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Propagation of Fatigue Cracks in Wide Unstiffened Aluminium Alloy Sheets

by

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PROPAGATION OF FATIGUE CRACKS IN WIDE UNSTIFFENED ALUMINIUM ALLOY SHEETS

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K.D. Raithby

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SUMMARY

Results are given for rates of propagation of fatigue cracks, from an initial central slit up to the length at which the cracks became unstable, for four commonly used aluminium alloys. The test specimens in each case were flat sheets 48 in. wide and approximately 96 in. long and were subjected to fluctuating tensile stresses in a direction parallel to the rolling direction of the sheet. The tests confirmed that the high strength aluminium-zinc alloy has a high rate of crack propagation and a short unstable length compared with aluminium-copper alloys, particularly if the aluminium-copper alloy is in the solution treated state.

Replaces R.A.E. Tech Note No. Structures 305 - A.R.C. 23,573

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1 INTRODUCTION

In assessing the relative merits of different materials to be used in aircraft construction important considerations are the rate at which fatigue cracks will grow under various loadings and the length to which they will grow before catastrophic failure results.

A considerable effort has been put into the determination of the "unstable crack length" of various materials and the results of such tests will appear in the Fatigue Data Sheets of the Royal Aeronautical Society[1]. The tests described in this Note were aimed primarily at determining rates of growth of fatigue cracks and, by testing wide sheets, it was hoped to minimise the effects of the free edges of the sheet. A length/width ratio of 2 was chosen to avoid as far as possible end effects from the test rig.

The object of this Note is to compare the behaviour of fatigue cracks in four commonly used aluminium alloys under mean and alternating stresses corresponding to typical stress levels that occur in flight in the wing of a transport aircraft.

2 TEST SPECIMENS AND METHOD OF TEST

Each specimen consisted of an 8 ft × 4 ft sheet of clad aluminium alloy with a central slit, 1.25 in. long, of the form indicated in Fig.1. This slit was intended to simulate an initial fatigue crack. The following four alloys were tested:-

(i) DTD546 aluminium-copper alloy, solution treated and precipitation hardened.

(ii) DTD610 aluminium-copper alloy, solution treated.

(iii) DTD687 aluminium-zinc alloy, solution treated and precipitation hardened.

(iv) 2024-T3 American aluminium-copper alloy, solution treated.

Details of the specification properties of these alloys are given in Appendix 1. Three thicknesses of sheet were tested (0.04 in., 0.08 in., and 0.16 in.) but insufficient tests have yet been done to establish whether there is a pronounced thickness effect. The thickness of each sheet was measured close to the crack after failure.

Each sheet was tested in tension by means of a horizontally mounted hydraulic jack which applied loads to one end, the other end being connected by steel links to the vertical members of a test frame. Hydraulic pressure in the jack was used to indicate the applied load but the test rig was first calibrated using strain gauged links between the jack and the specimen.

Fine wires cemented to the surface of the sheet were used to measure crack growth. Each wire was in circuit with an electrical counter which stopped when the wire broke, hence the rate of growth of the crack could be determined from the counter readings. An approximation to the unstable crack length* was given by the length of crack at the beginning of the load cycle in which final failure occurred.

No attempt was made to prevent lateral buckling of the sheet.

Further details of the method of test are given in Appendix 2.

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*The unstable crack length is the length beyond which the crack continues to propagate across the sheet without any further increase in applied load.

3 DISCUSSION OF TEST RESULTS

In Appendix 3 the results of all tests are given but discussion will be confined to the 0.08 in. sheets, as there is insufficient evidence to show whether there is a significant thickness effect.

Typical crack growth curves (crack length against number of cycles) are given in Fig.2 for four different alloys tested under the same nominal stresses. It is evident from these plots that there is a big difference in rate of propagation between the materials tested and that there is some correlation between rate of propagation and unstable crack length. The high strength Al-Zn alloy DTD687 has only about one twentieth of the life and one fifth of the unstable crack length of the solution treated Al-Cu alloy 2024-T3.

In Fig.3 the variation of rate of crack growth, $\frac{dl}{dN}$, is plotted against total length of crack to illustrate how the rate of growth varies with crack length for the different materials. Again, this shows that DTD687 has a somewhat higher rate of growth than the other alloys, albeit of the same order as that for DTD546 when the length is short. However the low number of cycles to failure in the case of DTD687 is partly due to the fact that the unstable crack length is very much shorter. Unlike the results of Frost's study[2] of the early stages of a fatigue crack, there does not appear to be a simple relationship between $\frac{dl}{dN}$ and crack length. Plotting log $\frac{dl}{dN}$ against log l gives even less consistency.

In Figs.4 to 7, log $\frac{dl}{dN}$ is plotted against log alternating stress. While the results available are too few to draw reliable conclusions they do indicate certain trends. For crack lengths of up to about one fifth of the unstable length the rate of growth appears to be roughly proportional to the cube of the alternating stress, thus agreeing with Frost's observations[2], except in the case of DTD687 which seems rather less sensitive to stress variation. At longer crack lengths the effect of stress becomes more and more marked, reaching something like the fifth power of the alternating stress at half the unstable crack length.

4 CONCLUDING REMARKS

The results presented are insufficient to draw definite conclusions but they do indicate certain trends.

The superiority of the solution treated Al-Cu alloys has been demonstrated with regard to both rate of growth of fatigue cracks and the length of crack which can be tolerated without catastrophic failure.

The sensitivity of rate of crack propagation to alternating stress indicates that extreme care must be taken to ensure accuracy of loading and of measurement of crack length in any experiments to determine rate of crack growth.

Further experiments are needed to investigate thickness effects. The major contribution to thickness effects is likely to be lateral buckling of the sheet as the crack progresses, but there are some inconsistencies in the present results which need further investigation.

Further work is also needed to investigate scatter, both in rate of propagation and in unstable lengths.

LIST OF REFERENCES

Ref. No.	Author	Title, etc.
1	-	Royal Aeronautical Society data sheets on fatigue. Data sheets on unstable crack lengths - to be published.
2	Frost, N.E.	Propagation of fatigue cracks in various sheet materials. J.Mech Eng Science Vol.1 No. 2 September, 1959.
3	Heywood, R.B. Norris, G.M.	Crack propagation and fatigue strength of some aluminium alloy panels. R.A.E. Tech. Note No. Structures 223 A.R.C. 19543 March, 1957.

APPENDIX 1

SPECIFICATION PROPERTIES OF MATERIALS USED

1 DTD546B Clad, high tensile aluminium alloy sheet.

(i) Chemical composition

Copper	Not less than 3.5 nor more than 4.8 per cent.
Iron	Not more than 1.0 per cent.
Silicon	Not more than 1.5 per cent.
Magnesium	Not more than 0.6 per cent.
Manganese	Not more than 1.2 per cent.
Titanium	Not more than 0.3 per cent.
Aluminium	The remainder.

(ii) Heat treatment

Solution treated by heating at 510 ±5°C. Quenched in oil or water. Aged at 155 to 205°C for an appropriate time.

(iii) Strength properties

(a) 0.1 per cent proof stress: not less than 21 tons/sq in.

(b) Ultimate tensile stress: not less than 27 tons/sq in.

(c) Elongation: not less than 8 per cent for sheets thicker than 12 s.w.g. (0.104 in.).

2 DTD610B Clad, high tensile aluminium alloy sheet.

(i) Chemical composition

As given for DTD546B above.

(ii) Heat treatment

Solution treated by heating at 510 ±5°C. Quenched in oil or water at not exceeding 40°C. Aged at room temperature not less than 48 hours.

(iii) Strength properties

(a) 0.1 per cent stress: not less than 15 tons/sq in.

(b) Ultimate tensile stress: not less than 25 tons/sq in.

(c) Elongation: not less than 15 per cent for sheets thicker than 12 s.w.g. (0.104 in.).

3 DTD687A Clad, high tensile aluminium alloy sheet.

(i) Chemical composition

Copper	Not more than 1.5 per cent.
Magnesium	Not less than 2.0 nor more than 3.5 per cent.
Silicon	Not more than 0.5 per cent.

Iron	Not more than 0.5 per cent.
Manganese	Not less than 0.3 nor more than 1.0 per cent.
Zinc	Not less than 4.5 nor more than 6.5 per cent.
Titanium	Not more than 0.3 per cent.
Chromium	Not more than 0.5 per cent.
Aluminium	The remainder.

Chemical composition of coating.

Zinc	Not less than 0.8 nor more than 1.2 per cent.
Aluminium	The remainder.

(ii) Heat treatment

Solution treated by heating at 465 ±5°C. Quenched in water or oil. Precipitation treated at 110 - 140°C for an appropriate time.

