The SAE Cumulative Fatigue Damage Test Program

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FOREWORD

The current Fatigue Design & Evaluation Committee, Cumulative Fatigue Damage Division, is a continuation of a group originally organized in 1962 under ISTC Division 4. This group consisted mostly of engineers from the ground vehicle industry involved in component stress analysis and durability testing.

The original objective of the group was to exchange information on methods of testing and life estimation, and to develop inter-industry cooperation for further understanding of complex fatigue problems.

Since one of the major unknowns was the effect of occasional overloads on life, early test programs were designed to provide insight into this phenomena. While this insight was valuable, the data was not generally applicable for fatigue life analysis and lacked "realness" for many members of the committee. Also, during this same time, additional methods of fatigue analysis and more complex lab equipment became available such that actual service load histories could be applied to laboratory specimens or components and life predictions could be made using reological material models and digital computers. From this capability, grew a plan to test a component under real load histories and compare the test results to cumulative damage fatigue life estimates. The data base will also be useful in determining the acceptability of testing techniques such as accelerating frequency or eliminating "insignificant" cycles.

It is important to emphasize that there was no intention in this plan to establish standard load histories or spectra for components, specimen, or material life evaluation. The load histories selected are simply typical of ground vehicle industry histories but are in no way all inclusive. The testing program conducted was limited. The considerable cost of this test program was borne by the following companies or universities who provided test time.

A. O. Smith Corporation

Battelle Memorial Institute
Caterpillar Tractor Company
Deere & Company
Ford Motor Company
General Motors
Massey Ferguson
MTS Systems Corporation
Rexnord
University of Illinois
University of Waterloo

INTRODUCTION

In early 1970, a test program was designed to provide a set of basic data for determining the validity of various fatigue life prediction methods. Three variable amplitude load histories were obtained from service strain-time histories submitted by committee members. Each history was reduced to digital form and one pass through the digital sequence was considered one block. A test program was conducted using a notched member containing many of the complexities of actual components and incorporating two steels commonly used in the ground vehicle industry. Basic material properties data was generated for both materials. In addition, constant amplitude tests were performed on the "component like" specimen to provide basic load-life data including processing and manufacturing effects. The variable amplitude test program consisted of 57 individual tests using the three histories at several load levels. Test load levels were scaled to provide fatigue lives ranging from less than 2 blocks to more than 100,000 blocks (2.6×10^8 reversals).

This report is a documentation of the test program. It includes an analysis of the service load histories, a discussion of the specimen design, a list of the basic material and component properties, and analysis of the variable amplitude test results.

ABSTRACT

Results of the SAE Fatigue Design and Evaluation Committee, Cumulative Damage Division test program are reported. This includes a description of the test specimen geometry, variable amplitude load histories, material properties and fatigue data. The data set produced can be used to generally evaluate methods of fatigue life prediction and laboratory simulation.

LOAD HISTORIES

In selecting the load histories to be used for the test program, over 30 different analog records of load of strain measurements from components operating under actual service conditions were examined. Vehicles involved were tractors, farm implements, and automobiles. From these 30 histories, three were selected as being representative of a wide variety of actual operating conditions. (Fig. 1) These load histories selected were:

1. A load history with primarily compressive mean load obtained from the bending moment on a vehicle *suspension* component driven over an accelerated durability course. This history provided a mixture of random excitation with superimposed maneuver forces.

2. A vibration with nearly constant mean load obtained on a mounting *bracket* being excited by vehicle operation over a rough road. This vibration represents an almost classical case of a narrow band random vibration.

3. A load history with a drastic change of a mean load obtained from *transmission* torque measured on a tractor engaged in front-end loader work.
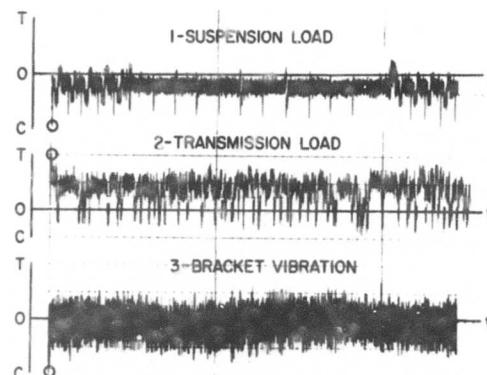

Fig 1 - Amplitude-time delay of service histories

While not all inclusive, these histories were felt to be representative of the "typical" data designers and test engineers in the ground vehicle industry must work with, and were sufficiently different from one another to challenge people who would use the data to check cumulative damage procedures and laboratory simulation methods.

The histories, recorded originally on magnetic tape, were each converted to a digital series of peaks and valleys. While the original sequence of events was preserved, no attempt was made to retain the original frequency content (nominally 1 to 30 hertz). For scaling purposes, the largest peak or valley, (positive or negative voltage) for each history was normalized to a value of $\pm$ 999. Valleys and peaks were then defined as being separated by a range of at least 200. In this way, small ranges (less than 20% of the maximum value) were filtered out of the original analog data with resulting data then reduced to sequences of values which could be applied to the test specimens in a few minutes. The sequence of peaks and valleys, listed in Appendix A, could be used for fatigue tests and life estimates. The character of the three signals can be seen in Figures 2 thru 6 which show the peak, valley and range histograms and cumulative distribution functions. Note that peak and valley plots are counting method independent while the range data shown was obtained from application of a rain flow counting alogarithm (1)*. A rain flow based range-mean matrix is presented in

Appendix B.

In using these three histories and the corresponding fatigue test data, one should keep in mind that these data came from specific short histories and do not take into account the "run to run" variability which is generally present in service usage. Variability of maximum peak has been observed to be as large as 1.6:1 for multiple recordings made over the same route, and should be taken into account in the development of load histories for life estimation or laboratory tests. A technique for estimating the variability of service histories which has general validity involves the use of largest extreme value statistics (2).
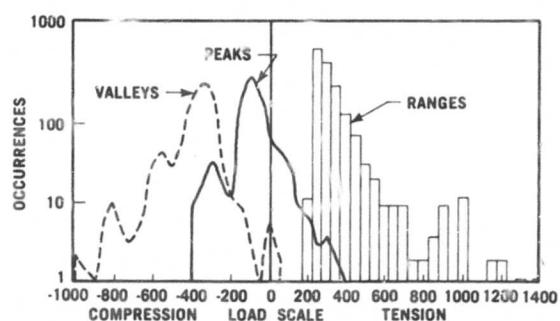
Fig 2 - Suspension histograms
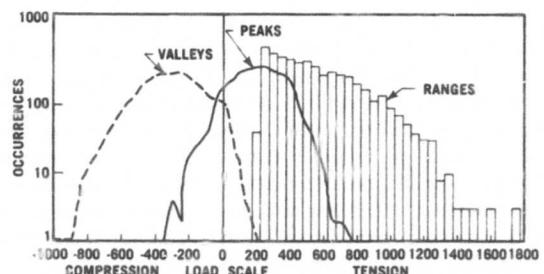
Fig 3 - Bracket histograms
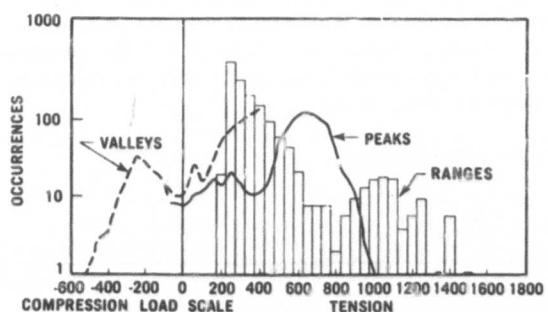
Fig 4 - Transmission histograms

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*Numbers in parenthesis refer to references listed at the end of the text.
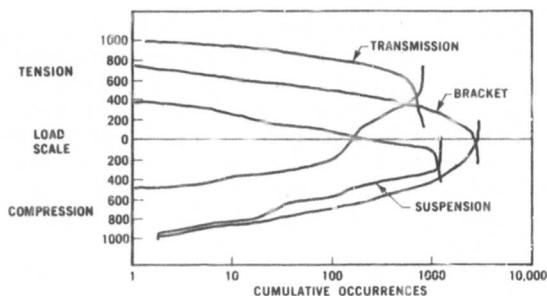
Fig 5 - Cumulative distributions of peaks and valleys
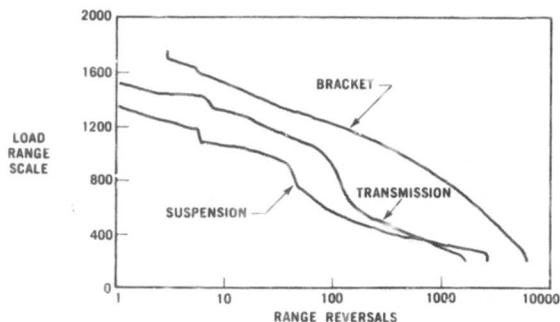
Fig 6 - Cumulative distributions of ranges

crack propagation behavior.

For each alloy, specimens were cut from a single heat of 3/8" hot rolled plate. As indicated in Fig. 7, the rolling direction was parallel to the direction of crack growth (perpendicular to the applied load). The hole was drilled and reamed with no edge preparation and was then saw cut from one side to provide the notch. This left the specimen with a notched condition similar to many production parts.

The materials selected were U.S. Steel's Man-Ten and Bethlehem's RQC-100. A summary of the basic smooth specimen material properties from Appendix C is given in Table 1.

For all notched specimen tests, loads were applied to the "component" thru a close tolerance monoball fixture which allowed both tensile and compressive loading. Figure 9 is a photograph illustrating the loading fixtures.
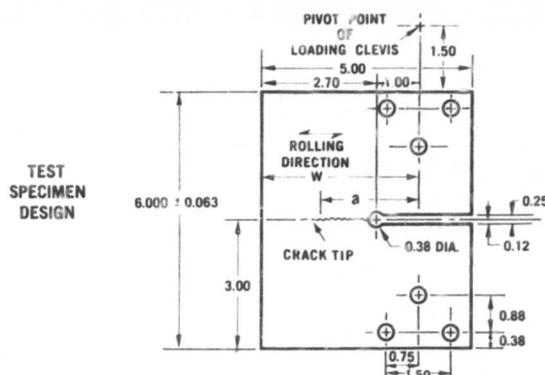
Fig 7 - Test specimen design

SPECIMEN AND MATERIALS

The specimen designed (Fig. 7) for this program was the result of six months of discussion between various members of the committee. It was strongly influenced by known shortcomings of previous designs. It is a compromise design which has the advantages of: 1) being relatively stiff (high strain for low machine deflection); 2) a stress concentration factor and stress state typical of component design practice; 3) having a minimum of critical dimensions and all surfaces either as supplied or as machined; and 4) permitting studies of both crack initiation and crack propagation.

A finite element analysis (3) has been made and results agree with measured strains at the notch root very closely (Fig. 8) thus providing the necessary information for calculation of both crack initiation and

Fig 8 - Comparison of measured & calculated notch root strain

Table 1:   Smooth Specimen Stress-Strain and Fatigue Properties

Property	Man-Ten	RQC-100
Modulus of Elasticity, E	29,500 ksi (203 KN/mm^2)	29,500 ksi (203 KN/mm^2)
Cyclic Strain Hardening Exponent, n'	0.193	0.100
Cyclic Strength Coefficient, k'	160 ksi (1186 N/mm^2)	167 ksi (1151 N/mm^2)
Fatigue Strength Coefficient, σ_f'	133 ksi (930 N/mm^2)	168 ksi (1165 N/mm^2)
Fatigue Strength Exponent, b	−0.095	−0.075
Fatigue Ductility Coefficient, ϵ_f'	0.26	1.06
Fatigue Ductility Exponent, c	−0.47	−0.75
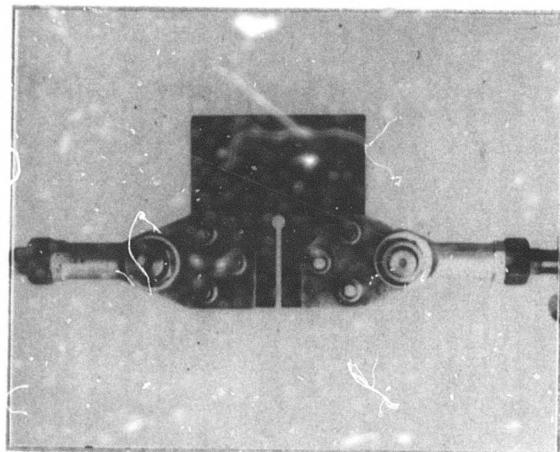
Fig 9 - Loading fixture

CONSTANT AMPLITUDE TEST PROGRAM RESULTS

Constant amplitude fatigue tests were performed to obtain a

load-cycles plot for the "component." Completely reversed loads were applied in 15 tests and zero to maximum in three tests. Life to crack initiation, crack propagation and final fracture are recorded in Tables 2 and 3. Crack initiation was arbitrarily defined as an average crack of 0.1'' (2.54 mm). This definition of crack initiation is arbitrary. However, it does result in a measurable value which is approximately the same size as the defined failure of the smooth polished material specimen. A plot of load range vs. cycles to initiation is shown in Fig. 10. Crack length vs. cycles data were also taken on each specimen. This data is recorded in tabular form in Appendix D.
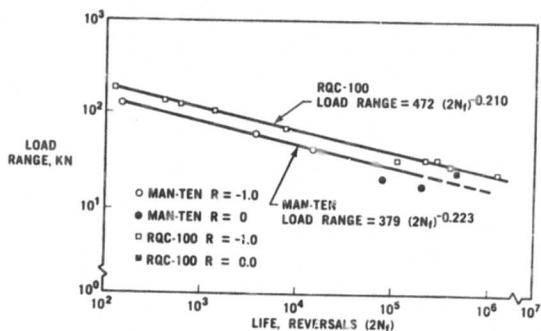
Fig 10 - Constant amplitude load-life plot

Table 2: Constant Amplitude Fatigue Test Results - Man-Ten Steel

Identi-fication Number	Load Maximum lbs.	(KN)	Minimum lbs.	(KN)	Crack, Initiation Reversals	Fatigue Life Crack Propagation Reversals	Total Life* Reversals
8FS	14000	(62.3)	−14000	(−62.3)	144	4	148
9FS	7000	(31.1)	− 7000	(−31.1)	3580	1160	4740
10FS	5000	(22.2)	− 5000	(−22.2)	14400	—	—
5R	6030	(27.0)	995	(4.4)	79000	45000	124000
6R	5030	(23.4)	995	(4.4)	203000	101100	304100
11FS	2000	(8.9)	− 2000	(− 8.9)	—	—	2428000

*Total Life = Crack Initiation + Crack Propagation

Table 3: Constant Amplitude Fatigue Test Results - RQC-100 Steel

Identi-fication Number	Load Maximum lbs.	(KN)	Minimum lbs.	(KN)	Crack Initiation Reversals	Fatigue Life Crack Propagation Reversals	Total Life* Reversals
18FS	20000	(88.9)	−20000	(−88.9)	120	—	—
12FS	15000	(66.7)	−15000	(−66.7)	388	6	394
4CT	14000	(62.3)	−14000	(−62.3)	580	70	650
17FS	12000	(53.4)	−12000	(−53.4)	1300	—	—
13FS	8000	(35.6)	− 8000	(−35.6)	7200	—	—
14FS	4000	(17.8)	− 4000	(−17.8)	110000	61200	171200
3CT	4000	(17.8)	− 4000	(−17.8)	215000	93800	308800
2CT	4000	(17.8)	− 4000	(−17.8)	280000	59000	339000
15FS	3500	(15.6)	− 3500	(−15.6)	400000	101800	501800
7R	7020	(31.2)	995	(4.4)	472000	160000	632000
1CT	3000	(13.3)	− 3000	(−13.3)	1210000	171000	1381000
16FS	3000	(13.3)	− 3000	(−13.3)	—	—	2233120

*Total Life = Crack Initiation + Crack Propagation

VARIABLE AMPLITUDE TEST PROGRAM RESULTS

As previously stated, the three variable amplitude histories were linearly scaled to produce failure from short to long fatigue life. Originally each history was scaled to three levels with three replications of each level for each material (54 test total). For three material-load history combinations, one or two levels were added to give longer life data than obtained with the original test plan resulting in a total of 57 tests. The fatigue life in blocks to crack initiation, blocks of crack propagation and total life are recorded for each test in Tables 4 and 5. Plots of maximum load range* vs. blocks to crack initiation for all tests are presented in Figs. 11 thru 13. Again, crack initiation was arbitrarily defined as an average crack length of 0.1" (2.54 mm). Each specimen

*Maximum load range is defined as the most positive tensile load in the history minus the most negative compressive load in the history. Note these values are not adjacent peak and valley points in the histories but are the largest range as defined by rainflow counting.

