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The Influence of a Single Application of Heat on Fatigue Crack Propagation in DTD 5070A (RR58) Aluminium Alloy Sheet

by

F. E. Kiddle

Structures Dept., R.A.E., Farnborough

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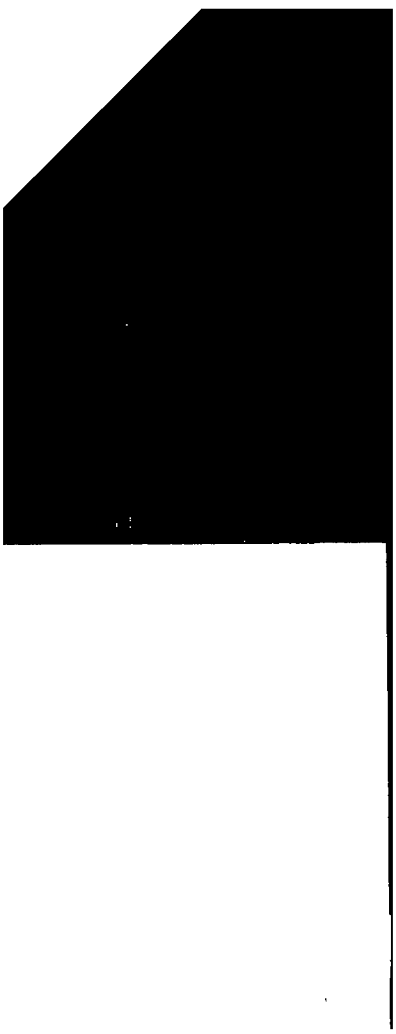

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THE INFLUENCE OF A SINGLE APPLICATION OF HEAT ON FATIGUE CRACK PROPAGATION IN DTD 5070A (RR58) ALUMINIUM ALLOY SHEET

by

F. E. Kiddle

SUMMARY

Tests were conducted to investigate the influence of a single application of heat on fatigue crack propagation in DTD 5070A aluminium alloy sheet. Two possible effects of heat were investigated; the effect of heat on the overall crack propagation characteristics and local effects on the plastically worked material ahead of the crack tip. It is shown that the effect of heating was a slight slowing down of subsequent crack propagation. This is attributed to a change in material properties which modifies the overall crack propagation characteristics. Although no short term effect was detected that could be attributed to a local change in the conditions at the crack tip, under aircraft service conditions, heating occurs many times and the cumulative effect of even small changes in crack propagation rate could be significant.

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* Replaces RAE Technical Report 72108 - ARC 34274

CONTENTS

1 INTRODUCTION

Under the flight conditions of supersonic aircraft, fatigue crack propagation may be influenced by the periodical heating of the structure. In addition to possible changes in the material properties which may affect the overall crack propagation characteristics, it is conceivable that there may be significant effects from changes in the plastically worked material ahead of the crack tip during each heating period such as loss of work hardening and redistribution of stress due to creep.

To investigate the magnitude of these possible effects a programme of crack propagation tests was carried out on DTD 5070A sheet material in which a single application of heat was applied at some stage of the crack propagation to determine the effect on subsequent growth of the crack. It was concluded that the effect of heating was a slight slowing down of subsequent crack propagation, by changing the overall crack propagation characteristics. No short term effect was detected that could be attributed to a local change in the conditions at the crack tip.

2 MATERIAL

The material used in this investigation was a nominally fully heat treated aluminium - 2% copper alloy to specification DTD 5070A. All material was from a single heat treatment batch and was in the form of 16 swg clad sheet. The chemical composition stated by the manufacturer was as follows:

	Fe	Cu	Si	Mn	Mg	Ti	Ni	Zn	Al
Content %	1.06	2.38	0.11	0.03	1.65	0.06	1.15	0.09	Remainder

To check that the material was precipitation heat treated to maximum ultimate strength, tensile specimens were extracted from four sheets selected at random and, after heating for various times at 190°C, the temperature of the original precipitation treatment, were tested statically. The results of these tests are given in Table 1 and Fig.1 shows that any additional heat treatment caused loss in static strength indicating that the material as received was not underaged.

3 SPECIMENS

Six crack propagation panels were extracted from each sheet of material (see Fig.2), the remainder of the sheet being retained to provide tensile specimens. Fig.3 shows the dimensions of the tensile specimen and the crack propagation specimen. The crack propagation specimen had a length to width ratio of 2 and contained a central notch to facilitate crack initiation, consisting of a 3/16 inch hole and a slot of overall length ½ inch cut by a fret saw. The ends of the panels were jig drilled to ensure good alignment with the loading axis. When the panels were positioned in the fatigue machine, the ends were clamped by ⅜ inch diameter high tensile steel bolts between ⅜ inch thick mild steel plate end fittings.

4 FATIGUE TESTS

All specimens were tested in a 20 ton long-base Schenck resonant-fatigue machine under fluctuating tension of constant amplitude at a frequency of approximately 30 c/s and at an average ambient temperature of 20°C. The load amplitude was measured by semiconductor strain gauges attached to the fatigue machine dynamometer and was accurate to within ±3%.

The crack length during the test was recorded continuously using an electrical resistance method[2]. This method involves the attachment of a 0.0005 inch thick, 1.5 inch wide copper foil to the specimen so that as the fatigue crack grows in the specimen, a corresponding crack is produced in the foil (see Fig.4). As the crack grows, the resistance of the gauge increases in proportion to the crack length and by applying a constant current through the foil, the change in resistance can be measured by a millivoltmeter and bridge circuit. This method gives a maximum error of ±4% in the crack length at the shortest crack lengths measured.

In order to get a measure of the scatter in crack propagation characteristics, preliminary tests without heating were conducted on two sheets of material. Two different fatigue alternating stresses, 9000 ±6000 lb/in^2 and 9000 ±2000 lb/in^2 were investigated and 6 specimens were tested at each condition.

To investigate the effect of heat on the crack propagation properties, a single period of heat was applied to each specimen. The period of heat was applied prior to the fatigue test in some specimens and in others, the fatigue test was interrupted by the period of heat when the crack had grown to either 1, 2 or 3 inches in length. Each specimen was compared with two 'cold control' tests on specimens from the same sheet. The period of heat soaking used in all tests was 1000 h at 150 ±2°C. This particular time and temperature condition was chosen to represent the degree of overageing which is typical for a transport aircraft flying at M = 2.2 during a service life including 20000 h at 120°C.

5 METHOD OF ANALYSIS

As described earlier, the crack length gauge provided a continuous record of the change of crack length during a test. From this curve discrete points were read off so that by use of a computer programme, crack growth rates could be evaluated for a number of crack lengths. To obtain crack growth rates for continuous fatigue tests, in general a quartic was fitted to five values of crack length taken in sequence from the crack length *versus* cycles curve and this quartic was used to calculate the slope of the curve at the middle point. This process was repeated for all values of crack length read off the curve with the exception of the two points at each end of the curve for which only four or three points were used to obtain the quartic which best fitted the data.

For specimen tests in which the crack growth was interrupted by a period of heat, it was assumed that the heat would create a discontinuity in the curve of crack rate *versus* cycles if it affected the overall crack propagation characteristics of the material or if there were a short term effect on the material at the crack tip. For greatest sensitivity in detecting a discontinuity, an alternative method of analysis was used which assumed that the rate of crack growth at the mid point between two crack lengths points was equal to the average rate of crack growth between these two crack lengths, i.e. the curve was considered to consist of a series of straight segments.

6 DISCUSSION

The work reported here was initiated to determine whether or not a single period of heat soaking affected the crack propagation characteristics of a material. It was considered that heat could affect crack growth in two possible ways; firstly by changing the metallurgical state of the material by an overageing mechanism and thus altering its resistance to crack growth, and secondly by changing the state of the plastic zone in front of the crack tip and changing the cracking characteristics over a small increment of crack length. To investigate both these possible effects heat was applied either before commencing the fatigue test or at a particular value of crack length during the fatigue test. The former test provided a means of evaluating the effect of heat on material properties and the second test also provided a measure of the effect of heat on the crack tip.

As a preliminary to investigating the effect of heat, a study was made of the scatter in the crack growth properties of the material in the as received condition. Six tests were made at each of the two stress conditions selected for investigation, all the specimens for tests at one stress condition being extracted from the same sheet. Detailed results are given in Tables 2 and 3 and crack growth rate *versus* crack length curves are shown in Figs.5 and 6. From the figures it can be seen that curves obtained from tests at the same stress condition are similar in shape and that for tests under both stress conditions, scatter between specimens is not appreciable at slower crack growth rates than 4×10^{-4} in/cycle.

In assessing the effect of heat soaking on subsequent crack growth, each specimen tested was compared with two specimens from the same sheet tested in the as received condition. Results from these cold control tests are given in Tables 4 and 5 for specimens tested at the higher stress condition and in Tables 7 and 8 for specimens tested at the lower stress condition. Considering first the effect of prior soaking on specimens tested at the higher stress condition, 9000 ±6000 lb/in^2, detailed results are given in Table 6 and curves of crack growth *versus* crack length rate are shown in Figs.7 and 8; each curve being compared with the corresponding cold control curves. In general, the comparisons show that crack propagation is slower in a specimen which has been heat soaked. However, if the results for both cold control specimens and prior heat soaked specimen are compared with results obtained from the scatter tests, it can be seen that any changes in crack propagation rates due to heat are not greater than variations in the rates between six specimens due to inherent scatter in the material. When similar results obtained under the lower stress condition, 9000 ±2000 lb/in^2, are examined (Table 9 and Figs. 9 and 10), it can be seen that the effect of prior heat soaking is even smaller, although there is still a tendency for the crack propagation rate to be reduced by heat.

To investigate whether a period of heat changes the crack growth immediately following heating, three fatigue tests were interrupted by a period of heat at nominal crack lengths of 1, 2 and 3 inches respectively. Detailed results are given in Table 10 and are illustrated in Figs.11-13. In each case, the curve of crack rate *versus* length for the heated specimen is compared with the corresponding cold control curves obtained from two specimens extracted from the same sheet of material. Results show that in all cases the effect of the period of heat was, if anything, small, and subsequent crack growth was similar to that found after heat soaking prior to fatigue.

7 CONCLUDING REMARKS

It is generally concluded that the effect of heating was a slight slowing down of subsequent crack propagation. This is attributed to a change in material properties which modifies the overall crack propagation characteristics. Although no short term effect was detected that could be attributed to a local change in the conditions at the crack tip, under aircraft service conditions, heating occurs many times and the cumulative effect of even small changes in crack propagation rate could be significant.

