

AD-271167

BOEING-WICHITA MATERIALS & RESEARCH
DEVELOPMENT PROGRAMS 1957-1961

SUMMARY REPORT NO. 2

1 JULY 1961 TO 30 SEPTEMBER 1961

BY

THE BOEING COMPANY
WICHITA DIVISION

PREPARED BY

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AIR FORCE CONTRACT AF33(616)-8141
PROJECT NO. 1(8-7381)
TASK NO. 73812

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PREPARED FOR

INFORMATION PROCESSING SECTION
APPLICATION LABORATORY
DIRECTORATE OF MATERIALS & PROCESSES
AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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CODIFICATION OF MATERIALS R&D

Class of Material	Nature of R&D	Primary Objective of R&D
1. Iron and Steel	1. Extraction, Synthesis and Purification	1. Structural and Mechanical
2. Light Metals and Alloys	2. Alloying, Compounding & Effects of Variations	2. Electrical and Magnetic
3. Heavy Non-Ferrous Metals & Alloys	3. Methods of Processing	3. Optical & Acoustical (incl. Transducer)
4. Inorganic Non-Metallic Solids	4. Surface Treatment and Coating	4. Chemical
5. Elastomers	5. Methods of Analysis Test & Inspection	5. Protection against Ballistic & Other Hazards
6. Plastics (including Reinforced Plastics)	6. Joining (Adhesive Bonding, Brazing, Soldering, Welding)	6. High Temperature
7. Liquid & Semi-Solid High Polymers	7. Mechanical & Physical Properties	7. Low Temperature
8. Fibrous and Filamentary Materials	8. Effects of Chemical & Physical Environments	8. Radiological and Nuclear
9. Composite Materials	9. Research and Theory Development	9. Deterioration Prevention (including Packaging)
0. Miscellaneous and General	0. Miscellaneous	0. Miscellaneous

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- 6-6-1 Various Room Temperature Cured Adhesives
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 - 9-8-3 Decals
- 0. Miscellaneous and General
 - 0-1-4 Chemical Intermediate, Biphenyl Compounds, Hexahydroxybiphenyl
 - 0-5-0 JP-4 Fuel (MIL-J-5624E)
 - 0-7-1 Establish Maximum Angular Limits 2024-C Aluminum, 7075-C Aluminum, and 321-L Stainless Steel

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

III. GENERAL DESCRIPTION:

The objective of this program was to determine the longitudinal and transverse tensile properties of three different gages of A1 350 at room temperature, 600°F, 800°F and 1000°F., after prior exposure at these temperatures under zero stress conditions.

IV. DEVELOPMENTAL BACKGROUND:

In conjunction with advanced design studies on supersonic aircraft, a literature survey was made to determine the optimum material for wing skins operating between 600°F and 800°F. Principle requirements were: oxidation and corrosion resistance, strength and stability at temperature, and fabricability. A1 350 seemed to be the most likely candidate, and this study was conducted to provide reliable design data on this alloy.

AUTHOR: G. Wadsworth *GW*

DATE: 9-12-61

PAGE 1.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Tensile - Given in Tables I - XI and Figures 1 - 8. All values are for condition SCT.
2. Thermal Stability - Given in Tables I - II and Figures 1 - 8.

AUTHOR: G. Wadsworth *W*

DATE: 9-12-61

PAGE 2.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

III. PRINCIPAL PROPERTIES: (continued)

a. Mechanical (continued)

TABLE I.

**TENSILE PROPERTIES OF 125 GRK M250 STEEL
 NO. 100-100000**

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Test Temp. T.	Ultimate Tensile Strength K.S.F.	Tensile Yield 0.2% Offset K.S.F.	Elong. %	RC REDUCTION	
					Before Strain	After Strain
11	R	172.6	172.0	16.0	44.0	No Report
21		171.7	172.2	16.5	44.1	
31		172.1	177.4	17.5	44.1	
41		172.1	173.1	16.7	44.2	
11		179.0	162.5	15.0	43.8	
21		177.0	160.1	16.0	43.6	
31		172.0	162.8	15.0	44.6	
41		177.0	161.1	15.3	44.0	
11	600°	172.4	130.9	10.0	43.1	
21		172.6	122.9	12.0	44.0	
31		172.4	126.4	11.5	44.3	
41		171.8	125.4	10.2	43.8	
11		171.7	131.2	8.0	43.1	
21		175.0	129.0	8.5	43.1	
31		169.7	133.0	8.5	44.1	
41		172.1	134.3	9.0	43.1	
11	600°	169.9	124.4	11.0	43.2	
21		164.6	123.0	10.0	44.2	
31		167.2	119.6	10.0	43.0	
41		164.6	122.0	10.3	43.5	
11		162.4	117.2	9.5	43.1	
21		163.2	121.2	9.5	43.2	
31		162.1	113.0	11.0	43.5	
41		162.2	117.3	9.7	43.1	
11	1200°	138.5	112.0	10.5	42.3	
21		136.3	111.2	10.5	42.5	
31		132.4	98.4	8.5	44.0	
41		135.7	117.4	9.8	42.9	
11		134.6	99.5	8.5	42.0	
21		137.9	98.3	8.0	42.0	
31		137.7	111.9	10.0	42.0	
41		134.4	122.6	9.5	42.0	

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TABLE I

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AH 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE I

**TENSILE PROPERTIES OF .125 GAGE WSSC AFTER
 FIVE HOURS
 OF 10 HR AT 600°F.**

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Test Temp. °F.	Kiloste Tensile Strength K.S.F.	Tensile Yield C.25 Offset		RC RESPONSE	
			K.S.F.	Eng. %	Before Drossing	After Drossing
14	RT	196.3	166.6	12.0	4.6	4.2
15		189.0	159.2	12.5	4.7	4.2
15L		182.4	152.6	14.0	4.5	4.2
15T		191.2	161.0	12.8	4.6	4.2
16	600°F.	166.3	123.2	9.5	4.2	4.5
17		164.9	122.6	10.5	4.2	4.5
17L		163.2	121.4	10.5	4.5	4.5
17T		164.0	125.4	11.2	4.2	4.3
18	800°F.	147.7	112.3	10.5	4.7	4.2
20		145.1	111.9	11.0	4.6	4.1
20L		145.6	110.2	11.5	4.6	4.1
20T		146.1	113.7	11.0	4.4	4.2
21	1000°F.	124.4	102.1	7.0	4.4	4.0
21L		127.0	104.3	9.0	4.4	4.0
21T		127.0	99.8	9.0	4.2	4.4
21L		131.6	105.7	8.0	4.3	4.1

TABLE II

AUTHOR: G. Wadsworth

DATE: 9-12-51

PAGE 4.

I. CATEGORY: Metals

CODE: 1-C-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE II.

**TENSILE PROPERTIES OF .125 GAGE 8000 STAIN
 LESS STEEL
 OF 50 MP at 600°F.**

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Test Temp. °F.	Ultimate Tensile Strength K.S.I.	Stress Yield 0.2% Offset K.S.I.	Elong. %	RE BOUNCES	
					Before Exposure	After Exposure
49	RT	191.7	162.9	14.0	43.7	43.8
50		188.9	161.6	14.5	43.0	43.8
51		188.8	161.3	13.5	44.0	43.6
52		189.8	161.9	14.0	43.6	43.7
53	600°F.	169.0	129.4	13.0	42.8	43.5
54		172.8	129.2	2.5	43.3	43.0
55		177.1	135.3	15.0	43.1	43.0
56		173.0	131.3	9.5	43.0	43.2
57	500°F.	165.9	114.5	13.0	44.0	43.1
58		165.0	118.0	9.5	43.8	43.1
59		165.9	127.4	9.5	43.7	43.3
60		167.0	125.0	9.7	43.8	43.2
61	1000°F.	139.7	117.1	13.0	43.4	44.0
62		131.2	96.4	2.5	43.5	43.1
63		143.8	118.5	9.5	43.6	43.8
64		138.2	112.0	9.3	42.8	43.3

TABLE III

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I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE IV.

**TENSILE PROPERTIES OF .125 CAL AM350 STEEL
 PER SPECIFICATION
 OF 12 SEP 51T.**

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Temp. T.	Tensile Strength		Elong. %	Reduction of Area	
		Long. L.S.T.	Trans. T.S.T.		Before Fracture	After Fracture
25	R	194.6	169.4	17.5	43.6	42.1
26		198.2	166.0	17.5	42.9	43.1
27		193.5	162.0	17.5	43.6	43.9
28		192.8	167.2	17.5	43.4	43.0
29	600°F.	172.7	131.1	11.5	43.0	44.2
30		171.4	131.6	9.5	43.8	44.0
31		169.4	134.9	9.0	43.6	43.5
32		170.5	132.5	10.0	43.4	43.9
33	800°F.	171.2	125.6	8.0	42.9	43.7
34		167.2	117.5	9.5	43.0	44.1
35		165.6	119.2	9.5	44.3	44.1
36		162.0	122.2	9.0	43.4	44.0
37	1000°F.	122.3	89.2	9.0	43.0	44.3
38		121.4	97.9	9.5	43.6	44.1
39		121.0	92.2	9.0	43.8	44.2
40		120.1	95.3	9.2	43.4	44.2

TABLE V

AUTHOR: G. Wadsworth *W*

DATE: 9-12-61

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I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE VI. **TENSILE PROPERTIES OF 125 GAGE SPECIMENS AFTER**
HEAT TREATMENT
OF 50 HRS. AT 800° F.

* Specimen marked with an "L" suffix indicates longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Heat	Tensile Strength K.S.I.	Yield 0.2% Offset K.S.I.	Elong. %	RE BURNED	
					Before	After
611	H	196.9	170.0	17.0	42.6	44.6
612		196.9	168.2	17.0	43.2	45.0
613		198.6	172.2	17.0	43.5	44.0
614		197.5	170.0	17.0	45.1	44.5
615	600° F.	168.8		9.5	43.5	44.5
616		165.8	132.9	9.5	43.2	44.3
617		167.4	137.7	8.5	43.7	44.5
618		167.3	135.3	9.2	43.4	44.4
619	800° F.	163.2	123.0	9.5	42.5	44.6
620		163.4	126.4	9.0	43.3	44.3
621		164.0	124.4	9.5	44.2	44.5
622		163.5	124.6	9.3	43.3	44.4
711	1200° F.	132.4	96.0	9.5	42.1	44.2
712		132.3	103.7	8.5	43.1	44.2
713		129.7	97.5	7.5	43.9	44.4
811		136.4	98.2	8.5	43.0	44.4

TABLE VI

AUTHOR: G. Wadsworth *GW*

DATE: 9-12-61

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I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE VII

TENSILE PROPERTIES OF J15 CASE HARD STEEL
PER SECTION
OF 100 HKS. OR SOFT.

* Specimen marked with an "L" suffix indicates longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RE BURNED	
					Before	After
97E	R	191.1	171.1	16.5	6.2	4.9
97E		191.2	172.1	16.5	6.1	4.2
97E		191.8	172.0	16.5	6.6	4.0
97E		191.2	172.8	16.5	6.3	4.2
100E	600F.	167.1	136.7	8.0	6.1	4.2
100E		167.1	129.6	7.5	6.6	4.0
100E		162.0	134.0	9.0	6.3	4.0
100E		167.5	133.1	8.2	6.0	4.0
100E	800F.	161.2	116.0	7.5	6.2	4.5
100E		161.3	121.6	7.5	6.0	4.5
100E		162.2	127.1	8.0	6.8	4.7
100E		162.2	121.7	7.7	6.0	4.9
100E	1000F.	121.7	91.8	7.5	6.1	4.2
100E		121.9	89.9	8.5	6.2	4.1
100E		121.2	91.7	9.5	6.6	4.6
100E		121.5	91.1	8.5	6.3	4.1

TABLE VII

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AK 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE VIII. MECHANICAL PROPERTIES OF AK 350 STAINLESS STEEL
OF 10 IN. AT 100°F.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Test	Ultimate Strength K.S.I.	Yield Point K.S.I.	Elong. %	RE BOUNDS	
					Before Impact	After Impact
37	K	170.2	144.0	13.5	4.9	36.1
38		168.5	142.5	13.0	4.1	37.1
39		171.1	136.8	14.5	4.1	35.9
40		169.6	141.1	13.7	4.1	36.5
41	600°F.	138.1	118.8	9.0	4.8	36.0
42		139.2	122.1	9.5	4.1	36.6
43		138.1	122.0	8.5	4.9	36.1
44		138.1	123.3	8.8	4.6	36.3
45	800°F.	130.0	107.1	7.0	4.0	36.9
46		130.0	107.6	9.0	4.1	37.2
47		130.9	109.1	9.0	4.9	36.0
48		131.3	108.0	9.0	4.0	36.7
49	1200°F.	107.8	87.6	12.5	4.8	37.1
50		107.9	87.0	11.5	4.1	36.8
51		107.8	86.5	11.0	4.9	36.6
52		107.8	87.0	11.0	4.9	36.8

TABLE VIII

AUTHOR: G. Hadsworth

DATE: 9-12-61

PAGE 10.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE III.

**TENSILE PROPERTIES OF 125 GAGE SIZE
 TENSILE SPECIMENS**

OF 50 H. K. 1007.

* Symbols marked with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Heat No.	Ultimate Tensile Strength K.S.I.	Tensile Yield K.S.I.		Elongation %	
			0.25 Offset	0.2 Offset	Before Test	After Test
72	H	121.2	128.6	13.5	4.1	36.2
73		121.5	129.0	13.0	4.9	35.8
74		121.6	129.0	13.0	4.0	36.0
75		121.1	128.9	13.1	4.5	36.0
76	607.	141.2	146.0	8.5	4.2	35.6
77		142.8	146.5	8.5	4.1	36.4
78		141.7	146.5	7.0	4.2	35.9
79		141.2	147.0	8.0	4.0	36.0
80	807.	131.6	132.8	9.0	4.6	35.9
81		132.6	136.5	8.0	4.2	36.3
82		132.6	137.7	8.5	4.9	36.5
83		132.9	136.3	8.5	4.2	36.2
84	1007.	111.1	95.7	11.0	4.5	36.2
85		112.2	95.2	12.5	4.1	36.0
86		112.9	95.5	11.0	4.7	37.0
87		111.2	94.1	12.0	4.1	36.4

TABLE IV

AUTHOR: G. Wadsworth

DATE: 9-12-61

PAGE 11.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AY 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE I

TENSILE PROPERTIES OF 1/25 GAGE SIZE STEEL SPECIMENS

OF 100 PCS. IN 100%

* Specimens marked with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Heat No.	Tensile Strength		Elong. %	RC	
		0.2% Offset	0.2% Offset		Before Exposure	After Exposure
107	K	172.5	173.2	12.0	42.4	36.1
108		172.8	173.4	12.5	42.6	35.8
109		172.9	173.6	13.5	43.9	36.1
110		172.4	172.1	13.0	43.0	36.0
111	6007	141.7	115.5	8.0	43.0	36.2
112		141.7	114.8	8.5	42.2	35.6
113		139.8	115.9	8.5	43.0	36.0
114		142.7	115.4	8.3	43.4	35.9
115	8007	175.1	173.6	8.0	42.6	36.1
116		175.6	173.6	8.5	42.1	36.0
117		172.6	173.8	8.5	43.9	35.5
118		172.4	173.6	8.3	42.8	35.8
119	1007	162.4	82.4	10.5	43.5	35.3
120		167.7	82.8	10.5	42.7	35.4
121		161.7	82.8	11.0	42.6	35.4
122		166.3	82.3	11.0	43.2	35.4

TABLE I

AUTHOR: G. Wadsworth

DATE: 9-12-61

PAGE 12.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A# 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE II		TENSILE PROPERTIES OF 350 CASE HARD STEEL AS FURNISHED				* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples
Spec. No.	Heat	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	R. REDUCTION Before After Drawing Drawing	
11	H	198.2	146.4	11.5	0.1	In Square
21		199.4	170.6	12.0	0.9	
31		195.0	146.6	14.0	0.3	
41		197.5	146.5	12.5	0.1	
12		196.2	139.4	13.0	0.3	
22		196.3	173.3	12.0	0.2	
32		195.0	146.8	12.0	0.3	
42		199.8	149.8	12.3	0.3	
43	6007.	172.1	131.8	5.0	0.7	
53		182.9	138.2	5.5	0.9	
63		173.7	132.5	5.5	0.9	
73		176.2	136.2	5.3	0.8	
44		165.0	128.2	5.5	0.8	
54		167.5	131.3	6.5	0.8	
64		167.6	133.3	5.5	0.8	
74		166.7	130.9	5.8	0.8	
75	8007.	162.7	98.2	8.0	0.2	
85		165.5	157.8	7.5	0.8	
95		177.8	129.4	7.0	0.8	
105		168.7	109.1	7.5	0.1	
86		170.1	111.5	7.5	0.2	
96		163.4	152.2	6.0	0.1	
106		168.2	122.7	5.5	0.6	
116		163.6	114.8	6.3	0.6	
87	1007.	159.3	80.6	7.5	0.3	
97		161.8	155.9	6.0	0.3	
107		163.1	159.3	6.5	0.9	
117		161.4	97.3	6.7	0.2	
88		157.0	97.7	6.0	0.9	
98		158.1	98.1	5.5	0.7	
108		151.9	98.1	6.0	0.1	
118		151.6	98.1	5.2	0.7	

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TABLE II

AUTHOR: G. Wadsworth *Wk*

DATE: 9-12-61

PAGE 13.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XII

TENSILE PROPERTIES OF AM 350 STAINLESS STEEL
TEMPERATURE

OF 15 MIL. GAGE

* Specimen marked with an "L" indicates longitudinal samples while those with a "T" indicate transverse samples

Temp., °F.	Temp., °C.	Tensile Strength		Elong., %	Red. Area	
		U.S.I.	K.S.I.		U.S.I.	K.S.I.
70	21	177.0	173.2	13.0	11.5	0.8
100	38	186.8	175.8	11.5	0.1	0.7
150	66	196.4	182.1	13.5	0.3	0.7
200	93	197.4	173.7	12.7	0.3	0.4
300	150	172.6	130.3	3.5	0.8	0.0
350	177	172.6	137.2	5.0	0.5	0.6
400	204	167.5	122.3	7.0	0.7	0.7
450	232	169.9	129.9	5.8	0.9	0.1
500	260	167.9	122.3	5.5	0.5	0.6
550	288	162.3	127.7	4.5	0.8	0.4
600	316	172.8	117.6	5.0	0.4	0.5
650	343	169.3	121.9	5.0	0.3	0.5
700	371	156.5	85.9	7.5	0.9	0.4
750	399	116.1	87.4	6.0	0.2	0.8
800	427	137.0	125.9	5.0	0.1	0.3
850	455	129.2	93.1	5.2	0.1	0.2

TABLE XII

AUTHOR: G. Hadsworth

DATE: 9-12-51

PAGE 11.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE III

Mechanical Properties of AM 350 Steel
PER INCHES
at 50 F. and 600 F.

* Specimen marked with an "L" suffix indicates longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Temp. T.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	R _e HARDNESS	
					Before	After
AM 350	R	201.2	171.5	11.5	41.2	41.7
		197.0	172.1	12.5	41.5	42.0
		196.1	165.7	12.5	41.8	42.0
		198.1	172.2	11.5	41.5	41.6
AM 350	600 F.	172.2	136.4	6.5	40.5	41.0
		173.2	135.1	6.5	40.5	40.9
		171.6	134.7	7.0	41.0	41.2
		173.0	135.4	6.6	41.2	41.6
AM 350	800 F.	167.5	121.5	7.5	41.1	41.3
		172.1	135.4	5.5	41.0	41.6
		173.5	123.1	6.0	41.4	41.4
		171.0	123.0	6.3	41.2	41.4
AM 350	1300 F.	173.0	84.8	9.5	41.6	41.8
		158.5	90.3	8.0	41.4	41.5
		112.2	87.2	7.5	41.4	41.5
		177.5	87.4	8.3	41.1	41.6

TABLE III

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AN 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XIII

TENSILE PROPERTIES OF 1/2" GAGE LENGTH AFTER
HEAT TREATMENT
OF 100 INCH. AT 600°F.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Heat Treat.	Ultimate Tensile Strength K.S.I.	Yield Point 0.2% Offset K.S.I.	Elong. %	RE BURNED		
					Before	After	
10000	N	222.6	172.1	12.5	0.8	0.1	
		235.4	172.5	12.0	0.7	0.6	
		235.6	172.4	11.5	0.5	0.3	
10001	N	221.9	175.0	12.0	0.7	0.3	
		600°F.	168.6	126.6	7.0	0.1	0.5
			172.8	135.8	6.0	0.3	0.5
172.8	131.1		6.0	0.1	0.1		
10002	N	172.4	131.2	6.3	0.2	0.7	
		800°F.	172.2	125.7	6.5	0.2	0.2
			172.6	126.0	5.5	0.2	0.0
172.9	132.2		5.0	0.2	0.0		
10003	N	173.2	128.0	5.7	0.7	0.4	
		1200°F	221.5	80.2	15.5	0.2	0.1
			225.1	82.5	6.0	0.5	0.5
222.0	96.4		1.0	0.3	0.1		
10004	N	222.0	85.4	6.0	0.3	0.2	

TABLE XIV

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AK 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE IV

TENSILE PROPERTIES OF AK 350 CASE HARDENED STEEL

TEMPERATURE

AS SUPPLIED

OF 10 MILS THICK

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Test Temp. °F.	Minimum Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RE REDUCTION	
					Before Damage	After Damage
208	RT	197.2	175.5	9.5	41.5	43.0
209		197.3	173.8	10.0	41.1	43.0
210		196.7	172.7	11.5	41.4	42.0
211		197.1	174.0	10.5	41.3	42.6
212	600°	172.0	136.6	4.5	42.0	42.5
213		174.4	137.0	7.0	41.2	43.0
214		171.0	134.9	6.5	41.2	43.0
215		172.5	134.8	6.0	41.7	42.8
216	800°	172.3	130.9	4.5	41.5	43.0
217		169.0	127.7	4.0	41.4	45.5
218		166.2	129.2	4.5	41.4	45.0
219		169.5	124.1	4.3	41.4	42.5
220	1200°	95.4	52.2	13.0	41.5	45.5
221		91.2	71.0	11.5	41.6	44.0
222		105.1	56.0	2.0	41.4	43.0
223		71.0	72.1	9.8	41.5	44.1

TABLE XV

AUTHOR: G. Madsworth *gic*

DATE: 3-12-61

PAGE 17.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XV

Mechanical Properties of AM 350 Steel

OF 50 HRC ± 0.07.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Heat	Tensile Strength K.S.I.	Yield 0.2% Offset K.S.I.	Elong. %	Reduction of Area	
					Before	After
1888	K	175.4	125	13.5	0.5	0.5
		175.5	125	12.5	0.9	0.3
		175.5	125	12.5	0.8	0.1
		175.5	125	12.5	0.9	0.1
1889	657	122.2	6.5	6.5	0.5	0.0
		122.2	7.5	7.5	0.5	0.0
		127.4	1.5	1.5	0.8	0.7
		122.9	6.5	6.5	0.8	0.9
1890	657	122.2	6.5	6.5	0.1	0.8
		122.1	1.5	1.5	0.5	0.8
		122.0	1.5	1.5	0.1	0.5
		122.4	1.5	1.5	0.9	0.7
1891	1207	95.7	6.5	6.5	0.1	0.8
		94.2	1.5	1.5	0.1	0.8
		100.6	1.5	1.5	0.8	0.1
		94.2	1.5	1.5	0.3	0.9

TABLE XVI

W

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AE 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE VIII		TENSILE PROPERTIES OF AE 350 STAINLESS STEEL					* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples
		OF 100 P.S.I. IN 2 INCHES			BY METHOD		
Spec. No.	Test	Tensile Strength K.S.I.	Yield 0.2% Offset K.S.I.	Elong. %	Before Strain	After Strain	
97	T	176.7	176.9	11.5	0.1	0.5	
98	T	176.6	176.3	11.5	0.3	0.5	
99	T	176.9	177.1	13.5	0.4	0.5	
100	T	176.7	176.8	12.2	0.3	0.7	
101	60Y	176.1	176.2	3.5	0.1	0.5	
102	60Y	176.2	176.4	3.5	0.7	0.5	
103	60Y	176.6	176.1	4.5	0.5	0.5	
104	60Y	176.2	176.2	3.8	0.8	0.8	
105	20Y	176.1	176.0	4.2	0.2	0.5	
106	20Y	176.6	176.0	4.5	0.4	0.0	
107	20Y	176.4	176.5	4.0	0.6	0.5	
108	20Y	176.0	176.8	4.3	0.4	0.3	
109	100Y	176.9	176.0	6.0	0.6	0.5	
110	100Y	176.3	176.6	5.5	0.4	0.5	
111	100Y	176.6	176.4	4.5	0.2	0.3	
112	100Y	176.5	176.4	5.3	0.4	0.8	

TABLE VIII

AUTHOR: G. Hadsworth *GH*

DATE: 9-12-61

PAGE 19.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AX 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE	SHEET	TENSILE PROPERTIES OF TEST SPECIMENS AFTER					* Specimen marked with an "L" suffix indicates longitudinal samples while those with a "T" suffix indicates transverse samples
		Ultimate Tensile Strength	Tensile Yield	Elong.	RE BOUNDS		
Test No.	Temp.	K.S.I.	K.S.I.	%	Before	After	
37	R	174.4	150.0	11.0	0.2	34.8	
		174.2	149.7	11.5	0.5	34.6	
		173.1	149.7	11.5	0.4	35.0	
		173.9	149.8	11.3	0.3	34.8	
38	600Y.	145.7	126.7	6.0	0.0	34.2	
		143.4	122.7	5.5	0.0	34.5	
		142.7	122.6	4.5	0.2	34.2	
		142.9	122.7	5.3	0.0	34.5	
39	300Y.	132.2	112.1	5.0	0.5	34.4	
		137.2	112.0	5.5	0.6	35.1	
		137.0	114.5	4.0	0.0	34.9	
		137.5	112.5	4.5	0.0	34.8	
40	100Y.	82.0	62.4	12.0	0.1	34.4	
		133.6	81.9	13.0	0.2	34.0	
		134.5	83.6	8.5	0.2	34.6	
		97.0	75.3	12.2	0.2	34.3	

TABLE XVIII

AUTHOR: G. Wedsworth

lv

DATE: 9-12-61

PAGE 20.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE XVIII

TENSILE PROPERTIES OF A1 350 STAINLESS STEEL

AS RECEIVED

Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RC	
					Before Exposure	After Exposure
73L	RT	176.2	133.0	12.0	0.2	34.4
73T		177.6	142.3	12.0	0.9	34.5
73L		176.4	135.1	12.5	0.1	34.4
73T		176.7	139.5	12.2	0.4	34.4
76L	600°	147.3	121.6	4.5	0.1	34.6
77L		144.3	118.2	5.0	0.4	34.3
78L		147.5	115.8	5.0	0.3	34.6
79L		146.2	115.5	4.8	0.3	34.5
79L	800°	142.7	114.5	4.5	0.4	34.7
80L		142.7	114.5	4.5	0.8	34.7
81L		138.0	107.4	4.5	0.6	34.4
82L		141.1	112.1	4.5	0.9	34.6
82L	1000°	117.0	95.1	6.5	0.6	33.9
83L		129.5	95.1	7.5	0.0	34.9
84L		115.4	95.1	6.5	0.6	32.9
85L		114.3	95.6	6.8	0.7	34.6

TABLE XIX

AUTHOR: G. Wadsworth

DATE: 9-12-61

PAGE 21.

I. CATEGORY: Metals

CCDE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TABLE II. TENSILE PROPERTIES OF A1 350 AFTER TEMPERING AT 1100°F.

OF 1/8 IN. G. DIA.

* Specimen numbers with an "L" suffix indicate longitudinal samples while those with a "T" suffix indicate transverse samples

Spec. No.	Temp. °F.	Ultimate Tensile Strength K.S.I.	Tensile Yield 0.2% Offset K.S.I.	Elong. %	RE REDUCTION	
					Before	After
137	R	175.0	135.5	11.0	41.1	34.0
138		176.2	135.0	15.0	41.3	33.2
139		175.3	135.2	12.0	41.0	33.3
140		174.7	135.2	12.0	41.1	33.5
141	600°	144.8	114.9	7.0	41.8	33.0
142		147.5	115.4	5.0	41.8	33.5
143		144.8	116.7	5.0	41.9	34.7
144		145.8	117.1	5.7	41.6	33.5
145	800°	138.2	112.5	7.0	42.0	34.6
146		142.1	112.5	5.6	42.5	33.0
147		135.9	100.5	5.0	42.0	33.7
148		132.1	102.1	5.7	41.5	33.8
149	1000°	124.3	83.0	3.0	42.4	34.3
150		125.3	81.1	2.5	42.0	33.7
151		124.0	81.4	2.8	42.6	33.2
152		124.7	82.8	2.3	42.7	33.7

TABLE XI

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AH 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

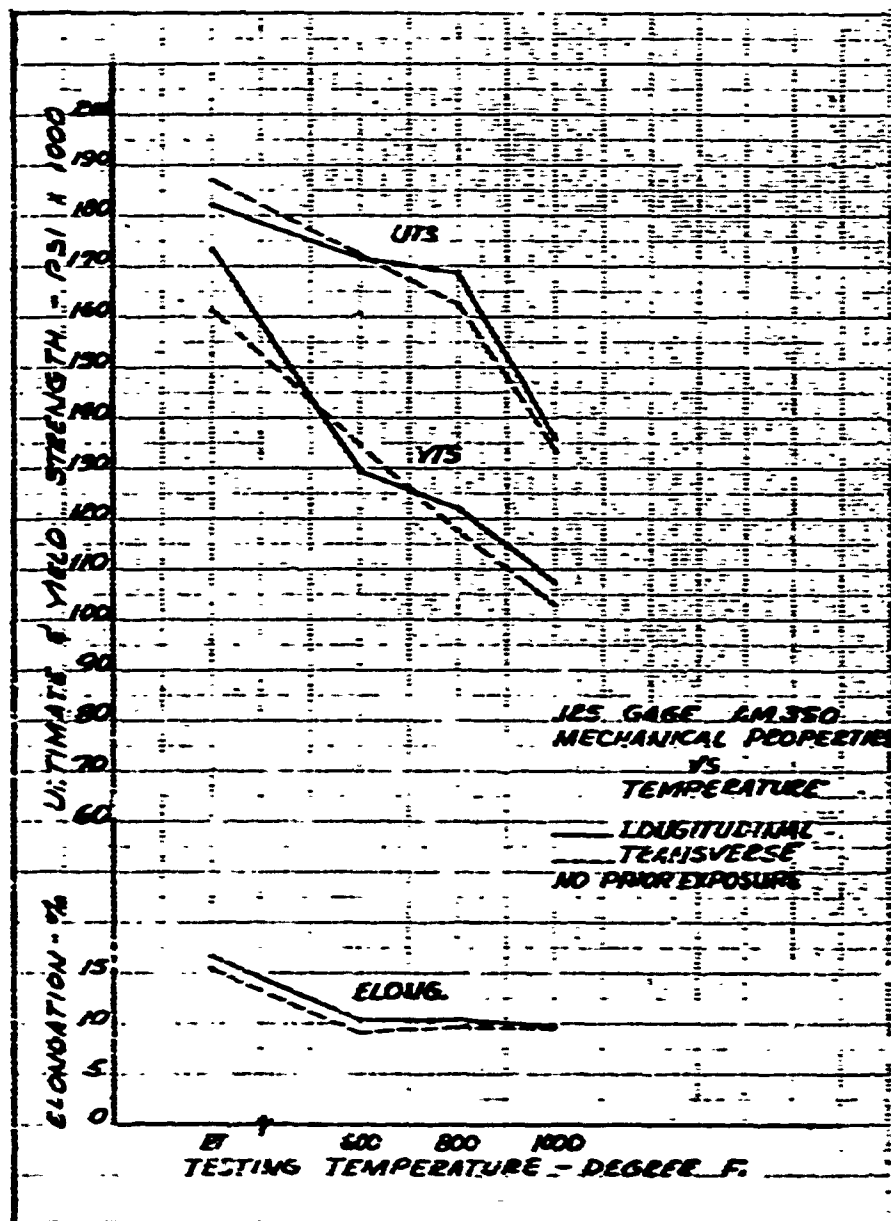


FIGURE 1

AUTHOR: G. Radsworth

DATE: 6-12-61

PAGE 23

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

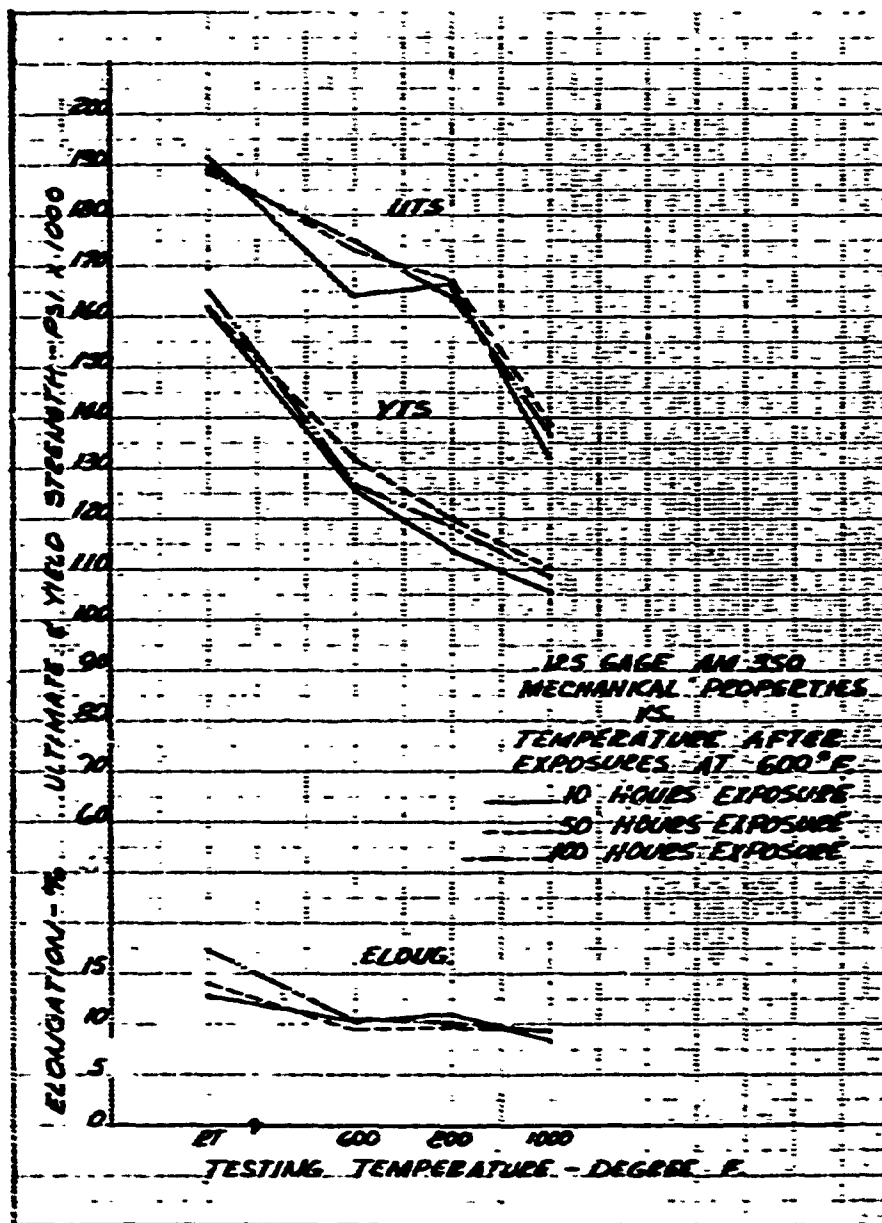


FIGURE 2

AUTHOR:

G. Wadsworth *lylv*

DATE: 9-12-61

PAGE 24.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AE 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

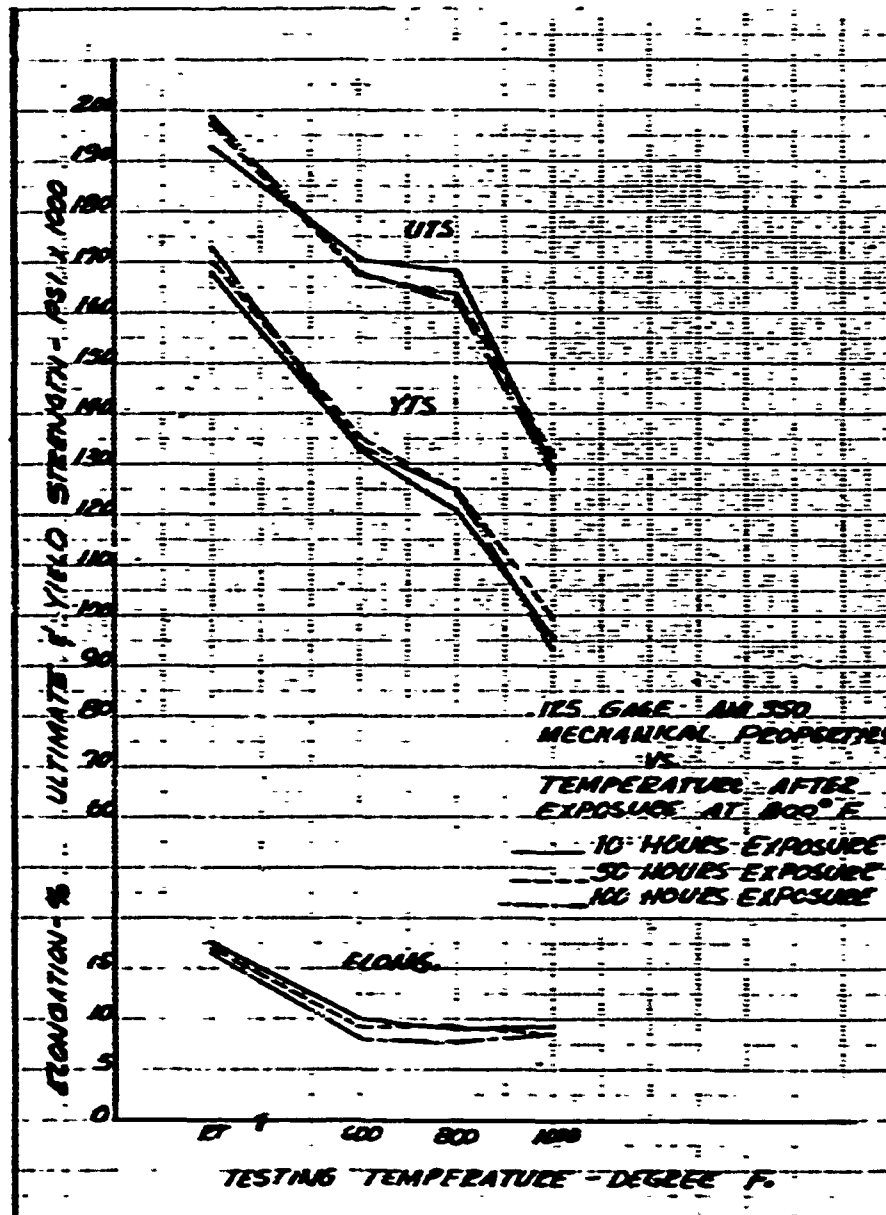


FIGURE 3

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A3 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

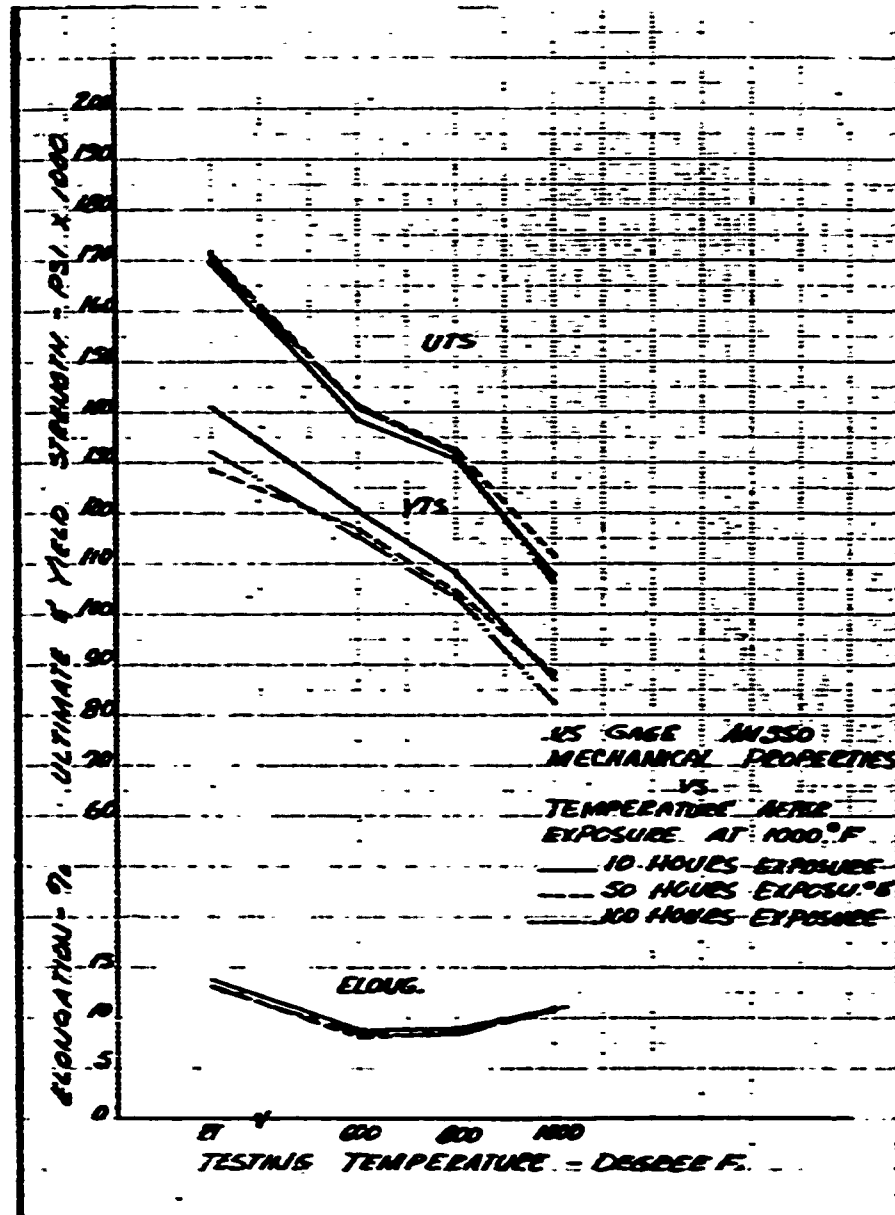


FIGURE 4

AUTHOR: G. Wainworth *GW* DATE: 9-12-61

PAGE 26.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AX 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

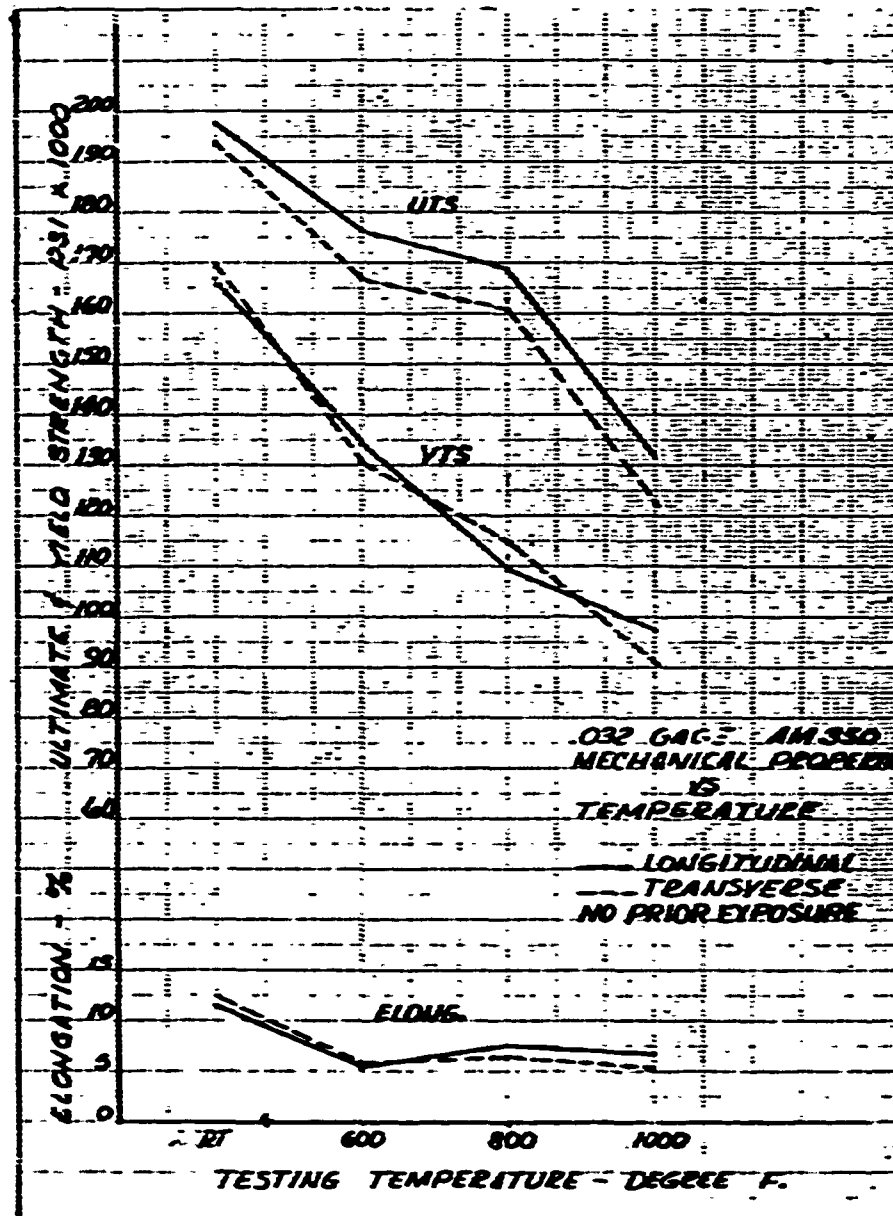


FIGURE 5

AUTHOR: G. Waisworth

DATE: 9-12-61

PAGE 27.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AH 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