Table 4:   Variable Amplitude Fatigue Test Results - Man-Ten Steel

Identi-fication Number	(−) Minimum Load (+) Maximum Load lbs.	(KN)	Load Range lbs.	(KN)	Fatigue Life Crack Initiation Blocks	Crack Propagation Blocks	Total Life** Blocks
SM1-1-FM	−16,000	(−71.2)	21,500	(95.7)	7.7	2.8	10.5
SM1-2-JD	−16,000	(−71.2)	21,500	(95.7)	−	−	(Specimen Buckled)
SM1-3-AOS	−16,000	(−71.2)	21,500	(95.7)	28	20	48
SM2-1-B	− 9,000	(−40.0)	12,100	(53.8)	430*	1,790	2,200
SM2-2-GM	− 9,000	(−40.0)	12,100	(53.8)	208*	357	565
SM2-3-GM	− 9,000	(−40.0)	12,100	(53.8)	162	605	767
SM3-1-FS	− 6,000	(−26.7)	8,060	(35.9)	1,750*	22,858	24,608
SM3-2-FS	− 6,000	(−26.7)	8,060	(35.9)	2,240*	29,644	31,884
SM3-3-W	− 6,000	(−26.7)	8,060	(35.9)	1,410	−	Suspended @ 25,353
SM4-2-MTS	− 4,500	(−20.0)	6,050	(26.9)	4,700	19,966	24,666
SM4-3-MTS	− 4,500	(−20.0)	6,050	(26.9)	−	−	Suspended @ 6,742
SM5-1-FS	− 3,000	(−13.3)	4,030	(17.9)	−	−	Suspended @ 85,370
BM1-1-MTS	−16,000	(−71.2)	27,800	(123.6)	1.5*	0.7	2.2
BM1-2-B	−16,000	(−71.2)	27,800	(123.6)	2.6*	0.3	2.9
BM1-3-AOS	−16,000	(−71.2)	27,800	(123.6)	2	1.0	3
BM2-1-MTS	− 8,000	(−35.6)	13,900	(61.8)	20.8*	11.0	31.8
BM2-2-FM	− 8,000	(−35.6)	13,900	(61.8)	11.5	8.0	19.5
BM2-3-JD	− 8,000	(−35.6)	13,900	(61.8)	23	21.0	44
BM3-1-MTS	− 3,500	(−15.6)	6,080	(27.0)	1,588	3,356	4,944
BM3-2-MTS	− 3,500	(−15.6)	6,080	(27.0)	270	784	1,054
BM3-3-FS	− 3,500	(−15.6)	6,080	(27.0)	510	2,116	2,626
BM4-2-FS	− 3,000	(−13.3)	5,210	(23.2)	−	−	Suspended @ 9,910
BM4-3-MTS	− 3,000	(−13.3)	5,210	(23.2)	2,666	1,410	4,076
BM5-1-FS	− 2,500	(−11.1)	4,340	(19.3)	−	−	Suspended @ 20,630
TM1-1-FM	+16,000	(71.2)	23,900	(106.3)	8.4	0.5	8.9
TM1-2-JD	+16,000	(71.2)	23,900	(106.3)	12.8	3.2	16
TM1-3-W	+16,000	(71.2)	23,900	(106.3)	12.5	1.5	14.0
TM2-1-B	+ 8,000	(35.6)	11,950	(53.2)	420	117	537
TM2-2-GM	+ 8,000	(35.6)	11,950	(53.2)	154	39	193
TM2-3-AOS	+ 8,000	(35.6)	11,950	(53.2)	74	12	86
TM3-1-FS	+ 3,500	(15.6)	5,230	(23.2)	5,800	1,157	6,957
TM3-2-FS	+ 3,500	(15.6)	5,230	(23.2)	4,270*	1,510	5,780
TM3-3-MTS	+ 3,500	(15.6)	5,230	(23.2)	3,755	2,165	5,920

*Estimated from crack propagation data of other repititions of the same test.

**Total Life = Crack Initiation + Crack Propagation

Table 5:   Variable Amplitude Fatigue Test Results - RQC-100 Steel

Identi-fication Number	(-) Minimum Load (+) Maximum Load lbs.	(KN)	Load Range lbs.	(KN)	Crack Initiation Blocks	Fatigue Life Crack Propagation Blocks	Total Life*** Blocks
SR-1-FM	−16,000	(−71.2)	21,500	(95.7)	19.9	7.6	27.5
SR1-2-JD	−16,000	(−71.2)	21,500	(95.7)	24.4	75.6	100
SR1-3-AOS	−16,000	(−71.2)	21,500	(95.7)	64	154	218
SR-1-B	− 9,000	(−40.0)	12,100	(53.8)	–	–	Suspended @ 3,300**
SR2-2-GM	− 9,000	(−40.0)	12,100	(53.8)	1,710	–	Suspended @ 5,535
SR3-2-FS	− 7,000	(−31.1)	9,400	(41.8)	11,200	39,924	51,124
SR4-1-FS	− 6,000	(−26.7)	8,060	(35.9)	48,000	–	Suspended @ 106,732
BR1-1-FS	−16,000	(−71.2)	27,800	(123.6)	3.3*	2.0	5.3
BR1-2-B	−16,000	(−71.2)	27,800	(123.6)	5.1*	2.3	7.4
BR1-3-MTS	−16,000	(−71.2)	27,800	(123.6)	4.2	2.4	6.6
BR2-1-FS	− 8,000	(−35.6)	13,900	(61.8)	87.5*	98.5	186
BR2-2-FM	− 8,000	(−35.6)	13,900	(61.8)	47.0	61	108
BR2-3-JD	− 8,000	(−35.6)	13,900	(61.8)	113	99	212
BR3-1-MTS	− 3,500	(−15.6)	6,080	(27.0)	2,673	5,000	7,673
BR3-3-FS	− 3,500	(−15.6)	6,080	(27.0)	5,020	7,499	12,519
TR1-1-B	+16,000	(71.2)	23,900	(106.3)	29.9	5.7	35.6
TR1-2-AOS	+16,000	(71.2)	23,900	(106.3)	23.5	2.5	26
TR1-3-W	+16,000	(71.2)	23,900	(106.3)	22.2	1.8	24
TR2-1-FM	+ 8,000	(35.6)	11,950	(53.2)	269	28	297
TR2-2-JD	+ 8,000	(35.6)	11,950	(53.2)	460*	60	520
TR2-3-GM	+ 8,000	(35.6)	11,950	(53.2)	374	62	436
TR3-1-FS	+ 3,500	(15.6)	5,230	(23.2)	–	–	57,090
TR3-2-MTS	+ 3,500	(15.6)	5,230	(23.2)	–	–	Suspended @ 88,020
TR3-3-MTS	+ 3,500	(15.6)	5,230	(23.2)	–	–	Suspended @ 88,020

*Estimated from crack propagation data of other repititions of the same test.
**Small non-propagating crack present.
***Total Life = Crack Initiation + Crack Propagation
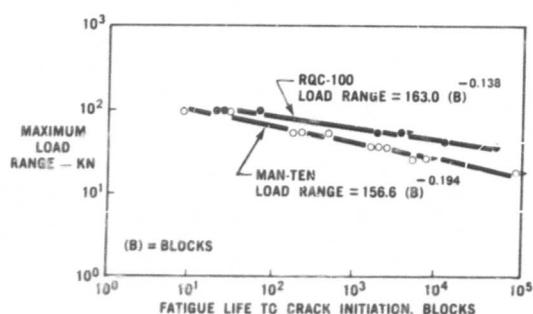
Fig 11 - Fatigue life plot for suspension history
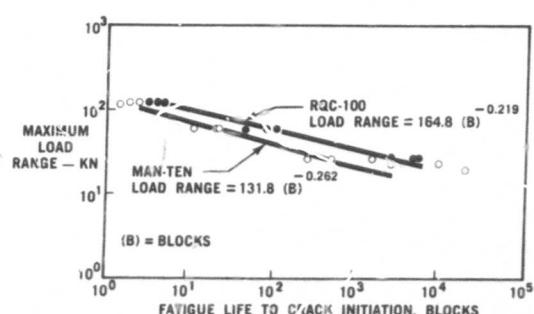
Fig 12 - Fatigue life plot for bracket history
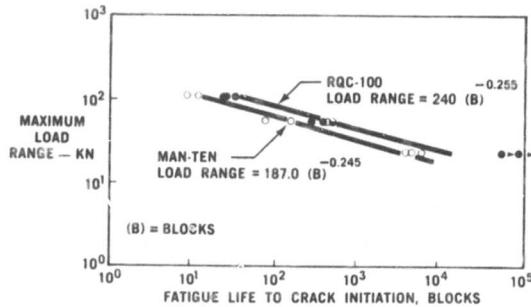
Fig 13 — Fatigue life plot for transmission history

was coded with a test number which identified the service history, material, load level, replication number, and testing laboratory. This code is explained in Table 6.

Crack length vs. block data was also taken for each specimen. This data is recorded in tabular form in Appendix E. Crack length is given as recorded by the testing laboratory. From the crack length data, the cracked area was calculated assuming a straight crack front from side to side. Additionally, a dimensionless a/W ratio is calculated where a is the distance from the load line to the tip of the crack and W is the distance from the load line to the back edge of the specimen. Fig. 7 illustrates these dimensions on the specimen.

SUMMARY

Although not exhaustive, this test program has produced a set of fatigue data of sufficient generality that methods of fatigue life prediction (both crack initiation and propagation) and laboratory simulation can be reasonably evaluated. The test data also provides other insights:

. Generally, the stronger steel had the longer crack initiation life and crack propagation life at all load levels for all histories.
. The inverse slope of the variable amplitude life lines varied from −3.8 to −7.25. Compressive mean loads resulted in less steep slopes.

REFERENCES

1. N. E. Dowling, "Fatigue Failure Predictions for Complicated Stress-Strain Histories." ASTM Jrl. of Materials, March 1972. (See also, "Fatigue Failure Predictions for Complicated Stress-Strain Histories." TAM Report No. 337, Dept. of Theoretical and Applied Mechanics, University of Illinois, Urbana, 1970.)
2. N. J. Sheth, S. L. Bussa and N. M. Mercer, "Determination of Accumulated Structural Loads from S/N Gage Resistance Measurements", SAE Paper 730139, presented at the Int. Auto. Engrg. Congress, January 8, 1973.
3. G. E. Barron, "The Use of Elastic-Plastic Finite Element Analysis in the Calculation of Cumulative Fatigue Damage," International Conference on Vehicle Structural Mechanics SAE P-52, p.81.

APPENDIX A

SEQUENCE OF PEAKS AND VALLEYS FOR THE TEST LOADS

0	513	292	562	267	585	314	524	299	513	1 AXLE
299	569	272	525	298	523	291	560	444	683	2 AXLE
396	678	374	701	276	607	331	642	339	572	3 AXLE
274	500	285	565	274	491	237	495	-76	142	4 AXLE
-276	71	-309	19	-249	137	-93	658	275	534	5 AXLE
240	612	360	690	315	689	306	698	417	666	6 AXLE
392	699	374	701	368	655	345	650	403	610	7 AXLE
393	637	400	618	285	630	385	616	374	703	8 AXLE
-174	136	-331	334	98	510	151	542	84	642	9 AXLE
398	651	-197	44	-197	125	-121	228	-17	631	10 AXLE
387	657	408	623	218	553	291	640	408	693	11 AXLE
453	657	356	642	400	658	330	571	337	689	12 AXLE
395	647	377	594	227	631	299	682	411	663	13 AXLE
404	629	306	631	306	614	409	648	414	683	14 AXLE
374	575	324	691	379	585	368	621	371	610	15 AXLE
373	582	-8	240	-227	248	-205	285	-89	470	16 AXLE
248	460	136	519	317	517	278	503	179	615	17 AXLE
324	559	219	679	421	683	-254	34	-222	243	18 AXLE
-19	495	270	629	291	560	351	657	243	608	19 AXLE
373	663	269	653	156	663	443	690	249	612	20 AXLE
229	602	339	738	231	498	237	614	-167	39	21 AXLE
-261	437	192	503	103	682	201	589	226	480	22 AXLE
135	561	347	548	145	494	260	661	158	467	23 AXLE
-184	161	-105	550	248	445	132	712	276	529	24 AXLE
301	524	309	564	195	467	35	378	-294	188	25 AXLE
-308	245	-211	607	41	526	205	506	218	513	26 AXLE
249	693	261	712	506	727	194	400	-244	173	27 AXLE
-276	610	405	615	360	642	403	641	353	556	28 AXLE
340	655	433	669	422	662	457	796	403	671	29 AXLE
78	549	285	616	376	650	18	731	108	578	30 AXLE
282	629	170	748	181	578	342	604	261	585	31 AXLE
330	694	349	614	313	521	290	533	266	565	32 AXLE
291	645	-228	1	-286	157	-87	725	183	714	33 AXLE
393	621	194	426	152	561	235	551	213	691	34 AXLE
136	487	164	549	244	558	162	507	249	716	35 AXLE
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283	522	222	546	345	570	191	500	280	658	40 AXLE
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-487	24	-447	437	-305	-34	-679	265	-201	147	419	BRACKET
-191	118	-383	457	-34	374	-659	162	-290	54	420	BRACKET
-349	290	-231	329	-437	206	-349	182	-359	314	421	BRACKET
-133	497	-506	-63	-743	265	-103	290	-255	113	422	BRACKET
-285	319	-319	206	-408	-113	-433	398	-433	236	423	BRACKET
-63	255	-349	329	-187	162	-624	536	59	300	424	BRACKET
-182	250	-664	172	-536	270	-383	216	-118	83	425	BRACKET
-364	142	-437	324	-536	-187	-393	201	-531	172	426	BRACKET
-123	137	-546	359	-290	182	-226	177	-369	4	427	BRACKET
-319	329	-378	-54	-561	211	-364	314	-157	378	428	BRACKET
-531	0	-423	388	-24	206	-383	226	-177	201	429	BRACKET
-447	-152	-354	191	-49	280	-772	-137	-413	644	430	BRACKET
-536	437	-590	447	-324	-24	-492	305	-418	63	431	BRACKET
-624	34	-300	295	-649	290	-206	206	-457	123	432	BRACKET
-216	300	-211	137	-482	-49	-300	275	-305	569	433	BRACKET
-339	103	-561	29	-246	349	-295	103	-497	329	434	BRACKET
-629	201	-63	226	-437	-19	-457	152	-477	246	435	BRACKET
-433	398	-49	246	-546	-19	-295	588	-73	231	436	BRACKET
-999	255	-875	201	-177	433	-487	-172	-708	182	437	BRACKET
-201	295	-196	63	-354	113	-167	63	-191	44	438	BRACKET
-172	34	-177	34	-246	137	-226	177	-506	191	439	BRACKET
-142	314	-388	108	-113	334	-433	113	-329	359	440	BRACKET
-305	88	-585	113	-344	24	-221	319	-413	19	441	BRACKET
-324	285	-108	388	-191	216	-600	118	-162	177	442	BRACKET
-757	236	-29	408	-374	359	-226	177	-403	275	443	BRACKET
-255	34	-442	88	-226	275	-472	-84	-447	196	444	BRACKET
-369	265	-177	34	-383	226	-314	103	-290	231	445	BRACKET
-467	44	-275	260	-433	211	-285	329	-310	211	446	BRACKET
-398	68	-255	118	-383	206	-39	157	-285	73	447	BRACKET
-167	354	-565	260	-270	9	-290	433	-132	93	448	BRACKET
-492	-59	-433	123	-157	59	-447	241	-290	738	449	BRACKET
-280	364	-679	260	29	310	-556	255	-14	201	450	BRACKET
-452	-83	-324	295	-354	206	-501	132	-216	49	451	BRACKET
-201	177	-349	108	-447	241	-383	167	-275	54	452	BRACKET
-182	285	-275	24	-378	201	-462	127	-442	319	453	BRACKET
-196	172	-551	270	-211	201	-428	290	-442	241	454	BRACKET
-344	152	-359	-9	-664	403	-49	285	-467	54	455	BRACKET
-324	182	-201	88	-511	73	-437	472	-9	329	456	BRACKET
-374	236	-516	383	-172	295	-280	329	-639	314	457	BRACKET
-314	-24	-595	283	-191	147	-580	167	-280	255	458	BRACKET
-226	329	-393	0	-703	265	-255	211	-442	285	459	BRACKET
-29	383	-172	246	-570	172	-605	344	-442	324	460	BRACKET
-354	0	-442	265	-452	167	-34	265	-679	290	461	BRACKET
-206	250	-78	241	-359	123	-467	182	-187	221	462	BRACKET
-314	295	-314	88	-177	226	-285	398	-521	393	463	BRACKET
-142	285	-250	24	-265	275	-344	177	-644	-275	464	BRACKET
-492	398	14	546	-59	378	-826	359	-285	83	465	BRACKET
-787	98	-383	0	-393	226	-393	423	-147	172	466	BRACKET
-374	462	-393	270	-196	260	-132	191	-221	364	467	BRACKET
-93	310	-359	118	-132	147	-265	246	-236	329	468	BRACKET
-98	408	-772	152	-127	285	-123	103	-344	-4	469	BRACKET
-290	103	-354	295	-63	167	-457	295	-29	187	470	BRACKET
-433	275	-226	127	-521	236	-260	147	-182	167	471	BRACKET
-433	442	-24	354	-713	103	-765	408	-270	359	472	BRACKET
-270	226	-526	132	-541	132	-442	113	-127	472	473	BRACKET
-383	260	-521	295	-29	255	-388	88	-418	211	474	BRACKET
-359	63	-329	516	-63	182	-693	413	93	403	475	BRACKET
-68	206	-634	34	-418	63	-516	303	-103	113	476	BRACKET
-393	34	-393	231	-162	349	-137	221	-649	255	477	BRACKET
-575	265	-54	172	-132	221	-324	265	-63	152	478	BRACKET
-339	275	-103	339	-501	255	-108	127	-575	34	479	BRACKET
-246	437	-551	216	-324	177	-255	497	-447	423	480	BRACKET
-211	162	-295	324	-191	73	-177	201	-137	231	481	BRACKET
-319	383	-78	182	-388	-9	-310	187	-152	201	482	BRACKET
-147	98	-290	236	-575	24	-246	241	-34	310	483	BRACKET
-374	236	-221	295	-127	324	-275	349	-265	182	484	BRACKET
-344	324	-98	132	-280	0	-506	206	-211	118	485	BRACKET
-132	157	-305	226	-314	260	-34	349	-467	191	486	BRACKET
-250	73	-497	378	-482	49	-250	54	-241	344	487	BRACKET
-428	54	-659	329	-44	433	-482	226	-467	344	488	BRACKET
-191	9	-265	14	-201	201	-147	113	-191	152	489	BRACKET
-216	226	-354	423	-191	265	-472	177	-275	388	490	BRACKET
-310	354	-285	649	-580	-34	-285	300	-349	73	491	BRACKET
-137	339	-359	142	-270	423	-152	344	-280	-44	492	BRACKET
-428	388	-206	231	-275	177	-236	211	-162	280	493	BRACKET
-344	182	-472	9	-231	93	-103	236	-501	29	494	BRACKET
-246	310	-226	270	-541	246	-231	285	-196	408	495	BRACKET
-336	127	-167	177	-246	162	-63	191	-570	201	496	BRACKET
-196	191	-270	334	-142	477	-216	34	-211	305	497	BRACKET
-316	191	-423	295	-383	152	-162	319	-305	44	498	BRACKET
-265	226	-492	73	-255	132	-211	132	-359	93	499	BRACKET
-152	182	-162	211	-295	413	-152	265	-344	551	500	BRACKET
-236	250	-157	260	-442	324	-275	201	-364	196	501	BRACKET
-383	-54	-280	201	-329	236	-280	-9	-398	280	502	BRACKET
-93	113	-393	-24	-428	49	-167	265	-59	241	503	BRACKET
-639	88	-250	388	-108	265	-447	467	-59	285	504	BRACKET
-654	329	-369	324	-59	339	-103	236	-364	9	505	BRACKET
-585	319	0	418	-19	344	-433	-132	-467	541	506	BRACKET
-4	270	-442	-152	-433	467	34	359	-177	206	507	BRACKET
-447	-123	-477	270	-310	-29	-433	167	-462	177	508	BRACKET
-147	182	-34	216	-241	34	-201	98	-177	270	509	BRACKET
-354	206	-265	152	-408	201	-472	162	-575	265	510	BRACKET
-457	-24	-280	201	-68	127	-285	-73	-275	245	511	BRACKET
-280	-34	-452	187	-108	211	-172	157	-418	93	512	BRACKET
-457	-39	-250	83	-152	383	-152	270	-393	127	513	BRACKET
-147	127	-374	123	-329	221	-123	172	-359	132	514	BRACKET
-231	182	-275	73	-492	152	-172	241	-177	132	515	BRACKET
-245	132	-88	211	-9	201	-378	275	-546	369	516	BRACKET
0	501	-344	408	-728	93	-132	305	-142	314	517	BRACKET
-295	14	-482	285	-344	49	-246	172	-359	255	518	BRACKET
-452	334	-29	354	-191	123	-674	255	-78	162	519	BRACKET
-378	-137	-521	162	-167	408	-59	162	-265	93	520	BRACKET
-295	369	-270	226	-374	305	-437	123	-393	383	521	BRACKET
78	339	-393	191	-73	339	-378	-83	-305	206	522	BRACKET
-132	329	-270	157	-221	265	-462	182	-54	265	523	BRACKET
-561	280	-182	127	-280	300	-497	285	-118	201	524	BRACKET
-516	275	-182	418	-255	147	-393	344	-177	123	525	BRACKET
-433	152	-147	221	-442	127	-413	177	-654	393	526	BRACKET
-118	226	-506	236	-196	433	-516	408	-226	88	527	BRACKET
-334	201	-270	374	-285	142	-290	-19	-344	349	528	BRACKET
-305	280	-497	-49	-305	250	-300	418	-226	24	529	BRACKET
-359	167	-142	118	-521	216	-364	349	-201	137	530	BRACKET
-216	34	-280	49	-196	216	-182	250	-196	216	531	BRACKET
-369	137	-241	88	-191	221	-172	231	-403	78	532	BRACKET
-310	349	-383	236	-472	521	-68	334	-565	127	533	BRACKET
-98	506	-132	305	-541	211	-152	334	-78	142	534	BRACKET
-388	93	-428	452	-246	246	-388	344	0	211	535	BRACKET
-393	265	-78	305	-221	44	-241	187	-388	231	536	BRACKET
-423	359	-191	54	-418	408	-255	344	-275	191	537	BRACKET
-546	324	-428	206	-29	359	-285	172	-241	152	538	BRACKET
-167	172	-354	344	-250	88	-265	137	-108	98	539	BRACKET
-260	98	-255	63	-393	246	-103	275	-418	265	540	BRACKET
-344	216	-285	-19	-383	142	-187	132	-300	152	541	BRACKET
-201	216	-561	531	-595	182	-536	103	-472	78	542	BRACKET
-182	152	-452	142	-88	236	-73	191	-541	113	543	BRACKET
-477	433	19	349	-206	221	-743	265	-118	103	544	BRACKET
-580	241	-250	123	-167	236	-354	83	-428	39	545	BRACKET
-339	393	-113	123	-570	191	-236	-19	-354	226	546	BRACKET
-324	260	-216	39	-270	108	-354	359	-157	167	547	BRACKET
-447	265	-536	73	-600	595	-305	-34	-477	142	548	BRACKET
-290	374	-152	118	-462	231	-132	246	-433	191	549	BRACKET
-364	201	-383	246	-698	211	-187	408	-162	147	550	BRACKET
-418	329	-231	360	-250	0	-255	231	-236	54	551	BRACKET
-339	310	-4	265	-728	172	-408	211	-83	378	552	BRACKET
-241	300	-182	118	-270	310	-536	182	-378	34	553	BRACKET
-575	132	-88	452	19	418	-83	216	-477	383	554	BRACKET
-98	433	-236	137	-433	398	-241	39	-211	9	555	BRACKET
-275	83	-250	241	-398	73	-364	-93	-516	319	556	BRACKET
49	305	-565	221	-29	236	-63	147	-501	162	557	BRACKET
-305	383	-24	324	-600	201	-152	73	-624	270	558	BRACKET
-63	137	-98	172	-270	113	-324	246	-132	113	559	BRACKET
-246	201	-280	265	-310	34	-191	226	-447	137	560	BRACKET
-127	93	-241	108	+172	167	-157	206	-457	-9	561	BRACKET
-324	300	-260	191	-152	59	-541	260	-113	408	562	BRACKET
-300	344	-369	344	-216	255	-34	201	-191	103	563	BRACKET
-344	270	-123	78	-250	211	-344	477	-14	314	564	BRACKET
-216	314	-556	497	-68	201	-226	4	-570	329	565	BRACKET
-113	152	-270	162	-187	24	-211	49	-182	34	566	BRACKET
-226	280	-364	137	-241	152	-349	98	-413	-4	567	BRACKET
-255	201	-191	29	-423	49	-413	442	-59	187	568	BRACKET
-374	-137	-349	285	-201	113	-339	319	-187	324	569	BRACKET
-369	236	-295	172	-73	246	-487	-216	-433	241	570	BRACKET
4	231	-497	324	-73	314	-344	221	-388	216	571	BRACKET
-280	388	-314	157	-142	98	-152	147	-457	407	572	BRACKET
-182	241	-236	196	-403	241	-437	246	-295	-63	573	BRACKET
-310	152	-93	236	-265	83	-172	49	-408	314	574	BRACKET
-191	152	-280	201	-319	14	-231	221	-216	-14	575	BRACKET
-241	364	-437	457	-191	359	-295	255	-314	403	576	BRACKET
-428	63	-511	472	-290	177	-634	329	-152	285	577	BRACKET
-634	221	-231	319	-88	191	-339	177	-152	241	578	BRACKET
-482	162	-191	83	-462	265	-487	68	-211	49	579	BRACKET
-300	191	-19	270	-457	246	-610	260	-329	132	580	BRACKET
-472	275	-132	113	-211	98	-462	162	-162	167	581	BRACKET
-295	56	-551	132	-132	132	-285	408	-211	0	582	BRACKET
-290	0	-344	113	-191	49	-275	113	-226	123	583	BRACKET
-255	108	-536	113	-364	-152	-433	344	-821	39	584	BRACKET
-359	290	-201	54	-610	275	-354	354	-211	39	585	BRACKET
-492	137	-620	231	-442	172	-310	305	-191	113	586	BRACKET
-418	-93	-339	34	-344	418	-241	63	-472	73	587	BRACKET
-280	295	-34	226	-205	-14	-624	265	-147	191	588	BRACKET
-393	93	-433	280	-314	9	-221	211	-49	152	589	BRACKET
-703	275	-29	206	-506	73	-182	241	-442	383	590	BRACKET
-226	78	-241	241	-595	428	-226	255	-447	314	591	BRACKET
-428	246	-447	44	-334	98	-285	241	-575	250	592	BRACKET
-242	196	-314	78	-403	14	-255	295	-295	142	593	BRACKET
-152	44	-191	54	-182	29					594	BRACKET