Table 1

VARIATION IN TENSILE PROPERTIES WITH ADDITIONAL HEAT TREATMENT

Specimen No.	Time at $190^{o}C$ hours	UTS lbs/in^2	0.1% PS lbs/in^2
50307	0	61400	58500
50308	0	61400	58200
50507	0	61400	57800
50508	0	60900	57600
50707	0	60900	57300
50708	0	60900	57300
50807	0	61800	58900
50808	0	61400	58200
50301	1	60900	57800
50501	1	60900	57300
50701	1	60900	57300
50801	1	60900	57300
50302	2	60700	57100
50502	2	60900	57800
50702	2	60300	56400
50303	3	60900	57300
50503	3	60900	57600
50703	3	60000	56400
50803	3	60900	57300
50304	4	61200	56900
50504	4	60900	57300
50704	4	59400	56200
50804	4	60000	56400
50305	7	59800	55100
50505	7	60900	56900
50705	7	59600	55100
50805	7	60900	56700
50306	9	59800	55100
50506	9	60000	55300
50706	9	59600	54700
50806	9	59800	55300

Table 2

VARIATION OF CRACK GROWTH WITHIN A SHEET - FATIGUE STRESS CONDITION 9000 ±6000 lb/in^2

SPECIMEN 51031			SPECIMEN 51032			SPECIMEN 51033		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.044	0.66	-	0.043	0.59	2.22	0.038	0.58	2.22
0.053	0.68	1.48	0.052	0.61	2.22	0.047	0.60	2.22
0.062	0.70	3.33	0.061	0.63	2.22	0.056	0.62	2.22
0.071	0.74	4.63	0.070	0.65	2.13	0.065	0.64	2.13
0.080	0.78	4.44	0.079	0.67	2.78	0.074	0.66	2.78
0.089	0.82	4.26	0.088	0.70	3.33	0.083	0.69	3.33
0.098	0.86	5.46	0.097	0.73	3.98	0.092	0.72	3.98
0.107	0.92	7.41	0.106	0.77	3.98	0.101	0.76	3.89
0.116	0.99	7.87	0.115	0.80	3.06	0.110	0.79	3.80
0.125	1.06	7.59	0.124	0.83	4.44	0.119	0.83	4.35
0.134	1.13	8.70	0.133	0.88	5.65	0.128	0.87	5.46
0.143	1.22	10.9	0.142	0.93	6.11	0.137	0.93	7.32
0.152	1.33	14.4	0.151	0.99	6.67	0.146	1.00	8.43
0.161	1.48	17.5	0.160	1.05	6.76	0.155	1.08	8.89
0.170	1.65	22.1	0.169	1.12	10.6	0.164	1.16	9.07
0.179	1.89	31.4	0.178	1.24	13.4	0.173	1.25	12.2
0.188	2.22	41.0	0.187	1.36	15.4	0.182	1.38	14.7
0.197	2.65	54.0	0.196	1.52	18.7	0.191	1.52	19.2
0.206	3.30	100	0.205	1.70	22.8	0.200	1.73	25.3
0.211	4.00	165	0.214	1.94	30.3	0.209	1.98	32.1
			0.223	2.26	42.3	0.218	2.33	38.9
			0.232	2.73	67.2	0.227	2.85	94.4
			0.241	3.45	88.8	0.234	4.00	246
			0.247	4.00	81.4			

Table 2 (concluded)

SPECIMEN 51034			SPECIMEN 51035			SPECIMEN 51036		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.037	0.59	1.02	0.035	0.62	3.15	0.038	0.57	-
0.046	0.61	2.69	0.044	0.64	1.85	0.047	0.58	1.94
0.055	0.63	1.57	0.053	0.66	2.78	0.056	0.60	2.32
0.064	0.64	1.48	0.062	0.69	3.33	0.065	0.62	2.13
0.073	0.66	2.96	0.071	0.72	3.80	0.074	0.64	2.69
0.082	0.69	2.78	0.080	0.76	5.00	0.083	0.67	3.98
0.091	0.71	2.59	0.089	0.81	6.30	0.092	0.71	4.54
0.100	0.74	3.98	0.098	0.87	6.11	0.101	0.75	4.44
0.109	0.78	4.35	0.107	0.92	5.83	0.110	0.79	4.35
0.118	0.82	5.56	0.116	0.98	7.57	0.119	0.83	4.91
0.127	0.88	6.85	0.125	1.06	10.9	0.128	0.88	6.20
0.136	0.94	6.48	0.136	1.20	13.2	0.137	0.94	6.67
0.145	1.00	7.69	0.145	1.32	14.9	0.146	1.00	7.32
0.154	1.08	9.54	0.154	1.47	17.2	0.155	1.07	7.04
0.163	1.17	10.3	0.163	1.64	23.1	0.164	1.13	7.87
0.172	1.27	13.3	0.172	1.90	33.8	0.173	1.22	12.5
0.181	1.41	15.7	0.181	2.26	43.3	0.182	1.35	14.6
0.190	1.56	20.8	0.190	2.78	82.2	0.191	1.48	15.1
0.199	1.79	27.6	0.199	4.00	208	0.200	1.63	19.4
0.208	2.06	34.7				0.209	1.83	23.6
0.217	2.43	44.0				0.218	2.06	30.1
0.226	2.93	75.3				0.227	2.37	34.5
0.235	4.00	178				0.236	2.70	44.0
						0.245	3.22	74.9
						0.253	4.00	121

Table 3

VARIATION OF CRACK GROWTH WITHIN A SHEET - FATIGUE STRESS CONDITION 9000 ±2000 lb/in^2

SPECIMEN 51041			SPECIMEN 51042			SPECIMEN 51043		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.716	0.60	-	0.723	0.64	0.340	0.357	0.68	0.092
0.888	0.62	0.271	1.317	0.81	0.502	0.633	0.73	0.249
1.060	0.67	0.271	1.661	0.96	0.369	0.873	0.80	0.334
1.232	0.71	0.257	1.970	1.08	0.552	1.080	0.88	0.485
1.404	0.76	0.281	2.211	1.25	0.819	1.321	1.02	0.563
1.576	0.81	0.378	2.452	1.47	0.946	1.596	1.17	0.706
1.748	0.89	0.489	2.693	1.73	1.42	1.905	1.47	1.13
1.920	0.97	0.388	2.830	1.95	1.72	2.146	1.79	1.59
2.092	1.03	0.446	2.968	2.20	1.83	2.284	2.04	2.11
2.264	1.13	0.654	3.071	2.40	2.27	2.387	2.28	2.56
2.436	1.25	0.727	3.174	2.67	2.75	2.456	2.46	2.43
2.608	1.38	0.795	3.277	2.97	3.28	2.525	2.63	3.06
2.780	1.53	1.00	3.381	3.35	3.71	2.576	2.81	3.64
2.952	1.73	1.33	3.415	3.49	4.51	2.628	3.00	3.63
3.124	1.98	1.45	3.449	3.68	7.07	2.662	3.13	4.29
3.296	2.24	1.88	3.484	4.00	10.7	2.714	3.40	5.66
3.450	2.57	1.97	3.518	4.50	17.9	2.765	3.72	7.21
3.519	2.72	2.76	3.536	4.95	39.3	2.800	4.00	8.79
3.571	2.88	3.16	3.553	5.94	78.0	2.834	4.36	9.67
3.622	3.04	2.98	3.557	6.30	89.6	3.869	4.98	9.13
3.657	3.15	3.78				2.886	5.85	152
3.691	3.30	4.70				2.891	6.80	248
3.726	3.47	4.99						
3.760	3.65	6.14						
3.794	3.88	6.58						
3.812	4.00	6.97						
3.829	4.13	8.66						
3.846	4.30	10.9						
3.863	4.52	17.3						
3.880	4.90	27.0						
3.898	5.43	29.7						

Table 3 (concluded)

SPECIMEN 51044			SPECIMEN 51045			SPECIMEN 51046		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.970	0.66	0.388	1.045	0.65	0.197	0.872	0.59	0.017
1.348	0.78	0.303	1.423	0.76	0.360	1.182	0.63	0.199
1.658	0.89	0.427	1.836	0.93	0.470	1.457	0.69	0.230
2.071	1.12	0.684	2.180	1.12	0.711	1.732	0.76	0.321
2.346	1.33	0.783	2.559	1.45	0.869	2.042	0.89	0.497
2.518	1.48	1.08	2.868	1.75	1.25	2.420	1.12	0.755
2.690	1.70	1.30	3.143	2.21	2.27	2.695	1.36	0.962
2.862	1.94	1.74	3.212	2.37	2.23	2.936	1.62	1.27
2.948	2.10	1.81	3.281	2.53	2.67	3.108	1.86	1.33
3.034	2.26	2.14	3.350	2.75	3.68	3.280	2.13	2.34
3.120	2.48	2.97	3.418	3.04	4.14	3.366	2.36	2.79
3.206	2.77	3.62	3.487	3.42	9.65	3.452	2.62	3.49
3.292	3.11	4.16	3.522	3.80	9.29	3.521	2.89	4.30
3.378	3.57	7.38	3.591	4.35	12.0	3.572	3.13	4.94
3.555	7.18	41.6	3.608	4.62	19.1	3.624	3.42	6.80
			3.625	5.09	20.5	3.658	3.68	8.16
			3.642	6.11	139	3.693	3.98	8.83
			3.652	8.27	342	3.727	4.33	13.1
						3.762	4.98	15.9
						3.779	5.50	54.3
						3.793	6.77	136

Table 4

CRACK PROPAGATION TESTS WITHOUT HEAT

FATIGUE STRESS:- 9000 ±6000 lb/in^2

SPECIMEN 51071			SPECIMEN 51076		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.036	0.56	0.833	0.054	0.57	1.81
0.054	0.58	1.57	0.072	0.61	2.55
0.072	0.62	2.87	0.090	0.66	3.01
0.090	0.68	3.29	0.108	0.72	3.84
0.108	0.74	4.07	0.126	0.80	5.00
0.126	0.83	5.65	0.144	0.90	6.24
0.144	0.94	5.65	0.162	1.02	6.15
0.162	1.06	10.4	0.171	1.08	8.39
0.171	1.17	13.4	0.180	1.17	10.5
0.180	1.30	15.5	0.189	1.27	13.2
0.189	1.45	18.0	0.198	1.41	16.5
0.198	1.63	22.6	0.207	1.57	20.5
0.207	1.87	31.6	0.216	1.79	27.8
0.216	2.22	39.0	0.225	2.10	42.7
0.225	2.76	100	0.234	2.65	86.8
0.232	4.00	267	0.245	4.20	218

