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TORSIONAL MODULUS OF RUPTURE OF THICK-WALLED MAGNESIUM ALLOY FS-1 TUBING

BY

DELBERT R. COX

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE, PHYSICS MAJOR

Rolla, Missouri

1951

Approved by - Harold Q Fuller
Professor of Physics

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ACKNOWLEDGMENT

The writer wishes to express his appreciation of the sincere interest and encouragement of Dr. Harold Q Fuller, Chairman of the Physics Department, Missouri School of Mines and Metallurgy, Rolla, Missouri.

The Dow Chemical Company of Midland, Michigan, generously supplied the material tested in this investigation with the final authorization of Dr. J. C. McDonald, Director of the Metallurgical Laboratories. They also supplied information on the properties of magnesium alloys in the form of company bulletins. This assistance is gratefully acknowledged.

The Air Material Command of the United States Air Force extended assistance in obtaining references for the work and offered suggestions for specimen dimensions. They are also supplying more test specimens for the continued investigation on this subject.

The writer also wishes to acknowledge the assistance of Dr. A. J. Miles and the Mechanical Engineering Department of the Missouri School of Mines and Metallurgy, for the machining that was necessary in the preparation of the specimens for testing.

Messrs. Richard H. Duncan, William C. Chamberlain, and Leland S. Hofer extended much needed assistance in the actual testing and machining operations.

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TABLE I

SYMBOLS USED IN PAPER

D -------Outside diameter of tubing in inches

G -------Modulus of rigidity

J -------Polar moment of inertia

K -------Distance from center of twist to scale on troptometer

L -------Length of tubing in inches

r -------Radius of tubing

r_m ------Radius of arithmetic mean fibre of tubing

r_i ------Radius of hole in tubing

S -------Shearing stress in pounds per square inch

S_R ------Torsional modulus of rupture in P.S.I.

$S_{t\text{-}ult.}$--Ultimate tensile strength in P.S.I.

T -------Torque in inch pounds

t -------Wall thickness of tubing in inches

ε -------Inches of twist as read from troptometer scale

θ-------Angle of twist in degrees for entire specimen

ϕ-------Angle of twist in radians of troptometer gage length

τ-------Shear stress at median fibre in P.S.I.

INTRODUCTION

Magnesium is taking a more prominent position in the structure of aircraft, and because of this, it is important that the mechanical properties of the material be understood more fully. In the high speeds of today, the tendency is toward the use of thick-walled tubing instead of the thin-walled tubing with stiffening structures. For this reason, it is of interest to note the characteristics of thick-walled tubing when subjected to torsion.

This thesis was first suggested by a circular letter on proposed thesis titles from the Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio. When interest was expressed in the thesis subject on modulus of rupture, the Air Force responded by suggesting the investigation of the torsional properties of magnesium alloys in low D/t ratios. Since there is very little published in the periodicals on the subject, a copy of a Munitions Board publication was forwarded, which publication was helpful as a reference.(1)

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(1) Anonymous. Strength of Metal Aircraft Elements, ANC-5a. Munitions Board Aircraft Committee. May 1949. p. 106.

On further correspondence, the Air Force was of assistance in obtaining a classified bulletin from the National Bureau of Standards,(2) and also information was forthcoming on the size of the specimens that could be used. It was suggested that the material tested be either Dow Chemical Company's O-1 HTA or FS-1 alloy.

The Dow Chemical Company was then contacted and generously furnished the material for the tests, as well as data on the mechanical properties of magnesium alloys in the form of company bulletins.(3) (4)

In this paper, the torsional modulus of rupture is calculated by the well known torsion formula

$$S = \frac{Tr}{J} \qquad (1)$$

assuming elastic action all the way to failure. This is the normal manner for calculating modulus of rupture. Also, the stress at the mean fibre is calculated from this equation by letting r be the radius of the mean fibre (r_m).

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(2) Anonymous. Revision of Figure 5-9 ANC-5 "Torsional Modulus of Rupture of Aluminum Alloy Round Tubing". National Bureau of Standards. Report 65173-1. April 11, 1945.

(3) Eastman, E. J., McDonald, J. C., Moore, A. A. The Relation of Stress to Strain in Magnesium Base Alloys. Dow Chemical Company, Midland, Michigan. 1944.

(4) Mathes, J. C. Magnesium Design Consideration and Applications. Dow Chemical Company, Midland, Michigan, 1944.

REVIEW OF LITERATURE

There is little reference to thick-walled tubing in the published material because until recently most of the tubing used in actual practice was thin-walled. There is an abundance of material for the thin-walled investigations. The assumption that has been made in most of the literature is that the torsional modulus of rupture is constant over the range of diameter to thickness ratios of two to ten.

The writer was unable to find any reference of previous work with magnesium in torsion other than data curve shown in the Munitions Board publication, ANC-5a;(5) however, he feels that the inclusion of some of the results obtained from tests on other materials are of interest, even though they are not within the range of D/t ratios intended to be investigated.

In 1924, N. S. Otey performed a series of tests(6) on nickel steels and duraluminum alloys, investigating the variation of torsional modulus of rupture with D/t ratios.

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(5) Anonymous. Strength of Metal Aircraft Elements, ANC-5a. Munitions Board Aircraft Committee. p. 106. May 1949.

(6) Otey, N. S. Torsional Strength of Nickel Steel and Duraluminum Tubing as Affected by the Ratio of Diameter to Gage Thickness. National Advisory Committee for Aeronautics, Technical Note 189. April 1924.

The results of his investigations yielded the curves shown in Figures 1 and 2, and also, he used the empirical formulae

$$S_R = \frac{135,500}{\sqrt[5]{\frac{D}{t}}} \tag{2}$$

for nickel steel 2330 with an ultimate tensile strength of 125,000 p.s.i. and

$$S_R = \frac{127,500}{\sqrt{\frac{D}{t}}} \tag{3}$$

for duraluminum having an ultimate tensile strength of 55,000 p.s.i.

It should be noted that these are empirical formulae and apply only to the material tested, as are all of the empirically derived equations found in the literature.

The Munitions Board publication included the following empirical curve shown in Figure 3 for the variation of torsional modulus of rupture with D/t ratios for magnesium tubing.

