GENERAL DYNAMICS | CONVAIR

Report No. 8926-066

Materials - Finishes and Coatings - Acrylic Paints

Laboratory and Service Evaluations

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24 April 1958

Published and Distributed
Under
Contract AF33(657)-8926

Post Office Box 1950, San Diego 12, California CYpress 6-6611
Material Post Office Box 2071 BRoadway 3-8000 | Accounting Post Office Box 510

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Abstract

The Mil-E-7729 enamel paint system used on the F-106 airplane was criticized as (1) slow drying, (2) a three coat system, (3) limited temperature resistance of about 275°F, and (4) limited weather and oil resistance in comparison with some other finishes. The advantages claimed for acrylic paint systems, and confirmed by tests, are (1) faster drying comparable to nitro-cellulose lacquers, (2) excellent corrosion protection afforded with a two coat system (3) color change absent up to 400°F, (4) superior weathering resistance, and (5) superior resistance to Mil-L-7808 and di-ester lubricants. The disadvantages cited for acrylic paint systems are (1) 15 to 20 per cent less gloss than enamel, (2) softening above 200°F, (3) flow at 365°F and 13-1/2 psi dynamic pressure, (4) greater brittleness than enamel. A seven months service evaluation on a flight test airplane revealed the acrylic finish capable of (1) retaining original gloss and (2) resisting di-ester lubricating oil and hydrocarbon fuels. The acrylic paint system, however, exhibited severe crazing and cracking during service evaluation.

References: 1. Mappus, L. A., George, J. C., Keller, E. E., "Acrylic Paint System, Evaluation of," General Dynamics/Convair Report MP 57-934, San Diego, California, 24 April 1058. (Reference attached).

2. Mappus, L. A., George, J. C., Keller, E. E., "Acrylic Paint System, Evaluation of," General Dynamics/Convair Report MP 57-934.1, San Diego, California, 12 February 1959. (Reference attached).

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
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STRUCTURES-MATERIALS LABORATORIES

REPORT 57-934
DATE 2-24-58
MODEL F-106

TITLE

REPORT NO. 57-934

ACRYLIC PAINT SYSTEM -

EVALUATION OF

MODEL: F-106
CONTRACT NO: AF33(600)-30169

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NO. OF PAGES 12

NO. OF DIAGRAMS 7

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

FORM 1512A-4

TN 57-934

ACRYLIC PAINT SYSTEM -

EVALUATION OF

Introduction:

The enamel system now specified for the exterior finish on the Model 8 has the following shortcomings: (a) It is slow drying; (b) It is a three coat system; (c) Temperature resistance is limited to approximately 275°F; (d) Weather resistance and oil resistance are not as good as some other finishes.

Several of the manufacturers' representatives had proposed to us the use of an acrylic finish system in place of the conventional MIL-E-7729 alkyd enamel system to overcome these shortcomings. Therefore, this program was initiated to evaluate several proprietary acrylic systems against the performance requirements of the MIL-E-7729 specification. Provided these results were satisfactory, a second objective of this program would be the actual painting of a F-102 or F-106 aircraft and service evaluation of the finish system.

Object:

1. To compare the performance of several proprietary acrylic finishes with the performance of the MIL-E-7729 enamel system.

2. To select the outstanding acrylic system for further evaluation if performance advantages exist.

3. To apply the best acrylic system to an aircraft for actual service evaluation if performance advantages exist.

Conclusions:

1. Comparison of the acrylics, as a group, to the MIL-E-7729A enamel system is as follows:

(a) Advantages -

(1) Acrylics are much faster drying - drying characteristics similar to a lacquer system.

(2) They can be used as a two-coat system and still offer excellent corrosion protection.

(3) The acrylics do not change color at temperatures up to 400°F.

(4) They have superior resistance to weathering.

(5) The acrylics have superior resistance to MIL-L-7808 di-ester lubricant.

(b) Disadvantages -

(1) The acrylics have from 15 to 50% less initial gloss than the enamel.

(2) Acrylics are thermoplastic and soften above 200°F. At a temperature of 365°F and with a dynamic pressure of 13-1/2 psi, all of the acrylic submittals tended to flow.

(3) The acrylics are more brittle than the enamel.

2. The acrylic system that performed best under overall testing was the Sherwin Williams special wash prime, P40GCI, plus the Sherwin Williams acrylic top coat, M49AC10. This system weighs approximately two thirds as much as the presently used MIL-E-7729A system (Ref. Table II). There is no critical recoat time on the special wash primer, P40GCI, so it could be used for a shop coat.

3. The Sherwin Williams acrylic system will be applied to a F-106, ship no. 456, in the Experimental Factory at Convair, San Diego. An addendum report, 57-934-1, will be issued after service evaluation.

Test Specimens and Procedures:

A. Test Specimens-

The base material and surface treatment for each of the various tests is shown in Table I.

In addition to the MIL-E-7729A finish system, which was tested as the control, five proprietary acrylic top coats over their recommended prime systems were tested. These systems are shown in Table II.

B. Test Procedures -

1. Control: A control specimen was retained for each finish system. These specimens were not subjected to any exposures and were used to make visual comparisons after testing.

2. Hot Air Impingement: Specimens were exposed to a pre-heated air blast at the following temperatures: 260°F, 365°F, and 425°F. Exposure at each temperature was for 5 minutes or until a change was noticed and the dynamic pressure was held constant at 13-1/2 psi. The angle of impingement of the hot air on the specimen was 15°.

