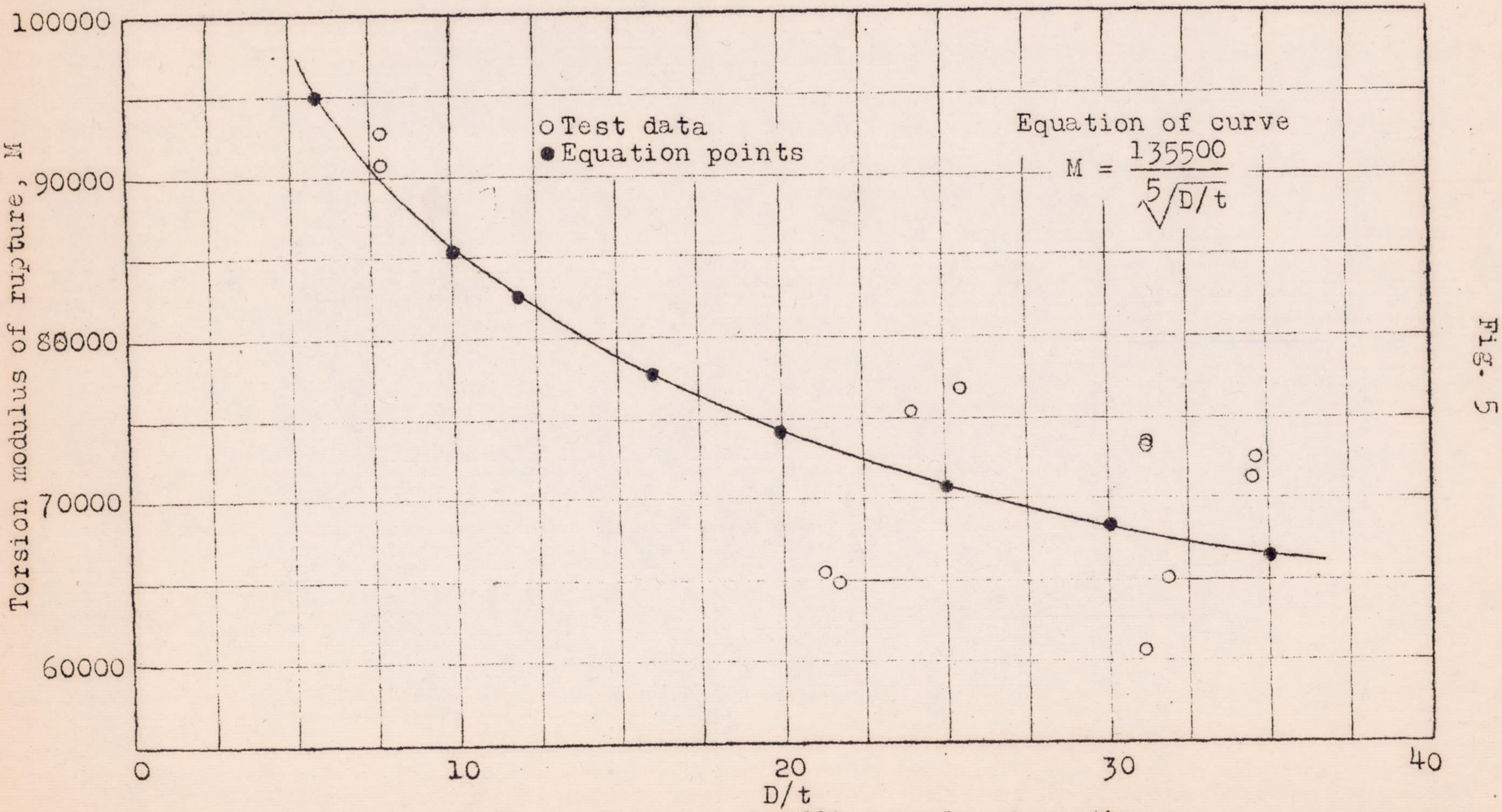


Fig. 5 2330 steel tubing 125000 tensile strength

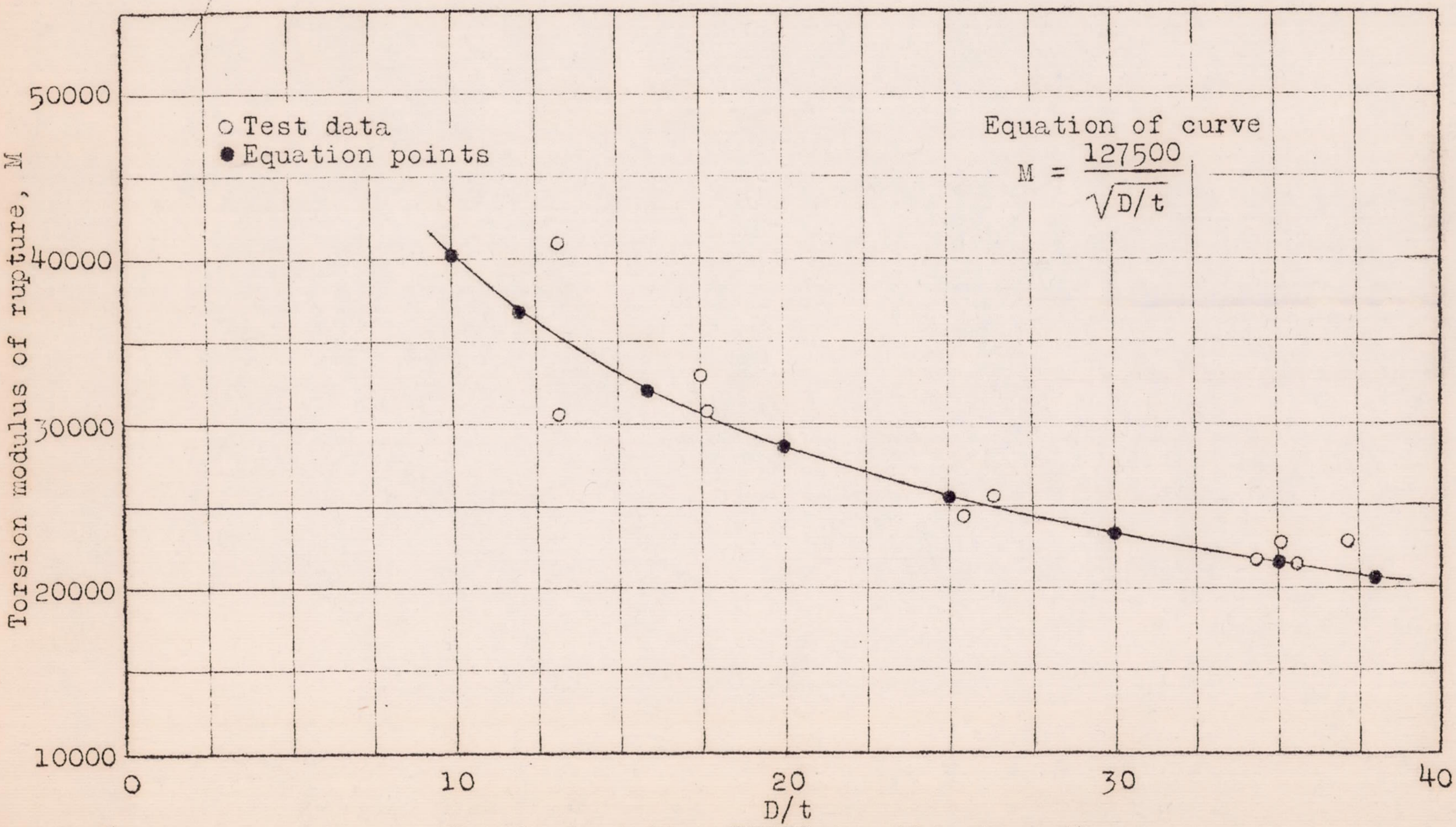


Fig. 6 Duralumin tubing 55000 tensile strength