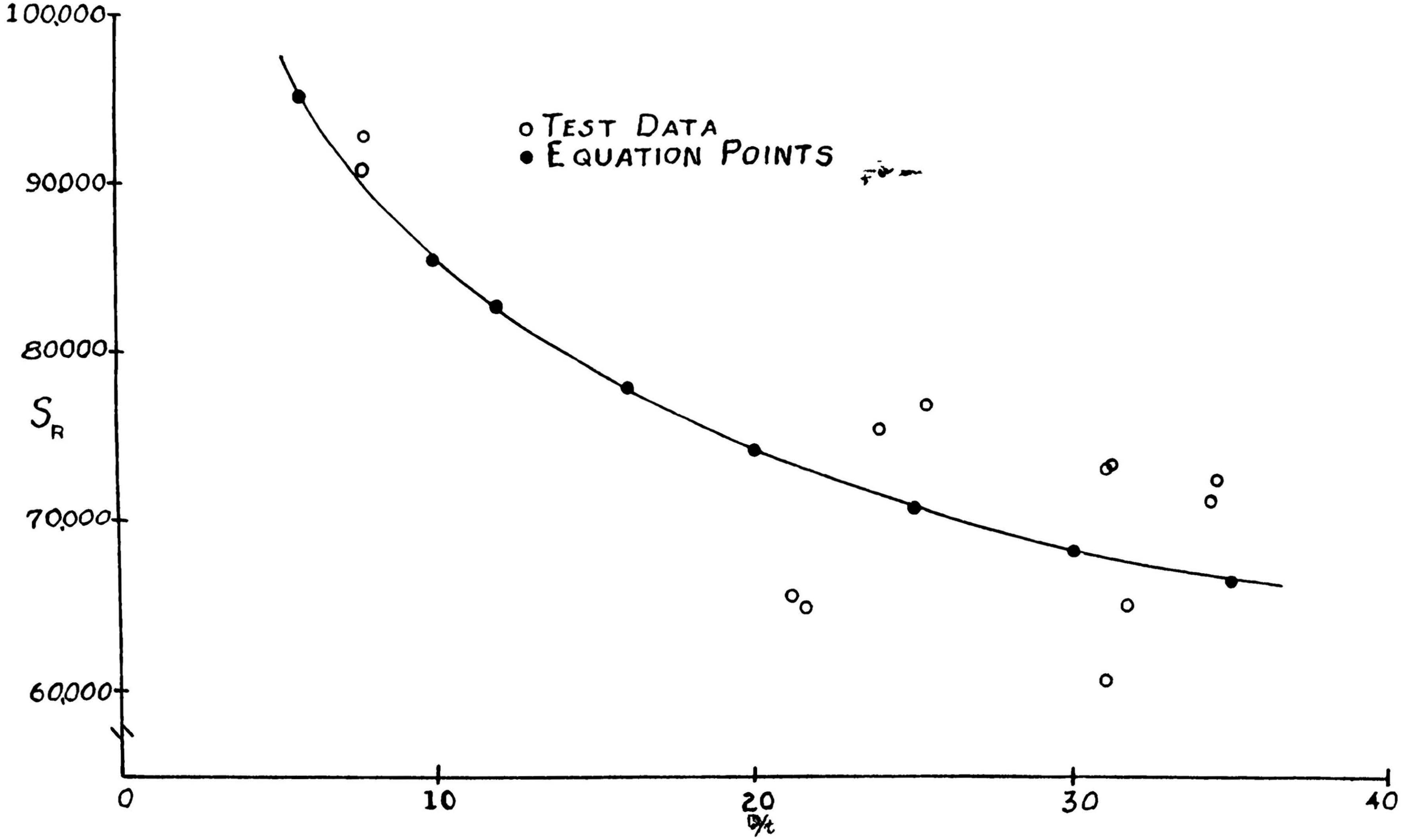

FIGURE 1 S_R VS. D/t 2330 STEEL N.A.C.A. T.N. 189

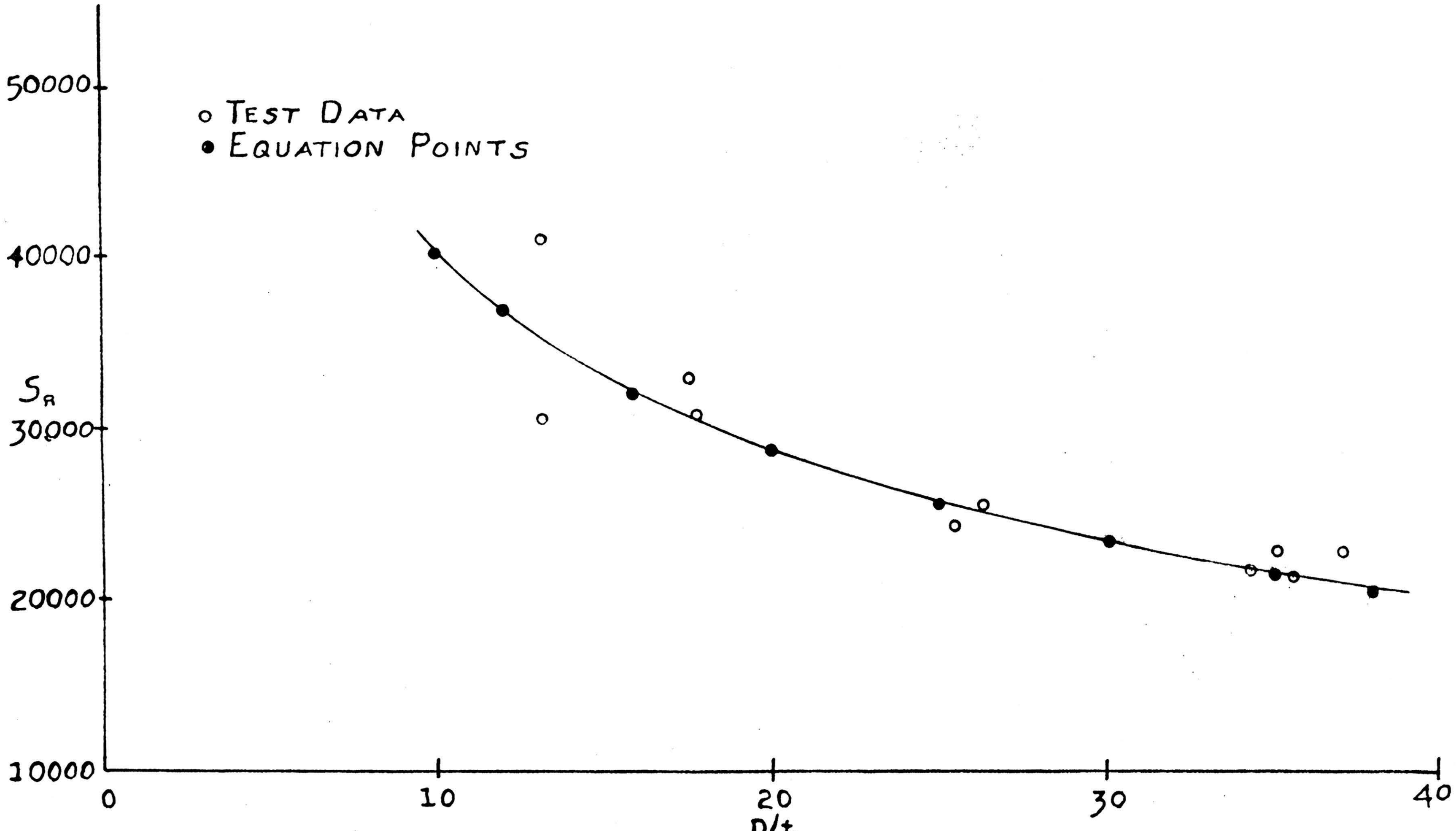

FIGURE 2. S_R VS. D/t DURALUMIN N.A.C.A. T.N.189

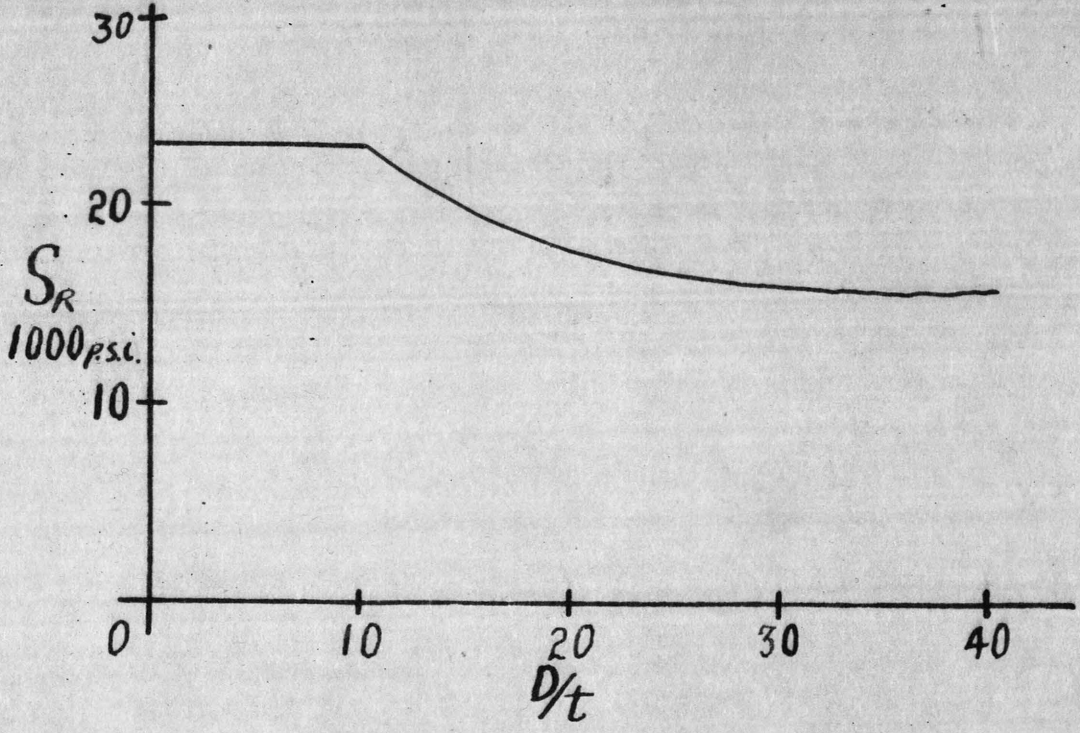

Figure 3. S_R vs. D/t Magnesium -- ANC-5a

It seemed illogical that there should be such an abrupt change in the variation of modulus of rupture in the region of D/t ratios of ten. If the material is homogeneous, there should be a smooth curve showing the variation of modulus of rupture from the solid bar to high D/t ratios. It is assumed that this is an empirical curve with the modulus of rupture taken as about 64% of the ultimate tensile strength in D/t ratios of less than ten.