3. Specification Tests: The following tests were run in accordance with the methods as given in Specification MIL-E-7729A.

Test	Method
Condition in container	Paragraph 4.5.1.4
Brushing properties	Paragraph 4.5.1.4.6
Spraying properties	Paragraph 4.5.1.4
Skinning	Paragraph 4.5.1.4
Baking properties	Paragraph 4.5.1.4.7
Drying time	Paragraph 4.5.1.4.8
Flexibility	Paragraph 4.5.1.4.9
Primer absorption	Paragraph 3.5.10.5
Lifting properties	Paragraph 4.5.1.4.10
Tape test	Paragraph 4.5.1.4.11
Anchorage	Paragraph 4.5.1.4.12
Water resistance	Paragraph 4.5.1.4.13
Hydrocarbon resistance	Paragraph 4.5.1.4.14
Resistance to loss of gloss	Paragraph 4.5.1.4.15
Di-ester oil resistance	Paragraph 4.5.1.4.16
Humidity resistance	Paragraph 4.5.1.4.17
Weather resistance	Paragraph 3.5.11.6

4. Salt Spray Exposure: Bi-metallic panels were exposed in the salt spray cabinet in accordance with Specification QQ-M-151A, Amendment 3, for 336 hours.

Discussion of Procedures:

Hot Air Impingement - This test was used to simulate aerodynamic heating conditions of the Model 8 in flight. According to the Thermodynamics Group, the following temperature conditions are encountered:

Model	Temperature on Leading Edge	Temp. on Majority of Fuselage
F-102	200°F	160°F
F-106	260°F	216°F
F-106C	425°F	365°F

The acrylics are thermoplastic type materials and the object of the hot air impingement test was to determine if they would flow at the above temperatures under a dynamic pressure of 13-1/2 psi.

These tests were run on equipment designed and operated by Thermodynamics Laboratory personnel at the Convair Ramp Facility.

Specification Tests - If the acrylics performed as well as the MIL-E-7729A enamel, then there should be no objection, engineering-wise, to substituting an acrylic system for the present enamel system. Therefore, the acrylic submittals were subjected to the applicable performance requirements of Specification MIL-E-7729A.

To simulate particular conditions of use at Convair, the following exceptions were made to the MIL-E-7729A specification procedures: (a) Bare aluminum alloy panels were used instead of clad; (b) Alodine 600 surface treatment was used instead of anodize; (c) Where primed panels were called for, the MIL-E-7729 enamel was applied over MIL-C-8514 wash coating plus MIL-P-8585 zinc-chromate primer. The acrylics were applied over the prime system recommended by the manufacturer and specified in Table II.

Salt Spray Exposure - To compare the corrosion resistance properties of the MIL-E-7729A enamel system vs the acrylic systems, it was decided to use bi-metallic couplings in the salt spray cabinet.

Magnesium panel and aluminum clip components of the bi-metallic specimens were coated with the appropriate prime systems prior to assembly. After assembly, the rivets were touched up with the prime system prior to application of the finish coat.

Results and Discussion:

Hot Air Impingement Test - Results of this test are shown in Table III. It appears that, from the standpoint of flowing under heat and pressure, the acrylics would be satisfactory for use where the temperature of the skin did not exceed 260°F and the dynamic pressure was 13-1/2 psi or less. In the case of the Model 8, they would be satisfactory on theF-102, F-106A, and F-106B. A temperature of 365°F seems to be just above the border line for the Rinshed Mason and Sherwin Williams acrylic systems. With a slight formula modification, these finishes could probably be made to perform satisfactory at this temperature.

Specification Tests - The performance of each acrylic system compared to the control, MIL-E-7729A enamel, is shown in Table IV.

Relative to the MIL-E-7729A enamel, the acrylics as a group rated as follows:

Superior	Same	Inferior
Skinning	Condition in container	Brushing properties
Baking properties	Spraying properties	Flexibility
Drying time	Primer absorption	Anchorage
Tape test	Lifting	
Loss of gloss	Water Resistance	
Di-ester oil resistance	Hydrocarbon Resistance	
	Humidity Resistance	

Poorer brushing properties are to be expected since these are lacquer-type finishes that dry by solvent evaporation. Since application will be by the spray method, this shortcoming is not important.

The flexibility and anchorage tests reflected the inherent brittleness of the acrylics. Whether or not they are too brittle for practical use can only be determined by service evaluation.

Weights per square foot that are shown in Table II were determined by weighing the weather resistance panels before and after the application and curing of each coat.

The weather resistance tests are still in progress; however, most of the manufacturers have data from independent test laboratories in Florida showing the acrylics to be far superior to MIL-E-7729A enamel with respect to weathering.

Salt Spray Test - As a group, the acrylics offered better corrosion protection than the MIL-E-7729A enamel on the Bi-metallic specimens. The specimens coated with the Sherwin Williams acrylic system showed only slight corrosion after two weeks in the salt spray cabinet whereas the specimens coated with the MIL-E-7729A enamel system were severely corroded after one week of exposure. A photograph of the specimens after exposure is shown in Figure 1.

NOTE: The test data from which this report was prepared are recorded in Engineering Test Laboratories Data Book #3004.

