APPENDIX F—SMALL CRACK GROWTH

This appendix contains the small crack growth specimen assembly and calibration drawings, dimension of the titanium pins, crack growth test results, strain surveys, FEM stress distributions, and the load transfer with crack extension as discussed in section 7.

Page No.	Description
F-2	Small crack growth specimen assembly drawing (figure F-1)
F-6	Small crack growth specimen calibration drawing (figure F-2)
F-10	Dimensions of titanium pin, washer, shim, and cotter pin (figure F-3)
F-14	Crack growth test results (tables F-1 to F-15)
F-22	SCG-1s strain survey (figures F-4 to F-14)
F-28	SCG-2 strain survey (figures F-15 to F-37)
F-39	SCG-5 strain survey (figures F-38 to F-53)
F-47	SCG-6 strain survey (figures F-54 to F-67)
F-54	SCG-7 strain survey (figures F-68 to F-79)
F-60	SCG-8 strain survey (figures F-80 to F-89)
F-65	SCG-9 strain survey (figures F-90 to F-93)
F-67	SCG-11 strain survey (figures F-94 to F-103)
F-72	Specimen stress distributions (figures F-104 to F-106)
F-74	Change in load transfer with crack extension (figures F-107 to F-118)

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TER THE PIN HOLES

SURE TO COMPRESS
BLY, ADJUST THE
ZERO CLEARANCE
THE S224504296-0024

NOTE B: AN EQUIVALENT MATERIAL MAY BE SUBSTITUTED WITHOUT ENGINEERING APPROVAL.
NOTE A: AN EQUIVALENT PIN OR WASHER MAY BE SUBSTITUTED WITHOUT ENGINEERING APPROVAL.

QTY REQ PER NOTED DASH NO. -503	-501	-1	PART NO.	DESCRIPTION	STOCK SIZE	MATERIAL DESCRIPTION	MATERIAL SPECIFICATION	ZONE	NOTE
			ANSI Y14.5M -1994	STANDARD					
			DPS 4.710	PROCESS					
			DPS 3.02	PROCESS					
			DPS 2.70	PROCESS					
			DPS 1.999	PROCESS					
			DPS 1.07-2	PROCESS					
			DPS 1.001	AND THE FOLLOWING DOCUMENTS ARE REQUIRED TO SUPPLEMENT THE DRAWING					
AR	AR	AR	EA9330.3	ADHESIVE					B
2	2	2	EA-13-062AQ -350	STRAIN GAGE			(MEASUREMENTS GROUP INC. RALEIGH, NC)	9	
2	2	2	S224504296 -0024	PIN				9	A
4	4	4	NAS1252-10L	WASHER				8	
2			MS20392 -2A13	PIN				13	A
	2	2	MS20392 -2A9	PIN				9	A
AR	AR	AR	-13	SHIM		(MAKE FROM) NAS1252-10H		9	A
2			-11	DOUBLER	.125 x 3 x 7 GR LGWISE	SHEET BARE 2024-T3	QQ-A-250/4 TEMP T3	13	
	2		-9	DOUBLER	.063 x 3 x 7 GR LGWISE	SHEET 4130 A	MIL-S-18729 COND A	9	
		2	-7	DOUBLER	.063 x 3 x 7 GR LGWISE	SHEET BARE 2024-T3	QQ-A-250/4 TEMP T3	9	
4	4	4	-5	DOUBLER	.063 x 4 x 4	SHEET CLAD 2024-T3	QQ-A-250/5 TEMP T3	7	
1	1	1	-3	SPECIMEN	.063 x 4 x 19 GR LGWISE	SHEET BARE 2024-T3	QQ-A-250/4 TEMP T3	8	
•			-503	SPECIMEN ASSY				13	
	•		-501	SPECIMEN ASSY				9	
		•	-1	SPECIMEN ASSY				9	

NONE

TEST SPECIMEN - CRACK GROWTH

J1 88277 ZJ151920

FIGURE F-1. SMALL CRACK GROWTH SPECIMEN DETAIL DRAWINGS

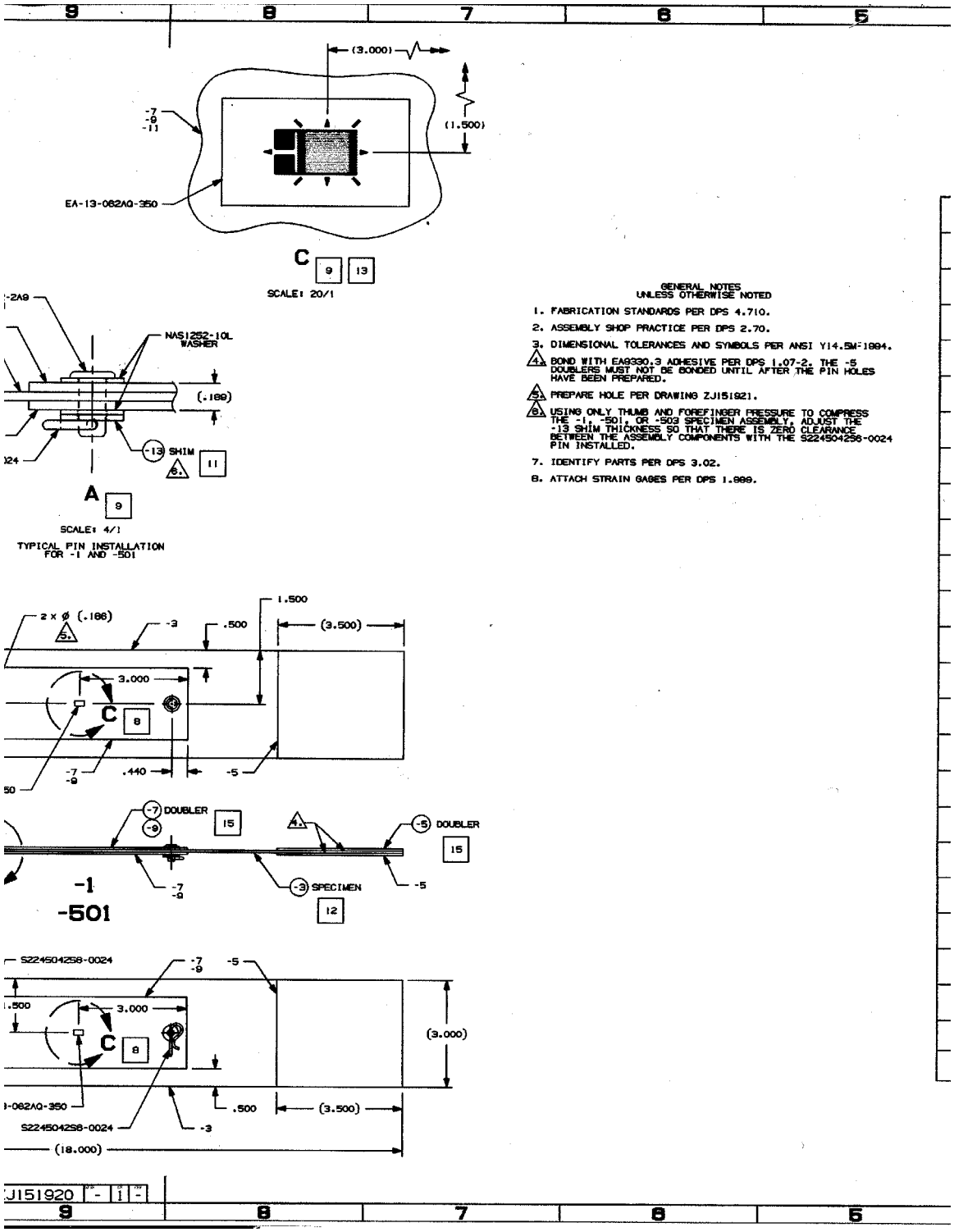

FIGURE F-1. SMALL CRACK GROWTH SPECIMEN DETAIL DRAWINGS (Continued)

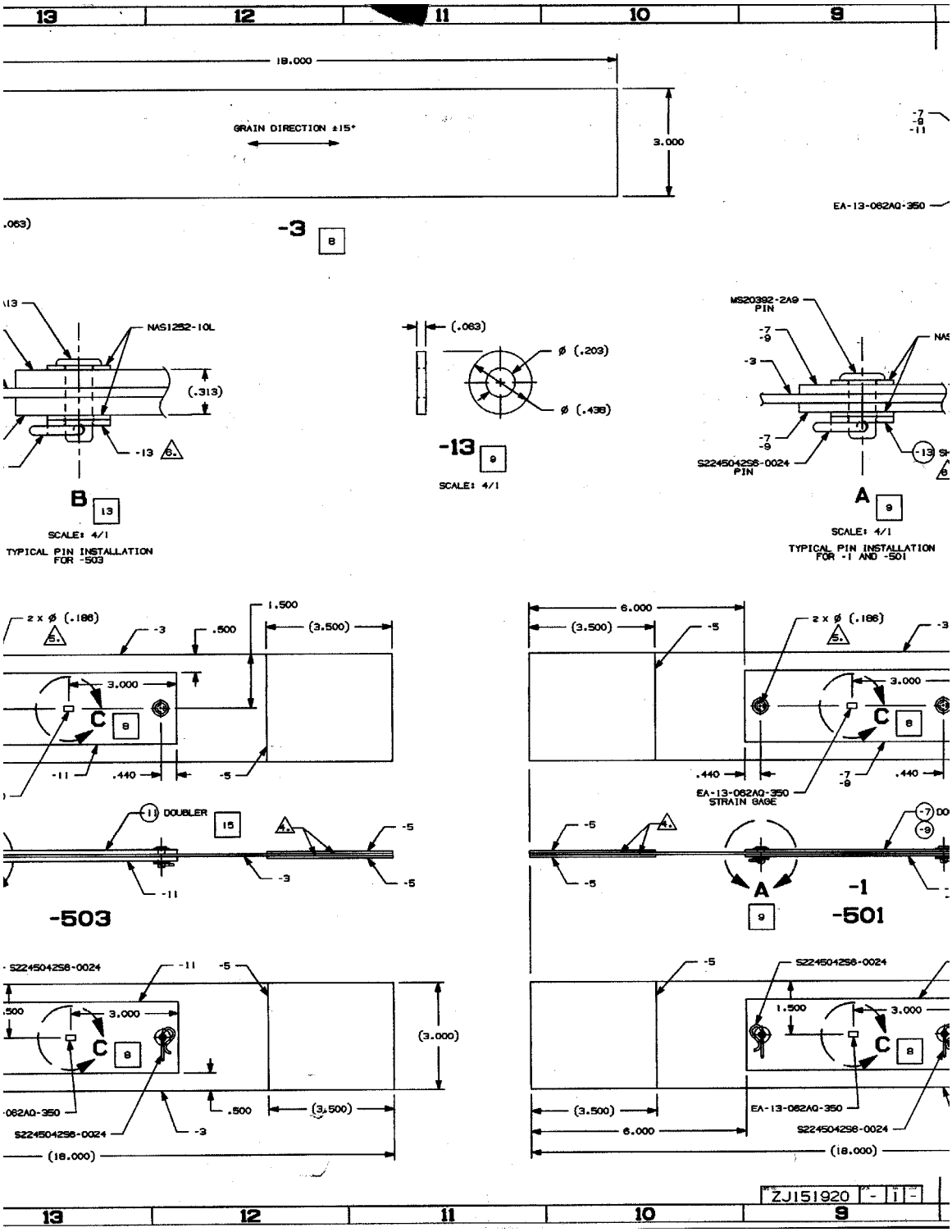

FIGURE F-1. SMALL CRACK GROWTH SPECIMEN DETAIL DRAWINGS (Continued)

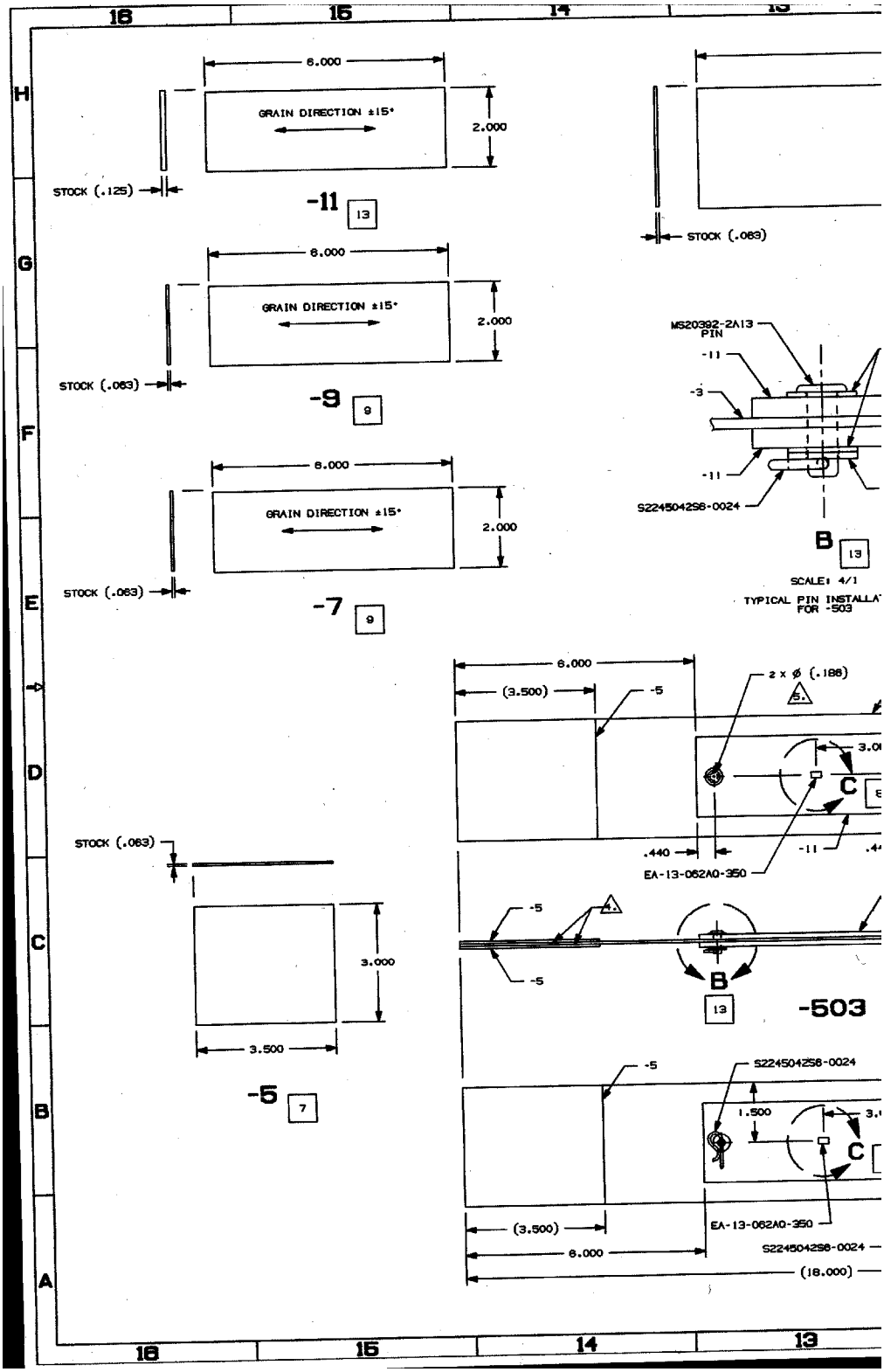

FIGURE F-1. SMALL CRACK GROWTH SPECIMEN DETAIL DRAWINGS (Continued)

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PER ANSI Y14.5M-1994.

) PART STACK-UP PER

ESSURE TO COMPRESS
ASSEMBLY, ADJUST THE
THERE IS ZERO
PONENTS WITH THE

IN GAGES ON THE -1,
IES PER TEST PLAN

E ZJ151920-3 SPECIMEN
01, OR -503 SPECIMEN
IBRATION.

J151921-1, -501, OR
SED IN THE
-503 SPECIMEN
D DRAWING

-503	-501	-1	PART NO.	DESCRIPTION	STOCK SIZE	MATERIAL DESCRIPTION	MATERIAL SPECIFICATION	ZONE
			NOTE A:	OBTAIN PART FROM DRAWING ZJ151920. BOTH ZJ151920 AND ZJ151921.		PART TO BE USED	ON CORRESPONDING ASSEMBLIES FO	
			ANSI Y14.5M -1994	STANDARD				
			DPS 4.710	PROCESS				
			DPS 3.02	PROCESS				
			DPS 2.70	PROCESS				
			DPS 1.001	AND THE FOLLOWING DOCUMENTS ARE REQUIRED TO SUPPLEMENT THE DRAWING				
2	2	2	S224504298 -0024	PIN				10
4	4	4	NAS1252-10L	WASHER				8
2			MS20392 -2A13	PIN				13
	2	2	MS20392 -2A9	PIN				9
AR	AR	AR	ZJ151920 -13	SHIM				9
2			ZJ151920 -11	DOUBLER				12
	2		ZJ151920 -9	DOUBLER				8
		2	ZJ151920 -7	DOUBLER				8
1	1	1	ZJ151920 -3	SPECIMEN				8
2	2	2	-3	CALIBRATION SPECIMEN	.063 x 4 x 10 GR LGWISE	SHEET BARE 2024-T3	QQ-A-250/4 TEMP T3	8
*			-503	CALIBRATION ASSY				13
	*		-501	CALIBRATION ASSY				9
		*	-1	CALIBRATION ASSY				9

QTY REQ PER NOTED DASH NO.

NONE

J. DOGUE 980651
J. DOGUE 980651

CALIBRATION ASSEMBLY
STRAIN GAGE, CRACK GR

J 88277 ZJ151921

NONE

FIGURE F-2. SMALL CRACK GROWTH SPECIMEN CALIBRATION ASSEMBLY

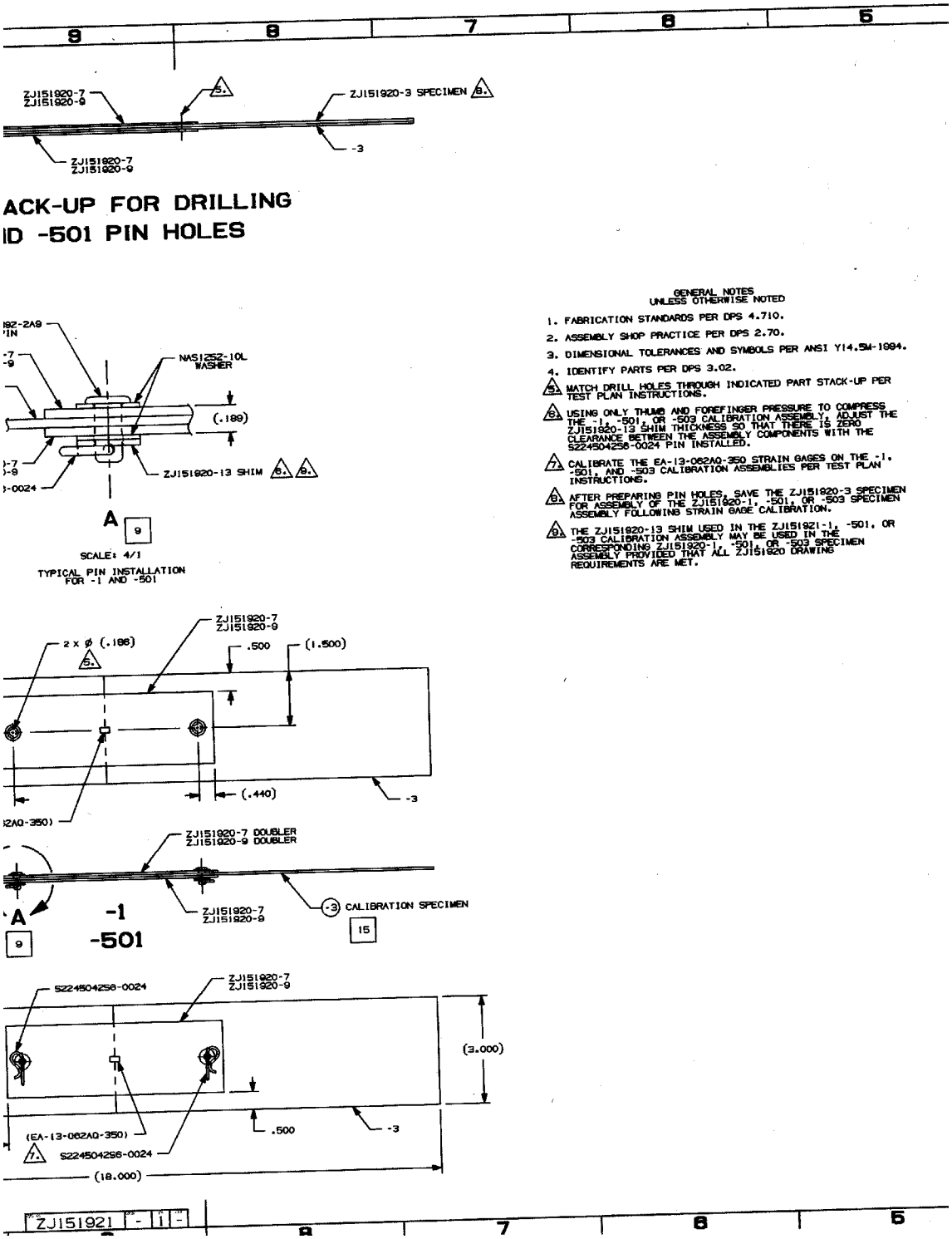

FIGURE F-2. SMALL CRACK GROWTH SPECIMEN CALIBRATION ASSEMBLY (Continued)

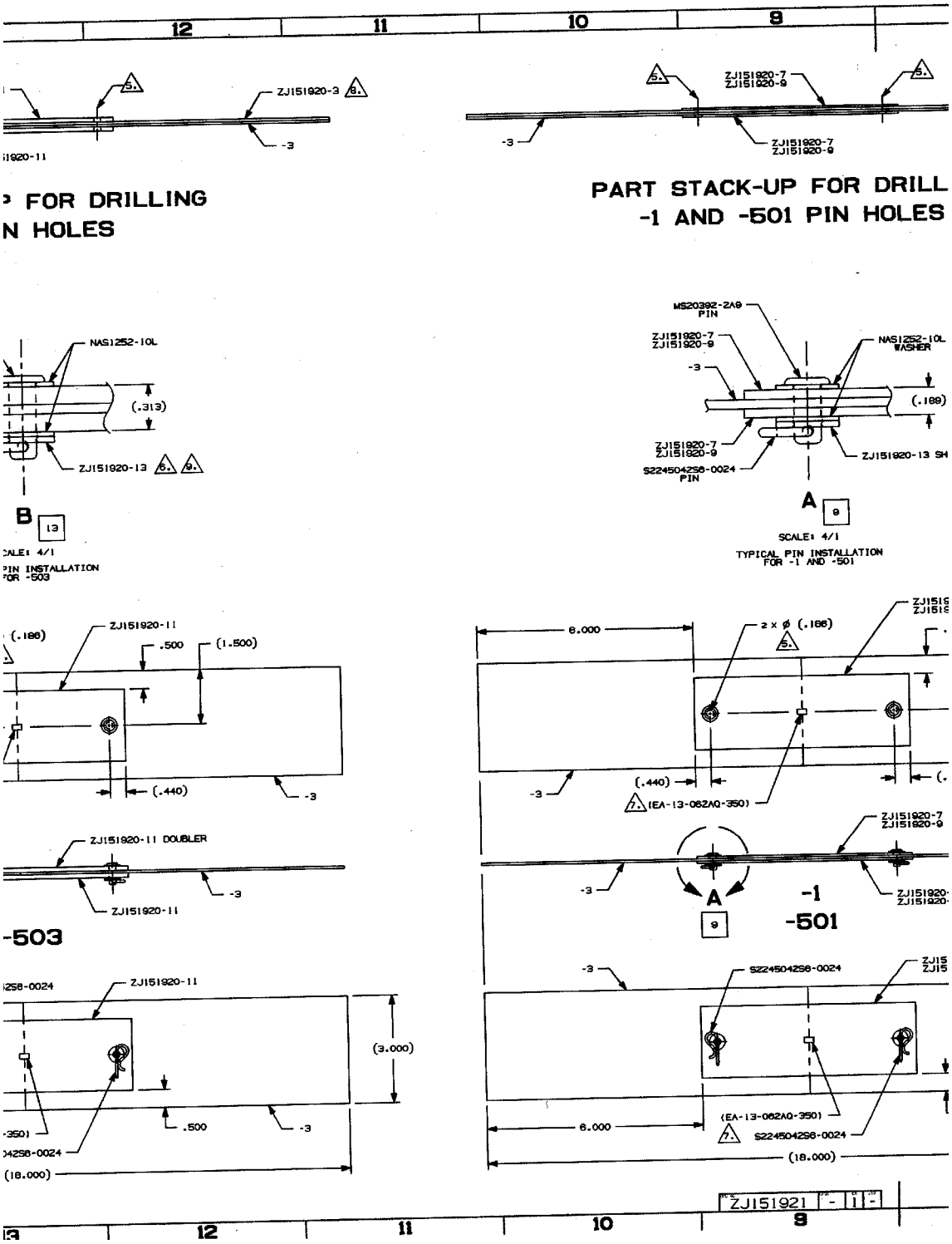

FIGURE F-2. SMALL CRACK GROWTH SPECIMEN CALIBRATION ASSEMBLY (Continued)

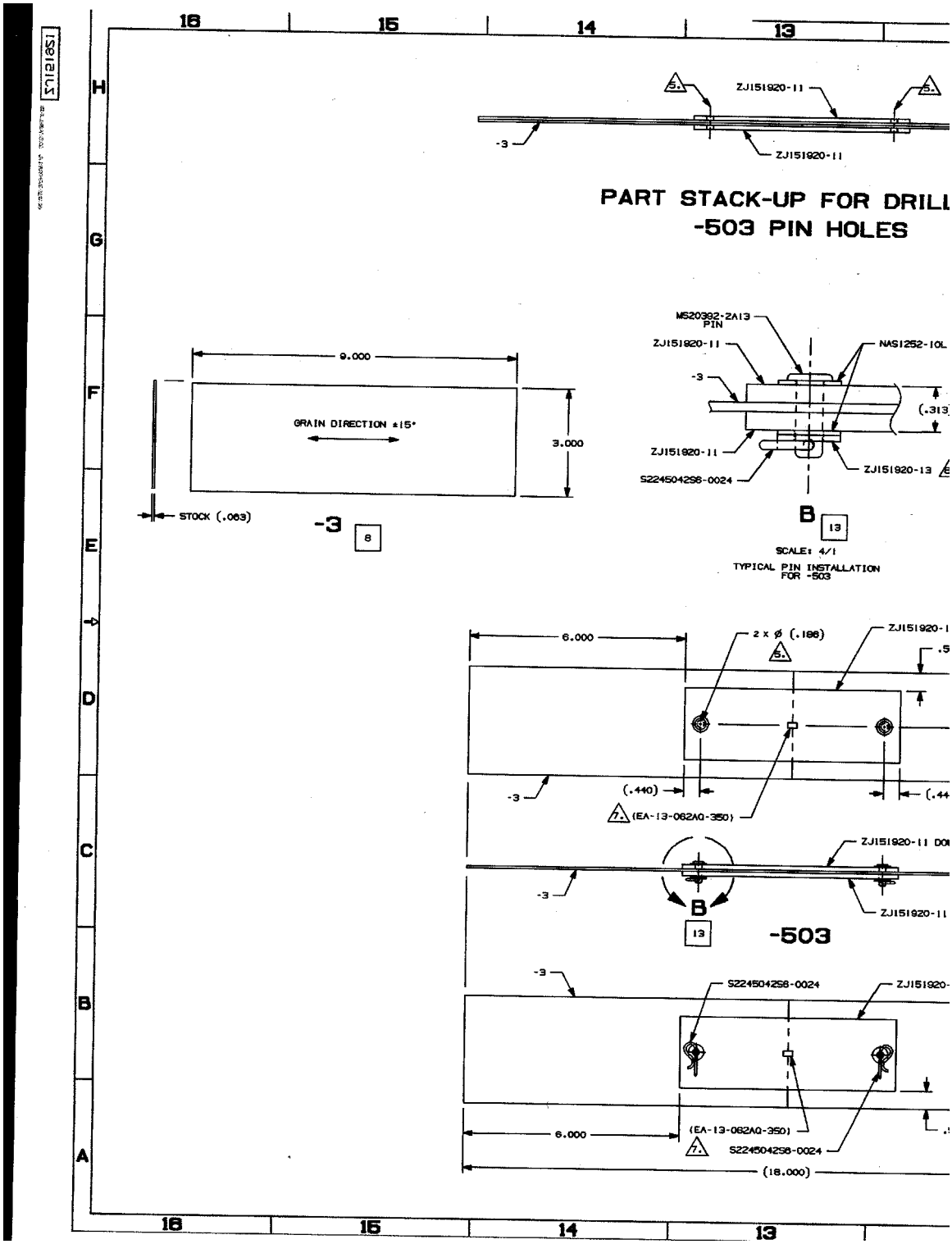

FIGURE F-2. SMALL CRACK GROWTH SPECIMEN CALIBRATION ASSEMBLY (Continued)

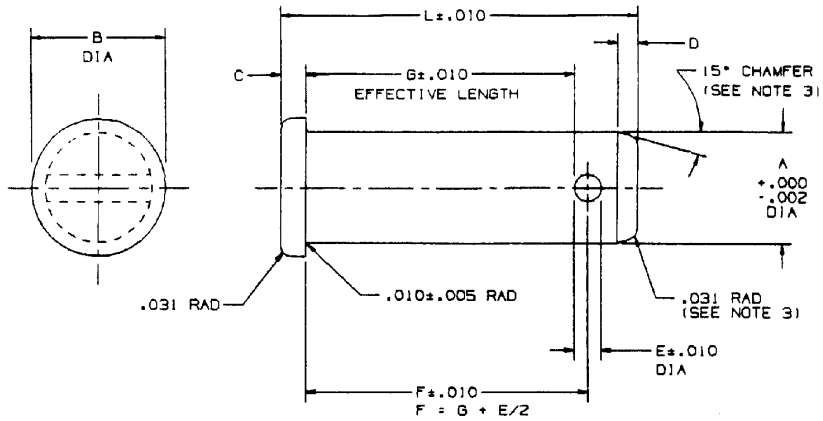

TABLE I

DIMENSION	DASH NUMBER DESIGNATING NOMINAL PIN DIAMETER												
	1	13	2	3	4	5	6	7	8	9	10	11	12
	.125	.156	.188	.250	.312	.375	.438	.500	.562	.625	.750	.875	1.000
A	.124	.155	.186	.248	.311	.373	.436	.497	.560	.622	.747	.871	.996
B	.250	.281	.312	.375	.437	.500	.562	.625	.687	.750	.875	1.062	1.187
C	.046	.046	.046	.062	.062	.062	.093	.093	.093	.093	.093	.125	.125
D	.046	.046	.046	.062	.078	.078	.078	.078	.078	.078	.078	.093	.093
E	.070	.070	.078	.078	.108	.108	.108	.108	.141	.141	.141	.171	.171
	MIN DOUBLE SHEAR STRENGTH (LBS)												
STEEL 1/	1,840	2,860	4,140	7,360	11,500	16,580	22,540	29,440	37,280	46,020	66,280	90,200	117,820
CRES	3,080	4,780	6,900	12,280	19,180	27,620	37,580	49,080	62,120	76,700	110,460	150,320	196,360
TITANIUM	2,340	3,640	5,240	9,320	14,580	21,000	28,560	37,300	47,220	58,300	83,940	114,240	149,220
STEEL,8740	2,660	4,120	5,960	10,600	16,560	23,860	32,480	42,420	53,680	66,260	95,420	129,880	169,640

1/ VALUES SHOWN ARE FOR 4037, 4130 OR 8630 STEEL.

REQUIREMENTS:

1. MATERIAL:
   STEEL ALLOY-UNS G40370 (AISI 4037) PER AMS 6300 OR UNS G41300 (AISI 4130) PER MIL-S-6758 OR UNS G86300 (AISI 8630) PER MIL-S-6050.
   STEEL ALLOY-UNS G87400 (AISI 8740) PER MIL-S-6049.
   CORROSION RESISTANT STEEL (CRES) (PH 13Mo)-UNS S13800 (AISI 13800) PER AMS 5629.
   TITANIUM ALLOY (Ti-6AL-4V)-UNS R56400 PER MIL-T-9047.

2. FINISH:
   STEEL ALLOY-CADMIUM PLATED IN ACCORDANCE WITH QQ-P-416, TYPE II, CLASS 2.
   CRES-CHROME PLATED IN ACCORDANCE WITH QQ-C-320, CLASS 2.
   CRES-CLEANED, DESCALED AND PASSIVATED IN ACCORDANCE WITH ASTM A380.
   TITANIUM ALLOY-NO FINISH
   TITANIUM ALLOY-ALUMINUM COATED IN ACCORDANCE WITH MIL-C-83438, CLASS 3, AND LUBRICATED WITH SOLID FILM LUBRICANT IN ACCORDANCE WITH MIL-L-46010.

EXAMPLE OF PART NUMBER

MS20392 -1 C 33 = .125 NOMINAL DIA X 1.031 EFFECTIVE LENGTH, STEEL ALLOY, 4037, 4130 OR 8630, CADMIUM PLATED.

- "G" - EFFECTIVE LENGTH IN 1/32 (SEE TABLE I)
- MATERIAL AND FINISH
  - "C" = STEEL ALLOY, 4037, 4130 OR 8630, CADMIUM PLATED
  - "S" = STEEL ALLOY, 8740, CADMIUM PLATED
  - "R" = CORROSION RESISTANT STEEL, PH13-8Mo, CHROME PLATED
  - "T" = TITANIUM ALLOY, Ti-6AL-4V, NO FINISH
  - "A" = TITANIUM ALLOY, Ti-6AL-4V, ALUMINUM COATED AND LUBRICATED WITH SOLID FILM LUBRICANT
  - "P" = CORROSION RESISTANT STEEL, PH13-8Mo, CLEANED, DESCALED AND PASSIVATED
- PIN DIA (NOM.) DASH NUMBER (SEE TABLE I)
- MILITARY STANDARD NUMBER

PROCUREMENT SPECIFICATION: MIL-P-5673

MS20392	PIN, STRAIGHT, HEADED, DRILLED SHANK	REVISED (E) 07-12-84

REVISED 09-12-88

07.010
1 OF 3

FIGURE F-3. DETAIL DIMENSION OF TITANIUM PIN, WASHER AND SHIM, AND COTTER PIN

NOTES:

1. DIMENSIONS SHOWN ARE AFTER FINISH.
2. TOLERANCES ON DECIMALS SHALL BE ±.016 AND ON ANGLES SHALL BE ±1/2°.
3. THE SHANK END OF PINS MAY HAVE EITHER A CHAMFER OR RADIUS AT THE OPTION OF THE VENDOR.
4. DASH NUMBER SPECIFYING EFFECTIVE LENGTH "G" IN 1/32 INCREMENTS. USE ONLY THOSE DASH NUMBERS LISTED IN TABLE II.

TABLE II

		LENGTH												
PIN DIA (NOM)		.125	.156	.188	.250	.312	.375	.438	.500	.562	.625	.750	.875	1.000
4 DASH NO.	G	L	L	L	L	L	L	L	L	L	L	L	L	L
- 7	.219	.391	.391	.391										
- 9	.281	.453	.453	.453										
- 11	.344	.516	.516	.516	.547	.594								
- 13	.406	.578	.578	.578	.609	.656								
- 15	.469	.641	.641	.641	.672	.719	.719	.750	.750	.797	.797	.797		
- 17	.531	.703	.703	.703	.734	.781	.781	.812	.812	.859	.859	.859		
- 19	.594	.766	.766	.766	.797	.844	.844	.875	.875	.922	.922	.922	1.000	1.000
- 21	.646	.828	.828	.828	.859	.906	.906	.938	.938	.984	.984	.984	1.062	1.062
- 23	.719	.891	.891	.891	.927	.969	.969	1.000	1.000	1.047	1.047	1.047	1.125	1.125
- 25	.781	.953	.953	.953	.984	1.031	1.031	1.062	1.062	1.109	1.109	1.109	1.188	1.188
- 27	.844	1.016	1.016	1.016	1.047	1.094	1.094	1.125	1.125	1.172	1.172	1.172	1.250	1.250
- 29	.906	1.078	1.078	1.078	1.109	1.156	1.156	1.188	1.188	1.234	1.234	1.234	1.312	1.312
- 31	.969	1.141	1.141	1.141	1.172	1.219	1.219	1.250	1.250	1.297	1.297	1.297	1.375	1.375
- 33	1.031	1.203	1.203	1.203	1.234	1.281	1.281	1.312	1.312	1.359	1.359	1.359	1.438	1.438
- 35	1.094	1.266	1.266	1.266	1.297	1.344	1.344	1.375	1.375	1.422	1.422	1.422	1.500	1.500
- 37	1.156	1.328	1.328	1.328	1.359	1.406	1.406	1.438	1.438	1.484	1.484	1.484	1.562	1.562
- 39	1.219	1.391	1.391	1.391	1.422	1.469	1.469	1.500	1.500	1.547	1.547	1.547	1.625	1.625
- 41	1.281	1.453	1.453	1.453	1.484	1.531	1.531	1.562	1.562	1.609	1.609	1.609	1.688	1.688
- 43	1.344	1.516	1.516	1.516	1.547	1.594	1.594	1.625	1.625	1.672	1.672	1.672	1.750	1.750
- 45	1.406	1.578	1.578	1.578	1.609	1.656	1.656	1.688	1.688	1.734	1.734	1.734	1.812	1.812
- 47	1.469	1.641	1.641	1.641	1.672	1.719	1.719	1.750	1.750	1.797	1.797	1.797	1.875	1.875
- 49	1.531	1.703	1.703	1.703	1.734	1.781	1.781	1.812	1.812	1.859	1.859	1.859	1.938	1.938
- 51	1.594	1.766	1.766	1.766	1.797	1.844	1.844	1.875	1.875	1.922	1.922	1.922	2.000	2.000
- 53	1.656	1.828	1.828	1.828	1.859	1.906	1.906	1.938	1.938	1.984	1.984	1.984	2.062	2.062
- 55	1.719	1.891	1.891	1.891	1.922	1.969	1.969	2.000	2.000	2.047	2.047	2.047	2.125	2.125
- 57	1.781	1.953	1.953	1.953	1.984	2.031	2.031	2.062	2.062	2.109	2.109	2.109	2.188	2.188
- 59	1.844	2.016	2.016	2.016	2.047	2.094	2.094	2.125	2.125	2.172	2.172	2.172	2.250	2.250
- 61	1.906	2.078	2.078	2.078	2.109	2.156	2.156	2.188	2.188	2.234	2.234	2.234	2.312	2.312
- 63	1.969	2.141	2.141	2.141	2.172	2.219	2.219	2.250	2.250	2.297	2.297	2.297	2.375	2.375
- 65	2.031	2.203	2.203	2.203	2.234	2.281	2.281	2.312	2.312	2.359	2.359	2.359	2.438	2.438
- 67	2.094	2.266	2.266	2.266	2.297	2.344	2.344	2.375	2.375	2.422	2.422	2.422	2.500	2.500
- 69	2.156			2.328	2.359	2.406	2.406	2.438	2.438	2.484	2.484	2.484	2.562	2.562
- 71	2.219			2.391	2.422	2.469	2.469	2.500	2.500	2.547	2.547	2.547	2.625	2.625
- 73	2.281			2.453	2.484	2.531	2.531	2.562	2.562	2.609	2.609	2.609	2.688	2.688
- 75	2.344			2.516	2.547	2.594	2.594	2.625	2.625	2.672	2.672	2.672	2.750	2.750
- 77	2.406			2.578	2.609	2.656	2.656	2.688	2.688	2.734	2.734	2.734	2.812	2.812
- 79	2.469			2.641	2.672	2.719	2.719	2.750	2.750	2.797	2.797	2.797	2.875	2.875
- 81	2.531			2.703	2.734	2.781	2.781	2.812	2.812	2.859	2.859	2.859	2.938	2.938
- 83	2.594			2.766	2.797	2.844	2.844	2.875	2.875	2.922	2.922	2.922	3.000	3.000
- 85	2.656			2.828	2.859	2.906	2.906	2.938	2.938	2.984	2.984	2.984	3.062	3.062
- 87	2.719			2.891	2.922	2.969	2.969	3.000	3.000	3.047	3.047	3.047	3.125	3.125
- 89	2.781			2.953	2.984	3.031	3.031	3.062	3.062	3.109	3.109	3.109	3.188	3.188
- 91	2.844			3.016	3.047	3.094	3.094	3.125	3.125	3.172	3.172	3.172	3.250	3.250
- 93	2.906			3.078	3.109	3.156	3.156	3.188	3.188	3.234	3.234	3.234	3.312	3.312
- 95	2.969			3.141	3.172	3.219	3.219	3.250	3.250	3.297	3.297	3.297	3.375	3.375

REVISED 09-12-88

REVISED (E) 07-12-84	PIN, STRAIGHT, HEADED, DRILLED SHANK	MS20392

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2 OF 3

FIGURE F-3. DETAIL DIMENSION OF TITANIUM PIN, WASHER AND SHIM, AND COTTER PIN (Continued)

TABLE II CONTINUED

		LENGTH												
PIN DIA (NOM)		.125	.156	.188	.250	.312	.375	.438	.500	.562	.625	.750	.875	1.000
DASH NO.	G	L	L	L	L	L	L	L	L	L	L	L	L	L
- 97	3.031				3.234	3.281	3.281	3.312	3.312	3.359	3.359	3.359	3.438	3.438
- 99	3.094						3.344	3.375	3.375	3.422	3.422	3.422	3.500	3.500
-101	3.156						3.406	3.438	3.438	3.484	3.484	3.484	3.562	3.562
-103	3.219						3.469	3.500	3.500	3.547	3.547	3.547	3.625	3.625
-105	3.281						3.531	3.562	3.562	3.609	3.609	3.609	3.688	3.688
-107	3.344						3.594	3.625	3.625	3.672	3.672	3.672	3.750	3.750
-109	3.406						3.656	3.688	3.688	3.734	3.734	3.734	3.812	3.812
-111	3.469						3.719	3.750	3.750	3.797	3.797	3.797	3.875	3.875
-113	3.531						3.781	3.812	3.812	3.859	3.859	3.859	3.938	3.938
-115	3.594						3.844	3.875	3.875	3.922	3.922	3.922	4.000	4.000
-117	3.656						3.906	3.938	3.938	3.984	3.984	3.984	4.062	4.062
-119	3.719						3.969	4.000	4.000	4.047	4.047	4.047	4.125	4.125
-121	3.781						4.031	4.062	4.062	4.109	4.109	4.109	4.188	4.188
-123	3.844						4.094	4.125	4.125	4.172	4.172	4.172	4.250	4.250
-125	3.906						4.156	4.188	4.188	4.234	4.234	4.234	4.312	4.312
-127	3.969						4.219	4.250	4.250	4.297	4.297	4.297	4.375	4.375
-129	4.031												4.438	4.438
-131	4.094												4.500	4.500
-133	4.156												4.500	4.500
-135	4.219												4.625	4.625
-137	4.281												4.688	4.688

REVISED 09-12-88

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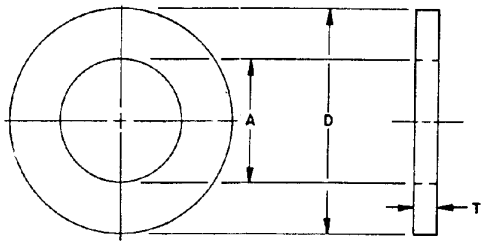
MS20392	PIN, STRAIGHT, HEADED, DRILLED SHANK	REVISED (E) 07-12-84

07.010
3 OF 3

FIGURE F-3. DETAIL DIMENSION OF TITANIUM PIN, WASHER AND SHIM, AND COTTER PIN (Continued)



THREAD SIZE	A ± .010 DIAMETER	D + .020 − .005 DIAMETER	DASH NUMBERS T THICKNESS .032 ± .004	DASH NUMBERS T THICKNESS .063 ± .006
.112	.125	.312	4L	
.138	.149	.375	6L	
.164	.174	.375	8L	
.190	.203	.438	10L	10H
.250	.265	.500	416L	416H
.3125	.328	.562	516L	516H
.375	.390	.625	616L	616H
.4375	.453	.750	716L	716H
.500	.515	.875	816L	816H
.5625	.578	1.062	916L	916H
.625	.640	1.188	1016L	1016H
.750	.765	1.312	1216L	1216H
.875	.890	1.500	1416L	1416H
1.000	1.015	1.750	1616L	1616H
1.0625	1.078	1.812	1716L	1716H
1.125	1.140	1.875	1816L	1816H
1.250	1.265	2.000	2016L	2016H
1.3125	1.328	2.062	2116L	2116H
1.375	1.640	2.375	2616L	2616H
1.875	1.890	2.625	3016L	3016H
2.250	2.265	3.000	3616L	3616H
2.500	2.515	3.250	4016L	4016H

MATERIAL: 7075-T6 ALUMINUM ALLOY PER QQ-A-250/12

FINISH: * ANODIZE, MIL-A-8625 Type II CLASS 2 (YELLOW), ELECTRICALLY NON-CONDUCTIVE
* CHEMICAL CONVERSION COATING, MIL-C-81706 CLASS 3 FORM II PER MIL-C-5541 CLASS 3, ELECTRICALLY CONDUCTIVE

DISCOLORATION IS PERMITTED WHERE WASHER MAKES CONTACT WITH WIRE WHICH SUSPENDS WASHER IN SOLUTION

CODE: DASH NUMBER INDICATES THREAD SIZE.
"C" SUFFIX INDICATES CHEMICAL CONVERSION COATING (OMIT FOR ANODIZE).