(iii) Strength properties

(a) 0.1 per cent proof stress: not less than 27 tons/sq in.

(b) Ultimate tensile strength: not less than 32 tons/sq in.

(c) Elongation: not less than 8 per cent for sheets thicker than 12 s.w.g. (0.104 in.).

4 2024-T3 Clad, high tensile aluminium alloy sheet.

(i) Chemical composition

Copper	Not less than 3.8 nor more than 4.9 per cent.
Magnesium	Not less than 1.2 nor more than 1.8 per cent.
Manganese	Not less than 0.3 nor more than 0.9 per cent.
Iron	Not more than 0.5 per cent.
Silicon	Not more than 0.5 per cent.
Zinc	Not more than 0.25 per cent.
Chromium	Not more than 0.1 per cent.
Others	Not more than 0.15 per cent.
Aluminium	The remainder.

(ii) Heat treatment

Solution treated by heating at 488 - 499°C. Quenched in water. Aged at room temperature for four days.

(iii) Strength properties

(a) 0.2 per cent proof stress: not less than 18 tons/sq in.

(b) Ultimate tensile strength: not less than 27 tons/sq in.

(c) Elongation: not less than 15 per cent between 10 and 24 s.w.g. (0.125 - 0.021 in.)

APPENDIX 2

DESCRIPTION OF HYDRAULIC LOADING RIG AND METHOD OF CRACK MEASUREMENT

The sheets were tested in the slow loading hydraulic rig described in Ref.3, but with an improved loading jack. The ends of each sheet were clamped between pairs of 4 ft long steel plates and loaded through connecting links by a hydraulic ram. A general view of the rig is shown in Fig.8.

End clamping by means of forty eight $\frac{1}{2}$ in. diameter bolts was found an effective method of attaching the sheet.

All specimens were subjected to a repeated load cycle, alternating between some maximum and minimum value, read off pressure gauges on the line of the loading ram. The progress of the fatigue crack was followed by means of a number of fine wires cemented to the sheet normal to the direction of cracking and connected to electrical counters. The wires covered a total distance of about 20 in., which was usually enough to enable detection and progress of the fatigue crack to be followed until complete failure occurred. The wire used was No. 47 s.w.g. (0.002 in. diameter), enamel covered copper wire. The wires were spaced approximately 0.4 in. apart, and each wire was bonded to the sheet by means of cold setting synthetic resin glue.

Other methods of fixing the wires to the sheets were previously tried. The first method attempted consisted of the wire sandwiched between two strips of transformer paper, stuck to the sheet with adhesive. A second attempt was made using only a single sheet of the paper, under the wire. It was found that as the crack approached the paper, it rose from the surface of the metal, causing the wire to break many cycles before the crack reached the wire. Hot setting synthetic resin glue was also tried, but this was found to have insufficient shear stiffness, and there was a danger that the high temperatures required to set it might affect the mechanical properties of the sheet.

The ends of the wire projecting from the glue were fixed to the sheet by means of adhesive tape until the sheet was bolted into position in the rig. Then a small portion was stripped of insulation and soldered to contacts leading to electrical counters. As long as the wire remained unbroken, a micro switch, operated by extension of the specimen, operated the counters and associated indicator lights. As the fatigue crack reached and broke each wire the corresponding counter stopped and the indicator light went out. Successive counter readings indicated the number of cycles taken for the crack to travel from one wire to the next, hence it was possible to plot the total length of crack against number of cycles.

As a check on the accuracy of loading the rig was calibrated over the whole range of loads applied in the test programme. For this calibration a pair of strain gauged steel links was inserted between the loading ram and the specimen. The strain gauged links were previously calibrated in a Losenhausen static test machine, this being used as a criterion for all test machines in the fatigue laboratory.

The calibration showed that the loading was accurate to within -2 per cent at the highest loads applied and to within -5 per cent at the lowest loads.

APPENDIX 3

SUMMARY OF TEST RESULTS

Discussion has been confined to the results of tests on sheet of one thickness at a constant mean stress of 14,000 lb/in.^{2}. However, a number of other results were obtained for thinner and thicker sheets with the same mean stress and also with other mean stresses. The results cover four alloys under a mean stress of 14,000 lb/in.^{2}; three alloys under a mean stress of 12,000 lb/in.^{2} and one alloy (DTD546) under a mean stress of 10,000 lb/in.^{2}.

A summary of these results is given in Table 1 and all test results are given in Table 2.

TABLE 1

Summary of results

Material	Thickness in.	Specimen No.	Maximum stress* in cycle lb/in.^{2}	Mean* stress lb/in.^{2}	Alternating stress* lb/in.^{2}	Cycles to failure	Unstable crack length in.	Net stress at failure lb/in.^{2}
DTD546	0.04	12	16,000	12,000	4,000	31,547	13.80	22,500
		13	16,000	10,000	6,000	23,180	15.14	23,400
		10	18,000	14,000	4,000	23,952	12.67	24,500
		11	20,000	14,000	6,000	13,837	10.21	25,400
	0.08	9	16,000	14,000	2,000	131,903	12.02	21,300
		20	16,000	10,000	6,000	14,418	13.34	22,500
		14	18,000	14,000	4,000	17,049	11.86	23,900
		15	20,000	14,000	6,000	7,522	8.68	24,400
	0.16	19	16,000	14,000	2,000	98,869	17.93	25,500
		7	16,000	12,000	4,000	16,554	17.11	24,900
		21	16,000	10,000	6,000	6,472	17.56	25,300
DTD610	0.04	26	18,000	14,000	4,000	155,819	> 20 †	> 30,900
		27	20,000	14,000	6,000	13,994	> 20 †	> 34,300
		36	20,000	14,000	6,000	18,184	18.66	32,700
	0.08	28	16,000	14,000	2,000	297,879	> 20 †	> 27,400
		29	18,000	14,000	4,000	45,619	> 20 †	> 30,900
		30	20,000	14,000	6,000	21,686	> 20 †	> 34,300
	0.16	32	16,000	14,000	2,000	336,557	25.89	34,700
		31	16,000	12,000	4,000	46,342	22.50	30,200
DTD687	0.04	22	18,000	14,000	4,000	22,340	5.73	20,500
		23	20,000	14,000	6,000	3,969	3.77	21,700
	0.08	16	16,000	14,000	2,000	25,320	5.36	18,000
		17	18,000	14,000	4,000	8,647	5.42	20,300
		18	20,000	14,000	6,000	559	3.44	21,500
		37	20,000	14,000	6,000	2,157	4.57	22,100
	0.16	24	16,000	12,000	4,000	4,176	5.49	18,000
		25	16,000	14,000	2,000	34,426	6.52	18,500
2024-T3	0.08	33	16,000	14,000	2,000	509,119	> 21 †	> 28,400
		34	18,000	14,000	4,000	55,473	> 21 †	> 32,000
		35	20,000	14,000	6,000	17,176	17.92	31,900

* Nominal stress on gross cross sectional area

† Observations unreliable above 20 in.

TABLE 2

Results of tests

For each specimen the lengths in inches are given for both halves of the crack growing either side of the initial slot (see Fig.1). The initial slot length (1.25 in.) is not included in the lengths given

Specimen No. 7*				Specimen No. 9				Specimen No. 10				Specimen No.11			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.27	8,230	0.28	8,353	0.26	51,611	0.25	47,964	0.26	13,543	0.28	15,945	0.24	6,933	0.27	7,390
0.69	12,330	0.70	12,429	0.69	91,119	0.63	92,635	0.68	20,373	0.70	19,460	0.63	11,916	0.68	11,540
1.07	14,020	1.08	14,033	1.06	102,718	1.05	108,894	1.06	24,109	1.10	23,892	1.05	13,025	1.08	12,785
1.49	14,989	1.47	14,921	1.47	120,762	1.49	118,167	1.46	26,674	1.49	26,219	1.44	13,515	1.51	13,410
1.88	15,451	1.86	15,492	1.84	125.054	1.89	123,931	1.87	27,842	1.87	27,434	1.82	13,603	1.90	13,636
2.28	15,702	2.26	15,788	2.25	127,459	2.25	127,013	2.27	28,563	2.26	28,231	2.22	13,768	2.28	13,723
2.68	15,980	2.66	16,135	2.66	129,219	2.65	128,800	2.68	28,746	2.66	28,563	2.63	13,804	2.70	13,781
3.10	16,135	3.06	16,295	3.03	130,666	3.10	130,351	3.03	28,854	3.05	28,787	3.02	13,823	3.10	13,809
3.50	16,249	3.48	16,431	3.44	131,583	3.49	130,724	3.49	28,895	3.48	28,879	3.41	13,831	3.52	13,824
3.91	16,335	3.86	16,499	3.84	131,894	3.90	131,179	3.90	28,926	3.88	28,914	3.82	13,826	3.92	13,831
4.33	16,387	4.28	16,537	4.03	131,903	4.30	131,463	4.30	28,938	4.29	28,937	4.24	13,837	4.34	13,836
4.73	16,429	4.70	16,539			4.70	131,616	4.70	28,946	4.71	28,945			4.7[illegible]	13,837
5.14	16,460	5.09	16,543			5.10	131,728	5.10		5.10	28,950				
5.54	16,482	5.49	16,545			5.50	131,808	5.51	28,951	5.51	28,952				
5.95	16,498	5.90	16,547			5.90	131,867	5.91	28,952						
6.33	16,508	6.29	16,549			6.32	131,898								
6.72		6.70	16,550			6.74	131,903								
7.13	16,525	7.13	16,554												
7.52	16,536														
7.93	16,544														
8.34	16,550														
8.73	16,554														

*Specimens numbered 1-6 and 8 were discarded

TABLE 2 (contd.)