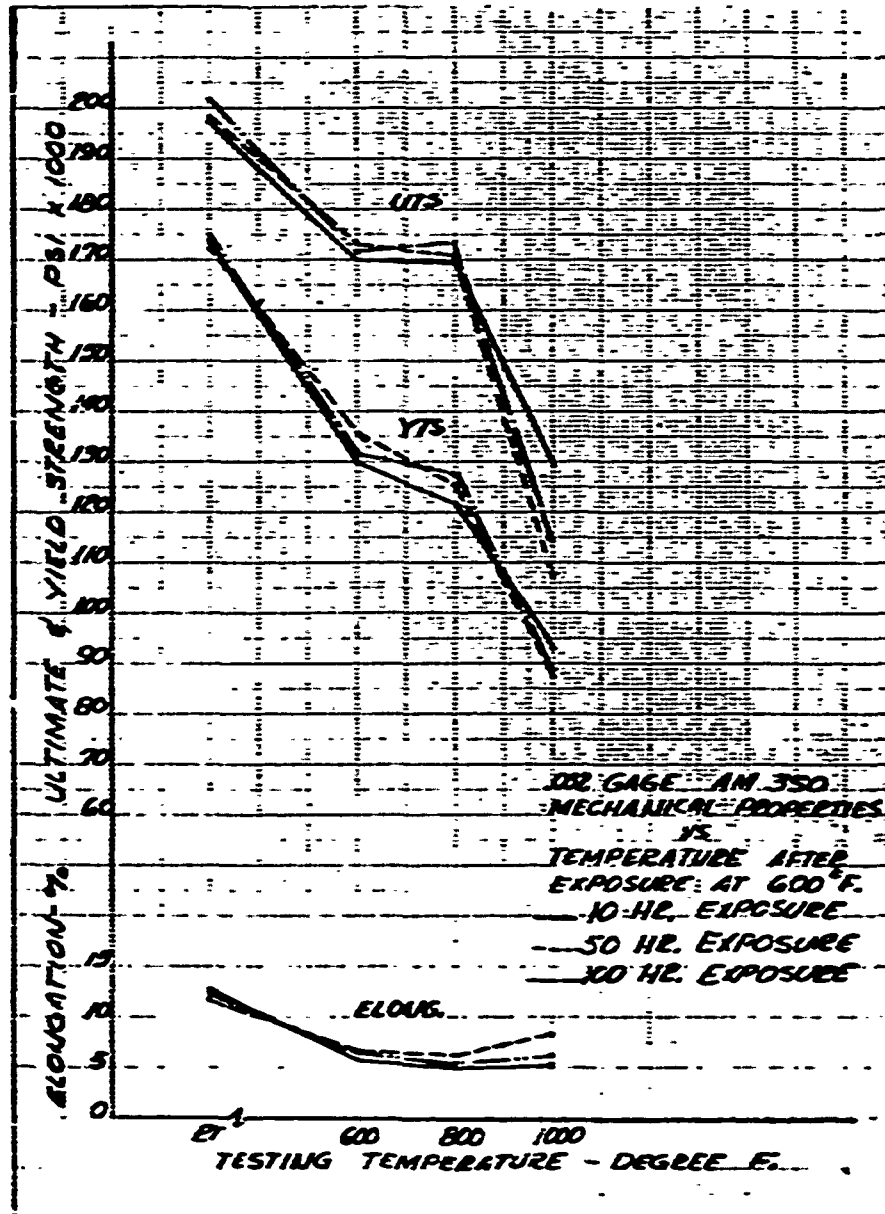


FIGURE 6

AUTHOR: G. Hadsworth

DATE: 9-12-61

PAGE 23.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AK 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

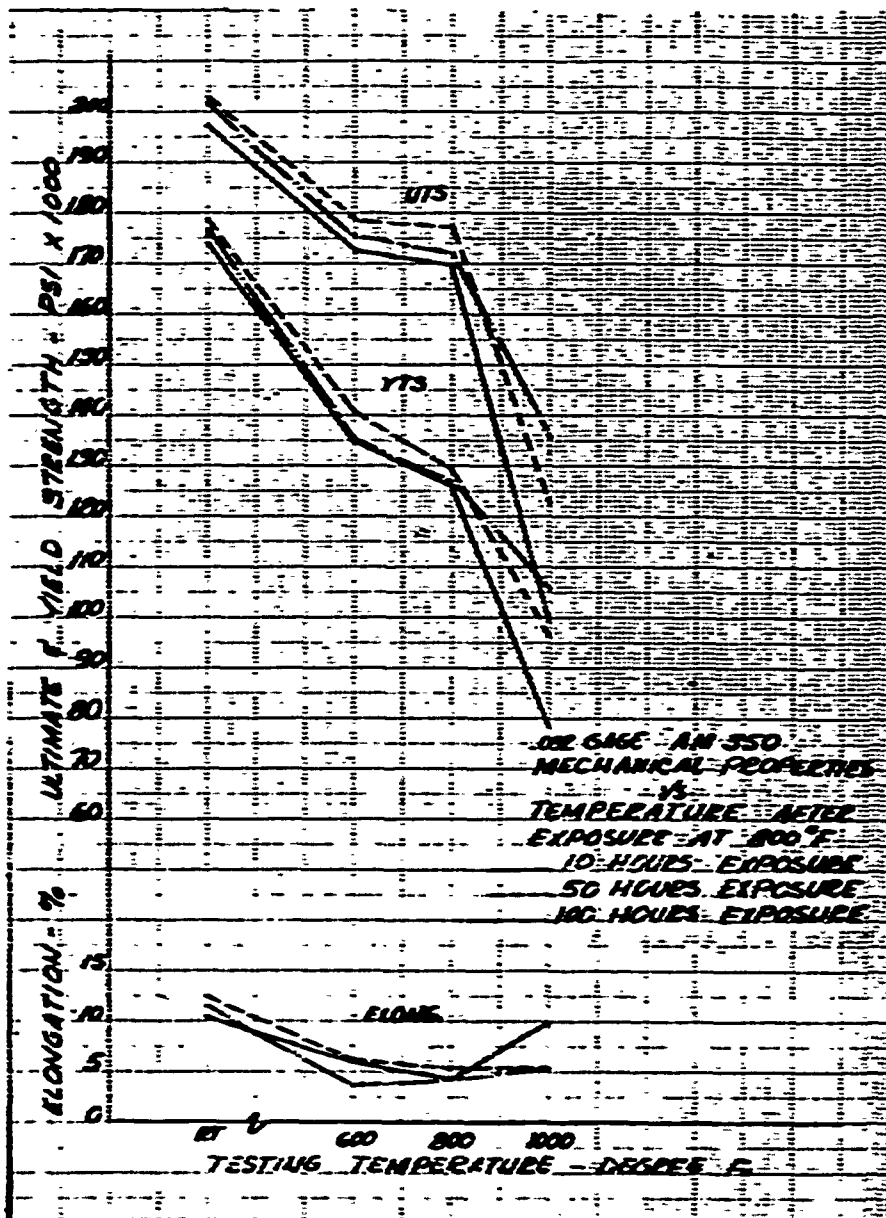


FIGURE 7

AUTHOR: G. Hadsorth

DATE: 9-12-61

PAGE 29.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: -AH 350 Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

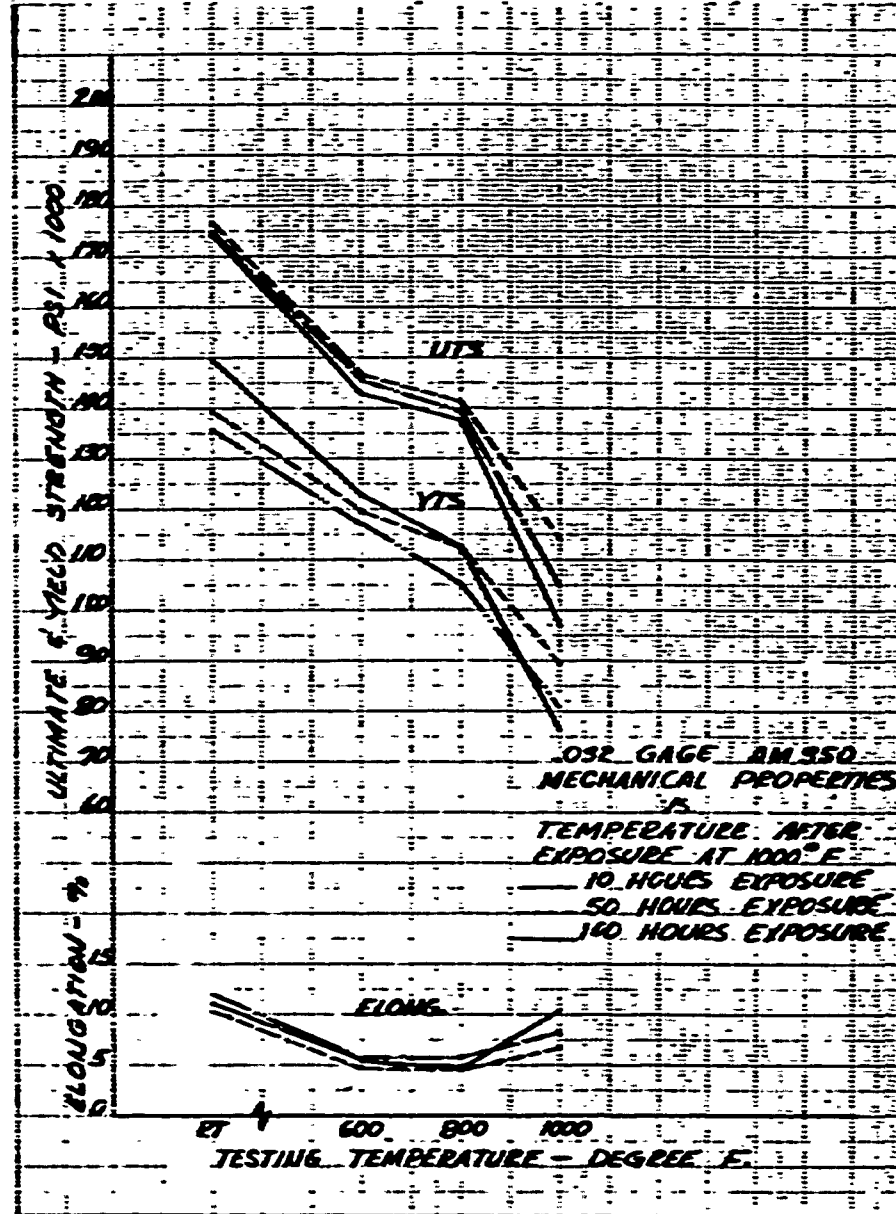


FIGURE 3

AUTHOR: G. Macsworth

DATE: 9-12-61

PAGE 30

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AH 350 Stainless Steel

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: A1 350 Stainless Steel

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

AUTHOR: G. Hadsworth *GH*

DATE: 9-12-61

PAGE 33.

MATERIALS & PROCESS UNIT

I. CATEGORY: Metals

CODE: 1-0-0

II. MATERIAL NAME: AM 350 Stainless Steel

VI. RECOMMENDED USES:

This alloy is recommended for use to 500°F in oxidizing or moderately corrosive environments where strengths to 200,000 psi are required.

VII. SUPPLIERS AND TRADE NAMES:

A. Suppliers

Allegheny-Iudlum - Others under licensing agreements.

B. Availability

Sheet, bar, plate and forging stock.

VIII. REFERENCES:

A. Materials and Process Job Report W-3-36, Investigation of Tensile Properties of AM 350.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-austenitic PH Steels

III. GENERAL DESCRIPTION:

The objective of this program was to determine if chemical etching and chemical milling will adversely affect the stress corrosion properties or promote intergranular attack on semi-austenitic PH steels.

IV. DEVELOPMENTAL BACKGROUND:

Future airborne and space vehicles will necessarily be made from heat resistant materials. Some of the materials currently being considered for these applications are semi-austenitic PH (precipitation hardening) steels. These steels are difficult to fabricate by conventional methods, especially on thin gauge sheets. The chemical milling of these steels would alleviate some of the fabrication problems if this milling does not adversely affect the other properties of these steels.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Chemical milling does not cause intergranular attack or affect stress corrosion properties of semi-austenitic PH steels.
2. Chemical milling cuts in excess of 0.04 inch per side causes roughening of the surface on Fil5-7Mo, 17-7PH and Vasco Jet 1000 steels in the fully heat treated condition.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion
Properties of Semi-Austenitic PH Steels

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The thermophysical properties of these chemical milled steels were not evaluated. However, there should be no difference in the thermophysical properties of chemical milled and mechanical milled parts.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion
Properties of Semi-austenitic PH Steels

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties of these chemical milled steels were not tested but should not vary from those of mechanical milled parts.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion
Properties of Semi-Austenitic FH Steels

V. PRINCIPAL PROPERTIES:

D. Chemical

The chemical properties of these chemical milled steels were not tested
but should vary only slightly from those of mechanical milled parts.

I. CATEGORY: Iron and Steel

CODE: 1-8-1

II. MATERIAL NAME: Influence of Chemical Etching on Stress Corrosion Properties of Semi-Austenitic PH Steels

VI. RECOMMENDED USES:

Chemical milling could be used as a fabrication procedure for semi-austenitic PH steels. However, further investigation would be necessary to reduce the surface roughness resulting from milling these steels in the fully heat treated condition.

VII. SUPPLIERS AND TRADE NAMES:

The following companies are qualified to chemical mill these steels in the annealed condition only:

- A. The Boeing Company
Seattle, Washington
- B. Altemil Corporation
El Segundo, California
- C. Anadite Corporation
South Gate, California
- D. Straza Industries
El Cajon, California
- E. Chemical Contour Corporation
Gardens, California
- F. U.S. Chemical Milling Corporation
Manhattan Beach, California

VIII. REFERENCES:

- A. Boeing Company Process Specification BAC 5759, Chemical Milling Steel.
- B. Turco Products, Incorporated, Process Manual, Chem-Mill, Los Angeles, California.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

III. GENERAL DESCRIPTION:

The objective of this program was to qualify 6AL-4V titanium alloy fasteners for use on Boeing products.

IV. DEVELOPMENTAL BACKGROUND:

Titanium possesses several properties which make it very desirable for use on aerospace vehicles. The two main properties which are of interest to the aircraft industry are high strength and low density. The density of 6AL-4V titanium alloy is .161 pounds per cubic inch which is 40% less than steel, yet it is heat treatable above 95,000 psi shear. Therefore, steel fasteners can be replaced with titanium fasteners with no reduction in joint strength.

Titanium is also immune to corrosion in most oxidizing environments which is another desirable property.

The combination of these properties have led to much research, testing and usage in the aerospace industry.

AUTHOR: Cecil Eckhoff *CE*

DATE: 9-12-51

PAGE 1.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Tensile - The ultimate tensile strength of titanium alloy (6Al-4V) fasteners is shown on Tables 13 through 29.
2. Double Shear - The ultimate double shear strength of titanium alloy (6Al-4V) fasteners is shown on Tables 18 through 29.
3. Tension - Tension Fatigue - The tension-tension fatigue life cycles at various loads of titanium alloy (6Al-4V) fasteners is shown on Tables 1 through 28.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

STATIC TENSILE					DOUBLE SHEAR			TENSILE-TENSILE FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
							BAC 21	1	500	125	60,200	ST
								2			55,200	
								3			50,200	
								4			60,200	
								5			62,600	
								6			62,600	
								7	500	125	62,900	ST
							Ref.:	8-2-215				

TABLE 1

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - Rivet HI-Shear, 100° Head, Interference Fit, Titanium Alloy											
Part No.: BAC H153K6-8						Test Nut Used:					
Supplier: HI-Shear Rivet Tool Company						Test Temperature: Ambient					
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE	
							HIGH	LOW			
Required =				Required =				Required =			
							500	125	48,000	C	
							↑	↑	69,500	C	
							↑	↑	69,500	C	
							↑	↑	86,300	C	
							↓	↓	86,300	C	
							↓	↓	111,900	C	
							500	125	68,100	MF	

C - Collar Failure
 MF - No Failure
 H - Head Failure

Ref.: Fatigue Test of Titanium Fasteners
 W-2-128

TABLE 2

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - Rivet El-Shear, Flat Head, Interference Fit, Titanium Alloy										
Part No.: BAC R15R8-9						Test Nut Used:				
Supplier: Val-Star Mfg. Company						Test Temperature: Ambient				
STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
							HIGH	LOW		
Required =				Required =			Required =			
					BAC 41		900	200	60,000	KF
					↑				60,000	
					2				60,400	
					3				60,400	
					4				65,400	
					5				65,200	
					6				64,700	
					BAC 41		900	200		KF
KF - No Failure										
Ref.: Fatigue Test of Titanium Fasteners for Vendor Qualification W-2-213										

TABLE 3

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Rivet Hi-Shear, 100° Head, Interference Fit, Titanium Alloy											
Part No.: BIC R15K1D-20						Test Nut Used:					
Supplier: Vol-Son Mfg. Company						Test Temperature: Ambient					
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
								HIGH	LOW		
Required =				Required =				Required =			
					BIC #1	1		1400	325	57,000	H
					↑	2		↑	↑	58,800	H
					↑	3		↑	↑	54,200	H
					↑	4		↑	↑	60,400	H
					↑	5		↑	↑	65,400	H
					↓	6		↓	↓	65,400	H
					BIC #1	7		1400	325	64,700	H
H = Head failure C = Collar failure NF = No failure Ref.: 8-2-213											

TABLE 1.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (5AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" - Rivet Hi-Shear, Flat Head, Interference Fit, Titanium Alloy												
Part No.: BAC B15B12-17						Test Nut Used:						
Supplier: Vol-Span Mfg. Company						Test Temperature: Ambient						
STATIC TESTS				DC-SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
							BAC 41	1	2000	500	60,200	无 断 裂 现 象
							↑	2	↑	↑	60,200	
							↑	3	↑	↑	60,000	
							↑	4	↑	↑	60,000	
							↑	5	↑	↑	60,200	
							↑	6	↑	↑	60,200	
							BAC 41	7	2000	500	60,200	
KF - No failure												
Ref.: M-2-213												

TABLE 5

I. CATEGORY: Light Metals and Alloys CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" - Rivet Hi-Shear, 100° Head, Interference Fit, Titanium Alloy												
Part No.: BAC R15M12-20						Test Std Code:						
Supplier: Vol-Shea						Test Temperature: Ambient						
STATIC TENSION				DOCKER SERIE				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
							BAC M1	1	2000	500	61,500	RF
							↑	2	↑	↑	61,500	↑
							↑	3	↑	↑	60,200	↑
							↑	4	↑	↑	62,200	↑
							↑	5	↑	↑	61,700	↑
							↑	6	↑	↑	62,300	↑
							BAC M1	7	2000	500	62,300	RF
							Ref., W-2-213					

TABLE 6

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - Bolt-Lock, Shear, Flat Head Pall Type, Titanium Alloy												
Part No.: BAC B30C28-10						Test Nut Used						
Supplier: Val-Span						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
							BAC #1	1	900	220	60,400	NP
							↑	2	↑	↑	60,400	↑
							↑	3	↑	↑	60,100	↑
							↑	4	↑	↑	60,100	↑
							↓	5	↓	↓	60,300	↓
							↓	6	↓	↓	60,300	↓
							BAC #1	7	900	220	60,300	NP
Ref.: 4-2-213												

TABLE 7

AUTHOR: Ozzie Eckhoff *Oc*

DATE: 9-12-61

PAGE 9.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Bolt-Lock, tension, Flat Head, Strip Type, Titanium Alloy

Part No.: SAC 855710-16
 Supplier: Vol-Shan Mfg. Company

Test Nut Used:
 Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE	
								HIGH	LOW			
Required =				Required =				Required =				
								24000	3600	1,000,100	RF	
								↑	↑	1,000,100	↑	
								↓	↓	750,600	↓	
										750,600		
										60,000		
										50,000		
										60,000	RF	
								Ref.: 2-23				

TABLE 8

AUTHOR: Ozzie Eckhoff *OE*

DATE: 9-12-61

PAGE 10.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Bolt-Lock, Shear, 100° Feed, Stamp Type, Titanium Alloy												
STATIC TENSION					LOGICAL SHEAR			TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE		
							HIGH	LOW				
Required =				Required =			Required =					
							BAC M1	1	1100	325	33,800	M
								2			61,500	M
								3			60,300	M
								4			60,300	M
								5			63,500	M
								6			62,300	M
							BAC M1	7	1100	325	62,300	M
							Ref.: 1-2-213					

TABLE 9

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I. CATEGORY: Light Metals and Alloys CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - "Hi-Lok" Fastener Assembly, 100° CSK Shear Head (Titanium Pin-Sleeve Collar)

Part No.: HLL1776-6-8
 Supplier: HI Shear

Test Std Used:
 Test Temperature: Ambient

STATIC TESTS					DOUBLE SHEAR				TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE		TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS		FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =					Required =				Required =			
						1	1130		113		7,600	F
						2	1130		113		13,000	F
						3	1130		113		7,000	F
						4	950		95		532,000	F
						5	950		95		31,000	F
						6	950		95		45,000	F

TABLE 10

AUTHOR: Uzzie Eckhoff *UE*

DATE: 9-12-61

PAGE 12.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Hi-Lock Fastener Assembly - 100°CSK Shear Head (Titanium Pin-Aluminum Collar)												
Part No.: H11V70-10-12					Test Nut Used:							
Supplier: B5-Shear					Test Temperature: Ambient							
STATIC TENSION				DOUBLE SHEAR			TENSILE-TENSILE FATIGUE					
TREATED BY	SPECIMEN NUMBER	ULTIMATE TENSILE LOAD POUNDS	TYPE OF FAILURE	TREATED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TREATED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
							Boeing Wichita	1	3280	328	3,000	H ↑ ↓ S
								2	3280	328	3,000	
								3	3280	328	2,000	
								4	2300	230	15,000	
								5	2300	230	15,000	
								6	2300	230	11,000	
								7	1640	164	142,000	
								8	1640	164	173,000	
								9	1640	164	199,000	
							Below Spec. 2	1	2300	230	6,000	S ↑ ↓ H
							Angle under Collar	2	2300	230	6,000	
								3	2300	230	11,000	

TABLE 11

I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (5AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt-Head, Close Tolerance, Titanium Alloy (6AL-4V)											
Part No.: KAS 6747-10						Test Part Used:					
Supplier: Vol-Stan						Test Temperature: Ambient					
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE	
							HIGH	LOW			
Required =				Required =				Required =			
					1		2500	625	60,200	WF	
					2		↕	↕	60,200		
					3				60,300		
					4				60,200		
					5				60,200		
					6				60,200		
					7		2500	625	60,100		

NOTE: These specimens were heat treated at 1700°F and had good microstructures

TABLE 12

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (5AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/16" - "Hi-Lok" Fastener Assembly - Protruding Shear Head (Titanium Pin-Aluminum Collar)												
Part No.: H11070-6-6						Test Nut Used:						
Supplier: HI-Shear						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
Boeing Wichita	1	2060	C				Boeing Wichita	1	500	125	1,000,000	NF
	2	1940	C					2				
	3	1970	C					3				
	4	1900	C					4				
	5	1860	C					5				
	6	1940	C					6				
	7	1940	C					7	500	125	1,000,000	XF
	8	1840	C					8	1130	113	21,000	T
	9	1850	C					9	1130	113	8,000	
	10	1880	C					10	1130	113	13,000	
								11	950	95	52,000	
								12	950	95	59,000	
								13	950	95	105,000	
								14	564	56	216,000	
								15	564	56	236,000	T

TABLE 13

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - "H-Iok" Fastener Assembly - Protruding Shear Head - (Titanium Pin-Aluminum Collar)

Part No.: H1070-S-8 Test Wet Ends
Supplier: H-Shear Test Temperature: Ambient

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
Boeing Michita	1 2 3	3180 3290 3300	C C C				Boeing Michita	1 2 3 4 5 6 7 8 9 10 11 12 13	900 ↑ 900 2050	220 ↓ 220 205	1,000,000 2,000,000 25,000 15,000 15,000 11,000 112,000 73,000 95,000 102,000 109,000	NP NP NP NP NP NP NP NP NP NP NP

TABLE 14

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (5AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPES OF FAILURES	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
Boeing Michita	1	3260	C				Boeing Michita	1	900	220	150,000	H
	2	3440	C					2	900	220	321,000	H
	3	3540	C					3	900	220	139,000	H
	4	3340	C					4	2050	205	31,000	H
								5	2050	205	50,000	T
								6	2050	205	36,000	H
								7	2050	205	9,000	H
								8	2050	205	299,000	H
								9	1710	171	31,000	T
								10	1710	171	114,000	T
								11	1710	171	176,000	T
								12	1710	171	73,000	H
								13	1710	171	36,000	H
								14	1710	171	18,000	H
								15	1280	128	627,000	H
								16	1280	128	2,002,000	XF
								17	1280	128	2,006,000	XF
								18	1280	128	259,000	T
								19	1280	128	2,241,000	XF
								20	1025	103	2,139,000	XF

TABLE 15

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" - Hi-Lok Fastener Assembly - Protruding Shear Head (Titanium Pin-Aluminum Collar)											
Part No.: HLC70-10-10						Test Nut Used:					
Supplier: Hi-Shear						Test Temperature: Ambient					
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE			
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE	
							HIGH	LOW			
Required =				Required =				Required =			
Boeing	1	6050	C				1100	325	1,000,000	MP	
Nichita	2	5850	C						1,000,000	MP	
	3	6000	C						1,000,000	MP	
	4	5950	C						1,000,000	MP	
	5	5860	C						446,000	T	
	6	5970	C						1,000,000	MP	
	7	5880	C						625,000	T	
							1100	325	39,000	T	
							3280	328	10,000	H	
							3280	328	15,000	H	
							2300	230	135,000	T	
							2300	230	188,000	T	
							2300	230	129,000	H	
							1610	161	1,104,000	MP	
							1610	161	1,564,000	MP	

TABLE 16

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (CAL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" - Hi-Lok Fastener Assembly - Protruding Shear Head (Titanium Pin-Aluminum Collar)												
Part No.: H1070-12						Test Method Used:						
Supplier: HI-Shear						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR			TENSION-TENSION FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE		
							HIGH	LOW				
Required =				Required =			Required =					
	1	8330	C									
	2	8410	C				Boeing	2000	500	1,000,000	MF	
	3	8110	C				Wichita	↑	↑	↑	↑	
	4	8470	C				↓	↓	↓	↓	↓	
	5	8380	C									
	6	8450	C									
	7	8340	C					2000	500	1,000,000	MF	

TABLE 17

AUTHOR: Ozzie Echhoff *OE*

DATE: 9-12-61

PAGE 19.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" - Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)												
Part No.: KAS674V-10						Test Mat Used:						
Supplier: Tel-Star						Test Temperature: Ambient						
STATIC TENSION				BENDING STRAP				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	6,650		Boeing Wichita	1	10,150	Boeing Wichita	1	2500	625	63,300	KT
	2	6,750			2	10,000		2			63,300	KT
	3	6,310			3	9,800		3			60,800	KT
	4	6,350			4	9,600		4			60,800	KT
	5	6,700			5	10,200		5			60,100	KT
	6	6,710			6	9,950		6			62,500	KT
	7	6,550			7	10,250		7	2500	625	122,800	KT
	Avg	6,573			Avg	9,993						

NOTE: These specimens fabricated from over heated rod stock and solution heat treated at 1750°F. They contain large prior beta grains.

TABLE 13

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/4" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)												
Part No.: KAS 6747-10						Test Nut Used:						
Supplier: Vol-Shan						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	6510		Boeing Wichita	1	9,750	Boeing Wichita	1	2500	625	60,300	XF
	2	6920			2	10,150		2			60,300	
	3	673			3	10,200		3			60,300	
	4	6710			4	10,150		4			60,300	
	5	6800			5	10,300		5			60,800	
	6	6430			6	9,550		6			60,800	
	7	6460			7	10,100		7	2500	625	60,300	XF
	Avg.	6651			Avg.	10,086						
NOTE: These specimens were solution heat treated at 1800°F. They contained large prior beta grains.												

TABLE 19

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

STATIC TENSION				DOUBLE SHEAR			TENSILE-TENSILE FATIGUE					
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =			Required =					
Boeing Wichita	1 2 3 4 5 6 7 Avg.	10,250 10,700 10,500 10,300 10,500 10,400 10,500 10,454	Not Recorded	Boeing Wichita	1 2 3 4 5 6 7 Avg.	15,000 15,100 15,150 15,000 15,400 14,850 15,300 15,077	Boeing Wichita	1 2 3 4 5 6 7	4,040 3,040	3,010 1,010	570,000 246,000 385,000 607,500 198,200 542,600 191,400 364,185	Not Recorded
	Ref.: 8-2-359											

TABLE 20

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3/8" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)												
Part No.: NAS 676V-12 (3/8" dia.)						Fatigue NAS 679-46						
Suppliers: Hi-Shear Rivet & Tool Co.						Test Nut Used: Tensile EAC K108-064						
Test Temperature: Ambient												
STATIC TENSION				DOUBLE SHEAR				TENSILE-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	15,250	Not Recorded	Boeing Wichita	1	21,200	Boeing Wichita	1	6,200	1,550	269,500	Not Recorded
	2	15,000			2	21,100		2			211,100	
	3	15,100			3	21,200		3			144,700	
	4	14,900			4	21,150		4			221,800	
	5	15,300			5	21,500		5			199,300	
	6	14,700			6	21,350		6			286,500	
	7	15,000			7	21,600		7	6,200	1,550	254,600	
	Avg.	15,036		Avg.	21,300		Avg.			226,785		
	Ref.: i-2-359											

TABLE 21

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

7/16" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6Al-4V)												
Part No.: SAS 677N-21						Test Nut Used:						
Supplier: Vol-Stan						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
BAC ml	1	20,300	Not Recorded	BAC ml	1	29,000	Boeing	1	2,400	2,100	35,000	T
	2	20,800			2	29,900	Michita	2	↕	↕	43,000	T
	3	19,300			3	29,400		3			50,000	T
	4	29,800			4	28,100		4			47,000	T
	5	20,440			5	30,400		5			60,000	HE
	6	19,680			6	29,300		6			32,000	T
	7	20,206			7	29,357		7			23,000	T
	Avg.	20,206		Avg.	29,357							
Ref.	A.C. Laboratory Report G-1311S, dated 1-28-58											

TABLE 22

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

7/16" Bolt - Hex Head, Close Tolerances, Titanium Alloy (6AL-4V)												
Part No.: S/S 677-23						Test Nut Grade:						
Supplier: Val-Span						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	20,200		Boeing Wichita	1	28,600	MC 11	1	8400	2100	42,900	T
	2	20,500			2	29,100		2	↑	↑	11,700	W
	3	17,800			3	29,800		3	↑	↑	60,200	W
	4	19,400			4	29,500		4	↓	↓	60,200	W
	5	20,400			5	29,600		5	↓	↓	60,200	W
	6	20,160			6	29,200		6	↓	↓	65,100	T
	7	20,066			7	29,475		7	8400	2100	60,100	W
	Avg.	20,066			Avg.	29,475						
	Ref. G-4615				Ref. G-4615				T - Tress Failure			
									See M-2-213			

TABLE 23

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/2" Bolt - Hex Head, Close Tolerance, Titanium Alloy (6AL-4V)												
Part No.: KAS 678V-16				Test Mat. Ends:				Fatigue KAS 1021-AB				
Supplier: Val-Spac				Test Temperature:				Tumble: MC NUCB-080 Ambient				
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita ↓	1 2 3 4 5 6 7	28,900 28,800 28,650 28,250 28,250 28,300 28,200	Not Recorded	Boeing Wichita ↓	1 2 3 4 5 6 7	40,900 40,400 38,300 40,000 38,900 39,550 40,200	Boeing Wichita ↓	1 2 3 4 5 6 7	11,400 ↕ 11,400	2,850 ↕ 2,850	182,000 99,000 63,000 79,000 78,000 37,000 38,000	Not Recorded
	Avg.	28,471			Avg.	39,807				Avg.	82,266	
	Ref.	W-2-319										

TABLE 24

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I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Tension, 100° Head, Pull Type, Titanium Alloy												
Part No.: BAC B308-8-8						Test Std. Used: MS 1080						
Supplier: Val-Shan						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TORSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FATIGUE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FATIGUE	TYPE OF FATIGUE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	4,530	Not Recorded	Boeing Wichita	1	10,050	Boeing Wichita	1	2330	233	173,000	Not Recorded
	2	4,420			2	10,225		2			375,000	
	3	4,120			3	9,950		3			530,000	
	4	4,550			4	10,300		4			545,000	
	5	4,870			5	10,300		5			474,000	
	6	4,280			6	9,900		6			240,000	
	7	4,570			7	10,150		7	2330	233	174,000	
	Avg.	4,477		Avg.	10,112				Avg.		358,714	
	Ref.:	M-2-319										

TABLE 25

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Tension, Pan Head, Pull Type, Titanium Alloy												
Part No.: SAC 83088-8						Test Set Used: SAS 1080-C8						
Supplier: Vol-Shen						Test Temperature: Ambient						
STATIC TENSION				JULI SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	4,680	Not Recorded	Boeing Wichita	1	10,000	Boeing Wichita	1	2330	233	73,000	Not Recorded
	2	4,950			2	10,450		2			75,000	
	3	4,860			3	9,800		3			66,000	
	4	4,610			4	10,250		4			62,000	
	5	4,460			5	10,500		5			87,000	
	6	4,810			6	10,400		6			106,000	
	7	4,770			7	10,400		7	2330	233	112,000	
	Avg.	4,734		Avg.	10,257			Avg.		82,857		
	Ref.:	M-2-319										

TABLE 26

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, Shear, Flat Head, Pail Type, Titanium Alloy												
Part No.: BAC 830C18-8						Fatigue MS 1080						
Supplier: Vol-Sum						Test Fat Seeds: Tensile MS 1040-C8						
						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita	1	3,460	Not Recorded	Boeing Wichita	1	9,200	Boeing Wichita	1	1250	125	62,000	Not Recorded
	2	3,250				2	10,350		↑	↑	86,000	
	3	3,260				3	10,000		↑	↑	90,000	
	4	3,470				4	10,100		↓	↓	42,000	
	5	3,240				5	10,100		↓	↓	47,000	
	6	3,270				6	9,400		↓	↓	20,000	
	7	3,310				7	9,800		1250	125	33,000	
	Avg.	3,323			Avg.	9,350			Avg.	61,429		
	Ref:	M-2-319										

TABLE 27

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1/4" Bolt - Lock, 120° Head, Full Type, Titanium Alloy												
Part No.: MC 1330C28-10						Test Std Used: NAS 1080-C8						
Supplier: Vol-Sum						Test Temperature: Ambient						
STATIC TENSION				DOUBLE SHEAR				TENSION-TORSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLES TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita ↓	1	3,600	Not Recorded	Boeing Wichita ↓	1	10,200	Boeing Wichita ↓	1	1250	125	78,000	
	2	3,620			2	10,200		2	↕	↕	74,000	
	3	3,520			3	10,050		3	↕	↕	2,234,000	
	4	3,520			4	10,050		4	↕	↕	93,000	
	5	3,590			5	10,200		5	↕	↕	63,000	
	6	3,710			6	10,250		6	↕	↕	307,000	
	7	3,640			7	10,050		7	1250	125	2,942,000	
	Avg.	3,573		Avg.	10,143				Avg.		825,714	
	Ref.	W-2-319										

TABLE 28

AUTHOR: *Carrie Eckhoff* *OE*

DATE: 9-12-61

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I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

5/16" Bolt - Lock, Tension, 100° Head, Full Type, Titanium Alloy												
Part No.: SAC B3CEK10-13						Test Nut Used						
Supplier: Val-Sar						Test Temperature: Ambient						
STATIC TENSION				Bolt SHEAR				TENSION-TENSION FATIGUE				
TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TYPE OF FAILURE	TESTED BY	SPECIMEN NUMBER	ULTIMATE LOAD POUNDS	TESTED BY	SPECIMEN NUMBER	FATIGUE LOAD POUNDS		CYCLING TO FAILURE	TYPE OF FAILURE
									HIGH	LOW		
Required =				Required =				Required =				
Boeing Wichita ↓	1	6,530	Not Recorded	Boeing Wichita ↓	1	16,400						
	2	6,720			2	15,200						
	3	6,520			3	15,800						
	4	6,600			4	15,800						
	5	6,790			5	15,300						
	6	6,680			6	15,580						
	7	6,480			7	15,700						
	Avg.	6,619			Avg.	15,837						
Ref.	U.C. Laboratory Report G-12803, dated 12-31-57			Ref.	Same as tension.							

TABLE 29

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

AUTHOR: Ozsie Eckhoff *OE*

DATE: 9-12-61

PAGE 32.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6AL-4V)

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

V. PRINCIPAL PROPERTIES:

D. Chemical

The composition of 6Al-4V titanium alloy by percent weight is as follows:

Aluminum	5.0 - 7.0
Vanadium	3.5 - 4.5
Carbon	.10 Max.
Iron	.30 Max.
Nitrogen	.07 Max.
Oxygen	.20 Max.
Hydrogen	.0175 Max.
Others	.40 Max.
Titanium	Resainder

AUTHOR:

Ozzie Eckhoff *OE*

DATE: 9-12-61

PAGE 34.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys **CODE:** 2-7-1

II. MATERIAL NAME: Titanium Fasteners (6Al-4V)

VI. RECOMMENDED USES:

6Al-4V titanium alloy fasteners are recommended for airframe usage where:

- a. High strength fasteners are required along with minimum weight;
- b. high strength fasteners are required in a high corrosive environment;
- c. high strength non-magnetic fasteners are required;
- d. any combination of the above three are required.

VII. SUPPLIERS AND TRADE NAMES:

Suppliers of 6Al-4V titanium alloy fasteners are as follows:

Hi-Shear Rivet and Tool Company
Voi-Shan Manufacturing Company
CarCar Screws and Manufacturing Company
Standard Pressed Steel Company

VIII. REFERENCES:

- A. Boeing-Wichita Materials and Process Unit Report W-2-181K, Fatigue Test of Titanium Fasteners, dated November 1957.
- B. Boeing-Wichita Materials and Process Unit Report W-2-213, Fatigue Test of Titanium Fasteners for Vendor Qualification, dated November 1957.
- C. Boeing-Wichita Quality Control Laboratory Report Q-1314S, dated 28 January 1958.
- D. Boeing-Wichita Quality Control Laboratory Report Q-10203, dated 31 December 1957.
- E. Boeing-Wichita Materials and Process Unit Report W-2-319, Qualification Tests of 6Al-4V Titanium Fasteners Manufactured by Voi-Shan Manufacturing Company, dated April 1959.
- F. Boeing-Wichita Materials and Process Unit W-2-215, Evaluation of a Special Group of Voi-Shan Titanium Fasteners, dated November 1957.
- G. Boeing-Wichita Quality Control Laboratory Report Q-4615, dated 30 September 1957.
- H. Boeing-Wichita Materials and Process Unit Report W-2-359, Qualification Tests of NAS675V-10 and NAS675V-12 6 Al-4V Titanium Fasteners, dated November 1959.
- I. Boeing Procurement Specification for Titanium Alloy Fasteners, SAC B301R.
- J. Boeing-Wichita Preliminary Report on Evaluation Tests of Titanium Hi-Lok Fasteners, dated 27 June 1958.

AUTHOR: Ozzie Eckhoff *OE*

DATE: 9-12-61

PAGE 35.

MATERIALS & PROCESS UNIT.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

III. GENERAL DESCRIPTION:

The objective of this program was to determine the feasibility of depositing aluminum by the vacuum plating technique.

IV. DEVELOPMENTAL BACKGROUND:

There are several attractive advantages of aluminum as a protective coating. Aluminum is anodic to most metals and thereby would be sacrificially protective to the basis metal. Aluminum is itself corrosion resistant. A corrosion protective coating of aluminum applied by the vacuum method would eliminate the problems of hydrogen embrittlement and excessive heating of the basis metal required by flame spraying. Thin films of aluminum are common but are known to be porous. As a protective coating, aluminum would be required to be substantially thicker. Aluminum can be electroplated but relatively thick coatings are difficult to obtain. No published literature is available on a method to sustain vacuum plating to produce thick films.

AUTHOR: T. G. Kozan *TK*

DATE: 9-12-61

PAGE 1

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Thin films of aluminum on smooth surfaces are bright and highly reflective.
2. Accurate control of thickness of thin films can be accomplished.
3. Thin films in the order of 5-10 millionths of an inch have very good covering power.
4. Thin films are porous exhibiting rather extensive very small pin holes.
5. The cleanliness of the surface to be plated with thin films is very important to produce sound coatings.
6. Thick coatings of aluminum on the order of .0001 inch lose brightness and become matte in appearance regardless of the surface of the substrate.
7. A light, dry grit blasting of metallic surfaces, just prior to vacuum deposition is necessary to provide satisfactory adhesion of thick aluminum deposits.
8. Vacuum deposited aluminum appears to be porous in thickness up to .003 inch.
9. Line of sight coverage is very apparent in plating with aluminum. Reverse sides of specimens plated received little or no plating.
10. Thick deposits are crystalline and are brittle.

AUTHOR: T. S. Kozan *TSK*

DATE: 9-1-61

PAGE 2

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

B. Thermophysical

No information is available on the elevated temperature properties of thin films of aluminum. The wide difference in the coefficient of thermal expansion of aluminum and most metal substrate presents serious problems of adhesion. Aluminum deposits .002 inch thick on grit blasted molybdenum exhibited good adhesion to room temperature bend-fracture test and temperature to approximately 1000°F. Near the melting point of aluminum, severe blistering of the aluminum occurred. Diffusion bonding was not apparent after short time heat treatment aging at 1000°F.

AUTHOR: T. G. Kozan *T.G.K.*

DATE: 9-11-61

PAGE 3

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties were not investigated in this work. It was assumed that these properties would closely correspond to the bulk metal properties. It should be pointed out that the vacuum plated aluminum is porous and as a result, the electrical properties such as resistivity could vary slightly from the bulk metal.

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

V. PRINCIPAL PROPERTIES:

D. Chemical

The chemical properties were not investigated in this work. The production of vacuum deposits, methods of sustaining plating to accomplishing thick deposits were directed toward high temperature oxidation protection. Adhesion difficulties prevented extensive studies of oxidation protection.

AUTHOR: T. G. Kozand *TK*

DATE: 9-11-61

PAGE 5

I. CATEGORY: Light Metals and Alloys

CODE: 2-7-9

II. MATERIAL NAME: Vacuum Plated Aluminum

VI. RECORDED USES:

Until satisfactory surface preparation and/or methods of diffusion bonding are determined, no recommendation can accurately be given.

VII. SUPPLIER AND TRADE NAME:

None

VIII. REFERENCES:

- A. Materials and Process Job Report F-1-1, Vacuum Deposition of Metals.
- B. Materials and Process Job Report F-3-15, Laminated Refractory Electrodeposits as High Temperature Protection of Molybdenum.
- C. Vacuum Deposition of Thin Films, L. Holland - Boeing Library - T.S. 213H 755 v.

AUTHOR: T. G. Egan *T.G.E.*

DATE: 9-11-51

PAGE 6.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

III. GENERAL DESCRIPTION:

The objective of this program was the evaluation of alkaline etch cleaning prior to Alodizing or Anodizing aluminum for potential increased salt spray resistance. The scope included in the testing of materials which were etch cleaned in comparison to materials which were not etch cleaned.

IV. ENVIRONMENTAL BACKGROUND:

Alkaline etch cleaning of machined 7175 aluminum alloy gives added protection to parts that have been Alodined. This has been indicated by improved salt spray resistance tests and fewer corrosion problems experienced in the shop since Alkaline cleaning was inaugurated.

WJK

AUTHOR: W. E. Kolins

DATE: 9-13-61

PAGE 1.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

A. Mechanical

These materials were not investigated from this standpoint as there existed no need under this program.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

B. Thermophysical

These materials were not investigated from this standpoint as there existed no need under this program.

W. H. Kolins
AUTHOR: W. H. Kolins

DATE: 9-13-61

PAGE 3.

MATERIALS & PROCESS UNIT

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

C. Electrical

These materials were not investigated from this standpoint as there existed no need under this program.

AUTHOR: W. H. Collins

DATE: 9-13-61

PAGE 4.

I. CATEGORY: Light Metals and Alloys

CODE: 2-3-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES:

D. Chemical

Chemical properties are depicted by following Tables I through VI and panels shown in Photographs E-159340 and E-159341. Based upon these characteristics, recommendations are made in Section VI of this report.

WJK
AUTHOR: W. H. Rolins

DATE: 9-13-61

PAGE 5.

I. CATEGORY: Light Metals and Alloys CODE: 2-3-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

SALT SPRAY RESISTANCE TESTS - ALODINED AND ANODIZED ALUMINUM ALLOY PANELS

PROCESSED AT WICHITA DIVISION

<u>Alloy</u>	<u>Processing Per SAC Specification</u> <u>Wichita Division</u>	<u>WICHITA</u> <u>SALT SPRAY</u>		<u>AERO-SPACE</u> <u>SALT SPRAY</u>	
		<u>No.</u>	<u>Eval.</u>	<u>No.</u>	<u>Eval.</u>
7178 Machined	Alodine	1	Fail	1-S	Fail
7178 Machined	Alkaline Etch Clean - Alodine	2	Pass	2-S	Marginal
7178 Machined	Alkaline Etch Clean - Zyglo - Shot Peen - Alodine	3	Pass	3-S	Pass
7178 Machined	Anodize	6	Fail	6-S	Marginal
7178 Machined	Alkaline Etch Clean - Anodize	7	Pass	7-S	Pass
7075 Rolled	Alodine	4	Pass	4-S	Pass
7075 Rolled	Alkaline Etch Clean - Alodine	5	Pass	5-S	Pass
7075 Rolled	Anodize	8	Pass	8-S	Pass
7075 Rolled	Alkaline Etch Clean - Anodize	9	Pass	9-S	Pass

TABLE I

W.H.H.
AUTHOR: W. E. Collins

DATE: 9-13-61

PAGE 6.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ALUMINUM PANELS PROCESSED BY AERO-SPACE DIVISION - SALT SPRAY EVALUATION

AERO-SPACE PROCESSED - WINGTA SALT SPRAY					AERO-SPACE PROCESSED - AERO-SPACE SALT SPRAY				
Panel No.	Alloy	Treat-ment*	Aero-Space Eval.	Misc Eval.	Panel No.	Alloy	Treat-ment*	Aero-Space Eval.	Misc Eval.
A3	2024	1	Fail	Fail	A1	2024	1	Fail	Fail
A4	2024	1	Fail	Fail	A2	2024	1	Fail	Fail
A7	2024	2	Fail	Fail	A5	2024	2	Fail	Fail
A8	2024	2	Fail	Fail	A6	2024	2	Fail	Fail
B3	2024	3	Pass	Marginal	B1	2024	3	Pass	Pass
B4	2024	3	Pass	Fail	B2	2024	3	Marginal	Fail
B7	2024	4	Pass	Fail	B5	2024	4	Pass	Marginal
B8	2024	4	Pass	Pass	B6	2024	4	Pass	Marginal
C3	7075	1	Fail	Fail	C1	7075	1	Pass	Marginal
C4	7075	1	Fail	Fail	C2	7075	1	Pass	Marginal
C7	7075	2	Fail	Fail	C5	7075	2	Pass	Marginal
C8	7075	2	Pass	Fail	C6	7075	2	Pass	Marginal
D3	7075	3	Pass	Fail	D1	7075	3	Pass	Pass
D4	7075	3	Pass	Fail	D2	7075	3	Pass	Pass
D7	7075	4	Fail	Fail	D5	7075	4	Pass	Pass
D8	7075	4	Fail	Fail	D6	7075	4	Pass	Pass
E3	7178	1	Fail	Fail	E1	7178	1	Pass	Pass
E4	7178	1	Fail	Fail	E2	7178	1	Pass	Pass
E7	7178	2	Fail	Fail	E5	7178	2	Pass	Pass
E8	7178	2	Fail	Fail	E6	7178	2	Pass	Pass
F3	7178	3	Fail	Fail	F1	7178	3	Pass	Pass
F4	7178	3	Fail	Fail	F2	7178	3	Pass	Marginal
F7	7178	4	Fail	Fail	F5	7178	4	Pass	Marginal
F8	7178	4	Fail	Fail	F6	7178	4	Pass	Marginal

General NOTES: All panels were processed in the manufacturing shop facilities and not air dried per SAC 5719.