EXAMPLE: NAS1252-10L = 7075-T6 AL ALY WASHER for .190 SCREW, .032 THICK, ANODIZE FINISH
NAS1252-516H = 7075-T6 AL ALY WASHER for .312 SCREW, .063 THICK, ANODIZE FINISH
NAS1252-516HC = 7075-T6 AL ALY WASHER for .312 SCREW, .063 THICK, CHEM CVRSN CTG FINISH

REMOVE ALL BURRS AND SHARP EDGES.

WASHER FACES SHALL BE PARALLEL WITHIN .002 INCH.

WASHER FACES SHALL BE FLAT WITHIN .007 FOR SIZES UP THROUGH .500 AND .010 FOR SIZES .562 TO 1.250 SIZE INCLUSIVE, AND .015 FOR 1.312 AND LARGER.

DIMENSIONS IN INCHES.

DESIGN CONSIDERATION

1. USE NAS1252 FOR GENERAL APPLICATION

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REVISED 08-01-90

REVISED REV. (2) 7-12-1984	WASHER-7075 ALUMINUM ALLOY FLAT	NAS1252

1-24.000

FIGURE F-3. DETAIL DIMENSION OF TITANIUM PIN, WASHER AND SHIM, AND COTTER PIN (Continued)

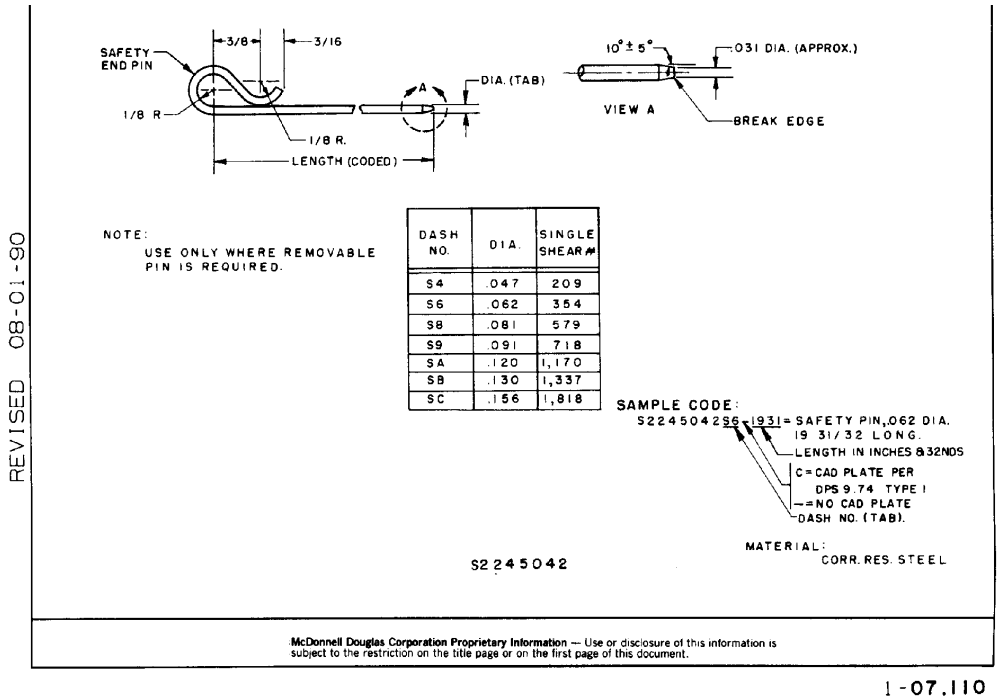

FIGURE F-3. DETAIL DIMENSION OF TITANIUM PIN, WASHER AND SHIM, AND COTTER PIN (Continued)

TABLE F-1. CRACK GROWTH DATA FOR SCG-1s

Doubler: 0.063″ Al			
Constant amplitude w/marker bands			
σ_{max} = 15 ksi			
Cycles	Crack Length, c (in)		
	Front	Back	Back Opposite
200	0.00855	0.00739	
2,200	0.0121	0.01227	
4,200	0.02096	0.02173	
9,400	0.04531	0.04509	
14,600	0.0712	0.07153	
19,800	0.09224	0.09407	
25,800	0.11347	0.11739	
31,800	0.13843	0.1431	
37,800	0.16081	0.16405	
43,800	0.18461	0.18594	
51,800	0.22273	0.21913	0.00535
57,800	0.2539	0.24894	0.01271
Failure Load: 8678 lbf.			

TABLE F-2. CRACK GROWTH DATA FOR SCG-2

Doubler: 0.063″ Al		
Constant amplitude w/marker bands		
σ_{max} = 15 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
0	0.0625	0.0628
2,000	0.07328	0.07635
4,000	0.08594	0.0887
6,000	0.09637	0.09917
8,000	0.10476	0.10783
10,000	0.11545	0.11766
12,000	0.12487	0.12575
14,000	0.13347	0.1344
20,000	0.16522	0.16513
26,000	0.19319	0.19343
32,000	0.22143	0.22284
38,000	0.24899	0.25303
Failure Load: 8964 lbf.		

TABLE F-3. CRACK GROWTH DATA FOR SCG-5

Doubler: 0.063″ Al		
Constant amplitude w/marker bands		
σ_{max} = 15 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
500	0.00852	0.00713
5,700	0.03063	0.02328
10,900	0.0506	0.05081
16,100	0.07756	0.07991
21,300	0.10375	0.10334
26,500	0.12451	0.12634
31,700	0.14616	0.14678
36,900	0.17365	0.17254
42,100	0.19837	0.19821
47,300	0.22443	0.2268
52,500	0.25319	0.25642
Failure Load: 8822 lbf.		

TABLE F-4. CRACK GROWTH DATA FOR SCG-6

Doubler: 0.120″ Al				
Constant amplitude w/marker bands				
σ_{max} = 12.5 ksi				
	Crack Length, c (in)			
Cycles	Front	Back	Front Opposite	Back Opposite
0	0.0042	0.00181		
5,200	0.0126	0.00849		
10,400	0.02373	0.02113		
20,800	0.05918	0.05796		
28,600	0.08433	0.08306		
36,600	0.11004	0.10618		
44,400	0.13215	0.12859		
52,200	0.14946	0.14916		
62,600	0.1742	0.17744		
73,000	0.207	0.20664		
83,400	0.24146	0.24393	0.06528	0.05081
Failure Load: 8542 lbf.				

TABLE F-5. CRACK GROWTH DATA FOR SCG-7

Doubler: 0.120″ Al			
Constant amplitude w/marker bands			
σ_{max} = 12.5 ksi			
	Crack Length, c (in)		
Cycles	Front	Back	Back Opposite
0	0.00394	0.00432	
2,000	0.00548	0.00661	
7,200	0.01085	0.01351	
12,400	0.02369	0.02647	
22,800	0.06548	0.06652	
30,300	0.09618	0.0953	
37,800	0.12149	0.11964	
45,300	0.14408	0.14571	
52,800	0.16812	0.17059	0.00241
Failure Load: 8406 lbf.			

TABLE F-6. CRACK GROWTH DATA FOR SCG-8

Doubler: 0.120″ Al		
EIFS Spectrum loading		
σ_{max} = 13.4 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
100	0.00203	0.0029
2,000	0.00216	0.00302
4,000	0.00295	0.00392
6,000	0.00304	0.00463
56,000	0.00742	0.01164
125,000	0.01063	0.01521
325,000	0.02606	0.02795
725,000	0.09575	0.09904
825,000	0.11889	0.12144
925,000	0.13969	0.14079
1,025,000	0.1644	0.16481
1,125,000	0.18749	0.18908
1,225,000	0.20963	0.21165
1,325,000	0.23377	0.23487
1,425,000	0.26048	0.26053
Failure Load: 8744 lbf.		

TABLE F-7. CRACK GROWTH DATA FOR SCG-9

Doubler: 0.120″ Al		
EIFS Spectrum loading		
σ_{max} = 13.4 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
200	0	0.00295
2,000	0	0.00299
4,000	0	0.00402
6,000	0.00187	0.00414
36,000	0.00548	0.00611
186,000	0.02189	0.01679
386,000	0.05851	0.05296
486,000	0.07816	0.0744
600,000	0.10256	0.10008
700,000	0.12498	0.12293
800,000	0.14705	0.14471
900,000	0.16812	0.16516
1,000,000	0.19058	0.18768
1,100,000	0.21513	0.21272
1,200,000	0.24168	0.24313
1,300,000	0.2665	0.26943

TABLE F-8. CRACK GROWTH DATA FOR SCG-11

Doubler: 0.063″ Steel		
Constant amplitude w/marker bands		
σ_{max} = 10 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
200	0.00238	0
2,000	0.00263	0.00307
30,000	0.03332	0.03745
50,000	0.07133	0.07578
60,000	0.08939	0.09237
80,000	0.12131	0.12848
95,000	0.14831	0.15097
110,000	0.17331	0.17662
130,000	0.21122	0.21278
145,000	0.23884	0.23984
160,000	0.26387	0.26814
Failure Load: 8828 lbf.		

TABLE F-9. CRACK GROWTH DATA FOR SCG-12

Doubler: 0.063″ Steel		
Constant amplitude w/marker bands		
σ_{max} = 10 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
200	0	0
2,000	0	0
4,000	0	0
6,000	0	0
11,000	0	0.0054
13,000	0	0.00622
15,000	0	0.00739
17,000	0.00482	0.00913
27,000	0.01572	0.02358
39,000	0.03714	0.04481
49,000	0.0581	0.06125
69,000	0.09089	0.09451
85,000	0.11629	0.12138
100,000	0.14164	0.14368
120,000	0.17571	0.17758
135,000	0.20305	0.20379
150,000	0.23196	0.23088
165,000	0.25889	0.25831

TABLE F-10. CRACK GROWTH DATA FOR SCG-16

No Doubler (open-hole)		
Constant amplitude with marker bands		
σ_{max} = 15 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
0	0	0
100	0	0.00414
500	0	0.00413
2,000	0	0.00412
4,000	0	0.00452
6,000	0	0.00529
8,000	0	0.00632
10,000	0.00178	0.00748
12,000	0.00261	0.00884
17,200	0.00811	0.01414
21,200	0.01684	0.02106
23,200	0.02033	0.0245
33,200	0.04632	0.04857
43,200	0.07583	0.07673
53,400	0.10457	0.10578
63,400	0.13837	0.13564
73,400	0.17371	0.17305
83,400	0.20969	0.21073
95,900	0.26217	0.26075

TABLE F-11. CRACK GROWTH DATA FOR SCG-17s

No Doubler (open-hole)		
Constant amplitude with marker bands		
σ_{max} = 15 ksi		
Cycles	Crack Length, c (in)	
	Front	Back
0	0.02668	0.02715
200	0.02817	0.02726
2,000	0.03258	0.03356
7,000	0.0472	0.04372
13,000	0.0463	0.04956
50,000	0.11166	0.11342
58,500	0.12868	0.13306
65,500	0.14845	0.15311
70,500	0.15961	0.16683
76,500	0.17555	0.1832
82,000	0.18587	0.20002
88,000	0.19936	0.21639
94,000	0.22007	0.23143
99,000	0.23368	0.245
104,500	0.25121	0.26366

TABLE F-12. CRACK GROWTH DATA FOR SCG-18s

No Doubler (open-hole)		
Spectrum loading		
Cycles	Crack Length, c (in)	
	Front	Back
0	0.0045	0.008
100,000	0.019	0.025
200,000	0.046	0.0455
250,000	0.0575	0.0575
300,000	0.068	0.0685
350,000	0.0795	0.081
425,000	0.0985	0.0995
475,000	0.111	0.1105
575,000	0.1365	0.1335
675,000	0.162	0.1595
775,000	0.1905	0.191
875,000	0.222	0.2175
975,000	0.252	0.2495

TABLE F-13. CRACK GROWTH DATA FOR SCG-19s

No Doubler (open-hole)		
Spectrum loading		
Cycles	Crack Length, c (in)	
	Front	Back
0	0.0155	0
50,000	0.0155	0.001
10,000	0.027	0.0165
200,000	0.054	0.043
250,000	0.065	0.0595
300,000	0.077	0.067
350,000	0.09	0.082
450,000	0.1155	0.1075
500,000	0.1315	0.1195
600,000	0.1585	0.1495
700,000	0.191	0.18
800,000	0.2185	0.2165
850,000	0.238	0.231
900,000	0.2565	0.247

TABLE F-14. CRACK GROWTH DATA FOR SCG-20s

No Doubler (open-hole)		
Constant amplitude (no marker bands)		
σ_{max} = 15 ksi		
	Crack Length, c (in)	
Cycles	Front	Back
0	0.0025	0.0015
10,000	0.0240	0.0185
20,000	0.0570	0.0330
30,000	0.0890	0.0905
35,000	0.1155	0.1120
40,000	0.1390	0.1320
45,000	0.1575	0.1570
50,000	0.1830	0.1745
	turned around	
55,000	0.2035	0.2010
60,000	0.2240	0.2260
65,000	0.2545	0.2535
75,000	0.3130	0.3120
85,000	0.3835	0.3880
95,000	0.4720	0.4750
98,000	0.5030	0.5045
108,000	0.6130	0.6130
118,000	0.7530	0.7585
126,562	failed	

TABLE F-15. CRACK GROWTH DATA FOR SCG-21

No Doubler (open-hole)		
Constant amplitude (no marker bands)		
σ_{max} = 15 ksi		
	Crack Length, c (in)	
Cycles	Front	Back
0	0.0000	0.0020
5,000	0.0000	0.0100
10,000	0.0000	0.0120
15,000	0.0000	0.0135
25,000	0.0000	0.0190
35,000	0.0000	0.0255
45,000	0.0030	0.0370
55,000	0.0065	0.0390
65,000	0.0065	0.0530
75,000	0.0065	0.0675
85,000	0.0140	0.0880
95,000	0.1125	0.1220
105,000	0.1685	0.1705
115,000	0.2320	0.2325
125,000	0.3225	0.3210
135,000	0.4620	0.4560
145,000	0.6780	0.6685

F.1 SMALL CRACK GROWTH SPECIMEN STRAIN SURVEY DATA.

Figures F-4 through F-14 are plots of calibration and periodic strain surveys. Calibration surveys, done before testing, used a split specimen to get 100% load transfer through the doublers. The strain surveys were taken at intervals during the crack growth testing.

F.2 SPECIMEN SCG-1s STRAIN GAGE DATA.

Specimen SCG-1s has a 0.063″ aluminum doubler and was cycled at a constant amplitude of 15 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection. This data came from the Air Force Research Laboratory.

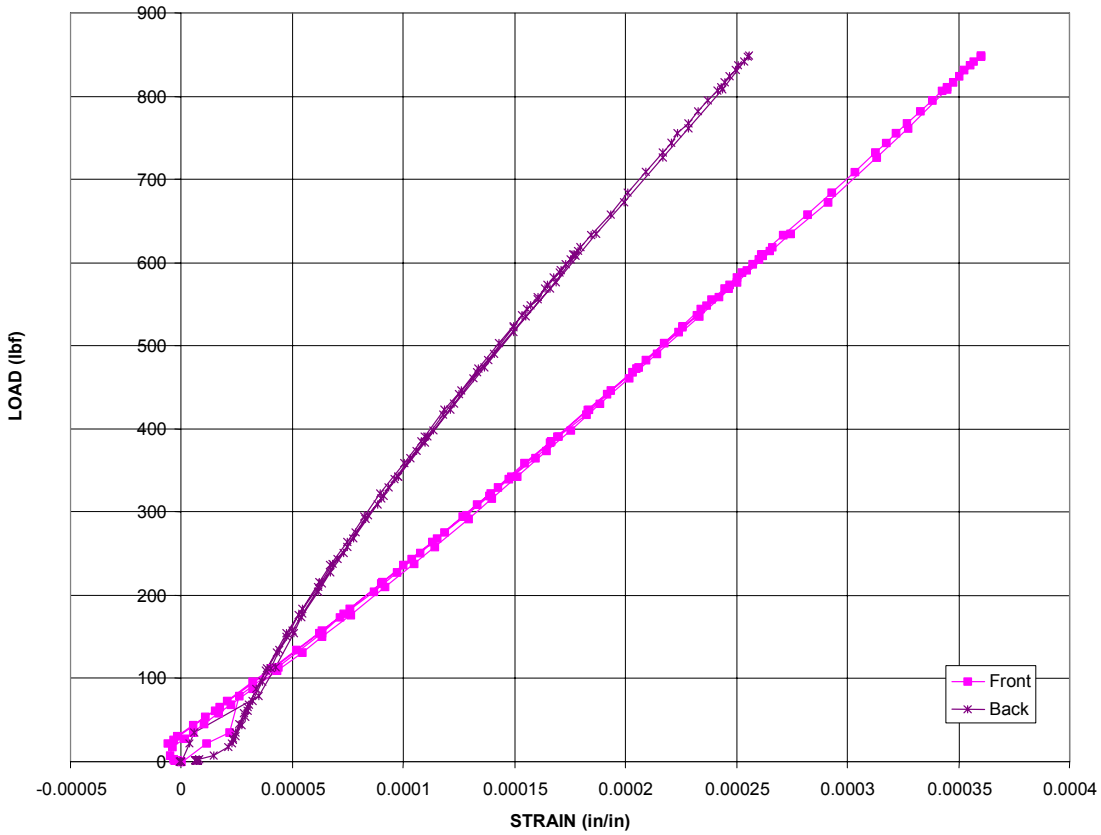

FIGURE F-4. STRAIN GAGE DATA, SCG-1s, CALIBRATION #1

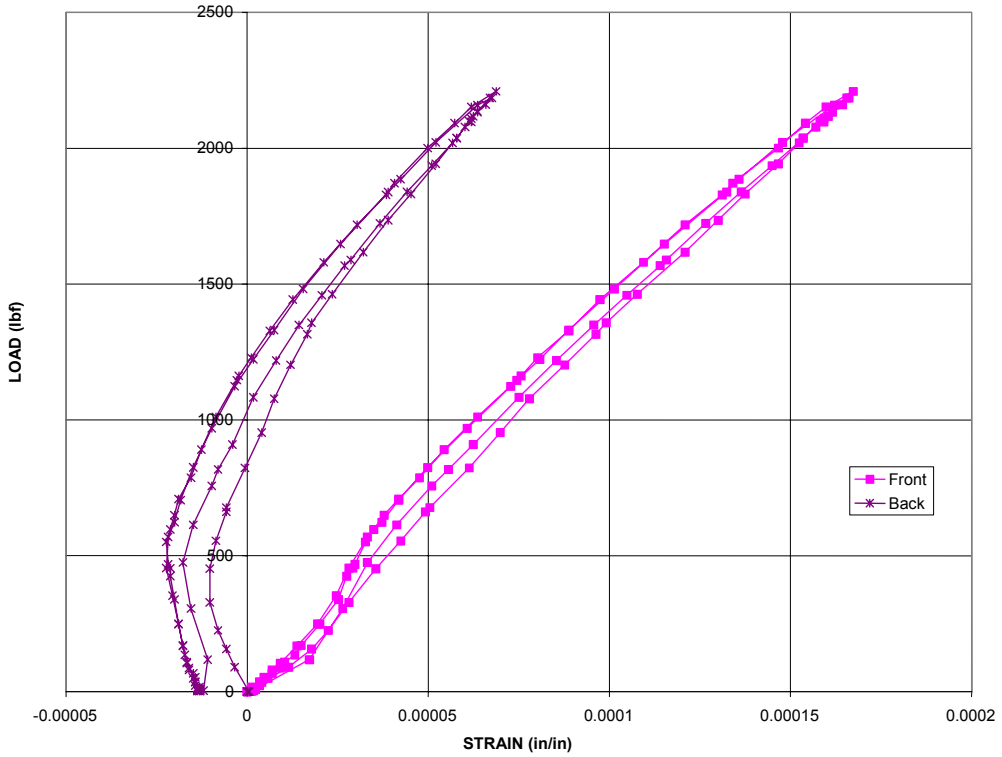

FIGURE F-5. STRAIN GAGE DATA, SCG-1s, 0 CYCLES NEW

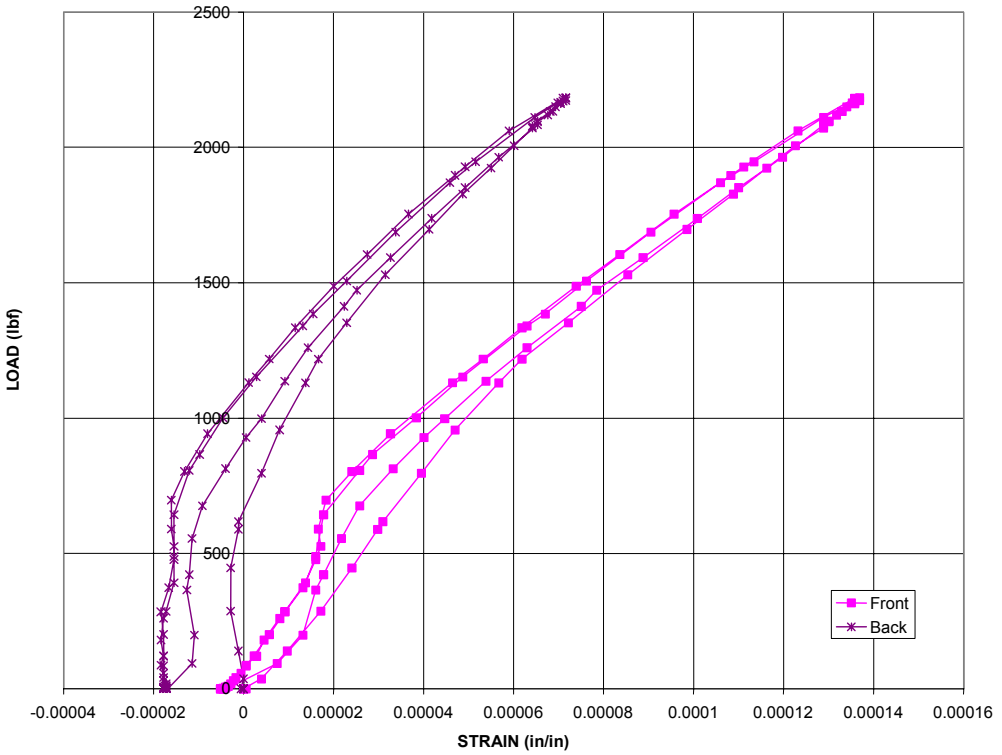

FIGURE F-6. STRAIN GAGE DATA, SCG-1s, 2200 CYCLES AFTER INSPECTION

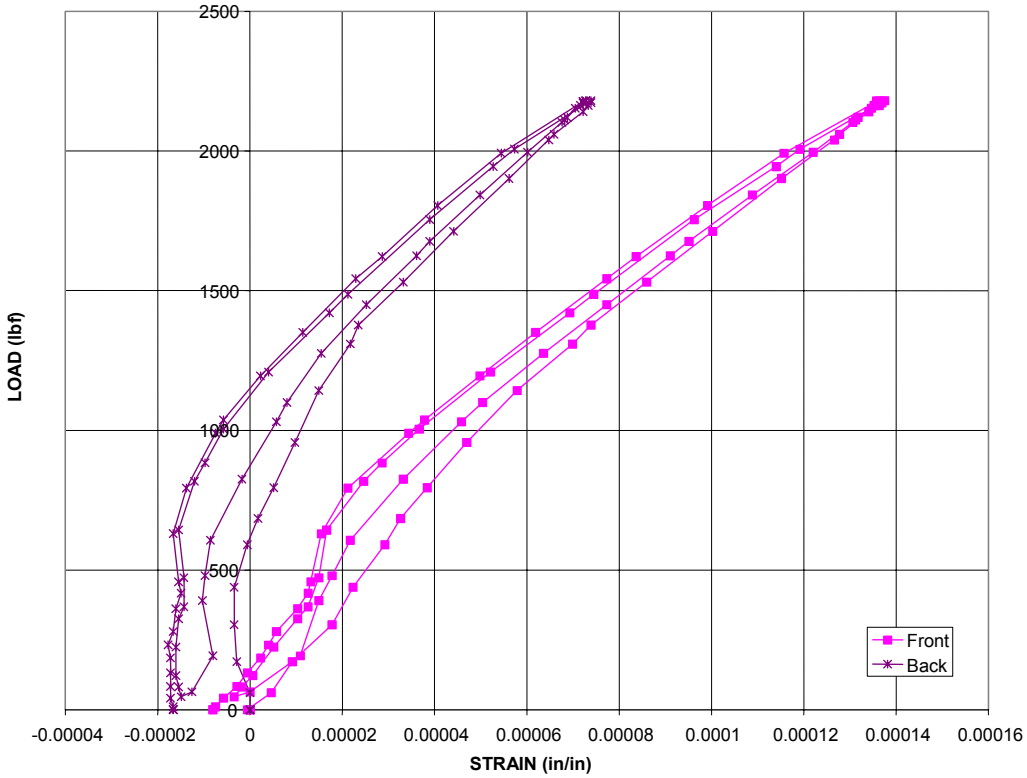

FIGURE F-7. STRAIN GAGE DATA, SCG-1s, 4200 CYCLES

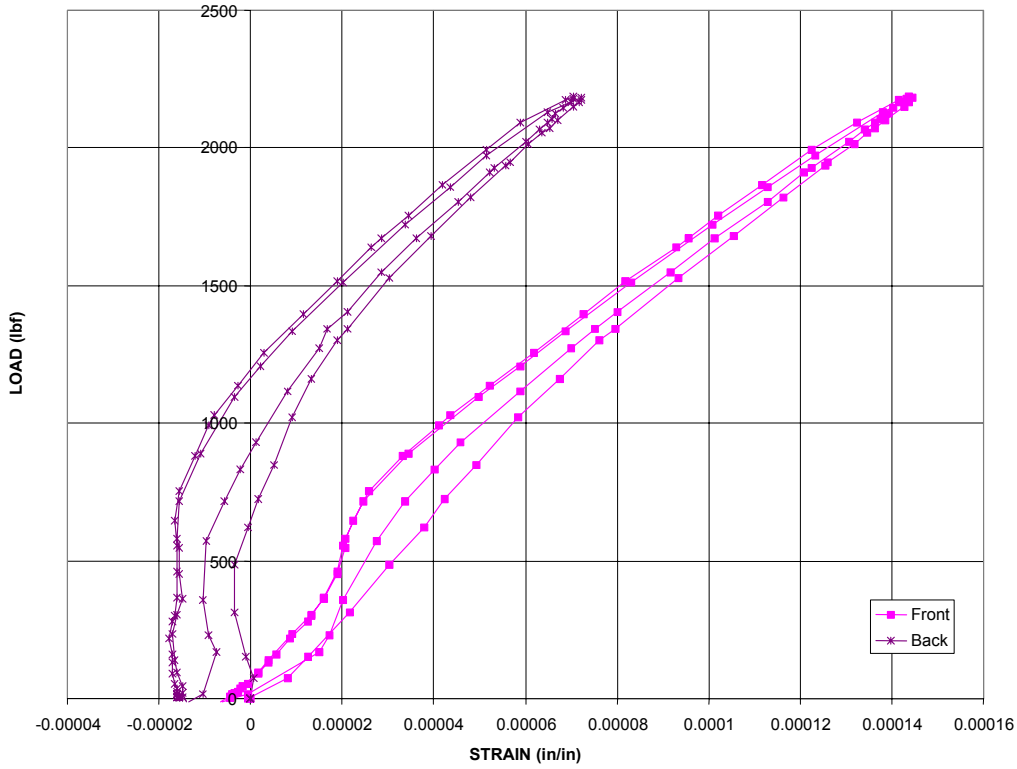

FIGURE F-8. STRAIN GAGE DATA, SCG-1s, 9400 CYCLES

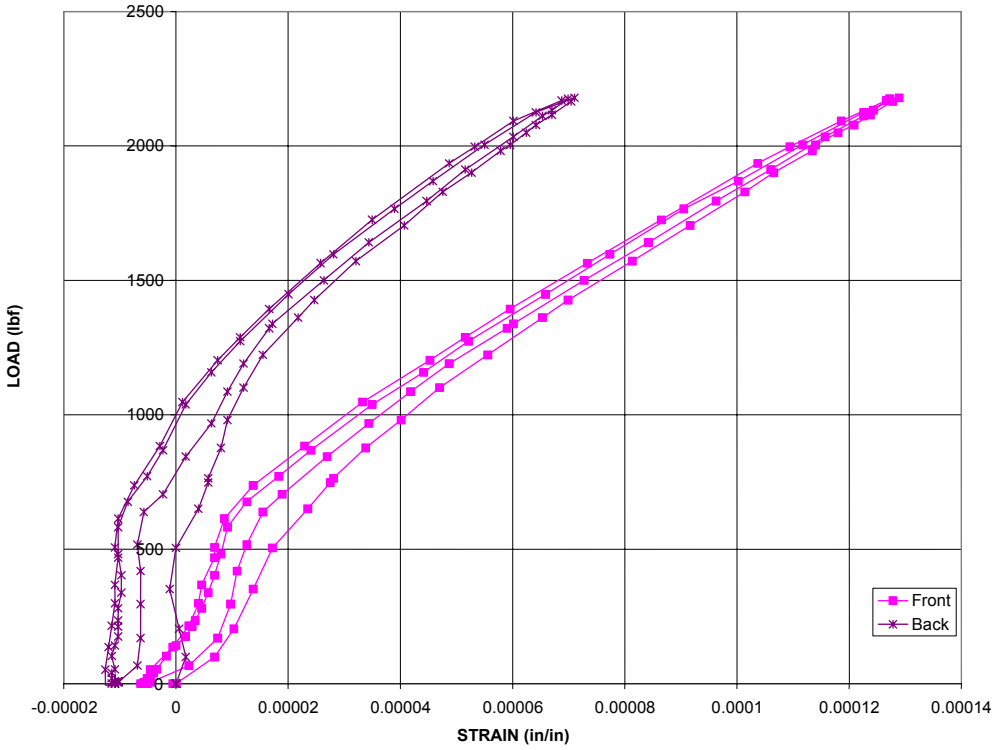

FIGURE F-9. STRAIN GAGE DATA, SCG-1s, 19,800 CYCLES

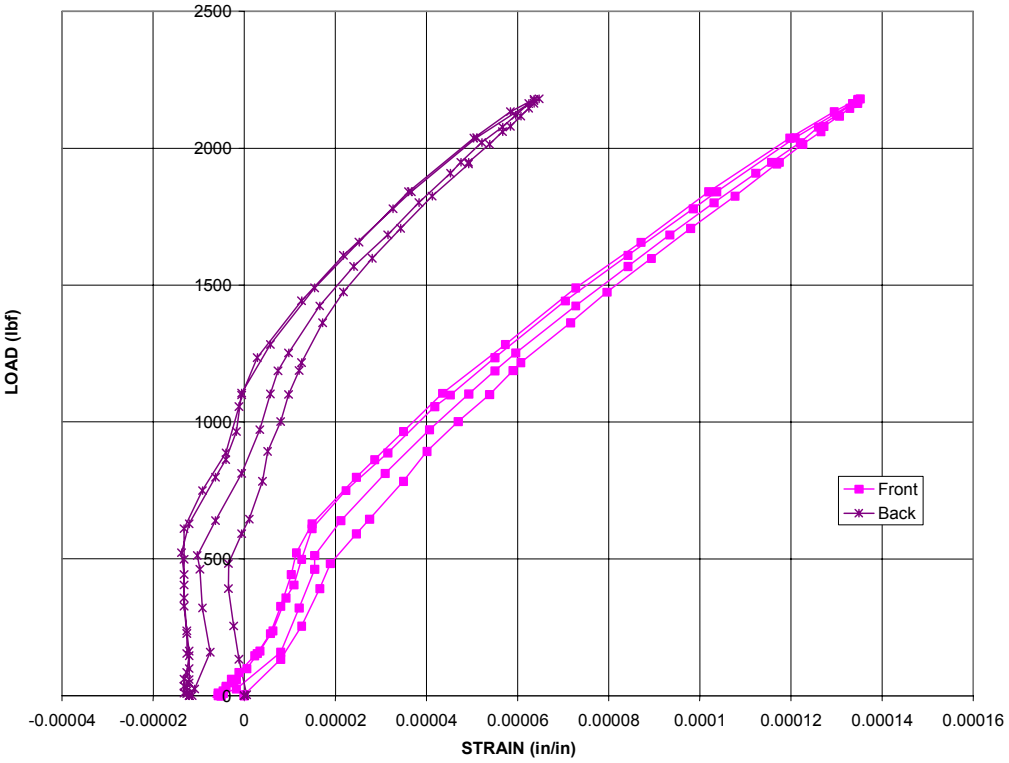

FIGURE F-10. STRAIN GAGE DATA, SCG-1s, 25,800 CYCLES

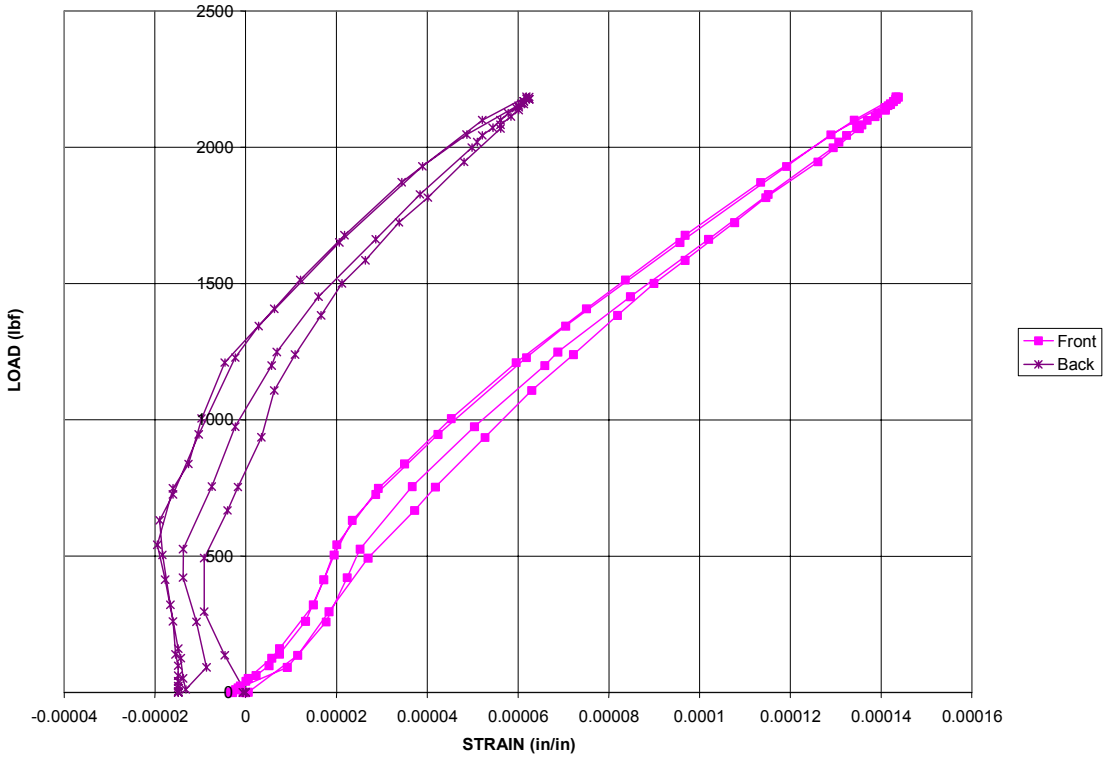

FIGURE F-11. STRAIN GAGE DATA, SCG-1s, 31,800 CYCLES

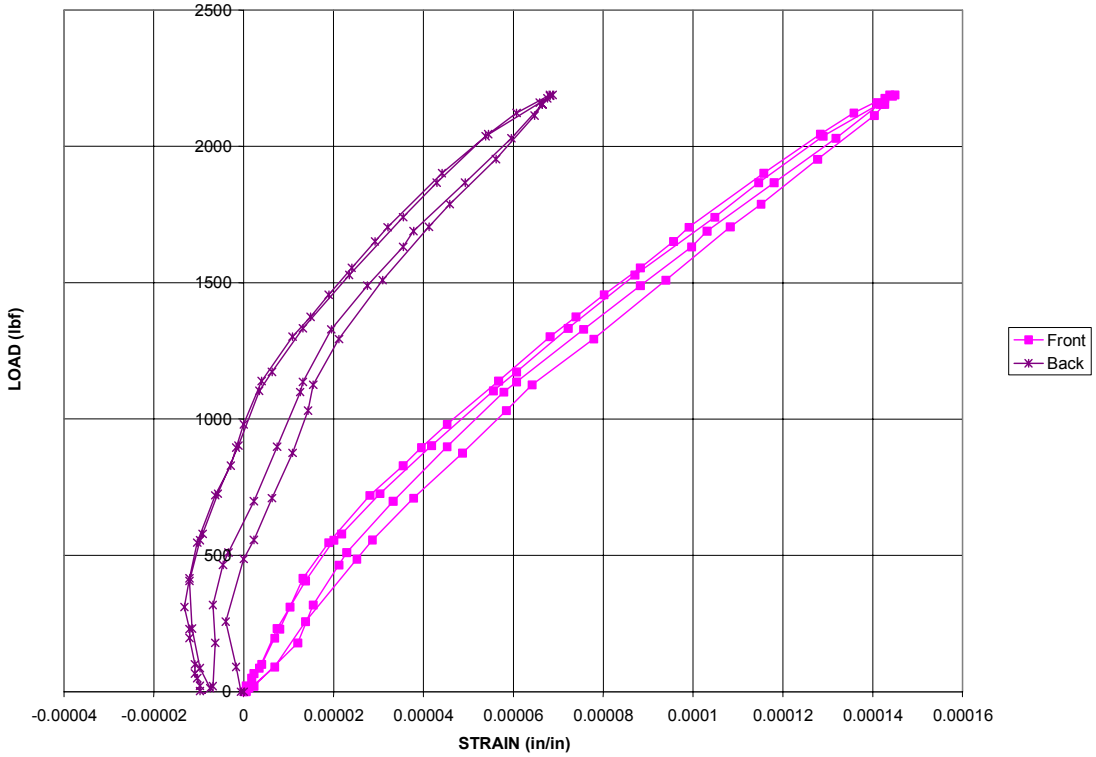

FIGURE F-12. STRAIN GAGE DATA, SCG-1s, 37,800 CYCLES

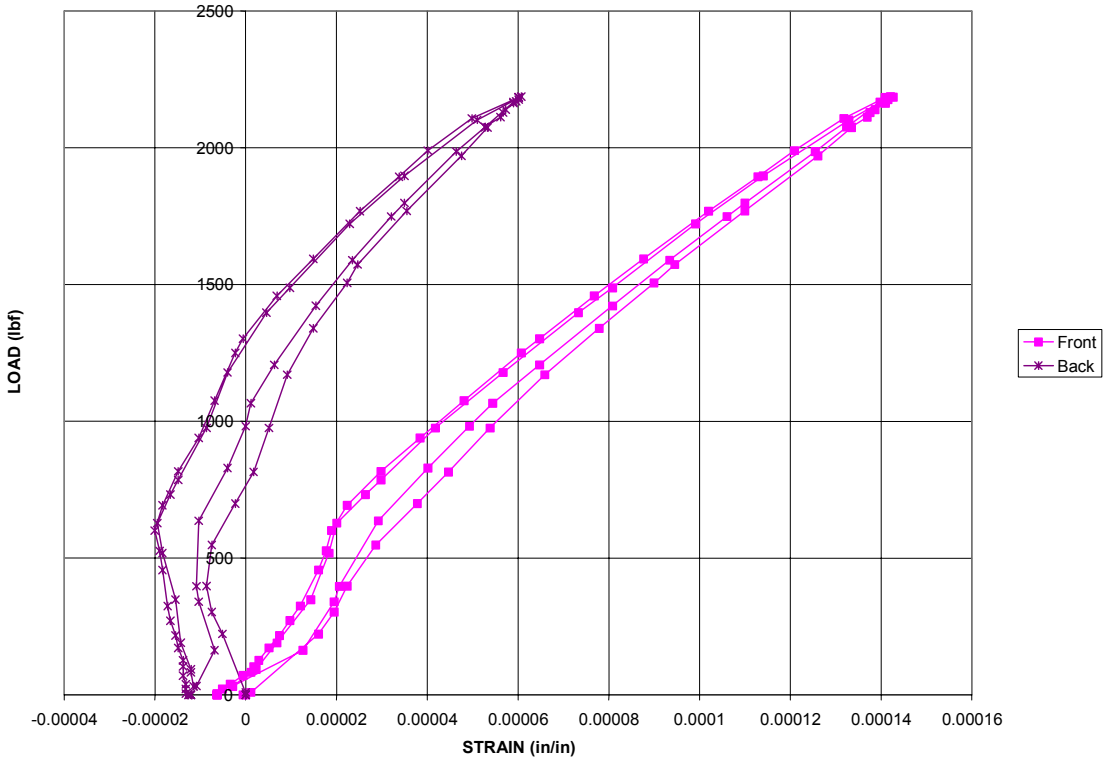

FIGURE F-13. STRAIN GAGE DATA, SCG-1s, 43,800 CYCLES

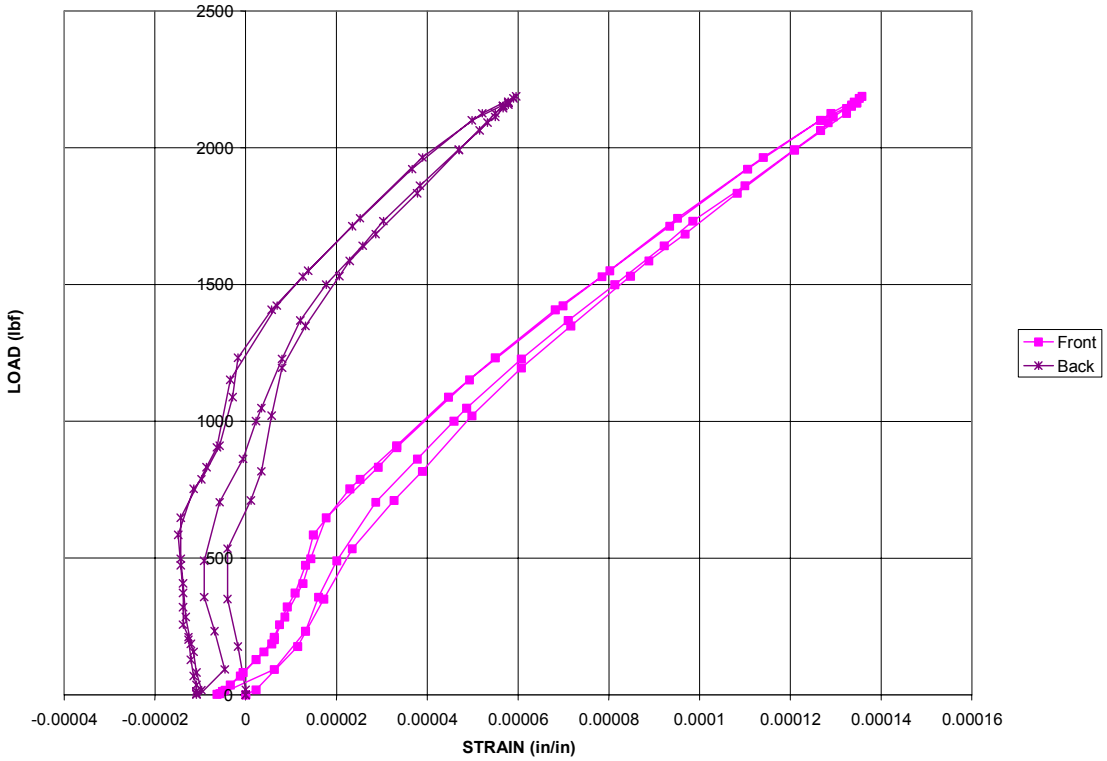

FIGURE F-14. STRAIN GAGE DATA, SCG-1s, 51,800 CYCLES

F.3 SPECIMEN SCG-2 STRAIN GAGE DATA.

Specimen SCG-2 has 0.063″ aluminum doublers and was cycled at a constant amplitude of 15 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection, which is noted in the figure title.

