SUBMILLIMETER ARRAY PROJECT
TECHNICAL MEMO 157

TITLE: **TESTING OF NYTEX TUBES FROM ANTENNA 1 AND SPARE TUBE INVENTORY**

FOREWORD: Arthur Davies (SGH) conducted the tests, summarized the test procedure, and documented the results in the form of Tables A, B and C. George Nystrom (SAO) has provided an engineering assessment and recommendations for future testing to ensure BUS safety and performance.

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REPORT ON SMA TESTING, ARTHUR DAVIES

SUBJECT: Strength of Carbon Fiber Tube Assemblies (Test Date: 27 March 2008)

SAMPLES: The tubes are identified as Antenna 1 and Spares. A total of thirty-two (32) carbon fiber tube assemblies were shipped to SGH from the SMA site on the summit of Mauna Kea, HI. The tube assemblies are numbered and listed by tube type. The tube type is per SMA drawing number: D-11700490000.

PROCEDURES

We followed the procedures outlined in "SMA-ASIAA Crack Bus Tube Test Procedure" SMA document number: A-41700490002, Revision OD and dated March 26, 2008. The following summarizes our procedure:

- We configured our MTS Testing Machine with a 10,000 lbf. Load cell and fixtures. We tested the same with a steel rod to calibrate the MTS.
- We screwed forged steel threaded eyebolts into both stainless steel ends of the carbon fiber tube assembly.

- We mounted both ends of the carbon tube assembly in the fixtures and applied a 20 lbf seating load.
- We aligned the specimens in the fixtures and moved the crosshead up at a rate of 1.5 mm/min.
- When the "Hold Load 1" in Table A was reached, we held the load for 5 minutes and recorded the distance the crosshead moved.
- After we confirmed that the creep rate was less than 5 microns/minute, we moved the crosshead up at a rate of 1.5 mm/minute until we reached the "Hold Load 2" value listed in Table A. We held the load at this value for 5 minutes.
- After we confirmed that the creep rate was less than 5 microns/minute we then unloaded and removed the test article.
- We recorded the applied load and resulting amount of creep for both sustained load segments.
- We then followed the same procedure for testing the Antenna 1 tubes and recorded the data in Table B.
- The test setup can be view by looking at the Test specification: A-41700490002 or Technical memo: TM-145.

TEST PHILOSOPHY AND RESULTS

The test philosophy was to repeat the testing done both at the manufacturer and at SGH to establish that the tubes strength (in tension) has not degraded. Load 1 is the maximum predicted tube load. SMA Technical memo 119 defines the computation for load 1. The computation used a wind velocity of 56M/sec, gravity, assembly loads and a temperature loading of ±25 degrees C. Load 2 is the tubes "proof load" which is 1.5 times load 1, thereby yielding a 1.5 factor of safety on the maximum expected load. Table 1, in Technical memo 119, was used here to specify the test loads. The Antenna 1 tubes are the first real test set from an Antenna, which has experienced the Summit environmental loads over an extended period. Antenna 1 was deployed in June 1999. We added two intermediate test loads to better determine the tube strength in case a failure occurred.

The test results are for both Antenna 1 and the spare tubes are listed in Tables A, B and C respectively. All thirty-two-carbon fiber tube assemblies tested passed the load testing with acceptable creep rates of less than 5 microns/minute with the creep rates shown in Table C.

