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737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

BOEING COMMERCIAL AIRPLANE COMPANY
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16. Abstract

The fourth annual flight service report was prepared in compliance with the requirements of contract NAS1-11668 and covers the flight service experience of 111 graphite-epoxy spoilers on 737 transport aircraft and related ground-based environmental exposure of graphite-epoxy material specimens for the period from May 1977 through April 1978. Spoilers have been installed on 28 aircraft representing seven major airlines operating throughout the world. An extended flight service evaluation program of 10 years is presently under way. As of April 30, 1978, a total of 977,853 spoiler flight-hours and 1,481,453 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 fourth year of service continue to indicate modest changes in composite strength properties.

The flight service program has been amended to include gathering of inflight moisture absorption data by three of the spoiler-participating airlines. The exterior-mounted specimens will be periodically removed and evaluated.

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FOREWORD

This is the fourth 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 programmed to provide 10 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. McCarthy, program manager.

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Robert L. Stoecklin
Boeing Commercial Airplane Company

PROGRAM SUMMARY AND STATUS

This fourth 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 May 1, 1977 through April 30, 1978. Segments of the data contained herein have appeared in previous documentation (refs. 1, 2 and 3).

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. One additional aircraft was added to the fleet in 1976. These units will be monitored under actual load and environmental conditions for a period of 10 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 added to this program is the gathering of moisture absorption data from graphite samples placed on the exterior of three 737 revenue aircraft presently flying graphite spoilers. These samples are scheduled to be periodically removed over a two year period and evaluated. All reporting of moisture absorption data will be made within this reporting system.

Significant events that have occurred during this period include:

- Completion of the fourth annual inspection of those spoilers in service
- Continuation of the spoiler repair program
- Continuation of the NDI sampling program and static-testing of spoilers from the flight service program
- Addition of one spoiler panel to the flight service program
- Initiation of the in-flight moisture absorption study
- Extension of laminate moisture absorption study

As of April 30, 1978, a total of 977,853 spoiler flight-hours and 1,481,453 spoiler landings had been accumulated by the fleet. The high-time spoiler has accumulated 12,416 flight-hours on Frontier Airlines 737 N7386F. Forty-three spoilers have accumulated in excess of 10,000 flight-hours since the beginning of the flight service program.

Based on postservice inspections, there is still no evidence of moisture migration into the honeycomb core and no evidence of core corrosion itself. Seven additional examples of exfoliation corrosion of aluminum edge members have been discovered. Continued investigation of this problem reaffirms accidental breaching of the corrosion-inhibiting system prior to final bonding in fabrication. No other corrosion sites have been identified.

Laboratory testing of spoilers returned from 4 years of flight service testing shows a stabilization of residual strengths for the three material systems. Improved performance of the T300/5209 system shows a levelling of residual strength and maintains residual strength levels within the bounds of the fabrication scatter band.

Maintenance damage and related repair activities have continued at a modest level in the past year. Three spoiler panels sustained actuator-interference damage, were repaired by Boeing, and the panels returned to service. One additional panel has received repair of an exfoliation-corrosion condition.

Airline interest in the program continues to exhibit both enthusiasm and confidence.

PROGRAM SCOPE

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 active participating airlines previously identified (ref. 3) continue to operate the 28 aircraft presently committed to the program.

The current participating airlines are:

- New Zealand National Airways—four aircraft
- Aloha Airlines—four aircraft
- Deutsche Lufthansa Airlines—six aircraft
- Piedmont Airlines—eight aircraft
- VASP Airlines (Brazil)—four aircraft
- Frontier Airlines—two aircraft

The geographic scope of the service-evaluation program continues as shown in figure 1.

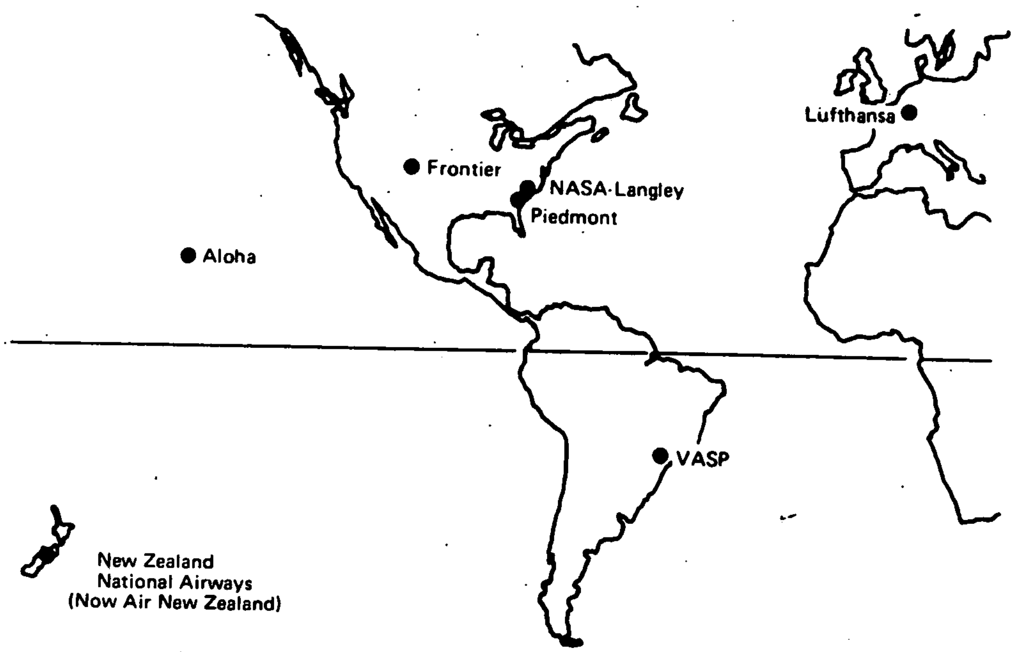


Figure 1.—Geographic Deployment of Current Participating Airlines

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 nearly one million flight hours of service in its 4.8 years of operation and is adding flight experience at the rate of nearly 20,000 hours per month.

The total flight experience to April 30, 1978, 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

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

A total of 43 spoiler panels have accumulated over 10,000 flight hours each. Their distribution, by airline and by skin material system, is shown in table 3.

Table 1.—Spoiler Service-Evaluation Program (As of 04-30-78)

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	15 843	18 165	10 162	15 109
0002	Test	—	—	—	—	—	—
0003	PSA	8 095	12 842	9 018	14 379	923	1 537
0003	VASP	9 018	14 379	18 281	24 564	9 263	10 185
0004	PSA	8 161	12 965	9 018	14 379	857	1 414
0004	VASP	9 018	14 379	18 281	24 564	9 263	10 185
0005	PSA	8 095	12 842	9 018	14 379	923	1 537
0005	VASP	9 018	14 379	18 281	24 564	9 263	10 185
0006	PSA	8 161	12 965	9 018	14 379	857	1 414
0006	VASP	9 018	14 379	18 281	24 564	9 263	10 185
0007	NZ	10 861	15 053	20 673	28 213	9 812	13 160
0008	NZ	10 861	15 053	20 673	28 213	9 812	13 160
0009	NZ	10 861	15 053	16 147	22 112	5 286	7 059
0010	NZ	10 861	15 053	20 673	28 213	9 812	13 160
0011	LH	11 274	15 681	20 307	26 924	9 033	11 243
b0011	LH	21 658	28 554	21 905	28 862	247	308
0012	LH	11 274	15 681	14 694	19 964	3 420	4 283
b0012	LH	15 148	20 528	15 793	21 324	645	796
b0012	LH	15 940	21 518	21 905	28 862	5 965	7 344
0013	LH	11 274	15 681	21 905	28 862	10 631	13 181
0014	LH	11 274	15 681	13 329	18 216	2 055	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	2 290	2 658
b0015	VASP	13 411	19 607	18 622	25 366	5 211	5 759
0016	PSA	8 651	13 711	9 399	14 936	748	1 225
0016	VASP	9 399	14 936	17 147	23 719	7 748	8 783
0017	PSA	8 651	13 711	9 399	14 936	748	1 225
0017	VASP	9 399	14 936	12 432	18 474	3 033	3 538
b0017	VASP	13 411	19 607	18 622	25 366	5 211	5 759
0018	PSA	8 651	13 711	9 399	14 936	748	1 225
0018	VASP	9 399	14 396	11 689	17 594	2 290	2 658
b0018	VASP	13 411	19 607	18 622	25 366	5 211	5 759
0019	LH	11 200	14 884	21 665	27 907	10 465	13 023
0020	LH	11 200	14 884	21 665	27 907	10 465	13 023
0021	LH	11 200	14 884	14 653	19 211	3 453	4 327
b0021	LH	15 425	20 178	21 665	27 907	6 240	7 729
0022	LH	11 200	14 884	21 665	27 907	10 465	13 023
0023	Aloha	9 207	24 932	17 773	48 327	8 566	23 395
0024	Aloha	9 207	24 932	10 974	29 694	1 767	4 762
b0024	Aloha	12 071	32 691	17 773	48 327	5 702	15 636
0025	Aloha	9 207	24 932	12 964	35 165	3 757	10 233
0026	Aloha	9 207	24 932	12 071	32 691	2 864	7 759
b0026	Aloha	8 287	14 823	10 395	20 494	2 108	5 671
0027	PI	12 329	20 204	20 488	32 576	8 159	12 372
b0027	PI	21 916	34 744	22 924	36 227	1 008	1 483

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
0028	PI	13 747	22 449	16 387	26 396	2 640	3 947
b0028	PI	17 201	27 670	24 604	38 659	7 403	10 989
0029	PI	12 329	20 204	22 924	36 227	10 595	16 023
0030	PI	13 747	22 449	24 604	38 659	10 857	16 210
0031	PI	13 747	22 449	24 604	38 659	10 857	16 210
0032	PI	12 329	20 204	14 411	23 348	2 082	3 144
b0032	PI	15 259	24 624	22 924	36 227	7 665	11 603
0033	PI	13 747	22 449	24 604	38 659	10 857	16 210
0034R	PI	12 329	20 204	22 924	36 227	10 595	16 023
0035	PI	5 681	3 056	7 673	5 964	1 992	2 908
b0035	PI	8 542	7 300	15 843	18 165	7 301	10 865
0036	PI	5 681	3 056	7 663	5 945	1 982	2 889
b0036	PI	8 542	7 300	15 843	18 165	7 301	10 865
0037	PI	5 681	3 056	15 843	18 165	10 162	15 109
0038	Aloha	11 340	30 745	17 631	48 218	6 291	17 473
					Subtotal	335 077	490 698
0041	Test	–	–	–	–	–	–
0042	PSA	5 003	8 092	9 600	16 525	4 597	8 433
0042	FL	9 600	16 525	17 409	25 010	7 809	8 485
0043	PSA	4 993	8 068	9 600	16 525	4 607	8 457
0043	FL	9 600	16 525	17 409	25 010	7 809	8 485
0044	PSA	5 003	8 092	9 600	16 525	4 597	8 433
0044	FL	9 600	16 525	13 201	20 370	3 601	3 845
b0044	FL	15 025	22 485	17 409	25 010	2 384	2 525
0045	PSA	4 993	8 068	6 896	11 280	1 902	3 212
0045	FL	10 064	16 998	17 409	25 010	7 345	8 012
0046	Aloha	6 447	9 087	13 058	26 664	6 611	17 577
b0046	Aloha	20 014	30 447	20 588	32 068	574	1 621
0047	Aloha	6 447	9 087	10 256	19 089	3 809	10 002
b0047	FL	14 728	16 350	19 153	21 328	4 425	4 978
0048	Aloha	6 447	9 087	9 103	16 022	2 656	6 935
b0048	Aloha	8 287	14 823	11 473	23 389	3 186	8 566
b0048	Aloha	15 912	36 880	16 989	39 745	1 077	2 865
0049	Aloha	6 447	9 087	12 050	23 911	5 603	14 824
b0049	Aloha	20 014	30 447	20 588	32 068	574	1 621
0050	NZ	10 539	14 075	15 771	21 303	5 232	7 228
0051	NZ	10 539	14 075	19 444	26 204	8 905	12 129
b0051	NZ	20 435	27 564	20 578	27 755	143	191
0052	NZ	10 539	14 075	14 057	18 964	3 518	4 889
b0052	NZ	14 707	19 835	20 578	27 755	5 881	7 920
0053	NZ	10 539	14 075	13 138	17 747	2 599	3 672
0054	LH	11 152	15 328	17 899	23 824	6 747	8 496
0055	LH	11 152	15 328	21 734	28 415	10 582	13 087

