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737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

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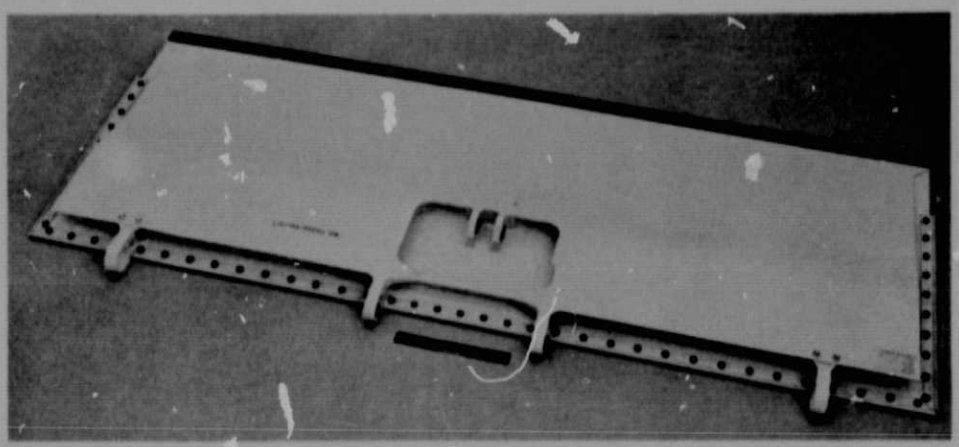
By Robert L. Stoecklin



SECOND ANNUAL REPORT
APRIL 1975 THROUGH MARCH 1976

Prepared under contract NAS1-11668 by
BOEING COMMERCIAL AIRPLANE COMPANY
P.O. Box 3707
Seattle, Washington 98124

for
Langley Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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NASA Technical Representative: Mr. Richard Pride

16. Abstract

The second annual flight service report was prepared in compliance with the requirements of contract NAS1-11668 and covers the flight-service experience of 110 graphite-epoxy spoilers on 737 transport aircraft and related ground-based environmental exposure of graphite-epoxy material specimens for the period from April 1975 through March 1976. Four spoilers have been installed on each of 27 aircraft representing seven major airlines operating throughout the world. A flight service evaluation program of at least 5 years duration is underway. As of February 29, 1976, a total of 503 787 spoiler flight-hours and 788 446 spoiler landings had been accumulated by this fleet. Based on visual, ultrasonic, and destructive testing, there has been no evidence of moisture migration into the honeycomb core and no core corrosion. Tests of removed spoilers and of ground-based exposure specimens after the second year of service indicate modest changes in composite strength.

Two advanced-design, all-composite spoilers were introduced into the program beginning December 18, 1975. Ten additional installations are planned.

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FOREWORD

This is the second progress report on the service evaluation of graphite-epoxy flight spoilers for 737 aircraft. This effort has been conducted as a portion of NASA contract NAS1-11668, "A Study of the Effects of Long-Term Ground and Flight Environment Exposure on the Behavior of Graphite-Epoxy Spoilers." The program is structured to gather and evaluate actual commercial service experience on a large number of graphite-epoxy specimens in a wide range of operating environments. Additional annual reports will be prepared and submitted for the duration of the flight-service period, which is intended to provide at least 5 years of flight service.

The program is administered by the Langley Research Center of the National Aeronautics and Space Administration. Mr. Richard Pride of the Materials Division is the technical monitor.

The program is being conducted at the Boeing Commercial Airplane Company by Robert L. Stoecklin, technical leader, under the direction of J. E. McCarty, program manager.

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CONTENTS

737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

Robert L. Stoecklin
Boeing Commercial Airplane Company

PROGRAM SUMMARY AND STATUS

This second annual flight-service report is submitted in accordance with the requirements of contract NAS1-11668 and covers the service-evaluation portion of this NASA contract for the period of April 1, 1975 through March 31, 1976. Segments of the data contained herein have appeared in previous documentation. (Ref. 1.)

A primary objective of this program is to produce 114 graphite- epoxy 737 flight spoilers for laboratory testing and service- evaluation deployment. One spoiler of each of the three different graphite-epoxy material systems used has been laboratory tested for stiffness and strength in partial fulfillment of FAA certification requirements. Four spoilers were initially installed on each of 27 aircraft representing six major airlines operating in different environmental circumstances. These units will be monitored under actual load and environmental conditions for a period of at least 5 years. Selected units are removed periodically to evaluate any material degradation as a function of time. Six environmental exposure racks have been fabricated and positioned at major airport terminals of the participating airlines in various parts of the world to gather ground-based environmental data to support the flight data gathered from the spoilers.

An additional objective of this program is the fabrication, certification, and deployment of 12 advanced-design, all-composite spoilers which are physically interchangeable with, and can be substituted for, the graphite-epoxy spoiler units deployed in the primary portion of this program. These 12 units are intended to participate in the flight-service program to the maximum extent possible and no removals are scheduled.

All information regarding the fabrication, processing, and developmental testing of the all-composite spoilers leading to FAA certification will be documented in the manufacturing and test report generated within this program. All information relative to the flight-service program involvement will be documented within this reporting system.

Significant events that have occurred during this period include:

- Completion of the second annual inspection of the spoilers in service.
- Completion of the spoiler repair program initiated last year.
- Certification and deployment of the first all-composite spoilers.

- Continuation of the NDI sampling program and static-testing of spoilers from the flight-service program.

- Expansion of the flight-service program to include Frontier Airlines

As of February 29, 1976, a total of 503 787 spoiler flight-hours and 788 446 spoiler landings had been accumulated by the fleet. The high time spoiler has accumulated 5628 flight-hours on Deutsche Lufthansa Airlines 737 D-ABEN. Thirty-six spoilers have accumulated in excess of 5000 flight-hours since the beginning of the flight-service program.

Based on the postservice inspections, there has been no evidence of moisture migration into the honeycomb core and no core corrosion. Two examples of corrosion of aluminum edge members have been discovered, but this problem does not appear to be generally prevalent.

Failure loads for spoilers in laboratory testing after 2 years of flight-service show significantly less degradation than was shown after 1 year of flight service. Tests of additional ground- based exposure specimens have been deferred until the third year of the program in anticipation of extending the ground-based data collection beyond 5 years.

A total of 29 spoilers have sustained inservice damage, principally as a result of the actuator interference problem previously identified in ref. 1. No further maintenance-related damage has occurred in the past year. All repair activity has been completed and the repaired spoiler panels returned to the flight-service program. A total of 100 task I spoilers are currently in the flight-service program.

Initial deployment of the task II all-composite spoilers occurred on December 18, 1975 in Honolulu when Aloha Airlines installed the first spoiler panel on N73711. Additional deployments (2 panels per participating airline) are in process.

Two examples of exfoliation corrosion in the aluminum spar have occurred with one operator. A fleet-wide survey has not uncovered additional corrosion. Preliminary study does not identify the presence of the graphite laminates as responsible for the corrosion.

Airline participation interest in the program continues at an enthusiastic level.

FLIGHT SERVICE EXPERIENCE

The service-evaluation program was established to place the 737 graphite-epoxy flight spoilers into a commercial service environment containing as many climatic variables as possible. The six participating airlines previously identified (ref. 1) have been realigned by the addition of Frontier Airlines (Denver) in place of Pacific Southwest Airlines (PSA) by virtue of the sale of PSA's one remaining participating aircraft to Frontier. Frontier will outfit a second aircraft when they receive two task II all-composite spoilers. The current participating airlines are:

- New Zealand National Airways–four shipsets (16 spoilers)
- Aloha Airlines–four shipsets (16 spoilers)
- Deutsche Lufthansa Airlines–six shipsets (24 spoilers)
- Piedmont Airlines–eight shipsets (32 spoilers)
- VASP Airlines (Brazil)–four shipsets (16 spoilers)
- Frontier Airlines–one aircraft (4 spoilers)

The geographic scope of the service-evaluation program is thus modified as shown in figure 1.

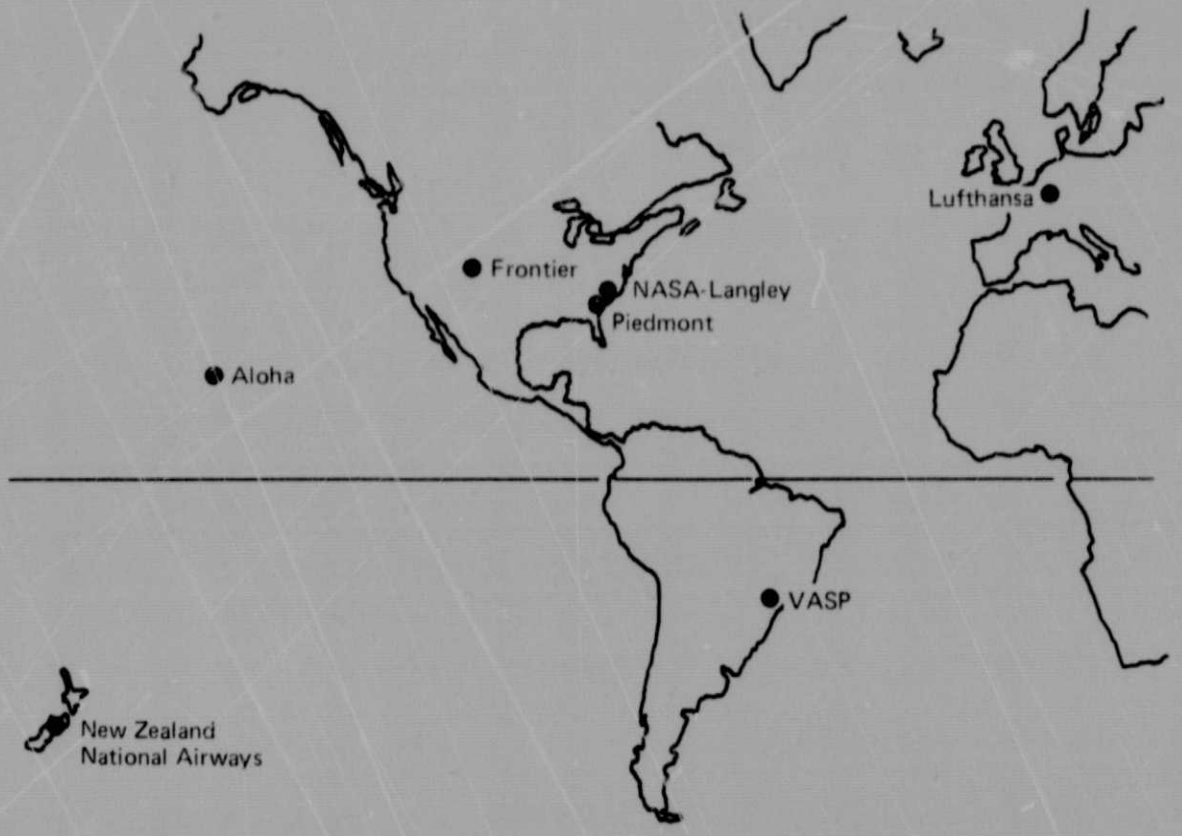

Figure 1.–Geographic Deployment of Current Participating Airlines

FLIGHT EXPERIENCE

The flight service-evaluation program, in operation since July 18, 1973, has achieved an exceptional level of commercial service exposure of graphite-epoxy structural aircraft components, in the form of the 737 flight spoiler. The program has generated over half a million flight-hours of service in its 2.7 years of operation, and is adding flight experience at the rate of nearly 20 000 hours per month.

The total flight experience to February 29, 1976, is detailed in table 1, with the breakdown by the spoiler serial number. Reinstallations are treated as a separate line item in this summary. Note that each of the graphite-epoxy material systems is designated by a separate block of serial numbers:

- Union Carbide T300/2544: 0001 to 0038
- Narmco T300/5209: 0041 to 0078
- Hercules AS/3501: 0081 to 0118

The material system utilized in the task II all composite spoiler skins is Union Carbide T300/P1700 polysulfone thermoplastic resin. The serial numbers associated with the spoiler panels are 0301 through 0320.

