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EVALUATION AND PREDICTION OF LONG TERM SPACE ENVIRONMENTAL EFFECTS ON NON-METALLIC MATERIALS

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I. INTRODUCTION:

The objective of this program is to determine the effects of prolonged space environment on a variety of spacecraft materials; and where possible, compare these results with predicted behavior.

II. TECHNICAL PROPERTIES SUMMARY

Task I - Physical Properties Testing

Ten materials have been evaluatee for electrical and mechanical properties following long term vacuum exposure.
This work was performed under subtask 1.1 in the schedule included in this report. Physical properties tests under subtask 1.1 have been completed on all available materials.

The materials tested during this reporting period are listed in Table 1.

Data obtained from these materials is presented in tabular form at the end of this report. Adhesion characteristics were evaluated for poly-thermaleze and therm-amid insulation. No adhesion defects were detected after any of the exposures.

TABLE 1

MATERIALS EVALUATED CLASSIFICATION AND TESTS

MATERIAL	CLASSIFICATION	TESTS
Poly-thermaleze insulation	Magnet wire insulation	Adhesion and dielectric strength
Therm-amid insulation	Magnet wire insulation	Adhesion and dielectric strength
Adlock 851	Phenolic laminate	Flexure and tensile properties
Vespel SP-1	Polyimide	Hardness
Cho-seal	Conductive elastomer	Volume Resistivity
Lexan	Poly carbonate	Tensile Properties
Polyethelene	Polyethelene	Tensile Properties
Polyurethane	Polyurethane	Tensile Properties
Lucite	Acrylic	Tensile Properties
Nylon	Polyamide	Tensile Properties

3

The first radiation-calibrated canister for subtask 1.2 was received by Martin Marietta from MSFC in late September and will not be loaded with specimens until mid-October dur to MMU work which pre-empted this task. Slippage of this task is indicated in the schedule included with this report.

The fixture fabrication for subtask 1.3 is completed and the unit has passed the helium leak test. The manipulator adaptor for the MSFC vacuum chamber is shown in figures 1 and 2. The front portion of the adaptor to be welded to the MSFC vacuum tank was shipped to MSFC at the end of September.

The electric impact wrench modification is nearing completion. This wrench is for loosening the vacuum chamber flange bolts with the manipulator arm.

Task II - Perform TGA/RGA

The thermal gravimetric analysis (TGA) and residual gas analysis (RGA) are being rescheduled for completion in mid-October. Comparison of pre and post exposure TGA/RGA data is continuing.

Work Planned:

1. Load cansiter for irradiation exposures.
2. Compare pre and post exposure TGA/RGA data.
3. Complete impact wrench modification
4. Begin to correlate isothermal weight loss with mechanical property changes.

Table 2

Polythermalese Insulated Wire (Belden Corp.)

Exposure	AWG	Dielectric Strength, KV Average	High	Low	Samples Tested
Baseline	20	9.5	11.2	8.1	3
	30	8.8	11.0	7.0	3
Heat Compatibility (1)	20	10.1	11.5	9.4	3
	30	7.7	9.0	6.6	3
Heat Compatibility (1) plus 30 day Thermal Vacuum (2)	20	8.7	11.7	7.1	3
	30	6.8	7.2	6.5	3
Heat Compatibility (1) plus 100 month Thermal Vacuum (2)	20	14.3	16.5	12.0	3
	30	8.7	9.5	8.0	3

Therm-Amid Insulated Wire (Rea Magnet Wire Co.)

Exposure	AWG	Dielectric Strength, KV Average	High	Low	Samples Tested
Baseline	20	12.7	14.5	11.0	3
	30	8.0	9.5	7.0	3
Heat Compatibility (1)	20	8.5	9.0	8.0	3
	30	8.7	9.8	8.1	3
Heat Compatability (1) plus 30 day Thermal Vacuum (2)	20	7.5	7.5	7.4	3
	30	6.5	6.5	6.4	2
Heat Compatibility (1) plus 100 month Thermal Vacuum (2)	20	11.3	11.5	11.0	3
	30	10.8	11.5	10.0	3

(1) Heat compatibility - 570 hours at 275°F (408°K) in N_2 atmosphere

(2) Tested at 10^{-5} Torr after exposure for the specified length of time at 150°F (338°K) and 10^{-6} Torr