- * 1. 5 Minutes Desiccate, 3 Minutes Alodine
- 2. 5 Minutes Desiccate, 5 Minutes Alodine
- 3. No desiccate, 3 Minutes Alodine
- 4. No desiccate, 5 Minutes Alodine

TABLE II

AUTHOR: W. H. Kolins

DATE: 9-13-61

PAGE 7.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ALUMINE PANELS PROCESSED AT MICHITA - SALT SPRAY - ALUMINUM

MICHITA PROCESSED - MICHITA SALT SPRAY					MICHITA PROCESS. 3 - AEROSPACE SALT SPRAY				
Panel No.	Alloy	Treatment	Aero-Space Eval.	Milac Eval.	Panel No.	Alloy	Treatment	Aero-Space Eval.	Milac Eval.
G1	2024	1	Pass	Pass	G1	2024	1	Pass	Pass
G2	2024	1	Pass	Pass	G2	2024	1	Pass	Pass
G3	2024	2	Pass	Pass	G3	2024	2	Pass	Pass
G4	2024	2	Pass	Pass	G4	2024	2	Pass	Pass
G5	2024	3	Pass	Pass	G5	2024	3	Pass	Pass
G6	2024	3	Pass	Pass	G6	2024	3	Pass	Pass
G7	2024	4	Pass	Pass	G7	2024	4	Pass	Pass
G8	2024	4	Pass	Pass	G8	2024	4	Pass	Pass
H1	7075	1	Pass	Pass	H1	7075	1	Pass	Pass
H2	7075	1	Pass	Pass	H2	7075	1	Pass	Pass
H3	7075	2	Pass	Pass	H3	7075	2	Pass	Pass
H4	7075	2	Pass	Pass	H4	7075	2	Pass	Pass
H5	7075	3	Pass	Pass	H5	7075	3	Pass	Pass
H6	7075	3	Pass	Pass	H6	7075	3	Pass	Pass
H7	7075	4	Pass	Pass	H7	7075	4	Pass	Pass
H8	7075	4	Pass	Pass	H8	7075	4	Pass	Pass
I1	7178	1	Pass	Pass	I1	7178	1	Pass	Pass
I2	7178	1	Pass	Pass	I2	7178	1	Pass	Pass
I3	7178	2	Pass	Pass	I3	7178	2	Pass	Pass
I4	7178	2	Pass	Pass	I4	7178	2	Pass	Pass
I5	7178	3	Pass	Pass	I5	7178	3	Pass	Pass
I6	7178	3	Pass	Pass	I6	7178	3	Pass	Pass
I7	7178	4	Pass	Pass	I7	7178	4	Pass	Pass
I8	7178	4	Pass	Pass	I8	7178	4	Pass	Pass

General info: It was noted that the panels had very dark color and nearly all had some powder ranging from "light" to very heavy. However, the normal immersion time for Alodine at Mich: is only two minutes. These panels were processed in the same manner as the 16 Aerospace and per spec 5219.

- 1. 5 Minutes Decidize, 3 Minutes Alodine.
- 2. 5 Minutes Decidize, 5 Minutes Alodine.
- 3. No Decidize, 3 Minutes Alodine.
- 4. No Decidize, 5 Minutes Alodine.

TABLE III

AUTHOR: W. H. Kollins

DATE: 9-13-61

PAGE 8.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ANODIZE PANELS PROCESSED AT AERO-SPACE DIVISION - SALT SPRAY EVALUATION

<u>AERO-SPACE PROCESSED - AERO-SPACE SALT SPRAY</u>				<u>AERO-SPACE PROCESSED - WICHITA SALT SPRAY</u>			
<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Aero-Space Evaluation</u>	<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Wichita Evaluation</u>
P-1	2024	Short	Fail	P-3	2024	Short	Border line
P-2	2024	Short	Fail	P-4	2024	Short	Border line
P-6	2024	Low	Fail	P-7	2024	Low	Acceptable
X-1	7075	Short	Fail	P-9	2024	Low	Acceptable
X-2	7075	Short	Fail	X-3	7075	Short	Failed
X-5	7075	Low	Fail	X-4	7075	Short	Failed
				X-7	7075	Low	Failed
				X-8	7075	Low	Failed

TABLE IV

W.H.K.
AUTHOR: W. H. Kolins

DATE: 9-13-51

PAGE 9.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ANODIZED PANELS PROCESSED AT WICHITA DIVISION - SALT SPRAY EVALUATION

<u>WICHITA PROCESSED - AEROSPACE SALT SPRAY</u>				<u>WICHITA PROCESSED - WICHITA SALT SPRAY</u>			
<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Aer. Space Evaluation</u>	<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Wibec Evaluation</u>
C-3	2024	Short	Fail	C-1	2024	Short	Fail
C-4	2024	Short	Fail	C-2	2024	Short	Fail
C-7	2024	Long	Pass	C-5	2024	Long	Pass
C-8	2024	Long	Pass	C-6	2024	Long	Pass
F-3	7075	Short	Fail	F-1	7075	Short	Fail
F-4	7075	Short	Fail	F-2	7075	Short	Fail
F-7	7075	Long	Pass	F-5	7075	Long	Pass
F-8	7075	Long	Pass	F-6	7075	Long	Pass

TABLE V

W.H.
AUTHOR: W. H. Kolins

DATE: 9-13-61

PAGE 10.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)

ANODIZED PANELS PROCESSED AT TEARSPORT DIVISION - SALT SPRAY EVALUATION

<u>TEARSPORT PROCESSED - AERO-SPACE SALT SPRAY</u>				<u>TEARSPORT PROCESSED - WENETA SALT SPRAY</u>			
<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Aero-Space Evaluation</u>	<u>Panel No.</u>	<u>Alloy</u>	<u>Anodize Cycle</u>	<u>Weneta Evaluation</u>
Q-1	2024	Long	Fail	Q-5	2024	Low	Pass
Q-2	2024	Low	Fail	Q-6	2024	Long	Pass
Q-3	2024	Long	Fail	Q-7	2024	Long	Pass
Q-4	2024	Long	Fail	Q-8	2024	Long	Pass
R-1	7075	Long	Fail	R-5	7075	Long	Fail
R-2	7075	Long	Fail	R-6	7075	Long	Fail
R-3	7075	Low	Fail	R-7	7075	Low	Fail
R-4	7075	Low	Fail	R-8	7075	Long	Fail

TABLE VI

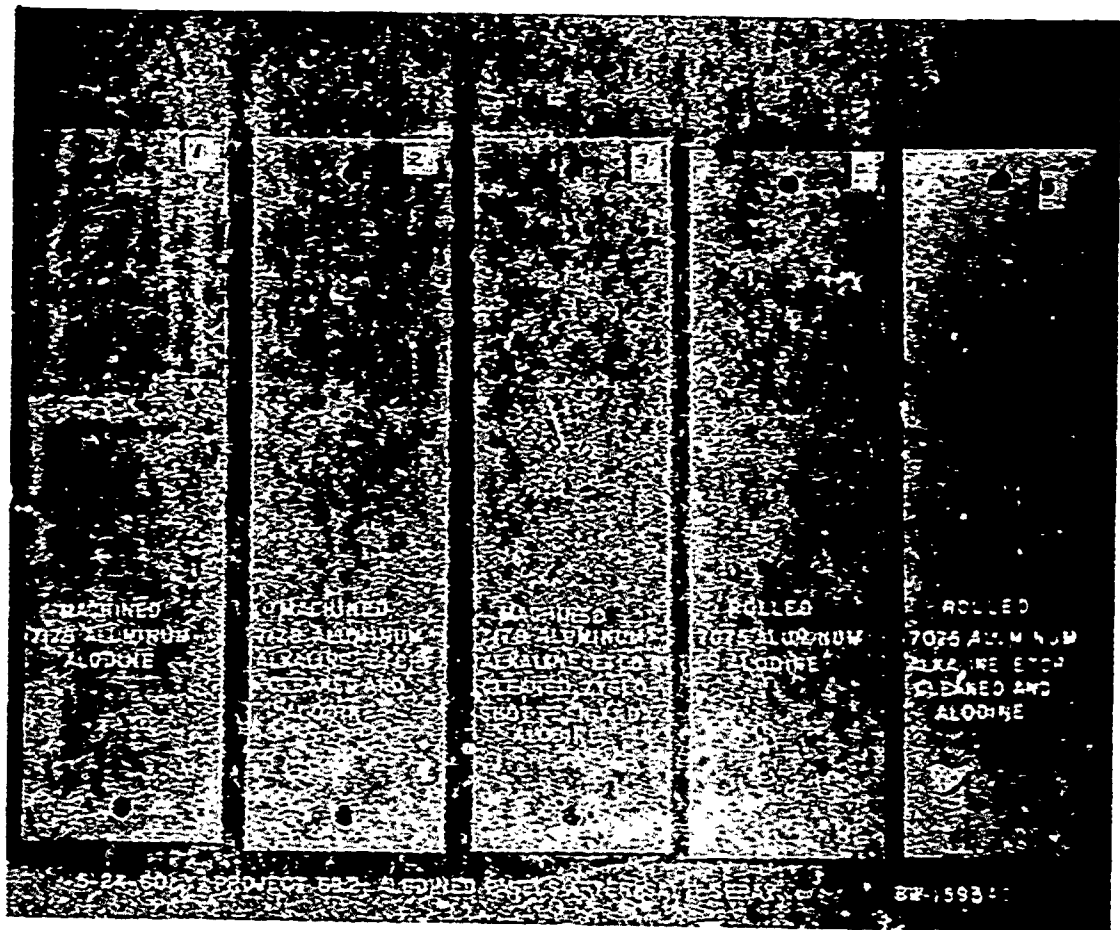
I. CATEGORY: Light Metals and Alloys

CODE: 2-8-1

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)



82-1593

W.H.K.
AUTHOR: W. H. Kelins

DATE: 9-13-62

PAGE 12.

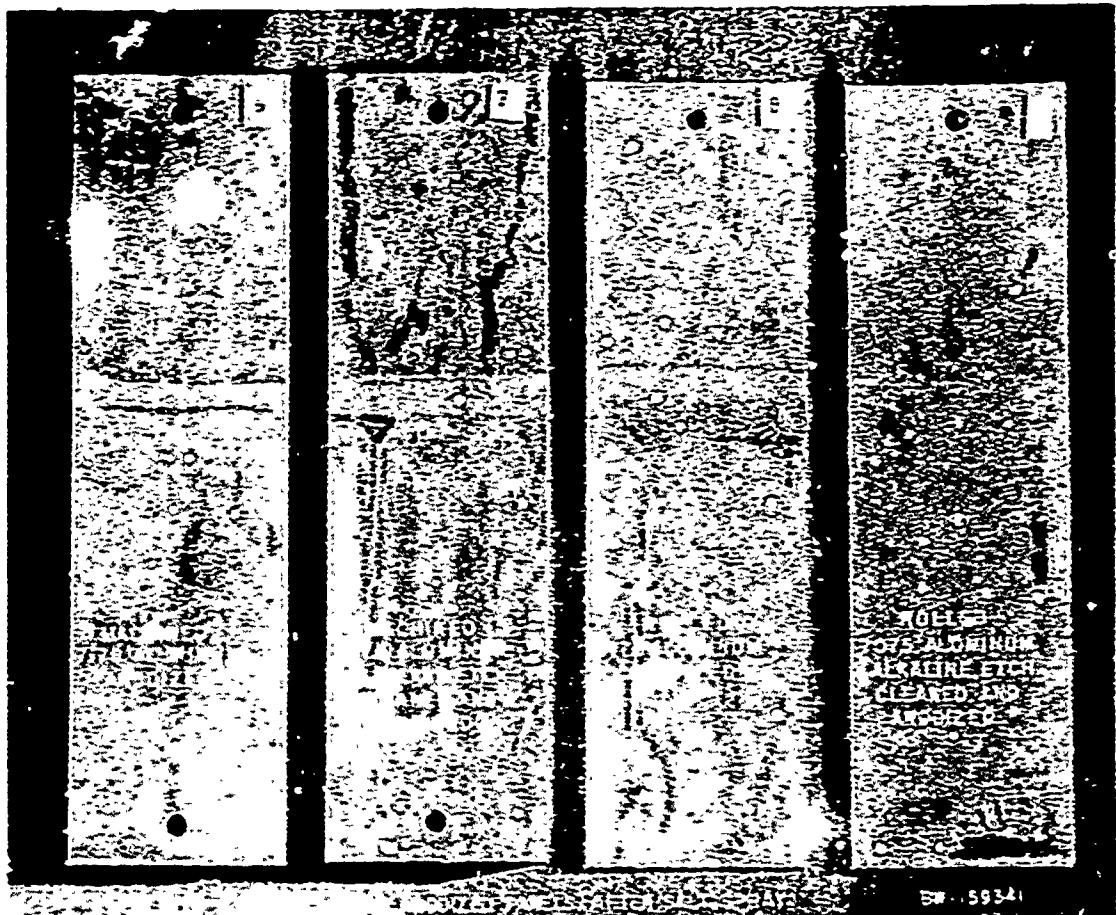
I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

V. PRINCIPAL PROPERTIES: (Continued)

D. Chemical (continued)



EW-159341

W.H.K.

AUTHOR: W. H. Kolins

DATE: 9-13-61

PAGE 13.

I. CATEGORY: Light Metals and Alloys

CODE: 2-8-4

II. MATERIAL NAME: Corrosion Resistance of Various Aluminums

VI. RECOMMENDED USES:

It is recommended that all extensively machined 7175 aluminum alloys be etch cleaned prior to Alodine or Anodize processing. It is not recommended that rolled 7075 aluminum alloy be etch cleaned prior to Alodine.

VII. SUPPLIERS AND TRADE NAMES:

Not applicable.

VIII. REFERENCES:

- A. Military Specification MIL-C-5541, "Chemical Films for Aluminum and Aluminum Alloys", and MIL-A-5525A, "Anodic Coatings for Aluminum Alloys and Aluminum".
- B. Boeing-Kichita Manufacturing Research Report 66.2, "Salt Spray Resistance Tests, Anodized and Alodined Aluminum Alloy, Etched vs Non-Etched".

WKK

AUTHOR: W. E. Kolins

DATE: 9-13-61

PAGE 14.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

III. GENERAL DESCRIPTION:

The purpose of this program was to investigate the properties of vacuum deposited cadmium plating, including corrosion resistance, adhesion of plate to base metal of steel and paint adhesion to vacuum deposited plate. A determination was made to detect any detrimental effect on the physical properties of AISI 4340 steel, heat treated 260,000 to 280,000 psi resulting from surface preparation and vacuum deposition of cadmium.

IV. DEVELOPMENTAL BACKGROUND:

Delayed brittle failures of stressed high strength steel parts have resulted from hydrogen pick up during electroplating sequences. A corrosion protective coating of cadmium applied by the vacuum method would eliminate the problem of hydrogen embrittlement associated with electrodeposited coatings. Since vacuum deposited coatings are more porous than electrodeposited coatings, the thickness requirements for adequate corrosion protection and a suitable surface preparation for adequate plate adhesion need to be established.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Adhesion of Vacuum Deposited Cadmium to Base Metal of Steel.
A light, dry grit blasting of the steel surface just prior to vacuum deposition is necessary to provide satisfactory adhesion of cadmium to steel.
2. Primer Adhesion to Vacuum Deposited Cadmium.
Vacuum deposited cadmium receiving a chromate conversion coating, CC-P-416A Type II, provides an adequate surface for good adhesion of zinc chromate primer.
3. Porosity.
Vacuum deposited cadmium is inherently porous and requires a thicker deposit than electrodeposited cadmium to provide adequate corrosion protection.
4. Embrittlement.
Cleaning, grit blasting and vacuum cadmium plating has no apparent effect on the tensile strength of 260,000 to 280,000 psi steel based on exposure to notched tensile tests.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information on the elevated temperature properties of this coating are not available. It is probable that this coating would present the elevated temperature properties identical with electroplated deposits. As a result this coating is not recommended for use on low alloy steels heat treated above 220,000 psi in environments of stress and temperatures above 500°F.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties were not investigated in this work since it was assumed that these properties would closely correspond to electroplated coatings. It should be pointed out that the vacuum plated cadmium is more porous and as a result the electrical properties such as resistivity could vary slightly from the solid metal.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

V. PRINCIPAL PROPERTIES:

D. Chemical

1. Corrosion Protection

a. Salt Spray

Vacuum deposited cadmium being more porous than electrodeposited cadmium offers less corrosion protection than an equal thickness of electrodeposited cadmium. However, a thickness of .0005 inch of vacuum deposited cadmium will withstand 240 hours in salt spray without appearance of red corrosion products.

Vacuum deposited cadmium .0005 inch thick, receiving a chromate conversion coating is equal in corrosion protection to an electrodeposited cadmium plate of equal thickness with chromate conversion coating.

b. Condensing Humidity

Vacuum deposited cadmium offers much less corrosion protection to a humid environment than an equal thickness of electrodeposited cadmium.

Vacuum deposited cadmium, .0005 inch thick, receiving a chromate conversion coating is equal in corrosion protection to electrodeposited cadmium of equal thickness with a chromate conversion coating.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-7-9

II. MATERIAL NAME: Vacuum Plated Cadmium

VI. RECOMMENDED USES:

Vacuum deposited cadmium at least .0005 inch thick with a subsequent chromate conversion coating is recommended as a corrosion and non-embrittling protective coating for high strength steel parts heat treated up to 250,000 psi, provided that the parts are given a light, dry grit blasting prior to vacuum deposition to provide good adhesion of the cadmium to the base metal.

VII. SUPPLIERS AND TRADE NAMES:

Suppliers meeting the requirements of MIL-C-8837, Coating, Cadmium, Vacuum Deposited, are available.

VIII. REFERENCES:

- (1) MIL-C-8837, Coating, Cadmium, Vacuum Deposited.
- (2) Boeing Document D3-1740, Properties of Vacuum Deposited Cadmium Plate on Steel.
- (3) Boeing Test Report T2-1398, Effects of Plating Variables on Hydrogen Embrittlement of 220,000 to 240,000 psi Steels.
- (4) Static Fatigue of High Strength Steel, R. H. Poring and J. A. Rinebolt, Transactions of the American Society for Metals, Vol. 48, 1956, pp 198-207.
- (5) Wichita Materials and Process Job Report F-1-3, Vacuum Deposition of Metals.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

III. GENERAL DESCRIPTION:

The objective of this program was to determine the feasibility of electrodepositing soft ductile (γ phase) manganese deposits and to determine if such deposits offer corrosion resistance protection for steel.

IV. DEVELOPMENTAL BACKGROUND:

There were several properties of manganese that prompted this investigation. Manganese is anodic to steel and should provide sacrificial corrosion protection and its higher melting point should extend the corrosion protection properties to a higher temperature range than the temperature ranges protected by zinc or cadmium deposits. Bright ductile (γ phase) manganese can be deposited from either acid or alkaline baths. The oxidation of the manganous ion is a major problem during the deposition of ductile manganese deposits; this oxidation can be inhibited by the addition of a salt of a strong reducing acid (sodium hypophosphite) or a salt of a weak organic acid (sodium acetate).

A literature survey indicated that codeposition of copper (1%) or nickel (2%) stabilized manganese in the γ phase. Copper was successfully codeposited with bright ductile manganese, but attempts to codeposit nickel gave either black deposits or deposits that were brittle.

Ductile manganese deposits up to .005 inches in thickness can be deposited and these deposits exhibit good resistance to salt spray and condensing humidity.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Melting point - No tests were made to determine the melting points of these deposits.
2. Density - No tests were made to determine the density of the electroplated manganese deposits.
3. Coefficient of Expansion - No tests were made to determine the coefficient of expansion of the electrolytic manganese deposits.
4. Hardness - The manganese deposits were hard enough scratch 4130 steel but were not scratched by 4130 steel.
5. Surface Roughness - The manganese and the manganese copper deposits had the same surface roughness as the base metal on which they were plated.
6. Adhesion - The manganese and the manganese copper deposits had good adhesion properties on both copper and steel cathodes.
7. Ductility - Manganese and manganese copper deposits are very ductile.
8. Color - Manganese and manganese copper deposits are bright silver to matte grey in color.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The thermophysical properties of manganese deposits have not been determined as no need for this data exists at this time.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties of electrodeposited manganese have not been determined.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

V. PRINCIPAL PROPERTIES:

D. Chemical

1. Oxidation and Finish Resistance - Manganese and manganese copper deposits are subject to oxidation by atmospheric oxygen. Passivation of manganese deposits with chromic acid solutions inhibits oxidation and increases tarnish resistance.
2. Corrosion Protection - Manganese deposits have good corrosion protection properties on steel in salt spray and condensing humidity atmospheres.
3. Chemical Resistance - Manganese deposits are readily attacked by acid (inorganic or organic) solutions; concentrated chromium trioxide solutions passivate manganese deposits; and strong alkali solutions do not attack manganese.

I. CATEGORY: Heavy Non-Ferrous Metals and Alloys CODE: 3-9-9

II. MATERIAL NAME: Electroplated Manganese

VI. RECOMMENDED USES:

There is not enough data available to warrant the recommendation of a use for electrodeposited manganese. It gives low temperature anodic protection to steel and should provide anodic protection at elevated temperatures.

VII. SUPPLIERS:

- A. None
- B. Availability - Not available
- C. Costs - Undetermined

VIII. REFERENCES:

- A. Materials and Process Job Report C-1-6, Ductile Manganese Plate
- B. Materials and Process Job Report F-1-15, Electrodeposition of Manganese, Process Developments

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

III. GENERAL DESCRIPTION:

The objective of this program was to screen-test, by means of tensile shear test only, some of the most recently developed metal-to-metal bonding adhesives, and assess their potential value for manufacturing.

IV. DEVELOPMENTAL BACKGROUND:

It was believed that some of the newer adhesives might serve as replacements for some conventional fasteners in the fabrication of aircraft, thereby, resulting in lower production costs. Further, it is well known that European aircraft manufacturers have been employing metal bonding adhesives for structures in place of conventional fasteners, with considerable success and substantial reductions in manufacturing costs.

The scope of the program was to obtain from various vendors potentially available metal-to-metal adhesives which would produce maximum tensile shear values, and conduct an evaluation.

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

V. PRINCIPAL PROPERTIES:

A. Mechanical

Heat cured adhesives appear to offer adequate strength and should be given wide consideration for Manufacturing concepts provided that further tests are accomplished toward proving specific materials for specific functions.

Mechanical Properties continued on following page entitled TABLE I.

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

V. PRINCIPAL PROPERTIES:

A. Mechanical

<u>Designation</u>	<u>Tensile-Shear Grand Average In psi</u>	<u>Remarks</u>
1. Armstrong Cork Company J-1154-E2	4000	Cured at 212°F for 2 hrs. This material no longer available.
2. Armstrong Cork Co. J-1156-E30	3900	Cured at 180°F for 1-1/2 hr.
3. Rubber & Asbestos Corp. M-611-CH60	3700	Cured at 340°F for 2-1/2 hrs.
4. Armstrong Cork Co. J-1151-E15	3500	Cured at 212°F for 2 hrs.
5. Reichhold Chemical Co. Experimental Material	3050	Cured at 350°F overnight.
6. Armstrong Cork Co. J-1151-E2	2700	Cured at 212°F for 2 hrs.
7. 3M's EC-1469 Without Catalyst	2550	Cured at 350°F for 1 hr.

TABLE I

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

V. PRINCIPAL PROPERTIES:

C. Electrical

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

V. PRINCIPAL PROPERTIES:

D. Chemical

This property was not investigated by Boeing-Wichita since such information was not required under the scope of this program.

AUTHOR: L. M. Sherran

Date: 9-11-61

PAGE 6

MATERIALS & PROCESS UNIT

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Heat Cured Metal Bonding Materials

VI. RECOMMENDED USES:

As a result of our investigative efforts, it was recommended that the heat cured metal-to-metal bonding adhesives, having a cure temperature of 212°F or below, be given further consideration for structural bonding of aircraft.

VII. SUPPLIERS & TRADE NAMES:

Armstrong Cork Co.

J-1151-E2
J-1156-E30
J-1151-E2
J-1151-E15

Rubber & Asbestos Corp.
Reichhold Chemical Co.
3M's Company

K-611-CH60
Experimental Material
EC-1469 without Catalyst

VIII. REFERENCES:

Boeing-Wichita, Manufacturing Research Report 78.1, "Adhesives - Metal-to-Metal Bonding Non-Military Aircraft and Commercial Applications".

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

III. GENERAL DESCRIPTION:

The objective of this program was to determine by screen test, by means of tensile-shear test only, some of the most recently developed metal-to-metal bonding adhesives, and to assess their potential value for Manufacturing.

IV. DEVELOPMENTAL BACKGROUND:

It was believed that some of the new adhesives might serve as replacements for some conventional fasteners in the fabrication of aircraft, thereby, resulting in lower production costs. Further, it is well known that European aircraft manufacturers have been employing metal bonding adhesives for structures in place of conventional fasteners with considerable success and substantial reductions in manufacturing costs.

The scope of the program was to obtain from various suppliers potentially available metal-to-metal adhesives which would produce maximum tensile shear values, and conduct an evaluation.

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

A. Mechanical

The following data supports the recommendation that room temperature cured adhesives not be used in manufacture of aircraft structures until materials possessing greater reliability and strength have been proven for specific applications.

See TABLE I for tensile shear data.

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

A. Mechanical

<u>Designation</u>	<u>Tensile-Shear Average In psi</u>	<u>Remarks</u>
1. 3M's EC-1751 A & B	2400	Cured 7 Days.
2. Armstrong Cork Co. J-1151-E1	2300	Cured 7 Days.
3. Armstrong Cork Co. J-1156-E30	2100	Cured 7 Days.
4. 3M's EC-1468 A & B	2050	Cured 7 Days - No EC-1290 Primer used.
5. Ren Plastics, Inc., RP-1250 with Hardener	1950	Cured 13 Days.
6. a. Rubber & Asbestos Corp. H-688-CH16	1850	Cured 5 Days.
b. Rubber & Asbestos Corp. H-611-CH16	1500	Cured 7 Days
7. Armstrong Cork Co. J-1151-E9	200	Cured 7 Days
8. a. Reichhold Chemical Co. Experimental Material	Less Than 100	5 Parts Compound A 3 Parts Compound B Cured 7 Days.
b. Reichhold Chemical Co. <u>New</u> Experimental Material	1300	Supplier submitted a second sample. Compounded and cured same as a. above.
c. Reichhold Chemical Co. <u>New</u> Experimental Material	2450	5 Parts Compound A 2 Parts Compound B Cured 7 Days.

ROOM TEMPERATURE CURED ADHESIVES - TENSILE-SHEAR DATA

TABLE I

AUTHOR: L. M. Sherman

Date: 9-12-61

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BOEING AIRPLANE COMPANY
MICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property has not been determined by Boeing-Michita since there was no requirement for this information under the scope of this program.

AUTHOR: L. M. Sherman

Date: 9-12-61

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MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

C. Electrical

This property has not been determined by Boeing-Wichita since there was no requirement for this information under the scope of this program.

AUTHOR: L. M. Sherman

Date: 9-12-61

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MATERIALS & PROCESS UNIT

I. CATEGORY: Plastics

CODE: 6-6-1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

V. PRINCIPAL PROPERTIES:

D. Chemical

This property has not been determined by Boeing-Michita since there was no requirement for this information under the scope of this program.

I. CATEGORY: Plastics

CODE: 6 1

II. MATERIAL NAME: Various Room Temperature Cured Adhesives

VI. RECOMMENDED USES:

Since the room temperature cured adhesives produce a lower tensile shear value, it is recommended that these adhesives not be considered for use in the manufacture of aircraft structures until materials are advanced which possess superior reliability and strength.

VII. SUPPLIERS & TRADE NAMES:

3M	EC-1751 A & B and EC-1468 A & B
Armstrong Cork Co.	J-1151-E1 J-1156-E30 J-1151-E9
Ren Plastics, Inc.	RP-1250 with Hardener
Rubber & Asbestos Corp.	K-688-CH16 K-611-CH16
Reichhold Chemical Co.	Experimental Material New Experimental Material.

VIII. REFERENCES:

Boeing-Wichita, Manufacturing Research Report 78.1, "Adhesives - Metal-to-Metal Bonding Non-Military Aircraft and Commercial Application".

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

III. GENERAL DESCRIPTION:

The objective of this program was to determine capabilities and qualities of Paraplast #33 as an expendable mandrel material for use in the plastic laminate shop. It was felt that the material offered certain qualities for a mandrel material, i.e., it is prepared easily by casting, removed easily because of solubility in water and is capable of being remelted or broken, without damage to the laminated part.

IV. DEVELOPMENTAL BACKGROUND:

This program developed from a need for a mandrel material which possessed those qualities stated under III (above).

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Handling and Melting Equipment

Paraplast #33 is procured as a powder. It must be melted (melting point approximately 260°F) and an intermittent mixing operation must be performed. This necessitates heating from the outside of the container toward the interior of the Paraplast. If re-use of the Paraplast is planned, the mixture being heated may consist of both powder and crushed (to some degree) solid Paraplast as well as molten material. Contact of the molten material with the cooler powder or solid may result in a setting up of the molten material and consequent "balling up" of the mixture. This combination of requirements and events results in a complex heat transfer relationship that severely restricts possible design variations of the facility itself.

The pilot plant operation indicates a desirable pour temperature of 320°F ± 10°F. No fumes or vapors are given off, according to the supplier, unless the temperature is in excess of 470°F. Complete decomposition occurs around 1200°F and any heating facility design should make provisions to avoid local "hot spots" in the Paraplast mixture in excess of 480°F.

A steam heated chamber or melt pot has obvious characteristics which make it appear the most desirable method of heating because of the upper limit of temperature available from a given steam supply. This unit is more costly (from the fabrication standpoint) than an electrically heated unit so only brief mention will be made of the steam design. Equipment Engineering, Boeing-Wichita, designed a pot - Drawing P239-1578-RSC - calling for steam at 150 psi. This is a temperature (non-super heated) of approximately 358°F. The design calls for a temperature control valve for the Paraplast pour spout. This valve is essential and should be incorporated in any design actually fabricated (Moristrom Plug Valve - wrench operated, flanged end, steam jacketed #2815, 1" I.D.).

In the pilot plant operation, a Glas-Col Apparatus Company Drum Heater with an 1800-watt bottom and a 6800-watt side capacity was procured and installed. It was completely unsatisfactory for this operation without modification. The heating element wires were too small, too thoroughly insulated (thermal) and too far from the heating surface. The bottom element burned out in less than 30 hours operating time.

AUTHOR: V. P. Massions

DATE: 9-12-61

PAGE 2.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1. (continued)

and the whole unit required exterior insulation application in order to be an effective heating installation.

A more reliable, effective and, it is felt, satisfactory unit can be in-Plant fabricated by forming a melting pot of 1/4" cold rolled steel and bolting strip type heating elements on the exterior of the steel pot. In order to avoid local hot spots at the interior of the pot, thermostat type temperature controllers should be located on the exterior surface of the pot and its contacts wired in series with the thermostat contacts actuated by the temperature of the molten Paraplast. This dual thermostat arrangement is inexpensive and protects against localized overheating and decomposition. In an electrical installation the Paraplast pour valve must be heated by means of an electric blanket-type heater. To date, a satisfactory valve and heater arrangement has been a Nordstron Glas-Col Flash Heating Mantles (Catalog #C-102-1000 H1 for a 1" I.D. Valve). The mantles were fastened together with "hog ring" wire clips and the two elements connected in series across the 120-volt supply. No temperature control was found necessary as they reached thermal equilibrium at the desired pour temperature. Sketches indicating pot configuration, heater location, size, and control connections are shown in Figures 1 and 2.

Since the melt pot itself is located above floor level, some means such as a crusher-type screw conveyor is needed for returning the solid cooled Paraplast from the pour area back to the melting pot for remelt. This would be a must in volume operation.

Although the supplier indicates a "common propeller type agitator is sufficient for agitation", an agitator of this type does not, in our experience, accomplish agitation properly. A scraper type stirrer, rotating about one axis, with this axis in turn rotating about the center of the pot is the most desirable type arrangement. Commercial versions are available which are entirely supported by the drive motor. In the pilot plant operation, a scraper type with four dashers or blades rotates about the center of the pot. The assembly is supported by a bronze bushed thrust bearing mounted in a spider, resting on the bottom of the tank. The assembly rotates at 12 r.p.m., which is considered optimum for the arrangement; but the

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DATE: 9-12-61

PAGE 3.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

1. (continued)

wear and weight involved appear excessive and it is felt that 10 r.p.m. about each axis would be a desirable rotational speed (with the off-center type agitator).

The thermostat (based on Paraplast temperature) should be located two or three inches above the bottom of the pot (below the minimum level line) and so that it senses the temperature of the Paraplast mixture. Due to the agitator configuration this is something of a problem; the apparent solution appears to be to locate it as shown in Figure 1.

The exterior of the melting pot should be insulated as fully as possible.

2. Manufacturers Recommendations

a. Heat Conductivity and heat transfer in granular, liquid and solid forms.

The heat conductivity and heat transfer characteristics of Paraplast products are essentially equal to those of water.

i.e. granular state = chopped ice, liquid state = water,
solid state = solid ice.

b. Specific heat and latent heat of fusion.

The Specific Heat of Paraplast products is approximately .30 to .33 BTU per pound per °F in a solid state, and is approximately .35 to .38 BTU per pound per °F in a liquid state.

c. Special handling requirements (i.e., precautions) due to physically detrimental properties.

The handling requirements of liquid Paraplast products are the same as for any hot (excess of 300°F) low viscosity liquid, i.e., use face shields, gloves, etc. As previously pointed out, the heat transfer properties of Paraplast products are approximately the same as for water, consequently if splashed or spilled on the skin, severe burns could result. However, Paraplast products do not

AUTHOR: V. P. Kassions

DATE: 9-12-61

PAGE 4.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. c. (continued)

ordinarily stick, combine and adhere to the skin the way resinous type materials do. The immediate area in which liquid Paraplast products are used should be well ventilated and arranged in such a manner that in the event of accidental spillage - no contact between hot or liquid Paraplast and combustible materials such as wood, paper, solvents and the like would come about. Hot Paraplast, in most cases, can ignite combustible materials.

Paraplast products are balanced systems with "built-in" pre-determined chemical equilibrium, stability, and contamination tolerance level - all based on the maximum practical "use life limit" of the product. In view of this, we again stress the point that modifications or additions of any other materials should not be attempted, as these modifications may disrupt the product in such a manner that considerable hazard and danger would result.

d. Toxicity while: (1) granular, (2) liquid and (3) solid.

(1) While granular, an amount of dust may be created from handling, similar to plaster and plaster type materials. The toxicity while in granular form is also of the same order as plaster.

(2) In a liquid state, no noticeable fumes or vapors are given off unless the temperature of the liquid Paraplast product is raised in excess of 150° F over the specification temperature, however, due to small amounts of contamination from use, handling etc., that inevitably get into every product used in this manner, small amounts of vapor or volatiles may be created. These vapors are usually not visually noticed, consequently, a "well-ventilated" area is strongly recommended for using all Paraplast products while in a liquid state.

(3) Solid Paraplast presents no severe toxicity problem relative to normal care in the handling of any chemical product. Relatively, Paraplast products are not quite as toxic as strong detergents. When re-use of Paraplast is intended, gloves are recommended for handling the solid material to help keep the water contamination at a minimum thus extending the usable working life of the Paraplast.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

e. Color Stability

Within the specified tolerable product temperature range, the color of Paraplast products is unaffected by repeated "heat cycling" or by varying the melting time provided that uniform heating is used.

Excessive overheating, localized "hot spots" heating, or other radical heat application may discolor Paraplast products.

f. Viscosity range

Paraplast #22 has a viscosity similar to water. Other Paraplast products (#33, #44, #55) have a viscosity similar to casting plaster.

g. Solubility

The solubility of Paraplast in water is as follows:

(per 100 parts water)

Cold water at 0°C = approximately 35 to 40 parts per 100 parts water.

Hot water at 100°C = approximately 215 to 230 parts per 100 parts water.

h. Flashpoint

Paraplast products do not have a flashpoint, instead they have a decomposition temperature that is in excess of 1200°F.

i. Melting tank size.

For the average user, a 20 to 30 gallon melting tank is adequate. Use any size melter that fills the demand as no "special" size is required.

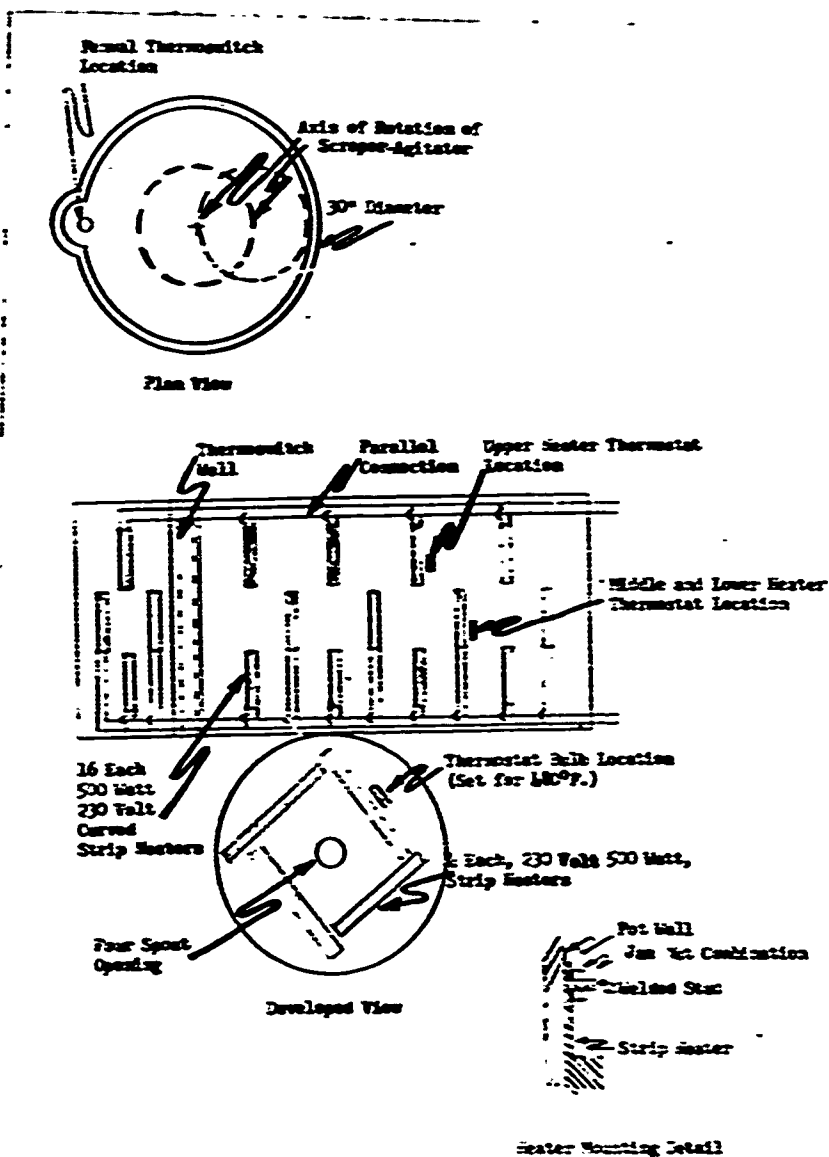
I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Paraplast Heater Configuration

FIGURE 1

125

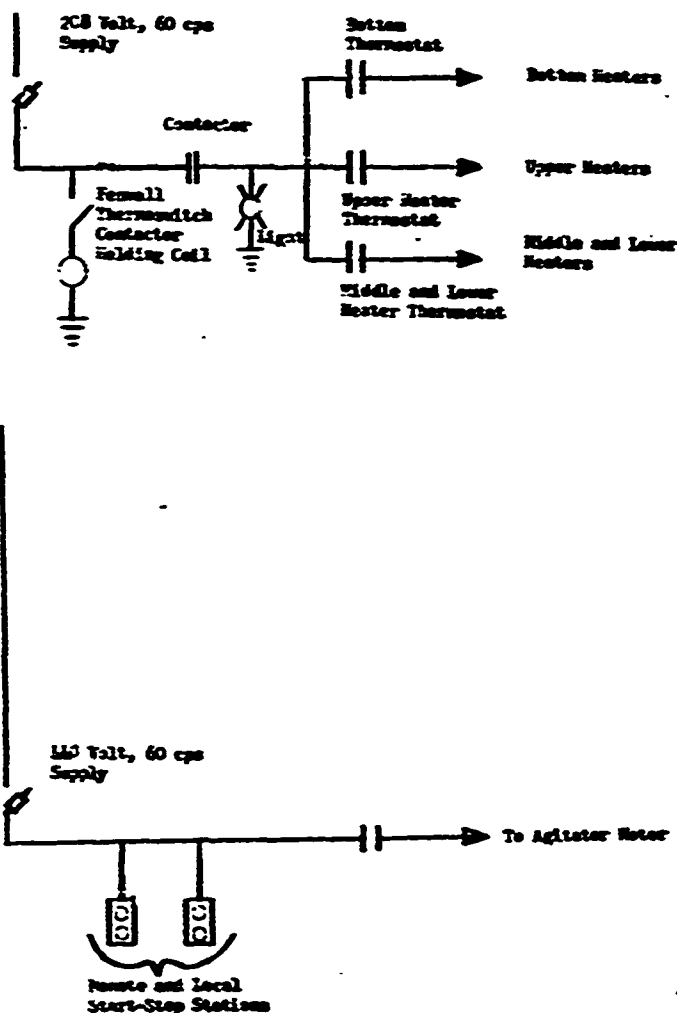
I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Paraplast Heater - Electrical Connections

FIGURE 2

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

j. Melting tank shape

Any shape (square, rectangular, circular, etc.) that does not prevent or impede thorough mixing and agitation of liquid Paraplast products is acceptable.

k. Agitator Requirements

The common propeller type agitator, inserted into the tank from one end is recommended.

l. Temperature control and range

Control within $\pm 5^{\circ}\text{F}$ at any temperature up to and including 550°F will allow the use of any Paraplast product (#22, 33, 44 or 55).

m. Discharge valve

A heated (thermostat controlled) discharge valve used to intermittently "tap off" varying amounts of liquid Paraplast is necessary the average size being one inch.

This valve is also used for draining purposes while cleaning or washing out the melting tank. Preferably, this valve should be made of the same type metal that is used for the melting tank.

n. Materials of construction

Cast iron and most grades of steel are very suitable materials for melting and processing equipment for Paraplast. Magnesium or high magnesium content alloys should never be used. Paraplast products are generally considered to be good electrolytes, therefore melting equipment, etc. should consist of a minimum number of different materials.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. (continued)

o. Dangers to avoid in melting equipment design

The smallest amount of Paraplast products (i.e., solid, liquid, or granular) that will be used, heated or placed in the melting tank at any time should be determined and the heating control (thermostat or etc.) should be designed and incorporated into the melting tank in such a manner that this minimum amount of Paraplast will be controlled the same as a full tank.

Heating a solid tank full of Paraplast from the bottom alone can develop sufficient pressure to rupture equipment or, more likely, to expel molten Paraplast through the solid surface.

Remelting solid Paraplast should be done in such a manner that the heating surface and heating walls of the melting tank, etc., extend above the level of the solid Paraplast with no erratic or localized heating.

3. Procedure Used to Fabricate Paraplast Mandrels

a. Procedure

- (1) Heat the mold to a temperature of approximately 150°F.
- (2) Adjust the temperature of liquid Paraplast so that the liquid Paraplast to be used is between 310°F and 315°F.
- (3) Pour Paraplast into this mold steadily until the mold is full.
- (4) Leave this liquid Paraplast in the mold for approximately 2-1/2 minutes, then pour Paraplast out.
- (5) Allow the mold, etc., to cool as required by specific mold configuration.
- (6) Break the mold apart and remove the mandrel.

IMPORTANT - After removing the mandrel from the mold, allow sufficient time for the mold to cool back to 150°F in all areas before casting another mandrel - this may take an hour or two.

AUTHOR:

V. P. Massions

DATE: 9-12-51

PAGE 10.

MATERIALS & PROCESS UNIT

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

3. (continued)

b. Control of Wall Thickness

(1) If it is desired to make a thinner wall mandrel, leave the liquid Paraplast in the mold for a shorter time. If a thicker wall mandrel is desired, do not leave liquid Paraplast in this mold longer than 2-1/2 minutes, as if it is left in this mold longer than 2-1/2 minutes, the thin sections of the mold dissipate heat and the thick sections of the mold absorb and maintain heat. With part of the mold hot, and part of the mold cool, a varied wall thickness in the mandrel will result.

(2) In order to make a thick wall mandrel, follow the above procedure (1) through (5) and then leave the mandrel and mold for 1/2 hour or so, enabling the mandrel in the mold to cool down. Then pour Paraplast right in on top of the mandrel that is in the mold repeating procedure (1) through (6). Using the above technique, good mandrels will result.

4. Cost Analysis of Paraplast No. 33 for Fiberglass Laminating Mandrels

The cost figures shown are average cost of a representative selection of currently fabricated parts. The comparative results of these average computations can be construed as typical of future part configurations.

The average mandrel fabrication and removal costs per part of the two methods are outlined as follows:

Present Method with Brak-A-Way Plaster

Mold Cost	\$ 1.00
Mandrel Fabrication and Removal	\$16.43
TOTAL COST	\$17.43

Thirty-two hours flow time for mold fabrication.

Proposed Method "A" Paraplast No. 33 (No Recovery)

Mold Cost	\$ 4.73
Mandrel Fabrication and Removal	\$ 6.43
TOTAL COST	\$11.16

AUTHOR: V. P. Massions

DATE: 9-12-61

PAGE 11.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

4. (continued)

Ninety-four hours flow time for mold fabrication

Proposed Method "B" Paraplast No. 33 (Recovery 97%)

Mold Cost	\$4.73
Mandrel Fabrication and Removal	\$1.98
Paraplast Cost	<u>\$.13</u>
TOTAL COST	<u>\$6.84</u>

Ninety-four hours flow time for mold fabrication.

It is apparent from these computations that an estimated savings of \$6.27 per part would accrue from proposed method "A" while savings of \$19.59 per part would be realized from proposed method "B".

NOTE: Savings shown do not reflect the reduction in flow time enjoyed as a result of the reduction of mandrel cure time, since flow time is not considered to be a cost factor in this analysis. At higher production rates, the savings in extra sets of molds would be considerable.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property has not been determined by Boeing-Wichita since such information would be of little or no value from the standpoint of the program as proposed.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

C. Electrical

This property has not been determined by Boeing-Nichita since such information would be of little or no value from the standpoint of the program as proposed.

I. CATEGORY: Plastics

CODE: 6-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

V. PRINCIPAL PROPERTIES:

D. Chemical

This property has not been determined by Boeing-Michita since such information would be of little or no value from the standpoint of the program as proposed.