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
0056	LH	11 152	15 328	21 734	28 415	10 582	13 087
0057	LH	11 152	15 328	15 633	20 997	4 481	5 669
0058	PSA	8 476	13 644	9 402	15 241	926	1 597
0058	VASP	9 402	15 241	18 560	25 366	9 158	10 125
0059	PSA	8 476	13 644	9 402	15 241	926	1 597
0059	VASP	9 402	15 241	10 900	17 164	1 498	1 923
b0059	VASP	13 181	19 621	18 560	25 366	5 379	5 745
0060	PSA	8 476	13 644	9 402	15 241	926	1 597
0060	VASP	9 402	15 241	14 715	21 102	5 313	5 861
b0060	VASP	17 529	24 227	18 560	25 366	1 031	1 139
0061	PSA	8 476	13 644	9 402	15 241	926	1 597
0061	VASP	9 402	15 241	18 560	25 366	9 158	10 125
0062	LH	11 450	15 759	21 853	28 661	10 403	12 902
0063	LH	11 450	15 759	21 853	28 661	10 403	12 902
0064	LH	11 450	15 759	21 853	28 661	10 403	12 902
0065	LH	11 450	15 759	21 853	28 661	10 403	12 902
0066	NZ	10 787	14 648	14 184	19 120	3 397	4 472
b0066	NZ	14 602	19 678	19 605	26 654	5 003	6 976
b0066	NZ	20 556	27 959	20 695	28 133	139	174
0067	NZ	10 787	14 648	20 695	28 133	9 908	13 485
0068	NZ	10 787	14 648	20 695	28 133	9 908	13 485
0069	NZ	10 787	14 648	20 695	28 133	9 908	13 485
0070	PI	13 908	22 649	24 727	38 995	10 819	16 346
0071	PI	13 908	22 649	24 727	38 995	10 819	16 346
0072	PI	13 908	22 649	24 727	38 995	10 819	16 346
0073	PI	15 070	24 630	24 838	39 216	9 768	14 586
0074	PI	13 908	22 649	19 600	31 548	5 692	8 899
0074	FL	14 728	16 350	19 153	21 328	4 425	4 978
0075	PI	15 070	24 630	24 838	39 216	9 768	14 586
0076	PI	15 070	24 630	24 838	39 216	9 768	14 586
0077	PI	15 070	24 630	24 838	39 216	9 768	14 586
0078	Aloha	9 343	25 410	11 340	30 728	1 997	5 318
b0078	Aloha	9 103	16 022	13 058	26 664	3 955	10 642
b0078	Aloha	20 014	30 447	20 588	32 068	574	1 621
					Subtotal	335 124	489 075
0081	Test	–	–	–	–	–	–
0082	LH	11 560	16 962	22 059	34 845	10 499	17 883
0083	LH	11 560	16 962	15 286	22 013	3 726	5 051
b0083	LH	16 901	26 080	22 059	34 845	5 158	8 765
0084	LH	11 560	16 962	15 286	22 013	3 726	5 051
b0084	LH	16 576	25 672	22 059	34 845	5 483	9 173
0085	LH	11 560	16 962	15 896	23 901	4 336	6 939
b0085	LH	16 901	26 080	22 059	34 845	5 158	8 765
0086	NZ	5 587	8 565	15 568	22 306	9 981	13 741
0087	NZ	5 587	8 565	9 516	13 797	3 929	5 232
b0087	NZ	10 647	15 393	15 568	22 306	4 921	6 913

See footnotes at end of table.

Table 1.–(Continued)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current hours	Net hours	Net landings
0088	NZ	5 587	8 565	9 516	13 797	3 929	5 232
b0088	NZ	10 647	15 393	12 556	18 020	1 909	2 627
b0088	NZ	14 149	20 361	15 568	22 306	1 419	1 945
0089	NZ	5 587	8 565	7 272	10 794	1 685	2 229
b0089	NZ	8 771	12 820	12 556	18 020	3 785	5 200
b0089	NZ	14 149	20 361	15 100	21 677	951	1 316
0090	Aloha	5 623	7 992	6 788	10 937	1 165	2 945
b0090	Aloha	11 344	30 728	17 631	48 218	6 287	17 490
0091	Aloha	5 623	7 992	8 287	14 823	2 664	6 831
b0091	Aloha	12 964	35 165	17 773	48 327	4 809	13 162
0092	Aloha	5 623	7 992	11 480	23 406	5 857	15 414
b0092	Aloha	15 916	36 893	16 989	39 745	1 073	2 852
0093	PI	13 879	22 839	16 461	26 759	2 582	3 920
b0093	PI	17 333	28 122	21 797	34 851	4 464	6 729
b0093	PI	24 051	38 238	24 647	39 066	596	828
0094	PI	13 879	22 839	16 461	26 759	2 582	3 920
b0094	PI	17 333	28 122	24 647	39 066	7 314	10 944
0095	PI	13 879	22 839	24 647	39 066	10 768	16 227
0096	PI	13 879	22 839	24 647	39 066	10 768	16 227
0097	NASA	–	–	–	–	–	–
b0097	Aloha	16 360	38 058	16 989	39 745	629	1 687
0098	Aloha	9 244	25 150	17 631	48 218	8 387	23 068
0099	PI	10 290	15 517	21 012	31 752	10 722	16 235
0100	PI	12 641	20 584	23 093	36 340	10 452	15 756
0101	PI	10 290	15 517	21 012	31 752	10 722	16 235
0102	PI	10 290	15 517	21 012	31 752	10 722	16 235
0103	PI	12 641	20 584	23 093	36 340	10 452	15 756
0104	Aloha	9 244	25 150	11 340	30 745	2 096	5 595
0105	Aloha	9 244	25 150	9 343	25 410	99	260
b0105	Aloha	6 916	11 247	8 287	14 823	1 371	3 576
0106	Aloha	5 623	7 992	11 473	23 389	5 850	15 397
b0106	Aloha	15 912	36 880	16 989	39 745	1 077	2 865
0107	Aloha	9 244	25 150	16 527	45 144	7 283	19 994
0108	PSA	8 621	13 711	9 568	15 160	947	1 449
0108	VASP	9 568	15 160	15 342	21 726	5 774	6 566
b0108	VASP	17 818	24 525	18 780	25 597	962	1 072
0109	PSA	8 621	13 711	9 568	15 160	947	1 449
0109	VASP	9 568	15 160	12 174	18 313	2 606	3 153
0110	PSA	8 621	13 711	9 568	15 160	947	1 449
0110	VASP	9 568	15 160	18 780	25 597	9 212	10 437
0111	PSA	8 621	13 711	9 568	15 160	947	1 449
0111	VASP	9 568	15 160	12 174	18 313	2 606	3 153
b0111	VASP	13 369	19 647	18 780	25 597	5 411	5 950
0112	LH	11 587	16 011	15 179	20 569	3 592	4 558
b0112	LH	16 309	21 974	21 817	28 719	5 508	6 745

See footnotes at end of table

Table 1.—(Concluded)

Spoiler serial number	Airline[a]	Hours at installation	Landings at installation	Current hours	Current hours	Net hours	Net landings
0113	LH	11 587	16 011	21 817	28 719	10 230	12 708
0114	LH	11 587	16 011	14 601	19 849	3 014	3 838
b0114	LH	15 179	20 569	21 817	28 719	6 638	8 150
0115	LH	11 587	16 011	18 322	24 487	6 735	8 476
b0115	LH	19 208	25 567	21 817	28 719	2 609	3 152
0116	PI	10 290	15 517	18 529	28 010	8 239	12 493
0117	PI	12 641	20 584	23 093	36 340	10 452	15 756
0118	PI	12 641	20 584	18 147	29 062	5 506	8 478
b0118	PI	19 709	31 351	23 093	36 340	3 384	4 989
					Subtotal	307 652	501 680

aPI is Piedmont Airlines.
VASP is Viacao Aerea Sao Paulo Airlines, Brazil
NZ is New Zealand National Airways.
LH is Lufthansa German Airlines.
FL is Frontier Airlines.
bReinstallation

Table 2.—Flight Spoiler Service Experience (Through April 30, 1978)

Airline	Number of aircraft in evaluation	Number of spoilers in evaluation	Total spoiler hours since installation	Total spoiler landings since installation
PSA	0	0	29 747	51 521
Aloha	4	17	110 318	297 657
New Zealand	4	16	131 772	179 080
Lufthansa	6	24	223 500	292 016
Piedmont	8	32	318 564	478 968
VASP	4	16	126 154	140 903
Frontier	2	6	37 798	41 308
Totals	28	111*	977 853	1 481 453

*Current total in service is 91 spoilers, with 20 spoilers either inactive or retired

Table 3.—Distribution of Spoilers with 10,000 or More Flight Hours

Part Number	Airline						
	VP	LH	PI	Aloha	Frontier	NZ	Total
-1 (T300/2544)	4	5	8	0	0	0	17
-2 (T300/5209)	2	6	3	0	4	0	15
-3 (AS/3501)	1	2	8	0	0	0	11
Total	7	13	19	0*	4	0*	43

* Short flight segments reduce rate of flight hour accumulation.
Both Aloha and New Zealand have panels with un-interrupted service records.

SPOILER REMOVALS

The rate of spoiler removals in the current reporting period has shown a moderate increase over the previous year. In addition to the six scheduled removals, a total of 9 panels were removed for all reasons during this reporting period, compared to 6 unscheduled removals the previous year. Since a complete schedule of removals was compiled in the third annual report (ref. 1), removals from previous reporting periods will not be repeated. Table 4 complies all removals for the current period, together with the action taken and final disposition.

A breakdown of the reasons for removal within the current period shows:

- 5 (33%) returned for delaminations
- 6 (40%) returned for scheduled evaluation/test
- 3 (20%) returned for exfoliation corrosion
- 1 (7%) returned for external doubler corrosion

Two panels (S/N 0009 and 0050), previously withdrawn from the program, are undergoing repair and will be returned to service following successful completion of the repair process.

Table 4.—Flight Spoiler Removals (Fourth Year)

(May 1, 1977 to April 30, 1978)

Spoiler Serial Number	Airline	Date Removed	Reason for Removal	Action Taken	Final Disposition
0005	VP	4-8-78	Exfoliation Corrosion	— in transit —	
0011	LH	8-21-77	4th Year Evaluation	NDT	Reinstalled
0016	VP	9-4-77	4th Year Evaluation	NDT	Static Test
0023	Aloha	4-20-78	Exfoliation Corrosion	NDT & Repair	in repair
0027	Piedmont	5-30-77	3rd Year Evaluation	NDT	Reinstalled
0045	Frontier	4-24-78	Alum. doubler delam.	NDT & Repair	Reinstall
0049*	Aloha	4-13-77	Exfoliation Corrosion	NDT & Repair	Reinstalled
0051	NZ	10-18-77	Blister delamination	NDT & Repair	Reinstalled
0066	NZ	10-28-77	Exfoliation Corrosion	NDT & Repair	Reinstalled
0071	Piedmont	3-6-78	4th Year Evaluation	NDT	Static Test
0074	Frontier	1-9-78	Blister delamination	NDT & Repair	Reinstall
0089	NZ	2-12-78	Skin delamination	NDT & Repair	to be reinst.
0093	Piedmont	3-30-77	Blister delamination	NDT & Repair	Reinstalled
0107	Aloha	8-17-77	4th Year Evaluation	NDT	Static Test
0111	VASP	4-10-78	4th Year Evaluation	— in transit —	

*Not covered in ref. 1.

STATIC TEST RESULTS

During this reporting period, a total of six spoilers were removed from the flight service program for evaluation and test. All removed spoilers (except S/N 0111 which has not yet been processed) were re-inspected using the ultrasonic through-transmission C-scan and the results compared to the records made at the time of original fabrication. No detectable differences were noted in this comparison. The sixth third-year spoiler S/N 0027, previously unreported, was processed through the ultrasonic inspection and returned to revenue service. Three of the fourth-year spoilers (S/N 0016, 0071, and 0107) were then selected to be destructively tested to measure residual static strength following the specified calendar period of exposure. Table 5 contains the residual strength and stiffness data relative to the fourth-year removals. Table 6 is repeated from reference 1 to complete the third year data. Figures 2, 3, and 4 show the spoiler panels after static testing. Figures 5, 6, and 7 are plots of the load-deflection data for these three panels.

A plot of the residual static strength data accumulated to date appears in figure 8, plotted as a function of time. This data continues to illustrate the data scatter previously discussed in ref. 1, while at the same time showing a significant reversal of the downward trend previously identified for the 250°F curing resin system. Based on the available data, continued retention of static strength levels can be anticipated.

Table 5.—Static Test Results (Fourth Year)

Spoiler serial number	Airline	NDI results	Failure load % DLL	Static test results		Time in service	Flight hours
				% change strength	% change stiffness		
0011 (-1)	LH	Clear	—	Not tested		47 mos 25 days	9033
0016 (-1)	VASP	Clear	220%	-11%	+6%	49 mos 2 days	8495
0066 (-2)	NZ	Clear	—	Not tested		45 mos 20 days	8400
0071 (-2)	PI	Clear	274%	- 5%	0%	48 mos 2 days	10,424
0107 (-3)	Aloha	Clear	212%	-12%	-5%	46 mos 22 days	7283
0111 (-3)	VASP	Not yet processed	—	Not scheduled for test		—	—

Table 6.—Static Test Results (Third Year)

Spoiler serial number	Airline	NDI results	Failure load % DLL	Static test results		Time in service	Flight hours
				% change strength	% change stiffness		
0026(-1)	Aloha	Clear	230%	- 6%	- 4%	37 mos 4 days	4972
0027(-1)	PI	Clear	—	Not tested		37 mos 7 days	8159
0054(-2)	LH	Clear	218%	-25%	-13%	36 mos 0 day	6747
0060(-2)	VP	Clear	—	Not tested		36 mos 26 days	6239
0115(-3)	LH	Clear	—	Not tested		35 mos 26 days	6735
0116(-3)	PI	Clear	247%	+ 2%	0%	36 mos 14 days	8239

