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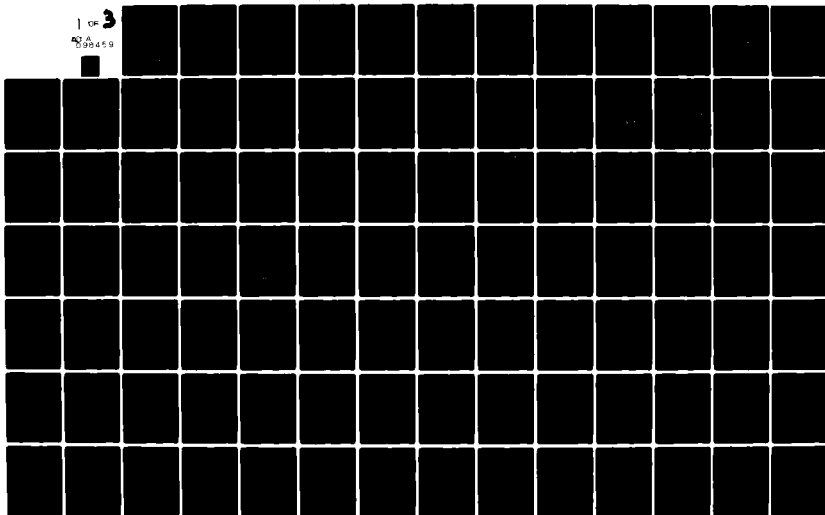
NAVAL AIR SYSTEMS COMMAND WASHINGTON DC
REPORT OF COMPOSITE MATERIAL AND METAL COMPOSITES JOINT WORKSHO--ETC(U)
1978

F/6 11/4

UNCLASSIFIED

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1 OF 3
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LEVEL II

(6) REPORT OF
COMPOSITE MATERIAL
AND

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①

METAL COMPOSITES JOINT
WORKSHOP

Washington DC on 11/18/78

24 AND 25 AUGUST, 1978

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24

NAVAL AIR SYSTEM COMMAND
U.S. DEPARTMENT OF THE NAVY

30/11/78

81 3 17 022



DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
WASHINGTON, D.C. 20361

IN REPLY REFER TO
52026B/79:JAB

AUG 18 1978

From: Commander, Naval Air Systems Command
To: Distribution List

Subj: Composite Material and Metal-Composite Joint Workshop Meeting

Ref: (a) Telecons between John Birken (AIR-52026B), Robert Wallenberg (Syracuse Research Corp., Syracuse, N.Y.) and others on Distribution List

1. This is to confirm that you have been invited to attend a workshop on composite material and metal-composite material joint electromagnetic properties to be held on 24 and 25 August 1978 at the Naval Air Systems Command (NAVAIR), Washington, D. C. in Room 664 JP-2 at 0900 in accordance with reference (a).
2. The meeting is directed towards instrumentation techniques and sample holders utilized to measure convenient size composite and composite-metal joint sample electromagnetic properties. Measurements of specific electromagnetic parameters and their inter-relationships will be discussed. Participants are invited to present reviews of their own work to date and their planned future efforts. Notify John Birken, (202) 692-3935, if more than 30 minutes presentation time is required.
3. A discussion of material sample panels and joints being prepared will be held and will include the composite-metal joints being prepared by W. Gajda (Notre Dame) under Contract Number N00019-77-C-0460. Available test techniques will be analyzed with regard to how they affect the required material samples being evaluated. In particular, the methods for holding samples need to be examined for uniform testing. It is hoped that present and future users of NAVAIR-supplied samples will provide required data, dimensions, and shapes for the samples they require.
4. A viewgraph projector will be available for use in the presentation of viewfoil material. If possible, it is also suggested, but not required, that written materials be included to augment the oral presentation. Copies of viewfoil and written material will be made available to all participants.
5. If you have any questions, need further information, or wish to modify the agenda, please do not hesitate to contact Dr. Birken (NAVAIR) or Dr. Robert Wallenberg, Syracuse Research Corporation, (315) 425-5228.

R A Retta

R. A. Retta
By direction

REPORT OF
COMPOSITE MATERIAL AND METAL
COMPOSITES JOINT WORKSHOP
24 and 25 August, 1978

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NTIS GRA&I	☒
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Unannounced	☐
Justification	
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Distribution	
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Washington, D.C.

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Table of Contents

FOREWORD

The Composite Material and Metal Composites Joint Workshop was hosted by the Naval Air Systems Command (NAVAIR). Invitation to attend was provided by NAVAIR letter 52026B/78: JAB of August 18, 1978. The workshop was held at NAVAIR on 24 and 25 August, 1978.

The purposes of the workshop were:

The meeting is directed towards instrumentation techniques and sample holders utilized to measure convenient size composite and composite-metal joint sample electromagnetic properties. Measurements of specific electromagnetic parameters and their inter-relationships will be discussed. Participants are invited to present reviews of their own work to date and their planned future efforts.

A discussion of material sample panels and joints being prepared will be held and will include the composite-metal joints being prepared by W. Gajda (Notre Dame) under Contract Number N00019-77-C-0460. Available test techniques will be analyzed with regard to how they affect the required material samples being evaluated. In particular, the methods for holding samples need to be examined for uniform testing. It is hoped that present and future users of NAVAIR-supplied samples will provide required data, dimensions, and shapes for the samples they require.

This report provides copies of the visual aids used for the formal presentations.

Note: In a few instances, viewgraphs have not been included as they were found to be unsuitable for reproduction.

Composite Material and Metal Composites

Joint Workshop

24 and 25 August 1978

Chairperson: Dr. John Birken

AGENDA

Thursday, August 24, 1978

A.M.

1. J. Birken, NASC
Overview of Joints in Composite Materials
2. W. Gajda, Notre Dame
Materials preparation, measurements, and
experimental setup at Notre Dame
3. R. Wallenberg, Syracuse Research Corporation

P.M.

4. R. Carri, Grumman Aerospace Corporation
5. J. Reardon, Naval Research Laboratory
6. E. Donaldson, EES, Georgia Tech
7. R. Stratton, Rome Air Development Center
8. D. Chang, University of Colorado

Friday, August 25, 1978

A.M.

1. S. Tompkins, NASA Langley
2. D. Swink, NSWC/Dahlgren
3. R. Prehoda, NSWC/Dahlgren

P.M.

4. G. Condon, General Electric
5. J. Roden, Syracuse Research Corporation
6. G. Becktal, NSWC/WO
7. C. Scouby, McDonnell Aircraft Corporation

8. Open Forum

Open discussion of best parameters to measure, comparison of techniques in accuracy, sample size, ease of sample preparation and ease of measurements adaptation of uniform planar jig.

Composite material sample dimension requirement from each participant. Units results will be reported in frequency of operation. NAVAIR will compile results, convert to common units compare and disseminate to all participants.

24, 25 AUGUST 1978 NAVAIR COMPOSITE JOINT WORKSHOP

<u>NAME</u>	<u>ORGANIZATION</u>	<u>PHONE NO.</u>
William G. Duff	Atlantic Research Corp	(703) 354-3400
N. Lynn Jarvis	Naval Research Lab.	(202) 767-3550
M. Stander	NAVAIR (52032D)	(202) 692-7543,5
Joseph P. Reardon	Naval Research Lab.	(202) 767-2998
Harry Z. Wilson	Aerospace	(213) 648-6253
C. D. Skouby	McDonnell Aircraft	(314) 232-3096
Walt Gajde	Notre Dame	(219) 283-3763
S.S. Tompkins	NASA - Langley	(804) 827-2434
Bob Carri	Grumman Aerospace	(516) 575-2754
David C. Chang	University of Colorado	(303) 492-7539
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Roy Stratton	RADC	
Robert Wallenberg	Syracuse Research Corp.	(315) 425-5228
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G. Bechtold	NSWC/WOL	(202) 394-1746
A. Somoroff	NAVAIR-320	(202) 692-2515)

Dr. John Birken

Naval Air Systems Command

Overview of Joints in Composite Materials

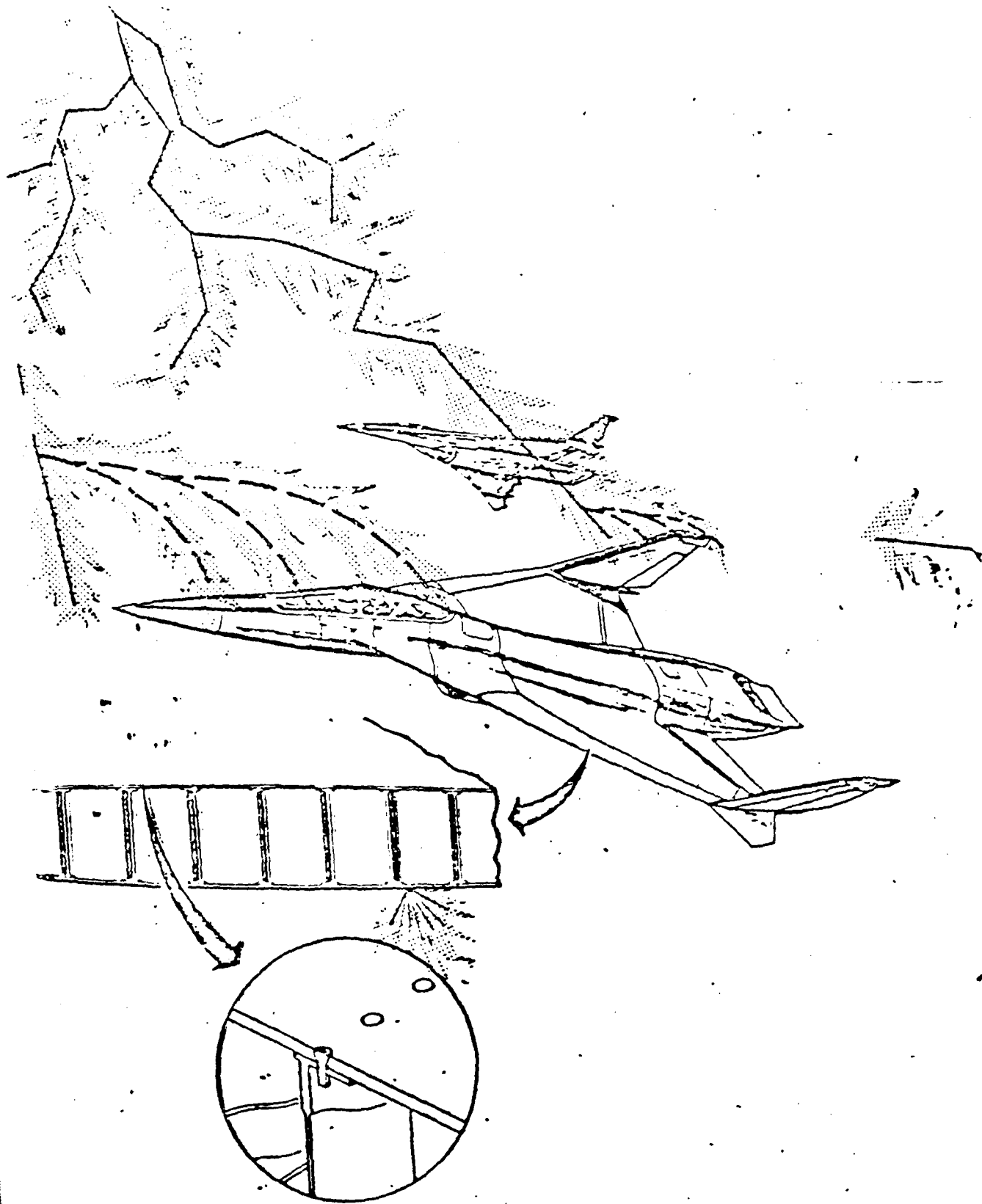
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FLEET

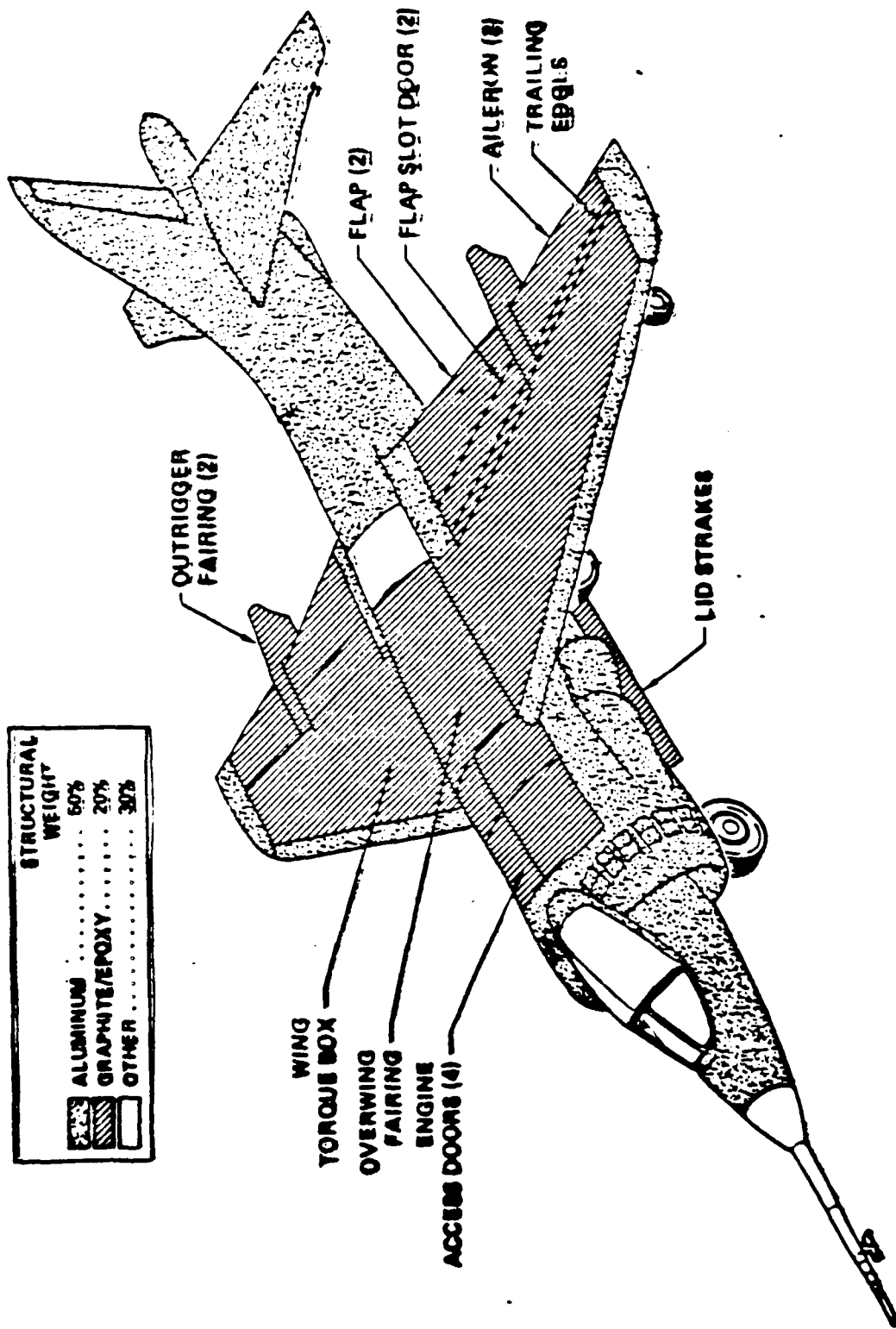


ELECTROMAGNETIC
TECHNOLOGY
TRANSFER

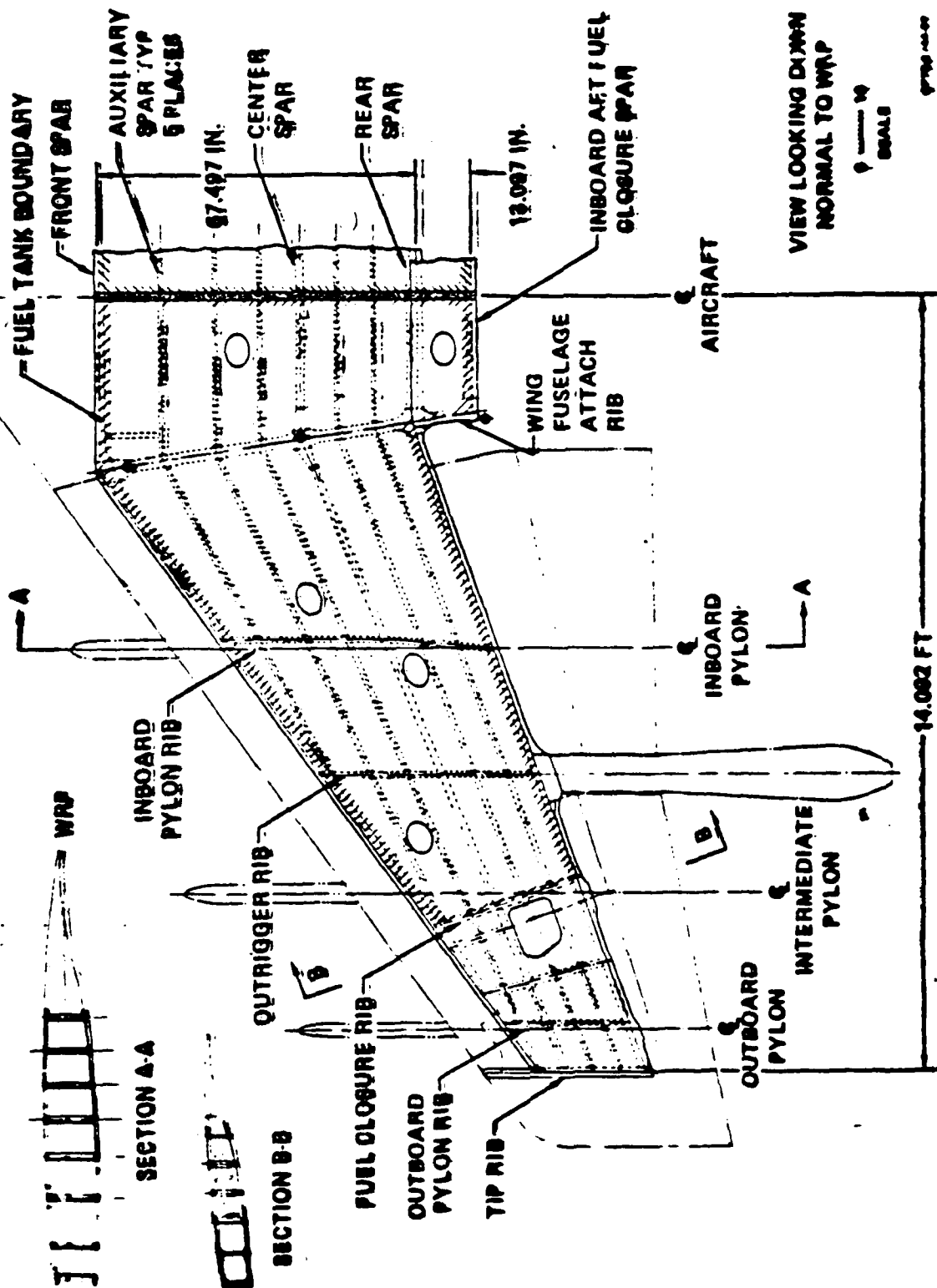
LAB

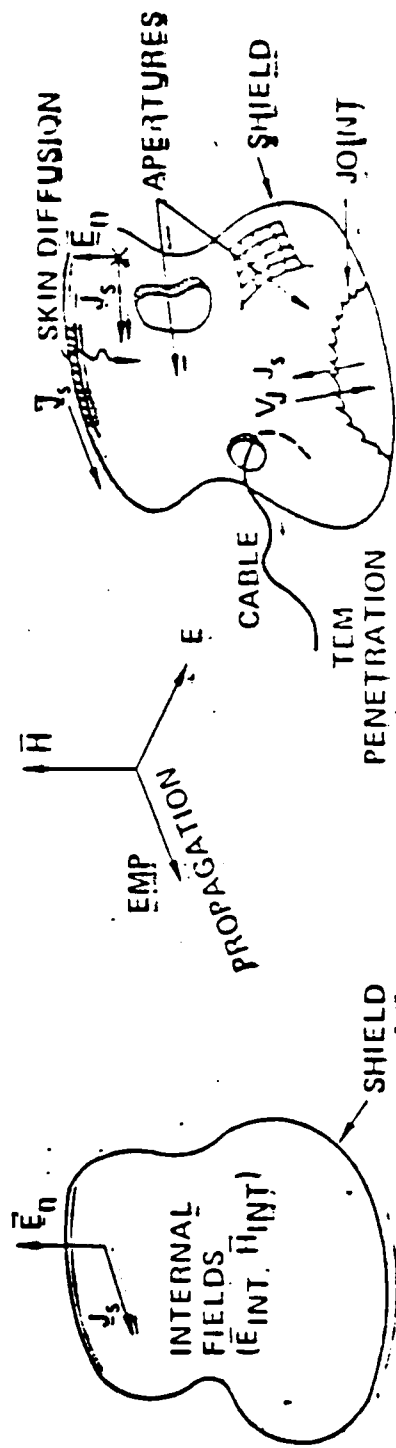


STRUCTURAL WEIGHT	
ALUMINUM	60%
GRAPHITE/EPOXY	20%
OTHER	30%



AV-8B COMPOSITE SUPER CRITICAL WING STRUCTURAL ARRANGEMENT





Coupling mechanisms:

- Skin diffusion (direct field propagation thru skin)
- Apertures (antennas, windows, holes, cracks, meshes)
- Joints and seals (door seals, skin material joints)
- TEM coupling (insulated cable currents penetrating skin)

Coupling analysis procedure:

- Calculate shield exterior surface current ($\vec{J}_s$) and charge (normal $\vec{E}$ field $\vec{E}_n$) due EMP
- Calculate interior incident fields from exterior response $\vec{J}_s, \vec{E}_n$ considering all coupling mechanisms.
- Calculate interior total fields, currents, voltages, etc, from interior incident fields and geometry.

Figure 3 The EMP Coupling Problem

$$D(f) + T_1(f) + T_2(f) + T_3(f) + T_4(f) + T_5(f) = V_{ij}(f)$$

THREAT

SHIELDING
MATERIAL

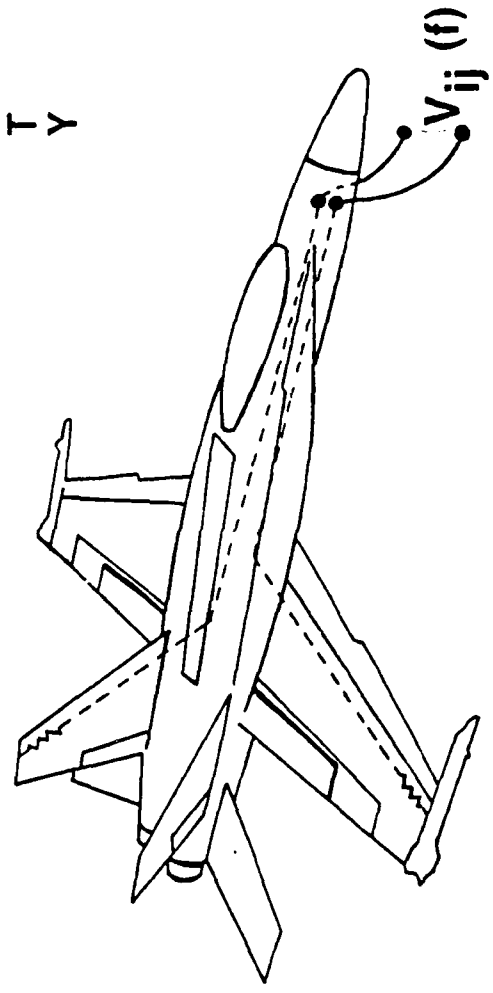
AIRFRAME
SHAPE

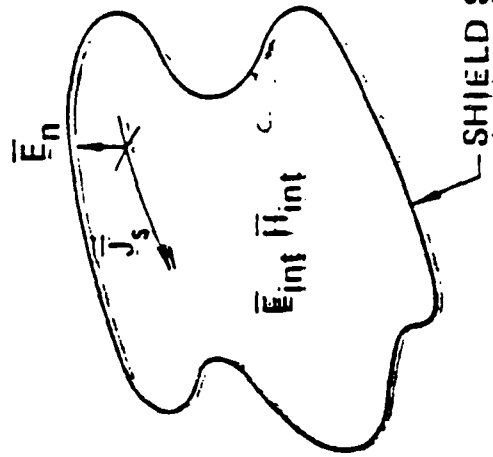
JOINT
LEAKAGE

CABLE
SHIELDING

SUSCEPTIBILITY
SUBSYSTEM

VOLTAGE
SUBSYSTEM





8

$$\left\{ \begin{array}{l} \vec{E}_{int} \\ \vec{H}_{int} \end{array} \right\} = \iint_S [(\vec{\alpha}_d + \vec{\alpha}_m + \vec{\alpha}_j) \cdot \vec{J}_s + \vec{\alpha}_p \cdot \vec{E}_n] ds$$

Skin diffusion:

$$\vec{G}_d \sim Z_{sd} \text{ (open circuit diffusion transfer impedance; ohms/square)}$$

Distributed aperture coupling (meshes):

$$\vec{G}_p \sim P \text{ (surface electric polarizability; farads)}$$

$$\vec{G}_m \sim M \text{ (surface magnetic polarizability; meters)}$$

Joint coupling

$$\vec{G}_j \sim \frac{1}{Y_j} ; Y_j \text{ (joint admittance per unit of joint width or run; phasors/meter)}$$

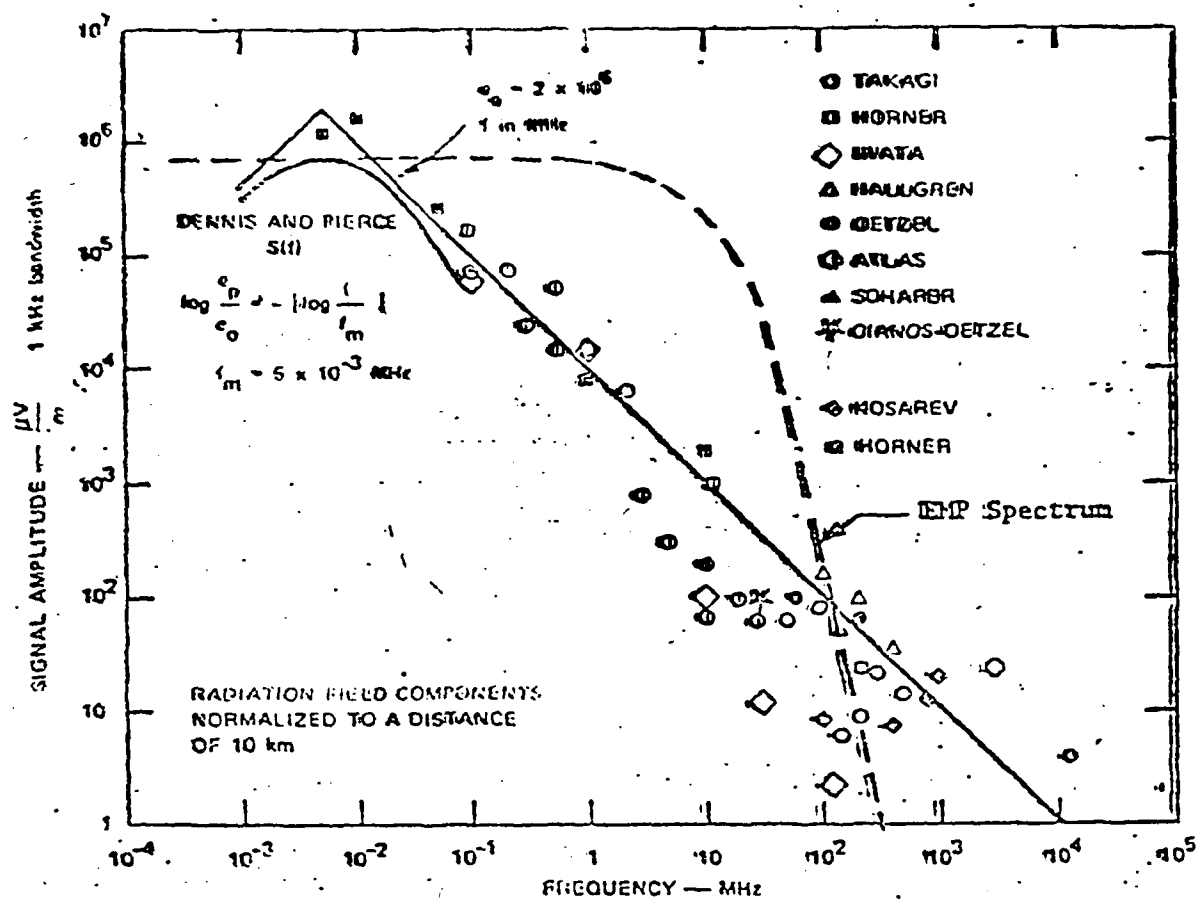


Figure 1.3.3 Peak Received Amplitude for Signals
Radiated by Lightning Compared
to an EMP Spectrum at 10 km

(Lightning Spectrum after 'Cianos & Pierce)

F. 2. 3

SYSTEMATIC EM DESIGN AND SYNTHESIS

FREQUENCY REGIONS (MHz)



THREAT

NATURAL

LIGHTNING

PRECIPITATION STATIC

MAN MADE

FRIEND & FOE

COMPOSITE TEST SAMPLES

PANELS (g/e, Bo, Si)

1 AND 2 DIMENSIONS JOINTS

YAV-8B WING & FUSELAGE

TEST TECHNIQUES

EXISTING ALGORITHMS

ALGORITHM MODIFICATIONS

INTEGRATION

TECHNICAL

GUIDELINES

PROTECTION TECHNIQUES

CO₂ YAG He-Ne

12 10

	<u>Graphite/Epoxy</u>	<u>Boron/Epoxy</u>	<u>Kevlar</u>
Permeability μ_R	1	1	1
Permittivity μ_R	Indeterminant	3.6	3.6
DC Conductivity (mhos/m)			
longitudinal σ_L	$2(10^4)$	80	$6(10^{-9})$
transverse σ_T	100	$2(10^{-8})$	$6(10^{-9})$
Anisotropy Ratios (σ_L/σ_T)	200	$1.5(10^9)$	1
High Field Thresholds			
longitudinal			
E_{NL} (volts/m)	250	not	not
J_{NL} (amps/m ²)	$4(10^5)$	measured	measured
transverse			
E_{NL} (volts/m)	4000	not	not
J_{NL} (amps/m ²)	$1(10^4)$	measured	measured

SUMMARY OF ELECTRICAL PROPERTIES OF MEASURED COMPOSITES

COMPOSITE MATERIAL FUNDAMENTAL

ELECTRICAL PROPERTIES

CONDUCTIVITY $\rho(f)$

PERMEABILITY $\mu(f)$

PERMITTIVITY $\epsilon(f)$

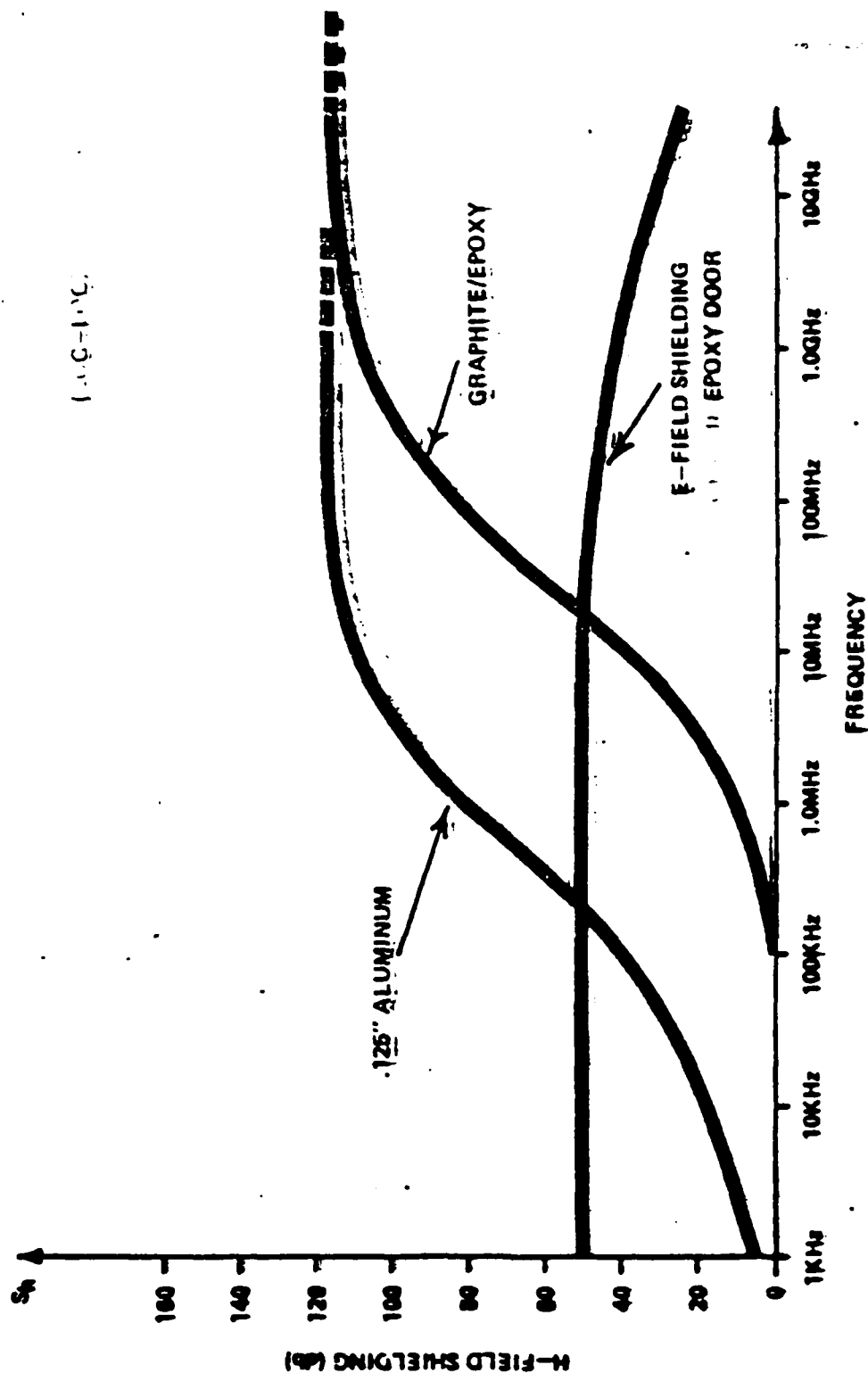
VARY WITH FREQUENCY

Table VI

SUMMARY OF FORMULAS FOR SHIELDING EFFECTIVENESS

Source	Attenuation A, dB	Reflection Loss R, dB	Correction Term C, dB
$ES = A + B + C$ (106) r = distance from source to shield, meters μ_r = relative permeability g_r = conductivity relative to copper f = frequency, Hz.			
Plane Wave $r \geq \frac{\lambda}{2}$ (140) and Table V or $r \geq 2\lambda$ (dipole)	$131.44 \sqrt{\mu_r g_r}$ (173)	$168 + 20 \log \sqrt{\frac{g_r}{\mu_r}}$ (183)	$\rho = 4 \frac{(1-m)^2 - 2m^2 - 12\sqrt{2m}(1-m)^2}{[(1+\sqrt{2m})^2 + 1]^2} + 1 =$ (187) $m = 9.27 \times 10^{-10} \sqrt{\frac{\mu_r}{g_r}}$ (188) $C = 20 \log 1 - 10^{-\frac{\rho}{10}} (\cos 0.23A - j \sin 0.23A) $ (189)
Loop, Near Field $r \leq \frac{\lambda}{10}$	$131.44 \sqrt{\mu_r g_r}$ (173)	$-9 + 20 \log \left[\frac{3.32 \times 10^{-2}}{r} \sqrt{\frac{g_r}{\mu_r}} \right]$ (194) $-1 + 15.1r \sqrt{\frac{g_r}{\mu_r}}$ (194)	$\rho = 4 \frac{(1-m)^2 - 2m^2 - 12\sqrt{2m}(1-m)^2}{[(1+\sqrt{2m})^2 + 1]^2}$ (196) $m = \frac{4.7 \times 10^{-2}}{r} \sqrt{\frac{\mu_r}{g_r}}$ (197) $C = 20 \log 1 - 10^{-\frac{\rho}{10}} (\cos 0.23A - j \sin 0.23A) $ (179)
Electric Dipole, Near Field $r \leq \frac{\lambda}{10}$	$131.44 \sqrt{\mu_r g_r}$ (173)	$322 + 20 \log \frac{1}{r} \sqrt{\frac{g_r}{\mu_r}}$ (200)	$\rho = 4 \frac{(1-m)^2 - 2m^2 - 12\sqrt{2m}(1-m)^2}{[(1+\sqrt{2m})^2 + 1]^2}$ (203) $m = 0.205 \times 10^{-16} r \sqrt{\frac{\mu_r}{g_r}}$ (204) $C = 20 \log 1 - 10^{-\frac{\rho}{10}} (\cos 0.23A - j \sin 0.23A) $ (179)