Fig. 6

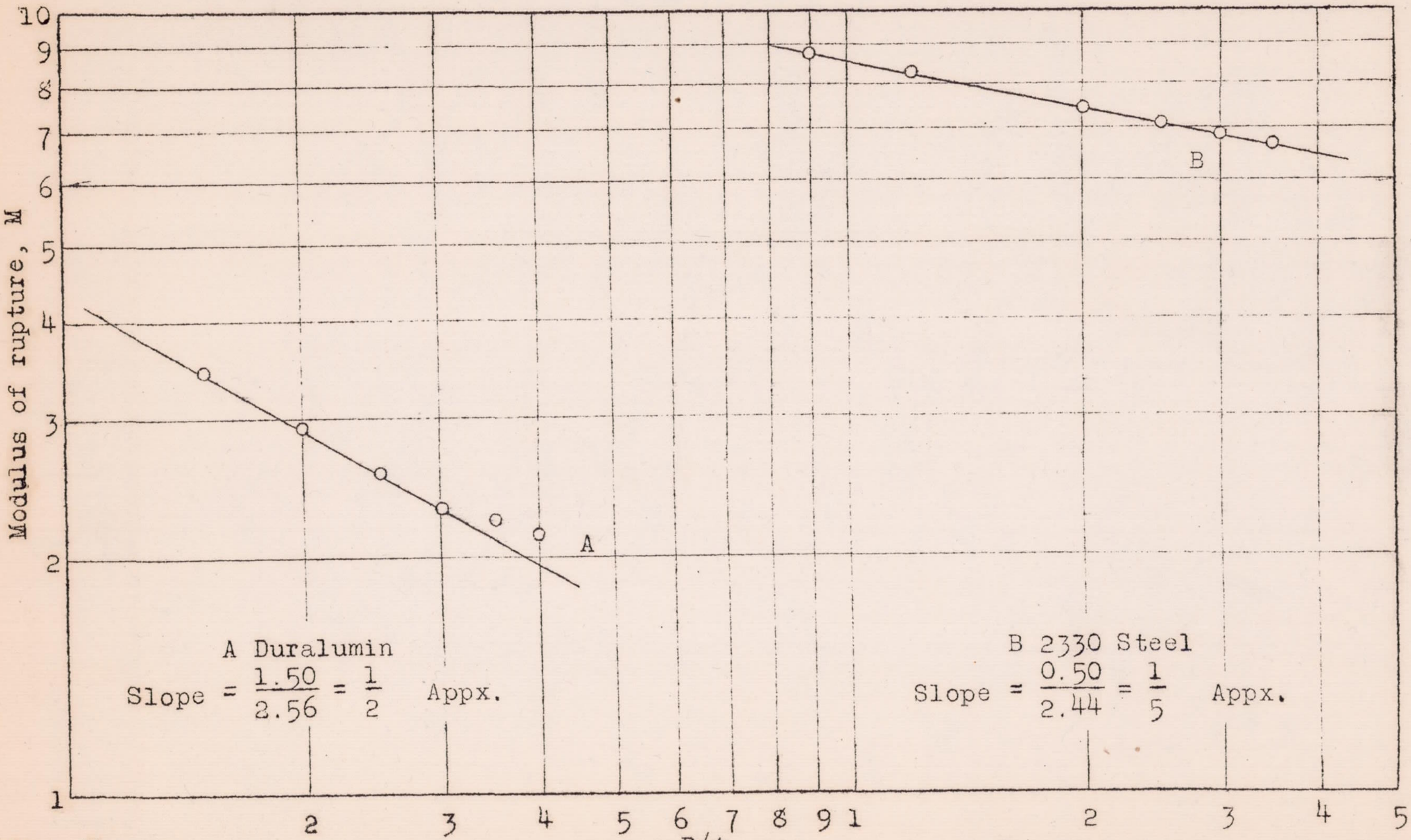

Modulus of rupture, M
D/t
A
B
A Duralumin
Slope = 1.50/2.56 = 1/2 Appx.
B 2330 Steel
Slope = 0.50/2.44 = 1/5 Appx.