Table 5

CRACK PROPAGATION TESTS WITHOUT HEAT

FATIGUE STRESS:- 9000 ±6000 lb/in^2

SPECIMEN 51081			SPECIMEN 51086		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.061	0.57	8.07	0.108	0.52	5.51
0.101	0.66	2.28	0.126	0.62	5.51
0.118	0.73	6.13	0.144	0.72	5.79
0.135	0.86	8.78	0.162	0.84	8.94
0.142	0.92	8.38	0.180	1.03	9.72
0.152	1.00	8.50	0.189	1.12	11.8
0.169	1.20	17.8	0.198	1.24	13.4
0.179	1.40	17.5	0.207	1.36	13.9
0.189	1.56	18.3	0.216	1.50	18.6
0.202	1.90	32.0	0.225	1.70	24.9
0.213	2.28	39.5	0.234	1.95	30.9
0.219	2.60	58.9	0.243	2.27	35.7
0.229	3.60	156	0.252	2.72	77.2
			0.261	4.00	232

Table 6

CRACK PROPAGATION TESTS WITH PRIOR APPLICATION OF HEAT

FATIGUE STRESS:- 9000 ±6000 lb/in^2

SPECIMEN 51072			SPECIMEN 51082		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack Growth rate (10^{-5} in/cycle)
0.045	0.54	0.509	0.054	0.55	0.648
0.063	0.56	1.53	0.072	0.58	2.22
0.081	0.59	1.71	0.090	0.62	2.13
0.099	0.62	1.53	0.108	0.66	3.06
0.117	0.65	2.50	0.126	0.73	3.94
0.135	0.71	3.43	0.144	0.80	4.49
0.153	0.77	3.33	0.162	0.89	4.63
0.171	0.84	5.65	0.180	0.97	5.23
0.189	0.97	7.08	0.198	1.09	8.19
0.207	1.09	7.08	0.216	1.27	11.7
0.225	1.24	10.4	0.234	1.52	15.6
0.243	1.47	14.6	0.252	1.88	27.3
0.261	1.77	18.8	0.261	2.17	36.1
0.279	2.18	28.1	0.270	2.56	43.4
0.288	2.47	36.6	0.279	3.19	121
0.297	2.86	49.2	0.286	4.70	326
0.306	3.43	84.3			
0.311	4.00	131			

Table 7

CRACK PROPAGATION TESTS WITHOUT HEAT

FATIGUE STRESS:- 9000 ±2000 lb/in^2

SPECIMEN 51051			SPECIMEN 51056		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
1.068	0.60	0.150	1.218	0.53	-
1.240	0.62	0.276	1.390	0.58	0.131
1.412	0.67	0.266	1.562	0.61	0.266
1.584	0.71	0.291	1.734	0.67	0.276
1.756	0.77	0.325	1.906	0.70	0.145
1.928	0.82	0.305	2.078	0.73	0.271
2.100	0.88	0.417	2.250	0.79	0.286
2.272	0.96	0.426	2.422	0.83	0.339
2.444	1.03	0.509	2.594	0.91	0.484
2.616	1.14	0.712	2.766	0.99	0.446
2.788	1.27	0.766	2.938	1.07	0.586
2.960	1.41	0.984	3.110	1.19	0.669
3.132	1.61	1.18	3.282	1.30	0.741
3.304	1.83	1.61	3.454	1.45	0.930
3.390	1.98	1.80	3.626	1.62	1.09
3.476	2.14	1.95	3.798	1.83	1.31
3.562	2.32	2.28	3.970	2.10	2.11
3.631	2.49	2.62	4.056	2.30	2.39
3.700	2.69	3.52	4.142	2.51	2.54
3.751	2.88	3.00	4.211	2.69	2.61
3.803	3.03	4.38	4.262	2.83	2.97
3.837	3.21	5.39	4.314	3.00	3.51
3.872	3.40	5.98	4.365	3.20	4.59
3.906	3.62	6.43	4.400	3.37	4.94
3.941	3.84	6.44	4.434	3.54	4.86
3.975	4.07	7.01	4.469	3.73	7.36
3.992	4.19	7.23	4.486	3.87	8.31
4.009	4.32	8.27	4.503	4.02	9.88
4.027	4.50	12.5	4.520	4.21	11.4
4.044	4.78	20.1	4.537	4.41	11.9
4.061	5.27	41.8	4.555	4.64	17.0
4.078	6.40	98.5	4.572	5.00	24.3
			4.589	5.43	23.5

Table 8

CRACK PROPAGATION TESTS WITHOUT HEAT

FATIGUE STRESS:- 9000 ±2000 lb/in^2

SPECIMEN 51061			SPECIMEN 51066		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
1.619	0.62	0.337	0.967	0.60	0.085
1.935	0.70	0.241	1.290	0.68	0.349
2.257	0.80	0.386	1.999	0 90	0.211
2.551	0.92	0.278	2.448	1.00	0.373
2.777	0.98	0.476	2.670	1.10	0.511
2.967	1.10	0.613	2.902	1.23	0.591
3.128	1.20	0.766	3.096	1.35	0.655
3.257	1.31	0.744	3.289	1.49	0.874
3.451	1.43	0.900	3.483	1 68	0.932
3.580	1.57	1.04	3.612	1.80	1.03
3.709	1.70	1.13	3.741	1 95	1.26
3.838	1.87	1.46	3 870	2.13	1.64
3.967	2.08	1.82	3.999	2.37	1.88
4.096	2 35	2.56	4.128	2.62	2.23
4.160	2.52	2.47	4.257	2.96	3.01
4.225	2.67	2.31	4.386	3.40	3.63
4.289	2.83	2.74	4.450	3.66	4.80
4.354	3.04	4.11	4.515	4.02	6.25
4.418	3.36	5.48	4.547	4.23	6.22
4.483	3.73	5.42	4 579	4.45	8.70
4.515	3.92	6.83	4.612	4.83	14.7
4.547	4.20	11.1	4.644	5.45	25.1
4.579	4.67	18.1	4.676	6.56	45.7
4.612	5.43	30.5			
4.628	6.00	40 9			

Table 9

CRACK PROPAGATION TESTS WITH PRIOR APPLICATION OF HEAT

FATIGUE STRESS:- 9000 ±2000 lb/in^2

SPECIMEN 51052			SPECIMEN 51062		
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth rate (10^{-5} in/cycle)
0.973	0.56	0.053	1.166	0.58	-
1.145	0.58	0.179	1.338	0.59	-
1.317	0.62	0.276	1.510	0.63	-
1.489	0.67	0.252	1.682	0.78	-
1.661	0.71	0.315	1.854	0.83	0.266
1.833	0.78	0.422	2.026	0.89	0.383
2.005	0.85	0.392	2.198	0.96	0.397
2.177	0.92	0.489	2.370	1.03	0.494
2.349	1.02	0.610	2.542	1.13	0.591
2.521	1.13	0.727	2.714	1.23	0.601
2.693	1.27	0.833	2.886	1.34	0.683
2.865	1.42	1.01	3.058	1.47	0.882
3.037	1.62	1.22	3.230	1.64	0.959
3.209	1.84	1.35	3.402	1.81	1.28
3.381	2.11	2.07	3.574	2.08	1.53
3.467	2.30	2.08	3.746	2.34	1.73
3.553	2.48	2.46	3.832	2.50	2.01
3.622	2.67	2.86	3.918	2.68	2.03
3.691	2.87	3.02	3.987	2.82	2.24
3.743	3.03	2.97	4.056	2.99	2.53
3.777	3.14	4.11	4.107	3.13	3.36
3.811	3.30	3.92	4.159	3.32	3.01
3.846	3.41	3.79	4.193	3.42	3.82
3.880	3.57	5.03	4.228	3.58	4.63
3.897	3.66	5.51	4.262	3.73	4.31
3.915	3.76	6.06	4.297	3.89	5.20
3.932	3.87	6.78	4.331	4.12	9.91
3.949	4.00	8.82	4.348	4.30	8.96
3.966	4.18	12.0	4.365	4.44	9.06
3.983	4.42	15.9	4.383	4.64	15.4
4.001	4.76	29.7	4.400	4.97	20.9
4.018	5.36	33.6	4.417	5.37	26.9
4.035	5.56	-	4.434	5.97	46.0

Table 10

CRACK PROPAGATION TESTS INTERRUPTED BY A SINGLE APPLICATION OF HEAT

FATIGUE STRESS - 9000 ±2000 lb/in^2

SPECIMEN 51053				SPECIMEN 51054			
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth* rate (10^{-5} in/cycle)	Associated* crack length (in)	Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth* rate (10^{-5} in/cycle)	Associated* crack length (in)
1.273	0.56	-	-	0.597	0.57	-	-
1.651	0.58	0.053	0.57	0.975	0.59	0.053	0.58
1.995	0.61	0.087	0.595	1.388	0.64	0.121	0.615
2.270	0.66	0.182	0.635	1.732	0.73	0.262	0.685
2.528	0.70	0.155	0.68	1.973	0.79	0.249	0.76
2.821	0.75	0.171	0.725	2.248	0.87	0.291	0.83
3.027	0.82	0.340	0.785	2.454	0.95	0.388	0.91
3.199	0.88	0.349	0.85	2.661	1.03	0.386	0.99
3.454	0.98	0.392	0.93	2.902	1.15	0.498	1.09
1000 h at 150°C heat applied				3.142	1.29	0.583	1.22
0.000	0.98	-	-	3.383	1.45	0.664	1.37
0.172	1.06	0.465	1.02	3.555	1.61	0.930	1.53
0.344	1.17	0.640	1.115	3.727	1.78	0.988	1.695
0.516	1.29	0.698	1.23	3.875	2.00	1.49	1.89
0.688	1.46	0.988	1.375	1000 h at 150°C heat applied			
0.826	1.60	1.01	1.53	0.000	1.97	-	-
0.963	1.72	0.876	1.66	0.036	2.03	1.67	2.00
1.101	1.92	1.45	1.82	0.070	2.10	2.06	2.065
1.238	2.14	1.61	2.03	0.105	2.17	2.00	2.135
1.376	2.40	1.88	2.27	0.139	2.22	1.47	2.195
1.479	2.70	2.91	2.55	0.174	2.29	2.00	2.255
1.548	2.94	3.48	2.82	0.208	2.35	1.76	2.32
1.617	3.24	4.35	3.09	0.242	2.41	1.76	2.38
1.686	3.61	5.36	3.425	0.277	2.51	2.86	2.46
1.720	3.82	5.59	3.715	0.311	2.59	2.35	2.55
1.754	4.08	7.65	3.95	0.346	2.65	1.71	2.62
1.789	4.31	6.57	4.195	0.380	2.72	2.06	2.685
1.806	4.67	21.2	4.49	0.414	2.82	2.94	2.77
1.823	5.14	27.6	4.905	0.707	4.80	8.28	3.81
1.840	5.95	47.6	5.545	0.715	4.97	21.3	4.885
1.846	6.80	142	6.375	0.724	5.26	32.2	5.115
				0.733	5.66	44.4	5.46
				0.741	6.45	98.8	6.055
				0.743	6.90	225	6.675