MAGNETIC SHIELDING VS. FREQUENCY FOR SEVEN LAYERS GRAPHITE/EPOXY OVERLAY AND ALUMINUM



26-12-77

NASA LANGLEY RESEARCH CENTER

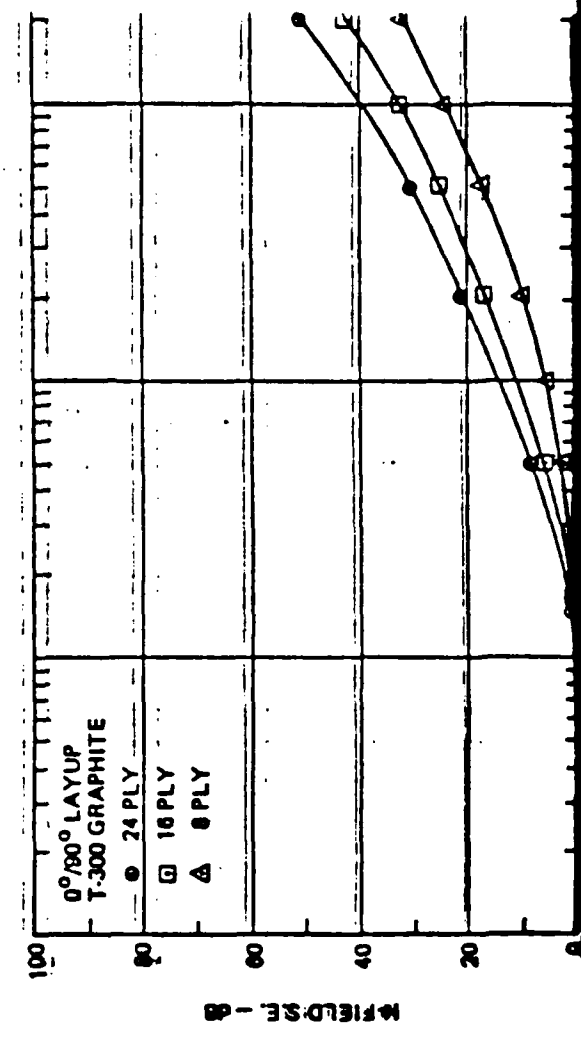
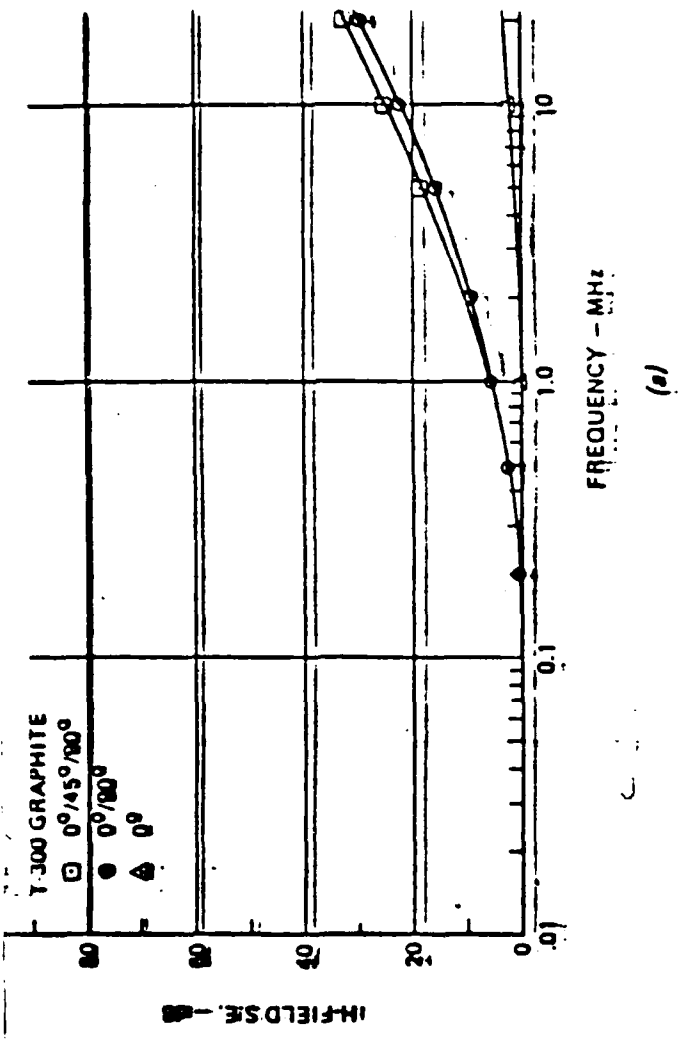
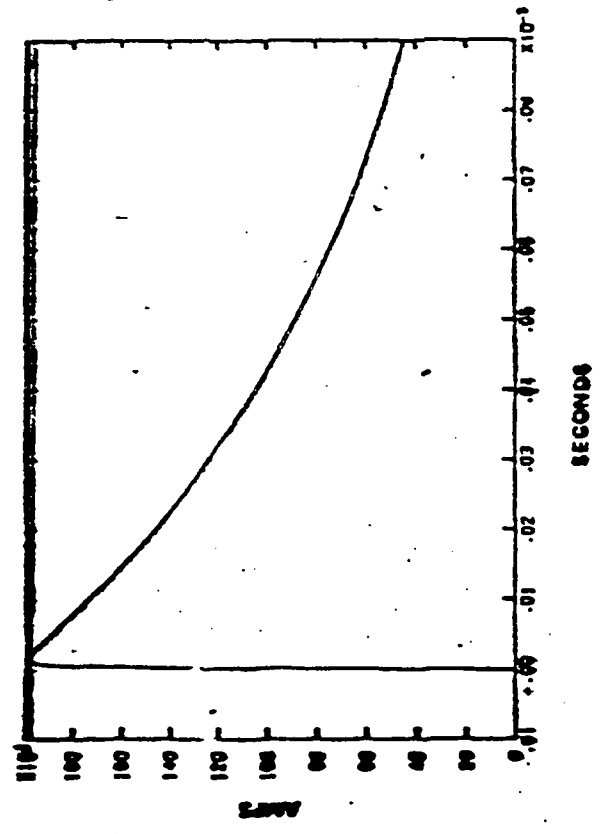
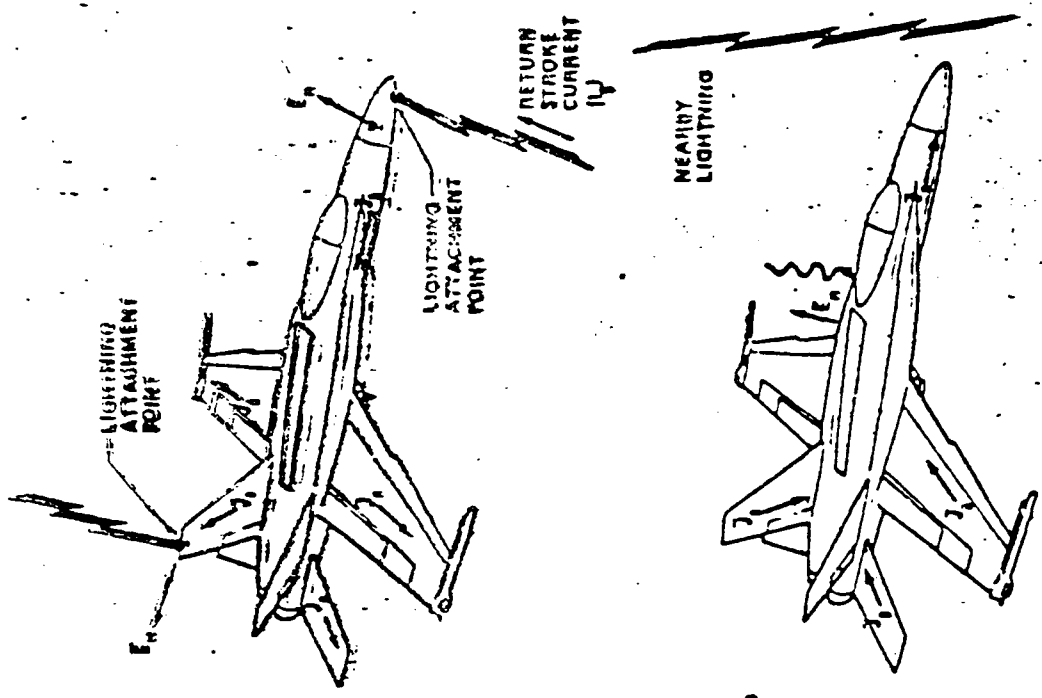


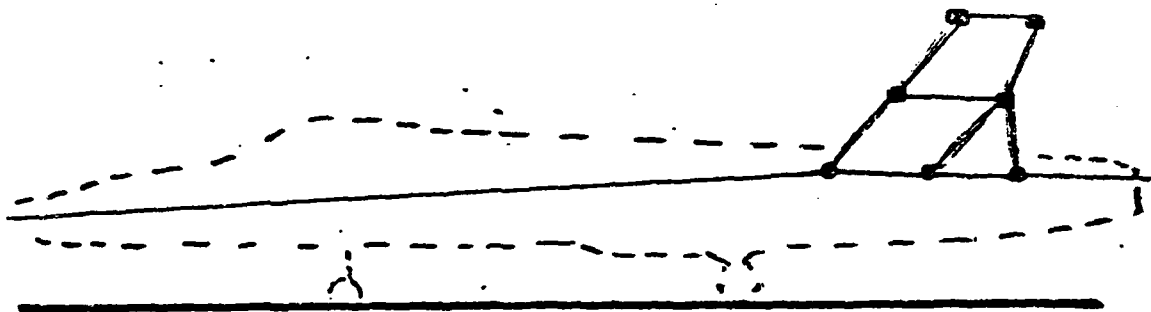
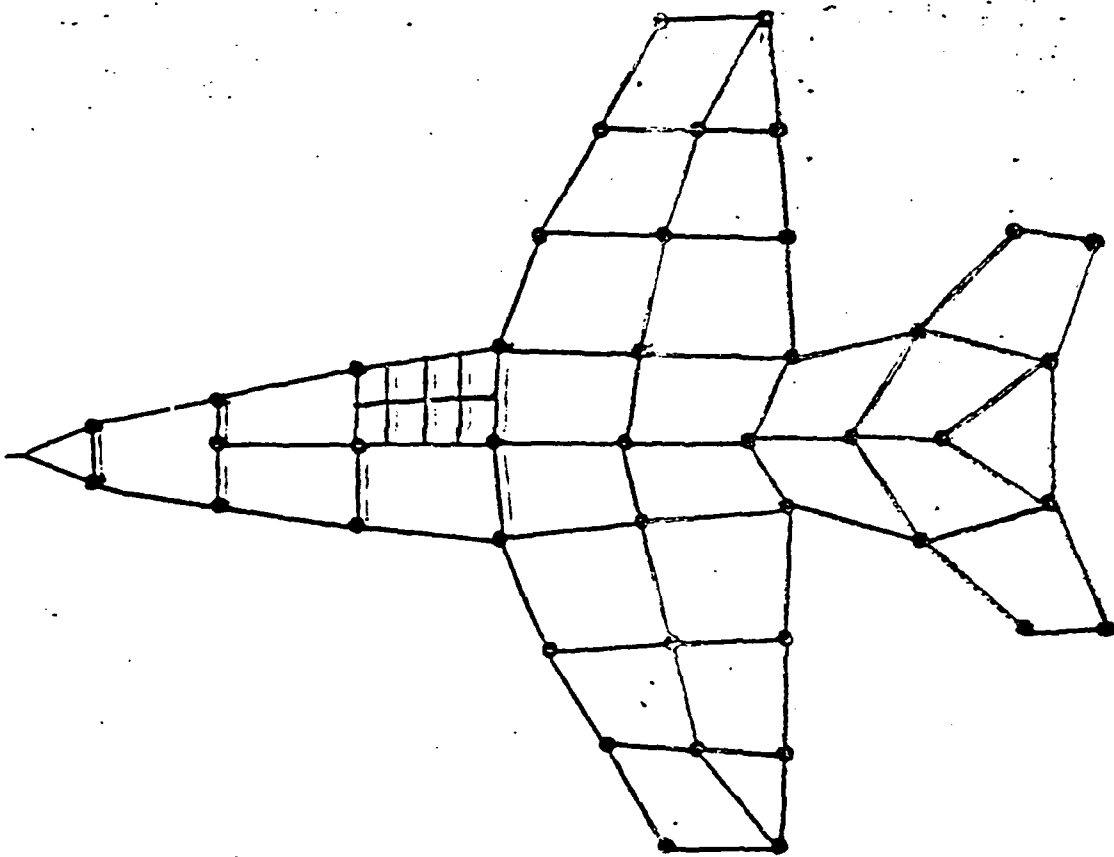
TABLE 11

Z₀ OF COMPOSITES, COATINGS AND COATED COMPOSITESZ₀ .08 BELOW 1 OHM)

MATERIAL	FREQUENCY (MHz)				
	.01	.1	1	10	100
64 Mil Aluminum*	-87	-122.6	-225	-571	-850
8 Ply T300 Graphite	-27	-27	-27	-27.5	-33.5
1 Ply T300 Graphite	-35.8	-35.8	-36	-45	-102
1 Ply Hts Graphite	-30	-30	-30	-32	-52
24 Ply Rig 5505 Boron*	-	-	-	-8.1	-18.1
GREENS					
18 Mesh Aluminum	-56	-56	-54	-36	-17
Mesh Aluminum	-60.5	-61	-63	-57.7	-44.4
0 Mesh Aluminum	-57.4	-57.4	-58.2	-60.4	-54.9
200 Mesh Aluminum	-47.7	-47.7	-48	-48.3	-53
20 Mesh Phosphor Bronze	-52	-51	-51.5	-52.5	-47
0 Mesh Phosphor Bronze	-45.8	-45.8	-46	-47	-45.5
120 Mesh Phosphor Bronze	-47.4	-47.4	-47.4	-48	-53
4 Mesh Steel-27	-50	-48	-42	-27	-7
FOILS					
7 Mil Copper	-74	-74	-74.2	-83	-123
1 Mil Aluminum	-64	-64	-64.5	-69.5	-96.5
1 Mil Aluminum	-58	-58	-58	-59	-66.4
1 Mil Conetic Foil	-48	-62	-130*		
COATED COMPOSITES					
1 Ply T300 + 2 Mil Aluminum	-64	-64	-71.4	-95.4	-195*
1 Ply T300 + 40 Mesh Aluminum	-60.5	-60.5	-64.4	-81.4	-143*
24 Ply T300 + 1 Mil Aluminum	-58	-58	-63.4	-84.9	-164*
1 Ply T300 + 120 Mesh Aluminum	-57.4	-57.4	-59.4	-81.4	-153*
24 Ply T300 + 80 Mesh Phosphor Bronze	-52	-52	-64.9	-75.4	-145*
1 Ply T300 + 120 Mesh Phosphor Bronze	-49	-49	-51.5	-72.5	-151*
12 Ply Hts + 120 Mesh Phosphor Bronze	-47.4	-47.4	-49.5	-60	-87
1 Ply Hts + 100 Mesh Phosphor Bronze	-48.7	-48.7	-49.3	-59.1	-81

CALCULATED





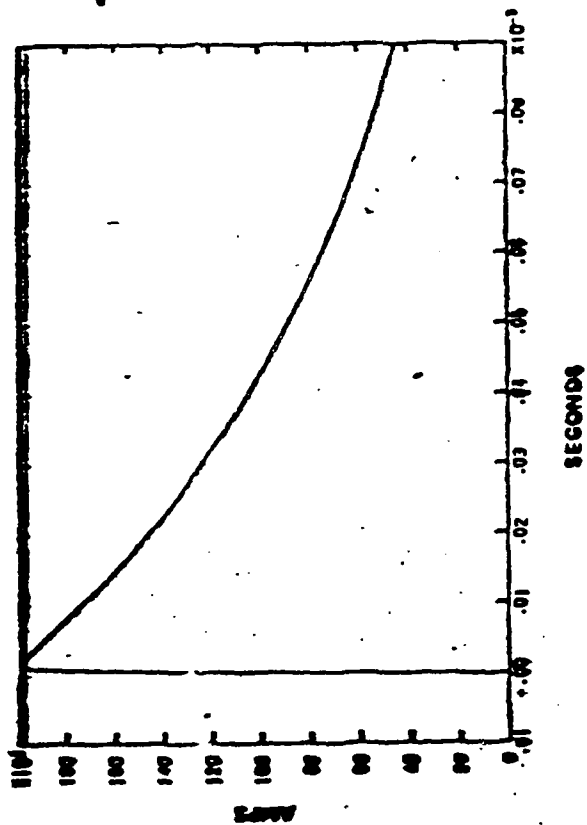
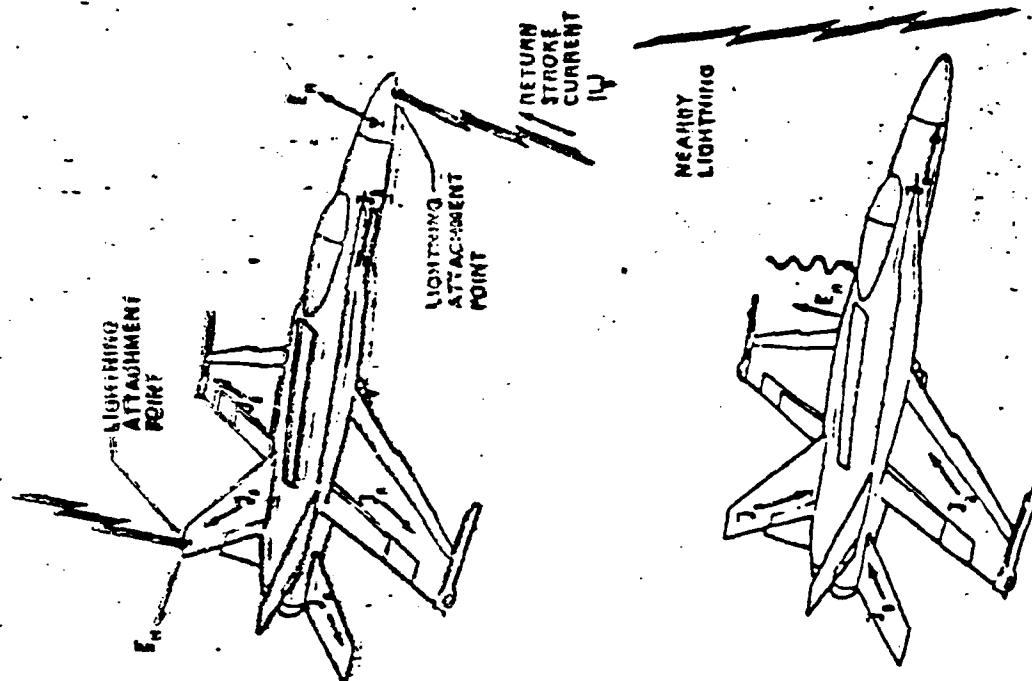


Table 5.—Peak Transients on Nose/Tail Wire

NOTE: Values are given for open circuit voltage (V_{oc}) and short-circuit current (I_{sc}) from wire to structural ground.

Threat		Transient source	Configuration						
			All metal (closed cockpit)	All metal (open cockpit)	All composite	Composite tail		Composite access doors	
						Diffusion	Joint	Diffusion	Joint
LEMP	Nose/tail attachment	V _{oc} , V	10.1	-4500	-32000	-28000	2400	-5500	1400
		I _{sc} , A	0.3	-67	-1100	-750	70	-180	48
	Nearby strike	V _{oc} , V	*	-90	250	-54	21	-130	28
		I _{sc} , A	*	-1.3	18.2	-1.8	10.70	-4.5	10.95
NEMP	E11 fuselage	V _{oc} , V	*	2200	102	15	-37	68	-19
		I _{sc} , A	*	28	1.5	0.15	-0.37	-0.83	-0.22
	E1 fuselage	V _{oc} , V	*	-	36	-	-	-	-
		I _{sc} , A	*	-	0.47	-	-	-	-

*Less than 0.1 volt (or amp)

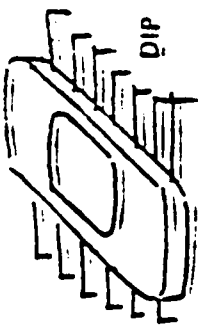
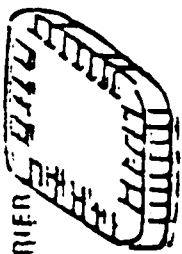
Table 6.—Peak Transients on Nose/Wing Tip Wire

*Less than 0.1 volt (or amp)

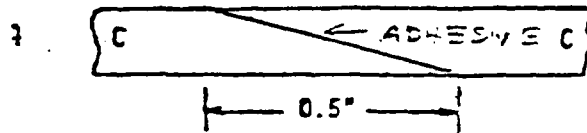
Note: Values are given for open circuit voltage (V_{oc}) or short circuit current (I_{sc}) from wire to structural ground.

Threat		Transient source	Configuration			
			All metal (closed cockpit)	All composite	Composite wing	
					Diffusion	Joint
LEMP	Nose/tail attachment	V_{oc} , V	-2.1	-6500	-	-
		I_{sc} , A	-0.1	-220	-	-
	Nose/wing tip attachment	V_{oc} , V	-5.4	-17000	-11300	2800
		I_{sc} , A	-0.2	-550	-370	95
NEMP	E11 fuselage	V_{oc} , V	*	84	-	-
		I_{sc} , A	*	1.3	-	-
	E1 fuselage	V_{oc} , V	*	76	188	-24
		I_{sc} , A	*	1.1	1.0	-0.33

TECHNOLOGY TRENDS

TUBES	DISCRETE TRANSISTORS	INTEGRATED CIRCUITS (IC)	LARGE SCALE INTEGRATED CIRCUITS (LSI)	VLSI LARGE SCALE INTEGRATED CIRCUITS (VLSI)
 250V 1 WATT/DEVICE	 TO-18 12V-24V 10-1-10-2 WATTS/DEVICE	 FLAT PACK 5V-12V 10-2-10-3 WATTS/TRANS	 DIP 5V-7V 10-3-10-4 WATTS/TRANS	 CHIP CARRIER 1.5V-3V 10-5-10-6 WATTS/TRANS
GLASS/ METAL/ CERAMIC	METAL/ CERAMIC	METAL/ CERAMIC/ EPOXY	METAL/ CERAMIC/ EPOXY	CERAMIC/ EPOXY
F-9	F-4	F-14	F-18	VSL
ALUMINUM	ALUMINUM	ALUMINUM/TITAN	GRAPHITE-EPOXY ALUMINUM	GRAPHITE-EPOXY
PRE-1960's	1960's	1960's	1970's	1980's

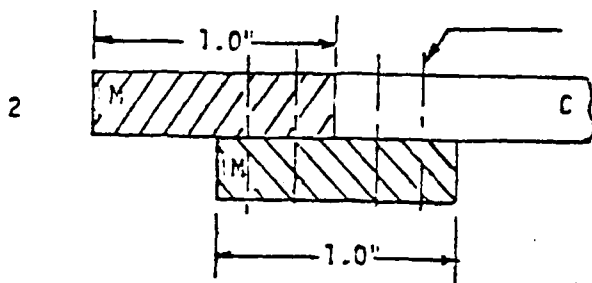
SKIRT JOINT



CYLINDER WAS FABRICATED EXTRA LONG, CUT, MACHINED AND SECONDARILY BONDED WITH EA-934 ADHESIVE.

$$Y_j \sim 2 \frac{\text{MHOS}}{\text{Meter}} \quad 0-100 \text{ MHz}$$

RIVETED JOINT

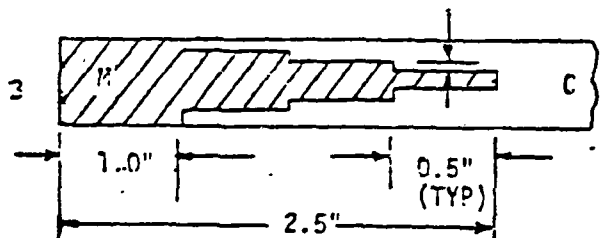


1/8-DIA RD. HD. RIVET C TO M
1/8 DIA BOLT M. TO M.

CYLINDER CENTER TOWARDS BOTTOM OF PAGE. METAL RINGS FABRICATED FROM ALUMINUM SHEET, CUT, ROLLED AND WELDED. THE RIVETS OR BOLTS WERE PLACED IN A CIRCUMFERENTIAL ROW APPROXIMATELY ONE INCH APART AND ALTERNATING 1/8 INCH TO EITHER SIDE OF THE CIRC. CTR LINE.

$$Y_j \sim 15 \frac{\text{MHOS}}{\text{Meter}} \quad 0-100 \text{ MHz}$$

DOUBLE STAIRCASE JOINT



FIRST THREE STEPS (4 PLY PER STEP) WERE PRECURED (COMPACTED). EA-934 APPLIED TO SANDED COMPOSITE STEPS, AND THEN LONGITUDINALLY SLIT METAL RING MANEUVERED INTO PLACE. REMAINING COMPOSITE STEPS WERE APPLIED TO EA-934 COATED METAL RING IN PLACE. METAL RING WAS FABRICATED FROM 2024 ALUMINUM.

$$Y_j \sim 230 \frac{\text{MHOS}}{\text{Meter}} \quad 0-100 \text{ MHz}$$

Figure 84.—Structural Joints

INDEX

ACCESS DOORS																
TAIL										WING				JOINT		
JOINT										JOINT				JOINT		
COMP.	9	15	60	90	230	COMP.	5	15	50	COMP.	4	9	15	60	90	

$\gamma_j = 15 \text{ mho/m}$ FOR JOINT NO. 5
 $\gamma_j = 230 \text{ mho/m}$ FOR JOINT NO. 4

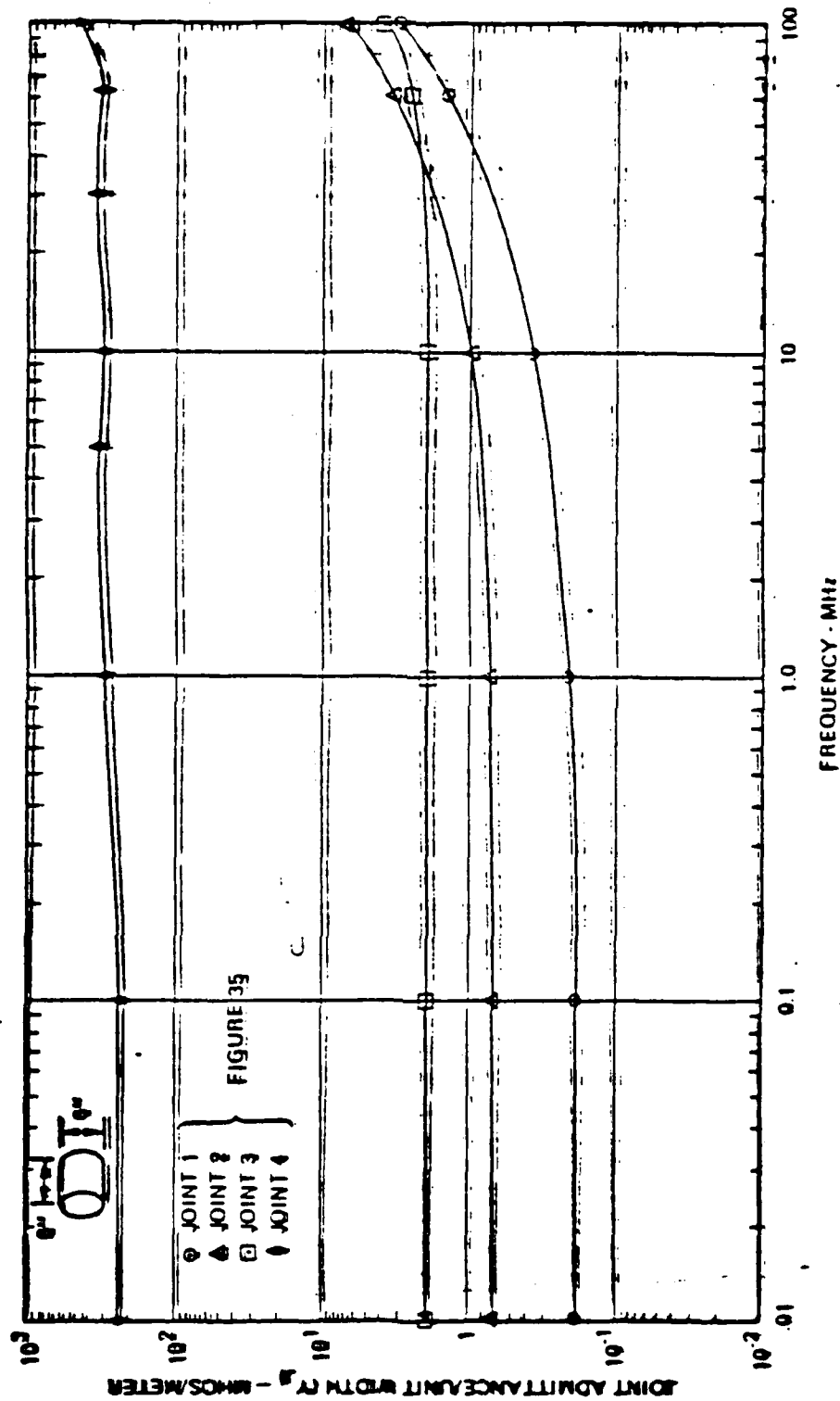


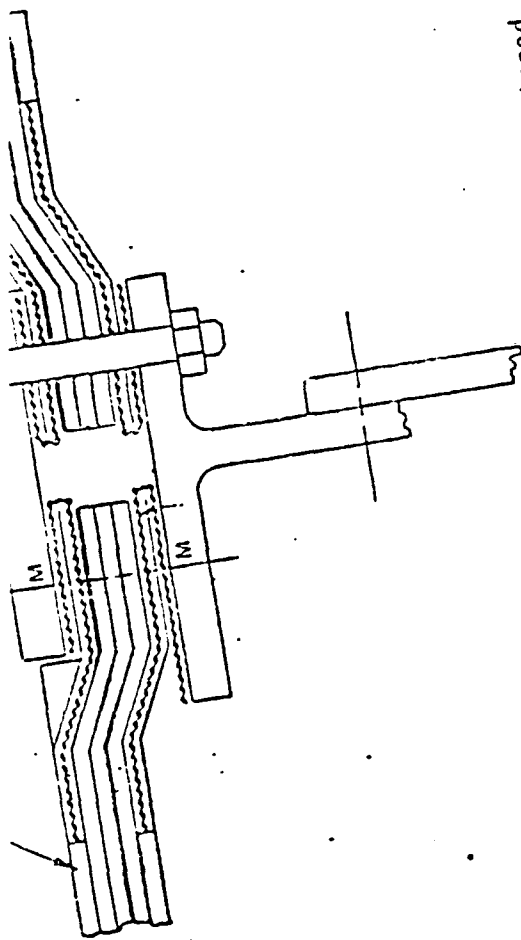
Figure 96 Measured Joint Admittance of Structural Joints

Table 7.—Peak Open Circuit Voltages for Composite Structures Versus Joints

	Tail				Wing				Access doors			
	Through composite contribution	Joint contribution			Through composite contribution	Joint contribution			Through composite contribution	Joint contribution		
		#1	#2	#3		#1	#2	#3		#1	#2	#3
LEMP	22 KV	116 KV	2.1 KV	0.14 KV	11 KV	21 KV	2.8 KV	0.18 KV	5.5 KV	11 KV	1.4 KV	0.09 KV
NEMP	15 V	1280 V	37 V	2.4 V	68 V	1190 V	25 V	1.6 V	68 V	140 V	19 V	1.2 V

Y_J = 2 mho/m for joint no. 1
 = 15 mho/m for joint no. 2
 = 230 mho/m for joint no. 3

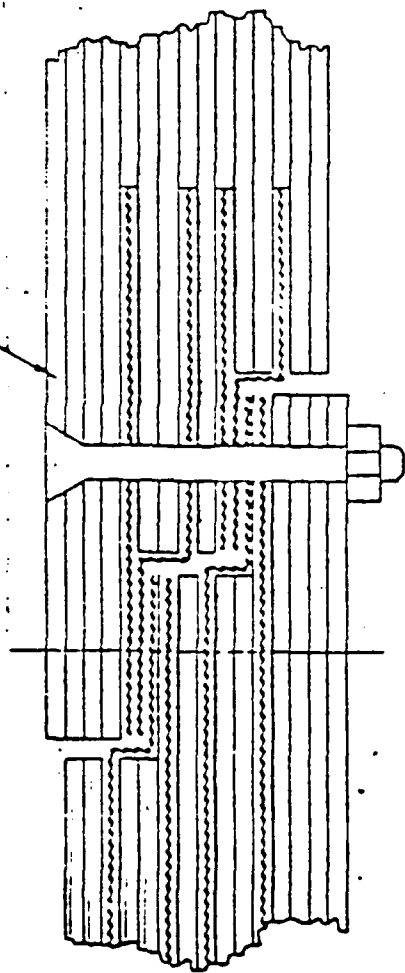
Note: The wire circuits are identical to those described for the previous calculations



Folded Multiple Screens, Mechanically Fastened
Joint with Metal Doublers

- o TYPICAL APPLICATION - SKIN SPLICE AT LONGERON OR SPAR CAP
- o LOAD TRANSFER MECHANISM - TITANIUM OR ALUMINUM SPLICE PLATES
- o POTENTIAL ADVANTAGE - EASIER FABRICATION DUE TO THE EXTERNAL SCREEN PLIES

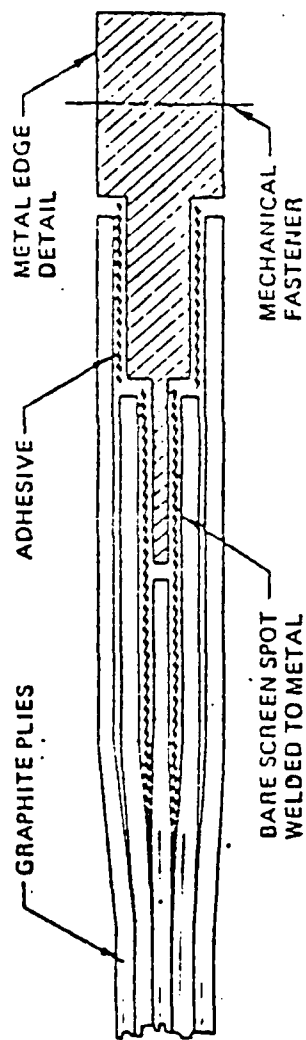
GRAPHITE PLIES



Multiple Exposed Screen, Mechanically Fastened
Stepped Lap Joint

MULTIPLE EXPOSED SCREEN, MECHANICALLY FASTENED STEPPED LAP JOINT

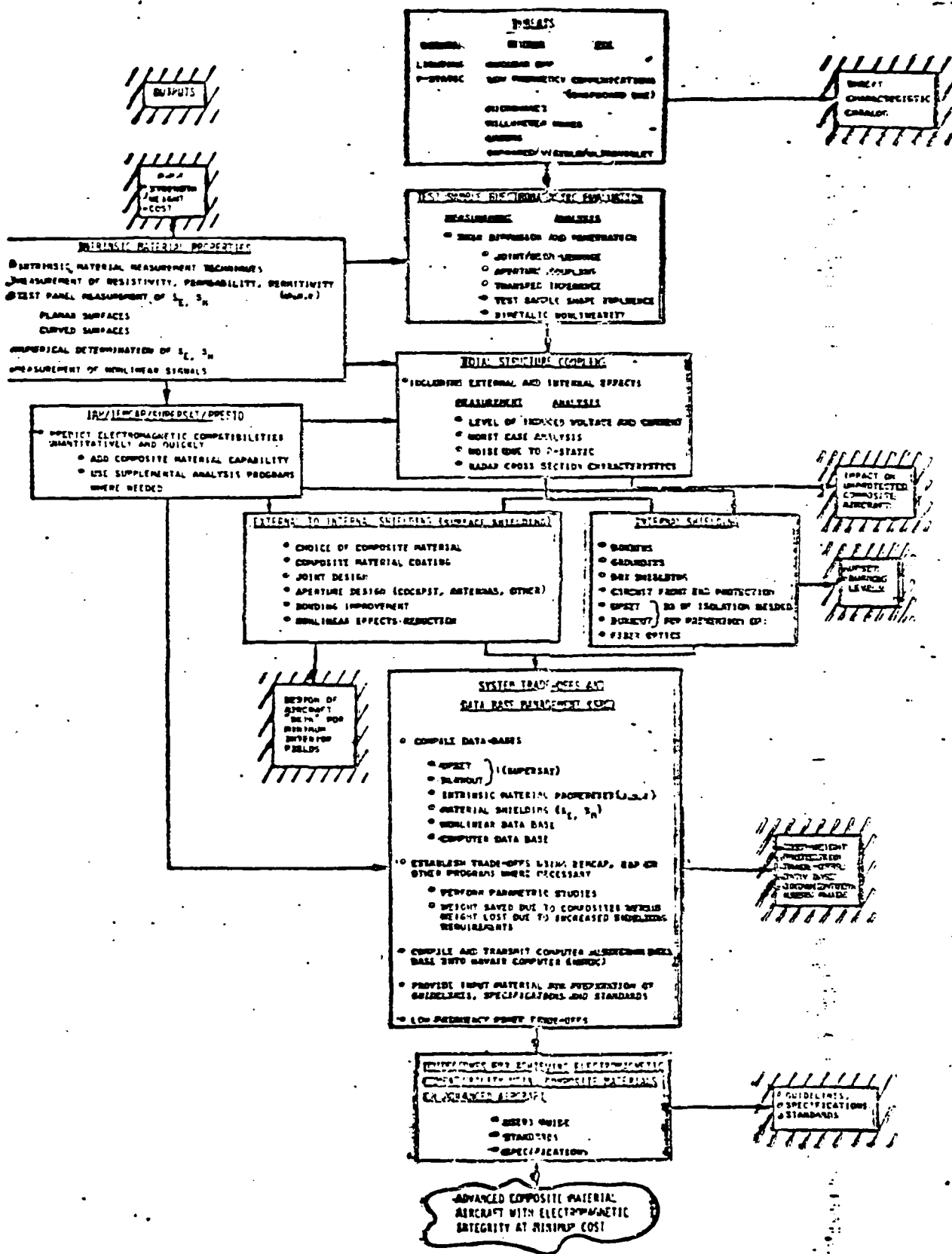
- o TYPICAL STEPPED LAP JOINT
- o LOAD TRANSFER MECHANISM - MECHANICAL FASTENERS
- o POSSIBLE ADVANTAGE - POSITIVE PRESSURE IN SCREEN INTERFACE AREA



Center Screen Stepped Lap Composite to Metal Joint

CENTER SCREEN STEPPED LAP COMPOSITE TO METAL JOINT

- o TYPICAL WING STEPPED JOINT
- o LOAD TRANSFER MECHANISM - ADHESIVE BOND



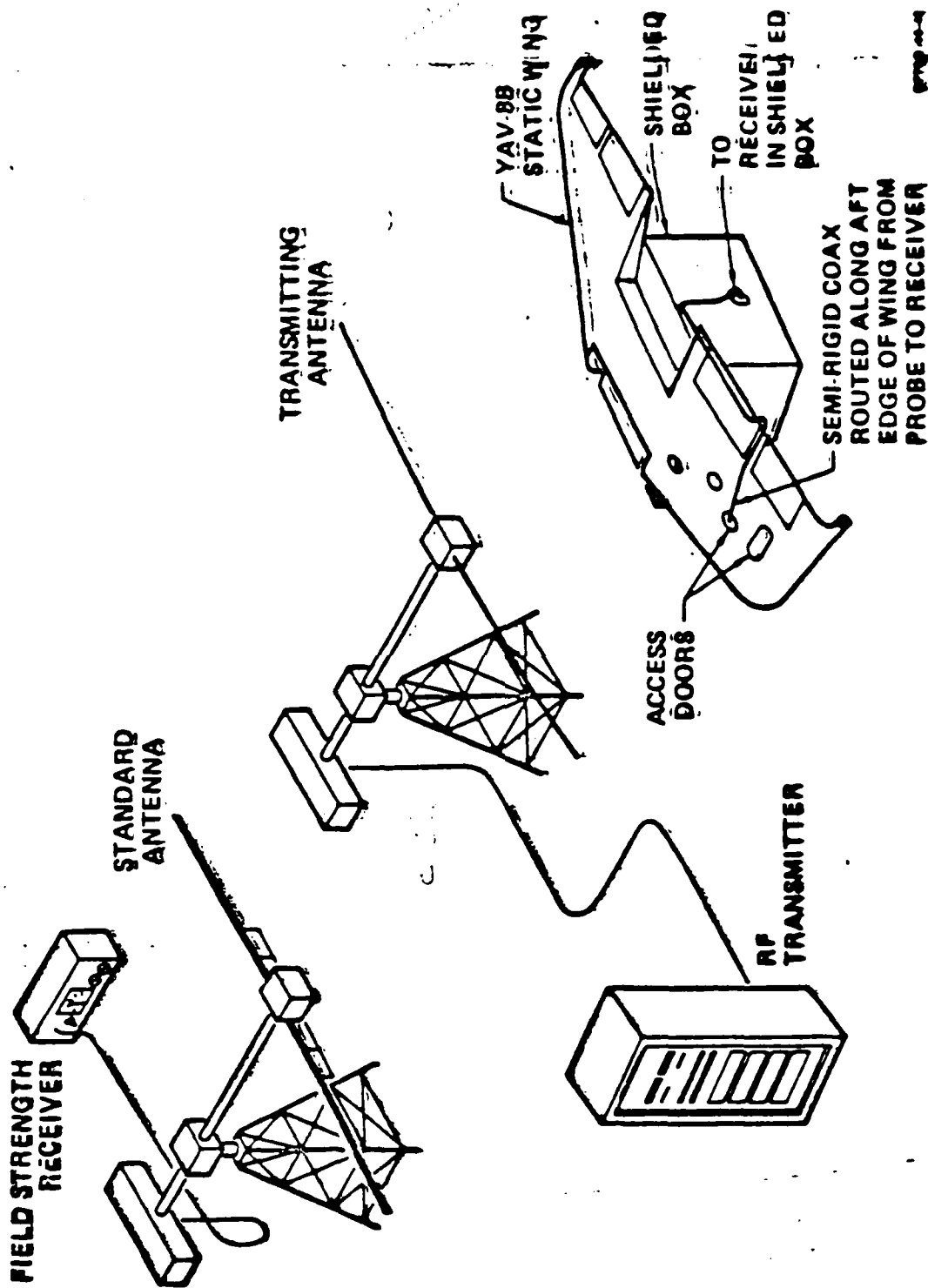
SYSTEM TRADE-OFFS AND
DATA BASE MANAGEMENT (SRC)

- COMPILE DATA BASES
 - UPSET } (SUPERSAT)
 - BURNOUT }
 - INTRINSIC MATERIAL PROPERTIES (ρ, μ, ϵ)
 - MATERIAL SHIELDING (S_E, S_H)
 - NONLINEAR DATA BASE
 - COMPUTER DATA BASE
- ESTABLISH TRADE-OFFS USING IEMCAP, IAP OR OTHER PROGRAMS WHERE NECESSARY
 - PERFORM PARAMETRIC STUDIES
 - WEIGHT SAVED DUE TO COMPOSITES VERSUS WEIGHT LOST DUE TO INCREASED SHIELDING REQUIREMENTS
- COMPILE AND TRANSMIT COMPUTER ALGORITHM DATA BASE INTO NAVAIR COMPUTER (NSRDC)
- PROVIDE INPUT MATERIAL FOR PREPARATION OF GUIDELINES, SPECIFICATIONS AND STANDARDS
- LOW FREQUENCY POWER TRADE-OFFS