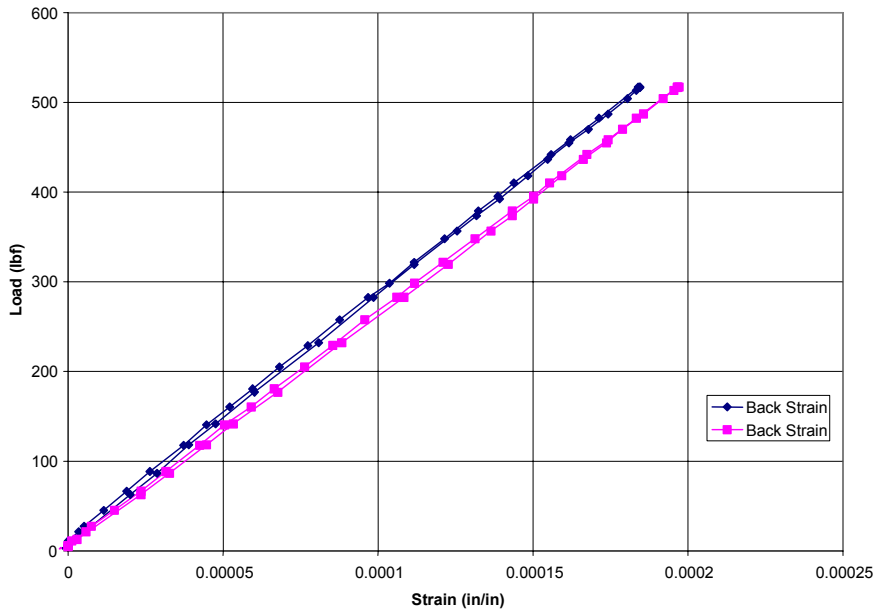

FIGURE F-15. STRAIN GAGE DATA, SCG-2 STRAIN CALIBRATION

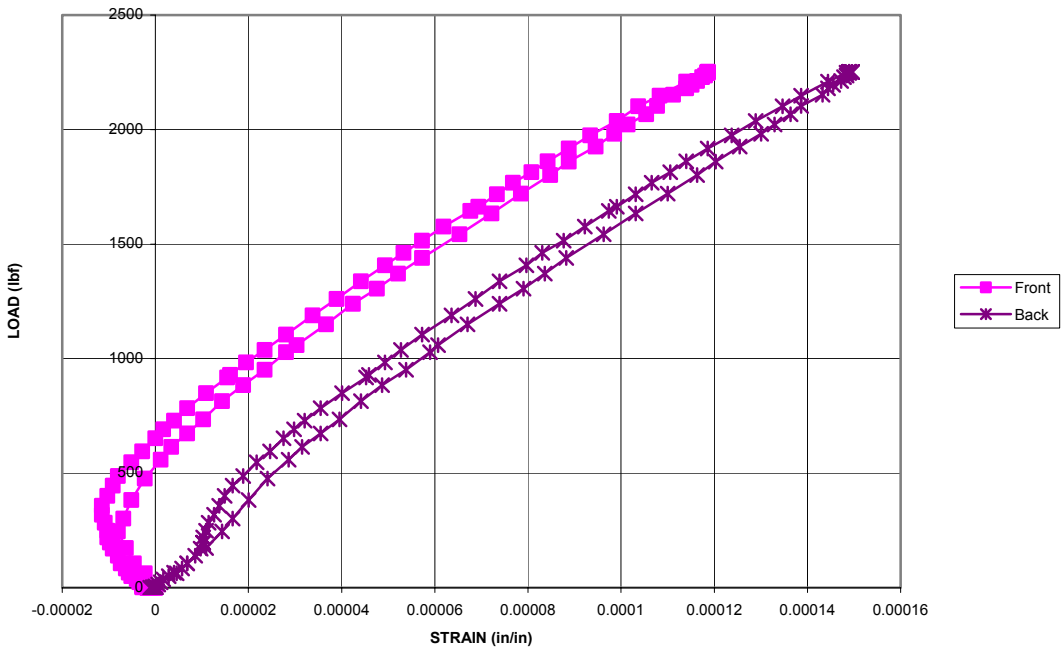

FIGURE F-16. STRAIN GAGE DATA, SCG-2, 12 ksi 0 CYCLES NEW

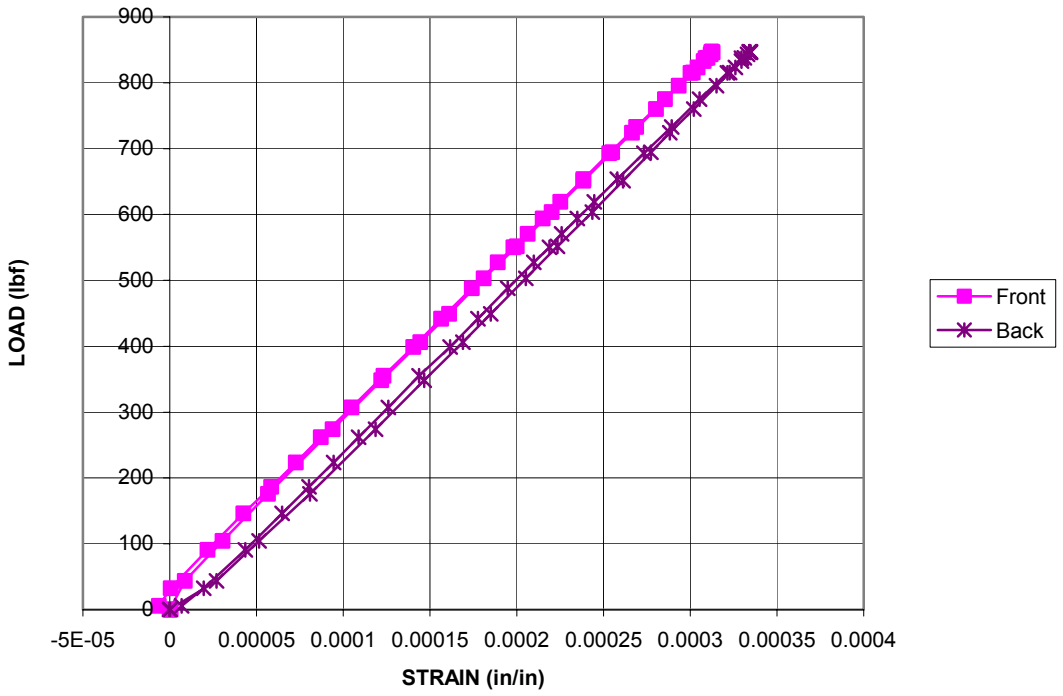

FIGURE F-17. STRAIN GAGE DATA, SCG-2 CALIBRATION #2

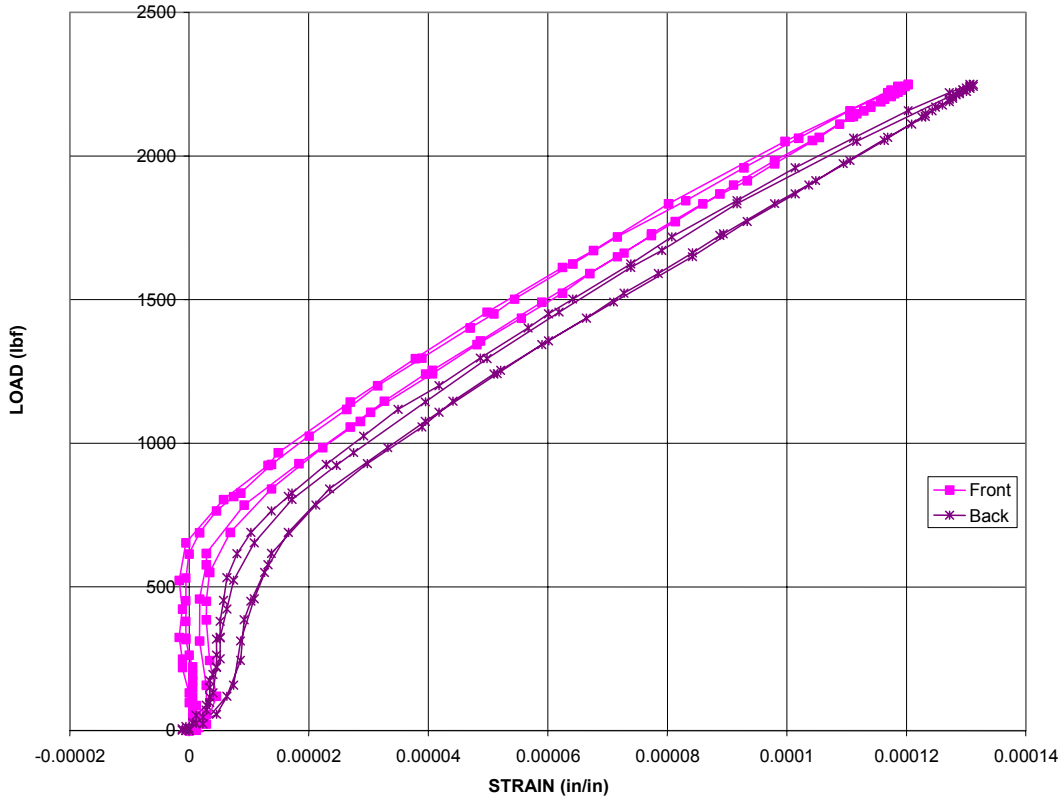

FIGURE F-18. STRAIN GAGE DATA, SCG-2, 2000 CYCLES AFTER

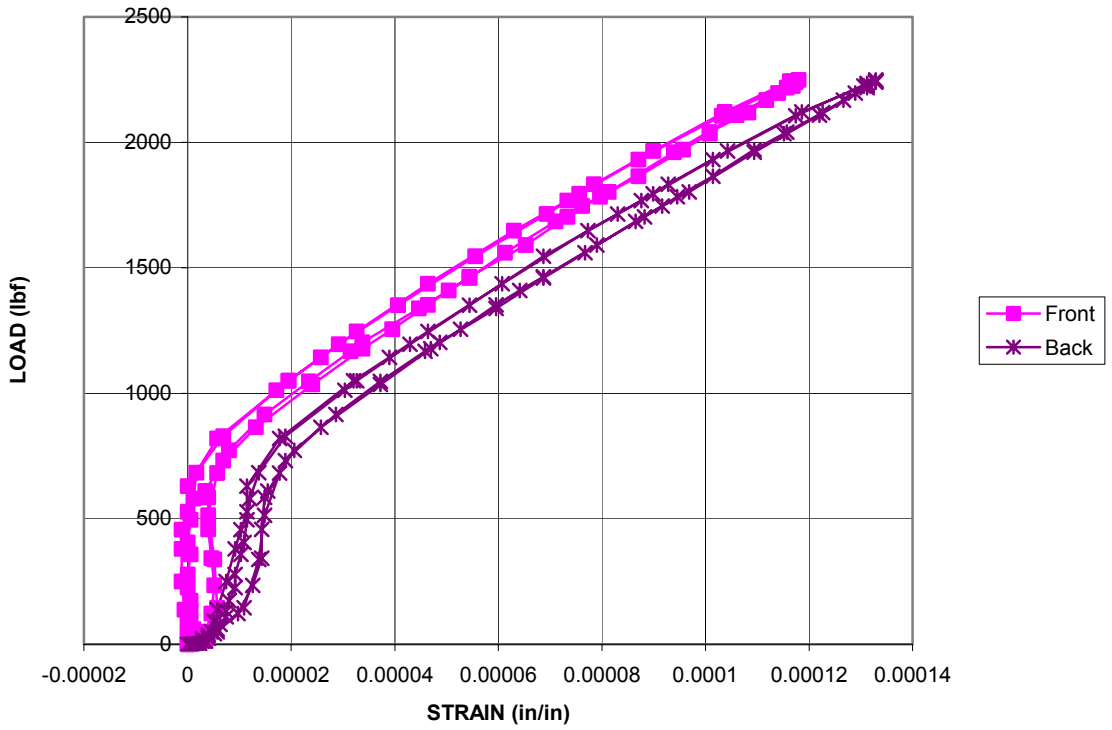

FIGURE F-19. STRAIN GAGE DATA, SCG-2, 4000 CYCLES BEFORE

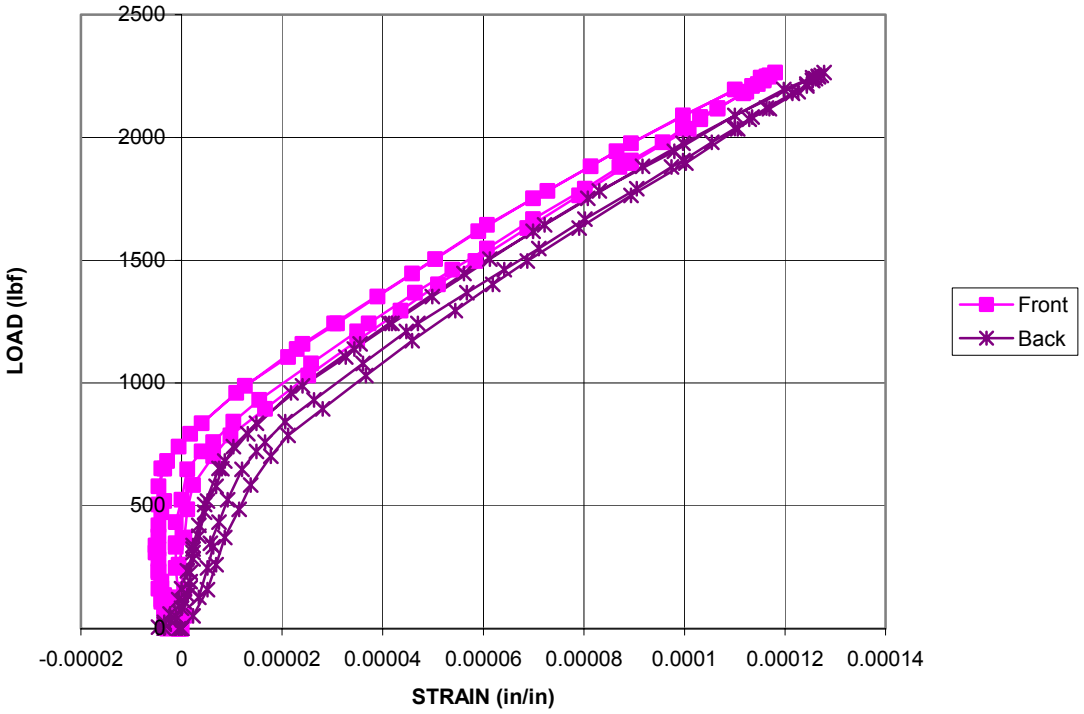

FIGURE F-20. STRAIN GAGE DATA, SCG-2, 4000 CYCLES AFTER

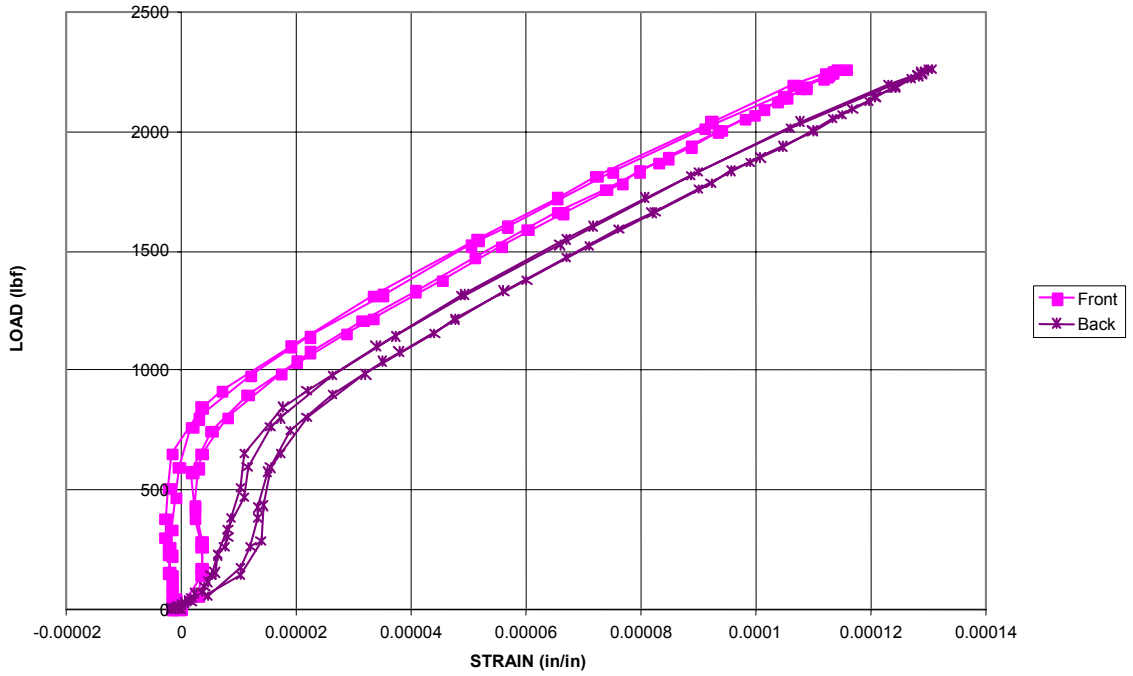

FIGURE F-21. STRAIN GAGE DATA, SCG-2, 6000 CYCLES BEFORE

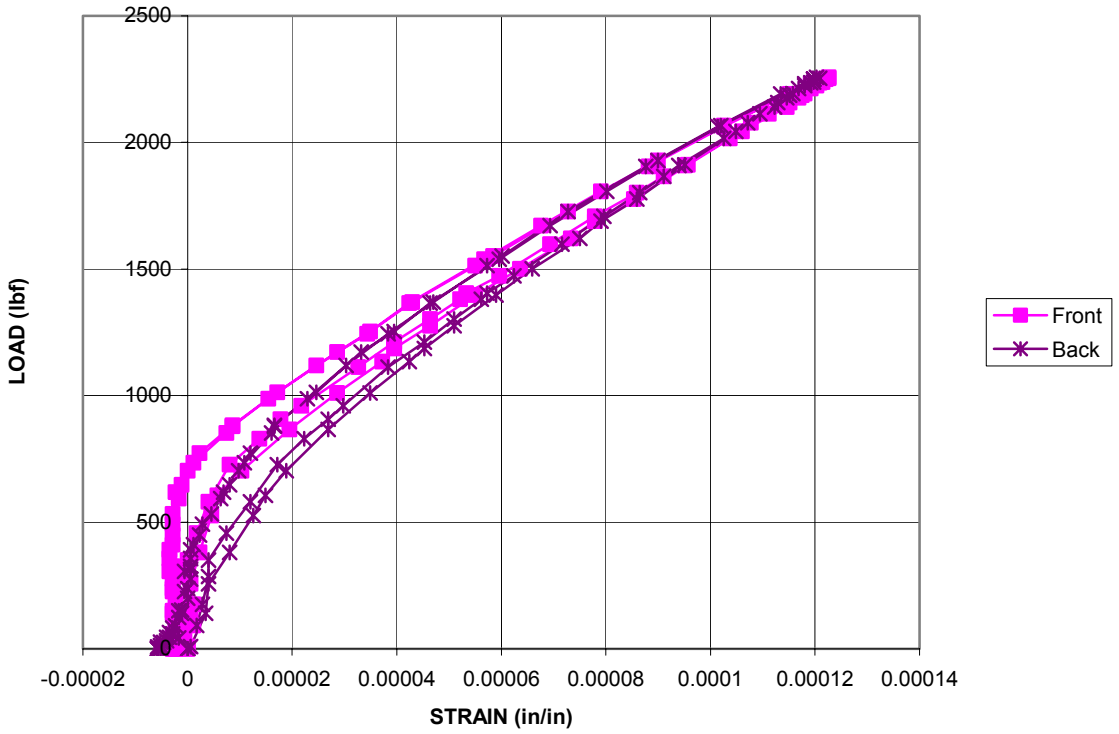

FIGURE F-22. STRAIN GAGE DATA, SCG-2, 6000 CYCLES AFTER

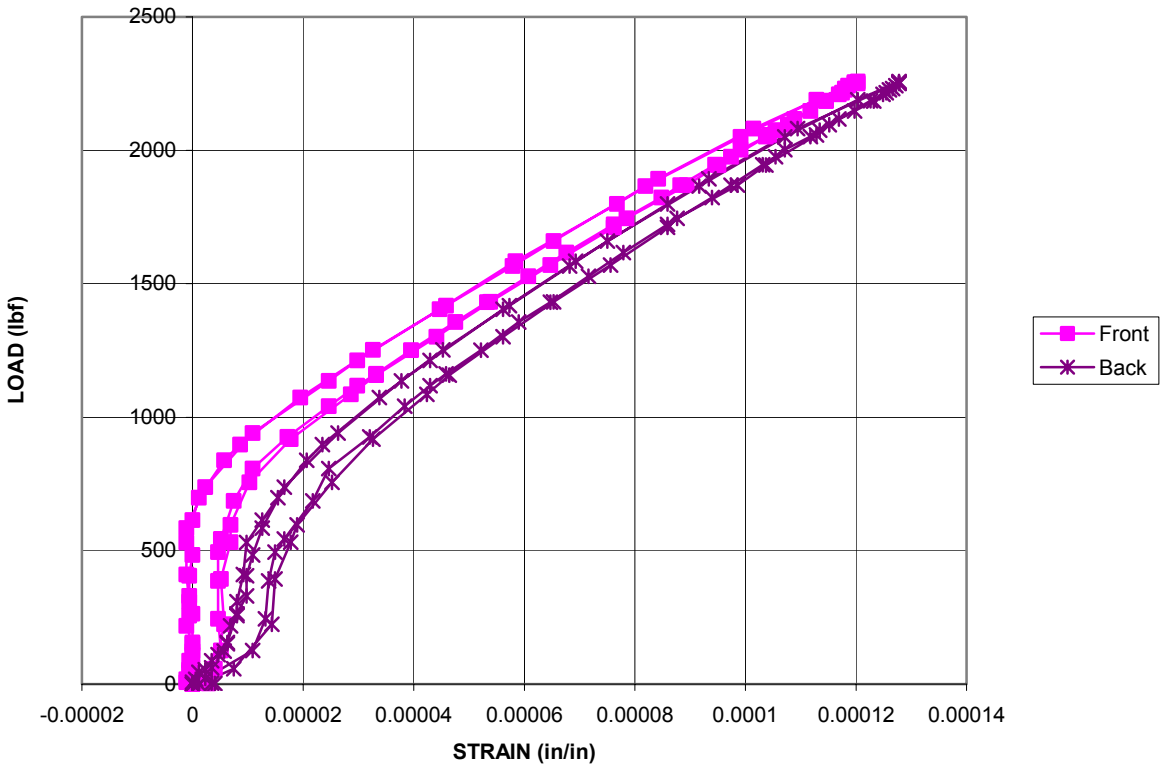

FIGURE F-23. STRAIN GAGE DATA, SCG-2, 8000 CYCLES BEFORE

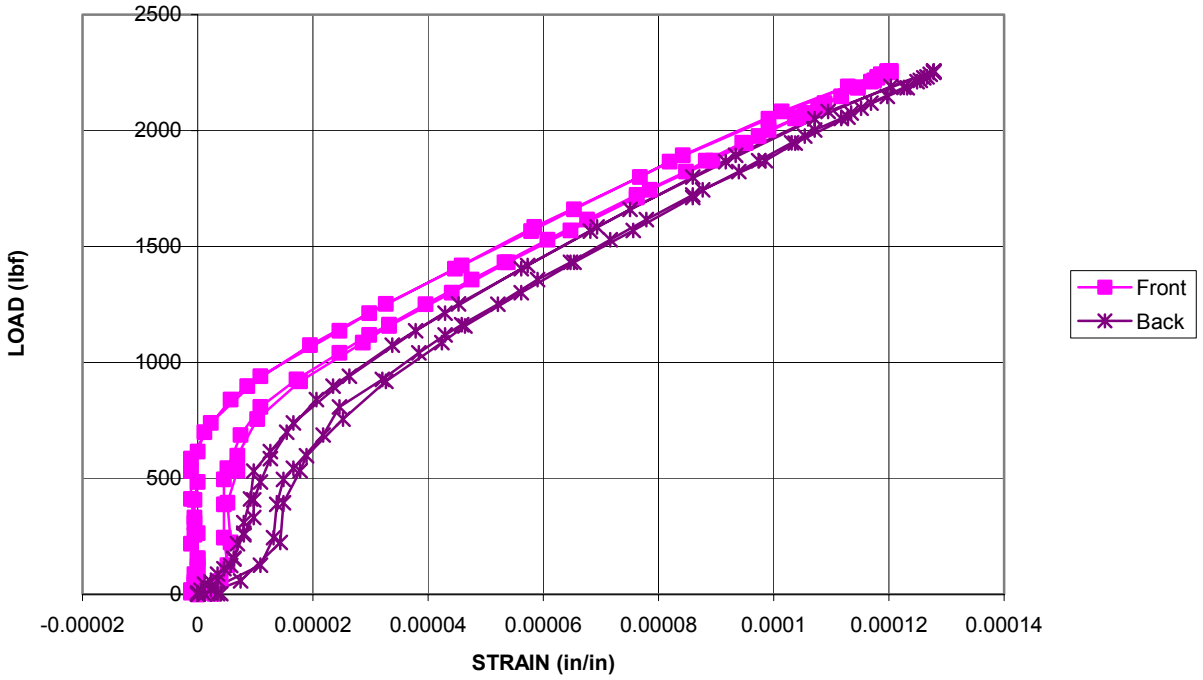

FIGURE F-24. STRAIN GAGE DATA, SCG-2, 8000 CYCLES AFTER

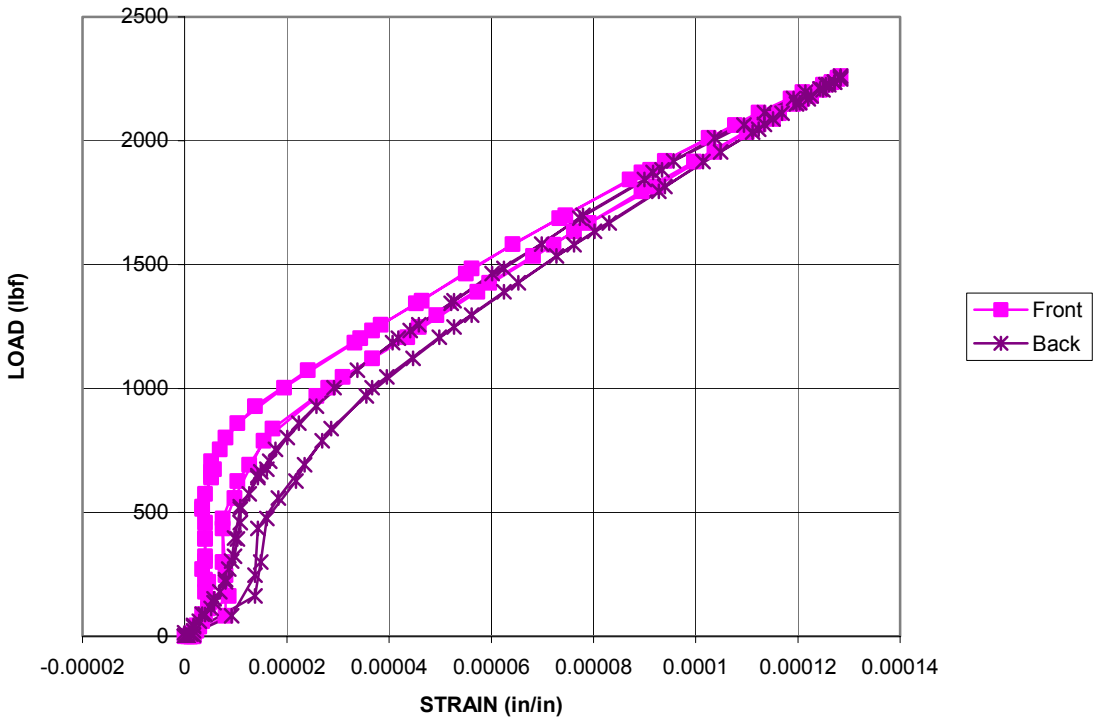

FIGURE F-25. STRAIN GAGE DATA, SCG-2, 10,000 CYCLES BEFORE

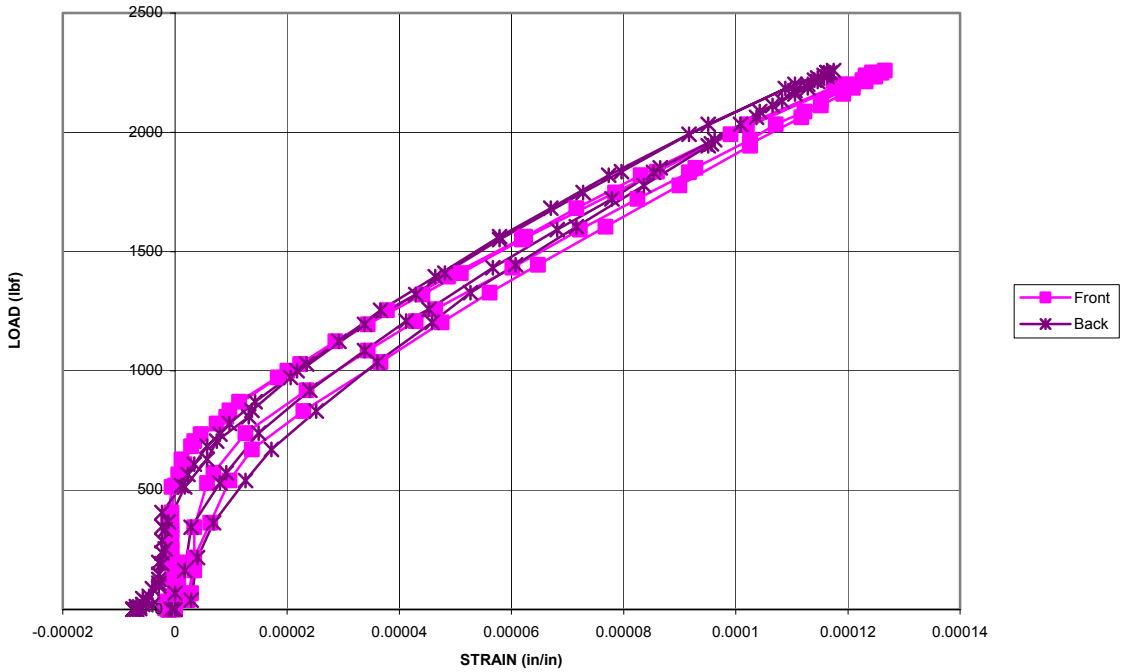

FIGURE F-26. STRAIN GAGE DATA, SCG-2, 10,000 CYCLES AFTER

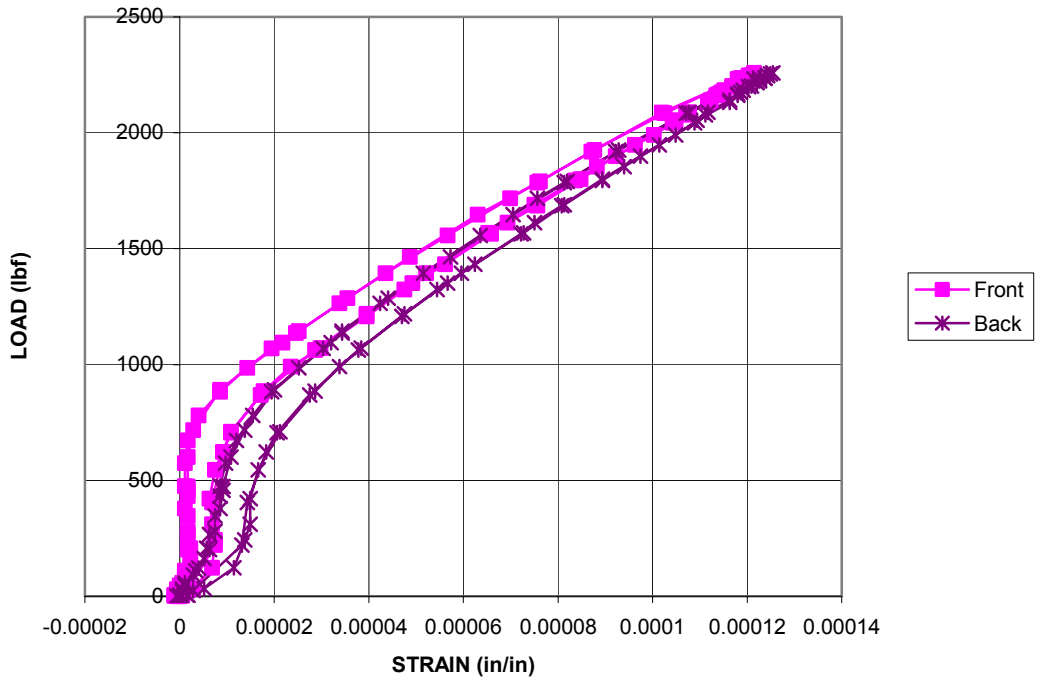

FIGURE F-27. STRAIN GAGE DATA, SCG-2, 12,000 CYCLES BEFORE

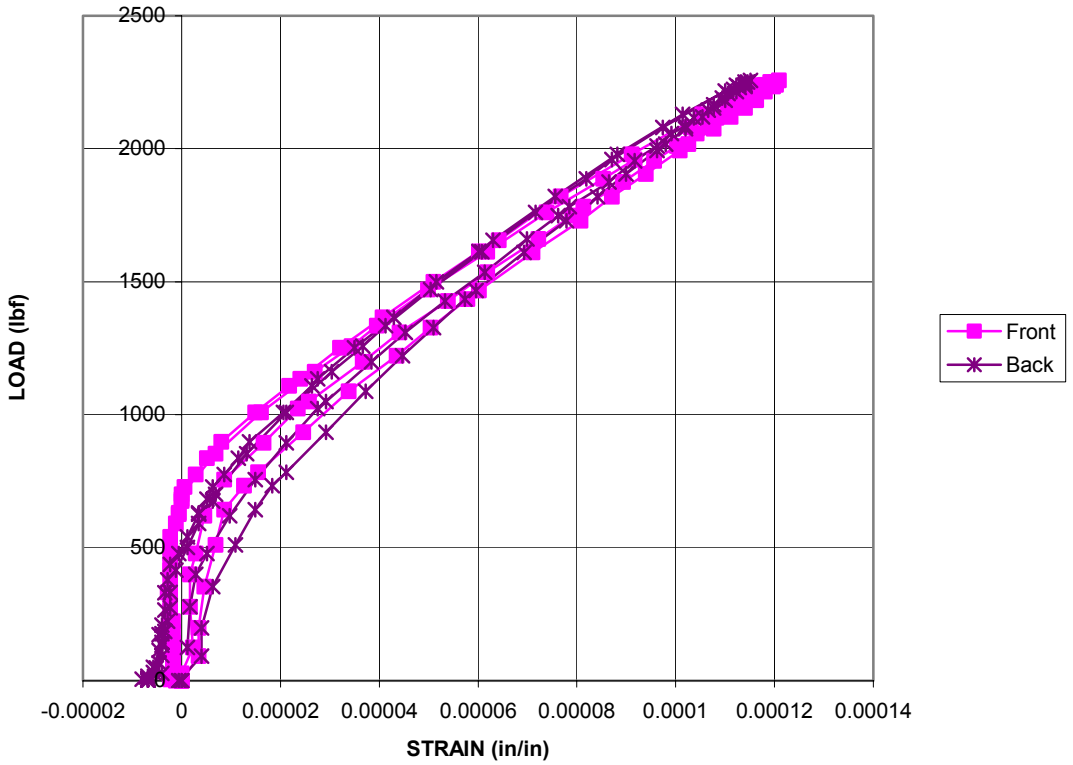

FIGURE F-28. STRAIN GAGE DATA, SCG-2, 12,000 CYCLES AFTER

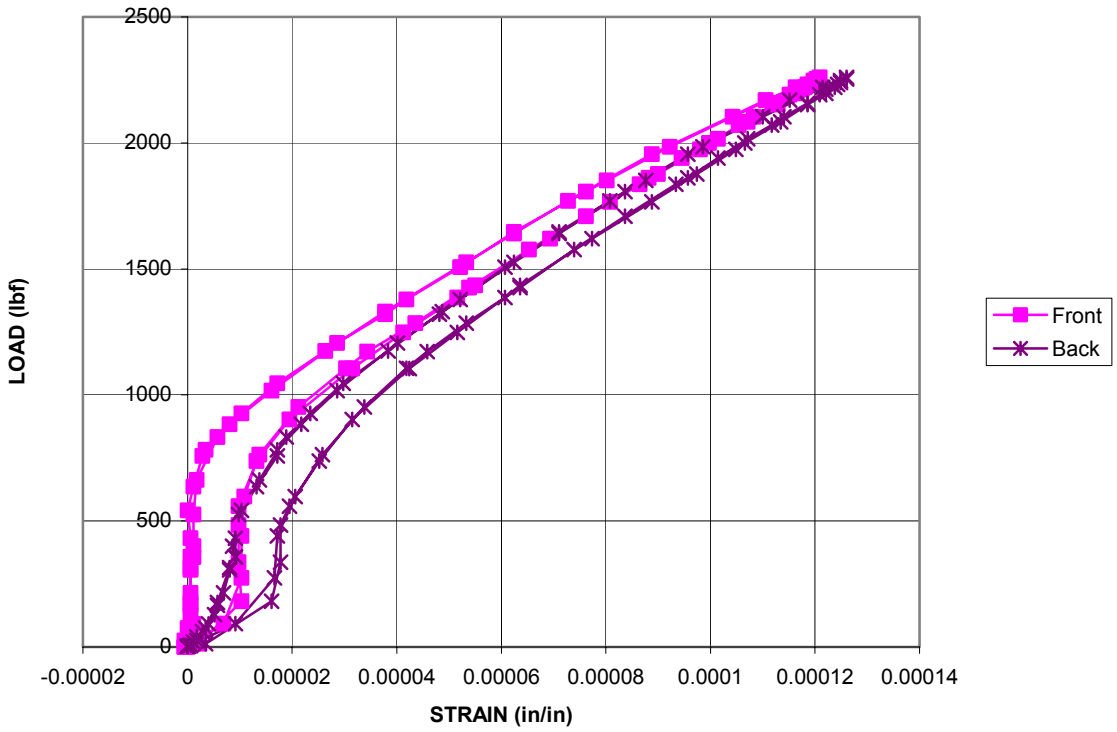

FIGURE F-29. STRAIN GAGE DATA, SCG-2, 14,000 CYCLES BEFORE

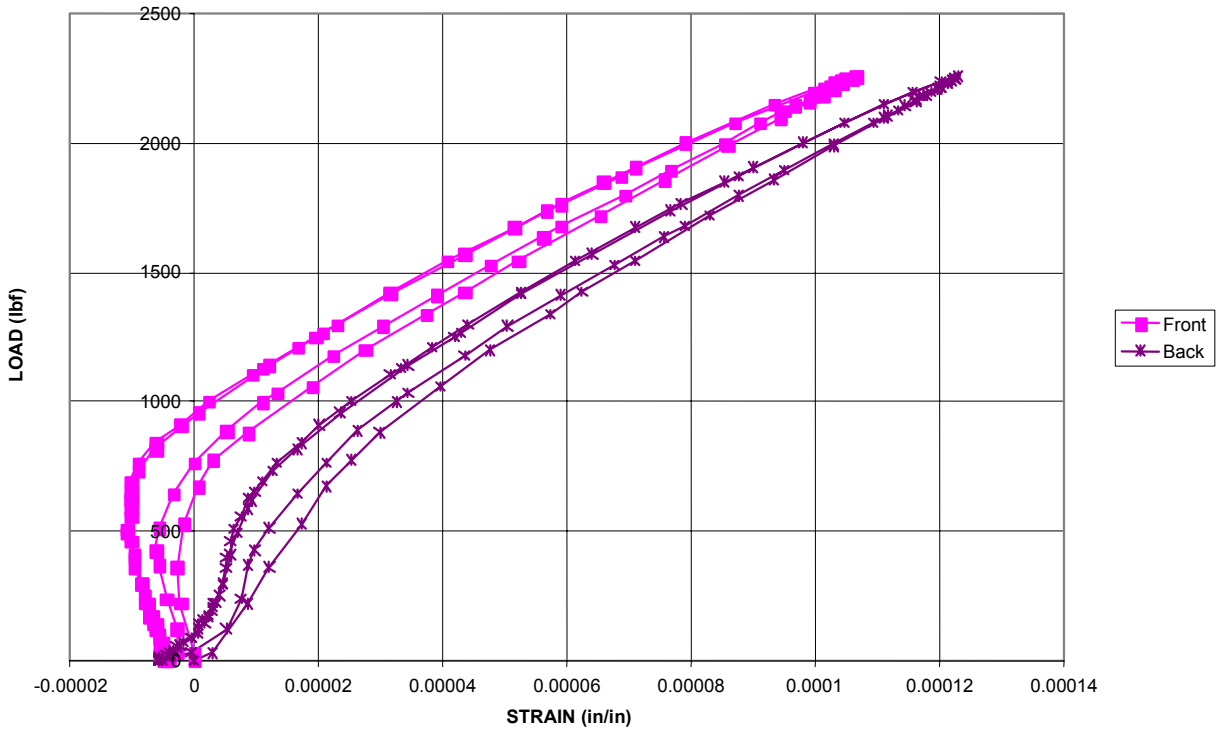

FIGURE F-30. STRAIN GAGE DATA, SCG-2, 14,000 CYCLES AFTER

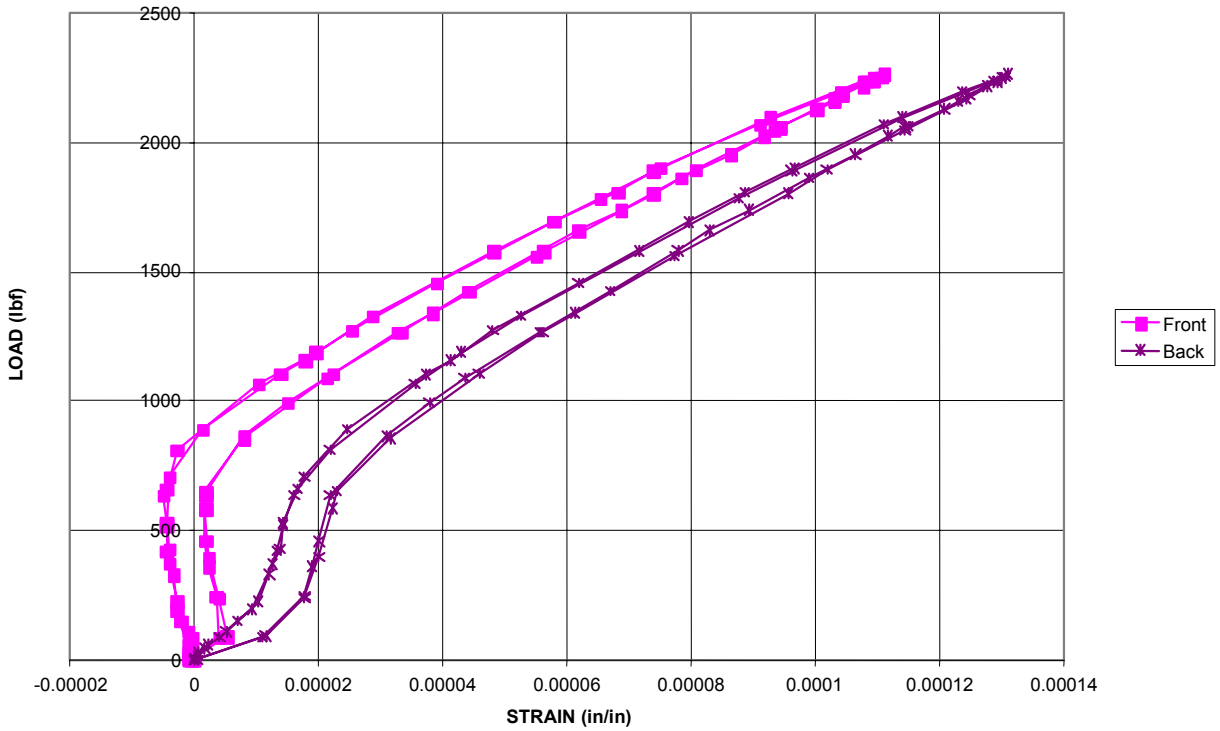

FIGURE F-31. STRAIN GAGE DATA, SCG-2, 20,000 CYCLES BEFORE

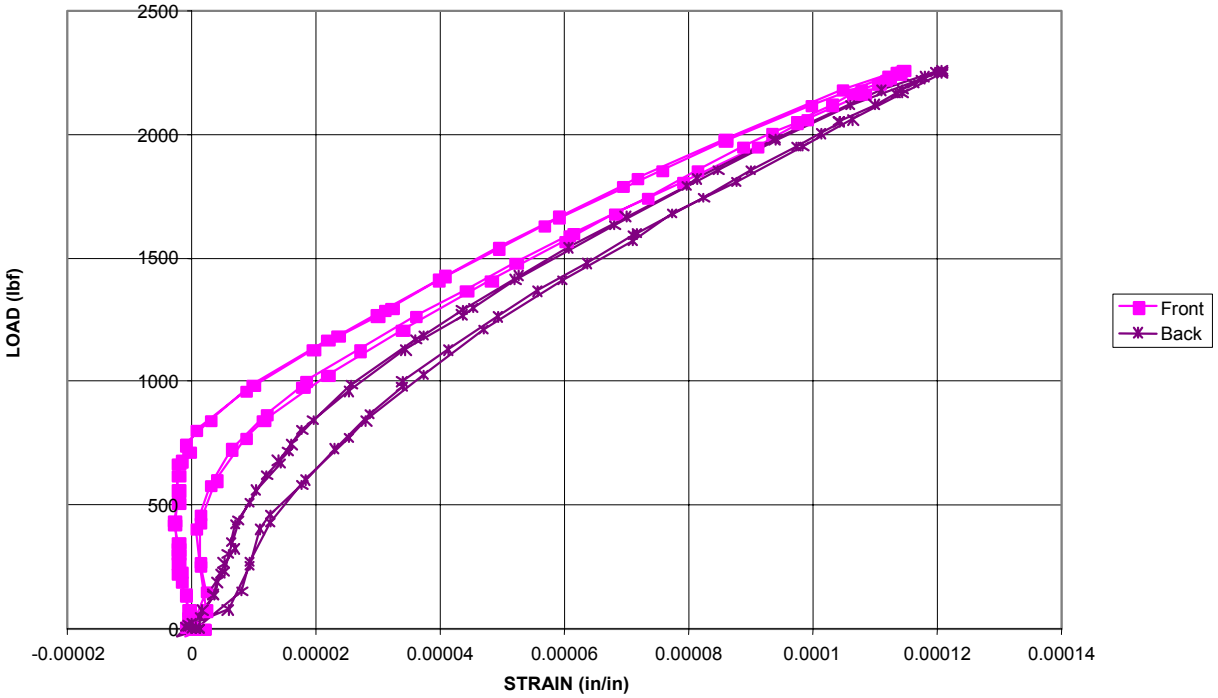

FIGURE F-32. STRAIN GAGE DATA, SCG-2, 20,000 CYCLES AFTER

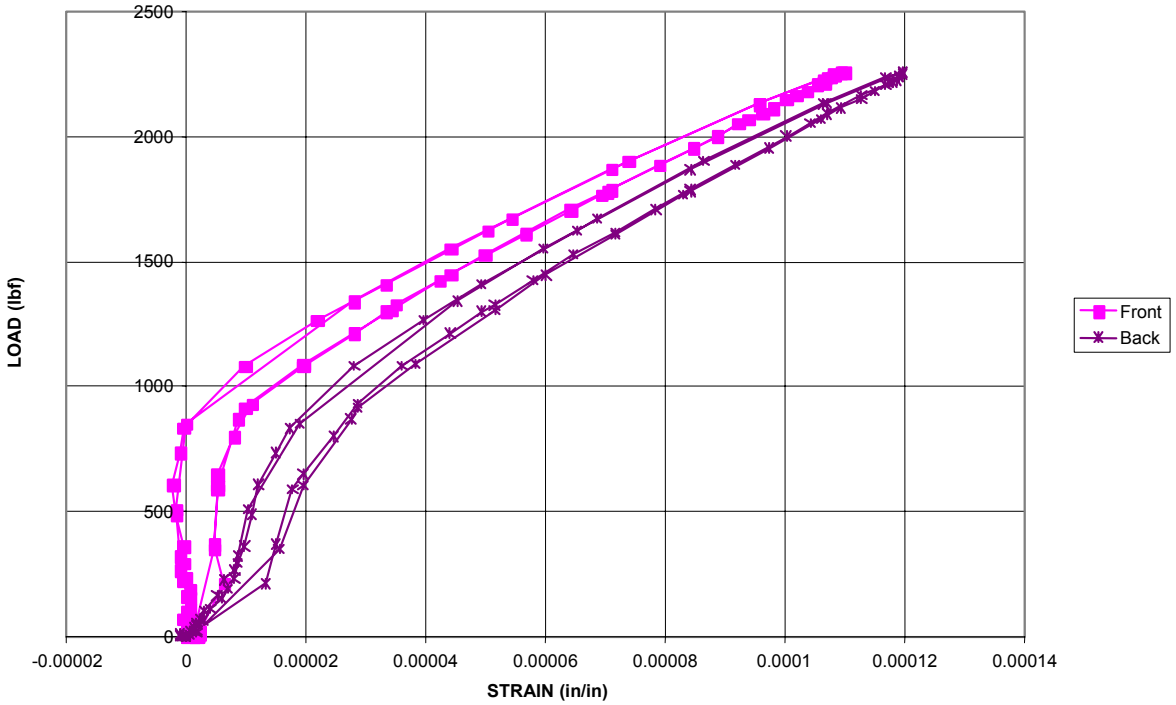

FIGURE F-33. STRAIN GAGE DATA, SCG-2, 26,000 CYCLES BEFORE

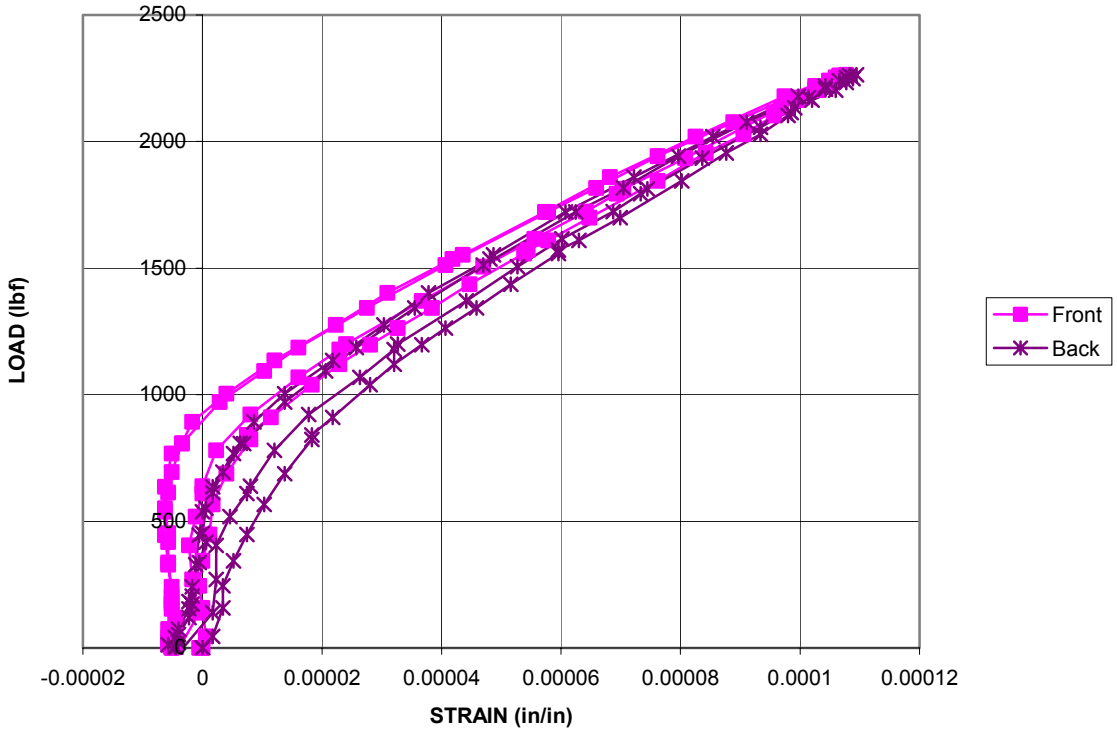

FIGURE F-34. STRAIN GAGE DATA, SCG-1, 26,000 CYCLES AFTER

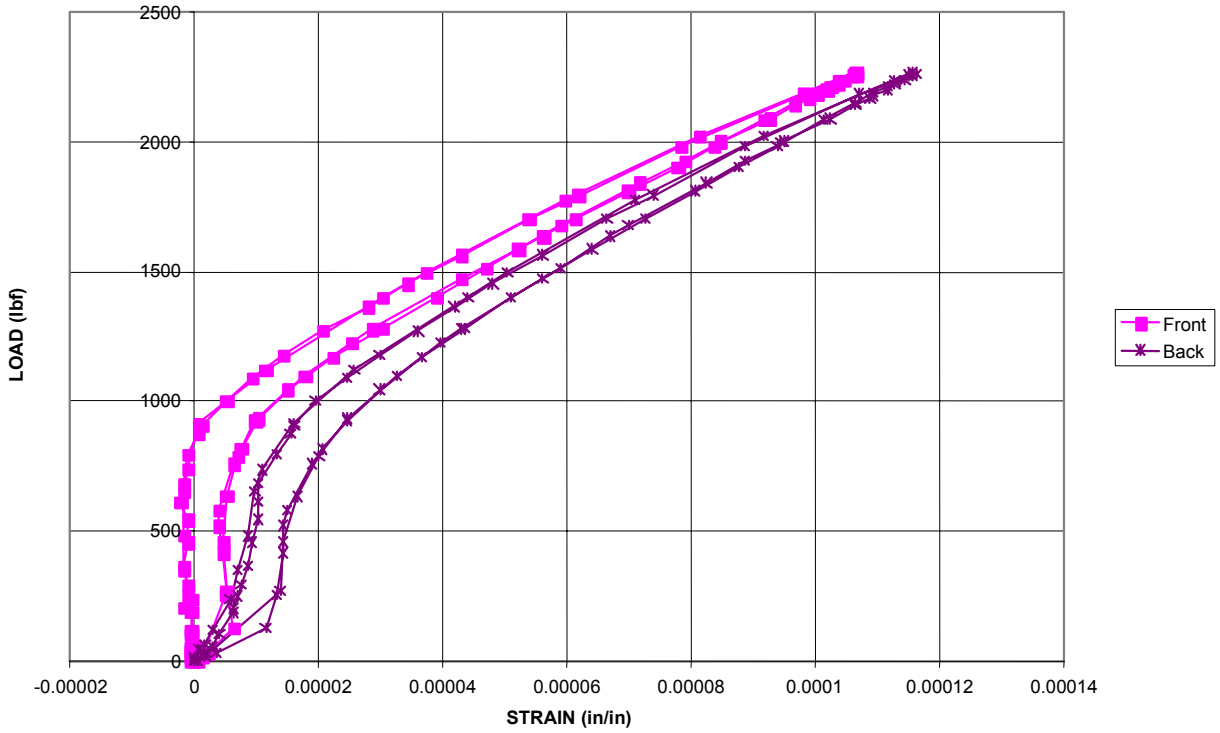

FIGURE F-35. STRAIN GAGE DATA, SCG-2, 32,000 CYCLES BEFORE

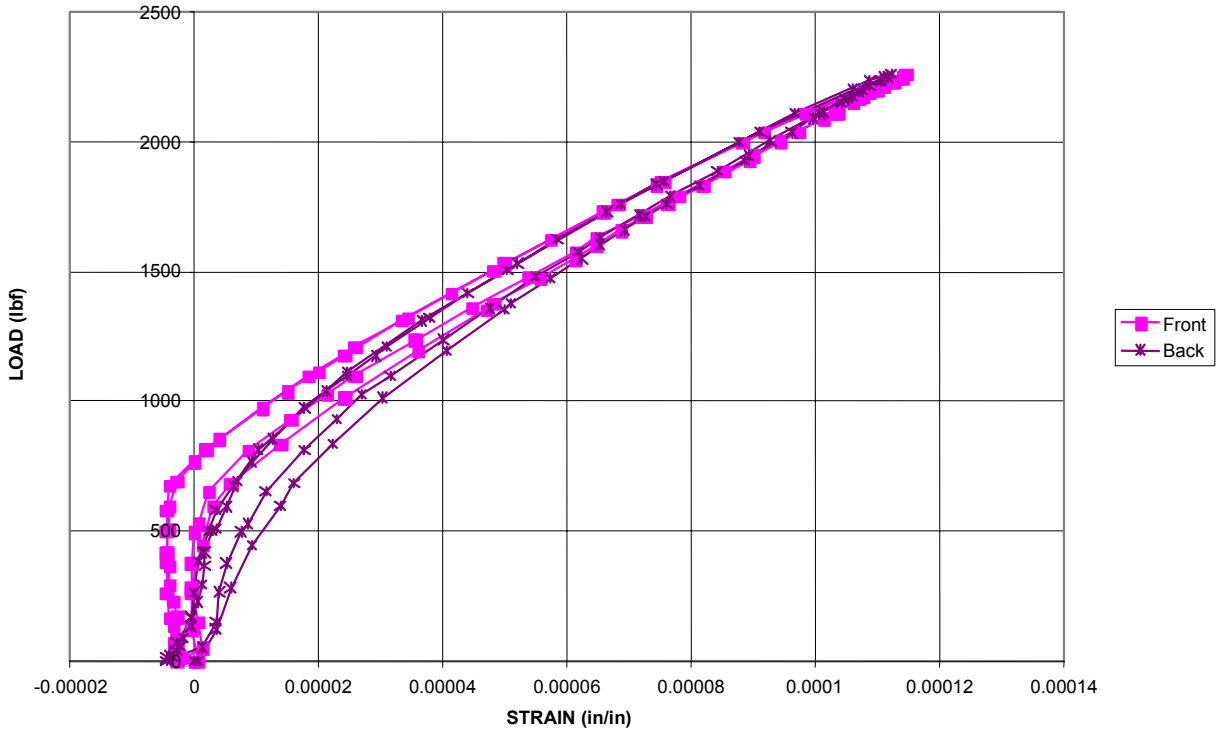

FIGURE F-36. STRAIN GAGE DATA, SCG-2, 32,000 CYCLES AFTER

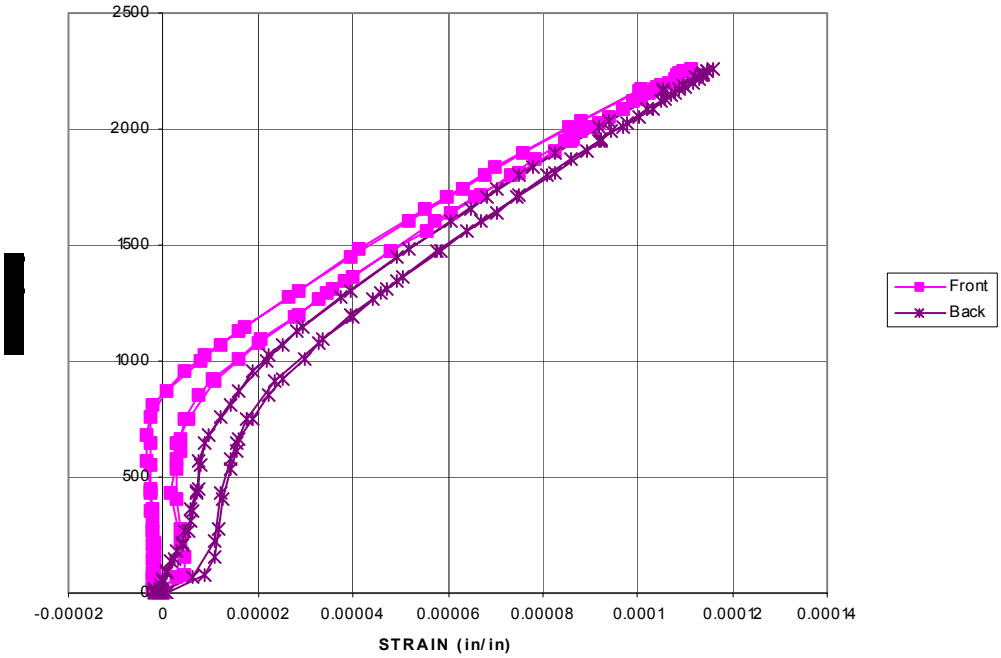

FIGURE F-37. STRAIN GAGE DATA, SCG-2, 38,000 CYCLES BEFORE

F.4 SPECIMEN SCG-5 STRAIN GAGE DATA.

Specimen SCG-5 has 0.063″ aluminum doublers and was cycled at a constant amplitude of 15 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection, which is noted in the figure title.

