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DEVELOPMENT OF A
SPECIAL PURPOSE SPACECRAFT INTERIOR COATING

Technical Report - Phase I

Contract NAS 9-14403

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FOREWORD

The work described herein, which was conducted by the Pennwalt Corporation, was performed under NASA Contract NAS 9-14403 during the period from 12 November 1974 through 11 June 1975. Mr. Dale Sauers of the Structures and Mechanics Division of the NASA L. B. Johnson Space Center was the Technical Monitor.

ABSTRACT

Coating formulations were developed consisting of latex blends of fluorocarbon polymers, acrylic resins, stabilizers, modifiers, other additives, and a variety of inorganic pigments. Suitable latex primers were also developed from an acrylic latex base.

The formulations dried to touch in about one hour and were fully dry in about twenty-four hours under normal room temperature and humidity conditions. The resulting coatings displayed good optical and mechanical properties, including excellent bonding to (pre-treated) substrates. In addition, the preferred compositions were found to be self-extinguishing when applied to non-flammable substrates and could meet the offgassing requirements specified by NASA for the intended application.

Improvements are needed in abrasion resistance and hardness.

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I. INTRODUCTION

There is a need in the space program for paints capable of meeting the stringent application and functional requirements imposed by a completely closed environment such as the crew cabin of a spacecraft. Operation of the planned Space Shuttle may require rapid refurbishment and reconfiguration of the Shuttle interior between missions. It is, therefore, important to have a coating system available that can be applied in the Shuttle cabin without requiring removal of subsystems. Thus, the coating must cure quickly without being baked and must not evolve toxic gases. To assure crew safety and to avoid contamination of adjacent systems, the cured coating is required to exhibit the following characteristics when tested pursuant to NASA Document NHB 8060.1A, "Flammability, Odor, Offgassing Requirements, and Test Procedures for Materials in Environments That Support Combustion":

a. Offgassing characteristics when tested after 24 hours or less of ambient temperature cure: Carbon monoxide $\leq 25 \mu g/g$, total organics $\leq 100 \mu g/g$, odor ≤ 2.5.

b. Containing no highly combustible or toxic solvents or diluents that would require elaborate ventilation or safety precautions during application.

c. Self-extinguishing when applied to nonflammable substrates.

d. Generating little or no visible smoke or toxic gases when subjected to radiant heating.

For applications that require exposure to deep space, the coating system must meet the following additional vacuum stability requirements when tested in accordance with NASA Document SP-R-0022, "Specification of Vacuum Stability Requirements of Polymeric Material for Spacecraft Application":

e. Volatile condensible material $\leq 0.1\%$

f. Total weight loss $\leq 1.0\%$

In addition, the coating should possess a range of physical properties comparable to those of currently available systems such as epoxy paints and be pigmentable to a variety of colors.

This report includes a description of the technical approach, coating experiments, and accomplishments of the first phase of the program.

II. TECHNICAL APPROACH

An analysis of the various requirements summarized in the Introduction, combined with a study of the potential offered by a number of novel or improved coating systems, led to the selection

of fluoropolymer coatings as preferred candidates for this development work. Pennwalt's expertise in the area of outdoor fluoropolymer coatings was expected to provide the necessary technical background for this program. Company-sponsored work carried out at our laboratories had demonstrated the potential of water-based fluoropolymer coating systems for those applications for which environmental and safety restrictions prevent the use of more conventional paints. A fluoropolymer system that had been found to be particularly promising for room temperature cure consisted of a terpolymer of vinylidene fluoride and two perfluoroolefins (designated as RC-9107). This composition was selected as the polymer system to be used as the basis for further development. Additional work needed included screening of stabilizers, coalescing aids, pH modifiers and other additives, primers, and a general evaluation of coating properties on different substrates.

III. COATING DEVELOPMENT

It was indicated in the previous section that the fluoropolymer selected as the base material for this project is a terpolymer of vinylidene fluoride and two perfluoroolefins that is designated as RC-9107. It is a white solid and possesses a film formation temperature lower than most fluoropolymers that are commercially available at the present time.