*Crack growth rate derived by method of segments (see section 5)

Table 10 (concluded)

SPECIMEN 51055			
Number of cycles (10^5 cycles)	Total crack length (in)	Crack growth* rate (10^{-5} in/cycle)	Associated* crack length (in)
0.416	0.58	-	-
0.760	0.60	0.058	0.59
1.207	0.62	0.045	0.61
1.448	0.66	0.166	0.64
1.689	0.72	0.249	0.69
1.895	0.79	0.340	0.755
2.102	0.84	0.242	0.815
2.343	0.92	0.332	0.88
2.583	1.02	0.417	0.97
2.824	1.16	0.581	1.09
3.031	1.27	0.531	1.215
3.271	1.41	0.583	1.34
3.443	1.56	0.872	1.485
3.615	1.72	0.930	1.64
3.787	1.91	1.10	1.815
3.959	2.14	1.34	2.025
4.131	2.47	1.92	2.305
4.303	2.83	2.09	2.65
4.491	3.33	2.66	3.08
1000 h at 150°C heat applied			
0.000	3.27	-	-
0.017	3.36	5.29	3.315
0.034	3.44	4.71	3.40
0.052	3.53	5.00	3.485
0.069	3.62	5.29	3.575
0.086	3.70	4.71	3.66
0.103	3.82	7.06	3.76
0.120	3.94	7.06	3.88
0.138	4.07	7.22	4.005
0.155	4.21	8.24	4.14
0.172	4.38	10.0	4.295
0.189	4.64	15.3	4.51
0.206	4.94	17.6	4.79
0.224	5.40	25.6	5.17
0.236	6.50	91.7	5.95

*Crack growth rate derived by method of segments (see section 5)

REFERENCES

No.	Author	Title, etc.
1	J.R. Heath-Smith F.E. Kiddle	Influence of ageing and creep on fatigue of structural elements in an Al 6% Cu alloy. RAE Technical Report 67093 (ARC 29543) (1967)
2	F.E. Kiddle T.J. Carter	An electrical resistance method of measuring fatigue crack growth by using an attached metallic foil. RAE Technical Report 70155 (ARC 32872) (1970)

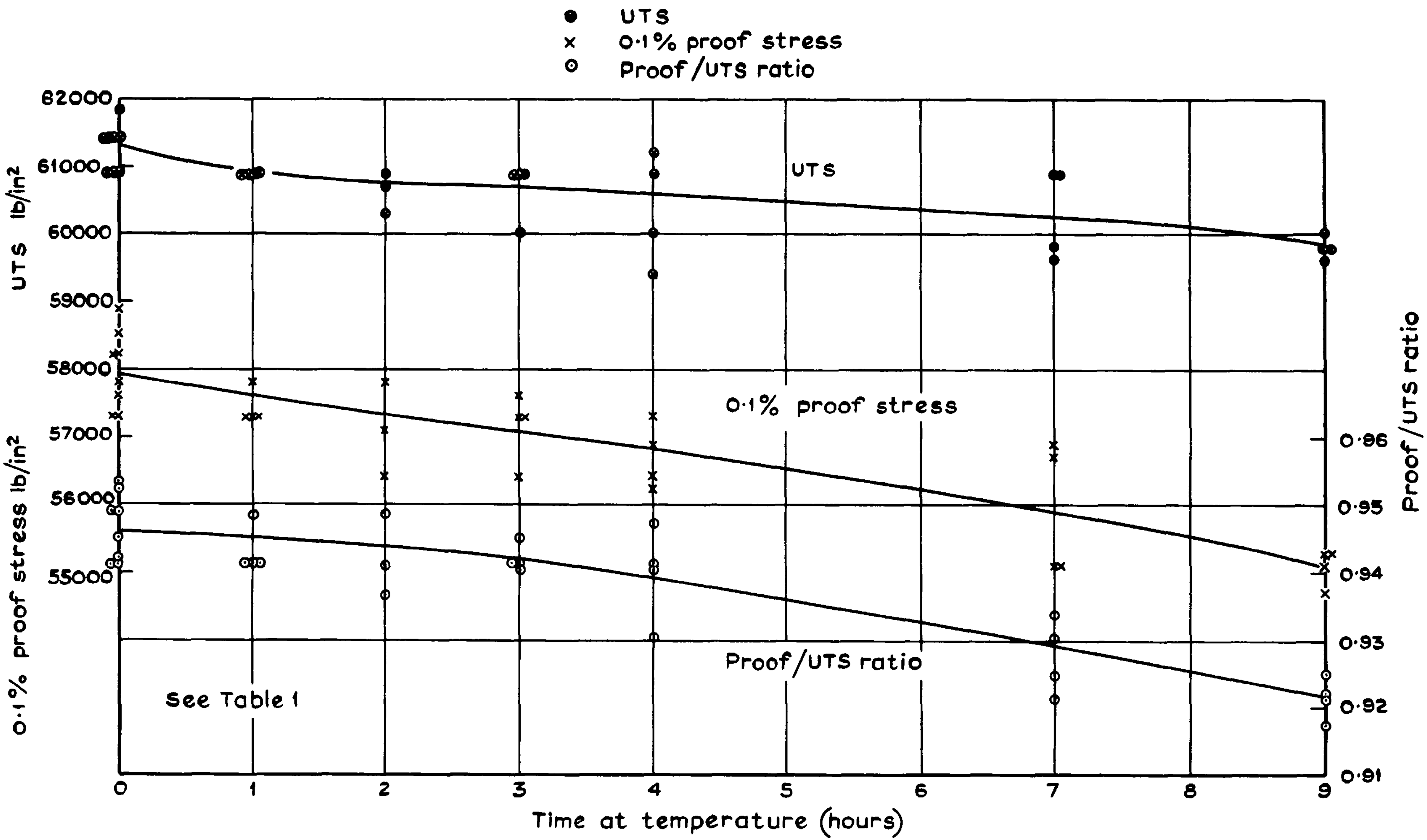


Fig. 1 Variation of tensile properties with additional heating at 190°C

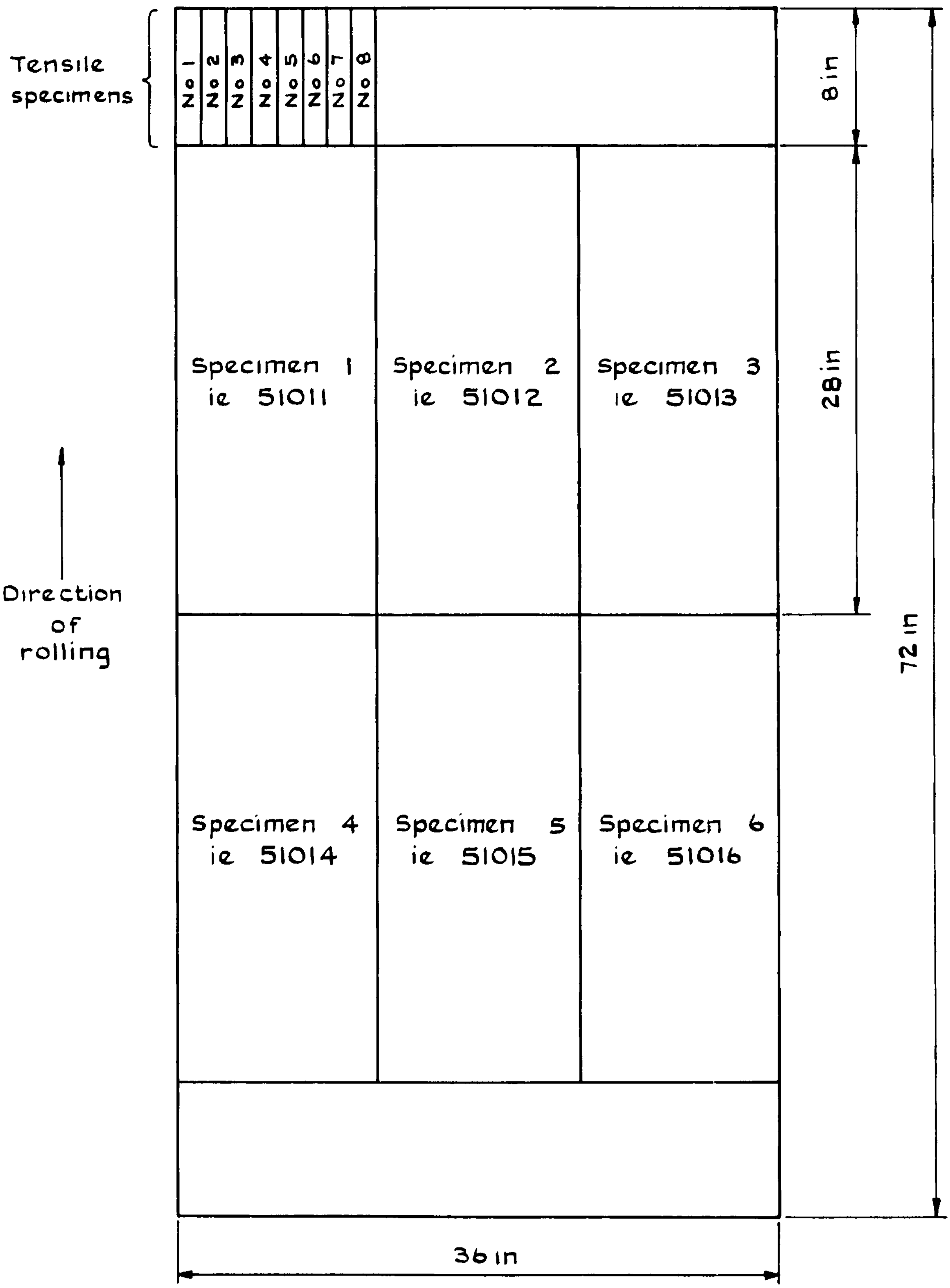
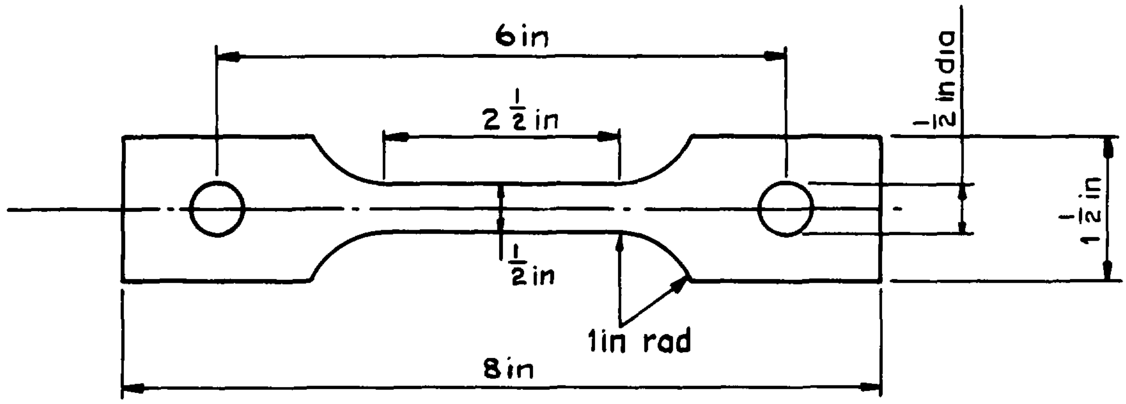
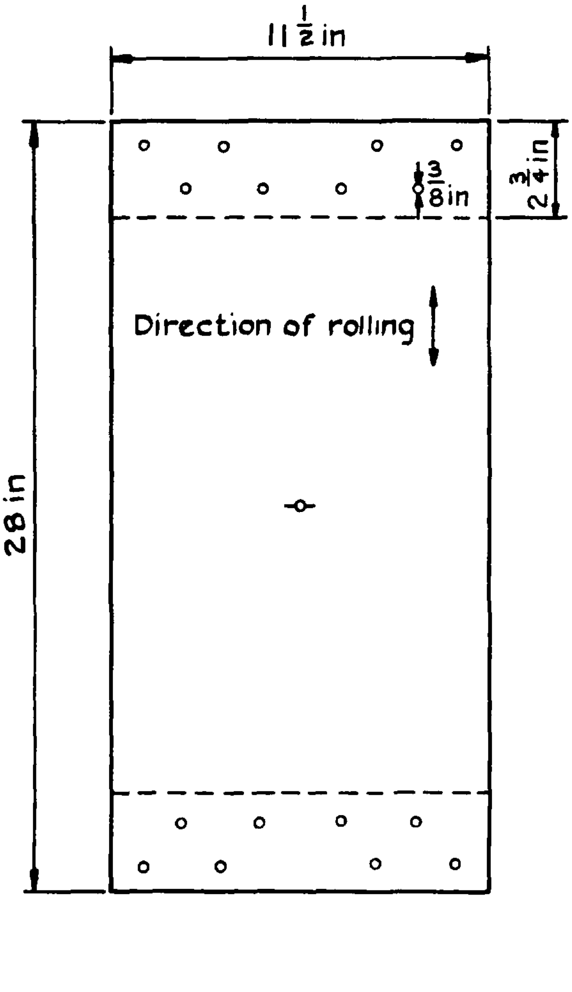