Table 3

Adlock 851

Tensile Strength and Modulus (ASTM D638-68)*

Property (1)	Exposure	Average MPA	Average KSI	High MPa	High Ksi	Low MPa	Low Ksi	Samples Tested
Ultimate Strength	Baseline	184	26.7	192	27.9	177	25.6	5
Ultimate Strength	Heat Compatibility (2)	208	30.1	244	35.4	174	25.2	5
Ultimate Strength	Heat Compatibility (2) plus 102 month Thermal Vacuum (3)	234	34.0	267	38.7	1.89	27.4	5
Elastic Modulus	Baseline	18300	2660	22100	3200	15900	2300	5
Elastic Modulus	Heat Compatibility (2)	17700	2570	21000	3040	15700	2280	5
Elastic Modulus	Heat Compatibility (2) plus 102 month Thermal Vacuum (3)	18600	2700	19300	2800	17900	2600	5

*Type I specimen tested at a crosshead rate of 1.3 mm/minute (.05 in/minute)

(1) Cured ½ hour at 250°F (394°K) plus 1 hour at 300°F (422°K) plus ½ hour at 350°F (449°K) plus 4 hours at 500°F (553°K)

(2) Heat compatibility - 5.0 hours at 275°F (408°K) in N_2 atmosphere

(3) Thermal Vacuum - Tested at 1×10^{-5} Torr after heat compatibility (2) and an initial exposure of 10 to 16 hours at 140°F (333°F) to 160°F (344°K) followed by an exposure at 120°F ± 10°F (322°K ± 6°K) for the time specified at a pressure of 1×10^{-6} Torr or less.

Table 4

Vespel SP-1

Hardness (ASTM D785 and D2240)

Exposure	Average Rockwell M	Average Shore D*	High Rockwell M	High Shore D*	Low Rockwell M	Low Shore D*	Samples Tested
Baseline	88.2	86	89.0	86	87.0	85	5
Heat Compatibility (1)	90.0	86	92.0	86	89.0	86	5
Tested in air after heat compatibility (1) plus 30 day thermal vacuum	89.6		91.0		87.0		5
Tested at $1 x 10^{-5}$ Torr after heat compatibility (1) plus 30 day thermal vacuum (2)		85		86		85	5
Tested at in air after heat compatibility (1) plus 102 day thermal vacuum	87.2		89		85		4
Tested at $1 x 10^{-5}$ Torr after haet compatibility (1) plus 102 month Thermal Vacuum		87		88		86	4

*Shore D Hardness was run as a comparison since Rockwell Tester could not be used in In-Situ. THermal vacuum test specimens were tested for Rockwell Hardness in air after Shore D test in vacuum.

(1) Heat compatibility - 570 hours at $275^{o}F$ ($408^{o}K$) in N_2 atmosphere.

(2) Exposed for the specified length of time to $150^{o}F$ ($338^{o}K$) and $1 x 10^{-6}$ Torr.

TABLE 6

MATERIAL: NYLON

TENSILE STRENGTH AND MODULUS

PROPERTY	EXPOSURE[1]	AVERAGE MPa	AVERAGE KSI	HIGH MPa	HIGH KSI	LOW MPa	LOW KSI	SAMPLES TESTED
ULTIMATE STRENGTH	BASELINE	59.34	8.6					4
ULTIMATE STRENGTH	3 MONTHS	70.52	10.22	75	10.87	67.9	9.84	4
ULTIMATE STRENGTH	6 MONTHS	61.41	8.9	65.52	9.51	57.8	8.38	4
ULTIMATE STRENGTH	96 MONTHS	84.59	12.26	93.36	13.53	79.28	11.29	4
ELASTIC MODULUS	BASELINE	12.42×10^5	1.8×10^5					4
ELASTIC MODULUS	96 MONTHS	13×10^5	1.9×10^5	15.2×10^5	2.2×10^5	10.4×10^5	1.5×10^5	

NOTES: 1 KSI = 6.9MPa

(1) THERMAL VACUUM - TESTED AT 10^{-5} TORR

TABLE 7

MATERIAL: POLYETHELENE

TENSILE STRENGTH AND MODULUS

PROPERTY	EXPOSURE[1]	AVERAGE MPa	AVERAGE KSI	HIGH MPa	HIGH KSI	LOW MPa	LOW KSI	SAMPLES TESTED
ULTIMATE STRENGTH	BASELINE	14.5	2.10					4
ULTIMATE STRENGTH	3 MONTHS	19.87	2.88	20.01	2.90	19.8	2.87	4
ULTIMATE STRENGTH	6 MONTHS	10.07	1.46	10.21	1.48	10.0	1.45	4
ULTIMATE STRENGTH	96 MONTHS	10.49	1.52	13.59	1.97	8.69	1.26	4
ELASTIC MODULUS	BASELINE							4
ELASTIC MODULUS	96 MONTHS	$46x10^3$	$6.7x10^3$	$53x10^3$	$7.7x10^3$	$38.6x10^3$	$5.6x10^3$	4