A. Preliminary Study of the RC-9107 Coating System from Organic Solvents

Initial efforts were directed toward preliminary testing of the RC-9107 coating system from organic solutions because they would provide the maximum coalescing effect to the polymer for the formation of a good continuous film at the room temperature drying conditions. The solvents chosen were mostly lower molecular weight ketones and esters and, as much as possible, those that conform to Rule 66 (Los Angeles County) restrictions. Examples of the types of solvents tested were ethyl acetate, cyclohexanone, cellosolve acetate, and methyl ethyl ketone. Lesser amounts of such solvents as diacetone alcohol, dimethylacetamide and other Rule 66 required solvents were tested, within Rule 66 specifications, as additives for purposes of control of evaporative rate. These solution coating formulations were prepared with different solid contents and were applied by either brush or spray.

Initial results were encouraging. The adhesion characteristics of the coatings were good, and performance evaluation was continued, including Weather-O-Meter testing at Dew-cycle conditions and unshielded Sunshine Carbon Arc. After 200 cycles the samples were still in

good condition, that is, at least equivalent to dispersion cast KYNAR 500* controls. The long-life, low maintenance, ultraviolet resistance and weatherability of KYNAR 500 are well established. In these coating properties, RC-9107 appeared to be equivalent to KYNAR 500. A latex coating system having the same fluoropolymer composition could conceivably have offered similar coating characteristics if properly fused or coalesced from a water base.

B. Latex Development

1. Stabilizers

The initial part of the latex development study consisted of efforts to produce latex formulations based on the RC-9107 terpolymer that would be stable at 50% minimum solid content by weight (wt.% NVM, Non Volatile Material). This latex system is designated as RC-9108.

Attempts to concentrate the raw latex directly from the reactor by an evaporative technique were unsuccessful. Coagulation occurred when the solid range of 40-45% NVM was reached. The procedure chosen to stabilize the latex sufficiently to permit the concentration and subsequent handling and formulation without coagulation was to use a compatible surfactant and, if necessary, a cellulosic protective colloid such as hydroxyethyl cellulose. An arbitrary level of 3 wt.% active surfactant based on total resin solid was used, and the protective colloid, Cellosize QP-4400, was chosen at 0, 0.25, and 0.50% by weight, also on total resin solids. The nonionic surfactants tested were Tritons X-100, X-114, X-207, X-405, N-57, CF-10, and Pluronic F-108.

Tritons X-207 and N-57 were not effective. Coagulation occurred during the concentration step. Triton CF-10 was only marginally effective in this screening, the resulting latex being somewhat shear sensitive, and the sample with 0.5% QP-4400 coagulated as the 50% NVM level was approached. Triton X-100, X-114, X-405 and Pluronic F-108 looked more promising. Subsequent screening reduced the candidate systems to two, F-108 and X-405. The results are summarized in Table I. The viscosity and thixotropic character of the latex increased, as expected, with the use of Cellosize QP-4400. The various factors involved in the latex development led eventually to the selection of Pluronic F-108 as the surfactant of choice.

*Trade name for Pennwalt's polyvinylidene fluoride outdoor coatings.

2. pH Modifiers

The RC-9108 latex was blended with an acrylic latex to obtain formulations with suitable film forming characteristics at toom temperature. Consequently a pH modifier was necessary to adjust the acidic RC-9108 before addition of the basic acrylic latex. Most acrylic latices suitable for use in this type of application are basic and coagulate if the pH is allowed to stray to the acid side. RC-9108 is stable in the pH range of 3-10 and thus its pH must be adjusted prior to blending with acrylate latices.

A brief screening of candidates for use as pH modifiers (Table II) indicated that NH_4OH (ammonium hydroxide), AMP (2-amino-2-methyl-1-propanol), and DMAE (2-dimethylaminoethanol) were good candidates. Testing of these candidates in finished formulations was then necessary to confirm their utility and to better define any limitations. This resulted in the selection of DMAE as the pH modifier of choice.