Specimen No. 12				Specimen No. 13				Specimen No. 14				Specimen No. 15			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.26	18,301	0.20	15,397	0.23	10,136	0.21	11,288	0.28	9,024	0.25	8,114	0.30	3,872	0.28	3,395
0.67	25,675	0.61	23,965	0.65	16,102	0.65	16,593	0.68	14,556	0.66	13,033	0.69	5,404	0.68	5,421
1.06	28,260	1.02	27,858	1.06	20,001	1.02	20,250	1.08	15,547	1.07	15,331	1.10	6,328	1.09	6,494
1.45	29,584	1.41	29,101	1.45	21,314	1.46	21,522	1.47	16,416	1.47	16,380	1.50	6,711	1.49	7,129
1.88	30,465	1.80	30,305	1.84	22,086	1.85	22,147	1.96	16,791	1.88	16,789	1.88	7,098	1.92	7,434
2.29	30,977	2.21	30,882	2.21	22,390	2.27	22,606	2.25	16,931	2.26	16,931	2.29	7,315	2.30	7,513
2.63	31,214	2.61	31,165	2.62	22,693	2.67	22,868	2.66	16,986	2.68	16,990	2.69	7,409	2.70	7,522
3.10	31,358	3.01	31,344	3.04	22,904	3.08	23,015	3.05	17,013	3.10	17,020	3.07	7,444		
3.50	31,430	3.40	31,425	3.42	23,019	3.48	23,092	3.45	17,029	3.50	17,035	3.48	7,473		
3.91	31,469	3.81	31,477	3.82	23,088	3.89	23,126	3.87	17,041	3.90	17,042	3.89	7,502		
4.31	31,492	4.22	31,492	4.29	23,127	4.29	23,146	4.29	17,045	4.31	17,047	4.31	7,519		
4.71	31,520	4.65	31,526	4.60	23,149	4.69	23,158	4.70	17,048	4.71	17,048	4.72	7,522		
5.13	31,534	5.02	31,535	5.07	23,160	5.09	23,163	5.10	17,048	5.11	17,049				
5.51		5.42	31,542	5.49	23,169	5.50	23,174	5.50	17,049						
5.94	31,543	5.83	31,545	5.88	23,174	5.89	23,177								
6.34	31,547	6.21	31,547	6.29	23,178	6.30	23,178								
				6.68	23,179	6.80	23,180								
				7.10	23,180										

TABLE 2 (contd.)

Specimen No. 16				Specimen No. 17				Specimen No. 18				Specimen No. 19			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.29	12,179	0.25	11,579	0.26	3,695	0.28	3,895	0.26	400	0.26	444	0.28	54,702	0.27	44,326
0.68	18,973	0.67	20,019	0.68	6,140	0.68	6,397	0.68	535	0.69	458	0.71	72,732	0.65	66,515
1.09	23,500	1.06	24,120	1.05	7,495	1.09	7,963	1.10	559	1.09	459	1.11	84,600	1.04	78,610
1.48	24,870	1.45	24,801	1.49	8,353	1.48	8,647					1.48	89,613	1.47	86,634
1.90	25,311	1.83	25,320	1.88	8,494							1.86	92,454	1.86	89,729
2.28	25,320			2.27	8,643							2.27	95,052	2.27	92,849
				2.69	8,647							2.67	96,298	2.69	95,385
												3.05	97,182	3.08	96,805
												3.46	97,845	3.47	97,546
												3.87	98,334	3.89	98,370
												4.29	98,611	4.28	98,600
												4.70	98,709	4.69	98,689
												5.10	98,741	5.11	98,736
												5.51	98,772	5.53	98,780
												5.91	98,788	5.92	98,804
												6.30	98,809	6.31	98,820
												6.72	98,825	6.71	98,836
												7.12	98,842	7.09	98,854
												7.55	98,856	7.52	98,866
												7.96	98,868	7.91	98,868
												8.36	98,869	8.33	98,869

TABLE 2 (contd.)

Specimen No. 20				Specimen No. 21				Specimen No. 22				Specimen No. 23			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.25	6,356	0.25	5,716	0.31	3,321	0.24	2,984	0.25	12,309	0.23	11,045	0.28	2,968	0.22	2,419
0.67	9,967	0.66	9,991	0.72	4,730	0.66	4,481	0.65	19,107	0.61	18,365	0.67	3,942	0.63	3,776
1.06	11,660	1.04	11,912	1.11	5,385	1.07	5,221	1.08	21,326	1.05	21,353	1.07	3,969	1.05	3,958
1.47	12,599	1.44	13,125	1.52	5,795	1.44	5,613	1.48	22,196	1.45	22,159			1.45	3,969
1.88	13,225	1.83	13,811	1.94	6,085	1.83	5,852	1.89	22,336	1.82	22,300				
2.27	13,587	2.23	14,170	2.34	6,247	2.23	6,075	2.27	22,340	2.21	22,340				
2.67	13,942	2.62	14,334	2.73	6,352	2.62	6,182								
3.09	14,096	3.01	14,358	3.13	6,415	3.02	6,267								
3.50	14,179	3.42	14,383	3.54	6,443	3.43	6,317								
3.90	14,256	3.85	14,393	3.96	6,454	3.83	6,360								
4.32	14,294	4.26	14,408	4.35	6,456	4.23	6,391								
4.72	14,343	4.67	14,411	4.77	6,458	4.65	6,407								
5.11	14,363	5.05	14,414	5.14	6,462	5.03	6,429								
5.53	14,384	5.46	14,418	5.55	6,464	5.43	6,439								
5.93	14,400			5.96	6,467	5.83	6,447								
6.32	14,407			6.37	6,469	6.24	6,449								
6.72	14,411			6.78	6,472	6.66	6,452								
7.13	14,418					7.09	6,454								
						7.49	6,457								
						7.90	6,462								
						8.30	6,464								
						8.70	6,466								
						9.11	6,471								
						9.53	6,472								

TABLE 2 (contd.)

Specimen No. 24				Specimen No. 25				Specimen No. 26				Specimen No. 27			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.27	2,829	0.26	2,629	0.28	13,287	0.25	15,540	0.65	142,823	0.63	137,814	0.23	7,188	0.27	8,183
0.63	3,663	0.67	3,754	0.67	23,152	0.65	24,933	1.06	153,610	1.04	150,257	0.64	11,410	0.66	11,469
1.06	4,001	1.09	4,011	1.07	29,391	1.02	30,185	1.47	158,809	1.64	157,568	1.03	12,872	1.04	12,875
1.46	4,147	1.86	4,160	1.51	32,763	1.42	32,409	1.87	160,977	1.83	160,336	1.41	13,236	1.45	13,241
1.89	4,176	2.35	4,176	1.92	33,668	1.81	33,486	2.26	162,355	2.21	161,570	1.81	13,446	1.86	13,477
				2.30	34,221	2.20	34,220	2.67	163,251	2.62	162,929	2.21	13,581	2.29	13,594
				2.69	34,426	2.58	34,426	3.09	164,128	3.02	163,939	2.59	13,658	2.67	13,674
								3.50	164,550	3.41	164,479	2.99	13,706	3.08	13,717
								3.90	164,837	3.83	164,815	3.40	13,755	3.49	13,763
								4.30	165,099	4.23	165,071	3.81	13,778	3.90	13,781
								4.69	165,243	4.65	165,242	4.23	13,800	4.30	13,803
								5.09	165,381	5.14	165,380	4.65	13,827	4.70	13,816
								5.51	165,465	5.44	165,458	5.04	13,835	5.13	13,836
								5.92	165,513	5.86	165,564	5.45	13,848	5.52	13,842
								6.29	165,582	6.24	165.601	5.84	13,893	5.92	13,885
								6.69	165,638	6.66	165,639	6.23	13,910	6.32	13,897
								7.10	165,678	7.07	165,666	6.64	13,919	6.71	13,916
								7.51	165,697	7.51	165,703	7.09	13,934	7.09	13,926
								7.92	165,722	7.91	165,734	7.49	13,942	7.51	13,934
								8.31	165,758	8.29	165,748	7.51	13,970	7.92	13,942
								8.72	165,777	8.69	165,765	8.30	13,975	8.32	13,956
								9.13	165,787	9.12	165,786	8.68	13,983	8.72	13,975
								9.54	165,801	9.52	165,797	9.10	13,990	9.12	13,983
								> 10.0	165,819	>10.0	165,819	9.51	13,994	9.51	13,992
														> 9.6	13,994

TABLE 2 (contd.)

