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WADD TECHNICAL NOTE 60-300

COMPATIBILITY OF ELASTOMERS WITH FUEL ANTI-ICING ADDITIVE

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WRIGHT AIR DEVELOPMENT DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report was prepared by the Elastomers and Coatings Branch and was initiated under Project No. 3048, "Aviation Fuels" Task No. 30178, "The Effect of Fuels on Fuel Systems". It was administered under the direction of the Nonmetallic Materials Laboratory, Materials Central, Wright Air Development Division, with Philip A. House acting as project engineer.

This report covers work conducted from January 1959 to July 1959.

The assistance of Richard L. Kinsey is gratefully acknowledged.

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ABSTRACT

Fuel anti-icing additives have proved helpful in eliminating ice in aircraft fuel systems. One such additive was flight tested until it was found that a coating material used in integral fuel tanks was deteriorating. Available laboratory tests did not predict this development. A study of the non-correlation between laboratory and flight test data is given in this report, as well as an investigation of the compatibility of all aircraft elastomeric materials with this additive. It was found that the particular additive in its present form cannot be used due to the lack of compatibility but evaluation methods are given for future compatibility evaluation of anti-icing additives.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER

R T Schwartz

R. T. SCHWARTZ, Chief
Nonmetallic Materials Laboratory
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SUMMARY

The Phillips Petroleum Company's Anti-Icing Additive No. 52 helped eliminate inflight icing incidences and improved ground drainage of aircraft. The additive, however, caused deterioration of the buna N-phenolic resin topcoat material that is used as a protective coating in the aircraft integral fuel tanks and therefore cannot be used in its present form. There was also a slight increase in volume change of buna N and neoprene when it was immersed in additive fuel at 275°F. One fuel tank sealant exhibited a gradual decrease in strength as additive concentration was increased. These other factors, however, were not considered serious enough to preclude use of the additive. No other materials gave indication of being affected by the additive.

Attempts have been made to alter the topcoat to overcome this difficulty, but as yet these attempts have not been successful. New topcoat materials are being evaluated and probably a suitable product will be found, however, the task of replacing the topcoat in present aircraft would be tremendous. Evaluation of nonmetallic materials for compatibility with new and improved anti-icing additives such as Phillips Petroleum Company's No. 55MB have met with much more success than with the No. 52 additive and these data are presented in a forthcoming WADD report.

The compounds tested were not developed or intended by the manufacturers for the conditions to which they have been subjected. Any failure or poor performance of a material is therefore not necessarily indicative of the utility of the material under less stringent conditions or for other applications.

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SECTION I

INTRODUCTION

A large number of engine malfunctions in jet type aircraft have been encountered which have been attributed to the formation of ice in the fuel system. The possibility of using anti-icing additives in order to eliminate or at least reduce this problem was investigated by Fuels and Lubricants Branch, Applications Laboratory, Materials Central, Wright Air Development Division and Boeing Airplane Company, Wichita Division. It was found that the use of such additives was feasible as far as this problem was concerned. The additive used was Phillips Petroleum Company's Fuel Additive No. 52.

Compatibility studies of elastomers with No. 52 additive were started and shortly thereafter, flight tests were underway at Loring Air Force Base using B-52 and KC-135 aircraft. Flight tests were conducted also at Boeing Airplane Company, Seattle and Wichita Divisions, and Edwards Air Force Base. The flight tests revealed a definite improvement, both in the reduction of inflight malfunctions and the ability to drain accumulated water from the fuel tanks.

Approximately forty-five days of flight tests revealed that the Buna N-Phenolic resin coating material used in the integral fuel tanks was becoming tacky and in some cases was peeling off, a fact that was not predicted by laboratory tests. The flight tests on the aircraft with integral fuel tanks were stopped immediately but the tests were continued on the aircraft with bladder cells until all of the additive fuel was consumed.

An extensive investigation was conducted to determine the reason for the non-correlation of laboratory and flight test data. This report contains the results of that investigation as well as compatibility studies of Phillips No. 52 with all elastomer types that are found in aircraft and ground support equipment. The report also contains recommendations for testing in future compatibility studies.

Manuscript released by author for publication as a WADD Technical Note, March 1961.

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SECTION II

COMPATIBILITY STUDIES

A. General

It was determined that the concentration of Phillips No. 52 additive to be used in the JP-4 would be 0.1% by volume. Most of the evaluations were conducted, however, at a concentration of 0.2% additive in order to accelerate any effect that might be obtained. Results obtained with additive fuel were compared with results obtained with fuel without the additive. Immersions were conducted at 75°F, 140°F, 275°F and 400°F depending on the material being tested with all testing being done at 75°F. Properties evaluated were tensile strength, elongation, hardness, and volume change for most materials and peel strength for sealants and bladder cells. Materials that may be physically located in the bottoms of fuel tanks were evaluated not only in fuel mixtures but also in water and varying concentrations of the additive in water since such materials would actually be exposed to such conditions in service due to settling out and condensation of water. It was originally believed, but later proven false, that using the 0.1% concentration in JP-4, the highest obtainable concentration of Phillips No. 52 additive in an adjacent water phase was 28%. Therefore, additive concentration of 15%, 30%, and 45% in water were chosen for evaluating materials.

B. Hose, Seals, Gaskets in Fuel Systems

The rubber most often found in the fuel systems of today's aircraft is Buna N. Most hose,"O"-ring seals, and gasketing materials are made from this rubber. Some of the large size hose are neoprene. Polyurethane is used in some applications as well as Viton A* and fuel resistant silicone. Some aircraft possess Marman** clamps on the fuel lines which contain a sleeve made of a mixture of Buna N and SBR. All of these were evaluated in varying concentrations of Phillips No. 52 additive in fuel and water. Teflon is used also in fuel systems but it is covered in the electrical insulation section.

1. Buna N. Most of the work was done using a standard stock with a low acrylonitrile polymer. "O"-rings qualified to MIL-P-5315, the fuel "O"-ring specification, were also evaluated. Immersions were done at 75°F, 140°F and 275°F. There was a slight increase in volume change in the additive fuel as compared to the non-additive fuel but this increase is not considered serious. Results are given in Table I for the 140°F immersions. Table II shows the 275°F aging and Table III gives results obtained on the qualified "O"-rings.

*Trademark of E. I. du Pont de Nemours and Company

**Product of Aeroquip Corporation, Marman Division

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Table I

Properties of Buna N after Immersion at 140°F

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	2723	255	75	
After aging 72 hours at 140°F, 24 hours at 75°F in:				
JP-4	1404	166	65	+24.6
JP-4 + 0.1% No. 52				+27.6
JP-4 + 0.2% No. 52	1302	156	65	+27.4
15% No. 52 - 85% water	2329	216	71	+ 7.4
30% No. 52 - 70% water	2328	213	71	+ 8.9
45% No. 52 - 55% water	2106	220	71	+ 9.3
100% No. 52				+36.1
Rerun				+36.6

Table II

Properties of Buna N after Immersion at 275°F

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	3336	306	70	
After aging 72 hours at 275°F in:				
JP-4*	1212	154	50	+34.3
JP-4 + 0.2% No. 52	957	157	47	+38.7
JP-4*	967	157	46	+37.5
JP-4 + 0.1% No. 52	1046	173	45	+40.4

*Different batches of JP-4. 0.2% additive fuel is same fuel as first JP-4; 0.1% additive fuel is same fuel as second JP-4.