Fig. 7

Fig. 7

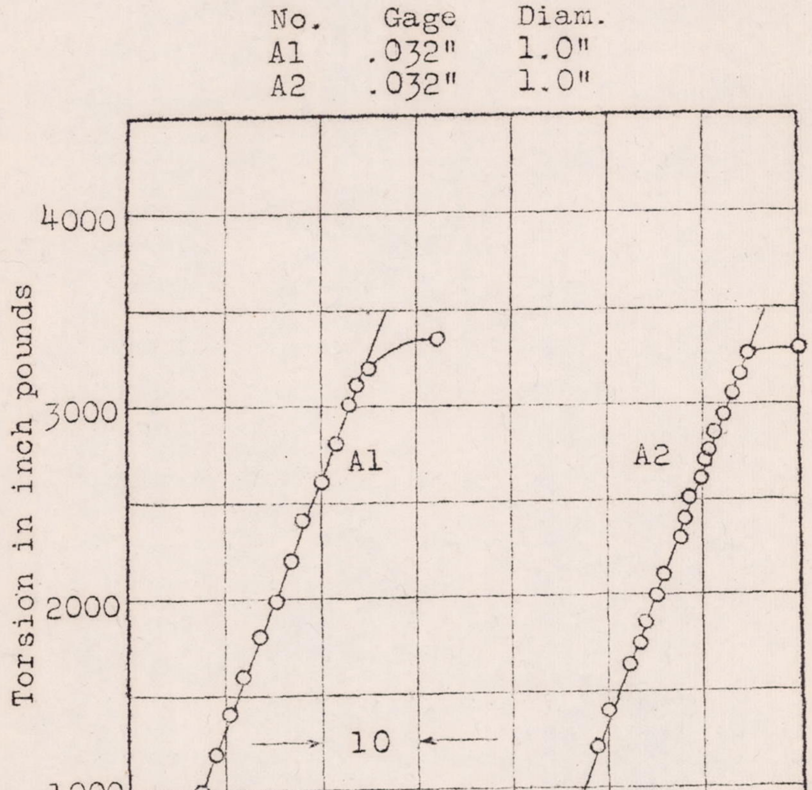


Fig. 8 Alloy steel tubing

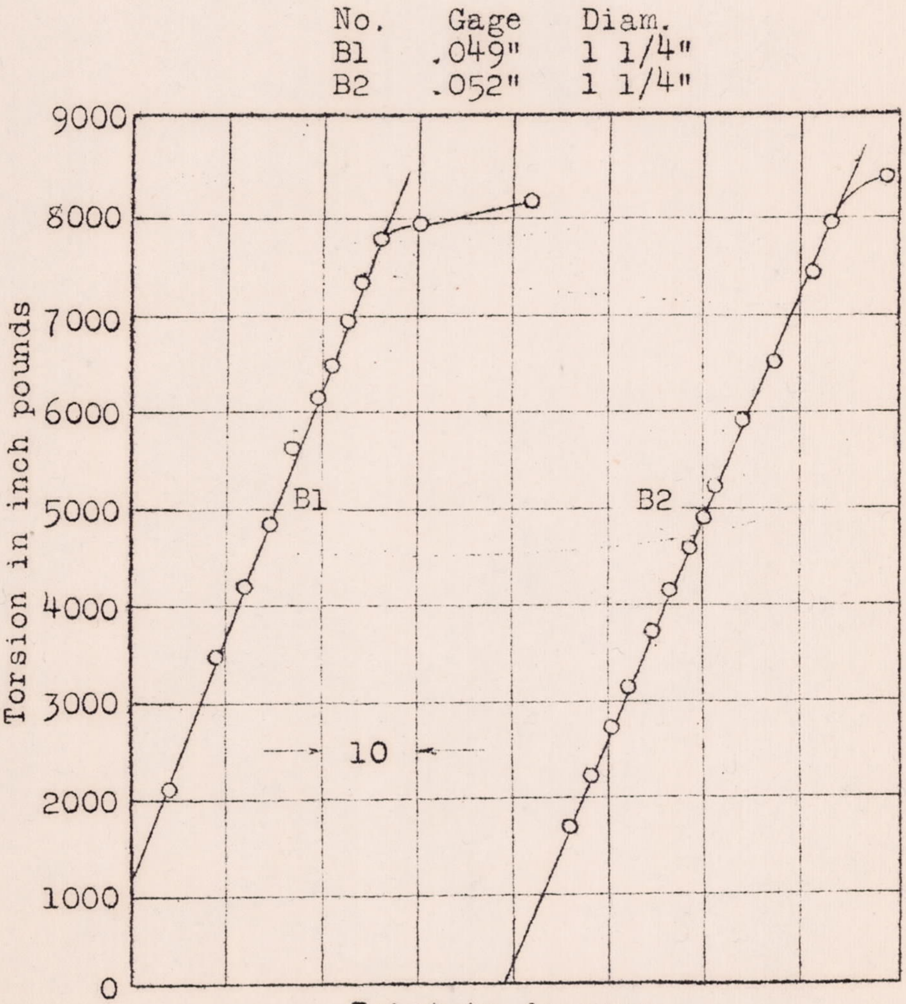