Specimen No. 28				Specimen No. 29				Specimen No. 30				Specimen No. 31			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.25	90,350	0.28	91,504	0.23	17,162	0.26	18,710	0.32	10.694	0.26	10.037	0.21	11,654	0.29	13,953
0.65	155,116	0.70	157,873	0.65	28,531	0.67	30,178	0.72	16,204	0.64	16,159	0.62	23,165	0.70	24,609
1.05	197,265	1.07	197,780	1.03	34,710	1.08	37,484	1.13	20,101	1.03	19,961	1.04	30,703	1.09	31,193
1.46	228,136	1.50	227,745	1.44	39,266	1.48	40,827	1.53	22,249	1.44	22,221	1.43	34,752	1.51	35,520
1.83	246,891	1.89	245,800	1.87	42,113	1.85	42,385	1.92	23,264	1.87	23,325	1.81	37,883	1.93	38,471
2.23	259,098	2.29	259,893	2.24	43,063	2.25	43,334	2.31	23,637	2.28	23,730	2.20	40,131	2.32	40,303
2.63	266,846	2.70	267,348	2.65	43,809	2.66	44,016	2.72	23,960	2.68	23,980	2.59	41,522	2.74	41,824
3.03	273,216	3.11	273,911	3.05	44,297	3.02	44,398	3.09	24,114	3.08	24,173	2.98	42,938	3.14	42,908
3.43	278,247	3.53	279,587	3.45	44,585	3.45	44,712	3.50	24,240	3.49	24,325	3.40	42,724	3.55	43,875
3.84	282,066	3.90	283,927	3.87	44,906	3.86	44,989	3.90	24,342	3.90	24,404	3.80	44,408	3.95	44,433
4.25	285,792	4.33	287,285	4.26	45,043	4.27	45,155	4.32	24,418	4.31	24,507	4.22	44,922	4.36	44,874
4.66	288,304	4.73	290,175	4.66	45,153	4.68	45,263	4.72	24,444	4.71	24,524	4.64	45,470	4.76	45,368
5.05	290,285	5.13	292,430	5.07	45,269	5.08	45,366	5.10	24,521	5.11	24,553	5.03	45,644	5.17	45,560
5.46	292,062	5.54	294,052	5.48	45,335	5.49	45,461	5.52	24,535	5.52	24,570	5.44	45,845	5.58	45,739
5.86	293,432	5.94	295,447	5.90	45,461	5.88	45,500	5.90	24,589	5.93	24,602	5.84	45,942	5.98	45,894
6.27	294,582	6.32	295,815	6.29	45,488	6.26	45,530	6.31	24,598	6.32	24,615	6.23	46,052	6.38	45,971
6.67	295,595	6.72	296,474	6.69	45,514	6.68	45,558	6.73	24,607	6.71	24,627	6.62	46,116	6.76	46,056
7.08	296,215	7.12	297,388	7.09	45,528	7.10	45,568	7.16	23,614	7.11	24,637	7.08	46,188	7.17	46,140
7.48	296,861	7.54	297,761	7.49	45,546	7.52	45,578	7.56	24,626	7.52	24,645	7.46	46,233	7.59	46,184
7.90	297,211	7.94	297,831	7.90	45,569	7.93	45,594	7.98	24,637	7.92	24,654	7.89	46,271	7.99	46,221
8.29	297,549	8.33	297,848	8.29	45,583	8.33	45,608	8.37	24,645	8.33	24,662	8.28	46,282	8.37	46,241
8.72	297,764	8.74	297,860	8.71	45,594	8.74	45,619	8.78	24,654	8.73	24,671	8.69	46,302	8.79	46,279
9.11	297,820	9.15	297,871	9.12	45,603			9.16	24,662	9.13	24,679	9.07	46,314	9.19	46,291
9.52	297,860	9.54	297,879	9.51	45,612			9.58	24,670	9.51	24,686	9.49	46,324	9.55	46,302
>10.0	297,879			> 9.6	45,619			> 10.0	24,686			10.30	46,342	10.95	46,342

TABLE 2 (contd.)

Specimen No. 32				Specimen No. 33				Specimen No. 34				Specimen No. 35			
Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.30	107,909	0.23	94,438	0.27	179,311	0.23	184,786	0.24	18,518	0.26	18,935	0.26	8,053	0.26	8,032
0.68	17[illegible],881	0.64	167,458	0.71	302,133	0.65	302,587	0.65	35,022	0.67	35,142	0.67	12,411	0.67	12,165
1.08	220,022	1.02	212,693	1.11	373,693	1.04	375,315	1.05	42,702	1.06	42,622	1.07	14,167	1.09	14,055
1.48	249,564	1.42	245,455	1.49	398,844	1.46	406,691	1.47	46,445	1.46	47,282	1.47	15,505	1.47	15,427
1.93	276,104	1.81	269,514	1.88	431,069	1.87	445,593	1.87	50,443	1.86	50,219	1.[illegible]8	16,230	1.85	16,168
2.32	295,668	2.20	288,371	2.27	459,945	2.27	463,807	2.27	52,415	2.25	52,271	2.28	16,534	2.25	16,517
2.71	304,377	2.59	299,765	2.67	471,190	2.66	473,541	2.67	53,535	2.65	53,4[illegible]8	2.66	16,730	2.65	16,727
3.13	314,000	2.99	308,088	3.05	479,480	3.07	481,145	3.07	54,106	3.03	54,021	3.07	16,857	3.04	16,857
3.53	318,634	3.40	314,024	3.45	484,590	3.48	487,201	3.48	54,466	3.45	54,435	3.48	16,941	3.46	16,934
3.94	325,041	3.81	320,148	3.87	489,579	3.88	492,006	3.90	54,732	3.86	54,702	3.89	17,011	3.87	17,002
4.35	3[illegible]6,428	4.22	323,500	4.29	493,257	4.30	495,728	4.31	54,920	4.28	54,883	4.32	17,056	4.27	17,056
4.76	323,675	4.63	327,409	4.71	496,772	4.69	498,418	4.70	55,059	4.68	55,027	4.71	17,091	4.68	17,092
5.15	330,265	5.02	329,013	5.10	499,211	5.10	500,543	5.10	55,165	5.08	55,146	5.11	17,116	5.08	17,115
5.56	331,619	5.43	330,797	5.50	501,235	5.50	502,798	5.51	55,240	5.48	55,226	5.53	17,130	5.50	17,126
5.97	332,543	5.83	331,950	5.87	503,363	5.92	504,950	5.91	55,298	5.87	55,289	5.94	17,147	5.90	17,149
6.37	333,284	6.22	332,832	6.29	505,157	6.32	506,110	6.33	55,339	6.29	55,336	6.32	17,155	6.29	17,152
6.76	334,064	6.63	333,664	6.71	506,553	6.72	507,084	6.72	55,390	6.70	55,373	6.72	17,161	6.70	17,156
7.15	334,807	7.06	334,483	7.14	507,152	7.11	507,985	7.11	55,407	7.12		7.11	17.170	7.12	17.168
7.59	335,417	7.48	335,003	7.53	508,002	7.52	508,640	7.50	55,427	7.53	55,422	7.54	17,172	7.52	17,171
7.96	335,856	7.90	335,534	7.93		7.91	508,827	7.91	55,441	7.93	55,437	7.92	17,175	7.94	17,174
8.37	336,064	8.[illegible]8	335,880	8.36	508,836	8.32	508,958	8.33	55,454	8.32	55,4[illegible]2	8.34	17,176	8.33	17,176
8.75	336,286	8.69	336,188	8.76	508,997	8.73	509,006	8.72	55,461	8.72	55,456				
9.18	336,362	9.08	336,305	9.15	509,097	9.13	509,103	9.12	55,468	9.13	55,466				
9.57		9.50	336,360	9.57	509,106	9.52	509,109	9.51	55,475	9.53	55,471				
12.08	336,557	12.56	336,557	>10.0	509,119	>10.0	509,119	>9.6	55,476	>9.6	55,476				

TABLE 2 (contd.)