Table 2 summarizes the same data by airline. VASP and Frontier data include only flight experience since acquisition of the respective aircraft from PSA.

SPOILER REMOVALS

The spoiler removals discussed in the first annual report (ref. 1) have continued into this reporting period. The skin blister problem continued to manifest itself until all of the 10-60779-182 actuator rod-ends were replaced with 10-60779-175 rod ends (ref. 2). A total of 41 spoilers have been returned by the participating airlines since the first installation 2.7 years ago. A breakdown of the reasons for removal shows:

24 spoilers (59%) returned for rod-end blister problem

11 spoilers (27%) returned for scheduled evaluation/test

5 spoilers (12%) returned for maintenance damage

1 spoiler (2%) returned as surplus (replaced by task II)

Table 3 lists each of the recorded removals and the disposition associated with the removal. The last blister repair was completed on December 5, 1975 and no subsequent reports of this problem have been received.

Table 1.–Spoiler Service-Evaluation Program (As of February 29, 1976)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0001R	PI	5 681	3 056	10 000	9 631	4319	6 575
0002	Test	–	–	–	–	–	–
0003	PSA	8 095	12 842	9 018	14 379	923	1 537
0003	VASP	9 018	14 379	13 280	19 252	4262	4 873
0004	PSA	8 161	12 965	9 018	14 379	923	1 537
0004	VASP	9 018	14 379	13 280	19 252	4262	4 873
0005	PSA	8 095	12 842	9 018	14 379	923	1 537
0005	VASP	9 018	14 379	13 280	19 252	4262	4 873
0006	PSA	8 161	12 965	9 018	14 379	923	1 537
0006	VASP	9 018	14 379	13 280	19 252	4262	4 873
0007	NZ	10 861	15 053	16 279	22 295	5418	7 242
0008	NZ	10 861	15 053	16 279	22 295	5418	7 242
0009	NZ	10 861	15 053	16 147	22 112	5286	7 059
0010	NZ	10 861	15 053	16 279	22 295	5418	7 242
0011	LH	11 274	15 681	16 902	22 735	5628	7 054
0012	LH	11 274	15 681	14 694	19 964	3420	4 283
[b]0012	LH	15 148	20 528	15 793	21 324	645	796
[b]0012	LH	15 940	21 518	16 902	22 735	962	1 217
0013	LH	11 274	15 681	16 902	22 735	5628	7 054
0014	LH	11 274	15 681	13 320	18 216	2055	2 535
0015	PSA	8 651	13 711	9 399	14 936	748	1 225
0015	VASP	9 399	14 936	11 689	17 594	2290	2 658
[b]0015	VASP	13 411	19 607	13 583	19 795	172	188
0016	PSA	8 651	13 711	9 399	14 936	748	1 225
0016	VASP	9 399	14 936	13 583	19 795	4184	4 859
0017	PSA	8 651	13 711	9 399	14 936	748	1 225
0017	VASP	9 399	14 936	12 432	18 474	3033	3 538
[b]0017	VASP	13 411	19 607	13 583	19 795	172	188
0018	PSA	8 651	13 711	9 399	14 936	748	1 225
0018	VASP	9 399	14 936	11 689	17 594	2290	2 658
[b]0018	VASP	13 411	19 607	13 583	19 795	172	188
0019	LH	11 200	14 884	16 700	21 784	5500	6 900
0020	LH	11 200	14 884	16 700	21 784	5500	6 900
0021	LH	11 200	14 884	14 653	19 211	3453	4 327
[b]0021	LH	15 425	20 178	16 700	21 784	1275	1 606
0022	LH	11 200	14 884	16 700	21 784	5500	6 900
0023	Aloha	9 207	24 932	13 943	37 810	4736	12 878
C024	Aloha	9 207	24 932	10 974	29 694	1767	4 762
[b]0024	Aloha	12 071	32 691	13 943	37 810	1872	5 119
0025	Aloha	9 207	24 932	12 964	35 165	3757	10 233
0026	Aloha	9 207	24 932	12 071	32 691	2864	7 759
[b]0026	Aloha	8 287	14 823	9 370	17 739	1083	2 916
0027	PI	12 329	20 204	17 216	27 717	4887	7 513
0028	PI	13 747	22 449	16 387	26 396	2640	3 947
[b]0028	PI	17 201	27 670	19 016	30 487	1815	2 817

See footnotes at end of table.

Table 1.—(Continued)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0029	PI	12 329	20 204	17 216	27 717	4887	7 513
0030	PI	13 747	22 449	19 016	30 487	5269	8 038
0031	PI	13 747	22 449	19 016	30 487	5269	8 038
0032	PI	12 329	20 204	14 411	23 348	2082	3 144
[b]0032	PI	15 259	24 624	17 216	27 717	1957	3 093
0033	PI	13 747	22 449	19 016	30 487	5269	8 038
0034R	PI	12 329	20 204	17 216	27 717	4887	7 513
0035	PI	5 681	3 056	7 673	5 964	1992	2 908
[b]0035	PI	8 542	7 300	10 000	9 631	1458	2 331
0036	PI	5 681	3 056	7 663	5 945	1982	2 889
[b]0036	PI	8 542	7 300	10 000	9 631	1458	2 331
0037	PI	5 681	3 056	10 000	9 631	4319	6 575
0038	Aloha	11 340	30 745	13 865	37 711	2525	6 966
				Sub-total		170 245	257 070
0041	Test	–	–	–	–	–	–
0042	PSA	5 003	8 092	9 600	16 525	4597	8 433
0042	FL	9 600	16 525	10 565	17 507	925	982
0043	PSA	4 993	8 068	9 600	16 525	4607	8 457
0043	FL	9 600	16 525	10 565	17 507	925	982
0044	PSA	5 003	8 092	9 600	16 525	4597	8 431
0044	FL	9 600	16 525	10 565	17 507	925	982
0045	PSA	4 993	8 068	6 896	11 280	1902	3 212
[b]0045	FL	10 064	16 998	10 565	17 507	501	509
0046	Aloha	6 447	9 087	10 400	19 476	3953	10 389
0047	Aloha	6 447	9 087	10 256	19 089	3809	10 002
0048	Aloha	6 447	9 087	9 103	16 022	2655	6 935
[b]0048	Aloha	8 287	14 823	9 370	17 739	1083	2 916
0049	Aloha	6 447	9 087	10 400	19 476	3953	10 389
0050	NZ	10 539	14 075	15 771	21 303	5232	7 228
0051	NZ	10 539	14 075	15 953	21 538	5414	7 463
0052	NZ	10 539	14 075	14 057	18 964	3518	4 889
[b]0052	NZ	14 707	19 835	15 953	21 538	1246	1 703
0053	NZ	10539	14 075	13 138	17 747	2599	3 672
0054	LH	11 152	15 328	16 712	22 344	5560	7 016
0055	LH	11 152	15 328	16 712	22 344	5560	7 016
0056	LH	11 152	15 328	16 712	22 344	5560	7 016
0057	LH	11 152	15 328	15 633	20 997	4481	5 669
0058	PSA	8 476	13 644	9 402	15 241	926	1 597
0058	VASP	9 402	15 241	13 393	19 816	3991	4 575
0059	PSA	8 476	13 644	9 402	15 241	926	1 597
0059	VASP	9 402	15 241	10 900	17 164	1498	1 923
[b]0059	VASP	13 181	19 621	13 393	19 816	212	195
0060	PSA	8 476	13 644	9 402	15 241	926	1 597
0060	VASP	9 402	15 241	13 393	19 816	3991	4 575
0061	PSA	8 476	13 644	9 402	15 241	926	1 597

See footnotes at end of table

Table 1.–(Continued)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0061	VASP	9 402	15 241	13 393	19 816	3991	4 575
0062	LH	11 450	15 759	16 799	22 483	5349	6 724
0063	LH	11 450	15 759	16 799	22 483	5349	6 724
0064	LH	11 450	15 759	16 799	22 483	5349	6 724
0065	LH	11 450	15 759	16 799	22 483	5349	6 724
0066	NZ	10 787	14 648	14 184	19 120	3397	4 472
[b]0066	NZ	14 602	19 678	16 072	21 796	1470	2 118
0067	NZ	10 787	14 648	16 072	21 796	5285	7 148
0068	NZ	10 787	14 648	16 072	21 796	5285	7 148
0069	NZ	10 787	14 648	16 072	21 796	5285	7 148
0070	PI	13 908	22 649	19 194	30 899	5286	8 250
0071	PI	13 908	22 649	19 194	30 899	5286	8 250
0072	PI	13 908	22 649	19 194	30 899	5286	8 250
0073	PI	15 070	24 630	19 243	31 043	4173	6 413
0074	PI	13 908	22 649	19 194	30 899	5286	8 250
0075	PI	15 070	24 630	19 243	31 043	4173	6 413
0076	PI	15 070	24 630	19 243	31 043	4173	6 413
0077	PI	15 070	24 630	19 243	31 043	4173	6 413
0078	Aloha	9 343	25 410	11 340	30 728	1997	5 318
[b]0078	Aloha	9 103	16 022	10 400	19 476	1297	3 454
				Sub-totals		174 237	268 878
0081	Test	–	–	–	–	–	–
0082	LH	11 560	16 962	17 000	26 211	5440	9 249
0083	LH	11 560	16 962	15 286	22 013	3726	5 051
[b]0083	LH	16 901	26 080	17 000	26 211	99	131
0084	LH	11 560	16 962	15 286	22 013	3726	5 051
[b]0084	LH	16 576	25 672	17 000	26 211	424	539
0085	LH	11 560	16 962	15 896	23 901	4336	6 939
[b]0085	LH	16 901	26 080	17 000	26 211	99	131
0086	NZ	5 587	8 565	11 065	15 961	5478	7 396
0087	NZ	5 587	8 565	9 516	13 797	3929	5 232
[b]0087	NZ	10 647	15 393	11 065	15 961	418	568
0088	NZ	5 587	8 565	9 516	13 797	3929	5 232
[b]0088	NZ	10 647	15 393	11 010	15 961	418	568
0089	NZ	5 587	8 565	7 272	10 794	1685	2 229
[b]0089	NZ	8 771	12 820	11 065	15 961	2294	3 141
0090	Aloha	5 623	7 992	6 788	10 937	1165	2 945
[b]0090	Aloha	11 344	30 728	13 865	37 711	2521	6 983
0091	Aloha	5 623	7 992	8 287	14 823	2664	6 831
[b]0091	Aloha	12 964	35 165	13 943	37 810	979	2 645
0092	Aloha	5 623	7 992	9 370	17 739	3747	9 747
0093	PI	13 879	22 839	16 461	26 759	2582	3 920
[b]0093	PI	17 333	28 122	18 878	30 545	1545	2 423
0094	PI	13 879	22 839	16 461	26 759	2582	3 920
[b]0094	PI	17 333	28 122	18 878	30 545	1545	2 423