R. L. Moore and Marshall Holt of the National Advisory Committee for Aeronautics performed some tests on 61S-T aluminum tubing.(7) They found that the moduli of failure for the test specimens of D/t ratios greater than ten, where the plastic buckling occurred, followed the empirical relation

$$S_R = \frac{S_{t-ult.}}{2} \left(3.7\frac{t}{D} + 0.93\right) \qquad (4)$$

and of course, this equation holds for only this alloy and differs from the empirical equations derived by other men for other aluminum alloys.

They made the assumption that the stress was uniformly distributed throughout the wall of the material.

The assumption that the shear stress is uniformly distributed across the wall gives an error of 33% for D/t = 2, but this error is decreased to only 5% for a D/t of 20. Using equation 1, the modulus of rupture for this alloy is about 60,000 pounds per square inch for a D/t ratio of two, but assuming uniform shear, the modulus of rupture is about 42,000 p.s.i., while at a D/t ratio of 20, equation 1 gives 44,000, and the uniform stress theory gives 41,000.

They found that the limit for plastic buckling for the 61S-T alloy was around a D/t = 10. Of course, there was no strict dividing line, but for ratios of D/t less than ten, most specimens failed in plastic shear, while those greater failed in plastic buckling, and at even higher ratios (in

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(7) Moore, R. L. and Holt, Marshall. Beam and Torsion Tests of Aluminum Alloy 61S-T Tubing. National Advisory Committee for Aeronautics, Technical Note 867. October 1942.

the region of D/t = 60) elastic buckling due to instability occurred.

R. L. Moore continued the investigation and has a later paper published.(8) In this article, he also assumed that the shear is constant across the wall. However, he also included a curve showing the extreme fibre stress as calculated from the well known torsion formula (equation 1).

For the assumption of uniform shear across the section, Moore used the formula

$$S = \frac{3T}{2\pi(r^3 - r_1^3)} \qquad (5)$$

He points out that for D/t ratios of greater than 10 that the stress calculated by equation 5 is, for all factual purposes, the same as the mean fibre stresses as would be calculated from equation 4 letting r be the radius of the mean fibre.

In Figure 4 is shown the comparative curves for the assumptions that were made as well as the stress calculated from equation 1, assuming elastic action for 17S-T Aluminum.

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(8) Moore, R. L. Torsional Strength of Aluminum--Alloy Tubing. National Advisory Committee for Aeronautics, Technical Note 879. January 1943.

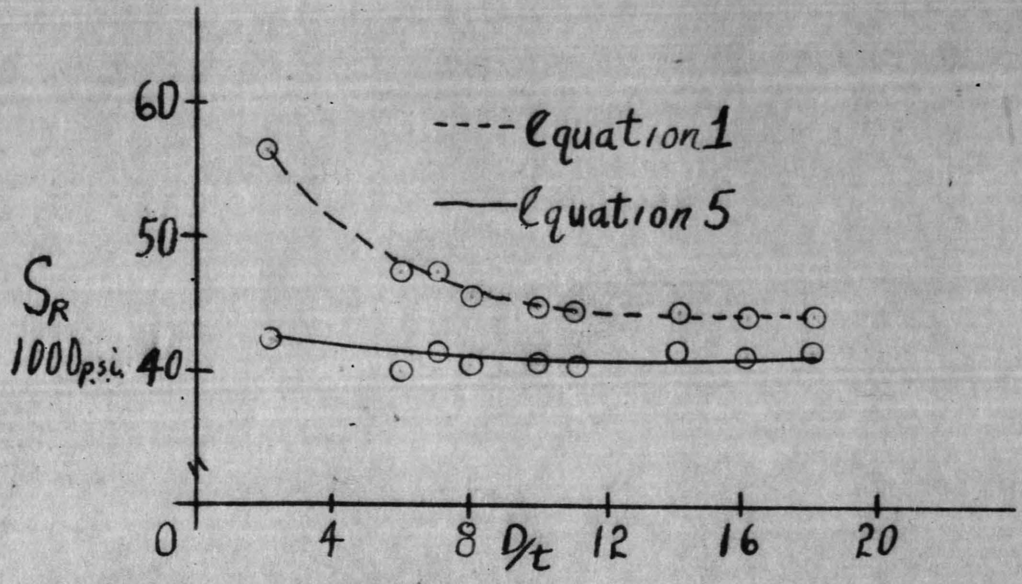

Figure 4. S_R vs. D/t 17S-T Aluminum, N.A.C.A., T.N. 879

Mr. Moore suggests that the assumption of equal shear across the section is more consistent; however, it seems that this would only be valid if the material were actually thin-walled, since the strain is proportional to the distance from the center of twist, and assuming elastic action, stress and strain are proportional.

W. H. Bachle (9) in a thesis at Texas A. & M. College performed tests on 24S-T Aluminum Alloy. He tested thin-walled supported sections in torsion to get a stress-strain curve in pure shear for the material. Using the data from these tests, he derived an expression for the variation of

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(9) Bachle, W. H. Torsional Modulus of Rupture of Thick-Walled Tubing. Thesis, Agricultural and Mechanical College of Texas, College Station, Texas. 1950.

the shear stress across the wall of the tube and from that derived an expression for the maximum torque that the specimen could carry. This expression is:

$$T = \frac{2\pi r_i^3 F_{su}}{3.163}\left[1 - \left(\frac{r_i}{r}\right)^{3.163}\right] \qquad (6)$$

where: F_{su} = ultimate strength in shear from first tests.

The constant 3.163 is for the 24S-T alloy only and would change for any other material. He then used this expression to solve for a stress substituting the value of torque, which he derived from torsion tests, and solving for an F_{su}.

DISCUSSION

The material tested in this investigation was Dow Chemical Company's magnesium alloy FS-1. The mechanical properties of this material, as supplied by the Dow Chemical Company, are shown in table II.

TABLE II

MECHANICAL PROPERTIES
AS SUPPLIED BY DOW CHEMICAL COMPANY

Outer Diameter	Ultimate Tensile Strength (pounds per square inch)
3/4 inch	39,600
1 inch	40,000
1 3/4 inch	37,600
2 inch	39,500

The material was shipped in the form of extruded solid rods. This necessitated machining to obtain the test specimens that were needed. The material was first drilled to give the size of hole that was desired. In drilling the material, some difficulty was encountered in centering the holes. This obstacle was overcome by drilling from one end only and then placing the material in a lathe between centers and turning down the surface until a round tubing with the hole at the center was formed.

The machine used in testing the specimens is a Tinius-Olsen 60,000 inch pound capacity torsion machine with scale division of ten inch pounds. This machine is shown in Figure 5. The chucks are equipped with four jaws, which are numbered to facilitate centering.

Figure 5 also shows a test specimen with the troptometer attached. The troptometer is an instrument for measuring the inches of twist on a large radius and over a specified gage length. The actual angle of twist over this gage length is found by the expression

$$\phi = \frac{\varepsilon}{K} \qquad (7)$$

The inches of twist were read by means of a scale divided into hundredths of an inch. The troptometer gage length used in these tests was eight inches for the thick-walled specimens. The troptometer was read by means of a magnifying glass and a pointer.