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Table III

Volume Change of Buna N "O"-Rings Qualified to MIL-P-5315

After aging 72 hours at 75°F in:	Volume Change %
JP-4	+27.8
JP-4 + 0.2% No. 52	+27.4

2. Neoprene. A standard stock was used of Neoprene WRT. Immersions were done at 140°F and 275°F. There was a slight increase in volume change for the samples that were aged at 275°F in the additive fuel as compared with the non-additive fuel but this is not considered serious. Results of the 140°F immersions are given in Table IV and results of the 275°F immersions are given in Table V.

Table IV

Properties of Neoprene after Immersion at 140°F

	Tensile Strength psi	Elongation %	Hardness Points	Volume Change %
Original Properties	3515	365	80	
After aging 72 hours at 140°F, 24 hours at 75°F in:				
JP-4	1708	227	60	+46.6
JP-4 + 0.2% No. 52	1843	252	60	+46.5
15% No. 52 - 85% water	2857	283	72	+ 6.2
30% No. 52 - 70% water	2917	272	72	+ 7.0
45% No. 52 - 55% water	2649	249	72	-----
100% No. 52				+ 7.4

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Table V

Properties of Neoprene after Immersion at 275°F

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	3361	308	72	
After aging 72 hours at 275°F in:				
JP-4*	1378	269	35	+65.2
JP-4 + 0.2% No. 52	1285	308	38	+74.6
JP-4*	1049	281	33	+69.6
JP-4 + 0.1% No. 52	1024	277	32	+72.3

3. Polyurethane. The polyurethane used for evaluation was Adiprene C**. Immersion was conducted at 75°F. There was a slight increase in volume change in the additive fuel as compared to the non-additive but this condition is not considered serious. Results are shown in Table VI.

Table VI

Properties of Polyurethane

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	4418	374	85	
After aging 72 hours at 75°F in:				
JP-4	3512	316	75	+14.6
JP-4 + 0.2% No. 52	3482	325	75	+17.4

4. Viton A. Immersions were conducted at 75°F and 400°F. There were only very slight differences in results of additive fuel and non-additive fuel. There was a tremendous volume increase in 100% No. 52 thus eliminating the material for applications where 100% No. 52 would be encountered. Results for 75°F immersions are shown in Table VII and for 400°F immersions in Table VIII.

* Different batches of JP-4. 0.2% additive fuel is same fuel as first JP-4; 0.1% additive fuel is same fuel as second JP-4.

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Table VII

Properties of Viton A after Immersion at 75°F

	Tensile Strength psi	Elongation %	Hardness Points	Volume Change %
Original Properties	2238	237	75	
After aging 72 hours at 75°F in:				
JP-4	2147	246	73	- 0.1
JP-4 + 0.2% No. 52	2097	243	73	+ 0.1
50% No. 52 - 50% water				+ 0.6
Rerun				+ 0.3
100% No. 52				+187
Rerun				+182

Table VIII

Properties of Viton A after Immersion at 400°F

	Tensile Strength psi	Elongation %	Hardness Points	Volume Change %
Original Properties	2523	234	72	
After aging 72 hours at 400°F in:				
JP-4	2048	250	60	+12.6
JP-4 + 0.2% No. 52	1923	230	59	+13.0

5. Fuel Resistant Silicone. The material evaluated as a fuel resistant silicone was LS-53*. Immersion was done at 75°F and 275°F. There were no significant differences between the results obtained in additive fuel and non-additive fuel. Table IX gives results for the 75°F immersions and Table X gives results for the 275°F immersions.

* Product of Dow Corning Corporation.

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Table IX

Properties of Fuel Resistant Silicone after Immersion at 75°F

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	898	183	60	
After aging 72 hours at 75°F in:				
JP-4	559	143	60	+ 9.0
JP-4 + 0.2% No. 52	590	146	55	+ 9.8

Table X

Properties of Fuel Resistant Silicone after Immersion at 275°F

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	1070	164	54	
After aging 72 hours at 275°F in:				
JP-4	498	117	45	+17.2
JP-4 + 0.2% No. 52	420	113	46	+18.1

6. Marman Clamp Material. There are two suppliers of the Marman Clamp material. They are the Kirkhill Rubber Company and the Pacific Moulded Products Company. The materials were immersed at 140°F. There were no significant differences between additive fuel and non-additive fuel. Table XI gives results for the Kirkhill Rubber Company material and Table XII gives results for the Pacific Moulded Products Company material.

Table XI

Properties of Kirkhill Rubber Company Material

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	2107	377	70	
After aging 72 hours at 140°F, 24 hours at 75°F in:				
JP-4	362	120	53	+113
JP-4 + 0.2% No. 52	421	123	52	+113

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Table XII

Properties of Pacific Moulded Products Company Material

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original Properties	1396	296	70	
After aging 72 hours at 140°F, 24 hours at 75°F in:				
JP-4	340	128	53	+105
JP-4 + 0.2% No. 52	317	112	51	+105

C. Fuel Tank Materials

The containment of the fuel in today's jet aircraft is mostly accomplished by bladder cells or by integral fuel tanks. Bladder cells consist of a Buna N innerliner, Nylon* barrier, Nylon fabric, and a final outer coating of Buna N. The integral fuel tank is basic aircraft structure designed and fabricated to be fluid tight. Fuel is in direct contact with skins, spars, and the like. The structure is made fluid tight by applying a highly viscous liquid polysulfide sealant along all seams and edges of reinforcing members of the structure as well as over rivets and bolts. This material cures at ambient temperatures to a rubbery solid. The sealant is covered by a Buna N-Phenolic Resin topcoat. This topcoat was originally used to protect the sealant from fuel degradation but now that more fuel resistant sealants are available the topcoat is used for corrosion protection of the metal surfaces. It is important to note that this topcoat material is not actually cured but it is only a drying process and the material is very susceptible to solvent action.

Another method of sealing the integral fuel tank is through the use of groove sealants. These are extremely viscous polysulfide materials that are applied from the outside of the wing of the aircraft with high pressure injection equipment into a groove cut into one of two mating surfaces. This sealant does not cure and new material can be injected into the groove to stop fuel leaks during the life of the aircraft.

1. Bladder Cell Material. An actual bladder cell was used for evaluation and properties tested were tensile strength of the cell wall and adhesion of the seams and plies. Immersions were conducted at 140°F. There was a slight decrease in tensile strength in the 45% additive-55% water solution but this is not considered serious. Test results are shown in Table XIII.