GUIDELINES FOR ACHIEVING ELECTROMAGNETIC
COMPATIBILITY USING COMPOSITE MATERIALS
ON ADVANCED AIRCRAFT

- USERS GUIDE
- STANDARDS
- SPECIFICATIONS

EMI TEST SET-UP



STATIC WING CABLE ROUTING AND PROBE LOCATION

CABLE PATH
NO. 1

CABLE PATH NO. 2

REPEATER

FIBER OPTIC
CABLE LOOPS

TERMINATION
BOXES

0 10 20
Scale

⊕ Probe Locations

VIEW LOOKING DOWN NORMAL TO WRP

1000000

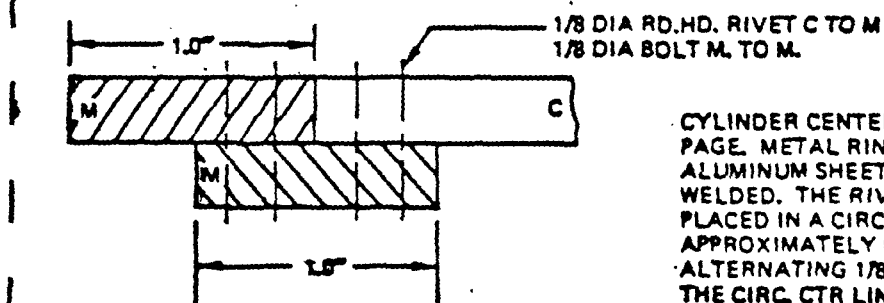
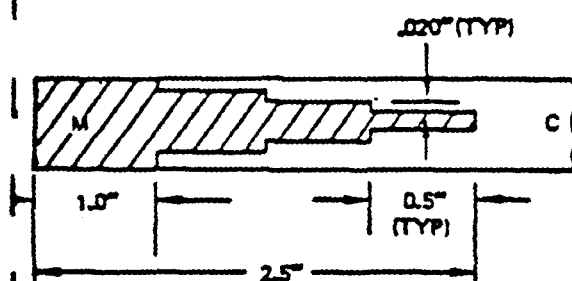
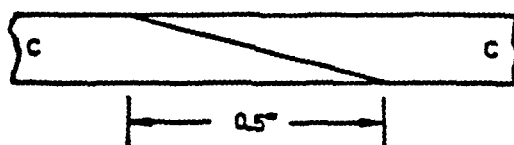
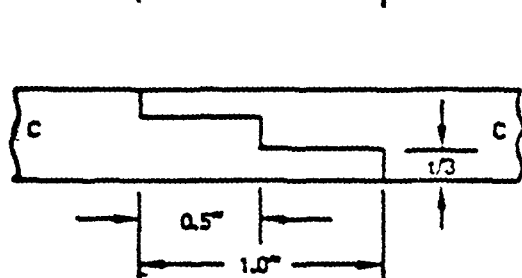
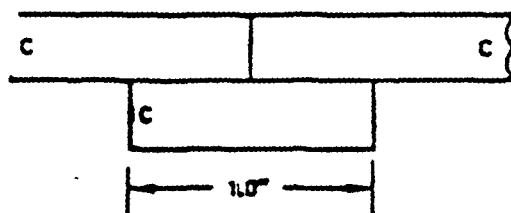
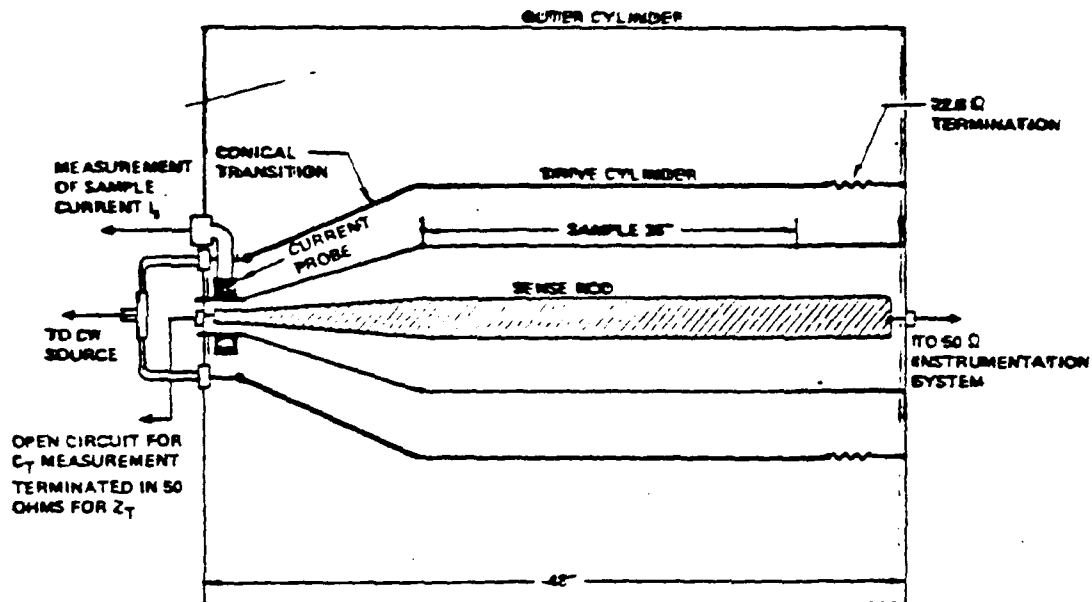
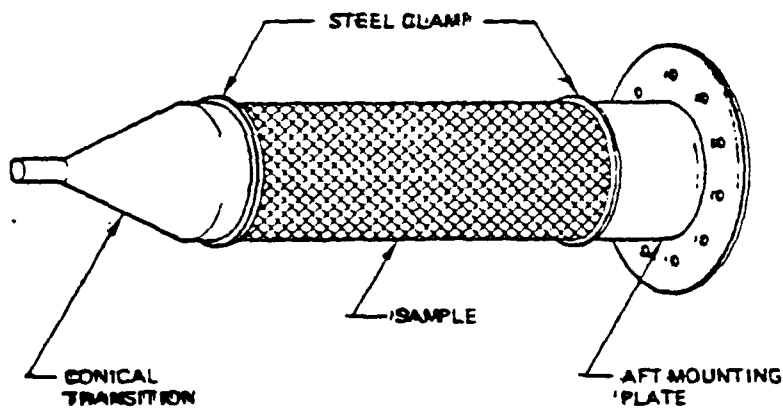


Figure 35 Structural Joints for Quadraz Test Specimens



(a) Schematic of quadraxial test fixture



(b) Sample cylinder clamping arrangement

Figure 5.6-1. Quadraz Test Fixture

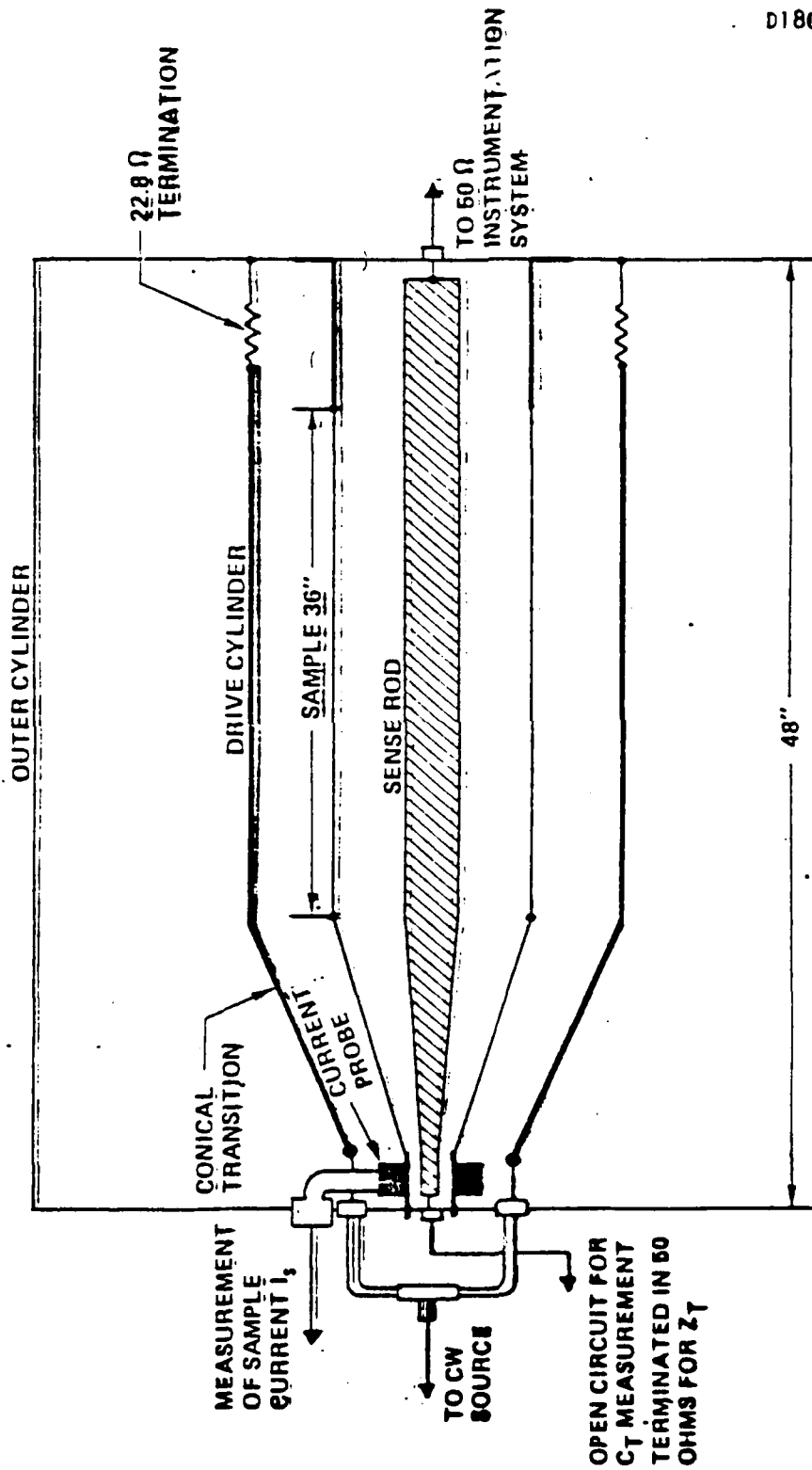
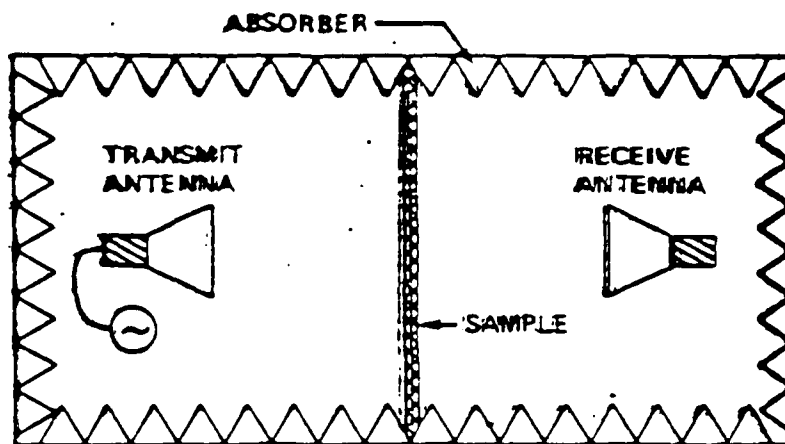
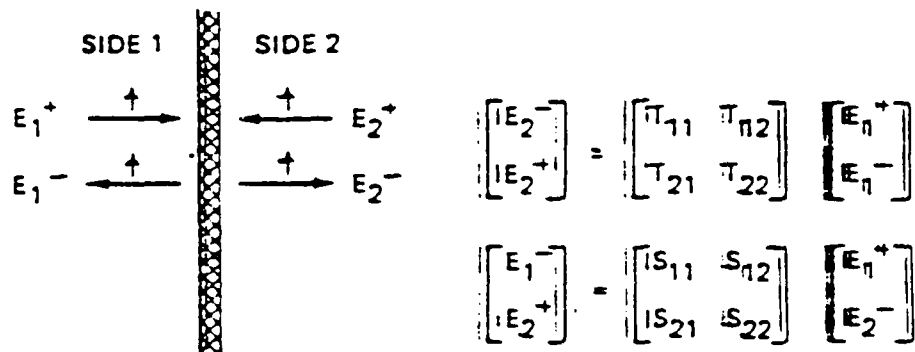


Figure 2.1.1-2 Schematic of Quadraxial Test Fixture



a) Anechoic chamber



b) Transmission (T) and scattering parameter (S) parameters of the material sheet

Figure 2.1-7 Transmission Parameter Measurement in an Anechoic Chamber

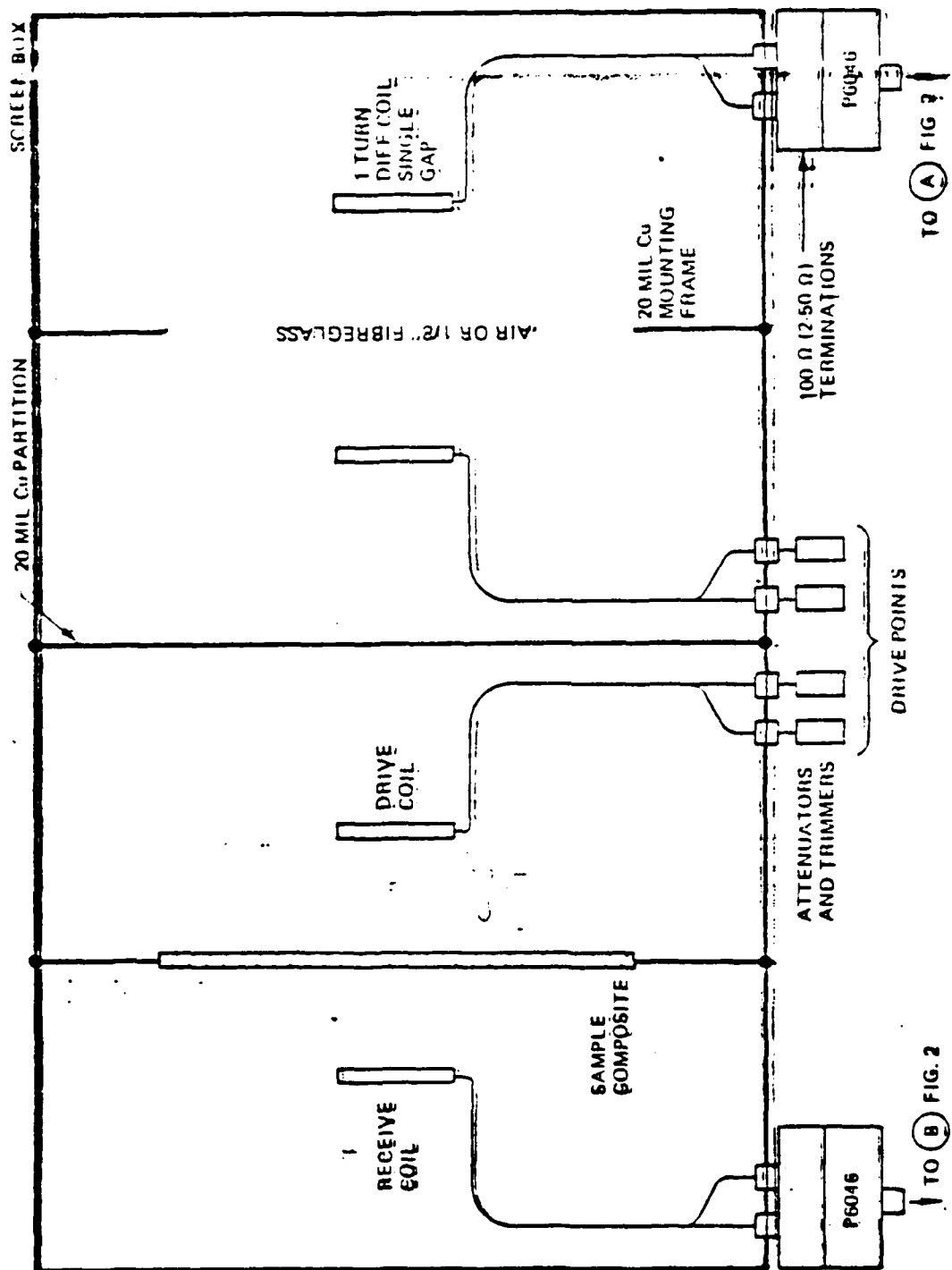
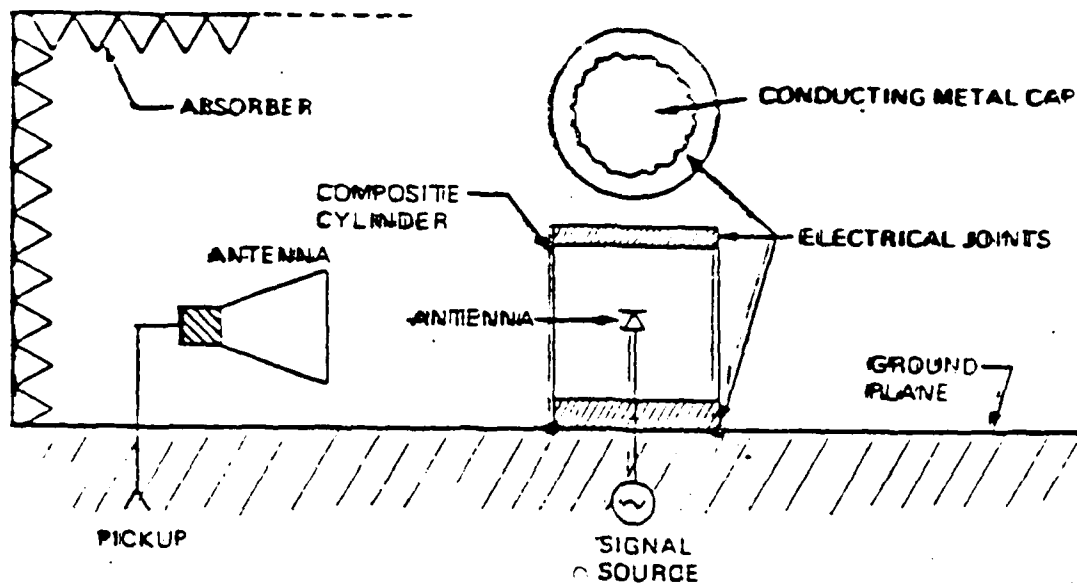
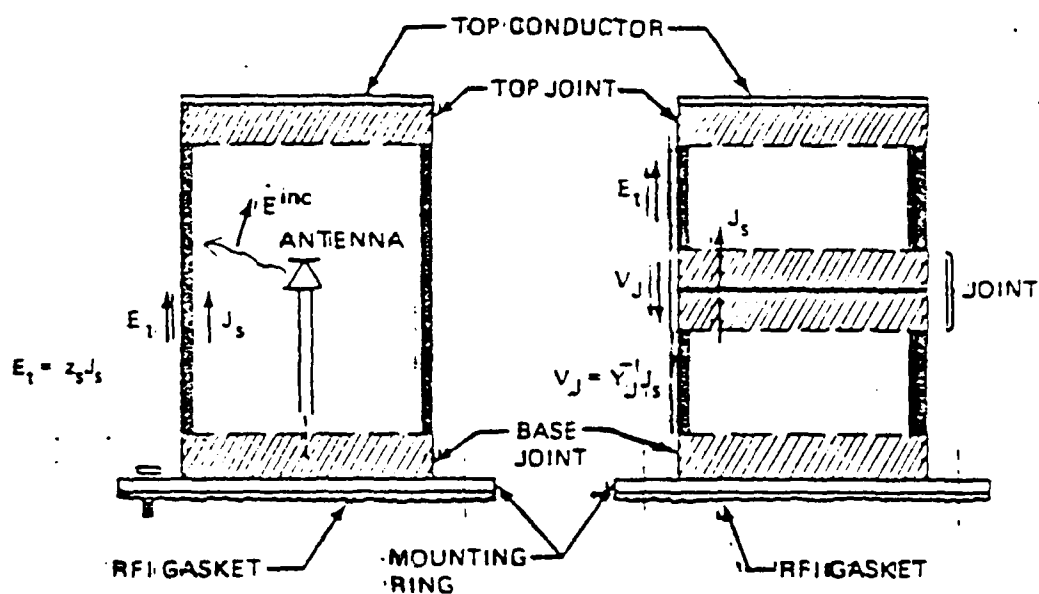


Figure 16 H-Field S.E. Test Setup

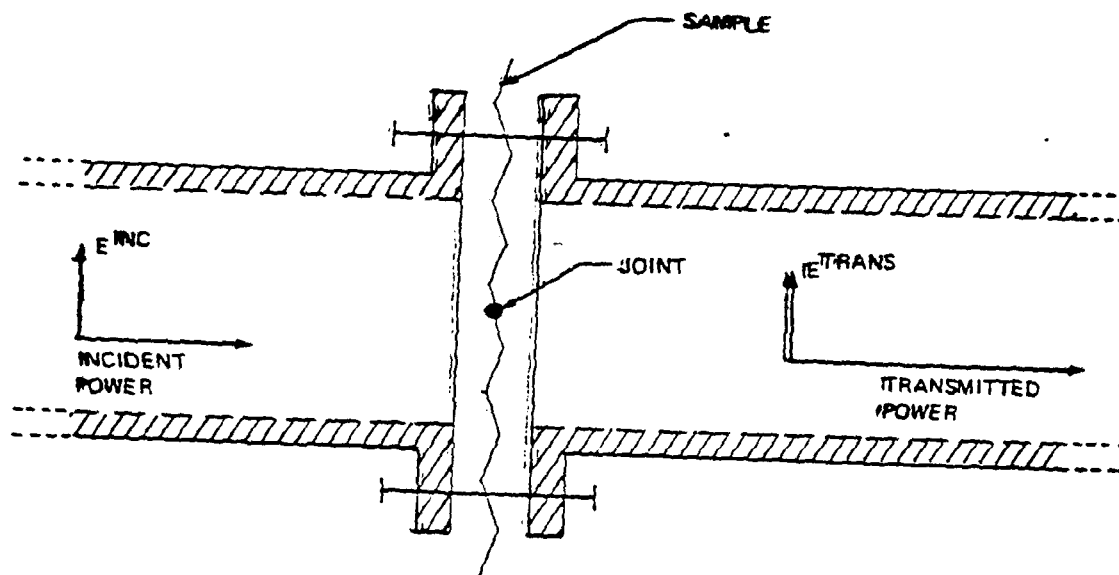


a) Test setup



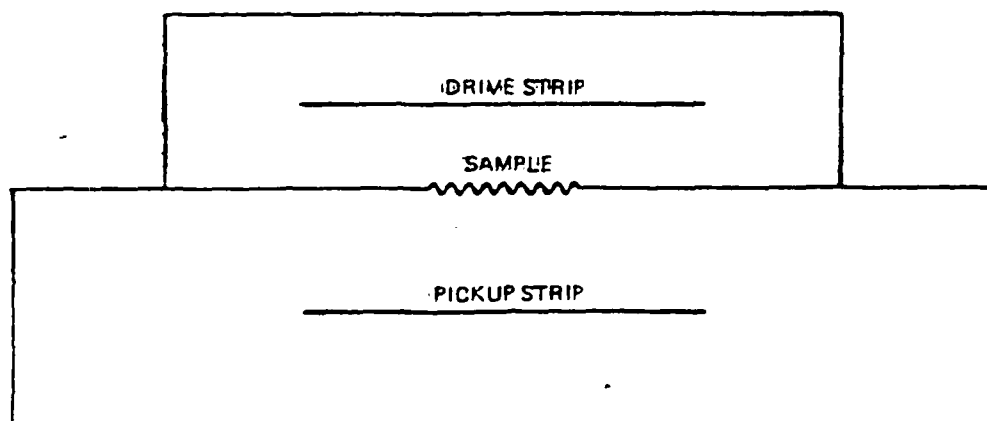
b) Cylindrical sections

Material Parameters from Shielding Measurements on Cylindrical Sections



$$\frac{E^{TRANS}}{E^{INC}} = \frac{1}{Y_i}$$

The Waveguide Transmission Concept



$$\frac{V_R}{V_G} \sim \frac{1}{Y_j}$$

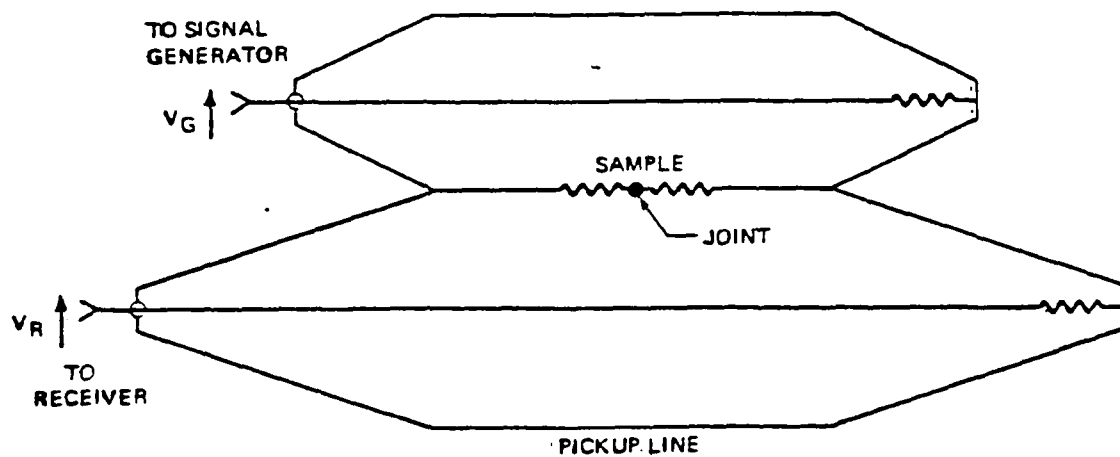
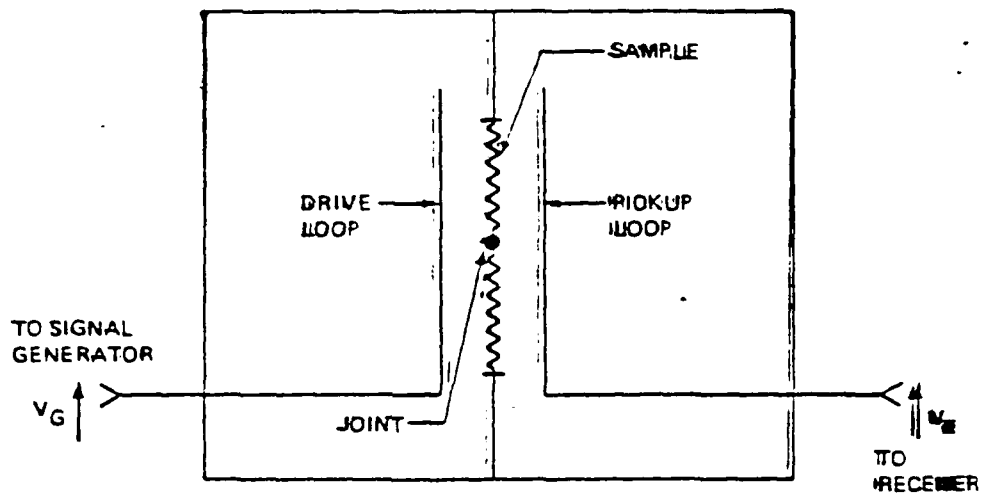
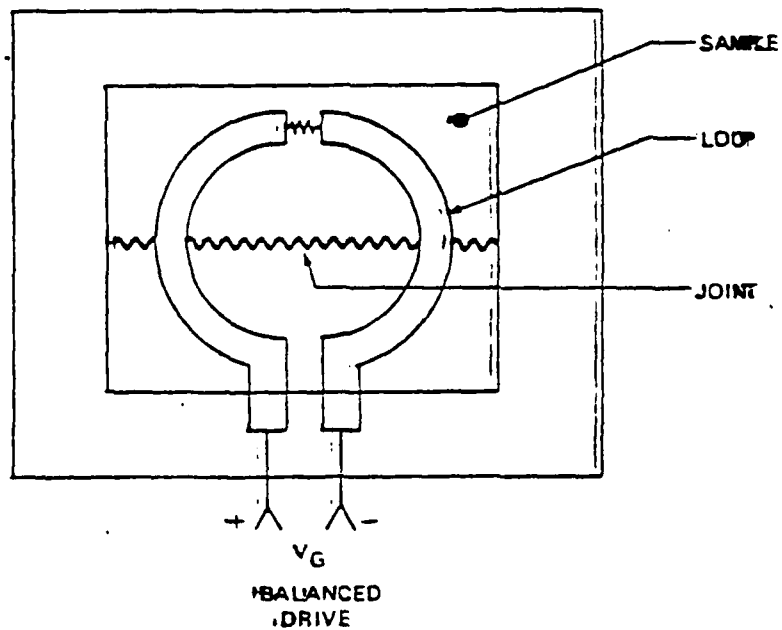


Figure 2.1-1 The Strip Line Joint Measurement Concept



$$\frac{V_R}{V_G} \sim \frac{1}{Y_i}$$



The Circular Stripline

NAVAIR SPONSORED COMPOSITE

MATERIAL EM EFFORTS

SMALL SAMPLES

EFFORT

PARTICIPANT

FREQUENCY

.01 MHz TO 50 MHz

.01 MHz TO 50 MHz

.01 MHz TO 50 MHz

.10 MHz TO 50 MHz

.01 MHz TO 100 MHz

100 MHz TO 18,000 MHz

SELECTED IR VISIBLE, X-RAY

SELECTED Y-RAYS

DC TO DAYLIGHT AND BEYOND

LIGHTNING

MATERIAL PENETRATION

JOINT LEAKAGE

PSTAT

EMP

JOINT LEAKAGE

MATERIAL PENETRATION

DEVICE INTERACTION

SYSTEM TRADEOFFS

CULHAM LABORATORY

NOTRE DAME

NOTRE DAME

NADC/NOSC/AFFDL

NSWC/WO

NADC/BOEING

NOTRE DAME

NSWC/WO

SRC

1 OCT

1 OCT

NAVAIR/GOVERNMENT COOPERATIVE EFFORTS
SMALL SAMPLES

<u>FREQUENCY</u>	<u>EFFORT</u>	<u>PARTICIPANT</u>
.01 MHZ TO 50 MHZ	FLIGHT MEASUREMENT LIGHTNING DRIVING FUNCTION	AFFDL/BOEING/SRI
.01 MHZ TO 1000 MHZ	INTRINSIC PARAMETERS	RADC/UNIVERSITY SUPPORT
.1 MHZ TO 1000 MHZ	MATERIAL/JOINT PENETRATION	GEORGIA TECH. / ARMY 6-22 / 4-1-66
50 MHZ TO 2.5 GHz	MATERIAL/JOINT PENETRATION	LAWRENCE LIVERMORE LABORATORY/DIA
100 MHZ TO 1000 MHZ	MATERIAL/JOINT PENETRATION	UNIVERSITY OF COLORADO/QUIR
SELECTED FREQUENCIES	MATERIAL/JOINT PENETRATION	NAVY SECTION AFNL

NAVAIR SPONSORED COMPOSITE MATERIAL EM EFFORTS

TOTAL STRUCTURE COUPLING

FREQUENCY

.014 MHZ TO 18,000 MHZ

.014 MHZ TO 18,000 MHZ

EFFORT

WING

FORWARD FUSELAGE

PARTICIPANT

NADC/NOSC/MCAIR

NADC/NOSC/MCAIR

Dr. Walt Gajda
Notre Dame

Materials Preparation, Measurements,
and Experimental Setup at Notre Dame.