Table A
Spare tubes

Tube Number	Type	Load 1 (Lbs)	Load 2 (Lbs)	Creep 1 μ/min	Creep 2 μ/min	Pass/Fail	Measured Total Strain (μ) Load 1	Load 2	Calulated strain CREF tube (μ) Load 1	Load 2
10-01-09	1	719	1060	3.68	2.5	Pass	490	676	288	425
1-1-SGH	1	719	1060	1.0	1.0	Pass	480.5	663	288	425
10-2-13	2	681	1000	.667	1.33	Pass	354	496	257	378
10-2-14	2	681	1000	0	0.67	Pass	321	461.5	257	378
9-2-16	2	681	1000	1.0	0.5	Pass	358.5	498.5	257	378
9-2-18	2	681	1000	0	1.00	Pass	349	487	257	378
8-3-13	3	647	950	0.83	1.00	Pass	383	542.5	263	386
10-3-17	3	647	950	0.83	1.00	Pass	307	446	263	386
14-3-26	3	647	950	0.67	0.83	Pass	362	508	263	386
14-3-01	3	647	950	0.83	1.50	Pass	397.5	551	263	386
4-4-SGH	4	258	387	0.17	0.33	Pass	122.5	173.5	68.6	103
9-5-11	5	331	500	0.50	0.67	Pass	171	245	86.4	130
9-05-12	5	331	500	2.00	1.33	Pass	163	234	86.4	130
9-5-22	5	331	500	1.33	1.83	Pass	206	292.5	86.4	130
8-05-24	5	331	500	1.50	1.17	Pass	134	203.5	86.4	130
12-05-25	5	331	500	1.33	0.59	Pass	176	251	86.4	130
05-05-SGH	5	331	500	0.33	0.17	Pass	150	215.5	86.4	130
10-7-41	7	238	360	0	0.50	Pass	108	150	28.4	42.9
9-7-SGH	7	238	360	.33	0.50	Pass	102.5	144.5	28.4	42.9
11-11-SGH	11	588	882	0.83	1.00	Pass	228.5	330.5	45	67.6
8-12-?	12	850	1270	0.67	0.50	Pass	300	424.5	91.2	136.3
14-12-SGH	14	800	1200	1.00	1.17	Pass	285	397.5	55	86.6
14-14-SGH	14	800	1200	1.00	1.17	Pass	303.5	419	55	86.6
10-15-17	15	654	970	0.83	0.83	Pass	226.5	321	52.3	78
10-16-33	16	557	840	0.17	0.33	Pass	185	263	28.4	42.9
10-16-14	16	557	840	0.67	0.83	Pass	203	281.5	28.4	42.9
16-16-SGH	16	557	840	0.67	0.67	Pass	221	304	28.4	42.9
13-17-46	17	415	620	0.33	0.50	Pass	149	210	36	53.8
19-18-04	19	1384	2076	1.50	2.17	Pass	524	725	142.3	213.5

Table B
Antenna 1 Tubes

Comments: These tubes represent the first test after exposure to operational loads at Summit of Mauna Kea. We added several load steps to guard against premature breakage. The load steps used were 75, 100, 125 and 150 percent of the "in service" load.

Tube number	Tube Type	Load 1 Lbs.	Load 2 Lbs.	Load 3 Lbs.	Load 4 Lbs.	Creep 1 μ/min	Creep 2 μ/min	Creep 3 μ/min	Creep 4 μ/min	Pass/Fail
A1-5	5	248	331	414	500	0.33	0.33	0.50	0.33	Pass
A1-11	11	441	588	735	882	0.17	0.17	0.33	0.33	Pass
A1-17	17	311	415	519	620	0.50	0.33	0.67	0.67	Pass

Table C
Average Creep per Applied Load (μ/Min)