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Table XIII

Properties of Bladder Cell Material

	Tensile Strength lbs./in.	Seam Adhesion lbs./in.	Ply Adhesion lbs./in.
Original Properties	294	17.6	14.5
After aging 168 hours at 140°F, 24 hours at 75°F in:			
JP-4	272	13.7	12.3
JP-4 + 0.2% No. 52	268	12.1	11.7
15% No. 52 - 85% water	269	11.4	9.1
30% No. 52 - 70% water	271	10.9	9.1
45% No. 52 - 55% water	247	9.3	9.8

2. Fuel Tank Sealant, MIL-S-7502. Materials falling into this category have been used for sealing integral fuel tanks for a number of years. They are the ones that require the Buna N-Phenolic Resin topcoat for added fuel protection. Materials chosen as representative were CS-3201, Class B-2 manufactured by Chem Seal Corporation and PR-385M, Class B-2 manufactured by Products Research Company. The most important and the most indicative property that can be evaluated is peel strength. Here the actual value that is obtained is important but of at least equal importance is that the material must fail cohesively. Adhesive failure will result in fuel leakage in service. Sealant was applied to 2 3/4" x 6" x 0.040" 7075 clad aluminum panels and cured seven days at 75°F. Immersions were done at 140°F and there were no significant differences between panels except that the PR-385 M values showed a downward trend as the concentration of No. 52 additive increased. If the additive were used, longer immersions should be conducted on this material. All failures were 100% cohesive. Results are shown in Table XIV.

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Table XIV

Peel Strength of MIL-S-7502 Sealants

	Peel Strength lbs./in.	
	CS-3201	PR-385M
Original Properties	65.0	54.0
After aging 168 hours at 140°F, 24 hours at 75°F in:		
JP-4	59.7	41.4
JP-4 + 0.2% No. 52	63.7	38.0
15% No. 52 - 85% water	45.6	33.7
30% No. 52 - 70% water	47.4	28.8
45% No. 52 - 55% water	42.5	27.5

3. Fuel Tank Sealant, MIL-S-8802. Materials meeting this specification are more fuel resistant than MIL-S-7502 types. When the work was initiated the only qualified compound was PR-1422 manufactured by Products Research Company. Peel strength panels were tested as they were with the MIL-S-7502 sealants. The material was applied to 2 3/4" x 6" x .040" 7075 clad aluminum and cured fourteen days at 75°F. Adhesive failures were obtained in additive water solutions and when the material failed adhesively very low values were obtained. Results are shown in Table XV. Failures were 100% cohesive unless otherwise noted.

Table XV

Peel Strength of PR-1422, Class B-2, Clad Aluminum

	Peel Strength lbs./in.
Original	16.5 (unusually low)
After aging 168 hours at 140°F, 24 hours at 75°F in:	
JP-4	24.6
JP-4 + 0.2% No. 52	25.1
15% No. 52 - 85% water	3.8 (100% adhesive failure)
30% No. 52 - 70% water	I 21.1 (100% cohesive failure except for slight traces)
	II 3.0 (100% adhesive failure)
45% No. 52 - 55% water	2.5 (100% adhesive failure)

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It appeared that a serious problem might exist with this material and an extensive evaluation program was initiated. Three metal surfaces were used: 7075 clad aluminum, anodized* aluminum and iridite treated** aluminum. Immersions were at 75°F and 140°F in seven fluids. These fluids were:

1. JP-4
2. JP-4 + 0.1% No. 52
3. JP-4 + 0.2% No. 52
4. 100% Distilled Water
5. 15% No. 52 - 85% Water
6. 30% No. 52 - 70% Water
7. 45% No. 52 - 55% Water

The anodized and iridite treated aluminum panels were furnished by Boeing Airplane Company. The anodized and iridite treated peel strength panels were prepared by applying a brushable version of PR-1422, curing four hours at 120°F, the regular PR-1422 applied, and cured 48 hours at 75°F followed by 24 hours at 140°F. The brushable material was not applied to the clad panels and cure was 48 hours at 75°F followed by 24 hours at 140°F. No failures were obtained on panels immersed in fuel or additive fuel. The sealant was satisfactory on the iridite treated panels in all solutions. Some adhesive failure was noted on the anodized panels in water-additive solutions but it appeared to be no worse than that obtained on the panels immersed in water. Panels anodized by Products Research Company were evaluated and no failures were obtained. The clad panels revealed some adhesive failure in the water immersion and there was 100% adhesive failure in the water additive solutions at 140°F. No failures were encountered with the 75°F immersions on clad panels.

The only serious failures that were obtained were the 140°F clad panels. It is believed that relatively few fuel tanks possess this surface; however, if the additive were used, all airframe manufacturers were to be contacted concerning this factor. The B-52G and KC-135 do not contain this surface and it was believed safe to use the additive with this sealant. Table XVI gives results for clad aluminum, Table XVII for anodized aluminum, Table XVIII for iridite treated aluminum, and Table XIX gives the results for the Products Research Company prepared panels. All failures are cohesive unless otherwise noted.

*In accordance with MIL-A-8625A.

**Chemical film in accordance with MIL-C-5541, product of Allied Research Products, Inc.

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Table XVI

Repeat on Peel Strength of PR-1422, Class B-2, Clad Aluminum

	Peel Strength lbs./in. 75°F	140°F
Original	23.1	
After aging 168 hours in:		
JP-4	18.2	35.6
JP-4 + 0.1% No. 52	21.5	22.9
JP-4 + 0.2% No. 52	26.0	36.2
100% distilled water	32.0	28.8 (partial adhesive failure)
15% No. 52 - 85% water	24.3	4.2 (100% adhesive failure)
30% No. 52 - 70% water	28.9	4.3 (100% adhesive failure)
45% No. 52 - 55% water	28.5	3.5 (100% adhesive failure)

Table XVII

Peel Strength of PR-1422, Class B-2, Anodized Aluminum

	Peel Strength lbs./in. 75°F	140°F
Original	33.9	
After aging 168 hours in:		
JP-4	26.9	30.1
JP-4 + 0.1% No. 52	44.5	38.5
JP-4 + 0.2% No. 52	41.2	44.7
100% distilled water	I 6.7 (100% adhesive failure)	I 13.3 (60% adhesive failure)
		35.2 (40% cohesive failure)
	II 49.0	II 35.4
15% No. 52 - 85% water	39.5	I 7.5 (100% adhesive failure)
		II 38.3
30% No. 52 - 70% water	46.8	47.9
45% No. 52 - 55% water	44.7	4.5 (50% adhesive failure)
		46.6 (50% cohesive failure)

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Table XVIII

Peel Strength of PR-1422, Class B-2, Iridite Treated Aluminum

	Peel Strength lbs./in. 75°F	140°F
Original	34.8	
After aging 168 hours in:		
JP-4	27.2	34.8
JP-4 + 0.1% No. 52	29.1	34.0
JP-4 + 0.2% No. 52	24.0	31.8
100% distilled water	41.4	39.2
15% No. 52 - 85% water	40.9 (10% adhesive failure)	40.5 (Trace adhesive failure)
30% No. 52 - 70% water	43.7	42.6 (Slight trace adhesive failure)
45% No. 52 - 55% water	39.4	43.5 (Trace adhesive failure)

Table XIX

Peel Strength of PR-1422, Class B-2, Anodized Aluminum, Prepared by Products Research Company

	Peel Strength lbs./in.
After aging 7 days at 140°F, 1 day at 75°F in:	
100% distilled water	22.2
15% No. 52 - 85% water	24.5
30% No. 52 - 70% water	25.5
45% No. 52 - 55% water	19.5

4. Coast Pro-Seal 890, Class B-2. This is a polysulfide sealing compound that, since the evaluation, has become a qualified product under Specification MIL-S-8802. The material is manufactured by Coast Pro-Seal and Manufacturing Company. Peel strength panels were evaluated. The sealing compound was applied to 2 3/4" x 6" x 0.40" 7075 clad aluminum and cured forty-eight hours at 75°F, followed by twenty-four hours at 140°F. Immersions were conducted at 140°F and there were no differences between the additive solutions and the control solutions. Results are shown in Table XX.