ND EFFORT IN COMPOSITES

RADC

AFOSR

NASC

975

SURVEY
STATE OF ART

.76

INTRINSIC
MEASUREMENTS &
MODIFICATION

.977

INTRINSIC
MEASUREMENTS

MODELS &
MODIFICATION

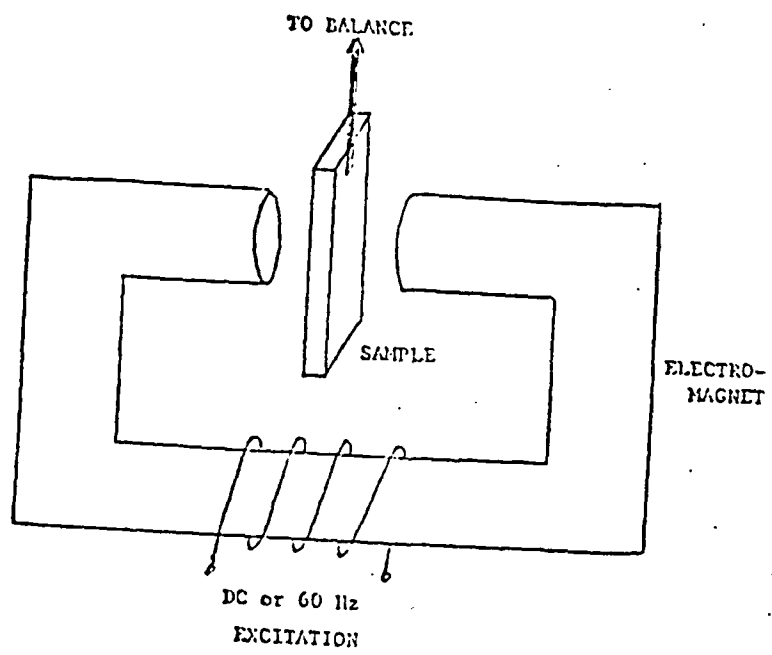
SAMPLE
FABRICATION

78

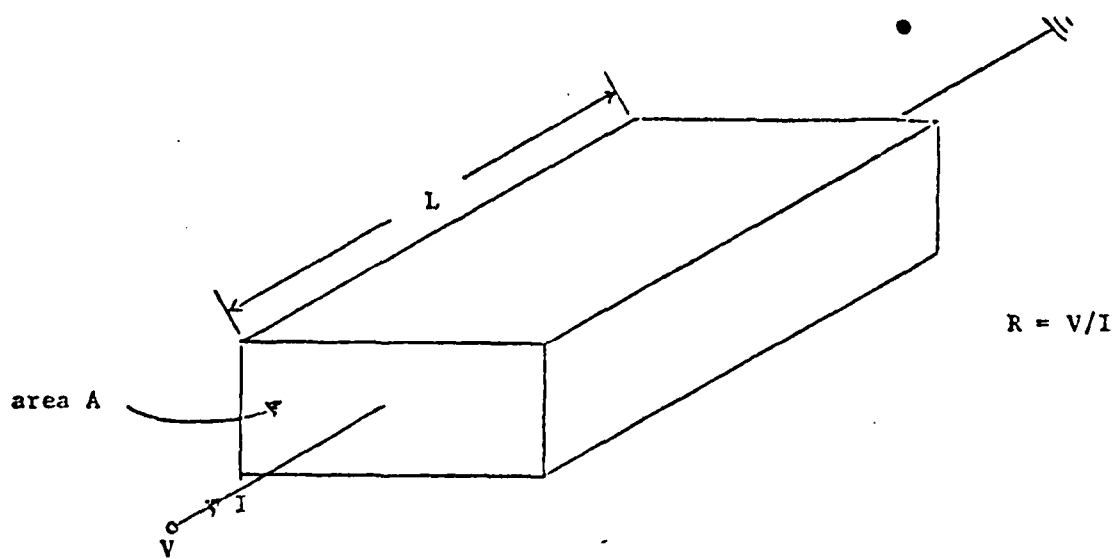
COMPLETED

MODELS &
MODIFICATION

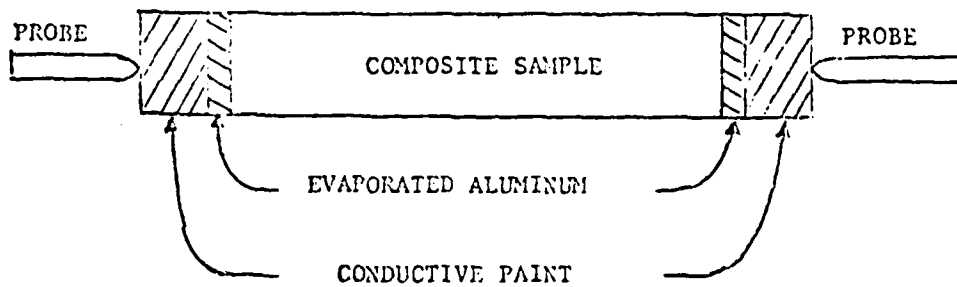
JOINT
FABRICATION +



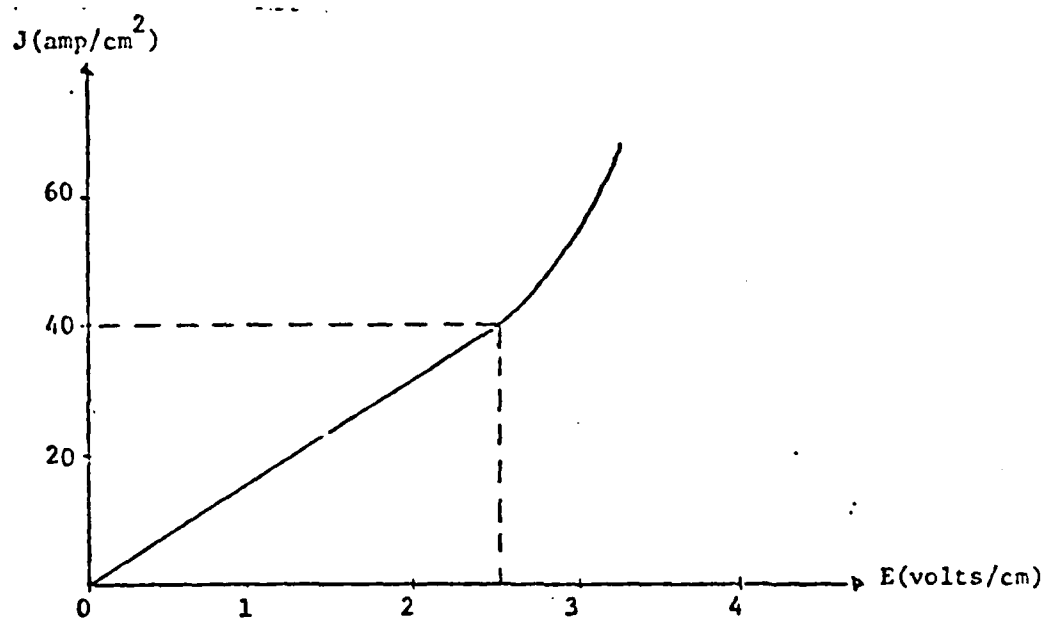
PERMEABILITY MEASUREMENT



TWO-POINT CONDUCTIVITY MEASUREMENT



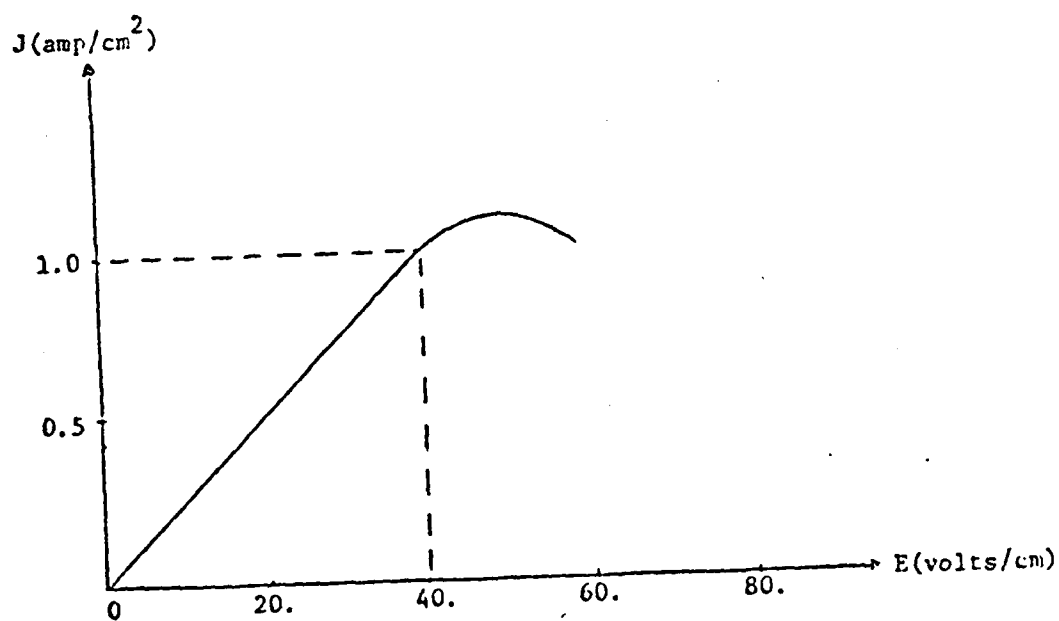
SKETCH OF CONTACT FORMATION



LONGITUDINAL CURRENT DENSITY vs. APPLIED FIELD

6.22 mcs 5213

No tests done yet
on 5208, 3301



TRANSVERSE CURRENT DENSITY vs. APPLIED FIELD

NARMCO 5213

No tests done yet
on 5208, 3521

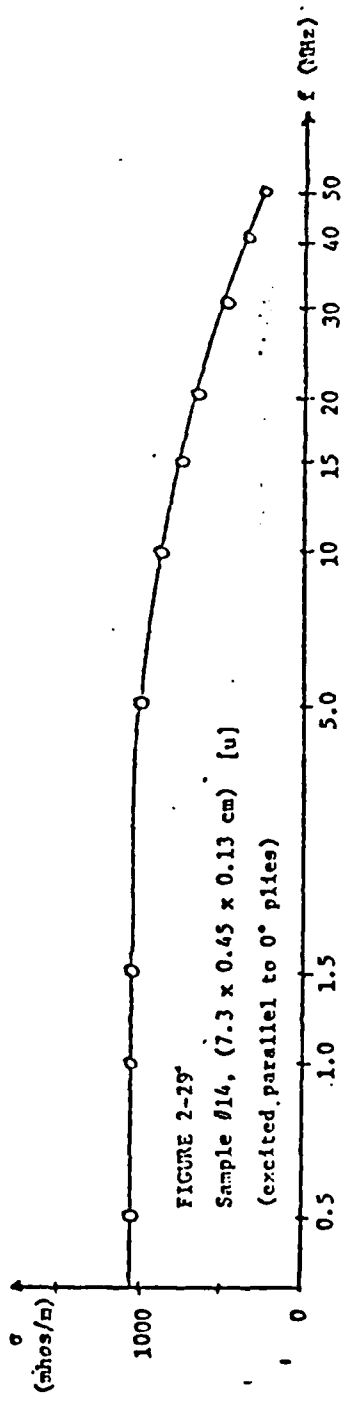
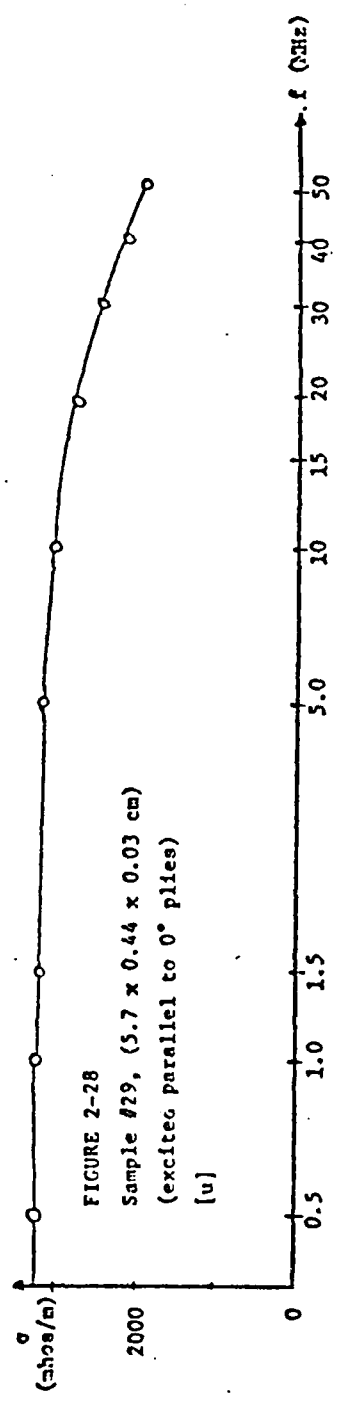
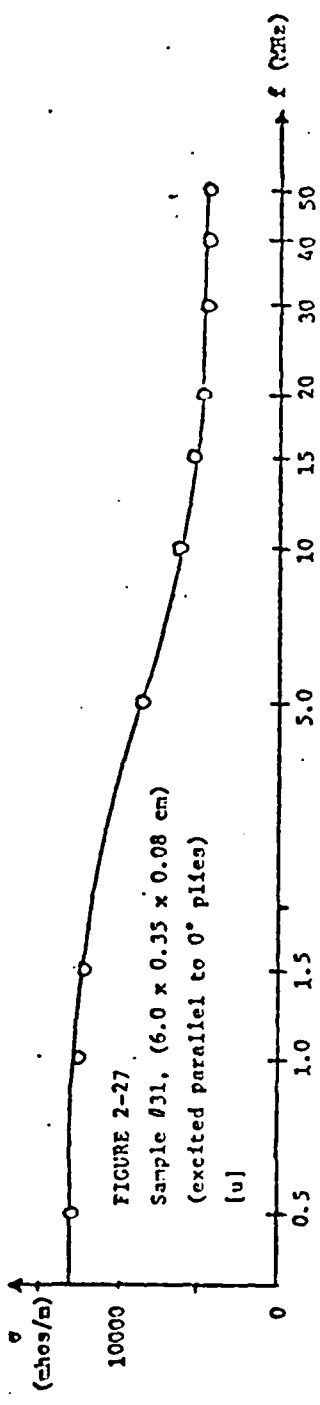
Breakdown Thresholds

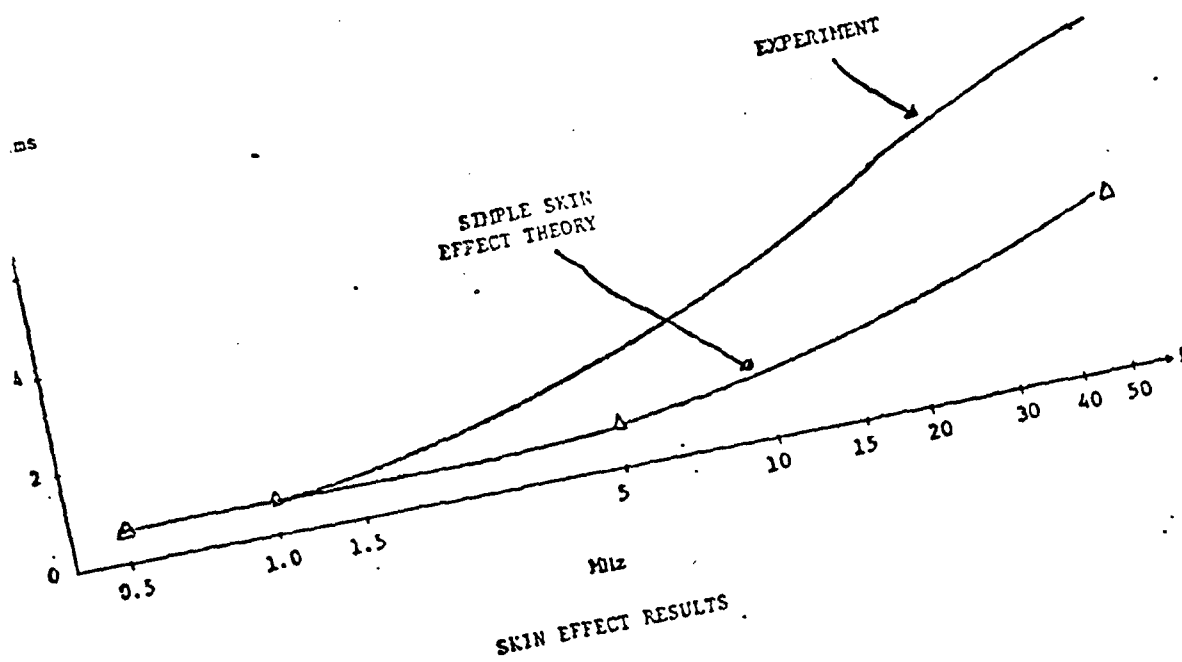
	E(volts/m)	J(amp/m ²)
minimum	3.2(10 ³)	57.6(10 ⁶)
average	3.7(10 ³)	103.2(10 ⁶)
maximum	4.4(10 ³)	125.1(10 ⁶)

T 360 Fibers

$$\frac{125(10^6)}{4(10^3)} = 31.25 \text{ amp/m}$$

the σ vs f conductivities
 σ vs f conductivities



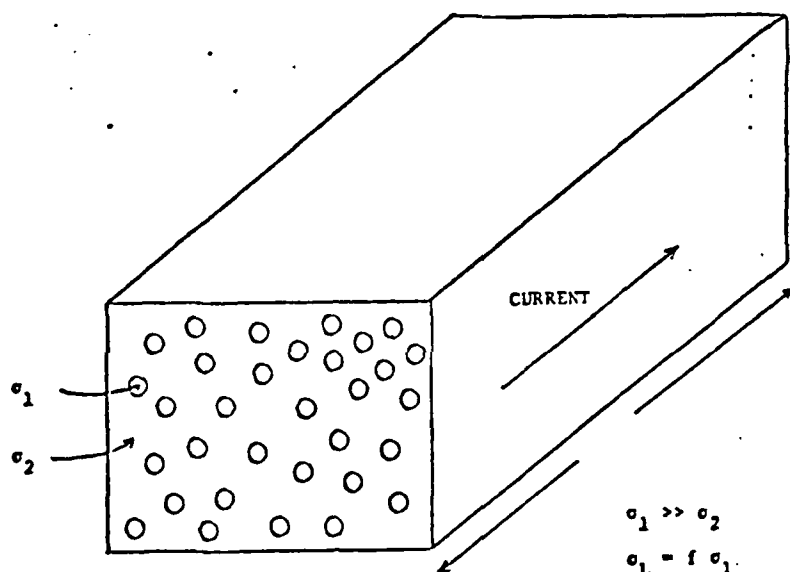


	<u>Graphite/Epoxy</u>	<u>Boron/Epoxy</u>	<u>Kevlar</u>
Permeability ν_R	1	1	1
Permittivity ϵ_R	Indeterminant	5.6	3.6
DC Conductivity (mhos/m)			
longitudinal σ_L	$2(10^4)$	30	$6(10^{-9})$
transverse σ_T	100	$2(10^{-8})$	$6(10^{-9})$
Anisotropy Ratios (σ_L/σ_T)	200	$1.5(10^9)$	1
High Field Thresholds			
longitudinal			
E_{NL} (volts/m)	250	not	not
J_{NL} (amps/m ²)	$4(10^5)$	measured	measured
tranverse			
E_{NL} (volts/m)	4000	not	not
J_{NL} (amps/m ²)	$1(10^4)$	measured	measured

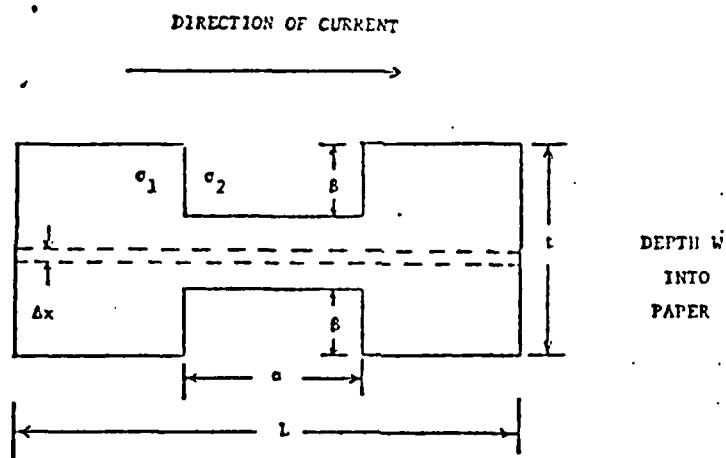
SUMMARY OF ELECTRICAL PROPERTIES OF MEASURED COMPOSITES

*Ind because $\sigma \gg \omega \epsilon$
at measured freq.*

$$\sigma_L = \sigma_1 f + \sigma_2 (1-f)$$



MODEL FOR DETERMINATION OF σ_L



CONDUCTIVITY MODELS

LONGITUDINAL $\sigma_L = f \sigma_f \approx 2(10^4)$

TRANSVERSE $\sigma_T = 2(10^2)$

$\sigma_f = 5(10^3)$

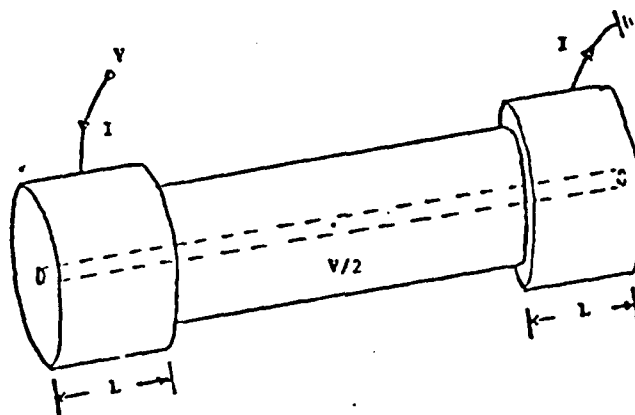
$$\sigma_e = \frac{1}{N} \sum_{i=1}^N \sigma_i$$

1 conductivities in mhos/meter.

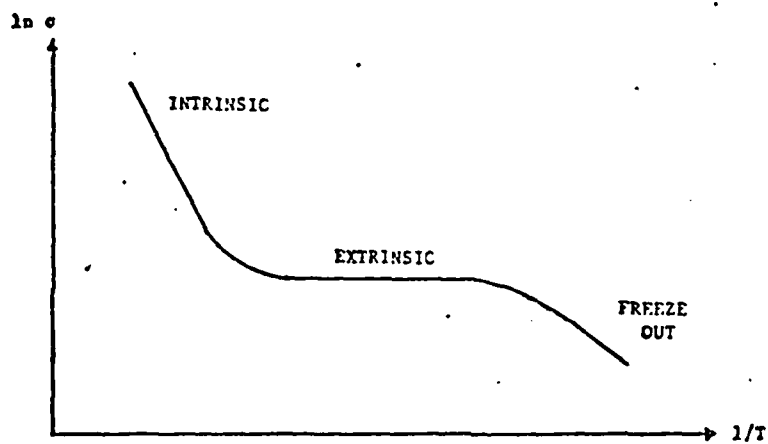
1000 1000 1000 1000

$$1000 + 4(95) \Rightarrow \sigma = 6.6(10^3)$$

$$1000 + 4(95) \Rightarrow \sigma = 5.7(10^3)$$



GEOMETRY FOR CALCULATION OF σ_B



CONDUCTIVITY-TEMPERATURE PROFILE

FOR A SIMPLE
SEMICONDUCTOR

$$\lambda = \frac{12.398}{1.4} \approx 6000 \text{ \AA} \quad 6 \mu\text{m}$$

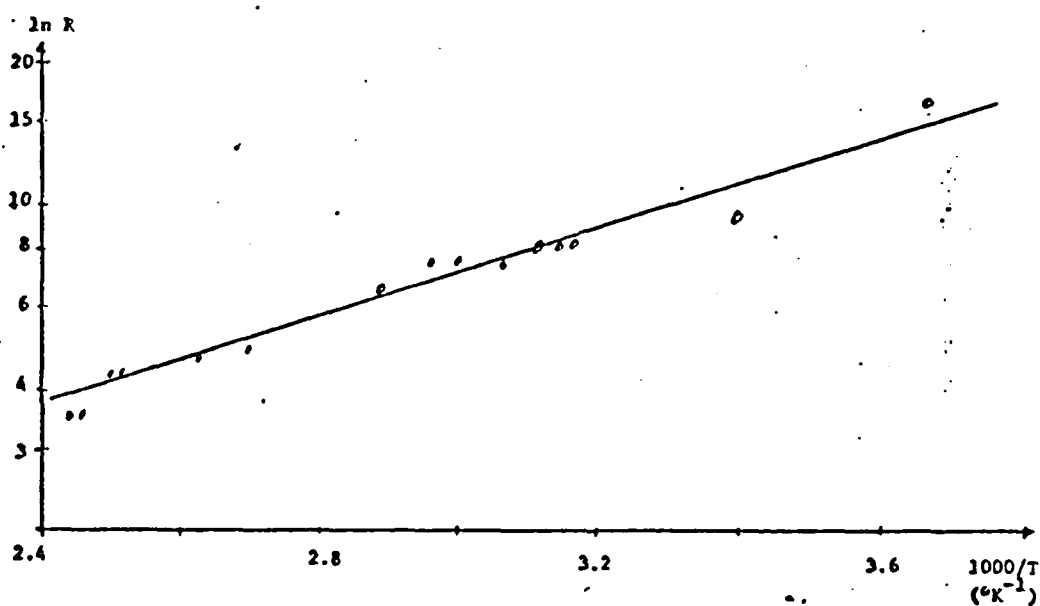
$$E = h\nu = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34}) (3 \times 10^8)}{E} = \frac{1.986 \times 10^{-25}}{E(\text{J})}$$

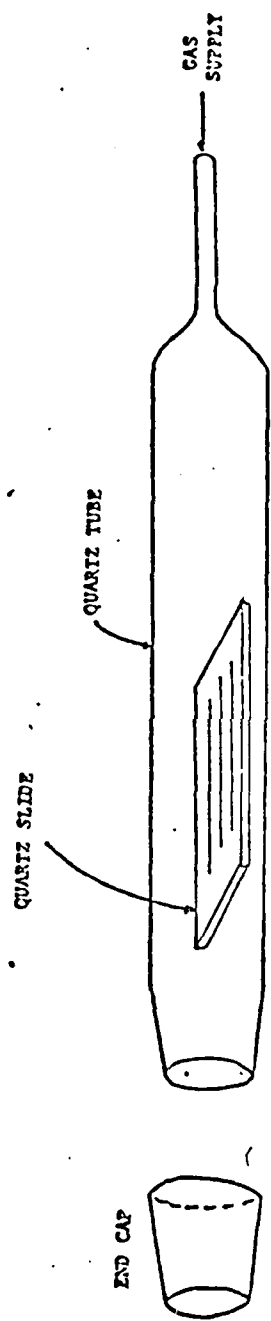
$$= \frac{12 (10^{-7})}{E(\text{eV})} \Rightarrow \frac{12 (10^3)}{E} = \lambda(\text{\AA})$$

$$E_g \approx 0.17 \text{ eV}$$

$$\lambda_g \approx 6 \mu\text{m}$$

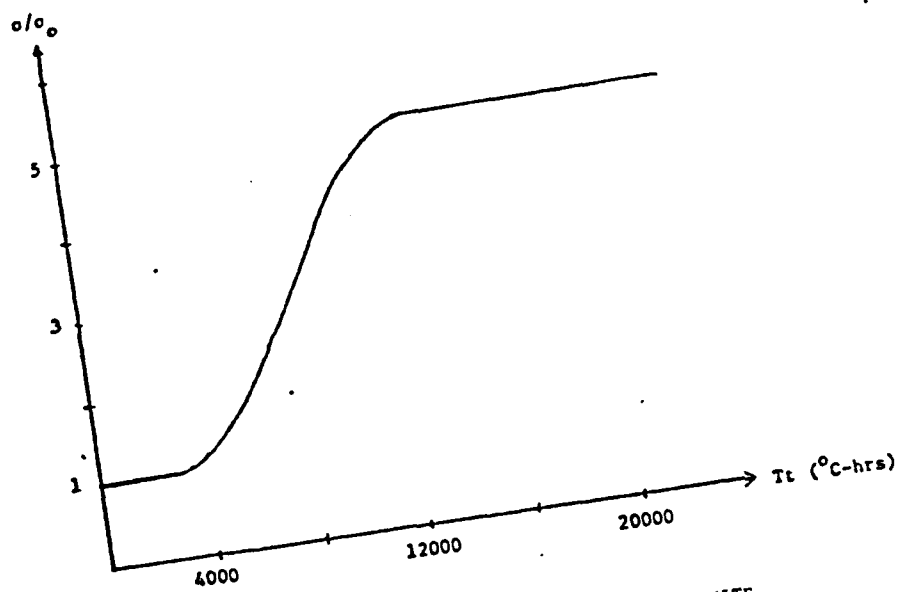


BORON FIBER ENERGY GAP

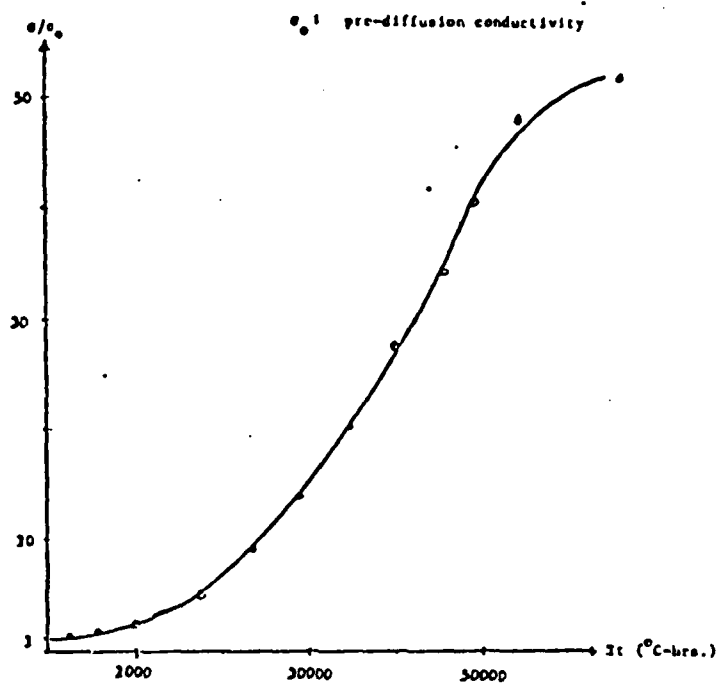


BASIC DIFFUSION FURNACE

σ_0 : pre-diffusion conductivity

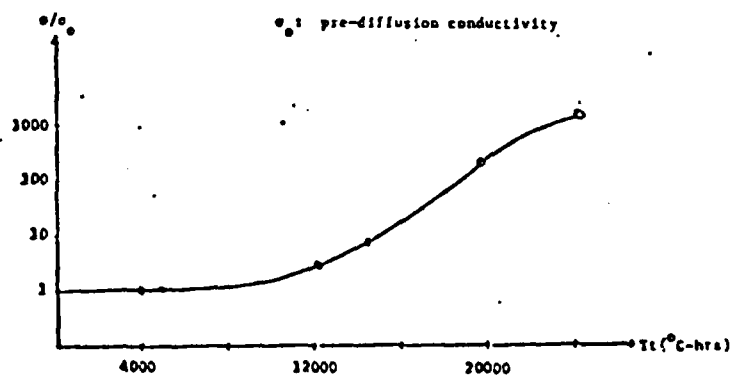


CONDUCTIVITY ENHANCEMENT IN GRAPHITE



CONDUCTIVITY ENHANCEMENT IN GRAPHITE
HIGH TEMPERATURE

FIGURE 16

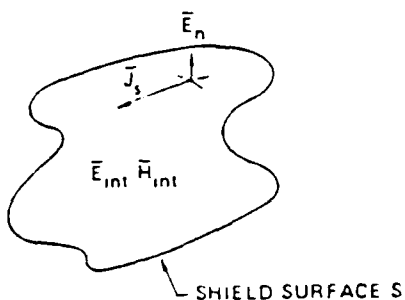


CONDUCTIVITY ENHANCEMENT IN BORON

FIGURE 17

Dr. Robert Wallenberg

Syracuse Research Corporation



Skin diffusion:

$$\bar{G}_d \sim Z_{sd} \text{ (open circuit diffusion transfer impedance, ohms/square)}$$

Distributed aperture coupling (screens):

$$\bar{G}_p \sim P \text{ (surface electric polarizability, farads)}$$

$$\bar{G}_m \sim M \text{ (surface magnetic polarizability, meters)}$$

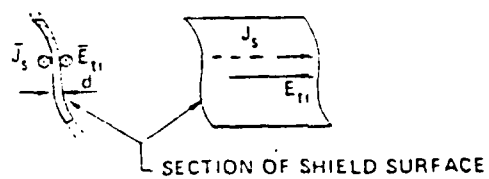
$$\begin{Bmatrix} \bar{E}_{int} \\ \bar{H}_{int} \end{Bmatrix} = \iint_S [(\bar{G}_d + \bar{G}_m + \bar{G}_j) \cdot \bar{J}_s + \bar{G}_p \cdot \bar{E}_n] ds$$

Joint coupling

$$\bar{G}_j \sim \frac{1}{Y_j} \quad Y_j \text{ (joint admittance per unit of joint width or run mhos/meter)}$$

Figure D-6.—The Relation Between Surface Response and Internal Fields

SNC



$$\vec{E}_{t1} = z_{sd} \vec{J}_s$$

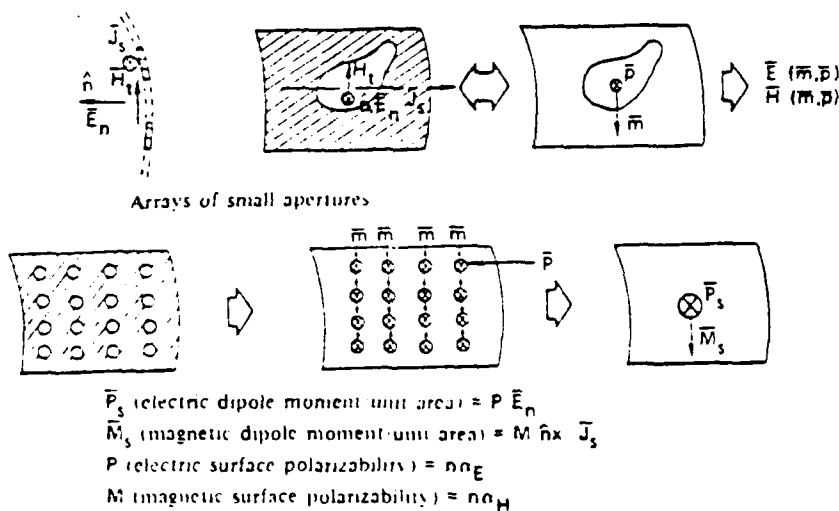
$$z_{sd} = \frac{E_{t1} \text{ (inner surface tangential electric field)}}{J_s \text{ (outer surface skin current)}}$$

THIN FOIL SURFACE

$$z_{sd} = \frac{\hat{n}}{\sinh \frac{\gamma d}{2}} : \hat{n} = \sqrt{\frac{j\omega\mu}{\sigma}} \quad \& \quad \gamma = \sqrt{j\omega\mu\sigma}$$

Figure D-7.—Diffusion

SNC



Example For circular apertures of radius r_0

$$\alpha_E = \frac{4}{3} r_0^3 \quad \alpha_H = \frac{8}{3} r_0^3$$

Figure D-8.—Quasi-Static Aperture Coupling

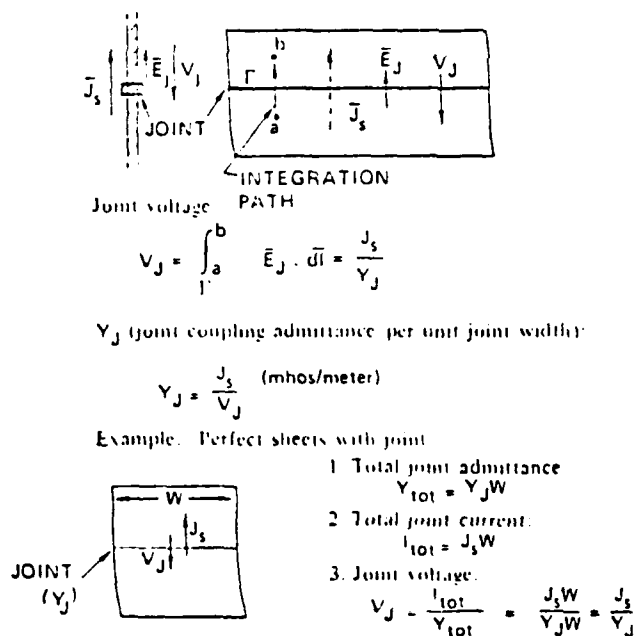
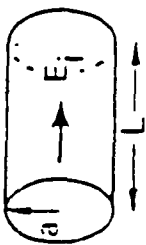


Figure D-9.—Joint Coupling

Surface transfer impedance
(diffusion and mag.aperture coupling)

$$J_s, I_s = 2\pi a J_s$$

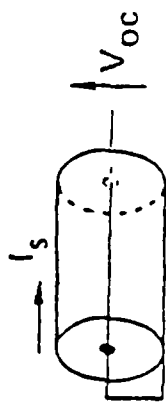


$$E_i = J_s z_s = I_s Z_T$$

WHERE

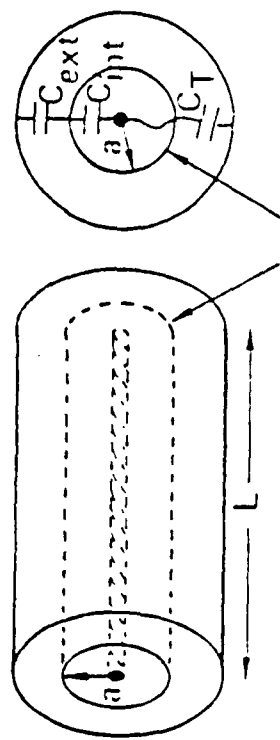
$$z_s = z_{sd} + \frac{j\omega\mu_0 M}{2} \quad (\text{ohms/square})$$

$$Z_T = \frac{z_s}{2\pi a} \quad (\text{ohms/meter})$$



$$V_{oc} = Z_T L I_s$$

Surface transfer admittance
(electric aperture coupling)



Transfer capacitance:

$$C_T = \frac{P C_{int} C_{ext}}{4\pi a c^2} \quad (\text{farads/meter})$$

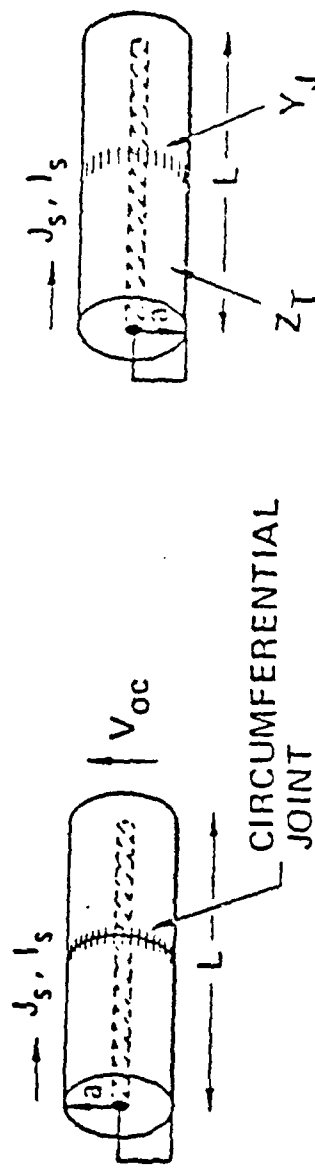
TEST
SURFACE

Transfer admittance per unit length:

$$Y_T = j\omega C_T$$

Figure D-10.—Surface Transfer Impedance and Admittance

5716



$$V_{oc} = V_J = J_s \frac{t}{Y_J} = \frac{l_s}{2\pi a Y_J}$$

$$Y_J = \frac{l_s}{2\pi a V_J}$$

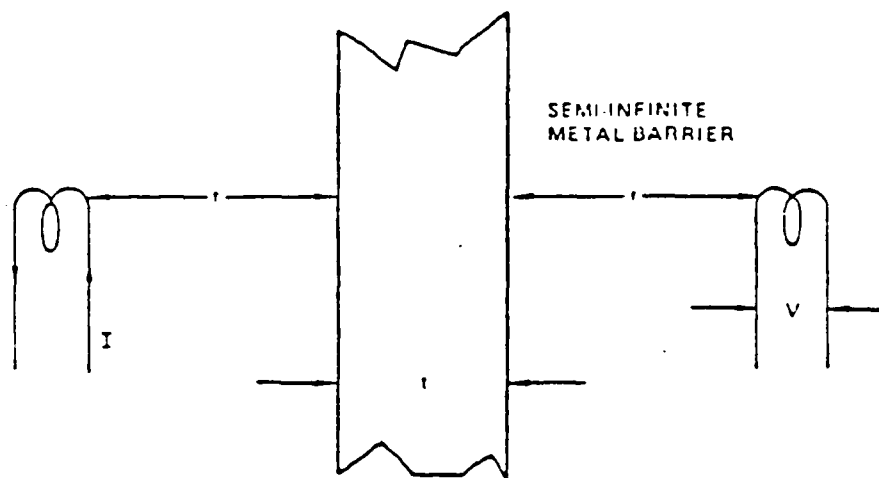
$$V_{oc} = l_s \left(Z_T L + \frac{1}{Y_J 2\pi a} \right)$$

$$Y_J^{-1} = 2\pi a \left(\frac{V_{oc}}{l_s} - Z_T L \right)$$

$$Z_T, Y_T, Y_J \leftrightarrow z_{sd}, P, M, Y_J$$

Figure D-11.—Joint Admittance

SHC



MSE = MAGNETIC SHIELDING EFFECTIVENESS = $20 \log_{10} \frac{V_1}{V_2}$ DECIBELS.

WHERE V_1 IS MEASURED WITH BARRIER ABSENT AND V_2 WITH BARRIER PRESENT, I BEING KEPT CONSTANT.

$$MSE = A + R_1 + R_2 \quad (1)$$

WHERE

$$A = \text{ABSORPTION LOSS (dB)} = 3.3 \times 10^{-3} t \sqrt{10\mu} \quad (2)$$

$$R_1 = \text{REFLECTION LOSS (dB)} =$$

$$20 \log_{10} \left[\frac{0.46}{r} \sqrt{\frac{\mu}{10}} + 0.14r \sqrt{\frac{0.1}{\mu}} + 0.35 \right] \quad (3)$$

$$R_2 = \text{RE-REFLECTION LOSS (dB)} =$$

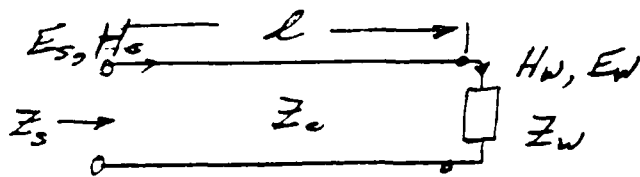
$$10 \log_{10} \left[1 - (2 \times 10^{-0.1A}) (\cos 0.23A) + 10^{-0.2A} \right] \quad (4)$$

AND WHERE

- t = METAL THICKNESS (MILS)
- σ = CONDUCTIVITY RELATIVE TO COPPER
- μ = PERMEABILITY RELATIVE TO VACUUM
- r = SOURCE TO BARRIER DISTANCE (IN.)
- f = FREQUENCY (HZ)

Figure D-12.—Magnetic Shielding Effectiveness Equations for Flat Plate Test

SRC



$$Z_0 = \sqrt{\frac{j\omega\mu_0}{\sigma + j\omega\epsilon}}$$

$$\gamma = \sqrt{j\omega\mu_0(\sigma + j\omega\epsilon)}$$

FOR COMPOSITE MATERIAL: $\sigma \gg \omega\epsilon$

$$Z_0 = \sqrt{\frac{j\omega\mu_0}{\sigma}}$$

$$\gamma = \sqrt{j\omega\mu_0\sigma}$$

IN FAR FIELD $Z_w = \sqrt{\frac{\mu_0}{\epsilon_0}}$ (Plane Wave Conditions)

MAGNETIC SHIELDING: $20 \log_{10} \left(\frac{H_w}{H_s} \right)$

$$\frac{H_w}{H_s} = \frac{1}{\cosh \gamma l + \frac{Z_w}{Z_0} \sinh \gamma l} \approx \frac{1}{1 + \sqrt{\frac{\sigma}{j\omega\epsilon}} \sinh \gamma l}$$

ELECTRIC SHIELDING: $20 \log_{10} \left(\frac{E_w}{E_s} \right)$

$$\frac{E_w}{E_s} = \frac{1}{\cosh \gamma l + \frac{Z_0}{Z_w} \sinh \gamma l} \approx \frac{1}{1 + \sqrt{\frac{j\omega\epsilon}{\sigma}} \sinh \gamma l}$$

TRANSFER IMPEDANCE:

$$Z_{sd} = \frac{E_w}{J_s} = \frac{Z_w}{\cosh \gamma l + \frac{Z_w}{Z_0} \sinh \gamma l} \approx \frac{Z_0}{\sinh \gamma l}$$

ERC

USE OF JOINT ADMITTANCES AND TRANSFER IMPEDANCES

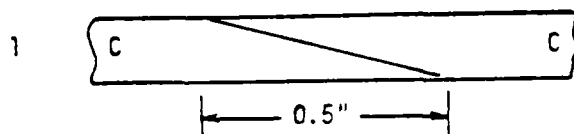
$$V_{pk} = \frac{2E_{pk}}{\gamma_j \eta_o} = \frac{2 \times 50 \times 10^3}{15 \times 377} = 17.7 \text{ volts}$$

The full peak is just the direct plus reflected signals, or

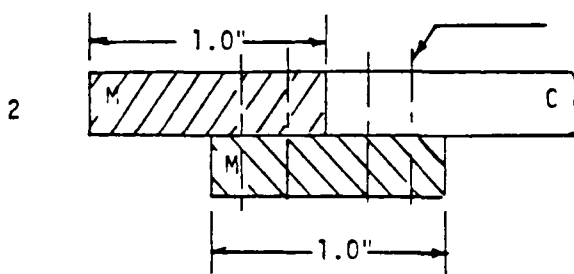
$$V_{pk} = \frac{2E_{pk}}{\gamma_j \eta_o} \times \frac{2Z_o}{Z_o + Z_L} = \frac{2 \times 50 \times 10^3}{15 \times 377} \times \frac{2 \times 100}{100 + 30} = 27.2 \text{ volts}$$

$2Z_o/(Z_o + Z_L)$ = factor for constructive interference of direct and reflected waves

$$\begin{aligned} V_{pk} &= \frac{1}{\alpha_d} E_{pk} \frac{2L_{eff}}{\eta_o} \frac{2Z_o}{Z_o + Z_L} \\ &= \frac{1}{10^4 \times .0025} \times 50 \times 10^3 \times \frac{2 \times 5.17}{377} \times \frac{2 \times 100}{100 + 30} = 84.4 \text{ volts} \end{aligned}$$

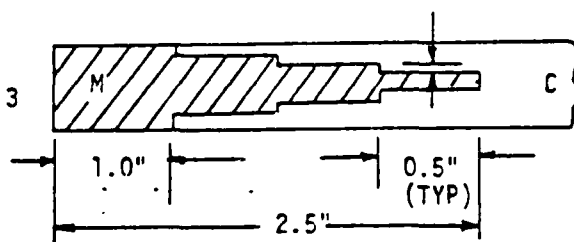


CYLINDER WAS FABRICATED EXTRA LONG, CUT, MACHINED AND SECONDARILY BONDED WITH EA-934 ADHESIVE.



1/8 DIA RD.HD. RIVET C TO M
1/8 DIA BOLT M. TO M.

CYLINDER CENTER TOWARDS BOTTOM OF PAGE. METAL RINGS FABRICATED FROM ALUMINUM SHEET, CUT, ROLLED AND WELDED. THE RIVETS OR BOLTS WERE PLACED IN A CIRCUMFERENTIAL ROW APPROXIMATELY ONE INCH APART AND ALTERNATING 1/8 INCH TO EITHER SIDE OF THE CIRC. CTR LINE.