TABLE I

TEST PANEL PREPARATION

Test	Substrate	Size	Surface Treatment	No. Test per System
Control	2024T86 bare aluminum alloy	.032x3x10 inches	Alodine 600	1
Hot Air Impingement	Same	.032x6x6 inches	Same	3
Brushing Properties	Same	.032x12x12 in.	None	1
Baking Properties	Same	.032x3x10 inches	None	1
Drying Time	Plate Glass	.120x7x7 inches	None	1
Flexibility	7075T6 bare aluminum alloy	.016x3x10 in.	Alodine 600	2
Primer Absorption	2024T86 bare aluminum alloy	.032x3x10 inches	Same	1
Lifting Properties	Same	Same	Same	2
Tape Test	Same	Same	Same	1
Anchorage	Same	Same	Same	2
Anchorage	QQ-M-44 magnesium	.032x3x10 inches	None	1
Water Resistance	2024T86 bare aluminum alloy	Same	Alodine 600	2
Hydrocarbon Resistance	Same	Same	Same	2
Resistance to Loss of Gloss	Same	Same	Same	2

TABLE I (CONTINUED)

TEST PANEL PREPARATION

Test	Substrate	Size	Surface Treatment	No. Test per System
Di-ester Lube Oil Resistance	2024T86 bare aluminum alloy	.032x3x10 inches	Alodine 600	2
Humidity Resistance	QQ-M-44 magnesium	.032x3x10 inches	Mil-M-3171, Type I	2
Weather Resistance	2024T86 bare aluminum alloy	.032x12x12 in.	Alodine 600	2
Salt Spray	Panel: QQ-M-44 Magnesium, Cond.H	.032x5x16 inches	Mil-M-3171, TypeIII	
	Clip: 2024T4 bare aluminum alloy	.032x.75x.75x3	Alodine 600	2
	Rivets: 5056S aluminum alloy(Un.)	1/8 in. diam.	Chromic acid anodized	

TABLE II

FINISH SYSTEMS

Report Designation	Specification or Formula	Manufacture	Normal Thickness	Approximate wt./ft^2 for normal application
Mil-E-7729A enamel system	Mil-C-8514	Andrew Brown	.2 mils	.5 grams
	Mil-P-8585	Andrew Brown	.3 mils	1.2 gms.
	Mil-E-7729A	W.P. Fuller	1.3 mils	4.1 gms.
				5.8 gms.
Andrew Brown acrylic system	Mil-C-8514	Andrew Brown	.2 mils	.5 gms.
	Mil-P-7962	Glidden	.4 mils	1.7 gms.
	H-10-X	Andrew Brown	1.2 mils	3.6 gms.
				5.8 gms.
Glidden acrylic system	Mil-C-8514	Andrew Brown	.2 mils	.5 gms.
	Mil-P-7962	Glidden	.4 mils	1.7 gms.
	RL-15254	Glidden	1.2 mils	4.0 gms.
				6.2 gms.
W.P. Fuller acrylic system	Mil-C-8514	Andrew Brown	.2 mils	.5 gms.
	Mil-P-7962	Glidden	.4 mils	1.7 gms.
	171-H-88	W.P. Fuller	.8 mils	3.1 gms.
				5.3 gms.
Rinshed-Mason acrylic system	J-15107	Rinshed-Mason	.7 mils	2.6 gms.
	J-11297	Rinshed-Mason	.8 mils	2.9 gms.
				5.5 gms.
Sherwin Williams acrylic system	P40GC1	Sherwin Williams	.4 mils	.9 gms.
	M49AC10	Sherwin Williams	.8 mils	2.9 gms.
				3.8 gms.

TABLE III

HOT AIR REINFORCEMENT TEST

Finish System	At 260°F	At 365°F	At 425°F
Mil-E-7729A enamel	Not affected after 5 minutes	Very slight scorching after 5 minutes	Moderate scorching after 5 minutes
Andrew Brown Acrylic	Not affected after 5 minutes	Severe flowing within 1 minute	Severe flowing within 1 Min.
Glidden Acrylic	Not affected after 5 minutes	Severe flowing within 1 minute	Severe flowing within 1 min.
U.P. Fuller Acrylic	Not affected after 5 minutes	Severe flowing within 1 minute	Severe flowing within 1 min.
Rinshed-Mason Acrylic	Not affected after 5 minutes	Very slight flowing after 3 min.	Severe flowing within 1 min.
Sherwin Williams Acrylic	Not affected after 5 minutes	Slight flowing after 1 minute	Severe flowing within 1 min.