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Table XX

Peel Strength of Pro-Seal 890, Class B-2, Clad Aluminum

	Peel Strength lbs./in.
Original	57.5
After aging 144 hours at 140°F, 24 hours at 75°F in:	
JP-4	52.5
JP-4 + 0.1% No. 52	54.8
JP-4 + 0.2% No. 52	49.9
100% distilled water	61.1
15% No. 52 - 85% water	59.8
30% No. 52 - 70% water	58.6
45% No. 52 - 55% water	56.2

5. MIL-S-4383 Topcoat. Materials qualified to this specification are used as coatings for integral fuel tanks to provide fuel protection for the sealant and corrosion protection for the metal. Peel strength panels were prepared on clad, anodized and iridite treated aluminum and immersions were conducted at 75°F and 140°F. The material retained satisfactory peel strength except for 140°F aging in 45% No. 52 - 55% water on clad and anodized panels. There were no failures at lower concentrations of the additive and no failures at all in the 75°F immersions. It was felt that the failures observed were obtained under very severe conditions and that such conditions would not exist during the flight tests at Loring Air Force Base. Test results are shown in Table XXI for the clad panels and Table XXII for the anodized and iridite treated panels.

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Table XXI

Peel Strength of MIL-S-4383 Topcoat, Clad Aluminum

	Peel Strength lbs./in.	
	75°F	140°F
Original	7.7	
After aging 7 days in:		
JP-4	7.5	13.7
JP-4 + 0.1% No. 52	11.7	16.5
JP-4 + 0.2% No. 52	8.1	11.7
100% Distilled water	6.8	10.4
15% No. 52 - 85% water	10.1	6.0
30% No. 52 - 70% water	11.2	5.3
45% No. 52 - 55% water	15.0	0-0.3

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Table XXII

Peel Strength of MIL-S-4383 Topcoat,
Anodized and Iridite Treated Aluminum

	Peel Strength lbs./in.	
	Anodize	Iridite
Original	10.6	5.5
After aging 6 days at 140°F, 1 day at 75°F in:		
JP-4	12.7	16.4
JP-4 + 0.1% No. 52	14.3	10.3
JP-4 + 0.2% No. 52	12.9	8.6
100% distilled water	7.9	11.4
15% No. 52 - 85% water	6.7	19.6
30% No. 52 - 70% water	8.6	18.4
45% No. 52 - 55% water	0.2	15.8

As stated before, the topcoat started becoming tacky and some peeling off was noted in the Boeing and Edwards Air Force Base flight test aircraft. An investigation was then conducted to determine the reasons for the non-correlation of the laboratory and the flight test data.

The first study undertaken was to determine if the topcoat failure had been caused by the sloshing of fuel in the aircraft. The factor of daily fluid changing was also incorporated. Panels of clad aluminum measuring 1" x 6" x .040" were dipcoated in EC-776SR which is manufactured by Minnesota Mining and Manufacturing Company and is a qualified product under Specification MIL-S-4383. The panels were dried 48 hours in a draft-free enclosure to prevent bubbling. Such a procedure results in approximately 1.5 mils of coating on each side of the panel which is the approximate thickness found in aircraft. The panels were exposed to the following fluids:

1. JP-4
2. JP-4 + 0.1% No. 52
3. JP-4 + 0.2% No. 52
4. 100% Distilled Water
5. 15% No. 52 - 85% Water
6. 30% No. 52 - 70% Water

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7. 45% No. 52 - 55% Water

8. 75% No. 52 - 25% Water

9. 100% No. 52

The panels were placed in quart jars and sufficient fluid was added so that the panels were half immersed giving a submerged area and a vapor area. Each jar contained one panel, and two panels were subjected to each fluid under slosh conditions and one panel to each fluid under static conditions. The panels that were subjected to the slosh condition were held firmly in the jars by placing a small amount of MIL-S-7502 sealant on the top end of the panel and adhering it to the side of the jar. This prevented the panel from moving with the fluid. The slosh condition was caused by securely holding the jars on a table that was moved in a circular motion in the vertical plane. The radius of the circle through which the table moved was 1/2" and the rate was 2.9 cycles per second. Such a motion caused severe agitation of the fluid. Ambient temperature during the testing period ranged from 70°F to 90°F.

Significant findings as the test progressed are as follows:

10 minutes - 75% and 100% additive solutions caused noticeable dissolving of topcoat on static panels. 100% slosh panels completely dissolved. 75% slosh panels, topcoat eroded off one side.

30 minutes - All 45% No. 52 - 55% water exposed panels tacky.

2 hours - JP-4, JP-4 + 0.1% No. 52, JP-4 + 0.2% No. 52, 100% water, and 15% additive solution panels are unaffected. 30% additive panels show very slight attack. Topcoat can be rubbed off with finger on all 45% additive panels. Slosh panels slightly worse than static panels.

17 hours - Same conditions as after 2 hours.

22 hours - 30% additive, both static and slosh panels starting to go, can be nicked with finger nail, slosh panels slightly more affected than the static panels. 15% additive panels not affected.

24 hours - Fluids changed. JP-4, JP-4 + 0.1% No. 52, JP-4 + 0.2% No. 52, 100% water, and 15% additive solution panels are not affected other than loss of color in additive-fuel solutions (topcoat contains a red fuel-soluble dye). 30% additive panels, topcoat weakened, can be cut with finger nail, but not tacky. 45% additive panels, topcoat tacky and pulled away from edge on slosh panels. 75% additive panels, topcoat remained firm but has no adhesion. Topcoat under slosh condition completely eroded off and floating in jar as a film. 100% additive panels, topcoat completely dissolved under slosh conditions. Submerged area of static panel completely dissolved. Topcoat in vapor area messy, sticky and no adhesion. There is little significant difference between the static panels and the slosh panels. Slosh tests on the 75% and 100% additive solutions discontinued.

48 hours - Fluids changed. JP-4 and JP-4 + 0.1% No. 52 panels unaffected. JP-4 + 0.2% No. 52 panels can all be nicked with finger nail.

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100% water panels can be nicked with finger nail but stronger than JP-4 + 0.2% No. 52 panels. 15% additive panels are about the same condition as JP-4 + 0.2% No. 52 panels. 30% additive panels are weaker than 15% additive panels. 45% additive panels, topcoat can be rubbed off with finger on all panels. Slosh panels are slightly worse than static panels. 75% and 100% additive panels show no change.

72 hours - Fluids changed. JP-4 and JP-4 + 0.1% No. 52 additive panels are unaffected. JP-4 + 0.2% No. 52 panels exhibit same condition as before. Vapor area of static panel is tacky. 100% water panels are same condition as before. 15% additive panels are not as strong as JP-5 + 0.2% No. 52 panels. Softer in vapor area of static panel than in submerged area. 30% additive panels are fairly easy to nick. 45% additive panels are tacky and topcoat can be rubbed off with finger.