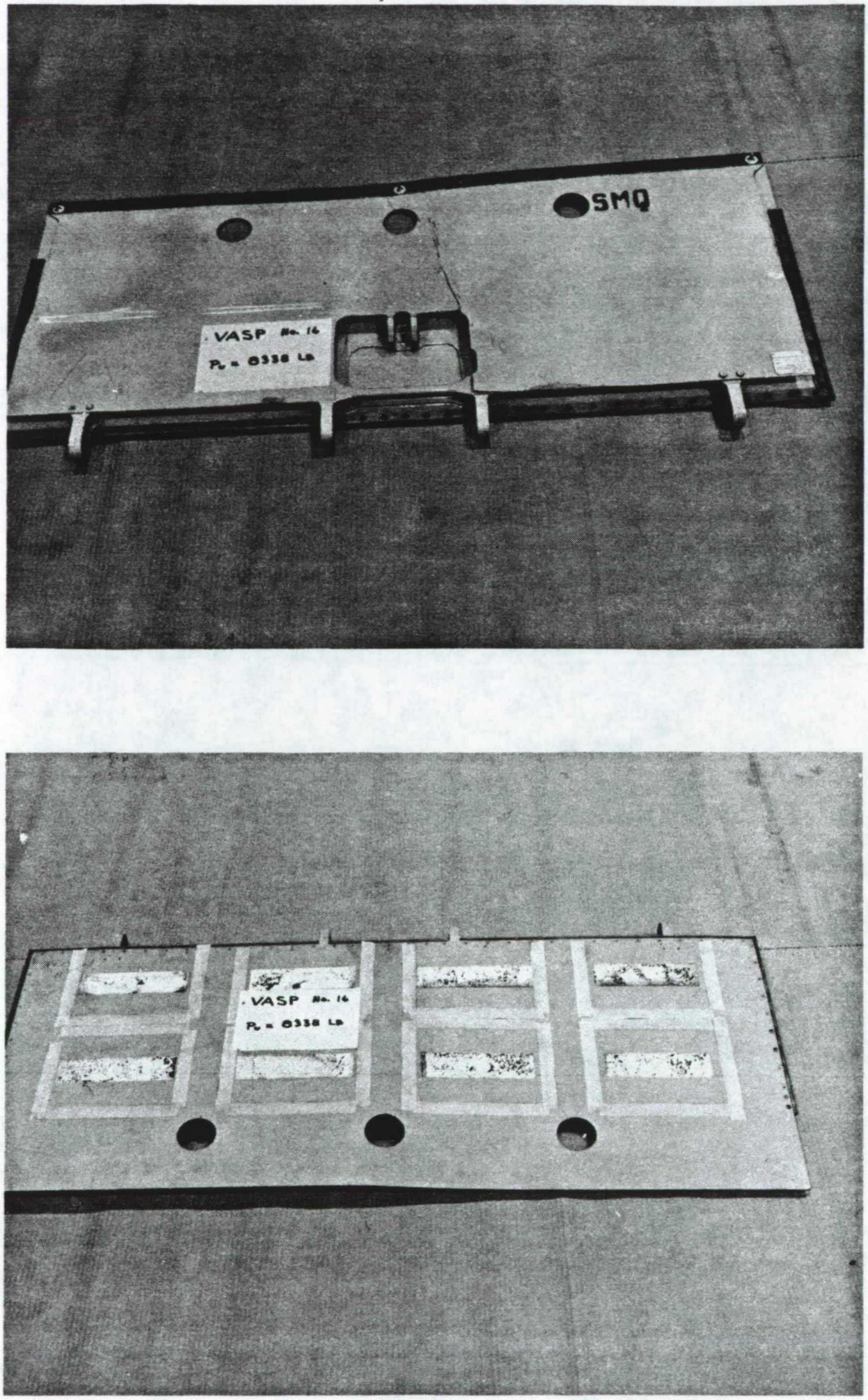
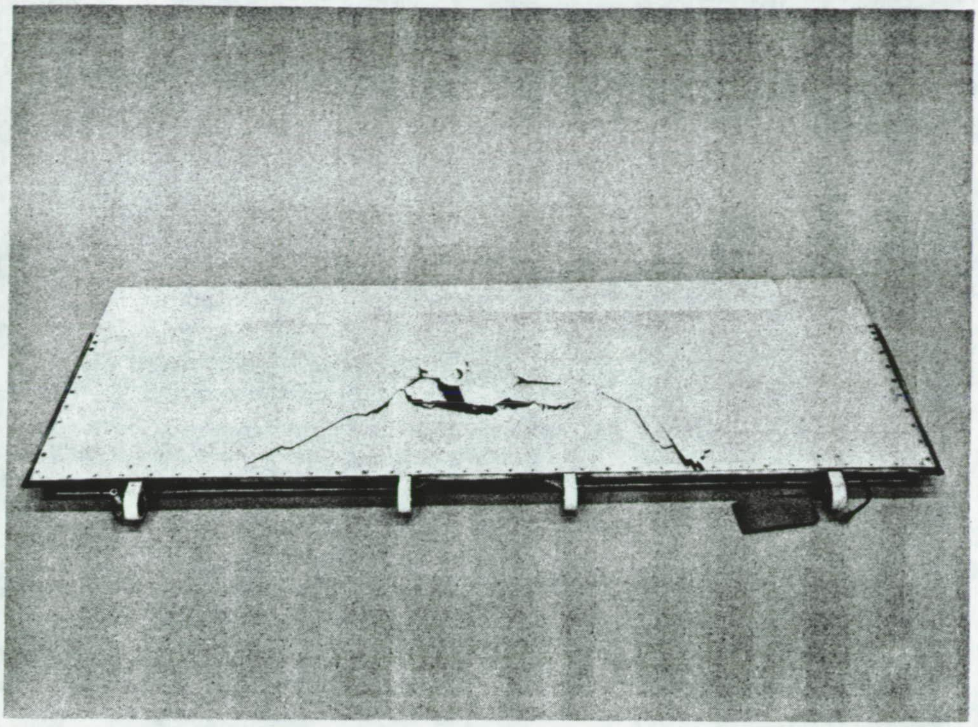


Figure 2.–Spoiler S/N 0016 Static Test



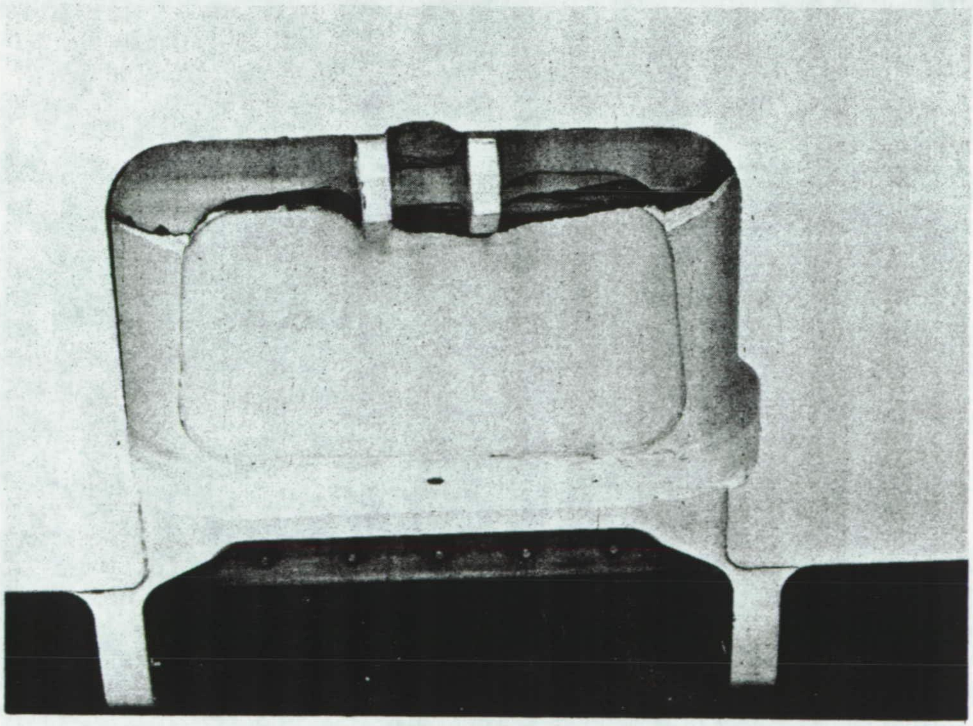


Figure 3.—Spoiler S/N 0071 Static Test

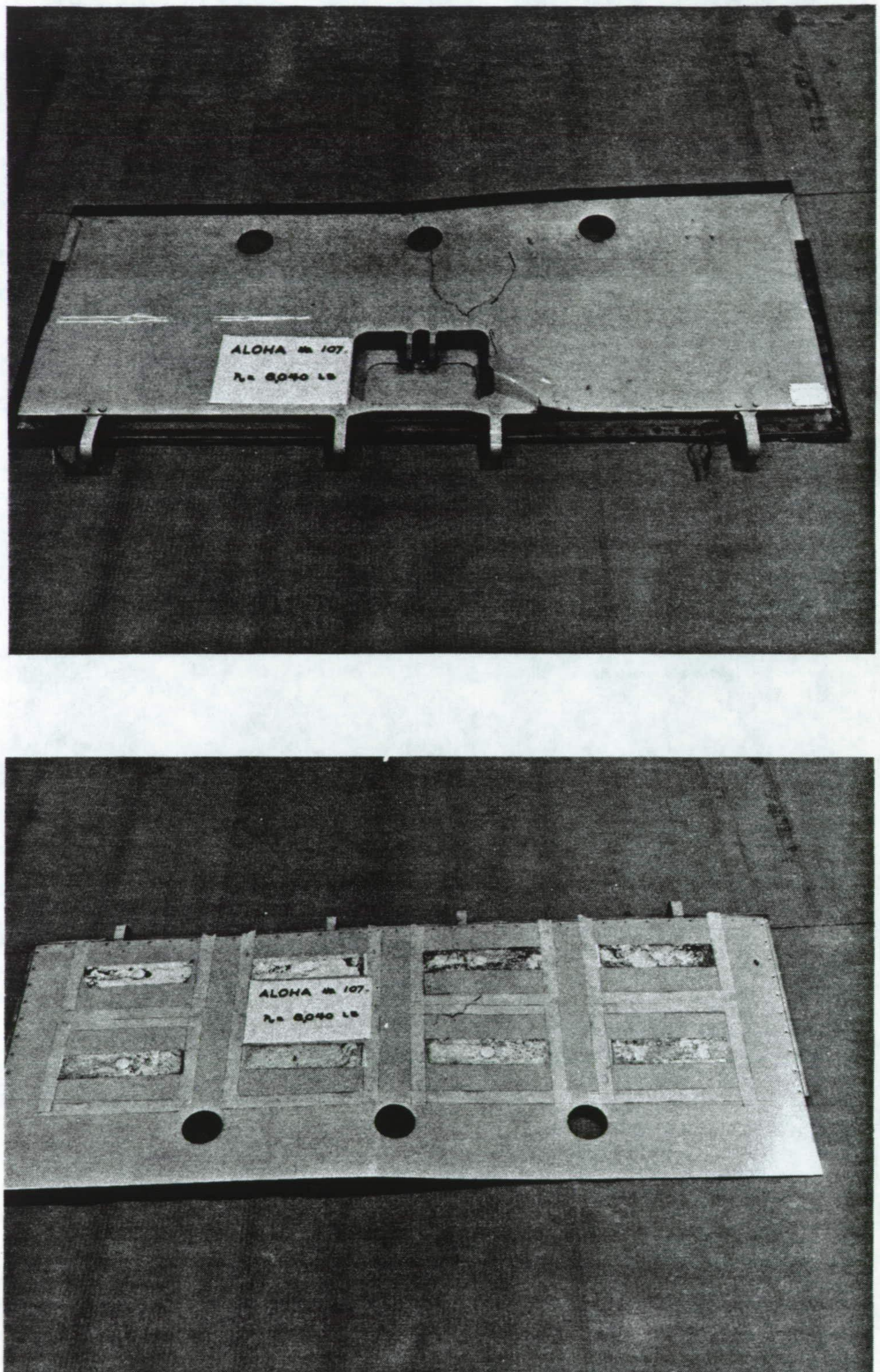


Figure 4.—Spoiler S/N 0107 Static Test

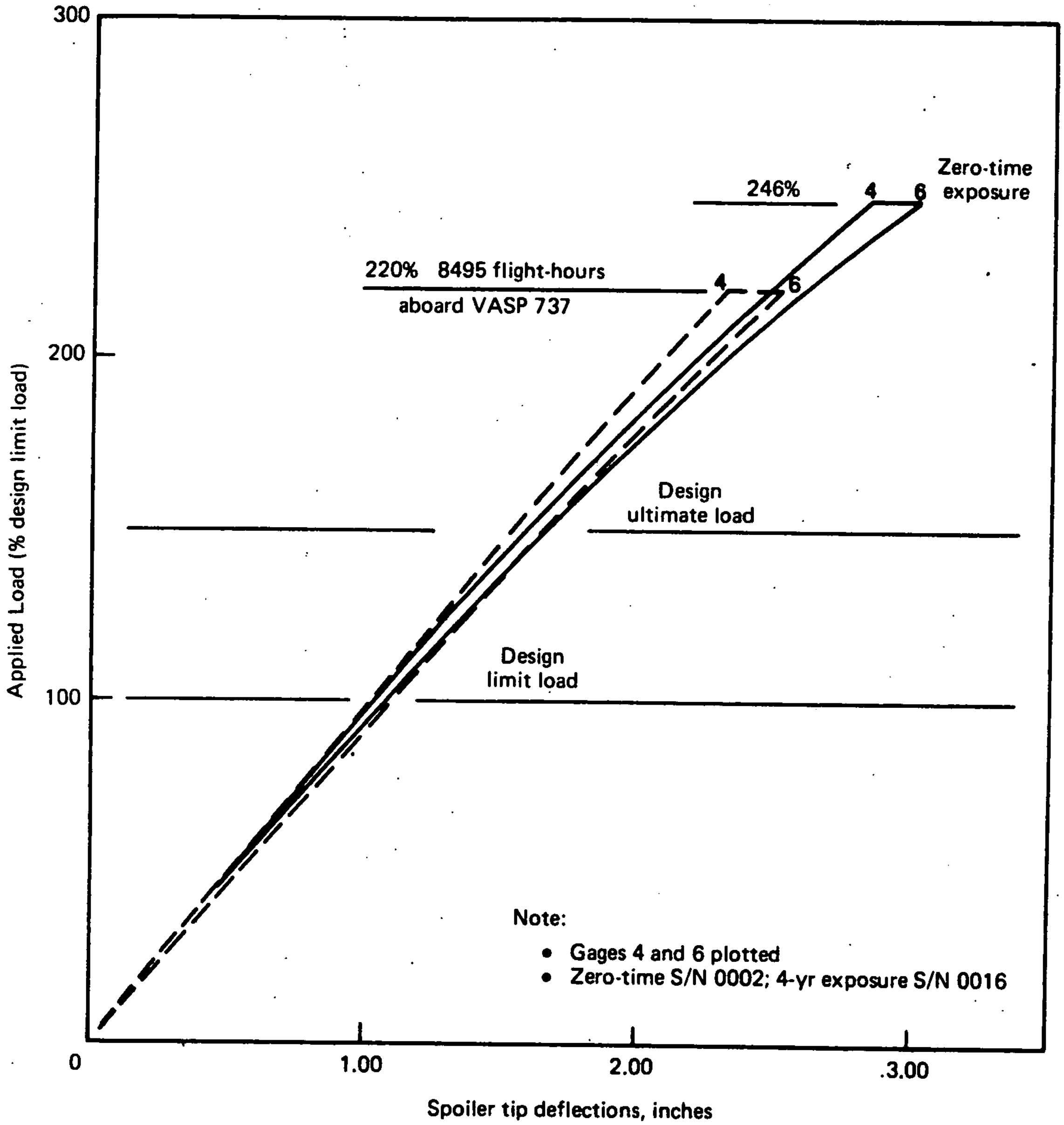


Figure 5.—Load-Deflection Curves—Zero-Time and 4-Year Exposure (Union Carbide T300/2544 Material System)