3. RC-9108/Acrylic Latex Blends

It was indicated earlier that adequate film forming characteristics were expected for blends of RC-9108 with an acrylic latex. Thus, a compatibility study involving the fluoropolymer system and selected acrylic latices was necessary. Table III illustrates the results of a study involving RC-9108 with different stabilizers and commercially available acrylic latices with a RC-9108/acrylic ratio of 75/25 by weight. These RC-9108/acrylic blends, as well as the RC-9108 latex alone, were cast onto glass plates and air dried. The castings, (2-2.5 mils wet and 1-1.3 mils dry, film thickness), were dry to the touch within 10 minutes but were allowed 24 hours to dry. Results of the observations made on the resultant films indicated that film clarity and overall quality varied from best to worst in this order: RC-9108/AC-35; RC-9108/MV-1; RC-9108/AC-61; RC-9108 alone; RC-9108/B89A. RC-9108 latex samples, with either stabilizing system, F-108 or X-405 gave equivalent results. Subsequent formulation studies led to the selection of F-108 as the surfactant of choice, as indicated earlier.

The compatibility of RC-9108/acrylic latices was further screened by preparing and casting on glass the blends 100/0, 90/10, 85/15, 80/20, 75/25, 70/30, 60/40, and 50/50, by weight, of both RC-9108/

AC-35 and RC-9108/B89. Sets of films were dried 24 hours at room temperature (73-78°F @ 53-58% R.H.), 120°, 140°, 160°, 180°, 200°, and 225°F, respectively. Film clarity was measured by placing a black glass glossmeter standard behind the sample of film and glass in the sample beam of the Color-Eye (Y-filter setting). Light reflectance measurements were then made. The results are given in Tables IV and V in which lower values indicate better clarity and higher readings indicate translucence or opacity. These data confirmed the superiority of Rhoplex AC-35 for blending with the RC-9108 latex.

While this investigation was in progress, production of the Rhoplex AC-35 was discontinued by the manufacturer (Rohm and Haas Co.). It was replaced by Rhoplex HA-4, the general performance of which was found to be comparable or perhaps superior to that of AC-35.

4. Formulation Studies

The initial attempts at formulation preparation were carried out with an approach that would yield the highest NVM in the finished formulation. This approach involved the technique of grinding the pigment (TiO_2), using RC-9108 as the fluid medium. In this manner, the water that is conventionally used in the grind base can be eliminated, thereby increasing NVM content and decreasing the quantity of water to be removed. This technique resulted in total coagulation of the RC-9108 after approximately half the normal grinding time. The results indicated that RC-9108 has limited shear stability. The more conventional approach, which involved first grinding the pigment in a water medium together with surfactants, anti-foam agents, and other necessary modifiers, was then used. The latex was then added to the pigment suspension to give stable RC-9108 formulations. Subsequent addition of the preferred acrylic component and pH modifier produced the finished shelf-stable formulation.

5. Additional Pigmentation Studies

In addition to titanium dioxide and zinc oxide, colored inorganic pigments, including the Shepherd line of inorganic oxides and ceramic type pigments, were tested for compatibility with our latex system and were found to be acceptable. Extenders were not evaluated.

6. Base Coatings (Primers)

Parallel to the development of topcoat latex formulations was the effort devoted to the preparation of suitable latex primer compositions for the purpose of improving adhesion, abrasion, and anticorrosion properties of the coating systems. The effort resulted in two preferred formulations based on an acrylic latex (Rhoplex MV-2) and corrosion inhibitors such as ONCOR-M50 (lead silicochromate) and basic zinc chromate with a pigment consisting of a mixture of titanium dioxide, calcium carbonate, mica, and zinc oxide. As the next section indicates, these formulations were found to be nonflammable and to have offgassing properties well within acceptable limits.

7. Samples of Coating Formulations Submitted to NASA for Additional Testing

Samples of coating formulations were periodically submitted to NASA, per the contract, for evaluation of flammability, offgassing, and other properties. The samples submitted for testing are listed in Table VI together with a summary of the important characteristics of the formulations. Performance data obtained by NASA are shown in Table VII. The composition and properties of the optimum topcoat and primer formulations are summarized in Table VIII.