Fig. 9 Alloy steel tubing

Fig. 10

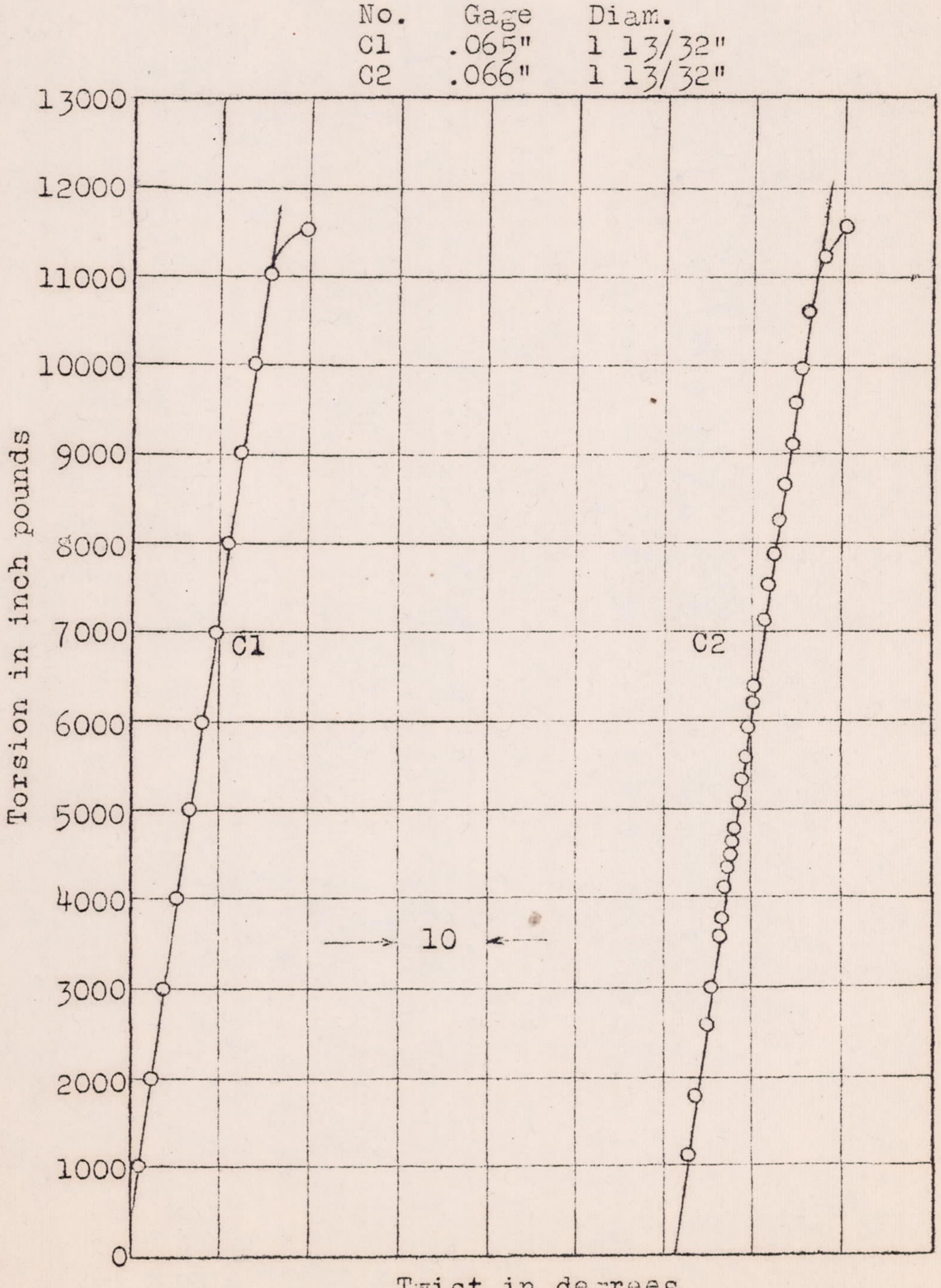