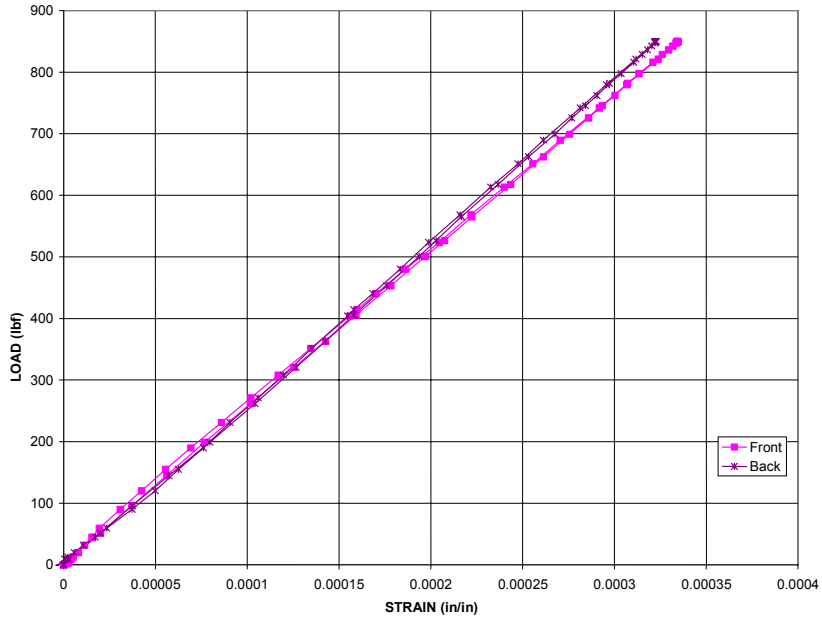

FIGURE F-38. STRAIN GAGE DATA, SCG-5, CALIBRATION #1

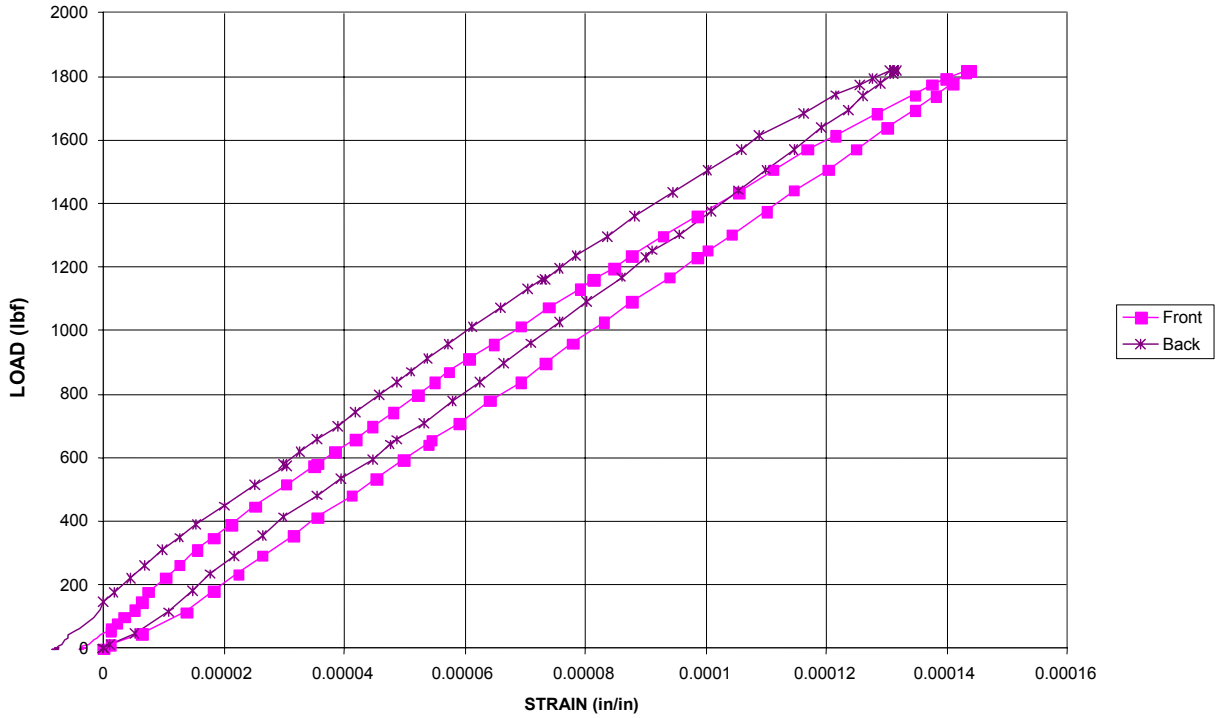

FIGURE F-39. STRAIN GAGE DATA, SCG-5, 0 CYCLES NEW

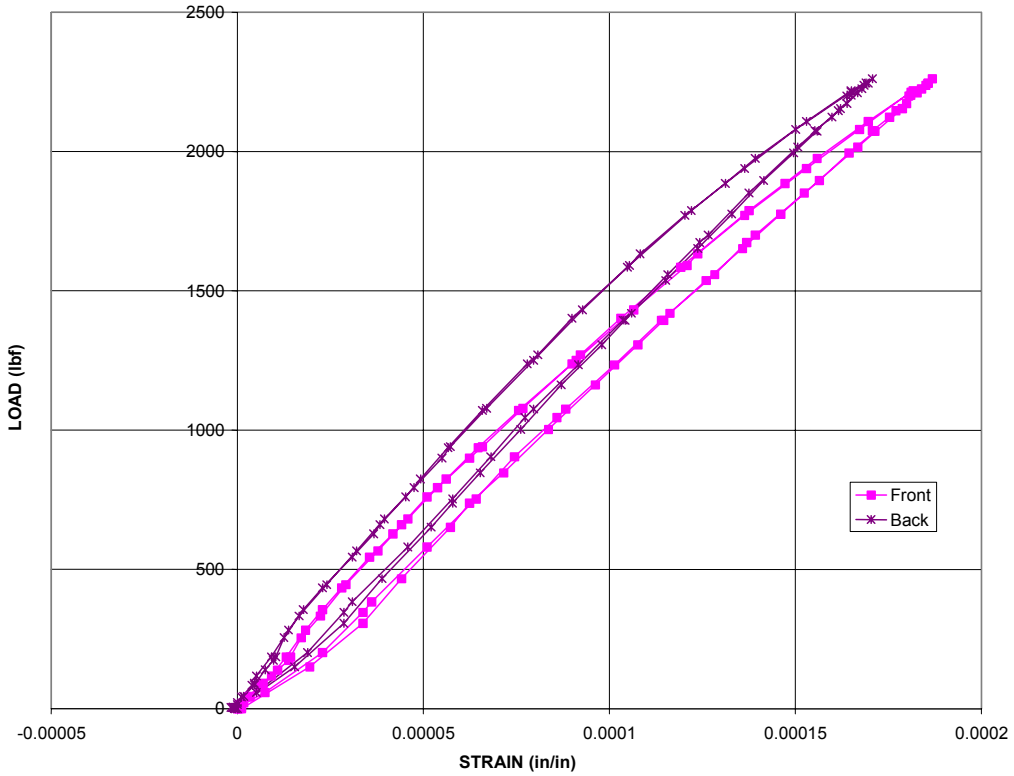

FIGURE F-40. STRAIN GAGE DATA, SCG-5, 500 CYCLES BEFORE

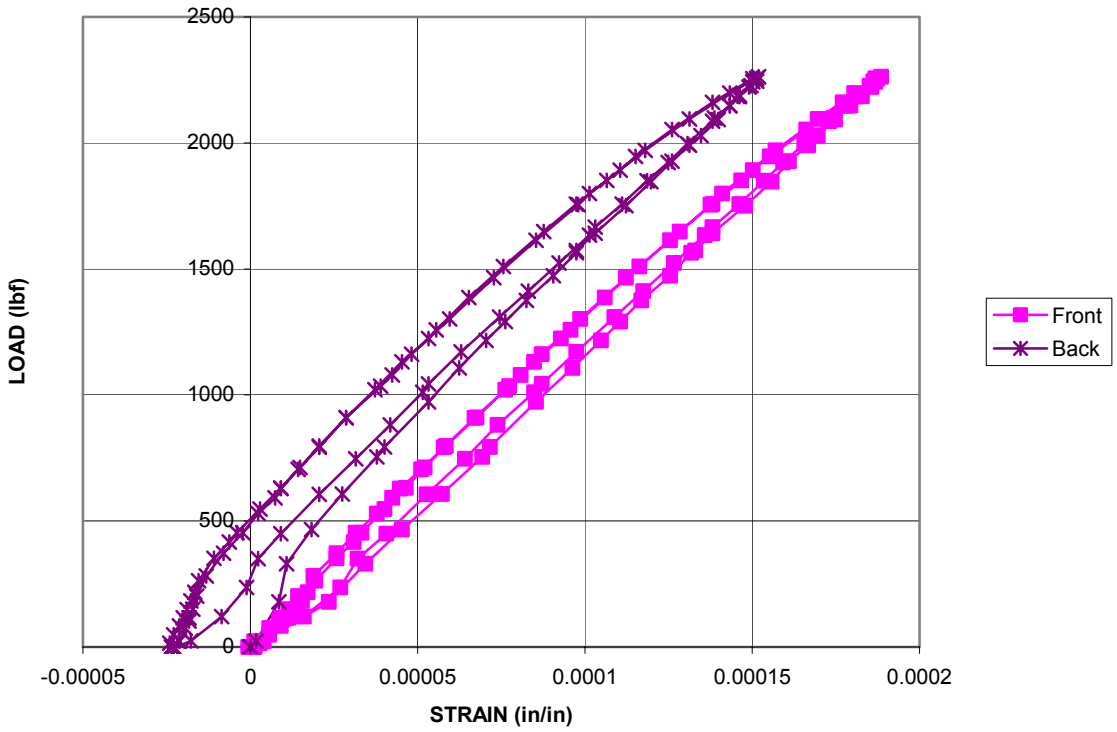

FIGURE F-41. STRAIN GAGE DATA, SCG-5, 500 CYCLES AFTER

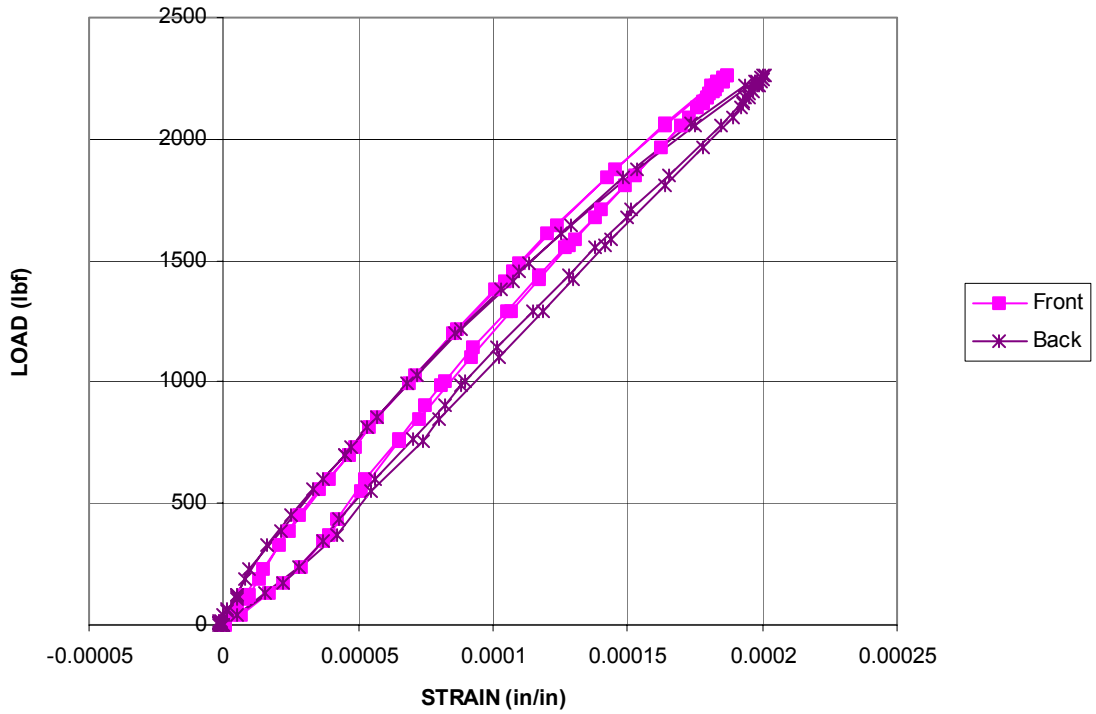

FIGURE F-42. STRAIN GAGE DATA, SCG-5, 5700 CYCLES BEFORE

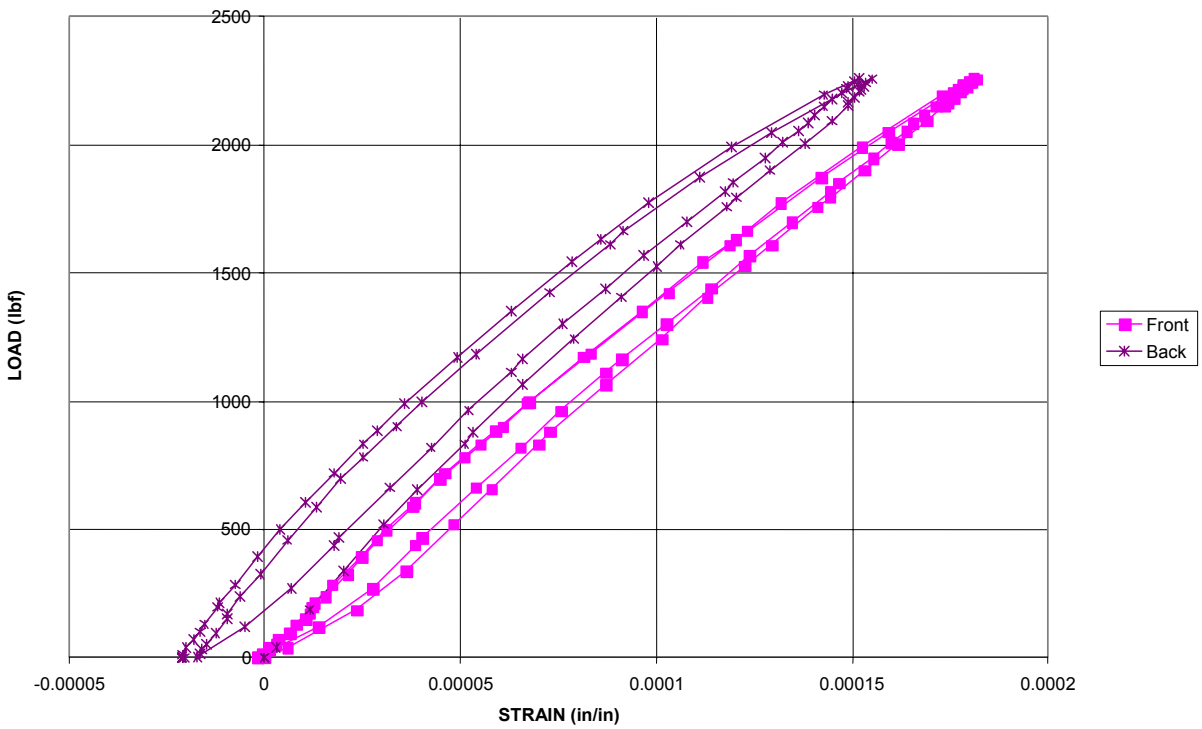

FIGURE F-43. STRAIN GAGE DATA, SCG-5, 5700 CYCLES AFTER

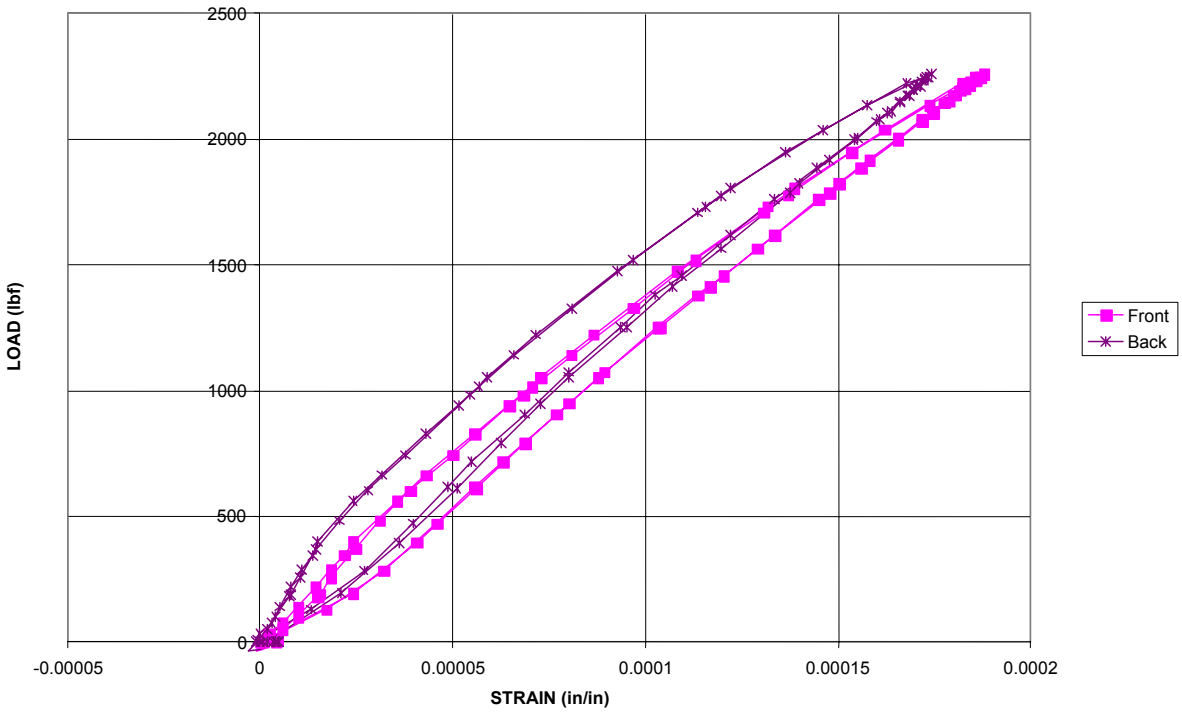

FIGURE F-44. STRAIN GAGE DATA, SCG-5, 10,900 CYCLES BEFORE

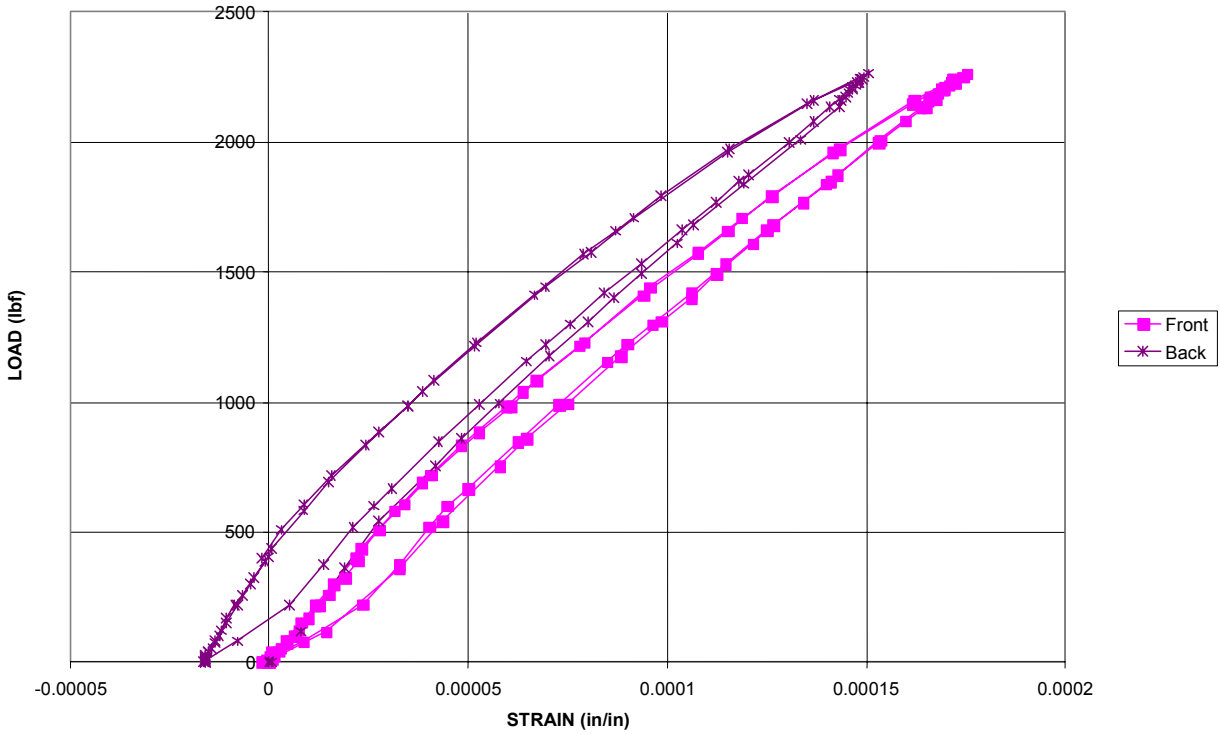

FIGURE F-45. STRAIN GAGE DATA, SCG-5, 10,900 CYCLES AFTER

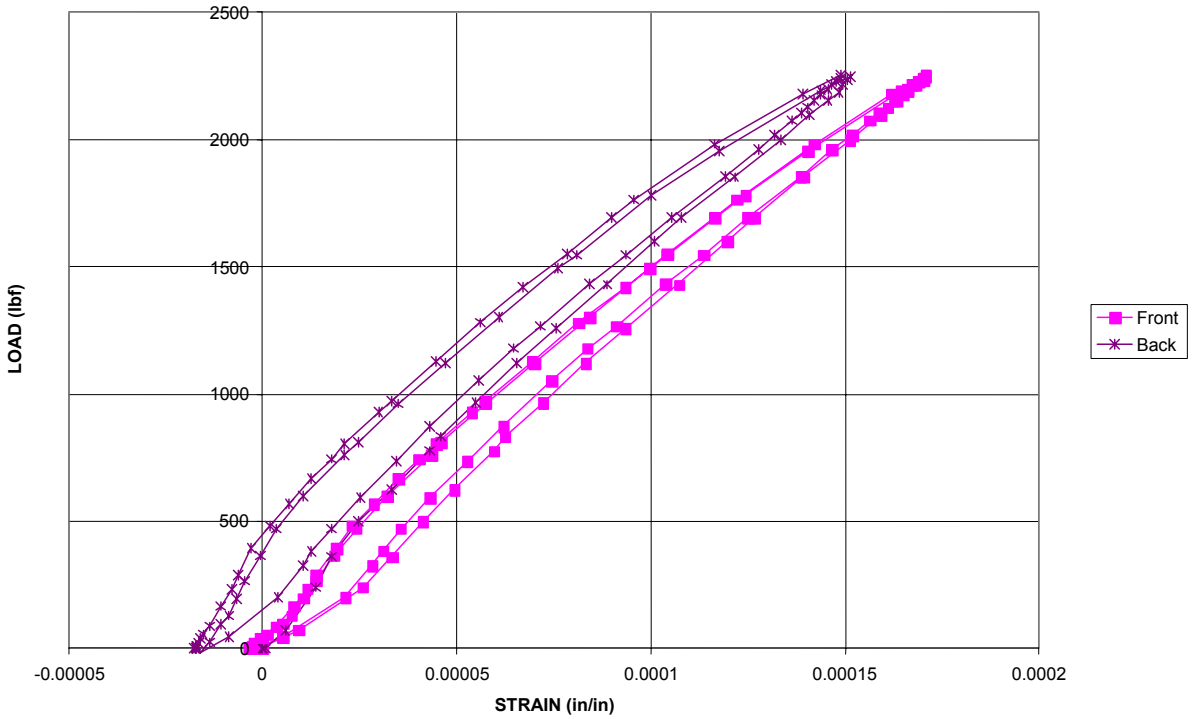

FIGURE F-46. STRAIN GAGE DATA, SCG-5, 16,100 CYCLES

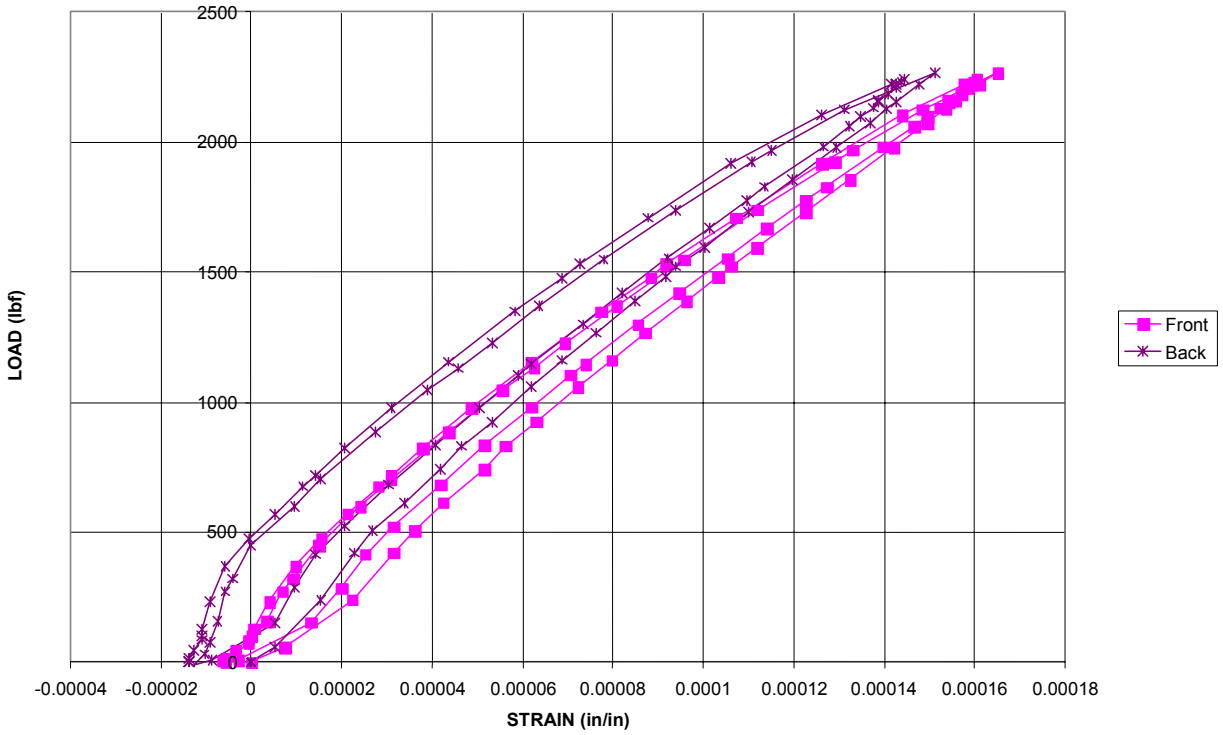

FIGURE F-47. STRAIN GAGE DATA, SCG-5, 21,300 CYCLES

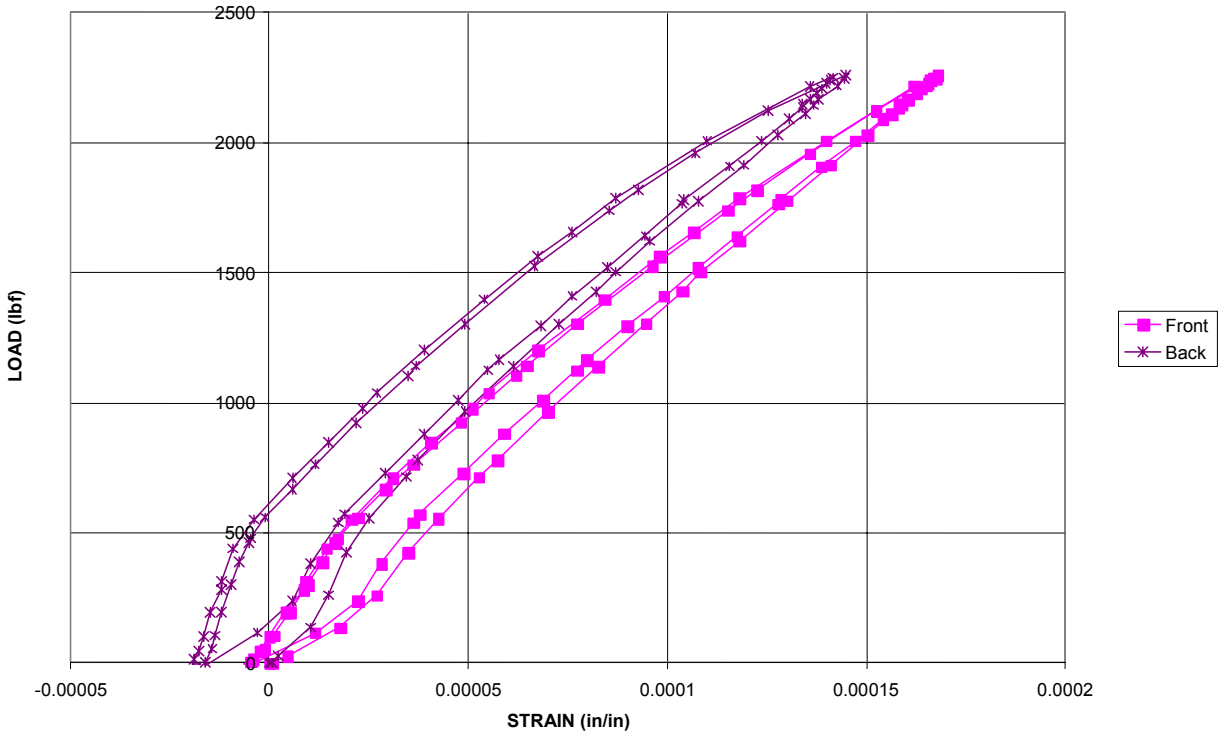

FIGURE F-48. STRAIN GAGE DATA, SCG-5, 26,500 CYCLES

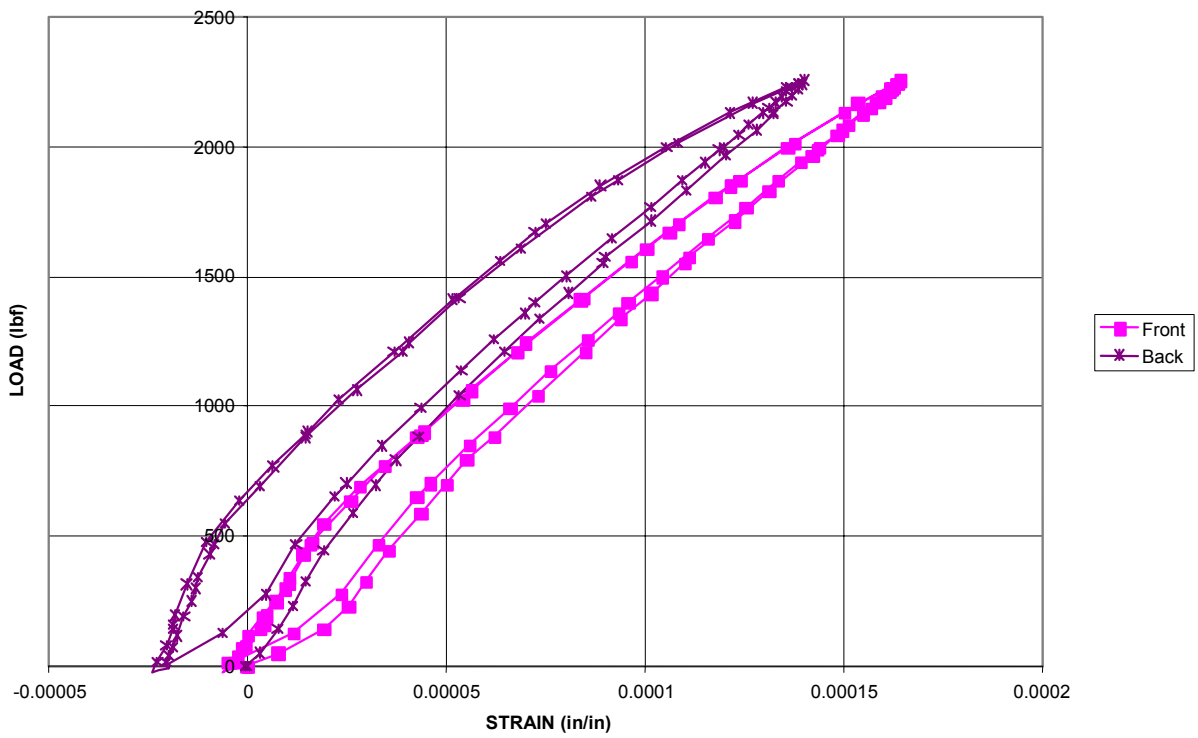

FIGURE F-49. STRAIN GAGE DATA, SCG-5, 31,700 CYCLES

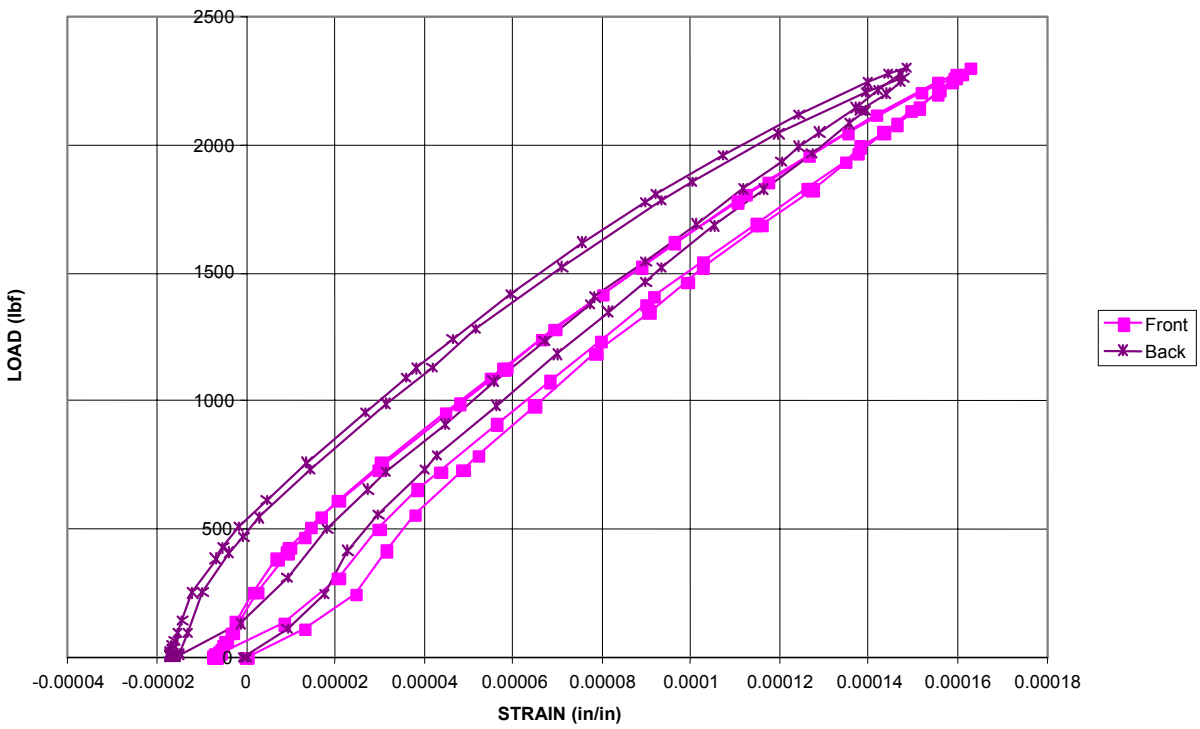

FIGURE F-50. STRAIN GAGE DATA, SCG-5, 36,900 CYCLES

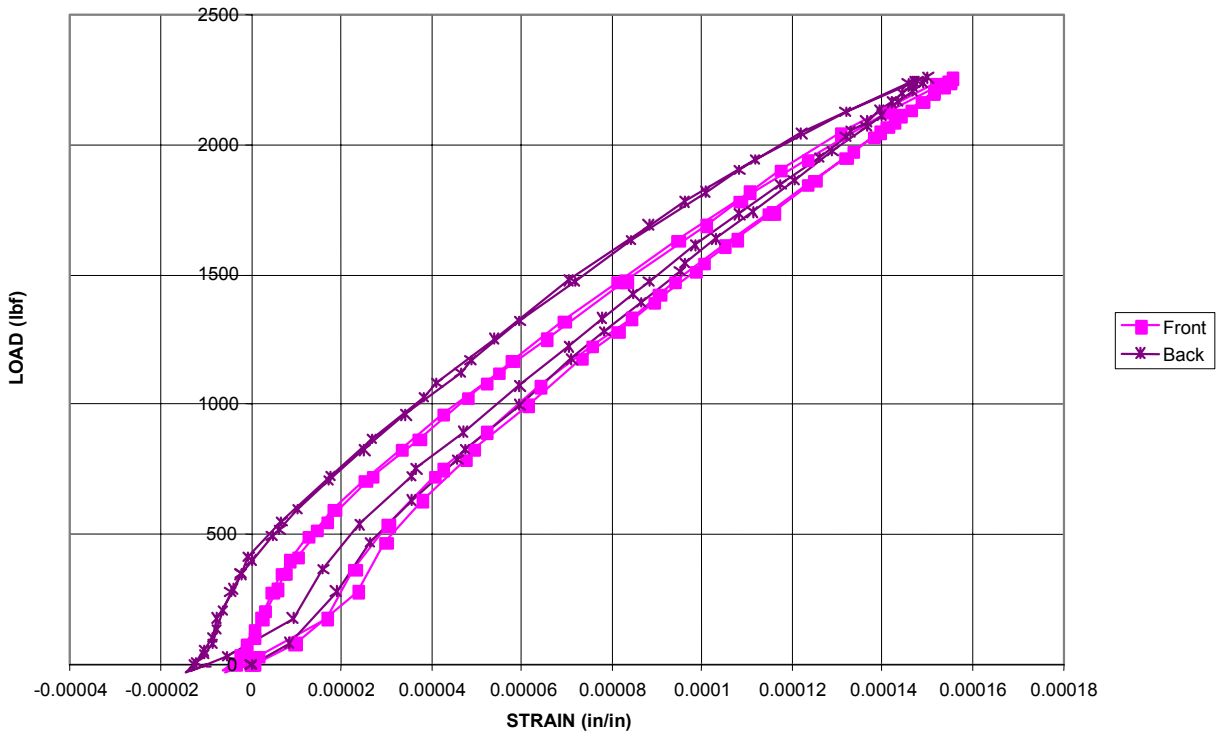

FIGURE F-51. STRAIN GAGE DATA, SCG-5, 42,100 CYCLES

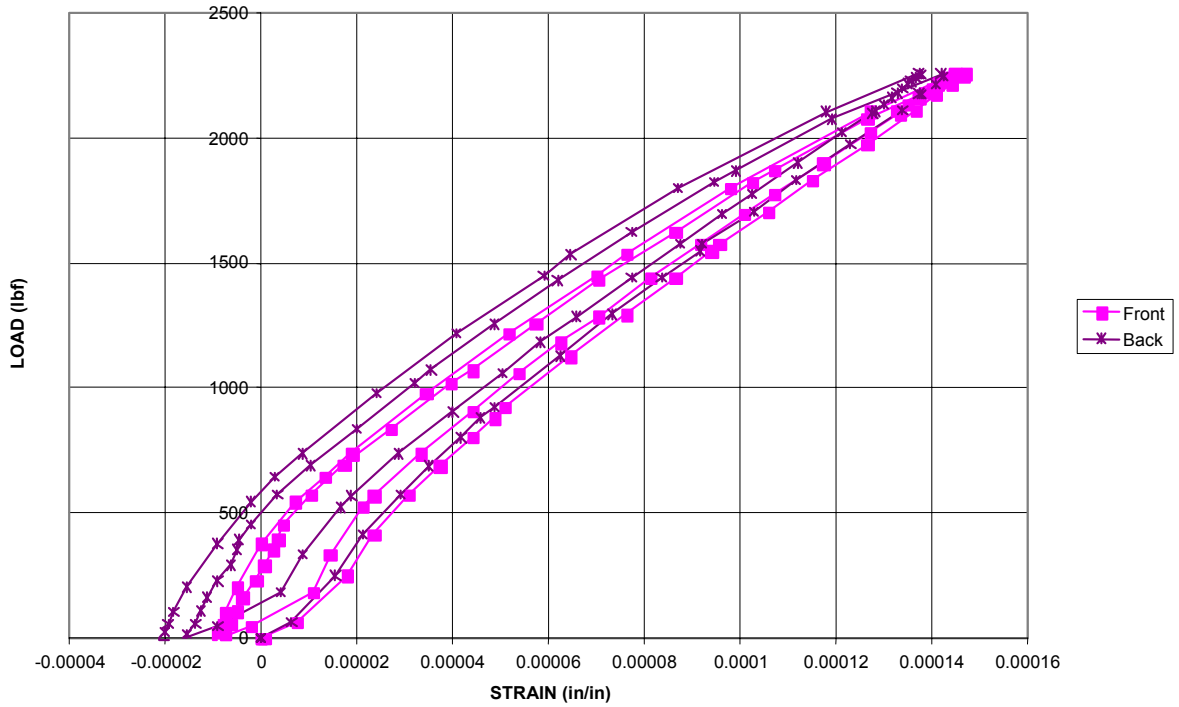

FIGURE F-52. STRAIN GAGE DATA, SCG-5, 47,300 CYCLES

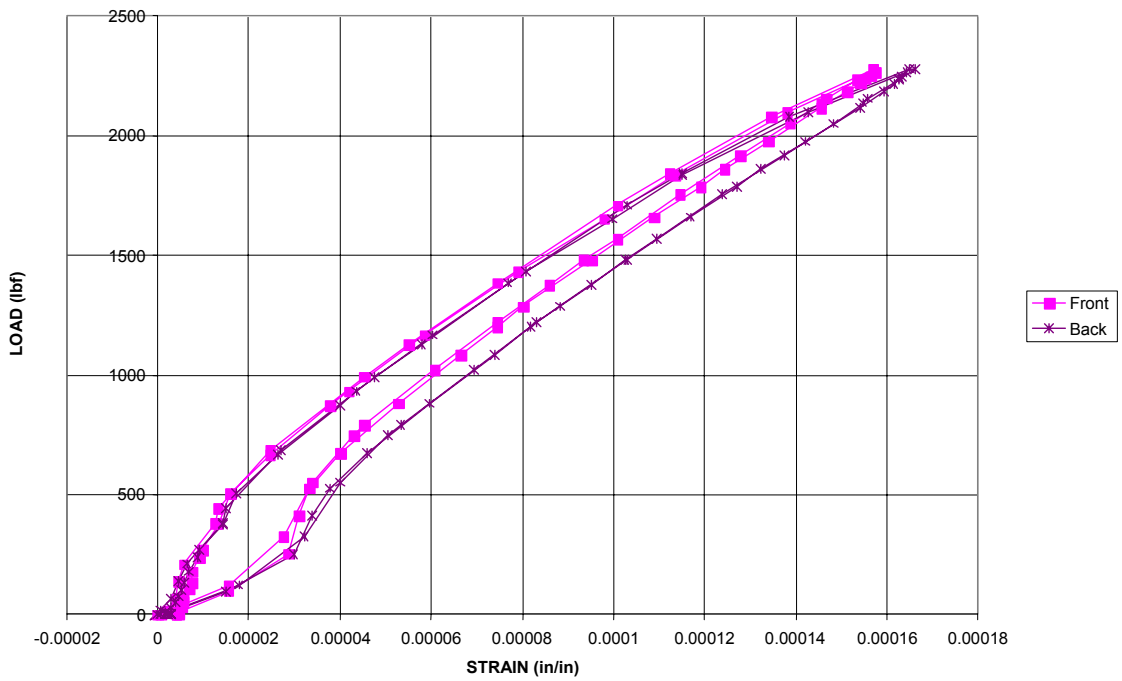

FIGURE F-53. STRAIN GAGE DATA, SCG-5, 52,500 CYCLES BEFORE