4 days - Fluids changed. JP-4 panels are unaffected. JP-4 + 0.1% No. 52 panels can be nicked with the finger nail. Slightly weaker in vapor area of static panel. JP-4 + 0.2% No. 52 panels are easier to nick than before. Panels are also tacky and conditions are more pronounced in vapor area. 100% water panels are better than fuel-additive panels. 15% additive panels can be nicked fairly easily but not as easily as JP-4 + 0.2% No. 52 panels. 30% additive panels are very easy to nick. 45% additive panels are in very bad shape. 75% and 100% additive panels show no change.

5 days - Fluids changed. JP-4 panels are unaffected. JP-4 + 0.1% No. 52 panels are about the same as they were after 4 days. JP-4 + 0.2% No. 52 panels, topcoat is still a pretty good film. 15% additive panels, topcoat is still a fair film, not as good as 100% water panels. 30% additive panels, topcoat pretty weak, not as good as JP-4 + 0.2% No. 52 panels. 45% additive panels are about the same as they were after 4 days. 75% and 100% additive panels, no change.

6 days - Fluids changed. JP-4 panels are unaffected. JP-4 + 0.1% No. 52 panels, no change. JP-4 + 0.2% No. 52 panels, topcoat can be removed by hard rubbing with finger. Static panel is tacky in vapor area and static panel in worse condition than slosh panels. 100% water panels, no change. 15% additive panels, no change. 30% additive panels, no change. Topcoat cannot be rubbed off like JP-4 + 0.2% No. 52 panels. (Comparing 30% and + 0.2% panel, 30% stronger film, 0.2% more tacky, neither have adhesion.) 45%, 75% and 100% additive panels, no change.

The tests continued for a total of 26 days fluid immersion and 18 fluid changes. Slosh tests were discontinued after 8 days since this condition was not causing any more effect than the static condition. The JP-4 sample could be nicked with the finger nail on the 11th day. Other than this, there were no significant changes on the panels. The panels were evaluated visually at the end of the test as well as by the pencil hardness test. The pencil hardness test consists of 20 drawing pencils ranging from 9B to 9H hardness. The wood is cut back approximately 3/8" and the lead squared by fine abrasive paper or cloth. The pencil is pushed forward against the film at an approximate 45°angle. The film is said to have a pencil hardness of the hardest pencil that can be so pushed without cutting the film. The 9B pencil is the softest and the order from softest to hardest is 9B, 8B, 7B . . . . .2B, B, HB, F, H, 2H . . . . .8H, 9H. Only 4B through 9H pencils were available at the time of the test. The results obtained using this test are as follows:

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Original	3H Hardness
JP-4	B Hardness
JP-4 + 0.1% No. 52	4B Hardness
JP-4 + 0.2% No. 52	Softer than 4B
100% water	4B Hardness
15% No. 52 - 85% water	Softer than 4B
30% No. 52 - 70% water	Softer than 4B
45% No. 52 - 55% water	Softer than 4B

Another set of panels were subjected to the same fluids as before except the 75% No. 52 -25% water and 100% No. 52 solutions were eliminated. A solution of JP-4 + 1.0% No. 52 was added as another fluid since the previous test had pointed out the fact that slightly elevated concentration of additive in fuel was detrimental. The purpose of this test was to prove the effect of fluid changing. Panels were prepared and aged half submerged as before. Temperature was 75°F and the panels were held under static conditions, that is, there was no sloshing of fluids. The panels were subjected to 13 days of fluid immersion, one set of panels to no fluid changing, another set to 7 fluid changes.

It was found that the JP-4 + 1.0% No. 52 fluid was very severe on the topcoat. After 2 days immersion in this fluid the attack was worse than on the 45% No. 52 - 55% water panels and after 4 days the attack was worse than on the previous 75% No. 52 - 25% water panels. It was determined that the fuel-additive solutions caused more attack when the fluids were changed than when they were not. This was not the case in the water-additive solutions.

Another possible contributing factor to the degradation of the topcoat in the flight test aircraft was higher concentration of additive in water than was believed obtainable. The highest possible concentration in water, using the 0.1% concentration in fuel was supposed to be 28%. Water samples drained from fuel tanks at Loring Air Force Base averaged approximately 30% additive and one sample was 81% additive.

The factors that were discovered by the fluid immersion tests are:

1. The additive caused the topcoat to lose adhesion in all cases.

2. JP-4 + 0.2% No. 52, JP-4 + 1.0% No. 52, and 45% 75% and 100% additive-water fluids caused tackiness.

3. The fuel-additive solutions caused more attack in the vapor area than in the submerged area.

4. Attack is accelerated by daily changing of fluid.

5. The sloshing of fuel accelerated the attack on the topcoat only slightly for the first few days.

6. The fluids listed in order of decreasing severity of attack are:

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a. 100% No. 52

b. JP-4 + 1.0% No. 52

c. 75% No. 52 - 25% water

d. JP-4 + 0.2% No. 52

e. 45% additive - 55% water

f. 30% additive - 70% water

g. 15% additive - 85% water

h. 100% water

i. JP-4 + 0.1% No. 52

j. JP-4

The reasons for non-correlation of laboratory and flight test data are:

1. Higher concentrations of additive in water than were expected.

2. The topcoat was originally tested in the form of peel panels. This results in the thickness of topcoat being 5 to 10 mils. When tested in 1 to 2 mils thickness, which is the actual thickness in the aircraft, early deterioration was found.

3. Original panels were subjected to only one fluid, that is, there was no fluid changing. The daily changing of fluid resulted in acceleration of the deterioration.

4. Too much emphasis was placed on high concentrations of the additive in water. Slightly higher concentrations in fuel than were used are much more serious.

6. Groove Sealant. Groove sealants are very viscous materials that are injected from the outside of the wing with high-pressure injection equipment into a groove cut in one of two mating surfaces. This groove is around the entire outside of the tank and it is entirely filled with the material. The groove sealant does not cure and so can be reinjected in case of fuel leakage. The material evaluated was PR-703, a polysulfide, manufactured by Products Research Company. Samples were immersed in the fluids and then subjected to a pressure rupture test. The test consists of packing the material in a special jig and determining the air pressure required to cause it to rupture. No significant differences were found. Results are shown in Table XXIII.

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Table XXIII

Groove Sealant, Pressure Rupture Test

	Pressure psi
Original	25
After aging 168 hours at 140°F in:	
JP-4	18.5
JP-4 + 0.1% No. 52	27.3
JP-4 + 0.2% No. 52	16.5
100% distilled water	22
15% No. 52 - 85% water	29
30% No. 52 - 70% water	38
45% No. 52 - 55% water	40

D. Insulation Materials

Aircraft fuel tanks contain items such as boost pumps and electrical wiring. The wire insulation and potting compounds come into direct contact with fuel. It is therefore important to evaluate the compatibility of these materials with the additive.

1. Polyethylene, Nylon*, Teflon*. These materials are used for wire insulation. Teflon is also used in fuel systems as hose and seals. These materials were evaluated for tensile strength and elongation after subjection to the fluids and all were tested in tubing form. No significant differences between additive fluids and control fluids were found. Results for polyethylene are given in Table XXIV, Nylon in Table XXV and Teflon in Table XXVI.

*Trademark of E. I. du Pont de Nemours and Co.