IV. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

It is apparent from the results that the fluoropolymer latex coating system investigated in this program represents a promising approach to the development of coatings suitable for application in the interior of a spacecraft. At the present stage of development the formulations dry at room temperature into attractive coatings with good adhesion to (pretreated) substrates such as aluminum and other metals. In addition, the formulations can meet the target requirements in the area of flammability and offgassing. However, the system investigated is still experimental, and much can be done to optimize its performance. The following is an outline of several areas of investigation that may lead to significant improvements in the properties of the coatings.

A. Hardness and Abrasion Resistance

The room temperature cure fluoropolymer coatings are still relatively soft. However, modifiers and fillers can be used to improve hardness and abrasion characteristics. Examples of potentially useful modifiers include

hard acrylics, crosslinking or crosslinkable latex acrylics, latex epoxies, some latex alkyds, and polyesters. Hardness and wear properties can also be enhanced by a filler such as glass (solid or hollow structures). This filler can also improve the flammability properties of the coating. Multifunctional silane coupling agents are available for use with glass fillers to improve further the reinforcing and filling functions of these components. An interesting possibility is offered by the use of hollow glass spheres as fillers, especially when the weight of the finished coating is critical. The density of common pigments and extenders fall in the 2.5-5.9 g/cc range, whereas the density of hollow glass spheres is in the 0.24-0.75 g/cc range. It is apparent that the use of a filler of this type can impart a significant weight reduction to the coating and at the same time improve other properties.

B. Flame Resistance

Efforts to improve the flame resistance of the coatings have been based on the use of pigments. Future activity in this area could involve a detailed study of the effect of pigment level, type, and blend, in addition to the use of fillers and/or extenders with flame retardant properties. This study could include the use of flame retardant additives with no hiding capability.

C. Pigments and Modifiers

Both areas have been discussed in part in the previous two sections. Additional pigmentation effects to be investigated include water, spot, and chemical resistance and light stability. The use of modifiers will also involve testing for compatibility with the fluoropolymer latex system, shelf-life, molecular weight, fusion characteristics, durability, and general performance.

D. Coalescing Aids

The experimental latices investigated under this program do not contain coalescing aids. The latter consist of organic liquids compatible with the latex system and designed to improve the film forming characteristics of the formulation through reduction of surface active forces. Proper selection of coalescing aids can also improve the adhesion between topcoat and

primer, which, in turn, can improve the abrasion resistance of the entire coating system. The use of specific coalescing aids, although somewhat constrained by the strict offgassing requirements for the coatings, represents another interesting area that should be investigated.

Table I

Viscosity Data for a Series of RC-9108 Latices

Sample No.	4278 161-1	4278 161-2	4278 161-3	4246 151-1	4246 151-2	4246 162-1	4246 159-1	4246 160-1	4246 161-1	4278 175-2	4246 174	4278 176-1	4246 153-1	4246 155-1
Wt. % NVM	56.7	50.0	52.4	58.0	51.2	56.4	52.4	55.5	50.0	51.9	48.4	47.7	55.0	49.5
3% Surfac.	F-108	F-108	F-108	X-100	X-100	X-100	X-114	X-114	X-114	X-405	X-405	X-405	CF-10	CF-10
% QP-4400	-----	0.25	0.50	-----	0.25	0.50	-----	0.25	0.50	-----	0.25	0.50	-----	0.25
Brookfield Viscosity: (Centipoises, cps)														
Spindle No. 3 Speed (rpm)														
0.3			64600											88000
0.6			39300											39100
1.5			18120											16700
3			10560											11900
6			6300											8870
12			3850											6340
30			2040											3824
60			1288											*
Spindle No. 2 Speed (rpm)														
0.3	---	16250	61300	1000	7200	30400		12650	10950				---	75650
0.6	250	7800	*	345	3750	15275		6775	6050				---	*
1.5	150	3930	*	290	1690	7870		3670	3280				---	*
3	125	2390	*	310	1065	5035		2300	2200				---	*
6	118	1450	*	230	675	3145		1425	1368				---	*
12	97	900	*	161	434	1986		891	888			548	45	*
30	67	498	*	102	252	*		486	508			319	40	*
60	57	328	*	75	170	*	25	310	337			215	36	*
Spindle No. 1 Speed (rpm)														
0.6							---			---	2165	4150	---	
1.5							---			---	1186	2264	48	
3							---			---	717	1306	46	
6							23			20	450	815	51	
12							22			18.5	283	*	48	
30							21			18	163	*	41	
60							20			18	*	*	35	