The troptometer was not used on the thin-walled specimens because of the fact that the troptometer is held in position by pointed screws to tighten the arms to the specimen, and it was feared that due to the thin walls of the specimens they would be considerably weakened by the indentations. The moveable head of the torsion machine, however, has a scale divided into degrees of twist, and this scale was used for the thin-walled specimens as well

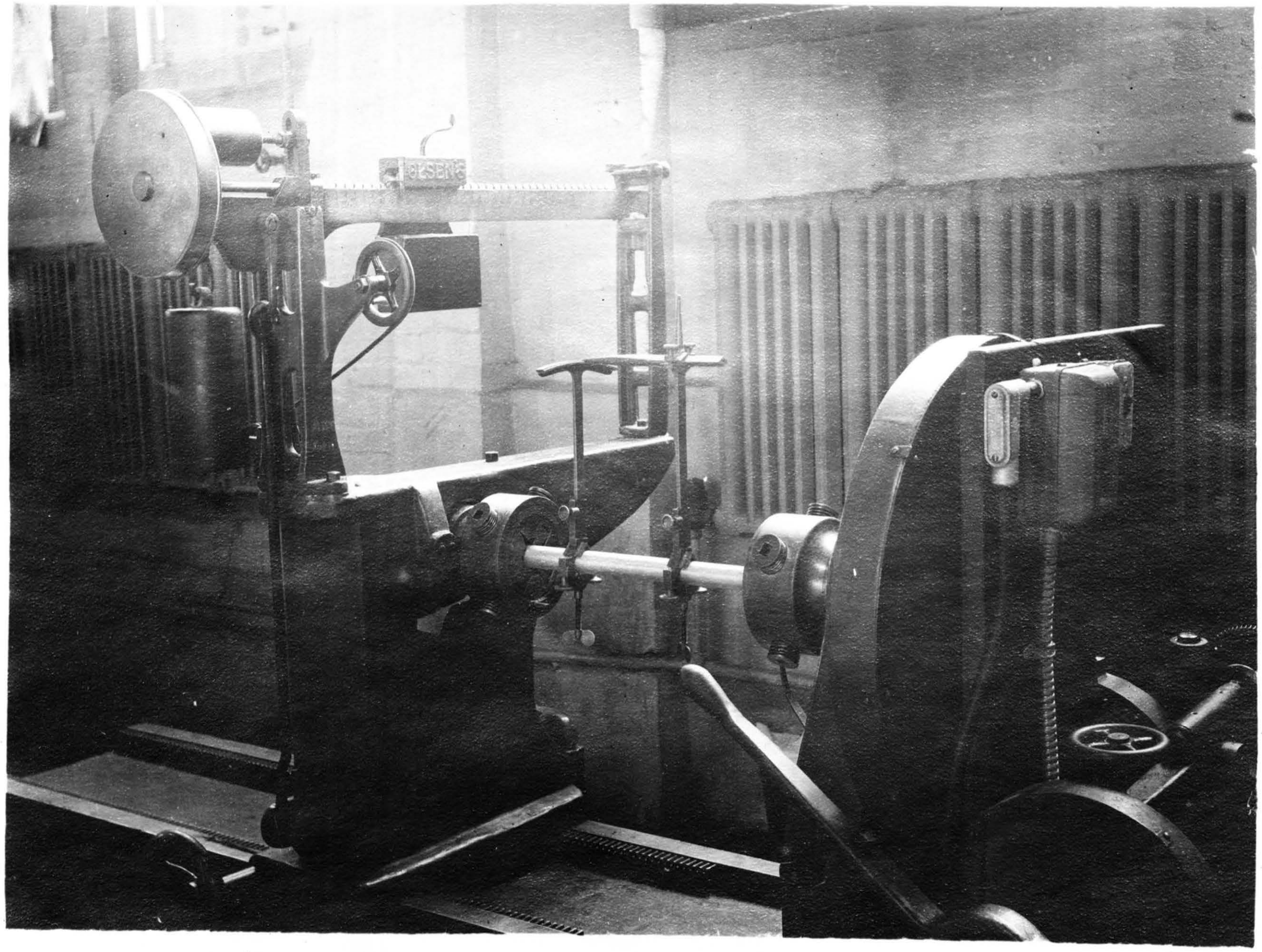

Figure 5

Tinius-Olsen Torsion Machine and Experimental Set-Up as for the thicker walled specimens after the material had yielded.

The torque was applied by continuous loading by a driving motor or hand crank. Continuous loading had to be maintained because of the tendency for the material to flow.

The troptometer scale and the degree of twist scale were read in increments of from 50 inch-pounds to 400 inch-pounds, depending upon the size of the test specimen, as the amount of twist is dependent upon size.

From the data taken in this manner, torque versus degree of twist curves were drawn for most of the test specimens. This was done in order to check the modulus of rigidity for comparison with the published values, and from this, the validity of the tests could be determined. The average value of the modulus of rigidity found by this manner is 2.38×10^6 pounds per square inch as compared to the published value of 2.4×10^6. This was considered to be a good degree of accuracy with the limitations of the equipment used, since much care must be taken in obtaining values to check the modulus.(10)

Curve 1 shows a typical torque vs. degree of twist curve for this material, and table III gives typical data as obtained in the tests.

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(10) Eastman, op. cit., pp. 3-4.

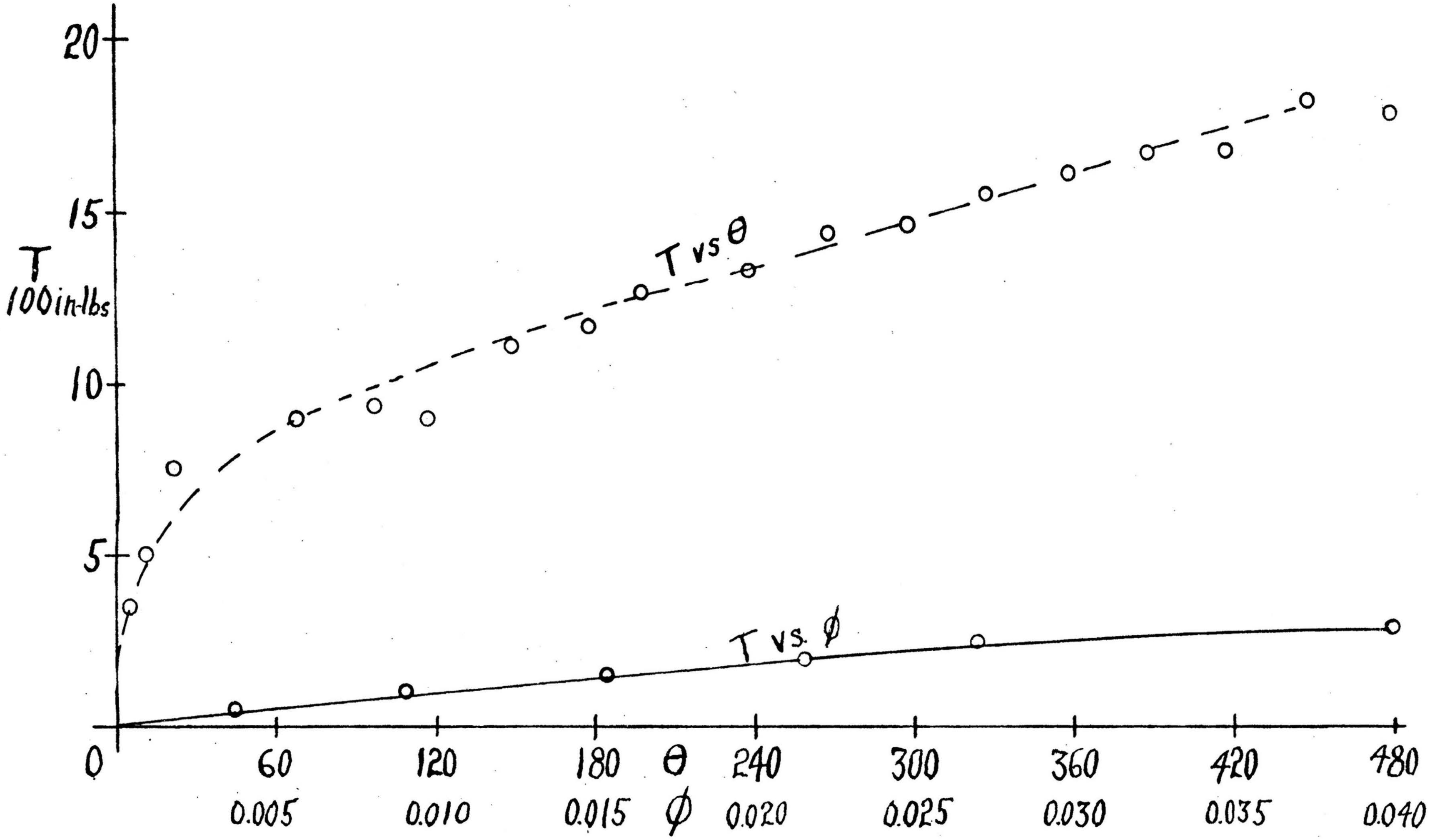
TABLE III

TYPICAL TEST DATA

Specimen No. 4	D = 0.739"
D/t = 4.06	L/D = 13
Troptometer Gage Length 8"	K = 11.1195"

Torque in. lbs.	ε inches	ϕ radians	θ degrees
0	0	0	(243°)
50	0.04	0.00359	
100	0.10	0.009	
150	0.17	0.0153	
200	0.24	0.0216	
250	0.30	0.027	
300	0.46	0.0414	
350	0.46	0.0414	5
400	0.59	0.053	
450	0.77	0.0691	
500	0.96	0.0873	10
550	1.13	0.103	
600	1.40	0.126	
650	1.65	0.148	
700	2.0	0.18	22½
750	2.54	0.223	
800	3.35	0.301	
850	4.71	0.429	
850	5.74	0.515	
860	5.79	0.52	
870	5.84	0.525	
870	5.9	0.53	
900*			67
930			97
900			117
1110			147
1170			177
1270			207
1330			237
1430			267
1470			297
1550			327
1610			357
1660			387
1670			417
1770			447
1790			477
1860			504-ult.