I. CATEGORY: Plastics

CODE: 5-7-1

II. MATERIAL NAME: Capabilities and Qualities of Paraplast #33

VI. RECOMMENDED USES:

Since Boeing-Michita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind. A critical review of our investigative efforts indicated that this material be used as a replacement for break-away plaster in the process of mandrel construction where part characteristics in production economy dictate. A proven procedure for the fabrication of paraplast mandrels is included in this report under A - Mechanical - subheading 3 - Procedure Used to Fabricate Paraplast Mandrels. The recommended procedure for the design criteria of paraplast mandrel parts is included in A - Mechanical - subheading 1 - Handling and Felting Equipment.

VII. SUPPLIERS AND TRADE NAMES:

Rezolin Corporation - Paraplast #33

VIII. REFERENCES:

- A. Boeing-Michita Manufacturing Research Report 21.6, "Production Evaluation Paraplast #33".

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

III. GENERAL DESCRIPTION:

It was the objective of this program to determine the feasibility of utilizing epoxy tubing and associated standardized fittings to produce close tolerance tooling structures.

IV. DEVELOPMENTAL BACKGROUND:

The fabrication of tooling requires much time in the manufacturing process. This program was initiated as a natural step in the continual review of the fabrication of tools. There appeared to be a potential economy available through the utilization of epoxy tubing and the associated standardized fittings. This system was intended to be designed exclusively for use in the Tooling Industry and to simplify fabrication stability for the construction of structural back-ups, for laminated tools, jigs and fixtures.

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES:

A. Mechanical

It was concluded that: (1) epoxy tubing is assembled with ease in the shop, (2) fabrication manhours required may be reduced through the use of epoxy tubing and associated standardized fittings, and (3) the reaction of the material to heat and temperature change imposes definite design limitations as demonstrated in the tables which follow: (Table I through IV give data, Figure I depicts test set-up).

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

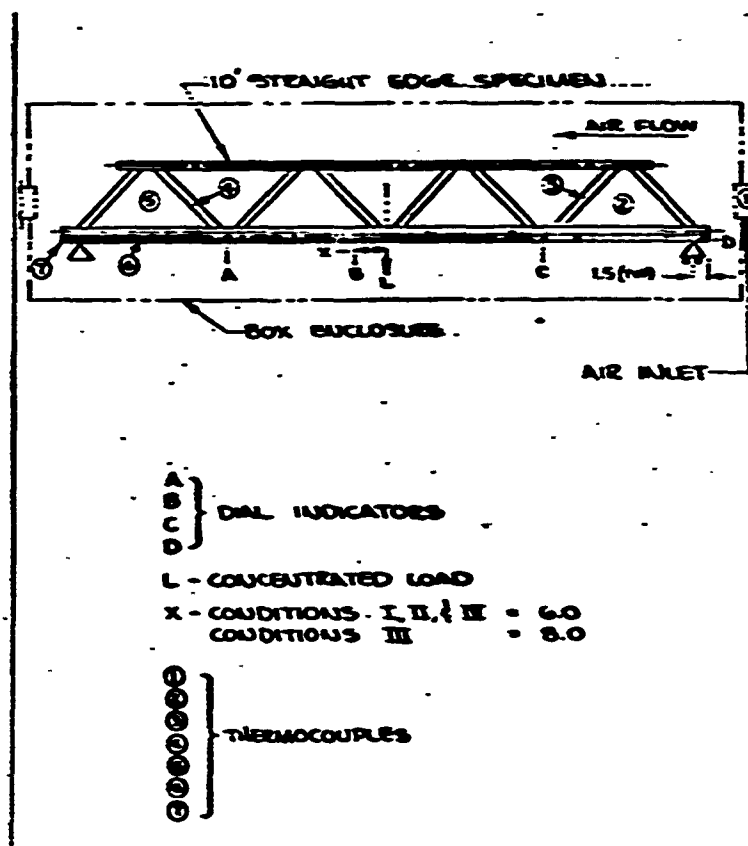


Diagram Test Set-up
10 Ft. Straight Edge Deflection Test

FIGURE I

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing
V. PRINCIPAL PROPERTIES: (Continued)
A. Mechanical (continued)

DEFLECTIONS UNDER VARIOUS CONCENTRATED LOADS AT AMBIENT TEMP. OF 69° F.

SPECIMEN DEFLECTIONS:



DIAL INDICATORS ZEROED AT ZERO LOAD

LOAD "L" (LBS)	DEFLECTIONS ~ IN. x 10 ⁻³		
	A	B	C
7.3	2.7	3.7	2.7
27.2	9.6	13.7	9.2
47.2	16.4	24.1	16.1
67.2	23.2	34.2	22.7
87.2	30.0	44.5	29.3
107.1	36.9	56.3	36.3
87.2	30.6	45.2	29.9
67.2	23.8	35.0	23.2
47.2	17.2	25.0	16.8
27.2	10.3	14.9	10.0
7.3	3.3	4.4	3.1
0	0.6	0.6	0.3

CONDITION I

10 Ft. Straight Edge Deflection Test

AUTHOR: V. P. Passions

TABLE I
DATE: 9-13-61

PAGE 1.

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTIONS AT NO LOAD UNDER
 VARYING TEMP.

SPECIMEN DEFLECTIONS



AT LAT (WAVE)	TEMPERATURE - °F				DEFLECTIOUS - MILS*		
	3	4	6	7	A	B	C
0	76	77	-	75	6	8	10
18	81	81	-	79	19	23	23
43	89	90	-	98	70	88	77
57	100	101	-	99	132	167	132
55	111	112	-	108	191	243	192
99	122	122	118	119	253	320	247
5	100	100	108	110	272	347	268
5	86	85	97	100	252	320	240
5	79	79	87	89	172	221	172
5	77	78	83	84	134	170	132
5	75	76	80	80	99	122	100
5	75	76	8	78	76	90	78
5	74	76	76	77	60	73	62
5	73	75	75	76	53	63	54
6	74	76	75	75	45	52	46
9	74	76	75	75	44	50	46
15	74	75	75	75	42	47	42
15	74	76	75	75	42	47	42
30	76	77	76	76	39	40	37
30	77	78	73	77	42	47	42

DEFINITION II

10 Ft. Straight Edge Deflection Test

TABLE II

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTION AT 100" CONCENTRATED
 LOAD UNDER VARIOUS TEMP.

▷ ZERO CONCENTRATED LOAD

SPECIMEN DEFLECTIONS:

ΔT DUAL 1st 2nd READ	TEMPERATURE - °F				DEFLECTION - IN. x 10 ⁻⁴		
	3	4	6	7	A	B	C
0	59	62	62	62	977▷	576▷	990▷
14	59	61	61	62	330	940	380
23	70	70	70	70	366	4	438
28	79	79	79	79	445	71	490
37	90	89	89	88	500	137	539
43	101	100	100	99	580	240	617
55	111	110	109	108	669	359	710
55	122	119	119	118	792	535	841
5	101	106	108	112	770	—	—
5	10	74	83	91	98	678	—
5	15	63	70	78	83	580	—
10	25	62	67	69	72	512	—
10	35	57	60	62	65	490	—
10	45	58	60	61	60	478	142
30	75	58	60	61	60	475	150
12	51	60	61	62	65	110▷	592▷

CONDITION III

10 Ft. Straight Edge Deflection Test

TABLE III

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

DEFLECTIONS AT 93.5% DISTRIBUTED
 LOAD UNDER VARYING TEMP

SPECIMEN DEFLECTIONS:



ΔT Temp. ΔT (Min.)	TEMPERATURE ~ °F				DEFLECTION ~ IN × 10 ⁻⁶		
	3	4	6	7	A	B	C
0	78	78	78	78	7	8	0
30	90	90	89	89	50	52	53
40	103	100	98	99	110	125	110
43	112	109	110	110	186	221	183
112	124	120	120	120	278	340	270
5	94	100	108	112	320	398	302
5	84	88	98	104	253	310	241
5	81	84	91	94	180	210	171
10	76	83	87	90	150	170	130
10	65	72	79	83	110	126	92
10	63	68	73	77	77	89	66
10	62	66	70	73	49	52	41
10	61	65	68	71	32	33	30
32	61	64	65	67	6	4	12
31	60	63	63	65	0	997	10
25	60	62	62	64	0	990	3
29	60	63	63	64	0	988	2
50	62	82	79	79	40	37	43

CONDITION IV

10 Ft. Straight Edge Deflection Test

TABLE IV

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES:

B. Thermophysical

These properties have not been determined by Boeing-Wichita since there was no existent need under the scope of this program.

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

V. PRINCIPAL PROPERTIES:

C. Electrical

These properties have not been determined by Boeing-Wichita since there was no existent need under the scope of this program.

I. CATEGORY: Plastics

CODE: 6-8-1

II. MATERIAL NAME: Epoxy Tubing

VI. RECOMMENDED USES:

Epoxy tubing cannot be recommended for use in close tolerance tooling structures because of the dimensional instability of the material.

VII. SUPPLIERS AND TRADE NAMES:

Burnham Products, Inc.

Ready-Fit Epoxy Tube and Fittings

VIII. REFERENCES:

- A. Boeing-Michita Manufacturing Research Report 60.2, "Epoxy Tubing and Fittings for Tooling".

I. CATEGORY: Plastics

CODE: 6-8-4

II. MATERIAL NAME: 3E-471 Plastic Tape

III. GENERAL DESCRIPTION:

It was the object of this program to evaluate the subject tape as a stop-off material for potential use in masking prior to anodizing.

IV. DEVELOPMENTAL BACKGROUND:

This program was begun in an effort to find a stop-off material for materials and parts, which are to be anodized in specific areas. Present materials used as stop-offs are time consuming in application and removal.

I. CATEGORY: Plastics

CODE: 6-2-4

II. MATERIAL NAME: 3M-471 Plastic Tape

V. PRINCIPAL PROPERTIES:

A. Mechanical

3M-471 poses handling difficulties and is only suitable for flat surfaces; therefore, the present material, lead-back tape, was considered adequate for the purpose, although further improvements in cutting and forming ability are desirable.

I. CATEGORY: Plastics

CODE: 6-3-4

II. MATERIAL NAME: 3E-471 Plastic Tape

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Plastics

CODE: 6-8-4

II. MATERIAL NAME: 3K-471 Plastic Tape

V. PRINCIPAL PROPERTIES:

C. Electrical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

W.H.H.
AUTHOR: W. H. Kolins

Date: 9-11-61

PAGE 4

MATERIALS & PROCESS UNIT

I. CATEGORY: Plastics

CODE: 6-8-4

II. MATERIAL NAME: 3E-471 Plastic Tape

V. PRINCIPAL PROPERTIES:

D. Chemical

This information not available due to the lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Plastics

CODE: 6-8-4

II. MATERIAL NAME: 3M-471 Plastic Tape

VI. RECOMMENDED USES:

This tape cannot be recommended for masking of anything other than flat surfaces.

VII. SUPPLIERS AND TRADE NAMES:

3M-471 supplied by Minnesota Mining & Manufacturing Company.

VIII. REFERENCES:

Boeing-Wichita, Manufacturing Research Report, 91.1A, "Stop-Off Materials and Procedures for Anodized Parts".

W.H.K.
AUTHOR: W. H. Kolins

Date: 9-11-61

PAGE 6

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy-Mat Mold Dies

III. GENERAL DESCRIPTION:

It was the object of this project to evaluate mat mold die materials, Furane 10Q and 10P, filled with special aluminum fibers.

IV. DEVELOPMENTAL BACKGROUND:

A large proportion of the cost of fabricating Kirksite mat mold dies lies in the hours required to hand finish the cavity. In addition, porosity of Kirksite is such that a machine finish which will produce high quality surface of the finished plastic part is quite difficult to obtain. Use of plastics as a mat mold die material is not new. It has been recognized that materials other than Kirksite could produce a superior surface finish. Plastic parts molded in plastic mat mold dies have improved surface finishes, parting problems are reduced and the die construction costs are decreased. For this reason, interest is always shown toward improvements in plastics which may be used for this purpose.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

A. Mechanical

Upon completion of the tool it was found that heat transfer was poor and that considerable warpage occurred. The die was heated from the base by a heated platen on the press. Heat transfer was so poor that the platen temperatures had to be elevated to 400°F. before the die cavity reached 210°F. Specific requirements are 225 - 250°F for the curing of the resins. However, sample parts were cured at the lower temperatures. Surface finish for the cured parts proved to be better than that obtained with conventional Kirksite dies. Consideration was given to finding ways to improve the heat transfer characteristics of the existing tool but it was decided that any rework attempt would not be economical. Purane Plastics, Inc., was asked to provide data to support their claim that a higher aluminum ratio would provide heat transfer desired. This information was never furnished and the project was closed.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property was not determined since there was no existent need under the program for its determination.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

C. Electrical

This property was not determined since there was no existent need under the program for its determination.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

V. PRINCIPAL PROPERTIES:

D. Chemical

This property was not determined since there was no existent need under the program for its determination.

I. CATEGORY: Plastics

CODE: 6-8-6

II. MATERIAL NAME: Epoxy Mat Mold Dies

VI. RECOMMENDED USES:

As a result of the investigative efforts expended, it was recommended that unless new developments occur which improved this procedure, that it not be considered or recommended for production.

VII. SUPPLIERS & TRADE NAMES:

Furane Plastics, Inc.
Reynolds Aluminum Co.

Curing Resins 10Q and 10P
#200 Aluminum Powder

VIII. REFERENCES:

Boeing-Wichita, Manufacturing Research Report 60.6, "Plastic Mat Mold Die Fabricated from Furane 10Q High Temperature Gel-Coat and 10P High Temperature Bonding Resins".

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

III. GENERAL DESCRIPTION:

The objective of this job was to evaluate the properties of a blend consisting of Epon 828, Epon 812, and Versamid 115-125.

IV. DEVELOPMENTAL BACKGROUND:

At the time the evaluation of the epoxy-polyamide system was originated, bonding of fiberglass reinforcing doublers to fuel tank fiberglass backing boards was accomplished using a polyester resin for the adhesive. Poor quality bonds coupled with accelerated production rates required a change to a more suitable adhesive.

Preliminary testing indicated that an epoxy-polyamide system would produce good quality, high strength bonds, and that the adhesive could be cured in a relatively short time.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Fuel Resistance

- a. Lap shear specimens with one-half inch overlaps were prepared by bonding polyester laminates (B/S 8-9) to themselves with the adhesive. Bonds were cured for 15 minutes at 250°F under 10-15 psi pressure.
- b. Specimens were immersed for seven days at room temperature in MIL-H-3136 Type III and MIL-F-5624 type JP-4 fuels.
- c. The specimens were tested in shear at the end of the soak period and, in each instance, the fiberglass laminate failed at loads below those required to fail the bond.

2. Water Resistance

- a. Other specimens prepared at the same time as A.1. above were immersed in water for seven days at room temperature, and tested in shear. The bonds on these specimens failed at loads on the order of 1000 psi. Visual examination indicated the adhesive had been softened by exposure to water.

3. Environmental Resistance

Many tests involving different materials have been bonded with the epoxy-polyamide described herein, after the origination of the initial work described above. Salt spray cabinet, humidity cabinet and weather cabinet tests have been conducted where the adhesive was used over solvent cleaned surfaces, chemically cleaned surfaces and over different primers. These tests were run independently of each other at different times over a long period of time. Therefore, comparative data would be of little value. A general summary is therefore given below:

- a. Generally it has been found in nearly all tests that the condition of the metal surface influences the resistance of the adhesive to different environments. Surfaces which have been hand cleaned by solvent degreasing only, nearly always fall apart in handling after exposure to salt spray for 30 days. Humidity cabinet tests and accelerated weather test data usually are not as severe but test values are lowered.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (Continued)

- b. Panels which have been cleaned by a sodium dichromate sulphuric acid solution show little if any difference in bond strength after environmental aging.
- c. Bonds where the adhesive is used over a primer are limited only by the strength of the primer. Bond failures therefore are the result of the primer failing to the metal surface.
- d. It has been found that failures of the solvent cleaned bonds are due to interfacial penetration at the bond interface. Apparently no degradation of the material occurs.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The epoxy-polyamide combination used at Boeing-Wichita and covered by this report is thermoplastic. The cured material softens between 160°F and 180°F.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

It has been determined that a blend consisting of equal proportions of epoxy and polyamide is useful in many non-structural applications where a high strength (in shear), flexible adhesive is required. Its ease of application, fast cure rate and compatibility with many different materials is beneficial.

Careful consideration to all problems related to a specific application is necessary however, because of its marginal weather resistance and poor heat resistance. The cured material should not be used in exterior applications unless the metal surfaces are either chemically etched, or primed prior to adhesive application. In the latter instance, it has been found that EC-776R (a nitrile rubber base material) used as a primer improves the weather resistance of an epoxy-polyamide bond.

Since the epoxy-polyamide blend discussed in this report is thermoplastic, its use should be limited to service temperatures which do not exceed 140°F.

VII. SUPPLIERS AND TRADE NAMES:

A. The supplier designations and location are as follows:

Epon 828 and Epon 812 - Shell Chemical Corporation
Pittsburg, California

Versamid 115 and
Versamid 125 General Mills Incorporated
Kankakee, Illinois

B. Availability

The individual materials are packaged in one pint, one quart, and one gallon containers.

C. Costs

Epon 828	\$1.58 per pound
Epon 812	1.87 " "
Versamid 115	0.85 " "
Versamid 125	1.10 " "

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Epoxy-Polyamide

VIII. REFERENCES:

- (1) Wichita Materials and Process Unit Report AP-2-127, Evaluation of an Epoxy-Polyamide Resin Combination.
- (2) Wichita Materials and Process Unit Report AP-2-13, Salt Spray Tests on Plastic to Aluminum Bonds.
- (3) Wichita Materials and Process Unit Report AP-2-91, BPS 10-11 As An Adhesive Primer.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

III. GENERAL DESCRIPTION:

The objective of this program was to conduct preliminary tests on a new one-part air curing silicone adhesive.

IV. DEVELOPMENTAL BACKGROUND:

Dow Corning Q-3-0121 is a new development product which appears to offer many advantages for repair or production bonding of non-structural silicone rubber parts.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Rubber to Rubber Bonds

Rubber-to-rubber peel test specimens of the configuration shown in Figure 1 were bonded in accordance with MIL-A-25457A. Specimens were assembled after an open air dry time of 15-30 minutes, and, after no open dry time. The bonds were cured for six hours, 24 hours, and 168 hours at room temperature.

Failures on those specimens assembled immediately were generally in the rubber. Photograph EAA-12201 presents a typical failure. Those specimens which were assembled after an open air dry time resulted in failures at loads on the order of nine pounds per inch width.

On the basis of the above failures and because of the limited amount of adhesive available for test, it was decided that further testing on the type specimens depicted on Figure 1 should be discontinued. Therefore, the test specimen configuration was changed to conform to the requirements of MIL-A-25457A (Douglas T-Peel Method). Data on rubber-to-rubber bonds in Table I were obtained on these type specimens.

It will be noted from Table I, that those specimens assembled while the adhesive was wet resulted in cohesive failures while those specimens which were assembled after an open air dry time (tacky) were adhesive failures.

2. Rubber to Metal Bonds

Peel test specimens were prepared by bonding strips of MIL-R-5847 Grade 50 rubber to .064 clad panels per MIL-A-25457A. The bonds were assembled and cured in the same manner as those in Section A.1. above.

Failures on all specimens were generally cohesive failures with some isolated adhesive failures. Test values are shown on Table I.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

A. Mechanical

SPECIMEN CONFIGURATION

RUBBER TO RUBBER

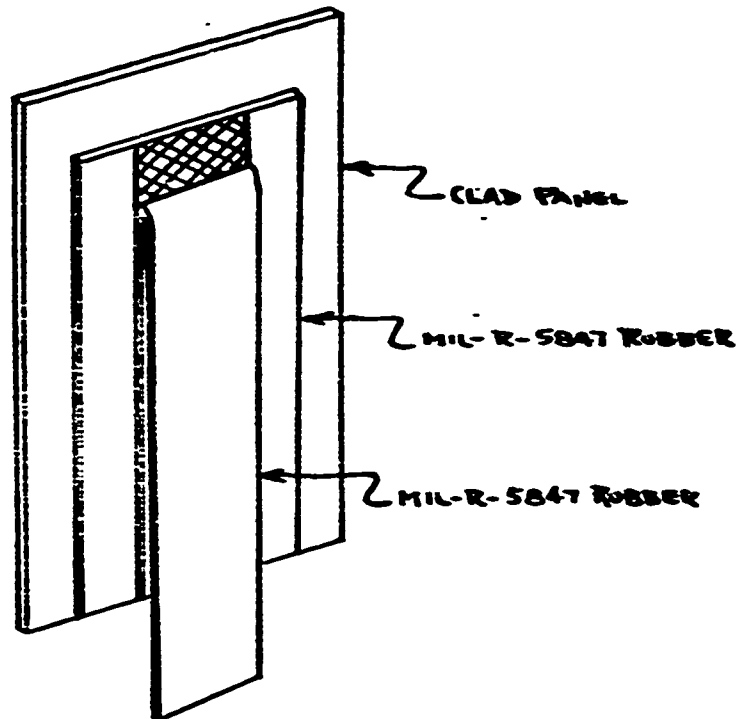


FIGURE 1

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

C. Electrical Properties

METHOD OF ASSEMBLY	CURED 6 HRS PEEL %/IN.	FAILURE	CURED 24 HRS PEEL %/IN.	FAILURE	CURED 7 DAYS PEEL %/IN.	FAILURE
TACKY- 15-30 MINUTE OPEN TIME	13.0	COHESIVE	12.0	COHESIVE	15.0	COHESIVE
	11.0	"	12.0	"	16.5	"
	13.0	"	12.0	"	15.5	"
	8.0	ADHESIVE	12.0	"	15.5	"
	8.0	ADHESIVE	11.0	"	15.5	"
WET- ASSEMBLED IMMEDIATELY	11.0	30-40% Gd	16.0	COHESIVE	21.0	COHESIVE
	16.0	COHESIVE	17.0	"	20.0	"
	17.0	"	19.0	"	22.5	"
	17.0	"	19.0	"	22.0	"
	17.0	"	18.0	"	22.0	"

Rubber to Metal

TACKY- 15-30 MINUTE OPEN TIME	5.0	ADHESIVE	4.0	ADHESIVE	5.5	ADHESIVE
	3.0	"	4.0	"	5.0	"
	3.0	"	4.0	"	6.25	"
	3.0	"	4.0	"	4.5	"
	4.0	"	4.0	"	4.5	"
WET- ASSEMBLED IMMEDIATELY	13.0	COHESIVE	12.5	90% Gd	15.0	COHESIVE
	12.0	"	13.5	COHESIVE	16.5	RUBBER BRK
	12.0	"	13.0	"	15.5	COHESIVE
	13.0	"	12.5	"	15.5	"
	13.0	"	15.0	"	15.5	"

- Rubber to Rubber

TABLE I

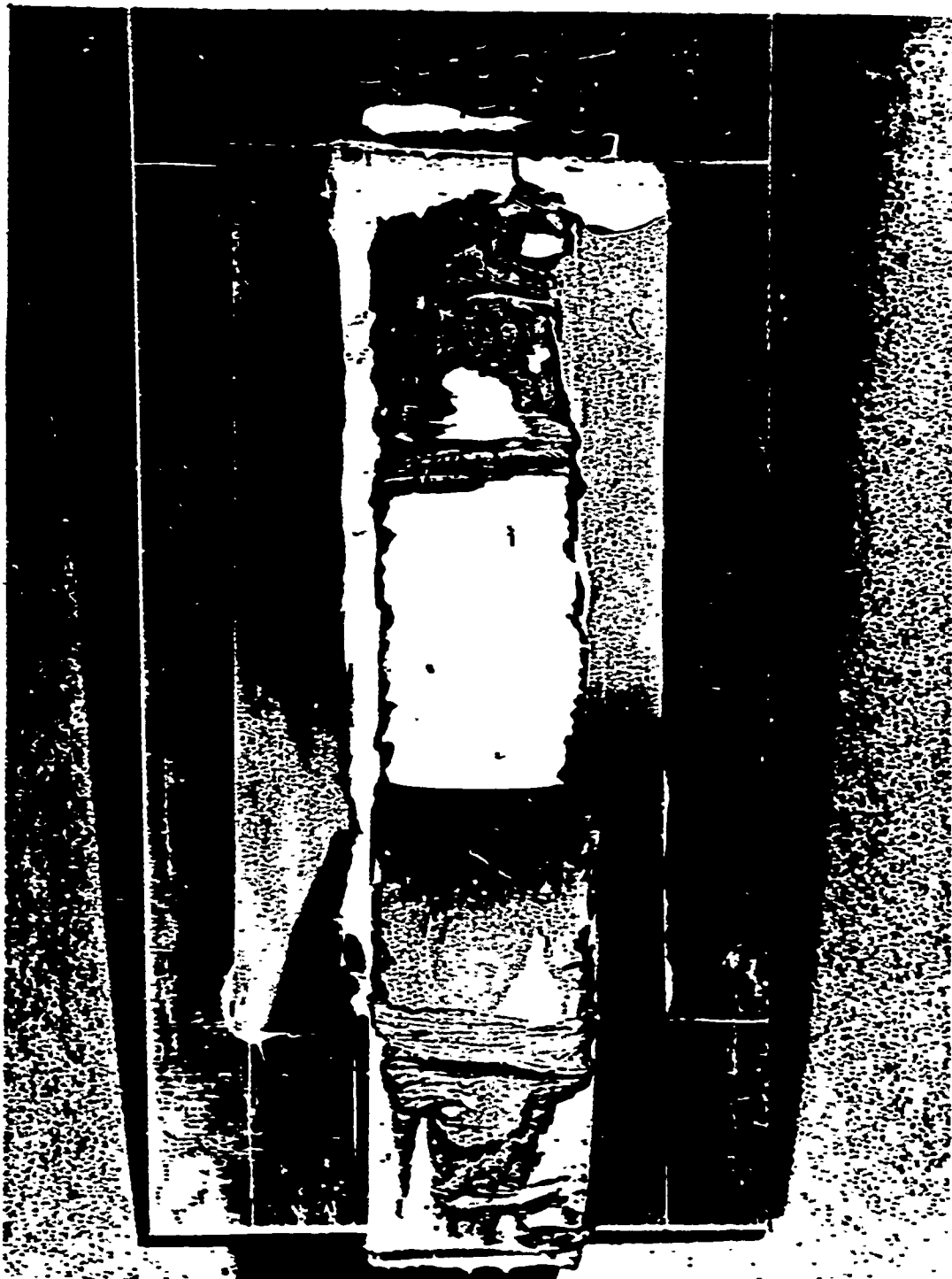
AUTHOR: Marilyn Harp

15 August 1961

PAGE 4

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121



I. CATEGORY: Liquid and Semi-Solid High Polyzers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

3. Thermophysical

Rubber to clad peel test specimens as prepared in Section A.2, but cured for 24 hours, were placed in an oven and further aged for 24 hours at 212°F. A two pound weight was suspended from the unbonded end of the rubber. Inspection for separation or other signs of degradation was conducted after 24 hours. No failure was evident, so the temperature was raised to 400°F for 24 hours, and, re-inspected. No degradation was noted at this temperature, so the temperature was raised to 500°F for 24 hours. Upon inspection it was noted that the bond could be separated easily by hand. There was also evidence that the material tends to revert at this temperature.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita investigating this property.

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Silicone Q-3-0121

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

The bond strength of Q-3-0121 is superior to any silicone adhesive (either RTV or heat vulcanizing types) tested to date. The elimination of a primer, the elimination of separate curing agents and the simplicity of application makes the adhesive extremely useful for non-structural silicone rubber bonding applications, both in the field and in production shops.

Q-3-0121 should be limited to applications where the service temperatures do not exceed 400°F. Also for best bond strengths, bond closure should be effected as soon as possible after the adhesive has been applied to the faying surfaces.

VII. SUPPLIERS AND TRADE NAMES:

A. The vendor designation and location is as follows:

Dow Corning Q-3-0121 Silicone Adhesive
Dow Chemical Corporation
Midland, Michigan

B. Availability

Q-3-0121 is packaged in two ounce and eight ounce collapsible metal tubes, or in polyethylene sealant cartridges.

C. Costs

The price of Dow Corning Q-3-0121 is approximately \$2.50 for a two ounce package.

VIII. REFERENCES:

- (1) Wichita Materials and Process Unit Report AP-2-75, Testing of Dow Corning Q-3-0121 Silicone Adhesive.
- (2) EAC Process Specification 5010, Application of Adhesives.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

III. GENERAL DESCRIPTION:

The objective of this program was to determine the best cure conditions, effect of bond line thickness, and environmental resistance of Shell Epon 928.

IV. DEVELOPMENTAL BACKGROUND:

Epon 928 is a thixotropic, two-part, non-metallic adhesive material. Interest in the material was generated when a project developed which required the use of a non-metal filled material for plastic-to-plastic structural bonding.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Determination of Cure Conditions

- a. Lap shear panels of an epoxy laminate (DEX332) were bonded together to form one-half inch overlap joints.
- b. The cure temperature, cure time, and order of bonding was in accordance with the experimental plan below:

Cure Temp. °F	200				250				300				350			
Cure Time, Min.	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
Bonding Order	(14)(12)(16)(10)				(9)(4)(8)(5)				(2)(7)(1)(11)				(6)(3)(13)(15)			

NOTE: The bonding order was a random selection. The plan was repeated three times.

- c. The results of the cure cycle determination are summarized on Table I. Figure 1 illustrates graphically the effect of each factor on bond strength.

2. Effect of Bondline Thickness

- a. Lap bond panels of .064 clad were bonded together to form one-half inch overlap joints. The metal details were cleaned per SAC 5765, Method 2.
- b. Bond line thicknesses were varied as shown below:

Bond Thickness - Inches	.005	.010	.025	.030
-------------------------	------	------	------	------

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

A. Mechanical

Cure Temp °F	200				250				300				350			
	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
	1805	1574	1555	1415	1910	1993	1932	2077	1550	1507	1463	1350	1935	1624	1720	1525
	1877	2206	2008	1818	1543	1156	2077	1797	1310	1588	1904	1576	1543	1557	2009	1500
	1506	2027	1915	1594	2009	1592	1939	1257	1530	1946	1932	1570	1746	1847	2065	1592
AVERAGE	1846	2009	1725	1492	1929	1727	1910	1957	1520	1557	1550	1500	1903	1563	1933	1593

CURE TIME--

15 MINUTES

AVERAGE: 1846

30 MINUTES

AVERAGE: 1932

45 MINUTES

AVERAGE: 1505

60 MINUTES

AVERAGE: 1506

CURE TEMPERATURE--

200°F

AVERAGE: 1935

250°F

AVERAGE: 1721

300°F

AVERAGE: 1885

350°F

AVERAGE: 1967

Different Cure Conditions Lap Shear - PSI

TABLE I

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

A. Mechanical

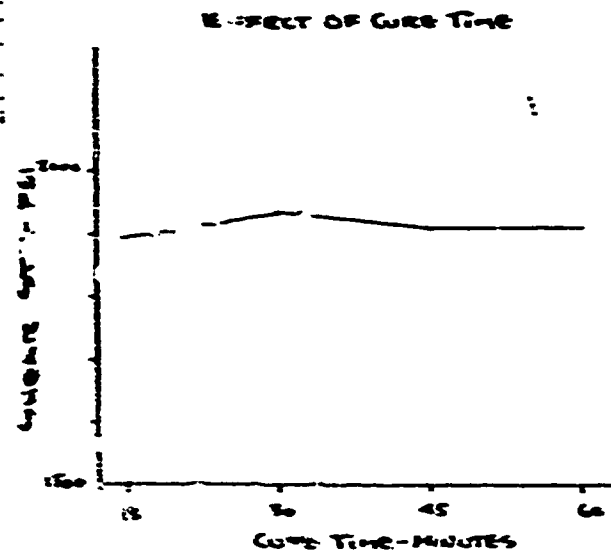
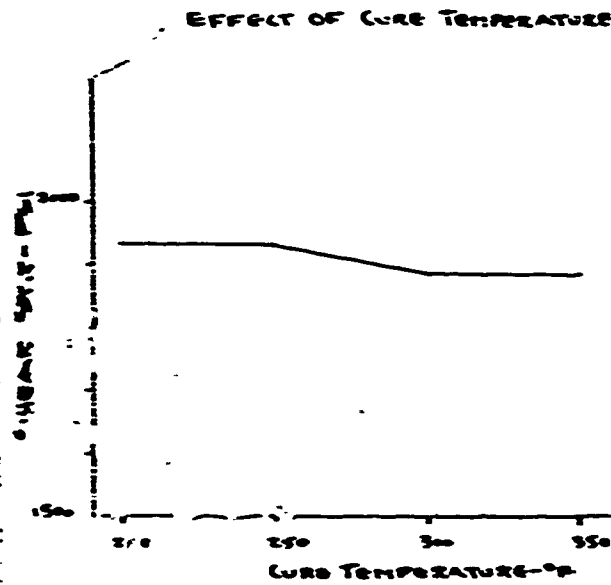


FIGURE 1

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

c. The effect of bondline thickness is shown on Figure 2 and Table II through Table V.

3. Environmental Tests

a. Lap bond panels of the same description as in A.1. were prepared except the bonds were cured for 30 minutes at 250°F. Five bonded assemblies were fabricated for each of the following environments:

30 day Humidity Cabinet Test per Reference (2), Method 6201.
30 day Salt Spray Test per Reference (2), Method 6061.
30 day Weather Cabinet Test per Reference (2), Method 6152.
30 day immersion in toluene at room temperature.

b. Two specimens from each panel were retained for control aging at room temperature.

c. The environmental test data are summarized in Table VI.

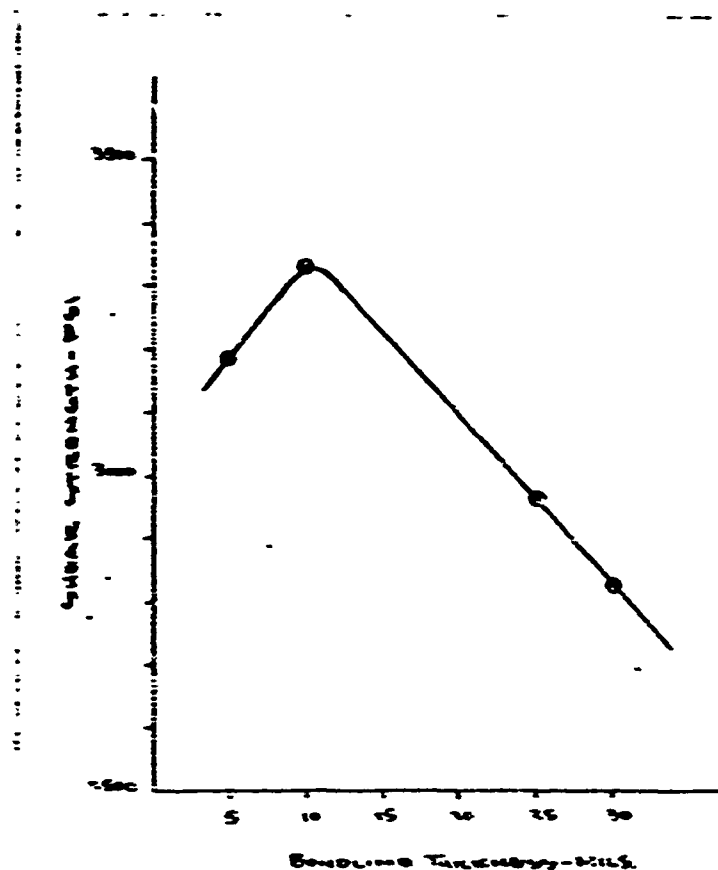
d. All failures were in the resin surface layer of the laminates.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



Effect of Bondline Thickness on Bond Strength

FIGURE 2

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.064 CLAD AL.	250°F	30 MIN	3-5 P.S.I.

COMMENTS: .005 BOND LINE THICKNESS

METAL

PLATE ✓

PULL RATE: 600-700 LB PER MIN

PULL DATE: DEN 3-21-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.005 1-①	.007	.52	1.003	1310	2519	
②	.007		.995	1395	2698	
③	.005		1.003	1325	2548	
④	.005		1.001	1600	3077	
⑤	.005	.52	1.004	1550	2980	2764 AVERAGE
.005 2-①	.006	.50	1.002	1665	3330	
②	.006	1	.995	1785	3591	
③	.005	.50	1.003	1775	3550	
④	.006	1	1.001	1815	3630	
⑤	.006	.50	1.004	1470	2990	3408 AVERAGE
.005 3-①	.006	.50	1.002	1585	3170	
②	.005	.51	.995	1620	3195	
③	.005	.51	1.002	1835	3598	
④	.005	.51	1.002	1800	3529	
⑤	.007	.52	1.004	1755	3375	3373 AVERAGE

Effect of Bondline Thickness 5 MIL Thick Bond

TABLE II

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.064 CLAD AL.	250 °F	30 MIN	3-5 P.S.I.

COMMENTS: .010 BOND LINE THICKNESS

AUTOCLAVE

PULL RATE: 600-700 LB/Min.

PLATE ✓

PULL DATE: DEH 3-21-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.010 1-①	.009	.51	1.002	1765	345	
②	.011		.995	1635	3323	
③	.010		1.002	1775	3483	
④	.010		1.003	1650	3235	3375 AVERAGE
⑤	.011	.51	1.003			1735 not recorded
.010 2-①	.011	.52	1.002	1735	3336	
②	.010	.52	.995	1795	3472	
③	.010	.52	1.002	1805	3471	
④	.009	.52	1.001	1870	3592	
⑤	.010	.51	1.004	1790	3510	3577 AVERAGE
.010 3-①	.010	.51	1.002	1575	3059	
②	.010	.51	.995	1500	2959	
③	.010	.52	1.002	1675	3221	
④	.010	.52	1.001	1640	3154	
⑤	.009	.52	1.004	1620	3231	3130 AVERAGE

Effect of Bondline Thickness 10 MIL Thick Bond

TABLE III

135

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR. 6-22	.064 CLAD AL.	250°F	30 MIN.	3-5 P.S.I.

COMMENTS: .025 BONDLINE THICKNESS

ADHESIVE

PULL RATE: 600-700 LB/min

PLATE

PULL DATE: DEN 3-22-61

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.025 1-①	.024	.51	1.002	1525	2990	
②	.025		.995	1485	2929	
③	.025		1.003	1370	2696	
④	.025		1.002	1265	2490	
⑤	.025	.51	1.004	1520	2980	2913 AVERAGE
.025 2-①	.024	.51	1.004	1615	3167	
②	.023		1.001	1645	3225	
③	.025		1.003	1560	3059	
④	.025		.995	1470	2899	
⑤	.025	.51	1.002	1440	2823	3035 AVERAGE
.025 3-①	.024	.52	1.004	1615	3125	
②	.023	.52	1.001	1580	3073	
③	.023	.52	1.002	1510	2924	
④	.024	.52	.995	1530	2959	
⑤	.025	.51	1.003	1630	3176	3044 AVERAGE

Effect of Bondline Thickness 25 MIL Thick Bond

TABLE IV

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

ADHESIVE	MATERIAL	TEMP.	TIME	PRESSURE
LR 6-22	.063 CLAD ALUM	250°F	30 MIN.	3-5 P.S.I.

COMMENTS: .030 BOND LINE THICKNESS

ANTICLAVE

PLATE ✓

PULL RATE: 600-700 LB./min

PULL DATE: ^{DLH} ~~SEP. 3-21-41~~

SPECIMEN	BOND	LAP	WIDTH	LOAD	PSI	REMARKS:
.030 1-①	.031	.52	1.004	1,450	2717	
②	.030		1.003	1,395	2633	
③	.030		1.002	1,355	2606	
④	.030		.996	1,525	2950	
⑤	.031	.52	1.003	1,480	2846	2775 AVERAGE
.030 2-①	.031	.51	1.005	1,555	3049	
②	.031		1.002	1,355	2657	
③	.031		1.003	1,495	2921	
④	.032		.995	1,235	2435	
⑤	.031	.51	1.002	1,395	2735	2761 AVERAGE
.030 3-①	.029	.52	1.005	1,595	3067	
②	.029		1.002	1,470	2527	
③	.030		1.003	1,490	2865	
④	.031		.996	1,530	2959	
⑤	.031	.52	1.002	1,545	2971	2935 AVERAGE

Effect of Bondline Thickness 30 MIL Thick Bond

TABLE V

I. CATEGORY: Liquid and Semi Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TOLUENE		SALT SPRAY		HUMIDITY		WEATHER-O-METER	
CONTROL	TEST	CONTROL	TEST	CONTROL	TEST	CONTROL	TEST
2318	2505	2251	1923	2336	2167	2288	1761
2455	2397	2206	1809	2355	1966	2050	1752
2002	2366	2052	2155	1887	1901	2132	1462
1957	1963	2085	2027	1917	2038	2154	1719
2036	1989	2046	1914	2302	2070	2366	1666
1944	1927	2026	1861	2356	2077	2150	1502
2056	1844	2022	1760	2098	2054	2322	1576
2254	2049	1990	1820	2020	1966	1907	1715
2156	2066	2010	1701	2252	1966	1557	1706
2515	2236	2138	1861	2134	2057	1761	1501
	2090		1826		2263		1522
	2165		1965		2332		1558
	2444		2100		1972		1735
	2335		2206		1919		2022
	2209		2591		1925		1715
2061	2175	2069	1976	2161	2009	2157	1801

Environmental Tests

TABLE VI

I. CATEGORY: Liquid and Semi Solid High Polyzers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

B. Thersophysical

Information not available due to lack of need for Boeing Wichita's
investigating this property

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Shell Epon 928

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with this end usage in mind.

The tests in this report demonstrate the versatility of Epon 928 in curing. The material will cure at room temperature or it can be force cured at any time-temperature interval between 200-350°F for 15-60 minutes. This flexibility in curing allows the designer to apply the adhesive at nearly any production step in the fabrication of a plastic part. It can be applied and cured at the bench on a detail part, or applied to the major assembly and cured at temperatures which are required to cure other parts of the assembly.

Some sacrifice in bond strength may be expected where bondline thicknesses exceed 10 mils. However, the strengths obtained on the thicker bondlines indicates the material would be useful in gap filling applications where a high strength bond is also required.

VII. SUPPLIERS AND TRADE NAMES:

A. The Supplier designation and location is as follows:

Epon 928 - Shell Chemical Corporation, Pittsburg, California.

B. Availability:

Epon 928 is packaged in pint, quart, and gallon containers.

C. Costs:

The price of Epon 928 is approximately \$9.00 per quart.

VIII. REFERENCES:

- (1) Wichita Materials and Process Unit Report AP-1-35, Testing Shell Epon 928.
- (2) Federal Test Method Standard No. 141.
- (3) BAC 5765, Cleaning and Decidgizing Aluminum Alloys.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

III. GENERAL DESCRIPTION:

The objective of this program was to determine the effect of certain variables on cured adhesive bonds with HT-424 Adhesive and Aluminum.

IV. DEVELOPMENTAL BACKGROUND:

HT-424 Adhesive has been approved by Boeing for use as a heat resistant structural bonding material for aluminum (metal-to-metal and honeycomb sandwich) on flight vehicles. The adhesive is qualified under MIL-A-5090.

Boeing specifications governing the use of this adhesive specify the minimum requirements in BES 5-17 and SAC 5450. There are many conditions specified by design that cannot reasonably be covered in general usage specifications. Since this is a heat resistant adhesive, testing at elevated temperatures is also required and complicates the evaluation of properties. It was thought to be worthwhile to investigate variables in test methods and to determine properties of the material (on which data are not readily available) for use in advising design and manufacturing shops.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. The effect of heat-up time (to cure temperature) on peel and 500°F lap shear strength is shown in Figures 1 and 2. The single (1/2 inch overlap) shear specimens were made from 2024-T3 clad aluminum 0.063 inch thick. The peel specimens were 5052 alloy aluminum core (perforated), 3/16 inch cell size x .002 inch foil x 5/8 inch thick with 2024-T3 clad aluminum skins, .020 gage bonded together with HT-424. Peel testing was done with a "climber" peel tester per MIL-A-25463.

Varying the heat-up time between 20 and 60 minutes to cure temperature had no appreciable effect on peel strength. Lap shear strength appeared to be lower when the assembly was heated up between 20 and 40 minutes to cure temperature compared to a slower heat time of 40 to 60 minutes.

2. The effect of room temperature exposure of uncured HT-424 on subsequent bond strengths is shown in Figure 3. Bond materials and test methods were the same as specified in (1) above. Cure conditions were also the same - 325 to 350°F for 45 minutes.
3. The effect of glue line thickness on 500°F lap shear strength of HT-424 adhesive in clad aluminum joints is shown in Figure 4. Apparently, there is a considerable difference in strength due to bond thickness depending upon the degree of porosity of the glue line. No effort was made in the Boeing bonded panels to restrain the adhesive in the joint, and thereby minimize porosity. The Bloomingdale bonded panels were bonded in such a manner as to restrain the adhesive in the joint, thereby providing a more dense glue line. It is thought that a thick, dense glue line would be more representative of actual assemblies.
4. Figure 5 shows the relationship of temperature and pressure on uncured HT-424 adhesive (and others) in a closed container. The test data are designed to give information on the amount of bonding pressure required to bond a 5/8 inch thick non-perforated sandwich. These data do not take into account pressure leak-off through the cloth carrier during cure. Therefore, the data represents maximum pressure that could ever be experienced in curing such as assembly.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HF-424

V. PRINCIPAL PROPERTIES:

a. Mechanical (continued)

5. Table 1 and Figures 6 through 10 give the effects of variables in the 500°F lap shear test on shear strength of HF-424 in clad aluminum bonds. All panels were bonded at 325°F for 45 minutes on the same day from the same batch of HF-424 adhesive. This particular batch happened to be about 150 psi lower in shear strength than the average material received over the past two years.