APPENDIX B

RANGE – MEAN MATRICES OBTAINED BY RAINFLOW COUNTING

BRACKET DATA

Cycle Range	Mean −500	−450	−400	−350	−300	−250	−200	−150	−100	−50	0	50	100	150	200	250	300	350
200	0	0	0	0	0	0	0	0	12	6	10	4	10	0	0	0	0	0
250	0	0	0	0	24	34	46	104	146	74	116	52	94	42	8	4	0	0
300	0	0	0	0	20	10	56	102	108	92	92	28	74	44	10	6	0	0
350	0	0	8	8	14	12	40	58	98	86	86	32	54	42	20	4	0	0
400	2	2	2	14	4	14	54	50	62	78	78	34	54	34	10	2	2	0
450	0	0	2	6	8	6	50	54	58	58	58	32	48	22	20	6	4	0
500	0	0	0	12	4	8	64	64	52	52	52	34	48	16	8	2	2	0
550	0	0	2	8	8	12	66	66	78	78	78	42	42	8	12	4	0	0
600	0	0	0	12	0	8	18	78	72	66	62	31	42	2	10	2	0	0
650	0	2	2	8	2	12	40	44	92	54	66	14	24	16	4	0	2	0
700	0	0	0	14	2	2	30	48	54	46	36	28	16	2	12	6	0	0
750	0	0	0	6	2	2	16	60	80	34	16	16	12	6	2	0	0	0
800	0	0	2	2	2	6	26	58	102	42	34	18	14	2	6	4	0	0
850	0	0	0	8	4	2	14	28	80	16	18	14	16	2	8	2	0	0
900	0	0	0	12	0	2	32	48	48	34	34	16	24	2	4	8	0	0
950	0	0	0	12	2	4	12	37	28	22	16	14	16	16	2	12	2	0
1000	0	0	0	12	2	2	12	36	48	20	20	31	14	2	4	4	0	0
1050	0	0	0	0	2	2	4	24	22	6	10	0	12	6	2	0	0	0
1100	0	0	0	0	0	4	6	30	15	14	14	2	12	4	0	2	2	0
1150	0	0	0	0	0	0	8	16	16	18	14	0	14	2	0	6	0	0
1200	0	0	0	0	0	0	4	18	18	2	4	2	6	0	2	0	0	0
1250	0	0	0	0	0	3	5	37	14	12	0	0	4	4	6	0	0	0
1300	0	0	0	0	0	0	0	12	10	8	2	0	0	0	4	4	2	0
1350	0	0	0	0	0	0	0	4	4	4	0	0	0	2	6	0	0	0
1400	0	0	0	0	0	0	0	6	6	2	0	4	2	2	0	2	0	0
1450	2	0	2	2	2	0	4	0	0	0	0	0	0	2	4	0	0	0
1500	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
1550	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
1600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
1700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1750	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0

SUSPENSION DATA

Mean

Cycle Range	−550	−500	−450	−400	−350	−300	−250	−200	−150	−100	−50	0	50	100	150
200	0	0	0	0	0	0	2	10	0	0	0	0	0	0	0
250	4	18	40	36	12	14	434	482	38	14	10	10	4	8	4
300	2	4	18	20	2	16	276	282	24	24	6	2	2	2	4
350	0	0	16	6	0	2	134	138	22	14	4	2	0	0	0
400	0	0	0	6	4	0	66	50	10	12	2	0	0	0	0
450	0	0	0	2	12	0	20	14	12	6	0	0	0	2	0
500	0	0	0	0	4	0	12	12	6	0	0	0	0	2	0
550	0	0	0	0	2	4	0	12	0	2	0	0	0	2	0
600	0	0	0	0	0	2	4	4	0	0	0	0	0	0	0
650	0	0	0	0	4	4	0	2	0	0	0	0	0	0	0
700	0	0	0	2	4	0	2	0	2	0	0	0	0	0	0
750	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
800	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
850	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
900	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0
950	0	0	0	0	8	0	1	0	0	0	0	0	0	0	0
1000	0	0	0	2	8	2	1	0	0	0	0	0	0	0	0
1050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1150	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
1200	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
1250	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1350	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

TRANSMISSION DATA

Mean

Cycle Range	−200	−150	−100	−50	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
200	0	0	0	0	0	0	0	0	0	0	0	2	4	6	2	2	2	2	0	0	0
250	0	14	10	8	12	16	10	22	4	6	16	22	66	86	96	102	60	26	14	2	2
300	4	2	6	6	6	4	4	6	8	4	6	12	30	58	82	58	34	16	4	2	0
350	0	2	6	2	2	4	0	2	6	2	4	20	38	36	24	36	20	8	6	2	0
400	0	2	2	6	4	4	8	0	2	2	2	10	24	28	24	30	10	2	2	0	0
450	0	2	2	2	2	6	4	0	0	0	0	10	22	24	6	10	8	4	0	0	0
500	0	0	2	2	4	6	2	0	0	0	6	2	4	16	12	2	2	2	0	0	0
550	0	0	2	0	6	0	0	0	0	0	0	8	6	10	6	0	2	2	2	0	0
600	0	2	2	0	0	0	0	0	0	0	0	4	0	10	0	4	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0	0	2	4	2	0	0	0	0	0	0	0
700	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0
800	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
850	0	0	0	0	0	0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	2	0	6	2	0	0	0	0	0	0	0	0	0	0
950	0	0	0	0	0	0	0	0	0	6	8	0	0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	2	0	2	12	2	0	0	0	0	0	0	0	0	0	0
1050	0	0	0	0	0	0	0	0	7	8	4	0	0	0	0	0	0	0	0	0	0
1100	0	0	0	0	0	0	0	0	2	2	8	6	0	0	0	0	0	0	0	0	0
1150	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
1200	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0
1250	0	0	0	0	0	0	0	0	2	2	6	0	0	0	0	0	0	0	0	0	0
1300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1400	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0
1450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

APPENDIX C

MATERIALS DESCRIPTION AND MECHANICAL PROPERTIES

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Chemical compositions and processing treatments for the Man-Ten and RQC-100 steels are summarized in Table C-1. A compilation of monotonic tension properties is presented for Man-Ten steel in Table C-2 and for RQC-100 steel in Table C-3. Property definitions and analysis procedures can be found in Ref. C-1.
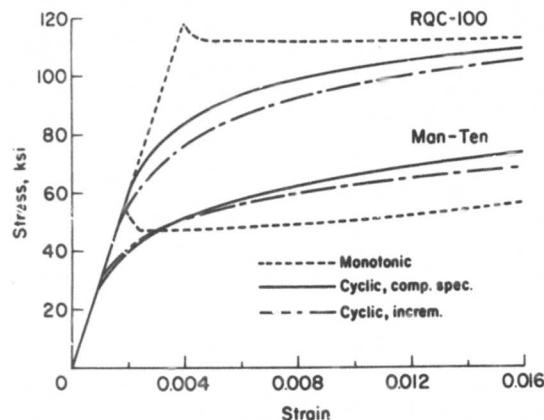
Fig.C-1 Monotonic and cyclic stress-strain curve for man-ten and rqc-100 steels

Constant-amplitude, strain-controlled fatigue data generated by testing cylindrical specimens in axial push-pull are tabulated for the two steels in Tables C-4 and C-5. Tests were performed generally in accordance with procedures described in Ref. C-2. These data were then analyzed to obtain a cyclic stress-strain relation:

$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\varepsilon_e}{2} + \frac{\Delta\varepsilon_p}{2} = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2K'}\right)^{1/n'}$$

and a strain amplitude-fatigue life relation:

$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\varepsilon_e}{2} + \frac{\Delta\varepsilon_p}{2} = \frac{\sigma_f'}{E}(2N_f)^b + \varepsilon_f'(2N_f)^c$$

The resulting cyclic properties, obtained by linear regression analysis of the appropriate data, are given in Table C-6. Definitions of these properties can likewise be found in Ref. C-1.

In Fig. C-1 the cyclic stress-strain curves are compared to the initial portions of the monotonic curves for the two steels. Cyclic curves determined both from constant-amplitude tests and incremental step tests are presented in this figure. Strain amplitude-life curves with elastic, plastic and total strain points plotted are shown in Figs. C-2 and C-3.
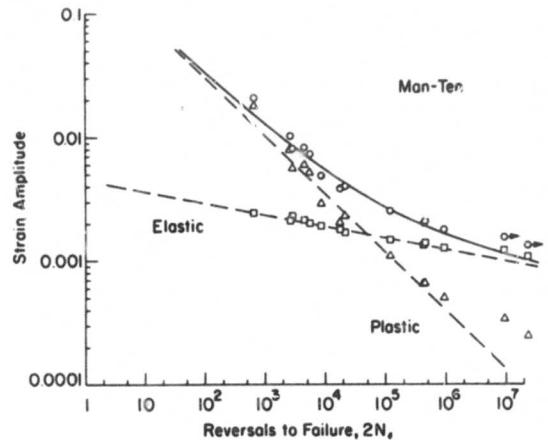
Fig.C-2 Strain amplitude-fatigue life curve for man-ten steel
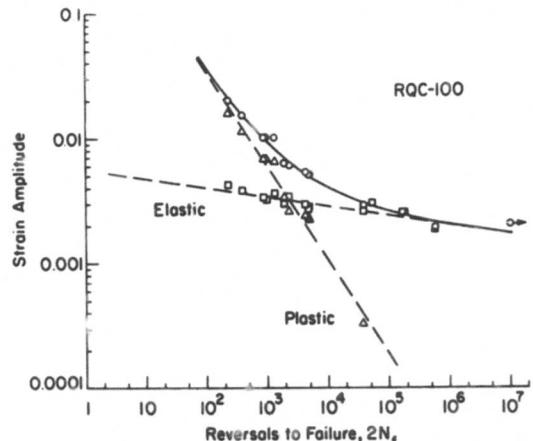
Fig.C-3 Strain amplitude-fatigue life curve for rqc-100 steel

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C-2. "Manual on Low Cycle Fatigue Testing," ASTM STP 465. Philadelphia: American Society for Testing and Materials, 1969.

C-3. P. C. Rosenberg, "Fatigue Behavior of Smooth and Notched Specimens of Man-Ten Steel." M. S. Thesis, Department of Theoretical and Applied Mechanics, University of Illinois, 1968.

C-4. L. E. Tucker, Deere and Company, SAE committee correspondence.

C-5. T. M. Johnson, General Motors Corporation, SAE committee correspondence.

C-6. D. Parks and R. M. Wetzel, Ford Motor Company, SAE committee correspondence.