Fig. 10 Alloy steel tubing

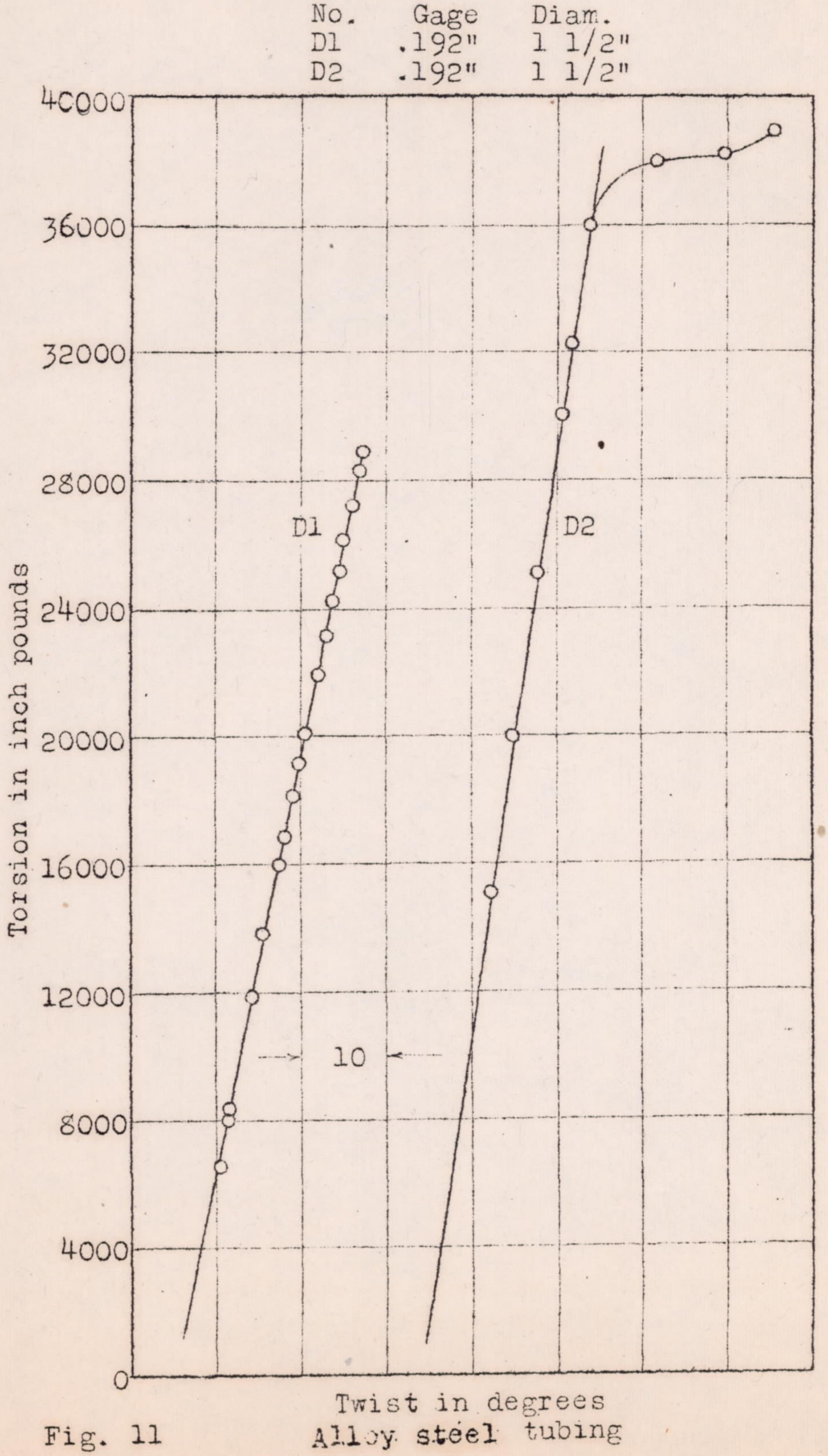
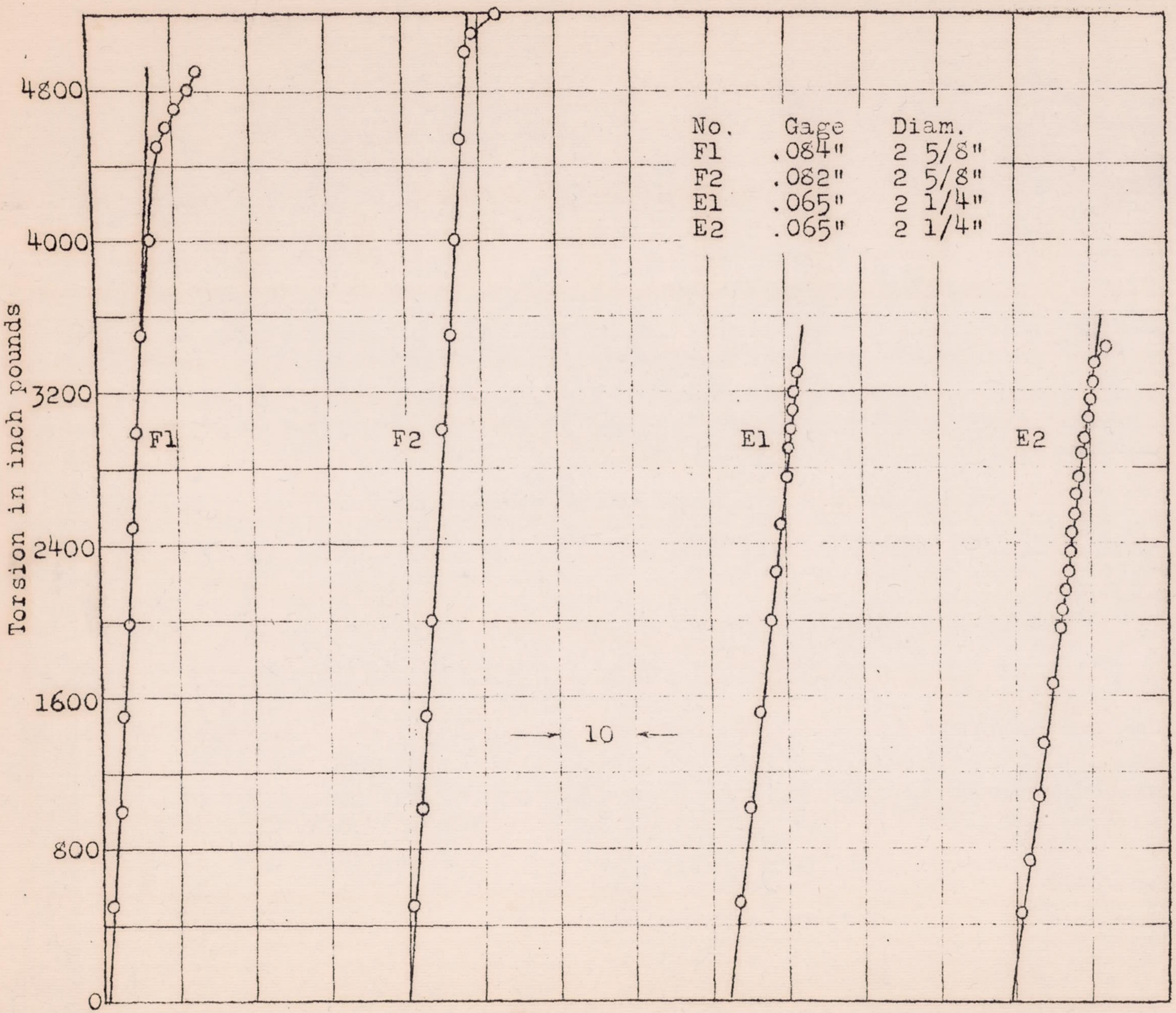