See footnotes at end of table

Table 1.—(Concluded)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current landings	Net hours	Net landings
0095	PI	13 879	22 839	18 878	30 545	4999	7 706
0096	PI	13 879	22 839	18 878	30 545	4999	7 706
0097	—	—	—	—	—	—	—
0098	Aloha	9 244	25 150	13 865	37 711	4621	12 561
0099	PI	10 290	15 517	15 537	23 564	5247	8 047
0100	PI	12 641	20 584	17 546	28 117	4905	7 533
0101	PI	10 290	15 517	15 537	23 564	5247	8 047
0102	PI	10 290	15 517	15 537	23 564	5247	8 047
0103	PI	12 641	20 584	17 546	28 117	4905	7 533
0104	Aloha	9 244	25 150	11 340	30 745	2096	5 595
0105	Aloha	9 244	25 150	9 343	25 410	99	260
[b]0105	Aloha	6 916	11 247	8 287	14 823	1371	3 576
0106	Aloha	5 623	7 992	9 370	17 739	3747	9 747
0107	Aloha	9 244	25 150	13 865	37 711	4621	12 561
0108	PSA	8 621	13 711	9 568	15 160	947	1 449
0108	VASP	9 568	15 160	13 605	19 884	4037	4 724
0109	PSA	8 621	13 711	9 568	15 160	947	1 449
0109	VASP	9 568	15 160	12 174	18 313	2606	3 153
0110	PSA	8 621	13 711	9 568	15 160	947	1 449
0110	VASP	9 568	15 160	13 605	19 884	4037	4 724
0111	PSA	8 621	13 711	9 568	15 160	947	1 449
0111	VASP	9 568	15 160	12 174	18 313	2606	3 153
[b]0111	VASP	13 369	19 647	13 605	19 884	236	237
0112	LH	11 587	16 011	15 179	20 569	3592	4 558
[b]0112	LH	16 309	21 974	16 761	22 542	452	568
0113	LH	11 587	16 011	16 761	22 542	5174	6 531
0114	LH	11 587	16 011	14 601	19 849	3014	3 838
[b]0114	LH	15 179	20 569	16 761	22 542	1582	1 973
0115	LH	11 587	16 011	16 761	22 542	5174	6 531
0116	PI	10 290	15 517	15 537	23 564	5247	8 047
0117	PI	12 641	20 584	17 546	28 117	4905	7 533
0118	PI	12 641	20 584	17 546	28 117	4905	7 533
					Sub-total	158 790	261 112
					Total Task I	503 272	787 060

Task II All-Composite Spoilers

0306	Aloha	13 572	36 811	13 943	37 810	371	999
0307	Aloha	10 256	19 [illegible]9	10 400	19 476	144	387
					Total Task II	515	1 386
					Grand Total (Task I & Task II)	503 787	788 446

[a]PI is Piedment Airlines.
VASP is Viacao Aerea Sao Paulo Airlines, Brazil.
NZ is New Zealand National Airways.
LH is Lufthansa German Airlines.
FL is Frontier Airlines

[b]Reinstallation

Table 2.—Flight Spoiler Service Experience (Through February 29, 1976)

Airline	Task I		Task II all-composite		Spoiler count (Task I only)			
	Total spoiler hours	Total spoiler landings	Total spoiler hours	Total spoiler landings	Currently in service	Out for repair	Out for evaluation	Destroyed in static test
PSA	29 87[illegible]	51 747	0	0	0	0	0	0
Aloha	64 982	173 487	515	1386	14	0	2	2
New Zealand	78 422	106 140	0	0	13	0	2	1
Lufthansa	118 961	154 275	0	0	22	0	0	2
Piedmont	151 186	232 333	0	0	32	0	0	0
VASP	56 566	65 603	0	0	15	0	0	1
Frontier	3 276	3 455	0	0	4	0	0	0
Totals	503 [illegible]	787 060	515	1386	100	0	4	6
Grand totals	503 787	788 466						

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Table 3.—Flight Spoiler Removal Summary (As of February 23, 1976)

Spoiler serial number	Airline	Date removed	Reason for removal	Action taken	Final disposition
0009	NZ	2-4-76	Spar corrosion	Analyze only	Await disp.
0012	Lufthansa	3-4-75	Upper skin blister	NDT & repair	Reinstalled
0014	Lufthansa	7-29-74	1-yr evaluation	NDT & repair	Static test
0015	VASP	5-13-75	Upper Skin Blister	NDT & repair	Reinstalled
0017	VASP	9-21-75	2-yr evaluation	NDT	Reinstalled
0018	VASP	5-13-75	Upper skin blister	NDT & repair	Reinstalled
0021	Lufthansa	3-29-75	Upper skin blister	NDT & repair	Reinstalled
0024	Aloha	7-11-74	Upper skin blister	NDT & repair	Reinstalled
0025	Aloha	8-18-75	2-yr evaluation	NDT	Static test
0026	Aloha	2-25-75	Upper skin blister	NDT & repair	Reinstalled
0028	Piedmont	2-24-75	1-yr evaluation	NDT	Reinstalled
0032	Piedmont	1-28-75	Upper skin blister	NDT & repiar	Reinstalled
0035	Piedmont	4-18-75	Upper skin blister	NDT & repair	Reinstalled
0036	Piedmont	4-16-75	Upper skin blister	NDT & repiar	Reinstalled
0045	PSA/Frontier	7-14-74	1-yr evaluation	NDT	Reinstalled
0047	Aloha	1-7-76	Replaced by Task II	NDT	Await reinst
0048	Aloha	2-25-75	Upper skin blister	NDT & repair	Reinstalled
0050	NZ	1-28-76	Spar corrosion	Analyze only	Scrapped
0052	NZ	2-27-75	Upper skin blister	NDT & repair	Reinstalled
0053	NZ	9-24-74	1-yr evaluation	NDT	Static test
0057	Lufthansa	9-7-75	2-yr evaluation	NDT	Static test
0059	VASP	1-14-75	Upper skin blister	NDT & repair	Reinstalled
0066	NZ	2-27-75	Upper skin blister	NDT & repair	Reinstalled
0078	Aloha	10-24-74	Upper skin blister	NDT & repair	Reinstalled
0083	Lufthansa	5-17-75	Maintenance damage	NDT & repair	Reinstalled
0084	Lufthansa	5-17-75	Upper skin blister	NDT & repair	Reinstalled
0085	Lufthansa	9-4-75	2-yr evaluation	NDT	Reinstalled
0087	NZ	6-11-75	Upper skin blister	NDT & repair	Reinstalled
0088	NZ	6-11-75	Upper skin blister	NDT & repair	Reinstalled
0089	NZ	6-21-74	Maintenance damage	NDT & repair	Reinstalled
0090	Aloha	5-2-74	Upper skin blister	NDT & repair	Reinstalled
0091	Aloha	5-16-75	Upper skin blister	NDT & repair	Reinstalled
0093	Piedmont	4-1-75	Upper skin blister	NDT & repair	Reinstalled
0094	Piedmont	4-1-75	1-yr evaluation	NDT	Reinstalled
0104	Aloha	10-25-74	1-yr evaluation	NDT	Static test
0105	Aloha	10-17-73	Upper skin blister	NDT & repair	Reinstalled
0105	Aloha	5-16-75	2nd upper skin blister	NDT & repair	Scrapped
0109	VASP	7-29-75	2-yr evaluation	NDT	Static test
0111	VASP	7-29-75	Upper skin blister	NDT & repair	Reinstalled
0112	Lufthansa	6-20-75	Maintenance damage	NDT & repair	Reinstalled
0114	Lufthansa	3-9-75	Upper skin blister	NDT & repair	Reinstalled

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On January 28, 1976 New Zealand National Airways (NZNAC) reported a problem of delamination along the front spar/skin interface of spoiler S/N 0050 (fig. 2). The panel was removed from the aircraft. Additional inspection activity at NZNAC identified another spoiler, S/N 0009, which exhibited a similar though less severe delaimination. Both panels were returned to Boeing for evaluation.

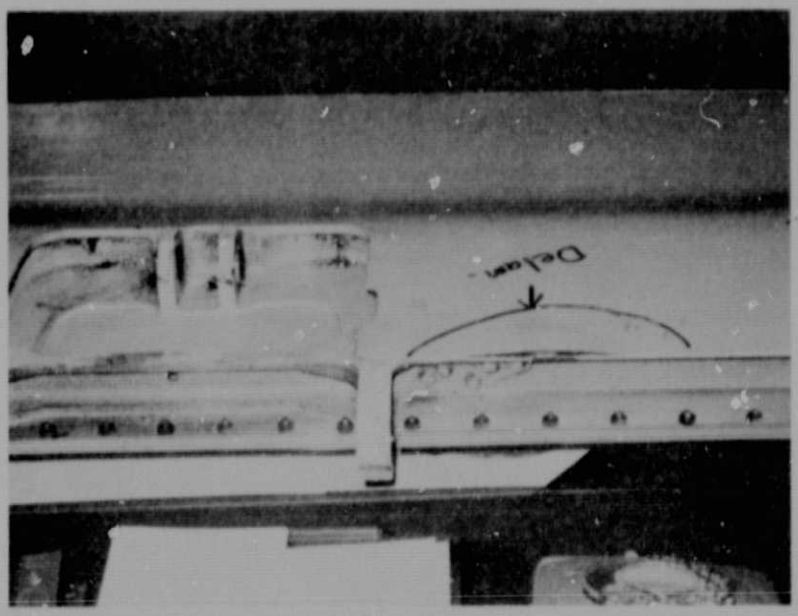

Figure 2.—Delamination Resulting from Exfoliation Corrosion Under Skin

Detailed examination of both units revealed that the fundamental problem was one of exfoliation corrosion of the aluminum spar element. The corrosion commenced at the hinge fitting/spar butt joint and progressed outboard within the spar chord. Expansion of the corroding aluminum generated the expanding force which precipitated the skin delamination. The corrosion was contained entirely on the spar side of the adhesive bondline and no evidence was found to suggest that the presence of the graphite skin accelerated the corrosion. No corrosion was found in the center hinge fitting nor in the aluminum core adjacent to the corroding spar. The corrosion is attributed to intrusion of moisture through a crack in the sealant material and through a suspected defect in the BAC 5555 surface preparation. Spoiler S/N 0050 has been removed from the program; S/N 0009 is being evaluated further.

A fleet survey was initiated to look for additional examples of exfoliation corrosion. To date, responses covering 63% of the spoilers in service have not uncovered additional corrosion problems.

An additional moisture/corrosion investigation was undertaken following the discovery of corrosion in the aluminum spar elements. Spoiler S/N 0025, having been tested to destruction following 2 years of flight-service in Hawaii, was selected for core corrosion exploration. The lower skin element was peeled extensively, beginning in the vicinity of the center hinge fitting (fig 3). Minute examination of the core cells failed to identify any corrosion of the internal structural elements.

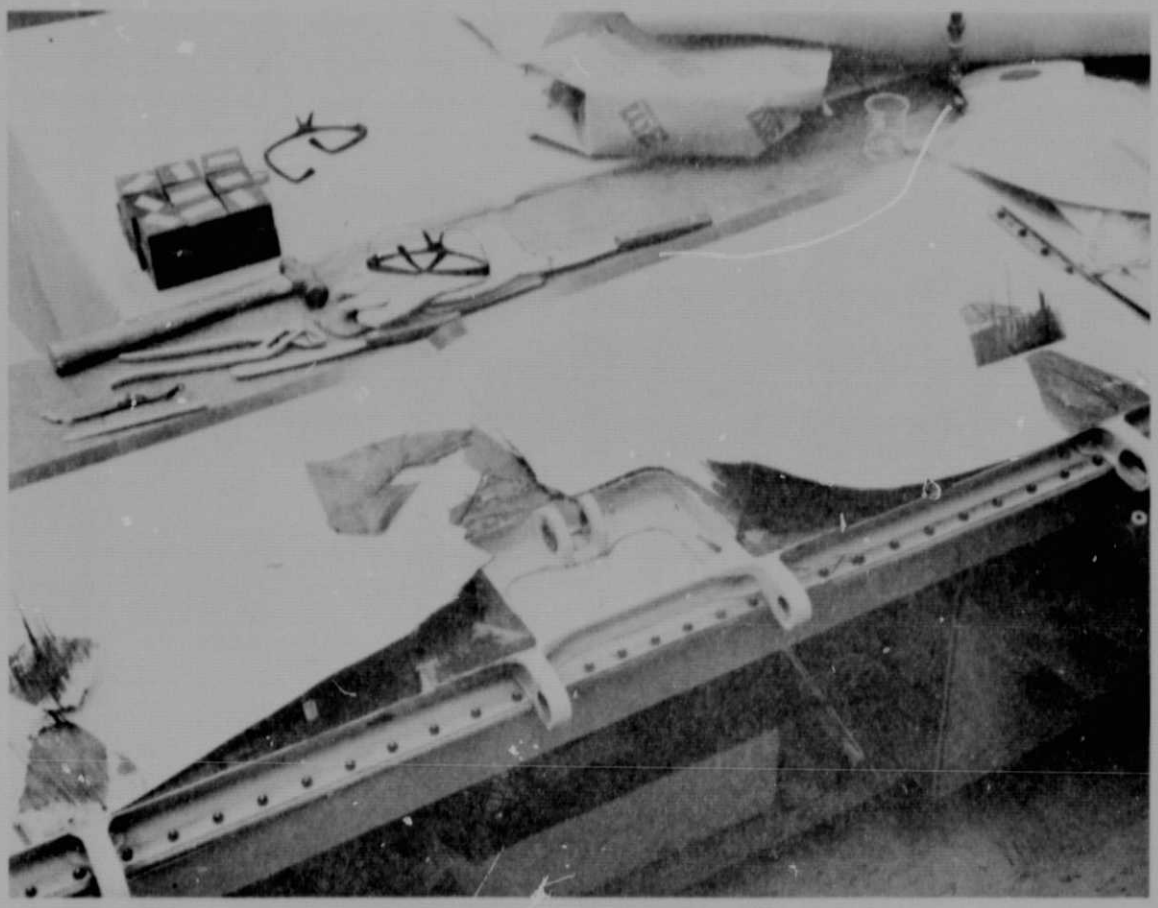

Figure 3.—Core Corrosion Examination of Static Test Spoiler S/N 0025

S/N 0025 had accumulated 3757 flight-hours and 10 233 landings over a period of 2 years flight service.