Table C-1 - Material Compositions and Processing

Compositions

	Man-Ten	RQC-100
Carbon	0.23 wt.%	0.19 wt.%
Manganese	1.57	0.79
Phosphorus	0.016	0.005
Sulfur	0.022	0.021
Silicon	0.01	0.24
Copper	0.22	–
Boron	–	0.0028

Processing

Man-Ten (U. S. Steel Corp.) - 3/8 in. plate, hot-rolled to 45-50 ksi yield strength.

RQC-100 (Bethlehem Steel) - 3/8 in. plate, roller quenched from approximately 1,650°F; tempered at 900°F or higher to 100 ksi minimum yield strength.

Table C-2 - Monotonic Properties of Man-Ten Steel

	Reference		
	C-3	C-4	C-5
Elastic modulus, E, ksi(MPa)	30×10^3 (207×10^3)	29.6×10^3 (204×10^3)	30×10^3 (207×10^3)
Yield strength (0.2%), S_y, ksi(MPa)	46 (317)	47 (324)	47 (324)
Ultimate strength, S_u, ksi(MPa)	82 (565)	82 (565)	78 (538)
Reduction in area, %RA	69	64	68
True fracture strength, σ_f, ksi(MPa)	145 (1000)	135 (931)	151 (1040)
True fracture ductility, e_f	1.19	1.03	0.97
Strength coefficient, K, ksi(MPa)	–	134 (924)	155 (1070)
Strain hardening exponent, n	0.21	0.19	0.23

Table C-3 - Monotonic Properties of RQC-100 Steel

<u>Orientation* (Reference)</u>

	<u>T(C-5)</u>	<u>L(C-6)</u>	<u>T(C-6)</u>	<u>L(C-4)</u>	<u>T(C-4)</u>
Elastic modulus, E, ksi(MPa)	31.2×10^3 (215×10^3)	29.4×10^3 (203×10^3)	29.4×10^3 (203×10^3)	30×10^3 (207×10^3)	30×10^3 (207×10^3)
Yield strength (0.2%) S_y, ksi(MPa)	109 (752)	111 (765)	112 (772)	128 (883)	130 (896)
Ultimate strength, S_u, ksi(MPa)	115 (793)	119 (821)	119 (821)	135 (931)	136 (938)
Reduction in area, %RA	41	68	48	67	43
True fracture strength, σ_f, ksi(MPa)	161 (1110)	197 (1360)	162 (1120)	193 (1330)	155 (1070)
True fracture ductility, e_f	0.53	1.15	0.65	1.02	0.56
Strength coefficient, K, ksi(MPa)	–	192 (1320)	164 (1130)	170 (1170)	170 (1170)
Strain hardening exponent, n	–	0.114	0.075	0.06	0.06

* L = parallel to rolling direction

 T = transverse to rolling direction

Table C-4 — Fatigue Results for Man-Ten Steel

Total Strain Ampl., $\frac{\Delta \epsilon}{2}$	Stress Ampl.,* $\frac{\Delta \sigma}{2}$, ksi(MPa)	Elastic Strain Ampl.,* $\frac{\Delta \epsilon_e}{2}$	Plastic Strain Ampl.,* $\frac{\Delta \epsilon_p}{2}$	Reversals to Failure, $2N_f$	Reference
0.0201	75 (517)	0.0024	0.0177	670	C-3
0.0099	66 (455)	0.0021	0.0078	2,640	C-3
0.0080	59 (407)	0.0021	0.0059	4,600	C-4
0.0079	59 (407)	0.0023	0.0056	2,400	C-5
0.0071	58 (400)	0.0020	0.0051	5,610	C-3
0.0048	50 (345)	0.0019	0.0029	8,800	C-5
0.0039	50 (345)	0.0017	0.0022	22,100	C-3
0.0038	46 (317)	0.0018	0.0020	18,100	C-5
0.0025	42 (290)	0.0014	0.0011	120,000	C-3
0.0020	38 (262)	0.0013	0.0007	446,000	C-3
0.0020	40 (276)	0.0014	0.0006	475,000	C-4
0.0017	37 (255)	0.0012	0.0005	965,000	C-3
0.0015	35 (241)	0.0012	0.0003	9,500,000**	C-3
0.0013	33 (228)	0.0011	0.0002	24,000,000**	C-3

* Data from stable hysteresis loops.

** No failure

Table C-5 - Fatigue Results for RQC-100 Steel

Total Strain Ampl., Δe/2	Stress Ampl.,* Δσ/2, ksi(MPa)	Elastic Strain Ampl.,* Δeₑ/2	Plastic Strain Ampl.,* Δeₚ/2	Reversals to Failure, 2N_f	Reference
0.0198	126 (869)	0.0042	0.0156	22	C-4
0.0150	114 (786)	0.0038	0.0112	390	C-4
0.0100	91 (627)	0.0033	0.0067	880	C-6
0.0100	88 (607)	0.0032	0.0068	978	C-6
0.0100	108 (745)	0.0036	0.0064	1,320	C-4
0.0062	84 (579)	0.0029	0.0033	1,900	C-5
0.0060	102 (703)	0.0034	0.0026	2,330	C-4
0.0053	79 (545)	0.0029	0.0024	4,240	C-5
0.0050	81 (558)	0.0027	0.0023	4,400	C-6
0.0050	82 (565)	0.0028	0.0022	4,460	C-6
0.0030	90 (621)	0.0030	—	54,900	C-4
0.0029	72 (496)	0.0026	0.0003	38,300	C-5
0.0025	76 (524)	0.0025	—	167,000	C-6
0.0025	73 (503)	0.0025	—	185,000	C-6
0.0020	60 (414)	0.0020	—	10,000,000**	C-6
0.0019	55 (379)	0.0019	—	580,000	C-5

* Data from stable hysteresis loops.

** No failure

Table C-6 — Cyclic Properties of Man-Ten and RQC-100 Steels

	Man-Ten	RQC-100
Elastic modulus, E, ksi(MPa)	29.5×10^3 (203×10^3)	29.5×10^3 (203×10^3)
Yield strength (0.2%), S_y', ksi(MPa)*	48/47 (331/324)	90/80 (621/552)
Strength coefficient, K', ksi(MPa)*	160/136 (1100/938)	167/203 (1150/1400)
Strain hardening exponent, n' *	0.19/0.17	0.10/0.15
Fatigue strength coefficient, σ_f', ksi(MPa)	133 (917)	168 (1160)
Fatigue ductility coefficient, e_f'	0.26	1.06
Fatigue strength exponent, b	−0.095	−0.075
Fatigue ductility exponent, c	−0.47	−0.75

* constant amplitude tests/incremental step test

APPENDIX D

CONSTANT AMPLITUDE CRACK PROPAGATION DATA

Table 1D - Constant Amplitude Crack Propagation Data

    Test No.   8FS
    Max. Load: +14000 lbs. [62 300 N]
    Min. Load: -14000 lbs. [-62 300 N]
    Material: Manten

Reversals	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm^2]	
136	0.12 [3.05]	0.05 [1.27]	0.0319	[20.58]	.3439
144	0.15 [3.81]	0.05 [1.27]	0.0375	[24.19]	.3480
146	0.17 [4.32]	0.06 [1.52]	0.0431	[27.81]	.3520
148	0.24 [6.10]	0.07 [1.78]	0.0581	[37.48]	.3628
	Fracture				

Crack Initiation Life 144 Reversals; Fracture Life 148 Reversals

Table 2D - Constant Amplitude Crack Propagation Data

    Test No.   9FS
    Max. Load: +7000 lbs. [31 100 N]
    Min. Load: -7000 lbs. [-31 100 N]
    Material: Manten

Reversals X10^{-3}	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm]	
3.42	0.08 [2.03]	0.05 [1.27]	.024	[15.48]	.3385
3.58	0.15 [3.81]	0.05 [1.27]	.038	[24.52]	.3480
3.72	0.17 [4.32]	0.12 [3.05]	.054	[34.84]	.3601
3.88	0.25 [6.35]	-- --	.094	[60.65]	.3885
4.56	0.57 [14.48]	-- --	.214	[138.06]	.4750
4.74	0.92 [23.37]	-- --	.345	[222.58]	.5696
	Fracture				

Crack Initiation Life 3580 Reversals; Fracture Life 4740 Reversals

Table 3D - Constant Amplitude Crack Propagation Data

Test No.   10FS
Max. Load: +5000 lbs. [22 200 N]
Min. Load: -5000 lbs. [-22 200 N]
Material: Manten

Reversals X10^{-3}	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm^2]	
14.58	0.09 [2.29]	0.041 [1.04]	.025	[16.13]	.3386
15.02	0.13 [3.30]	0.048 [1.22]	.033	[21.29]	.3450
15.42	0.15 [3.81]	0.056 [1.42]	.039	[25.16]	.3488
15.82	0.16 [4.06]	0.060 [1.52]	.041	[26.45]	.3507
16.22	0.18 [4.57]	0.067 [1.70]	.046	[29.68]	.3543
16.62	0.20 [5.08]	0.075 [1.91]	.052	[33.55]	.3581
17.02	0.21 [5.33]	0.078 [1.98]	.054	[34.84]	.3599
17.42	0.23 [5.84]	0.086 [2.18]	.059	[38.06]	.3636
17.80	0.24 [6.10]	0.090 [2.29]	.062	[40.00]	.3655
18.20	0.25 [6.35]	0.093 [2.36]	.064	[41.29]	.3673
18.60	0.27 [6.86]	0.101 [2.57]	.070	[45.16]	.3711
19.00	0.29 [7.37]	0.108 [2.74]	.075	[48.39]	.3747
19.40	0.31 [7.87]	0.116 [2.95]	.080	[51.61]	.3785
19.80	0.32 [8.13]	0.120 [3.05]	.083	[53.55]	.3804
20.40	0.36 [9.14]	0.135 [3.43]	.093	[60.00]	.3878
21.00	0.40 [10.16]	0.150 [3.81]	.103	[66.45]	.3953

Crack Initiation Life 14,400 Reversals; Fracture Life   Reversals

Table 4D - Constant Amplitude Crack Propagation Data

Test No.   5R
Max. Load: 6030 lbs. [27 000 N]
Min. Load: 995 lbs. [4400 N]
Material: Manten

Reversals X10^{-3}	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm^2]	
76.0	* [*]	.090 [2.29]	.034	[21.94]	.3453
84.0	* [*]	.170 [4.32]	.064	[41.29]	.3669
92.0	* [*]	.250 [6.35]	.094	[60.65]	.3885
102.0	* [*]	.330 [6.38]	.124	[80.00]	.4101
107.0	* [*]	.410 [10.41]	.154	[99.35]	.4291
112.0	* [ ]	.490 [12.45]	.184	[118.71]	.4534
116.0	* [ ]	.570 [14.48]	.214	[138.06]	.4750
119.0	* [*]	.650 [16.51]	.244	[157.42]	.4966
120.6	* [*]	.730 [18.54]	.281	[181.29]	.5182
122.0	* [*]	.810 [20.57]	.304	[196.13]	.5399
123.1	* [*]	.890 [22.61]	.334	[215.48]	.5615
123.8	* [*]	.970 [24.64]	.364	[234.84]	.5831
124.0	* [*]	1.050 [26.67]	.394	[254.19]	.6047
124.2	Fracture				

*Cracks lengths not measured, but approximately equal.
Crack Initiation Life 79,000 Reversals; Fracture Life 124,200 Reversals

Table 5D - Constant Amplitude Crack Propagation Data

    Test No.   6R
    Max. Load: 5030 lbs. [23 400 N]
    Min. Load: 995 lbs. [4400 N]
    Material: Manten

Reversals X10^{-3}	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm^2]	
214.0	* [*]	.170 [4.32]	.064	[41.29]	.3669
226.0	* [*]	.250 [6.35]	.094	[60.65]	.3885
245.0	* [*]	.320 [8.13]	.120	[77.42]	.4074
262.0	* [*]	.410 [10.41]	.154	[99.35]	.4318
274.0	* [*]	.490 [12.45]	.184	[118.71]	.4534
280.6	* [*]	.570 [14.49]	.214	[138.06]	.4750
287.2	* [*]	.650 [16.51]	.244	[157.42]	.4966
292.4	* [*]	.730 [18.54]	.274	[176.77]	.5182
296.2	* [*]	.810 [20.57]	.304	[196.13]	.5399
298.8	* [*]	.890 [22.61]	.334	[215.48]	.5615
300.2	* [*]	.970 [24.64]	.364	[234.84]	.5831
301.6	* [*]	1.050 [26.67]	.394	[254.19]	.6047
302.2	* [*]	1.130 [28.70]	.424	[273.55]	.6264
303.2	* [*]	1.210 [30.73]	.454	[292.90]	.6480
304.0	* [*]	1.290 [32.77]	.484	[312.26]	.6686
304.1	Fracture				

*Crack length not measured, but approximately equal.
 Crack Initiation Life 203,000 Reversals; Fracture Life 304,100 Reversals

Table 6D - Constant Amplitude Crack Propagation Data

    Test No.   11FS
    Max. Load: +2000 lbs. [8900 N]
    Min. Load: -2000 lbs. [-8900 N]
    Material: Manten

Reversals X10^{-6}	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.^{2}	[mm^2]	
2.119	0.38 [9.65]	0.30 [7.62]	.128	[82.58]	.4128
2.18	0.45 [11.43]	0.40 [10.16]	.159	[102.58]	.4358
2.22	0.54 [13.72]	0.48 [12.19]	.191	[123.23]	.4588
2.27	0.75 [19.05]	0.55 [13.97]	.244	[157.42]	.4966
2.34	0.78 [19.81]	0.74 [18.80]	.285	[183.87]	.5264
2.408	1.20 [30.48]	1.10 [27.94]	.431	[278.06]	.6318
2.428	Fracture				

  Crack Initiation Life   Reversals; Fracture Life 2,428,000 Reversals

Table 7D - Constant Amplitude Crack Propagation Data

Test No.   12FS
Max. Load: +15000 lbs. [66 700 N]
Min. Load: -15000 lbs. [-66 700 N]
Material: RQC-100

Reversals	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.²	[mm²]	
388	0.07 [1.78]	0.17 [4.32]	.045	[29.03]	.3534
390	0.15 [3.81]	0.21 [5.33]	.068	[43.87]	.3696
392	0.20 [5.08]	0.25 [6.35]	.084	[54.19]	.3818
394	Fracture				

Crack Initiation Life 388 Reversals; Fracture Life 394 Reversals

Table 8D - Constant Amplitude Crack Propagation Data

Test No.   4C.T.
Max. Load: +14000 lbs. [62 300 N]
Min. Load: -14000 lbs. [-62 300 N]
Material: RQC-100

Reversals	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.²	[mm²]	
540	.000*	.000*			
580	.10 [2.54]	.10 [2.54]	.0375	[24.19]	.3480
650	Fracture				

*.125 crack in center of hole, but no cracks on sides of specimens.
Crack Initiation Life 580 Reversals; Fracture Life 650 Reversals

Table 9D - Constant Amplitude Crack Propagation Data

Test No.   13FS
Max. Load: +8000 lbs. [35 600 N]
Min. Load: -8000 lbs. [-35 600 N]
Material: RQC-100

Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.²	[mm²]	
6.84	0.08 [2.03]	0.06 [1.52]	.026	[16.77]	.3399
7.44	0.14 [3.56]	0.043 [1.09]	.034	[21.94]	.3457
7.88	0.20 [5.08]	0.075 [1.91]	.052	[33.55]	.3581
8.16	0.28 [7.11]	0.105 [2.67]	.072	[46.45]	.3730
8.40	0.36 [9.14]	0.135 [3.43]	.093	[60.00]	.3878
8.60	0.46 [11.68]	0.172 [4.67]	.119	[76.77]	.4064
8.80	0.55 [13.97]	0.206 [5.23]	.142	[91.61]	.4231
9.00	0.65 [16.51]	0.244 [6.20]	.165	[106.45]	.4418
--	1.10 [27.94]	0.412 [10.46]	.284	[183.23]	.5253
	Fracture				

Crack Initiation Life 7200 Reversals; Fracture Life   Reversals

Table 10D - Constant Amplitude Crack Propagation Data

Reversals X10⁻³	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
120.8	0.160 [4.06]	0.090 [2.29]	.047	[30.32]	.3547
132.8	0.210 [5.33]	0.210 [5.33]	.079	[50.97]	.3777
142.8	0.300 [7.62]	0.295 [7.49]	.112	[72.26]	.4014
152.8	0.415 [10.54]	0.420 [10.67]	.157	[101.29]	.4338
158.8	0.515 [13.08]	0.515 [13.08]	.193	[124.52]	.4601
160.8	0.560 [14.22]	0.565 [14.35]	.211	[136.13]	.4730
162.2	0.590 [14.99]	0.590 [14.99]	.221	[142.58]	.4804
164.2	0.645 [16.38]	0.645 [16.38]	.242	[156.13]	.4953
166.4	0.725 [18.42]	0.725 [18.42]	.272	[175.48]	.5169
167.4	0.770 [19.56]	0.770 [19.56]	.289	[186.45]	.5291
169.4	0.875 [22.23]	0.875 [22.23]	.328	[211.61]	.5574
170.0	0.915 [23.24]	0.915 [23.24]	.343	[221.29]	.5682
170.5	0.968 [24.59]	0.968 [24.59]	.363	[234.19]	.5826
170.86	1.020 [25.91]	1.020 [25.91]	.383	[247.10]	.5966
171.12	1.100 [27.94]	1.100 [27.94]	.413	[266.45]	.6182
171.24	1.180 [29.97]	1.180 [29.97]	.443	[285.81]	.6399

Crack Initiation Life 110,000 Reversals; Fracture Life 171,240 Reversals

Table 11D - Constant Amplitude Crack Propagation Data

Test No.   3C.T.
Max. Load: +4000 lbs. [17 800 N]
Min. Load: -4000 lbs. [-17 800 N]
Material: RQC-100