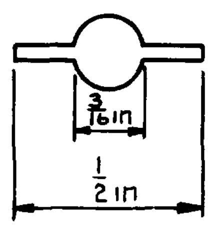
Fig. 2 Position of specimens in sheet



Tensile test piece



Crack propagation panel



Notch

Fig. 3 Test specimens

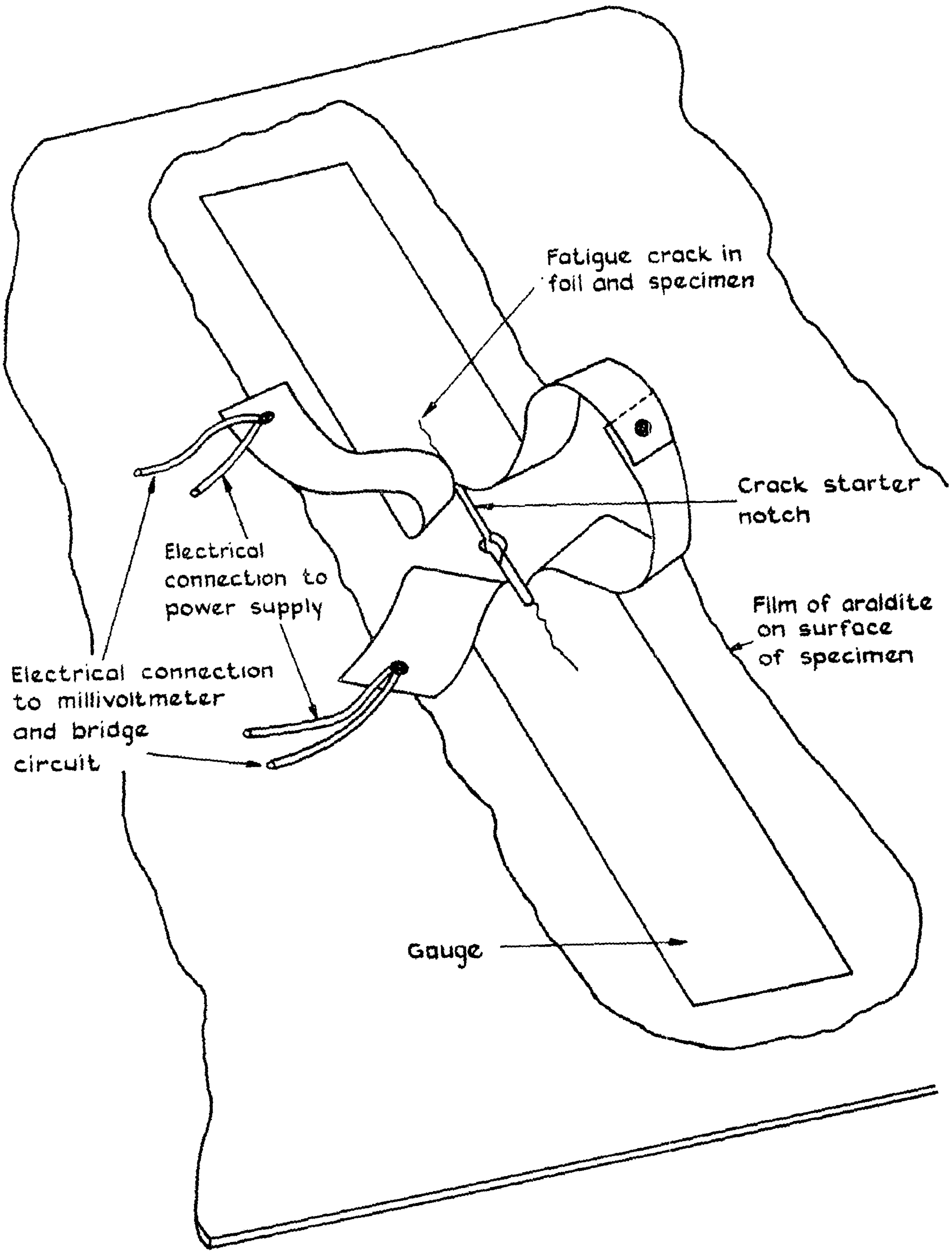


Fig. 4 Crack length gauge–schmatic diagram
symmetrical use of a pair about a centre crack