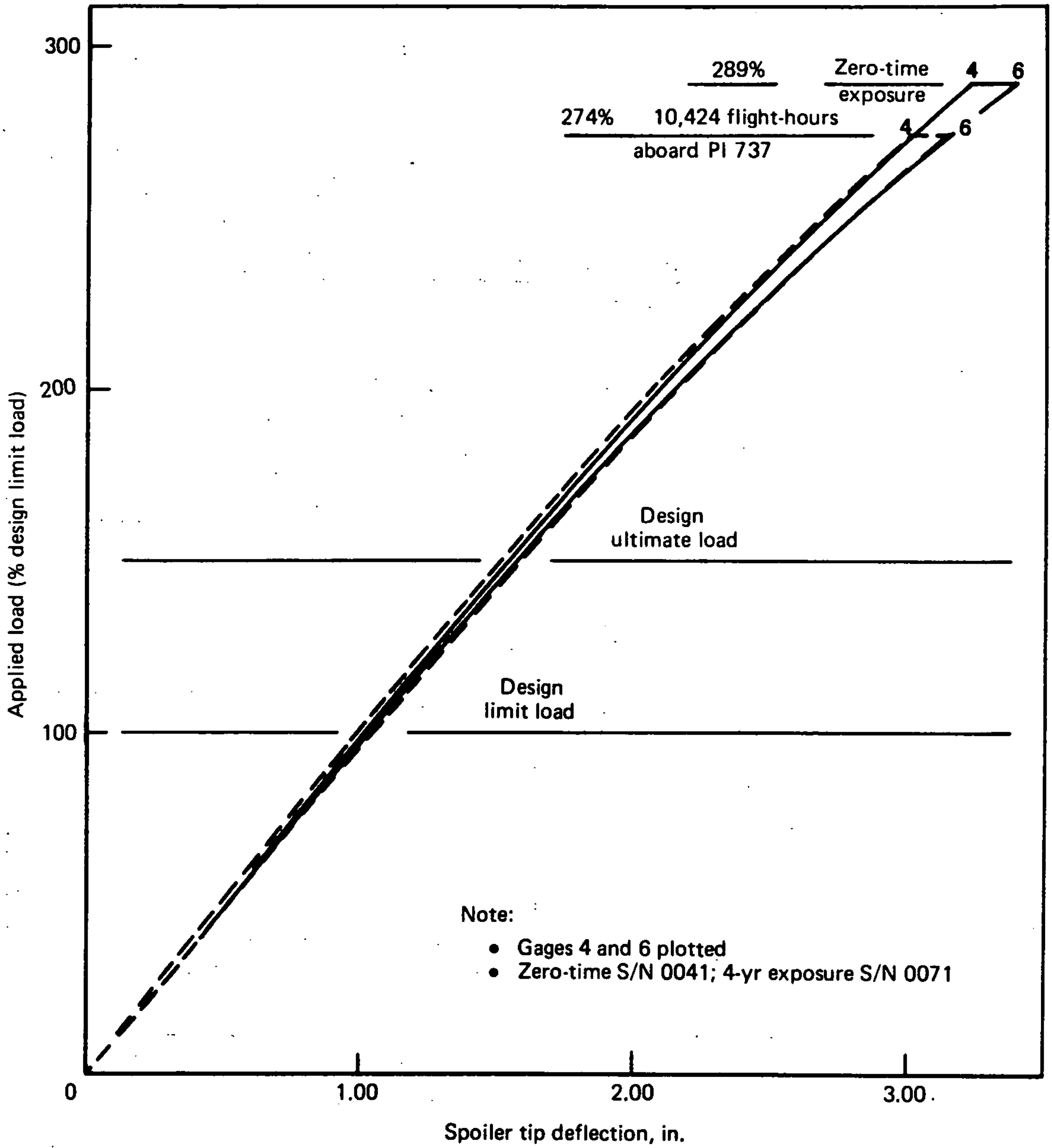


Figure 6.—Load-Deflection Curves—Zero-Time and 4-Year Exposure (Narmco T300/5209 Material System)

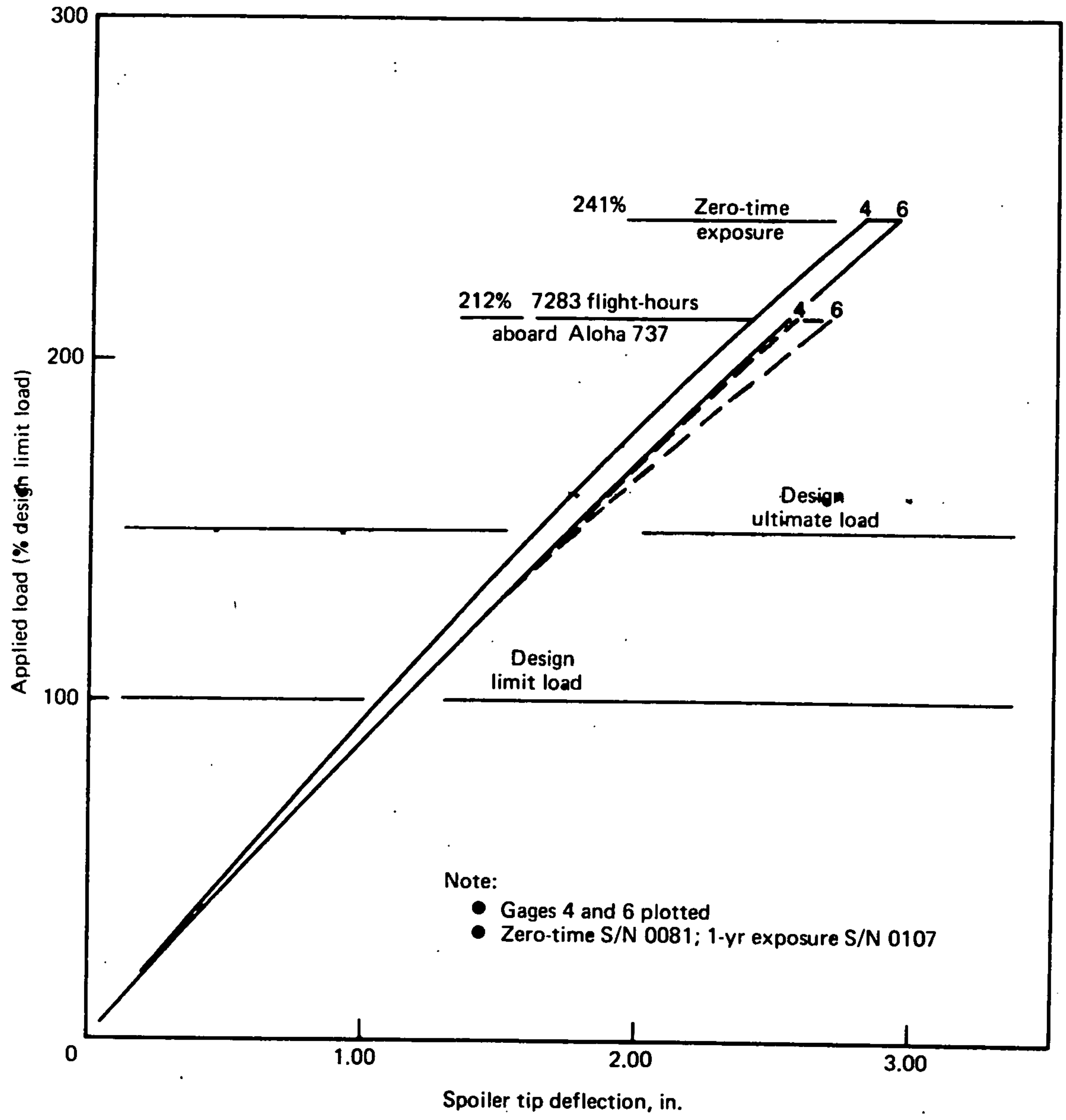


Figure 7.—Load-Deflection Curves—Zero-Time and 4-Year Exposure (Hercules AS/3501 Material System)

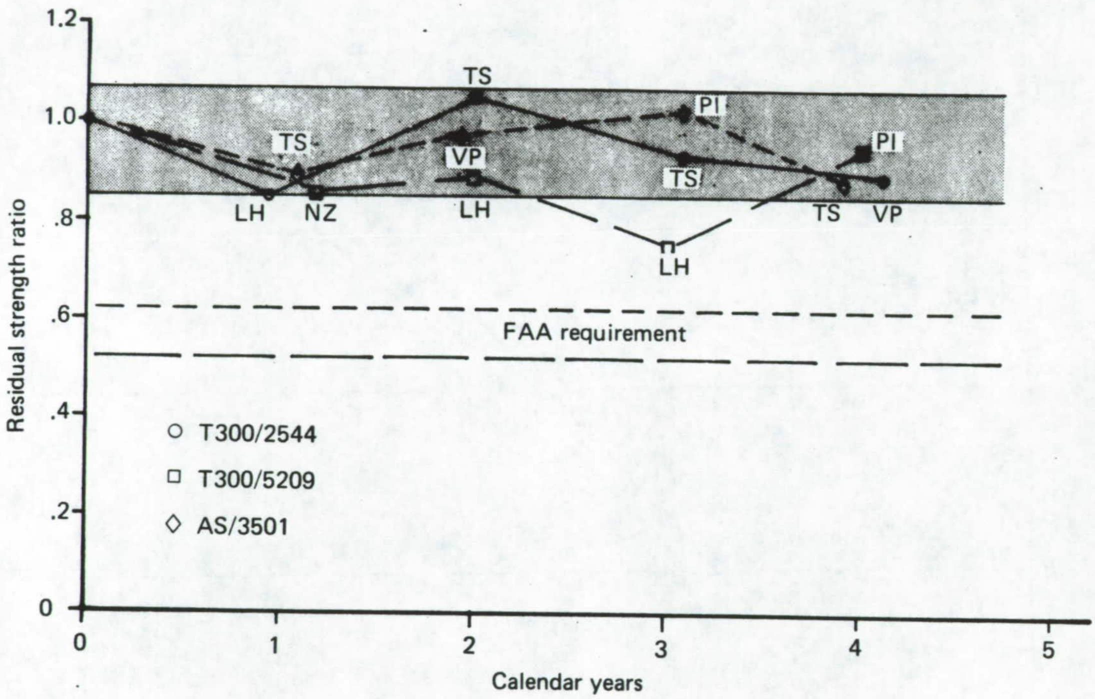


Figure 8.—Residual Strength After Exposure

CORROSION

During the current reporting period, only four panels were removed from the service evaluation for corrosion of all types. One of these was attributable to the external doubler corrosion reported previously in ref. 3. The other three panels contained exfoliation corrosion in the spar chord extrusion, evidenced in a similar fashion to the corrosion reported in ref. 1 on spoiler S/N 0049 from Aloha.

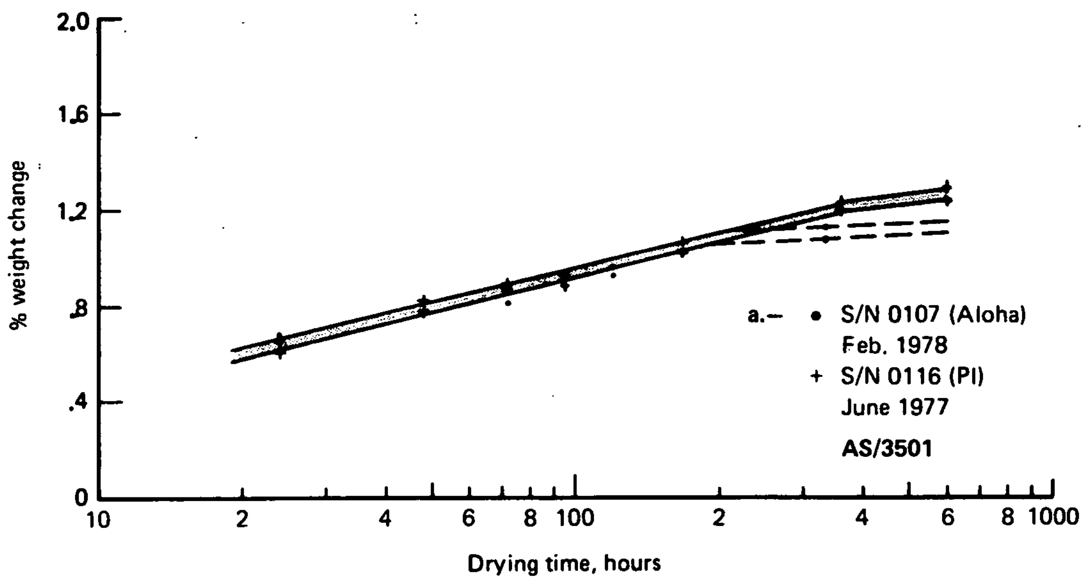
The external doubler corrosion problem on S/N 0049 was repaired by Boeing and returned for further flight service. The repair processing of the exfoliation corrosion condition is discussed in detail under "Repairs."