Reversals X10⁻³	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
159.2	--	.035 [.889]	--		
167.6	.090 [2.29]	.036 [.914]	.024	[15.48]	.3380
176.2	.090 [2.29]	.039 [.991]	.024	[15.48]	.3384
182.4	.095 [2.41]	.044 [1.12]	.026	[16.77]	.3397
188.4	.100 [2.54]	.052 [1.32]	.028	[18.06]	.3415
194.4	.110 [2.80]	.056 [1.42]	.031	[20.00]	.3434
200.0	.113 [2.87]	.063 [1.60]	.033	[21.29]	.3447
208.4	.117 [2.97]	.065 [1.65]	.034	[21.94]	.3455
215.8	.130 [3.30]	.069 [1.75]	.037	[23.87]	.3478
266.0	-- --	.238 [6.05]	--		
273.0	-- --	.262 [6.65]	--		
290.4	* [*]	.370 [9.40]	.139	[89.68]	.4209
293.4	* [*]	.401 [10.19]	.150	[96.77]	.4293
293.6	* [*]	.405 [10.29]	.152	[98.06]	.4304
294.2	* [*]	.412 [10.46]	.154	[99.35]	.4323
297.2	* [*]	.458 [11.63]	.172	[110.97]	.4447
298.6	* [*]	.486 [12.34]	.182	[117.42]	.4523
299.4	* [*]	.502 [12.75]	.188	[121.29]	.4566
300.2	* [*]	.524 [13.31]	.196	[126.45]	.4626
301.0	* [*]	.546 [13.87]	.205	[132.26]	.4685
305.2	* [*]	.739 [18.77]	.277	[178.71]	.5207
308.8	* [*]	Fracture			

*Crack lengths not measured, but approximately equal.
Crack Initiation Life 215,800 Reversals; Fracture Life 308,800 Reversals

Table 12D - Constant Amplitude Crack Propagation Data

Test No.   2C.T.
Max. Load: +4000 lbs. [17 800 N]
Min. Load: -4000 lbs. [-17 800 N]
Material: RQC-100

Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.²	[mm²]	
88.0	.002* [.051]*	.002* [.051]*	.001	[.64]	.3212
148.4	.014 [.336]	--	--	--	--
192.0	.017 [.432]	.015 [.381]	.006	[3.87]	.3253
204.6	.043 [1.09]	.025 [.635]	.013	[8.39]	.3301
215.4	.048 [1.22]	.030 [.762]	.015	[9.68]	.3315
224.0	.053 [1.35]	.030 [.762]	.016	[10.32]	.3322
229.4	.055 [1.40]	--	--	--	--
237.0	.061 [1.55]	.030 [.762]	.017	[10.97]	.3332
247.6	.073 [1.85]	.036 [.914]	.020	[12.90]	.3357
262.4	.090 [2.29]	.037 [.940]	.035	[22.58]	.3381
276.8	.125 [3.18]	.060 [1.52]	.035	[22.58]	.3459
278.0	.132 [3.35]	.065 [1.65]	.037	[23.87]	.3476
290.4	.175 [4.45]	.150 [3.81]	.061	[39.35]	.3649
297.6	.195 [4.95]	.185 [4.70]	.071	[45.80]	.3723
314.0	.360 [9.14]	.340 [8.64]	.131	[84.52]	.4155
324.6	.500 [12.7]	.500 [12.7]	.188	[121.29]	.4561
334.0		.640 [16.26]			
339.0	Fracture				

*Cracks evident at both corners.
Crack Initiation Life 280,000 Reversals; Fracture Life 339,000 Reversals

Table 13D - Constant Amplitude Crack Propagation Data

Test No.   15FS
Max. Load: +3500 lbs. [15 600 N]
Min. Load; -3500 lbs. [-15 600 N]
Material: RQC-100

Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
	Painted Side	Unpainted Side	In.²	[mm²]	
425.8	0.17 [4.32]	0.26 [6.60]	.081	[52.26]	.3791
427.8	0.19 [4.83]	0.28 [7.11]	.088	[55.77]	.3845
429.8	0.20 [5.08]	0.28 [7.11]	.090	[58.06]	.3858
431.8	0.22 [5.59]	0.28 [7.11]	.094	[60.65]	.3885
433.8	0.23 [5.84]	0.28 [7.11]	.096	[61.94]	.3899
435.8	0.25 [6.35]	0.28 [7.11]	.099	[63.87]	.3926
437.8	0.27 [6.86]	0.30 [7.62]	.107	[69.03]	.3980
447.8	0.28 [7.11]	0.30 [7.62]	.109	[70.32]	.3993
461.8	0.34 [8.64]	0.35 [8.89]	.129	[83.23]	.4142
471.8	0.48 [12.19]	0.45 [11.43]	.174	[112.26]	.4466
481.8	0.58 [20.32]	0.56 [14.22]	.214	[138.06]	.4750
491.8	0.68 [17.27]	0.65 [16.51]	.249	[160.64]	.5007
501.8	0.90 [22.86]	0.85 [21.59]	.328	[211.61]	.5574
	Fracture				

Crack Initiation Life 400,000 Reversals; Fracture Life 501,800 Reversals

Table 14D - Constant Amplitude Crack Propagation Data

Test No.   7R
Max. Load: 7020 lbs. [31 200 N]
Min. Load: 995 lbs. [4400 N]
Material: RQC-100

Reversals X10-3	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
498.0	.120	[3.05]	*	[*]	.045	[29.03]	.3534
578.0	.200	[5.08]	*	[*]	.075	[48.39]	.375
614.0	.280	[7.11]	*	[*]	.105	[67.74]	.3966
628.0	.360	[9.14]	*	[*]	.135	[87.10]	.4182
632.0	Fracture						

*Crack not measured, but approximately equal.
 Crack Initiation Life 472,000 Reversals; Fracture Life 632,000 Reversals

Table 15D - Constant Amplitude Crack Propagation Data

Test No.   1C.T.
Max. Load: +3000 lbs. [13 300 N]
Min. Load: -3000 lbs. [-13 300 N]
Material: RQC-100

Reversals 10-6	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
0.386	.002	[.051]					
0.510	.020	[.508]	.010*	[.254]	.006	[3.87]	.3250
0.566	.030	[.762]	.015*	[.381]	.008	[5.16]	.3270
1.114	.107	[2.72]	.015*	[.381]	.023	[14.84]	.3374
1.148	.150	[3.81]	.015*	[.381]	.031	[20.00]	.3432
1.228	.215	[5.46]	.015*	[.381]	.043	[27.74]	.3520
1.240	.215	[5.46]	.015*	[.381]	.043	[27.74]	.3520
1.247	.220	[5.59]	.050	[1.27]	.051	[32.90]	.3574
1.279	.300	[7.62]	.230	[5.84]	.099	[63.87]	.3926
1.302	.380	[9.65]	.320	[8.13]	.133	[85.81]	.4155
1.323	.460	[11.68]	.420	[10.67]	.167	[107 74]	.4399
1.343	.550	[13.97]	.520	[13.21]	.201	[129.68]	.4655
1.361	.680	[17.29]	.680	[17.27]	.258	[166.45]	.5047
1.369	.760	[19.30]	.750	[19.05]	.283	[182.58]	.5250
1.373	.840	[21.34]	.830	[21.08]	.313	[201.94]	.5466
1.381	Fracture						

*This crack did not join up with crack from painted side.
 Crack Initiation Life 1,210,000 Reversals; Fracture Life 1,381,000 Reversals

Table 16D - Constant Amplitude Crack Propagation Data

Test No.   16FS
Max. Load: +3000 lbs. [13 300 N]
Min. Load: -3000 lbs. [-13 300 N]
Material: RQC-100

Reversals	Crack Length Inches [mm]		Crack Area		
X10-6	Painted Side	Unpainted Side	In.2	[mm2]	a/W
2.22	0.27 [6.86]		.101	[65.16]	.3939
2.221	0.63 [16.00]		.236	[152.26]	.4912
2.221	0.69 [17.53]		.259	[167.10]	.5074
2.232	0.73 [18.54]		.274	[176.77]	.5182
2.232	0.78 [19.81]		.293	[189.03]	.5318
2.232	0.82 [20.83]		.308	[198.71]	.5426
2.233	0.85 [21.59]		.319	[205.81]	.5507

Crack Initiation Life   Reversals; Fracture Life 2,233,120 Reversals

APPENDIX E

VARIABLE AMPLITUDE CRACK PROPAGATION DATA

Table 1E - Crack Propagation Data

Test No. SM1-1-FM

Blocks	Reversals X10-3	Crack Length Inches (mm)		Crack Area		
		Painted Side	Unpainted Side	In.2	[mm2]	a/W
7.5	18.8			.0264	[17.03]	.3400
8.0	20.0			.0439	[28.32]	.3526
8.5	21.3			.0703	[45.35]	.3716
9.0	22.6			.0966	[62.32]	.3906
9.5	23.8			.1377	[88.84]	.4202
10.5	26.3			.2227	[143.68]	.4814

Crack Initiation Life 7.8 blocks @ a/W = 0.3480; Fracture Life 10.5 blocks

Table 2E - Crack Propagation Data

Test No. SM1-3-AOS

Blocks	Reversals X10-3	Crack Length Inches [mm]				Crack Area		
		Painted Side		Unpainted Side		In.2	[mm2]	a/W
24.0	60.144	-	-	-	-	-	-	-
25.0	62.650	.10	[2.54]	0	[0]			
28.0	70.168	.10	[2.54]	.10	[2.54]	.0375	[24.19]	.3480
29.0	72.674	.25	[6.35]	.10	[2.54]	.0656	[42.32]	.3682
30.0	75.180	.25	[6.35]	.25	[6.35]	.0938	[60.52]	.3885
32.0	80.194	.40	[10.16]	.35	[8.89]	.1406	[90.71]	.4223
35.0	87.710	.45	[11.43]	.40	[10.16]	.1594	[102.84]	.4358
36.0	90.212	.55	[13.97]	.50	[12.70]	.1969	[127.03]	.4628
38.0	95.228	.65	[16.51]	.65	[16.51]	.2438	[157.29]	.4966
42.0	105.252	.70	[17.78]	.70	[17.78]	.2625	[169.35]	.5101
46.0	115.276	.80	[20.32]	.87	[22.10]	.3131	[202.00]	.5466
47.0	117.782	.85	[21.59]	.85	[21.59]	.3180	[205.16]	.5506
48.0	120.288	Fracture						

Crack Initiation Life 28.0 Blocks @ a/W = 0.348; Fracture Life 48.0 Blocks

Table 3E - Crack Propagation Data

Test No. SM2-1-B

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.²	[mm²]	
460.0	1.15	.03	[0.76]					
471.0	1.18	.07	[1.78]					
480.0	1.20	.12	[3.05]					
492.0	1.23	.18	[4.57]					
515.0	1.29	.28	[7.11]					.3966
541.0	1.36	.32	[8.13]					.4076
577.0	1.44	.38	[9.65]					.4237
613.0	1.54	.42	[10.67]					.4345
636.0	1.59	.45	[11.43]					.4426
713.0	1.79	.49	[12.45]					.4534
742.0	1.86	.51	[12.95]					.4588
806.0	2.02	.53	[13.46]					.4642
873.0	2.19	.55	[13.97]					.4696
982.0	2.46	.59	[14.99]					.4804
1067.0	2.67	.63	[16.0]					.4912
1171.0	2.93	.65	[16.51]	.64	[16.26]	.242	[156.13]	.4953
1263.0	3.16	.68	[17.27]	.66	[16.76]	.251	[161.94]	.5020
1393.0	3.49	.78	[18.54]	.71	[18.03]	.270	[174.19]	.5155
1502.0	3.76	.77	[19.56]	.75	[19.05]	.285	[183.87]	.5264
1926.0	4.83	.98	[24.89]	.97	[24.64]	.366	[236.13]	.5845
1986.0	4.98	1.03	[26.16]	1.03	[26.16]	.386	[249.03]	.5993
2054.0	5.15	1.08	[27.43]	1.09	[27.69]	.407	[262.58]	.6142
2099.0	5.26	1.13	[28.70]	1.13	[28.70]	.424	[273.55]	.6264
2149.0	5.38	1.20	[30.48]	1.19	[30.23]	.448	[289.03]	.6439
2174.0	5.45	1.23	[31.24]	1.24	[31.50]	.463	[298.71]	.6547
2191.0	5.49	1.27	[32.26]	1.27	[32.26]	.476	[307.10]	.6642
2200.0	5.51	1.32	[33.53]	1.31	[33.27]	.493	[318.10]	.6764
2211.0	5.54	1.40	[35.56]	1.40	[35.56]	.525	[338.71[	.6993
2217.0	5.56	1.52	[38.61]	1.53	[38.86]	.572	[369.03]	.7331
2219.0	5.56	1.62	[41.15]	1.62	[41.15]	.607	[391.61]	.7588
2220.0	5.56	2.07	[52.58]	2.07	[52.58]	.776	[500.64]	.8804

Crack Initiation Life 430.0 blocks @ a/W = 0.3480; Fracture Life 2220.0 blocks
Crack length measurements were not taken on unpainted side until a 0.64"
crack had formed; up to this time, crack front was essentially straight.

Table 4E - Crack Propagation Data

Test No.   SM2-2-GM

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.²	[mm²]	
397.0	.994	.675	[17.14]	.675	[17.14]	.253	[163.22]	.5034
445.0	1.115	.760	[19.30]	.780	[19.81]	.289	[186.45]	.5291
460.0	1.153	.820	[20.83]	.810	[20.57]	.306	[197.42]	.5412
475.0	1.190	.840	[21.34]	.810	[20.57]	.309	[199.35]	.5439
490.0	1.228	.860	[21.84]	.820	[20.83]	.315	[203.22]	.5480
505.0	1.265	.900	[22.86]	.830	[21.08]	.324	[209.03]	.5547
520.0	1.303	.900	[22.86]	.840	[21.34]	.326	[210.32]	.5561
537.0	1.346	.910	[23.11]	.860	[21.84]	.332	[214.19]	.5601
550.0	1.378	.910	[23.11]	.890	[22.61]	.338	[218.06]	.5642
565.0	1.416	.990	[25.15]	.960	[24.38]	.366	[236.13]	.5845

Crack Initiation Life 208.0 blocks @ a/W = 0.3480; Fracture Life 565.0 blocks

Table 5E - Crack Propagation Data

Test No.   SM2-3-GM

Blocks	Reversals X10^{-6}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
150.0	.375	0	[0]	.055	[1.40]	.010	[6.45]	.3284
160.0	.400	.06	[1.52]	.12	[3.05]	.034	[21.94]	.3453
170.0	.426	.120	[3.05]	.16	[4.06	.053	[34.19]	.3588
180.0	.451	.22	[5.59]	.23	[5.84]	.084	[54.19]	.3817
195.0	.489	.34	[8.64]	.33	[8.38]	.126	[81.29]	.4115
225.0	.563	.46	[11.68]	.45	[11.43]	.170	[109.68]	.4439
255.0	.639	.56	[14.22]	.54	[13.72]	.206	[132.90]	.4696
345.0	.863	.68	[17.27]	.68	[17.27]	.255	[164.52]	.5047
390.0	.977	.73	[18.54]	.72	[18.29]	.272	[175.48]	.5169
435.0	1.090	.78	[19.81]	.77	[19.56]	.289	[186.45]	.5304
480.0	1.202	.82	[20.83]	.81	[20.57]	.306	[197.42]	.5412
535.0	1.341	.85	[21.59]	.88	[22.35]	.324	[209.03]	.5547
590.0	1.479	.94	[23.88]	.91	[23.11]	.374	[241.29]	.5709
625.0	1.566	.96	[24.38]	.96	[24.38]	.355	[229.03]	.5804
640.0	1.603	.98	[24.89]	.97	[24.64]	.366	[236.13]	.5844
675.0	1.691	1.04	[26.42]	1.00	[25.40]	.382	[246.45]	.5966
715.0	1.792	1.10	[27.94]	1.07	[27.18]	.407	[262.58]	.6142
730.0	1.829	1.12	[28.45]	1.10	[27.94]	.416	[268.38]	.6209
745.0	1.867	1.16	[29.46]	1.14	[28.96]	.431	[266.45]	.6318
760.0	1.905	1.20	[30.48]	1.17	[29.72]	.444	[286.45]	.6412
767.0	1.922	1.59	[40.39]	1.56	[39.62]	.591	[381.29]	.7466

Crack Initiation Life 162.0 blocks @ a/W = 0.3480; Fracture Life 767.0 blocks

Table 6E - Crack Propagation Data

Test No.   SM3-1-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
2,206.0	5.52	.21	[5.33]	.21	[5.33]	.079	[50.97]	.3777
2,867.0	7.18	.26	[6.60]	.24	[6.10]	.094	[60.65]	.3885
4,277.0	10.72	.32	[8.13]	.32	[8.13]	.120	[77.42]	.4074
6,158.0	15.43	.39	[9.91]	.37	[9.40]	.143	[92.26]	.4236
9,013.0	22.59	.48	[12.19]	.46	[11.68]	.176	[113.55]	.4480
11,662.0	29.22	.57	[14.48]	.55	[13.97]	.210	[135.48]	.4723
13,390.0	35.56	.65	[16.51]	.61	[15.49]	.237	[152.90]	.4912
16,078.0	40.29	.74	[18.80]	.71	[18.03]	.272	[175.48]	.5169
19,648.0	49.24	.88	[22.35]	.88	[22.35]	.330	[212.90]	.5588
21,078.0	52.82	.98	[24.89]	.95	[24.13]	.361	[232.90]	.5817
23,768.0	59.56	1.21	[30.73]	1.16	[29.46]	.444	[286.45]	.6412
24,458.0	61.29	1.40	[35.56]	1.37	[34.80]	.519	[334.84]	.6953
24,608.0	61.66	1.65	[41.91]	1.65	[41.91]	.619	[399.35]	.7669

Crack Initiation Life 1,750.0 blocks @ a/W = 0.3480; Fracture Life 24,608.0 blocks