Specimen No. 36				Specimen No. 37			
Top crack		Bottom crack		Top crack		Bottom crack	
Length	Cycles	Length	Cycles	Length	Cycles	Length	Cycles
0.25	8,486	0.24	7,989	0.32	1,349	0.22	1,121
0.65	14,967	0.64	13,863	0.45	1,577	0.35	1,516
1.07	16,667	1.06	15,709	0.58	1,732	0.48	1,601
1.47	17,142	1.44	16,723	0.72	1,842	0.60	1,730
1.88	17,496	1.82	17,120	0.84	1,947	0.71	1,832
2.26	17,707	2.22	17,505	0.95	2,035	0.84	1,947
2.68	17,855	2.61	17,704	1.08	2,094	0.97	2,052
3.09	17,941	3.03	17,872	1.21	2,145	1.10	2,088
3.49	17,954	3.41	17,934	1.33	2,166	1.22	2,129
3.90	18,036	3.83	17,992	1.45	2,190	1.35	2,153
4.30	18,067	4.25	18,036	1.58	2,197	1.49	2,172
4.70	18,087	4.67	18,065			1.61	2,191
5.10	18,105	5.05	18,039			1.74	2,197
5.51	18,126	5.45	18,105				
5.91	18,141	5.84	18,121				
6.30	18,155	6.25	18,129				
6.70	18,164	6.67	18,149				
7.09	18,169	7.10	18,159				
7.51	18,172	7.50	18,166				
7.92	18,177	7.92	18,171				
8.31	18,184	8.30	18,176				
		8.60	18,180				
		9.10	18,184				

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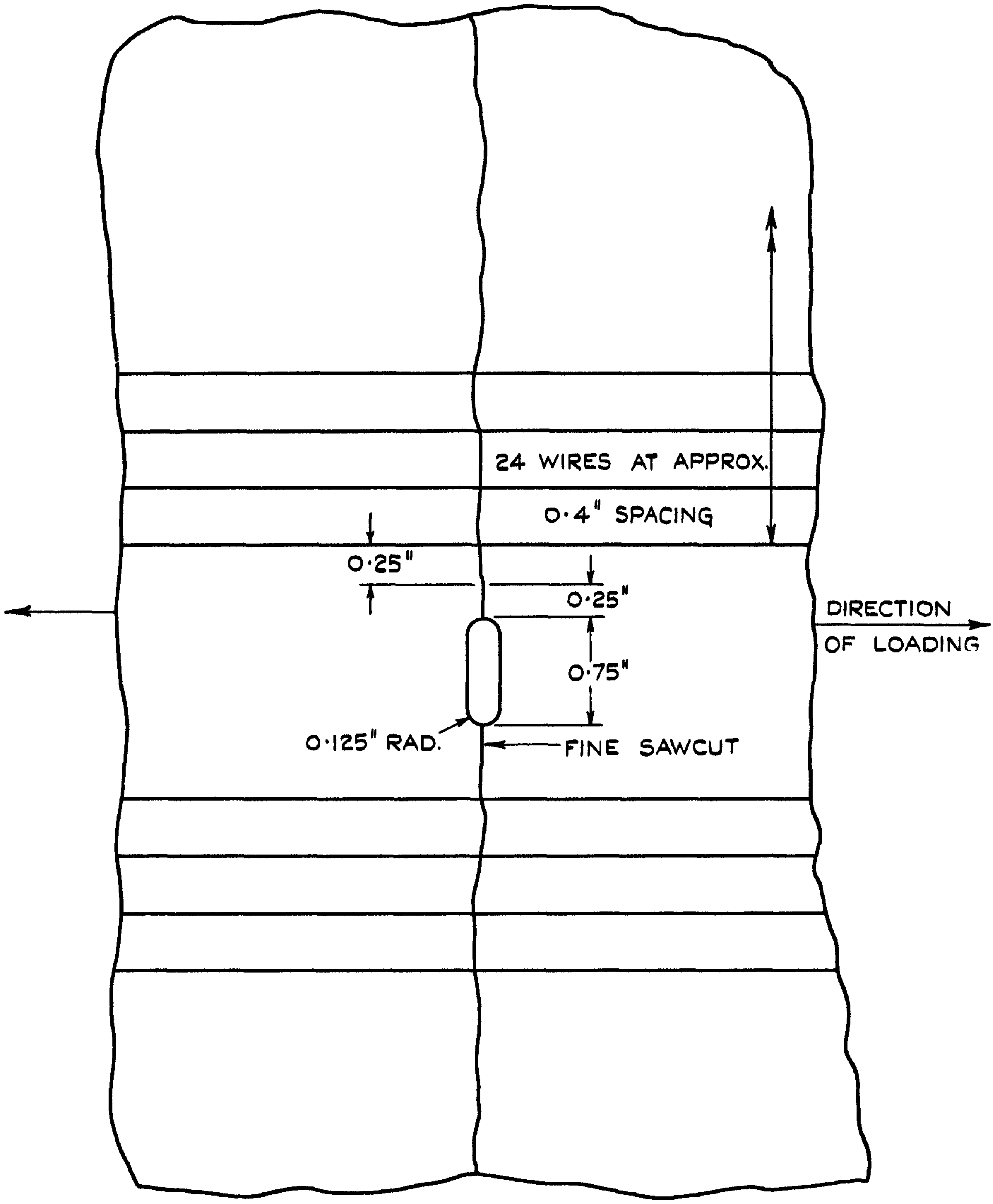

FIG. 1. CENTRAL SLIT AND POSITIONING OF INDICATOR WIRES.

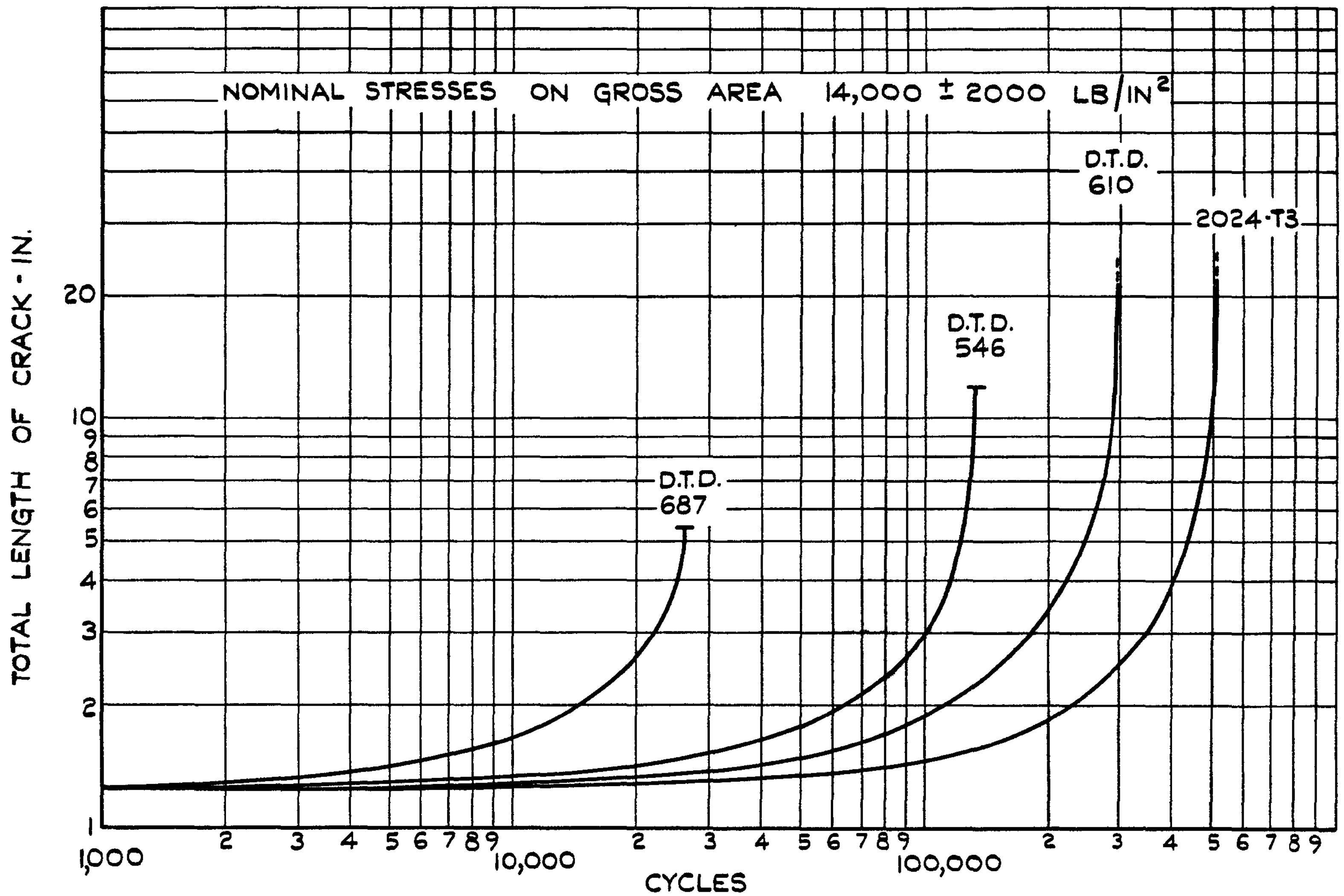

FIG. 2. CRACK LENGTH v No. OF LOAD CYCLES.