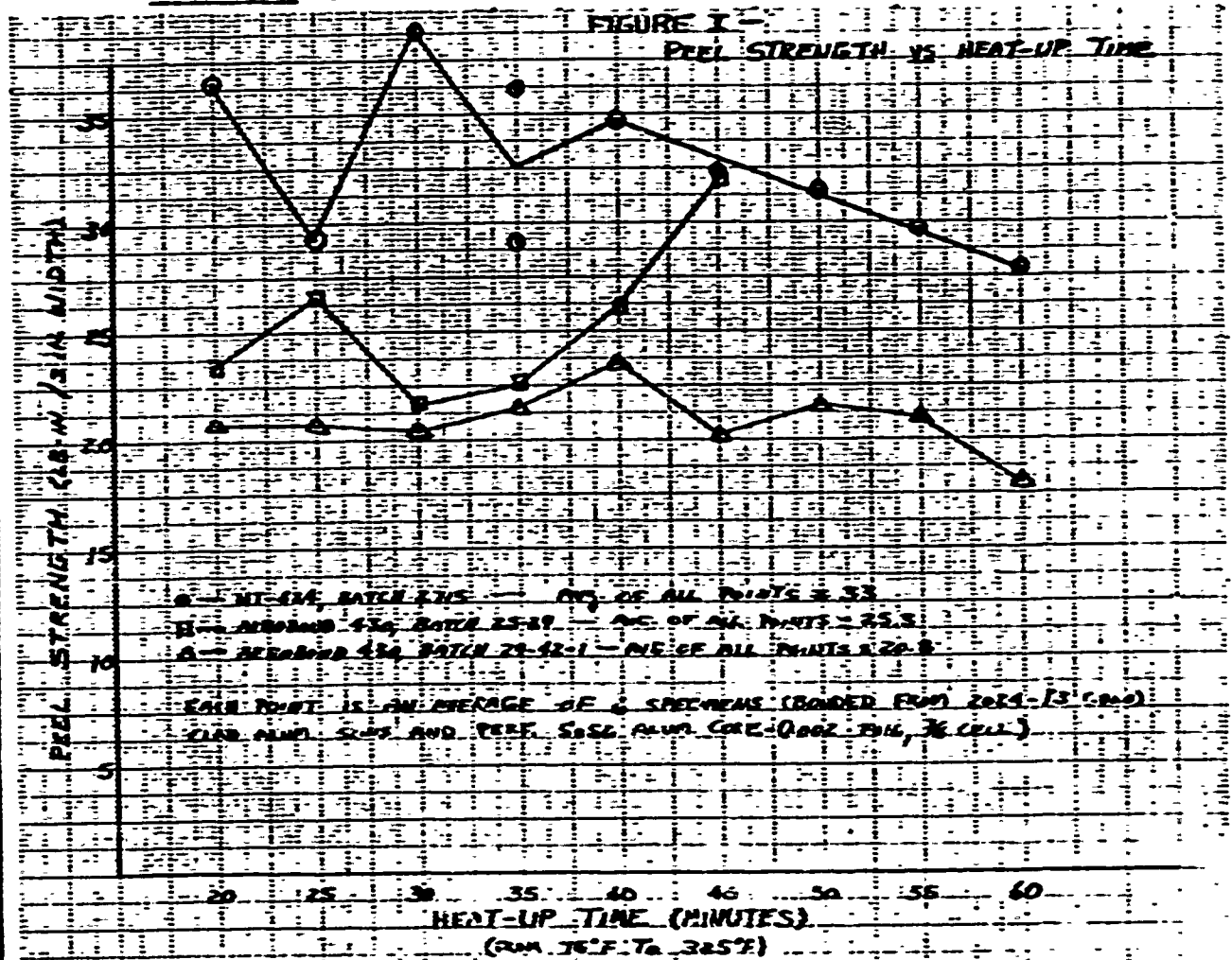
The data indicates that variations in heat-up time between 3 and 20 minutes to 500°F do not significantly affect 500°F lap shear strength. There is a significant difference (approximately 60 psi) between bonds aged 60 minutes at 500°F and those unaged (but tested) at 500°F. There is a significant difference in 500°F shear values with a 25°F change in temperature from 500°F. The test was not adequately controlled to determine conclusively whether there was a significant difference between bonds tested in an air circulating oven and those tested in a (radiant heat) Marshall furnace. However, it is believed that the difference is not significant.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

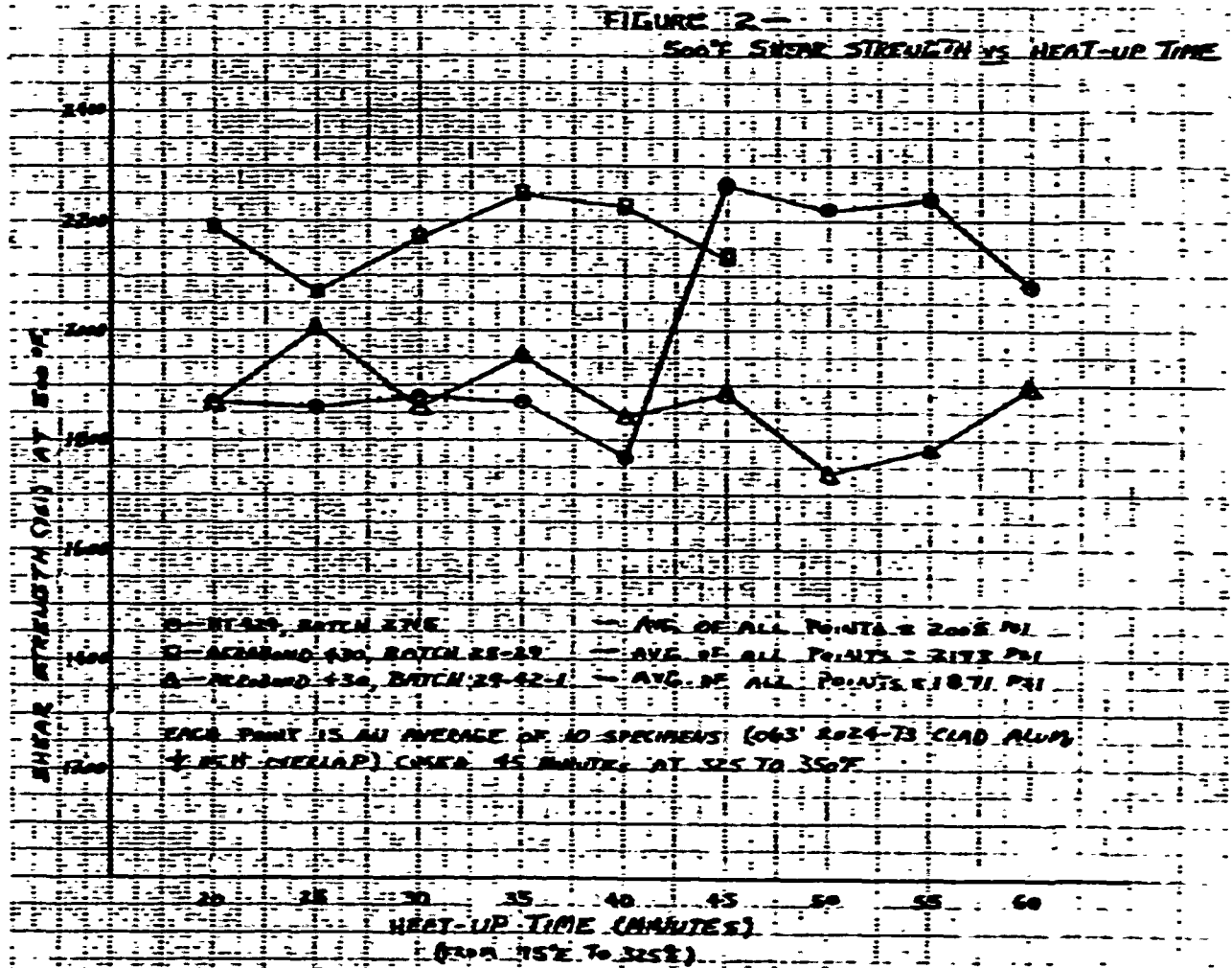


I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



AUTHOR:

K. Methvin

DATE: 8-24-61

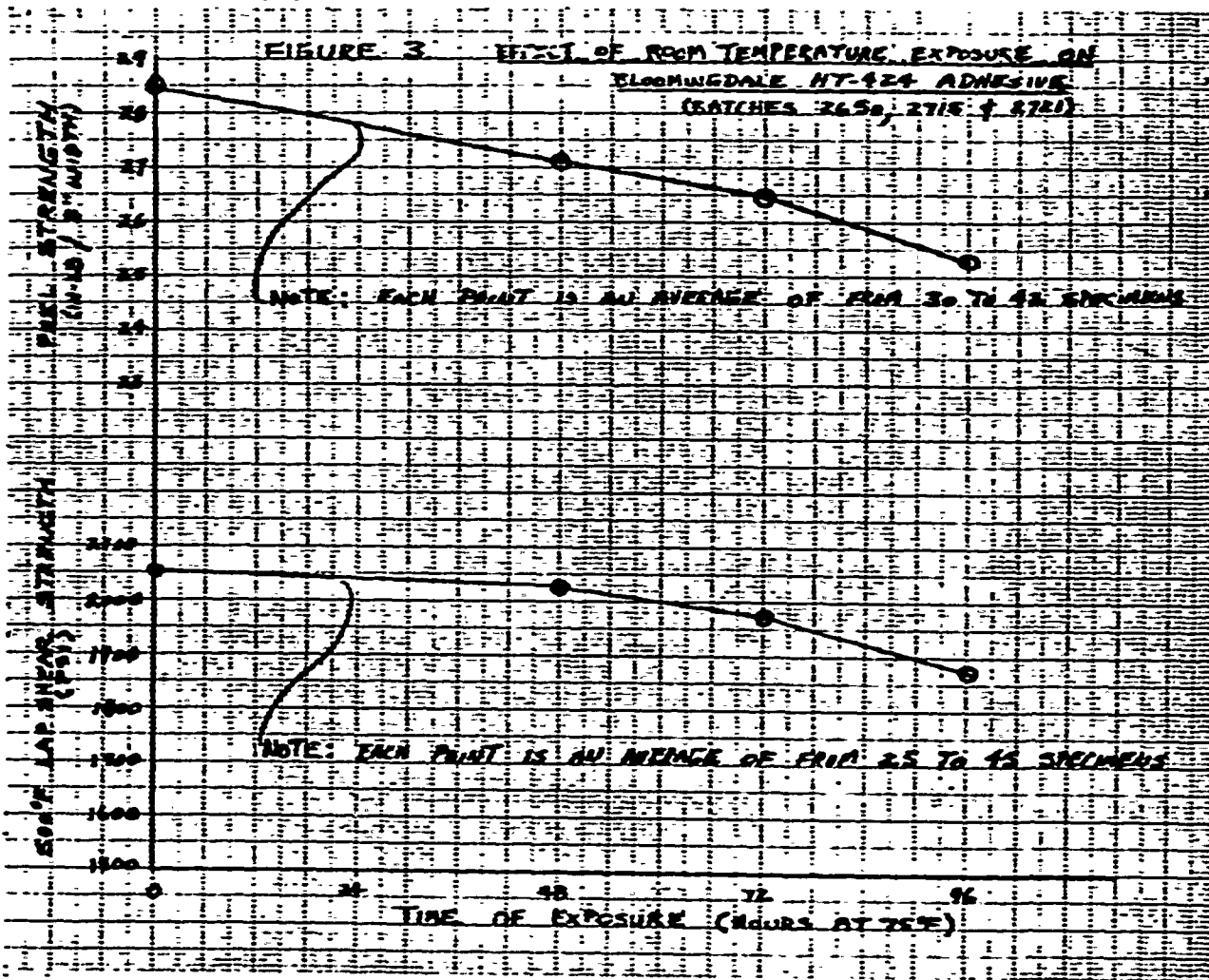
PAGE 5

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



AUTHOR: K. Kevin

DATE: 8-24-61

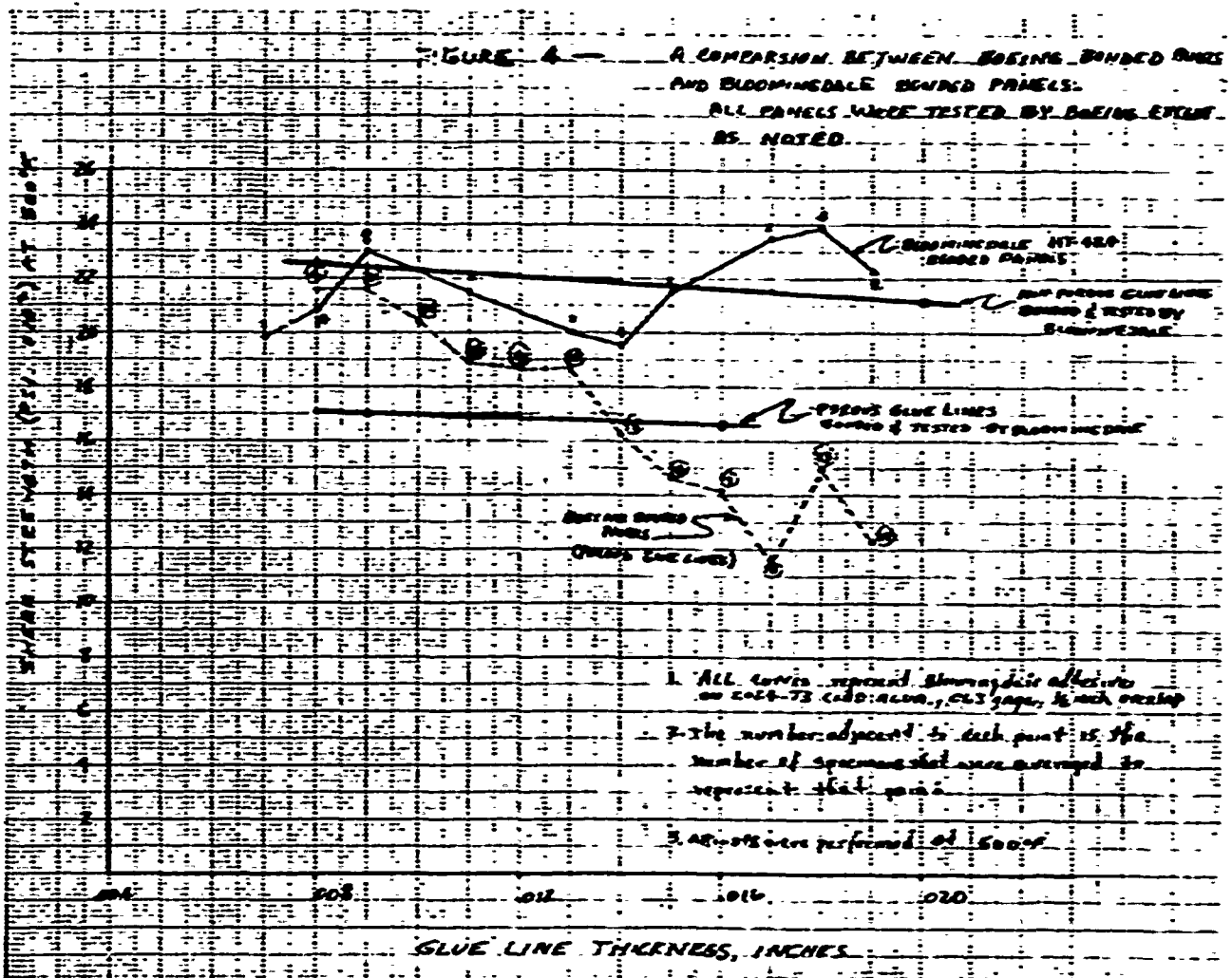
PAGE 6

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

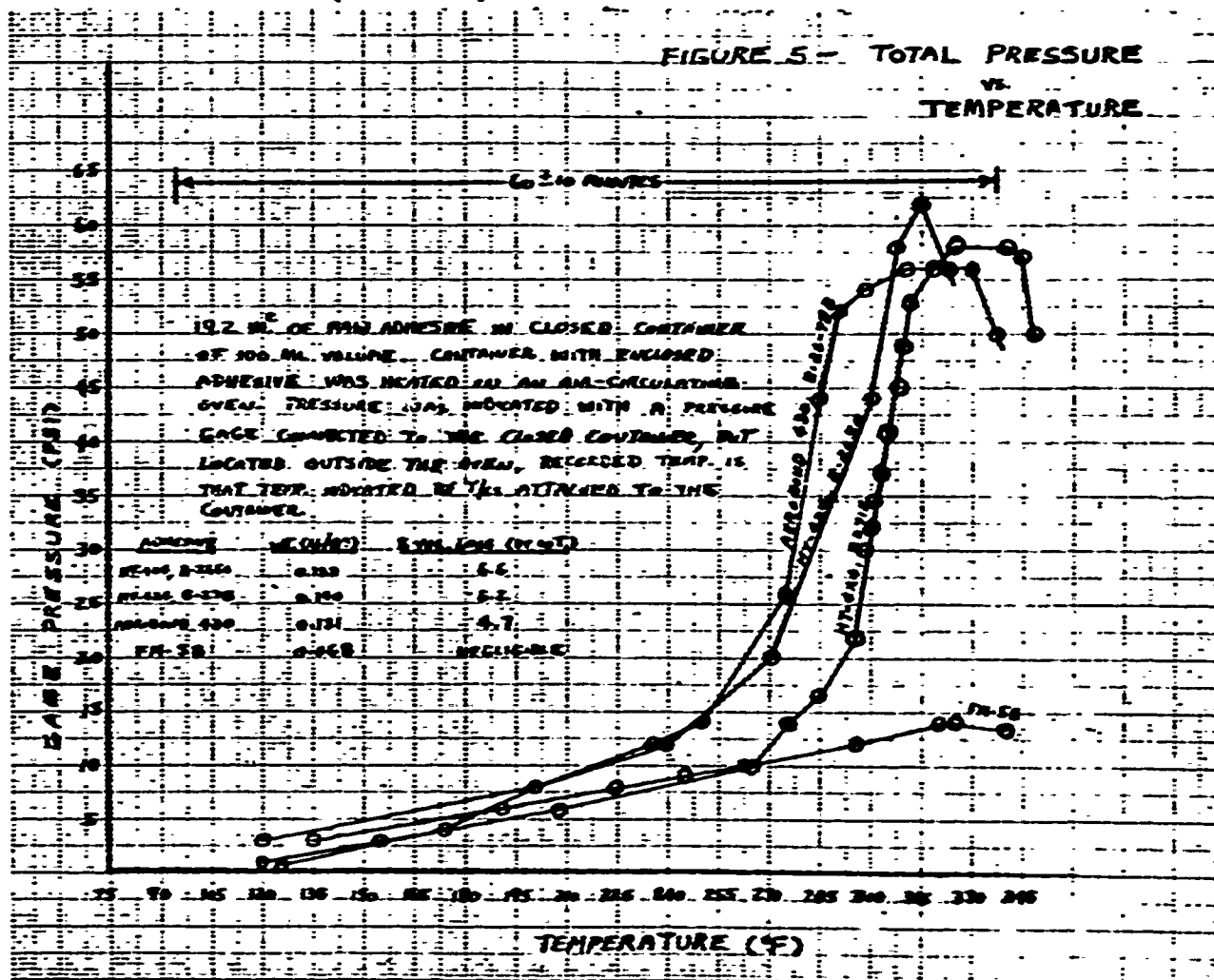


I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

SHEAR (PSI)	TEST TEMPERATURE		
	475°F	500°F	525°F
	1738.5	1676	1600

500°F SHEAR (Psi)	CIRCULATING AIR OVEN	
	SLOW HEAT-UP	FAST HEAT-UP
	1640	1611

500°F SHEAR (PSI)	JAWS OUT OF OVEN		
	30 SECS.	60 SECS.	90 SECS.
	1555	1541	1568

500°F SHEAR	SOAK TIME AT 500°F			
	5 MIN.	10 MIN.	20 MIN.	60 MIN.
	1640	1647.5	1636	1574

*Average of 9 specimens. All other values are averages of 10 specimens.

TABLE 1

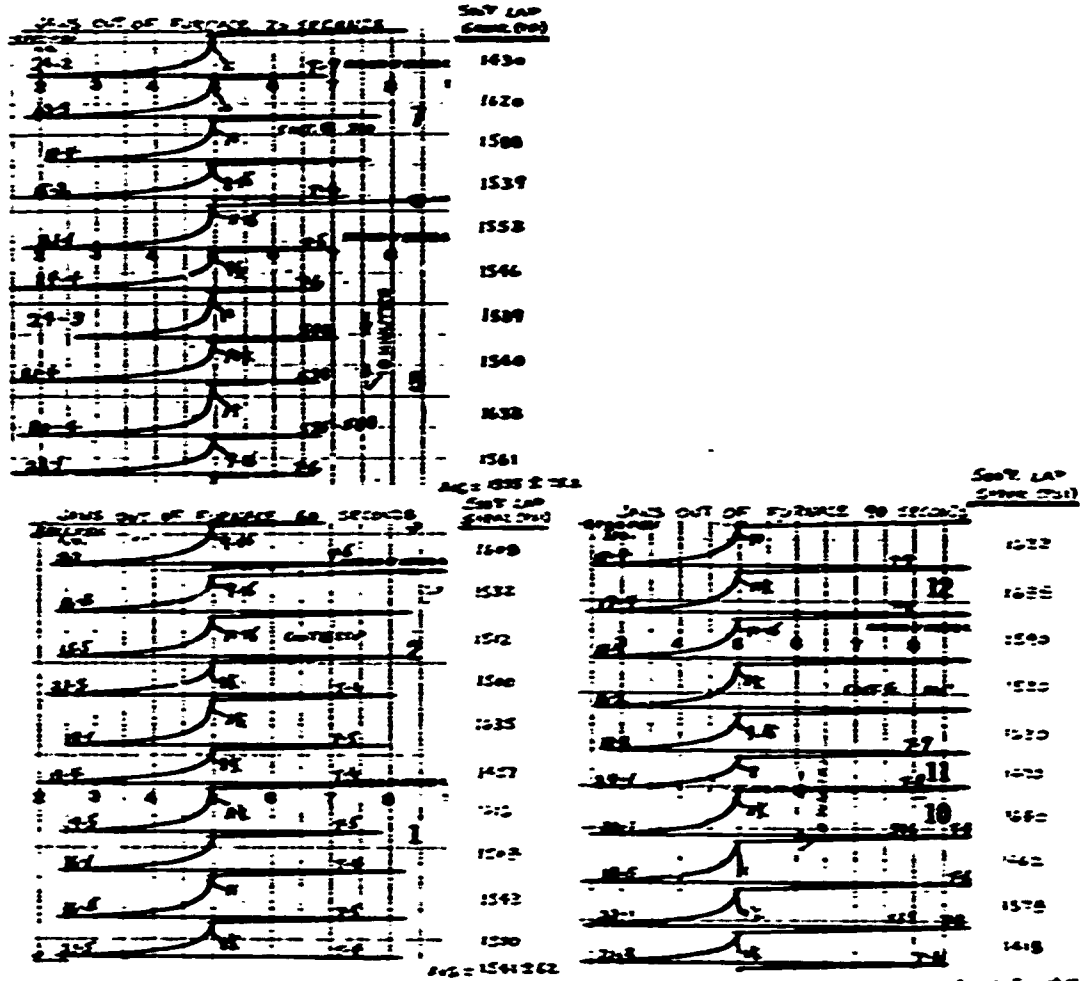


1 T/C clamped to center of lower half of all test specimens within 1/16 inch of adhesive flash. Calibration work was done with this T/C plus a T/C embedded in the bond. (Embedded T/C read 5°F lower than ext. T/C).

FIGURE 6 - Position of T/C on Test Specimen

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424



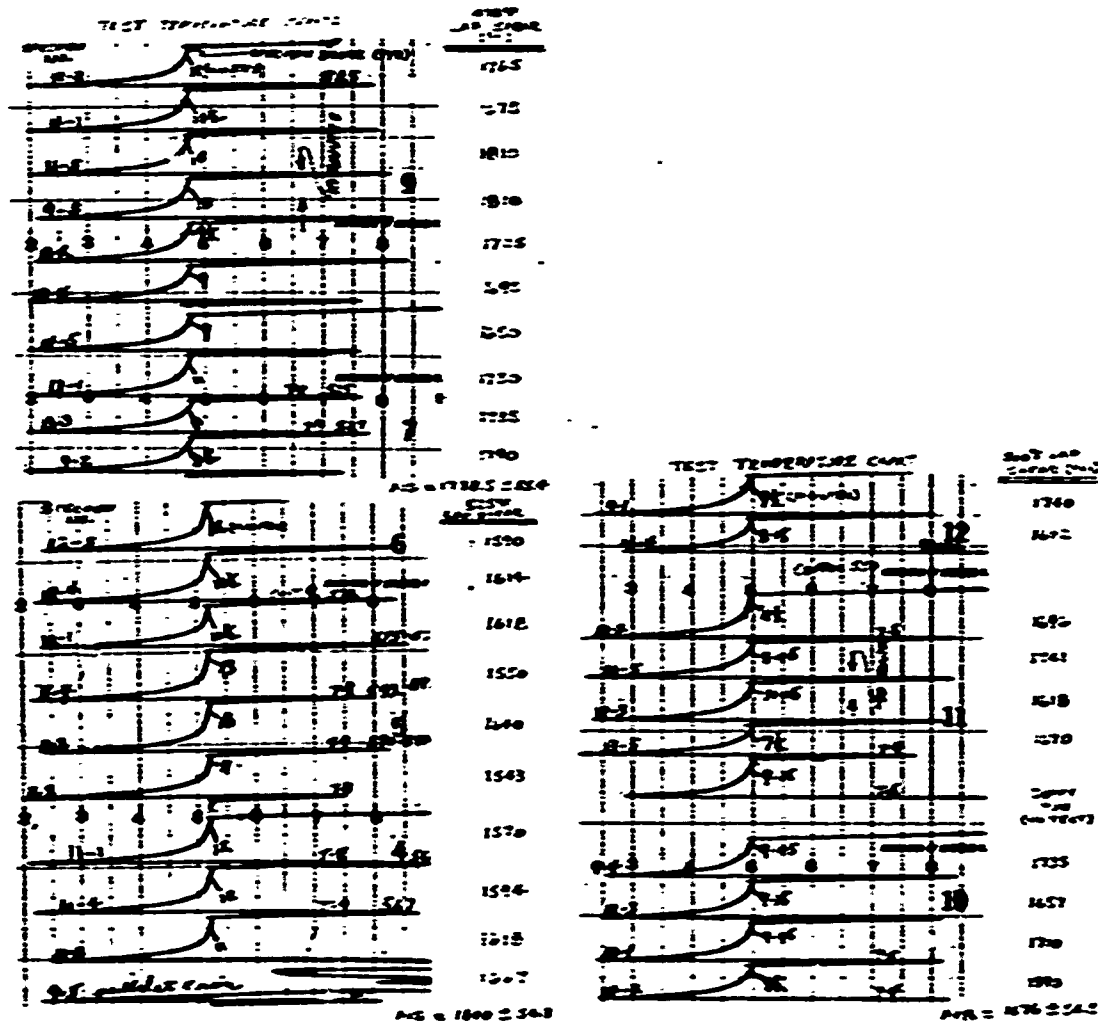
Bloomington HT-424 bonds made with .063 clad aluminum - tested in lap shear at 500°F in a Marshall furnace - Effect of heat-up rate (by varying heat loss of jaws).

FIGURE 7

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I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HF-424

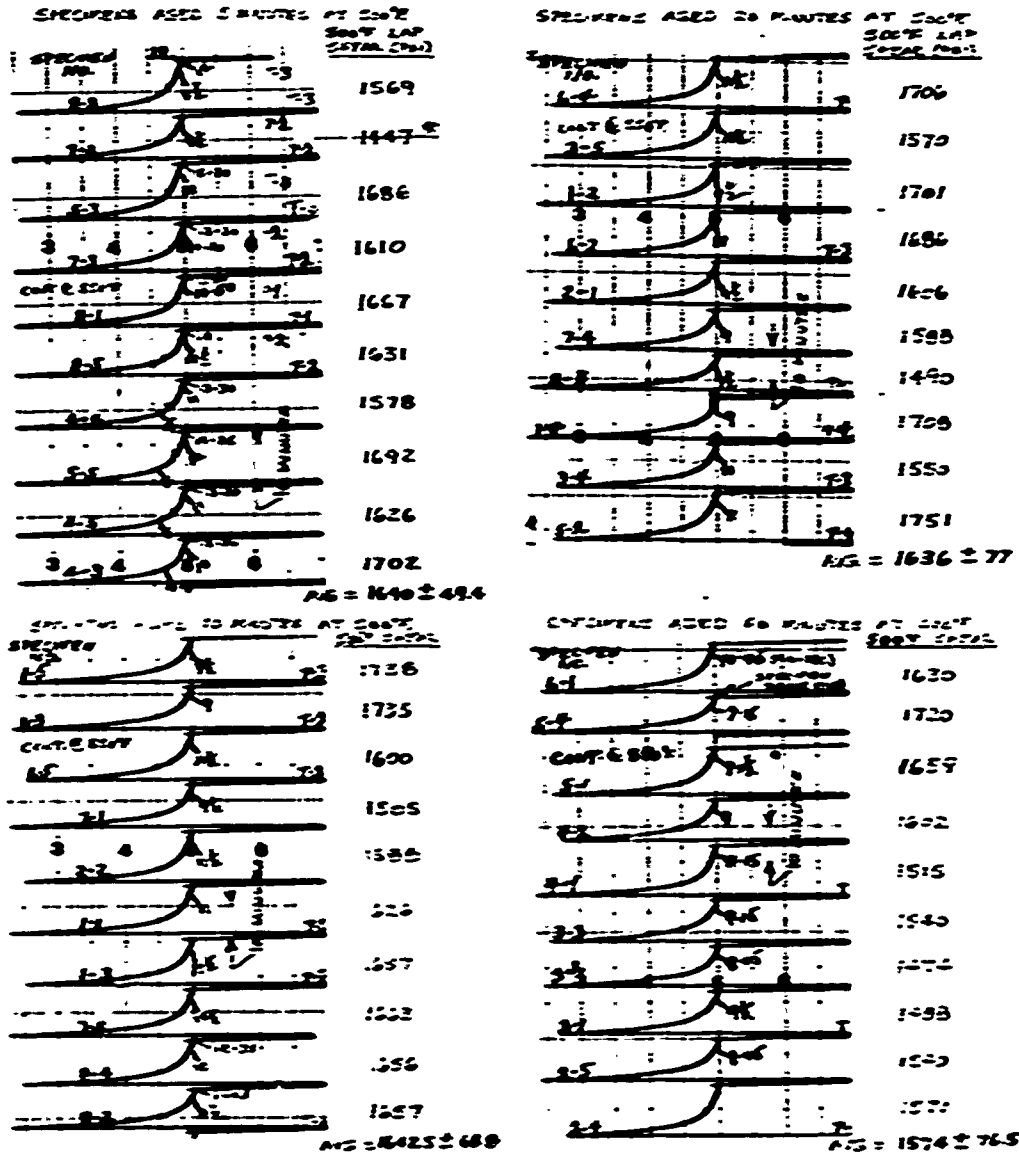


Effect of temperatures on Blomington HF-424 bonds made with .053 clad aluminum - tested in lap shear in Marshall furnace (Jaws out of furnace 60 seconds).

FIGURE 8

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

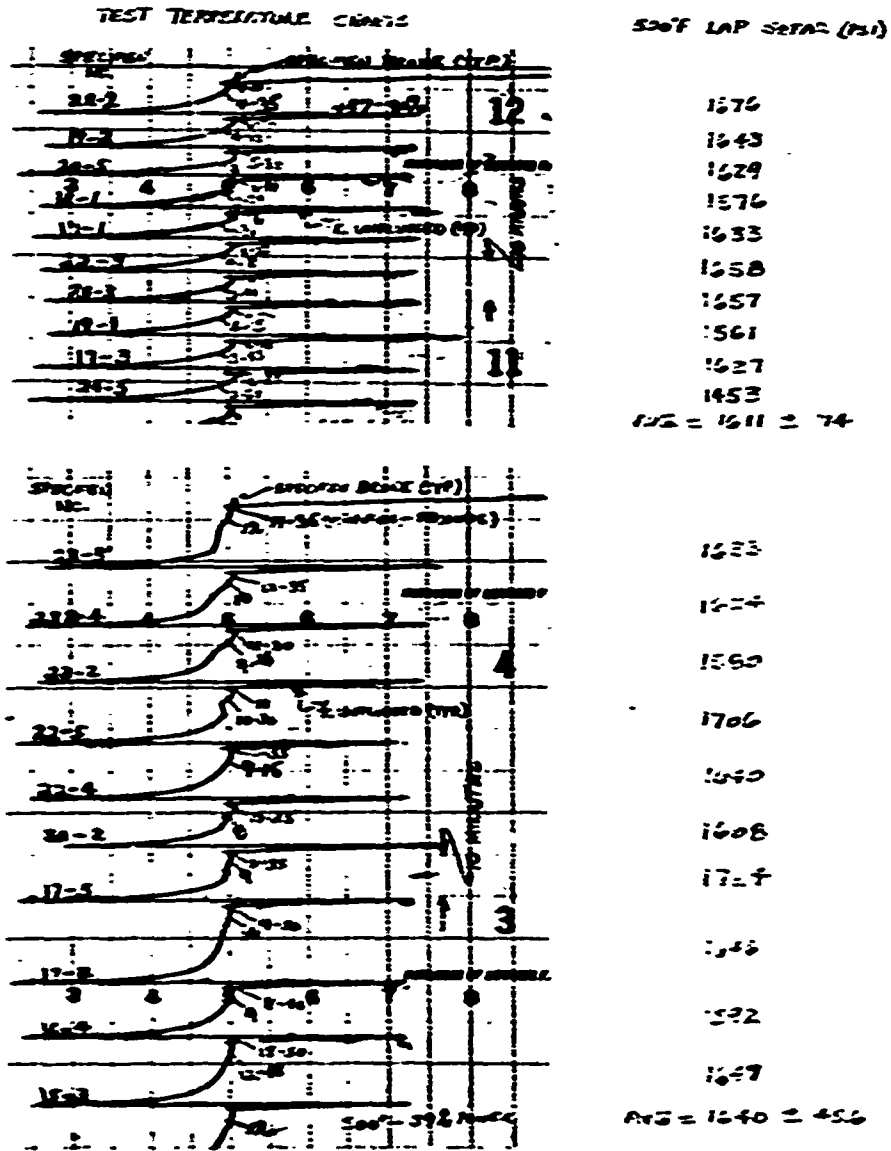


Effect of time at 500°F on Lockingdale HT-424 bonds made with 0.053 clad aluminum - tested in lap shear at 500°F in a Marshall furnace. (jaws out of furnace 60 seconds).

FIGURE 9

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. MATERIAL NAME: Adhesives, Structural, HT-424



Blowingdale HT-424 bonds made with 0.063 clad aluminum - tested in lap shear at 500°F in a circulating air oven - effect of heat-up rate.

FIGURES 10

I. CATEGORY: Liquid and semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polyzers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

V. PRINCIPAL PROPERTIES:

D. Chemical
Information not available due to lack of need for Boeing-Michita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, HT-424

VI. RECOMMENDED USES:

HT-424 is used extensively in bonding non-perforated aluminum sandwich for the B-52. It is recommended that the data obtained in this program be used by Materials and Process Unit Engineers as a guide in advising Design personnel and subcontractors.

VII. SUPPLIER AND TRADE NAME:

- A. HT-424 Adhesive is the trade name of this material. It is supplied by Bloomingdale Rubber Company of Aberdeen, Maryland.
- B. HT-424 is available in continuous tape form, approximately 38 inches wide and .012 to .014 inch thick. It is also available in other thicknesses supported on a glass cloth carrier. Refrigeration at 0°F is recommended.
- C. HT-424 costs approximately \$0.65/sq.ft. in large production quantities.

VIII. REFERENCES:

- A. "Investigation of EAS 5-17 Adhesive Cure Cycle", Job Report AP-2-27 (Boeing-Wichita) dated 6-24-59, by K. Methvin.
- B. "Room Temperature Exposure of EAS 5-17 Adhesive", Job Report AP-2-31 (Boeing-Wichita) dated 6-25-59, by K. Methvin.
- C. "Glueline Thickness versus Shear Strength", Job Report SA-2-169 (Boeing-Wichita) dated 10-22-58, by C. Edwards.
- D. "Investigation of Variables in 500°F Lap Shear Test", Job Report AP-2-174 (Boeing-Wichita) dated 8-30-61, by K. Methvin.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

III. GENERAL DESCRIPTION:

The objective of this program was to determine the effect of certain variables on cured adhesive bonds made with AF-30 adhesive and EC-1593 primer.

IV. DEVELOPMENTAL BACKGROUND:

AF-30 tape and EC-1593 primer adhesives have been approved by Boeing for use as a structural bonding system for aluminum and magnesium on flight vehicles. The adhesive system is qualified under MIL-A-5090.

Boeing's specifications governing the use of this adhesive system specify the minimum requirements in BPS 5-42 and BAC 5462. There are many conditions specified by design that cannot be reasonably covered by general usage specifications. Examples of such conditions are use of varying skin gages and difference in curing facilities throughout the industry. It was felt advisable to determine the effect of some of these variables on joint strength so that advice could be given to subcontractors and design groups when needed.

AUTHOR: K. Methvin

DATE: 12 July 1961

PAGE 1

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I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. The relationship between peel strength and lap shear strength for various bond line thicknesses is given in Figure 1. It appears that it is possible to tailor a bond for the optimum combination of shear and peel strength by controlling the thickness of the AF-30 adhesive.
2. The effect of width of overlap and metal thickness on lap shear strength of AF-30 (with and without EC-1593 primer) is shown in figures 2 and 3.
3. The effect of bond line pressure on one-half inch overlap shear bonds with Dow 7 magnesium coated with zinc chromate primer is shown in Figure 4. An optimum bonding pressure was not found. Bonding may be accomplished with equal results on test panels between 20 and 120 psi.
4. The effect of using positive pressure only and vacuum pressure in curing AF-30 bonds is shown in Figure 5. There appears to be no difference in one-half inch overlap bonds whether vacuum is used or not. In areas as large as one square foot use of vacuum during cure results in higher strengths than when no vacuum is used. A cure pressure of 40 psi was used.
5. The effect of cure temperature and cure time on one-half inch overlap bond strength is shown in Figure 6. Data presented was taken with AF-30 adhesive on clad .063 aluminum.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical

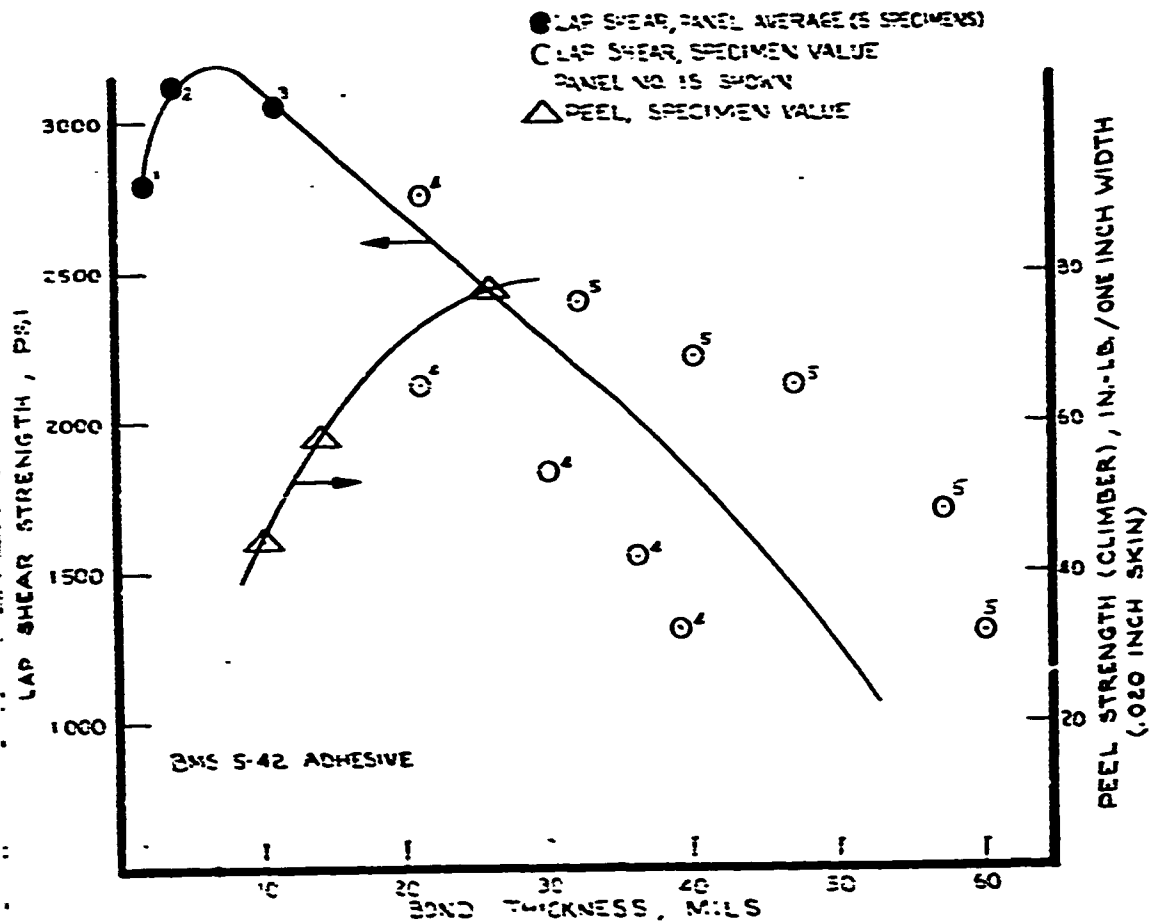


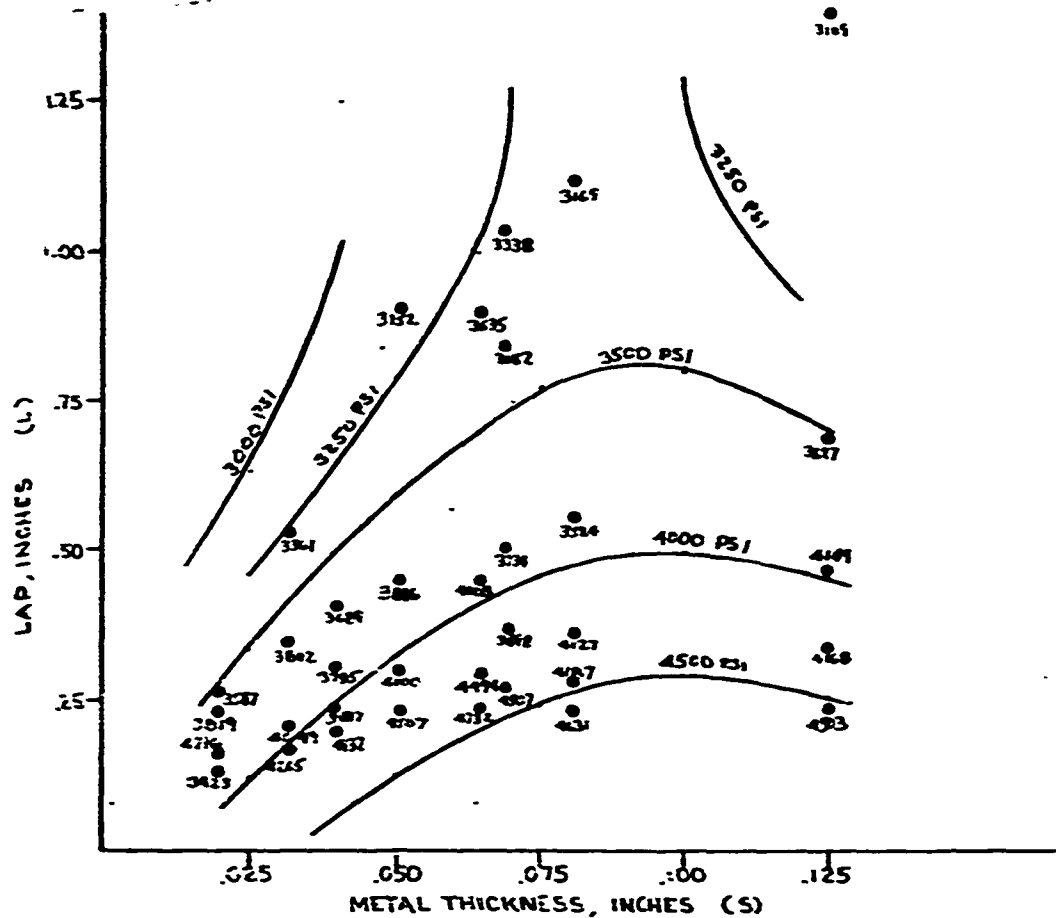
FIGURE 1

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical



2024-T3 CLAD AF-9330 ADHESIVE SYSTEM
FITTED EQUATION: $\bar{Y}(\text{PSI}) = 3626 - 2980L + 32,728S + 1289L^2 - 152,367S^2 - 3593LS$

CONTOUR DIAGRAM LAP SHEAR STRENGTH, LAP VS. THICKNESS CLAD ALUMINUM ALLOY, AF-9330 ADHESIVE

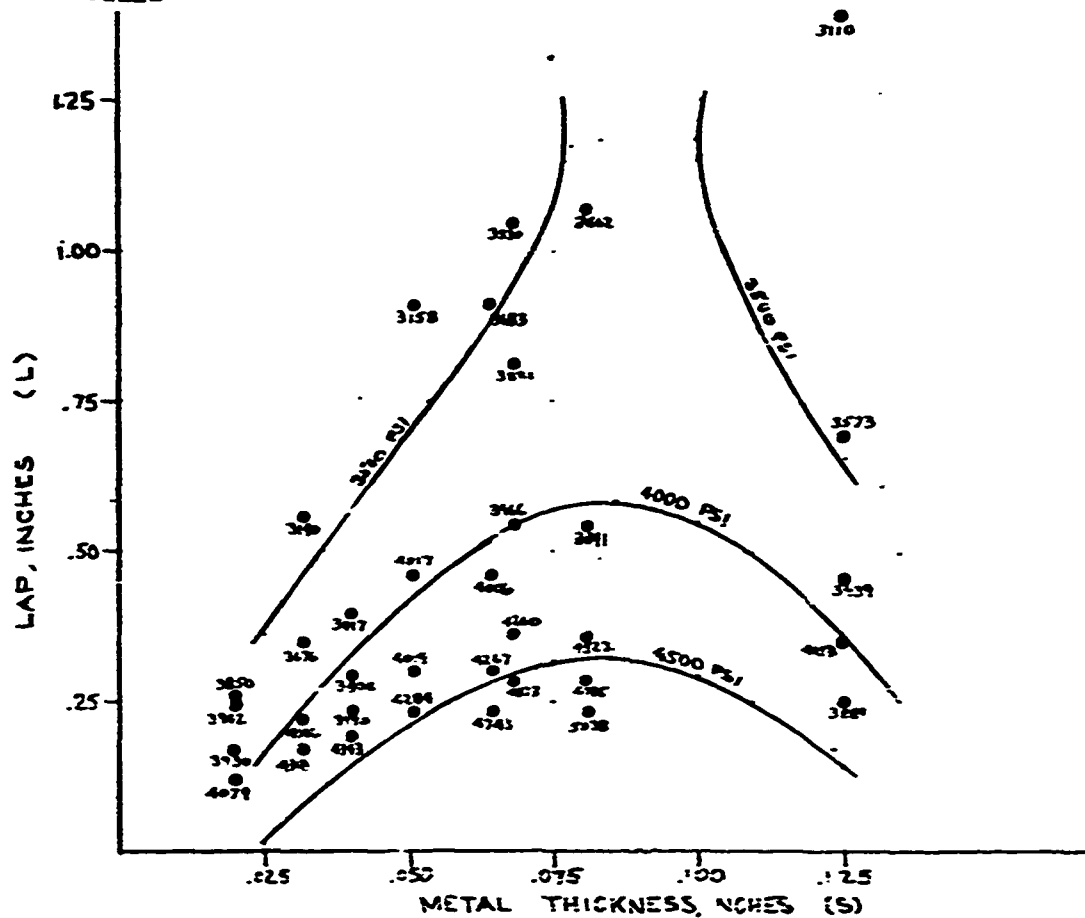
FIGURE 2

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical



2024-T3 CLAD ALUMINUM AF-30 ADHESIVE
 FITTED EQUATION: $\bar{Y}(\text{Psi}) = 3633 - 3392L + 43,635S + 33L^2 - 260,834S^2 + 3271LS$

CONTOUR DIAGRAM LAP SHEAR STRENGTH, LAP VS. THICKNESS CLAD ALUMINUM ALLOY, AF-30 ADHESIVE

FIGURE 3

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical

30 MIN. CURE

20 PSI	310°F (6)(X)(5)					320°F (7)(X)(7)					330°F (1)(X)(1)						
	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
2935	2955	2777	2965	2924	2753	2722	2787	2831	2791	2738	2736	2884	2767	2793	2867	2855	2735
3055	2963	2984	3159	3246	2937	2934	3100	3074	2992	3097	3042	2507	2355	2545	2496	2319	2623
3014	2728	2954	3024	3077	2942	3059	3022	2954	3086	3018	3123	2950	2931	2946	3088	2997	3016
2942	2940	2950	3137	2897	3135	3093	3070	3125	2783	2861	3020	2873	2791	3047	2891	2931	2875

40 MIN. CURE

20 PSI	310°F (7)(X)(7)					320°F (3)(X)(3)					330°F (3)(X)(3)						
	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
2790	2793	2777	2865	2912	2865	3056	3083	2895	2954	3010	2443	2777	2698	2725	2789	2837	2712
2947	3028	2750	2823	2796	2958	3189	3080	2946	3151	2936	3059	3000	2950	2763	2956	3129	3250
2940	3025	3191	2823	3125	2950	2976	2940	2891	3067	2901	2932	2940	2876	2934	2987	2935	2913
3235	3155	2942	3167	3084	3155	2952	2921	3076	3028	3115	2957	3115	3012	3133	3167	3015	2723

50 MIN. CURE

20 PSI	310°F (4)(X)(4)					320°F (3)(X)(3)					330°F (5)(X)(5)						
	40	60	80	100	120	20	40	60	80	100	120	20	40	60	80	100	120
3000	3125	2801	3065	3212	2930	2931	2937	2997	2901	3101	2707	2728	2704	2821	2913	3059	2725
2990	3058	2724	2733	2340	2367	2993	2901	2811	2319	2755	2974	2937	2949	2801	3018	2970	3026
2945	2785	2855	2803	2720	2774	3115	3112	3048	3066	3105	3137	2609	2974	2916	2988	2922	2810
2910	2743	3020	2796	2787	2904	2782	2939	2986	3038	3014	2955	2911	2929	2920	3149	2955	3097

① NO PRESSURE ON BONDLINE - CATEGORY AVERAGE AS SHOWN USED FOR ANALYSIS.