FIRST THREE STEPS (4 PLY PER STEP) WERE PRECURED (COMPACTED), EA-934 APPLIED TO SANDED COMPOSITE STEPS, AND THEN LONGITUDINALLY SLIT METAL RING MANEUVERED INTO PLACE. REMAINING COMPOSITE STEPS WERE APPLIED TO EA-934 COATED METAL RING IN PLACE. METAL RING WAS FABRICATED FROM 2024 ALUMINUM.

Figure 84.—Structural Joints

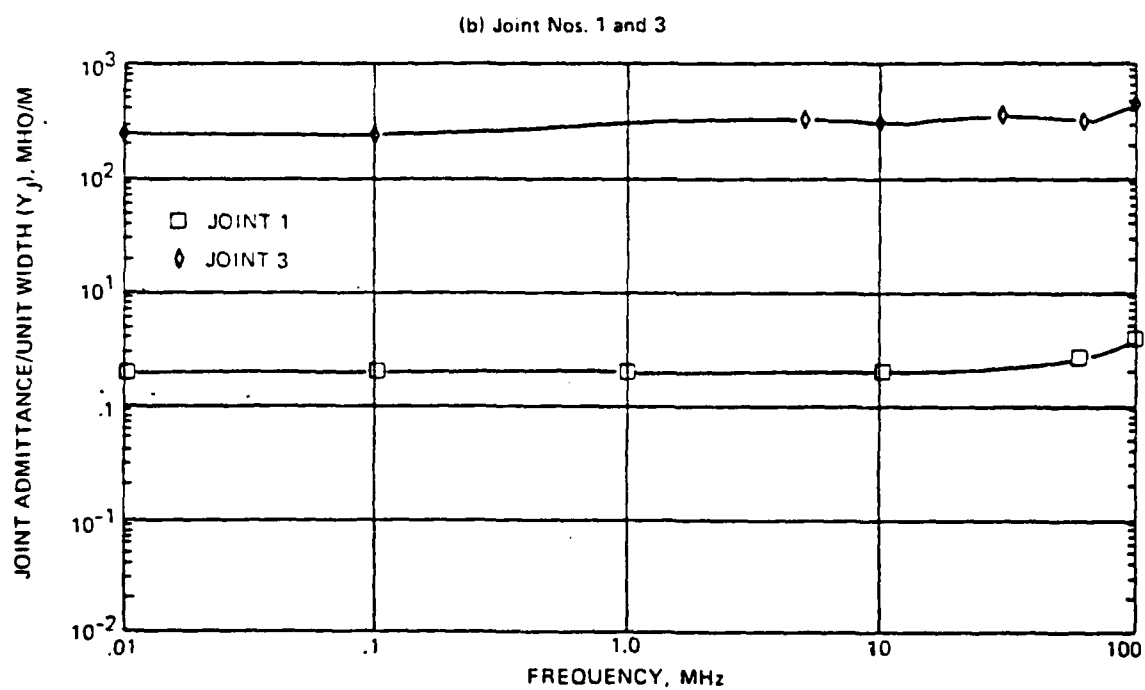
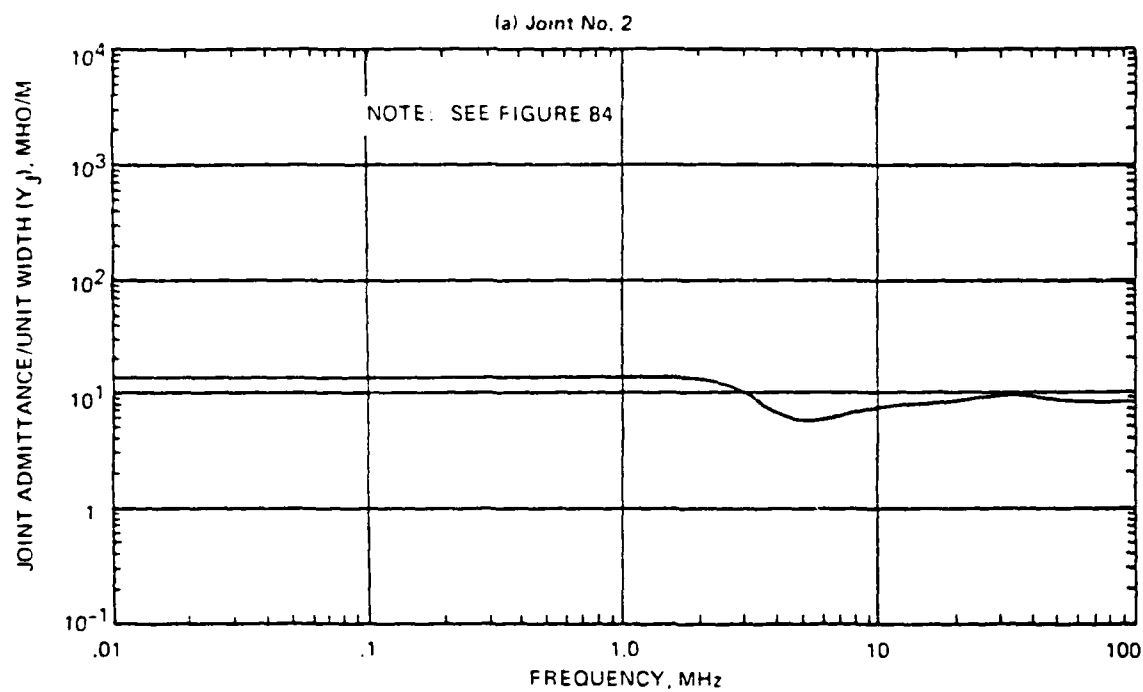


Figure 83.—Measured Joint Admittance

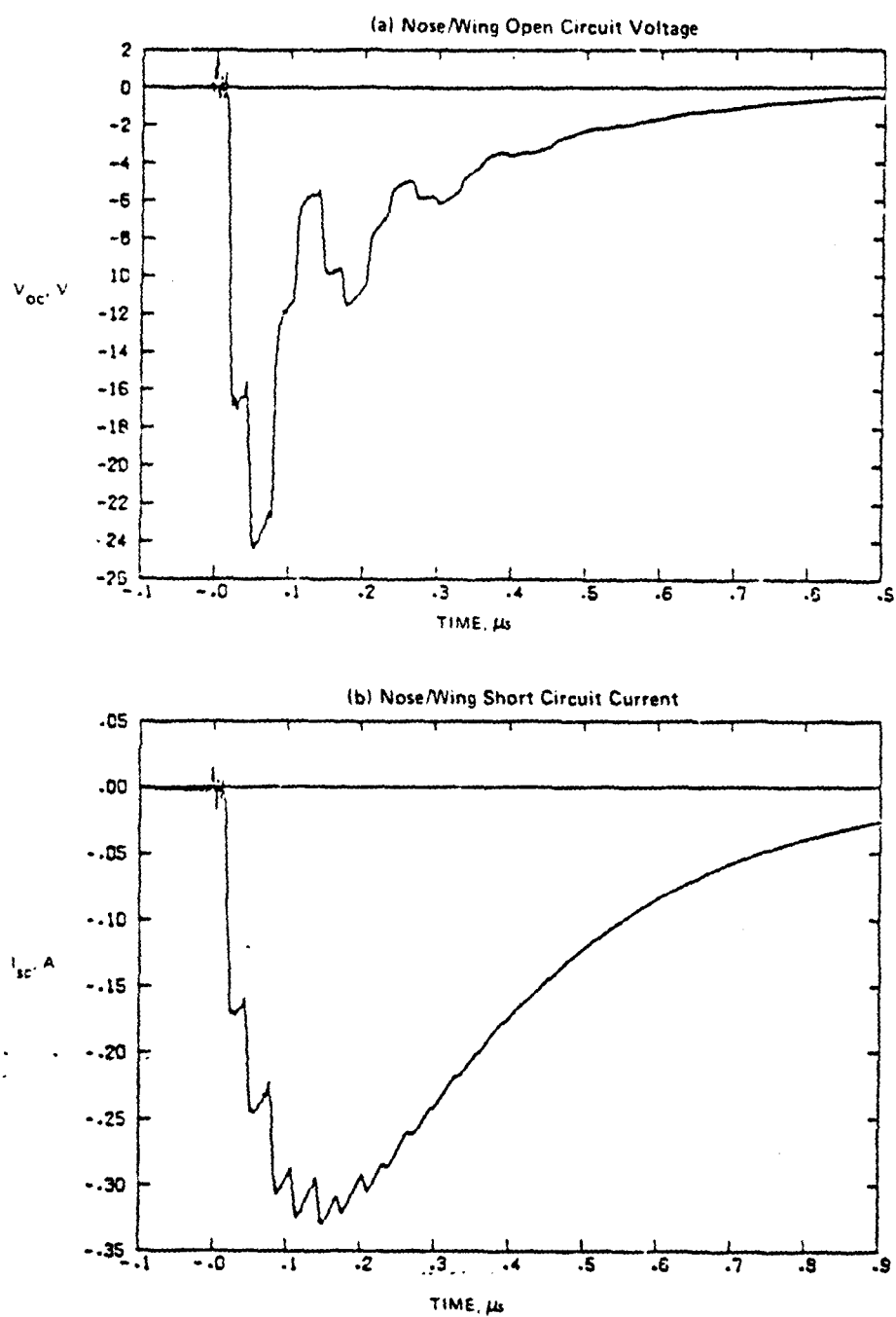


Figure 93.— V_{oc} , I_{sc} on Nose/Wing Tip Wire, NEMP, E to Fuselage, Wing Joint

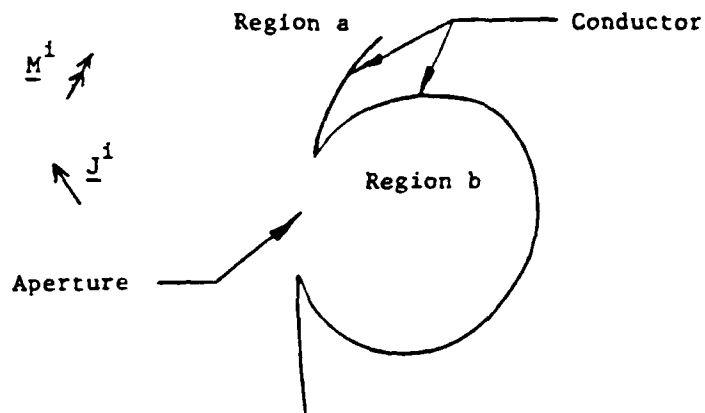
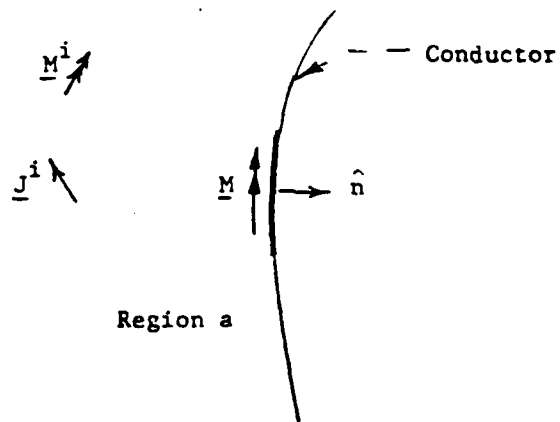
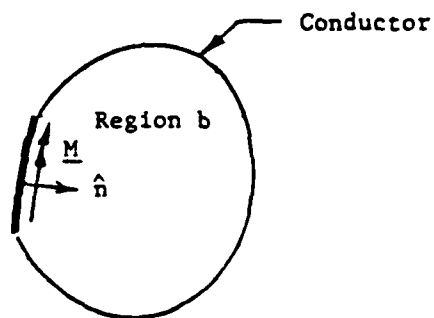


Figure 2.5.1 The General Problem of Two Regions Coupled by an Aperture



a) Equivalence for Region a



b) Equivalence for Region b

Figure 2.5.2 The Original Problem Divided into Two Equivalent Problems

SRP

GENERAL FORMULATION FOR APERTURES

$$\underline{M} = \hat{n} \times \underline{E},$$

$$H_t^a = H_t^i + H_t^a(\underline{M})$$

$$H_t^b = H_t^b(-\underline{M}) = -H_t^b(\underline{M})$$

$$H_t^a(\underline{M}) + H_t^b(\underline{M}) = -H_t^i$$

$$\underline{M} = \sum_n V_n \underline{M}_n$$

$$\sum_n V_n H_t^a(\underline{M}_n) + \sum_n V_n H_t^b(\underline{M}_n) = -H_t^i$$

$$\langle \underline{A}, \underline{B} \rangle = \iint_{\text{apert.}} \underline{A} \cdot \underline{B} \, ds$$

$$\sum_n V_n \langle \underline{W}_m, H_t^a(\underline{M}_n) \rangle + \sum_n V_n \langle \underline{W}_m, H_t^b(\underline{M}_n) \rangle = -\langle \underline{W}_m, H_t^i \rangle$$

$$[Y^a] = [\langle -\underline{W}_m, H_t^a(\underline{M}_n) \rangle]_{N \times N}$$

$$[Y^b] = [\langle \underline{W}_m, H_t^b(\underline{M}_n) \rangle]_{N \times N}$$

$$\vec{I}^1 = [\langle \underline{W}_m, H_t^i \rangle]_{N \times 1}$$

$$(\vec{V} = [V_n]_{N \times 1})$$

$$[Y^a + Y^b] \vec{V} = \vec{I}^1$$

$$\vec{V} = [Y^a + Y^b]^{-1} \vec{I}^1$$

SAC

GENERAL FORMULATION FOR APERTURES

$$\underline{M} = \hat{n} \times \underline{E},$$

$$H_t^a = H_t^i + H_t^a(\underline{M})$$

$$H_t^b = H_t^b(-\underline{M}) = -H_t^b(\underline{M})$$

$$H_t^a(\underline{M}) + H_t^b(\underline{M}) = -H_t^i$$

$$\underline{M} = \sum_n v_n \underline{M}_n$$

$$\sum_n v_n H_t^a(\underline{M}_n) + \sum_n v_n H_t^b(\underline{M}_n) = -H_t^i$$

$$\langle \underline{A}, \underline{B} \rangle = \iint_{\text{apert.}} \underline{A} \cdot \underline{B} \, ds$$

$$\sum_n v_n \langle \underline{W}_m, H_t^a(\underline{M}_n) \rangle + \sum_n v_n \langle \underline{W}_m, H_t^b(\underline{M}_n) \rangle = -\langle \underline{W}_m, H_t^i \rangle$$

$$[Y^a] = [\langle -\underline{W}_m, H_t^a(\underline{M}_n) \rangle]_{N \times N}$$

$$[Y^b] = [\langle -\underline{W}_m, H_t^b(\underline{M}_n) \rangle]_{N \times N}$$

$$\tilde{I}^1 = [\langle \underline{W}_m, H_t^i \rangle]_{N \times 1}$$

$$\tilde{V} = [v_n]_{N \times 1}$$

$$[Y^a + Y^b] \tilde{V} = \tilde{I}^1$$

$$\tilde{V} = [Y^a + Y^b]^{-1} \tilde{I}^1$$

SAC

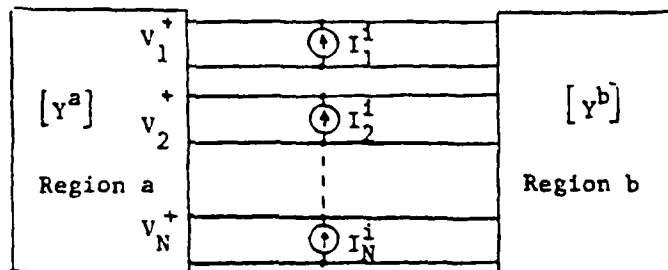


Figure 2.5.3 The Generalized Network Equivalent for an Aperture Problem

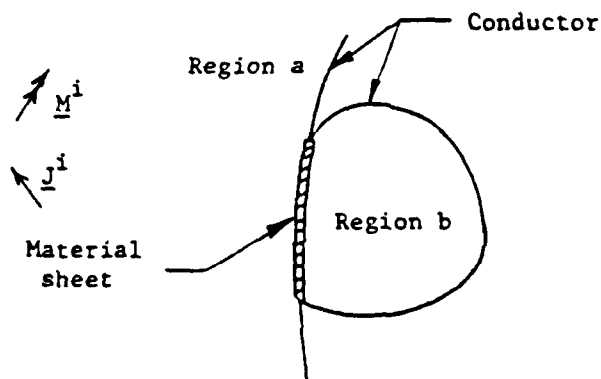


Figure 2.5.4 An Aperture Covered by a Material Sheet

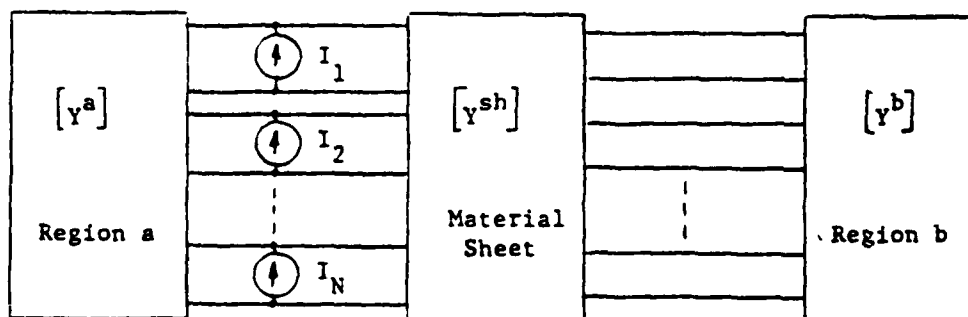
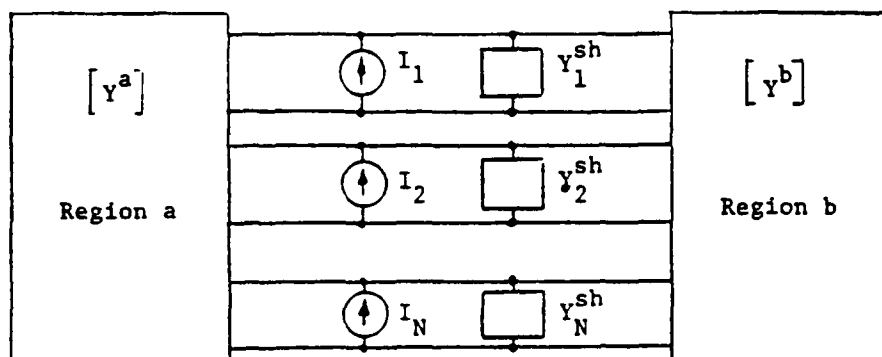
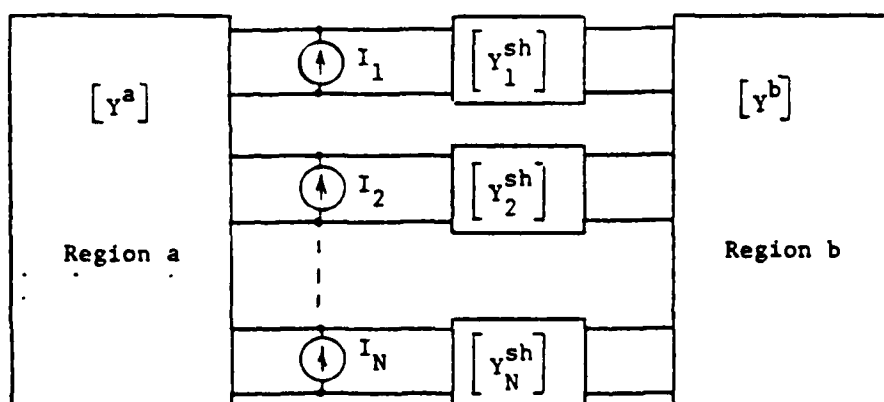


Figure 2.5.5 Generalized Network Equivalent for the Problem of Figure 2.5.4

ERC



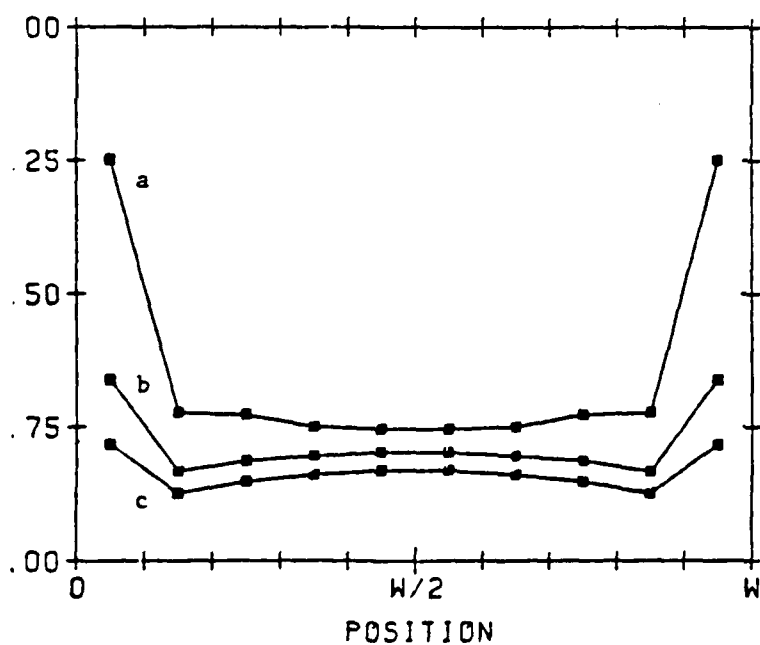
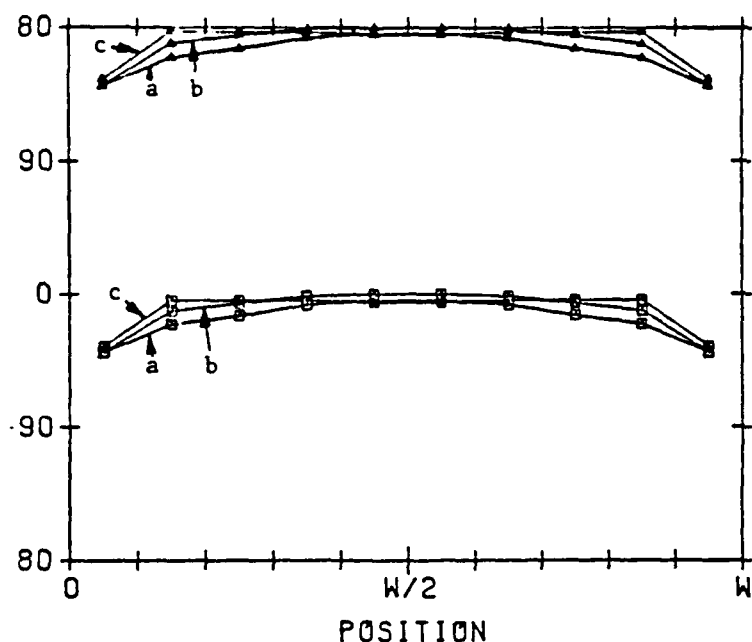
a) Thin Dielectric Sheet



b) Thick Material Sheet

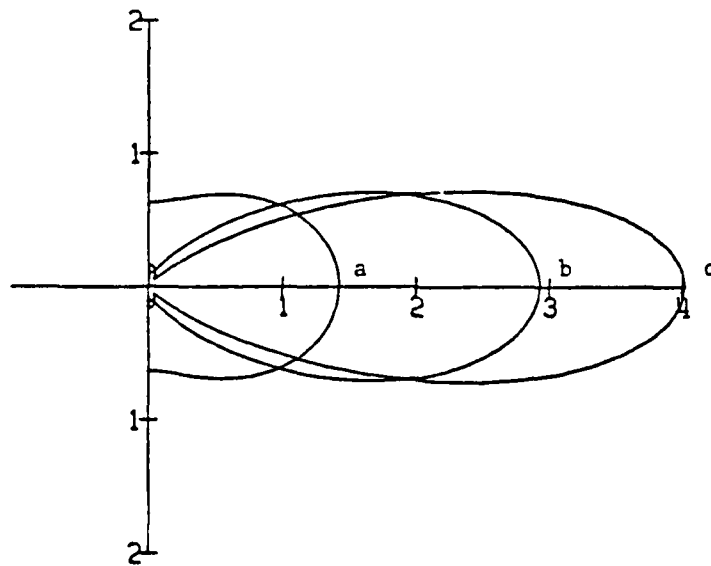
Figure 2.5.6 Approximate Network Equivalents
for the Sheet-covered Aperture

SRP



6. Magnitude and phase of $\bar{M}_1$ (squares) and $\bar{M}_2$ (triangles)
for slit $w = .4\lambda_a$, $d = .001\lambda_a$, $k_b = k_a = k_0$ and
a) $\epsilon_c = \epsilon_0$; b) $\epsilon_c = 5\epsilon_0$; c) $\epsilon_c = 10\epsilon_0$. $N = 10$.

5116



GAIN PATTERN

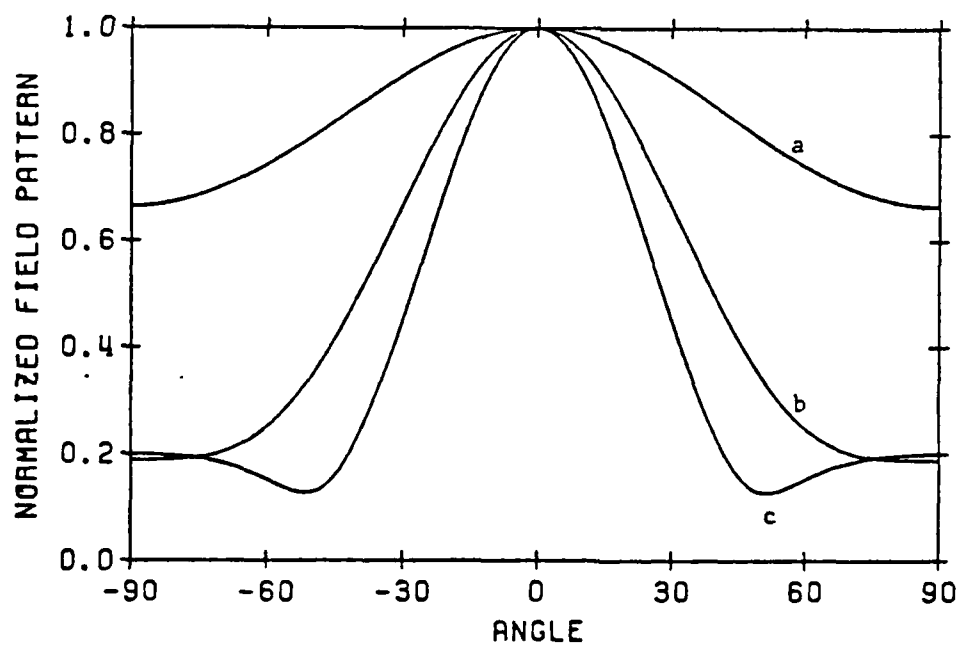


Fig. 8. Gain and normalized field patterns for slits in Fig. 6.

SNC

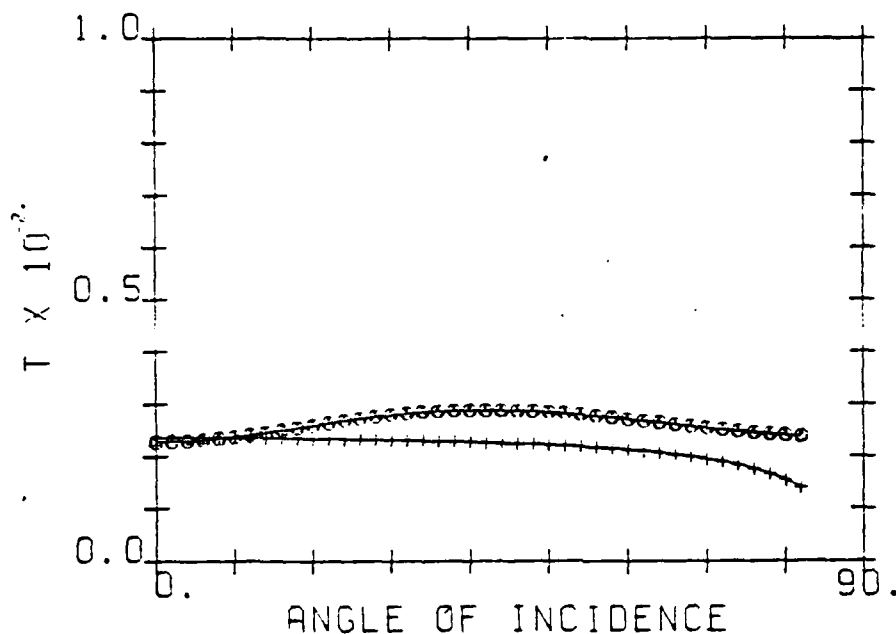


Fig. 5. Transmission coefficient when $w = 1\lambda_0$, $d = .01\lambda_0$, $\sigma = 10 \text{ V/m}$. Circles use method in [4], triangles use plane wave assumption, + 's use infinite slab transmission coefficient.

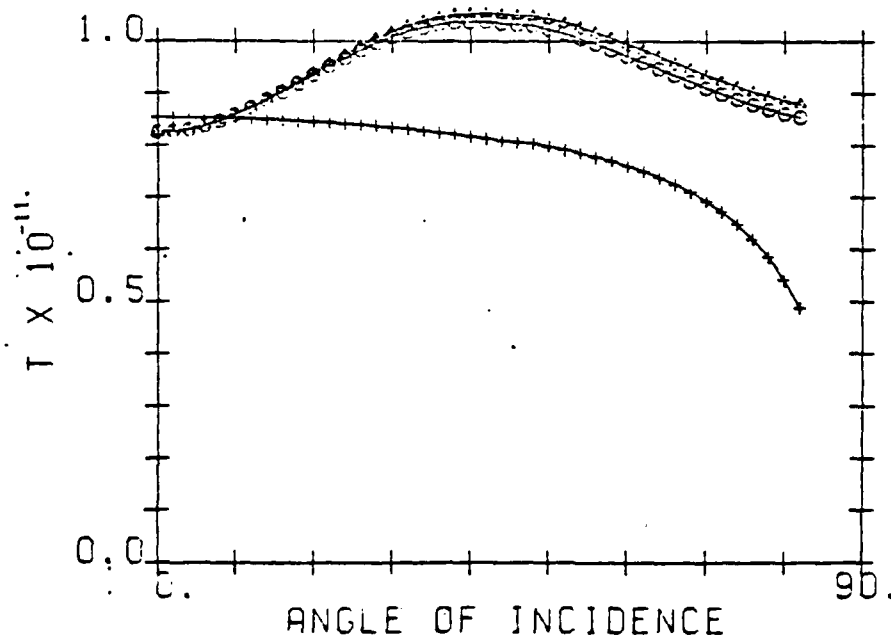


Fig. 6. Transmission coefficient when $w = 1\lambda_0$, $d = .1\lambda_0$, $\sigma = 10 \text{ V/m}$. (skin depth = $9.19 \times 10^{-3} \text{ m}$)

SNC

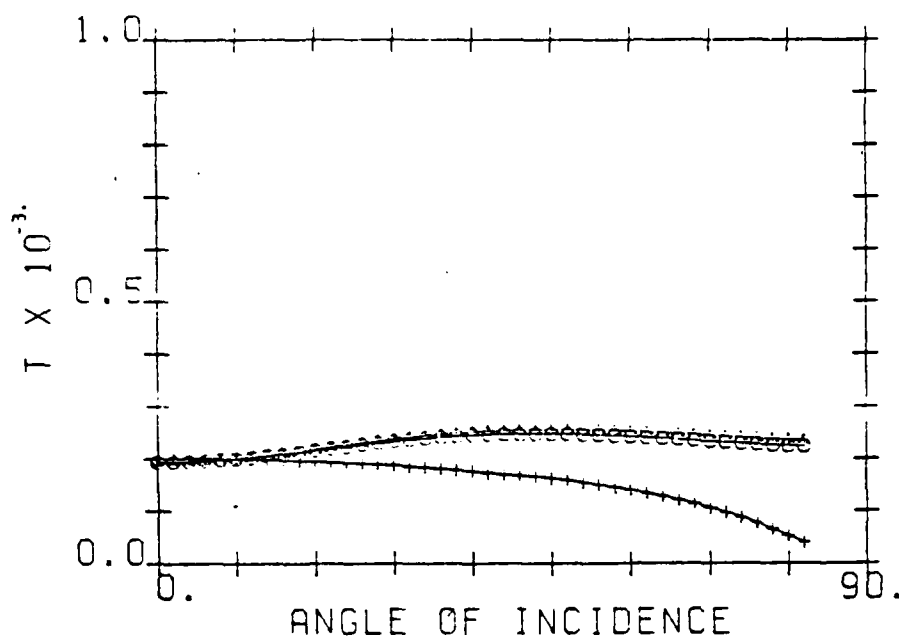


Fig 7. Transmission coefficient when $w = 1\lambda_0$,
 $d = .1\lambda_0$, $\sigma = 175/m$, (skin depth = $2.93 \times 10^{-2}m$)

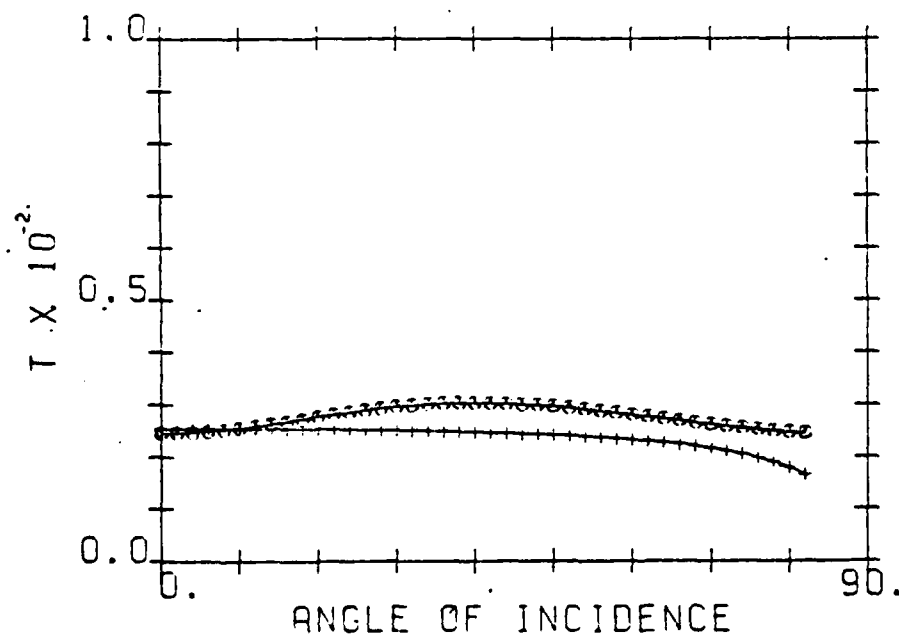


Fig 8. Transmission coefficient when $w = 1\lambda_0$,
 $d = .001\lambda_0$, $\sigma = 100V/m$, (skin depth = $2.9 \times 10^{-3}m$)

SNC

Robert Carri
Grumman Aerospace

AD-A096 459

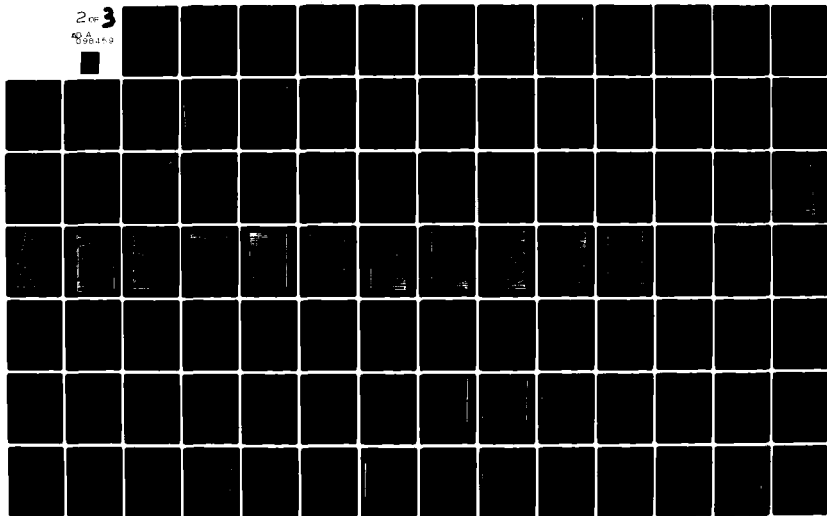
NAVAL AIR SYSTEMS COMMAND WASHINGTON DC
REPORT OF COMPOSITE MATERIAL AND METAL COMPOSITES JOINT WORKSHO--ETC(U)
1978

F/G 11/4

UNCLASSIFIED

NL

2 of 3
NO. 100-1-10



MULTIPLE THREATS ADDRESSED

OPERATIONAL

- LIGHTNING
 - DIRECT
 - INDIRECT
- STATIC ELECTRIFICATION (P_{STATIC})
- ELECTROMAGNETIC INTERFERENCE (EMI)

COMBAT

- HIGH ENERGY LASER (HEL)
- NUCLEAR ELECTROMAGNETIC PULSE (NEMP)

PROGRAM OBJECTIVE

DEVELOP PRACTICAL, OPTIMIZED, AND INTEGRATED
PROTECTION AND SHIELDING METHODOLOGIES
TO PROTECT COMPOSITE AIRCRAFT STRUCTURES
AGAINST MULTIPLE THREATS

SUBCONTRACTOR TASKS

- LIGHTNING TRANSIENTS RESEARCH INSTITUTE (LTRI),
ST PAUL, MINN.
 - MODEL ATTACH. TESTS
 - LIGHTNING, P STATIC & SHIELDING TESTS
- MISSION RESEARCH CORPORATION (MRC)
ALBUQUERQUE, NEW MEXICO
 - EM ANALYSIS
 - CONSULTANT ON EM TESTING
- AVCO SYSTEMS DIVISION
LOWELL, MASS.
 - LASER TESTING
 - THERMAL ANALYSIS

DISTRIBUTION OF STRIKE POINTS

TEST SERIES (NO.):	1	2	3	4	5	6	7
NOSE RADOME	28%	29%	29%	31%*	28		
LOWER FUSELAGE (ANTENNAS)	7	6	6	3	8		
AFT CANOPY	1	1	1		1		
WINGTIP	40	40	38	40	30	69	67
CANARD	1	1	1	1	3	4	
VERTICAL FIN	13	13	15	17*	17*	27	33
TAIL CONE	10	10	10	8	3		
TOTAL PERCENT	100	100	100	100	100	100	100
TOTAL DISCHARGES	72	72	72	72	72	101	18

*SLIGHTLY GREATER NUMBER OF STRIKES TO NOSE RADOME AND VERTICAL FIN COULD BE ARGUED AS INDICATING THAT STROKES ARE BEING DRAWN INTO AREA BY GRAPHITE VERTICAL FIN INSERT AND GRAPHITE FORWARD FUSELAGE, BUT THEY ARE NOT SUFFICIENTLY DIFFERENT TO BE STATISTICALLY SIGNIFICANT WITH OUT MANY MORE TESTS IN THE CRITICAL AREA.

NOTE: TOTAL NUMBER OF TEST DISCHARGES -- 517, INCLUDING ABOVE SEQUENCES PLUS SETUP TESTS AND RERUNS.