Table 7E - Crack Propagation Data

Test No.   SM3-2-FS

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
2,775.0	6.95	.19	[4.83]	.19	[4.83]	.071	[45.81]	.3723
5,446.0	13.6	.31	[7.87]	.31	[7.87]	.115	[74.19]	.4047
7,772.0	19.5	.37	[9.40]	.37	[9.40]	.138	[89.03]	.4209
12,142.0	30.4	.49	[12.45]	.48	[12.19]	.181	[116.77]	.4520
14,946.0	37.5	.55	[14.00]	.55	[14.00]	.205	[132.26]	.4696
17,674.0	44.3	.64	[16.26]	.62	[15.75]	.235	[151.61]	.4912
21,474.0	53.8	.75	[19.05]	.73	[18.54]	.276	[178.06]	.5209
25,514.0	63.9	.89	[22.61]	.88	[22.35]	.330	[212.90]	.5601
30,884.0	77.4	1.34	[34.04]	1.31	[33.27]	.495	[319.35]	.6791
31,224.0	78.2	1.65	[41.91]	1.65	[41.91]	.617	[398.06]	.7669
31,884.0	Fracture							

Crack Initiation Life 2,240.0 blocks @ a/W = 0.3480; Fracture Life 31,884.0 blocks

Table 8E - Crack Propagation Data

Test No.   SM3-3-W

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
1,373.0	3.43	0	[0]	.1615	[4.10]			
1,382.0	3.46	0	[0]	.1615	[4.10]			
1,410.0	3.53	.0395	[1.00]	.1615	[4.10]	.0375	[24.19]	.3481
1,420.0	3.56	.0716	[1.82]	.1615	[4.10]	.0437	[28.19]	.3524
1,431.0	3.58	.0786	[1.99]	.1615	[4.10]	.0445	[28.71]	.3534
1,516.0	3.80	.157	[3.99]	.193	[4.90]	.0656	[42.32]	.3682
2,266.0	5.67	.236	[5.99]	.260	[6.60]	.093	[59.99]	.3880
3,656.0	9.15	.264	[6.71]	.319	[8.10]	.109	[70.32]	.3997
6,081.0	15.3	.354	[8.99]	.367	[9.32]	.135	[87.10]	.4184
15,563.0	38.9	.456	[11.58]	.657	[16.69]	.209	[134.84]	.4714
23,600.0	59.2	.944	[23.98]	.904	[22.96]	.346	[223.23]	.5707
24,055.0	60.3	1.030	[26.16]	1.027	[26.10]	.385	[248.39]	.5989
24,338.0	60.9	1.098	[27.89]	1.071	[27.20]	.407	[262.58]	.6141
25,074.0	62.8	1.212	[30.78]	1.189	[30.20]	.457	[294.84]	.6454
25,352.0	63.5	1.342	[34.09]	1.338	[33.99]	.502	[232.87]	.6831
25,353.0	Test Suspended							

Crack Initiation Life 1,410.0 blocks @ a/W = 0.3480; Fracture Life _*_ blocks
*Test Suspended

Table 9E - Crack Propagation Data

Test No.   SMA-2-MTS

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
4742.0	11.9	.070	[1.78]	.146	[3.71]	0.0405	[26.13]	0.3501
4865.0	12.3	.124	[3.15]	.185	[4.70]	0.0579	[37.38]	0.3626
5120.0	12.8	.160	[4.06]	.220	[5.59]	0.0712	[45.97]	0.3723
5176.0	13.0	.175	[4.44]	.245	[6.22]	0.0788	[50.81]	0.3777
5388.0	13.5	.195	[4.95]	.285	[7.24]	0.0900	[58.06]	0.3858
5458.0	13.7	.210	[5.33]	.320	[8.13]	0.0994	[64.11]	0.3926
5567.0	14.0	.320	[8.13]	.400	[10.16]	0.135	[87.10]	0.4182
5642.0	14.1	.350	[8.89]	.464	[11.79]	0.153	[98.47]	0.4309
5762.0	14.4	.450	[11.43]	.510	[12.95]	0.180	[116.13]	0.4507
5839.0	14.6	.500	[12.70]	.560	[14.22]	0.199	[128.22]	0.4642
6054.0	15.2	.558	[14.17]	.640	[16.26]	0.225	[144.92]	0.4828
6224.0	15.6	.578	[14.68]	.682	[17.32]	0.236	[152.42]	0.4912
6657.0	16.7	.662	[16.81]	.707	[17.96]	0.257	[165.60]	0.5058
6736.0	16.9	.682	[17.32]	.745	[18.92]	0.268	[172.62]	0.5139
7026.0	17.6	.710	[18.03]	.762	[19.35]	0.276	[178.06]	0.5199
7462.0	18.7	.800	[20.2]	.780	[19.81]	0.296	[191.13]	0.5345
7904.0	19.8	.820	[20.83]	.837	[21.26]	0.311	[200.44]	0.5447
8882.0	22.3	.840	[21.34]	.890	[22.61]	0.324	[209.27]	0.5547
16307.0	40.9	1.116	[28.35]	1.085	[27.56]	0.413	[266.25]	0.6132
17187.0	43.1	1.150	[29.21]	1.120	[28.45]	0.426	[274.60]	0.6277
22832.0	57.2	1.250	[31.75]	1.280	[32.51]	0.474	[306.05]	0.6628
23842.0	59.7	1.412	[35.86]	1.412	[35.86]	0.530	[341.61]	0.7026
24666.0	61.8							

Crack Initiation Life 4700 blocks extrapolated from data at a/W = 0.3480
Fracture Life 24666.0 blocks

Table 10E - Crack Propagation Data

Test No. SM4-3-MTS

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
6742.0	16.9					

*Test suspended at 6742.0 blocks

Table 11E - Crack Propagation Data

Test No.   SM5-1-FS

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
85,370.0	213.937	No Cracks	No Cracks			

Test Suspended @ 85,370 Blocks

Table 12E - Crack Propagation Data

Test No.   BM1-1-MTS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
2.02	11.96	.28	[7.11]	.32	[8.13]	.113	[72.90]	.4020
2.12	12.61	.42	[10.67]	.42	[10.67]	.158	[101.94]	.4345
2.19	13.01	.57	[14.47]	.56	[14.22]	.212	[136.77]	.4736
2.23	13.23	.96	[24.38]	.93	[23.62]	.354	[228.39]	.5764

Crack Initiation Life 1.5 blocks @ a/W = 0.3480; Fracture Life 2.23 blocks

Table 13E - Crack Propagation Data

Test No.   BM1-2-B

Blocks	Reversals X10^{-3}	Crack Length Inches [mm]		Unpainted Side	Crack Area		a/W
		Painted Side			In.^{2}	[mm^2]	
2.61	15.49	.08	[2.03]				.3642
2.67	15.85	.16	[4.06]		.060	[38.71]	.3642
2.75	16.32	.29	[7.37]		.109	[70.32]	.3993
2.78	16.50	.37	[9.40]		.139	[89.68]	.4209
2.81	16.68	.46	[11.68]		.172	[110.97]	.4453
2.82	16.77	.54	[13.72]		.202	[130.32]	.4669
2.84	16.86	.63	[16.00]		.236	[152.26]	.4912
2.85	16.92	.70	[17.78]		.262	[169.03]	.5101
2.87	17.04	.79	[20.10]		.296	[190.97]	.5345
2.89	17.15	.90	[22.86]		.337	[217.42]	.5642
2.90	17.21	.95	[24.13]		.356	[229.68]	.5777

Crack Initiation Life 2.60 blocks @ 0.3480; Fracture Life 2.90 blocks

Crack length measurements taken on painted side only; periodic observations
revealed, however, that crack front remained essentially straight after
0.10 inches of crack growth.

Table 14E - Crack Propagation Data

Test No.   BM1-3-MTS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
2.0	11.9	.13	[3.30]	.07	[1.78]	.0375	[24.19]	.3480
3.0	17.8	Fracture						

Crack Initiation Life 2.0 blocks @ a/W = 0.3480; Fracture Life 3.0 blocks

Table 15E - Crack Propagation Data

Test No.   BM2-1-MTS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
24.26	144.0	.28	[7.11]	.30	[7.62]	.109	[70.32]	.3993
26.72	158.6	.44	[11.18]	.45	[11.43]	.167	[107.74]	.4412
27.29	162.0	.47	[11.93]	.49	[12.45]	.180	[116.13]	.4507
2..00	166.2	.52	[13.21]	.53	[13.46]	.197	[127.10]	.4628
28.47	169.0	.54	[13.72]	.55	[13.97]	.204	[131.61]	.4682
28.98	172.0	.57	[14.48]	.58	[14.73]	.216	[139.35]	.4764
29.26	173.7	.63	[16.00]	.65	[16.51]	.240	[154.84]	.4939
29.65	176.0	.69	[17.53]	.72	[18.29]	.264	[170.32]	.5115
30.19	179.2	.73	[18.54]	.74	[18.80]	.276	[178.06]	.5196
30.83	183.0	.80	[20.32]	.80	[20.32]	.300	[193.55]	.5372
31.20	185.2	.84	[21.33]	.86	[21.84]	.319	[205.81]	.5507
31.76	188.5	.98	[24.89]	.98	[24.89]	.368	[237.42]	.5858

Crack Initiation Life 20.8 blocks @ a/W = 0.3480; Fracture Life 31.76 blocks

Table 16E - Crack Propagation Data

Test No.   BM2-2-FM

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
10.0	59.4			.0059	[3.81]	.3225
11.0	65.3			.0352	[22.71]	.3463
11.5	68.3			.047	[30.32]	.3548
11.75	69.7			.065	[41.94]	.3678
14.5	86.1			.140	[90.32]	.4218
17.75	105.0			.211	[136.13]	.4730
19.5	116.0			.258	[166.45]	.5069

Failure

Crack Initiation Life 11.5 blocks @ a/W = 0.3480; Fracture Life 19.5 blocks

Table 17E - Crack Propagation Data

Test No.   BM2-3-JD

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
23.0	136.5	.15	[3.81]	.05	[1.27]	.0375	[24.19]	.3480
24.0	143.0	.20	[5.08]	.14	[3.56]	.064	[41.29]	.3669
25.0	148.0	.22	[5.59]	.15	[3.81]	.069	[44.52]	.3709
26.0	154.0	.31	[7.87]	.18	[4.57]	.092	[59.35]	.3872
32.0	190.0	.48	[12.19]	.50	[12.70]	.184	[118.71]	.4534
34.0	202.0	.50	[12.70]	.55	[13.97]	.197	[127.09]	.4628
36.0	214.0	.57	[14.48]	.60	[15.24]	.219	[141.29]	.4791
38.0	226.0	.65	[16.51]	.67	[17.02]	.248	[159.99]	.4993
40.0	237.0	.72	[18.29]	.74	[18.80]	.274	[176.77]	.5182
42.0	249.0	.85	[21.59]	.85	[21.59]	.319	[205.81]	.5507
43.0	255.0	.95	[24.13]	.95	[24.13]	.356	[229.68]	.5777
44.0	261.0	1.25	[31.75]	1.25	[31.75]	.488	[314.84]	.6588

Crack Initiation Life 23.0 blocks @ a/W = 0.3480; Fracture Life 44.0 blocks

Table 18E - Crack Propagation Data

Test No.   BM31-MTS

Blocks	Reversals X10-6	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.2	[mm2]	a/W
355	2.1	.050	[1.27]	.050	[1.27]	.0188	[12.10]	.3344
1404	8.3	.070	[1.78]	.090	[2.29]	.0300	[19.35]	.3426
1680	10.0	.100	[2.54]	.120	[3.05]	.0412	[26.61]	.3507
1990	11.8	.120	[3.05]	.120	[3.05]	.0450	[29.03]	.3534
2422	14.4	.150	[3.81]	.150	[3.81]	.0562	[36.29]	.3615
2766	16.4	.200	[5.08]	.200	[5.08]	.0750	[48.39]	.3750
3252	19.3	.240	[6.10]	.240	[6.10]	.0900	[58.06]	.3858
3451	20.5	.320	[8.13]	.300	[7.62]	.116	[75.00]	.4047
3777	22.4	.490	[12.45]	.490	[12.45]	.184	[118.55]	.4534
4001	23.7	.530	[13.46]	.530	[13.46]	.199	[128.23]	.4642
4357	25.9	.580	[14.73]	.580	[14.73]	.218	[140.32]	.4777
4663	27.7	.700	[17.78]	.700	[17.78]	.263	[169.35]	.5101
4898	29.1	1.060	[26.92]	1.060	[26.92]	.398	[256.45]	.6074
4933	29.3	1.250	[31.75]	1.250	[31.75]	.469	[302.42]	.6588
4942	29.3	1.870	[47.50]	1.870	[47.50]	.701	[452.42]	.8263
4944	29.3							

Crack Initiation Life 1588 blocks interpolated from data at a/w = 0.3480;
Fracture Life 4944 blocks

Table 19E - Crack Propagation Data

Test No.   BM3-2-MTS

Blocks	Reversals X10-6	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.2	[mm2]	a/W
1,011.0	6.011	0	[0]	.95	[24.13]			
1,021.0	6.071	1.04	[26.42]	1.02	[25.91]	.386	[249.03]	.5993
1,023.0	6.077	1.04	[26.42]	1.03	[26.16]	.388	[250.32]	.6007
1,036.0	6.158	1.16	[29.46]	1.17	[29.72]	.437	[281.93]	.6358
1,038.0	6.169	1.19	[30.23]	1.17	[29.72]	.443	[285.81]	.6399
1,043.0	6.195	1.23	[31.24]	1.21	[30.73]	.458	[295.48]	.6507
1,050.0	6.236	1.30	[33.02]	1.32	[33.53]	.491	[316.77]	.6750
1,051.0	6.241	1.34	[34.04]	1.35	[34.29]	.504	[325.16]	.6845
1,052.0	6.248	1.37	[34.80]	1.36	[34.54]	.512	[330.32]	.6899
1,053.0	6.254	1.48	[37.59]	1.45	[36.83]	.549	[354.19]	.7169
1,053.8	6.258	Fracture						

Crack Initiation Life   blocks @ a/W = 0.348; Fracture Life 1,053.8 blocks

Table 20E - Crack Propagation Data

Test No.   BM3-3-FS

Blocks	Reversals X10^-6	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
469.0	2.78			.10	[2.54]			
499.0	2.96	.05	[1.27]	.14	[3.56]	.036	[23.23]	.3466
564.0	3.35	.08	[2.03]	.14	[3.56]	.041	[26.45]	.3507
679.0	4.03	.11	[2.79]	.15	[3.81]	.049	[31.61]	.3561
754.0	4.48	.14	[3.56]	.15	[3.81]	.054	[38.84]	.3601
909.0	5.40	.21	[5.33]	.23	[5.84]	.083	[53.55]	.3804
1,001.0	5.94	.22	[5.59]	.24	[6.10]	.086	[55.48]	.3831
1,170.0	6.95	.28	[7.11]	.29	[7.37]	.107	[69.03]	.3980
1,285.0	7.63	.30	[7.62]	.32	[8.13]	.116	[74.84]	.4993
1,432.0	8.50	.35	[8.89]	.32	[8.13]	.126	[81.29]	.4115
1,782.0	10.57	.54	[13.72]	.48	[12.19]	.186	[120.00]	.4588
2,011.0	11.94	.60	[15.24]	.59	[14.99]	.223	[143.87]	.4818
2,110.0	12.52	.	[16.51]	.63	[16.00]	.240	[154.84]	.4930
2,340.0	13.89	.80	[20.32]	.78	[19.81]	.296	[190.97]	.5345
2,438.0	14.47	.91	[23.11]	.91	[23.11]	.341	[220.00]	.5669
2,626.0	15.59	1.65	[41.91]	1.65	[41.91]	.619	[399.35]	.7669

Crack Initiation Life 510 blocks @ a/W = 0.3480; Fracture Life 2,626.0 blocks

Table 21E - Crack Propagation Data

Test No. BM4-2-FS

Blocks	Reversals X10^-6	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
3,367.0	19.986	.140	[3.56]	.200	[5.08]	.064	[41.29]	.3669
3,865.0	22.942	.210	[5.33]	.250	[6.35]	.086	[55.48]	.3831
4,380.0	25.999	.240	[6.10]	.270	[6.86]	.096	[61.94]	.3899
4,855.0	28.819	.250	[6.35]	.270	[6.86]	.098	[63.23]	.3912
5,355.0	31.787	.270	[6.86]	.310	[7.87]	.109	[70.32]	.3993
5,824.0	34.571	.280	[7.11]	.320	[8.13]	.113	[72.90]	.4020
6,334.0	37.598	.310	[7.87]	.335	[8.51]	.121	[78.06]	.4081
6,819.0	40.477	.320	[8.13]	.340	[8.64]	.124	[80.00]	.4101
7,244.0	43.000	.330	[8.38]	.340	[8.64]	.126	[81.29]	.4115
8,213.0	48.752	.350	[8.89]	.360	[9.14]	.133	[85.81]	.4169
9,764.0	57.959	.360	[9.14]	.380	[9.65]	.139	[89.68]	.4209
9,910.0	58.825	.360	[9.14]	.380	[9.65]	.139	[89.68]	.4209
			Suspended					

Crack Initiation Life   blocks @ a/W = 0.3480; Fracture Life - Test Suspended

Table 22E - Crack Propagation Data

Test No. BM43-MTS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
2,660	15.8	.120 [3.05]	.070 [1.78]	.0355	[22.98]	.3466
2,770	16.0	.190 [4.83]	.070 [1.78]	.0488	[31.45]	.3561
2,731	16.2	.240 [6.10]	.125 [3.18]	.0684	[44.15]	.3703
2,816	16.7	.280 [7.11]	.250 [6.35]	.0994	[64.11]	.3926
2,828	16.8	.320 [8.13]	.300 [7.62]	.116	[75.00]	.4047
2,857	17.0	.375 [9.52]	.350 [8.89]	.136	[87.70]	.4189
3,043	18.1	.400 [10.16]	.390 [9.91]	.148	[95.56]	.4277
3,102	18.4	.440 [11.18]	.420 [10.67]	.161	[104.03]	.4372
3,131	18.6	.460 [11.68]	.450 [11.43]	.171	[110.08]	.4439
3,284	19.5	.530 [13.46]	.530 [13.46]	.199	[128.23]	.4642
3,471	20.6	.650 [16.51]	.650 [16.51]	.244	[157.26]	.4966
3,571	21.2	.780 [19.81]	.780 [19.81]	.292	[188.71]	.5318
3,752	22.3	.880 [22.35]	.880 [22.35]	.330	[212.90]	.5588
3,940	23.4	1.060 [26.92]	1.060 [26.92]	.398	[256.45]	.6074
4,019	23.9	1.200 [30.48]	1.200 [30.48]	.450	[290.32]	.6450
4,044	24.0	1.310 [33.27]	1.310 [33.27]	.491	[316.94]	.6750
4,055	24.1	1.375 [34.92]	1.375 [34.92]	.516	[332.66]	.6926
4,068	24.1	1.440 [36.58]	1.440 [36.58]	.540	[348.39]	.7101
4,072	24.2	1.560 [39.62]	1.560 [39.62]	.585	[377.42]	.7426
4,076	24.2	1.690 [42.93]	1.690 [42.93]	.634	[408.87]	.7777