TABLE IV

TEST RESULTS -- PERFORMANCE REQUIREMENTS OF Mil-E-7729A

Test	Mil-E-7729A Enamel	Andrew Brown Acrylic	Glidden Acrylic	W.P. Fuller Acrylic	Rinshed-Mason Acrylic	Sherwin Williams Acryl
Condition in container	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Brushing Properties	Good	Fair	Poor	Fair	Poor	Poor
Spraying Properties	Good	Good	Good	Good	Good	Good
Skinning	Satisfactory	Superior	Superior	Superior	Superior	Superior
Baking Properties	Satisfactory	Superior	Superior	Superior	Superior	Superior
Drying Time	Satisfactory	Superior	Superior	Superior	Superior	Superior
Flexibility	Good	Fair	Fair	Fair	Fair	Fair
Primer Absorption	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Lifting Properties	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Tape Test	Satisfactory	Superior	Superior	Superior	Superior	Superior
Anchorage	Satisfactory	Tended to flake	Tended to flake	Tended to flake	Satisfactory	Tended to flak
Water Resistance	Good	Good	Fair	Good	Good	Good
Hydrocarbon Resistance	Slight Discoloration	Slight Softening & Discoloration	Mod. Softening & Sl. Discolor.	Slight Discoloration	Slight Softening & Sl.Discoloration	Not Affected

TABLE IV (CONTINUED)

TEST RESULTS -- PERFORMANCE REQUIREMENTS OF Mil-E-7729A

Test	Mil-E-7729A Enamel	Andrew Brown Acrylic	Glidden Acrylic	W.P. Fuller Acrylic	Rinshed-Mason Acrylic	Sherwin Willi Acrylic
Resistance to Loss of Gloss	Poor	Good	Excellent	Excellent	Excellent	Excellent
Di-Ester Lube Oil Resist.	Satisfactory	Superior	Superior	Superior	Superior	Very Superior
Humidity Resistance	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Weather Resistance	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress

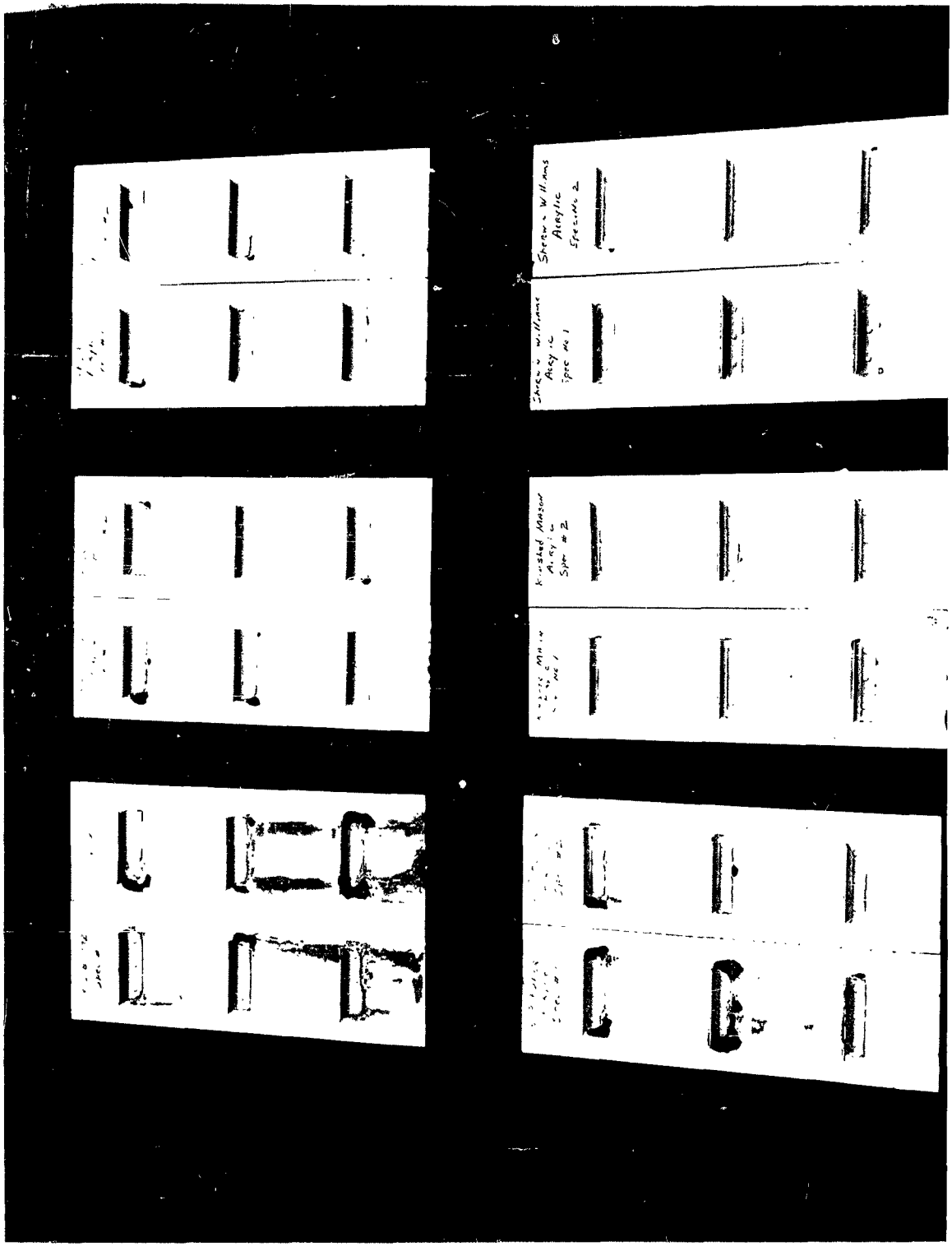

Figure 1
Bi-Metallic Specimens After 336 Hours Salt Spray Exposure

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STRUCTURES & MATERIALS LABORATORIES

REPORT 57-934.1

DATE 12 February 1959

MODEL F-106

TITLE

REPORT NO. 57-934.1

ACRYLIC PAINT SYSTEM -
EVALUATION OF

MODEL: F-106

CONTRACT NUMBER: AF 33(600)-30159

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REFERENCE Report No. 57-934
PR No. 791

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NO. OF PAGES 8

NO. OF DIAGRAMS 4

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

FORM 1812A-4

INTRODUCTION:

Five different acrylic finish systems were evaluated against Mil-E-7729A, Type I, alkyd enamel. Results of this evaluation were reported in Report No. 57-934. The acrylic system that performed the best was the Sherwin Williams P40GC1 special wash prime topcoated with Sherwin Williams M49AC10 gray acrylic. This addendum report covers the application and evaluation of the Sherwin Williams system on the F-106A aircraft. Results of a long term exterior exposure test are also reported.