* Off Scale

Table II

Effect of Different pH Modifiers For RC-9108 Latex

pH Modifier[a]	Observed pH Orig.	Days 1	2	5	6	7	8	9	16	23
NH_4OH	9.5	7.4	7.4	6.9	6.9	6.9	6.9	6.8	6.7	6.6
DMAE	9.4	7.6	7.6	7.3	7.3	7.3	7.3	7.3	7.1	6.9
DMAMP	10.2	7.8	(b)	-	-	-	-	-	-	-
AMP	9.4	8.7	8.7	8.2	8.0	7.8	7.7	7.6	7.4	7.3
DEA	9.2	6.1	6.1	5.8	5.6	5.6	5.5	5.4(b)	-	-
TEA	9.6	(c)	-	-	-	-	-	-	-	-

[a] NH_4OH = Ammonium Hydroxide
DMAE = 2-Dimethylaminoethanol
DMAMP = 2-Dimethylamino-2-methyl-1-propanol
AMP = 2-Amino-2-methyl-1-propanol
DEA = Diethylamine
TEA = Triethylamine

[b] 10-15% Coagulated, dropped from the test

[c] Totally coagulated within 24 hr

Table III

Compatibility Study of a Series of RC-9108 Latices with Selected Acrylic Latices Over a Four Day Period[a,b,c]

Sample No.	4278 161-1	4278 161-2	4278 161-3	4246 151-1	4246 151-2	4246 162-1	4246 159-1	4246 160-1	4246 161-1	4278 175-2	4246 174	4278 176-1	4246 153-1	4246 155-1
Wt. % NVM	56.7	50.0	52.4	58.0	51.2	54.4	52.4	55.5	50.0	51.9	48.4	47.7	55.0	49.5
3% Surfac.	F-108	F-108	F-108	X-100	X-100	X-100	X-114	X-114	X-114	X-405	X-405	X-405	CF-10	CF-10
% QP-4400	-----	0.25	0.50	-----	0.25	0.50	-----	0.25	0.50	-----	0.25	0.50	-----	0.25
Compatibility with:														
B-89-A	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Coag-1
AC-35	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Coag-1
AC-61	OK	OK	OK	OK	Coag-4	OK	OK	Coag-4	OK	OK	OK	OK	Coag-1	Coag-1
MV-1	OK	OK	OK	Coag-1	Coag-1	Coag-1	Coag-1	Coag-1	Coag-1	OK	OK	OK	Coag-1	Coag-1
PC-400	OK	OK	OK	OK	OK	Coag-3	OK	Coag-3	Coag-3	OK	OK	OK	Coag-1	Coag-1

[a]Coag-1 indicates coagulated within 1 day
Coag-3 " " " 3 days
Coag-4 " " " 4 "

[b]The RC-9108/Acrylic weight ratio is 75/25.

[c]The pH of the RC-9108 latices used in this study was modified with NH_4OH.

Table IV

Film Quality of RC-9108/Rhoplex AC-35 Blends[a]

Wt. % RC-9108	100	90	85	80	75	70	60	50
Wt. % Rhoplex AC-35	-	10	15	20	25	30	40	50
Drying Temp. (°F)	Observed Film Quality[b]							
R.T. (73-78)	6.82	3.06	1.95	2.52	2.14	2.05	3.34	3.82
120	6.38	2.92	1.82	2.50	2.38	4.06	4.58	2.66
140	5.55	2.10	1.56	1.86	1.72	1.64	2.13	2.90
160	4.67	2.29	1.81	1.74	1.36	1.33	1.41	1.90
180	3.39	1.10	1.12	1.02	0.93	1.08	1.13	1.60
200	1.94	0.82	1.15	1.16	1.26	1.17	0.94	0.96
225	0.72	0.96	0.82	1.26	1.30	0.89	1.42	1.06

[a] The readings in this table are not absolute values; they have greater meaning when used in a relative sense.