NUCLEAR ELECTROMAGNETIC PULSE (EMP) THREAT

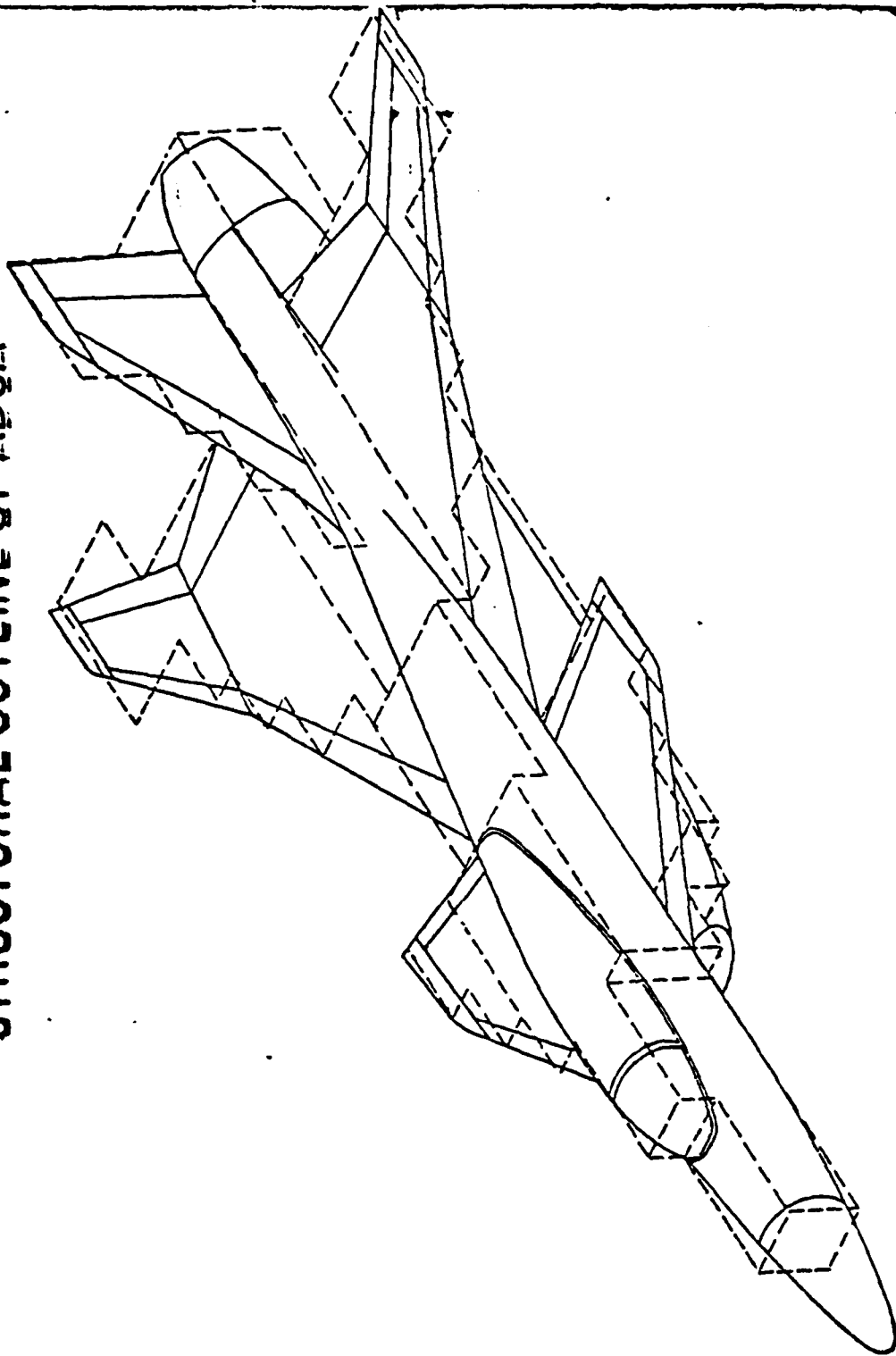
WEAPON:

NUCLEAR DEVICE OF KNOWN YIELD AND BURST ALTITUDE

EFFECTS:

- EXTERNAL COUPLING – CONVENTIONAL AIRCRAFT RESPONDS TO EMP AS AN ANTENNA; SURFACE CURRENTS AND CHARGES ARE INDUCED ON AIRCRAFT
- ELECTROMAGNETIC FIELDS PENETRATE THE AIRCRAFT VIA POINTS OF ENTRY (POE)
 - DIRECT DIFFUSION THRU AIRCRAFT SKIN
 - DELIBERATE ANTENNAS DESIGNED TO PICK UP THE ENERGY
 - INADVERTENT PENETRATIONS
- INTERNAL COUPLING – EM ENERGY IS COUPLED TO INTERNAL CONDUCTORS BY MEANS OF POE, AND PROPAGATES TO ELECTRONIC BOXES

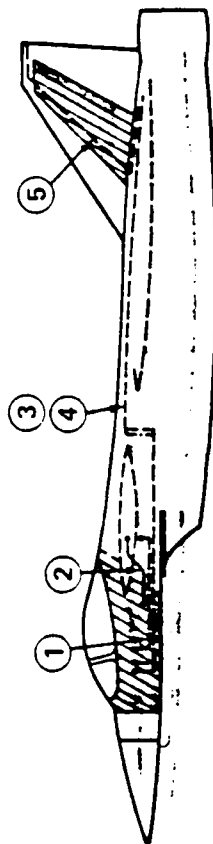
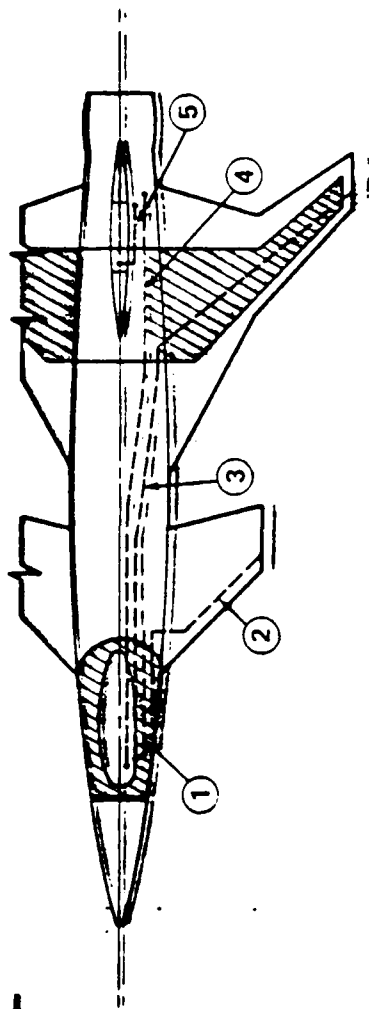
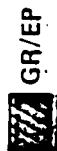
OVERLAY OF THREEDE MATHEMATICAL MODEL AND STRUCTURAL OUTLINE OF ADCA



MA: Mo: Co: TH: 3D: Fin: Tur: x: Hi: 84: 20: Co: Ex: Cu: Ch: | Sur: Ten: In:

Trans. Pict. Volume

EMP MODEL



- ① ENV. CONTR. SYSTEM - TWISTED PAIR - UNSHIELDED - 22 GA.
- ② ANTENNA - COAX CABLE - RG 214
- ③ SIDEWINDER - CABLE
- ④ FLY BY WIRE - CABLE
- ⑤ ANTENNA - COAX CABLE - RG 214

SIDEWINDER CABLE

- 26 GA - SHIELDED (1)
- 22 GA - TWISTED - NO SHIELD (3)
- 22 GA - NO SHIELD (1)

FLY-BY-WIRE CABLE

- 22 GA - NO SHIELD (1)
- 26 GA - SHIELDED TWISTED PAIR - SHIELD GROUNDED AT BOTH ENDS - CIRCUIT GROUNDED IN COCKPIT (1)
- 26 GA - SHIELDED TWISTED PAIR SHIELD GROUNDED AT ONE END IN COCKPIT-CIRCUIT GROUNDED IN COCKPIT (1)



NAH Model 1 doca

NEPP - ANALYSIS RESULTS

WORST CASE CABLE RESPONSES

	CONDUCTIVITY MHQ/M	OPEN CIRCUIT VOLTAGE (V)	SHORT CIRCUIT (CURRENT (MA)	
CANARD - ANTENNA (SHIELDED CABLE)	8000 15000 20000	14 4.8 3.1	149 61 41	VARIES Graded thickness Cable
HARNES (FLY BY WIRE)	8000	110	297	Varies in or short circuit terminals
ECS TWISTED PAIR	15000	47	203	Variable EAX
SIDEWINDER CABLE	20000	41	162	(Varies) Character Impedance

EXPERIMENTAL DATA EXTRAPOLATED TO THREAT LEVEL
(A7E AIRCRAFT - 45 FOOT FUSELAGE APERTURE COUPLING)

BETWEEN 370 MA AND 3.3 AMPS AVIONICS BAY (11 CABLES)
BETWEEN 920 MA AND 8.3 AMPS CABLES FROM WING (10)

V

GRAPHITE/EPOXY (AS/3501.5A)

10,000

1,000

100

10

1

0.1

$\Delta T, ^\circ F$

ALUMINUM

2.0

1.4

0.8

0.4

0

AREA, IN.²

0.001 IN.

CATEGORY	TYPE	VENDOR (1)	ULTIMATE TENSILE STRENGTH, KSI	TENSILE MODULUS, KSI X 10 ⁶	DENSITY, GY/CC	AVAILABILITY (3)
Polycrystalline Kevlar	FP-1	D	200	55	3.7	L
	FP-2	D	250	55	3.7	L
Kevlar	KEVLAR 29	D	550	9	1.44	P
	KEVLAR 49	D	950	19	1.45	L
Carbon (2)	4 MIL/W	A, CTI	475	58-60	2.160	P
	5.6 MIL/W	A, CTI	500	58-60	2.148	L
	4 MIL/CC	A	400	50	2.10	L
Glass	"E"	-	500	10.5	2.54	P
	"S"	-	1650	12.4	2.49	L
Graphite Low-Cost, High- Strength) (HS)	CELION	C	429	34	1.75	P
	A-S	M	420	34	1.81	P
	T-300	M	360	33	1.76	P
	TYPE III	M	350	33	1.78	L
	3T	G	300	30	1.8	P
Intermediate Modulus (IM)	T-400	U	425	33	1.78	L
	TYPE III	M	360	40	1.71	D
	HTS	H	410	36	1.82	L
	4T	G	350	38	1.80	D
High Modulus (HM)	HM	H	350	53	1.89	L
	T-50	U	300	57	1.87	L
	TYPE I	M	350	56	1.86	L
	5T	G	400	48	1.85	L
	6T	G	420	58	1.90	L
Ultra-High Modulus (UHM)	GY-70	C	250	75	1.86	P
Silicon (2) Carbide	4 MIL/W	A, CTI	480	62	3.41	D
	4 MIL/CC	A, CTI	480	62	2.99	D
	5.6 MIL/CC	A, CTI	480	62	3.07	D

) A - AVCO
 C - Celanese
 CTI - Composite Technology, Inc.
 D - Dupont
 G - Great Lakes
 H - Hercules
 M - Merganite
 U - Union Carbide

(2) W - Tungsten Core
 CC - Carbon Core

(3) IP - High Rate
 Production
 L - Limited Production
 D - Developmental
 Status

FIBER PROPERTIES AND AVAILABILITY

RELATIVE COST AND WEIGHT FACTORS OF POPULAR PROTECTION SYSTEMS

	WT LBS/SQ FT	MAT'L COST	LABOR COST
1100 AL ALLOY FLAME SPRAY t ≈ 6 MILS ρ ≈ 1 x 10 ⁶ MHOS/M	1	1	1
5056 AL ALLOY 120 GRID WIRE MESH ρ ≈ .7 - 2.0 MHOS/M	1.37	14.3	1.6
2024 AL ALLOY 4 MIL FOIL	1.14	6	1.3

STRUCTURAL FASTENERS AND APPLICATIONS

INTERFERENCE FIT

- BUCKED RIVETS - USE NOT PERMITTED FOR COMPOSITES (UNCONTROLLED EXPANSION)
- TAPER LOCKS = HIGH INSTALLATION COSTS
- STRESS WAVE RIVETING = GAC DEVELOPED (CONTROLLED EXPANSION)
- BF GOODRICH RIVNUT = WET WINGS (ELIMINATED "O" RING SEAL)

BOLTS - CLOSE TOLERANCE = IN GENERAL THEY DO NOT PROVIDE INTIMATE CONTACT WITH GRAPHITE FIBERS

- ACCESSIBLE = HI LOCKS, HI TORQUE RECESS ETC
- BLIND - JO BOLT, HUCK BOLT (COMPOSITE TO METAL)
- BIG FOOT (COMPOSITE TO COMPOSITE)

CONDUCTIVITY OF TYPE AS GRAPHITE EPOXY LAMINATES

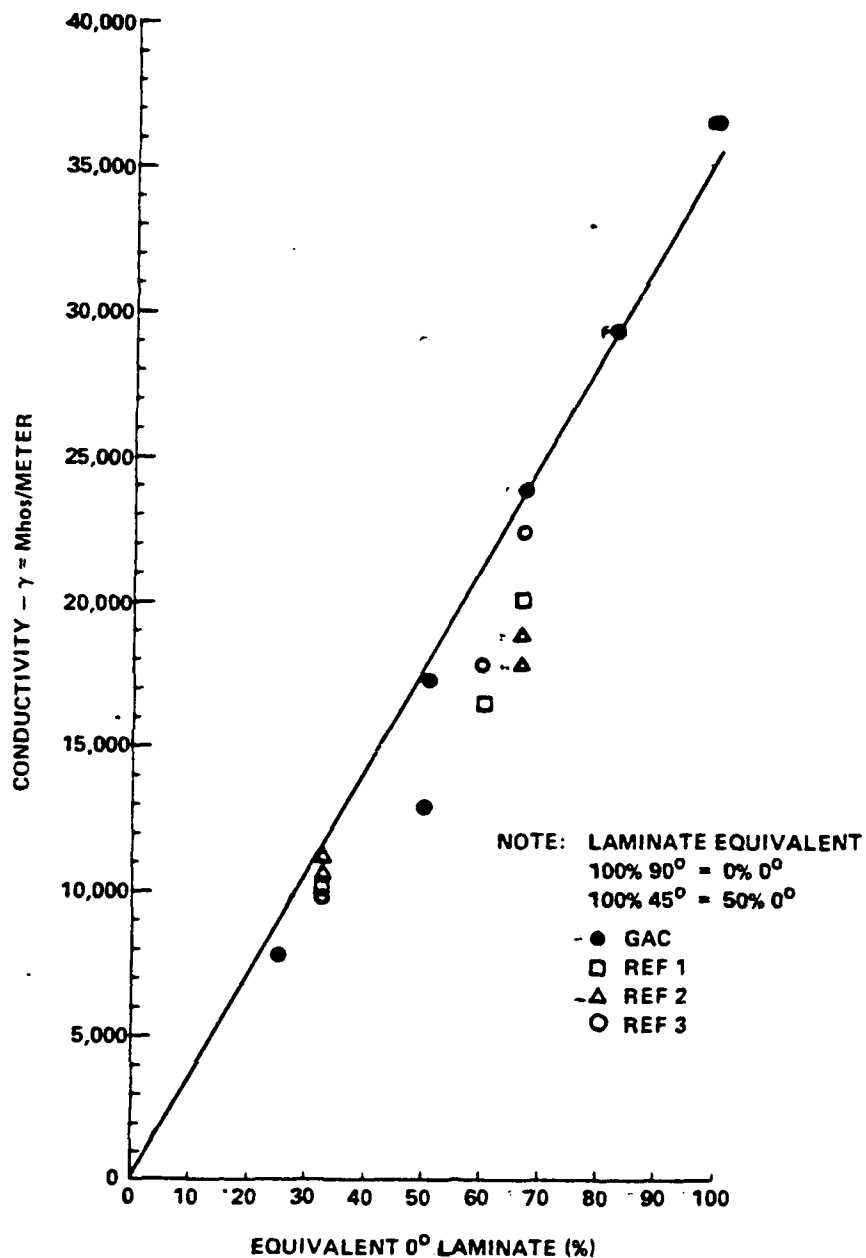
MAC-1
Pacir
G.D

LAMINATE	NO. PLIES	LAYUP, %			REFERENCE	CONDUCTIVITY 10 ³ Mhos/METER			EQUIVALENT % 0° LAMINATE
		0°	90°	±45°		MAX	MIN	AVG	
[0, ±45, 0] T	6	33	0	67	1	20.1	17.0	18.2	66
[90, ±45, ±45, 90] T	6	0	33	67	1	10.1	7.1	9.1	33
[0, ±45, ±45, ±45, 0] T	10	20	0	80	1	16.5	14.1	15.2	60
[±45, 90, 90, ±45] T	6	0	33	67	2	10.5	8.8	9.7	33
[90, 90, 0, 0, 90, 90] T	6	33	67	0	2	11.2	10.2	10.7	33
[±45, 0, 0, ±45] T	6	33	0	67	2	18.9	14.4	16.7	66
[0, 0, 90, 90, 0, 0] T	6	67	33	0	2	17.9	16.3	17.1	67
[0, ±45, ±45, 0] T	6	33	0	67	3	23.4	19.0	21.5	67
[0, ±45, ±45, ±45, 0] T	10	20	0	80	3	17.8	16.6	17.8	60
[90, ±45, ±45, 90] T	6	0	33	67	3	9.8	9.2	9.6	33
[0, 12] T	12	100	0	0	GAC	36.6	34.6	35.6	100
[±45, 0, 9, ±45] T	12	67	0	33	GAC	29.4	28.5	29.0	83
[±45, 90, 0, 9, 90, ±45] T	12	50	17	33	GAC	23.8	22.5	23.2	67
[±45, 90, 0, 9, 90, ±45, 2] T	12	17	17	67	GAC	12.8	12.5	*12.7	50
[±45, 6] T	12	0	0	100	GAC	17.5	17.4	17.5	50
[±45, 90, 2, ±45, 90, 3, ±45] T	12	0	50	50	GAC	7.7	5.4	*6.6	25

*TESTED AT AN EARLIER DATE USING LESS ACCURATE CONNECTION TECHNIQUES

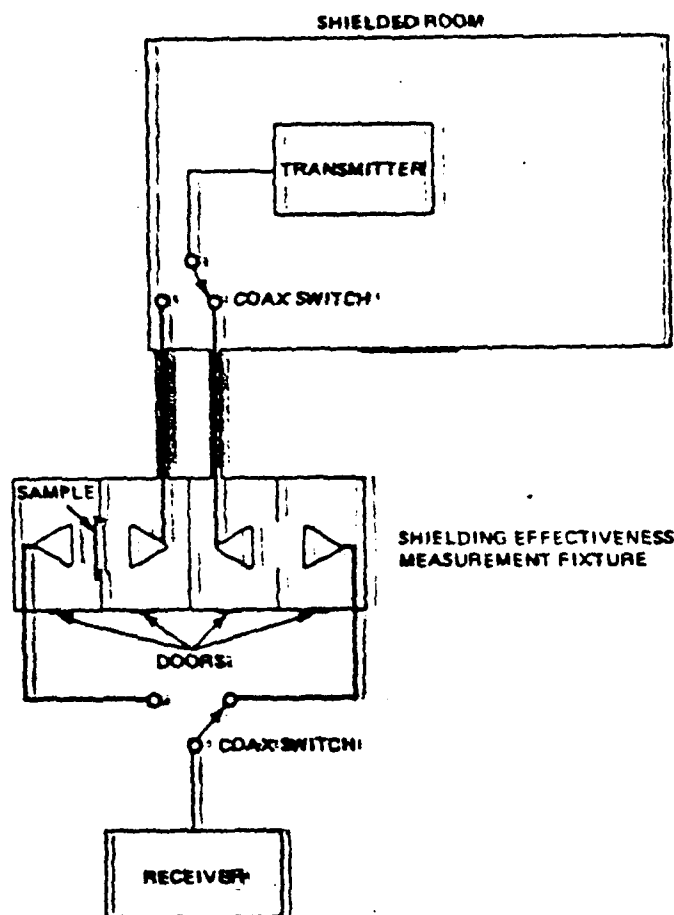
SEALING AN

RELATIVE CONDUCTIVITY VALUES FOR GR/EP LAMINATES



SHIELDING EFFECTIVENESS MEASUREMENTS - FLAT PLATE FACILITY

- FOUR COMPARTMENT FIXTURE - ONE PAIR OF COMPARTMENTS USED TO OBTAIN A REFERENCE WITH OPEN APERTURE - OTHER PAIR OF COMPARTMENTS HAS A MOUNTED SAMPLE IN THE APERTURE DIFFERENCE IN dBs IS THE SHIELDING EFFECTIVENESS OF THE MATERIAL BEING TESTED
- EACH PAIR OF ANTENNAS CHECKED FOR EQUIVALENCY TO INSURE CONDITIONS ARE THE SAME IN EACH PAIR OF COMPARTMENTS PRIOR TO TEST
- TRANSMITTER, RECEIVER AND ANTENNA EQUIPMENT USED DEPENDENT ON TYPE OF FIELD AND FREQUENCY RANGE



Shielding Effectiveness Measurement Set-Up

FIXTURE DESIGN

- ALL-WELDED ALUMINUM
- ALL APERTURES BOTH INTERNAL AND EXTERNAL HARDENED BY A 1/4 X 3/16 INCH RF METAL GASKET AT A DISTANCE OF 1/2 INCH FROM THE EDGE OF OPENING IN A RIGID MACHINED RECESSED GROOVE
- EXTERNAL DOORS - UQ904 TYPE MANUFACTURED BY UNIVERSAL SHIELDING CORPORATION
- NO THRU BOLT HOLES IN FIXTURE

SPECIMEN PREPARATION

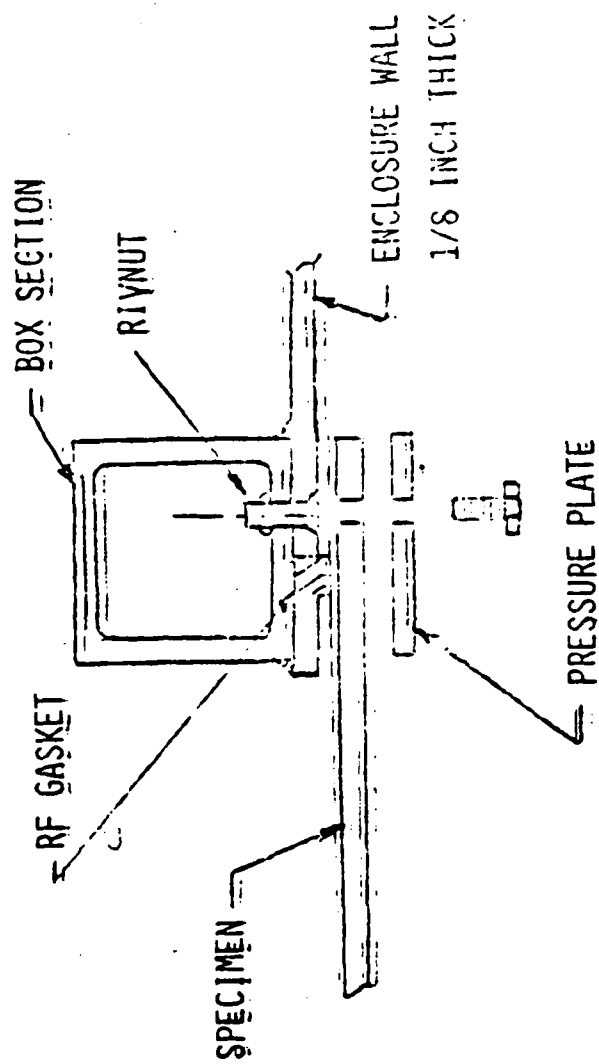
- SPECIMENS - (15 X 15 INCHES) TAPER GRIND EDGED AND PERIPHERAL FRAME WITH 1 1/2 INCH ALUM STRIP (BOTH SIDES) BONDED ON WITH A CONDUCTIVE ADHESIVE (SILVER FILLED EPOXY)

- PREDRILL SAMPLE

SPECIMEN MOUNTING

- INSTALL 15 X 15 INCH SAMPLE IN 12 X 12 APERTURE WITH AN ALUMINUM FRAME (PRESSURE PLATE) ON THE OUTER SURFACE 3/16 DIA FASTENERS, 1 INCH PITCH

DETAIL OF SPECIMEN MOUNTING



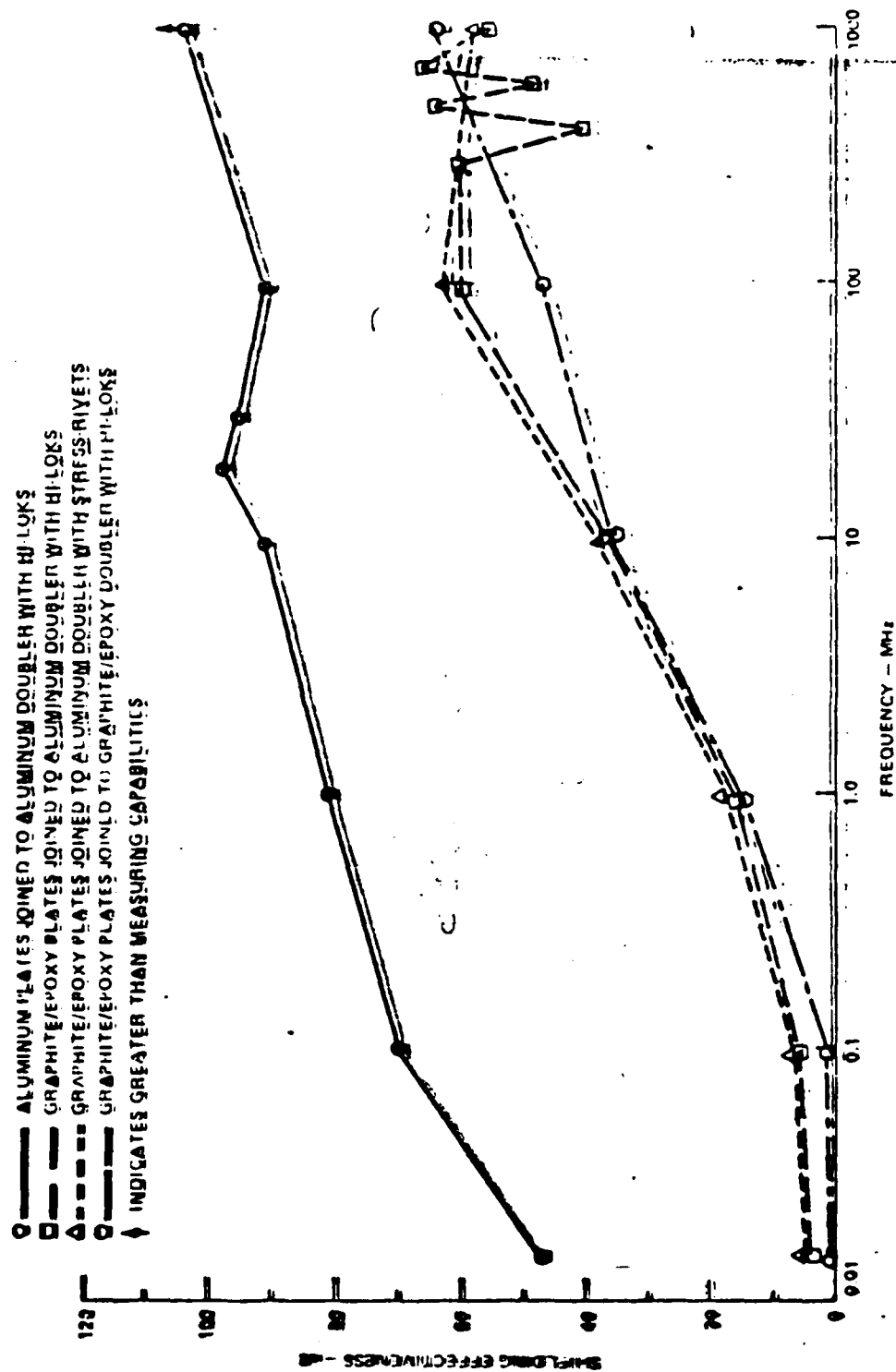


Figure 2-7 Magnetic Shielding Effectiveness of Tightly Joined Panels

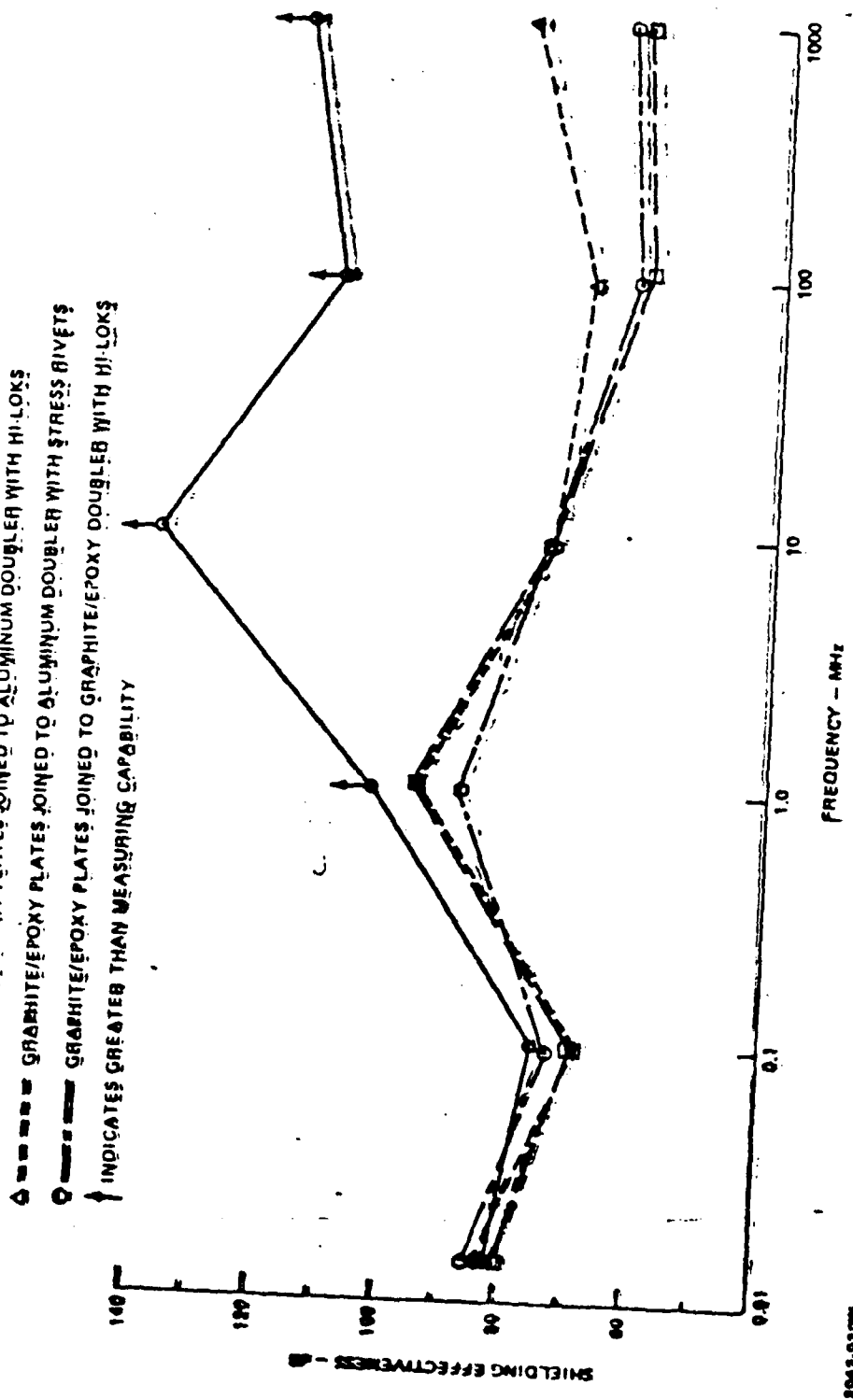


Figure 3-8 E-Field Shielding Effectiveness of Tightly Joined Panels

SHIELDING EFFECTIVENESS MEASUREMENT EQUIPMENT LIST

FREQUENCY RANGE	TRANSMITTER	TRANS ANTENNA	RECEIVER	REC ANTENNA	TYPE OF FIELD
10 KHz TO 32 MHz	H.P. 205 AG SIG GEN	LOOP	SINGER NM-17/27	LOOP	LOW IMP (H)
10 KHz TO 32 MHz	H.P. 606 SIG GEN	ROD	NM-17/27	ROD	HIGH IMP (E)
32 MHz TO 200 MHz	RLUS I.F.I. 5000	LOOP	SINGER NM-37/57	LOOP	(H)
32 MHz TO 200 MHz	AND I.F.I. M402 PWR AMP	ROD		ROD	(E)
200 MHz TO 500 MHz	H.P. 608 SIG GEN	LOOP		LOOP	(H)
200 MHz TO 500 MHz	AND H.P. 230 PWR AMP	ROD		ROD	(E)
500 MHz TO 1 GHz	H.P. 612 SIG GEN	LOOP		LOOP	(H)
500 MHz TO 1 GHz		ROD		ROD	(E)
1 GHz TO 2 GHz	H.P. 614 SIG GEN AND KELTEC LR605-10	LOOP	EMPIRE INF-112	LOG PERIODIC	(H)
		ROD			(E)
2 GHz TO 4 GHz	H.P. 618 SIG GEN AND H.P. 419C	LOOP			(H)
		ROD			(E)
4 GHz TO 7.6 GHz	H.P. 618 SIG GEN AND H.P. 493A	LOOP			(H)
		ROD			(E)
7.6 GHz TO 10 GHz	H.P. 620 SIG GEN AND H.P. 495A	LOOP			(H)
		ROD			(E)

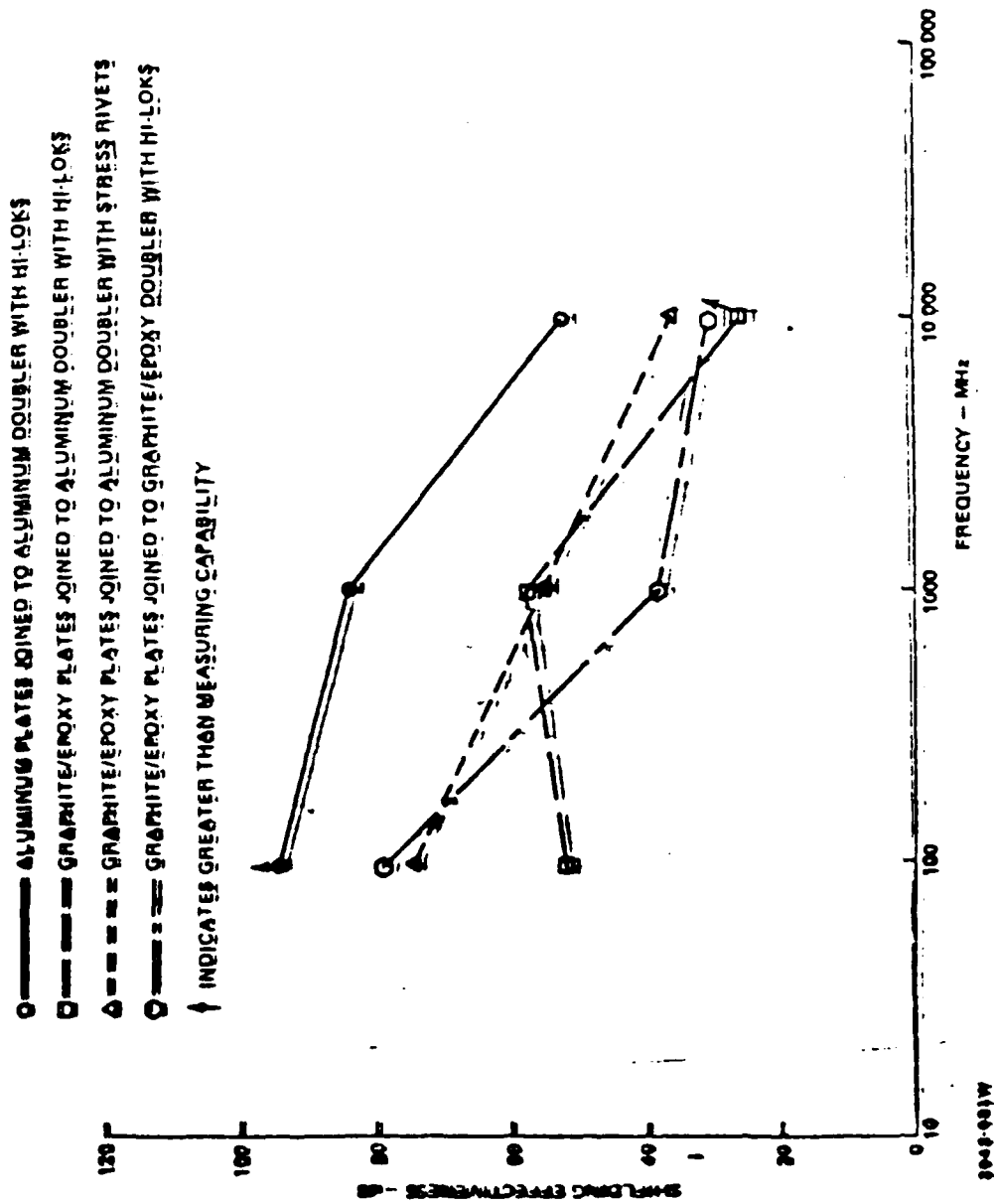
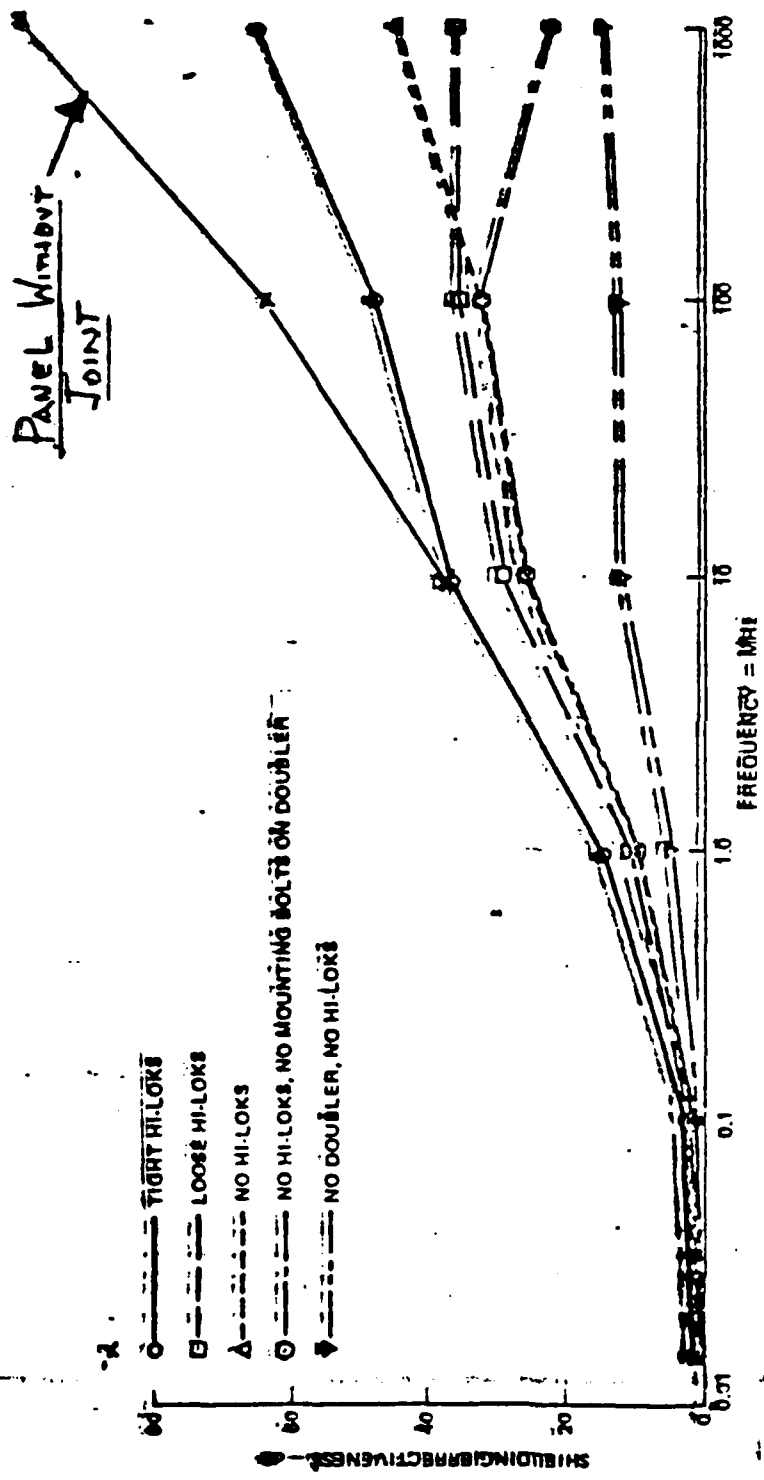