Fig. 11 Alloy steel tubing



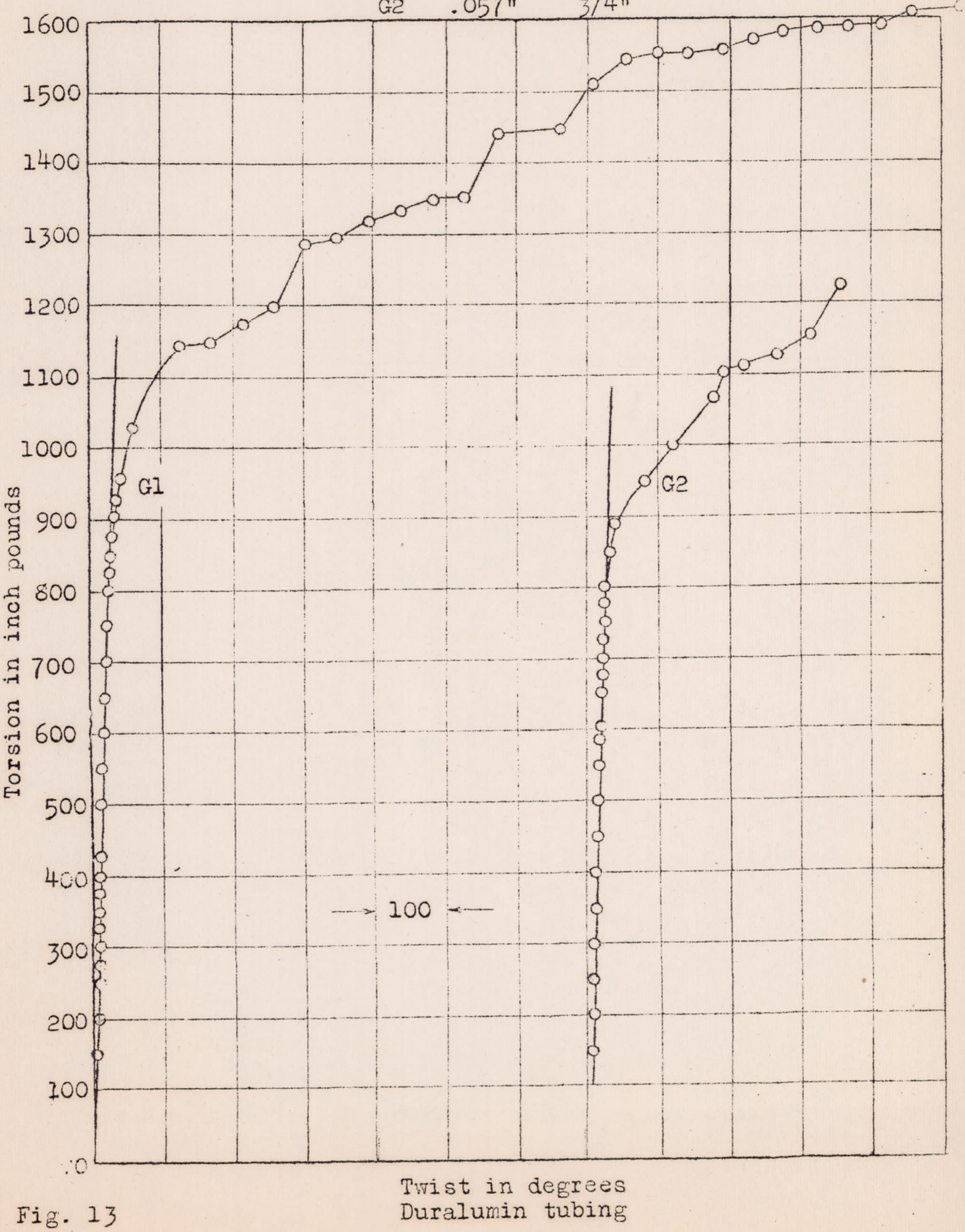
Twist in degrees
Alloy steel tubing

Fig. 12

Fig. 12

Fig. 13

No.	Gage	Diam.
G1	.057"	3/4"
G2	.057"	3/4"



Twist in degrees
Duralumin tubing

Fig. 13

No.	Gage	Diam.
H1	.057"	1.0"
H2	.057"	1.0"
I1	.040"	1 3/8"
I2	.039"	1 3/8"