OBJECT:

1. To report results of a service evaluation made on the Sherwin Williams acrylic finish system.

2. To report the results of exterior exposure tests of the Sherwin Williams M49AC10 acrylic system vs. the Mil-E-7729A, Type I, enamel system.

CONCLUSIONS:

1. Examination of the acrylic finish system on a F-106A after seven months of flight testing revealed the following:

   a) Slight to severe cracking of the acrylic paint film was observed on the underside of the fuselage from the main landing gear aft.

   b) The finish retained its' original gloss.

   c) Diester lube oil and hydrocarbons did not affect the finish.

   d) There was no noticeable difference in the performance of the acrylic when applied over the P40GC1 special wash prime as compared to the acrylic applied over Mil-P-7962 zinc chromate primer.

2. After ten months of exterior exposure, the Sherwin Williams M49AC10 gray acrylic showed no loss of gloss. The Mil-E-7729A, Type I, gray enamel showed a 60% loss of gloss during the same period.

RECOMMENDATIONS:

Difficulty was experienced in applying the Sherwin Williams M49AC10 acrylic finish in the Palmdale paint shop (Reference Palmdale trip report from W. J. Knox to J. W. Woodhouse, dated 20 November, 1958). Due to this and the fact that the acrylic showed considerable cracking on a F-106A after 7 months of flight testing at Edwards Air Force Base, it is recommended that no effort be made at this time to change the finish system of the Model 8 from Mil-E-7729 enamel to acrylic.

RECOMMENDATIONS: (Continued)

The exceptional weathering durability and the fast drying properties of the acrylics still make them promising for use in the aircraft industry. Most of the major paint manufacturers are continuing to develop the acrylics. When these manufacturers overcome the disadvantage of brittleness, this type of finish should be given further consideration for use on military and commercial aircraft.

PROCEDURES:

1. Application

On 10 April 1958, F-106A aircraft No. 60456 was painted in the Experimental Factory with the Sherwin Williams acrylic system. This ship had been painted with Mil-C-8514 wash prime and Mil-P-8585 zinc chromate prime prior to arrival in the Experimental Factory. This condition was representative of what would be encountered in production during a changeover from the present finish system. Where it was necessary to apply the Sherwin Williams acrylic over the aged Mil-P-8585, the following procedure was used:

a) A light coat of Mil-C-8514 wash prime was applied over the Mil-P-8585.

b) A cross coat of Mil-P-7962 lacquer type zinc chromate prime was applied over the Mil-C-8514.

c) The Sherwin Williams M49AC10 gray acrylic, thinned 1 part M49AC10 to 2 parts of R7KC235 thinner, was applied over the Mil-P-7962.

Several areas on the fuselage were stripped down to the bare metal and primed with the Sherwin Williams P40GC1 wash primer, mixed per the manufacturers instructions, and top coated with the M49AC10 acrylic. One of these areas was the detachable tail cone, which was cleaned and sprayed by Engineering Test Laboratory personnel under the direction of the Sherwin Williams Sales Representative, Mr. Howard Hinig.

With the exception of the tail cone, all painting was done by Experimental Factory personnel. A Test Engineer was present during the application to assure compliance with applicable Manufacturing Process Specifications and vendor's instructions.

PROCEDURES: (Continued)

Diagrams of the finish schedule applied to ship no. 50456 are shown in Figures 1 and 2.

2. Service Test

Ship no. 60456 left San Diego for Edwards Air Force Base on 26 May 1958. The acrylic finish was evaluated when it returned to San Diego on 10 December 1958 for an antenna modification. During the seven months at Edwards Air Force Base, this ship underwent 30 test flights. The top speed reached during these flights was Mach 1.5. Except for the time it was out on test flights the plane was in the hangar at Edwards Air Force Base.

3. Weather Resistance

On 20 February 1958, test panels of the Mil-E-7729A, Type I, gray enamel system and of the Sherwin Williams acrylic system were exposed at 45° angle facing south on the roof of Building 51, Convair, San Diego. Final evaluation of these panels was made on 20 December 1958 after 10 months of exterior exposure. Sixty degree gloss measurements before and after exposure were taken with a Photovolt Photoelectric Reflection Meter, Model 660A. Polished black carrara glass was used as a working standard. The instrument was set to read 96 for the black glass, which represents specular reflection in terms of a perfect mirror at 1000.

RESULTS AND DISCUSSION:

1. Application

Application of the acrylic finish on ship no. 60456 in the Experimental Factory presented no problems. The material handled like nitrocellulose lacquer. However, the M49AC10 acrylic gray could not be satisfactorily applied in the production paint shop at Palmdale due to the unusually strong drafts from the ventilators. These drafts caused dry spray and inadequate flow out.