[b] Readings below 2.00 = Reasonably good clarity
" 2.00 - 4.00 = Some translucent character
" 4.00 - 6.00 = Translucent
" above 6.00 = Translucent with some opacity

Control Measurement = 0.6 with glass plate plus black standard, no film

Table V

Film Quality of RC-9108/Rhoplex B-89 Blends[a]

Wt. % RC-9108	50	60	70	75	80	85	90	100
Wt. % Rhoplex B-89	50	40	30	25	20	15	10	-
Drying Temp. (°F)	Observed Film Quality[b]							
R.T. (73-78)	4.9	7.9	15.18	10.02	16.8	15.08	10.44	-
120	4.7	6.42	7.58	9.0	14.8	17.38	19.12	-
140	3.9	13.68	17.4	14.5	9.5	6.7	5.32	4.8
160	3.6	6.42	5.01	5.52	4.58	5.25	5.2	4.64
180	1.9	3.74	4.5	5.43	5.36	5.42	6.58	5.84
200	5.2	5.52	6.24	6.68	6.82	7.6	5.72	2.2
225	5.3	5.44	6.38	7.24	7.23	6.03	5.02	5.74

(a) The readings in this table have the most meaning when used in a relative sense.

(b) Readings below 2.00 = Reasonably good clarity
Readings 2.00 - 4.00 = Some translucent character
Readings 4.00 - 6.00 = Translucent
Readings 6.00 - 9.99 = Translucent with some opacity
Readings above 10.00 = Increasing opacity

Control measurement = 0.6 with glass plate plus black standard and no film sample

Table VI

Samples of Coating Formulations Submitted to NASA for Evaluation of Flammability, Offgassing, and Other Properties

Sample No.[a]	Type	Wt. % NVM	Resin/Pigment (by wt.)	Resin/Pigment (by vol.)	RC-9108/Acrylate[e] (by wt.)	RC-9108/Acrylate[e] (by vol.)	Corrosion Inhibitor
4367-3	Clear Topcoat	55.0	Unpigmented		75/25	64/36	
4334-94	White Topcoat[b]	55.4	76/24		80/20	70.4/29.6	
4334-95	"	56.2	66/34		80/20	70.4/29.6	
4334-109	Primer[c]	60.0	39.8/60.2		0/100	0/100	Oncor M-50[f] + Basic Zinc Chromate
4334-110	"	59.5	39.7/60.3		0/100	0/100	Oncor M-50[f]
4334-112	White Topcoat[b]	55.6	66.7/33.3	83.8/16.2	70/30	59/41	
4334-113	Gray Topcoat[d]	56.6	65/35	83.1/16.9	70/30	59/41	

[a]The formulations could be applied by either spray or brush.

[b]The pigment was a mixture of titanium dioxide and zinc oxide in 9/1 weight ratio.

[c]The pigment was a mixture of titanium dioxide, calcium carbonate, mica, and zinc oxide.

[d]The pigment was a mixture of titanium dioxide, zinc oxide, copper oxide, and chromium oxide.

[e]The acrylic resin was Rhoplex AC-35 for samples 4367-3 and 4334-94; Rhoplex MV-2 for 4334-109 and 4334-110; Rhoplex HA-4 for 4334-95, 4334-112, and 4334-113.

[f]Lead silico-chromate.