STATIC TEST RESULTS

During the period July 29, 1975 through September 21, 1975 a total of 5 spoilers were removed from the flight-service program for evaluation/test. The sixth removal is scheduled for April 1976. Of these spoilers, all were reinspected using the NDI color C-scan and the results compared to the original production C-scan records for degradation. No detectable differences were noted when compared to the original color scans. Three of the spoilers (S/N 0025, 0557, and 0109) were then selected to be destructively tested to measure residual static strength following the specified calendar period of exposure. Table 4 contains all the data relative to these removals.

It is significant to note that all three spoilers destructively tested yielded residual static strengths greater than the corresponding part-numbered units tested after 1 year of

Table 4.—Static Test Results

Spoiler S/N	Airline	NDI results	Failure load % DLL	Static test results		Time in service	Flight hours
				% change strength	% change stiffness		
0017(-1)	VP	Clear	–	Not tested		25 mon 19 days	3780
0025(-1)	Aloha	Clear	260%	+6%	0%	24 mon 0 days	3757
0057(-2)	LH	Clear	257%	-11%	-5%	24 mos 1 day	4481
0074(-2)	PI	(Removal in process)		Not scheduled for test		–	–
0085(-3)	LH	Clear	–	Not tested		23 mos 22 days	4336
0109(-3)	VP	Clear	237%	-2%	-11%	22 mos 29 days	3553

service. Figure 4 shows a plot of all test data plotted as a function of time. This data points out the potential scatter in the strength data being collected, and at the same time defines a degradation with time significantly lower than was indicated following completion of the first years testing. The test failures of the second year specimens are shown in figures 5 through 10.

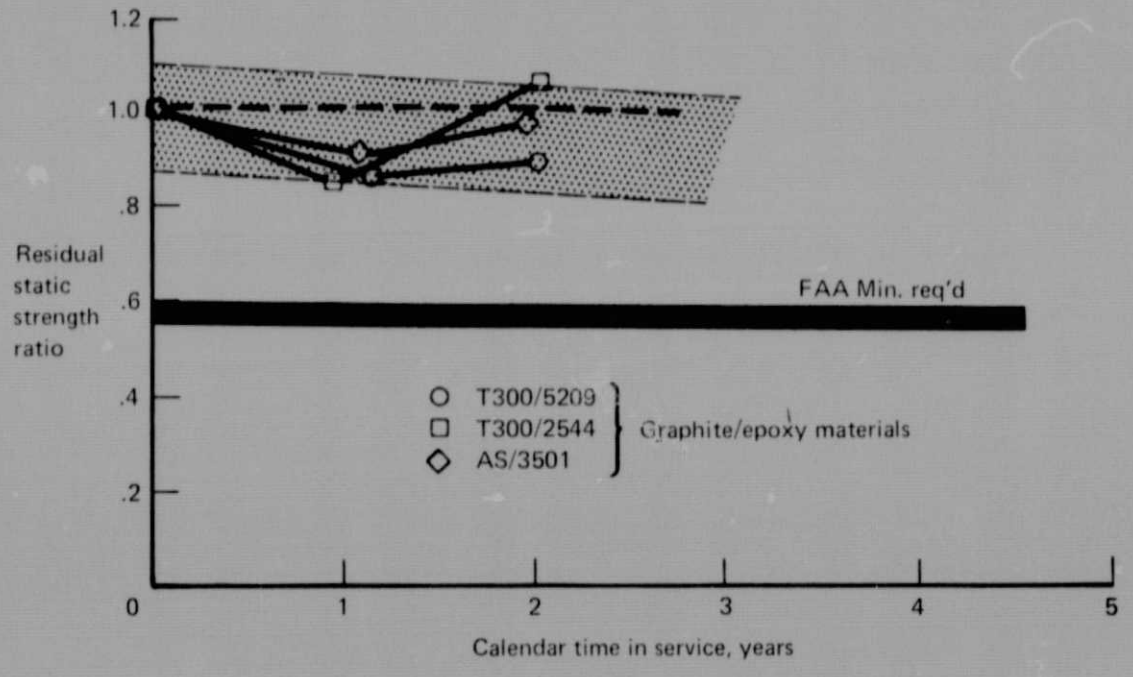

Figure 4.—Residual Static Strength of Graphite-Epoxy Spoilers After Removal From Flight Service

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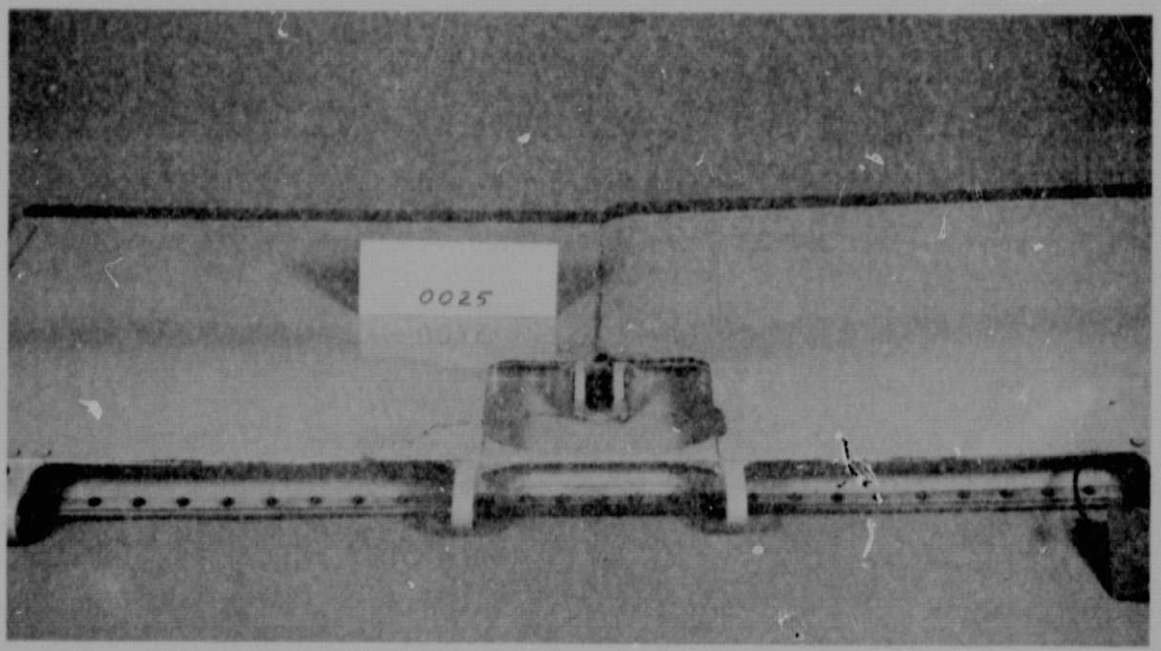