2. Service Test

The overall appearance of the acrylic finish on ship no. 60456 was good when it returned to San Diego after 7 months of flight testing. Gloss retention of the finish was excellent. It did not appear to be affected by either the hot di-ester lube oil from the engine bleed ducts or the hydrocarbon fuels. No defects were noticed on the upper surfaces of the fuselage. On the underside of the fuselage, from the main landing gear aft, there were small cracks which appeared to become more severe toward the aft end of the ship.

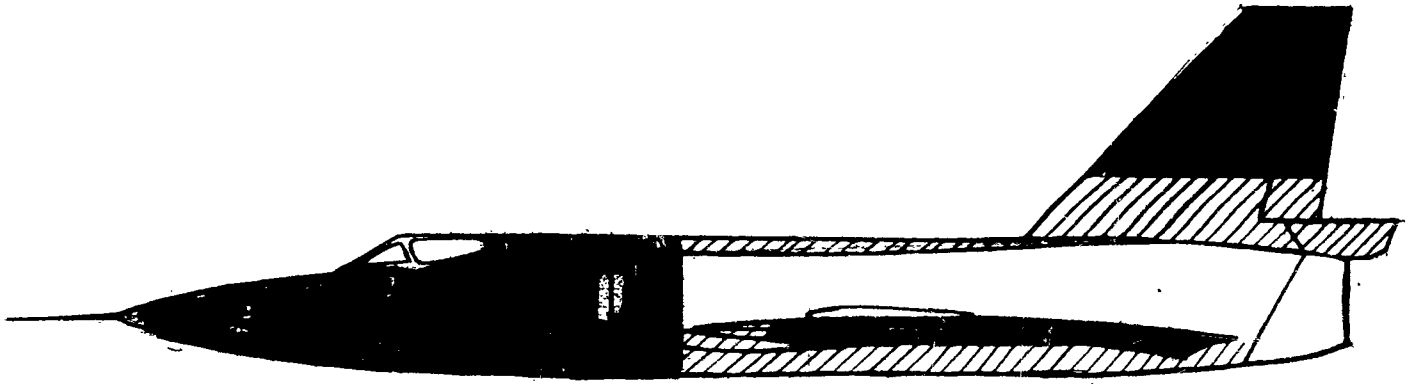
RESULTS AND DISCUSSION: (Continued)

Photographs of typical cracks found in the paint film are shown in Figures 2 and 3. The photographs represent a magnification of approximately 3X. The cracks may have been caused by heat or by vibrations in the skin. The detachable tail cone, which was painted over bare metal with the P40GC1 special wash prime and the M49AC10 acrylic top coat, showed severe cracking in the film. After evaluation, half of this cone was stripped and painted with the Mil-E-7729A enamel system. The other half was recoated with the acrylic. There were no signs of lifting or other defects when the acrylic was recoated. After further test flying at Edwards Air Force Base, a direct comparison between the enamel and the acrylic will be made.

3. Weather Resistance

The 60° gloss of the Mil-E-7729A, Type I, gray enamel went from an initial reading of 94 to a final reading of 37 after ten months exterior exposure. The original gloss of 79 for the acrylic did not change during the ten month exposure.

NOTE: The test data from which this report was prepared are recorded in Engineering Test Laboratories Data Book No. 3004.

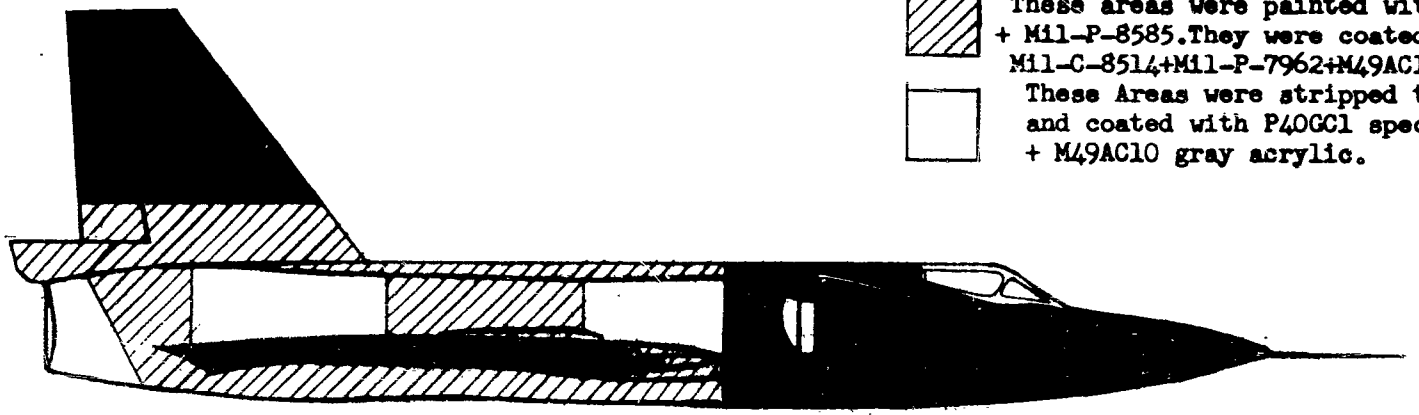


LEFT SIDE

Shaded areas represent areas covered by Day-Glo high conspicuity paint. These areas were not included in the test program.