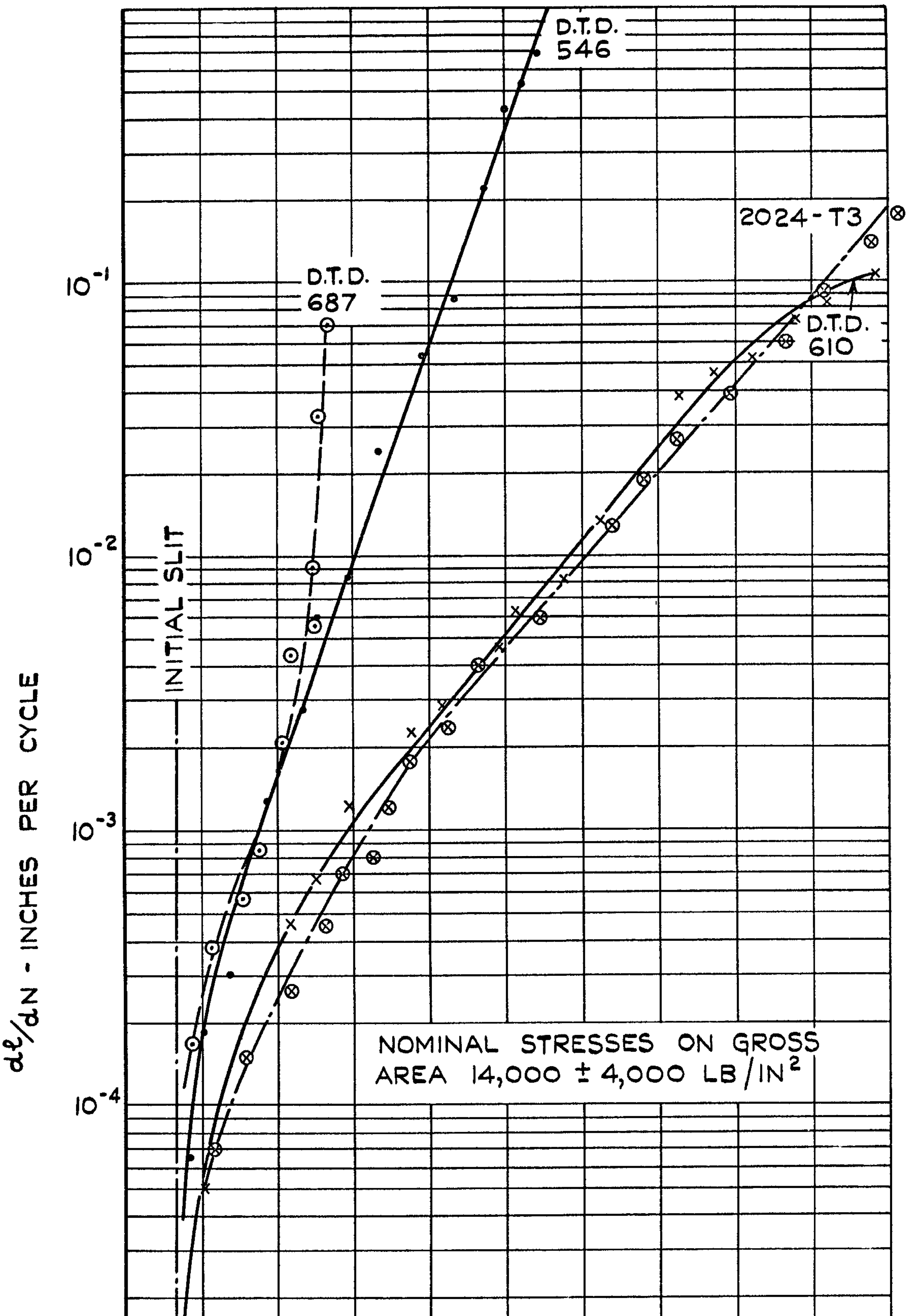

FIG. 3. VARIATION OF $d\ell/dN$ WITH CRACK LENGTH.

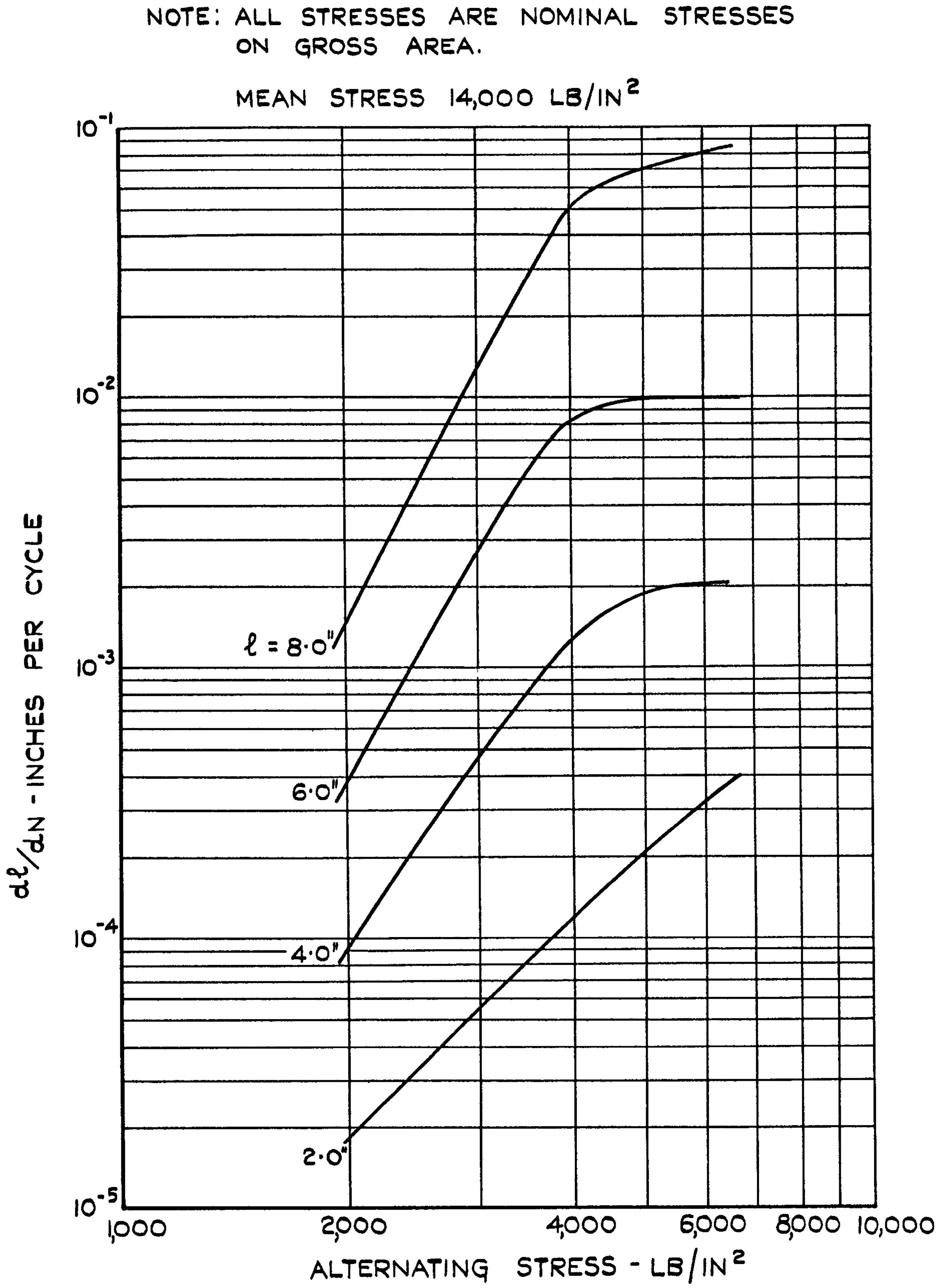

FIG. 4. VARIATION OF $d\ell/dN$ WITH ALTERNATING STRESS - D.T.D. 546.