Figure 5.—Failed Static Test Specimen S/N 0025

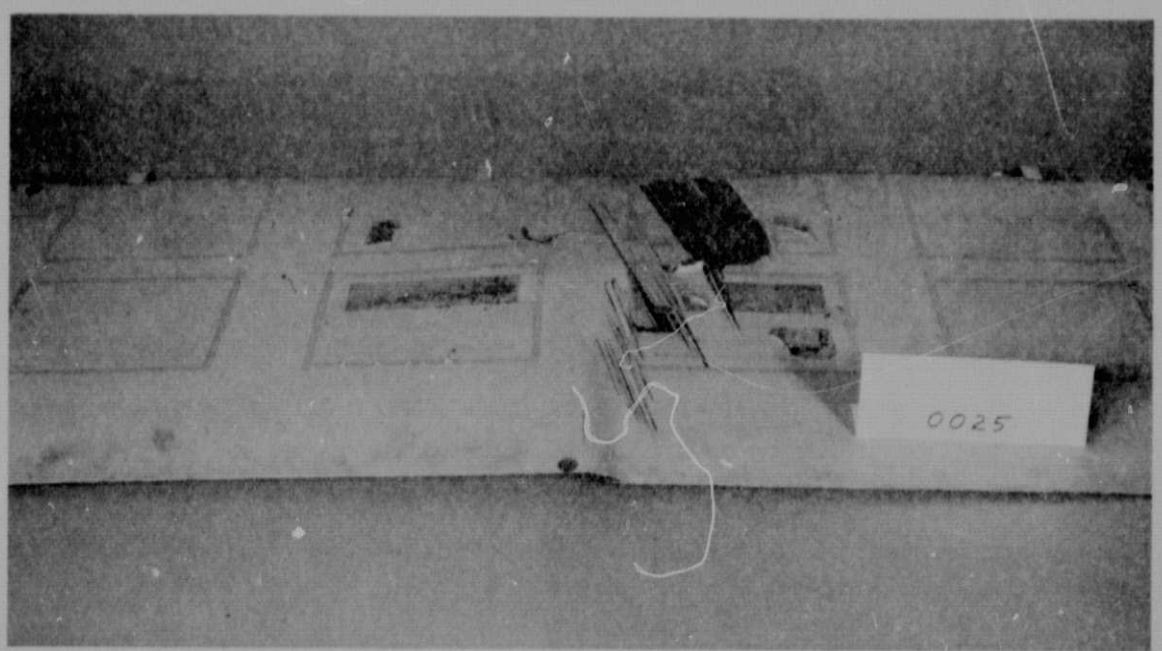

Figure 6.—Failed Static Test Specimen S/N 0025

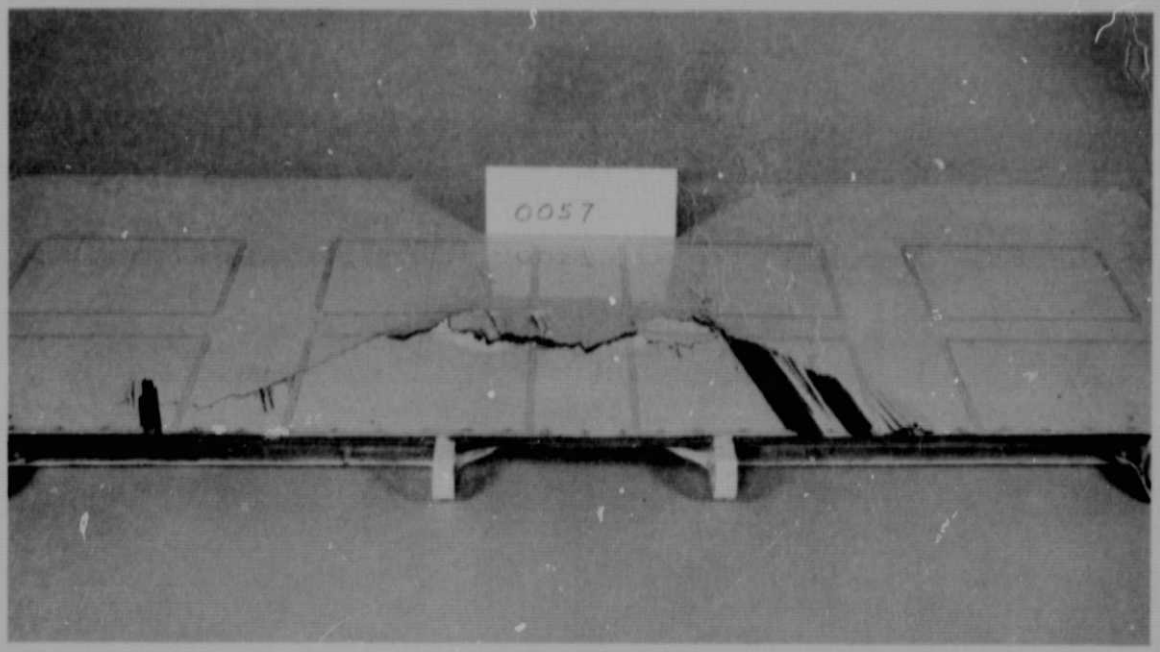

Figure 7.—Failed Static Test Specimen S/N 0057

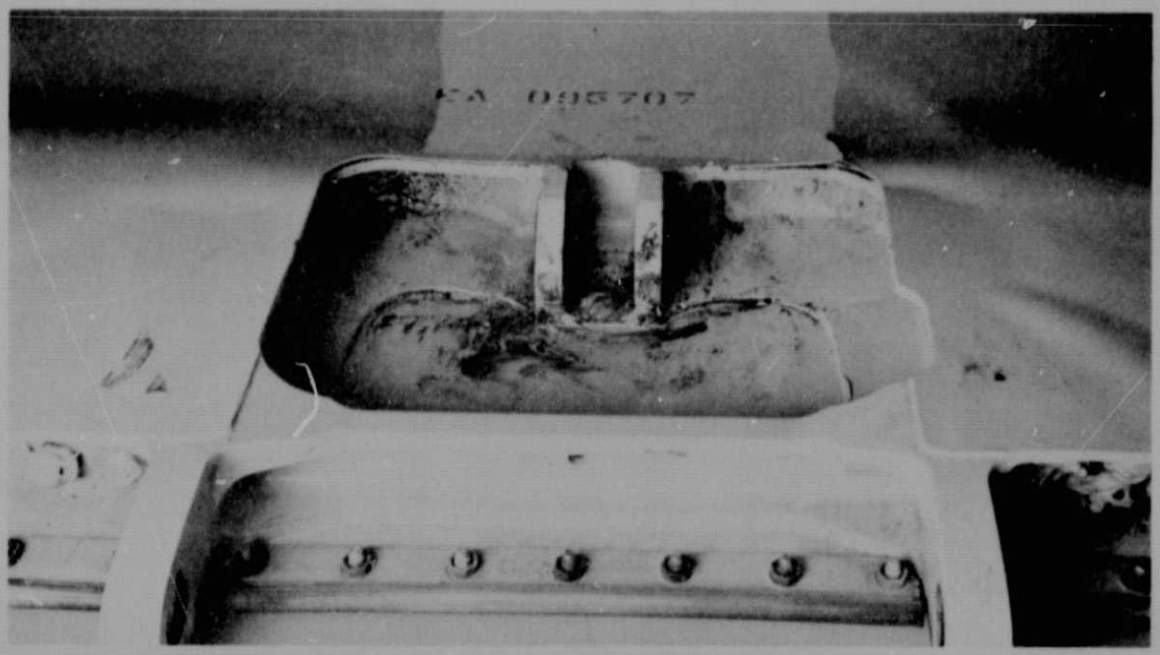

Figure 8.—Failed Static Test Specimen S/N 0057

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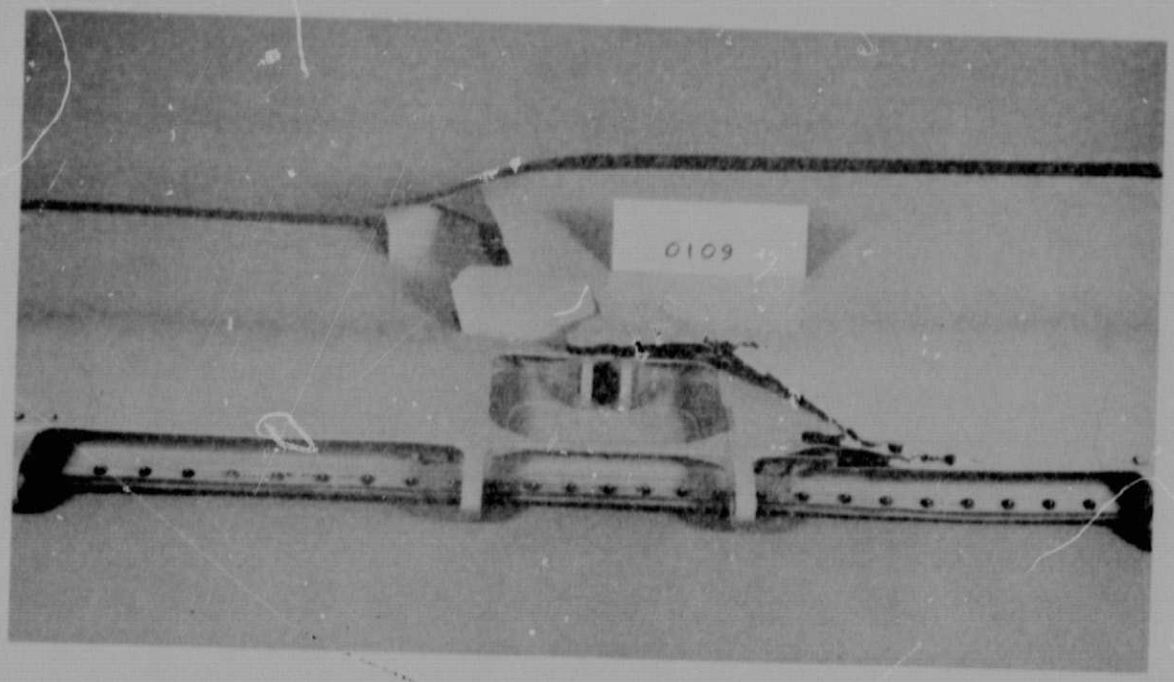

Figure 9.—Failed Static Test Specimen S/N 0109

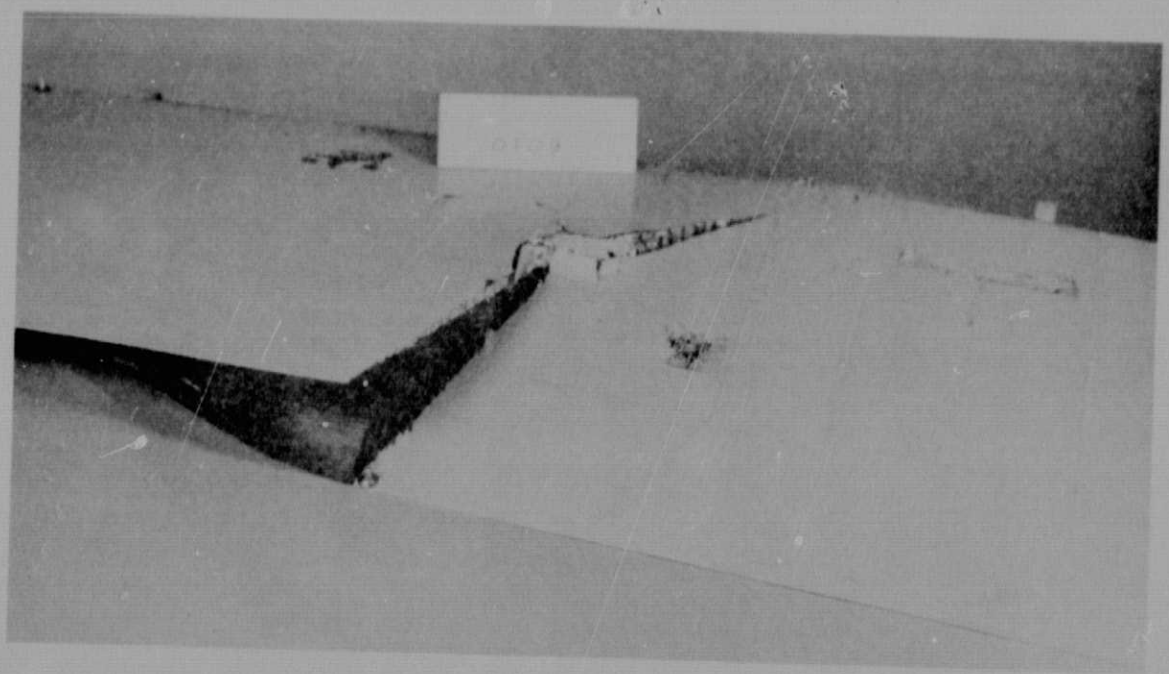

Figure 10.—Failed Static Test Specimen S/N 0109

SERVICE PROBLEMS/REPAIRS

As noted in the spoiler removal section, the majority of service problems occurred in the rod-end-induced delaminations on the spoiler upper skin surface. The repair of these delaminations necessitated only the removal of the delaminated plies, replacement with wet prepreg of the 250° F system (NARMCO T300/5209) and autoclave cure to the reduced-pressure cure cycle required for second stage curing. The layup presented little problem as the delaminations always occurred over the internal 0.016 in aluminum doubler (P/N 65-76327-11) which served as layup pressure plate to facilitate cure of the prepreg. A total of 24 repairs have been accomplished in this manner with little difficulty and no rejections. The first repair accomplished (an in-process repair on S/N 0014) did not employ adhesive film along the interface between the wet prepreg and the cured laminate. Subsequent examination revealed incomplete bonding along the interface evidenced by raised groups of fibers. The repair procedure was modified to add a 5-mil adhesive layer along the interface and co-cure with the wet prepreg. Subsequent examinations have not disclosed additional bondline repair failures.

The first annual report (ref. 1) discussed the repair of the spoiler S/N 0024, which suffered a large lower surface delamination due to a processing error. The entire lower surface skin was replaced and the panel returned to service. Latest inspection reports on S/N 0024 confirm trouble-free performance. S/N 0024 is not scheduled for removal from service prior to the completion of the program.

A different type of problem occurred with panel S/N 0112. The panel suffered puncture damage to the curved lower skin. Background information as to the source of the puncture was unobtainable. Since the damaged area had no underlying structure such as was available for the rod-end blister repairs, a special, one-ply piece of laminate was prepared and cured on the skin tool, then placed in the prepared repair area. This cured ply would serve as the first ply of the repair patch plus functioning as the caul plate required to support the remaining wet prepreg layers. The total layup was then successfully bagged and autoclaved. Repair of the honeycomb core cells was accomplished prior to repair of skin.

An interesting situation developed on spoiler S/N 0105, P/N 65-76327-3. This unit was returned by Aloha Airlines for repair of a second occurrence of a rod-end blister above the center hinge fitting. The repair was accomplished via the previously developed and now routine repair procedure. During the oven-drying cycle for the epoxy enamel finish (limited to 180° F (82° C)) a triangular skin blister occurred outside the center hinge fitting area, the outline of which is shown in figure 11. The blistered skin area subsequently removed and the part opened up as shown in figure 12. The extent of the damage to both the skin, the core, and the subsurface -11 aluminum doubler precluded further repair and the assembly was scrapped. Investigation of the circumstances of drying the epoxy enamel finish ruled out the possibility that the assembly had become overheated locally. The maximum temperature recorded in the drying room was 180° F (82° C). Flatwise tension tests were run on successive cures of EA9628 to establish any degradation as a result of reexposure of the adhesive to repeated curing cycles. The tests showed little change in tension properties.