*Unreliable



CURVE 1 TYPICAL TORQUE TWIST CURVE

After the tests were run, the modulus of rupture was calculated from equation I, using the maximum torque that the specimen withstood and assuming elastic action all of the way to failure. These results are shown in table IV and shown graphically in curve 2. There is some scattering of the points, and since the material had different size rods, it was decided to plot the ratio of the modulus of rupture to ultimate tensile strength versus diameter to wall thickness ratios. This is shown in curve 3. As can be seen by comparing curves 2 and 3, dividing the modulus of rupture by the tensile strength does bring about a little better correlation of the points. The remaining scattering of points can be attributed to the variation in testing and the variation in the material.

The results indicate that the modulus of rupture is constant over D/t ratios up to the ratio of about 5 where plastic buckling occurs. Figure 6 shows the types of failure that occurred. The specimens standing were all of a D/t ratio of higher than 5, and the wavy appearance is due to the fact that the specimens failed in plastic buckling before rupture. The standing specimen on the far right has a D/t ratio of 23.6. The modulus of rupture calculated for this specimen was very low (8,520 p.s.i.). The type of failure shown there is the failure due to elastic instability, that is a buckling in compression before the shearing stress has become high enough for the material to fail in either plastic buckling or shear.

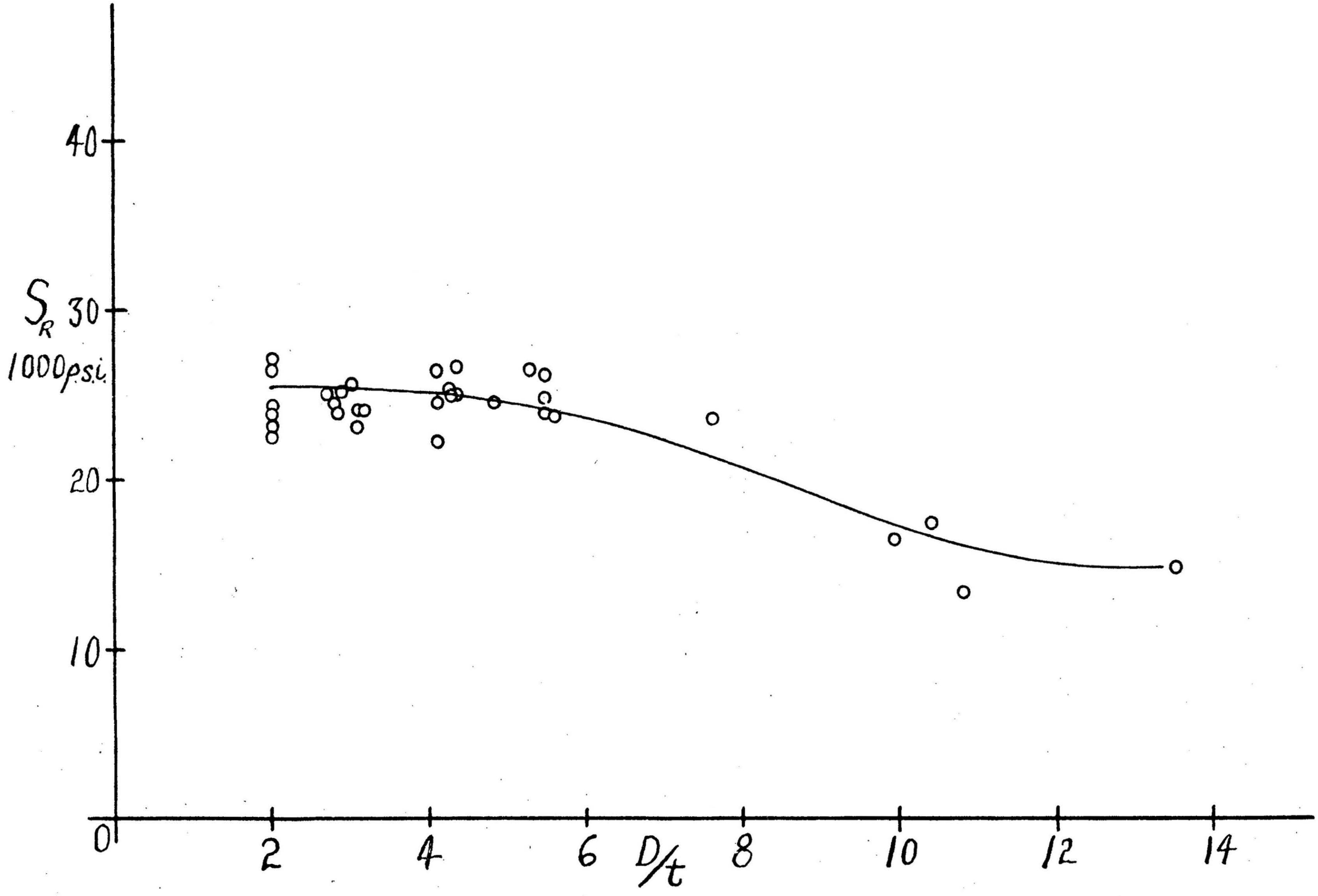
TABLE IV

DATA FROM TEST RESULTS

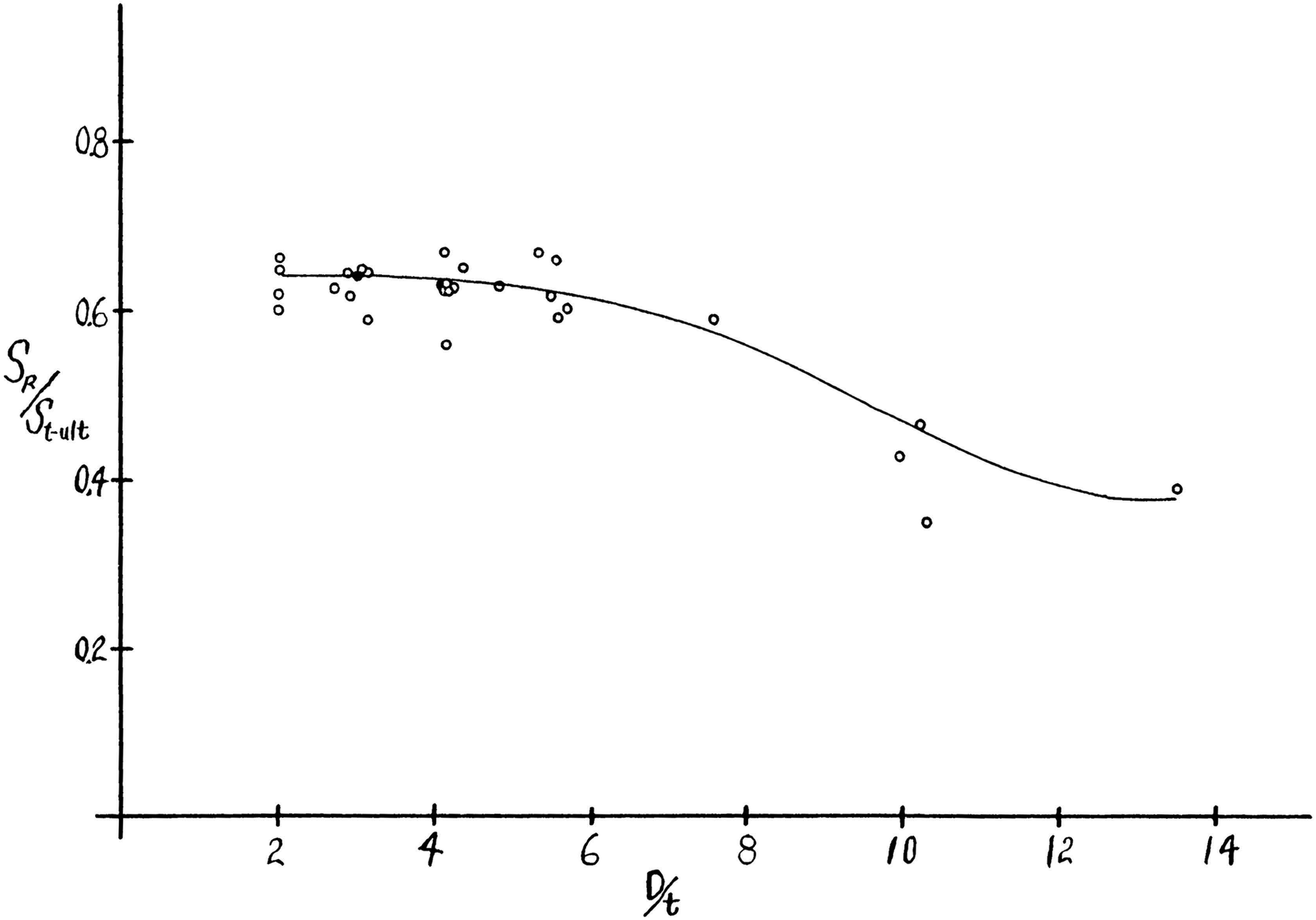
L/D = 13 Dow FS-L

Specimen Number	Diameter in inches	D/t	Torque in. lbs.	S_R p.s.i.	$\frac{S_R}{S_{t-ult.}}$
1	1.73	2	23,070	22,[illegible]50	0.605
8	0.981	2	4,480	23,950	0.60
11	0.727	2	1,830	24,200	0.614
12	1.794	2	30,270	26,600	0.673
49*	1.0	2	4,210	21,450	0.54
50*	1.75	2	24,540	23,300	0.62
51*	0.75	2	2,250	27,200	0.685
2	1.897	2.72	33,600	25,000	0.634
6	1.65	2.87	21,360	24,350	0.648
3	1.638	2.88	21,100	24,650	0.625
14	1.92	2.97	35,100	25,550	0.646
9	0.745	3.01	2,080	25,800	0.[illegible]53