NOTE: ALL STRESSES ARE NOMINAL STRESSES ON GROSS AREA.

MEAN STRESS 14,000 LB/IN²

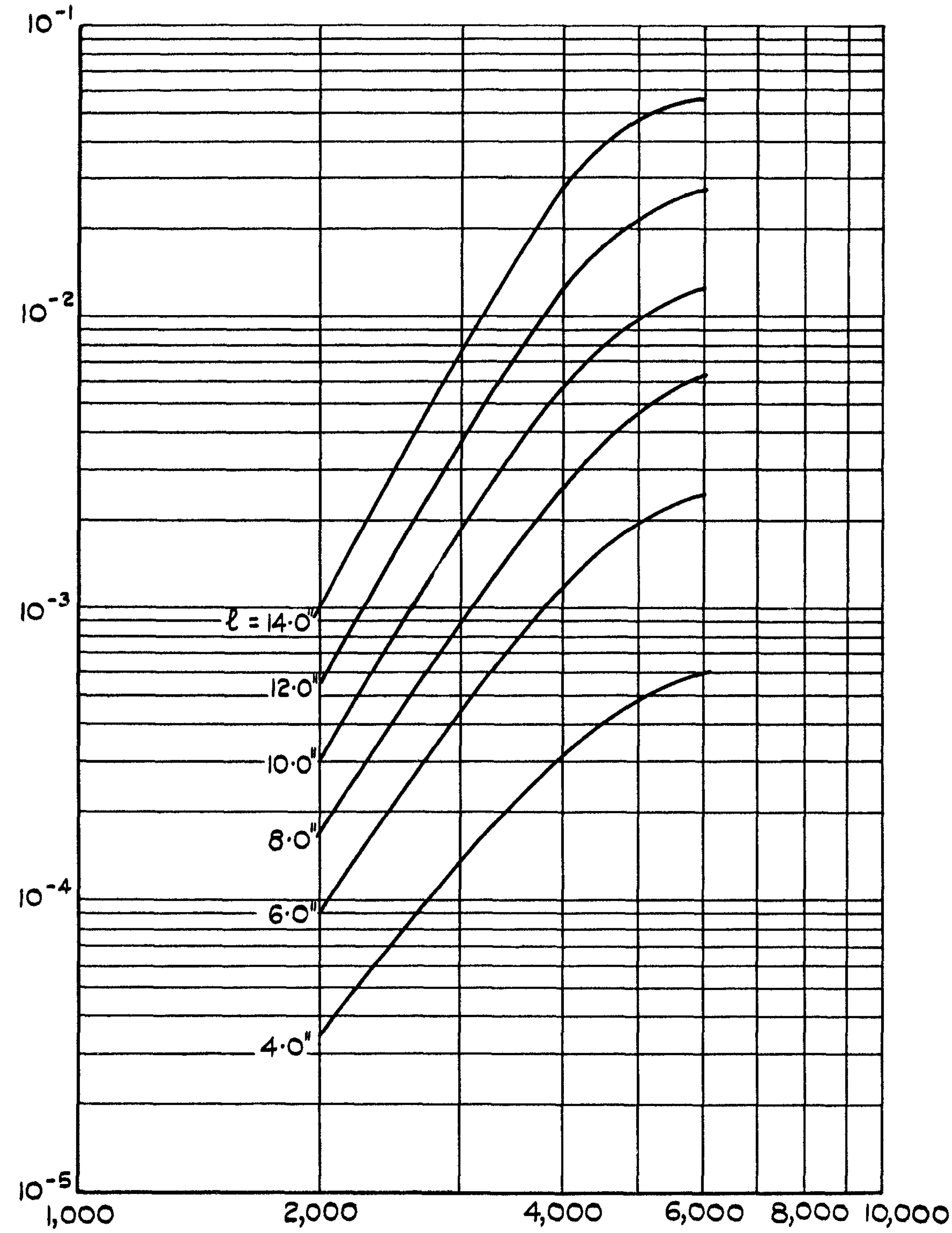

FIG. 5. VARIATION OF $d\ell/dN$ WITH ALTERNATING STRESS - D.T.D. 610.

NOTE: ALL STRESSES ARE NOMINAL STRESSES ON GROSS AREA.

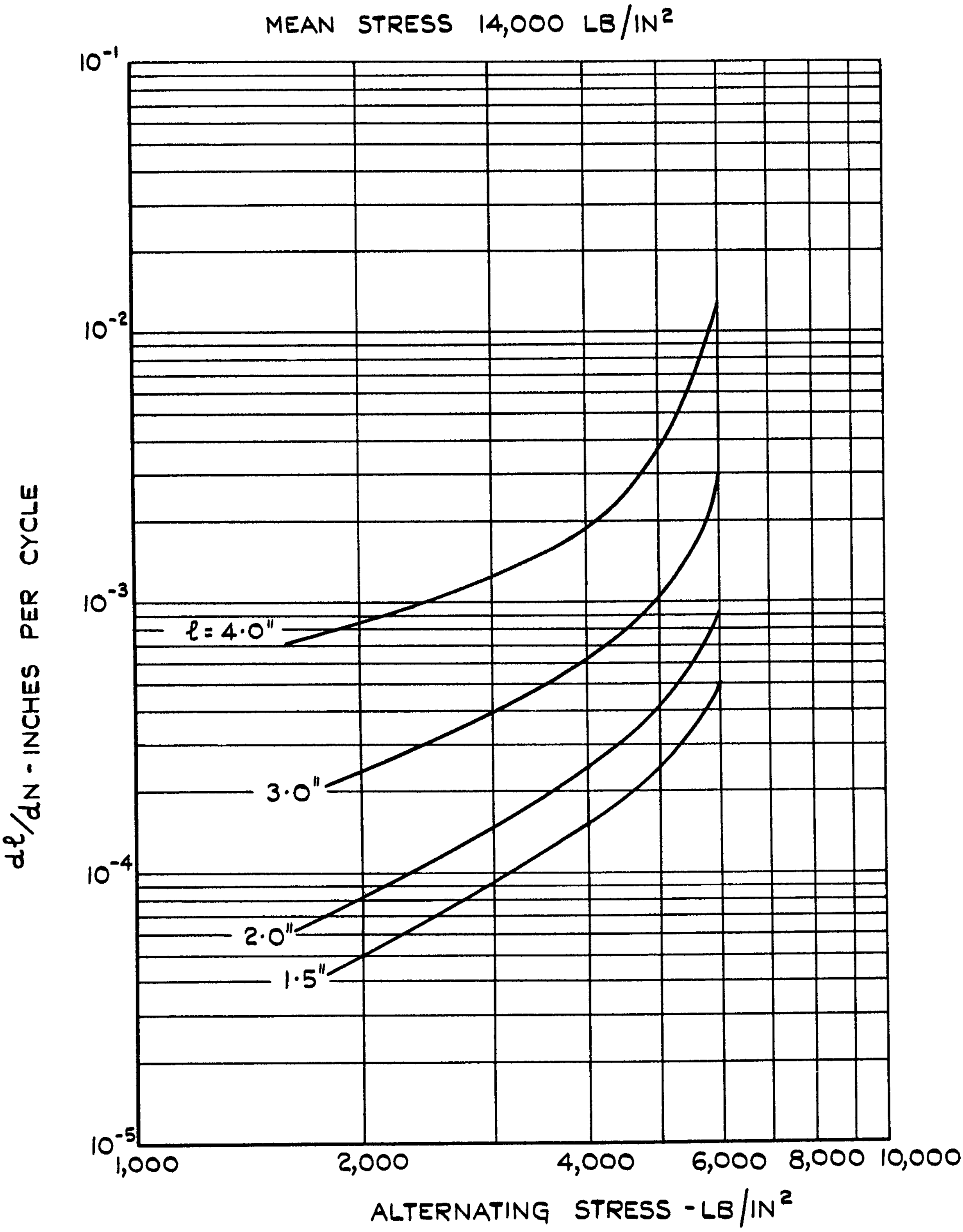

FIG. 6. VARIATION OF $d\ell/dN$ WITH ALTERNATING STRESS - D.T.D. 687.