Crack Initiation Life 2666 blocks interpolated from data at a/W = 0.3480
Fracture Life 4076 blocks

Table 23E - Crack Propagation Data

Test No. BM5-1-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
20,630.0	122.459	No Cracks	No Cracks			

Suspended Test after 20,630 Blocks

Table 24E - Crack Propagation Data

Test No. TM1-1-FM

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
8.5	14.5			.047	[30.32]	.3548
8.75	14.9			.094	[60.65]	.3887
8.90	15.2			.141	[90.97]	.4226

Failure

Crack Initiation Life 8.4 blocks @ a/W = 0.3480; Fracture Life 8.9 blocks

Table 25E - Crack Propagation Data

Test No. TM1-2-JD

Blocks	Reversals X10-3	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.2	[mm2]	
14.0	23.9	.090	[2.29]	.165	[4.19]	.478	[308.39]	.3554
16.0	27.3	.50	[12.70]	.53	[13.46]	.193	[124.52]	.4601

Crack Initiation Life 12.8 blocks @ a/W = 0.3480; Fracture Life 16.0 blocks

Table 26E - Crack Propagation Data

Test No. TM1-3-W

Blocks	Reversals X10-3	Crack Length Inches [mm]			Crack Area		a/W
		Painted Side	Unpainted Side		In.2	[mm2]	
10.5	18.0		.02	[0.508]			
13.0	22.2		.01	[0.254]			
13.9	23.7		.218	[5.54]	.08175	[52.74]	.3799
14.0	23.9		.336	[8.53]	.126	[81.29]	.3418
14.0	23.9	Fracture					

Crack Initiation Life 12.5 blocks @ a/W = 0.3480; Fracture Life 14.0 blocks

Table 27E - Crack Propagation Data

Test No. TM2-1-B

Blocks	Reversals X10-3	Crack Length Inches [mm]		Unpainted Side	Crack Area		a/W
		Painted Side			In.2	[mm2]	
420.0	717.0	.10	[2.54]				
430.0	734.0	.22	[5.59]		.0825	[53.23]	.3804
452.0	772.0	.29	[7.37]		.109	[70.32]	.3993
471.0	804.0	.36	[9.14]		.135	[87.10]	.4182
484.0	827.0	.43	[10.92]		.161	[103.87]	.4372
502.0	857.0	.52	[13.21]		.195	[128.81]	.4615
508.0	868.0	.55	[13.97]		.206	[132.90]	.4696
515.0	880.0	.60	[15.24]		.225	[145.20]	.4831
527.0	900.0	.67	[17.02]		.251	[161.94]	.5020
529.0	903.0	.73	[18.54]		.274	[176.77]	.5182
533.0	910.0	.80	[20.32]		.300	[193.55]	.5372
535.0	914.0	.93	[23.62]		.349	[225.16]	.5723
537.0	917.0	Failure					

Crack Initiation Life 420 blocks @ a/W = 0.3480; Fracture Life 537 blocks

Table 28E - Crack Propagation Data

Test No.   TM2-2-GM

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
134.0	228.872	.06	[1.52]	.09	[2.29]	.028	[18.06]	.3412
154.0	263.032	.09	[2.29]	.11	[2.79]	.037	[23.87]	.3480
182.0	310.856	.35	[8.89]	.36	[9.14]	.133	[85.81]	.4169
190.0	324.520	.61	[15.49]	.60	[15.24]	.227	[146.45]	.4845
191.0	326.228	.98	[24.89]	.94	[23.88]	.380	[245.16]	.5804
193.0	329.644	2.16	[54.86]	2.16	[54.86]	.810	[522.58]	.9047

Crack Initiation Life 154.0 blocks @ a/W = 0.3480; Fracture Life 193.0 blocks

Table 29E - Crack Propagation Data

Test No.   TM2-3-AOS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
64.0	109.312	.03 [.760]	0 [0]			
74.0	126.392	.1 [2.54]	.1 [2.54]	.0375	[24.19]	.3480
78.0	133.224	.25 [6.35]	.25 [6.35]	.0938	[60.52]	.3885
86.0	146.888	Fracture				

Crack Initiation Life 74.0 blocks @ a/W = 0.3480; Fracture Life 86.0 blocks

Table 30E - Crack Propagation Data

Test No.   TM3-1-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
5,527.0	9.44	.13 [3.30]	0 [0]			
5,799.0	9.90	.15 [3.81]	0 [0]			
6,957.0	11.88	1.30 [33.02]	1.3 [33.02]	.488	[314.84]	.6723

Crack Initiation Life 5,800.0 blocks @ a/W = 0.3480; Fracture Life 6,957.0 blocks.

Table 31E - Crack Propagation Data

Test No.   TM3-2-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
4,801.0	8.2	.30	[7.62]	.18	[4.57]	.90	[580.64]	.3858
4,976.0	8.5	.35	[8.89]	.25	[6.35]	.113	[72.90]	.4020
5,376.0	9.18	.58	[14.73]	.50	[12.70]	.203	[130.97]	.4669
5,681.0	9.7	.92	[23.37]	.89	[22.60]	.321	[207.10]	.5655
5,780.0	9.87	1.33	[33.78]	1.30	[33.02]	.493	[318.06]	.6764

Crack Initiation Life 4,270.0 blocks @ a/W = 0.3480; Fracture Life 5,780.0 blocks

Table 32E - Crack Propagation Data

Test No.   TM3-3-MTS

Blocks	Reversals X10⁻⁶	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
3637	6.2	.030	[0.76]	.060	[1.52]	.0169	[10.86]	.3331
3722	6.4	.080	[2.03]	.080	[2.03]	.0300	[19.34]	.3426
3772	6.4	.100	[2.54]	.120	[3.05]	.0412	[26.62]	.3507
4492	7.7	.120	[3.05]	.180	[4.57]	.0562	[36.29]	.3615
4768	8.1	.150	[3.81]	.200	[5.08]	.0656	[42.34]	.3682
5207	8.9	.360	[9.14]	.360	[9.14]	.135	[87.06]	.4182
5305	9.1	.480	[12.19]	.480	[12.19]	.180	[116.11]	.4507
5675	9.7	.600	[15.24]	.630	[16.00]	.231	[148.78]	.4872
5748	9.8	.660	[16.76]	.660	[16.76]	.248	[159.64]	.4993
5811	9.9	.750	[19.05]	.750	[19.05]	.281	[181.45]	.5236
5842	10.0	.940	[23.88]	.910	[23.11]	.347	[223.79]	.5709
5873	10.0	1.000	[25.40]	1.000	[25.40]	.375	[241.94]	.5912
5909	10.1	1.187	[30.15]	1.187	[30.15]	.445	[287.18]	.6418
5920	10.1							

Crack Initiation Life 3755 blocks interpolated from data at a/W = 0.3480; Fracture Life 5920 blocks

Table 33E - Crack Propagation Data

Test No.   SR1-1-FM

Blocks	Reversals X10⁻³	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
19.5	48.9			.0293	[18.90]	.3420
20.5	51.4			.0469	[30.26]	.3547
21.5	53.9			.0615	[39.68]	.3652
22.5	56.4			.0674	[43.48]	.3695
23.5	58.9			.0820	[52.90]	.3800
24.5	61.4			.0996	[64.26]	.3927
26.5	66.4			.1112	[71.74]	.4011
27.5	68.9			.1288	[83.10]	.4138

Failure

Crack Initiation Life 19.9 blocks @ a/W = 0.3480; Fracture Life 27.5 blocks

Table 34E - Crack Propagation Data

Test No. SR1-2-JD

Blocks	Reversals X10⁻³	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
22.0	55.0							
26.0	65.2	.21	[5.33]	.11	[2.79]	.060	[38.71]	.3642
27.0	67.7	.28	[7.11]	.22	[5.59]	.094	[60.65]	.3885
30.0	75.2	.35	[8.89]	.30	[7.62]	.121	[78.06]	.4088
32.0	80.2	.37	[9.40]	.34	[8.64]	.133	[85.8]	.4169
33.0	82.7	.39	[9.91]	.36	[9.14]	.141	[90.97]	.4223
35.0	87.7	.44	[11.18]	.39	[9.91]	.156	[100.64]	.4331
37.0	92.7	.47	[11.94]	.40	[10.16]	.163	[105.16]	.4385
42.0	105.3	.50	[12.70]	.44	[11.18]	.176	[113.55]	.4480
50.0	125.3	.57	[14.48]	.52	[13.21]	.203	[130.97]	.4682
55.0	137.8	.60	[15.24]	.56	[14.22]	.218	[140.64]	.4777
65.0	162.9	.69	[17.53]	.66	[16.76]	.253	[163.23]	.5034
75.0	188.0	.77	[19.56]	.73	[18.54]	.281	[181.29]	.5236
95.0	238.1	.97	[24.64]	.96	[24.38]	.362	[233.55]	.5818
100.0	250.6	1.33	[33.78]	1.46	[37.08]	.523	[337.42]	.6980

Crack Initiation Life 24.4 blocks @ a/W = 0.3480; Fracture Life 100.0 blocks

Table 35E - Crack Propagation Data

Test No. SR1-3-AOS

Blocks	Reversals X10⁻³	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.²	[mm²]	a/W
50.0	125.3							
58.0	145.3	.05	[1.27]	0	[0]	.0094	[6.065]	.3277
63.0	157.9	.10	[2.54]	.02	[.508]	.0225	[14.52]	.3372
64.0	160.4	.10	[2.54]	.1	[2.54]	.0375	[24.89]	.3480
68.0	170.4	.15	[3.81]	.125	[3.18]	.0516	[33.29]	.3581
74.0	185.4	.175	[4.45]	.15	[3.81]	.0609	[39.29]	.3649
82.0	205.5	.20	[5.08]	.20	[5.08]	.075	[48.39]	.3750
84.0	210.5	.25	[6.35]	.25	[6.35]	.0938	[60.52]	.3885
106.0	265.6	.275	[6.98]	.275	[6.98]	.1031	[66.52]	.3953
120.0	300.7	.30	[7.62]	.30	[7.62]	.1125	[72.58]	.4020
142.0	355.9	.35	[8.89]	.35	[8.89]	.1312	[64.84]	.4155
188.0	471.1	.70	[17.78]	.70	[17.78]	.2625	[169.35]	.5101
190.0	476.1	.80	[20.32]	.80	[20.32]	.3000	[193.55]	.5372
191.0	478.6	1.0	[25.4]	1.0	[25.4]	.3750	[241.94]	.5912
194.0	486.2	1.05	[26.67]	1.05	[26.67]	.3938	[254.06]	.6047
200.0	501.2	1.10	[27.94]	1.10	[27.94]	.4125	[266.13]	.6182
204.0	511.2	1.15	[29.21]	1.15	[29.21]	.4312	[276.19]	.6318
206.0	516.2	1.20	[30.48]	1.20	[30.48]	.4500	[290.32]	.6453
212.0	513.3	1.25	[31.75]	1.25	[31.75]	.4688	[302.45]	.6588
218.0	540.3	Fracture						

Crack Initiation Life 64.0 blocks @ a/W = 0.3480; Fracture Life 218.0 blocks

Table 36E - Crack Propagation Data

Test No.   SR2-1-B

Blocks	Reversals X10^-6	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.^{2}	[mm^2]	
945.0	2.37	.04 [1.02]	.02 [.51]	.011 [7.10]		.3291
1,108.0	2.78	.05 [1.27]	.02 [.51]	.013 [8.39]		.3304
1,667.0	4.18	.07 [1.78]	.03 [.76]	.019 [12.26]		.3345
1,800.0	4.51	.10 [2.54]	.03 [.76]	.024 [15.48]		.3385
1,954.0	4.90	.11 [2.79]	.03 [.76]	.026 [16.77]		.3399
2,032.0	5.09	.12 [3.05]	.04 [1.02]	.030 [19.35]		.3426
2,170.0	5.44	.12 [3.05]	.04 [1.02]	.030 [19.35]		.3426
2,283.0	5.72	.12 [3.05]	.04 [1.02]	.030 [19.35]		.3426
3,300.0	8.27	.12 [3.05]	.04 [1.02]	.030 [19.35]		.3426

No noticeable crack growth over last 3.20 x 10^6 reversals - test suspended

Table 37E - Crack Propagation Data

Test No.   SR2-2-GM

Blocks	Reversals X10^-6	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.^{2}	[mm^2]	
381.0	.955					
460.0	1.153	.02 [0.508]	.02 [0.508]	.0075 [4.84]		.3264
555.0	1.391	.05 [1.27]	.04 [1.02]	.0169 [10.90]		.3331
950.0	2.381	.10 [2.54]	.06 [1.52]	.03 [19.35]		.3426
1,101.0	2.759	.10 [2.54]	.07 [1.78]	.032 [20.65]		.3439
1,502.0	3.764	.10 [2.54]	.09 [2.29]	.036 [23.23]		.3466
1,631.0	4.087	.10 [2.54]	.09 [2.29]	.036 [23.23]		.3466
2,045.0	5.125	.11 [2.79]	.12 [3.05]	.043 [27.74]		.3520
2,500.0	6.265	.15 [3.81]	.12 [3.05]	.051 [32.90]		.3574
2,703.0	6.774	.17 [4.32]	.13 [3.30]	.056 [36.13]		.3615
3,173.0	7.952	.18 [4.57]	.14 [3.56]	.06 [38.71]		.3642
3,667.0	9.190	.18 [4.57]	.15 [3.81]	.062 [40.00]		.3655
5,001.0	12.532	.19 [4.83]	.15 [3.81]	.064 [41.29]		.3669
5,535.0	13.369	.20 [5.08]	.16 [4.06]	.068 [43.87]		.3696

Crack Initiation Life 1,710.0 blocks @ a/W = 0.3480; Fracture Life - Test
Suspended after 5,535 blocks

Table 38E - Crack Propagation Data

Test No.   SR3-2-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
11,098.0	27.811	.120	[3.05]	.070	[1.78]	.036	[22.98]	.3466
13,071.0	32.755	.180	[4.57]	.115	[2.92]	.055	[35.48]	.3608
13,793.0	34.565	.185	[4.70]	.135	[3.43]	.060	[38.71]	.3642
15,428.0	38.662	.185	[4.70]	.150	[3.81]	.063	[40.65]	.3662
18,204.0	45.619	.190	[4.83]	.150	[3.81]	.064	[41.29]	.3669
19,064.0	47.774	.270	[6.86]	.260	[6.60]	.099	[63.87]	.3926
19,718.0	49.413	.300	[7.62]	.270	[6.86]	.107	[69.03]	.3980
21,612.0	54.155	.320	[8.13]	.290	[7.37]	.114	[73.55]	.4034
23,831.0	59.720	.375	[9.53]	.300	[7.62]	.127	[81.94]	.4122
24,496.0	61.386	.405	[10.29]	.320	[8.13]	.136	[87.74]	.4189
26,410.0	66.183	.440	[11.18]	.410	[10.41]	.159	[102.58]	.4358
28,291.0	70.897	.470	[11.94]	.450	[11.43]	.173	[111.61]	.4453
28,947.0	72.541	.490	[12.45]	.470	[11.94]	.180	[116.13]	.4507
31,064.0	77.846	.490	[12.45]	.470	[11.94]	.180	[116.13]	.4507
33,764.0	84.612	.530	[13.46]	.485	[12.32]	.183	[118.06]	.4581
40,464.0	101.402	.730	[18.54]	.700	[17.78]	.268	[172.90]	.5142
42,594.0	106.740	.790	[20.10]	.750	[19.05]	.289	[186.45]	.5291
45,054.0	112.905	.835	[21.21]	.815	[20.70]	.309	[199.35]	.5439
46,924.0	117.591	.885	[22.48]	.835	[21.21]	.323	[208.39]	.5534
47,814.0	119.821	.940	[23.88]	.920	[23.37]	.349	[255.16]	.5723
49,904.0	125.059	1.180	[29.97]	1.150	[29.21]	.437	[281.93]	.6358
51,124.0	128.116	1.700	[43.18]	1.700	[43.18]	.638	[411.61]	.7804

Crack Initiation Life 11,200 blocks @ a/W = 0.3480; Fracture Life 51,124 blocks

Table 39E - Crack Propagation Data

Test No.   SR4-1-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
51,716.0	129.7	.10	[2.54]	.15	[3.81]	.047	[30.32]	.3547
55,091.0	138.1	.12	[3.05]	.17	[4.32]	.054	[38.84]	.3601
62,546.0	156.7	.17	[4.32]	.20	[5.08]	.069	[44.52]	.3709
76,432.0	191.5	.23	[5.84]	.28	[7.11]	.096	[61.94]	.3899
89,292.0	223.8	.25	[6.35]	.29	[7.37]	.101	[65.16]	.3939
106,732.0	267.5	.27	[6.86]	.32	[8.13]	.111	[71.61]	.4007

Above data from set of cracks which appeared to join.

Blocks	Reversals X10^{-6}	Painted Side		Unpainted Side		In.^{2}	[mm^2]	a/W
51,716.0	129.7	.22	[5.59]	-	-	.041	[26.45]	.3804
55,091.0	138.1	.25	[6.35]	-	-	.047	[30.32]	.3885
62,546.0	156.7	.26	[6.60]	-	-	.049	[31.61]	.3912
76,432.0	191.5	.36	[9.14]	.16	[4.06]	.098	[63.23]	.3912
89,292.0	223.8	.45	[11.43]	.40	[10.16]	.159	[102.58]	.4358
106,732.0	267.5	.56	[14.22]	.49	[12.45]	.197	[127.10]	.4628

Above data from second set of cracks.