Figure 2-8 Plane-Wave Shielding Effectiveness of Tightly Joined Panels



Variation of Magnetic Shielding Effectiveness of 2/28 Graphite/Epoxy
 Panels Joined to 24 Ply Graphite/Epoxy Doubler With Hi-Loks

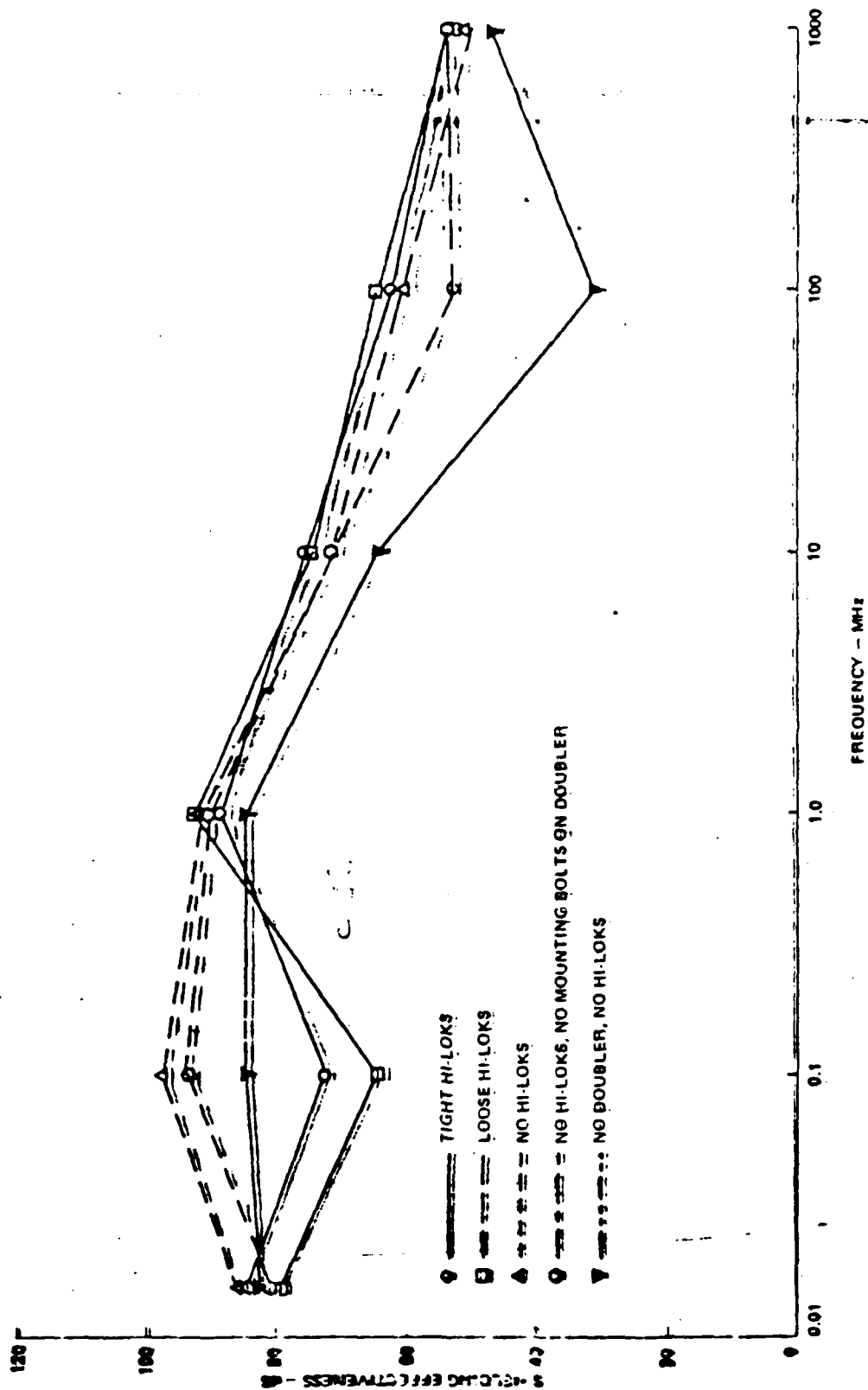
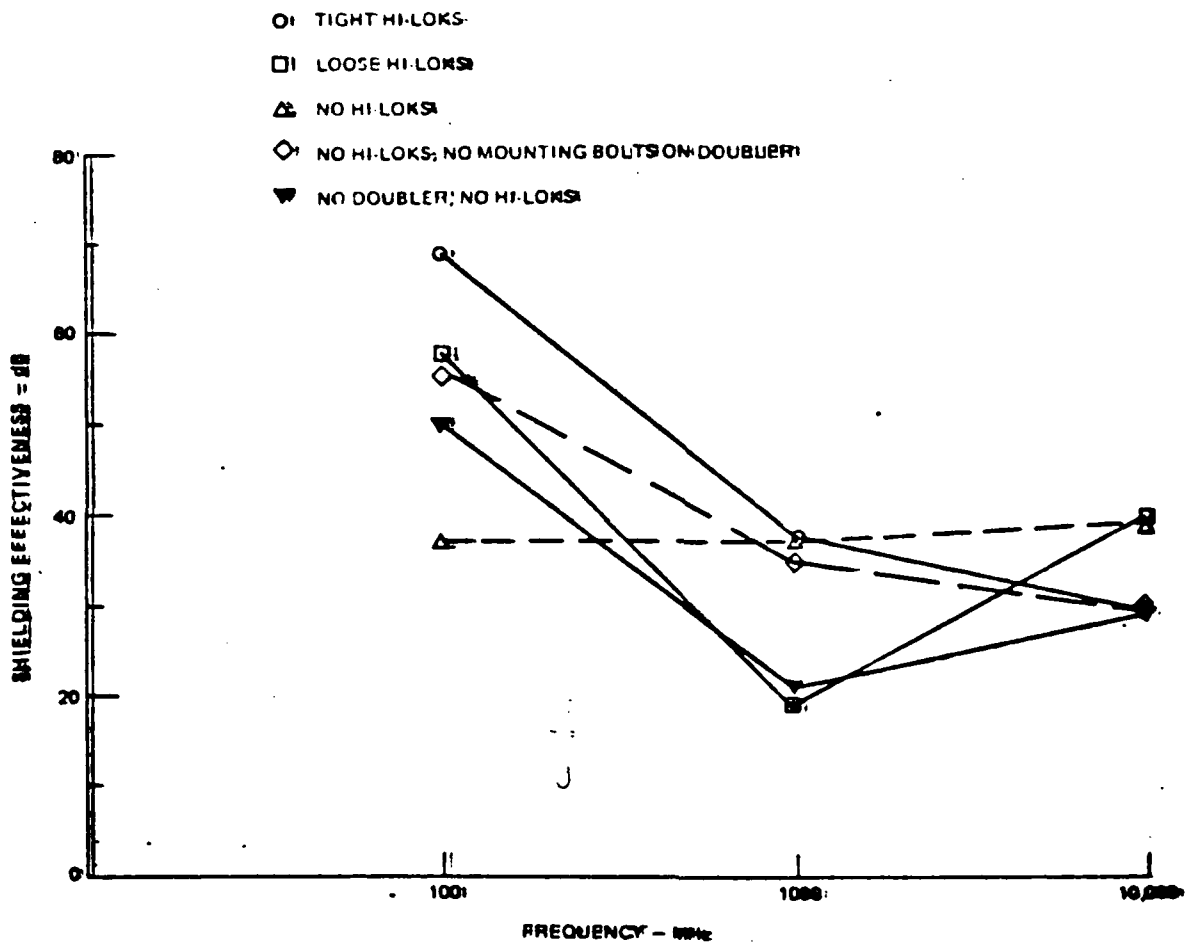


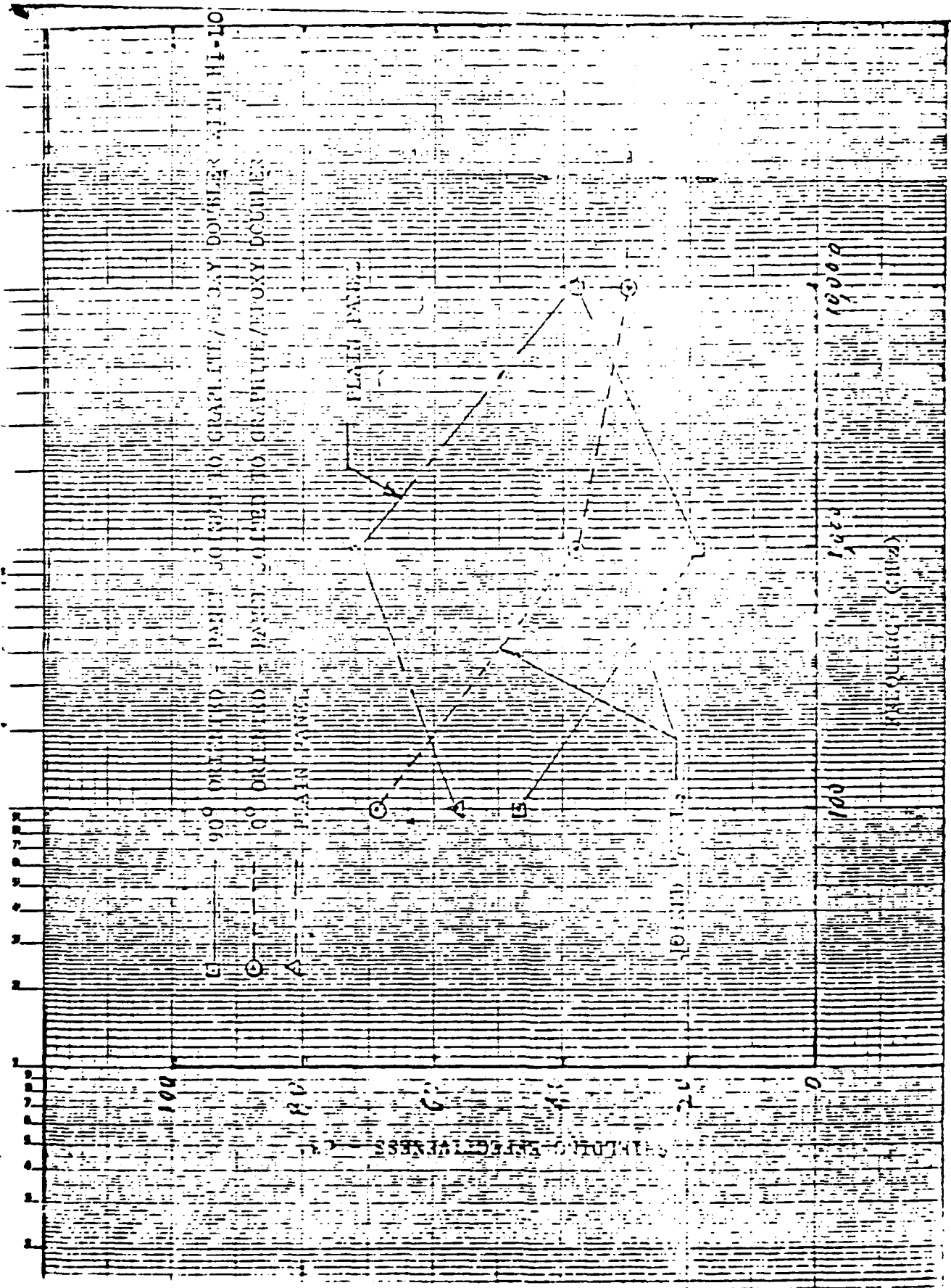
Figure 3-11 Variation of E-Field Shielding Effectiveness of 2/2/8 Graphite/Epoxy Panels Joined to 24 My Graphite/Epoxy Doubler With Hi-Loks

2042-023W



2042-0240

Figure 3-12 Variation of Plane-Wave Shielding Effectiveness for 2/2/8 Graphite/Epoxy Panels Joined to 24 Ply Graphite/Epoxy Doubler With HI-LOKS



PLAIN PANEL, GRAPHITE/POXY DOUBLER AND JOINT D PANELS

POAC ACCOMPLISHMENTS TO DATE

- 0 CONDUCTIVITY OF GRAPHITE/EPOXY MULTI-DIRECTIONAL LAMINATES SIMPLIFIED
ENGINEERING APPROACH SUBSTANTIATED BY TEST
- 0 LIGHTNING STRIKE MODEL STUDIES COMPLETED
- 0 NEMP COUPLING ANALYSIS COMPLETED
- 0 DEVELOPED PARALLEL RESISTOR ANALOGY FOR ANALYTICALLY OBTAINING SHIELDING
EFFECTIVENESS FOR GR/EP LAMINATES WITH A PROTECTION SYSTEM
- 0 LEMP COUPLING ANALYSIS - NINETY PERCENT COMPLETED
- 0 POAC COMPUTER PROGRAM - THIRTY PERCENT COMPLETED
- 0 THREAT MATRIX - EIGHTY PERCENT COMPLETED
- 0 SPARK PROOF WING TANK - AWAITING TEST AT LTRI
- 0 COMPOSITE JOINTS - SHIELDING DATA - TWENTY PERCENT COMPLETED
- 0 COMPLETED SWEEP STROKE TESTING ON FLAT PANELS
- 0 DEVELOPED PROCESS FOR SECONDARY APPLICATION OF ALUMINUM FLAME SPRAY
ON CURED GR/E STRUCTURE

27
BRL 11-11-61

•DESIGN AND MEASUREMENT OF STRUCTURAL/ELECTRICAL
COMPOSITE AIRFRAME JOINTS

PRESENTED TO

COMPOSITE MATERIAL AND METAL-COMPOSITE
JOINT WORKSHOP MEETING

PREPARED FOR

NAVAL AIR SYSTEMS COMMAND
WASHINGTON, D.C.

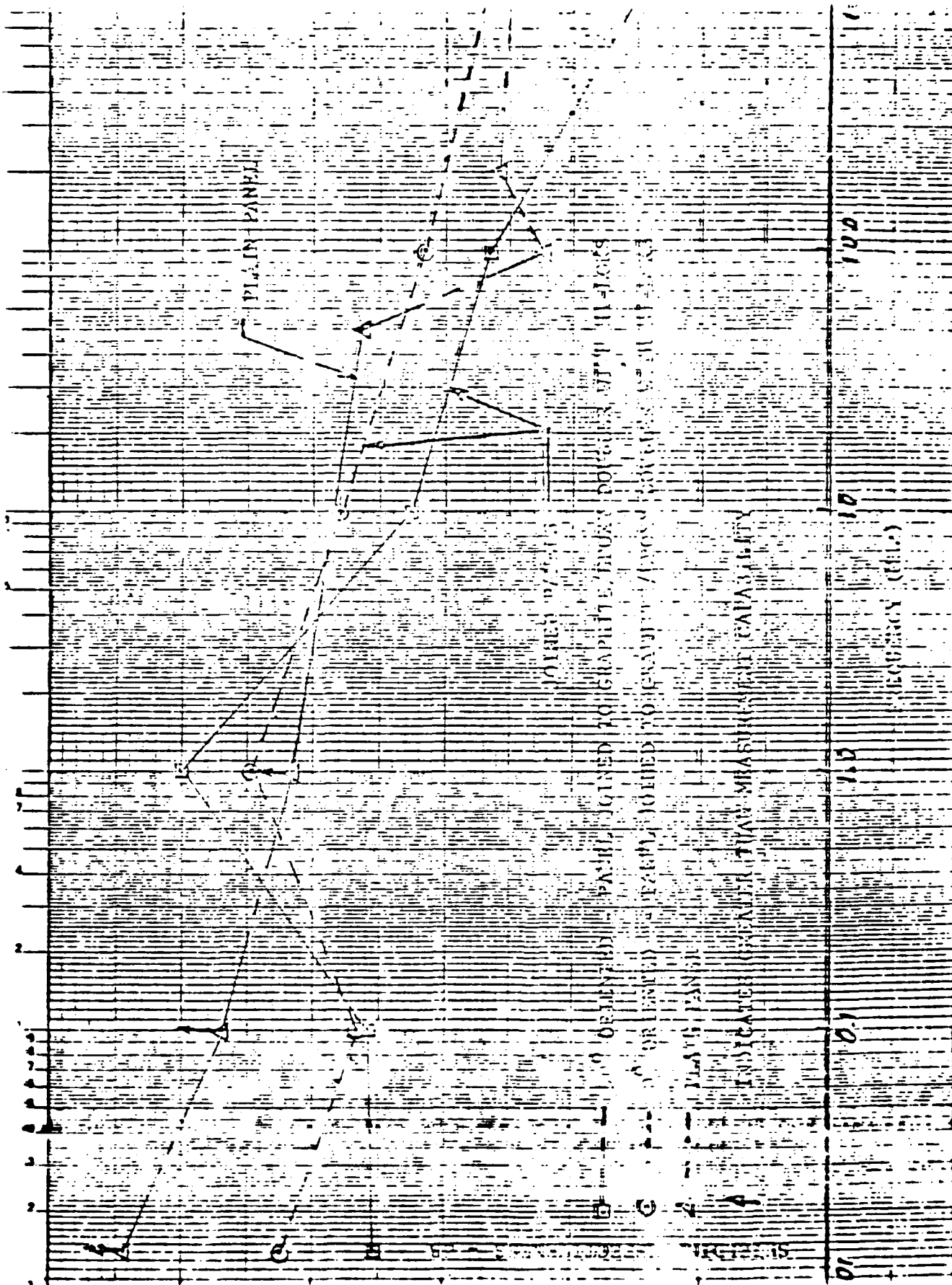
PREPARED BY

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK

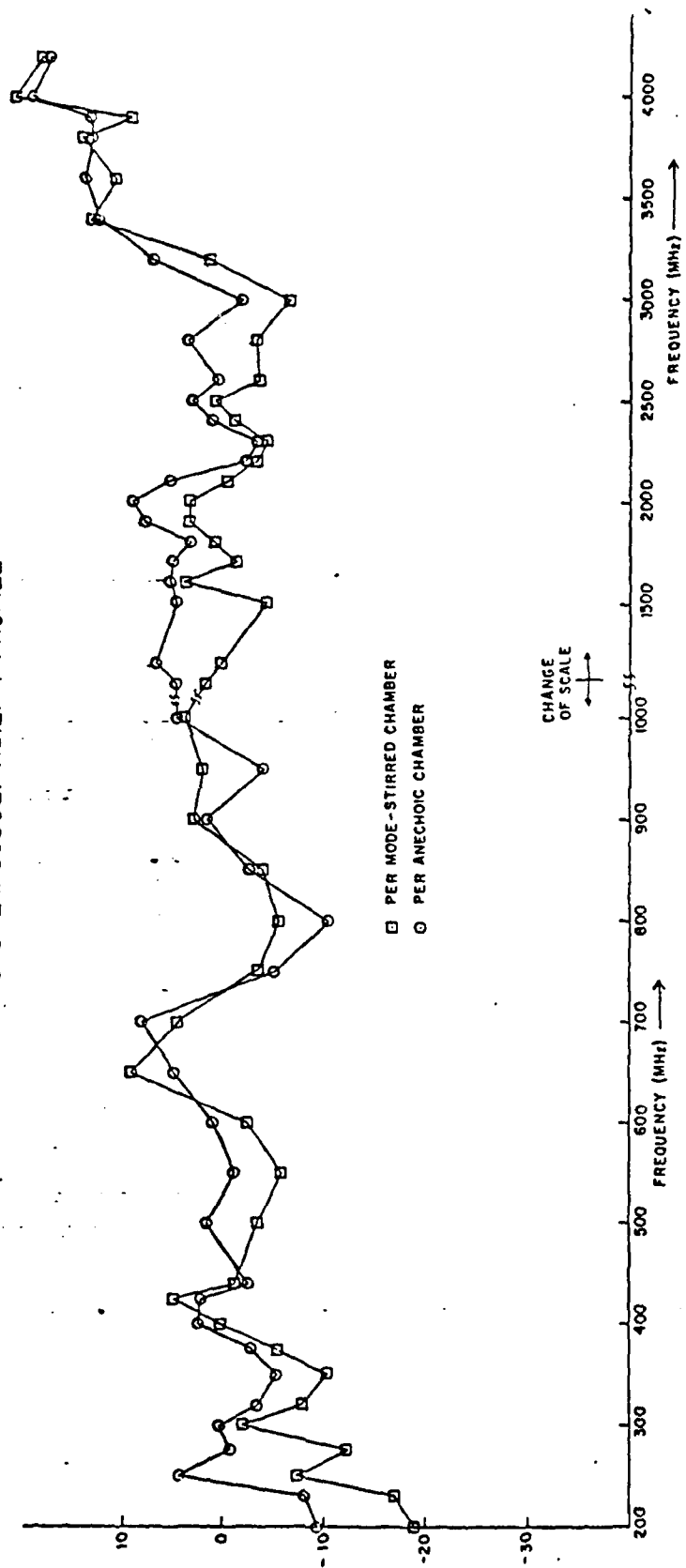
AUGUST 24, 1978

WORK PERFORMED BY GRUMMAN UNDER CONTRACT F33615-77-C-5169 SPONSORED BY
U.S.A.F. FLIGHT DYNAMICS LABORATORY





SYSTEM SUSCEPTIBILITY PROFILE



Joe Reardon
Naval Research Laboratory

NACM/TSCC Program Review
June 13-15, 1978
Paper C-11

Development of Electrically Conductive
Graphite-Fiber Reinforced Composites

Joseph P. Reardon
Code 6170, Naval Research Laboratory

The purpose of this new NAVAIR-sponsored program is to develop highly conductive graphite fiber suitable for incorporation into composites. It is expected that one or two plies of fiber of high electrical conductivity will suffice for providing greatly enhanced shielding of electronic equipment within a composite structure against electromagnetic interference (EMI) as well as improved protection against damage from lightening and accumulated electrostatic charge. NRL's first choice for this task is a highly graphitized pitch-base fiber developed by Union Carbide. The inherent high conductivity of this highly graphitized fiber can be further increased five- to tenfold by forming stable intercalation compounds. Conductivities about one-tenth that of aluminum have been achieved to date and further improvements are anticipated as new intercalants are tried. It is recognized, however, that the need for long-term chemical stability may preclude adoption of some of the electrically more favorable intercalants.

Intercalation of graphite fiber has to be done before prepregging. Consequently we elected to begin our work with woven fabric so we would be free to intercalate and prepreg the material in small lots, all in-house. Union Carbide has supplied us with the highly graphitized pitch fiber in a plain weave. The fiber has a density of 2.2 g/cc; the yarn tensile strength is about 400,000 psi and the Young's modulus is 110-120 million psi. Composites of epoxy and the intercalated fabric are visually indistinguishable from composites using the untreated fabric, and there has been no sign of escape of intercalant during cure. A series of composite plates is being fabricated that includes various proportions of the highly graphitized fabric (both untreated and with various intercalants) and T300 cloth. These plates are then being evaluated in terms of their electrical, mechanical, and chemical properties. The bulk of the EMI shielding evaluation will be carried out at NSWC-Dahlgren.

It is not our contention that better conductivity alone will solve the EMI and related problems. We do feel, however, that the hundred-fold increase in conductivity over that of current graphite/resin composites that we see as achievable will give the aeronautical engineer much more latitude in his design work.

Electromagnetic (EMI) Shielding

$$\text{Shielding effectiveness} = R + A + I$$

Absorptive Losses

$$A \propto t (f \sigma \mu)^{1/2}$$

Independent of impinging
source field

Predominate in composites

Reflective Losses

$$R \propto \log \left(\frac{\sigma}{f \mu} \right)$$

For plane waves

Predominate in metals

For electrostatic discharge
(ESD):

t = thickness

f = frequency

σ = conductivity

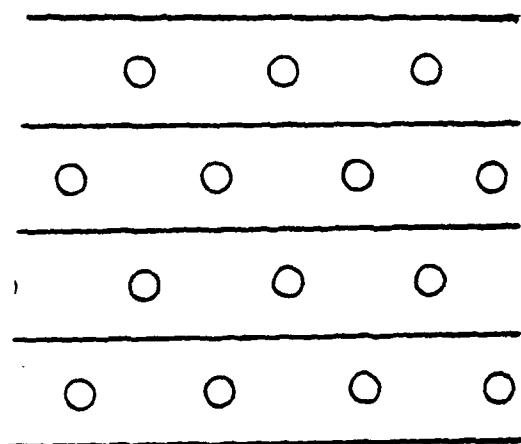
μ = permeability

$$\rho_{\text{surface}} \leq 10^9 \text{ ohm.}$$

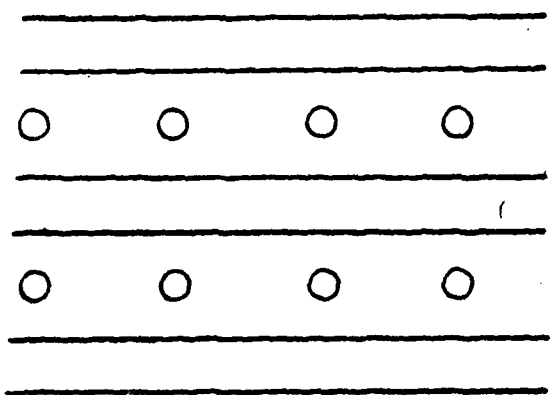
Intercalation

Graphite basal plane ———

Intercalant molecule ○



1st Stage



2nd Stage

etc.

	<u>PROPERTY</u>	<u>HGPF</u>	<u>T300</u>
	Diameter, μm	10	6-8
	Tensile str., psi	~ 400000	361000
	Modulus, psi	110-120 $\times 10^6$	32×10^6
ic	Weave	Plain	Plain
	Ends per inch	15 x 17	$12\frac{1}{2} \times 12\frac{1}{2}$
	Areal weight, oz/yd ²	12.2	5.77
	g/cm ²	0.041	0.019
	Ply thickness in composite, mils	24.3	8.2

HGPF = Highly graphitized pitch fiber

T300 = Thornel 300 cloth, woven by
HEXCEL.

(NRL)

<u>Material</u>	<u>Volume Conductivity, as $10^4 (\Omega \text{ cm})^{-1}$</u>
Copper	60
Aluminum	38
Aluminum alloys	16-33
Stainless steel 304	1.7
U.C. TP4101 (SbF_5)	4.6 (predicted)
" " (ICA)	3.2
" " (as rec'd)	0.58
Celanese GV70	0.10
Hercules AS	0.03

(NRL)

Epoxy Resin System — for fabrication
of composites with
conductive graphite fiber.

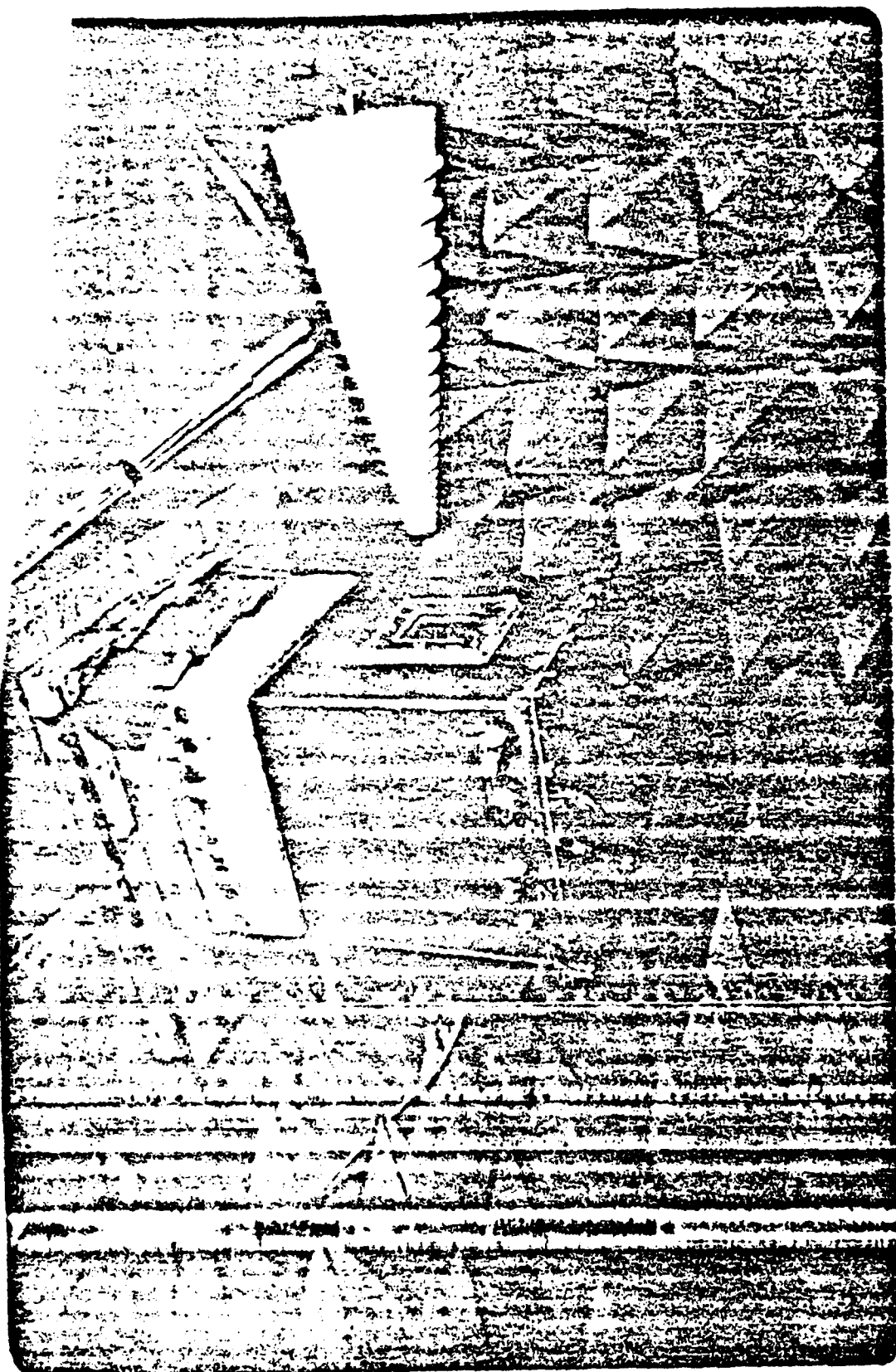
Shell's EPON 828 } Epoxide/Anhydride
HHPA } = 1.0/0.45

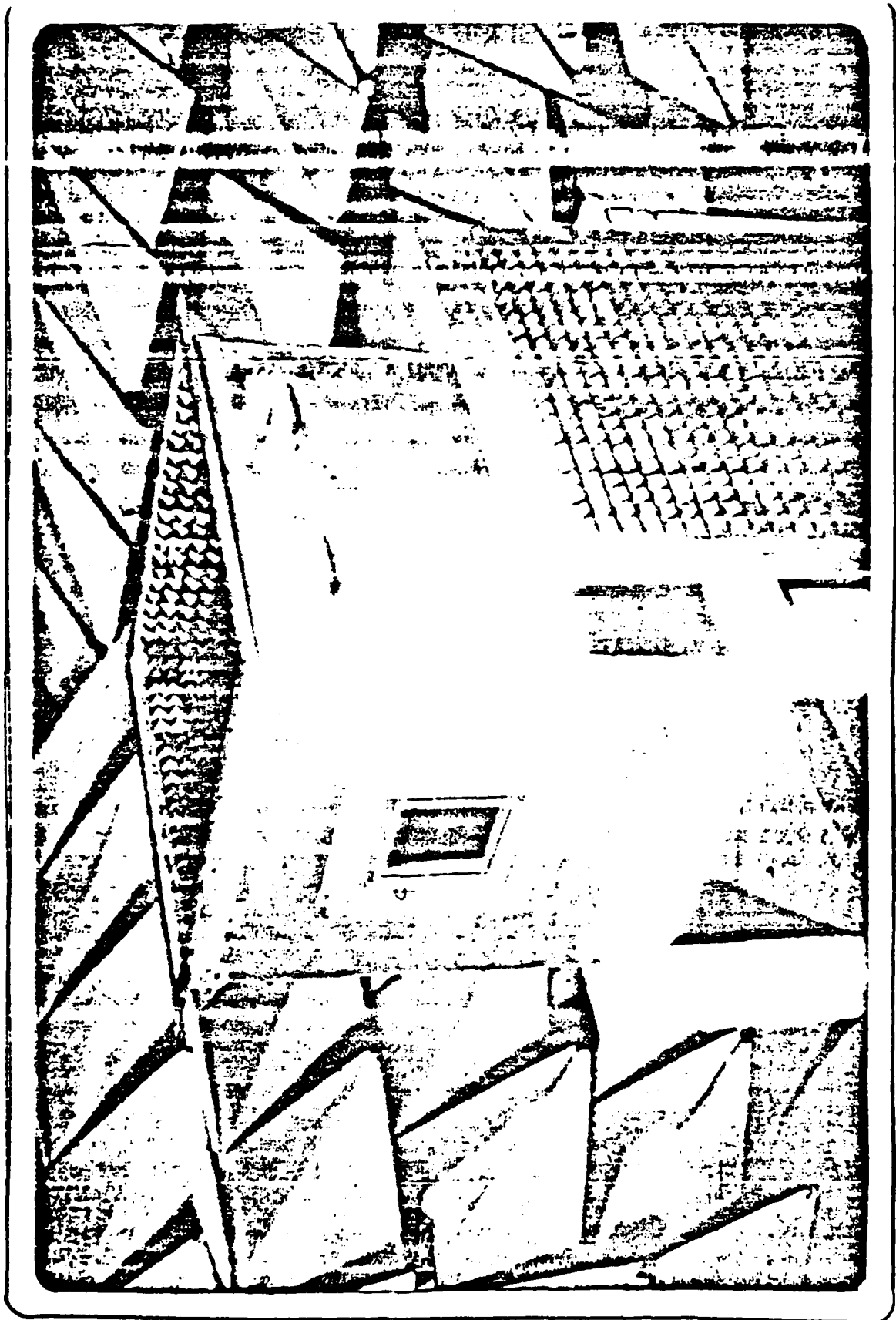
+ 0.2% by wt. dimethylbenzylamine
as catalyst

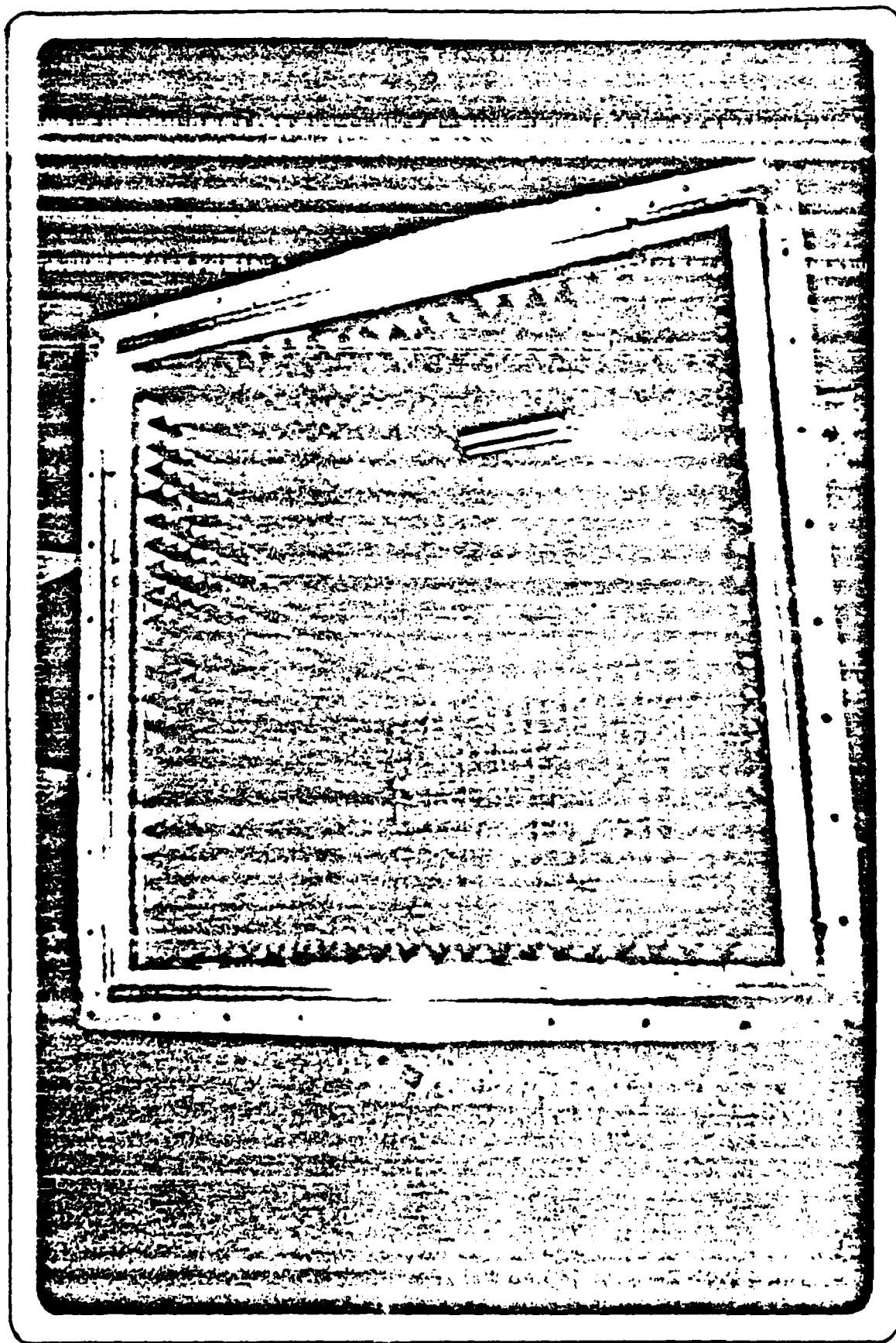
Cure: Up to 150°C (302°F)
at 100 psi.