② BONDED AT 345°F - CATEGORY AVERAGE AS SHOWN USED FOR ANALYSIS.

NOTE: NUMBERS IN PARENTHESES CORRESPOND TO RUN NO. FOR FIRST, SECOND, THIRD, AND FOURTH REPLICATE RESPECTIVELY. SPECIMEN CODE: REPLICATE NO.-RUN NO.-BOND PRESSURE-SPECIMEN NO.

AVERAGE PANEL STRENGTH - LAP SHEAR, PSI

FIGURE 4

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Mechanical RESULTS

4x6x.064 CLAD ALUM - 1/2 INCH BONDED OVERLAP			
16" VACUUM USED		NO VACUUM USED	
PANEL NO.	SHEAR (PSI)*	PANEL NO.	SHEAR (PSI)*
2-1	3396	1-1	3430
2-2	3485	1-2	3336
3-1	3545	4-1	3507
3-2	3451	4-2	3296
5-1	3487	7-1	3261
5-2	3460	7-2	3131
6-1	3146	8-1	3412
6-2	3569	8-2	3485
AVERAGE	3359	AVERAGE	3442

* AVERAGE OF 5 SPECIMENS

12x12x.040 CLAD ALUM - ENTIRE AREA BONDED			
16" VACUUM USED		NO VACUUM USED	
PANEL NO.	SHEAR (PSI)*	PANEL NO.	SHEAR (PSI)*
2	3301	1	3252
3	3255	4	2278
5	3015	7	2957
6	3240	8	2517
AVERAGE	3228	AVERAGE	2751
		9	2765
		10	2801
		AVERAGE	2763

* AVERAGE OF 10 SPECIMENS (LIMITED TO 2 INCH OVERLAP AS DEFINED IN PROCEDURE). PANEL NUMBERS 9 AND 10 WERE BONDED WITH A TOOL CONSISTING OF A 1" THICK ALUM PLATE BETWEEN THE PART BEING BONDED AND A STEEL BRADDER USED TO APPLY PRESSURE (COMPRESSED AIR). PANELS 1 THROUGH 8 WERE BONDED WITH THE SAME TOOL CONSISTING OF A 1" THICK ALUM PLATE BETWEEN THE PART AND THE BRADDER WAS AN ALUM-FACED PLYWOOD 1" THICK.

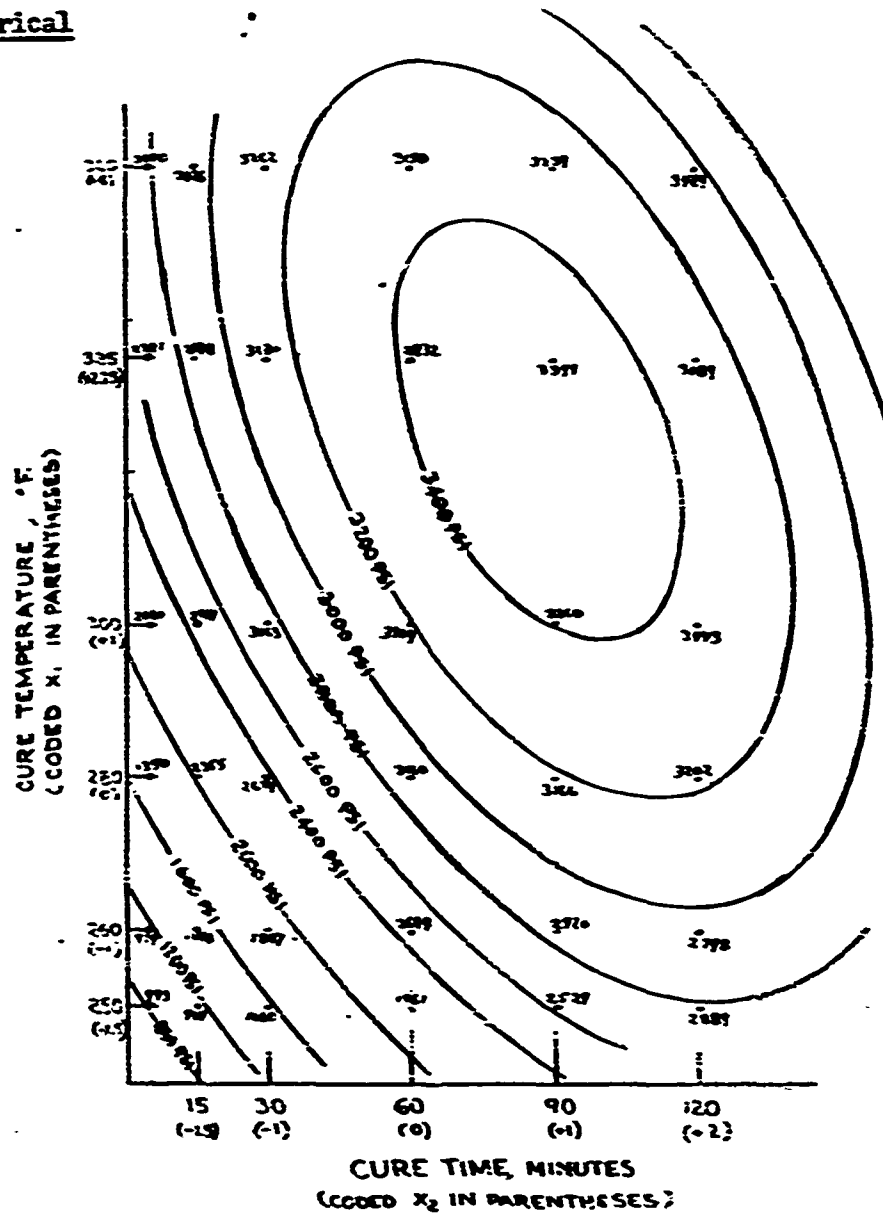
FIGURE 5

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

A. Electrical



FITTED EQUATION: $\hat{Y}(T_2) = 2892.491 + 366.8297x_1 + 486.2059x_2 - 0.0072x_1^2 - 120.3757x_2^2 - 82.3445x_1x_2$
 (USING CODED VALUES OF x_1 AND x_2)

NOTE: TEST VALUES SHOWN ON DIAGRAM.

FIGURE 6

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

B. Thermo Physical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polyzers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AP-30

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-6-1

II. MATERIAL NAME: Adhesive, Structural, AF-30

VI. RECOMMENDED USES:

It is recommended that the data obtained be used by Materials and Process Engineers as a guide in advising design personnel and Sub-Contractors.

VII. SUPPLIERS AND TRADE NAMES:

A. The supplier designation of the adhesive system used in these tests is AF-9330 adhesive by Minnesota Mining and Manufacturing Company.

B. Availability

EC-1593 primer is available in a 10% solids form. AF-30 tape is available in sheet form up to 30 inches wide and .010 to .014 inches thick.

C. Costs

AF-30 costs approximately \$0.75/ft.². EC-1593 costs approximately \$5.60/gal. (depending on quantity).

VIII. REFERENCES:

1. "Mechanical Properties of Structural Adhesives", Job Report AP-1-22 (Boeing-Wichita), dated 23 November 1960, by Don Brown.
2. "Bondline Pressure for AF-30 Bonded Magnesium", Job Report AP-2-68 (Boeing-Wichita), dated 1 September 1959, by Don Brown.
3. "Cure of AF-9330 Adhesive Without Vacuum", Job Report AP-2-119 (Boeing-Wichita), dated 1 July 1960, by K. Methvin.
4. "Joint Factors of Metal Bonded Joints", Job Report AP-3-4C (Boeing-Wichita), dated 25 January 1960, by Don Brown.
5. "Effect of Various Cure Cycles on AF-30", Job Report SA-2-170 (Boeing-Wichita), dated 6 January 1959, by Don Brown.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: Hi-Temperature Lubricants

III. GENERAL DESCRIPTION:

The object of this program was to investigate the thermal capabilities of various available experimental lubricants.

IV. DEVELOPMENTAL BACKGROUND:

A considerable effort is currently being made by various Military and Industrial groups to obtain, develop, synthesize and compound lubricants that are suitable over a greater temperature range than those covered by present Military Specification.

This report represents some of the work presently being conducted by Boeing toward the evaluation of a few of the available experimental high temperature lubricants. Various laboratory bench tests were used to establish the stability, wear characteristics, and physical and chemical properties of the materials.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Navy Gear Wear Test Data (at room temperature)

<u>Code No.</u>	<u>Wt. Loss of Brass Gear</u> <u>MG/1000 rev., 5 lb wt.</u>
299-56	27.9
316-57	5.1
317-57	10.4
318-57	3.3
319-57	1.3
320-57	9.0
321-57	1.2
395-57	30.6
79-50	12.8
273-50	11.1
292-50	15.9
293-50	1.3

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. Bearing Performance Test

a. Method 331.1 per FMS 791

Fixed Load - 3 lb Radial, 5 lb Thrust

Fixed Speed - 10,000 rpm

Bearing Material - 52100 Tool Steel, Cage

Cage Material - AISI 1008 Pressed Steel

Code No.	Bearing Temp °F	Total Hours	Termination Reason	Bearing Condition
298-57	250	324	Excessive Temp. Rise.	False Brinelling of race. Shaft out of balance.
387-57	300	577.8	Excessive Temp. rise. Grease was dry.	Cage worn, slight discoloration from heat. Balls slightly rough.
387-57	350	163.7	Excessive Temp. rise. Grease was dry.	Cage worn, broken. Heavy discoloration on ball path from heat.
387-57	325	158	Excessive Torque at start of cycle.	Cage worn. Ball path discolored from heat.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

2. b. Method 333 per FMS 791

Fixed Load - 5 lbs Radial, 5 lb Thrust

Fixed Speed - 10,000 rpm

Bearing Material - 18-4-1 Tool Steel

Cage Material - Silver Plated Copper

Beryllium (CRC L-35)

(For Graph of the following data see Figure 1)

Code No.	Bearing Temp °F	Total Hours	Termination Reason	Bearing Condition
315-57	490	120	Excessive Torque increase at start of cycle. Grease ran from bearing.	Cage worn, flaking of silver plate. Heavy discoloration from heat.
315-57	450	129	Excessive heat rise. Grease ran from bearing.	Cage worn, flaking of silver plate. Discolored from heat.
315-57	400	543.5	Excessive heat rise.	Bearing slightly rough, discolored from heat. Cage worn flaking of silver plate.
316-57	450	157.5	Excessive heat rise.	Bearing jammed badly burned.
79-60	350	1247.1	No failure - discontinued	

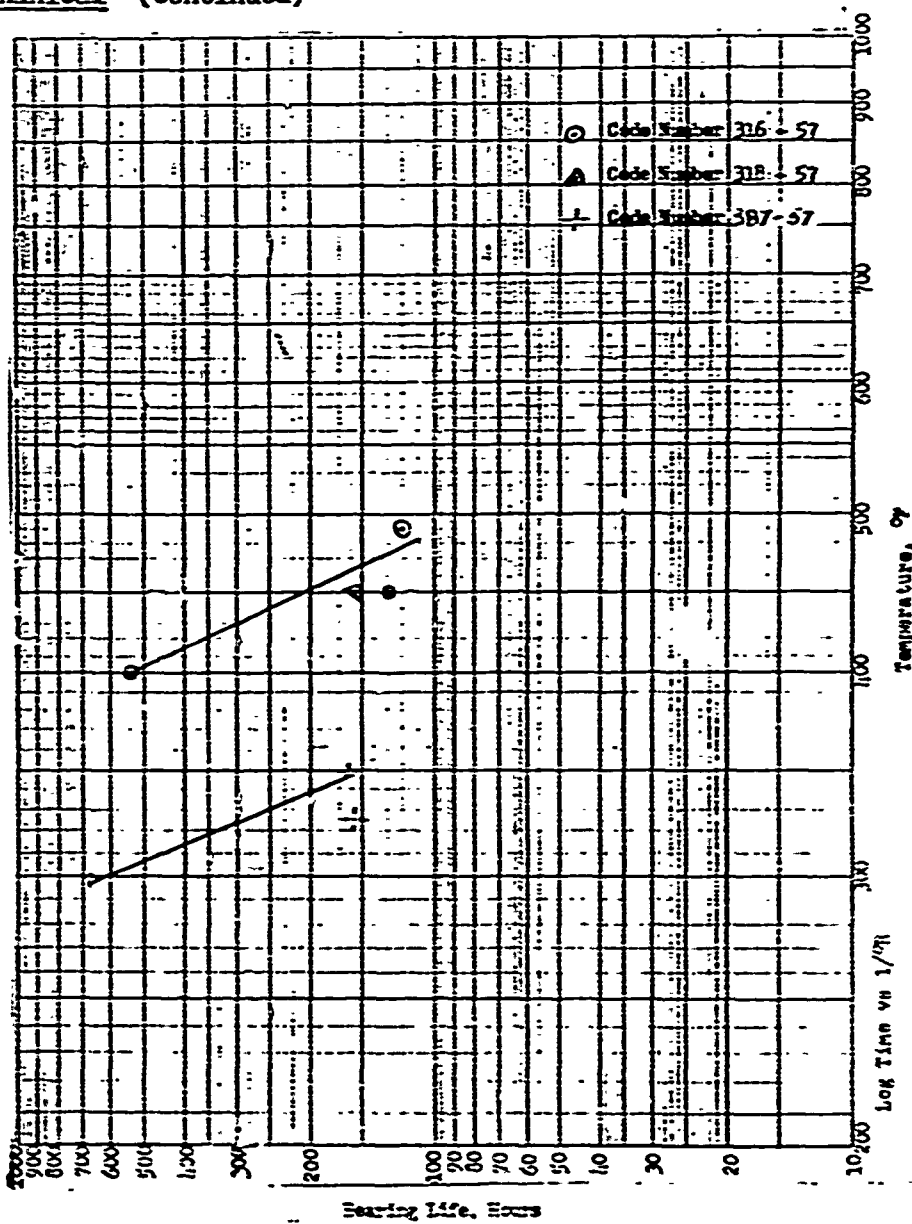
225

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



HIGH TEMPERATURE BEARING TESTS
(PINS-791, METHOD 333)

FIGURE 1

AUTHOR: C. E. Haines

DATE: 9-15-61

PAGE 5.

I. CATEGORY: Liquid and Semi-Solid High Polymers **CODE:** 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Code No.	Dropping Point, °F.	Oil Separation % wt. Loss, 30 Hours @212°F	Evaporation %wt. Loss, 22 Hours @400°F.	Oxidation Resistance lb. Drop 100 Hrs. @210°F	Corrosion Cu. Strip, 24 Hrs. @212°F (ASTM Class)
299-56	524			0	1 a
316-57	504	4.62		0	2 c
317-57	482	4.74	1.82	0	None
318-57	530	5.54	2.67	0	1 a
319-57	652	3.16	8.53	.2	1 b
320-57	501	3.37	3.62	1.5	Liq. ph - 4 a Vap. ph - 1 b
321-57	700	3.86		12	Liq. ph - None Vap. ph - 1 b
396-57	422			0	
79-60	362	3.04	6.03		
273-60	530	1.45	1.17		
290-60	120				
291-60	500		13.35		
292-60	408	2.86	9.29		
293-60	500		51.90		

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES: (Continued)

B. Thermophysical (continued)

Results of Thin Film Evaporation Tests, 2 1/2 Hrs. at Temperature

Code No.	200°F	300°F	350°F	400°F	450°F	500°F
299-57	a	b	c	d	g	h
315-57	a	a	b	b	c	d
317-57	a	b	c	d	e	f
318-57	a	b	c	d	e	f
319-57	b	g	h	h	h	h
320-57	a	b	c	h	h	h
321-57	c	f	g	g	g	g
396-57	a	b	c	h	h	h
387-57	b	c	d	f	f	h
79-60			a	b	c	d
273-60			a	a	b	c
291-60			e	c	e	e
292-60			b	c	d	f
293-60			c	d	h	h

Rating Code

- | | |
|-----------------------------------|------------------------------|
| a. Very little change. | e. Dried, thin soft residue |
| b. Slightly heavier consistency | f. Hard varnish like residue |
| c. Definitely heavier consistency | g. Dry brittle residue |
| d. Extremely heavier consistency | h. Ash or powdery residue |

AUTHOR: C. E. Baires

DATE: 9-15-61

PAGE 7.

MATERIALS & PROCESS UNIT

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES:

C. Electrical

The electrical properties of these materials have not been determined by Boeing-Wichita since such information would be of little or no value from a lubricant standpoint.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

V. PRINCIPAL PROPERTIES:

D. Chemical

Classification of Fluid and Thickener

<u>Code No.</u>	<u>Fluid Type</u>	<u>Thickener Type</u>
299-56	Silicone	Lithium Soap
316-57	Silicone	Non Soap
317-57	Silicone	Aryl Urea
318-57	Silicone	Aryl Urea
319-57	Petroleum	Clay Type
320-57	Silicone	Carbon Black
321-57	Petroleum	Clay Type
369-57	Silicone	Non Soap
79-50		
273-50	Silicone	Organic
290-50	Petroleum	Graphite
291-50	Silicone	Aluminum Organic Complex
292-50		
293-50		

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

VI. RECOMMENDED USES:

These materials are intended for use in high temperature grease applications. Probable upper temperature limitations for satisfactory bearing operation are:

<u>Code No.</u>	<u>Temperature, °F.</u>
299-57	300 (2)
316-57	375 (1)
317-57	300 (2)
318-57	300 (1)
319-57	250 (2)
320-57	300 (2)
321-57	200 (2)
396-57	300 (2)
387-57	300 (1)
79-60	350 (1)
273-60	450 (2)
291-60	350 (2)
292-60	450 (2)
293-60	300 (2)

(1) Temperature limit for 600 + hours on High Temperature Bearing Test per FHS No. 791 Method 333.

(2) Estimated from Thermophysical Properties.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

VII. SUPPLIERS AND TRADE NAMES:

<u>Code No.</u>	<u>Trade Name</u>	<u>Supplier</u>
299-57	Versilube G-300	General Electric Company
316-57	2-1176A	Shell Oil Company
317-57	Supernail ASU-M100	Standard Oil Company
318-57	Supernail ASU-M40	Standard Oil Company
319-57	Stanocelt 321	Standard Oil Company
320-57	D.C. 41	Dow Corning Corporation
321-57	Cactus Brand Sotol	Southwestern Petroleum Co.
396-57	TG-3195	The Texas Company
387-57	MIL-G-3545, Lubricating Grease	Sinclair Refining Company
79-60	ETR-H	Shell Oil Company
273-60	Mobiltemp 57	Socony Mobil Oil Company, Inc.
290-60	HiTemp 2409	E.F. Houghton and Company
291-60	MLG59-509	E.F. Houghton and Company
292-60	Cosmolube 5100	E.F. Houghton and Company
293-60	Cosmolube 5200	E.F. Houghton and Company

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-7-9

II. MATERIAL NAME: High Temperature Lubricants

VIII. REFERENCES:

- A. High Temperature Bearing Lubricants, Boeing Document D3-1625, C.W. Dufur, C.R. Spensler and R.L. Pinckney, 23 June 1958.
- B. Federal Test Method Standard No. 791, 15 December 1956.
- C. "Development and Evaluation of High Temperature Greases", WADC Technical Report 53-83, Part IV, E. Swakon, Standard Oil Company (Indiana). Contract No. AF33(036)-23687, Project No. 3044, September 1956.
- D. "Temperature Limitations of Various Lubricants", Boeing Research Job No. SW-1-5 (in progress).

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

III. GENERAL DESCRIPTION:

A number of enamels and lacquers were investigated to determine their resistance to temperatures up to 450°F for a period of 30 minutes.

IV. DEVELOPMENTAL BACKGROUND:

A. Materials Tested

Gloss Enamels, MIL-E-7729

1. ANA #502, Insignia Blue
2. ANA #505, Light Yellow
3. ANA #506, Orange Yellow
4. ANA #509, Insignia Red
5. ANA #511, White
6. ANA #515, Black

Gloss Lacquers, MIL-L-7178

7. ANA #502, Insignia Blue
8. ANA #506, Orange Yellow
9. ANA #509, Insignia Red
10. ANA #511, White
11. ANA #515, Black

Camouflage Lacquer, MIL-L-6805

12. ANA #604, Black

B. Test Procedure

The enamels and lacquers were applied to clean, unpainted panels (aluminum alloy, QQ-A-287, 7075-T6 alclad, or stainless steel alloy, QQ-S-7662, Type 321), aged a minimum of 48 hours at room temperature, and then placed in an oven and held at the designated temperature for 30 minutes. After cooling, the panels were examined.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

V. PRINCIPAL PROPERTIES:

A. Mechanical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquer.

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The thermophysical properties of these enamels and lacquers are shown in Table I.

The inconsistencies in the results of the tests on Sample No. 12 at 400°F and 450°F are attributed to variations in the material and/or variations in the test conditions.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquer

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Sample No.	Material	Color	Temperature, °F				
			200	300	350	400	450
1	Enamel	Insignia Blue	S	S	S	C,IG,S	C,IG,S
2	"	Light Yellow	S	S	IG,S	C,IG,S	C,IG,S
3	"	Orange Yellow	S	S	IG,S	C,IG,S	C,IG,S
4	"	Insignia Red	S	S	S	C,IG,S	C,IG,S
5	"	White	AP*	AP,C,S	C,S	C,IG,S	C,IG,S
6	"	Black	AP*	S	S	IG,S	IG,S
7	Lacquer	Insignia Blue	AP*	S	IG,S	C,IG,S	C,IG,S
8	"	Orange Yellow	AP*	S	IG,S	C,IG,S	C,IG,S
9	"	Insignia Red	S	S	S	C,S	C,S
10	"	White	AP*	IG,S	IG,S	C,IG,S	C,IG,S
11	"	Black	AP*	S	S	IG,S	C,IG,S
12	"	Black	AP*	S	S	AP,U	AP,S

KEY: AP - Adhesion Poor
 C - Color Changing
 IG - Loss of Original Gloss
 S - Satisfactory
 U - Unsatisfactory

* Probably due to poor initial adhesion due to lack of metal surface pre-treatment.

Effect of 30 Minutes Exposure at Various Temperatures

TABLE I

AUTHOR: L. R. Mason

Date: 9-14-61

PAGE 4

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

V. PRINCIPAL PROPERTIES:

C. Electrical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

7. PRINCIPAL PROPERTIES:

D. Chemical

Information was not obtained due to lack of need for Boeing-Wicaita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

VI. RECOMMENDED USES:

It is recommended that the information in Table I be used as a guide in predicting the probable temperature limitations of the enamels and lacquers tested.

VII. SUPPLIERS, AVAILABILITY, AND COSTS:

A. Suppliers

Enamel No. 5: Rinshed-Yason, Incorporated
Milford at Epworth
Detroit 10 Michigan

Enamel No. 3, 4, and 6; and lacquer No. 11:
Andrew Brown Company
5413 South District Blvd.
Los Angeles, California

Enamel No. 1: W. P. Fuller Company
Mission and Beale Streets
San Francisco, California

Enamel No. 2: The Glidden Company
10999 Madison Avenue
Cleveland 2, Ohio

Lacquers No. 7, 8, 9, 10, and 12:
Emar, Incorporated (Formerly Titanine, Incorporated)
1424 Eas. 25th Street
Wichita, Kansas

B. Availability

All these enamels and lacquers are currently available from their manufacturers.

C. Cost

These enamels and lacquers are all in the medium price range.

BOEING AIRPLANE COMPANY
WACATA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Enamels and Lacquers

VIII. REFERENCE:

1. Boeing Company Materials and Process Unit Document D3-1598,
"Temperature Limits of Marking Materials (Phase I)".

AUTHOR: L. R. Mason

Date: 9-14-51

PAGE 8

MATERIALS & PROCESS UNIT

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Epoxy Organic Coatings

III. GENERAL DESCRIPTION:

The organic coatings are used for protective and decorative purposes on the exterior or interior of aircraft. The organic coatings consists of a primer and an enamel. For interior purposes the primer alone is used and for exterior purpose both the primer and enamel are used as a system.

The materials for the organic coating are controlled by Boeing Material Specification 10-15. The only restriction on materials is that the vehicle used in the formulation of the primer and enamel shall be of a two component epoxy type. The color of the primer may be either off-white, light yellow or green. The color of the enamel is untinted white conforming to AN 511 of ANA Bulletin 166. Exact pigments to be used either for the primer or enamel is not restricted. In general, the formulation and specific properties will vary from manufacture to manufacture.

The epoxy organic coatings are applied by conventional spray equipment. Application by brush or air-less spray equipment is not recommended.

IV. DEVELOPMENT BACKGROUND:

The epoxy organic coatings were developed under Boeing Company Engineering Development Proposal 306, Flight Test Evaluation of Light Undercoat Exterior Finishes.

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

Since formulation of these epoxy organic coatings are given wide latitude, the principal properties are only known in-so-far as the epoxy coatings conform to the performance requirements of Boeing Material Specification 10-15.

A. Mechanical

1. Adhesion - excellent
2. Hardness - minimum pencil hardness of H
3. Glass - minimum of 85
4. Weather Resistance - excellent
5. Humidity Resistance - excellent

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-6-6

II. MATERIAL NAME: Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

B. Thermophysical

1. Heat Resistance - maximum operational temperature is 350°F.
2. Low Temperature Resistance - minimum operational temperature is 35°F.
3. Thermal Shock - no loss of adhesion upon rapid cooling from 140°F. to -55°F.

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-8-5

II. MATERIAL NAME: Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

C. Electrical

Information no available due to lack of need for Boeing - Wichita
investigating this property.

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Epoxy Organic Coatings

V. PRINCIPAL PROPERTIES:

D. Chemical

1. Fluid Resistance - Resistant to water, MIL-E-52014, MIL-L-7808 and MIL-S-3136 Type III.
2. Pot Life - minimum of 16 hours.

I. CATEGORY: Liquid and Semi-solid High Polymers CODE: 7-8-6

II. MATERIAL NAME: Epoxy Organic Coatings

VI. RECOMMENDED USES:

Since epoxy organic coatings are more expensive than the usual type of organic coating, use is recommended only for protection against severe environments.

VII. SUPPLIERS, AVAILABILITY AND COST:

Cost of the primer and enamel is the same and is approximately \$8.50 per mixed (base component plus catalyst) gallon.

Epoxy organic coatings conforming to Boeing Material Specification 10-15 are available from the following paint manufacturers:

1. Sherwin Williams
Los Angeles, California
2. Andrew Brown
Irving, Texas
3. W. P. Fuller Company
Los Angeles, California

VIII. REFERENCES:

- A. Boeing Materials Specification 10-15
- B. Boeing Engineering Development Proposal 305, Flight Test Evaluation of Light Undercoat Exterior Finishes

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

III. GENERAL DESCRIPTION:

The neoprene coating described herein is controlled by MIL-C-27315 which specifies a primer and white rain erosion resistant coating of a solvent dispersed elastomeric type suitable for brush or spray application to plastic laminates. The purpose of the coating system is to protect aircraft and missile exterior plastic parts from rain erosion and thermal radiation.

IV. DEVELOPMENT PROGRAM:

Engineering Change Proposal 939 changed the rain erosion resistant coating for B-52 exterior plastic parts from the non-thermal reflective MIL-C-7439 coating to the thermal reflective MIL-C-27315 coating. The topcoat of the sole qualified source was unsatisfactory for spray application due to excessive viscosity reduction of the package material to eliminate cobwebbing. Preliminary work indicated that an entirely different type of thinner was required from that recommended by the manufacturer. Thus, it was necessary that an appropriate thinner be found and also that the performance of the system not be impaired as a result of deviating from the manufacturers recommended viscosity reduction procedure. This work was done under Boeing-Wichita Job Report F-2-189, Investigation of MIL-C-27315 Thermally Reflective Rain Erosion Resistant Coating.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-E-9

II. MATERIAL NAME: Neoprene Organic Coating

V. PRINCIPAL PROPERTIES:

A. Mechanical

1. Adhesion - Excellent.
2. Water resistance - Excellent except for yellowing.
3. Weather resistance - Excellent except for yellowing.
4. Viscosity reduction - There is no known topcoat thinner that will provide both cobweb elimination and adequate film build without sags. The most satisfactory known viscosity reduction procedure is a 1:4 up to 1:6 reduction of topcoat at package viscosity with methyl ethyl ketone. At this reduction approximately 125 coats are required to obtain a 10 mil coating free of sags.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

V. PRINCIPAL PROPERTIES:

B. Thermophysical

1. Thermal Shock Resistance - The coating system suffers no loss of adhesion upon rapid cooling from 140°F to -65°F.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

V PRINCIPAL PROPERTIES:

D. Chemical

1. Aromatic Fuel Resistance - The coating system is resistant to aromatic fuel.

I. CATEGORY: Liquid and Semi-Solid High Polymers CODE: 7-8-9

II. MATERIAL NAME: Neoprene Organic Coating

VI. RECOMMENDED USE:

None other than that specified by MIL-C-27315.

VII. SUPPLIERS, AVAILABILITY AND COST:

1. The supplier of the neoprene coating investigated by The Boeing Company is given below. This neoprene coating is currently available.

Gates Engineering Company
Wilmington 99, Delaware

Gaco N-16 Primer (Red Color)
Gaco N-83 White Neoprene Topcoat

2. Cost:

- a. Primer \$14.00 per gallon.
- b. Topcoat \$12.50 per gallon.

VIII. REFERENCES:

1. MIL-C-27315, Coating System, Elastomeric Thermally Reflective, Rain Erosion Resistant and Antistatic, For Aircraft and Missile Exterior Plastic Parts.
2. MIL-C-74393, Coating System, Elastomeric, Rain Erosion Resistant and Rain Erosion Resistant with Anti-Static Treatment, for Exterior Aircraft and Missile Plastic Parts.
3. Boeing-Wichita Job Report F-2-189, Investigation of MIL-C-27315 Thermally Reflective Rain Erosion Resistant Coating.

- I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-5-0
- II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

III. GENERAL DESCRIPTION:

The object of this program was to investigate methods to decrease the amount of lint entering the fuel system by controlling lint production of uniforms worn by personnel.

IV. DEVELOPMENTAL BACKGROUND:

It was found that lint accounted for a large amount of the fuel contamination in the B-52C. This program was initiated in an effort to determine the lint shedding characteristics of cotton and synthetic garments, and to determine means of decreasing the amount of lint produced by these garments.

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

A. Mechanical

The following materials tabulated in their order of lint suppression effectiveness:

<u>Order</u>	<u>Trade Name</u>	<u>Chemical Name</u>	<u>Manufacturer</u>	<u>Strength of Solution</u>	<u>Method of Applying Material</u>
A	Elvanol	Polyvinyl	Dupont	1/8 by wt. Water	Test material immersed in solution
B	Revlon Hair Spray	Proprietary Cosmetic	Revlon, Inc., N.Y.	As Pkgd.	Material applied by spray from pressurized container
C	Methocel Partially Acetylated	Methyl-Cellulose	Dow Chem.	1/8 by wt. by water	Test material immersed in solution

The supporting data is shown in Table I and II as well as shown in Figures 1, 2, 3 and 4.

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

TEST SECTION	NEW MATERIAL Lint Weight Grams	USED MATERIAL Lint Weight Grams	COMMENTS New Material	COMMENTS Used Material
No Treatment	0.0208	0.0361	Average Value (Seven tests run for Standardization)	Average value (Two tests run for Standardization)
(Methylcellulose)				
Methocel 1% ^a	0.0246 ^a	0.0154	Less lint, but small particles of sizing material increased total weight.	Lint decreased appreciably.
(Methylcellulose)				
Methocel 5% ^a	0.0144	Not tested	Lint decreased - Material too stiff for personnel to wear.	Material would be too stiff for personnel to wear.
Polyac (MSR 301)	0.0332	0.0280	Heavy lint deposit, and particles of sizing material.	Slight weight decrease. Lint deposit heavy.
Starch (Lint) 1% ^a	0.227	0.0571	Heavy lint deposit, and particles of sizing material.	Heavy lint deposit break-down of test piece, in some areas gave high lint weight.
(Polyvinyl Alcohol) Grade 50-42				
Elvinal 1% ^a	0.0102	0.0087	Lint decreased sub- stantially. Material not excessively stiff.	Lint decreased substantially. Material not ex- cessively stiff.
Revlon Hair Spray	0.0215 ^a	0.0108	Lint decreased, small particles of sizing material present. Material not stiff.	Lint decreased, small particles of sizing material present. Material not stiff.
No treatment inside surface of garment tested	0.0229	0.0222	Slightly greater linting tendency than wear surface.	Slightly less linting tendency, than wear surface.
Material washed once with soap and water	0.0357	Not Tested	Sizing removed, shows more lint than un- washed material.	Material not tested due to previous washings.

^a The new material showed some inconsistencies due to removal of the sizing material during testing. The weight in cases shown was due to the presence of sizing material on the filter, and not entirely to the lint deposit. The used material data shows a more reliable indication as to results to be expected from use of the lint suppressing materials.

TABLE I

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabric for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

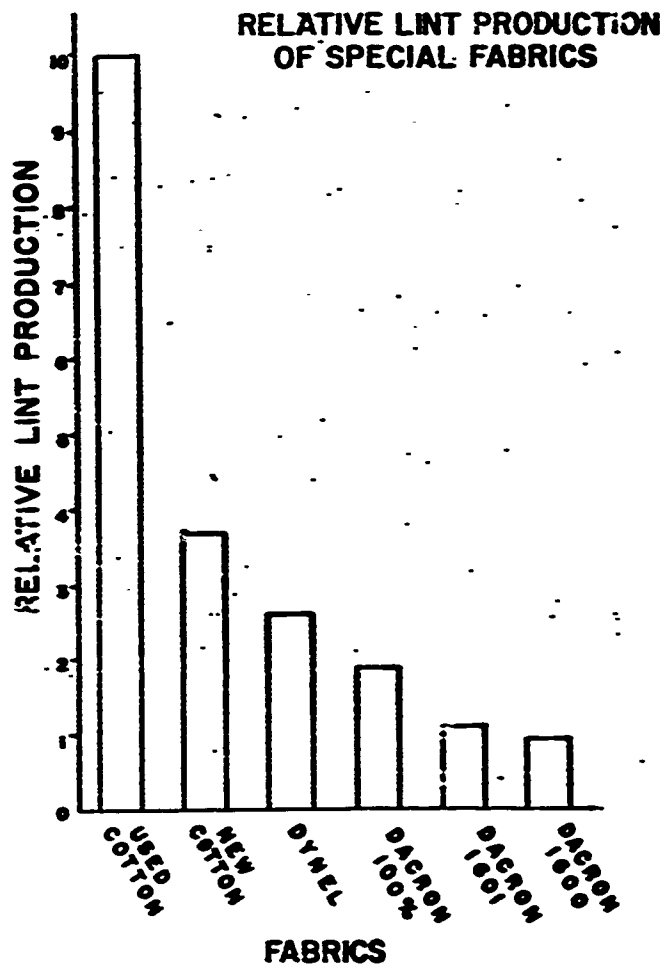


FIGURE 1

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

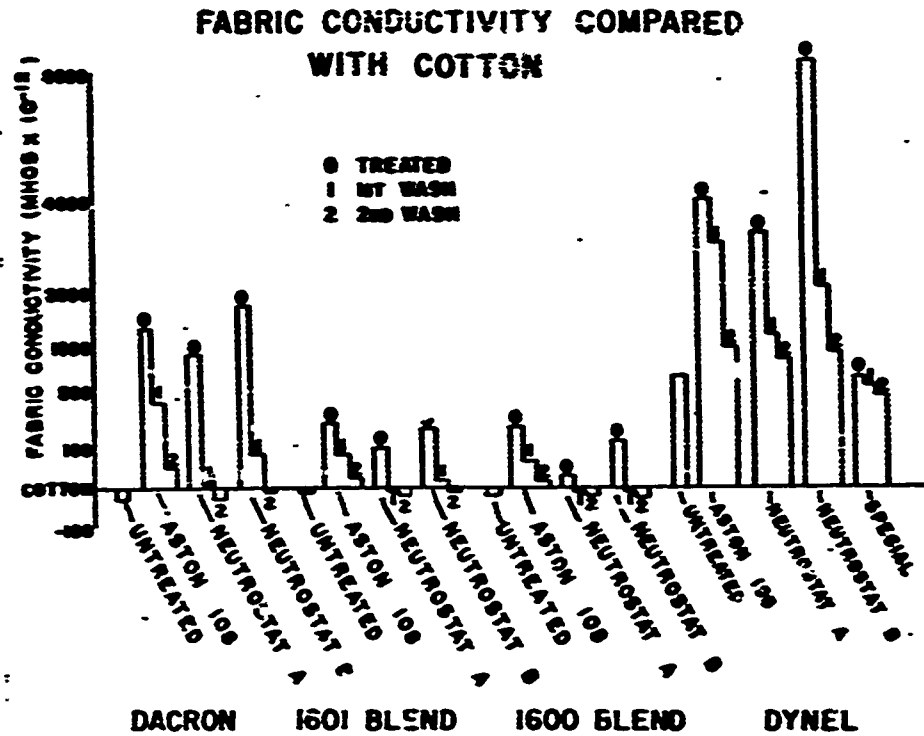


FIGURE 2

255

I. CATEGORY: Fibrous and Filamentary Materials CODE: E-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

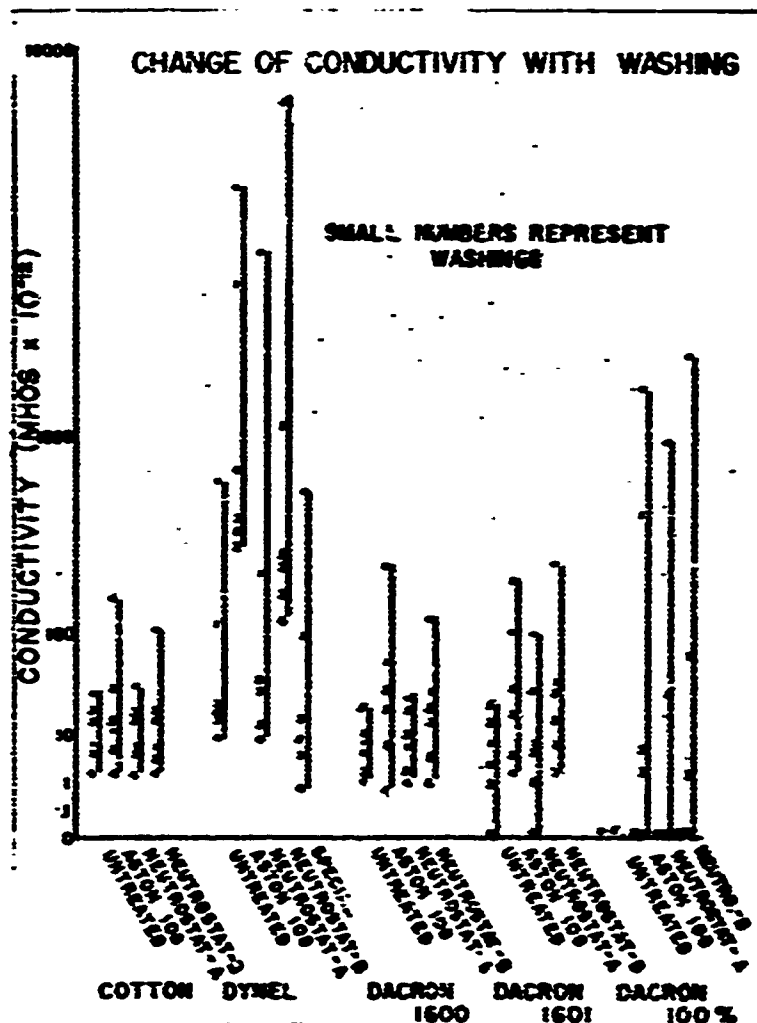


FIGURE 3

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

**PERCENT OF TREATMENT LOST
IN FIRST AND SECOND WASHING**

(DETERMINED FROM CONDUCTIVITY MEASUREMENTS)

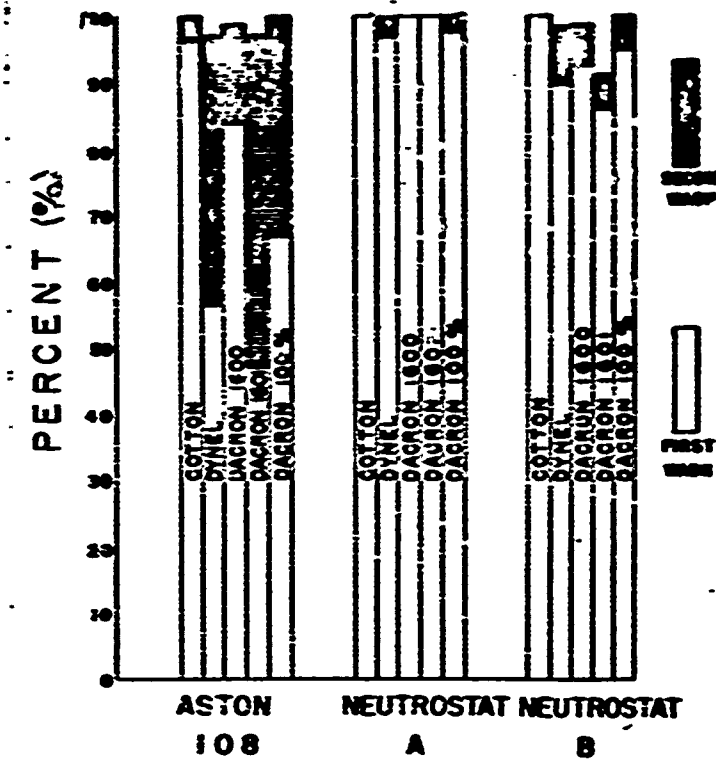


FIGURE 4

260

I. CATEGORY: Fibrous and Filamentary Materials **CODE:** 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

The strength of the material was determined for each sample and is recorded as follows:

<u>SAMPLE NUMBER</u>	<u>STRENGTH</u>	<u>REMARKS</u>
1	188	Standard Sample
2	202	Standard Sample
3	200	Standard Sample
4	208	Standard Sample
5	207	Standard Sample
6	212	Standard Sample
7	208	Standard Sample
8	206	4 days in NS 3-2, Type I
9	209	4 days in NS 11-7
10	223	4 days in methyl ethyl ketone
11	200	4 days in NS 3-2, Type I
12	200	4 days in NS 11-7
13	200	4 days in methyl ethyl ketone
14	228	8 days in NS 3-2, Type I
15	228	8 days in NS 11-7
16	220	8 days in methyl ethyl ketone
17	207	8 days in NS 3-2, Type I
18	201	8 days in NS 11-7
19	200	8 days in methyl ethyl ketone

• (7) Fill Direction (8) Warp Direction.

Test results indicate that no change in strength or weight of decron blend #1600 samples could be related to the samples being subjected to NS 3-2, (Type I), NS 11-7 and methyl ethyl ketone for a period of 8 days. The Quality Control Laboratory is not equipped to differentiate between decron blends and therefore cannot analyze the material to identify fabric composition.

TABLE II

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's investigation of this property.

I. CATEGORY: Fibrous and Filamentary Materials CODE: 6-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's investigation of this property.

BOEING AIRPLANE COMPANY
MICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Fibrous and Filamentary Materials CODE: 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Michita's investigation of this property.

AUTHOR: W. P. Massions

DATE: 9-13-51

PAGE II.

MATERIALS & PROCESS UNIT

I. CATEGORY: Fibrous and Filamentary Materials **CODE:** 8-8-0

II. MATERIAL NAME: Investigation of Fabrics for Lint-Free Condition

VI. RECOMMENDED USES:

Elvanol, Grade 50-42, recommended for addition to cotton protective clothing, the strength of the solution being one percent by weight in water, applied by immersion in the solution. It was further recommended that when new uniforms are ordered, that the cotton overalls be replaced by synthetic dacron blend #1600 fabrics. This recommendation is supported by Table II and Figures 1, 2, 3, and 4.

VII. SUPPLIERS AND TRADE NAMES:

Dacron 1600 Fabrics from Warklon, Inc.
253 West 28th Street
New York 1, New York

"Neutrostat B"
The Sinco Company
Lansdale, Pennsylvania

Dacron Blend #1600 - H.P. Ogden Co.
Empire State Building
New York, New York

Polyvinyl Alcohol
Elvanol Grade 50-42
E. I. duPont de Nemours Co.

VIII. REFERENCES:

- A. Boeing-Wichita Manufacturing Research Report 67.5, "Lintless Fabric Clothing vs Present Protective Clothing, Comparative Evaluation."

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

III. GENERAL DESCRIPTION:

The objective of this program was to prepare and apply combinations of ceramic adhesives and brazing alloys for metal to metal bonding suitable for use at elevated temperatures.