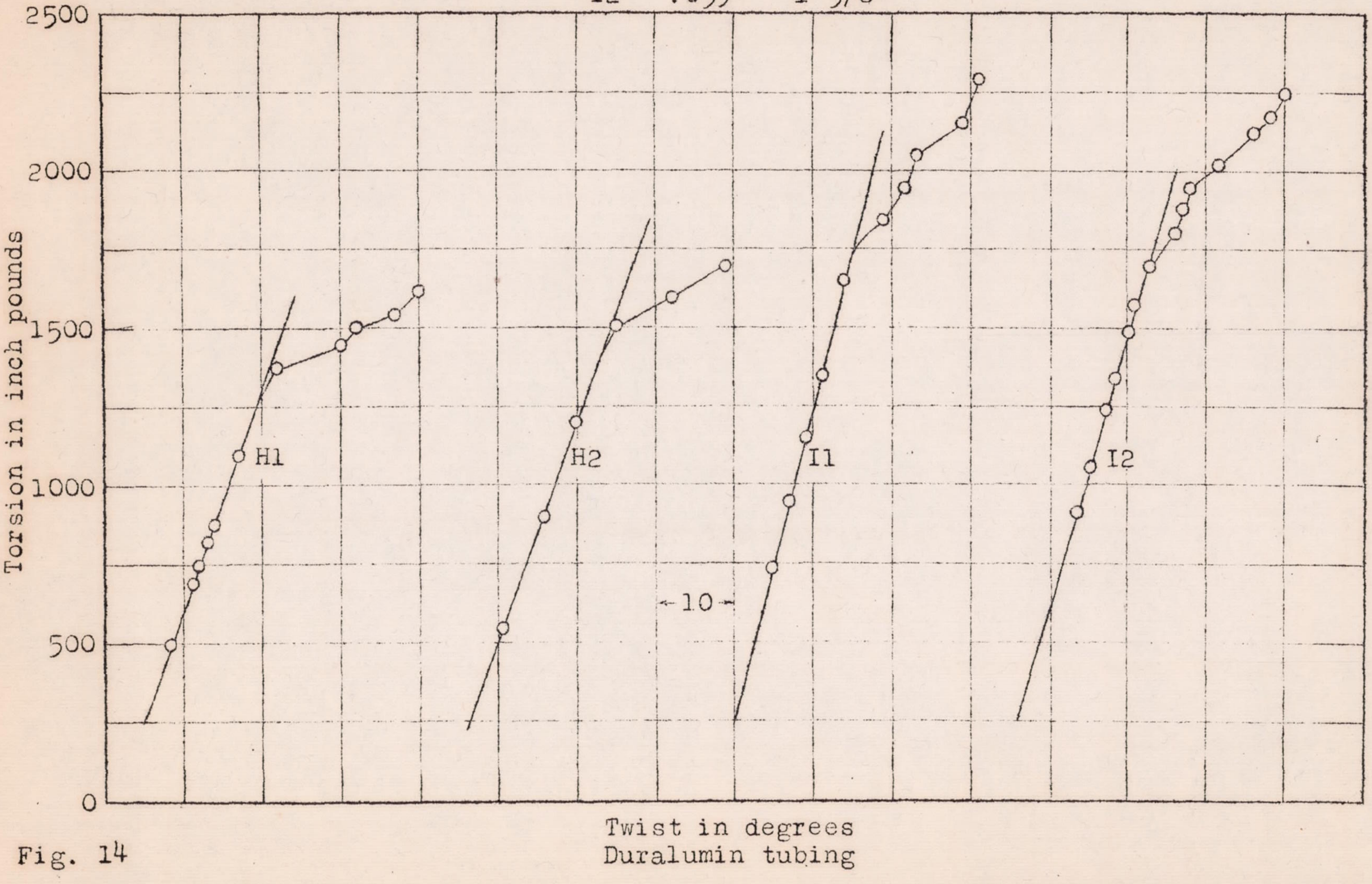
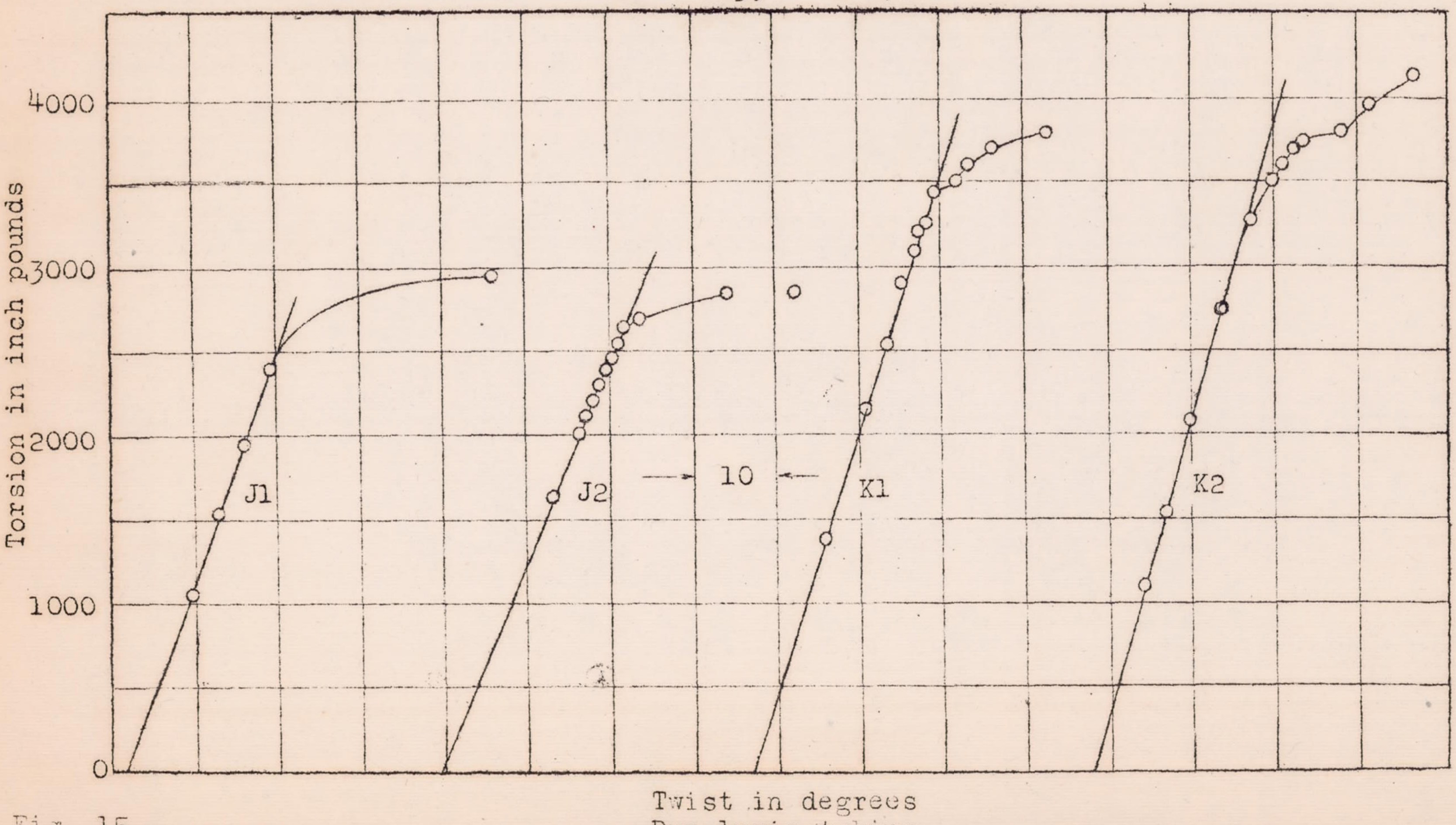


Fig. 14

Fig. 14

No.	Gage	Diam.
J1	.042"	1 1/2"
J2	.040"	1 1/2"
K1	.057"	1 1/2"
K2	.059"	1 1/2"



Duralumin tubing

Fig. 15

Fig. 15