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Table XXIV

Polyethylene Tubing, Tensile Strength and Elongation

	Tensile Strength psi	Elongation %
Original	1063	152
After aging 72 hours at 75°F in:		
JP-4	850	69
JP-4 + 0.2% No. 52	886	71
100% distilled water	1152	93
15% No. 52 - 85% water	1063	117
30% No. 52 - 70% water	1081	107
45% No. 52 - 55% water	1081	148

Table XXV

Nylon Tubing, Tensile Strength and Elongation

	Tensile Strength psi	Elongation %
Original	4474	283
After aging 72 hours at 75°F in:		
JP-4	4206	272
JP-4 + 0.2% No. 52	3758	231
100% distilled water	3110	226
15% No. 52 - 85% water	3288	237
30% No. 52 - 70% water	3065	217
45% No. 52 - 55% water	3624	238

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Table XXVI

Teflon Tubing, Tensile Strength and Elongation

	Tensile Strength psi	Elongation %
Original	5521	170
After aging 72 hours at 75°F in:		
JP-4	5198	162
JP-4 + 0.2% No. 52	5411	165
100% distilled water	5403	162
15% No. 52 - 85% water	5142	150
30% No. 52 - 70% water	5308	162
45% No. 52 - 55% water	5324	161

2. Potting Compound, MIL-S-8516. This material is used for sealing of electric connectors and wiring to protect against vibration failure, corrosion, and water contamination. The sealant evaluated was PR 1201Q manufactured by Products Research Company. Peel strength was evaluated on clad aluminum panels. Cure used was 48 hours at 75°F, followed by 48 hours at 158°F. No effect was noted except for a lesser value in the 45% No. 52 - 55% water fluid. All failures were 100% cohesive. Results are given in Table XXVII.

Table XXVII

Peel Strength of Potting Compound, Clad Aluminum

	Peel Strength lbs./in.
Original	32.0
After aging 72 hours at 75°F in:	
JP-4	29.4
JP-4 + 0.2% No. 52	31.6
100% distilled water	34.2
15% No. 52 - 85% water	32.2
30% No. 52 - 70% water	34.8
45% No. 52 - 55% water	21.2

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E. Non-Fuel Resistant Materials: Natural Rubber, Silicone Rubber, Silicone Sealant, Butyl, SBR (GR-S)

None of these materials should ever be used in a fuel system. They were evaluated to determine if they would be seriously affected by spillage of additive fuel. Tensile strength, elongation, hardness, and volume change were evaluated for all these materials. As was expected the materials were greatly degraded by the fuel, however, the additive fuel did not cause any further damage. Table XXVIII gives results for natural rubber, Table XXIX for silicone rubber, Table XXX for silicone sealant, Table XXXI for butyl, and Table XXXII for SBR.

Table XXVIII

Properties of Natural Rubber

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original	1449	191	82	
After aging 72 hours at 75°F in:				
JP-4	132	43	62	+115
JP-4 + 0.2% No. 52	213	65	62	+109
50% No. 52 - 50% water	-	-	-	+ 0.4
100% No. 52	-	-	-	+ 2.7

Table XXIX

Properties of Silicone Rubber

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original	817	314	62	
After aging 72 hours at 75°F in:				
JP-4	148	80	45	+117
JP-4 + 0.2% No. 52	178	79	43	+118

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Table XXX

Properties of Silicone Sealant

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original	133	183	40	
After aging 72 hours at 75°F in:				
JP-4	64	81	10	+304
JP-4 + 0.2% No. 52	59	73	5	+309

Table XXXI

Properties of Butyl Rubber

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original	1721	409	80	
After aging 72 hours at 75°F in:				
JP-4	214	97	52	+126
JP-4 + 0.2% No. 52	221	96	42	+129

Table XXXII

Properties of SBR

	Tensile Strength	Elongation	Hardness	Volume Change
	psi	%	Points	%
Original	2243	333	72	
After aging 72 hours at 75°F in:				
JP-4	319	94	53	+115
JP-4 + 0.2% No. 52	384	95	53	+115

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SECTION III

RECOMMENDATIONS FOR FUTURE ELASTOMER COMPATIBILITY TESTING

Advantages obtained by use of Phillips Petroleum Company's Anti-Icing Additive No. 52 make it mandatory that a search be made for other additives that will help alleviate the icing problem and be compatible with all components of the fuel system. This makes it necessary to set down methods of compatibility evaluation based on knowledge gained testing compatibility with the No. 52 additive. Materials evaluated, properties to be tested, and fluids to be used are necessary. Table XXXIII shows fluids to be used for each material and Table XXXIV shows the properties that are to be tested for each material. It is too restrictive to set requirements for the materials since an additive will be used if possible. Results obtained with additive solutions will be compared with control solutions, JP-4 and 100% distilled water, to determine if serious degradation has been caused by the additive.

A. Test Fluids

The test fluids to be used are:

1. JP-4.

2. JP-4 with the recommended use concentration of the additive.

3. JP-4 with twice the recommended use concentration of the additive.

4. 100% distilled water.

5. Highest concentration in water possible for twice the recommended use concentration of the additive.

6. Two layer liquid of 3 and 5.

7. Highest concentration of additive in fuel that is possible.

8. 100% additive.

Fluid No. 6 is used to determine if there is an effect on a material when additive fuel is over a high concentration of additive in water. Such a condition would probably result in the additive in the water migrating into the fuel, thus increasing the concentration. The first six fluids are considered the approval fluids, the last two are included for more academic reasons but in the case of very serious failure would probably result in further testing.

B. Fuel Tank Materials

The most critical items with respect to compatibility with an anti-icing additive will probably be found in the integral fuel tank and in particular the Buna N-Phenolic Resin topcoat. Therefore, the compatibility studies with the topcoat should be started first. The clad aluminum used for topcoat evaluation and peel strength testing shall be QQ-A-287, 7075-T6. The anodized and iridite treated panels shall be QQ-A-283, 7075-T6.

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1. MIL-S-4383 Topcoat. The panels shall be 1" x 6" x .040" clad aluminum, anodized aluminum, and iridite treated aluminum. Panels are cleaned by scrubbing and rinsing with soap-free and grease-free rags or paper towels using the solvent cleaner shown below. After rinsing and while still wet, the panels shall be wiped dry with a clean lint-free cloth. A topcoat qualified to Specification MIL-S-4383 is applied by a single dipcoat. The coated panels are dried by suspending or placing them vertically in a draft-free enclosure for 48 hours.

Formulation of Cleaner

Ingredient	Specification	Percent by Volume
Aromatic petroleum naphtha	TT-N-97, Type I, Grade B	50
Ethyl acetate	TT-E-751	20
Methyl-ethyl-ketone	TT-M-261	20
Isopropyl alcohol	MIL-F-5566	10

Four panels of each metal surface shall be exposed in closed, glass quart jars at 140°F to all eight test fluids. There shall be two panels in each jar and the jars shall be approximately half full, giving a submerged area and a vapor area. One set of panels shall be exposed to each fluid for a total of 14 days with daily fluid changing. The other set of panels shall be exposed for 70 days with the fluid changed every 14 days, not on the 70th day. The panels are examined at each fluid change to determine if there is a difference between the additive exposed panels and the control panels, JP-4 and 100% water. At the end of the immersion test, the panels can be evaluated by the pencil hardness test. It is hoped that an anti-icing additive can be found that does not cause any more deterioration than JP-4. In the absence of the pencil hardness test, the topcoat is examined for tackiness, lifting and loss of adhesion.