Sample	hold 1	xhead	time	xhead	time	delta xhead/time	hold 2	xhead	time	xhead	time	delta xhead/time
test- steel rod	719	385.0	0.37	387.0	4.15	0.53	1060	538.5	5.10	539.0	8.20	0.16
10-01-09	719	490.0	0.38	501.5	3.50	3.69	1060	671.0	4.00	678.5	7.00	2.50
1-1-sgh	719	480.5	0.34	483.5	3.34	1.00	1060	663.0	3.90	666.0	6.90	1.00
10-2-13	681	354.0	0.25	356.0	3.25	0.67	1000	496.0	3.59	500.0	6.59	1.33
10-2-14	681	321.0	0.23	321.0	3.23	0.00	1000	461.5	3.60	463.5	6.60	0.67
9-2-16	681	358.5	0.27	361.5	3.27	1.00	1000	498.5	3.56	500.0	6.56	0.50
9-2-18	681	349.0	0.24	349.0	3.24	0.00	1000	487.0	3.57	490.0	6.57	1.00
8-3-13	647	383.0	0.26	385.5	3.26	0.83	950	542.5	3.52	545.5	6.52	1.00
10-3-17	647	307.0	0.22	309.5	3.22	0.83	950	446.0	3.58	449.0	6.58	1.00
14-3-26	647	362.0	0.25	364.0	3.25	0.67	950	508.0	3.67	510.5	6.67	0.83
14-3-01	647	397.5	0.27	400.0	3.27	0.83	950	551.0	3.75	555.5	6.75	1.50
4-4-sgh	258	122.5	0.08	123.0	3.08	0.17	387	173.5	3.36	174.5	6.36	0.33
9-5-11	331	171.0	0.12	172.5	3.12	0.50	500	245.0	3.49	247.0	6.49	0.67
9-05-12	331	163.0	0.11	169.0	3.11	2.00	500	234.0	3.41	238.0	6.41	1.33
9-5-22	331	206.0	0.14	210.0	3.14	1.33	500	292.5	3.43	298.0	6.43	1.83
8-05-24	331	134.0	0.09	138.5	3.09	1.50	500	203.5	3.39	207.0	6.39	1.17
12-05-25	331	176.0	0.12	180.0	3.12	1.33	500	251.0	3.50	252.5	6.50	0.50
05-05-sgh	331	150.0	0.10	151.0	3.10	0.33	500	215.5	3.33	216.0	6.33	0.17
10-7-41	238	108.0	0.07	108.0	3.07	0.00	360	150.0	3.39	151.5	6.39	0.50
9-7-sgh	238	102.5	0.07	103.5	3.07	0.33	360	144.5	3.33	146.0	6.33	0.50
11-11-sgh	558	228.5	0.15	231.0	3.15	0.83	882	330.5	3.38	333.5	6.38	1.00
8-12-?	850	300.0	0.20	302.0	3.20	0.67	1270	424.5	3.35	426.0	6.35	0.50
14-12-sgh	800	285.0	0.19	288.0	3.19	1.00	1200	397.5	3.51	401.0	6.51	1.17
14-14-sgh	800	303.5	0.20	306.5	3.20	1.00	1200	419.0	3.71	422.5	6.71	1.17
10-15-17	654	226.5	0.15	229.0	3.15	0.83	970	321.0	3.58	323.5	6.58	0.83
10-16-33	557	185.0	0.12	185.5	3.12	0.17	840	263.0	3.48	264.0	6.48	0.33
10-16-14	557	203.0	0.14	205.0	3.14	0.67	840	281.5	3.42	284.0	6.42	0.83
16-16-sgh	557	221.0	0.15	223.0	3.15	0.67	840	304.0	3.35	306.0	6.35	0.67
13-17-46	415	149.0	0.10	150.0	3.10	0.33	620	210.0	3.48	211.5	6.48	0.50
19-18-04	1384	524.0	0.35	528.5	3.35	1.50	2076	725.0	3.89	731.5	6.89	2.17
A1-15	420	153.0	0.10	154.5	3.10	0.50	560	195.5	3.67	198.0	6.67	0.83
A1-5	248	114.0	0.07	115.0	3.07	0.33	331	148.0	3.43	149.0	6.43	0.33
A1-6	480	200.5	0.14	201.0	3.14	0.17	640	258.5	3.54	259.0	6.54	0.17
A1-15	700	238.0	7.13	240.0	10.13	0.67	840	279.5	10.35	281.5	13.35	0.67
A1-5	414	180.0	6.94	181.5	9.94	0.50	500	213.5	10.45	214.5	13.45	0.33
A1-6	800	314.5	6.85	315.5	9.85	0.33	960	370.0	10.31	371.0	13.31	0.33

ANALYSIS AND COMMENTS, GEORGE NYSTROM

The test results show that no discernible strength degradation has occurred since the tubes acceptance testing at the manufacturing site. The spare tubes have been stored in wooden boxes at the Summit. They have not been exposed to any loads other than Handling, temperature and moisture exposure. Therefore; the spare tubes are not a good representation of the BUS tubes health. However, are useful for monitoring aging effects. This is why we have begun to exchange the spare tubes for Antenna tubes.

The Antenna 1 tubes have been supporting the reflector since June of 1999, some 80 months. These tubes then have been exposed to the environmental loads, including our recent earthquake loading. They give us a better understanding of tube health even though a small statistical sample.

The large disparity between the calculated Tube strain and the measured strain is a result of the holding fixture. The holding fixture is relatively weak, when compared to the Tube assemblies, and therefore is the major contributor to the total strain measurement. In future testing the holding fixture needs to be changed to allow better measurements of the Tube strain.

A technical analysis between the Antenna 1 tubes and similar spare tubes is being prepared and will account for the fixtures contribution to tube strain.

CONCLUSIONS:

All tubes pass this testing without failure at a factor of safety of 1.5 times the expected load. This indicates that no loss of load carrying ability is evident in either Antenna 1 or the spare tubes. This gives a reasonable assurance that the BUS structures are sound.

The tube test program needs to continue on a yearly basis. The spare tubes need to be inserted in various BUS structures as rapidly as possible to yield a better understanding of environmental loading effects.