IV. DEVELOPMENT BACKGROUND:

The high temperature use of ceramic materials for various applications makes ceramic adhesives a logical method of bonding structures subjected to service temperatures in excess of the 400°F. maximum use temperature of organic adhesives.

Unfortunately, the strength and ductility of existing ceramic adhesives are not comparable with the competitive method of bonding which is brazing.

A disadvantage in the use of brazing lies in the fact that protective atmosphere must be used to prevent the metal from oxidizing.

It was proposed that brazing alloys be combined with ceramic adhesives. It was felt that the ceramic adhesive would prevent oxidation of the base metal, and the bonding characteristics of the adhesive coupled with the bonding ability and ductility of the braze material would produce a bond, when fired in air, which would be superior to the ceramic adhesives reported in the literature.

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

III. PRINCIPAL PROPERTIES:

A. Mechanical

1. Room temperature lap shear strengths of ceramic adhesive-Silvaloy 245 Pd after 100 hours exposure to salt spray test (MIL-STD-202B, Method 101A)

Standard (No Salt Spray Exposure)

100 Hours Salt Spray

<u>Specimen</u>	<u>Room Temp. Lap Shear Strength (psi)</u>	<u>Specimen</u>	<u>Room Temp. Lap Shear Strength (psi)</u>
1	24,300	1	24,342
2	23,125	2	25,107
3	29,155	3	24,060
Average	25,530	Average	24,915

2. See Section B for additional mechanical properties.

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Elevated temperature lap shear strengths of A-200 alloy bonded with ceramic adhesive-Silvaloy Ed 845 brazing alloy combination.

<u>Temp. (°F.)</u>	<u>Sample</u>	<u>Lap Shear Strength (psi)</u>
Room	1	24,000
	2	25,470
	3	25,289
	Average	25,379
250	1	20,413
	2	21,750
	3	21,328
	Average	22,910
500	1	14,175
	2	22,812
	3	15,500
	Average	16,996
750	1	9,718
	2	8,127
	3	
	Average	8,932
1000	1	5,025
	2	5,350
	3	
	Average	5,188

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing - Wichita's
investigating this property.

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

V. PRINCIPAL PROPERTIES:

D. Chemical

1. Ceramic Adhesive Composition

a. Frit Raw Batch Composition

Powdered Quartz	68
Sodium Nitrate	5
Sodium Carbonate	17
Calcium Carbonate	27
Boric Acid	185
Sodium Silico Fluoride	5

Smelted at 2300°F.

b. Mill Addition

Frit	100
Molybdenum Oxide	3/4
Chrome Oxide	4
Water	1 1/2

2. Brazing Alloy Composition

	(1)	(2)
Silver	92.5	84.5
Copper	7.3	7.4
Lithium	0.2	0.2
Palladium		2.4
Indium		5.5

I. CATEGORY: Composite Materials

CODE: 9-2-1

II. MATERIAL NAME: Ceramic Braze

VI. RECOMMENDED USES:

This method of bonding would be used for honeycomb sandwich lap bonded structures, and other metal joining problems where structural adhesives or brazing would be suitable. The present state of the research on this project does not make it ready for release as a pilot plant or production process.

VII. SUPPLIERS AND TRADE NAMES:

A. Brazing Alloys

1. Silver-Base Alloys

Hendy and Harmon
60-64 Fulton Street
New York 36, New York
"Lithobraze 925"

Engelhard Industries, Inc.
231 New Jersey R.R. Ave.
Newark, New Jersey
"Silvaloy Pd 845"
"Silvaloy AE 100"

B. Availability

Silver-base alloys available as foil, strip and powder. Ceramic adhesives would have to be smelted in own laboratory or by porcelain enamel frit manufacturers.

VIII. REFERENCES:

1. SAC Document D3-3025 "Ceramic Adhesive Systems"
2. SAC Document D3-3746 "Ceramic Adhesive Systems"

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

III. GENERAL DESCRIPTION:

The data presented herein covers some fatigue properties of Epon 828 - Tonox, Style 143V glass fabric laminates.

IV. DEVELOPMENTAL BACKGROUND:

The fatigue data was developed specifically for application to design of a 1/2 scale model. The scale model was designed with all plastic construction to duplicate deflections of a full-size all metal design.

I. CATEGORY: Composite Material

CODE: 9-7-1

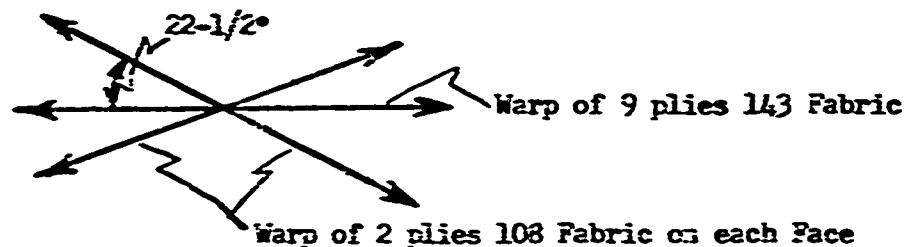
II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES:

A. Mechanical Properties - Fatigue

Laminate Preparation

All laminates were prepared by vacuum bag void-free techniques and post-cured three hours at 400°F. Resin composition was 26.5 parts by weight of Tonox to 100 parts Epon 828 by weight. Each laminate consisted of nine plies of parallel laminated 143V glass fabric and two plies of 108 glass fabric on each face. The 108 glass fabric was laid up as shown below:



Test Procedures

Static physical strengths were determined per LP-406b. Fatigue specimens were tested in Sonntag SF-10U fatigue machines. Photographs EWA-14566 and EWA-14567 show views of the test set-up. The first fatigue specimen (No. 1) had a test section width of 2.00 inches and a grip section width of 5.0 inches while the second specimen (No. 2) had a grip width of 3.5 inches. A two inch radius was used for transition from the test section to grip section. These specimens are shown in photograph EWA-19762. The remaining specimens contained an elliptical test section having a minimum width of 1.0 inch and a grip section width of 1.98 inches. These specimens are shown in photographs EWA-14429 and EWA-19763. Maximum stress levels used in conducting the tests ranged from 30,850 psi to 55,500 psi with a maximum to minimum stress ratio of 0.62.

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical Properties (continued)

Test Results

Specimens number 1 and number 2 failed in shear beginning in the radius and extending into the end fitting. These failures are shown in photograph EWA-19762.

Failure of the elliptical test specimens appeared to begin as tensile failure in the test section and then progress as shear into the end section. These failures are shown in photographs EWA-14429 and EWA-19763.

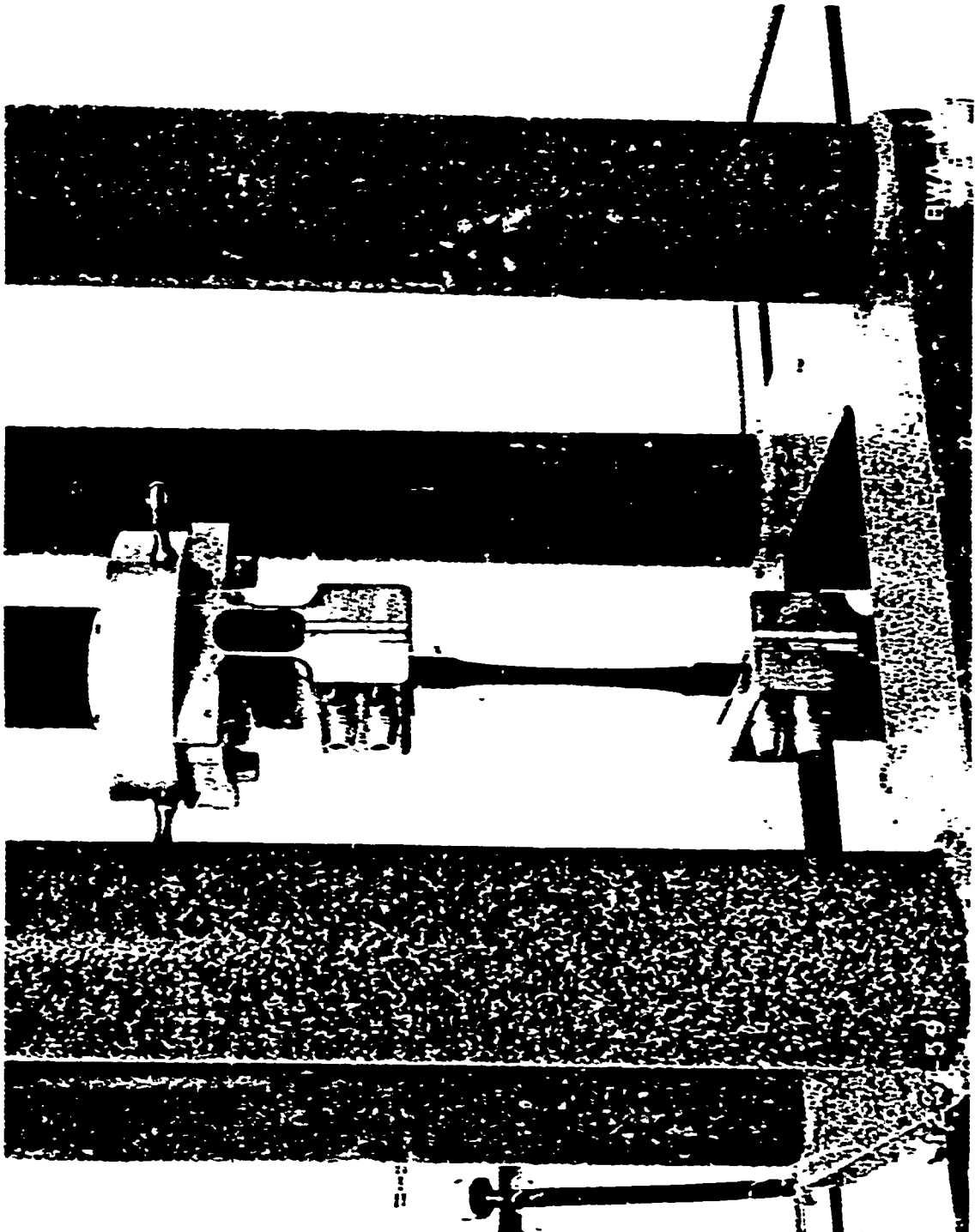
Failures varied from 1000 cycles at a maximum stress level of 55,500 psi to no failure after 50,000,000 cycles at a maximum stress level of 30,850 psi.

All data is presented in figures 1 through 5.

I. CATEGORY: Composite Material

CODE: 4-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Sifton

HWA-14566

14 August 1961

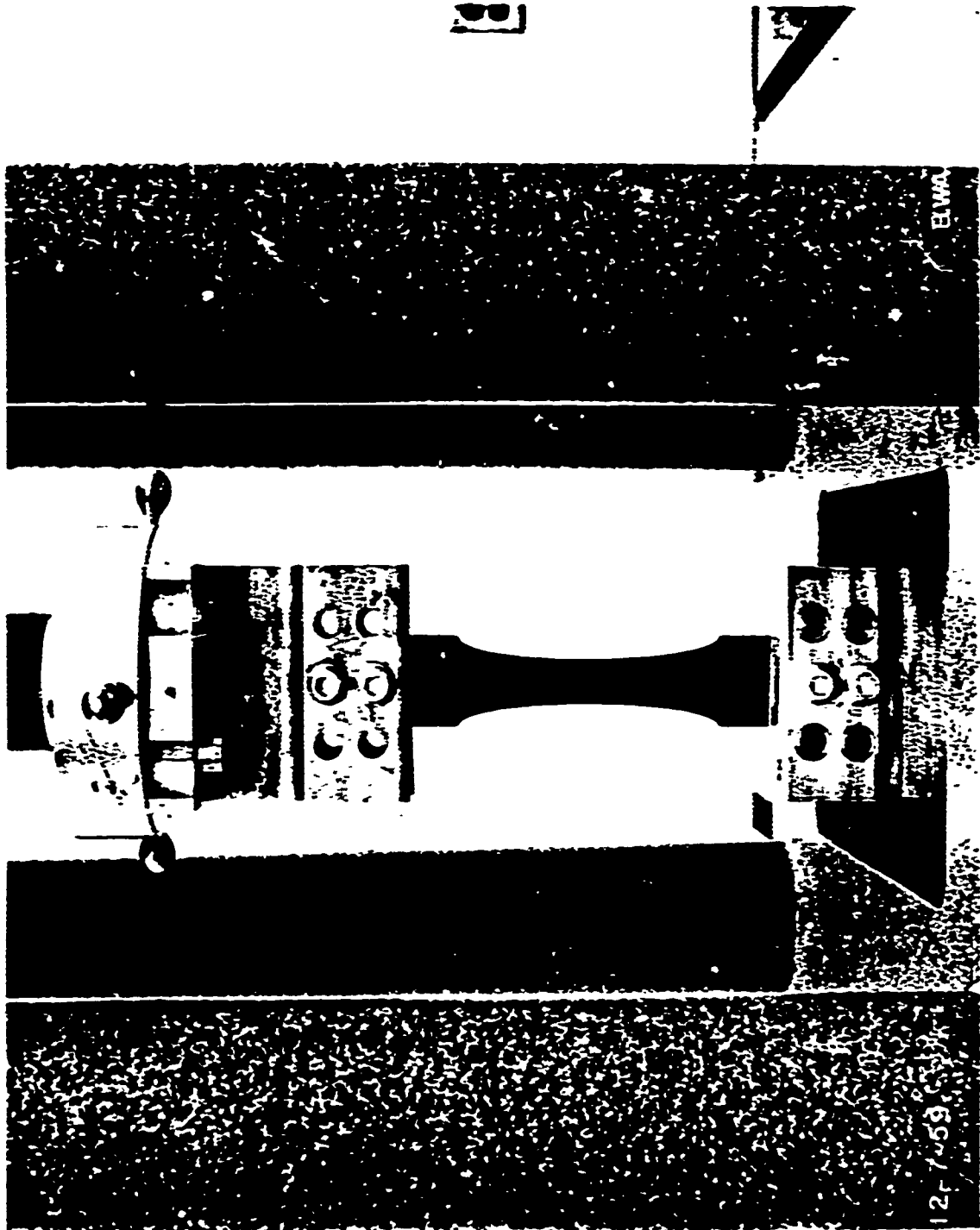
PAGE 4

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I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton jr

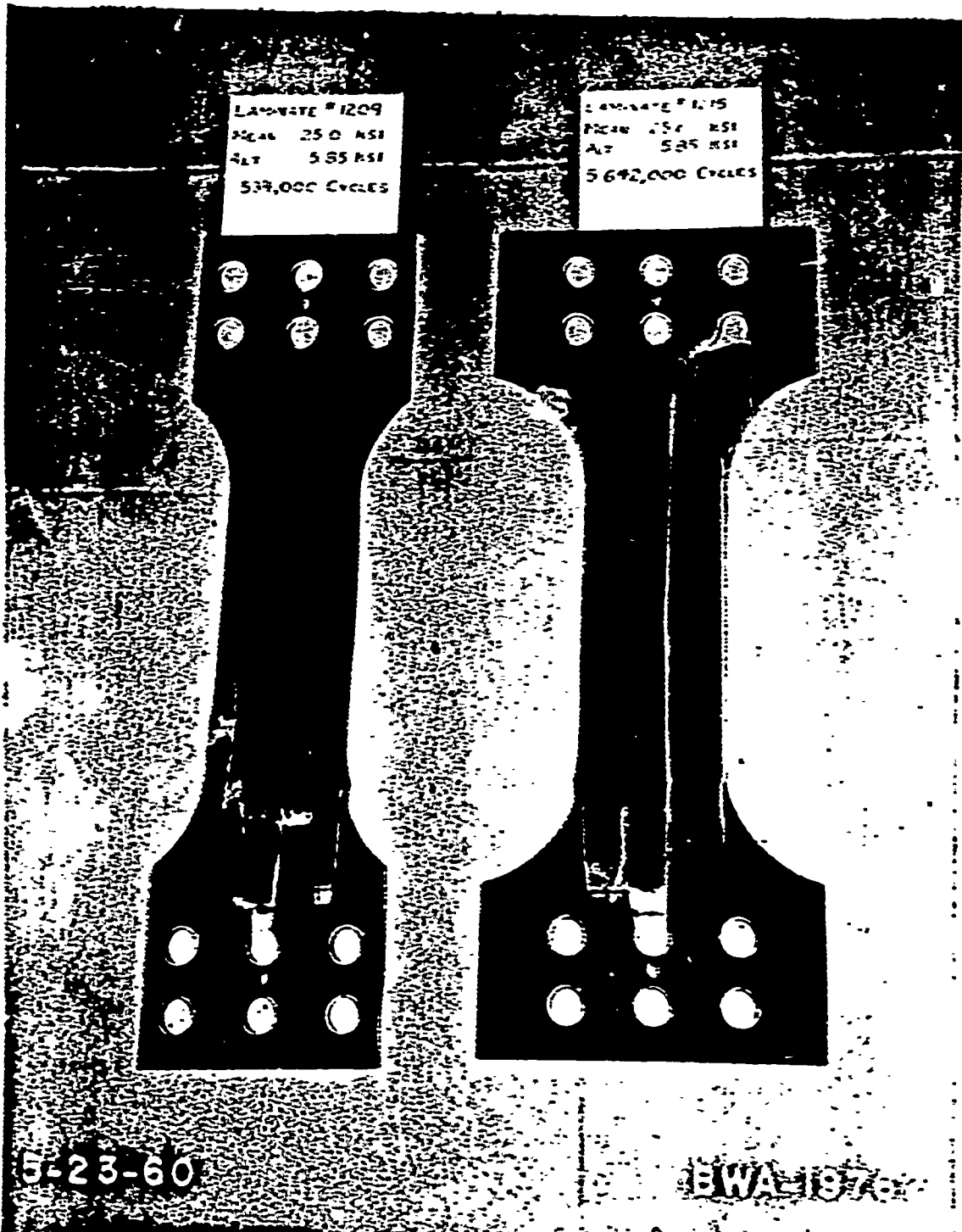
37A -1-5-7
14 August 1961

PAGE 5

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton JE

BWA-19762
14 August 1961

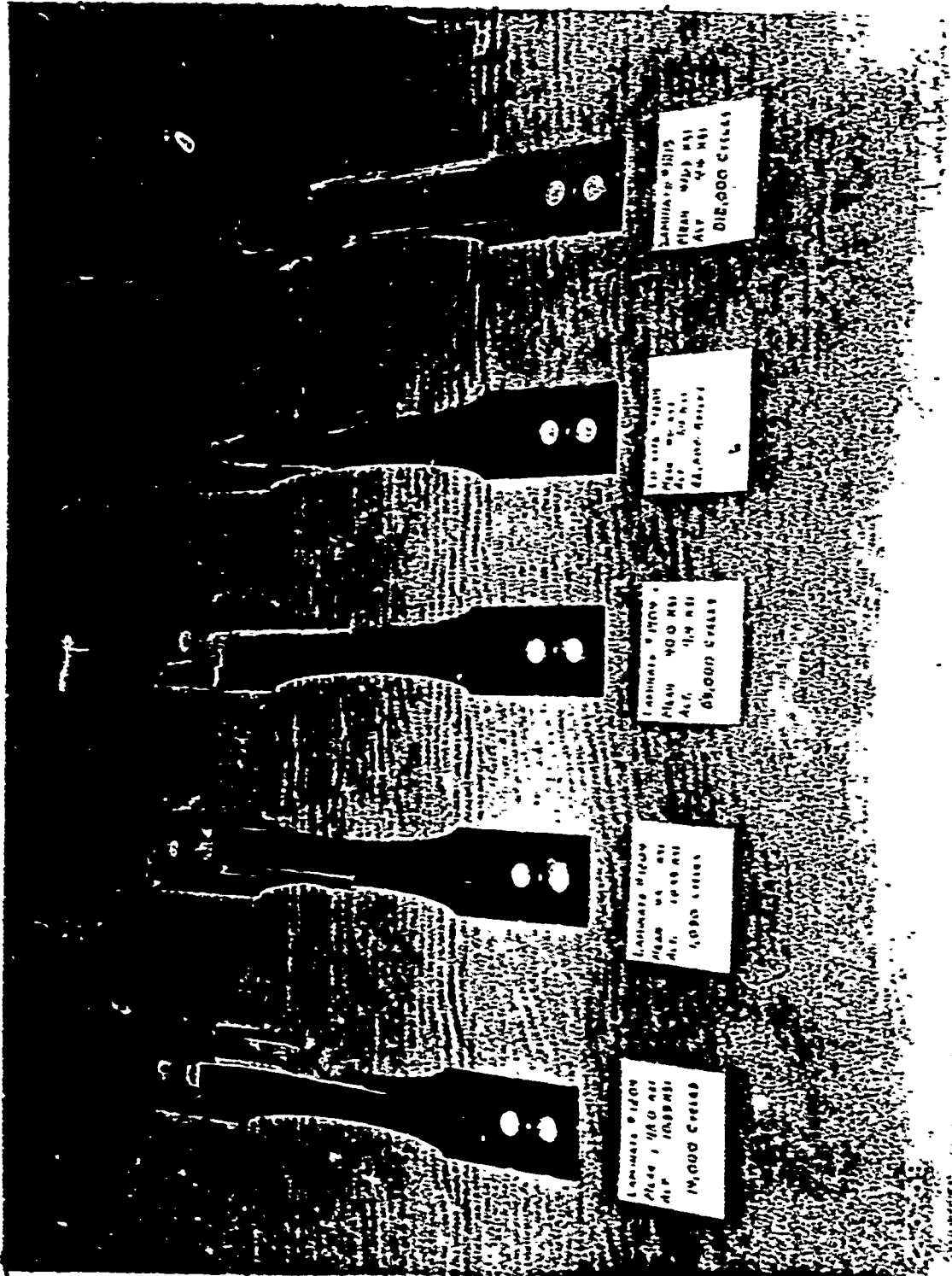
PAGE 6

MATERIALS & PROCESS UNIT

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 826 and 143 Glass Fabric Laminates



AUTHOR: J. Elton *JE*

BNA-14-29
14 August 1961

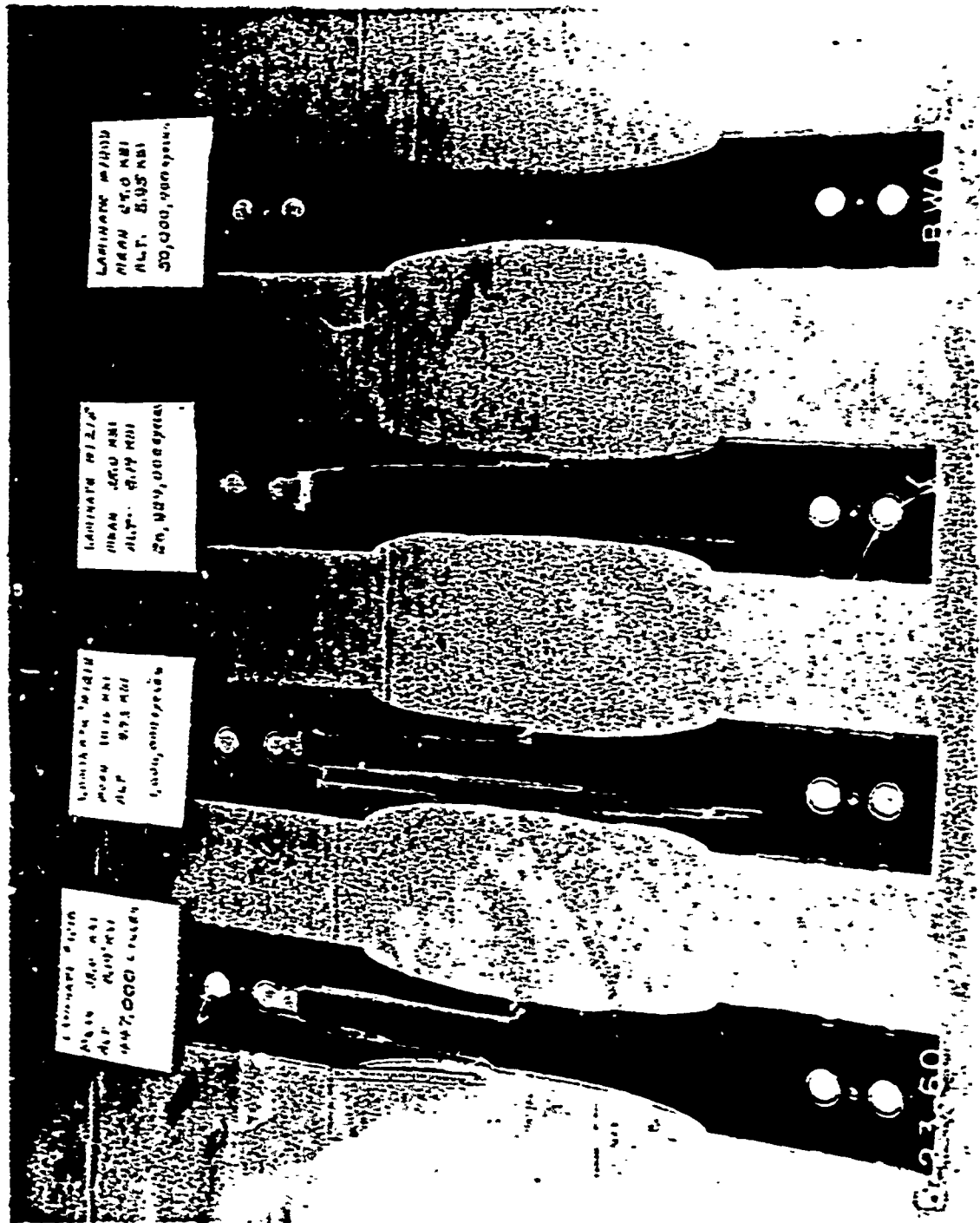
PAGE 7

MATERIALS & PROCESS UNIT

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



AUTHOR: J. Elton JE

EMA-19763
14 August 1961

PAGE 8

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

<u>SPECIMEN</u> <u>NUMBER</u>	<u>LAMINATE</u> <u>NUMBER</u>	<u>WIDTH</u> <u>INCHES</u>	<u>THICKNESS</u> <u>INCHES</u>	<u>STRESS LEVEL</u> <u>PSI</u>	<u>RANGE OF</u> <u>CYCLES TO</u> <u>FAILURE</u>	<u>TYPE OF</u> <u>FAILURE</u>
1	1215	2.00	.074	25,000 ± 5,850	5,612,000	Shear
2	1209	2.00	.078	25,000 ± 5,850	534,000	Shear
3	1209	0.98	.077	25,000 ± 5,850	30,000,000	No Failure
4	1215	1.14	.075	35,000 ± 8,190	26,829,000	
5	1216	1.15	.080	35,000 ± 8,190	447,000	
6	1215	1.14	.074	38,150 ± 8,930	3,606,000	
7	1215	1.16	.074	40,000 ± 9,400	212,000	
8	1209	1.16	.076	40,000 ± 9,400	22,000	
9	1204	1.16	.082	40,000 ± 9,400	65,000	
10	1204	1.15	.086	45,000 ± 10,590	1,000	
11	1204	1.15	.090	45,000 ± 10,590	14,000	

▷ Initial failure was tensile and then progressed as shear into the end fitting section.

FIGURE 1

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

Test No. 7270
 Part A Plate
 No. of Pile
 Rev.

Section Number No.
 Test Number
 Date of Testing

1. 100° at Room Temperature
 2. Boil 2 hrs in Dist. Water 140, Test. at RT

Spec. No.	Test Condition	Warp %	Shrink %	Area (sq in)	Area Concentration (lb/sq ft)	Weight (lb)	Weight Concentration (lb/sq ft)	Moisture (%)	Moisture Absorption (lb/sq ft)	Moisture Concentration (lb/sq ft)	Avg. Thickness (in)	Avg. Density (lb/in ³)
1	1	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
2	2	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
3	3	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
4	4	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
5	5	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
6	6	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
7	7	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
8	8	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
9	9	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
10	10	0.50	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00

0 = 0
 0.5 = 0.5
 1 = 1
 2 = 2
 3 = 3
 4 = 4
 5 = 5
 6 = 6
 7 = 7
 8 = 8
 9 = 9
 10 = 10

1 = Value of Specimen (inches)
 2 = Thickness of Specimen (inches)
 3 = Weight of Specimen (lb)
 4 = Weight Concentration (lb/sq ft)
 5 = Moisture Concentration (lb/sq ft)
 6 = Moisture Absorption (lb/sq ft)
 7 = Area Concentration (lb/sq ft)
 8 = Area (sq in)
 9 = Shrink %
 10 = Warp %

FIGURE 3

AUTHOR: J. Elton Jr

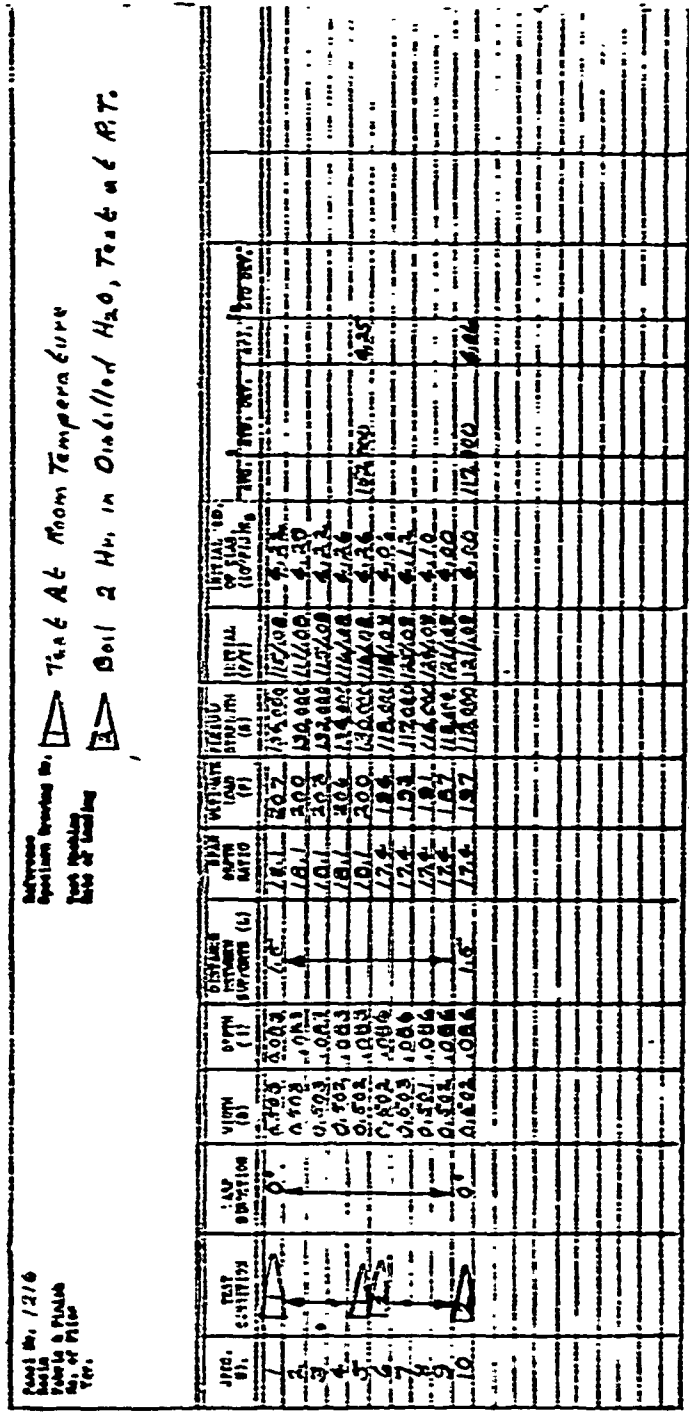
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I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates



0 = Flaws, cracks, etc.
 1 = Brittle failure, etc.
 2 = Failure between supports, laminar
 3 = Failure of body, laminar
 4 = Failure of body, laminar
 5 = Failure of body, laminar
 6 = Failure of body, laminar
 7 = Failure of body, laminar
 8 = Failure of body, laminar
 9 = Failure of body, laminar
 10 = Failure of body, laminar

FIGURE 4

AUTHOR: J. Elton JE

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I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

RESIN CONTENT										
Laminate No.	Spec. No.	Cru. No.	Cru. Spec. (g)	Cru. Wt. (g)	Spec. Wt. (g)	Ignited Cru. Spec. (g)	Loss of Wt. (%)	Thickness (inches)	% Resin	Avg. Resin Co. (%)
1216	1	117	19.2228	16.6300	2.5728	12.4726	0.7302	0.820	28.4	
	2	123	19.5732	16.9716	2.6116	12.8313	0.7519	0.830	28.8	
	3	125	19.0200	16.3515	2.6685	12.1206	0.8454	0.840	31.7	29.6

BARCOL HARDNESS

Laminate	1216	
Barcol Hardness	75	
	69	
	69	
	69	
	73	
	73	
	73	
	73	
	75	
Average Barcol Hardness	72	

AUTHOR: J. Elton jE

FIGURE 5
 14 August 1961

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I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES:

B. Thermophysical:

Information not available due to lack of need for Boeing-Wichita
investigating this property.

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES:

C. Electrical:

Information not available due to lack of need for Boeing-Wichita
investigating this property.

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

V. PRINCIPAL PROPERTIES:

D. Chemical:

Information not available due to lack of need for Boeing-Wichita investigating this property.

I. CATEGORY: Composite Material

CODE: 9-7-1

II. MATERIAL NAME: Epon 828 and 143 Glass Fabric Laminates

VI. RECOMMENDED USES:

1. Applications requiring the properties of this material.

VII. SUPPLIERS AND TRADE NAMES:

1. Epon 828, Shell Chemical Corporation.
2. Tonox, Naugatuck Chemical Company

VIII. REFERENCES:

1. Boeing-Wichita Job Report No. AP-1-18; Determination of The Fatigue Properties of Epon 828 Reinforced With 143 Glass Fabric.

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 1S1 Volan and 1S1-A-1100 Silane Finish Fabric

III. GENERAL DESCRIPTION:

The objective of this program was to determine the feasibility of using A-1100 silane finish fabric with epoxy resins.

IV. DEVELOPMENTAL BACKGROUND:

A variety of fabric finishes are available for glass cloth laminates. The proper finish must be selected to use with the correct resin to obtain the maximum properties from the finished product. Most fabric finishes falls into three categories, heat cleaned, chrome finished and Silane finished.

Volan A, a chrome finish fabric is the most universally used with epoxies and polyesters. A-1100, a Silane finish recently developed for use with epoxies and phenolics, has been reported to yield Mechanical Properties equal to the ones obtained with Volan finished fabric when used with epoxy resins.

Commercial literature released by leading glass fabric manufacturers, state that the wet retention strength of laminates using A-1100 is superior to other finishes because of the better wetability of the fabric. (This was found to be untrue).

It was felt that an evaluation of the Silane finished fabric was needed to verify the data released by commercial sources. Therefore, this job was initiated.

AUTHOR: E. Lofton

DATE: 9-11-61

PAGE 1.

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

A. Mechanical

Laminate No.	1298	1299	1302	1303
% Resin Content	25.2	27.5	33.3	27.9
Finish of Fabric	181 Volan A	181 Volan A	A-1100 Silane	A-1100 Silane
Direction of Fabric Layup	Parallel Kested	Isotropic 45°	Isotropic 45°	Parallel Kested
Av. Flexural Strength at R.T. PSI	115,200	78,200	55,300	81,100
Av. Flexural Modulus at R.T. PSI	4.65x10 ⁶	3.76x10 ⁶	2.93x10 ⁶	3.95x10 ⁶
Av. Flexural Strength at R.T. After Being Conditioned for 30 Minutes at 180°F PSI	111,700	74,800	58,100	84,900
Av. Flexural Modulus at R.T. After being Conditioned for 30 minutes at 180°F PSI	4.57x10 ⁶	3.70x10 ⁶	2.95x10 ⁶	3.97x10 ⁶
Av. Flexural Strength at R.T. after 2 Hr. Boil in distilled water, PSI	107,700	73,500	55,000	82,900
Av. Flexural Modulus at R.T. after a 2 Hr boil in Distilled Water PSI	4.60x10 ⁶	3.34x10 ⁶	3.00x10 ⁶	3.77x10 ⁶

I. CATEGORY: Composite Materials CODE: 9-7-1

II. MATERIAL NAME: 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

A. Mechanical (continued)

	1298	1299	1302	1303
Av. Flexural Strength at R.T. after being Con- ditioned for 192 Hrs. at 350°F PSI	109,900	79,600	65,000	89,300
Av. Flexural Modulus at R.T. after being Con- ditioned for 192 Hrs. at 350°F. PSI	4.63x10 ⁶	3.34x10 ⁶	3.21x10 ⁶	4.16x10 ⁶
Av. Tensile Strength at R.T. PSI	73,300	44,300	39,600	59,700
Av. Tensile Modulus at R.T. PSI	4.63x10 ⁶	3.47x10 ⁶	2.82x10 ⁶	3.92x10 ⁶
Av. Tensile Strength at R.T. After a 2 hr. Boil in Distilled water PSI	72,100	48,800	39,300	62,000
Av. Tensile Modulus at R.T. After a 2 Hr. Boil in Distilled Water PSI	4.61x10 ⁶	3.57x10 ⁶	2.55x10 ⁶	3.66x10 ⁶
Av. Tensile Strength at R.T. After Being Con- ditioned for 30 minutes at 180°F. PSI	72,100	47,000	40,000	61,800

AUTHOR: S. Lofton

DATE: 9-11-61

PAGE 3.

I. CATEGORY: Composite Materials CODE: 9-7-1

II. MATERIAL NAME: 161 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

	1298	1299	1302	1303
Av. Tensile Modulus at R.T. After being Conditioned for 30 minutes at 180°F PSI	4.77x10 ⁶	3.50x10 ⁶	2.81x10 ⁶	3.99x10 ⁶
Av. Edgewise Compressive Strength at R. T. PSI	68,900	52,600	45,300	61,500
Av. Edgewise Compressive Modulus at R. T. PSI	5.06x10 ⁶	4.15x10 ⁶	3.16x10 ⁶	4.40x10 ⁶
Av. Edgewise Compressive Strength at R.T. After a 2 Hr Boil in Distilled Water, PSI	46,800	52,900	49,300	62,500
Av. Edgewise Compressive Modulus After a 2 Hr. Boil in Distilled Water, PSI	5.03x10 ⁶	4.09x10 ⁶	2.93x10 ⁶	4.33x10 ⁶
Av. Edgewise Compressive Strength at R.T. After 192 Hrs. of Conditioning at 350°F., PSI	65,300	51,600	53,200	66,700
Av. Edgewise Compressive Modulus at R.T. After 192 Hrs. of Conditioning at 350°F., PSI	4.81x10 ⁶	3.63x10 ⁶	3.16x10 ⁶	4.27x10 ⁶

AUTHOR: E. Lofton

DATE: 9-11-61

PAGE 4.

I. CATEGORY: Composite Materials CODE: 9-7-1

II. MATERIAL NAME: 181Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

B. Thermophysical

	1298	1299	1302	1303
Av. Flexural Strength at 250°F After Being Conditioned for 192 Hrs. at 350°F, PSI	93,900	55,600	56,000	76,300
Av. Flexural Modulus at 250°F. After Being Conditioned for 192 Hrs. at 350°F, PSI	4.16x10 ⁶	3.02x10 ⁶	2.86x10 ⁶	3.76x10 ⁶
Av. Flexural Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F., PSI	60,000	46,300	47,000	65,400
Av. Flexural Modulus at 350°F After Being Conditioned for 192 Hrs. at 350°F, PSI	3.64x10 ⁶	2.58x10 ⁶	2.50x10 ⁶	3.54x10 ⁶
Av. Edgewise Compressive Strength at 180°F After 30 Min. of Conditioning at 180°F, PSI	55,000	52,200	46,300	61,500
Av. Edgewise Compressive Modulus at 180°F After 30 Min. of Conditioning at 180°F, PSI	3.43x10 ⁶	2.58x10 ⁶	2.05x10 ⁶	3.00x10 ⁶
Av. Edgewise Compressive Strength at 250°F After being Conditioned for 192 Hrs. at 350°F, PSI	57,000	39,000	43,000	59,400

AUTHOR: ^{E.L.} E. Lofton

DATE: 9-11-61

PAGE 5.

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES: (Continued)

B. Thermophysical (continued)

	1298	1298	1302	1303
Av. Edgewise Compressive Modulus at 250°F After Being Conditioned for 192 Hrs. at 350°F, PSI	3.31×10^6	2.51×10^6	2.10×10^6	3.04×10^6
Av. Edgewise Compressive Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F, PSI	46,600	33,400	32,000	45,600
Av. Edgewise Compressive Strength at 350°F After Being Conditioned for 192 Hrs. at 350°F., PSI	3.03×10^6	2.13×10^6	1.85×10^6	2.67×10^6

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 161 Volan A and A-1100 Silane Firish Fabric

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

AUTHOR: E. Lofton

DATE: 9-11-61

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MATERIALS & PROCESS UNIT

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 181 Volan A and A-1100 Silane Finish Fabric

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

E.L.
AUTHOR: E. Lofton

DATE: 9-11-51

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MATERIALS & PROCESS UNIT

I. CATEGORY: Composite Materials

CODE: 9-7-1

II. MATERIAL NAME: 181 Volan A and A-1100 Silane Finish Fabric

VI. RECOMMENDED USES:

Due to the results obtained in this investigation showing that the properties obtained with 181 A-1100 used as a reinforcement, are not equal to the ones obtained using Volan A finish fabric, it is recommended that where epoxy resins are to be used as a binder that Volan A finish fabric be used as a reinforcement.

VII. SUPPLIERS AND TRADE NAMES:

A. Vendors for 181 Volan A finish fabric and 181 A-1100 finish fabric include the following:

Coast Manufacturing Company
United Merchants
J. P. Stevens & Company, Inc.
Hess-Goldsmith and Company
Owens Corning Fiberglas Corporation

B. Availability

Standard rolls 125 yards long and 38 inches wide. Rolls with less and greater widths may be obtained for an additional cost.

C. Costs

Standard roll 125 yards long and 38 inches wide \$1.13 per linear yard.

VIII. REFERENCES:

A. Lee and Neville, "Epoxy Resins".

B. Union Carbide, "A-1100 and A-172 Silane Glass Finishes".

AUTHOR: E. Lofton

DATE: 9-11-61

PAGE 9.

I. CATEGORY: Composite Materials

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

III. GENERAL DESCRIPTIONS:

The data presented herein covers dielectric properties of some materials used for radome construction.

IV. DEVELOPMENTAL BACKGROUND:

This information was developed for use in computation of radome wall and sandwich thickness allowables and tolerances.

I. CATEGORY: Composite Material

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

A. Mechanical

Complete information not available due to lack of need for
Boeing-Wichita's investigating this property.

I. CATEGORY: Composite Material

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

B. Thermophysical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

I. CATEGORY: Composite Material

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

C. Electrical Properties

The following table and graph presents data on a few thermosetting resins laminated with 181V (EIL-F-9084) glass fabric unless otherwise noted. Dielectric properties were determined per ARTC W-4.

To obtain the greatest specimen uniformity, laminates were prepared to 1/8" thick skins and resin content varied by varying the number of plies of fabric. The cured laminates were then bonded together with the same resin to form the complete specimen. This specimen was then machined to form the dielectric specimen. All polyester type resins were catalyzed with benzoyl peroxide. Epon 828 resin was catalyzed in the ratio of 26.5 parts by weight of Itonox to 100 parts resin.

I. CATEGORY: Composite Materials

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

SUMMARIZED DATA

A. Electrical Properties

Laminate No.	No. of Plys 181 Volan	Type of Resin	Resin Content		Specific Gravity	Dielectric Constant	Loss Tangent
			Carbon	Dielectric Specimen			

DIELECTRIC PROPERTIES MEASURED AT 11,000 MEGACYCLES

1125	11	Epon	828	—	41.5	1.74	4.31	.021
1127	13	"	828	—	37.8	1.81	4.48	.017
1128	15	"	828	—	32.6	1.85	4.75	.018
1134	10	Laminac	4128	—	33.7	1.85	4.37	.011
1135	12	"	4128	32.9	34.1	1.88	4.46	.011
1136	14	"	4128	29.4	28.6	1.91	4.30	.011
1138	14	"	4128	—	32.3	1.90	4.43	.011
1139	10	Paraplex	P-43	—	48.0	1.74	4.09	.008
1142	12	"	P-43	—	39.1	1.82	4.27	.010
1145	14	"	P-43	—	34.8	1.85	4.44	.011

DIELECTRIC PROPERTIES MEASURED AT 9,375 MEGACYCLES

1169	12	Laminac	4128	35.9	36.4	1.83	4.21	.0066
1170	10	"	4128	44.0	44.2	1.72	4.08	.0084
1175	14	"	4128	30.2	30.6	1.92	4.51	.0078
1188	12	Selectron	5016	36.2	36.4	1.81	4.34	.0098
1196	14	"	5016	28.5	29.6	1.91	4.55	.0101
1197	10	"	5016	43.8	44.3	1.73	4.16	.0109
1188	10	Epon	828	45.3	45.6	—	4.11	.0188
1201	12	"	828	37.9	38.6	—	4.43	.0175
1206	9	"	828	50.7	50.6	1.63	4.16	.0180

SP-97	Scrimsloth	—	—	—	38.6	—	2.79	.0132
Epocast 8571A	As Received No Glass	—	—	—	—	—	3.62	.0209

CASTINGS AT 9,375 MEGACYCLES

Paraplex	P-43	—	—	—	—	—	2.91	.0069
Laminac	4128	—	—	—	—	—	2.91	.0105
Selectron	5016	—	—	—	—	—	2.90	.0145
Epon	828	—	—	—	—	—	3.21	.0324

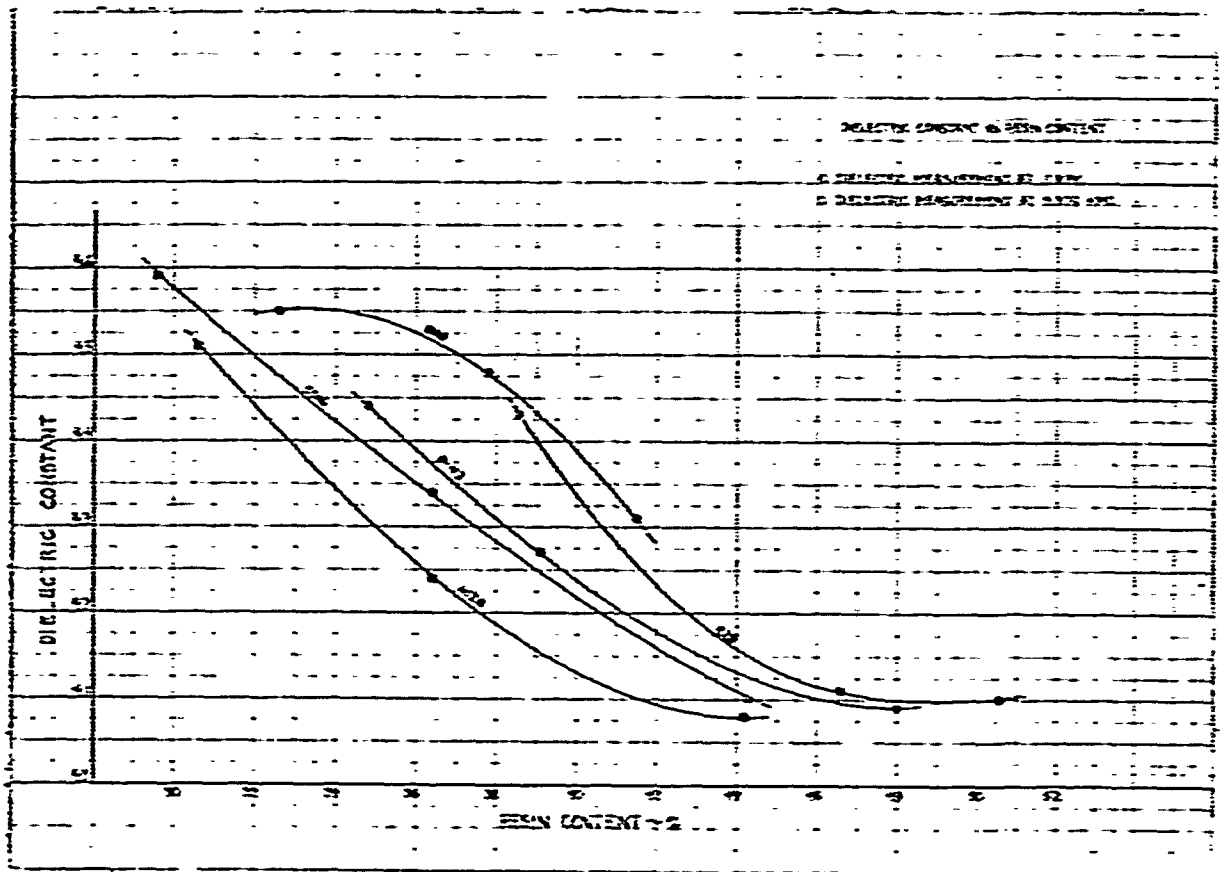
I. CATEGORY: Composite Materials

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

7. PRINCIPAL PROPERTIES:

C. Electrical Properties



BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Composite Materials

CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

V. PRINCIPAL PROPERTIES:

D. Chemical

Information not available due to lack of need for Boeing-Wichita's
investigating this property.