F.5 SPECIMEN SCG-6 CALIBRATION DATA.

Specimen SCG-6 has 0.120″ aluminum doublers and was cycled at a constant amplitude of 12.5 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection.

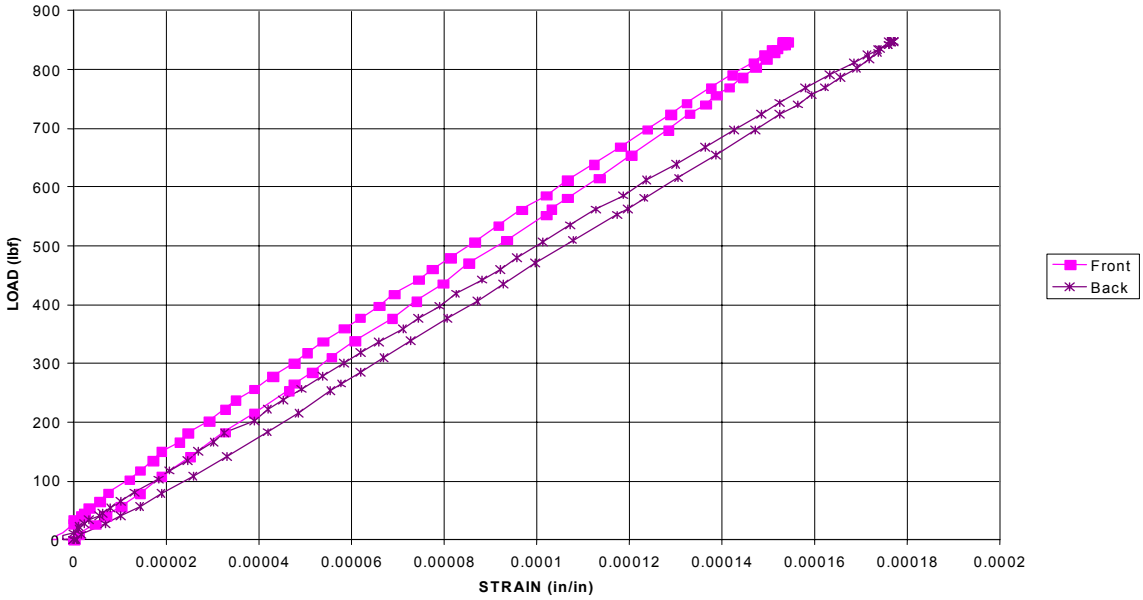

FIGURE F-54. STRAIN GAGE DATA, SCG-6, CALIBRATION #1

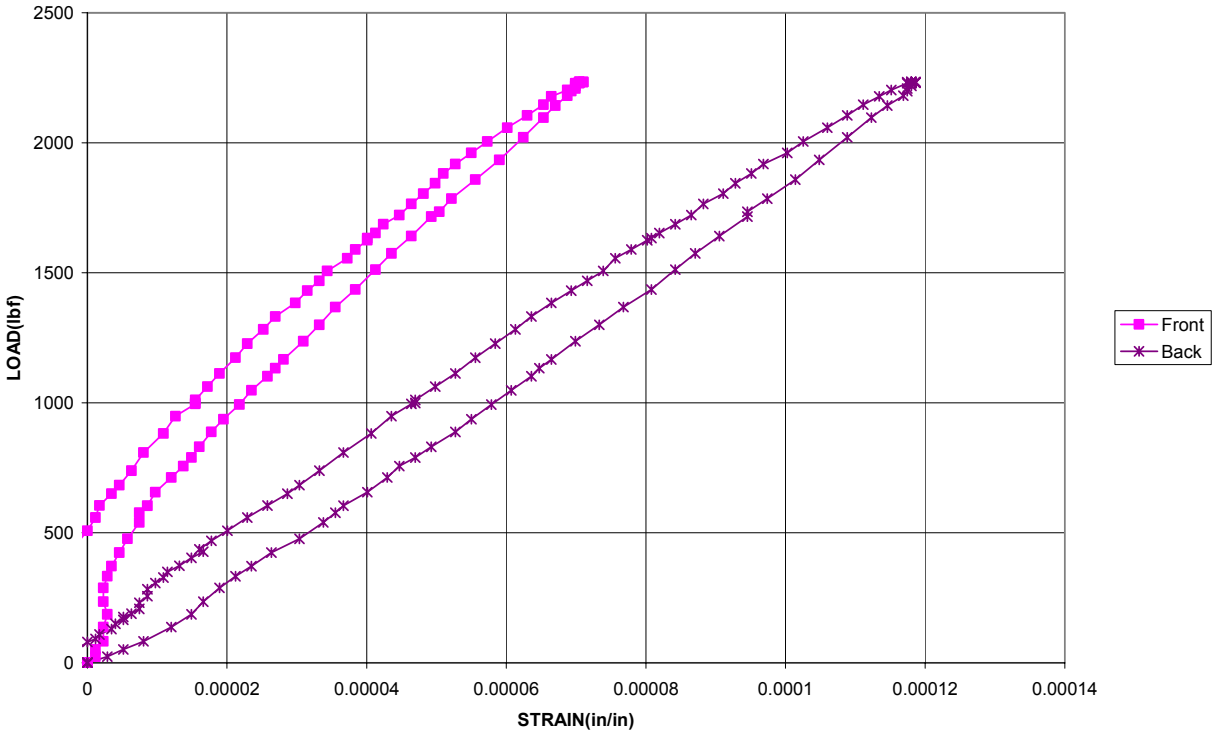

FIGURE F-55. STRAIN GAGE DATA, SCG-6, 0 CYCLES NEW

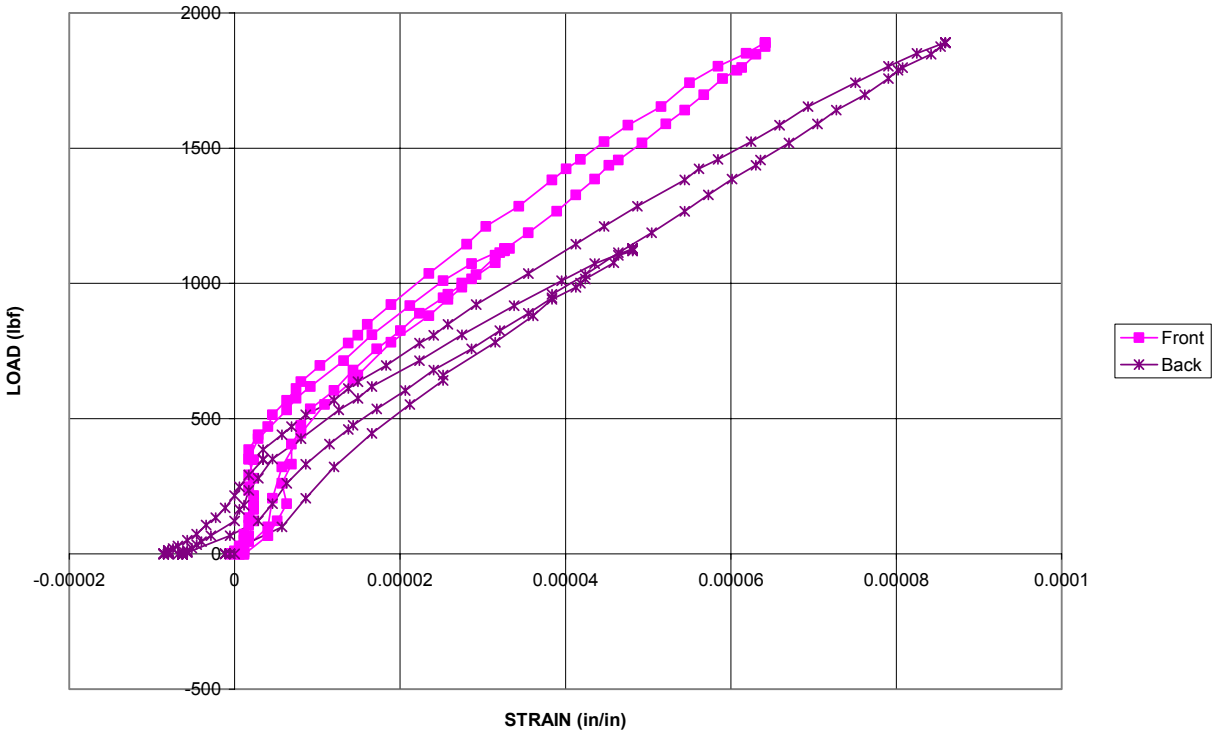

FIGURE F-56. STRAIN GAGE DATA, SCG-6, 0 CYCLES REDO

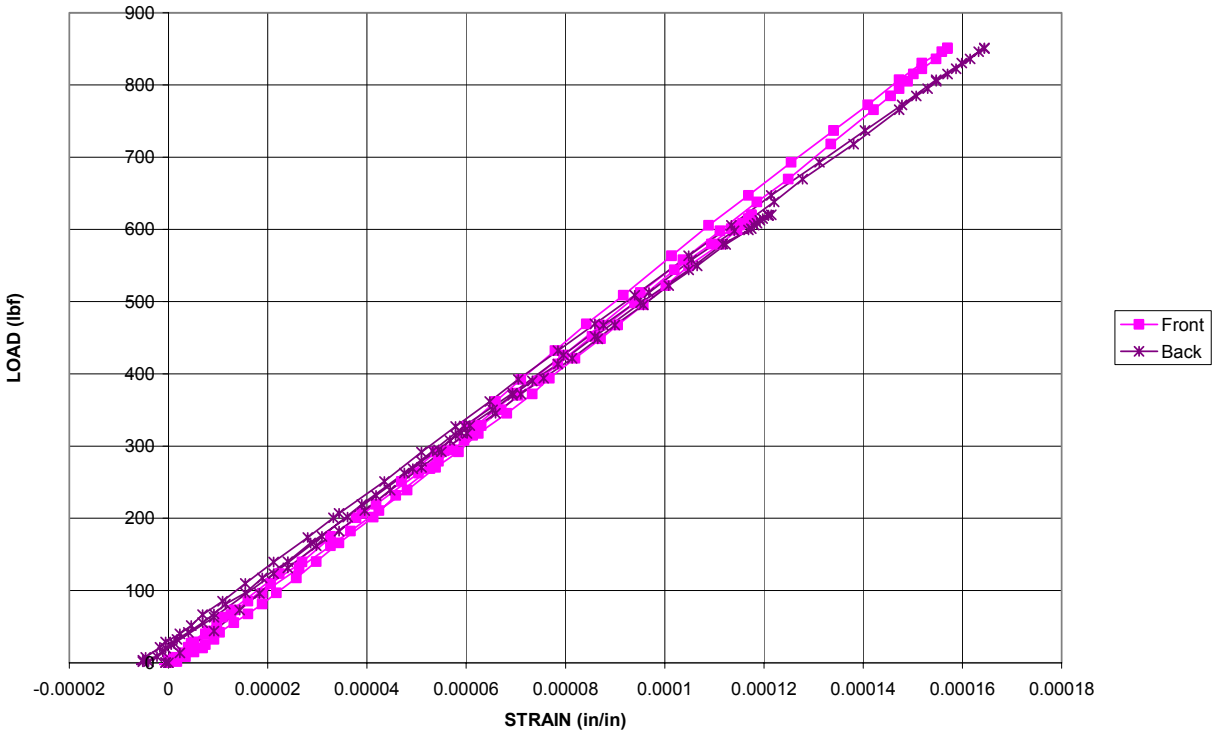

FIGURE F-57. STRAIN GAGE DATA, SCG-6, CALIBRATION #2

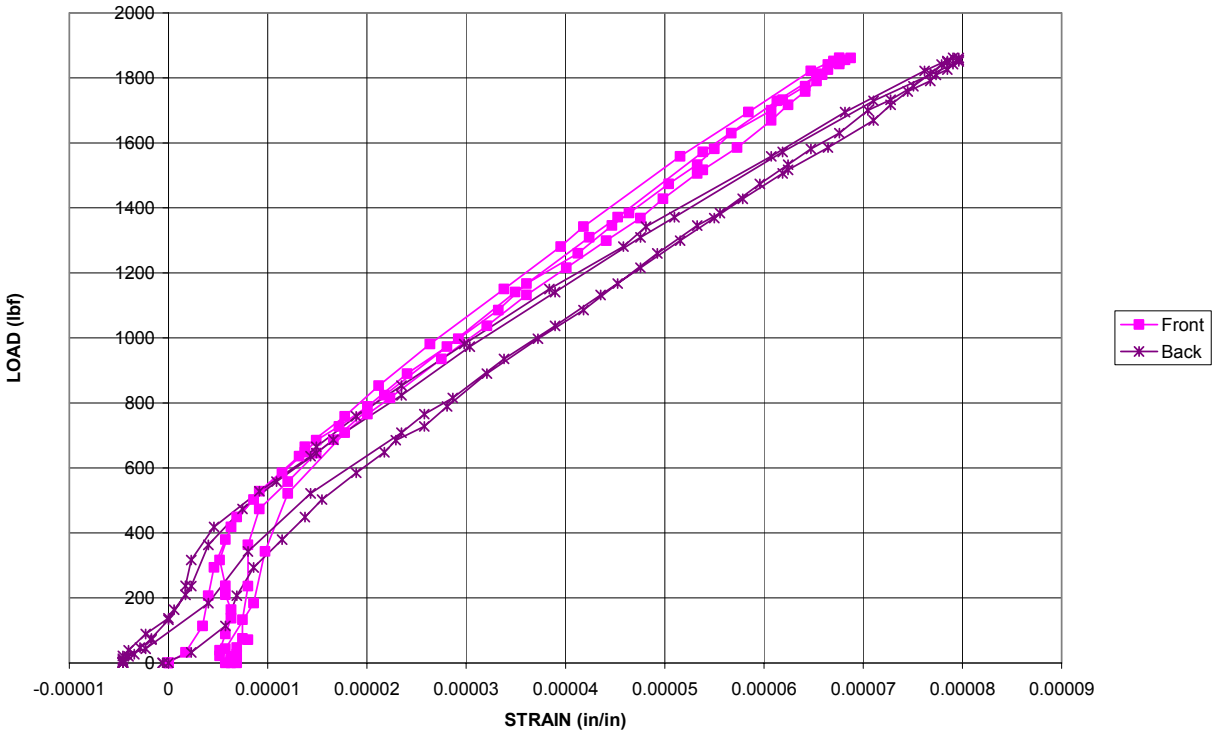

FIGURE F-58. STRAIN GAGE DATA, SCG-6, 0 CYCLES

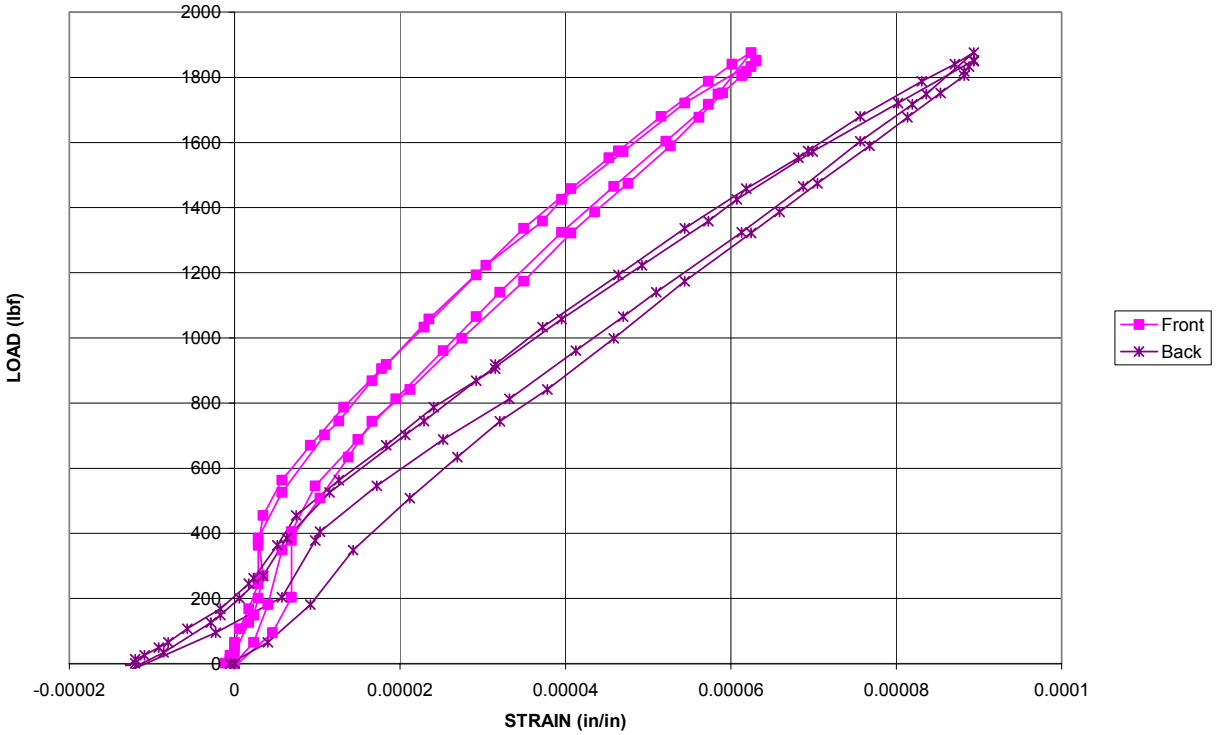

FIGURE F-59. STRAIN GAGE DATA, SCG-6, 5200 CYCLES

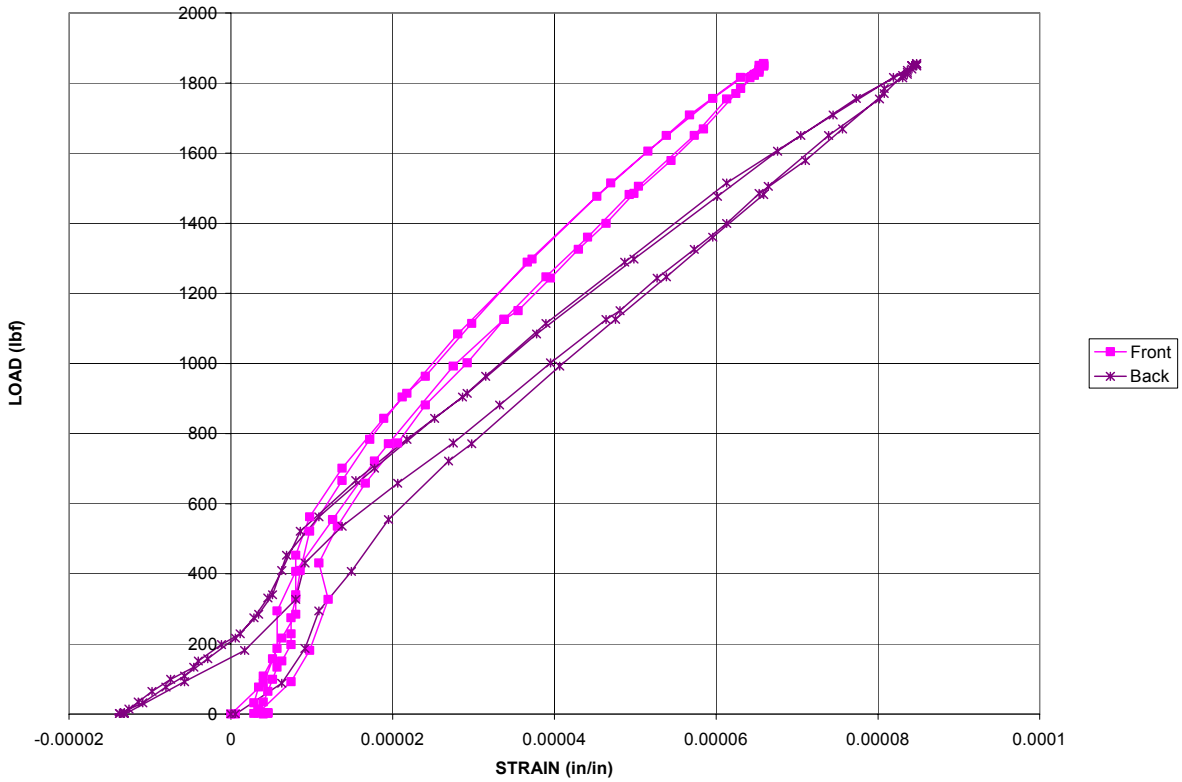

FIGURE F-60. STRAIN GAGE DATA, SCG-6, 10,400 CYCLES

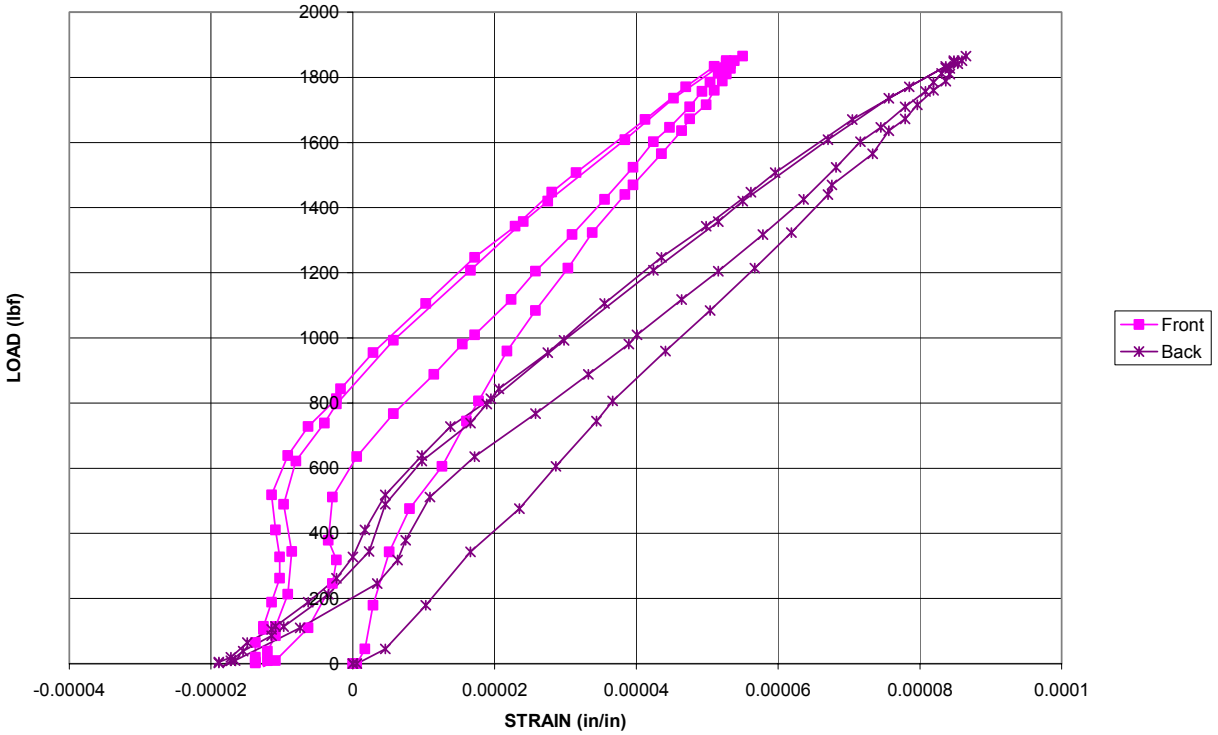

FIGURE F-61. STRAIN GAGE DATA, SCG-6, 20,800 CYCLES

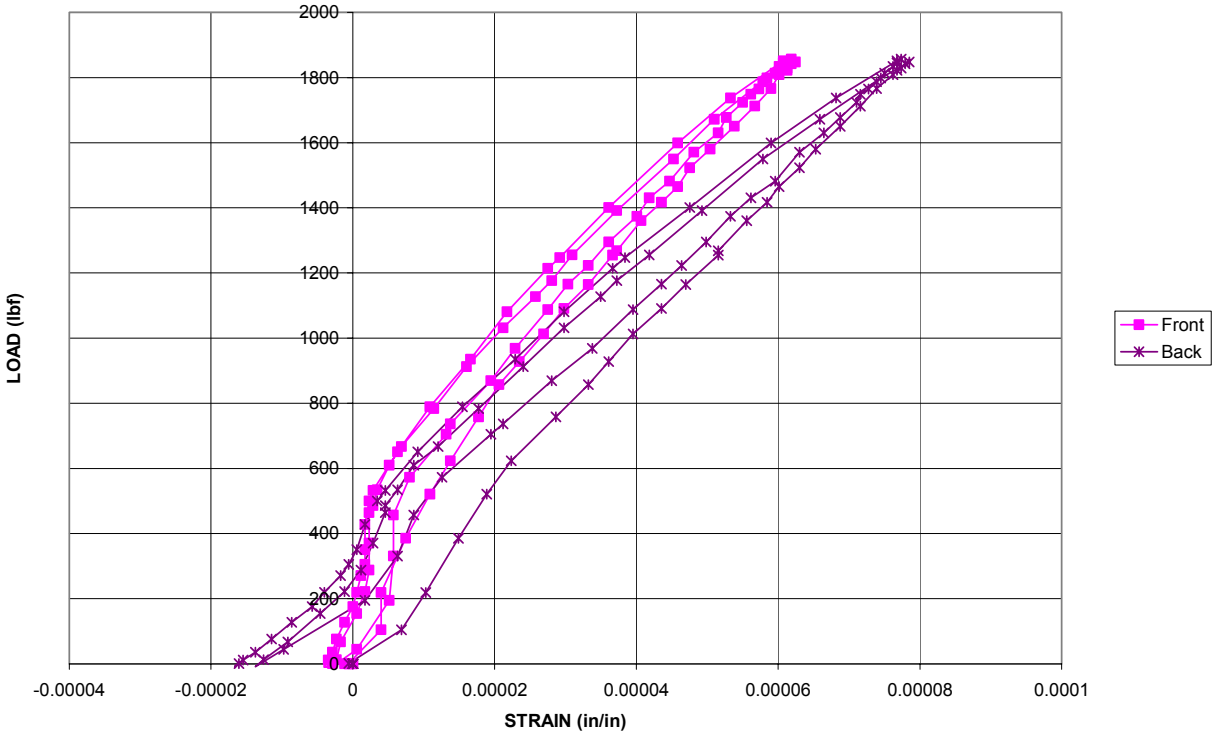

FIGURE F-62. STRAIN GAGE DATA, SCG-6, 28,600 CYCLES

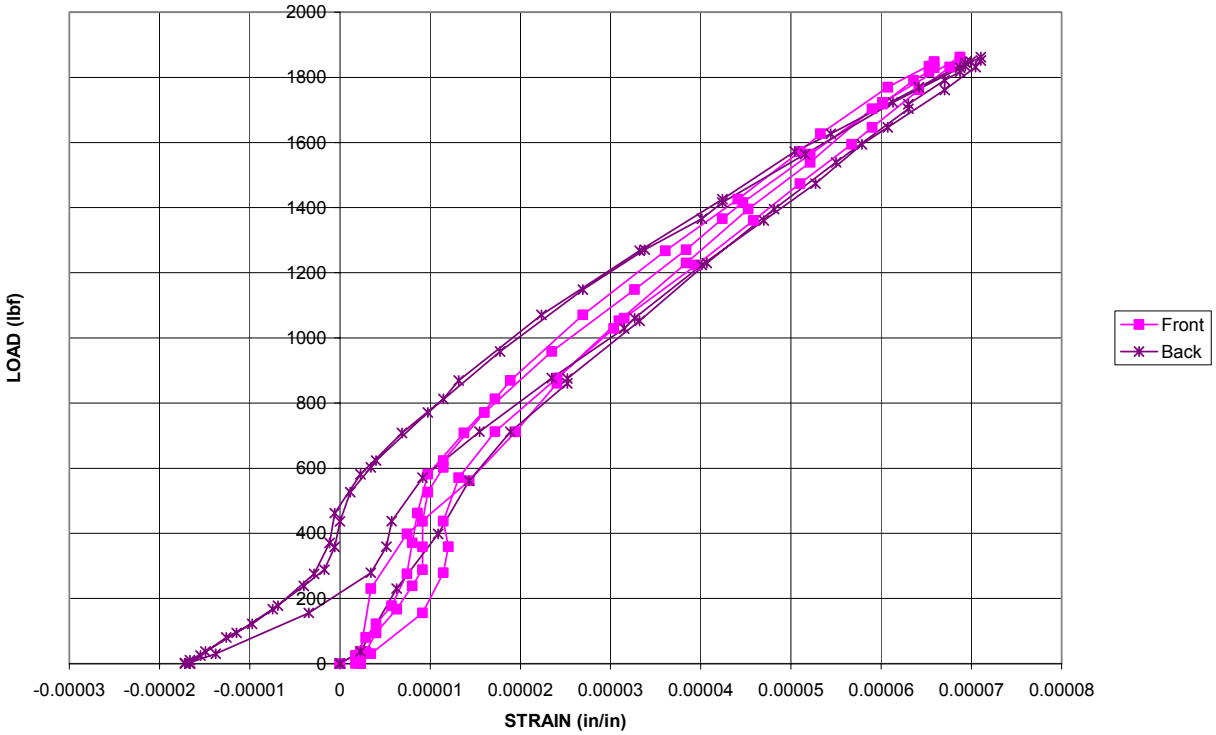

FIGURE F-63. STRAIN GAGE DATA, SCG-6, 36,600 CYCLES

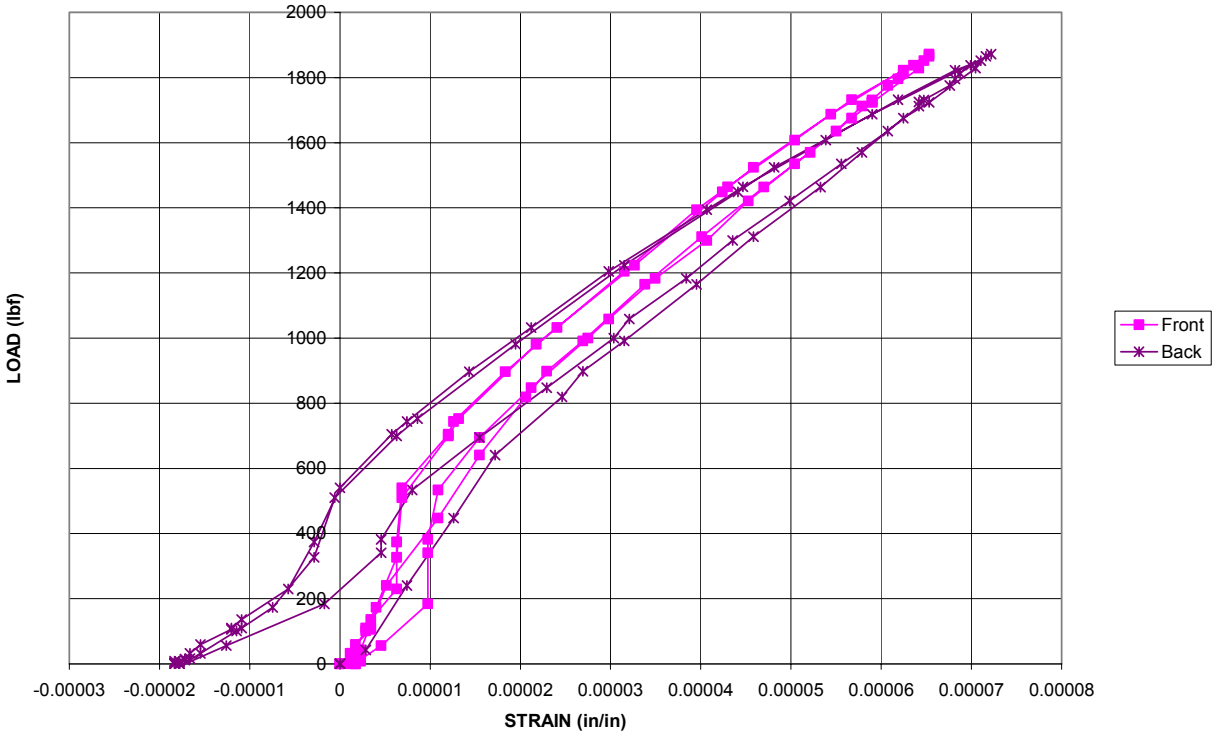

FIGURE F-64. STRAIN GAGE DATA, SCG-6, 44,000 CYCLES

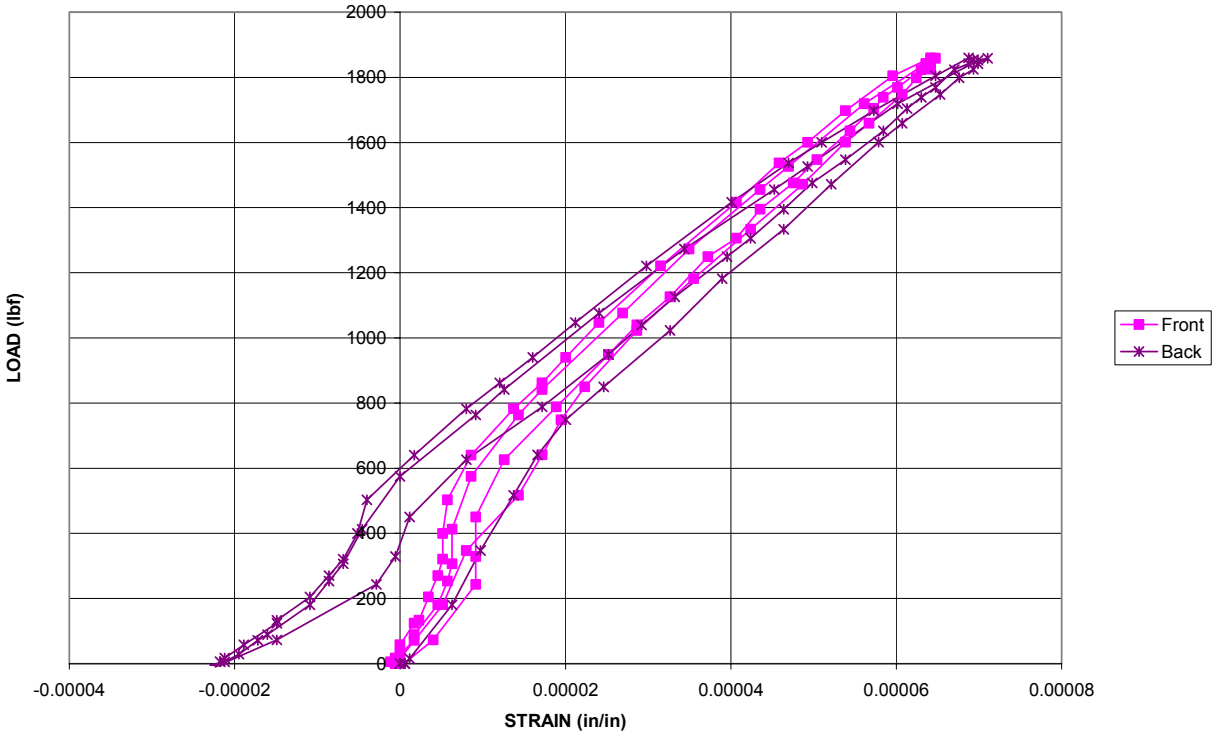

FIGURE F-65. STRAIN GAGE DATA, SCG-6, 52,200 CYCLES

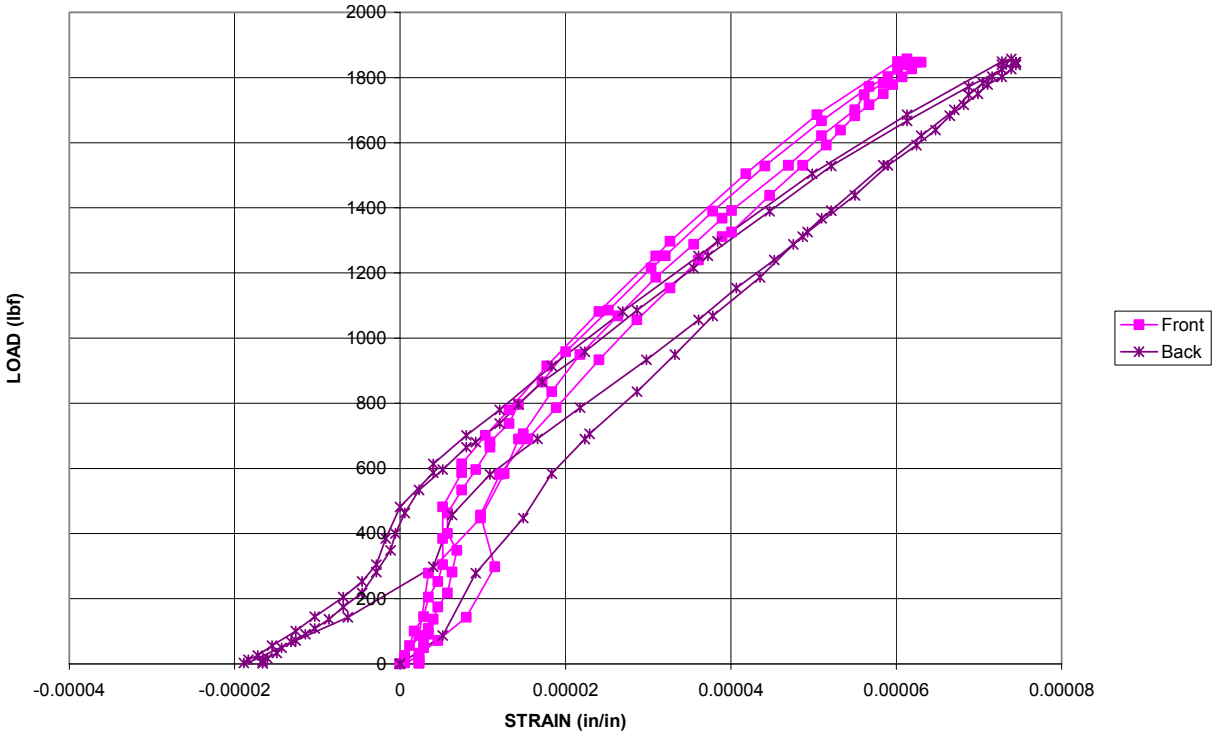

FIGURE F-66. STRAIN GAGE DATA, SCG-6, 62,600 CYCLES

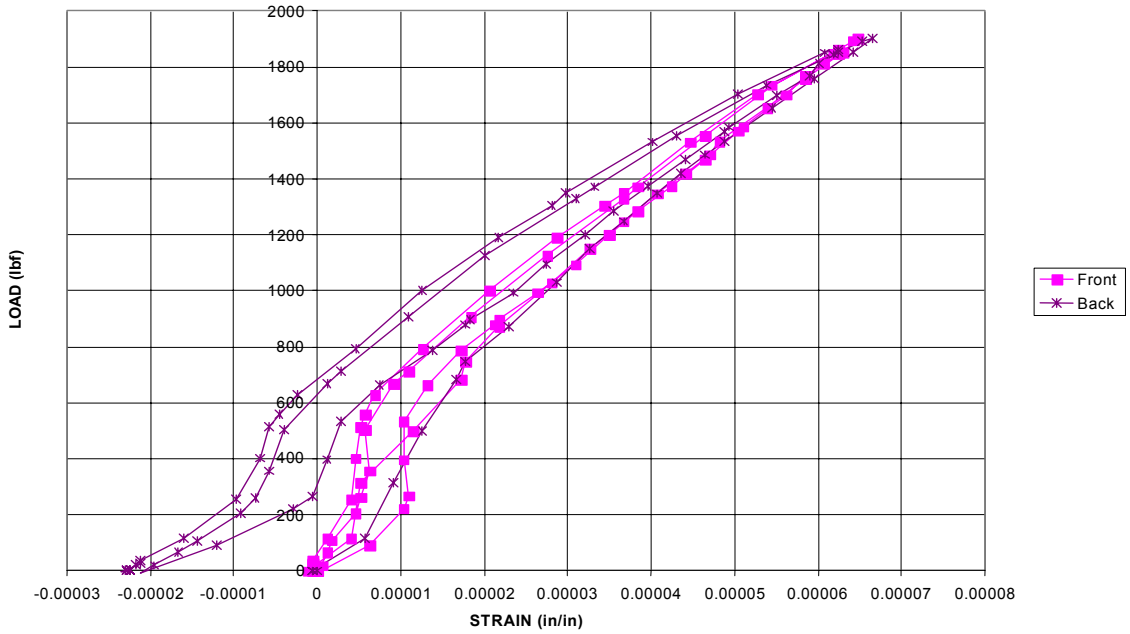

FIGURE F-67. STRAIN GAGE DATA, SCG-6, 73,000 CYCLES

F.6 SPECIMEN SCG-7 CALIBRATION DATA.