Additional core corrosion investigations conducted during this reporting period followed the previous technique of visual examination of the static test specimens subsequent to testing. Two of the specimens (S/N 0016 and 0107), were sectioned similar to spoiler S/N 0054 in ref. 1. Both panels were completely free of any evidence of corrosion in the honeycomb core.

MOISTURE ABSORPTION CORE SAMPLING

As a continuation of the moisture sampling technique initiated and described in ref. 1, additional core samples were obtained from two of the spoiler panels which were static-tested for residual strength (ref.: Static Test Results). Spoilers S/N 0016 (VASP) and 0107 (Piedmont) each had 3 core samples removed prior to static test. These six specimens were oven-dried at 160°F, with periodic measurement of weight changes. Plots of the weight changes as a function of time are shown in figure 9. This data, in conjunction with the previous core-sample data in reference 1, will be consolidated with other moisture-absorption data as it becomes available.

Comparable data from the third-year static test spoiler S/N 0116, unreported in last year's documentation due to unavailability, is also shown in fig. 9.



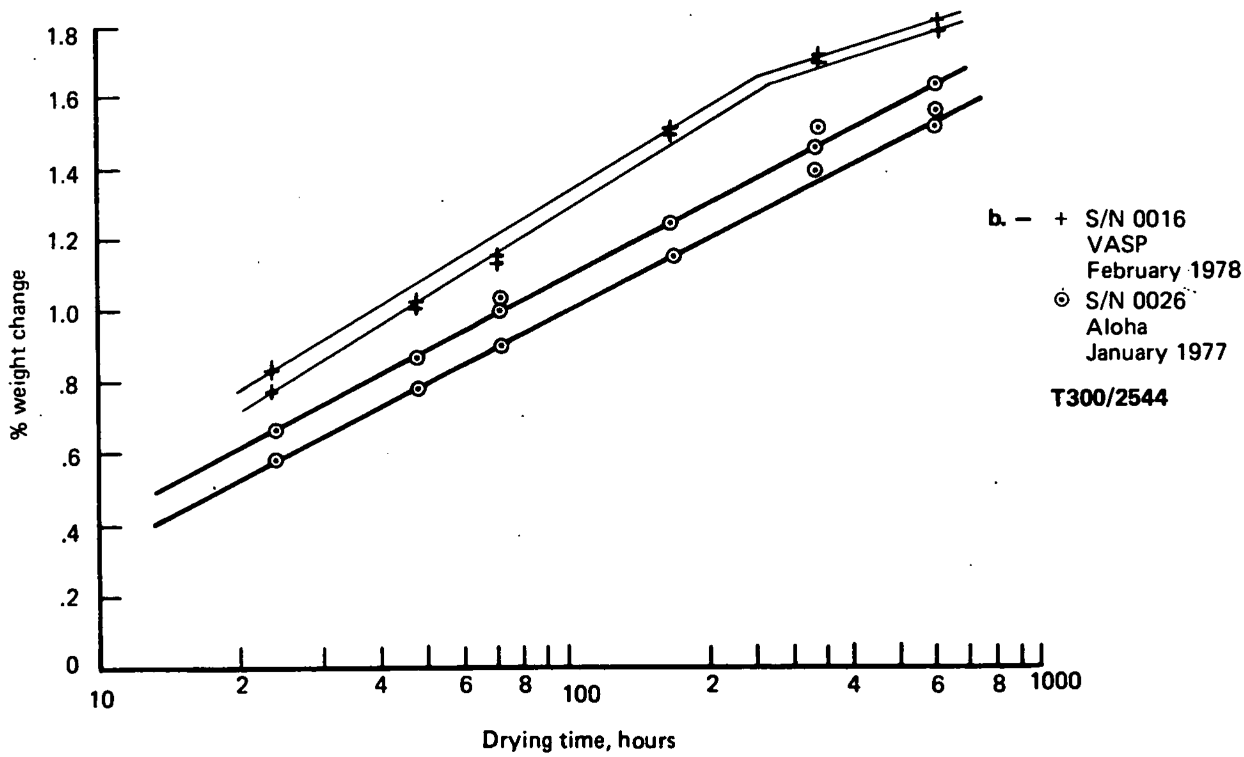


Figure 9.—Moisture Weight Change

TAILCONE MOISTURE PROGRAM

During the current reporting period a new facet of the spoiler program was initiated. Three participating airlines (Aloha, New Zealand National Airways, and Piedmont) agreed to install moisture collecting specimens of three graphite-epoxy materials, T300/5208, T300/5209, and AS/3501) on modified 737 flap fairing tailcones. These specimens, in both 8-ply and 16-ply unpainted configurations, were positioned to exposure for both solar (Fig. 10, upper surface) and non-solar (Fig. 11, lower surface) conditions. Sufficient specimens were deployed on one aircraft per airline to permit seven successive withdrawals over a 2-year period.

Preliminary data is presently being processed through the Boeing Materials Laboratory. Since the dryout cycle is lengthy (1200 hours), early data from the first three months is not conclusive, and trends are not yet apparent. The next scheduled report should present sufficient data to permit significant evaluation of the survey.

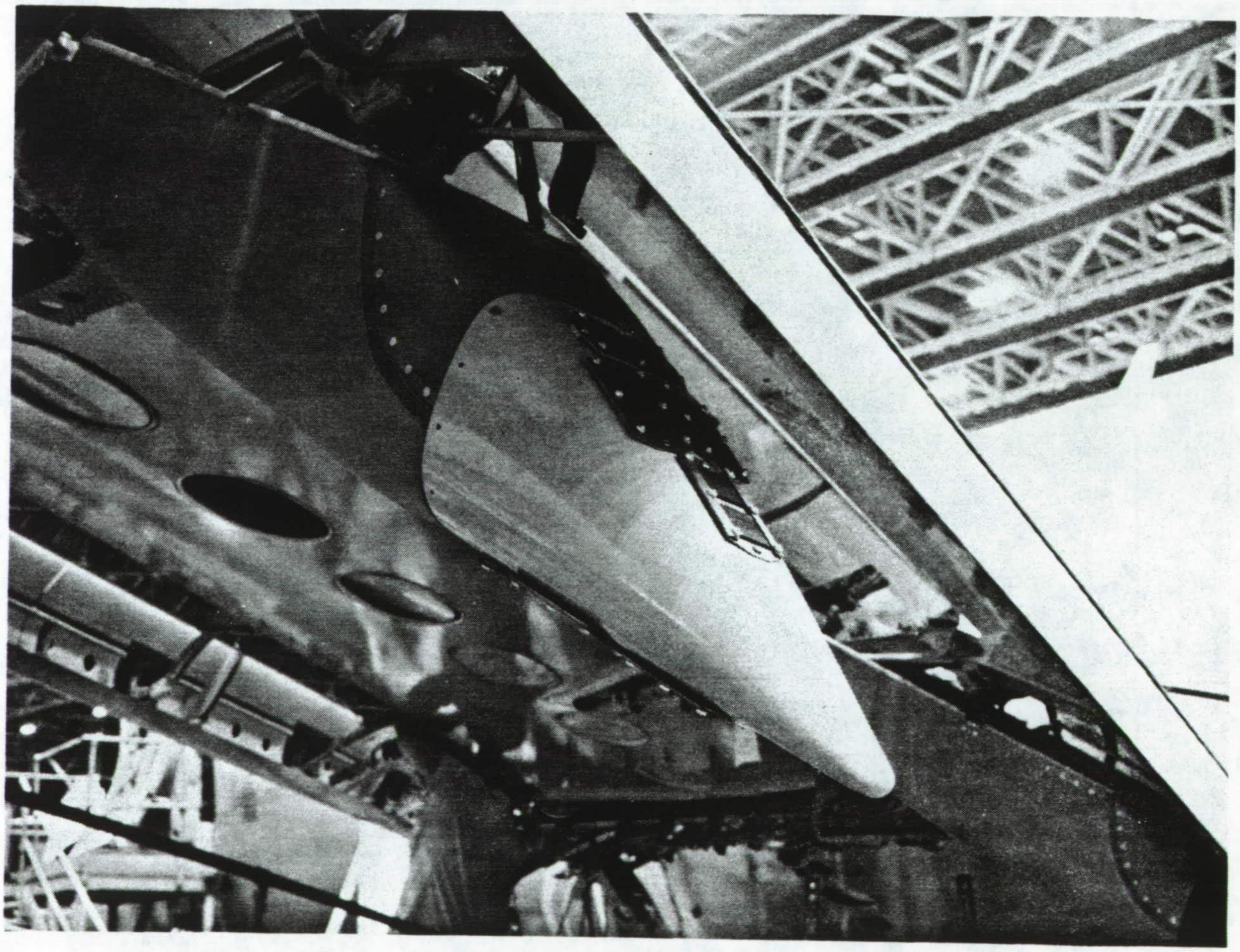


Figure 10.—Tailcone Moisture Samples (Solar)

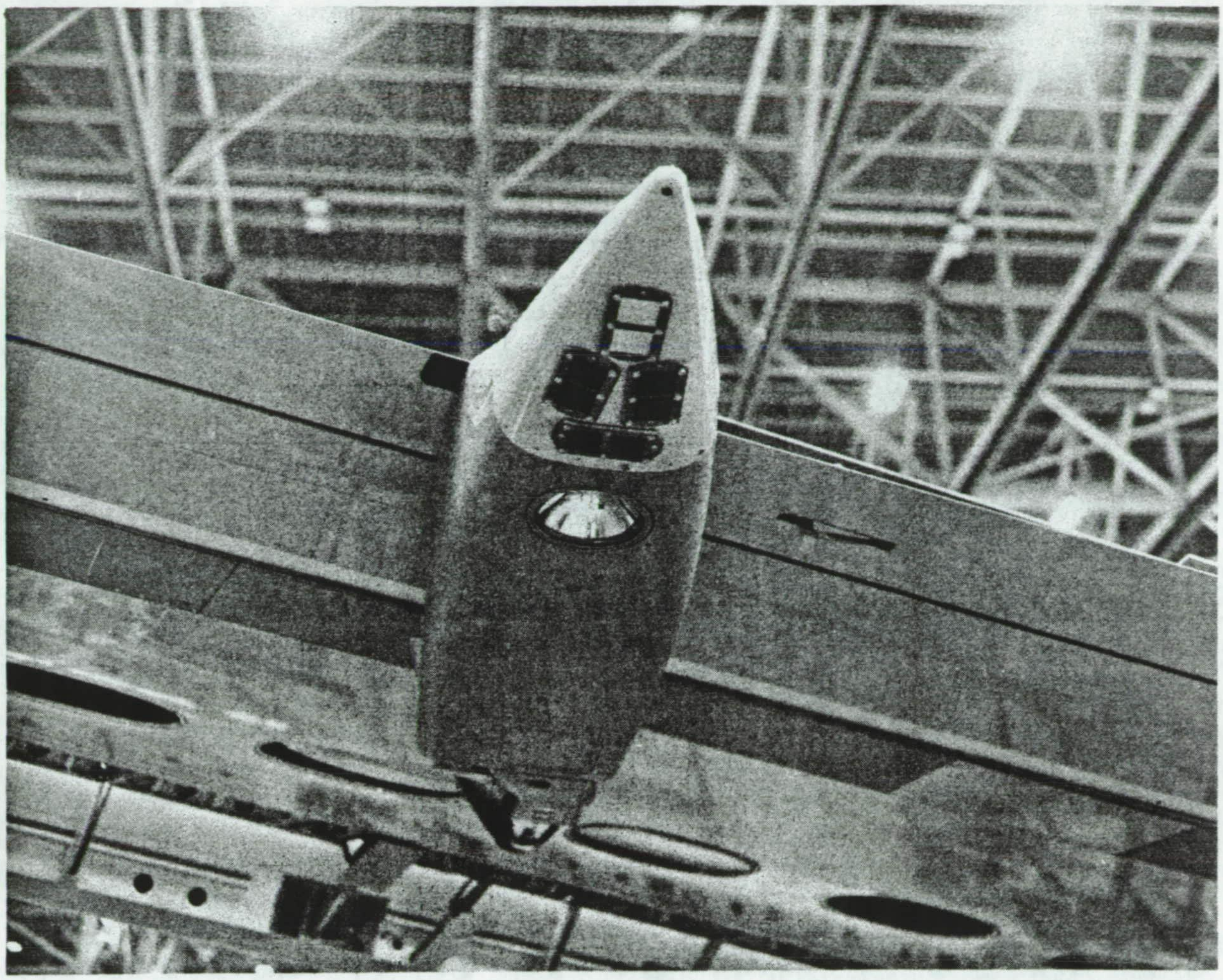


Figure 11.—Tailcone Moisture Samples (Non-solar)

SERVICE PROBLEMS

Service-related problems with the spoiler fleet during the current period have become more environmentally related than in the past two years when maintenance damage and design/interference factors predominated. A total of 8 panels experienced unscheduled removals in the past 12 months. A summary of these removals is shown in Table 7.