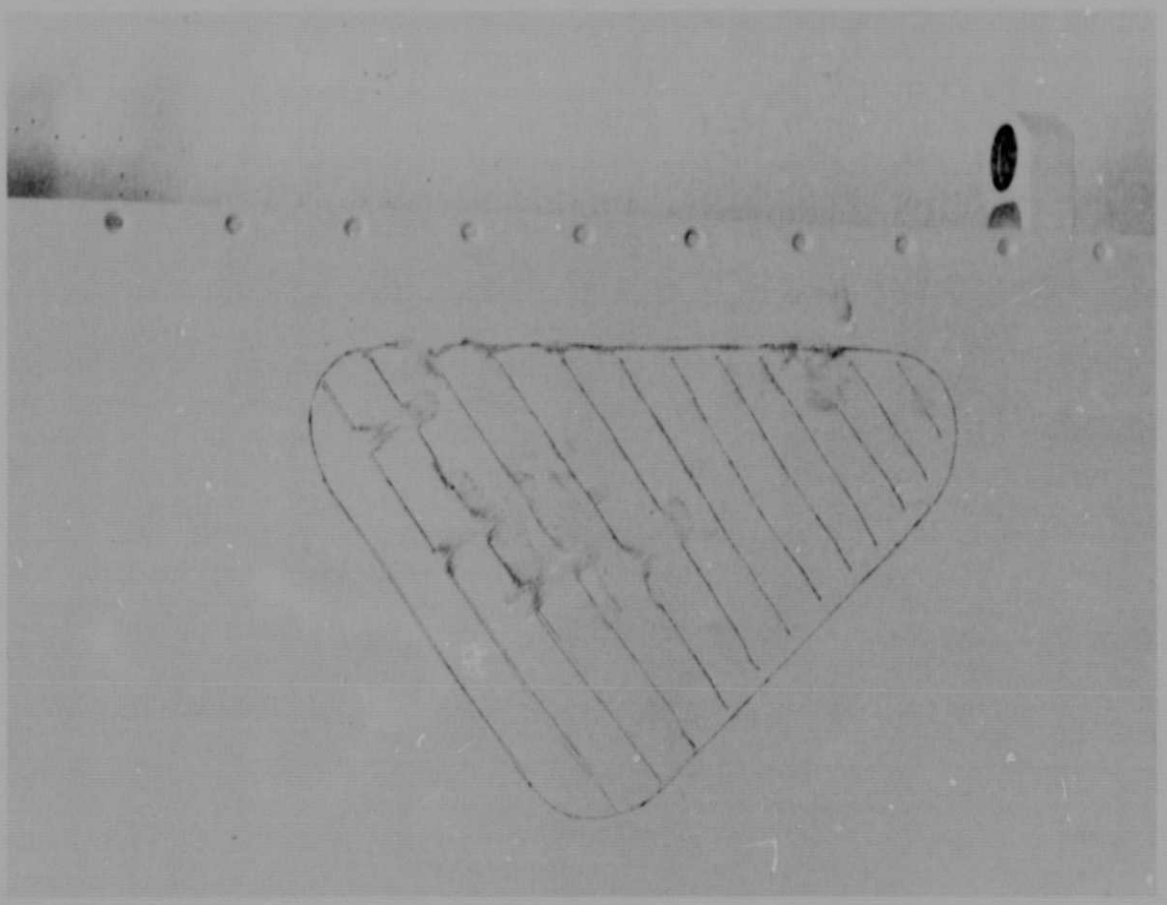

Figure 11.—Skin Blister—Upper Surface of S/N 0105

The failure hypothesis advanced for these circumstances is that the original adhesive cure produced a smaller than normal filleting between the skin and the core within the area of the triangular blister (fig. 12). These fillets were sufficient to produce an acceptable response in the ultrasonic C-scan recordings produced as part of the normal manufacturing sequence. Subsequent heating and cooling strains were sufficient to eventually produce a failure in the fillet bonds.

Corrosion on -23 doublers previously reported (p. 13, ref. 1) has been assessed as routine oxidation of unprotected aluminum alloy. Processing records substantiate phosphoric anodize treatment and corrosion-inhibiting primer application. With proper processing, the logical hypothesis necessarily indicates damage to the protective surface prior to application of the enamel finish, and most probably during abrasion of the surface conditioning coating applied under the epoxy enamel finish. No additional examples of this type of corrosion have been reported.

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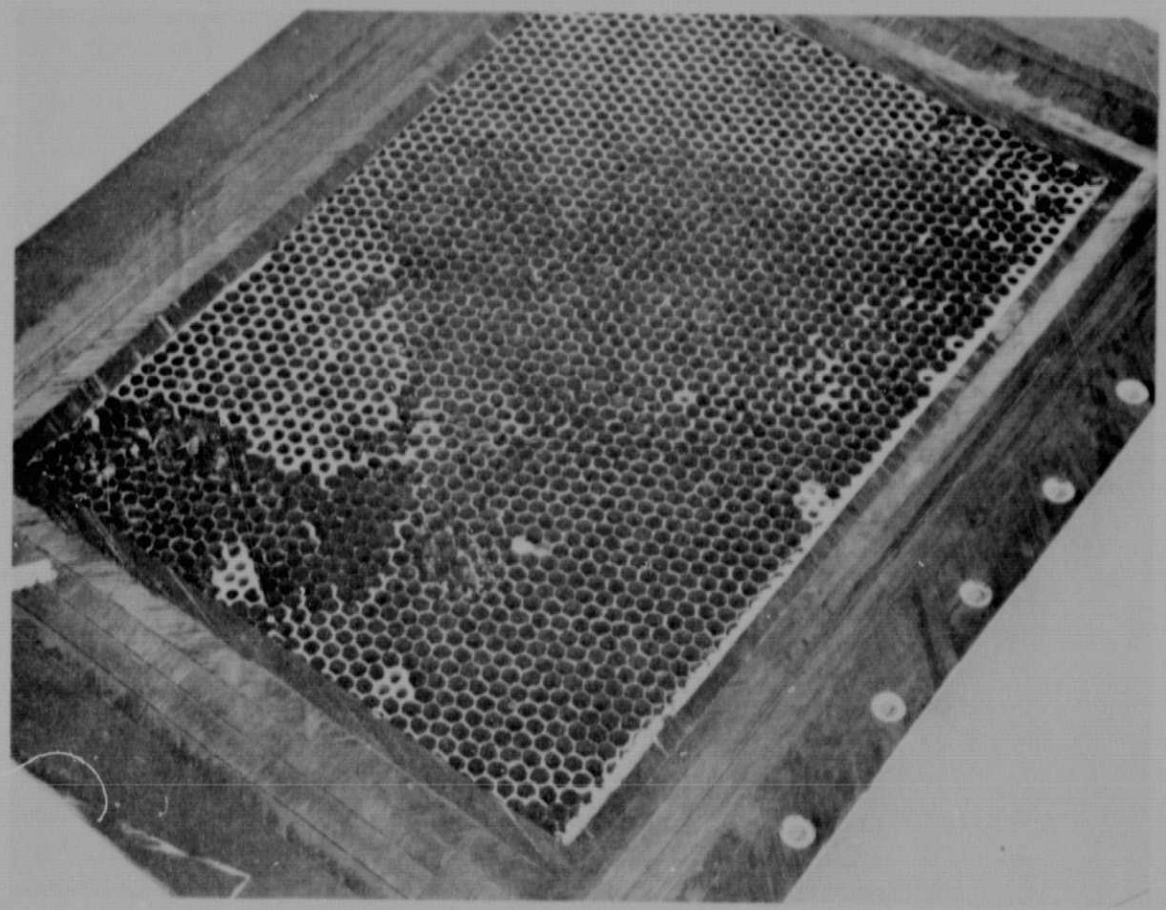

Figure 12.—Spoiler S/N 0105 With Section of Upper Skin Removed

REPAIR COSTS

Continuation of the repair activity described in the first annual report (ref. 1) proceeded through the major part of this reporting period and was completed on December 5, 1975. The direct charge system of cost accounting already in use at the Auburn fabrication facility continued to track man-hour costs associated with each repair. As before, each unit was identified using the rejection tag serial number to identify charges for each unit. Table 5 gives the breakdown of the repair hours accumulated for each repair reported. No material costs have been included in this accounting as they were considered to be insignificant. Those units previously reported (ref. 1) are not included in table 5.

Each spoiler repair was individually prepared and tailored to the situation presented. No attempt was made to automate the techniques nor to shortcut the procedures based on prior similar circumstances, since addressing repair problems is beyond the scope of this program.

Table 5.—Repair Cost Data (Man-Hour Charges)

Spoiler serial number	Airline	Final assembly	Detail assembly	Production control	Painting & finishing	Total
0012	Lufthansa	–	3.0	–	–	3.0
0015	VASP	–	4.4	–	6.1	10.5
0018	VASP	0.2	16.3	0.1	2.7	19.3
0021	Lufthansa	6.3	13.0	–	–	19.3
0026	Aloha	2.9	13.0	–	–	15.9
0032	Piedmont	–	13.6	–	–	13.6
0035	Piedmont	–	12.0	–	8.2	20.2
0036	Piedmont	2.8	16.8	–	8.3	27.9
0048	Aloha	5.3	11.1	–	–	16.4
0059	VASP	–	18.1	–	6.6	24.7
0083	Lufthansa	–	12.3	0.2	5.4	17.9
0084	Lufthansa	0.2	11.3	–	3.5	15.0
0087	New Zealand	–	14.5	–	6.1	20.6
0091	Aloha	2.8	23.7	0.3	7.2	34.0
0093	Piedmont	–	6.9	–	7.3	14.2
0105	Aloha	–	33.5	–	7.1	40.9
0112	Lufthansa	–	28.4	–	6.1	34.5
Total		20.5	251.9	0.6	74.6	347.6
Average		1.2	14.8	0.04	4.4	20.44

ALL-COMPOSITE (TASK II) SPOILERS

The last published program quarterly report (ref. 2 8th quarterly) discussed the fabrication and qualification efforts of the all-composite task II spoiler (P/N 65-76330-1). The events and circumstances culminating in the certification of the all-composite spoiler will be documented in the manufacturing and test report. All information relative to incorporation of these spoilers into the flight-service evaluation program will be included with the established flight-service annual reports.

The initial introduction of the task II spoiler into the flight service program occurred on December 18, 1975. Aloha Airlines installed unit S/N 0306 on aircraft N73711 in the RH outboard position (ref. 2, 1st quarterly, p. 15). Figure 13 illustrates the spoiler following installation. The second Aloha installation was accomplished on January 7, 1976 when S/N 0307 was installed in the RH outboard position on N73715. Subsequent installations are planned in the second quarter of 1976, with each participating airline deploying two task II spoiler units. If necessary, task I spoiler units will be removed to provide mounting positions for the new spoilers.

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Figure 13.–Installation of First All-Composite (Task II) Spoiler on Aloha N73711

As of February 29, 1976, these two spoilers had accumulated a total of 515 flight-hours and 1386 landings. It is planned that task II service experience reports will be separately identified from task I experience, with the total program experience expressed as the sum of task I and task II.

GROUND-BASED ENVIRONMENTAL SERVICE

Concurrent with the flight-service evaluation program of the flight spoilers, specimens of the same composite material systems are being subjected to long term environmental exposures at the main terminals of five of the participating airlines and at the NASA-Langley Research Center. There are no exposure facilities located at either Winston-Salem N. C. (Piedmont) nor at Denver, Colo. (Frontier). The facility in San Diego, Calif. (PSA) continues in operation, even though PSA no longer is an active participant in the flight-service program.

Periodic removal and tests of the exposed specimens are being performed to determine if the material properties are being degraded by ground-based exposure and to provide correlation with the static strength tests of spoilers removed from flight service.