2. MIL-S-7502 and MIL-S-8802 Integral Fuel Tank Sealants. There are two materials under MIL-S-7502 and three materials under MIL-S-8802 that require evaluation. A black material and a tan material will be tested under MIL-S-7502 and under MIL-S-8802 there will be PR-1422, Pro-Seal 890, and EC-1675.

The peel strength on clad, anodized and iridite treated aluminum will be determined for all of these materials. Peel strength panels are 2 3/4" x 6" x .040". They are cleaned, using the same procedure as for the topcoat panels. The sealant is mixed and a 1/8" coating is put on one side of the panel. A strip of cotton duck measuring 2 3/4" x 12" is placed over the sealant and an additional 1/32" coating applied. Previous to placing the duck on the panel, sealant should be worked into the duck with a spatula. Cure for the MIL-S-7502 materials is 7 days at 75°F and 50% relative humidity or 24 hours at 75°F followed by 24 hours at 120°F. Cure for the MIL-S-8802 materials is 14 days at 75°F and 50% relative humidity or 48 hours at 75°F followed by 24 hours at 140°F. The panels are to be completely immersed in all eight fluids, in closed, quart glass containers. There are two panels in each container. One set of panels is subjected to each fluid for 7 days at 140°F followed by one day at 75°F with no fluid changes. Another set of panels is subjected to each fluid for 70 days at 140°F followed by one day at 75°F with fluid changing every 14 days, not on the 70th day. The panels are removed from the fluid and the sealant cut through to the panel so that the

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middle inch of the 2 3/4" is available for peel strength testing. The peel strength is tested in a standard tensile testing machine and the sealant is peeled back at 180°. The numerical average of the peak loads is the peel strength. The sealant shall be cut through to the panel a minimum of three times to try to obtain an adhesive failure. The actual peel strength value is of importance but of at least equal importance is that the material must fail cohesively.

3. EC-1605. This material will be evaluated for peel strength exactly like the MIL-S-7502 and MIL-S-8802 except that it will be done on iridite treated aluminum only. Cure for the material is 14 days at 75°F and 50% relative humidity.

4. Fuel Cell Material, Buna N-Nylon Fabric. Tensile strength of the material and peel strength of the seams and between the plies shall be determined after aging 7 days at 140°F followed by 1 day at 75°F.

5. MIL-A-9117 Fuel Cell Repair Adhesive. The adhesive shall be used to cement 2" x 6" panels of fuel cell material together leaving a one-inch uncemented portion on the end. After 24 hours cure, two cemented panels shall be subjected to each of the eight test fluids for 7 days at 140°F followed by one day at 75°F. The panels are removed from the fluid and cut so that the middle inch is left for testing. The panels are tested in a suitable tensile testing machine using a 180° peel back. The peel strength is the numerical average of the peak loads.

6. Groove Sealant, PR-703. Pressure rupture blowout tests shall be conducted on this material after aging 7 days at 140°F, followed by one day at 75°F.

7. Structural Adhesives, FM-47, Melbond 4021, Epon 422, Epon VIII. All these materials will be tested for tensile shear strength. One-half inch lap-joint specimens, one inch wide by 7 1/2 inches long shall be prepared in accordance with MIL-A-5090B. Five specimens are subjected to each condition. One set of specimens shall be subjected to the eight fluids for 7 days at 140°F followed by one day at 75°F. Another set shall be subjected to the fluids for 70 days at 140°F followed by one day at 75°F with fluid changing every 14 days, not the 70th day.

C. Fuel System Materials, Buna N, Neoprene, Viton A, Fuel Resistant Silicone, Polyurethane, 2 Marman Clamp Materials

All of these materials shall be tested for tensile strength, elongation, hardness and volume change after aging 72 hours at 75°F in JP-4 and JP-4 with twice the recommended use concentration of the additive. Buna N, neoprene and fuel resistant silicone shall also be evaluated for the same properties after aging 72 hours at 275°F in JP-4 and JP-4 with twice the recommended use concentration of the additive. Viton A shall be evaluated after aging 72 hours at 400°F.

D. Insulation Materials, Polyethylene, Nylon, Teflon, Polysulfide Potting Compound

The tensile strength and elongation of the first three shall be tested after immersion for 72 hours at 75°F in all eight fluids. The peel strength of the potting compound on clad aluminum shall be evaluated after immersion for 72 hours at 75°F in all eight test fluids. The cure for this material is 48 hours at 75°F and 50% relative humidity followed by 48 hours at 158°F.

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E. Non-Fuel Resistant Materials, Natural, Silicone Rubber, Silicone Sealant, Butyl, SBR(GR-S), Polyvinyl Chloride

These are the least import nt materials to be evaluated. They will be evaluated, however, to determine if they could be seriously affected by spillage of additive fuel. Tensile strength, elongation, hardness and volume change will be determined after immersion for 72 hours at 75°F in JP-4 and JP-4 with twice the recommended use concentration of the additive. Hardness and volume change will not be conducted on the polyvinyl chloride.

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Table XXXIII

Fluids in which the Materials are Evaluated

Materials	Fluid 1	Fluid 2	Fluid 3	Fluid 4	Fluid 5	Fluid 6	Fluid 7	Fluid 8
MIL-S-4383 Topcoat	X	X	X	X	X	X	X	X
MIL-S-7502	X	X	X	X	X	X	X	X
MIL-S-8802	X	X	X	X	X	X	X	X
EC-1605	X	X	X	X	X	X	X	X
Fuel Cell Material	X	X	X	X	X	X	X	X
MIL-A-9117	X	X	X	X	X	X	X	X
Groove Sealant	X	X	X	X	X	X	X	X
Structural Adhesives	X	X	X	X	X	X	X	X
Buna N	X		X					
Neoprene	X		X					
Viton A	X		X					
Fuel Resistant Silicone	X		X					
Polyurethane	X		X					
Marman Clamp Materials	X		X					
Polyethylene	X	X	X	X	X	X	X	X
Nylon	X	X	X	X	X	X	X	X
Teflon	X	X	X	X	X	X	X	X
Potting Compound	X	X	X	X	X	X	X	X
Natural Rubber	X		X					
Silicone Rubber	X		X					
Silicone Sealant	X		X					
Butyl	X		X					
SBR	X		X					
Polyvinyl Chloride	X		X					

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Table XXXIV

Properties of the Materials to be Evaluated

Materials	Peel Strength	Tensile Strength	Elongation	Hardness	Volume Change
MIL-S-4383 Topcoat	Visual Inspection and Pencil Hardness Test				
MIL-S-7502	X				
MIL-S-8802	X				
EC-1605	X				
Fuel Cell Material	X	X			
MIL-A-9117	X				
Groove Sealant	Pressure Rupture Blowout Test				
Structural Adhesives	X				
Buna N		X	X	X	X
Neoprene		X	X	X	X
Viton A		X	X	X	X
Fuel Resistant Silicone		X	X	X	X
Polyurethane		X	X	X	X
Marman Clamp Material		X	X	X	X
Polyethylene		X	X		
Nylon		X	X		
Teflon		X	X		
Potting Compound	X				
Natural Rubber		X	X	X	X
Silicone Rubber		X	X	X	X
Silicone Sealant		X	X	X	X
Butyl		X	X	X	X
SBR		X	X	X	X
Polyvinyl Chloride		X	X		