Three removals for exfoliation corrosion were made, these in addition to the removal of S/N 0049 reported in ref. 1. As the result of successfully completing a corrosion repair on S/N 0049, the removals this year will be processed through a similar repair cycle with the objective of returning all such panels to revenue service for further evaluation of the panels and of the repairs in particular.

Upper surface blisters persist as a fleet problem, due principally to maintenance procedures and definition of the spoiler actuator package, which includes the rod-end. Periodic replacement of the actuator package frequently results in inadvertant replacement of the rod-end with the interference-prone -182 rod-end (ref. 3).

In an attempt to convey a summary of observed anomalies compiled through the annual inspections, Tables 8 and 9 were prepared to give the reader a better perspective of the distribution and frequency of these observed flight-service anomalies. Without reference to number of possible problems of a given type, the reader may conclude that the problems reported to date represent a significant deterioration of the panel fleet. Quite the contrary, several airline maintenance executives have expressed the opinion that the problems experienced on this program are significantly below their experience level with production spoiler panels.

In addition, the continuing assessment of the durability of skin repairs should be of significant importance to the overall performance assessment. Table 8 gives a summary of observations (including composite skin repairs) made during the annual inspection conducted in March 1978, while Table 9 is a cumulative summary of four years of inspections. The identification of anomalies in the noted categories represents the author's best effort at objectivity.

Table 7.—Unscheduled Flight Spoiler Removals

Spoiler serial number	Airline	Date removed	Reason for removal	Action taken	Final disposition
0005	VP	4-8-78	Spar Exfoliation Corrosion	– in transit –	
0023	Aloha	4-20-78	Spar Exfoliation Corrosion	NDT	Repair in process
0045	FL	4-24-78	Alum. Doubler delamination	NDT & repair	Repair in process
0051	NZ	10-18-77	Upper skin blister	NDT & repair	Reinstalled
0066	NZ	10-28-77	Spar Exfoliation Corrosion	NDT & repair	Reinstalled
0074	PI	1-9-78	Upper skin blister	NDT & repair	Repair in process
0089	NZ	2-12-78	Skin delamination	NDT & repair	Repair in process
0093	PI	3-30-77	Upper skin blister	NDT & repair	Reinstalled

Table 8.—Spoiler Service Inspection Compilation (Fourth Year Inspection—March 1978)

		NUMBER OF NOTED ANOMALIES									
	No. Panels	Rod-end Blisters	Edge Delamin-ations	Surface Delamin-ations	Surface Cracking	Upper Surface Mech. Damage	Upper Surface Nat/Environ. Damage	Lower Surface Mech. Damage	Lower Surface Nat/Environ. Damage	Exfoliation Corrosion Damage	Repair Condition OK/Not OK
Frontier	5	0	0	0	0	0	0	0	0	0	0/0
New Zealand	12	0	0	0	0	0	0	0	0	2	6/0
Lufthansa	20	2	1	0	0	0	0	0	0	1	4/0
Aloha	13	0	0	0	0	1	0	0	0	2	4/0
Piedmont	30	2	0	0	0	0	0	0	0	0	5/0
VASP	14	0	0	0	0	0	0	0	0	1	5/0
Totals	94	4	1	0	0	1	0	0	0	6	24/0

Table 9.—Spoiler Service Inspection Compilation (Cumulative 4 Years)

	No. Panels	NUMBER OF NOTED ANOMALIES									
		Rod-end Blisters	Edge Delamin-ations	Surface Delamin-ations	Surface Cracking	Upper Surface Mech. Damage	Upper Surface Nat/Environ. Damage	Lower Surface Mech. Damage	Lower Surface Nat/Environ. Damage	Exfoliation Corrosion Damage	Repair Condition OK/Not OK
Frontier	6	0	0	0	0	0	0	0	0	0	0/0
New Zealand	16	4	0	1	0	0	0	1	0	4	6/0
Lufthansa	24	4	1	0	0	0	0	2	0	1	5/0
Aloha	17	8	0	0	0	1	0	0	0	3	5/0
Piedmont	32	4	0	0	0	1	0	0	0	0	5/0
VASP	16	4	0	0	0	0	0	1	0	1	5/0
Totals	111	24	1	1	0	2	0	4	0	9	26/0

REPAIRS

In reference 1, spoiler panel S/N 0049 was reported as being in the repair process. The repair, which included dressing out the corrosion and re-processing the spar surface, was successfully accomplished on this panel, as well as on panel S/N 0009 (previously reported in ref. 2). This successful repair process is being followed by similar processing of those panels withdrawn from service during the present reporting period. Figure 12 shows the completed repair on S/N 0049 prior to surface refinishing. Not only was S/N 0009 refurbished with a spar repair in the manner of S/N 0049, but this panel also required repair of the three core samples removed as a portion of the core-sampling technique development in 1976. (Figure 13 shows both the cored trailing edge and a partially completed spar repair). Having successfully repaired the spar, the core-sample repair was then undertaken to return S/N 0009 to flight-worthy status.

To accomplish the refurbishment of S/N 0009, a repair procedure was developed which would splice a core plug into the panel (Fig. 14). The skin repair then employed the ply-for-ply replacement philosophy, with 1/4 inch steps in the skin replacement plies. Figure 15 is a close-up of one repaired core plug following cure of the skin prepreg. Present planning is to return this panel to the service-evaluation program, following Quality Control concurrence.