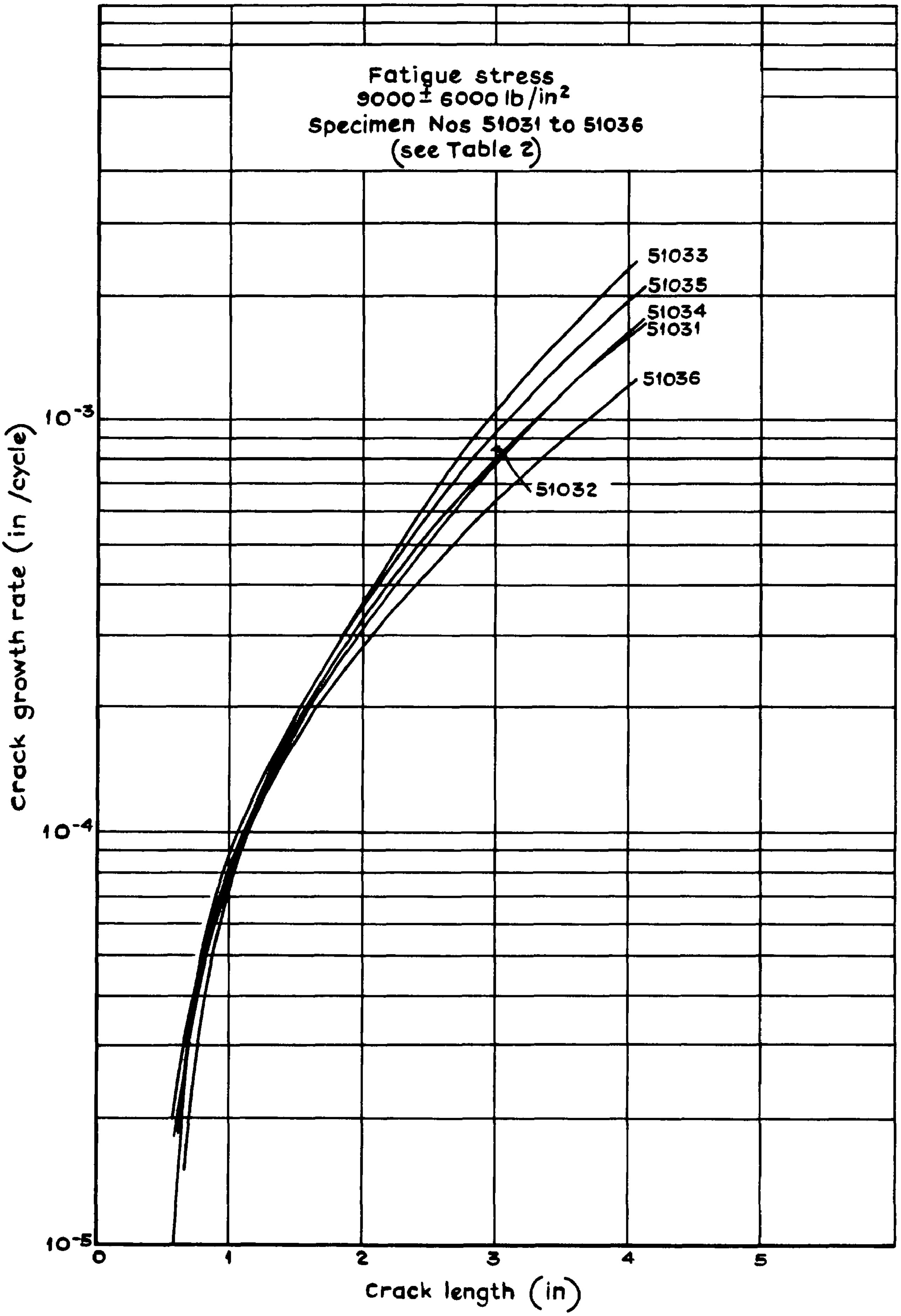


Fig. 5 Variation in crack growth within a sheet

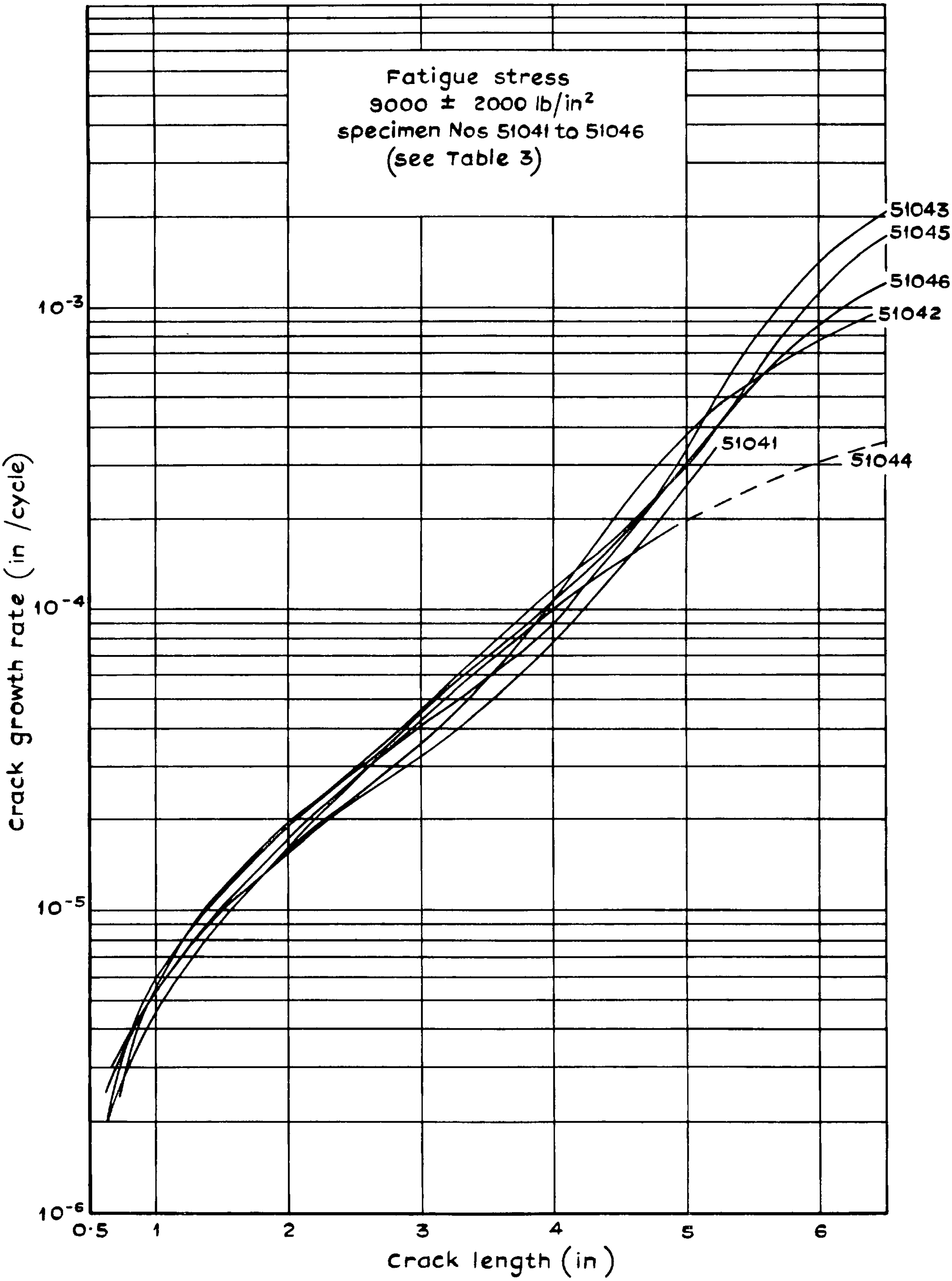


Fig. 6 Variation in crack growth within a sheet

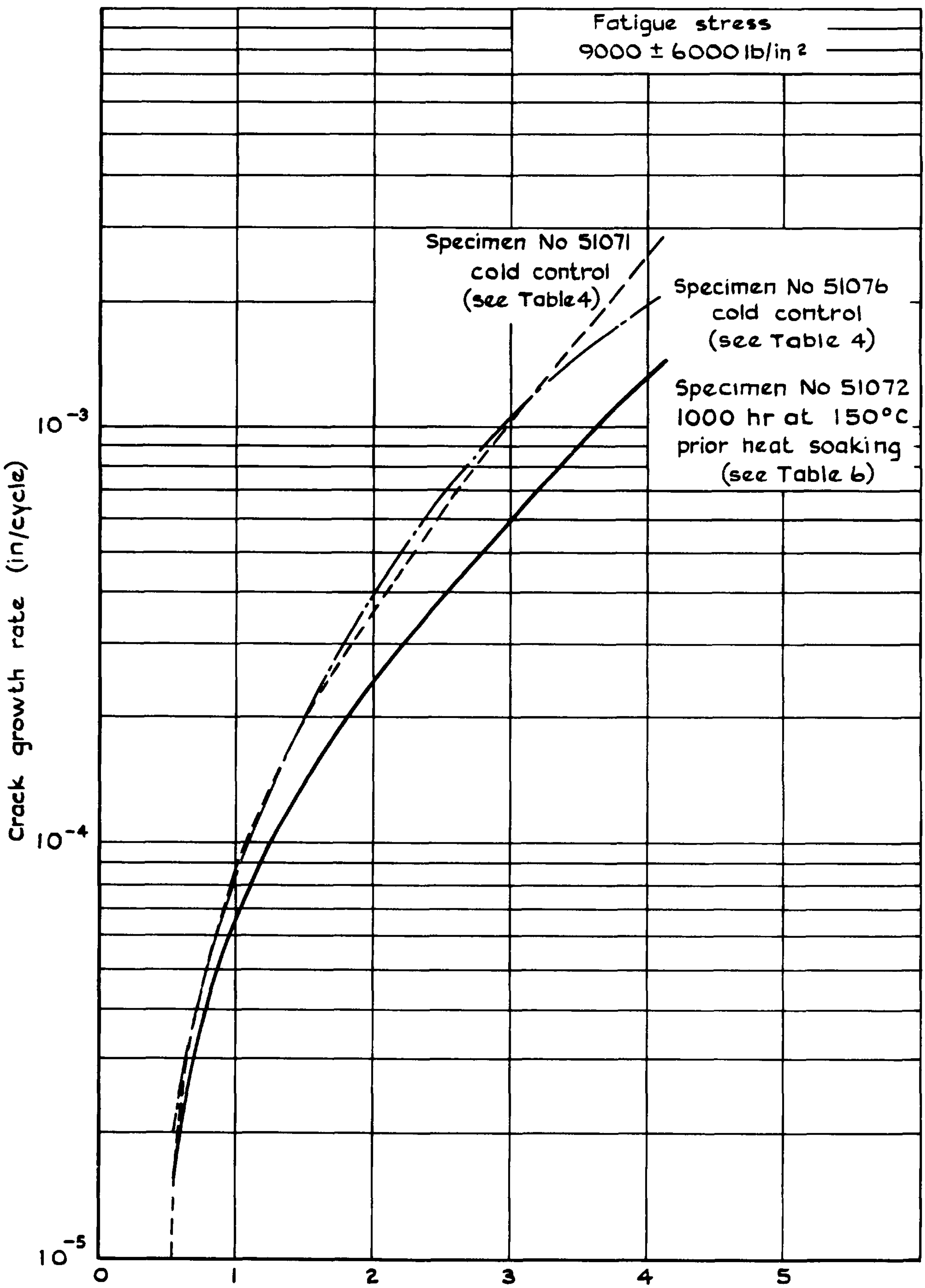


Fig. 7 Effect of a period of heat applied prior to fatigue test

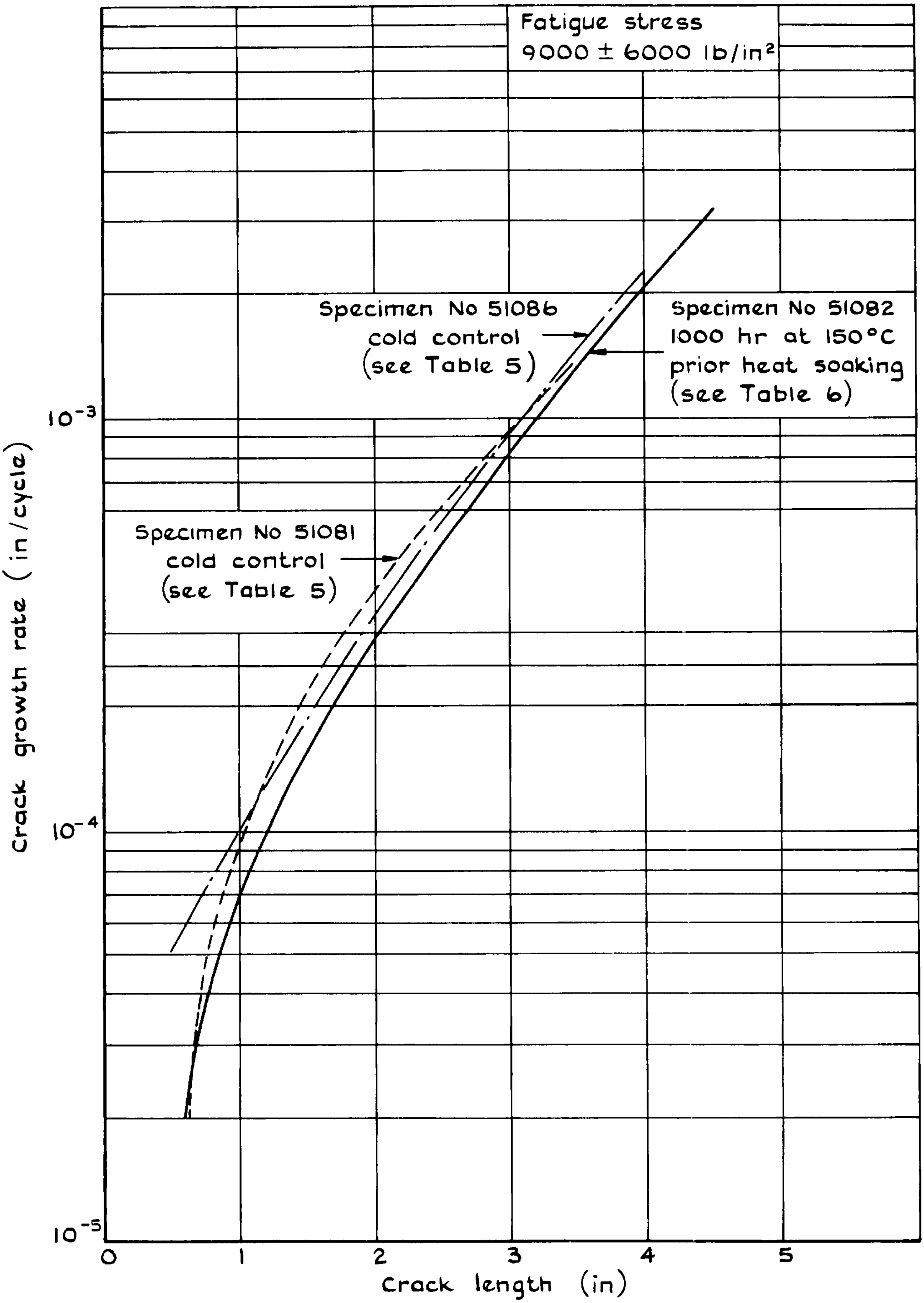


Fig. 8 Effect of a period of heat applied prior to fatigue test