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APPENDIX

SUGGESTED SOURCES OF MATERIALS

MIL-S-4383

Manufacturer's Designation	Manufacturer
CS 3600	Chem Seal Corporation 12910 Panama Street Los Angeles 66, California
3C-3001	Churchill Chemical Corporation 3137 East 26th Street Los Angeles 23, California
444 R	Coast Pro-Seal and Mfg. Company 2235 Beverly Blvd. Los Angeles 57, California
833-5	Magic Chemical Company 121 Crescent Street Brockton, Massachusetts
EC-776SR	Minnesota Mining and Mfg. Company 411 Piquette Avenue Detroit 2, Michigan
195.32	Presstite-Keystone Engineering Products Company 39th and Chouteau Avenue St. Louis 10, Missouri
PR-1005L	Products Research Company 3126 Los Feliz Blvd. Los Angeles 39, California

MIL-S-7502-Tan

Manufacturer's Designation	Manufacturer
CS-3201	Chem Seal Corporation
3C-401	Churchill Chemical Corporation
Pro-Seal 707	Coast Pro-Seal and Mfg. Company
EC-1239	Minnesota Mining and Mfg. Company
1170	Presstite-Keystone Engineering Products Company
PR-1221	Products Research Company

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MIL-S-7502-Black

Manufacturer's Designation	Manufacturer
Pro-Seal 247	Coast Pro-Seal and Mfg. Company
EC-801	Minnesota Mining and Mfg. Company
1100-2	Presstite-Keystone Engineering Products Company
PR-385M	Products Research Company

MIL-S-8802

Pro-Seal 890	Coast Pro-Seal and Mfg. Company
PR-1422	Products Research Company
EC-1675	Minnesota Mining and Mfg. Company

EC-1605

EC-1605	Minnesota Mining and Mfg. Company

Fuel Cell Material

----	The Goodyear Tire & Rubber Co. Akron, Ohio
----	The B. F. Goodrich Company Akron, Ohio
----	The United States Rubber Company Mishawauka, Indiana
----	The Firestone Tire & Rubber Co. Akron, Ohio

MIL-A-9117

EC-678	Minnesota Mining and Mfg. Company
Bondmaster G-513A	Rubber and Asbestos Corporation 225 Belleville Avenue Bloomfield, New Jersey

Groove Sealant

PR-703	Products Research Company

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Contrails

Structural Adhesives

Manufacturer's Designation	Manufacturer
FM-47	Bloomingdale Rubber Company Chester, Pennsylvania
Metbond 4021	Narmco Resins and Coatings, Inc. Costa Mesa, California
EPON 422	Shell Chemical Corporation 380 Madison Avenue New York 17, New York
EPON VIII	Shell Chemical Corporation

Buna N

Source - MIL-R-6855, Class I

Formulation used by WADD

Ingredients	Parts
Paracril 18-80	100
Philblack A	60
Zinc Oxide	5
Sulphur	1.5
Stearic Acid	1.5
Altax	1.5

Cure 20 minutes at 310°F

Neoprene

Source - MIL-R-6885, Class II

Formulation used by WADD

Ingredients	Parts
Neoprene (WRT)	100
Neozone A	2
Stearic Acid	0.5
MgO (Light)	2
NA-22	0.5
Zinc Oxide	5
HMF Black	50

Cure 20 minutes at 310°F

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Viton A

MIL-R-25897

Manufacturer's Designation	Manufacturer
17107	Precision Rubber Products Corp. 3110 Oakridge Drive Dayton 7, Ohio
V-WK-400	Acushnet Process Company New Bedford, Massachusetts
VL 1502 H12	Vernay Laboratories, Inc. Yellow Springs, Ohio
8070	Nichols Engineering Inc. Old Stratford Road Shelton, Connecticut
77-545	Parker-Hannifin Corporation 17325 Euclid Avenue Cleveland 12, Ohio
9671	Garlock Packing Company Palmyra, New York
SR-270-70	Stillman Rubber Company 5811 Marilyn Avenue Culver City, California

Fuel Resistant Silicone

MIL-R-25988

Polyurethane - Adiprene "C"

Manufacturer's Designation	Manufacturer
Adiprene C	E. I. du Pont de Nemours & Co. Wilmington, Delaware

Marman Clamp Material

Manufacturer's Designation	Manufacturer
----	Kirkhill Rubber Company Brea, California
----	Pacific Moulded Products Company Los Angeles 1, California

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Polyethylene

MIL-I-631

Manufacturer's Designation	Manufacturer
Resinite Poly Temp. E	The Borden Chemical Company 350 Madison Avenue New York 17, New York
M-1485	Union Carbide and Carbon Corp. 30 E. 42nd Street New York, New York
Aeroflex Tubing	Anchor Plastics Company, Inc. 36-36 36th Street Long Island City, New York
Natural Ply Tubing	Extruders, Inc. 3232 West El Segundo Blvd. Hawthorne, California
XN-10-44	New England Tape Co., Inc. 30 Tower Street Hudson, Massachusetts
Irvington Cat. #3015	Irvington Varnish & Insulator Div. Minnesota Mining and Mfg. Company 425 13th Street, N. W. Washington 4, D. C.
Turbo Polyethylene	The William Brand and Co., Inc. North and Valley Streets Willimantic, Connecticut

Nylon

Same sources as for polyethylene

Teflon

AMS-3651

Polysulfide Potting Compound

MIL-S-8516

3C-1300	Churchill Chemical Corporation
Pro-Seal 727	Coast Pro-Seal and Mfg. Company
EC-1641	Minnesota Mining and Mfg. Company
1156	Presstite-Keystone Engineering Products Company
PR-1201Q	Products Research Company

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Natural Rubber

MIL-R-3065 and MIL-STD-417

Silicone Rubber

MIL-R-5847

Silicone Sealant

Manufacturer's Designation	Manufacturer
----	Dow Corning Corporation Midland, Michigan
----	General Electric Company Silicone Department Mechanicville Road Wateford, New York
----	Union Carbide Silicones Division Tonawanda, New York

Butyl

MIL-R-3065 and MIL-STD-417

SBR

MIL-R-3065 and MIL-STD-417

Polyvinyl Chloride

MIL-I-7444

Natvar 362	Natvar Corporation 211 Randolph Avenue Woodbridge, New jersey
Irvington 3022 Irvington 3007	Irvington Varnish and Insulator Div.
Jayco Compound 7401	Jordan Manufacturing Company 1850 Miner Street Des Plaines, Illinois
EP-93 EP-93C	The Borden Chemical Co.
12373C	Surprenant Manufacturing Company 199 Washington Street Boston 7, Massachusetts

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Manufacturer's Designation	Manufacturer
Turbo 623, 783, 624	The William Brand and Company, Inc.
1700	Robert S. Crane Associates 500 Hutton Place Columbus 15, Ohio
Glitex 145	Genesee Laboratory, Inc. 16 Garden Street Auburn, New York
Syntholvar 107	Verflex Corporation Rome, New York
NETCO 10-183	New England Tape Company, Inc. 30 Tower Street Hudson, Massachusetts

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