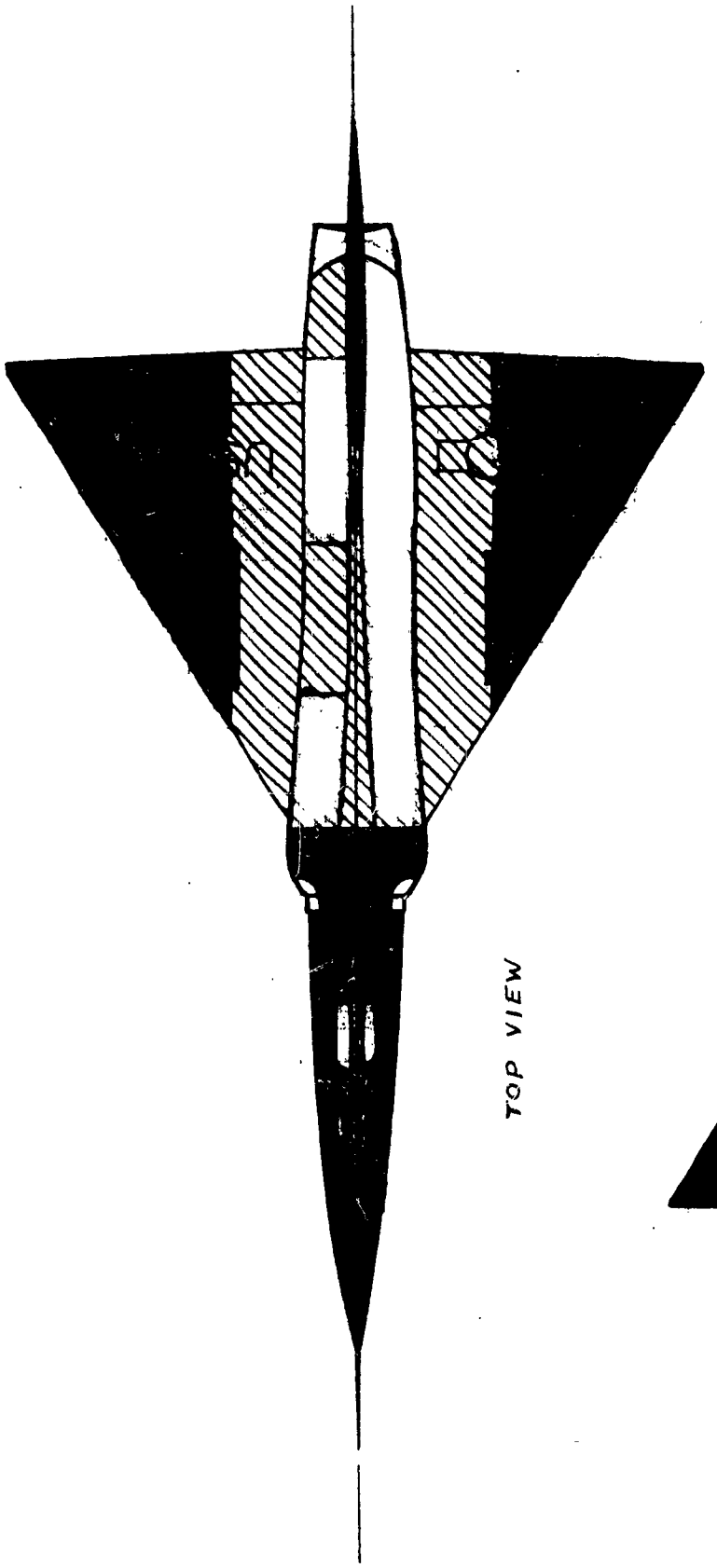
These areas were painted with Mil-C-8514 + Mil-P-8585. They were coated as follows: Mil-C-8514+Mil-P-7962+M49AC10 gray acrylic.

These Areas were stripped to bare metal and coated with P40GC1 special wash prime + M49AC10 gray acrylic.