Specimen SCG-7 has 0.120″ aluminum doublers and was cycled at a constant amplitude of 12.5 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection.

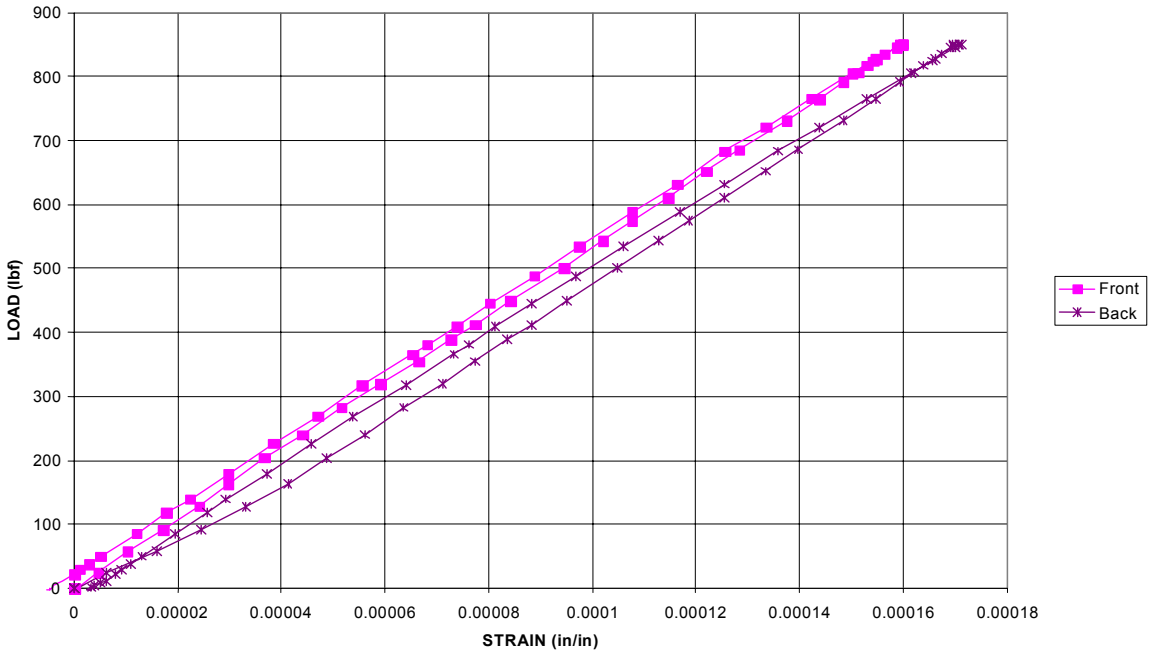

FIGURE F-68. STRAIN GAGE DATA, SCG-7, CALIBRATION #1

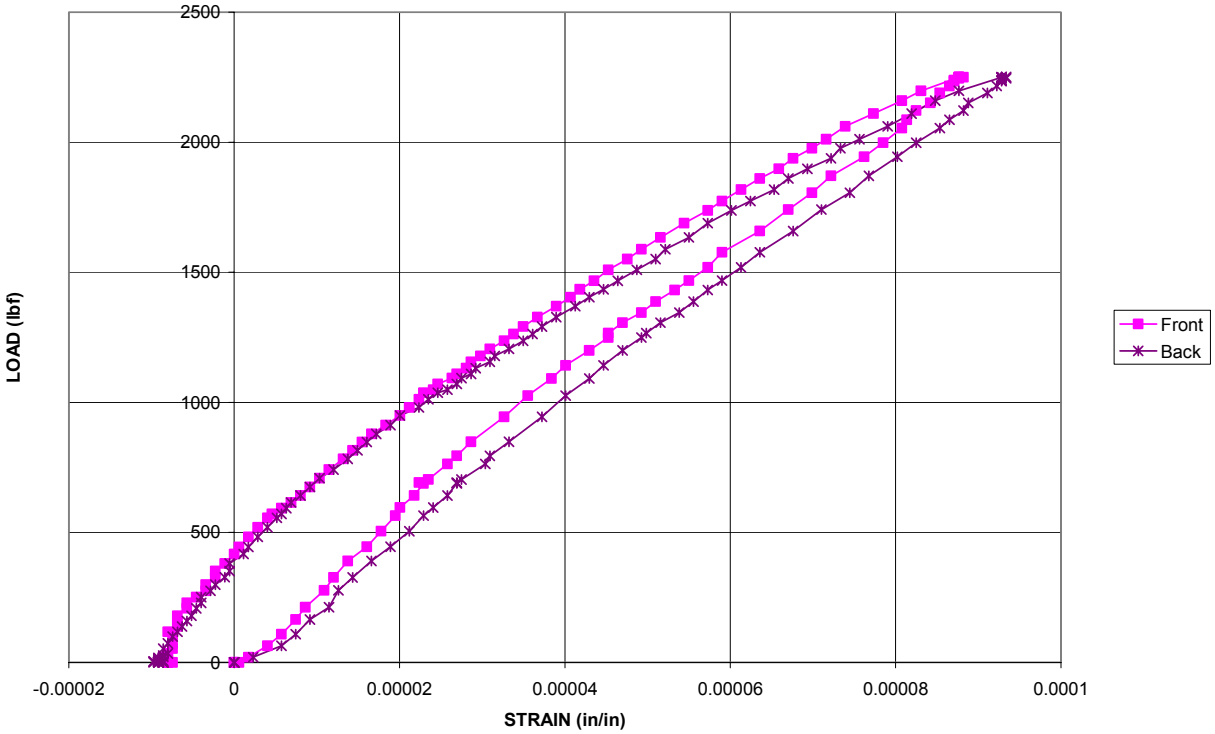

FIGURE F-69. STRAIN GAGE DATA, SCG-7, 0 CYCLES NEW

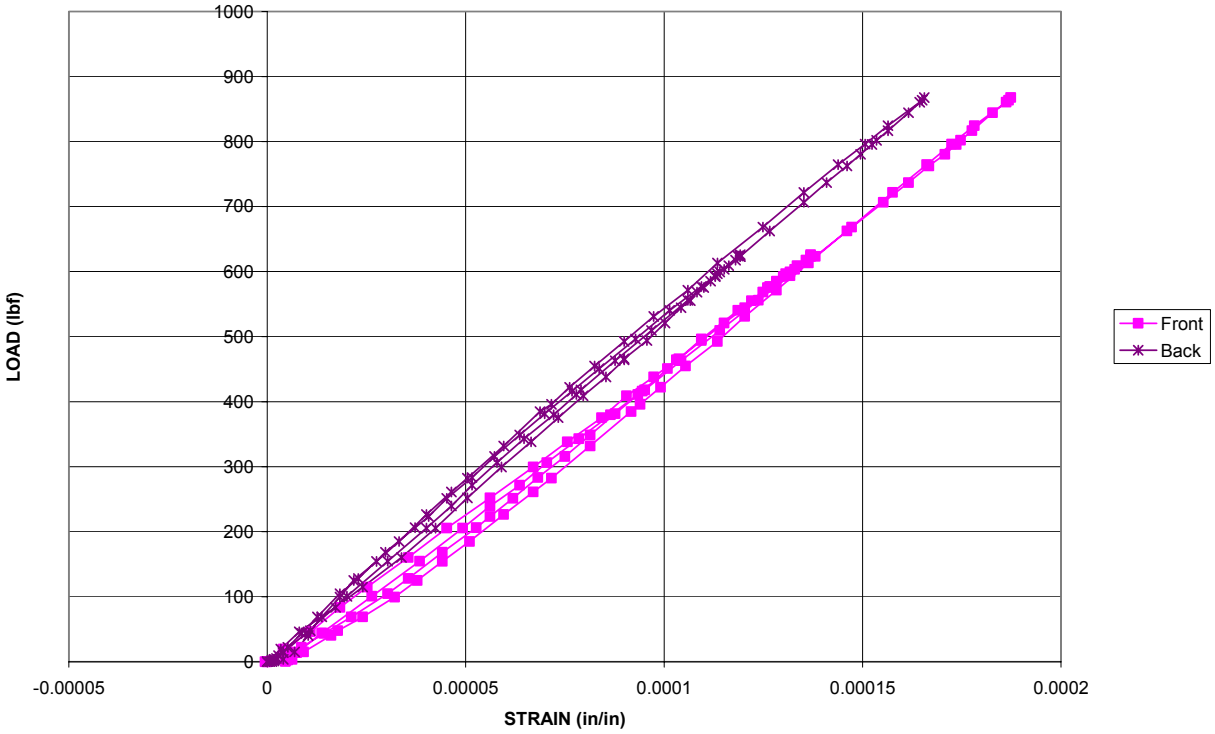

FIGURE F-70. STRAIN GAGE DATA, SCG-7, CALIBRATION #2

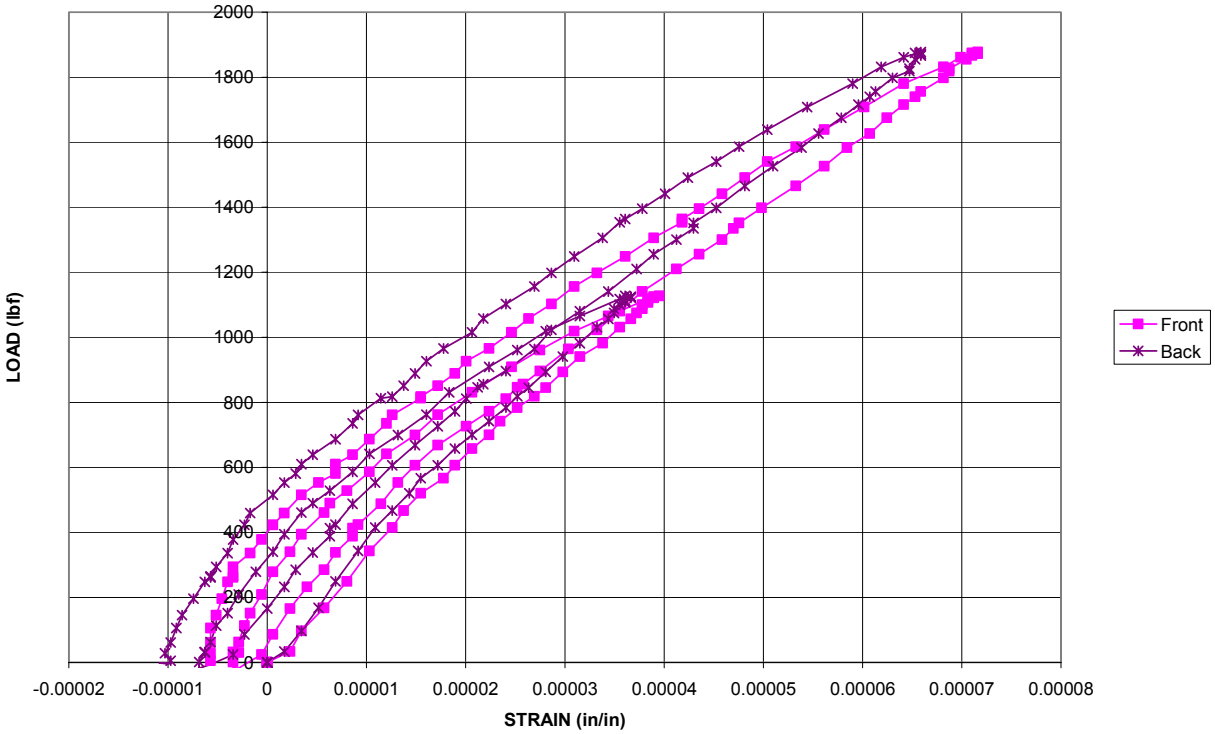

FIGURE F-71. STRAIN GAGE DATA, SCG-7, 0 CYCLES REDO

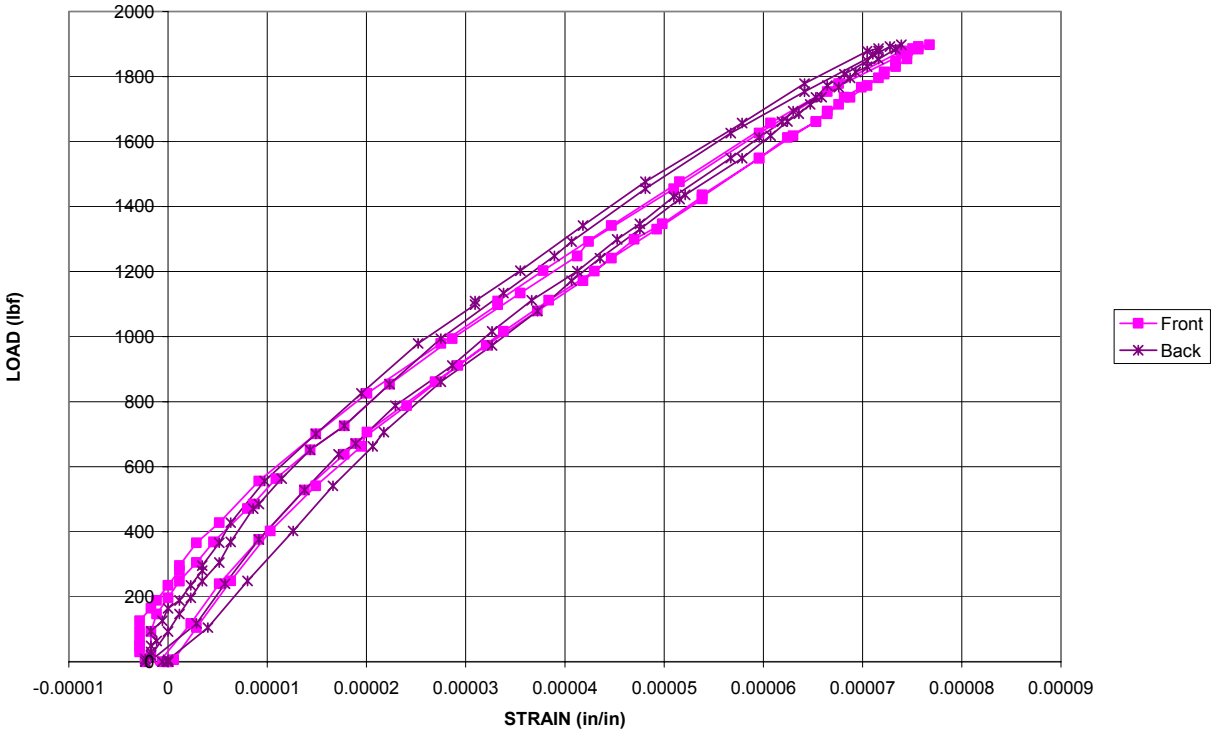

FIGURE F-72. STRAIN GAGE DATA, SCG-7, 0 CYCLES NEW STRAIN SURVEY

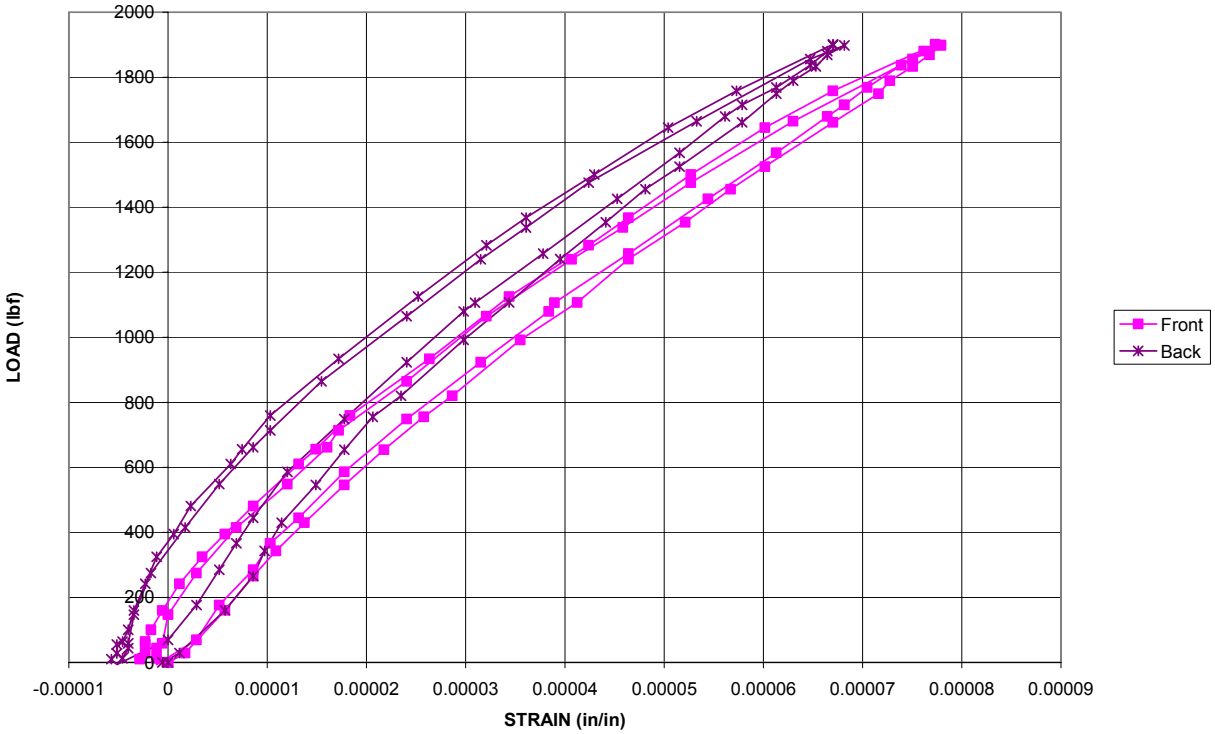

FIGURE F-73. STRAIN GAGE DATA, SCG-7, 2000 CYCLES

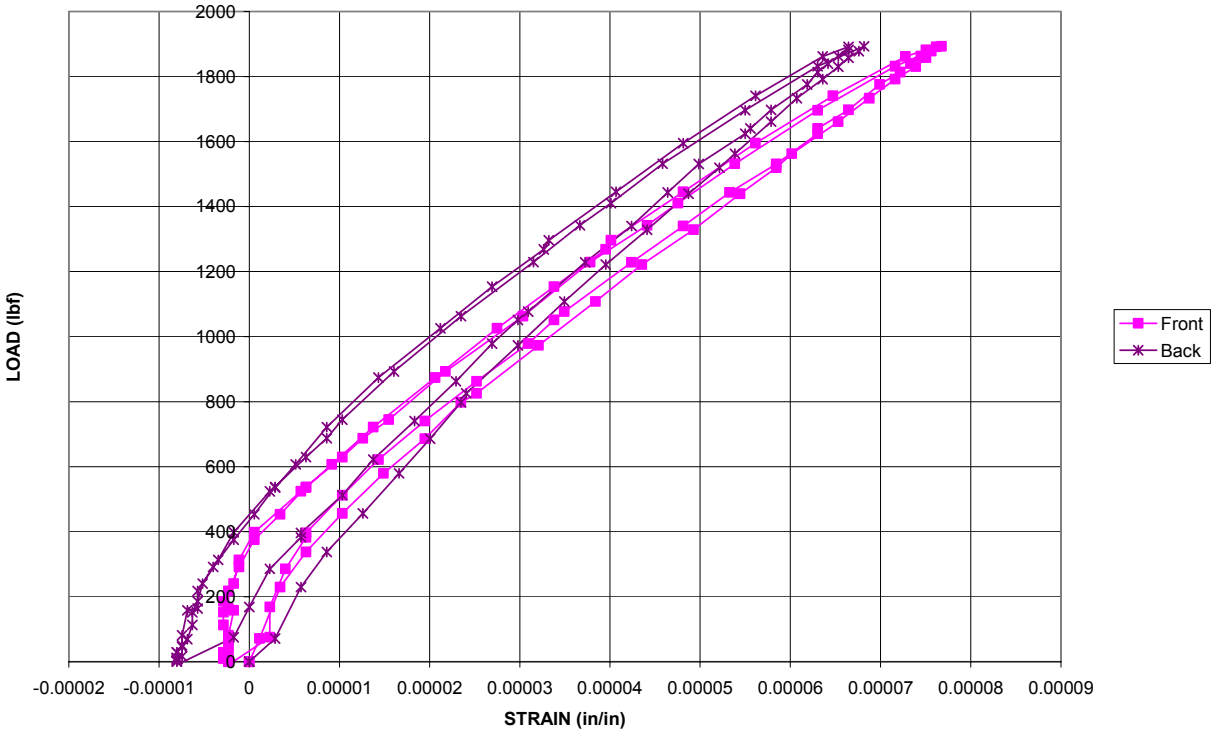

FIGURE F-74. STRAIN GAGE DATA, SCG-7, 7200 CYCLES

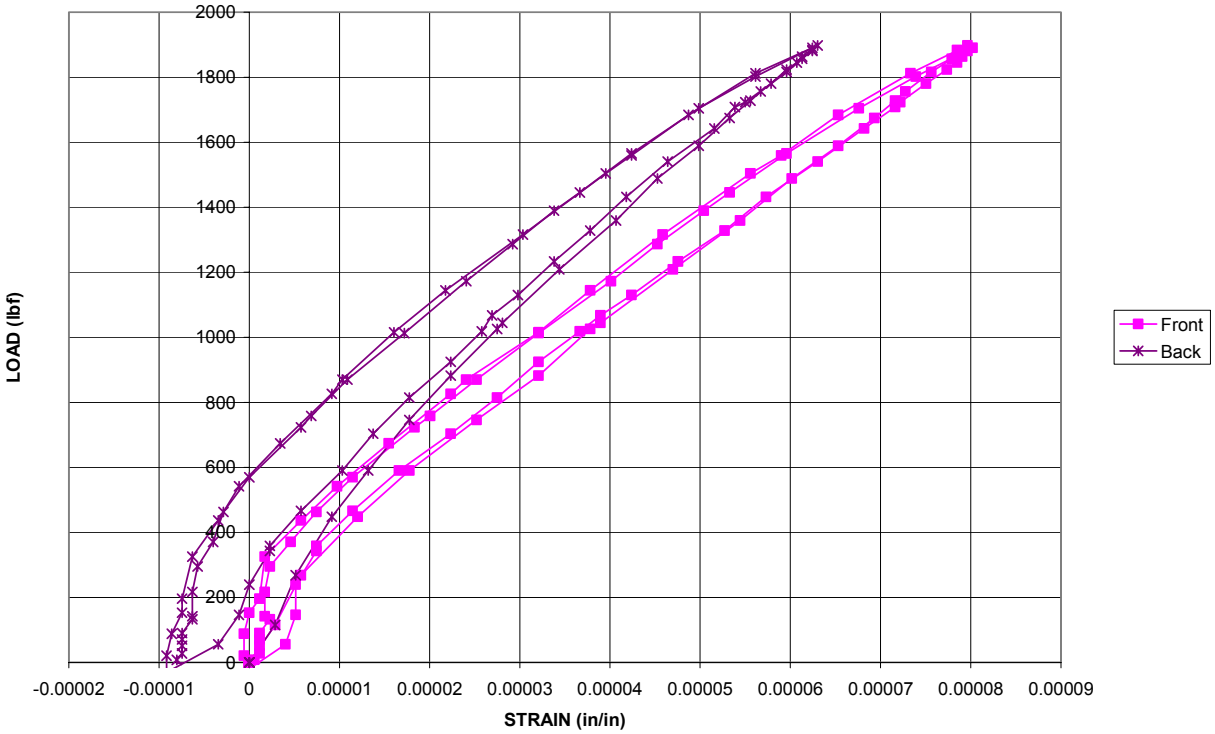

FIGURE F-75. STRAIN GAGE DATA, SCG-7, 12,400 CYCLES

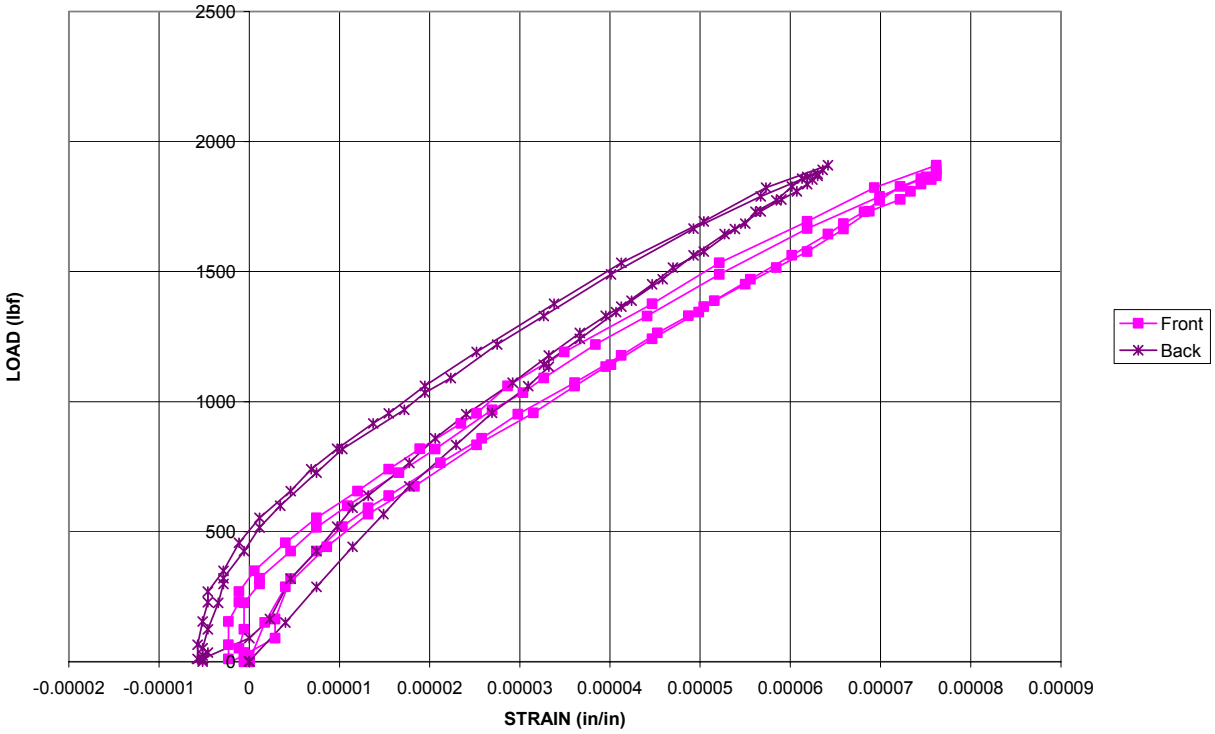

FIGURE F-76. STRAIN GAGE DATA, SCG-7, 22,800 CYCLES

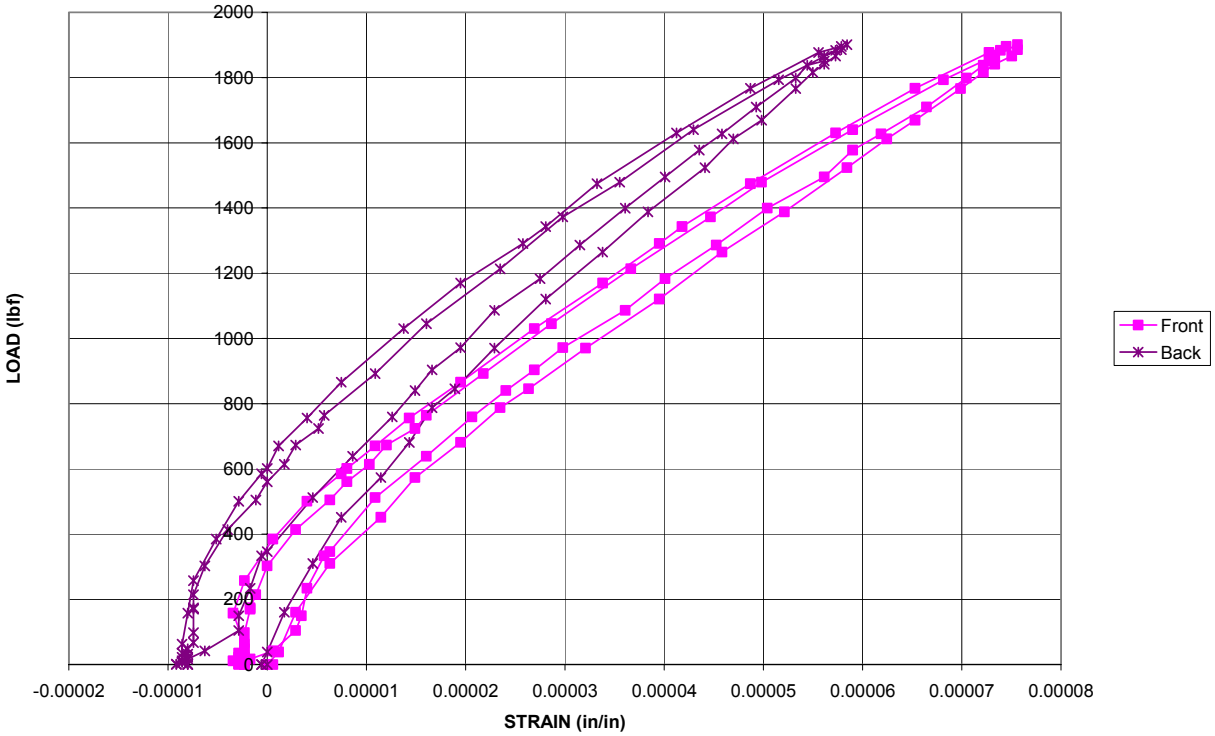

FIGURE F-77. STRAIN GAGE DATA, SCG-7, 30,300 CYCLES

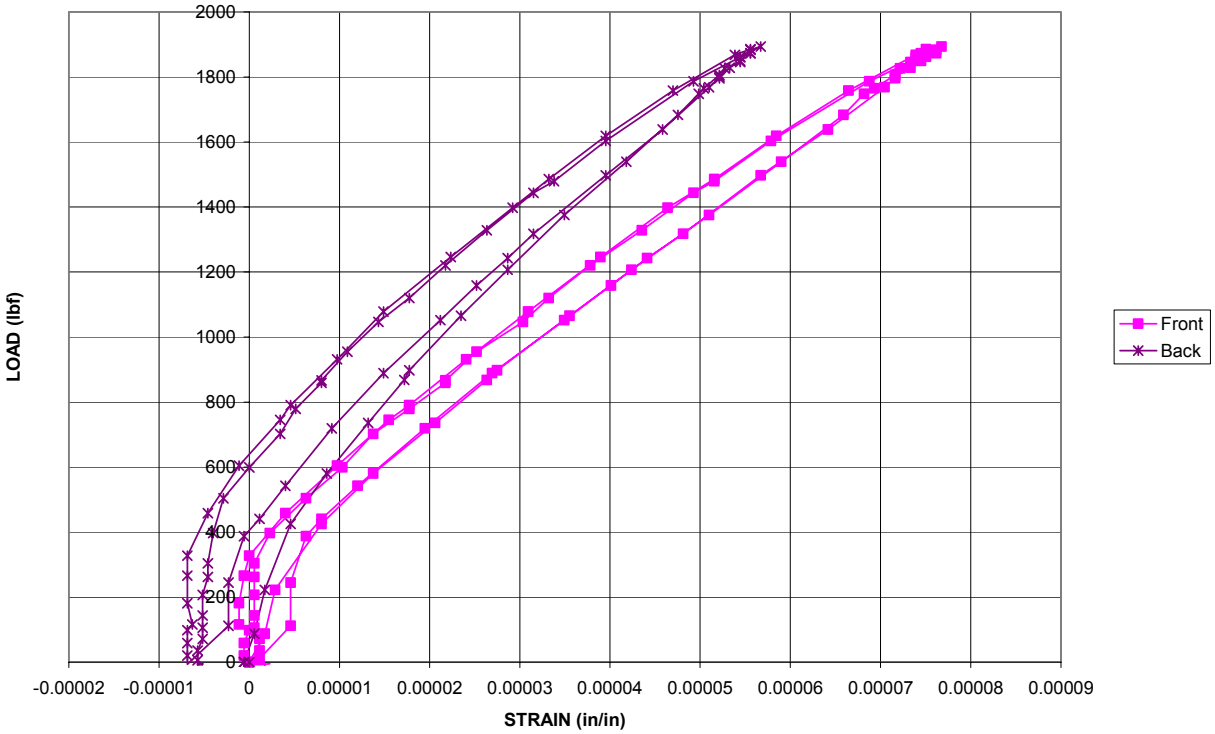

FIGURE F-78. STRAIN GAGE DATA, SCG-7, 37,800 CYCLES

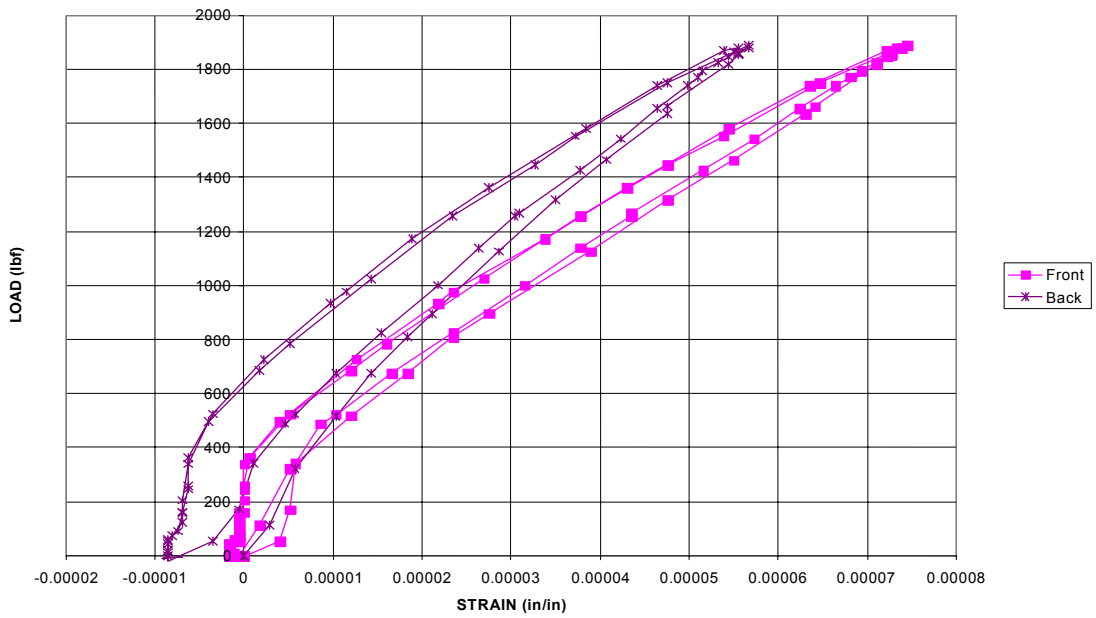

FIGURE F-79. STRAIN GAGE DATA, SCG-7, 45,300 CYCLES

F.7 SPECIMEN SCG-8 CALIBRATION DATA.

Specimen SCG-8 has 0.120″ aluminum doublers; the EIFS spectrum was applied with a maximum stress of 13.4 ksi. Strain surveys were taken before and after the specimen was disassembled for periodic inspection.