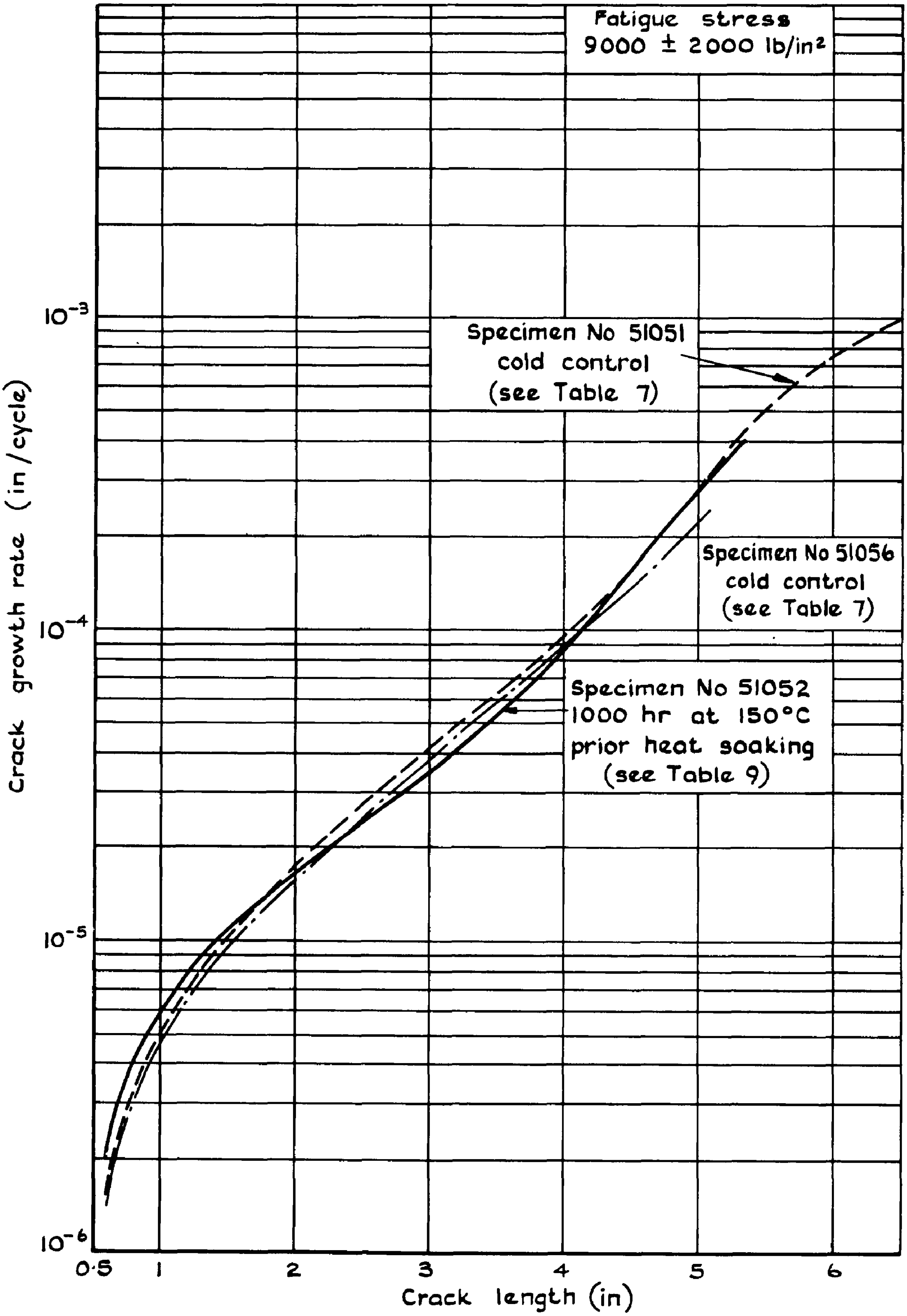


Fig. 9 Effect of a period of heat applied prior to fatigue test

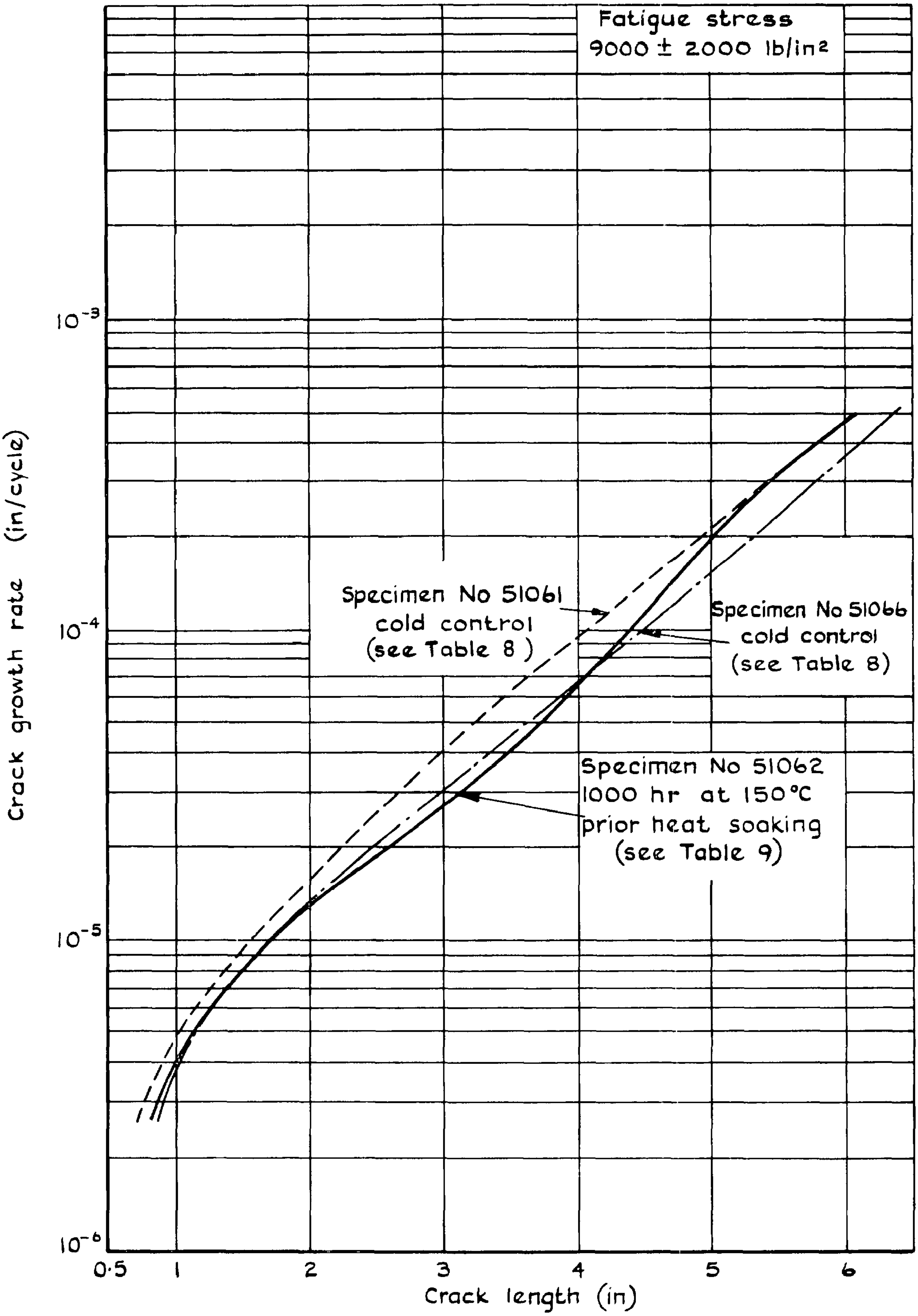


Fig.10 Effect of a period of heat applied prior to fatigue test

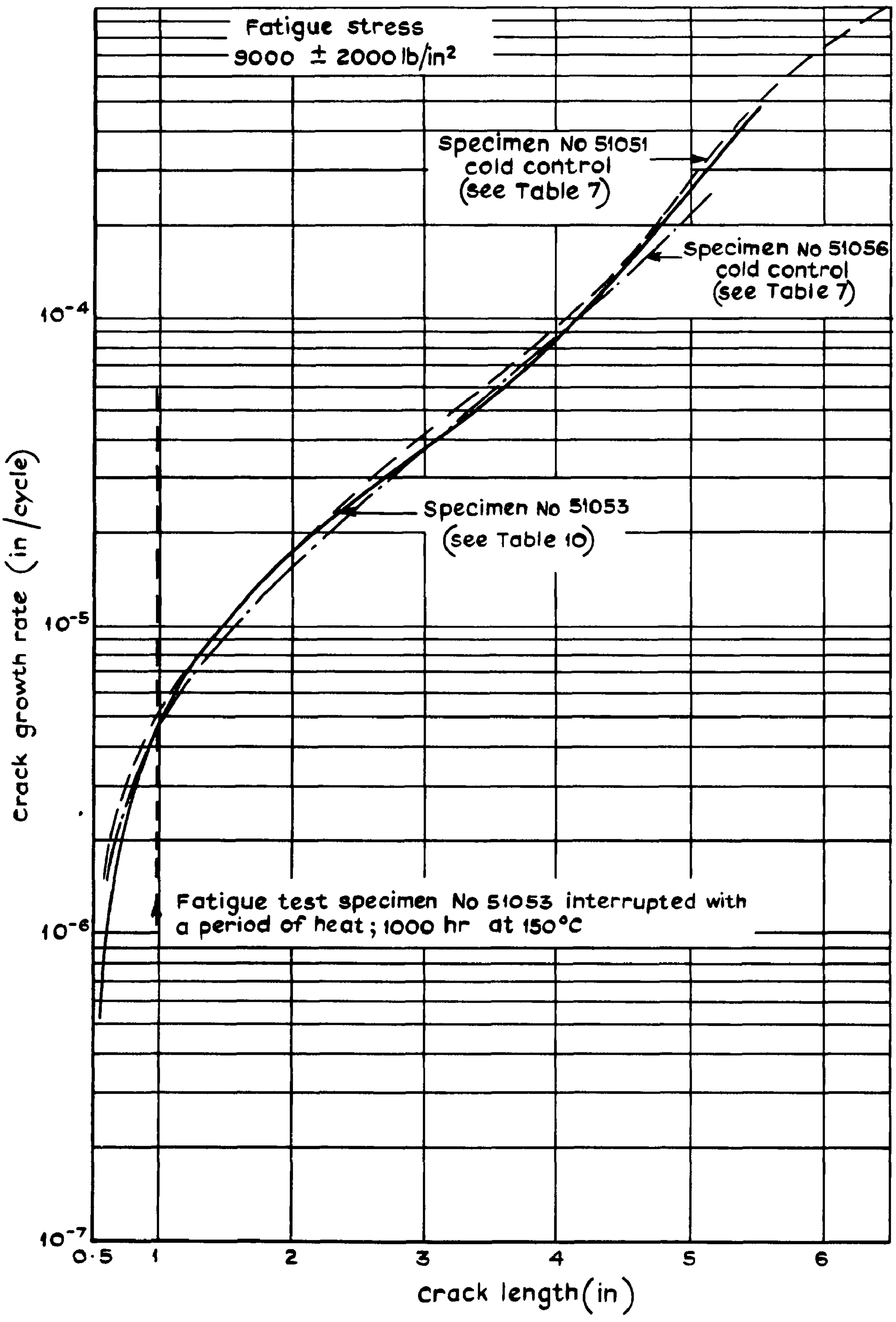


Fig. 11 Effect of heat applied when specimen has a 1 inch fatigue crack

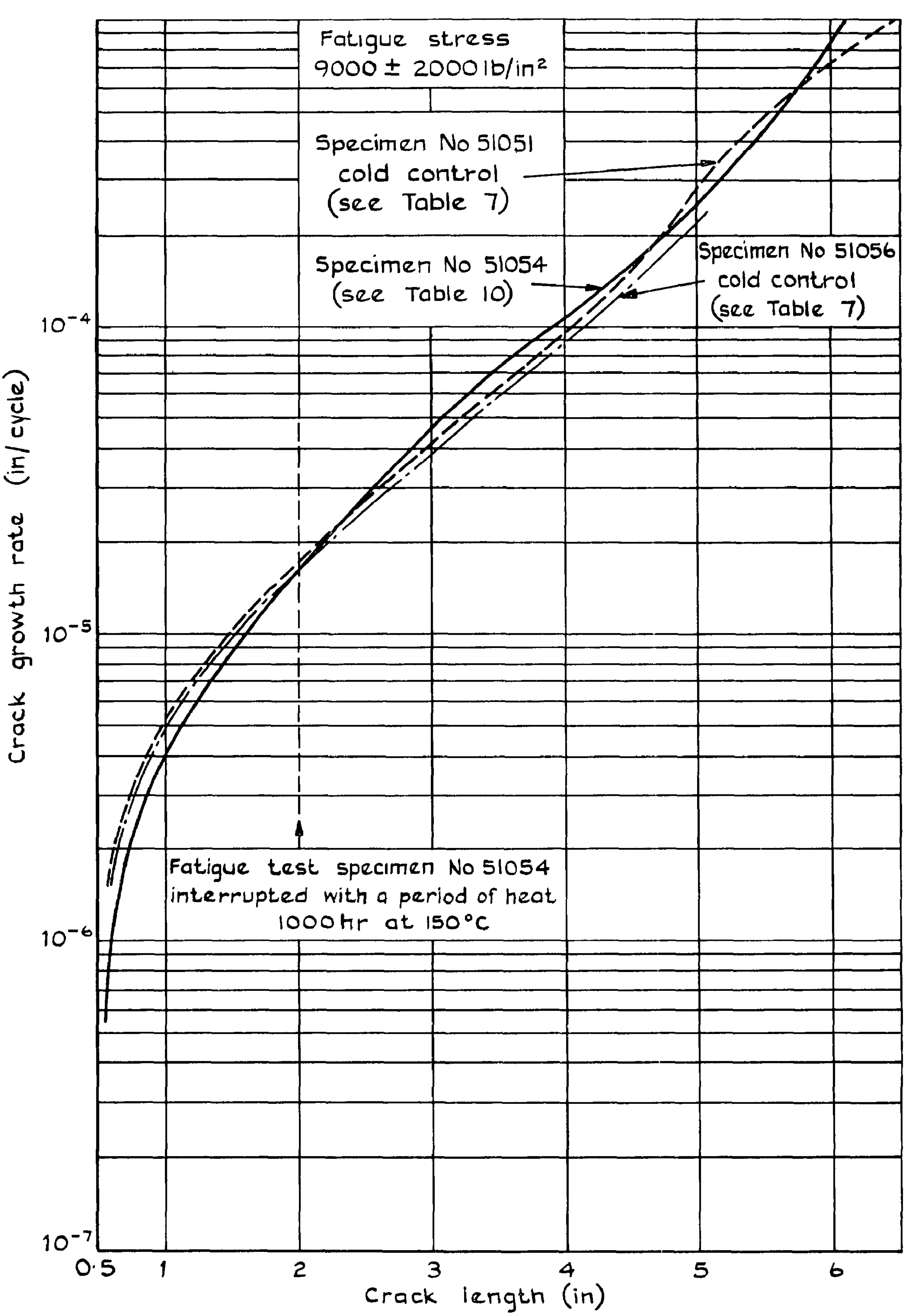