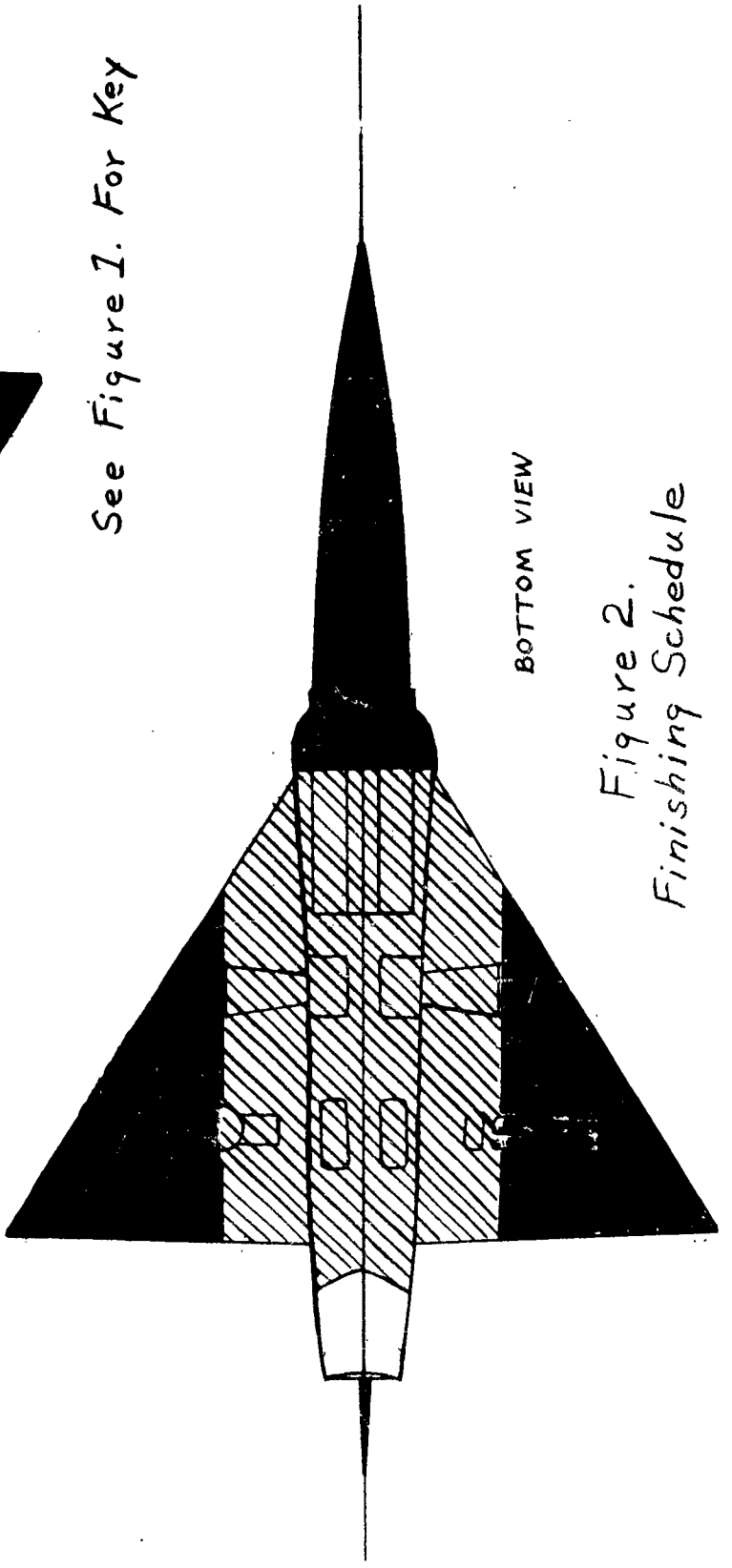
RIGHT SIDE

Figure 1.
Finishing Schedule



TOP VIEW

See Figure 1. For Key



BOTTOM VIEW

Figure 2.
Finishing Schedule

FIGURE 3
CRACKING OF ACRYLIC FINISH

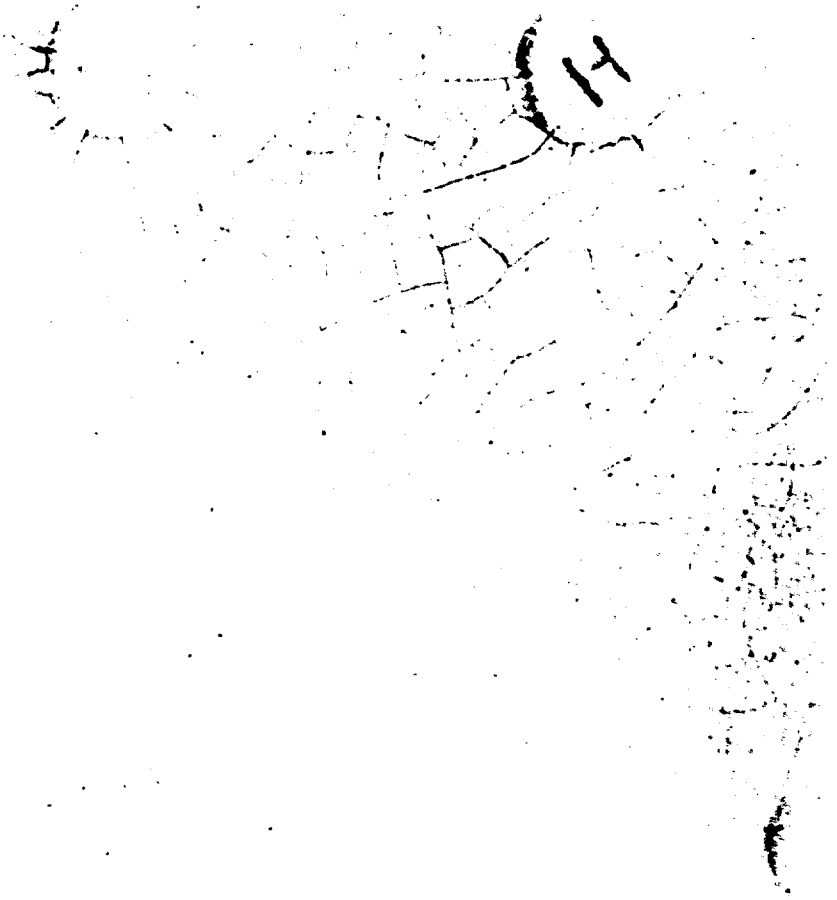


FIGURE 4
CRACKING OF ACRYLIC FINISH