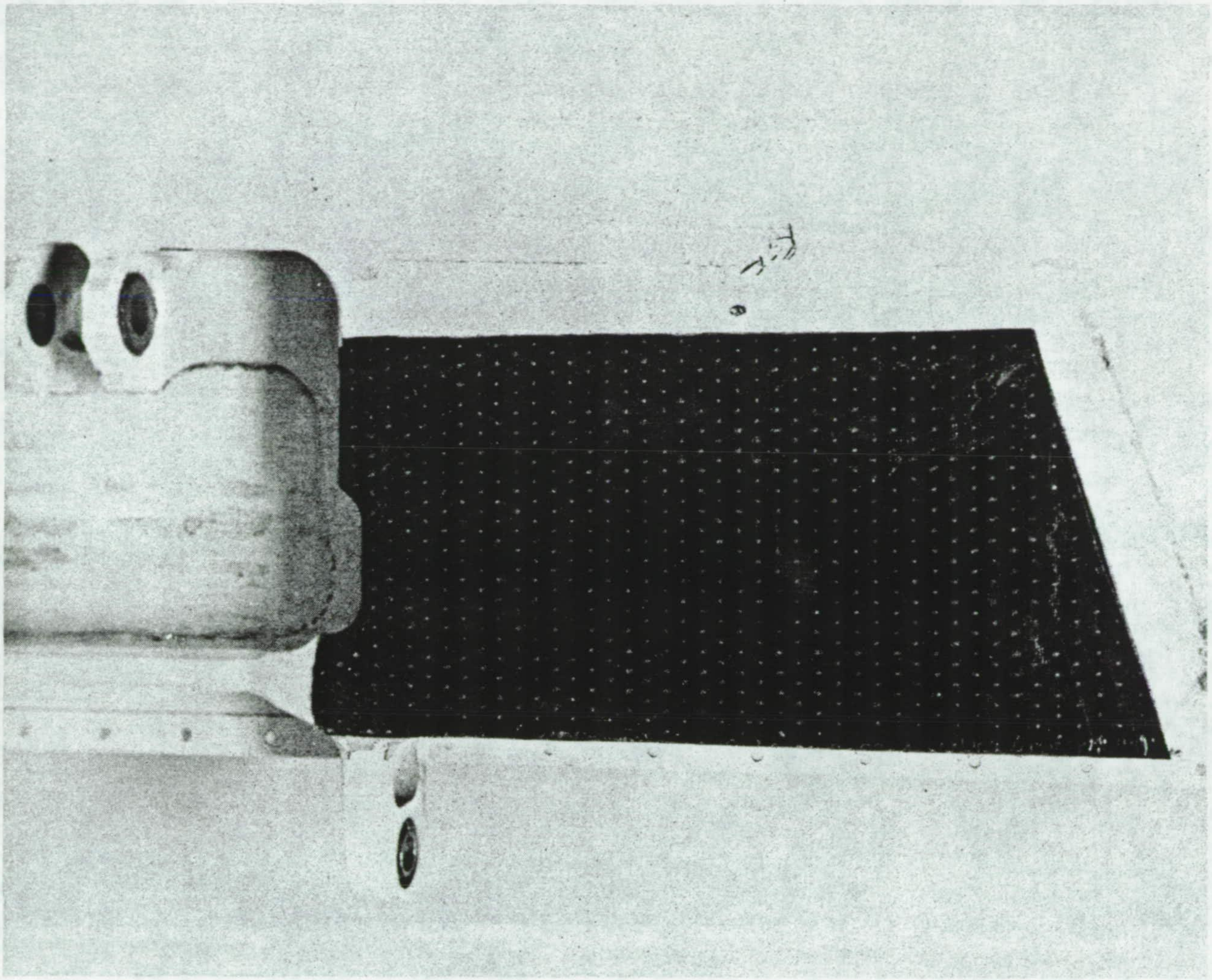


Figure 12.—Completed Rapair on Aloha's S/N 0049

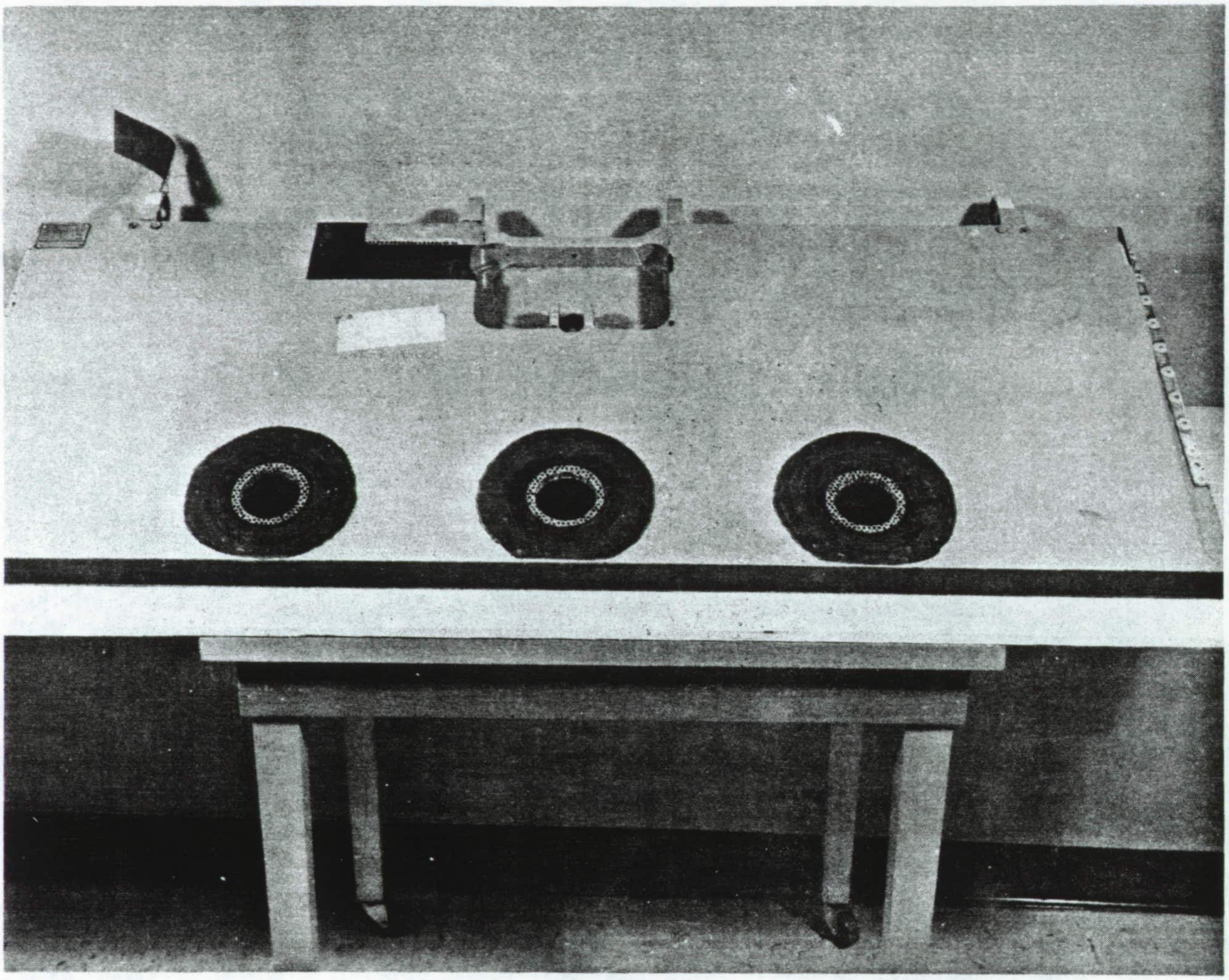


Figure 13.—Spoiler S/N 0009 Prepared for Repair

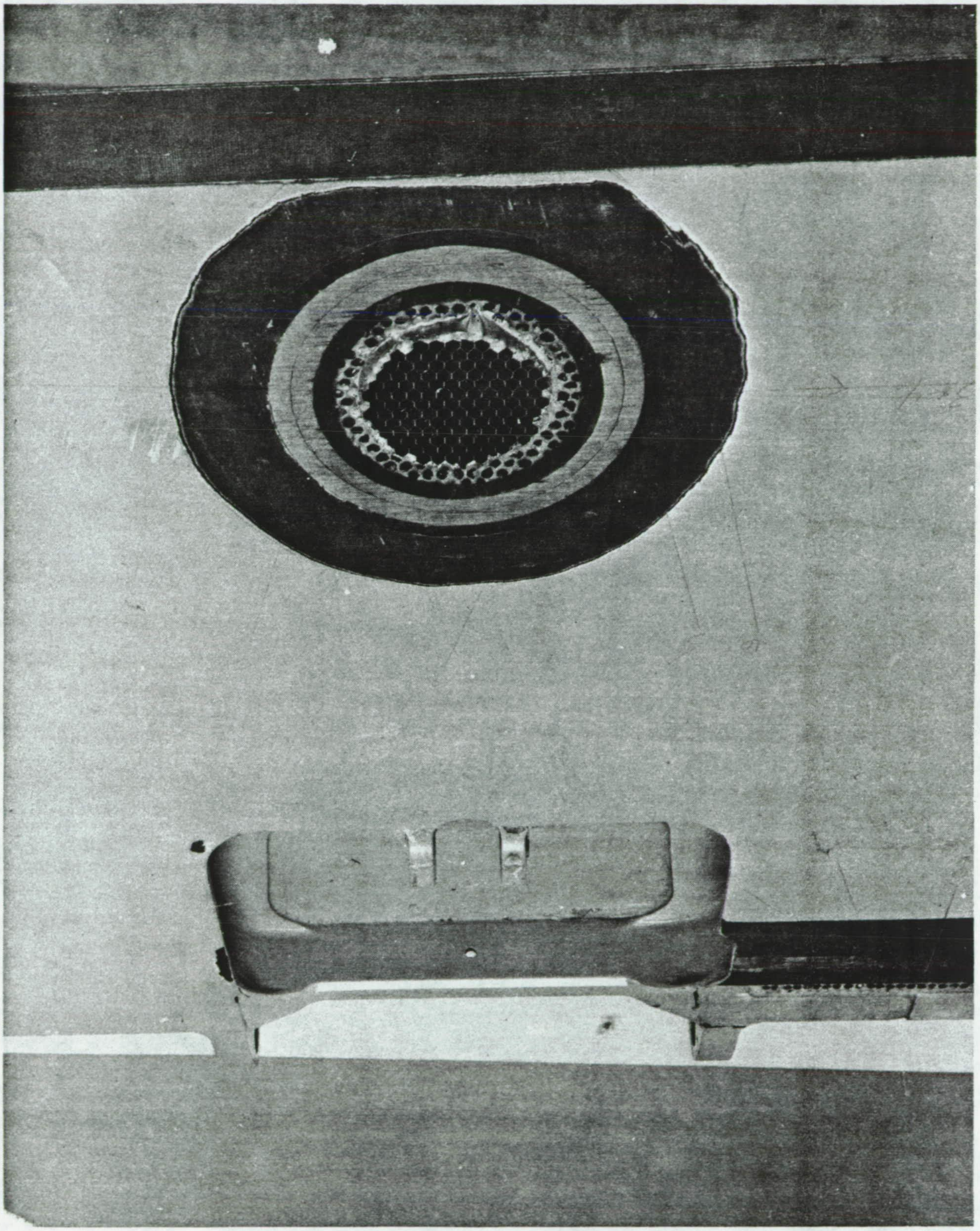


Figure 14.—Core Repair on S/N 0009

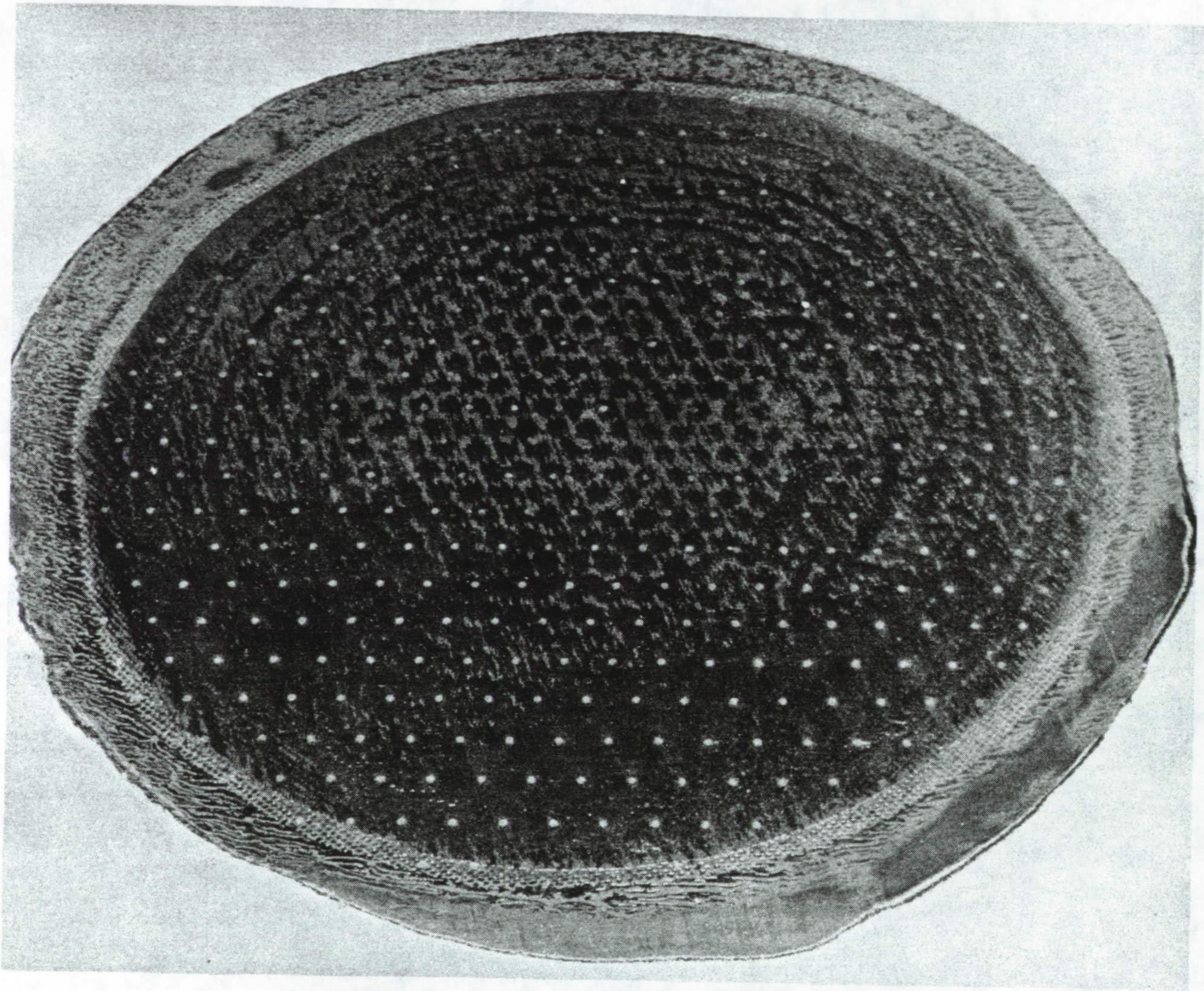


Figure 15.—Completed Skin Repair Over Core Repair S/N 0009

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. Environmental exposure data are being obtained on interlaminar shear, flexure, and compression specimens. The specimens are mounted in five replicate panels attached to each exposure rack in a manner that provides a maximum exposure to sunlight on one surface but allows free circulation of air and other weather effects around the specimens. Details of the exposure rack installations are given in reference 4.

Panels for one and three years exposure data at all sites except Sao Paulo, Brazil (VASP Airlines) have been previously tested, and the data reported in reference 1. The Sao Paulo panels were initially installed one year later than the other exposure sites and the three year data from Sao Paulo is reported herein. The overall plan calls for the remaining panels at all sites to be removed after five, seven, and ten years of exposure, respectively. Data being generated include stiffness and strength retention, moisture pickup, and ultraviolet weight loss.

All specimens were weighed and measured to obtain baseline data prior to environmental exposure. All specimens are weighed following removal from the exposure racks. Weight changes are attributed to the combined effects of moisture pickup and ultraviolet weight loss. After the flexure specimens are tested, they are dried to determine the absorbed moisture content. The ultraviolet weight loss is taken as the difference between the fully-dried weights before and after exposure.

Similar data are not generated for the shear specimens because of their small size, nor for compression specimens because of the glass/epoxy tabs bonded to the specimens. Figure 16 is a plot of the weight loss data resulting from three years outdoor ultraviolet exposure for all exposure sites except Sao Paulo. The Sao Paulo specimens are still being dried after testing. The weight loss data are presented as a function of exposure site latitude. The limited data obtained to date indicates that weight loss due to ultraviolet exposure is approximately inversely propositional to the distance of the exposure site from the equator. It should be pointed out that all specimens had bare surfaces.

Scanning electron micrographs of two areas on one of the T300-5209 graphite-epoxy specimens exposed at the Honolulu site are shown in figure 17. The left-hand area was shielded from the solar ultraviolet by the specimen mounting clamp on the exposure rack. The magnified view is essentially the original as-laminated surface, which is entirely epoxy. The right-hand area was typical of the unshielded portion of the same specimen. In this area the epoxy matrix has been removed by the ultraviolet weathering process, exposing a layer of individual graphite fibers. Although the effect looks severe, it is quite superficial for three years of exposure and can be prevented by painting the exposed specimen surface. Preliminary data from a limited number of specimens painted with a standard commercial aircraft paint indicate that, while there is a weight loss, the loss is attributed to the paint, which can be periodically refurbished, and no damage develops in the epoxy surface of the composite. However, the paint does not prevent moisture absorption.

* Prepared by Richard A. Pride of NASA-Langley Research Center

The amount of moisture absorbed by the several graphite-epoxy materials is shown in figure 18. These results represent the determinations made on flexure specimens after their worldwide outdoor exposures for times up to three years.

The weight gains shown have been corrected for the ultraviolet weight losses as described previously. The scatter bands indicated for the three year exposures contain all the data for three replicate specimens and five exposure sites. In general, there is no separation of individual sites by the magnitude of absorbed moisture. The largest variable appears to be the type of epoxy material used in the composite laminate.

Results of the residual strength tests on the short beam shear, compression, and flexure specimens removed from Sao Paulo, Brazil, after three years are presented in Tables 10, 11, and 12, which are repeated from reference 1 to include the Sao Paulo data.

Comparison with the previously published three-year data indicates little difference in strength retention, when compared to the other exposure sites.

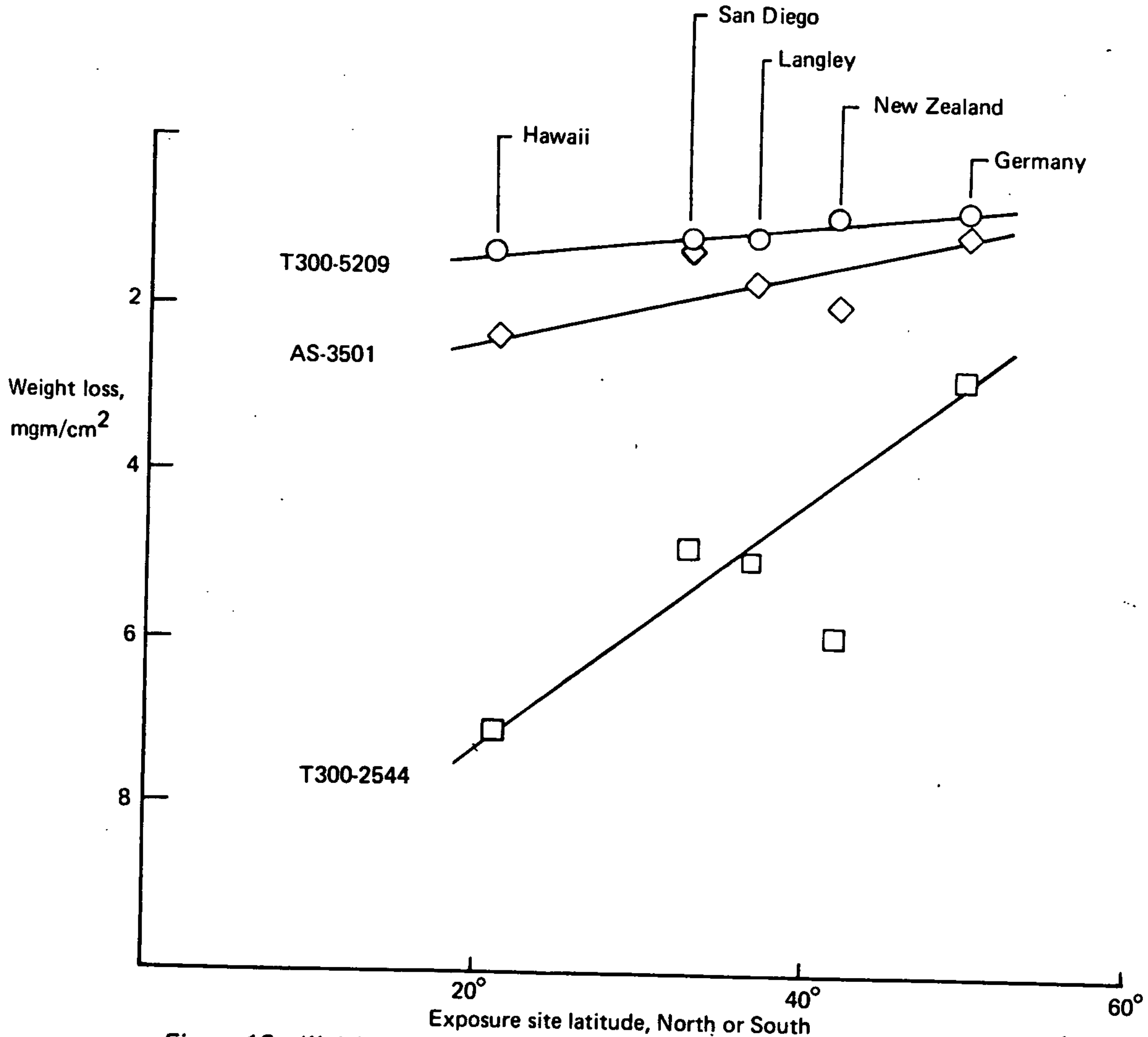


Figure 16.—Weight Loss From Environmental Exposure (Three Years)