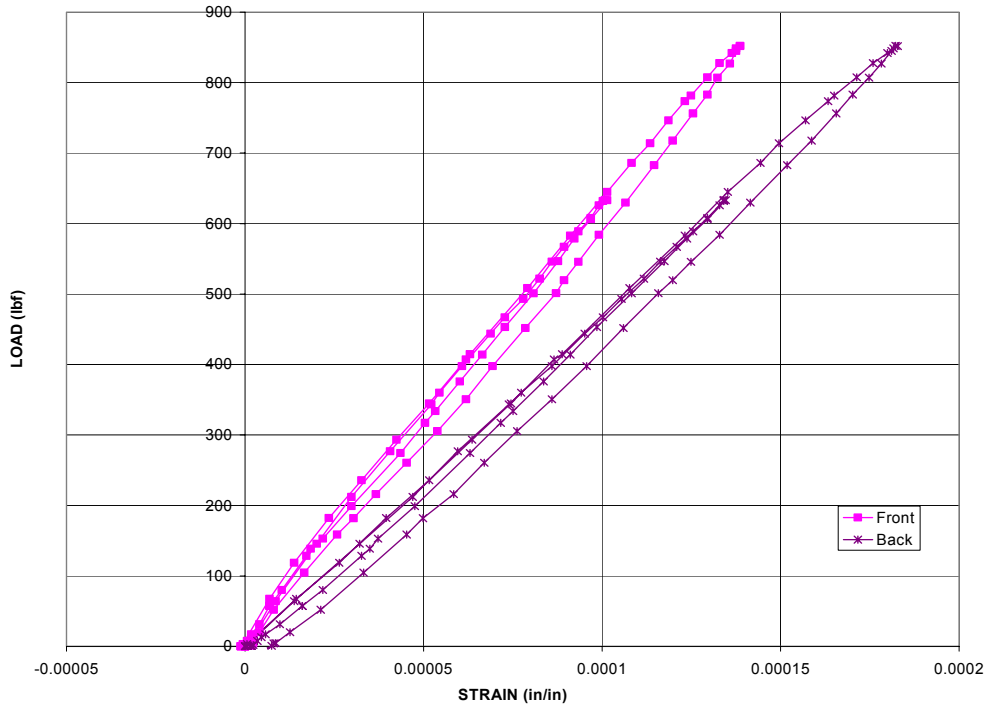

FIGURE F-80. STRAIN GAGE DATA, SCG-8, CALIBRATION

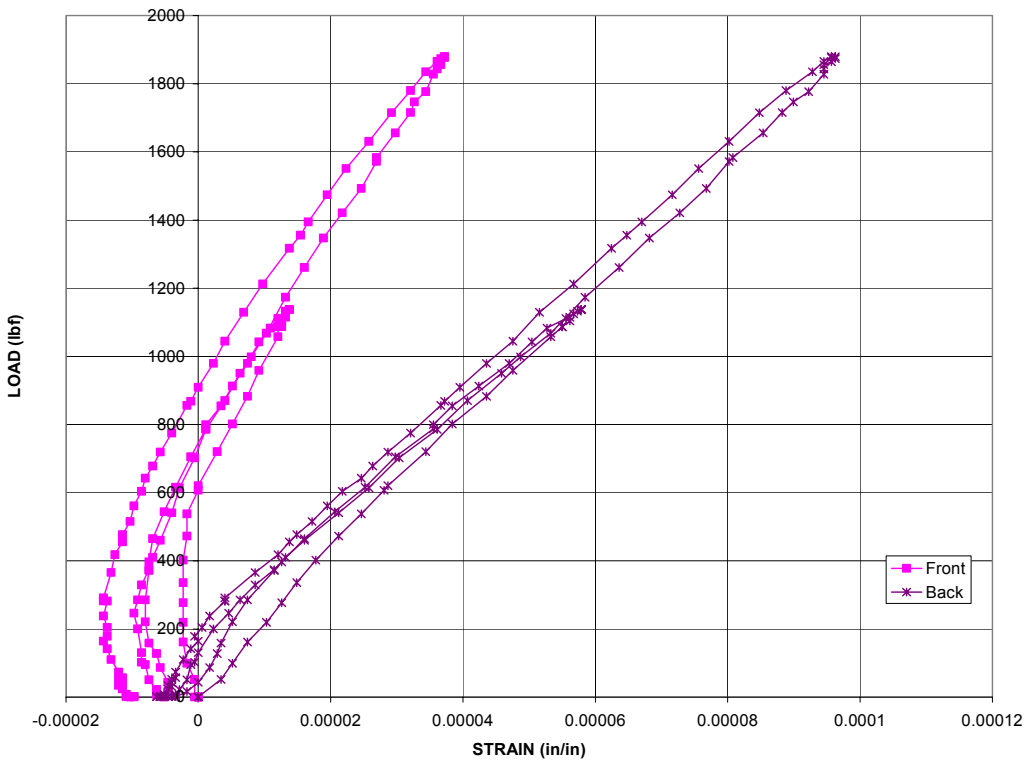

FIGURE F-81. STRAIN GAGE DATA, SCG-8, 0 CYCLES

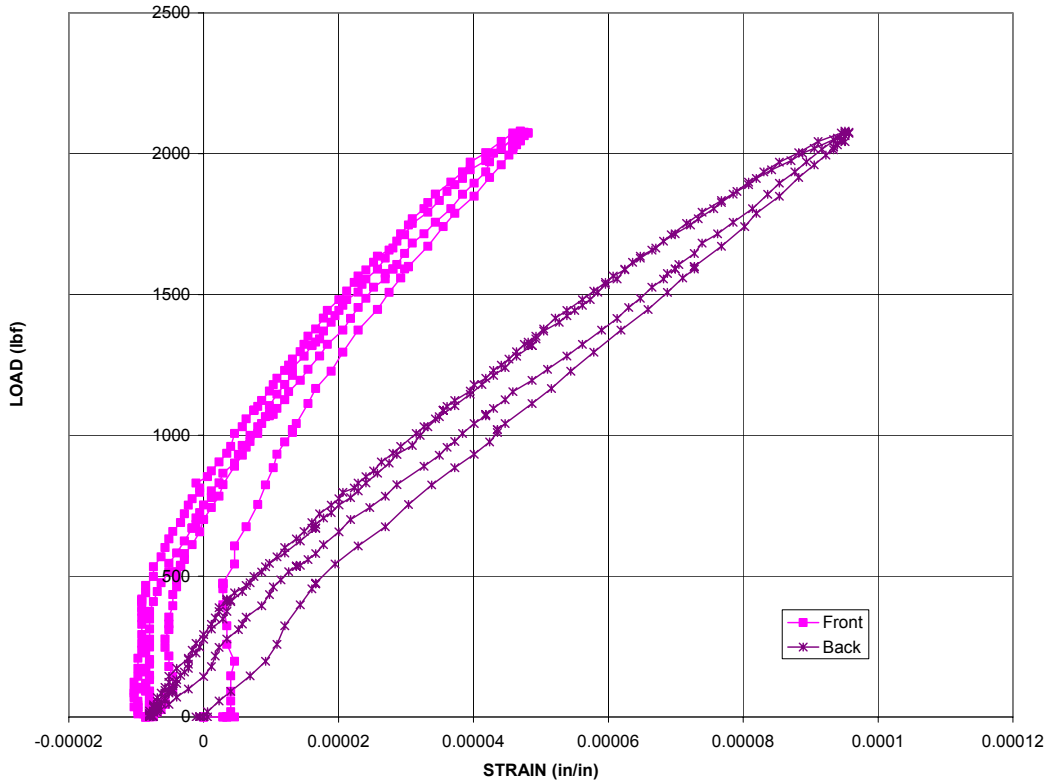

FIGURE F-82. STRAIN GAGE DATA, SCG-8, 325,000 CYCLES

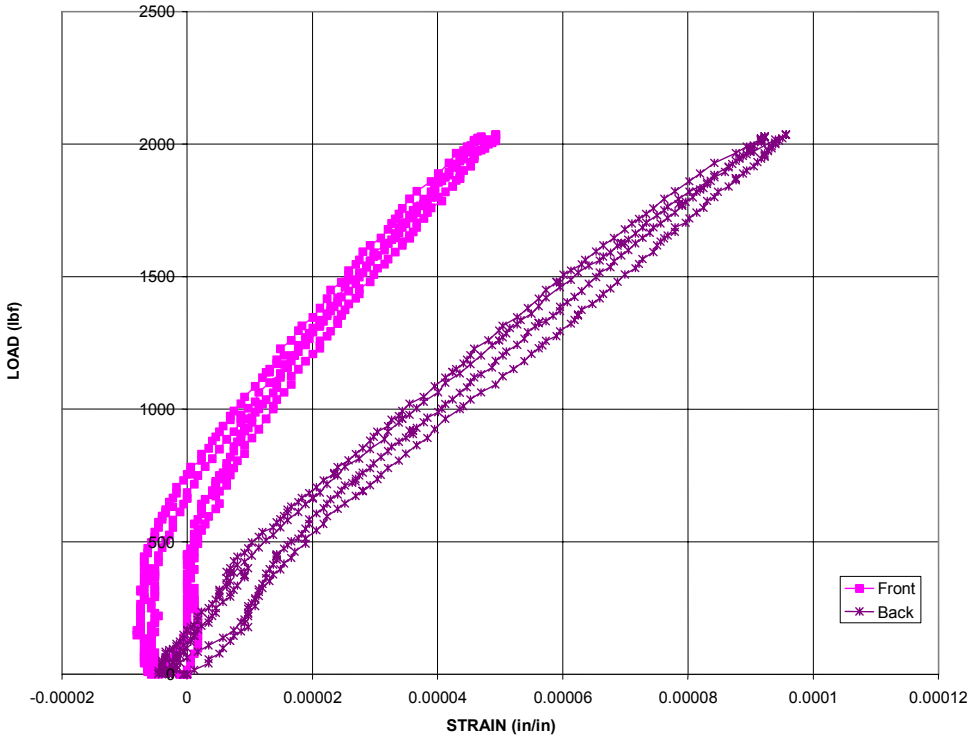

FIGURE F-83. STRAIN GAGE DATA, SCG-8, 725,000 CYCLES

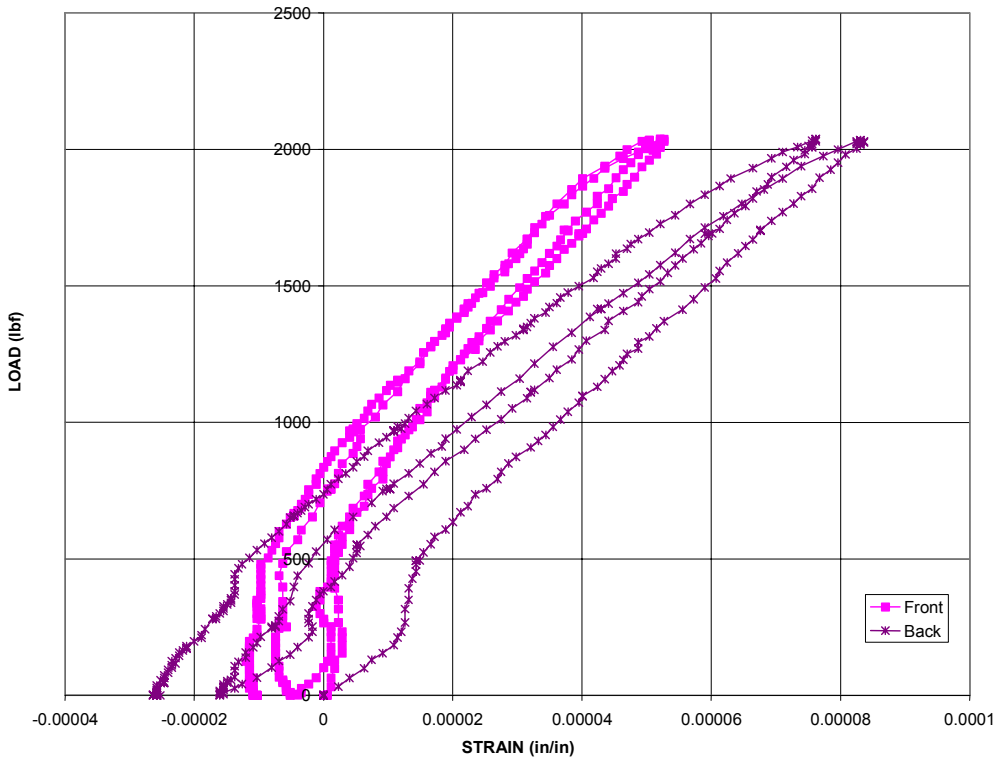

FIGURE F-84. STRAIN GAGE DATA, SCG-8, 825,000 CYCLES

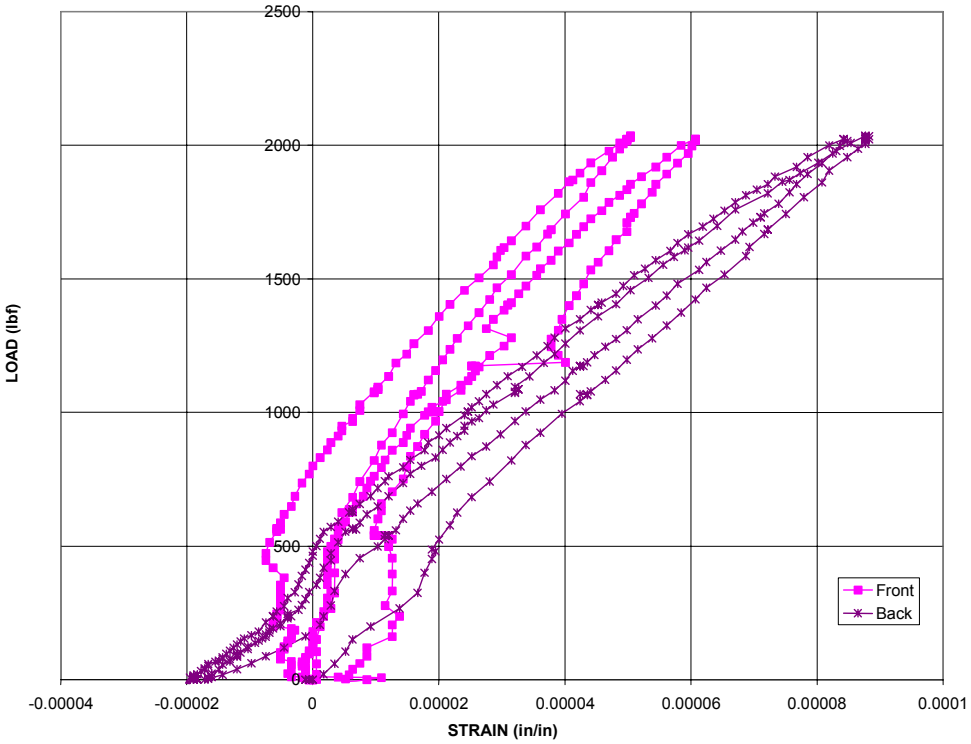

FIGURE F-85. STRAIN GAGE DATA, SCG-8, 925,000 CYCLES

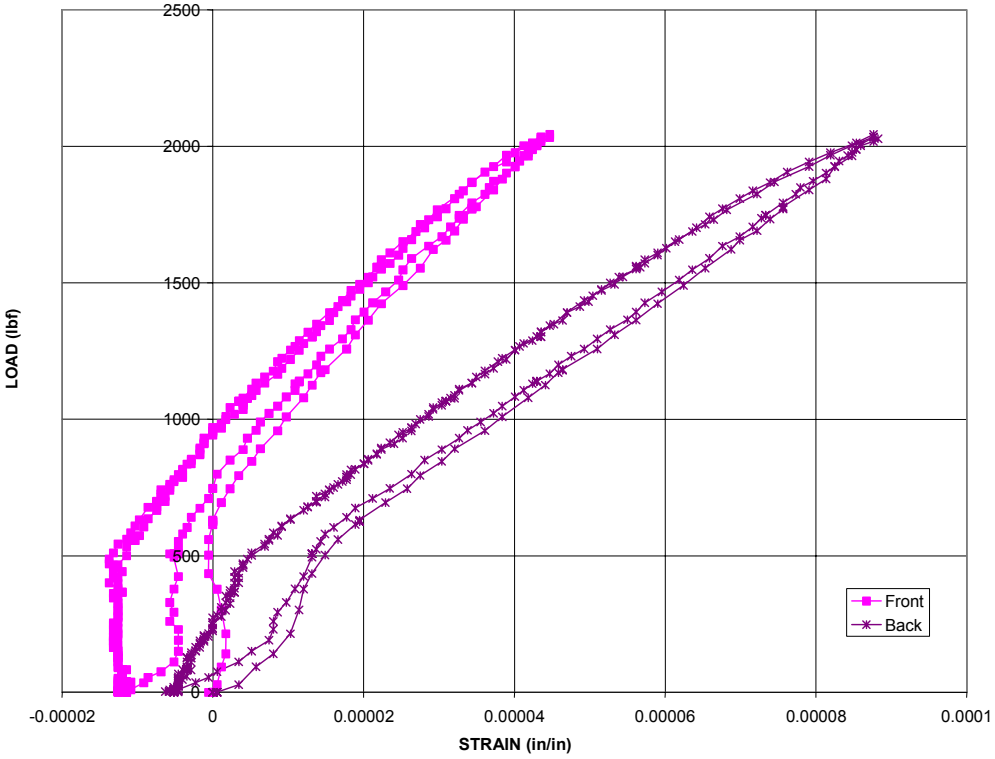

FIGURE F-86. STRAIN GAGE DATA, SCG-8, 1,025,000 CYCLES

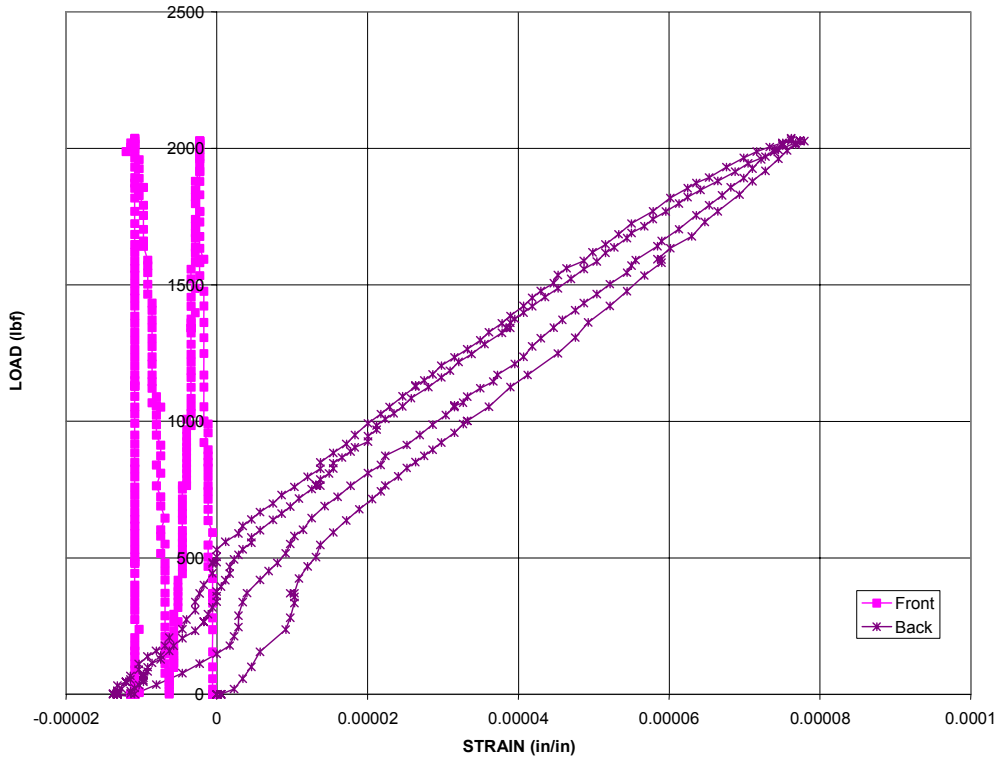

FIGURE F-87. STRAIN GAGE DATA, SCG-8, 1,125,000 CYCLES

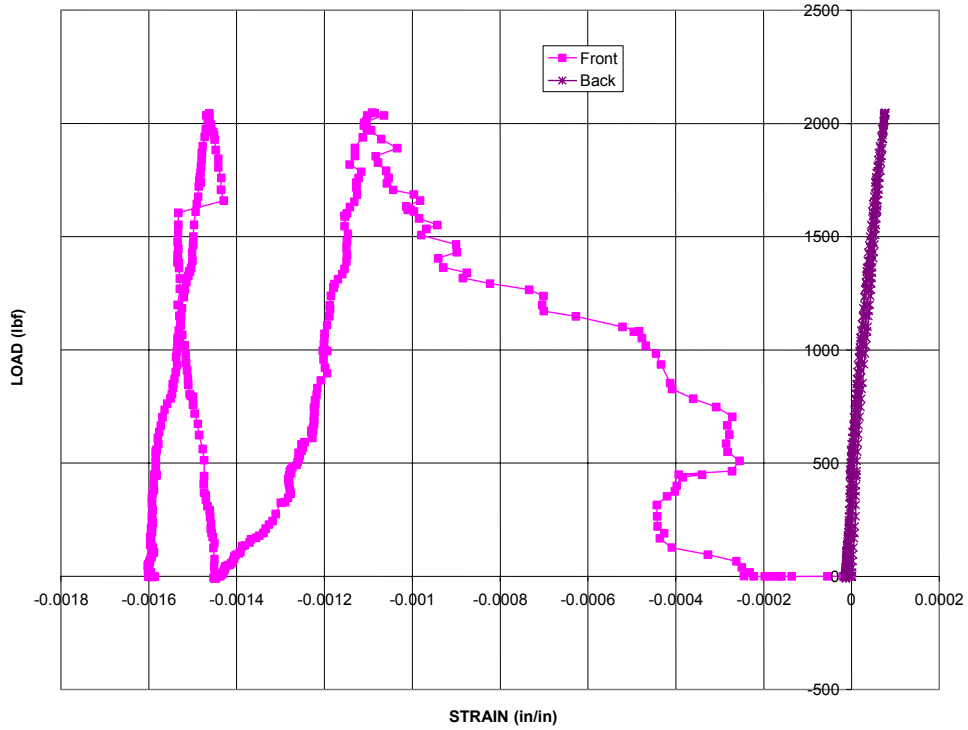

FIGURE F-88. STRAIN GAGE DATA, SCG-8, 1,225,000 CYCLES

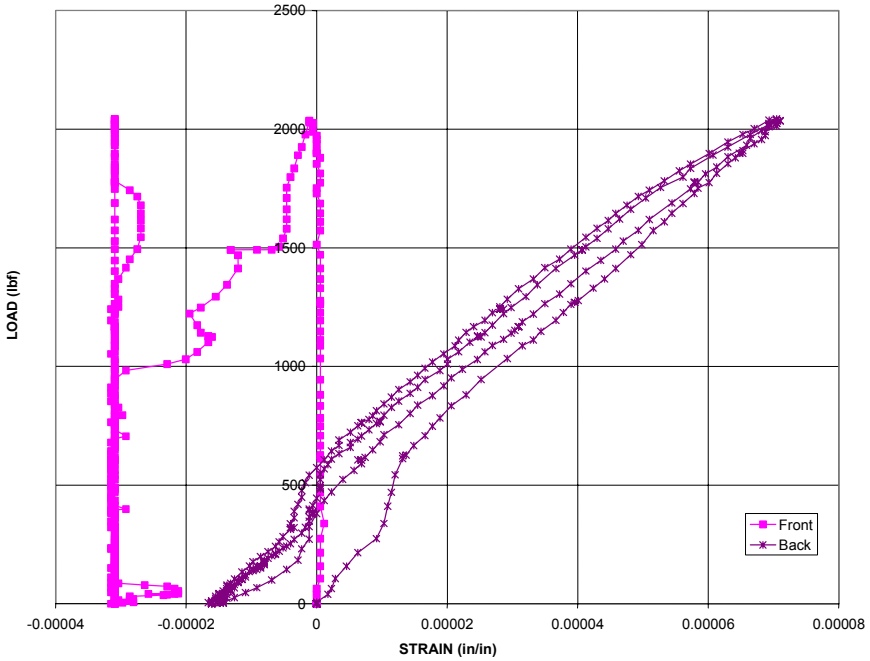

FIGURE F-89. STRAIN GAGE DATA, SCG-8, 1,325,000 CYCLES

F.8 SPECIMEN SCG-9 CALIBRATION DATA.

Specimen SCG-9 has 0.120″ steel doublers and was tested under EIFS spectrum loads with maximum stress of 13.4 ksi. Strain surveys were taken before and after the specimen was disassembled for periodic inspection.

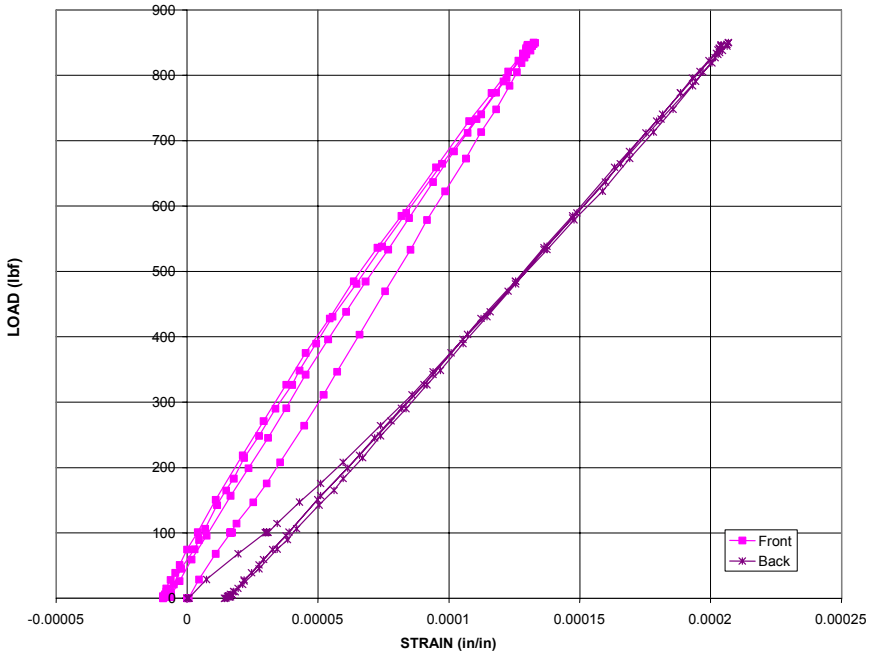

FIGURE F-90. STRAIN GAGE DATA, SCG-9, CALIBRATION #1

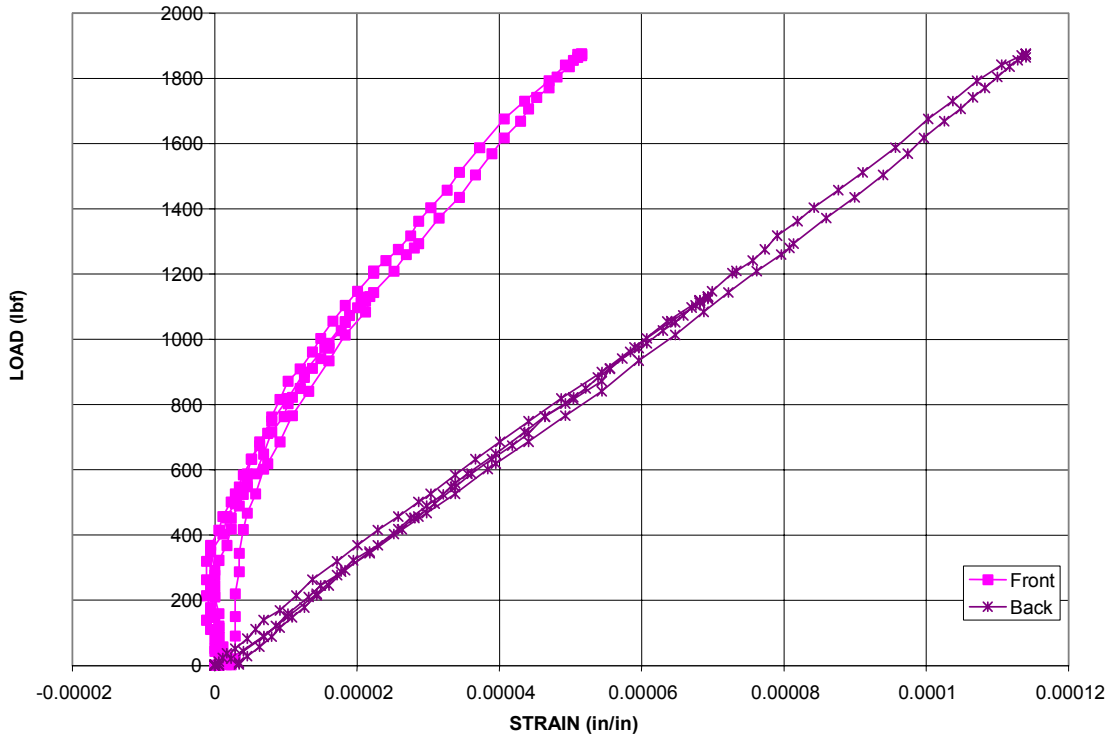

FIGURE F-91. STRAIN GAGE DATA, SCG-9, 0 CYCLES

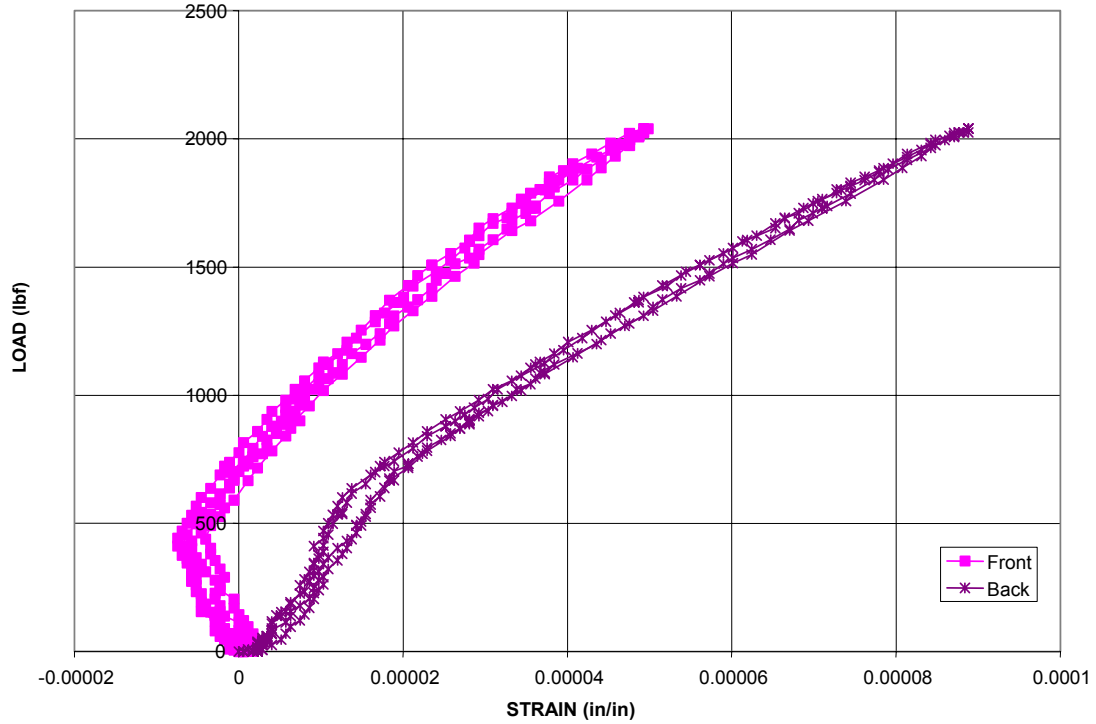

FIGURE F-92. STRAIN GAGE DATA, SCG-9, 1,100,000 CYCLES

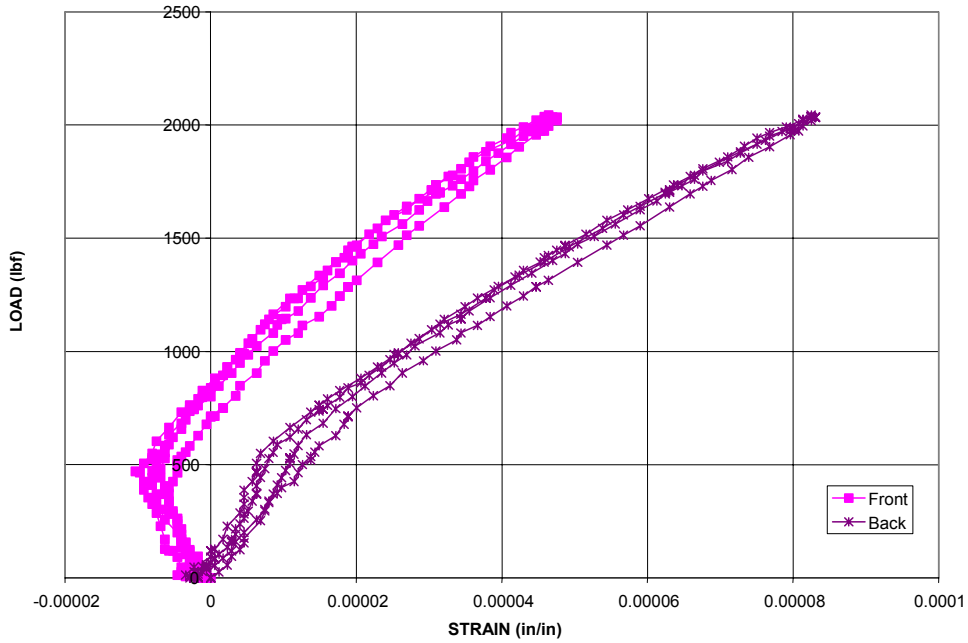

FIGURE F-93. STRAIN GAGE DATA, SCG-9, 1,200,000 CYCLES

F.9 SPECIMEN SCG-11 CALIBRATION DATA.

Specimen SCG-11 has 0.063″ steel doublers and was cycled at a constant amplitude of 10 ksi, R = 0.1. Strain surveys were taken before and after the specimen was disassembled for periodic inspection.