The schedule for removal of specimens from the exposure rack assembly has been modified during the past year. The second year removals have been delayed to the third year to facilitate extension of the total exposure schedule from 5 years to 10 years. Official extension remains to be negotiated but the delay in removal was necessary to preserve the available exposed specimens.

Specimens were removed from the NASA-Langley exposure rack following 2 years of exposure, weighed and returned to the rack. The weight change data acquired from these specimens has been plotted with the data acquired from the 1-year specimens and is plotted in figure 14. The data is quite significant and shows a strong trend toward stabilizing the change of composite weight due to moisture absorption. This trend should be further defined when the 3-year data is assembled late in 1976.

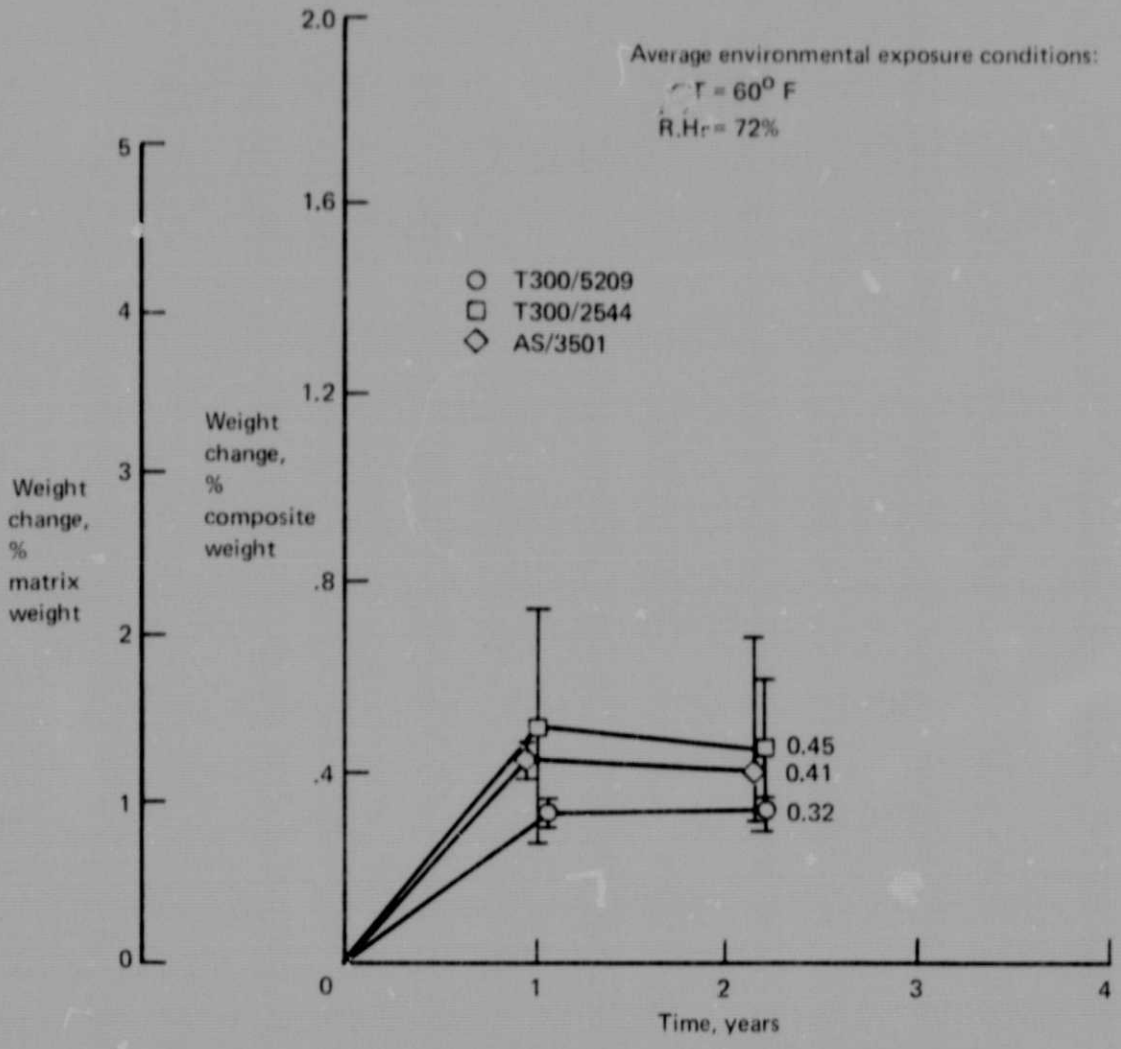

Figure 14.—Moisture Pickup in Exposed Epoxy-Matrix Laminates (Langley Research Center)

First year exposure data from Sao Paulo, Brazil has been collected and tabulated. The data is presented in tables 6, 7, and 8, which are similar to tables 6, 7 and 8 of reference 1. These tables are now complete for the 1-year environmental data report. The plots of strength retention have been similiarly completed for the first year and are shown in figures 15, 16, and 17.

Table 6.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Short-Beam Interlaminar Shear Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Av failure Number of specimens	Av failure stress		Av wt change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	5	77	11.2	–	–
1	LaRC	T300/5209	2	78	11.3	+0.0042	+0.58
1	Hawaii	T300/5209	3	78	11.3	+0.0034	+0.46
1	New Zealand	T300/5209	3	81	11.7	+0.0039	+0.50
1	Germany	T300/5209	3	72	10.4	+0.0032	+0.44
1	California	T300/5209	3	78	11.3	+0.0042	+0.53
1	LaRC[a] (painted specimens)	T300/5209	3	81	11.7	+0.0029	+0.34
1	Brazil	T300/5209	3	74	10.7	+0.0049	+0.69
0 (baseline)	LaRC	T300/2544	4	81	11.7	–	–
1	LaRC	T300/2544	3	74	10.7	+0.0082	+1.28
1	Hawaii	T300/2544	3	65	9.4	+0.0067	+1.07
1	New Zealand	T300/2544	3	73	10.6	+0.0075	+1.15
1	Germany	T300/2544	3	73	10.6	+0.0066	+1.09
1	California	T300/2544	3	74	10.8	+0.0071	+1.14
1	LaRC[a] (painted specimens)	T300/2544	3	80	11.6	+0.0063	+0.84
1	Brazil	T300/2544	3	70	10.1	+0.0107	+1.69
0 (baseline)	LaRC	AS/3501	5	87	12.6	–	–
1	LaRC	AS/3501	3	86	12.5	+0.0050	+0.80
1	Hawaii	AS/3501	3	89	12.9	+0.0045	+0.72
1	New Zealand	AS/3501	3	85	12.4	+0.0051	+0.84
1	Germany	AS/3501	3	78	11.3	+0.0057	+0.92
1	California	AS/3501	3	84	12.2	+0.0058	+0.89
1	LaRC[a] (painted specimens)	AS/3501	3	92	13.4	+0.0034	+0.48
1	Brazil	AS/3501	3	81	11.8	+0.0056	+0.94

[a]Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 7.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Compression[3] Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Number of specimens	Av failure stress		Av flex. modulus		Av wt change	
				MPa	ksi	GPa	psi (x 10⁶)	grams	%
0(baseline)	LaRC	T300/5209	5	1529	221.8	103.8	15.05	–	–
1	LaRC	T300/5209	3	1429	207.3	99.0	14.36	+10.0070	+0.32
1	Hawaii	T300/5209	3	1478	214.4	108.1	15.68	+0.0052	+0.23
1	New Zealand	T300/5209	3	1548	224.5	107.4	15.58	+0.0056	+0.27
1	Germany	T300/5209	3	1476	214.0	98.9	14.34	+0.0069	+0.32
1	California	T300/5209	3	1478	214.4	107.7	15.62	+0.0091	+0.41
1	LaRC[b] (painted specimens)	T300/5209	3	1470	213.2	106.8	15.49	+0.0073	+0.30
1	Brazil	T300/5209	3	1488	215.9	103.2	14.97	+0.0082	+0.37
0(baseline)	LaRC	T300/2544	5	1600	212.0	106.2	15.41	–	–
1	LaRC	T300/2544	3	1444	209.4	104.7	15.18	+0.0092	+0.50
1	Hawaii	T300/2544	3	1469	213.0	107.3	15.56	-0.0031	-0.18
1	New Zealand	T300/2544	3	1580	229.1	109.4	15.86	+0.0063	+0.34
1	Germany	T300/2544	3	1597	231.6	107.6	15.60	+0.0120	+0.62
1	California	T300/2544	3	1537	222.9	107.5	15.59	+0.0152	+0.81
1	LaRC[b] (painted specimens)	T300/2544	3	1603	232.5	111.8	16.21	+0.0138	+0.66
1	Brazil	T300/2544	3	1515	219.7	107.5	15.60	+0.0132	+0.69
0(baseline)	LaRC	AS/3501	5	1449	210.1	94.7	13.73	–	–
1	LaRC	AS/3501	3	1447	209.8	98.3	14.25	+0.0080	+0.43
1	Hawaii	AS/3501	3	1398	202.7	96.7	14.03	+0.0052	+0.28
1	New Zealand	AS/3501	3	1520	220.4	100.5	14.57	+0.0070	+0.41
1	Germany	AS/3501	3	1528	221.6	96.1	13.94	+0.0102	+0.53
1	California	AS/3501	2	1518	220.2	100.1	14.52	+0.0142	+0.74
1	LaRC[b] (painted specimens)	AS/3501	3	1638	237.6	99.8	14.48	+0.0087	+0.37
1	Brazil	AS/3501	3	1572	228.0	101.4	14.71	+0.0100	+0.54

[a]Flexure specimens were fabricated from laminates with ply orientations identical to spoiler skin orientation. Specimen length is oriented in the 90° direction of the laminate.

[b]Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 8.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Compression[a] Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Number of specimens	Av failure stress		Av wt change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	3	712	103.2	–	–
1	LaRC	T300/5209	3	760	110.3	+0.0494	+0.61
1	Hawaii	T300/5209	3	676	98.1	+0.0556	+0.70
1	New Zealand	T300/5209	3	647	93.8	+0.0551	+0.71
1	Germany	T300/5209	3	709	102.8	+0.0389	+0.49
1	California	T300/5209	3	716	103.9	+0.0588	+0.74
1	LaRC[b] (painted specimens)	T300/5209	3	654	94.9	+0.0361	+0.45
1	Brazil	T300/5209	3	710	103.0	+0.0658	+0.82
0 (baseline)	LaRC	T300/2544	4	1029	149.2	–	–
1	LaRC	T300/2544	3	985	143.3	+0.0544	+0.77
1	Hawaii	T300/2544	3	988	143.3	+0.0636	+0.86
1	New Zealand	T300/2544	3	865	125.5	+0.0723	+1.02
1	Germany	T300/2544	3	1022	148.3	+0.0497	+0.70
1	California	T300/2544	2	1031	149.6	+0.0560	+0.78
1	LaRC[b] (painted specimens)	T300/2544	3	1018	147.7	+0.0521	+0.74
1	Brazil	T300/2544	3	974	141.2	+0.0935	+1.34
0 (baseline)	LaRC	AS/3501	5	1107	160.6	–	–
1	LaRC	AS/3501	3	1045	151.6	+0.0440	+0.68
1	Hawaii	AS/3501	3	1080	156.6	+0.0461	+0.69
1	New Zealand	AS/3501	3	1002	145.4	+0.0493	+0.74
1	Germany	AS/3501	3	1161	168.4	+0.0374	+0.57
1	California	AS/3501	3	1105	160.2	+0.0531	+0.81
1	LaRC[b] (painted specimens)	AS/3501	3	1144	165.9	+0.0384	+0.58
1	Brazil	AS/3501	3	1048	152.1	+0.0611	+0.92

[a]Compression specimens were fabricated from laminates with ply orientations identical to spoiler skin ply orientation. Specimen length is oriented in the 90° direction of the skin laminate.