Table VII

Test Data Obtained by NASA for Topcoat and Primer Latex Formulations[a]

Sample No.[b]	Offgassing (μg/g)[c]		Odor[d]	Flammability[e]	Total Weight Loss (percent)[f]	Volatile Condensable Materials (percent)[f]	Thermogravimetric Analysis in Air(°C)	Maximum Optical Smoke Density (D_M)[g]
	Total Organics	Carbon Monoxide						
4367-3	3.8	2.0	2.4		0.89	0.049	<1% weight loss to ~ 170° ~ 4% weight loss at 270°	
4334-94				Self-extinguishing				
4334-95				"				
4334-109	14.0	3.0	1.2	Nonflammable	2.42	0.01		
4334-110	2.0	4.0	1.2	"	2.05	0.03		
4334-112	5.0	2.0		"	0.17	0		18
4334-112/ 4334-110[h]	13.0	2.0		"	1.30	0		

[a] NASA requirements for the various test parameters are as follows:
Total organics: ≤100μg/g
Carbon monoxide: ≤25μg/g
Odor: ≤2.5
Flammability: self-extinguishing
Total weight loss: ≤1%
Volatile Condensable Materials: ≤0.1%
Maximum Optical Smoke Density: 25

[b] See Table VI for composition and other characteristics of the samples.

[c] Test No. 7, NHB 8060.1, Category 5(c)1. 14.7 psia, air composition.

[d] Test No. 6, NHB 8060.1, Category 5(b). 14.7 psia, air composition.

[e] Test No. 1, NHB 8060.1, 23.8% O_2/76.2% N_2, 14.5 psia total pressure. The tests were performed on 2.5 x 12 x 0.003 inch aluminum foil substrate sample coupons coated to a thickness of 1.0±0.25 mils on one side only.

[f] Tests performed on aluminum substrates after 24 hr drying time at room temperature. Period: 24 hr. Final Pressure: 3.4×10^{-6}. Sample temp.: 125°C. Condenser temp.: 25°C.

[g] ASTM Special Technical Publication No. 422 (radiant heat source).

[h] Topcoat-primer combination.

Table VIII

Composition and Properties of Optimum Topcoat and Primer Formulations Developed During Phase I of the Program[a]

	White Topcoat (4334-112)[b]	Primer (4334-109)
Composition:		
Resin:	Pennwalt latex fluorocarbon terpolymer (RC-9108) blended with Rhoplex HA-4 latex acrylic resin (Rohm and Haas Co.) in the ratio of 70/30 by wt., 59/41 by vol.	Rhoplex MV-2 latex acrylic resin (Rohm and Haas Co.)
Pigment:	Mixture of titanium dioxide and zinc oxide in 9/1 ratio by wt.	Mixture of titanium dioxide, calcium carbonate, mica, and zinc oxide. The corrosion inhibitor is a mixture of lead silico-chromate (Oncor M-50) and basic zinc chromate.
Resin/Pigment Ratio:	66.7/33.3 by wt., 83.8/16.2 by vol.	39.8/60.2 by wt.
Wt.% NVM:	55.6	60.0
Offgassing (μg/g)[c]:		
Total Organics:	5.0	14.0
Carbon Monoxide:	2.0	3.0
Odor[d]:		1.2
Flammability[e]:	Non-flammable	Non-flammable
Total Weight Loss (%)[f]:	0.17	2.42
Volatile Condensable Materials (%)[f]:	0	0.01
Maximum Optical Smoke Density[g]:	18	

[a] NASA requirements for various test parameters are as follows:
Total organics: ≤100 μg/g
Carbon monoxide: ≤25 μg/g
Odor: ≤2.5
Flammability: self-extinguishing
Total weight loss: ≤1%
Volatile Condensable Materials: ≤0.1%
Maximum optical smoke density: 25

[b] A grey topcoat (4334-113) with similar characteristics has also been developed.

[c] Test No. 7, NHB 8060.1, Category 5(c)1. 14.7 psia, air composition.

[d] Test No. 6, NHB 8060.1, Category 5(b). 14.7 psia, air composition.

[e] Test No. 1, NHB 8060.1, 23.8% O_2/76.2% N_2, 14.5 psia total pressure. The tests were performed on 2.5 x 12 x 0.003 inch aluminum foil substrate sample coupons coated to a thickness of 1.0±0.25 mils on one side only.

[f] Tests performed on aluminum substrates after 24 hr drying time at room temperature. Period: 24 hr. Final Pressure: 3.4×10^{-6}. Sample temp.: 125°C. Condenser temp.: 25°C.

[g] ASTM Special Technical Publication No. 422 (radiant heat source).