Fig. 12 Effect of heat applied when specimen has a 2 inch fatigue crack

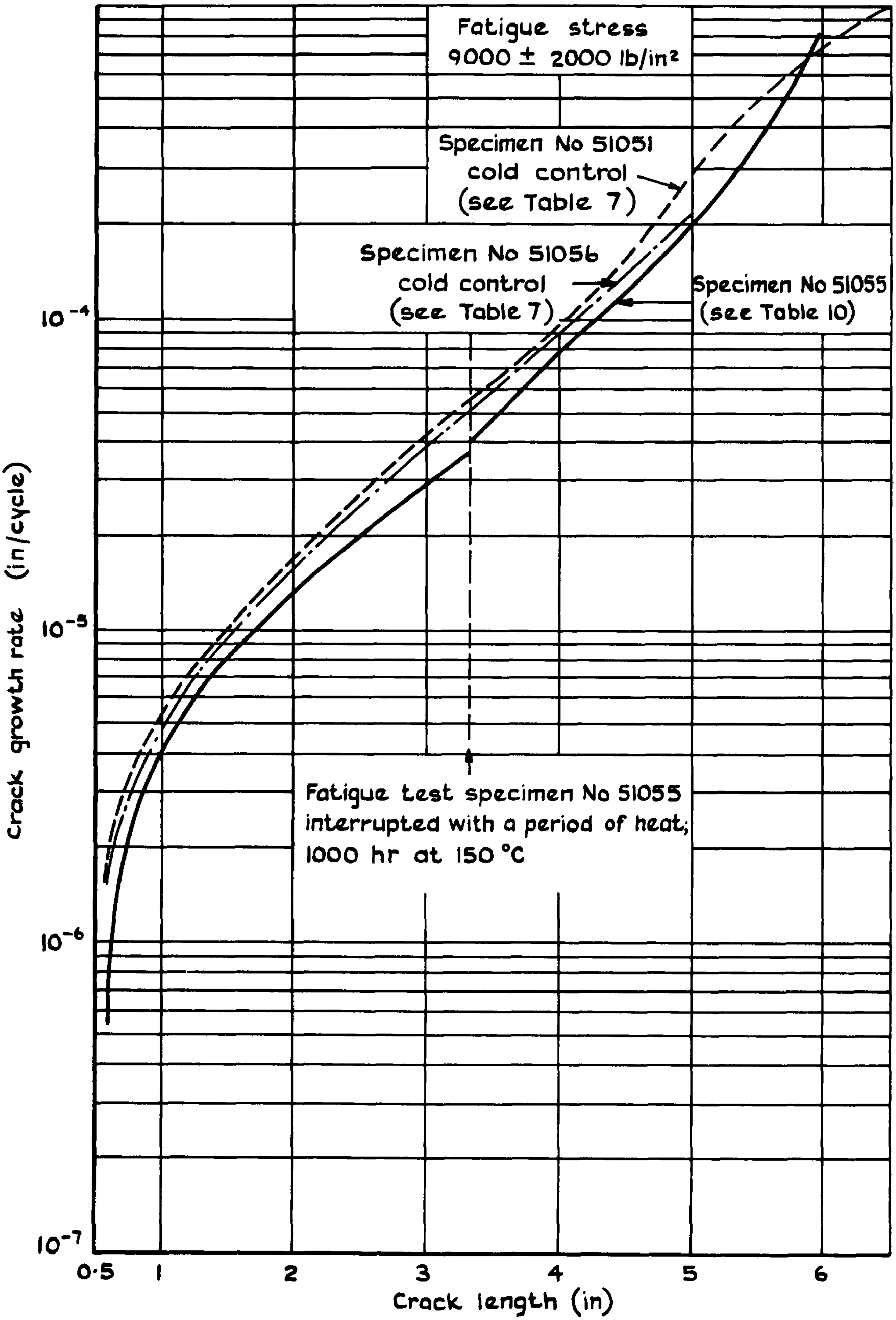


Fig. 13 Effect of heat applied when specimen has a 3·3 inch fatigue crack

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THE INFLUENCE OF A SINGLE APPLICATION OF HEAT ON FATIGUE CRACK PROPAGATION IN DTD 5070A (RR58) ALUMINIUM ALLOY SHEET

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