16	1.714	3.13	23,410	24,220	0.645
24	0.686	3.15	1,450	23,350	0.590
15	1.672	3.19	21,900	24,200	0.645
10	0.743	4.04	2,010	26,550	0.67
4	0.739	4.06	1,860	22,[illegible]50	0.564
21	0.739	4.06	1,820	24,650	0.626
22	0.729	4.12	1,780	25,150	0.635
5	0.965	4.14	4,140	25,210	0.63
20	0.721	4.17	1,700	25,000	0.633
26	0.933	4.31	3,900	26,6[illegible]0	0.655
23	0.645	4.8	1,160	24,950	0.631
48	1.223	5.26	8,230	26,800	0.678
13	0.989	5.43	3,970	24,820	0.621
19	0.982	5.5	4,050	26,100	0.650
18	0.975	5.57	3,610	23,820	0.596
47	1.175	5.62	6,290	23,800	0.604
38	1.699	.57	16,060	23,610	0.598
39	1.097	9.97	2,510	16,400	0.437
42	1.095	10.2	2,630	17,500	0.466
41	1.09	10.3	1,940	13,250	0.354
40	1.036	13.5	1,560	14,800	0.394
43	0.975	23.6	470	8,520	0.277

*As Extruded



CURVE 2 S_R VS. D/t



CURVE 3 $S_R/S_{t\text{-}ult}$ VS D/t

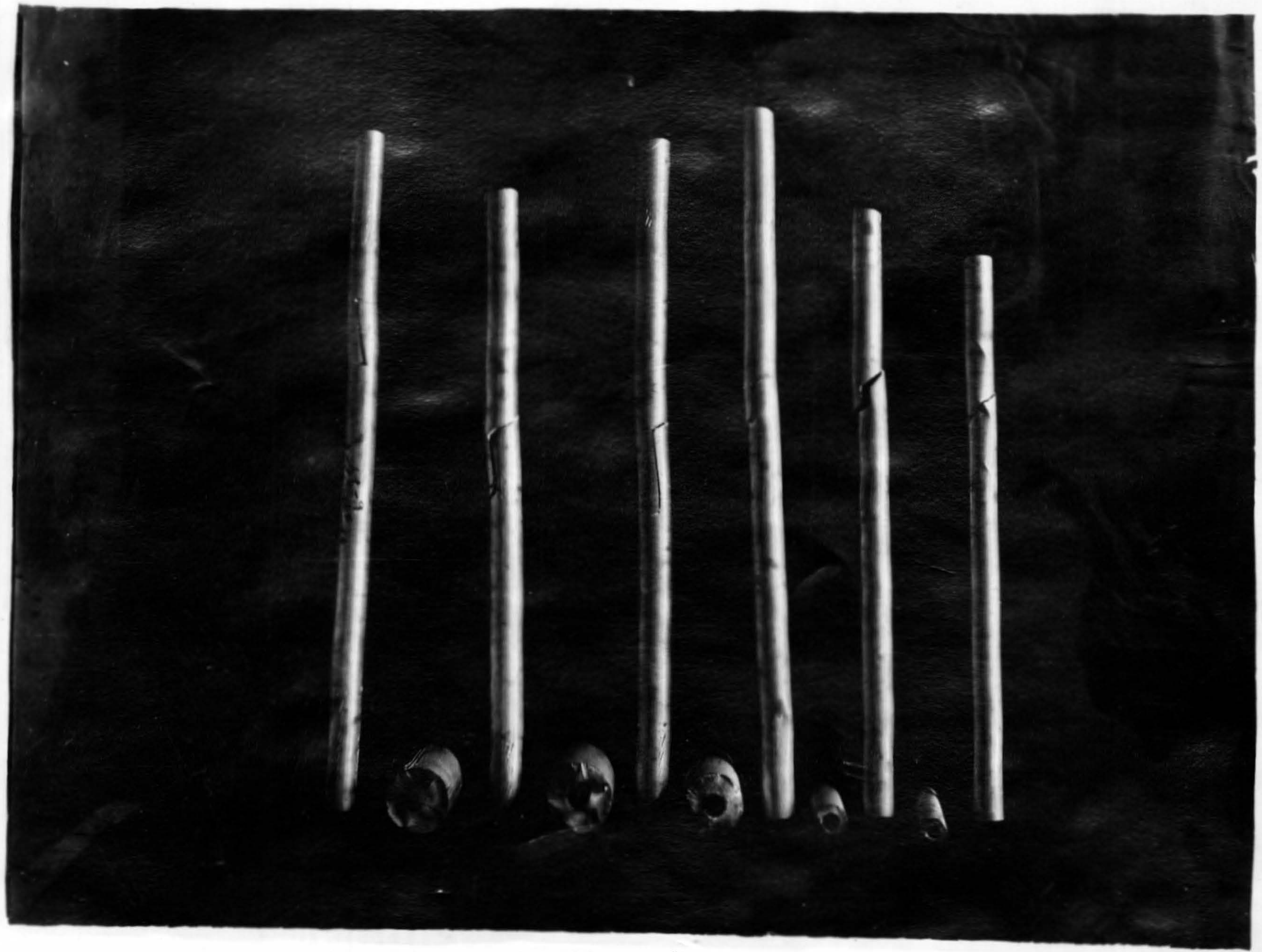


Figure 6

Types of Failure of Test Specimens

The horizontal specimens shown in Figure 6 are all of approximately the same D/t ratio (about 4). They show the type of failure that is due to pure shear.

In analyzing these types of failure, it occurred to the writer that probably a better indication of the action of the material could be obtained by plotting the arithmetic mean fibre stress versus the D/t ratios. Table V gives a list of the calculated values for this curve, and curve 4 is the plot of this data. The stress at the mean fibre was calculated by use of the equation

$$\tau = \frac{T_{max}\, r_m}{J} \tag{8}$$

Because of the variation of the ultimate tensile strength of the different size extrusions, curve 5 was plotted with the ratio mean fibre shear stress to ultimate tensile strength of the extrusion from which each specimen was machined versus the D/t ratio.

It can be seen from curve 4 and 5 that the shear stress on the mean fibre has a variation with respect to the D/t ratio that is quite indicative of the type of failure that will occur.

At first, the curve is constantly rising, showing an increased stress at the mean fibre as the D/t ratio τ increases and then levels off and begins decreasing, showing a decreased stress at the mean fibre with increasing D/t ratio.