Crack Initiation Life 48,000 blocks @ a/W = 0.3480;
Fracture Life - test suspended after 106,732 blocks

Table 40E - Crack Propagation Data

Test No. BR1-1-FS

Blocks	Reversals X10⁻³	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.²	[mm²]	
3.34	19.808	.18	[4.57]	0	[0]			
3.51	20.808	.21	[5.33]	.03	[.076]	.045	[29.03]	.3534
3.67	21.808	.24	[6.10]	.07	[1.78]	.058	[37.42]	.3628
3.84	22.808	.28	[7.11]	.12	[3.05]	.075	[48.39]	.3750
4.34	25.744	.33	[8.38]	.25	[6.35]	.109	[70.32]	.3993
4.51	26.744	.45	[11.43]	.38	[9.65]	.156	[100.64]	.4331
4.67	27.744	.62	[15.75]	.45	[11.43]	.201	[129.68]	.4655
4.84	28.744	.65	[16.51]	.50	[12.70]	.216	[139.35]	.4764
5.00	29.680	.65	[16.51]	.52	[13.21]	.219	[141.29]	.4791
5.17	30.680	.85	[21.59]	.80	[20.32]	.309	[199.35]	.5439
5.34	31.680	.90	[22.86]	.90	[22.86]	.338	[218.06]	.5642

Crack Initiation Life 3.3 blocks @ a/W = 0.3480; Fracture Life 5.34 blocks

Table 41E - Crack Propagation Data

Test No. BR1-2-B

Blocks	Reversals X10⁻³	Crack Length Inches [mm]		Unpainted Side	Crack Area		a/W
		Painted Side			In.²	[mm²]	
5.41	32.1	.14	[3.56]		.0525	[33.87]	.3588
5.45	32.4	.17	[4.32]		.0637	[41.10]	.3669
5.70	33.8	.23	[5.84]		.0862	[55.61]	.3831
5.80	34.4	.26	[6.60]		.0975	[62.90]	.3912
5.90	35.0	.30	[7.62]		.112	[72.26]	.4020
5.97	35.4	.32	[8.13]		.120	[77.42]	.4074
6.35	37.7	.38	[9.65]		.142	[91.61]	.4236
6.46	38.4	.41	[10.41]		.154	[99.35]	.4318
6.57	39.0	.46	[11.68]		.172	[110.97]	.4453
6.69	39.7	.53	[13.46]		.199	[128.39]	.4642
6.76	40.1	.58	[14.73]		.217	[140.00]	.4777
6.89	40.9	.62	[15.75]		.232	[149.68]	.4885
6.98	41.4	.67	[17.02]		.251	[161.94]	.5020
7.03	41.7	.77	[19.56]		.289	[186.45]	.5291
7.08	42.0	.84	[21.34]		.315	[203.23]	.5480
7.11	42.2	.87	[22.10]		.326	[210.32]	.5561
7.23	43.0	.96	[24.38]		.360	[232.26]	.5804
7.32	43.4	1.05	[26.67]		.394	[254.19]	.6047
7.37	43.7	1.09	[27.69]		.409	[263.87]	.6155
7.42	44.0	Fracture					

Crack Initiation Life 5.1 blocks @ a/W = 0.3480; Fracture Life 7.42 blocks

Crack length measurements taken on painted side only; periodic observations revealed, however, that crack front remained essentially straight after 0.10 inches of crack growth.

Table 42E - Crack Propagation Data

Test No. BR1-3-MTS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side		Unpainted Side		Crack Area In.^{2}	[mm^2]	a/W
4.00	23.75	.11	[2.79]	.05	[1.27]	.030	[19.35]	.3426
4.37	25.91	.13	[3.30]	.13	[3.30]	.049	[31.61]	.3561
4.77	28.29	.21	[5.33]	.22	[5.59]	.081	[52.26]	.3791
4.94	29.32	.26	[6.60]	.25	[6.35]	.096	[61.94]	.3899
5.20	30.87	.27	[6.86]	.26	[6.60]	.099	[63.87]	.3926
5.43	32.23	.34	[8.64]	.33	[8.38]	.126	[81.29]	.4115
5.69	33.80	.40	[10.16]	.39	[9.91]	.148	[95.48]	.4277
6.00	35.64	.51	[12.95]	.54	[13.72]	.197	[127.10]	.4628
6.43	38.19	.66	[16.76]	.65	[16.51]	.246	[158.71]	.4980
6.61	39.24	1.11	[28.19]	1.10	[27.90]	.414	[267.10]	.6196
6.66	39.49	1.11	[28.19]	1.12	[28.45]	.418	[269.68]	.6223

Crack Initiation Life 4.2 blocks @ a/W = 0.348; Fracture Life 6.66 blocks

Table 43E - Crack Propagation Data

Test No.   BR2-1-FS

Blocks	Reversals X10^{-3}	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.^{2}	[mm^2]	a/W
50.0	.291	.07 [1.78]	0 [0]			
56.0	.332	.09 [2.29]	0 [0]			
61.0	.362	.10 [2.54]	0 [0]			
66.0	.392	.12 [3.05]	0 [0]			
71.0	.421	.13 [3.30]	0 [0]			
76.0	.451	.14 [3.56]	0 [0]			
86.0	.510	.15 [3.81]	0 [0]			
96.0	.570	.19 [4.83]	.07 [1.78]	.049	[31.61]	.3561
106.0	.629	.21 [5.33]	.15 [3.81]	.068	[43.87]	.3696
116.0	.689	.26 [6.60]	.21 [5.33]	.088	[56.77]	.3845
126.0	.748	.30 [7.62]	.26 [6.60]	.105	[67.74]	.3966
136.0	.807	.35 [8.89]	.33 [8.38]	.128	[82.58]	.4128
156.0	.926	.50 [12.70]	.49 [12.45]	.186	[120.00]	.4547
186.0	1.104	.76 [19.30]	.76 [19.30]	.285	[183.87]	.5264

Crack Initiation Life 87.5 blocks @ a/W = 0.3480; Fracture Life 186.0 blocks

Table 45E - Crack Propagation Data

Test No.   BR2-3-JD

Blocks	Reversals X10^{-6}	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.^{2}	[mm^2]	
79.0	.469	.07 [1.78]	.02 [.508]	.017 [10.97]		.3331
83.0	.493	.08 [2.03]	.03 [.762]	.021 [13.55]		.3358
90.0	.534	.09 [2.29]	.05 [1.27]	.026 [16.77]		.3399
94.0	.558	.10 [2.54]	.06 [1.52]	.030 [19.35]		.3426
110.0	.653	.11 [2.79]	.07 [1.78]	.034 [21.94]		.3453
114.0	.677	.13 [3.30]	.08 [2.03]	.039 [25.16]		.3493
118.0	.700	.14 [3.56]	.09 [2.29]	.043 [27.74]		.3520
125.0	.742	.15 [3.81]	.10 [2.54]	.047 [30.32]		.3547
135.0	.801	.20 [5.08]	.15 [3.81]	.066 [42.58]		.3682
145.0	.861	.24 [6.10]	.21 [5.33]	.084 [54.19]		.3818
155.0	.921	.31 [7.87]	.28 [7.11]	.111 [71.61]		.4007
165.0	.979	.38 [9.65]	.36 [9.14]	.139 [89.68]		.4209
170.0	1.009	.43 [10.92]	.40 [10.16]	.156 [100.64]		.4331
175.0	1.039	.46 [11.68]	.44 [11.18]	.169 [109.03]		.4426
180.0	1.068	.51 [12.95]	.48 [12.19]	.186 [119.99]		.4547
185.0	1.098	.56 [14.22]	.52 [13.21]	.203 [130.97]		.4669
190.0	1.128	.61 [15.49]	.58 [14.73]	.223 [143.87]		.4818
195.0	1.158	.69 [17.53]	.66 [16.76]	.253 [163.22]		.5034
200.0	1.187	.77 [19.56]	.75 [19.05]	.285 [183.87]		.5264
205.0	1.217	.89 [22.60]	.86 [21.84]	.328 [211.61]		.5574
210.0	1.247	1.06 [26.92]	1.04 [26.42]	.394 [254.19]		.6047
212.0	1.258	1.52 [38.61]	1.52 [38.61]	.570 [367.74]		.7318

Crack Initiation Life 113.0 blocks @ a/W = 0.3480; Fracture Life 212.0 blocks

Table 44E - Crack Propagation Data

Test No.   BR2-2-FM

Blocks	Reversals X10^{-6}	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.^{2}	[mm^2]	
43.0	0.255			.0234 [15.10]		.3378
49.0	0.291			.0469 [30.26]		.3547
54.0	0.321			.0650 [41.94]		.3677
57.0	0.338			.0703 [45.35]		.3716
60.0	0.356			.0820 [52.90]		.3800
64.0	0.380			.0907 [58.52]		.3863
68.0	0.404			.1056 [68.13]		.3970
72.0	0.427			.1170 [75.48]		.4053
77.0	0.457			.1290 [83.23]		.4139
82.0	0.487			.1466 [94.58]		.4266
84.0	0.499			.1605 [103.55]		.4366
89.0	0.528			.1847 [119.16]		.4541
94.0	0.558			.2078 [134.06]		.4707
99.0	0.588			.2308 [148.90]		.4873
104.0	0.617			.3015 [194.52]		.5382
106.0	0.629			.3283 [211.81]		.5576
107.0	0.635			.3518 [226.97]		.5745
108.0	0.641			.4628 [298.58]		.6545

Failure

Crack Initiation Life 47.0 blocks @ a/W = 0.3480; Fracture Life 108.0 blocks

Table 46E - Crack Propagation Data

Test No.   BR31-MTS

Blocks	Reversals X10^-6	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
2381	14.1	.050 [1.27]	.030 [.76]	.0150	[9.68]	.3318
2722	16.2	.120 [3.05]	.100 [2.54]	.0412	[26.61]	.3507
3208	19.0	.120 [3.05]	.120 [3.05]	.0450	[29.03]	.3534
3732	22.2	.140 [3.56]	.180 [4.57]	.0600	[38.71]	.3642
4887	29.0	.150 [3.81]	.200 [5.08]	.0656	[42.34]	.3682
6492	38.5	.200 [5.08]	.200 [5.08]	.0750	[48.39]	.3750
6798	40.4	.240 [6.10]	.250 [6.35]	.0919	[59.27]	.3872
7089	42.1	.480 [12.19]	.480 [12.19]	.180	[116.13]	.4507
7324	43.5	.720 [18.29]	.700 [17.78]	.266	[171.77]	.5128
7412	44.0	.810 [20.57]	.810 [20.57]	.304	[195.97]	.5399
7460	44.3	.875 [22.22]	.905 [22.99]	.334	[215.32]	.5615
7511	44.6	.900 [22.86]	.900 [22.86]	.338	[217.74]	.5642
7537	44.7	1.000 [25.40]	1.000 [25.40]	.375	[241.94]	.5912
7561	44.9	1.060 [26.92]	1.060 [26.92]	.398	[256.45]	.6074
7582	45.0	1.125 [28.58]	1.125 [28.58]	.422	[272.18]	.6250
7623	45.3	1.250 [31.75]	1.250 [31.75]	.469	[302.42]	.6588
7673	45.5					

Crack Initiation Life 2673 blocks interpolated from data at a/W = 0.3480; Fracture Life 7673 blocks

Table 47E - Crack Propagation Data

Test No.   BR3-3-FS

Blocks	Reversals X10^-6	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
11,745.0	69.7	.44 [11.18]	.53 [13.46]	.182	[117.42]	.4520
12,074.0	71.7	.65 [16.51]	.79 [20.06]	.270	[174.19]	.5155
12,469.0	72.4	1.10 [27.94]	1.27 [32.26]	.444	[286.45]	.6412
12,519.0	72.7	1.65 [41.91]	1.68 [42.67]	.624	[402.58]	.7709

Crack Initiation Life   blocks @ a/W = 0.348; Fracture Life 12,519.0 blocks

Table 48E - Crack Propagation Data

Test No.   TR1-1-B

Blocks	Reversals X10^-3	Crack Length Inches [mm] Painted Side	Unpainted Side	Crack Area In.²	[mm²]	a/W
29.0	49.5	.02 [.508]	.07 [1.78]	.0169	[10.90]	.3331
30.0	51.2	.07 [1.78]	.15 [3.81]	.0412	[26.58]	.3507
31.0	52.9	.13 [3.30]	.23 [5.84]	.0675	[43.55]	.3696
31.7	54.1	.18 [4.57]	.27 [6.86]	.0844	[54.45]	.3818
32.4	55.3	.25 [6.35]	.34 [8.37]	.111	[71.61]	.4007
33.0	56.4	.31 [7.87]	.38 [9.65]	.129	[83.23]	.4142
33.4	57.0	.36 [9.14]	.42 [10.67]	.146	[94.19]	.4264
34.0	58.1	.45 [11.43]	.52 [13.21]	.182	[117.42]	.4520
34.3	58.7	.51 [12.95]	.57 [14.48]	.202	[130.32]	.4669
35.0	59.8	.69 [17.53]	.73 [18.54]	.266	[171.61]	.5128
35.3	60.3	.80 [20.32]	.83 [21.10]	.306	[197.42]	.5412
35.6	60.8	1.00 [25.4]	1.04 [26.42]	.382	[246.45]	.5966

Crack Initiation Life 29.9 blocks @ a/W = 0.3480; Fracture Life 35.6 blocks

Table 49E - Crack Propagation Data

Test No.   TR1-2-AOS

Blocks	Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.²	[mm²]	
22.0	37.576					
23.5	40.138	.1 [2.54]	.1 [2.54]	.0375	[24.19]	.3480
25.0	42.700	.15 [3.81]	.18 [20.57]	.0619	[39.93]	.3655
25.5	43.554	.5 [12.70]	.5 [12.70]	.1875	[120.97]	.4561
26.0	44.408	Fracture				

Crack Initiation Life 23.5 blocks @ a/W = 0.3480; Fracture Life 26.0 blocks

Table 50E - Crack Propagation Data

Test No.   TR1-3-W

Blocks	Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.²	[mm²]	
20.0	34.1		.010 [0.254]	.00375	[2.42]	.3236
22.2	37.9		.100 [2.54]	.0375	[24.20]	.3480
23.1	39.4		.366 [9.30]	.139	[89.68]	.4199
23.9	40.8		.572 [14.53]	.214	[138.06]	.4755
24.01	40.988	Fracture				

Crack Initiation Life 22.2 blocks @ a/W = 0.348; Fracture Life 24.0 blocks

Table 51E - Crack Propagation Data

Test No.   TR2-1-FM

Blocks	Reversals X10⁻³	Crack Length Inches [mm]		Crack Area		a/W
		Painted Side	Unpainted Side	In.²	[mm²]	
264.0	451.0			.012	[7.74]	.3296
266.0	454.0			.029	[18.71]	.3418
270.0	461.2			.065	[41.93]	.3677
274.0	468.0			.070	[45.16]	.3714
276.5	472.0			.082	[52.90]	.3800
283.0	483.0			.111	[71.61]	.4009
288.0	492.0			.152	[98.06]	.4305
291.5	498.0			.188	[121.29]	.4564
293.5	501.0			.234	[150.97]	.4896
295.0	504.0			.258	[166.45]	.5069
292.5	505.0			.293	[189.03]	.5321
297.0	507.0			.317	[204.51]	.5494
		Fracture				

Crack Initiation Life 269.0 blocks @ a/W = 0.348; Fracture Life 297.0 blocks

Table 52E - Crack Propagation Data

Test No. TR2-2-JD

Blocks	Reversals X10^{-3}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
509.0	869.0	.55	[13.97]	.50	[12.70]	.197	[127.10]	.4628
512.0	874.0	.62	[15.75]	.58	[14.73]	.225	[145.16]	.4831
515.0	880.0	.66	[16.76]	.68	[17.27]	.251	[161.93]	.5020
517.0	883.0	.73	[18.54]	.73	[18.54]	.274	[176.77]	.5182
519.0	886.0	.87	[22.10]	.86	[21.84]	.324	[209.03]	.5547
520.0	888.0	1.23	[31:24]	1.25	[31.75]	.477	[307.74]	.6561

Crack Initiation Life 460.0 blocks @ a/W = 0.3480; Fracture Life 520.0 blocks

Table 53E - Crack Propagation Data

Test No. TR2-3-GM

Blocks	Reversals X10^{-3}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
239.0	408.212	.10	[2.54]	0	[0]			
306.0	522.648	.10	[2.54]	0	[0]			
374.0	638.792	.20	[5.08]	0	[0]	.037	[23.87]	.3480
393.0	671.244	.22	[5.59]	.03	[.76]	.047	[30.32]	.3547
398.0	679.784	.22	[5.59]	.06	[1.52]	.053	[34.19]	.3588
403.0	688.324	.27	[6.86]	.10	[2.54]	.069	[44.52]	.3709
408.0	696.864	.28	[7.11]	.14	[3.56]	.079	[50.97]	.3777
415.0	708.820	.34	[8.64]	.22	[5.59]	.105	[67.74]	.3966
425.0	725.900	.46	[11.68]	.37	[9.40]	.156	[100.64]	.4331
432.0	737.856	.62	[15.75]	.56	[14.22]	.221	[142.58]	.4804
436.0	744.688	.90	[22.86]	.86	[21.84]	.330	[212.90]	.5588

Crack Initiation Life 374.0 blocks @ a/W = 0.3480; Fracture Life 436.0 blocks

Table 54E - Crack Propagation Data

Test No. TR3-1-FS

Blocks	Reversals X10^{-6}	Crack Length Inches [mm]				Crack Area		a/W
		Painted Side		Unpainted Side		In.^{2}	[mm^2]	
50,660.0	86.5							
57,090.0	97.5	1.45	[36.83]	1.45	[36.83]	.544	[350.97]	.7128

Crack Initiation Life _____ blocks @ a/W = 0.3480; Fracture Life 57,090.0 blocks