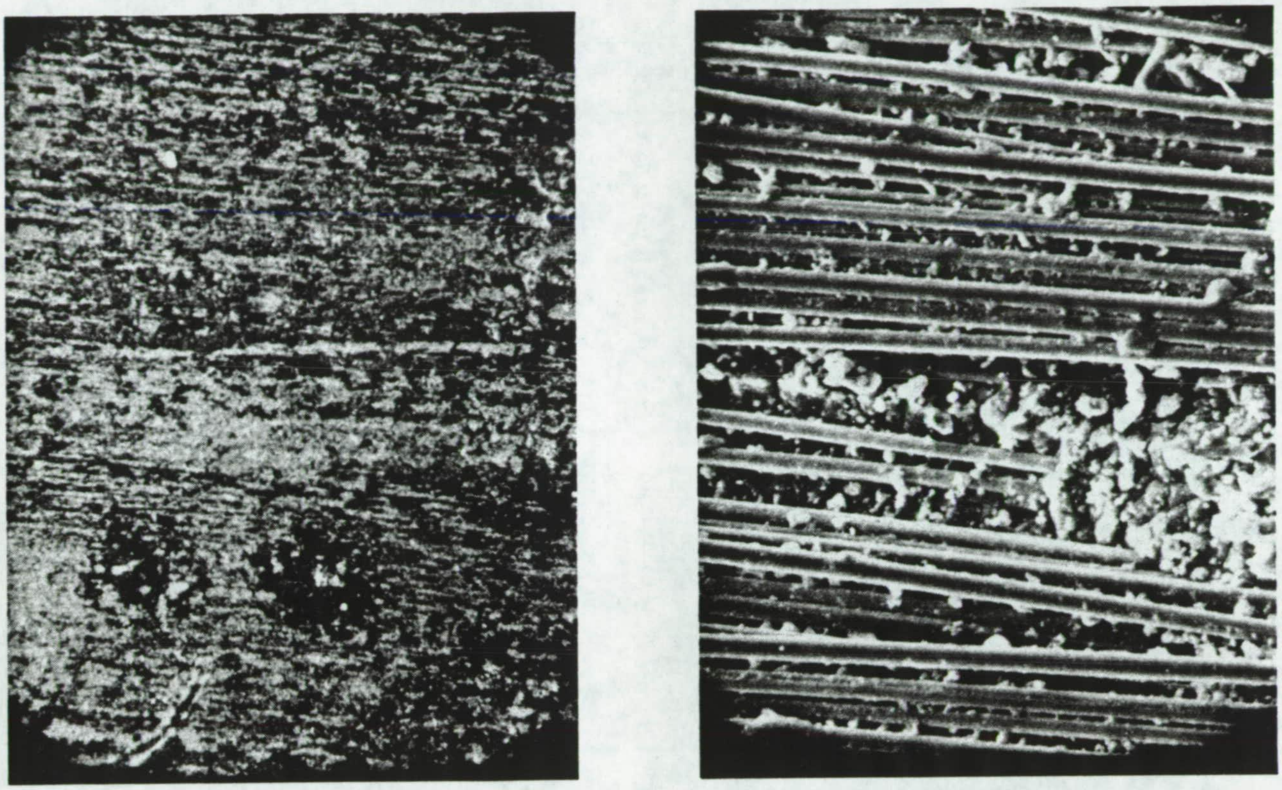


Figure 17.—Graphite/Epoxy Surface Degradation (3-Year Outdoor Exposure)

Table 10.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Short-Beam Interlaminar Shear Tests

Exposure time, yr	Exposure location	Graphite material system	Number of specimens	Average failure stress		Average weight change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	5	77	11.2	–	–
3	LaRC	T300/5209	3	78	11.3	+0.0039	+0.51
3	Hawaii	T300/5209	3	81	11.8	+0.0045	+0.60
3	New Zealand	T300/5209	3	77	11.2	+0.0046	+0.61
3	Germany	T300/5209	3	82	11.9	+0.0039	+0.53
3	California	T300/5209	2	79	11.5	+0.0040	+0.54
3	LaRC* (painted specimens)	T300/5209	3	77	11.1	+0.0034	+0.41
3	Brazil	T300/5209	3	79	11.4	–	–
0 (baseline)	LaRC	T300/2544	4	81	11.7	–	–
3	LaRC	T300/2544	3	67	9.7	+0.0081	+1.34
3	Hawaii	T300/2544	3	77	11.1	-0.0183	-2.62
3	New Zealand	T300/2544	3	64	9.3	+0.0117	+1.86
3	Germany	T300/2544	3	59	8.6	+0.0078	+1.38
3	California	T300/2544	3	66	9.6	+0.0069	+1.23
3	LaRC* (painted specimens)	T300/2544	3	68	9.9	+0.0090	+1.35
3	Brazil	T300/2544	3	70	10.1	–	–
0 (baseline)	LaRC	AS/3501	5	87	12.6	–	–
3	LaRC	AS/3501	3	91	13.2	+0.0045	+0.78
3	Hawaii	AS/3501	3	81	11.8	+0.0298	+5.08
3	New Zealand	AS/3501	3	76	11.0	+0.0084	+1.43
3	Germany	AS/3501	3	89	12.9	+0.0048	+0.86
3	California	AS/3501	3	85	12.4	+0.0050	+0.91
3	LaRC* (painted specimens)	AS/3501	3	85	12.3	+0.0037	+0.60
3	Brazil	AS/3501	3	85	12.4	–	–

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

Table 11.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Flexure[a] Tests

Exposure time, yr	Exposure location	Graphite-epoxy material system	Number of specimens	Average failure stress		Average flexure modulus		Average weight change	
				MPa	ksi	GPa	psi (x 10^6)	grams	%[b]
0(baseline)	LaRC	T300/5209	5	1529	221.8	103.8	15.05	–	–
3	LaRC	T300/5209	3	1638	137.5	104.5	15.15	+0.0052	+0.24
3	Hawaii	T300/5209	3	1387	201.1	103.5	15.01	+0.0049	+0.23
3	New Zealand	T300/5209	3	1349	195.6	108.9	15.80	+0.0080	+0.38
3	Germany	T300/5209	3	1592	230.9	103.8	15.05	+0.0056	+0.26
3	California	T300/5209	3	1644	238.4	104.7	15.19	+0.0045	+0.22
3	LaRC[c] (painted specimens)	T300/5209	3	1519	220.3	105.2	15.26	+0.0087	+0.34
3	Brazil	T300/5209	3	1485	215.4	102.5	14.86	–	–
0(baseline)	LaRC	T300/2544	5	1462	212.0	106.2	15.41	–	–
3	LaRC	T300/2544	3	1581	229.3	103.8	15.05	-0.0017	+0.26
3	Hawaii	T300/2544	-3	1584	229.7	102.3	14.84	-0.0114	-0.26
3	New Zealand	T300/2544	3	1435	208.2	101.1	14.67	+0.0053	+0.63
3	Germany	T300/2544	3	1638	237.6	104.8	15.20	+0.0088	+0.81
3	California	T300/2544	3	1691	245.2	107.4	15.58	-0.0019	+0.25
3	LaRC[c] (painted specimens)	T300/2544	3	1633	236.9	105.1	15.25	+0.0153	+1.08
3	Brazil	T300/2544	3	1528	221.6	100.8	14.62	–	–
0(baseline)	LaRC	AS/3501	5	1449	210.1	94.7	13.73	–	–
3	LaRC	AS/3501	3	1757	254.8	98.9	14.35	+0.0036	+0.53
3	Hawaii	AS/3501	3	1635	237.1	95.1	13.79	+0.0025	+0.47
3	New Zealand	AS/3501	3	1465	212.5	98.3	14.25	+0.0093	+0.83
3	Germany	AS/3501	3	1715	248.8	95.3	13.82	+0.0056	+0.63
3	California	AS/3501	3	1696	246.0	97.3	14.11	+0.0057	+0.64
3	LaRC[c] (painted specimens)	AS/3501	3	1770	256.7	101.8	14.77	+0.0077	+0.66
3	Brazil	AS/3501	3	1709	247.9	95.8	13.89	–	–

[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]Corrected to initial fully dry weight.

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

Table 12.—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	Average failure stress		Average weight change	
				MPa	ksi	grams	%
0 (baseline)	LaRC	T300/5209	3	712	103.2	–	–
3	LaRC	T300/5209	3	698	101.2	+0.0640	+0.80
3	Hawaii	T300/5209	3	560	81.2	+0.0735	+0.93
3	New Zealand	T300/5209	3	674	97.8	+0.0945	+1.18
3	Germany	T300/5209	3	688	99.8	+0.0498	+0.62
3	California	T300/5209	3	654	94.9	+0.0846	+1.04
3	LaRC[b] (painted specimens)	T300/5209	3	662	96.0	+0.0531	+0.65
3	Brazil	T300/5209	3	683	99.1	–	–
0 (baseline)	LaRC	T300/2544	4	1029	149.2	–	–
3	LaRC	T300/2544	3	955	138.5	+0.0985	+1.39
3	Hawaii	T300/2544	3	812	117.7	+0.0964	+1.38
3	New Zealand	T300/2544	3	860	124.8	+0.1139	+1.63
3	Germany	T300/2544	3	985	142.8	+0.0639	+0.91
3	California	T300/2544	2	1046	151.7	+0.1014	+1.50
3	LaRC[b] (painted specimens)	T300/2544	3	926	134.3	+0.0865	+1.20
3	Brazil	T300/2544	3	875	126.9	–	–
0 (baseline)	LaRC	AS/3501	5	1107	160.5	–	–
3	LaRC	AS/3501	3	1003	145.5	+0.0583	+0.89
3	Hawaii	AS/3501	3	998	144.8	+0.0607	+0.94
3	New Zealand	AS/3501	3	953	138.2	+0.0741	+1.10
3	Germany	AS/3501	3	1080	156.6	+0.0464	+0.70
3	California	AS/3501	3	1045	151.5	+0.0779	+1.19
3	LaRC[b] (painted specimens)	AS/3501	3	1068	154.9	+0.0570	+0.87
3	Brazil	AS/3501	3	1137	164.9	–	–

[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.

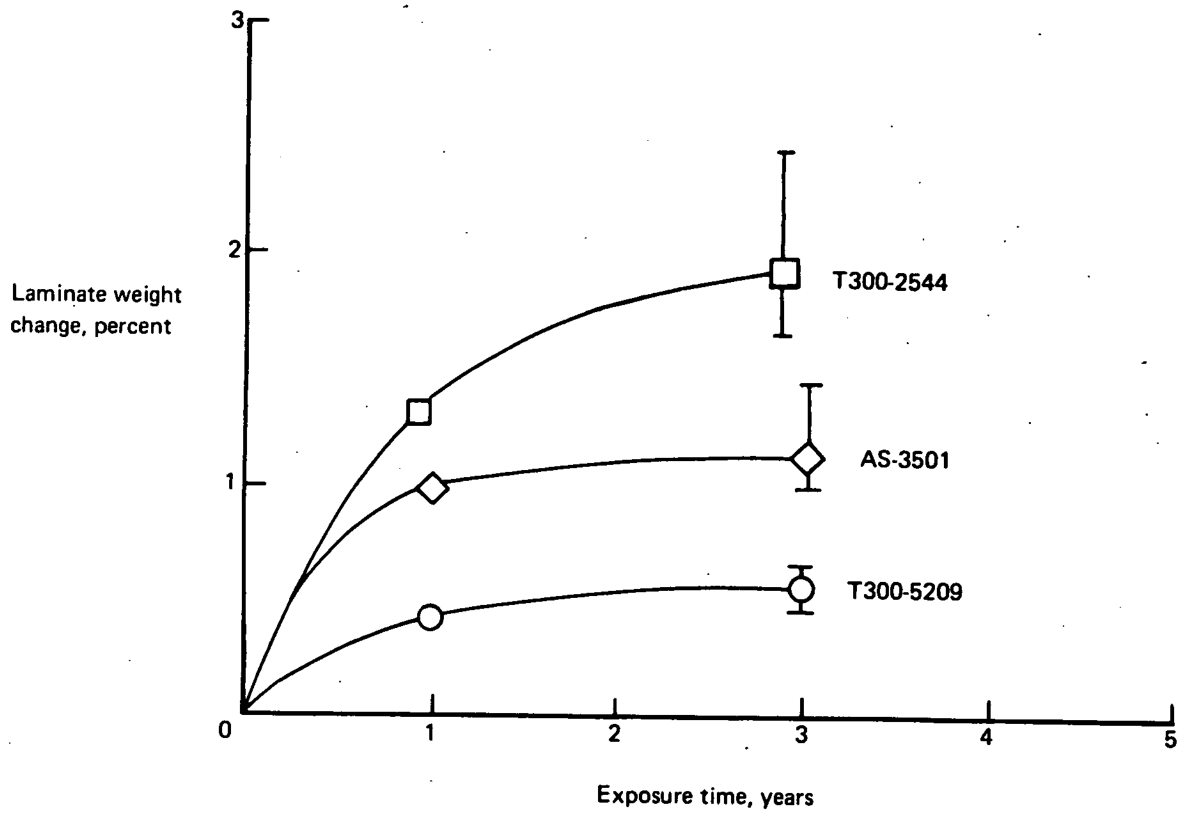


Figure 18.—Moisture Pickup for Composites After Worldwide Ground-Based Exposures

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