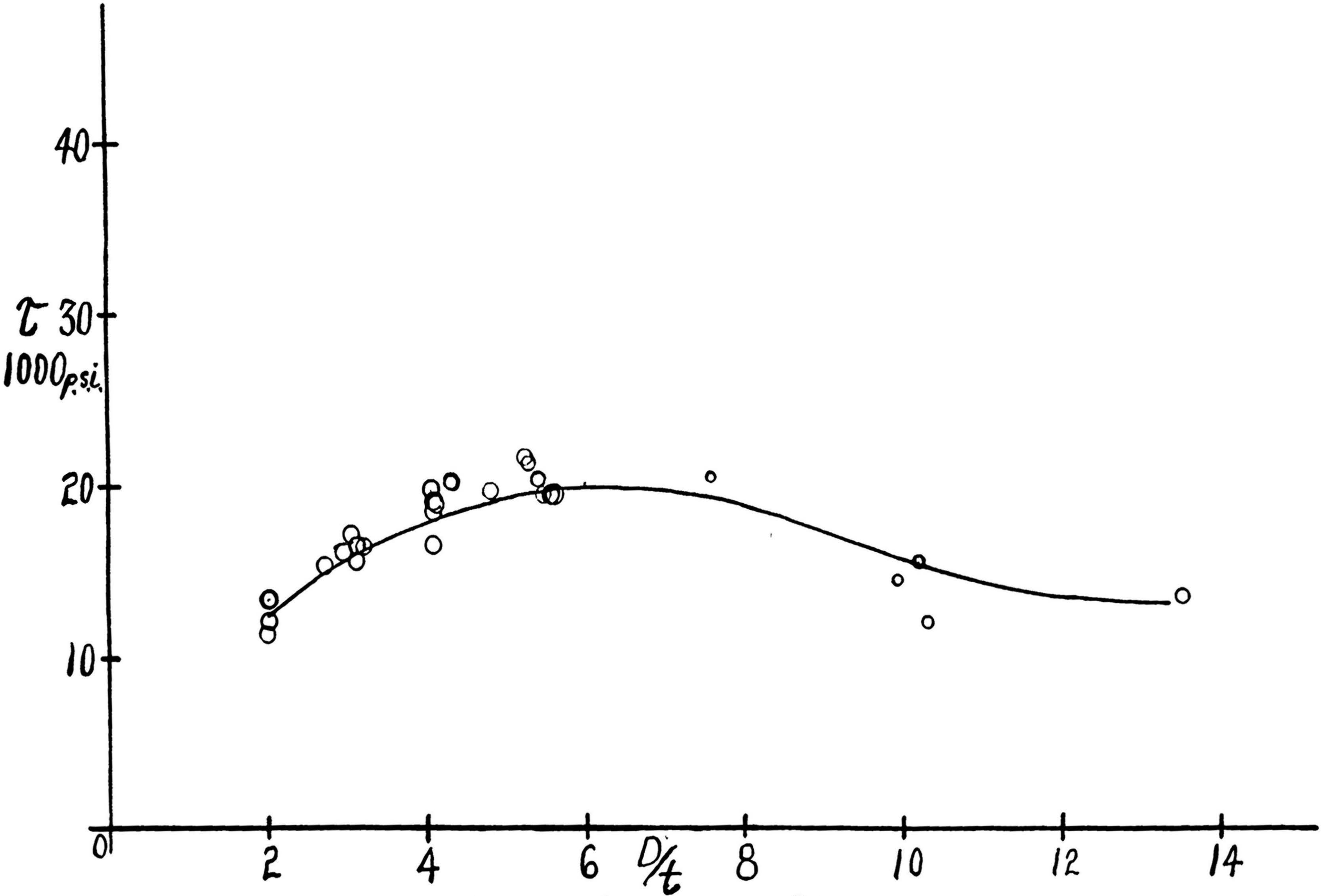
TABLE V

MEAN FIB STRESS DAT

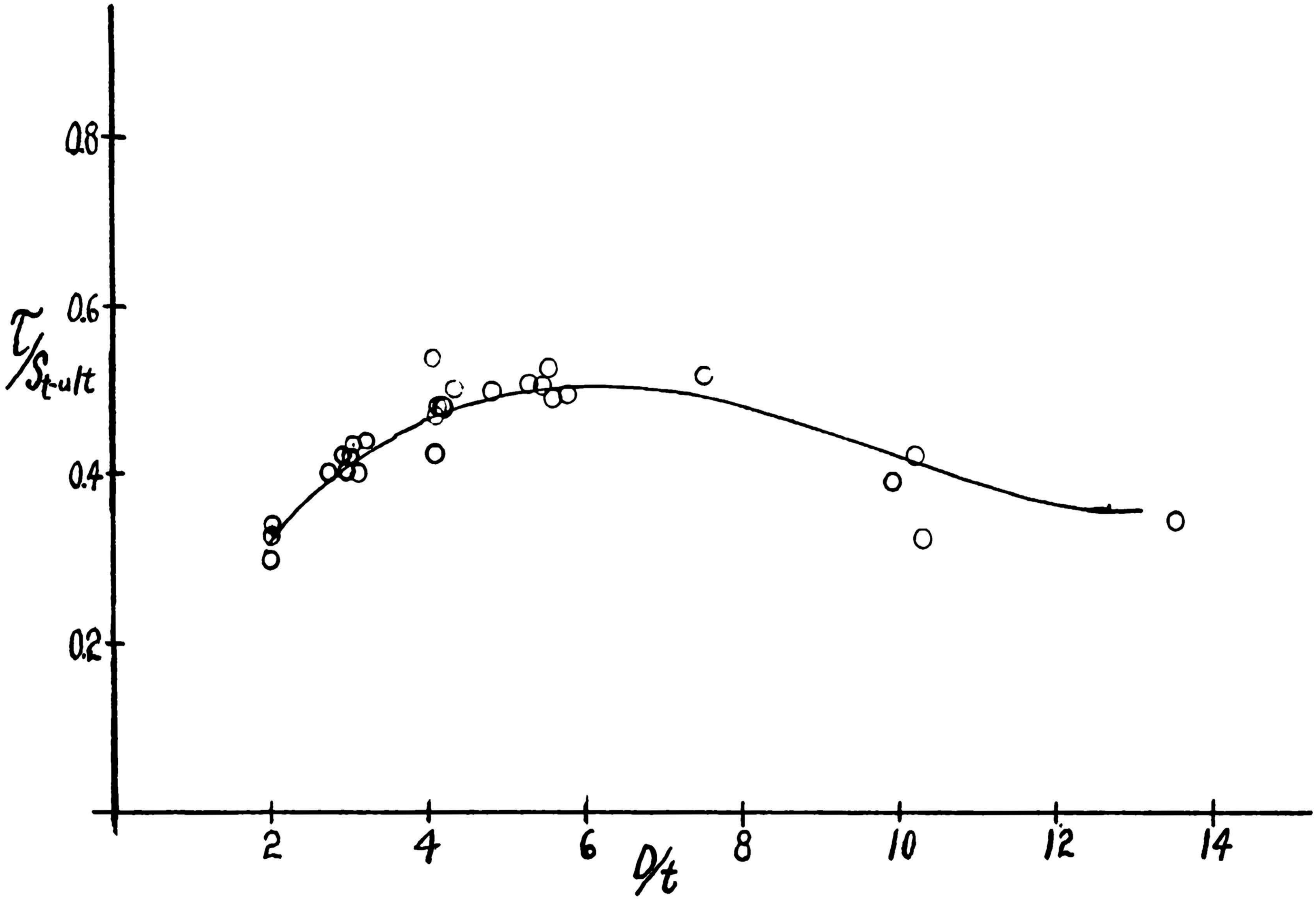
L/D = 13 Dow FS-1

Specimen Number	Diameter in inches	D/t	Tor ue in. lbs.	τ	$\frac{\tau}{S_{t\text{-ult.}}}$
1	1.73	2	23 070	11,375	0.303
8	0.981	2	4,480	11,975	0.30
11	0.727	2	1,830	12,100	0.307
12	1.794	2	30, 70	13,300	0.337
49*	1.0	2	4,210	10,725	0 27
50*	1.75	2	24,540	11,650	0.31
51*	0.75	2	2,250	13,600	0.343
2	1.897	2.72	33,600	15,800	0.4
6	1.65	2.87	21,360	15,900	0.422
3	1.638	2.88	21,100	16,100	0.407
14	1.92	2.97	35,100	16, 00	0.4 9
9	0.745	3.01	2,080	17,250	0.435
16	1.714	3.13	23,410	16 500	0.438
24	0.686	3.15	1,450	15,900	0.401
15	1.672	3.19	21,900	16,600	0.442
10	0.743	4.04	2,010	19,950	0.504
4	0.739	4.06	1,860	16,800	0.423
21	0.739	4.06	1,820	18,600	0.47
22	0.729	4.12	1,780	19,000	0.48
5	0.965	4.1	4,140	19,100	0.478
20	0.721	4.17	1,700	19,000	0.48
26	0.933	4.31	3,900	20,400	0.51
23	0.645	4.8	1,160	19,800	0.50
48	1.223	5.26	8,230	21,800	0.551
13	0.989	5.43	3,970	20,300	0.506
19	0.982	5.5	4,050	21,300	0.534
18	0.975	5.57	3,610	19,600	0.490
47	1.175	5.62	6,290	19,600	0.495
38	1.699	7.57	16,060	20,500	0.5 9
39	0.097	9.97	2,510	14,70	0.392
42	1.095	10.2	2,630	15,800	0 42
41	1.09	10.3	1,940	12,000	0.31
40	1.036	13.5	1,560	3,70	0.364
43	0.975	23.6	470	8,150	0.216