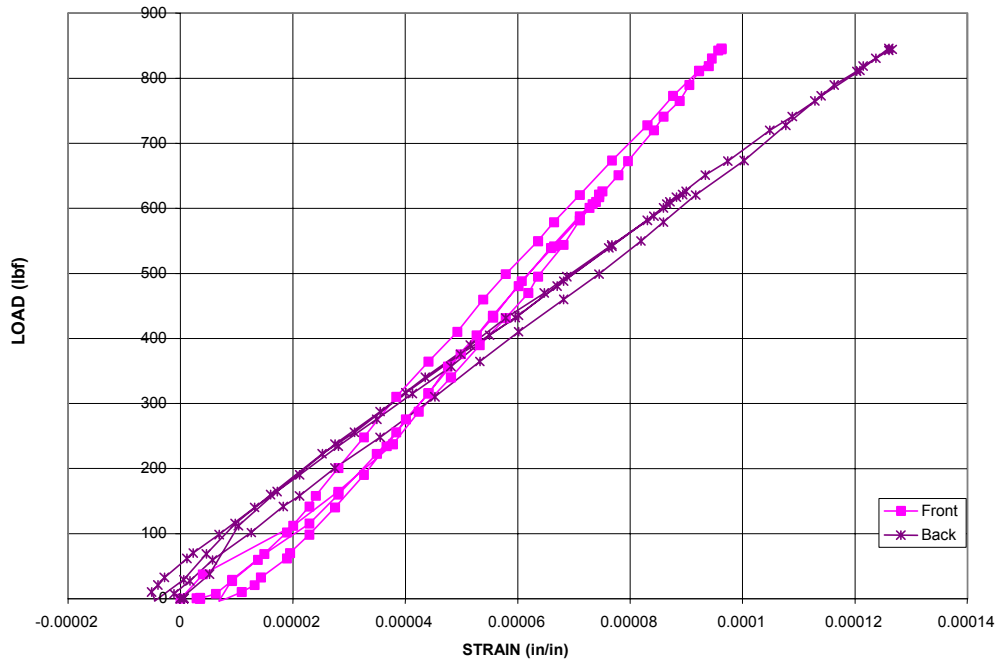

FIGURE F-94. STRAIN GAGE DATA, SCG-11, CALIBRATION #1 RUST REMOVED

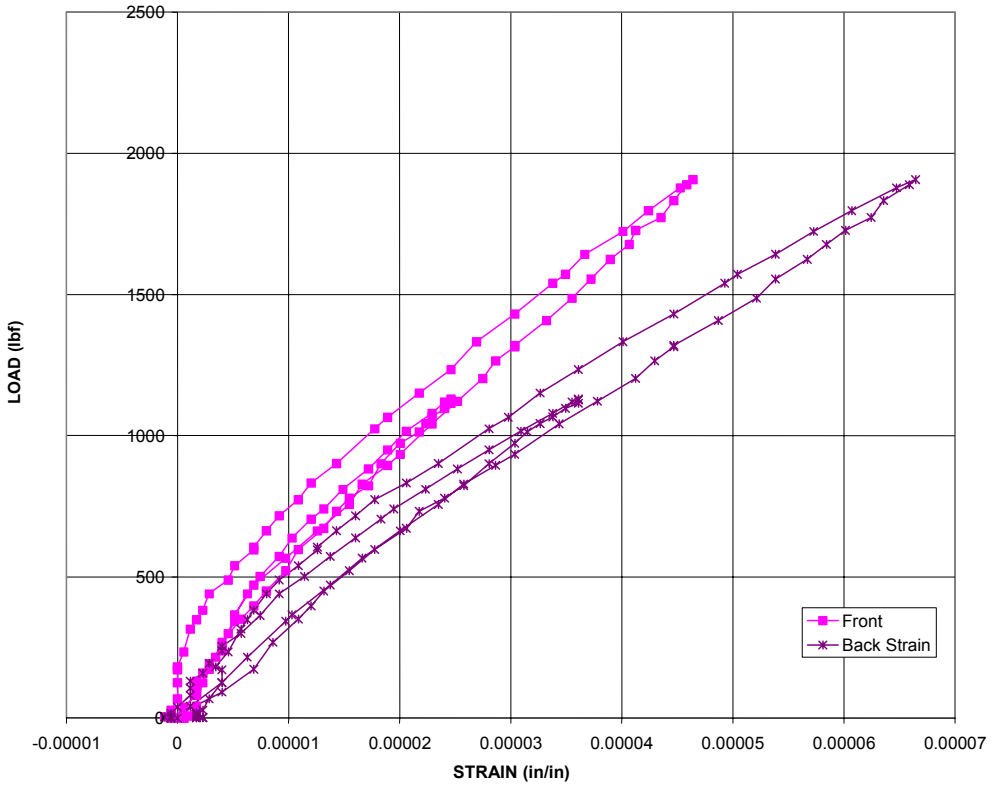

FIGURE F-95. STRAIN GAGE DATA, SCG-11, 0 CYCLES RUST REMOVED

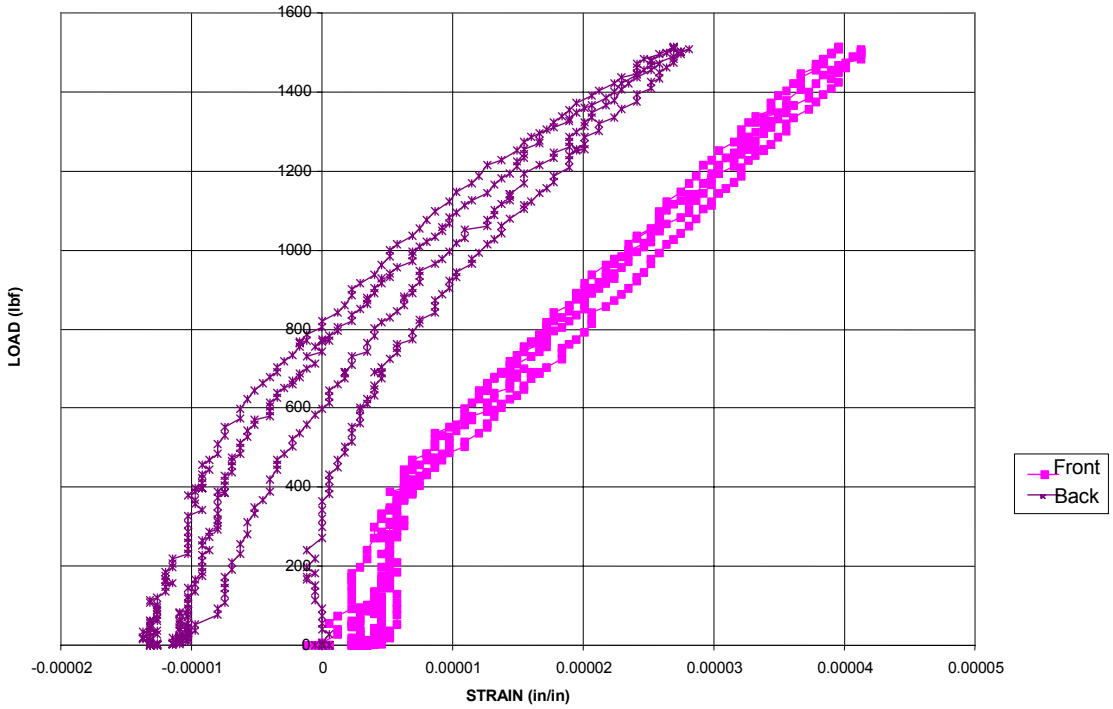

FIGURE F-96. STRAIN GAGE DATA, SCG-11, 30,000 CYCLES

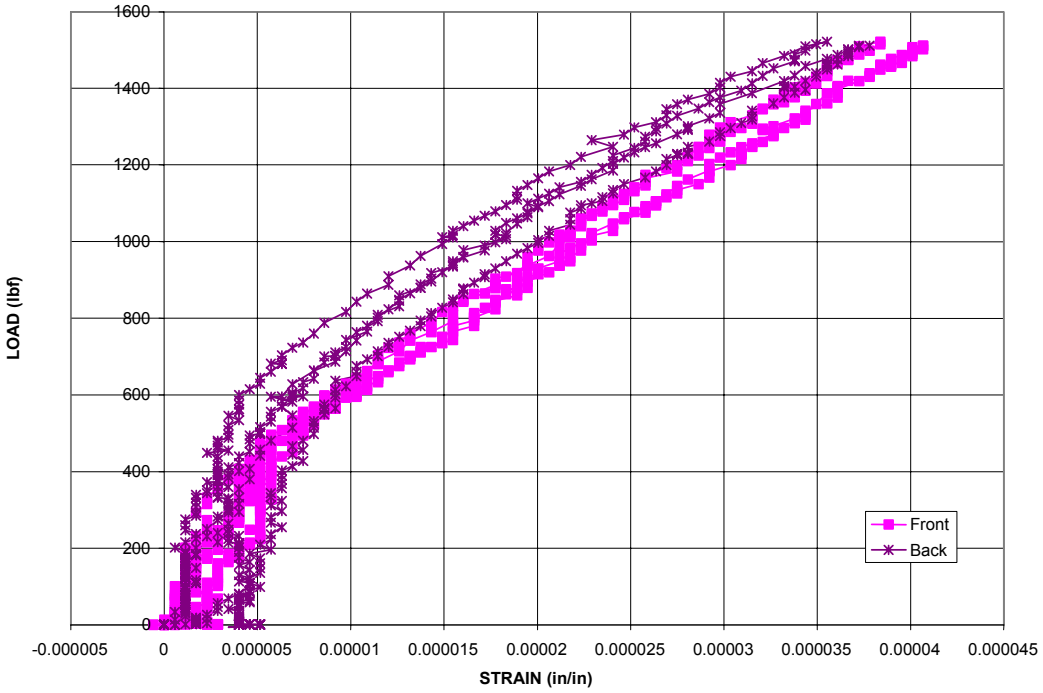

FIGURE F-97. STRAIN GAGE DATA, SCG-11, 50,000 CYCLES

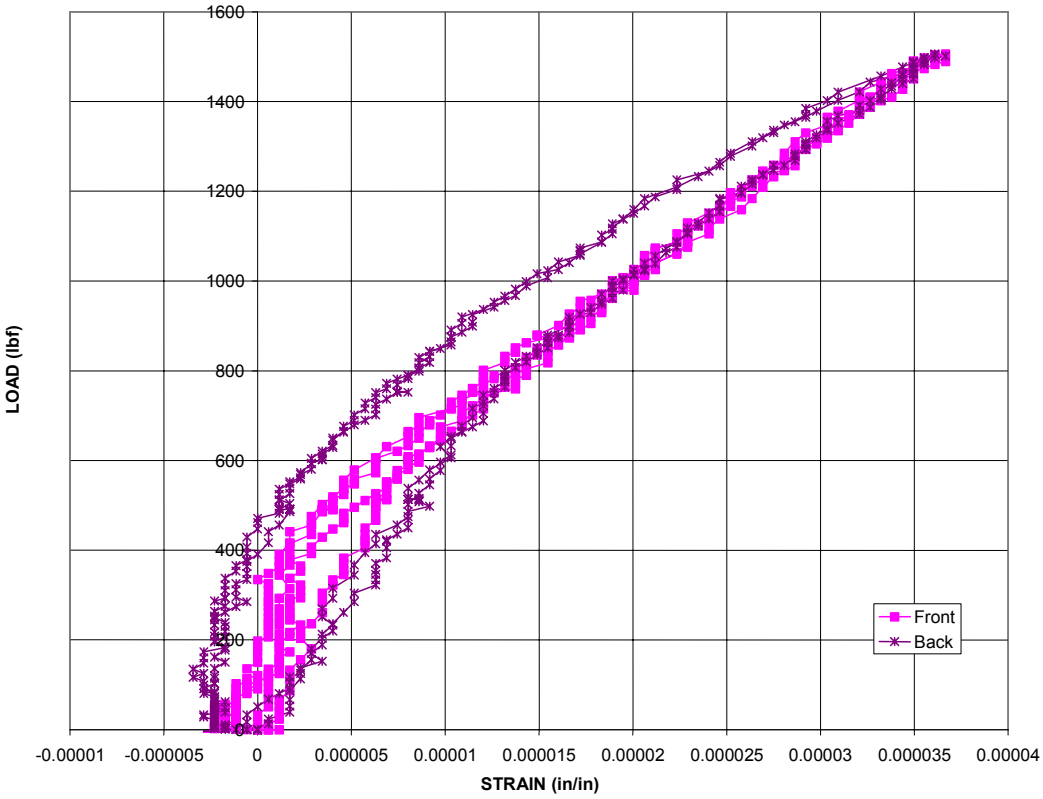

FIGURE F-98. STRAIN GAGE DATA, SCG-11, 60,000 CYCLES

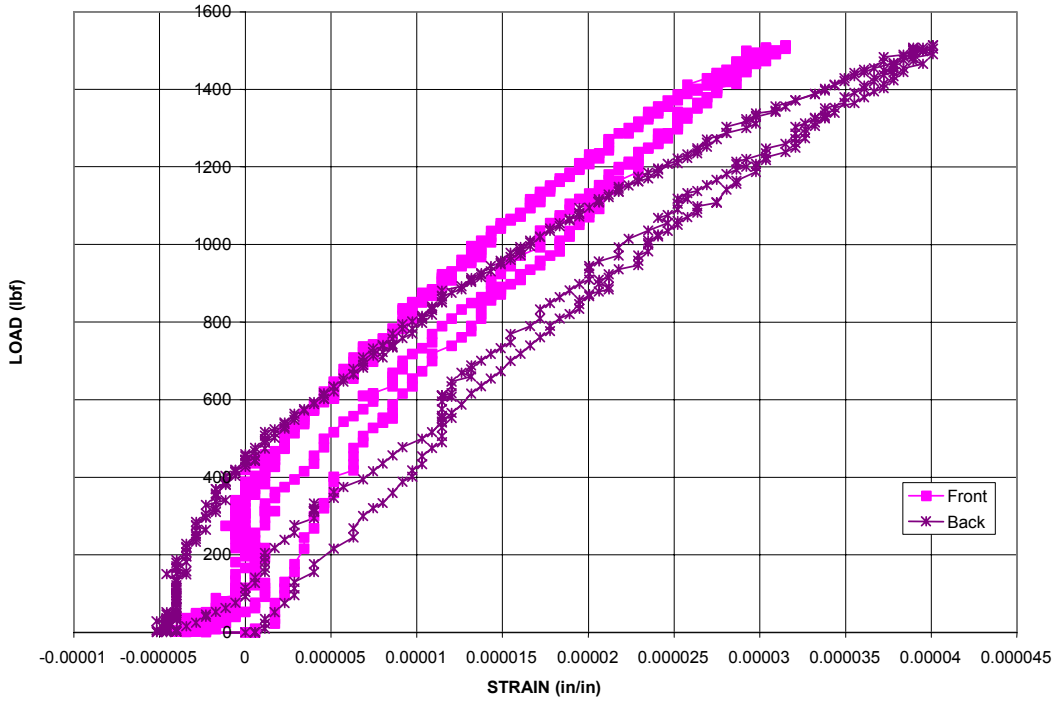

FIGURE F-99. STRAIN GAGE DATA, SCG-11, 80,000 CYCLES

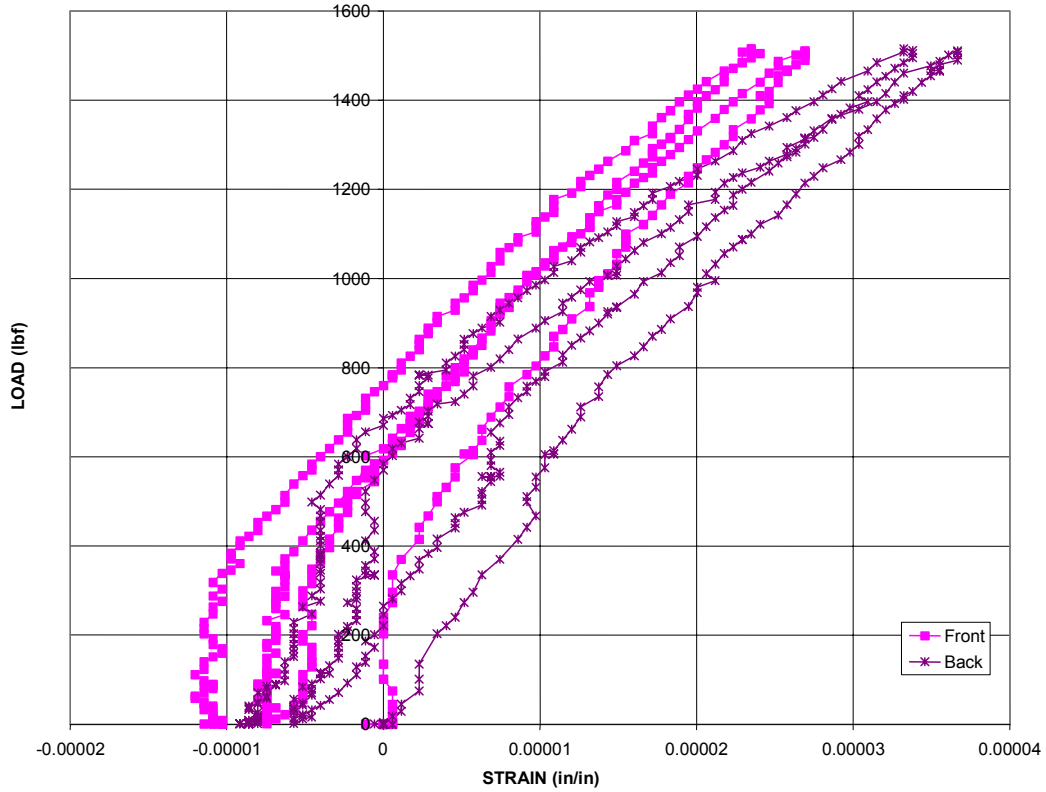

FIGURE F-100. STRAIN GAGE DATA, SCG-11, 95,000 CYCLES

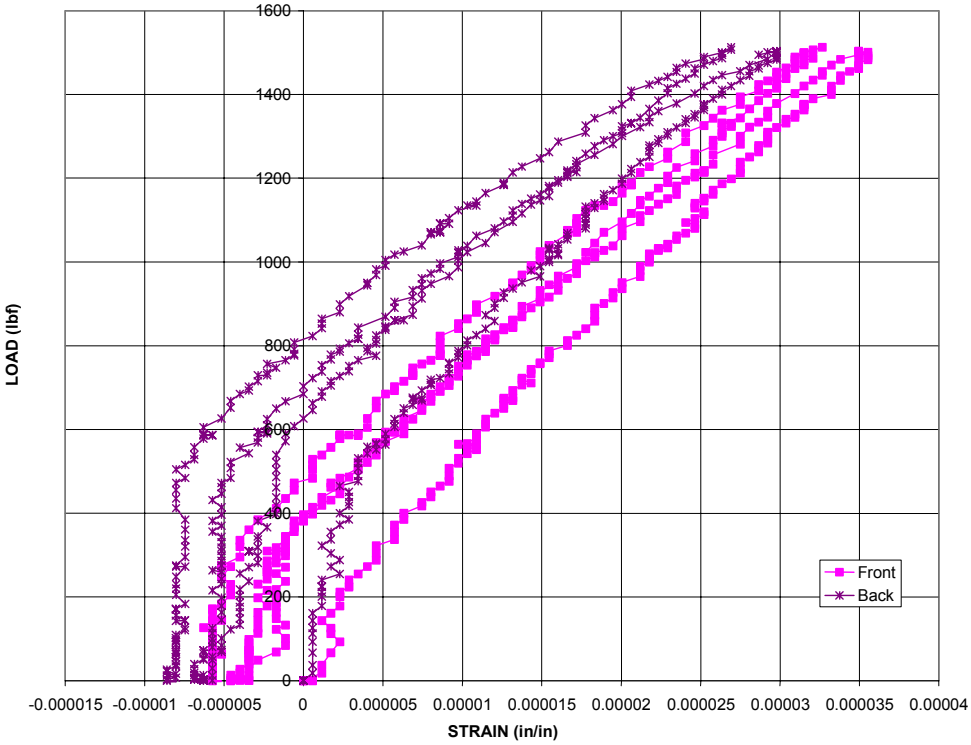

FIGURE F-101. STRAIN GAGE DATA, SCG-11, 110,000 CYCLES

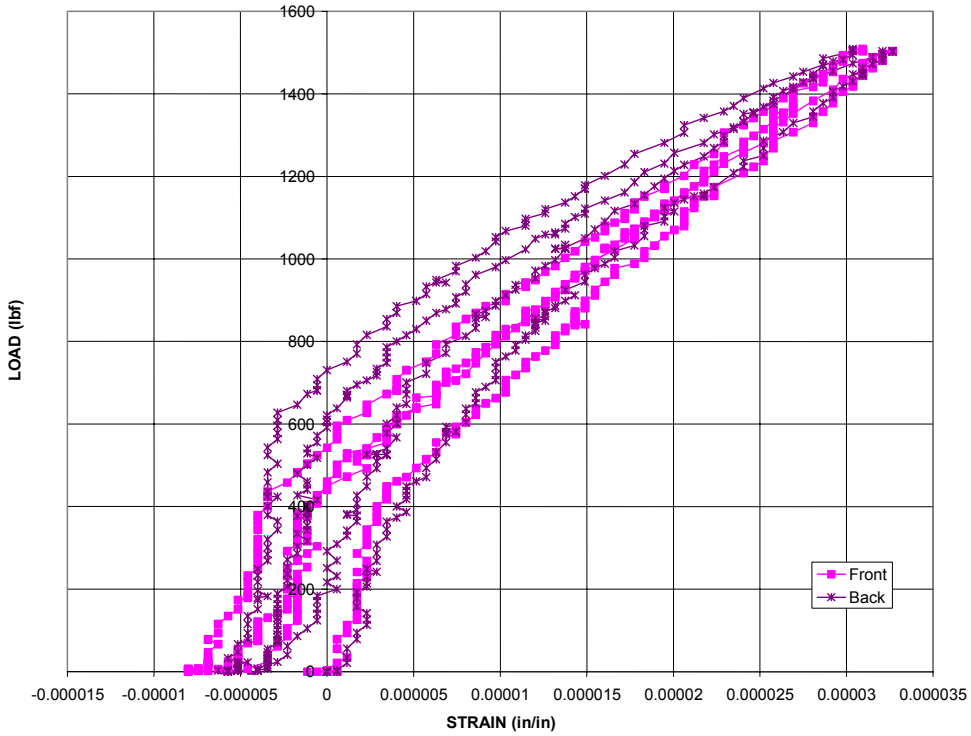

FIGURE F-102. STRAIN GAGE DATA, SCG-11, 130,000 CYCLES

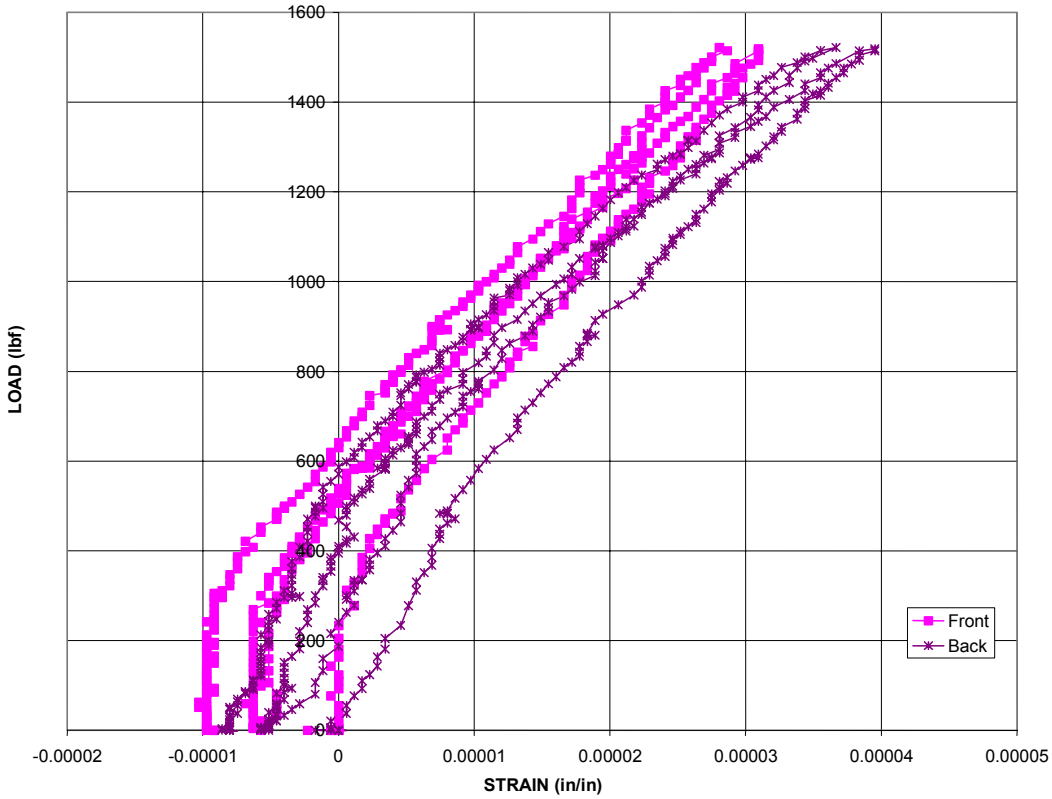

FIGURE F-103. STRAIN GAGE DATA, SCG-11, 145,000 CYCLES

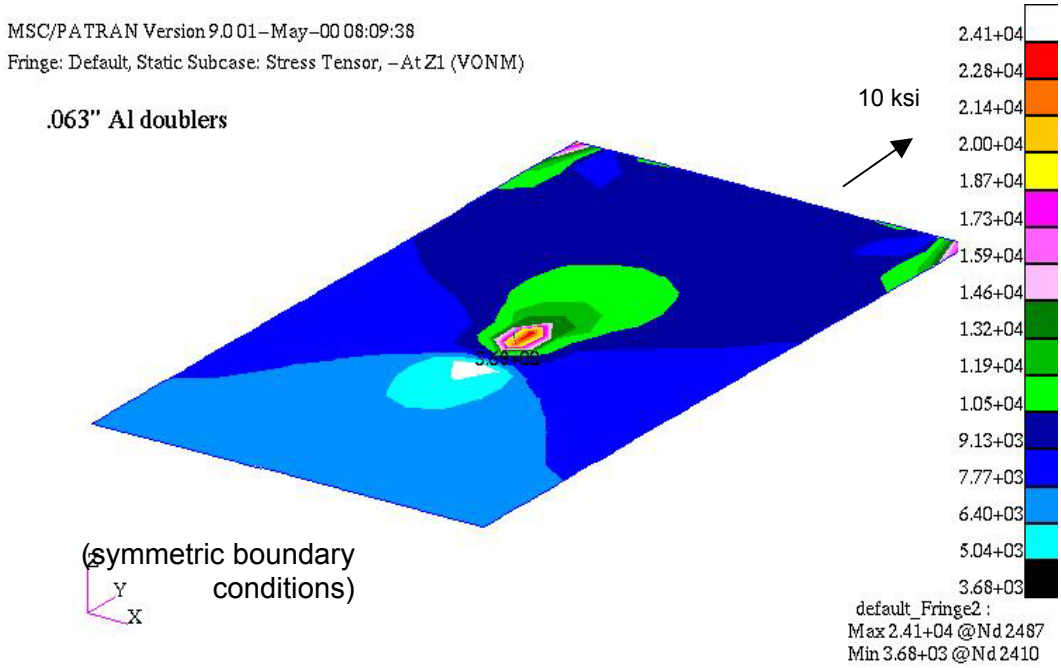

FIGURE F-104. STRESS DISTRIBUTION FOR HALF-MODEL WITH 0.063″ Al DOUBLERS

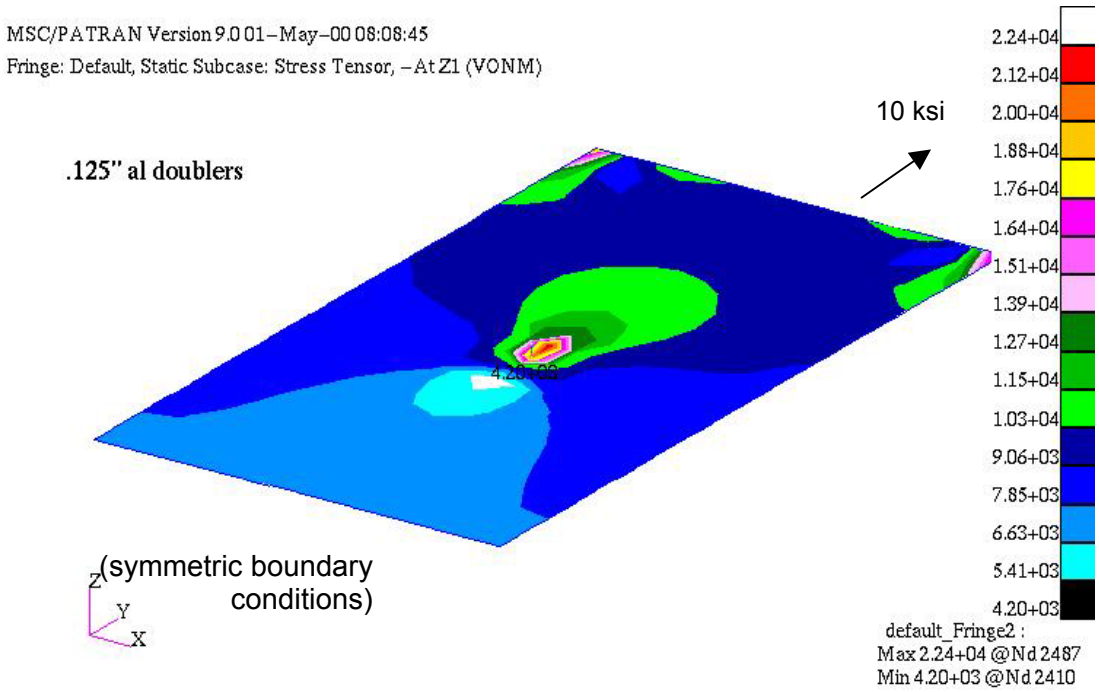

FIGURE F-105. STRESS DISTRIBUTION FOR HALF-MODEL WITH 0.125″ Al DOUBLERS

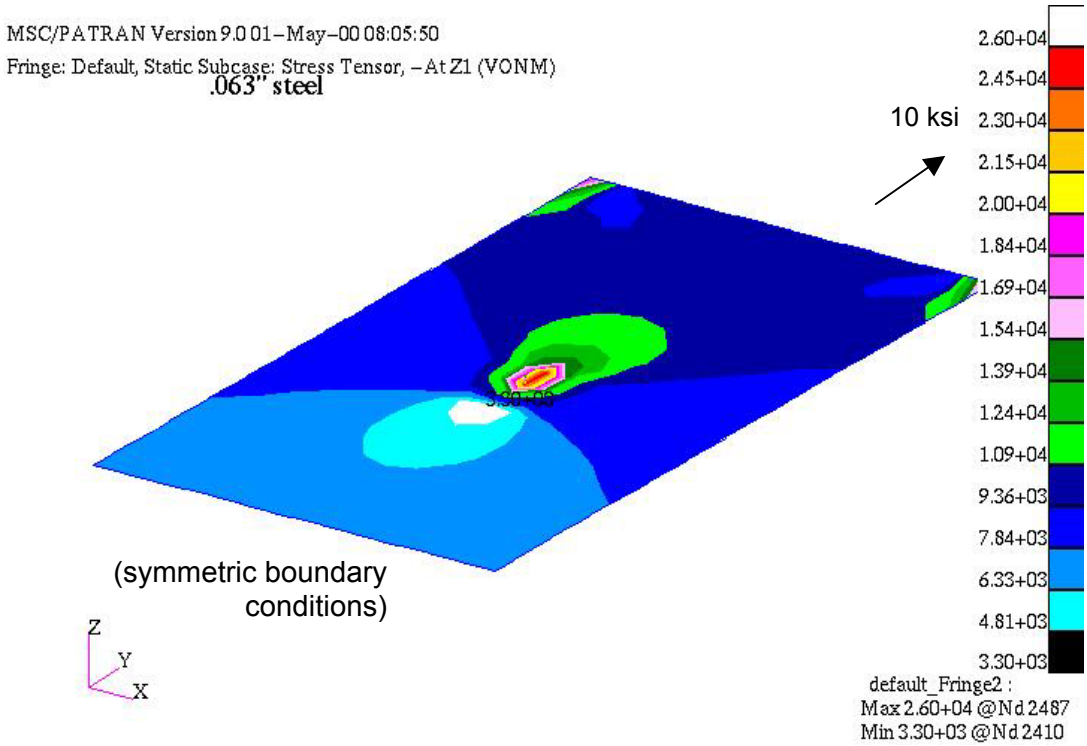

FIGURE F-106. STRESS DISTRIBUTION FOR HALF-MODEL WITH 0.063″ STEEL DOUBLERS

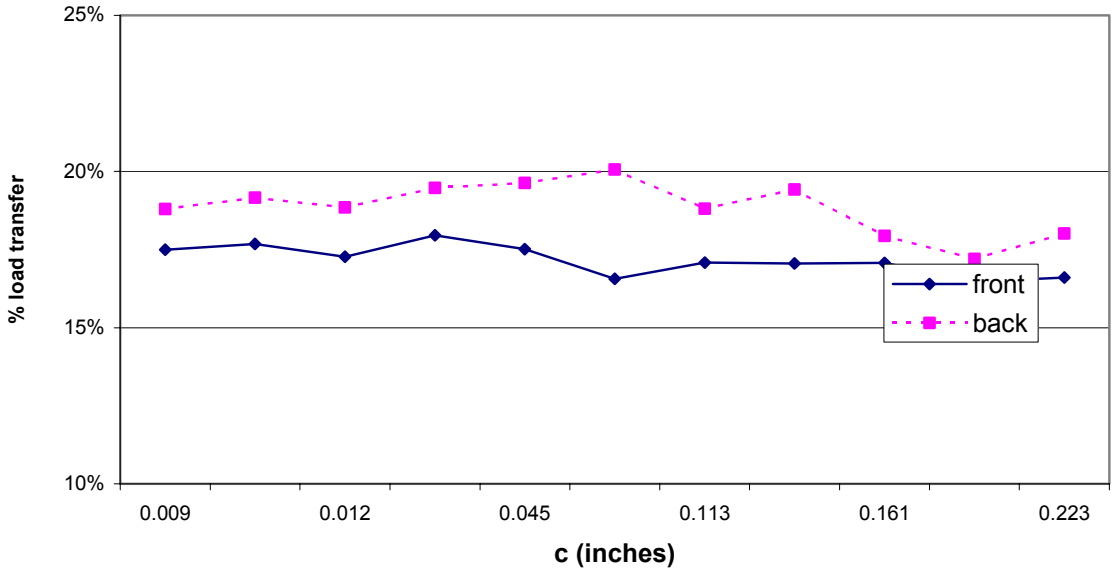

FIGURE F-107. CHANGE IN LOAD TRANSFER WITH CRACK EXTENSION, SCG-1s

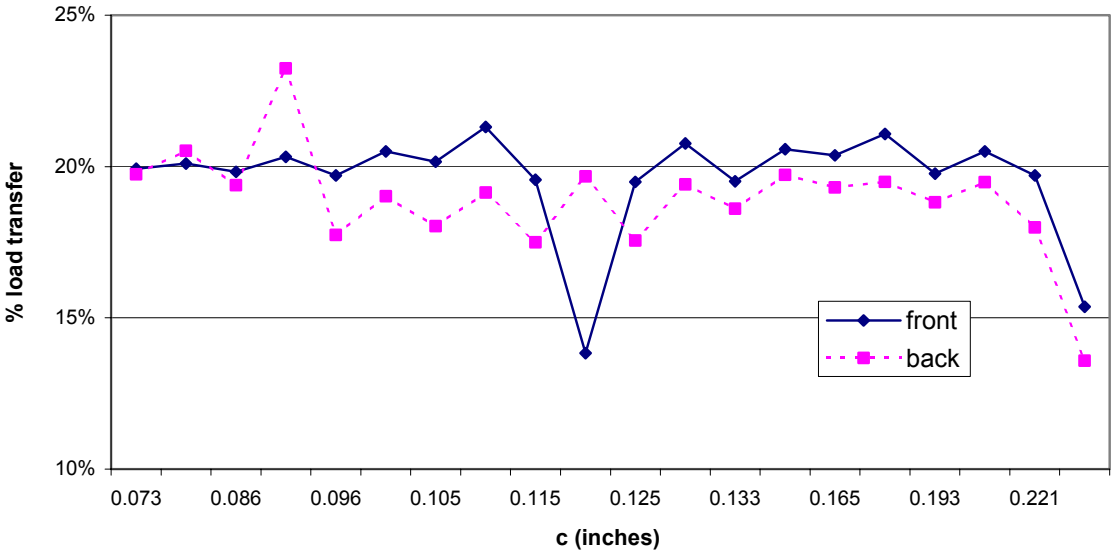

FIGURE F-108. CHANGE IN LOAD TRANSFER WITH CRACK EXTENSION, SCG-2

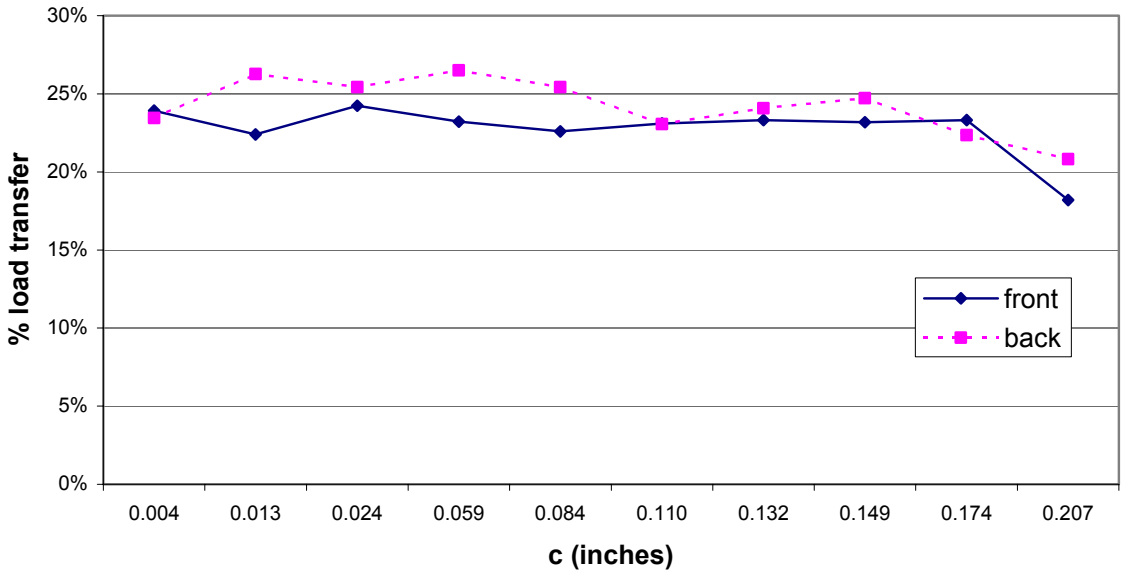

FIGURE F-109. CHANGE IN LOAD TRANSFER WITH CRACK EXTENSION, SCG-6

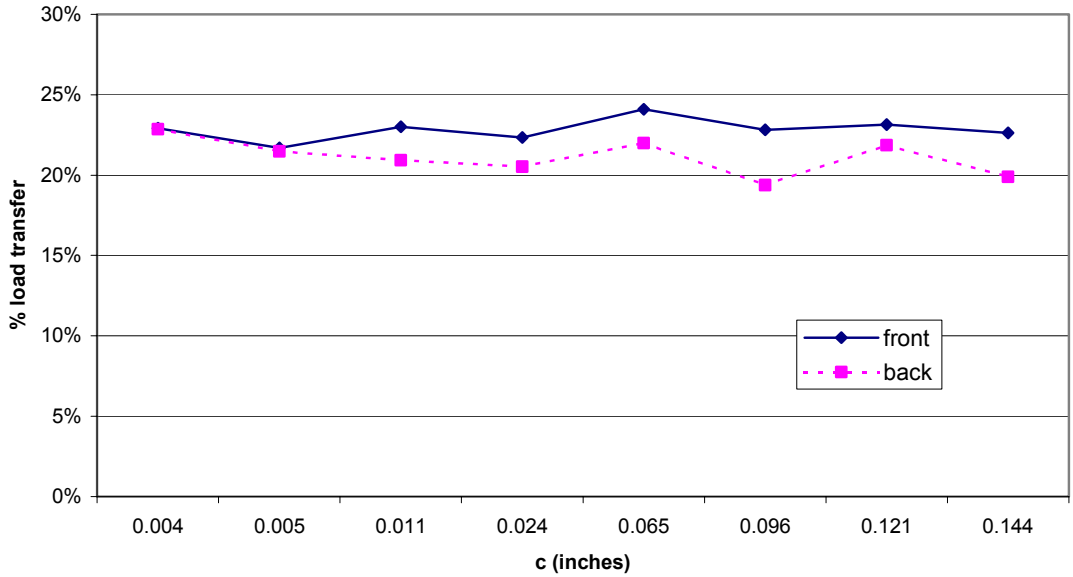

FIGURE F-110. CHANGE IN LOAD TRANSFER WITH CRACK EXTENSION, SCG-7

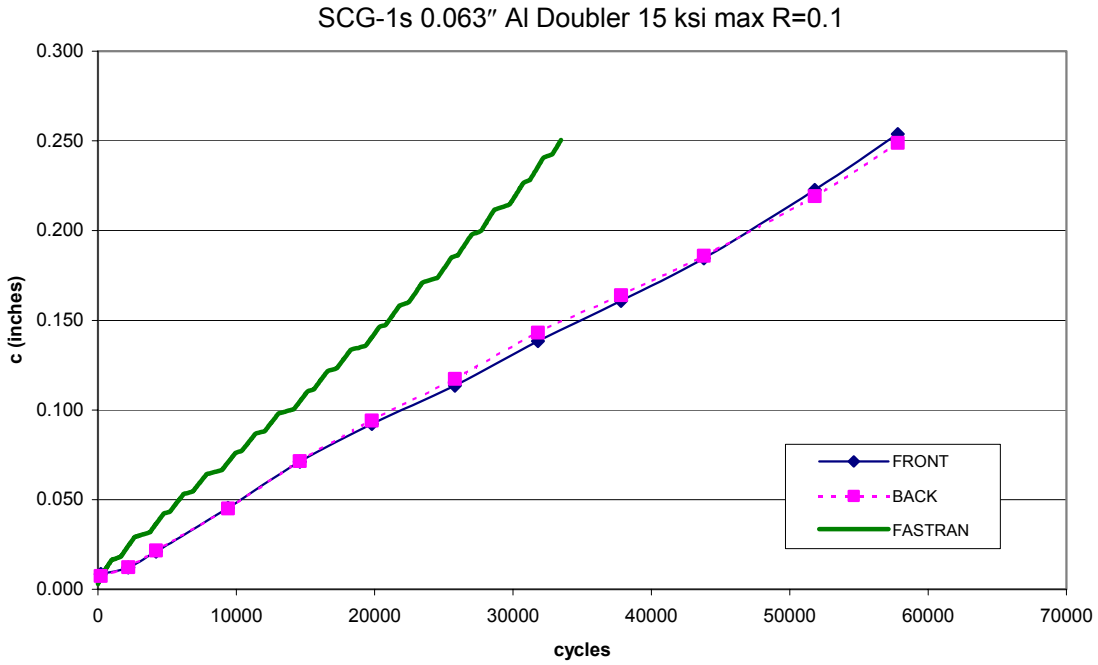

FIGURE F-111. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-1s

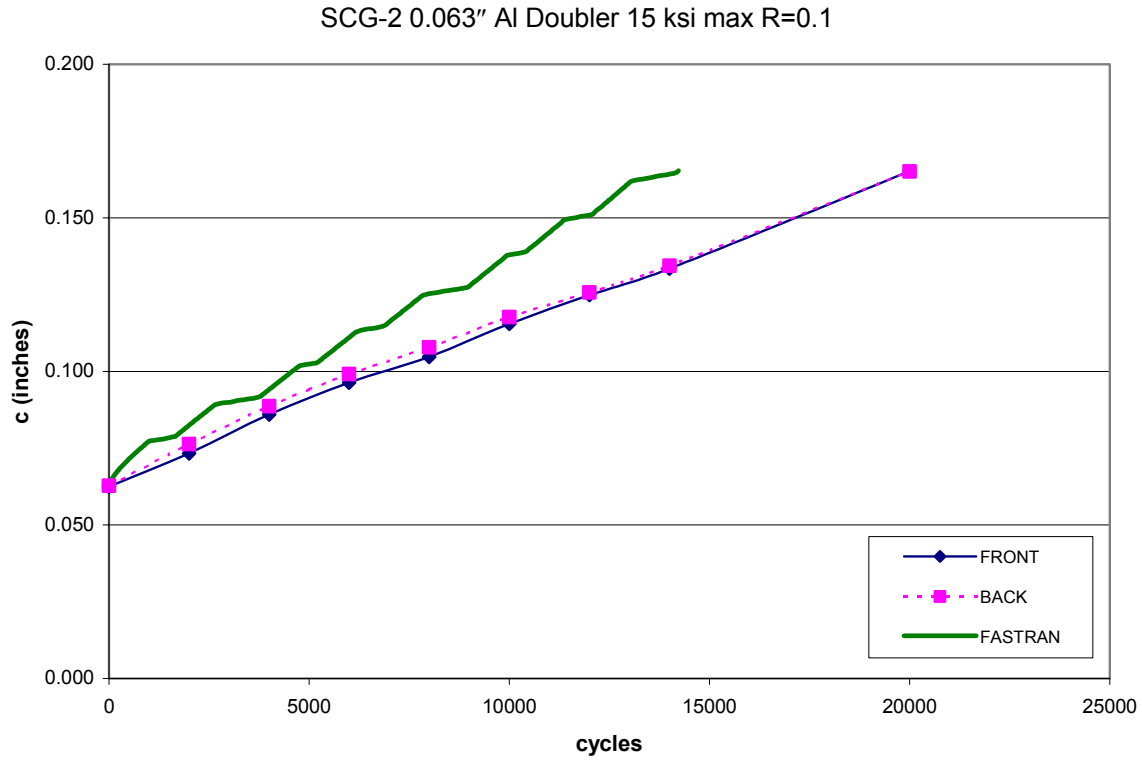

FIGURE F-112. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-2

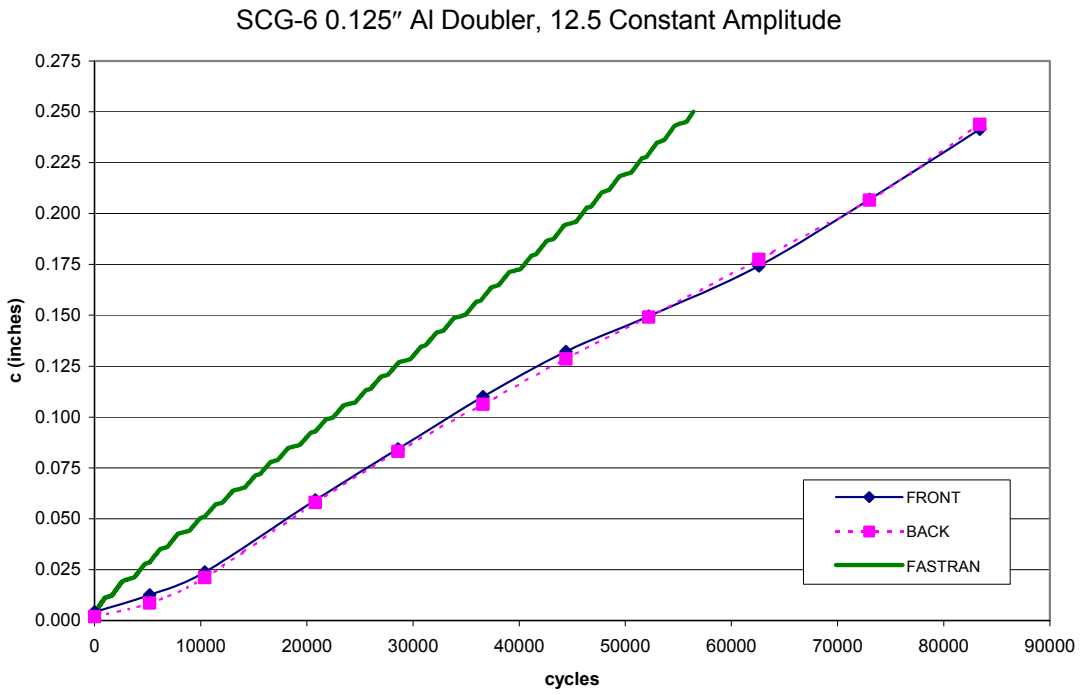

FIGURE F-113. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-6

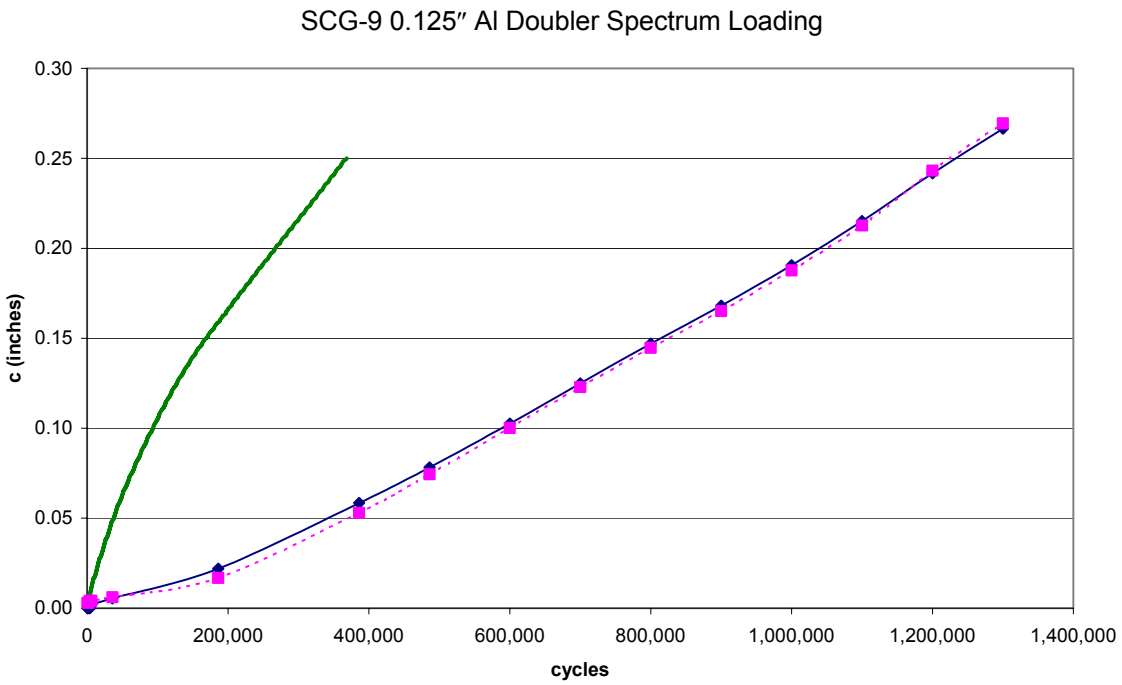

FIGURE F-114. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-9

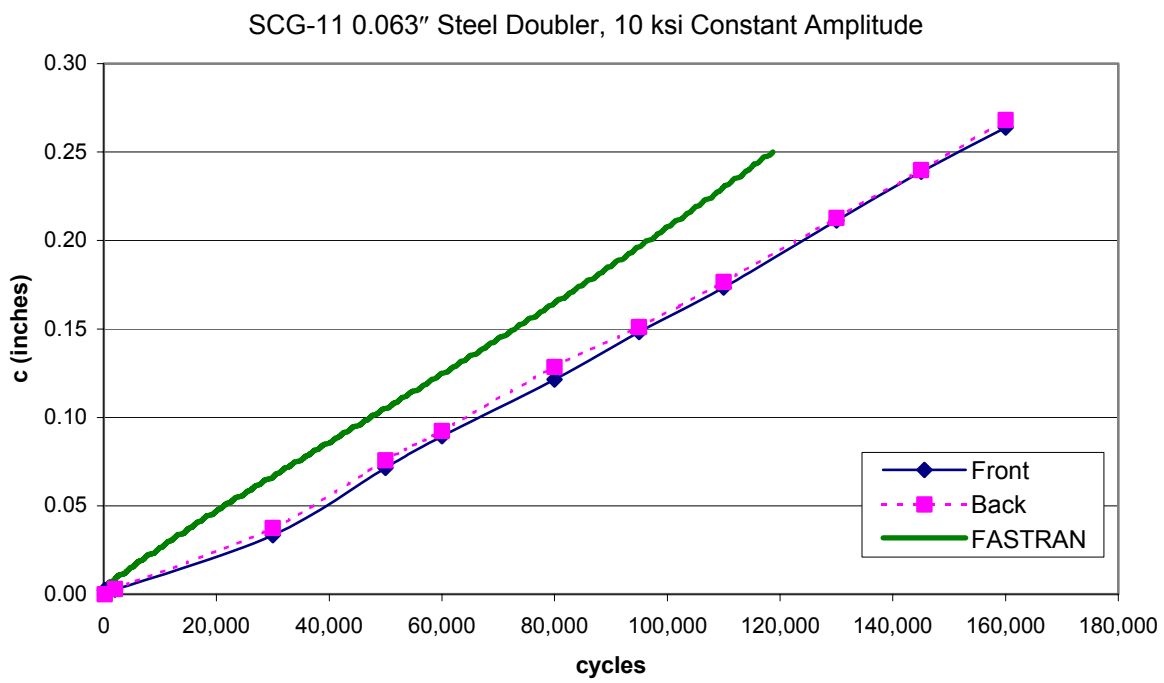

FIGURE F-115. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-11

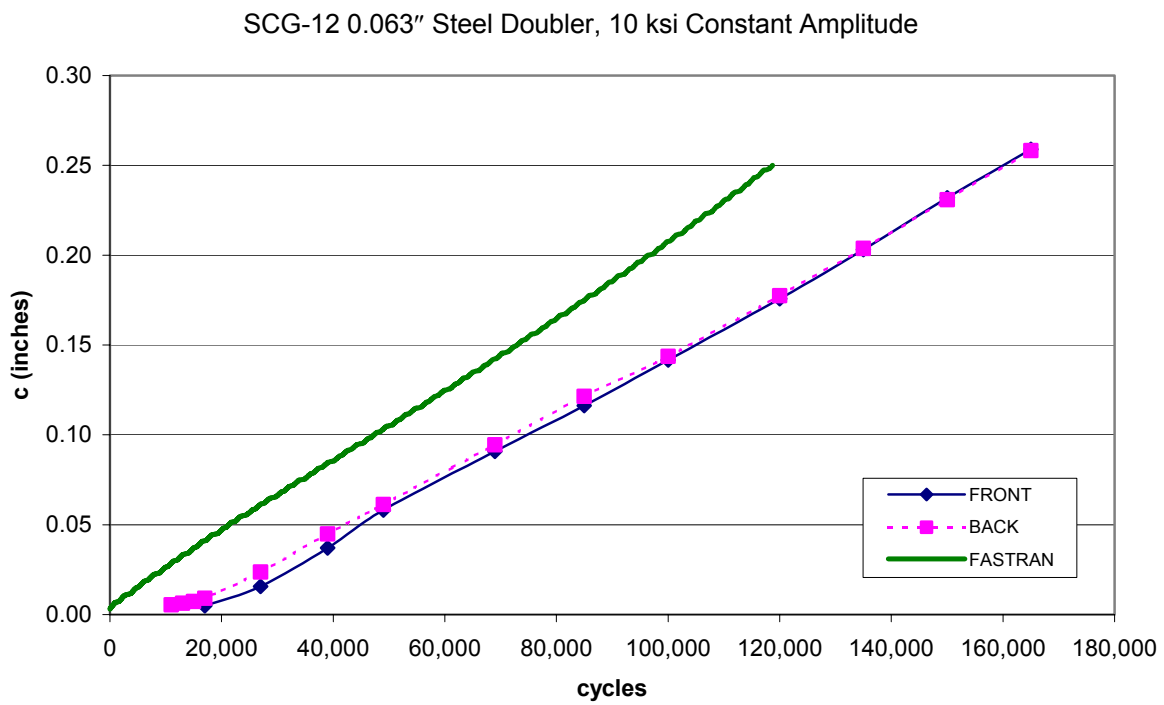

FIGURE F-116. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-12

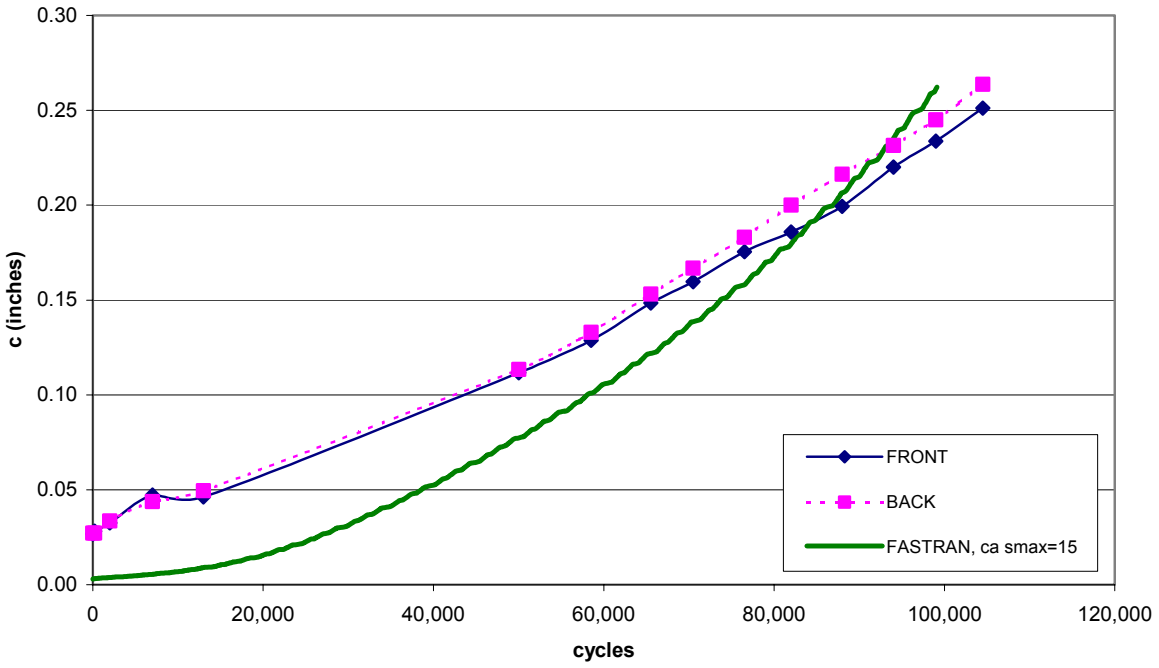

FIGURE F-117. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-17s NO DOUBLER

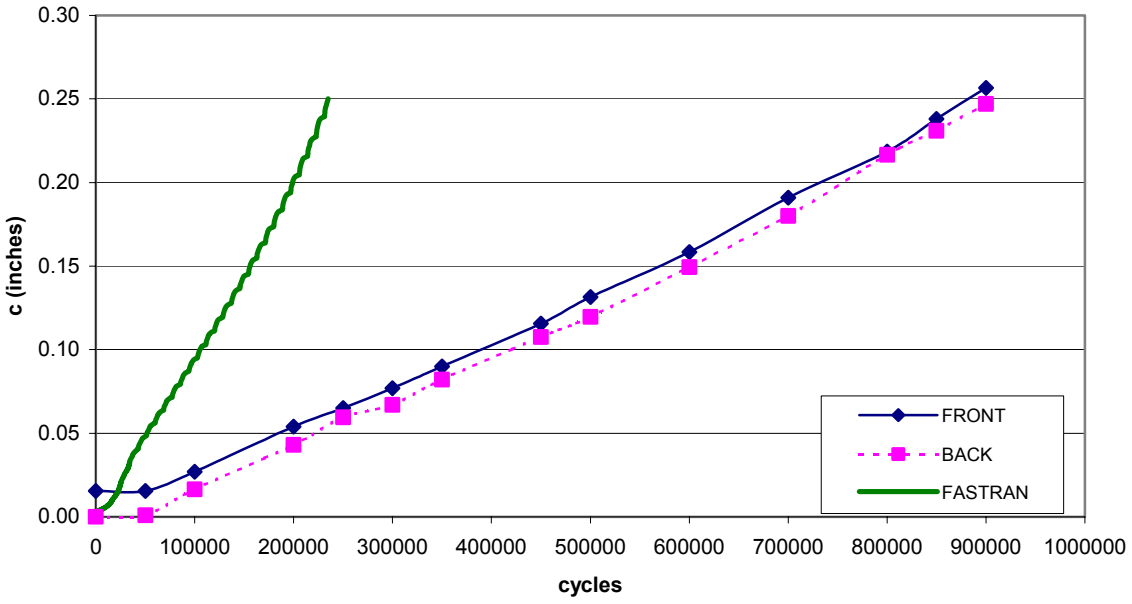

FIGURE F-118. FASTRAN/TEST COMPARISON, CRACK LENGTH VS CYCLES FOR SCG-19s