NOTES: (1) THERMAL VACUUM - TESTED AT 10^{-5} TORR

TABLE 8

MATERIAL: POLYURETHANE

TENSILE STRENGTH AND MODULUS

PROPERTY	EXPOSURE[1]	AVERAGE		HIGH		LOW		SAMPLES TESTED
		MPa	KSI	MPa	KSI	MPa	KSI	
ULTIMATE STRENGTH	BASELINE	59.9	8.1					4
ULTIMATE STRENGTH	3 MONTHS	21.87	3.17	28.29	4.10	6.42	0.93	4
ULTIMATE STRENGTH	6 MONTHS	6.69	0.97	6.76	0.98	6.42	0.93	4
ULTIMATE STRENGTH	96 MONTHS	56.1	8.13	59.4	8.47	54.3	7.87	4
ELASTIC MODULUS	BASELINE							4
ELASTIC MODULUS	96 MONTHS	11.7×10^3	1.7×10^3	13.1×10^3	1.9×10^3	7.6×10^3	1.1×10^3	4

NOTES: (1) THERMAL VACUUM - TESTED AT 10^{-5} TORR

TABLE 9

MATERIAL: LUCITE

TENSILE STRENGTH AND MODULUS

PROPERTY	EXPOSURE[1]	AVERAGE		HIGH		LOW		SAMPLES TESTED
		MPa	KSI	MPa	KSI	MPa	KSI	
ULTIMATE STRENGTH	BASELINE	89.3	12.94					4
ULTIMATE STRENGTH	3 MONTHS	69.55	10.08	83.84	12.15	48.65	7.05	4
ULTIMATE STRENGTH	6 MONTHS	91.56	13.27	97.08	14.07	82.94	12.02	4
ULTIMATE STRENGTH	96 MONTHS	81.70	11.84	85.7	12.42	74.24	10.76	4
ELASTIC MODULUS	BASELINE	11.7×10^5	1.7×10^5					4
ELASTIC MODULUS	96 MONTHS	15.9×10^5	2.3×10^5	17.3×10^5	2.5×10^5	14.5×10^5	2.1×10^5	4