*As Extruded



CURVE 4 τ VS D/t



CURVE 5 $\tau/S_{t\text{-}ult}$ VS D/t

Since the strain and stress are proportional to the distance from the center of twist, the shape of the versus D/t curve indicates the type of failure that will occur because of the kind of stress that is present across the wall of the tubing.

In the lower D/t ratios where the curve is rising, the failure is in plastic shear. The material close to the center of the rod has the smaller amount of shearing stress, and that stress is increasing as the distance from the center increases. The failure in plastic shear starts with rupture of the outermost fibre and progresses inward. The maximum torque taken is just before the failure of the outermost fibre. The shear failure indicates that the inner portion of the tubing is still in the elastic range and is acting as a stiffener for the entire tubing so that shear can take place. As the curve levels off, the D/t ratio has increased, and the shearing stress becomes more nearly constant across the wall. At the maximum of the curve, the material is passing through a transition between shear failure and plastic buckling failure. As the curve begins to fall at even higher D/t ratios, the entire tubing is in the plastic range, and there is no stiffening section to keep the tube from deforming into the wavy appearance shown in the standing specimens in Figure 6, which shows plastic buckling. At even higher D/t ratios, the material will not fail in the plastic range, but will fail in elastic instability before the material reaches the plastic range.

Another series of tests were run to see what the effect of the ratio of the length to the diameter would have upon the modulus of rupture. In table VI are listed the data from these tests, and curve 6 shows the graph of this data.

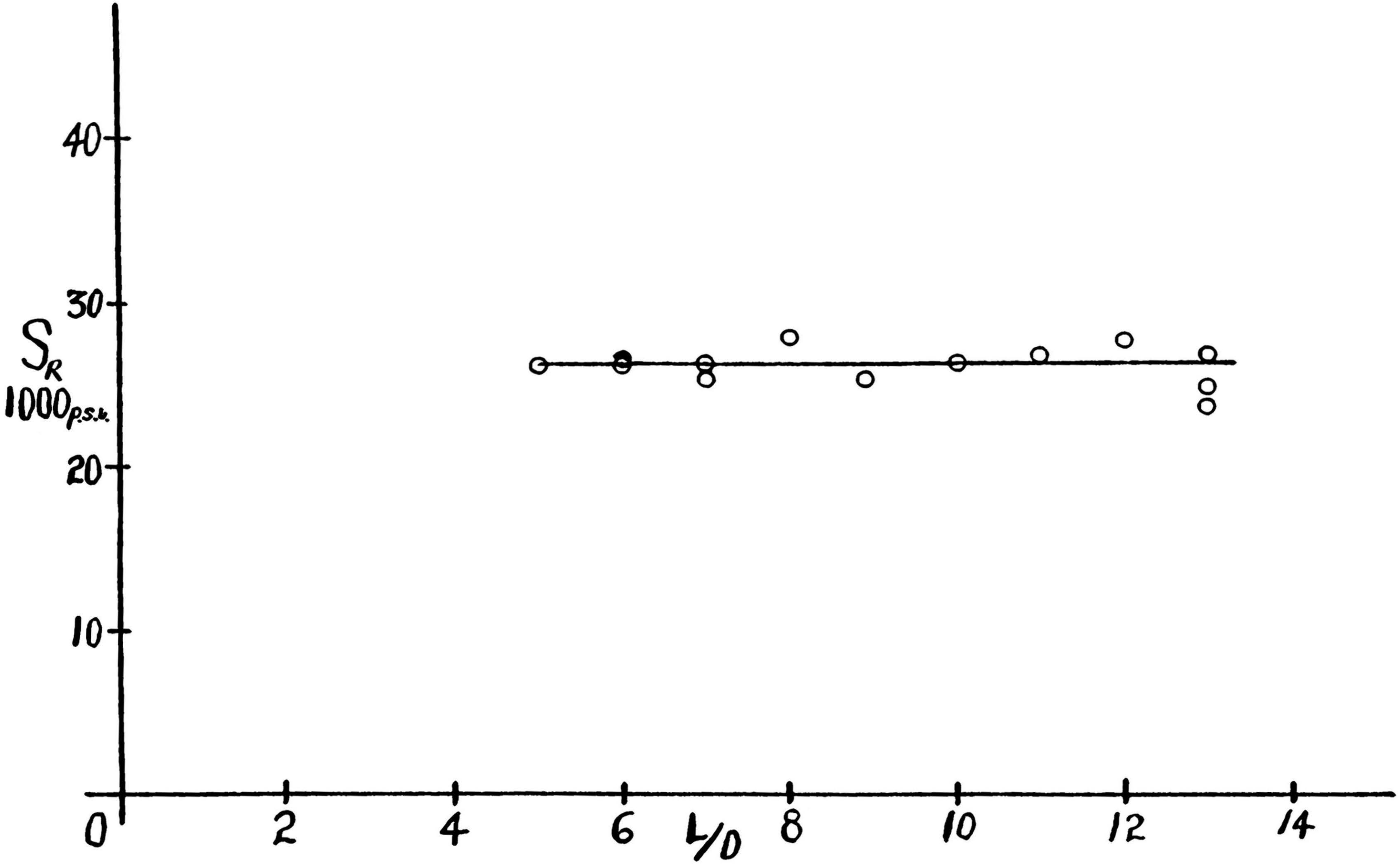
These tests indicate that for the D/t ratio tested (D/t = 4), the L/D ratio has no effect upon the modulus of rupture. This is as to be expected since these specimens were in the range that would fail in shear. However, the length would affect the modulus of rupture in D/t ratios in the range where elastic failure would occur.

TABLE VI

DATA FOR L/D VS. S_R

D/t approximately 4

Specimen Number	L/D	S_R
26	13	26,600
27	5	26,400
28	6	26,150
29	7	25,600
30	7	26,100
31	8	27,700
32	6	26,300
33	9	25,400
34	10	26,100
35	11	26,800
36	12	27,800



CURVE 6 S_R VS L/D

CONCLUSIONS

The investigation reported in this paper indicates that the modulus of rupture is not a function of the diameter to wall-thickness ratio for D/t ratios of less than 5 for magnesium tubing where the test specimens fail in shear. It does become a function of the D/t ratio for the range where plastic buckling occurs. Of course, there is no definite dividing line between shear and plastic failure, but there is a transition stage where the curve of τ vs. D/t reaches a maximum as shown in curve 4. The region for the transition from a shear failure to a plastic buckling failure will depend upon the mechanical properties of the material tested.

That there is no variation of the modulus of rupture with length to diameter ratios within the range of shear or plastic buckling failures is indicated by curve 6.

In the calculation of the shear stress at the mean fibre and the plotting of curves 4 and 5, it appears that the mean fibre stress gives a better indication of what is happening to the material and the type of failure that will occur.

The results of this paper are by no means conclusive, since only a small number of specimens were tested. The smooth curves resulting, however, indicate a fair degree of accuracy.

In the continued investigation on this subject, it might be well to insure good results by plugging all hollow test specimens to be sure that they will not be forced out of round by the tightening of the chucks on the torsion machine. Also, there should be quite a bit of work in the D/t ratios from 2 to 8, since the range from 4 to 8 is the transition range from shear failure to plastic buckling. From the data, it appears that the torsional modulus of rupture rises in the D/t ratios from 2 to 4. In the published literature, the points for the modulus of rupture at a D/t ratio of 2 is also low. This might prove interesting to investigate carefully.

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VITA

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