[b]Painted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

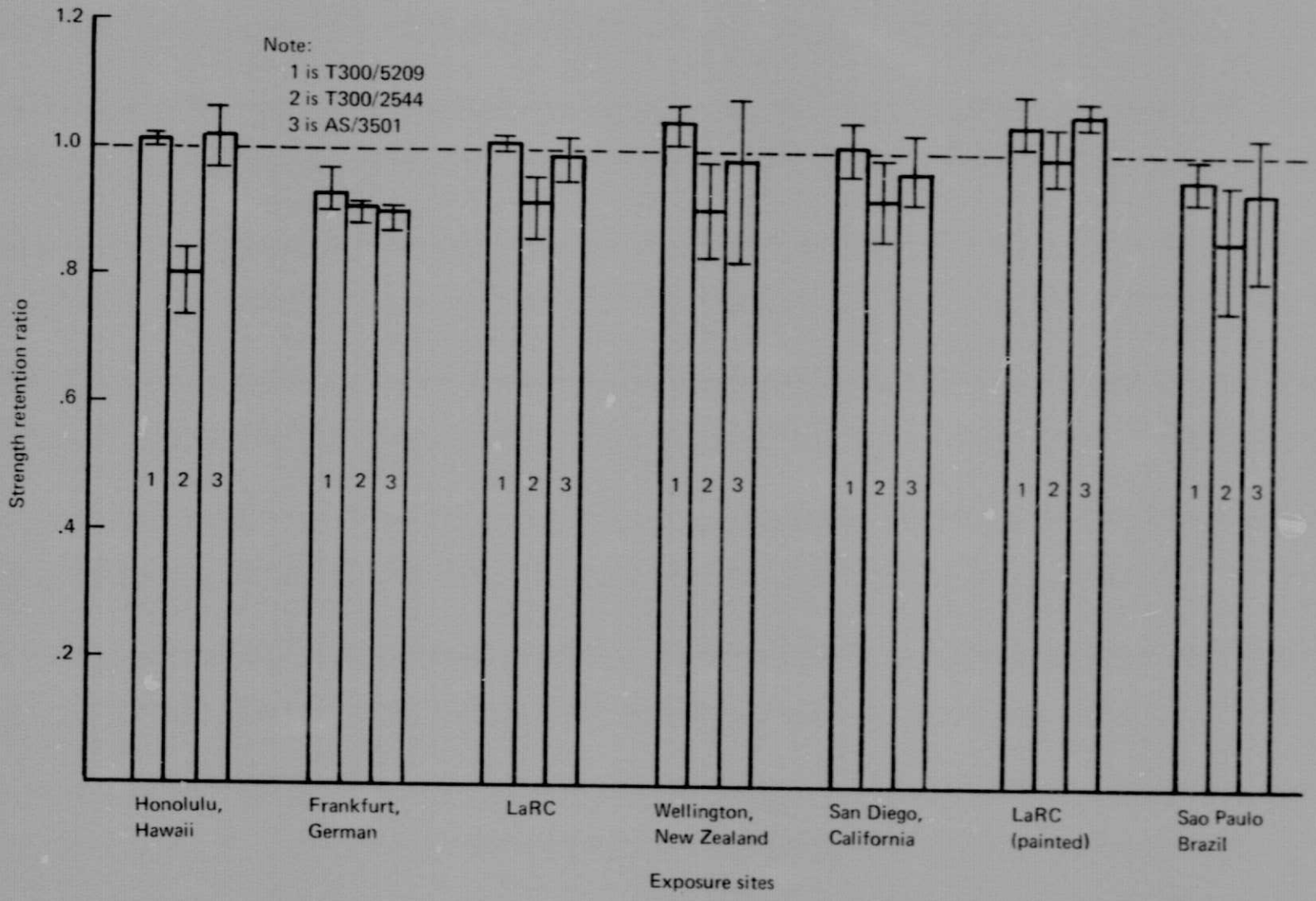

Figure 15.—Interlaminar Shear Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure

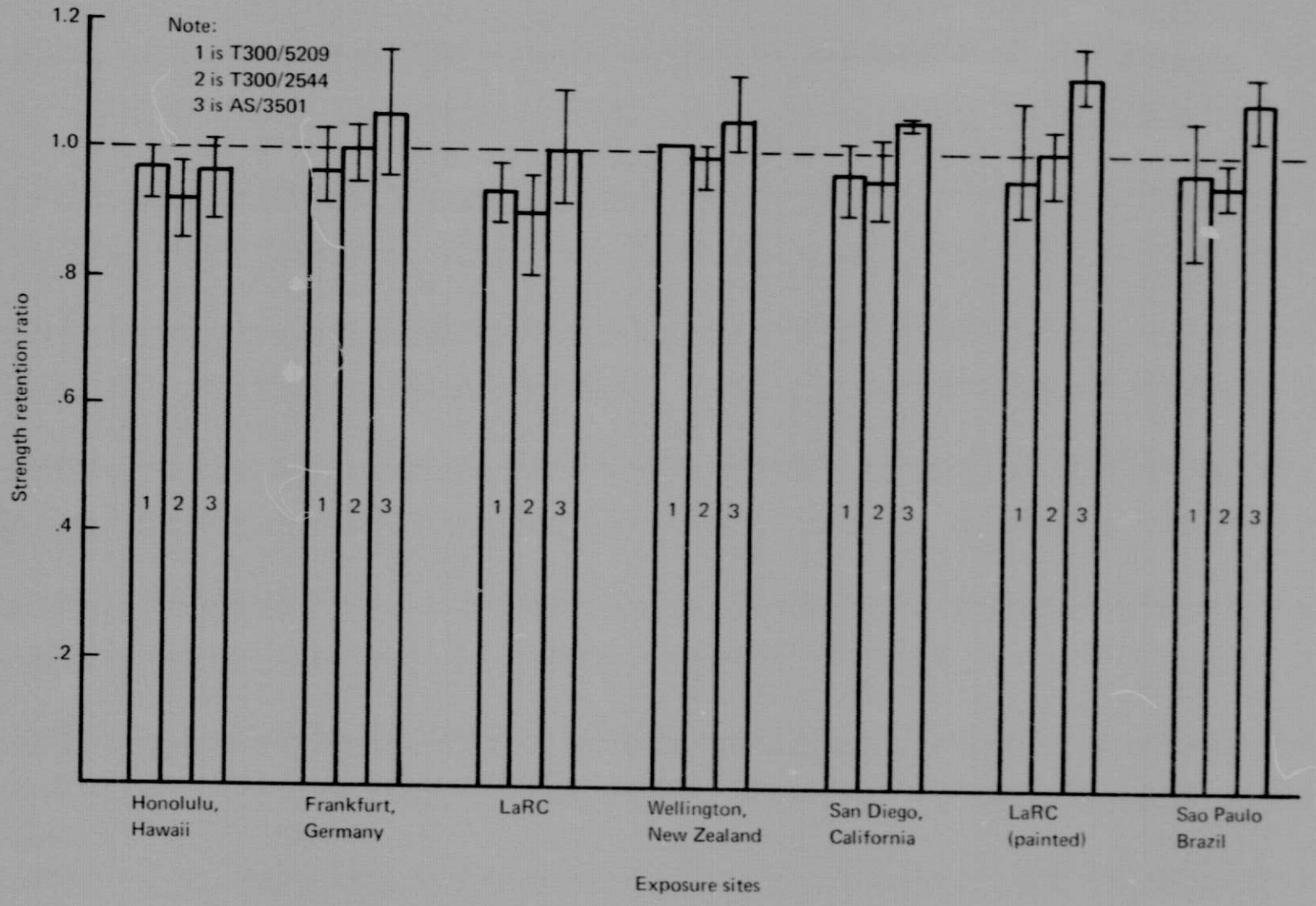

Figure 16.—Flexure Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure

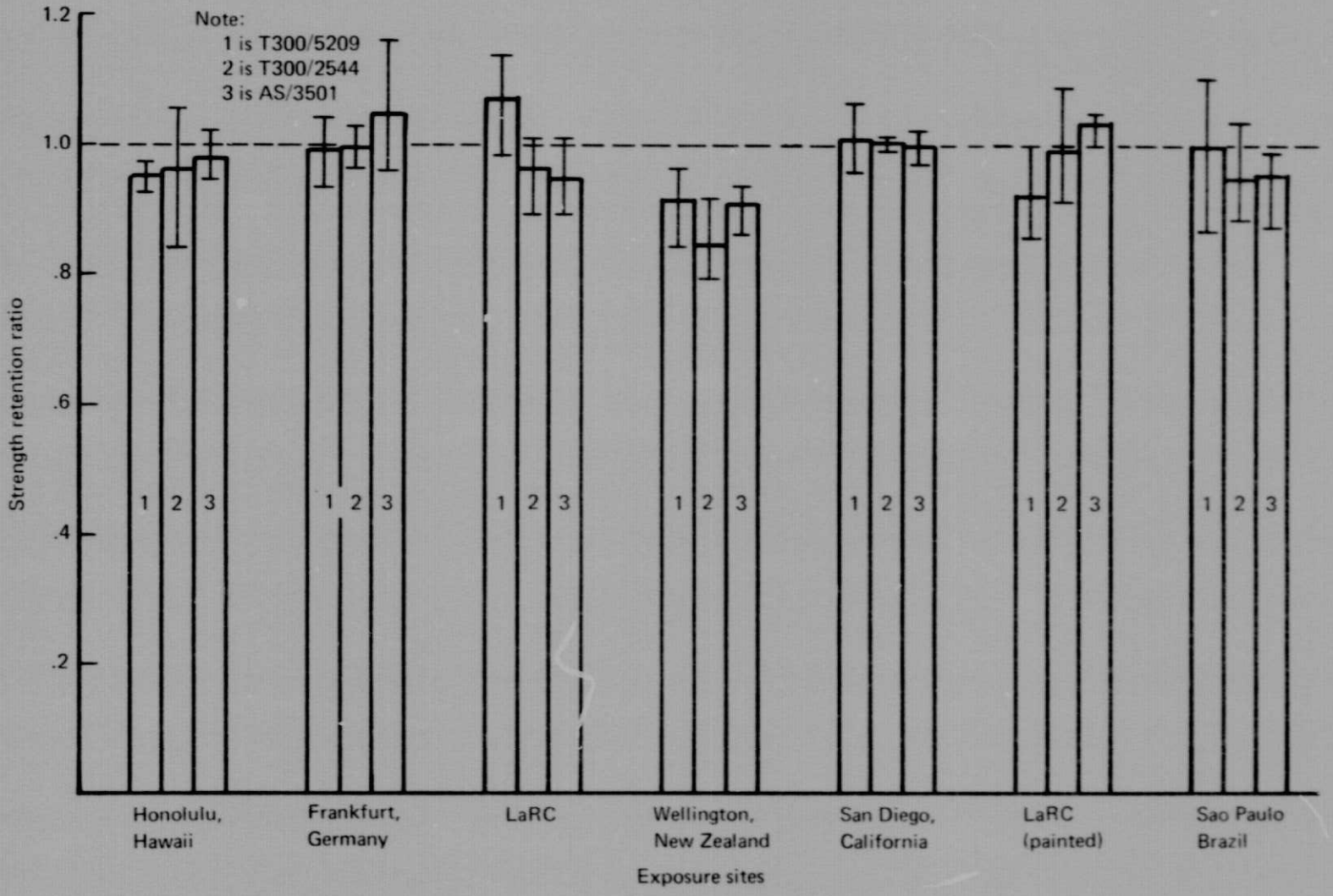

Figure 17.—Compression Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure

REFERENCES

1. Stoecklin, R. L.: *737 Graphite Composite Flight Spoiler Flight Service Evaluation*, NASA CR-132663, May 1975

2. Stoecklin, R. L.: *A Study of the Effects of Long-Term Ground and Flight Environment Exposure on the Behavior of Graphite-Epoxy Spoilers*. D6-60170-1 through -8 Quarterly Progress Reports (8). Boeing Commercial Airplane Company, October 1972 thorugh July 1974.