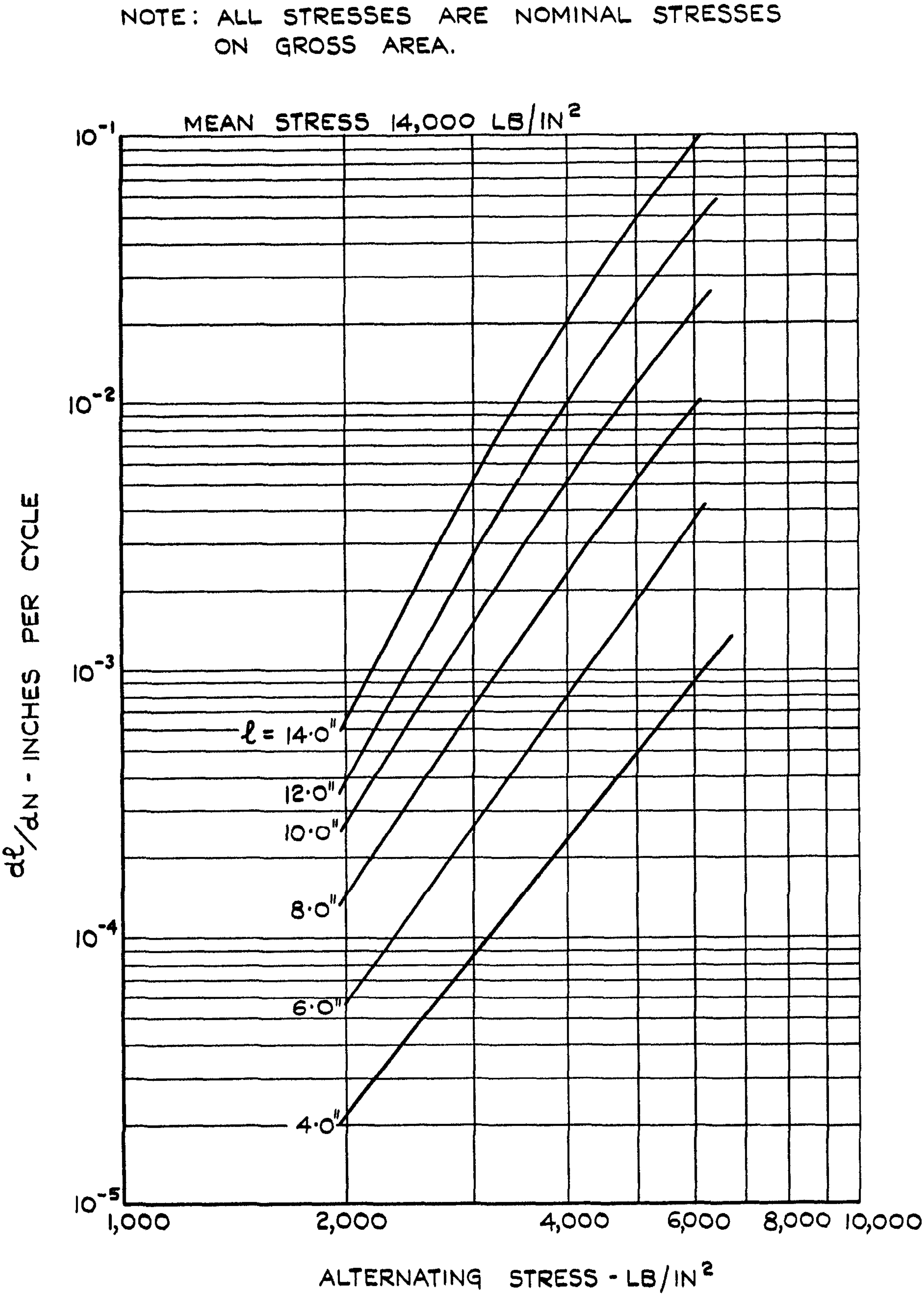

FIG. 7. VARIATION OF $d\ell/dN$ WITH ALTERNATING STRESS - 2024-T3.

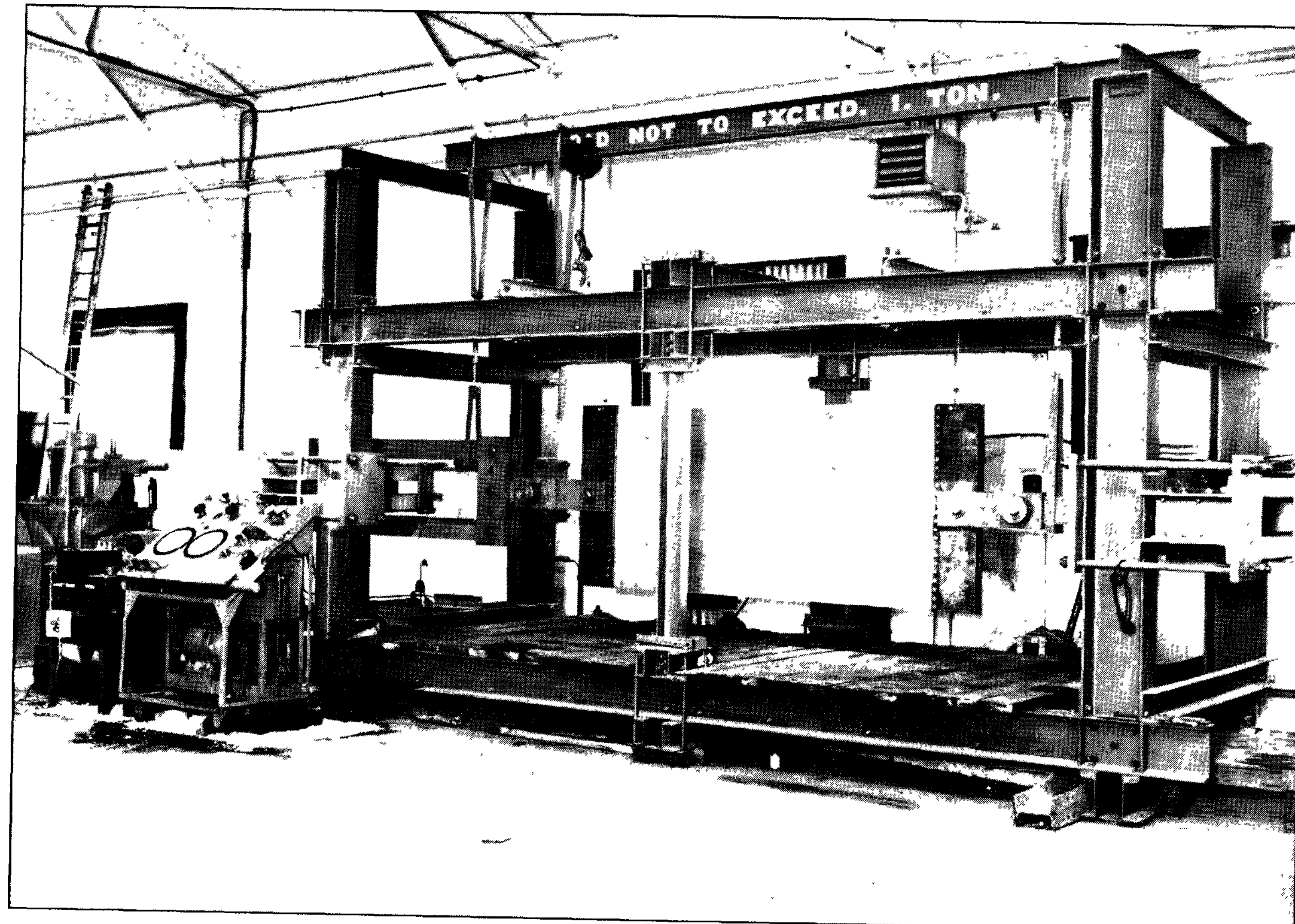

FIG.8. GENERAL VIEW OF TEST RIG

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539.431 :
669.715-4 :
539.219.2

PROPAGATION OF FATIGUE CRACKS IN WIDE UNSTIFFENED ALUMINIUM ALLOY SHEETS. Raithby, K.D. and Bebb, Marie E.
September, 1961.

Results are given for rates of propagation of fatigue cracks, from an initial central slit up to the length at which the cracks became unstable, for four commonly used aluminium alloys. The test specimens in each case were flat sheets 48 in. wide and approximately 96 in. long and were subjected to fluctuating tensile stresses in a direction parallel to the rolling direction of the sheet. The tests confirmed that the high strength aluminium-zinc alloy has a high rate of crack propagation and a short unstable length compared with aluminium-copper alloys, particularly if the aluminium-copper alloy is in the solution treated state.

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