AUTHOR: J. Elton *JE*

15 August 1961

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MATERIALS & PROCESS UNIT

I. CATEGORY: Composite Material CODE: 9-7-2

II. MATERIAL NAME: Reinforced Plastics for Radomes

VI. RECOMMENDED USES:

Material properties govern usage for specific applications.

VII. SUPPLIERS AND TRADE NAMES:

1. Epon 828, Shell Chemical Corporation.
2. Laminac 4128, American Cyanamid Company.
3. Paraplex P-43, Rohm & Haas.
4. Selectron 5016, Pittsburgh Plate Glass.
5. FK-97, Bloomingdale Rubber Company.
6. Epocast H991A, Furane Plastics Company.
7. Tonox, Nantucket Chemical Corporation.

VIII. REFERENCES:

1. Boeing-Wichita Materials and Process Unit Report No. AP-2-63,
RS-175 Radome Material.

I. CATEGORY: Composite Materials

CODE: 9-3-6

II. MATERIAL NAME: Decals

III. GENERAL DESCRIPTION:

A number of decals were investigated to determine their resistance to temperatures up to 800°F for periods of 30 minutes and 100 hours.

Three types of decals were included in this investigation:

1. Paint film decals.
2. Plastic film decals.
3. Metal-Cals (a trade name for decals produced on thin aluminum foil).

IV. DEVELOPMENTAL BACKGROUND:

A. Samples tested

1. Metal-Cal, silver letters on a red background, PS-3 adhesive.
(This is a pressure sensitive, cellophane backed adhesive.)
2. Metal-Cal, silver letters on a black background, PS-3 adhesive.
(This is a pressure sensitive, cellophane backed adhesive.)
3. Metal-Cal, PS-9 adhesive. (This adhesive is paper backed, and activated by heat or solvents.)
4. Metal-Cal, PS-10 adhesive. (This adhesive is paper backed, and activated by heat or solvents.)
5. Metal-Cal, Aluminum letters on a red background, PS-14 adhesive.
(This is a pressure sensitive, paper backed adhesive.)
6. Metal-Cal, aluminum letters on a black background, PS-14 adhesive.
(This is a pressure sensitive, paper backed adhesive.)
7. Paint film decal, white letters on a black background, water applied, slide-off.
8. Paint film decal, black letters on a gray background, face down, cement-applied.
9. Paint film decal, white letters on a brown background, water applied slide-off.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

IV. DEVELOPMENTAL BACKGROUND: (Continued)

A. Samples tested (continued)

10. Paint film decal, white letters on a brown background, water applied, slide-off.
11. Paint film decal, white letters on a red background, water applied, slide-off.
12. Paint film decal, white letters on a black background, face down, cement-applied.
13. Paint film decal, black letters on a light gray background, face down, cement-applied.
14. Paint film decal, type "SHR" (sustained heat resistance), water applied, slide-off.
15. Paint film decal, type "HHR" (high heat resistance), water applied, slide-off.
16. Plastic film decal, Scotchcal SS3-133, upside-down construction, edges sealed with EC-866 Edge Sealer.
17. Plastic film decal, No. 3665 black Scotchcal film, printed with No. 3903 (AMA No. 511) white Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.
18. Plastic film decal, No. 3650 white Scotchcal film, printed with No. 3905 (AMA No. 515) black Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.
19. Plastic film decal, No. 3651 red Scotchcal film, printed with No. 3903 (AMA No. 511) white Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.
20. Plastic film decal, No. 3659 aluminum colored Scotchcal film, printed with No. 3905 (AMA No. 515) black Scotchcal Screen Process Paste. (No edge sealing or overcoating.)

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

IV. DEVELOPMENTAL BACKGROUND: (Continued)

A. Samples tested (continued)

21. Plastic film decal, No. 3667 Insignia Blue Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste and overcoated with No. 3920 Gloss Clear.
22. Plastic film decal, No. 659 aluminum colored Scotchcal film, overcoated with No. 3920 Gloss Clear.
23. Plastic film decal, No. 659 aluminum colored Scotchcal film, printed with No. 3905 (ANA No. 515) black Scotchcal Screen Process Paste, and overcoated with No. 3920 Gloss Clear.
24. Plastic film decal, No. 667 Insignia Blue Scotchcal film, overcoated with No. 3920 Gloss Clear.
25. Plastic film decal, No. 667 Insignia Blue Scotchcal film, printed with No. 3903 (ANA No. 511) white Scotchcal Screen Process Paste and overcoated with No. 3920 Gloss Clear.

NOTE: Plastic film decals 16-21 have a pressure sensitive adhesive; decals 22-25 have a solvent activated adhesive. No. 659 Scotchcal film is identical to No. 3659 except for the adhesive. No. 667 Scotchcal film is identical to No. 3667 except for the adhesive.

B. Procedure

Each decal was applied per the manufacturer's instructions to a clean metal panel (aluminum alloy 2024-T3, 7075-T6 alclad, or stainless steel alloy 304-S-766a, Type 321) aged a minimum of 48 hours at room temperature, and then placed in an oven and held at the designated temperature for 30 minutes or 100 hours. After cooling, the decals were examined.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

A. Mechanical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The thermophysical properties of these decals are shown in Tables I and II.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

B. Thermophysical (continued)

Sample No.	Temperature, °F										
	200	300	350	400	450	500	600	700	800	900	1000
1	S	S	S	S	S	AP	AP,U	-	-	-	-
2	S	S	S	AL,S	AL,S	AP	AP,U	-	-	-	-
3	S	S	S	S	S	AL,S	AP,S	AP	AP,C,U	-	-
4	S	S	S	AL,S	AL,S	AL,S	AL,S	C,CS,S	AP,C	AP,C,U	-
5	-	-	-	-	-	AL	AP,U	-	-	-	-
6	-	-	-	-	-	AL,S	AP,U	-	-	-	-
7	S	C,S	C,S	C,S	C,S	C,S	C	FA	AP,C,U	-	-
8	S	C,S	C,S	C,S	AP,C	-	-	-	-	-	-
9	S	C,S	C,S	C,S	C,S	C	AP,C	-	-	-	-
10	S	C,S	C,S	C,S	C,S	-	-	-	-	-	-
11	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	-	-	-	-
12	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	C	C,U	-	-
13	S	C,S	C,S	C,S	C,S	C,S	AP,C,U	-	-	-	-
14	-	-	-	-	-	C,S	C,S	AP,C	AP,U	U	-
15	-	-	-	-	-	S	S	S	S	AP,S	AP,U
16	-	-	-	-	-	AP,E,U,Z	-	-	-	-	-
17	S	S	S	C,S	C,LC,S	AP,C,F,U	-	-	-	-	-
18	S	S	C,S	C,S	C,LC,S	AP,E,U	-	-	-	-	-
19	S	S	S	C,S	C,LC,S	AP,C,E,U	-	-	-	-	-
20	S	S	S	C,S	C,S	AP,C,E,U	-	-	-	-	-
21	S	S	S	C,S	C,S	AP,C,E,U	-	-	-	-	-
22	S	S	S	C,S	AP,U	-	-	-	-	-	-
23	S	S	S	C,S	AP,U	-	-	-	-	-	-
24	S	S	C,S	C,S	C,LC,S	-	-	-	-	-	-
25	S	S	C,S	C,S	C,LC,S	-	-	-	-	-	-

Effect of 30 Minute Exposure At Various Temperatures

TABLE I

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

B. Thermophysical (continued)

Sample No.	TEMPERATURE, °F									
	200	300	350	400	450	500	600	700	800	
1	S	S	C,S	AL,C	AP,C,U	AP,C,U	-	-	-	
2	S	S	AL	AL,C	AP,C,U	AP,C,U	-	-	-	
3	S	S	AP	AP	AP,C,U	AP,C,U	-	-	-	
4	S	S	AP	AP	AP,U	AP,C,U	-	-	-	
5	S	S	S	AL	AL,C	AP,C,U	-	-	-	
6	S	S	S	AL	AP,C,U	AP,C	AP,C,U	-	-	
7	S	C,S	C,S	C,S	C	AP,C	U	-	-	
9	S	C,S	C,S	AP,C	C	AP,C,U	-	-	-	
11	S	C,S	C,S	C,S	C	AP,C	U	-	-	
12	S	S	C,S	C,S	C	AP	U	-	-	
13	S	C,S	C,S	C,S	C	C	U	-	-	
14	S	S	S	S	C,S	S	AP,U	-	-	
15	S	S	S	S	C,S	S	S	S	AP,U	
16	S	C,S	C,S	AP,C,U	-	-	-	-	-	
17	S	C,S	C,S	C,S	C,U	-	-	-	-	
18	S	C,S	C,S	AP,C,U	-	-	-	-	-	
19	S	C,S	C,U	-	-	-	-	-	-	
20	S	C,S	C,S	C,S	C,S	AP,C,U	-	-	-	
21	S	C,S	C,S	C,S	C,U	-	-	-	-	

Effect of 100 Hour Exposure At Various Temperatures

TABLE II

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

3. Electrical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

V. PRINCIPAL PROPERTIES:

D. Chemical

Information was not obtained due to lack of need for Boeing-Wichita investigation of this property.

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

VI. RECOMMENDED USES:

It is recommended that the information in Tables I and II be used as a guide in predicting the probable temperature-time limitations of the decals tested. In case the operating conditions approach the limits indicated in these tables, further tests should be made.

VII. SUPPLIERS, AVAILABILITY, AND COSTS:

A. Suppliers

Decals 1 - 6 (Metal-Cals):

C & H Supply Company
1725 E. 2nd Street
Wichita, Kansas or

421 E. Beach Avenue
Inglewood 3, California or

Seattle, Washington

Decals 7 - 9 (Paint film decals):

Warren Burdick Company
1815 North Broadway
Wichita 4, Kansas

Decals 10 - 13 (paint film decals):

Woods-Beston Decal Company
1710 Laura Avenue
Wichita, Kansas

Decals 14, 15 (paint film decals):

The Meyercord Company
5323 West Lake Street
Chicago 44, Illinois

Decals 16-25 (plastic film decals):

Minnesota Mining & Mfg. Company
St. Paul 6, Minnesota

Edge Sealer No. EC-866:

Minnesota Mining & Mfg. Company
St. Paul 6, Minnesota

No. 3920 Gloss Clear (overcoating material):

Minnesota Mining & Mfg. Company
St. Paul 6, Minnesota

I. CATEGORY: Composite Materials

CODE: 9-8-6

II. MATERIAL NAME: Decals

VII. SUPPLIERS, AVAILABILITY, AND COSTS: (Continued)

A. Suppliers (continued)

Scotchcal Screen Process Pastes,
No. 3905 (black) and No. 3903
(white):

Minnesota Mining & Mfg. Company
St. Paul 6, Minnesota

Adhesives PS-3, PS-9, PS-10,
and PS-14:

Minnesota Mining & Mfg. Company
St. Paul 6, Minnesota

B. Availability

All materials listed are believed to be currently available
from the manufacturers.

C. Costs

The cost of the decals varies with a number of factors, such as size,
printing, number ordered etc., so that no estimate of cost can be
given.

VIII. REFERENCE:

1. Boeing Company Materials and Process Unit Document D3-1598,
"Temperature Limitations of Marking Materials (Phases I, II, III, and
IV)".

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

III. GENERAL DESCRIPTION:

The objective of this program was to develop biphenyl compounds carrying functional groups that would permit polymerization to be accomplished. The biphenyl nucleus is known to impart thermal stability to compounds that contain it.

IV. DEVELOPMENTAL BACKGROUND:

After three unsuccessful attempts to prepare 2,2', 3,3',4,4'-tetrahydroxybiphenyl by the C. Harries method described in Reference (2), a modification of the method as proposed in Reference (3) was successfully carried out. An aqueous solution of pyrogallol was mixed with a barium hydroxide solution, agitated, air excluded and finally acidified with HCl. The precipitated product was washed with water and recrystallized from water containing acetic acid.

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

A. Mechanical

As prepared, this material is a white, finely divided powder.

I. CATEGORY: Miscellaneous and General

CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The compound darkens at approximately 280°C and melts at 310°-320°C.
with decomposition.

I. CATEGORY: Miscellaneous and General CODE: C-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing-Wichita
investigating this property.

I. CATEGORY: Miscellaneous and General

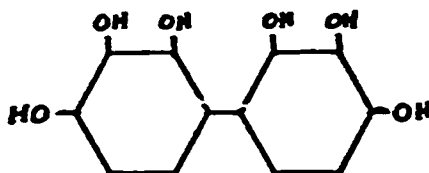
CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

V. PRINCIPAL PROPERTIES:

D. Chemical

The formula for 2,2',3,3',4,4' hexahydroxybiphenyl is:



The hydroxyl groups permit various degrees of modification to form esters, ethers and other compounds of interest. The epoxy substituted material is expected to have desirable characteristics. After curing with a hardening agent such as an amine or an anhydride, the resulting polymer should be highly cross-linked; this fact, together with the biphenyl back-bone structure should provide good thermal and chemical stability.

I. CATEGORY: Miscellaneous and General CODE: 0-1-4

II. MATERIAL NAME: Chemical Intermediate, Biphenyl Compounds,
Hexahydroxybiphenyl

VI. RECOMMENDED USES:

Preparation of polymers. For example, the hexaglycidyl ether can be prepared and hardened with the usual epoxy hardeners. New resins of this type represent an unexplored field. The biphenyl backbone structure is expected to impart both thermal and chemical stability to such resins.

VII. SUPPLIERS:

None.

VIII. REFERENCES:

- (1) D3-2867, "Molecular Engineering", C. A. Henriksen, 9 February 1960.
- (2) Berichte der Deutschen Gesellschaft. Ber. 35 2954-9 (1902).
- (3) Harries Di-Pyrogallol. Proc. Roy Soc. (London) A143, 207-8 (1933-4).

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5524E)

III. GENERAL DESCRIPTION:

The object of this program was to establish autoignition temperatures (AIT) of JP-4 fuel over a pressure range of 500 mm Hg to 2000 psi.

IV. DEVELOPMENTAL BACKGROUND:

This program was initiated as a result of considerable concern about the maximum operating temperatures of "Black Boxes" and air compressors on B-52 aircraft that might contact combustible concentrations of fuel vapors. A literature search for AIT information at various pressures indicated a need for additional experimental data.

Although standard definitions and methods of determination have been established for many of the physical and chemical properties of JP-4 fuel, there has been no general agreement on the definition or determination of ignition temperatures, consequently, determinations of this property by different investigators have varied widely both in numerical value and significance, with much resulting confusion and difficulty in the interpretation and practical application of the information.

It appears that, although the ignition characteristic of a material is doubtless a function of some actual property of the material, the measurement of that property by any means available is greatly affected by the ambient conditions, therefore, any practical definition of AIT which might be adopted must continue to be based on a careful definition and standardization of the test apparatus and procedure.

The apparatus and test procedure used for AIT determinations at simulated altitudes were those described in ASTM D 285-56T with modification to allow determinations at reduced pressures.

The value at 2200 psi (1.14×10^5 mm Hg) was determined using a high pressure stainless steel bomb (150 cc volume) with instrumentation to permit the recording of temperature and pressure within the bomb. The method for determining AIT with this bomb consisted of placing a specified amount of fuel in the bomb, pressurizing the bomb to the desired pressure, and heating the bomb until an ignition was obtained. The temperature at which the ignition occurred was the AIT of the fuel at the pressure recorded just prior to ignition. A pressure rise in excess of 6 times the initial pressure was estimated to have occurred upon ignition.

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5624E)

V. PRINCIPAL PROPERTIES:

A. Mechanical

Not applicable

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5024E)

V. PRINCIPAL PROPERTIES:

B. Thermophysical

The autoignition temperatures established for the pressure range investigated are presented in Figure I. Data from other investigators are presented for comparison.

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5624E)

V. PRINCIPAL PROPERTIES:

B. Thermophysical (cont'd)

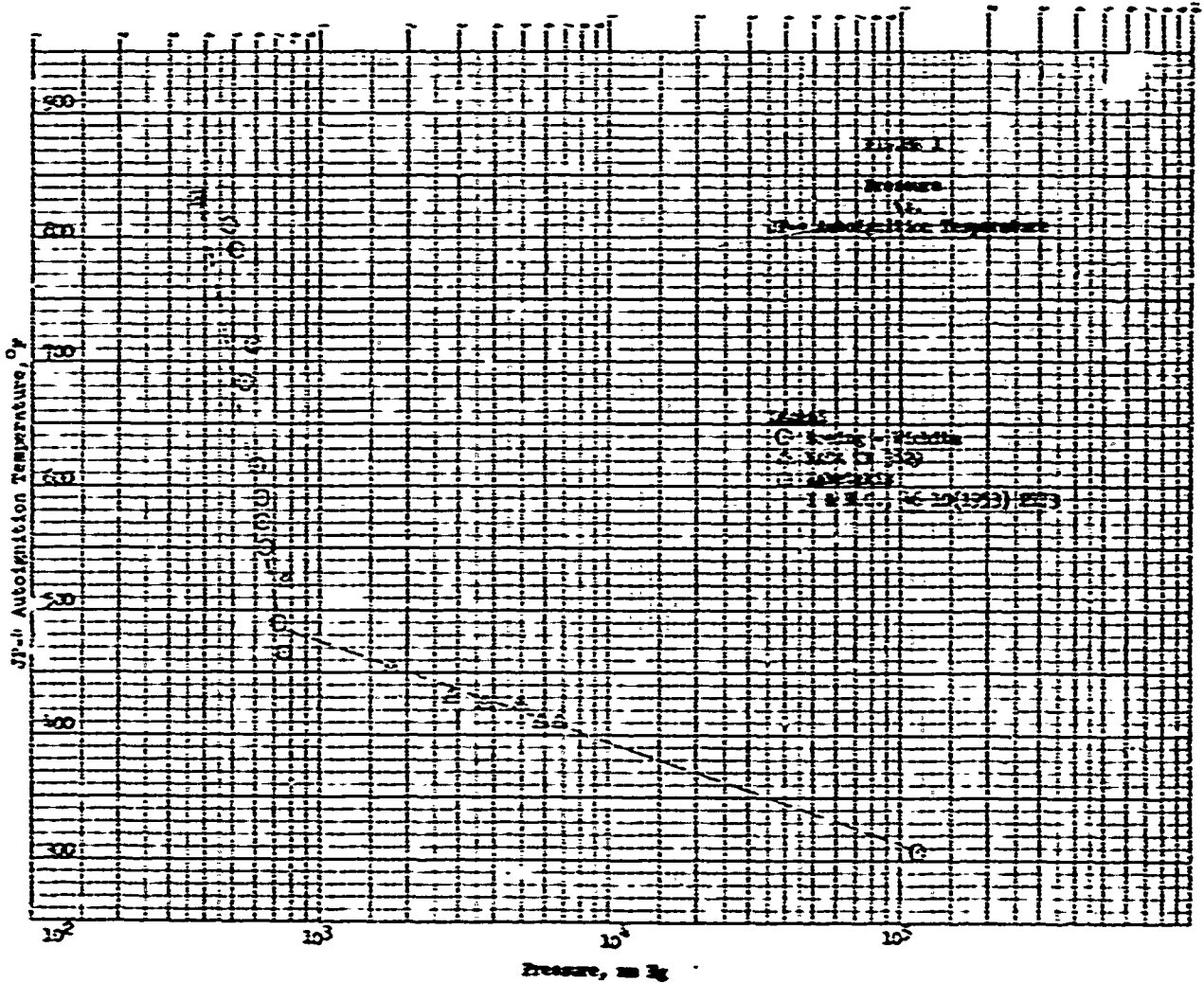


FIGURE I

AUTHOR: J. R. Gibson

DATE: 9-11-61

PAGE 1

BOEING AIRPLANE COMPANY
WICHITA DIVISION

AERONAUTICAL SYSTEMS DIVISION
Contract No. AF33(616)-8141
Project No.1(8-7381):Task No.73812

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5624E)

V. PRINCIPAL PROPERTIES:

C. Electrical

Information not available due to lack of need for Boeing - Wichita's
investigating this property.

AUTHOR: J. R. Gibson 9

DATE: 9-11-61

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MATERIALS & PROCESS UNIT

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5624E)

V. PRINCIPAL PROPERTIES:

D. Chemical

The fuel used during this investigation met MIL-J-5624E specifications.

I. CATEGORY: Miscellaneous and General

CODE: 0-5-0

II. MATERIAL NAME: JP-4 Fuel (MIL-J-5624B)

VI. RECOMMENDED TESTS:

It is recommended that the autoignition data presented herein be considered during the design of "Black Boxes", air compressors, etc., when the possibility of fuel contact exists.

VII. SUPPLIERS AND TRADE NAMES:

Major petroleum companies

VIII. REFERENCES:

1. ASTM Standards 1958, Part 7, Test Method D226-58T
2. Boeing - Wichita Materials and Process Unit Job No. SM-2-58
3. O'Neal, Cleveland Jr., Effect of Pressure on the Spontaneous Ignition Temperature of Liquid Fuels. NACA TR 3829
4. Zabetakis, M. G., Furno, A. L., and Jones, G. W.: Minimum Spontaneous Ignition Temperatures of Combustibles in Air. Ind. and Engr. Chem., Vol. 46, No. 10, Oct. 1954 pp 2173-2176

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, and 321-A Stainless Steel

III. GENERAL DESCRIPTION:

The objective of the program was to establish maximum angular shearturning capabilities for standard airframe materials, in varying thicknesses.

IV. DEVELOPMENTAL BACKGROUND:

This program deals primarily with the extension and determination of shear-turning capabilities and its limits. Essentially, this report discusses and fixes the angles to which a given material may be shearturned without failure.

AUTHOR: F. W. Stratton

DATE: 9-18-61

PAGE 1.

MATERIALS & PROCESS UNIT

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES:

A. Mechanical

Maximum angular limits for shearturn quality materials are:

321-A	15°
7075-0	16-1/2°
2024-0	16-1/2°

See Photograph BKA-23473

The limits established during testing are shown in Tables I, II and III, and seen in the plotted graphs of Figures 1, 2, and 3. The values shown in these tables supersede the above maximum angular limits at any thickness than .030" or greater than .190".

The above angles are defined as 1/2 the included angle of the part.

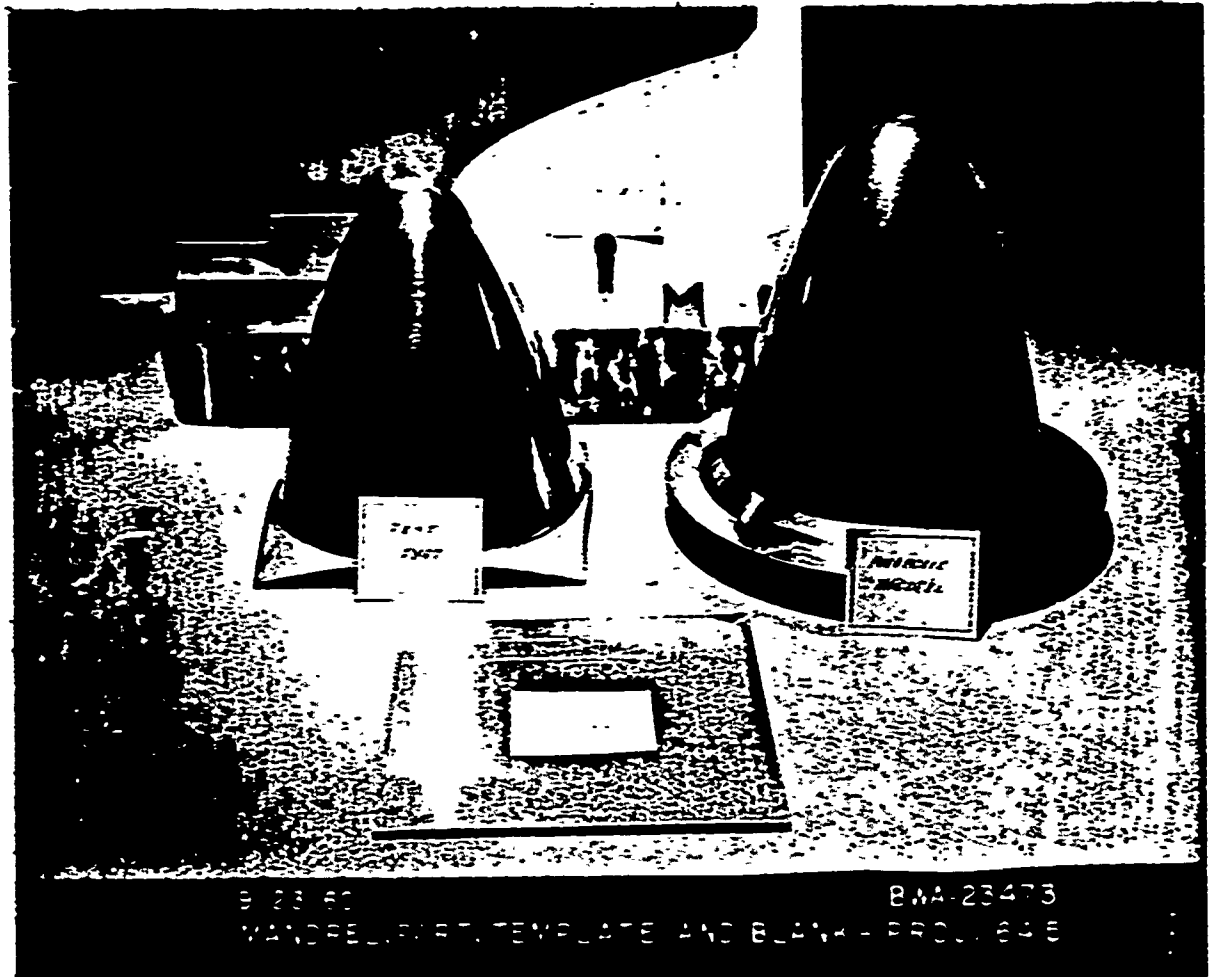
I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



B-23-60 BWA-23473
MANDREL, PART, TEMPLATE AND BLANK - PROJ. 646

BWA-23473

AUTHOR: F. W. Stratton *[Signature]*

DATE: 9-18-61

PAGE 3.

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

SAMPLE NUMBER	MATERIAL		MACHINE SETTINGS			TEST RESULTS			COMPUTATIONS		COMMENTS
	TYPE	ORIG. THICKNESS	FEDER FEEED MOSE BRUJIS	FEDD FEED	RPM	TOOLING ANGLE AT SETTING	ANGLE AT BREAK	TYPING AT BREAK	SME	ANGLE	
1	2024-0	.262	3/16	2 1/2	320	T.	-18°	.060	.301	17 1/2°	
2	"	"	3/16	2 1/2	320	T.	-18°	.060	.301	17 1/2°	
3	"	"	3/16	2 1/2	650	T.	-17°	.071	.271	15 3/4°	
4	"	"	3/16	2 1/2	350	T.	-18°	.073	.278	16°	
5	"	"	3/16	2 1/2	650	T.	-17°	.069	.263	15°	
6	"	"	3/16	2 1/2	1000	T.	-17°	.069	.263	15°	
7	2024-0	.186	3/16	2 1/2	350	T.	15°	.041	.220	15°	
8	"	"	3/16	2 1/2	350	T.	15°	.042	.226	15°	
9	"	.181	3/16	2 1/2	650	T.	-15°	.041	.226	15°	
10	"	.187	3/16	2 1/2	1000	T.	15°	.041	.219	15°	
11	7075-0	.187	3/16	2 1/2	350	T.	-16°	.048	.250	15°	
12	"	.188	3/16	2 1/2	350	T.	16°	.043	.228	15°	
13	"	"	3/16	2 1/2	650	T.	16°	.041	.218	15°	
14	"	"	3/16	2 1/2	1500	T.	-16°	.040	.212	12°	
15	221-A	.195	3/16	2 1/2	350	.125	18°	.037	.190	11°	TIGHT
16	"	.196	3/16	2 1/2	350	.150	-16°	.031	.160	9°	TIGHT
17	"	"	3/16	2 1/2	250	.175	-15°	.033	.170	10°	TIGHT
18	"	.195	3/16	2 1/2	350	.180	-15°	.034	.174	10°	TIGHT
19	2024-0	.125	3/16	2 1/2	350	T.	16°	.026	.208	12°	
20	"	"	3/16	2 1/2	350	T.	-15°	.026	.208	12°	
21	"	"	3/16	2 1/2	350	T.	-15°	.026	.208	12°	
22	"	"	3/16	2 1/2	350	T.	-15°	.029	.222	13°	
23	"	"	3/16	2 1/2	650	T.	-15°	.028	.226	13°	
24	"	"	3/16	2 1/2	1000	T.	-14°	.027	.218	12°	

TABLE I

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2021-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

SAMPLE NUMBER	MATERIAL		MACHINE SETTINGS			TEST RESULTS			COMPUTATIONS		COMMENTS
	TYPE	DRUMS INCHES	ROLLER NOSE DRUMS	FEED RATE	RPM	ANGLE BY SETTING	ANGLE BY BREAK	FEEDER AT BREAK	SINE	ANGLE	
25	7075-0	.127	3/16	2 1/2	350	T.	15°	.033	.260	15°	
26	"	"	3/16	2 1/2	350	T.	16°	.035	.276	16°	
27	"	"	3/16	2 1/2	350	T.	15°	.031	.245	14°	
28	"	"	3/16	2 1/2	350	T.	-16°	.034	.268	15°	
29	"	"	3/16	2 1/2	650	T.	-15°	.029	.228	15°	
30	"	"	3/16	2 1/2	1000	T.	-15°	.030	.236	14°	
21	221-A	.121	3/16	2 1/2	350	.110	16°	.042	.367	20°	LOSS
22	"	"	3/16	2 1/2	350	.090	16°	.035	.272	16°	
33	"	"	3/16	2 1/2	350	.090	-16°	.033	.272	16°	
34	"	"	3/16	2 1/2	650	.090	-16°	.026	.215	12°	
25	"	"	3/16	2 1/2	1000	.090	-16°	.024	.198	11°	
36	2024-B	.091	1/8	2 1/2	350	T.	22°	.038	.418	25°	LOSS DUST T. PLATE
37	"	"	1/8	2 1/2	350	T.	17°	.025	.275	16°	
38	"	"	1/8	2 1/2	350	.086	16°	.022	.242	14°	
39	"	"	1/8	2 1/2	350	.086	16°	.024	.266	15°	
40	"	"	1/8	2 1/2	350	.086	16°	.022	.242	14°	
41	"	"	1/8	2 1/2	650	.086	16°	.022	.242	14°	
42	"	"	1/8	2 1/2	1000	.086	16°	.022	.242	14°	
43	7075-0	.040	1/8	2 1/2	350	T.	16°	.022	.295	14°	
44	"	"	1/8	2 1/2	350	T.	16°	.023	.256	15°	
45	"	"	1/8	2 1/2	350	T.	-15°	.021	.236	14°	
46	"	"	1/8	2 1/2	350	T.	15°	.021	.236	14°	
47	"	"	1/8	2 1/2	650	T.	15°	.021	.236	14°	
48	"	"	1/8	2 1/2	350	T.	15°	—	—	—	

TABLE II

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

CARTRIDGE NUMBER	MATERIAL		MACHINE SETTINGS				TEST RESULTS			COMPUTATIONS		COMMENTS
	TYPE	GRINDING	ROLLER NOSE RADIUS	FEED RATE	RPM	TEMPERATURE NOSE SETTING	ANGLE BY BRICK	INCHES BY BRICK	SINE	ANGLE		
49	321-A	.090	4/8	2 1/2	350	.070	-15°	.022	.246	14°		
50	"	"	1/8	2 1/2	350	.070	15°	.022	.246	14°		
51	"	"	1/8	2 1/2	350	.070	15°	.020	.222	13°		
52	2024-B	.061	1/8	2 1/2	350	T.	-17°	.016	.262	15°		
53	"	"	4/8	2 1/2	350	T.	14°	.015	.246	14°		
54	"	"	1/8	2 1/2	350	T.	-15°	.015	.246	14°		
55	"	"	1/8	2 1/2	350	T.	-15°	.015	.246	14°		
56	7075-0	.040	1/8	2 1/2	350	.030					10032	
57	"	"	4/8	2 1/2	350	.045					"	
58	"	"	1/8	2 1/2	350	.040	16°	.021	.275	16°		
59	"	"	1/8	2 1/2	350	.040	-17°	.010	.250	15°		
60	2024-0	.012	1/8	2 1/2	350	.020						
61	"	"	1/8	2 1/2	350	.017	22°	.008	.445	26°		
62	"	"	1/8	2 1/2	350	.015	20°	.007	.390	23°		
63	"	"	1/8	2 1/2	350	.015	20°	.007	.390	23°		
64	"	"	1/8	2 1/2	350	.015	18°	.006	.334	20°		
65	A-286	.022	1/8	2 1/2	350	.019	22°	.010	.455	27°		
66	"	"	1/8	2 1/2	350	.015	20°	.008	.364	21°		
67	"	"	4/8	2 1/2	350	.012	20°	.008	.364	21°		

TABLE III

I. CATEGORY: Miscellaneous General

CODE: 0-7-i

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-O Aluminum, 7075-O Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

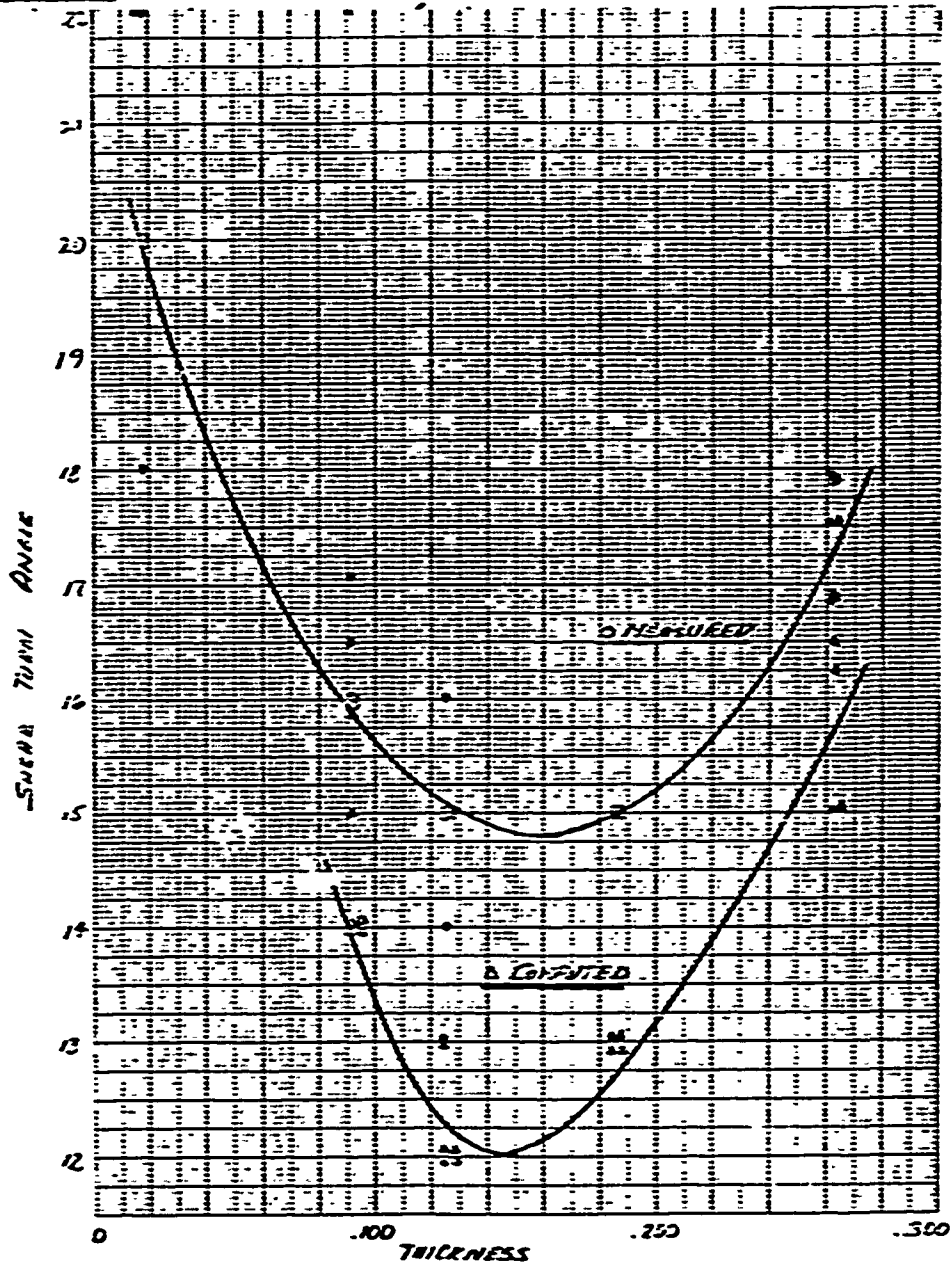


FIGURE 1

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-O Aluminum, 7075-O Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)

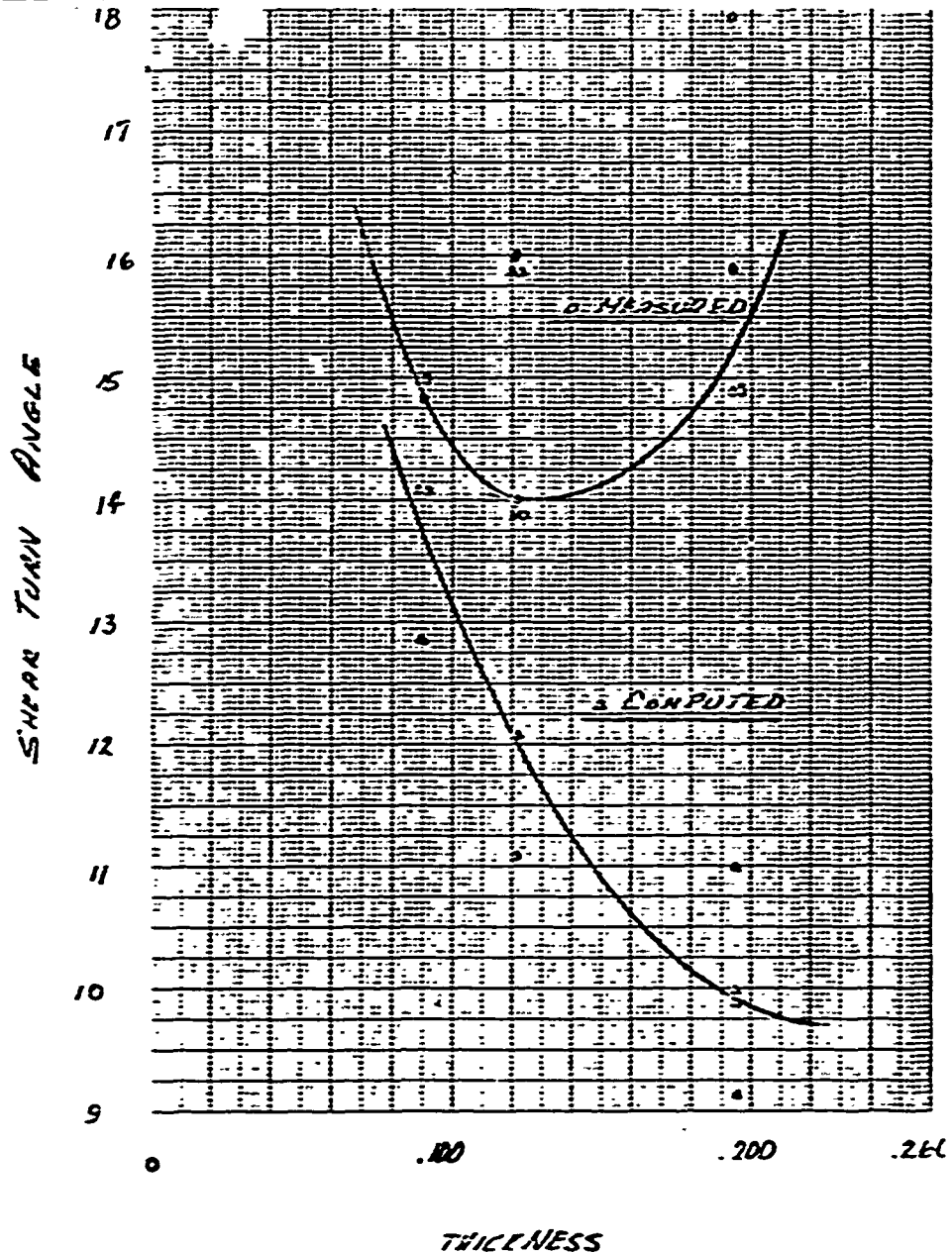


FIGURE 2

AUTHOR: F. W. Stratton DATE: 9-18-61

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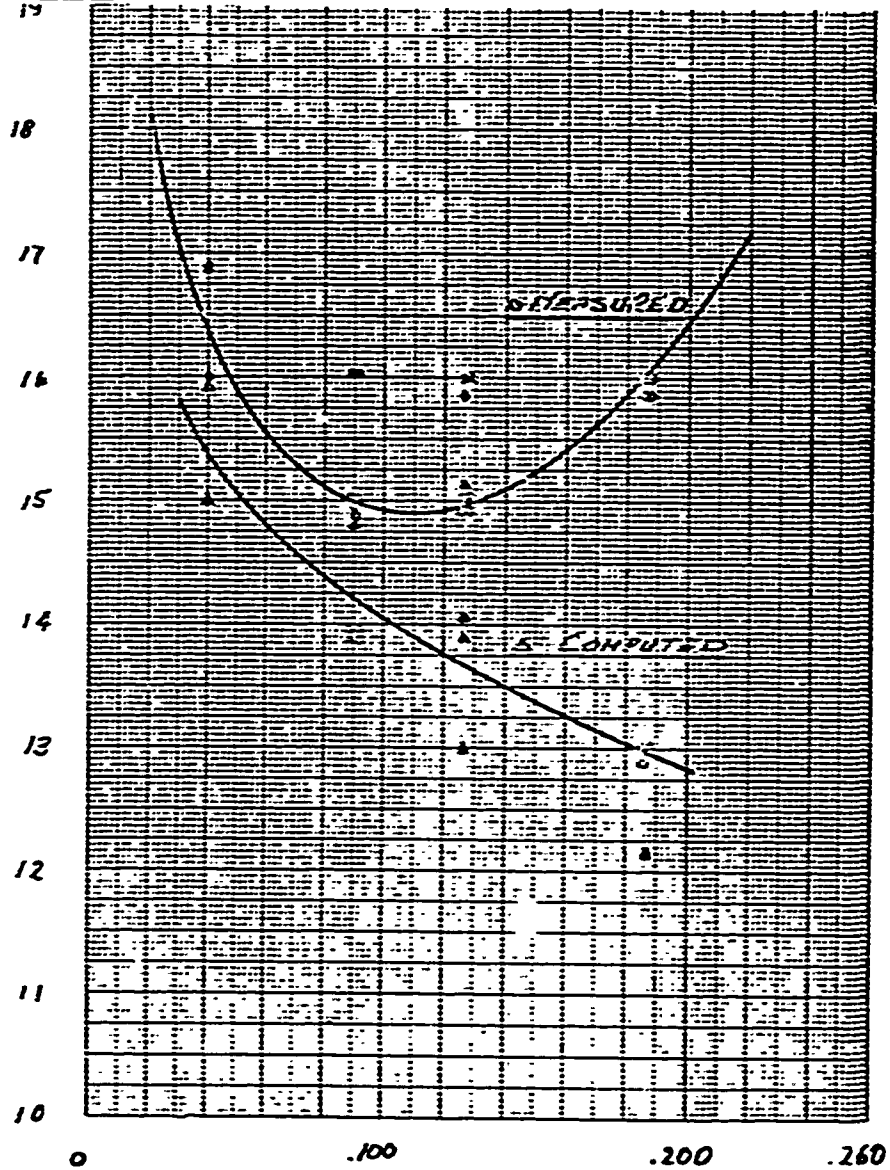
I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES: (Continued)

A. Mechanical (continued)



THICKNESS

FIGURE 3

AUTHOR: F. W. Stratton *[Signature]* DATE: 9-18-61

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I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES:

B. Thermophysical

This property has not been determined by Boeing-Michita since such information was not needed under the scope of this program.

I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES:

C. Electrical

This property has not been determined by Boeing-Wichita since such information was not needed under the scope of this program.

I. CATEGORY: Miscellaneous General

CODE: C-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

V. PRINCIPAL PROPERTIES:

D. Chemical

This property has not been determined by Boeing-Wichita since such information was not needed under the scope of this program.

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I. CATEGORY: Miscellaneous General

CODE: 0-7-1

II. MATERIAL NAME: Establish Maximum Angular Limits 2024-0 Aluminum, 7075-0 Aluminum, 321-A Stainless Steel

VI. RECOMMENDED USES:

Since Boeing-Wichita is primarily an airframe manufacturer, this material was reviewed with thin end usage in mind and the test procedure derived to make possible the determination of the property of new materials, should such materials call for the process of shearturning.

VII. SUPPLIERS AND TRADE NAMES:

Available from all standard Metal suppliers.

VIII. REFERENCES:

A. Boeing-Wichita Manufacturing Research Report 64.5, "Angular Shear Displacement Limits for Shearturned Metals".

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