NOTES: (1) THERMAL VACUUM - TESTED AT 10^{-5} TORR

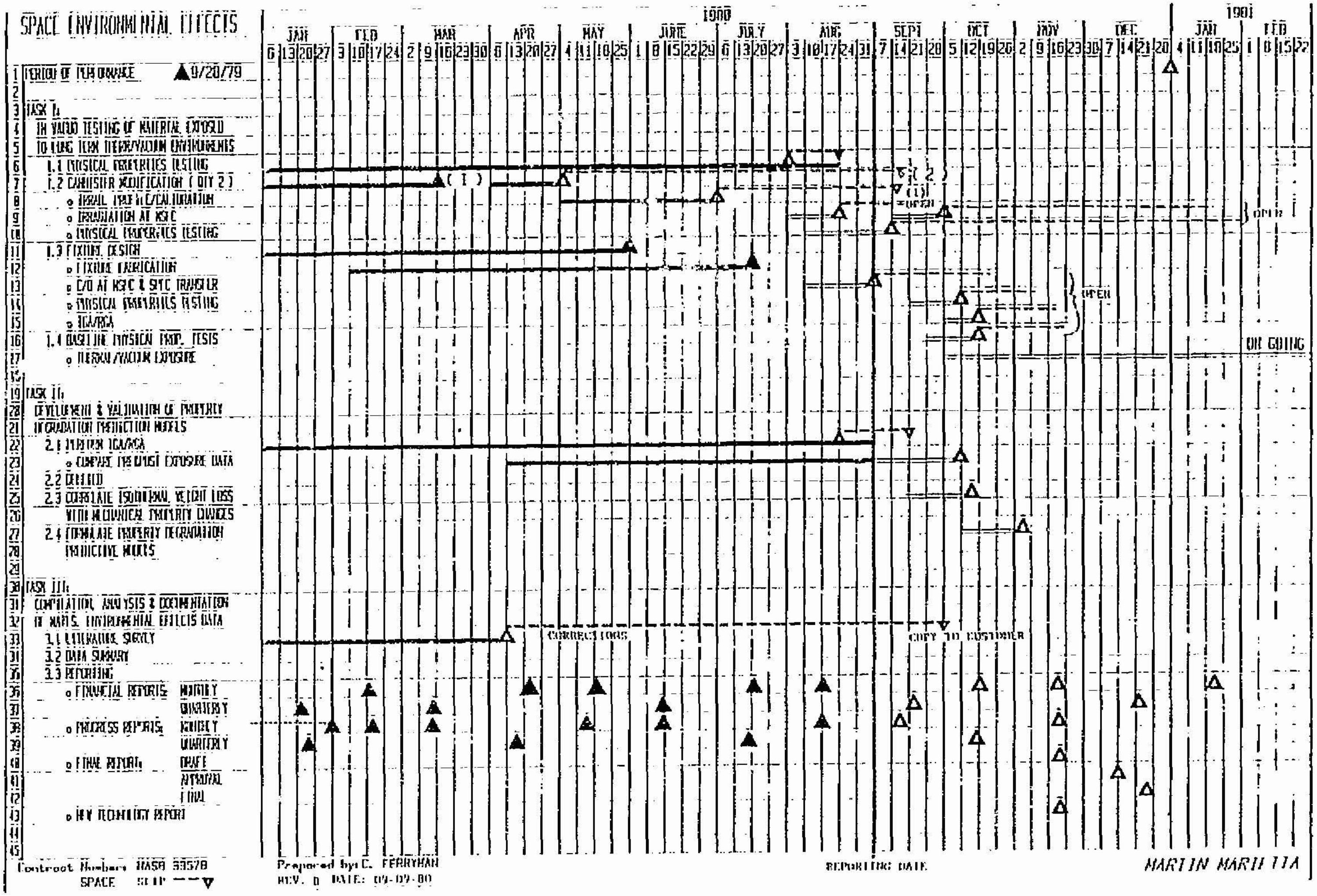
TABLE 10

MATERIAL: LEXAN

TENSILE STRENGTH AND MODULUS

PROPERTY	EXPOSURE[1]	AVERAGE MPa	AVERAGE KSI	HIGH MPa	HIGH KSI	LOW MPa	LOW KSI	SAMPLES TESTED
ULTIMATE STRENGTH	BASELINE	66.7	9.67					4
ULTIMATE STRENGTH	3 MONTHS	50.5	7.32	57.5	8.33	44.7	6.48	4
ULTIMATE STRENGTH	6 MONTHS	50.9	7.37	51.8	7.51	49.4	7.16	4
ULTIMATE STRENGTH	96 MONTHS	49.0	7.10	50.2	7.28	48.6	7.04	4
ELASTIC MODULUS	BASELINE	$8x10^5$	$1.2x10^5$					4
ELASTIC MODULUS	96 MONTHS	$7.2x10^5$	$1.04x10^5$	$7.6x10^5$	$1.1x10^5$	$6.6x10^5$	$.96x10^5$	4

NOTES: (1) THERMAL VACUUM - TESTED AT 10^{-5} TORR


SPACE ENVIRONMENTAL EFFECTS
1980
1981
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB
PERIOD OF PERFORMANCE 9/20/79
TASK I:
IN VACUO TESTING OF MATERIAL EXPOSED
TO LONG TERM THERM/VACUUM ENVIRONMENTS
1.1 PHYSICAL PROPERTIES TESTING
1.2 CANISTER MODIFICATION (QTY 2)
o THERMAL TRAFFIC/CALIBRATION
o IRRADIATION AT KSC
o PHYSICAL PROPERTIES TESTING
1.3 FIXTURE DESIGN
o FIXTURE FABRICATION
o C/O AT KSC & SPEC TRANSFER
o PHYSICAL PROPERTIES TESTING
o TGA/RGA
1.4 BASELINE PHYSICAL PROP. TESTS
o THERMAL/VACUUM EXPOSURE
TASK II:
DEVELOPMENT & VALIDATION OF PROPERTY
DEGRADATION PREDICTION MODELS
2.1 PERFORM TGA/RGA
o COMPARE PRE/POST EXPOSURE DATA
2.2 DEFINED
2.3 CORRELATE ISOTHERMAL WEIGHT LOSS
WITH MECHANICAL PROPERTY CHANGES
2.4 FORMULATE PROPERTY DEGRADATION
PREDICTIVE MODELS
TASK III:
COMPILATION, ANALYSIS & DOCUMENTATION
OF MATLS. ENVIRONMENTAL EFFECTS DATA
3.1 LITERATURE SURVEY
3.2 DATA SUMMARY
3.3 REPORTING
o FINANCIAL REPORTS: MONTHLY
QUARTERLY
o PROGRESS REPORTS: MONTHLY
QUARTERLY
o FINAL REPORT: DRAFT
APPROVAL
FINAL
o NEW TECHNOLOGY REPORT
OPEN
ON GOING
CORRECTIONS
COPY TO CUSTOMER
Contract Number: NAS8 33578
SPACE SLIP
Prepared by: C. FERRYMAN
REV. B DATE: 09-09-80
REPORTING DATE
MARTIN MARIETTA