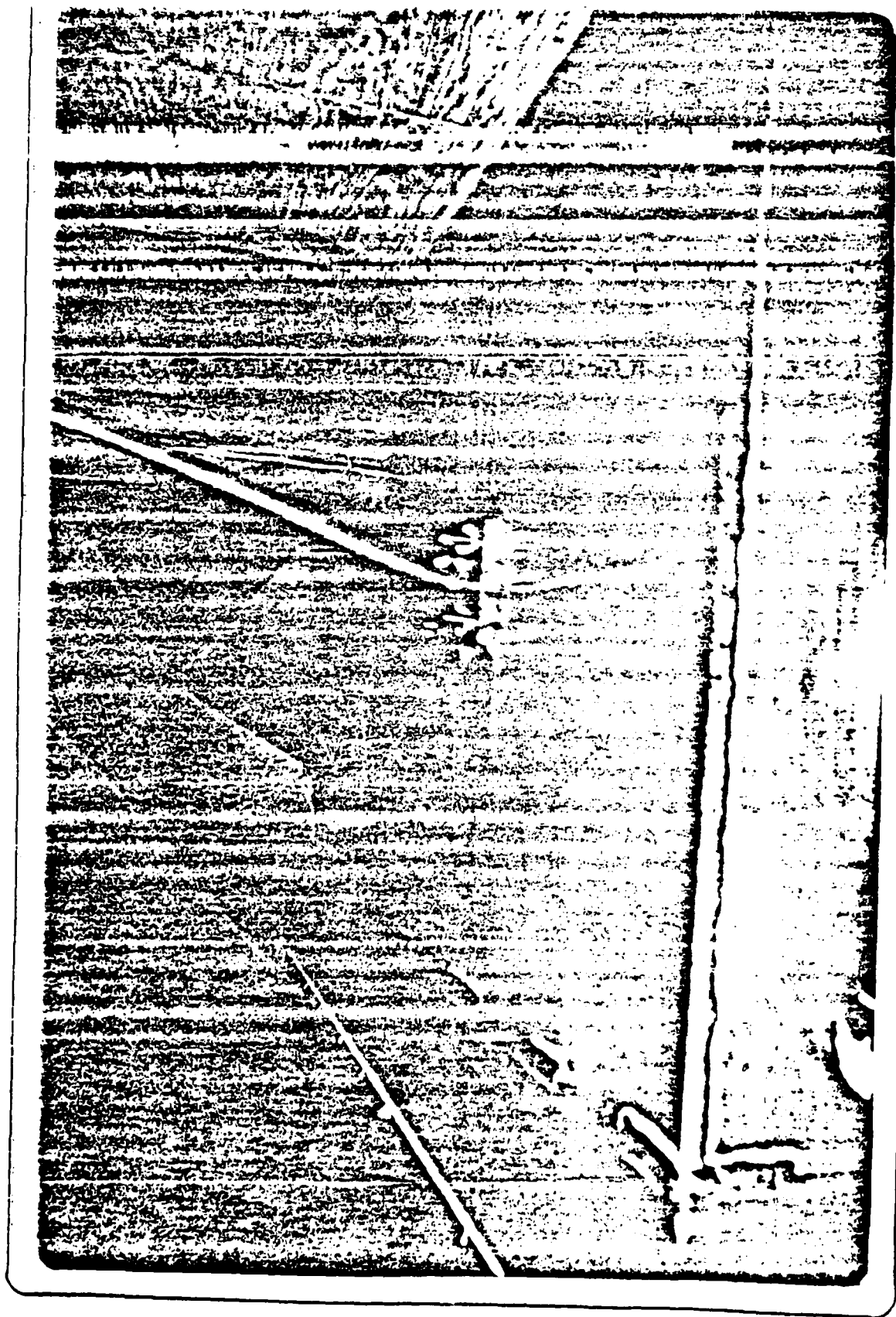
NRL

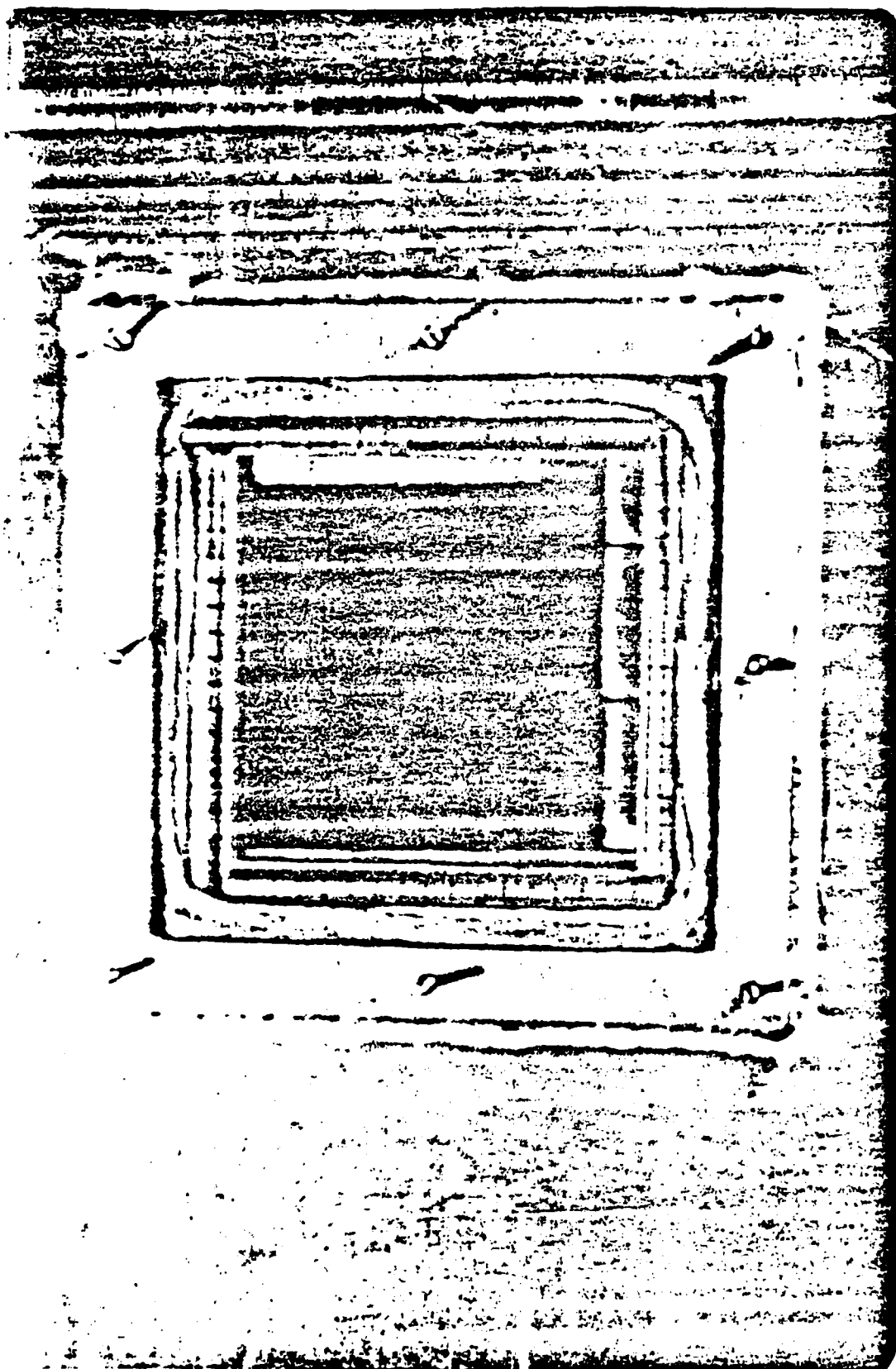
Ernest Donaldson
Georgia Institute of Technology

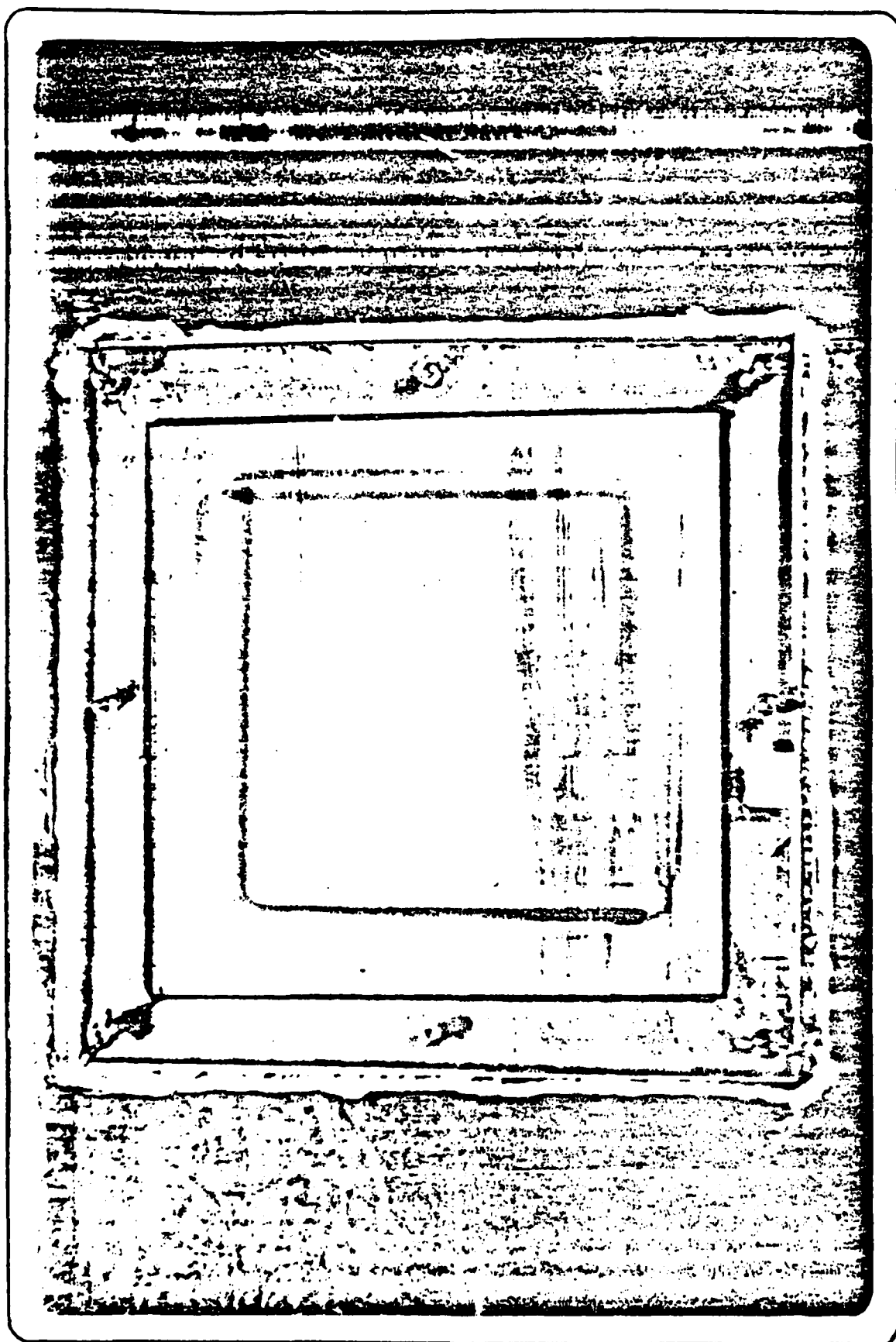


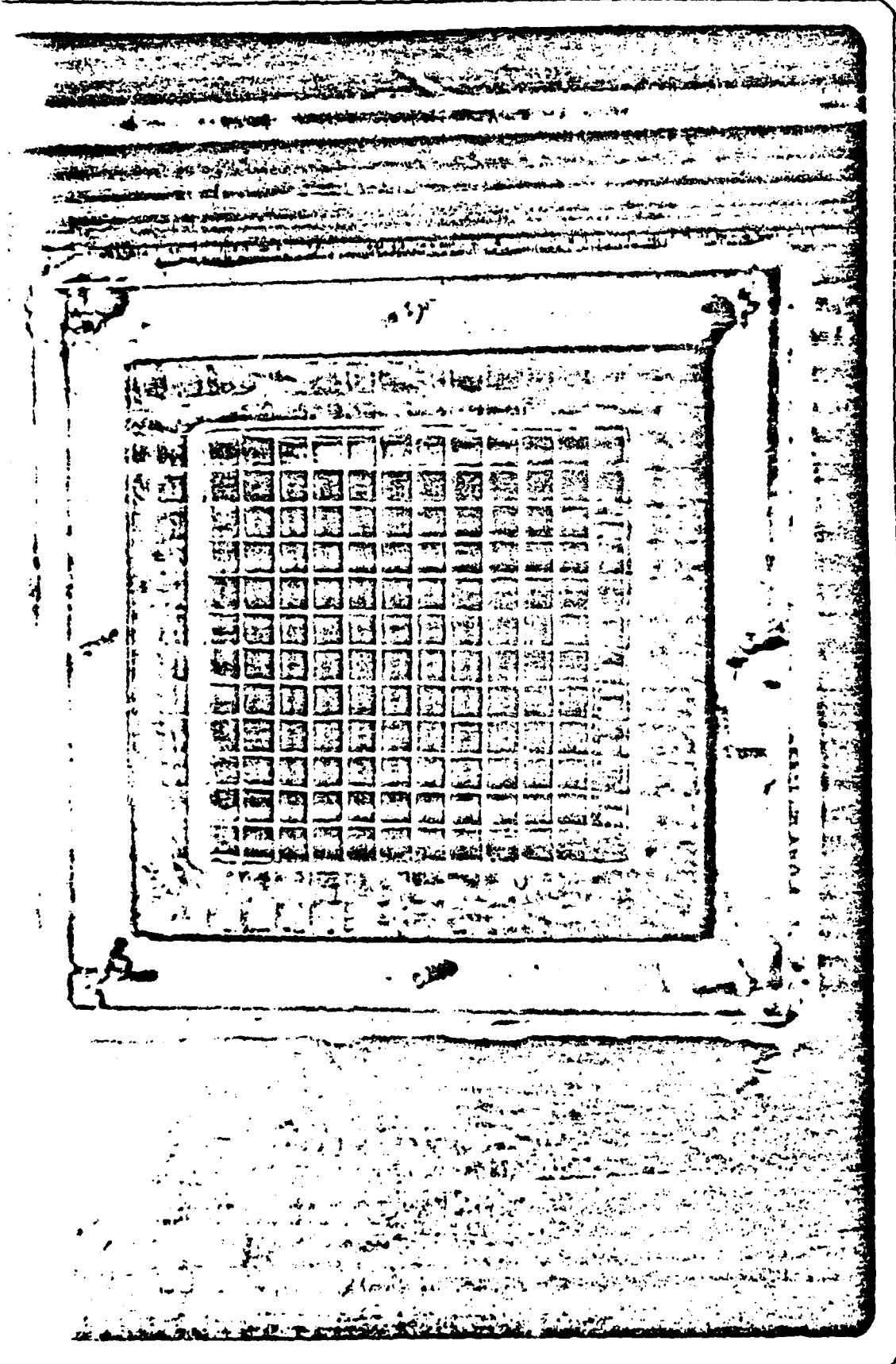


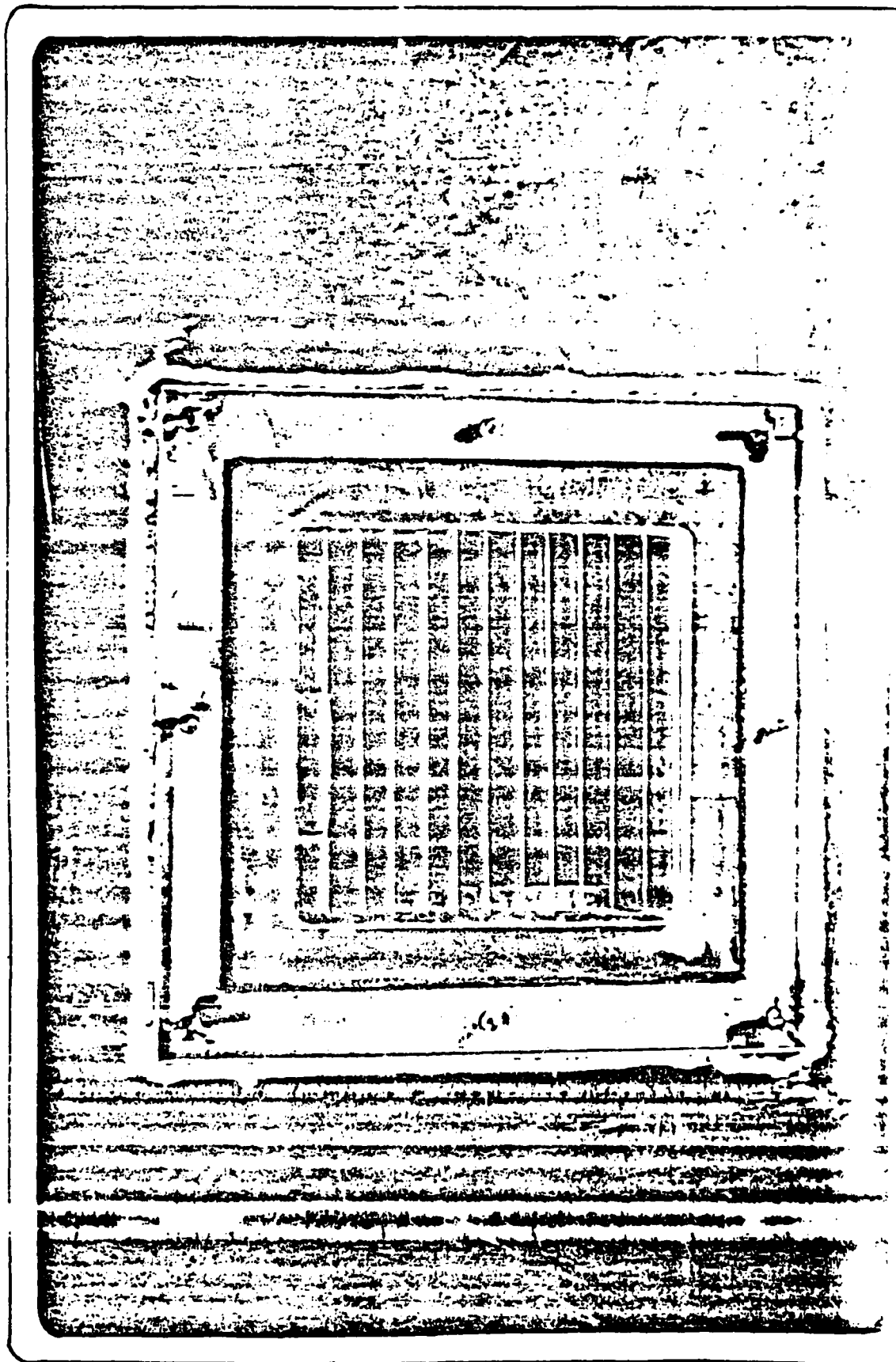


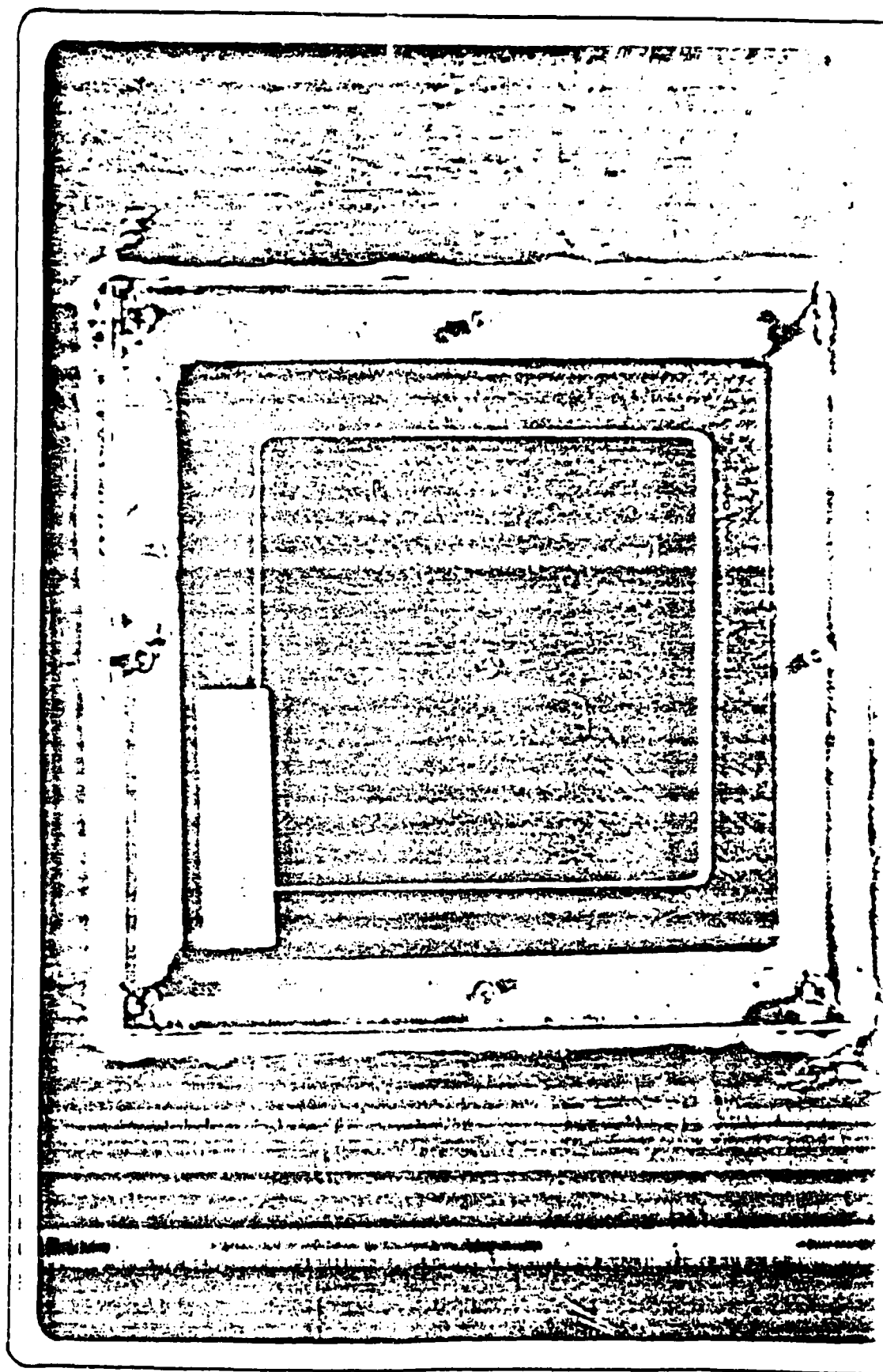


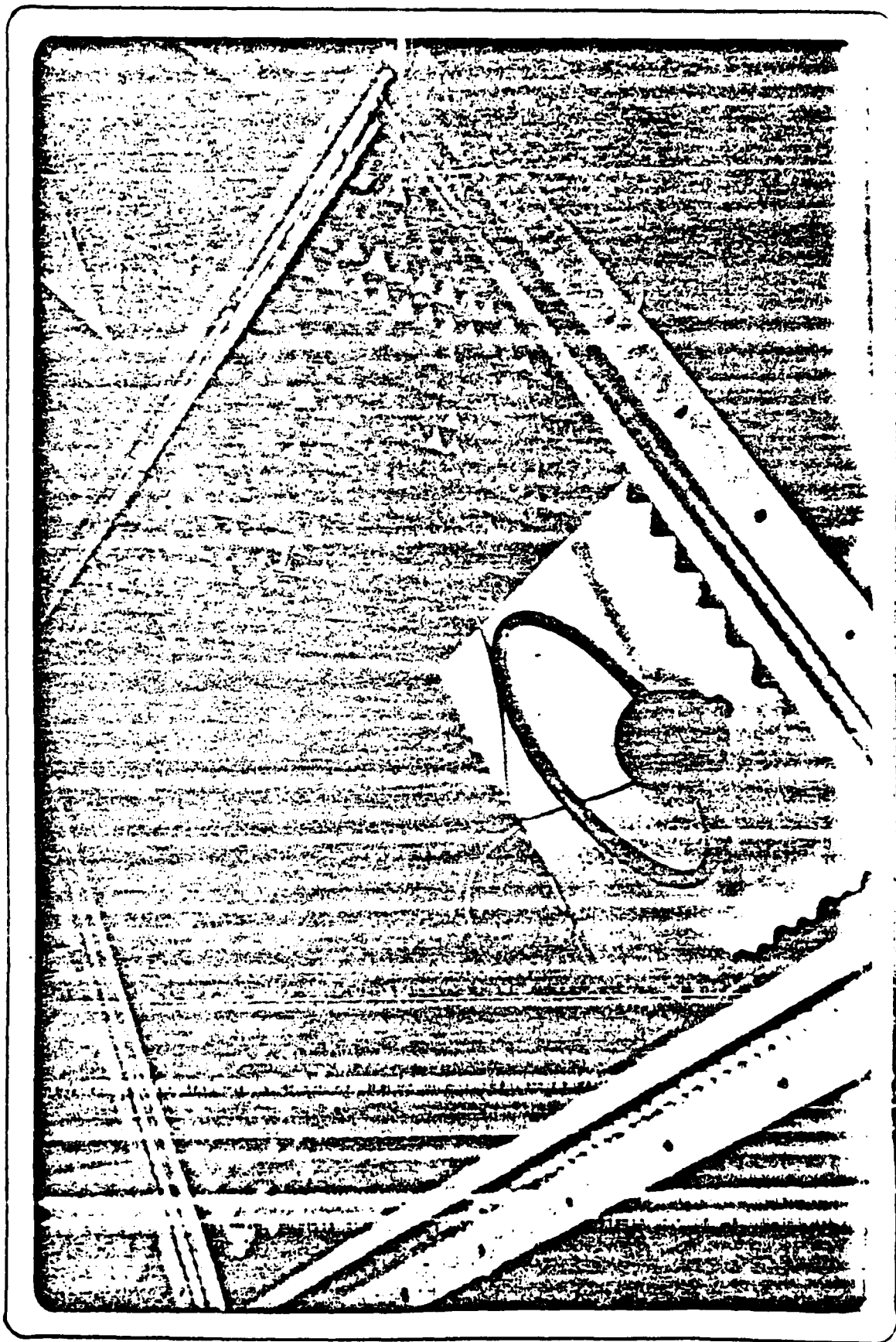


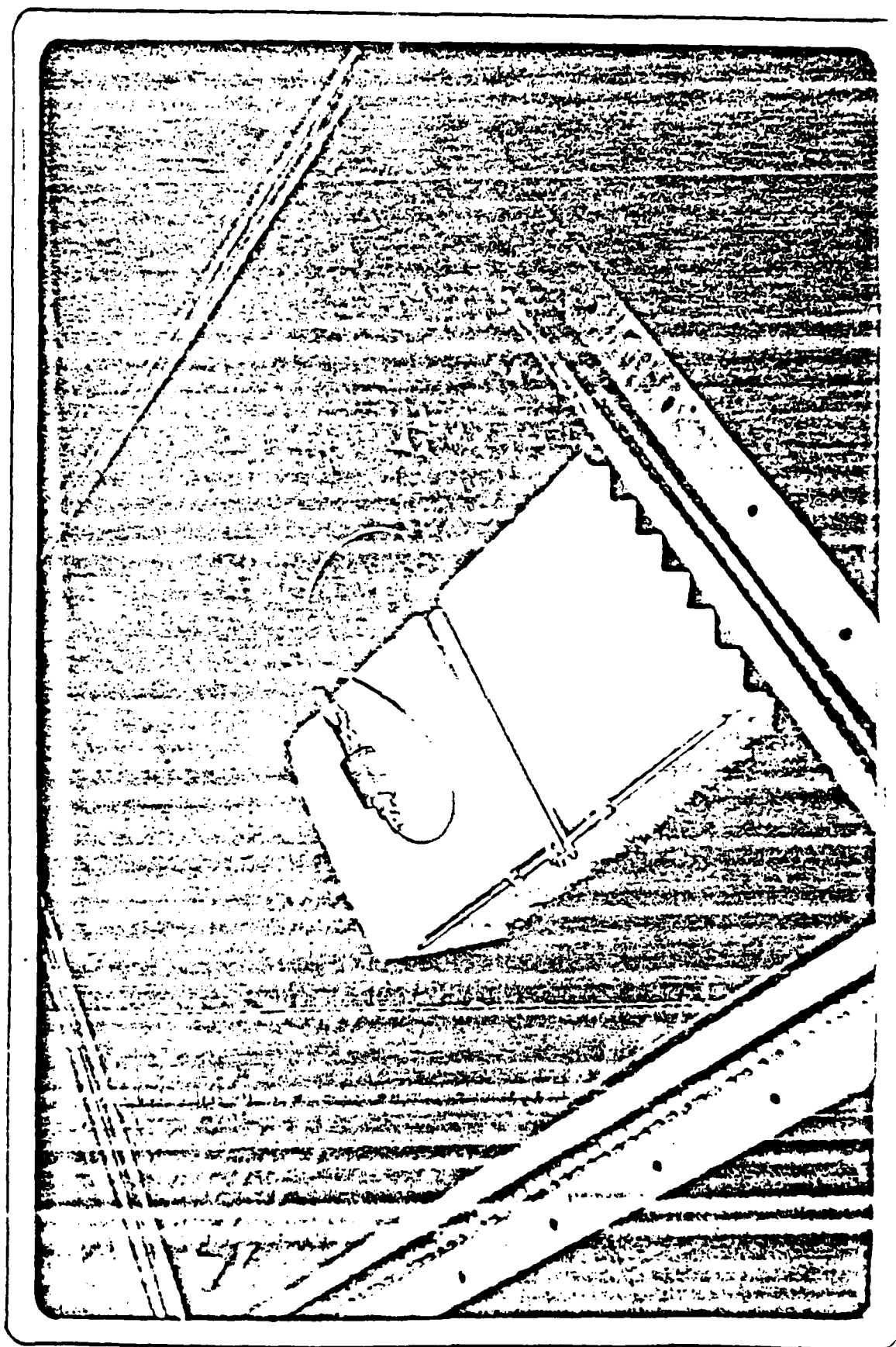


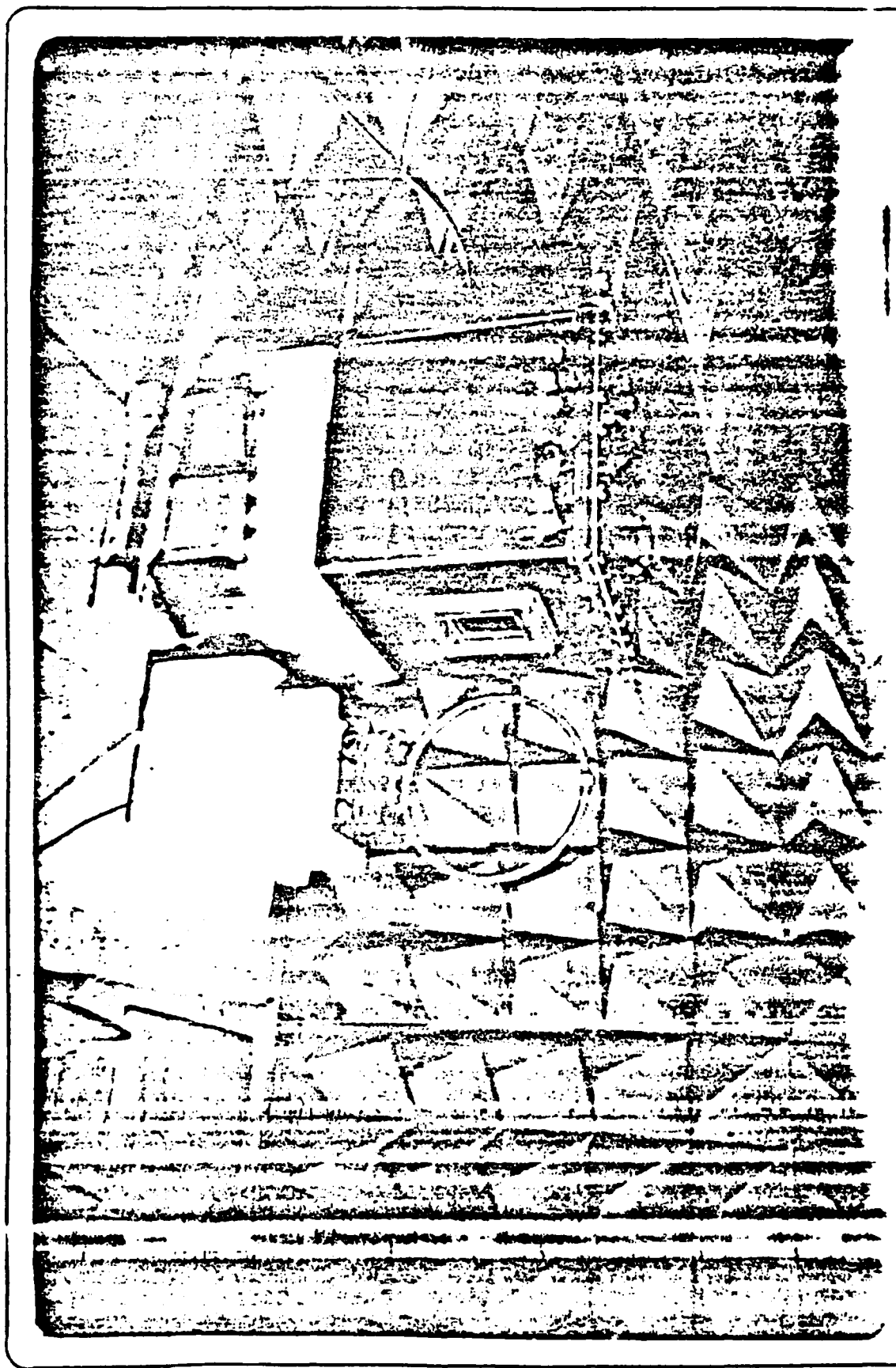


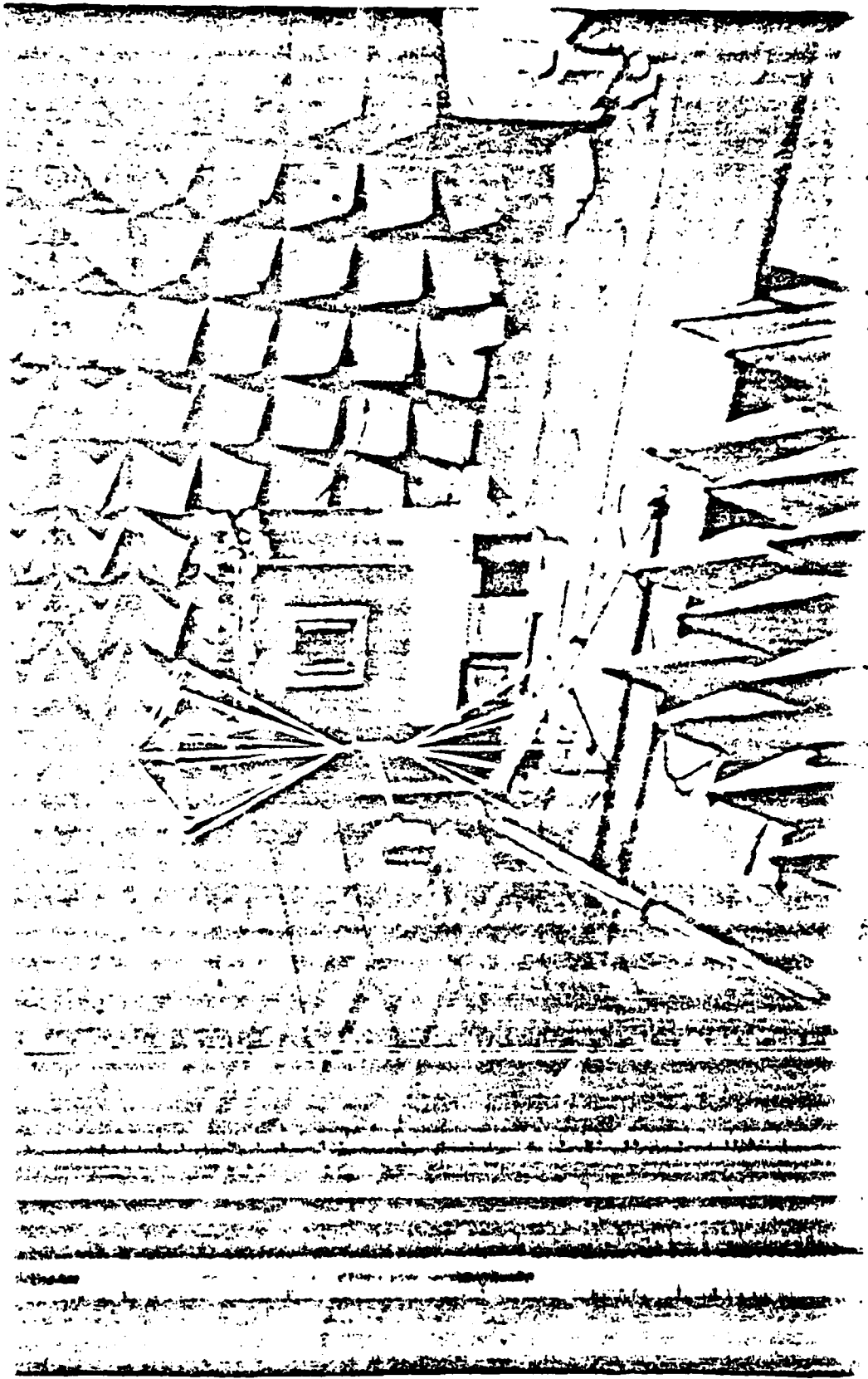












Dr. Roy Stratton

Rome Air Development Center

View Graphs Were not Available

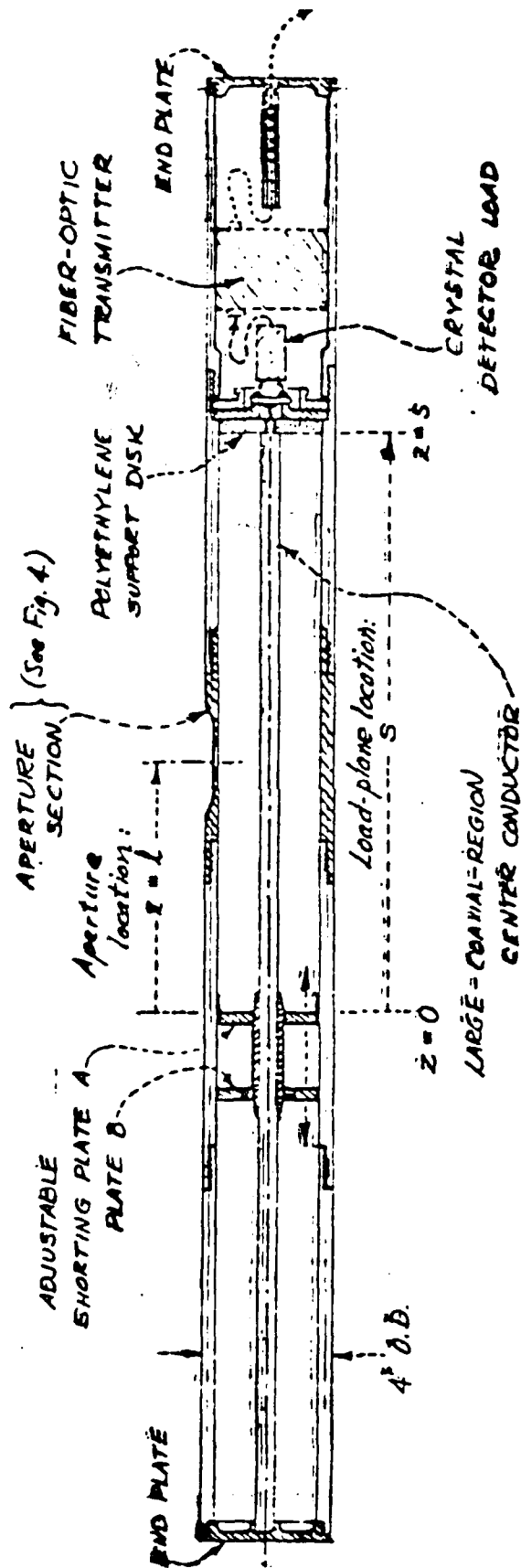


Figure 3. Sectional View of First Experimental Model

U. S.

Dr. S. S. Tompkins

NASA Langley Research Center

Alternate Composite Materials
to Minimize the Possible Carbon
Fiber Electrical Hazard

ALTERNATE COMPOSITE MATERIALS TO MINIMIZE

THE POSSIBLE CARBON FIBER ELECTRICAL HAZARD

DR. S. S. TOMPKINS
MATERIALS DIVISION
NASA LANGLEY RESEARCH CENTER
HAMPTON, VA 23665

ALTERNATE COMPOSITE MATERIALS

OBJECTIVE:

PROVIDE FIBERS, RESINS AND HYBRID COMPOSITES WHICH REDUCE THE ELECTRICAL HAZARD IDENTIFIED FOR CARBON FIBERS WHILE RETAINING OR IMPROVING THE STRUCTURAL PROPERTIES OF POLYMERIC RESIN MATRIX COMPOSITES FOR AEROSPACE APPLICATIONS.

ALTERNATE COMPOSITE MATERIALS

APPROACH

- FIBER MODIFICATIONS AND COATINGS
 - INTERCALATION OF GRAPHITE FIBERS
 - GLASS, CARBIDE, ORGANIC COATINGS
- IMPROVED MATRIX MATERIALS
 - IMPROVED CHAR FORMING
 - FIRE-RESISTANT, FLAME RETARDANT
- ALTER DISSEMINATION CHARACTERISTICS
 - INCREASE "CLUMPING" - HYBRIDS, WEAVES
 - INCREASE FALL VELOCITY - DIAMETER
- COMBUSTIBLE FIBERS
- NEW FIBERS
 - ORGANIC
 - BORON NITRIDE

ALTERNATE COMPOSITE MATERIALS

APPROACH	NASA CENTER
- FIBER MODIFICATIONS AND COATINGS - INTERCALATION OF GRAPHITE FIBERS - GLASS, CARBIDE, ORGANIC COATINGS - IMPROVED MATRIX MATERIALS - IMPROVED CHAR FORMING - FIBER-RESISTANT, FLAME RETARDANT - ALTER DISSEMINATION CHARACTERISTICS - INCREASE "CLUMPING" - HYBRIDS, WEAVES - INCREASE FALL VELOCITY - DIAMETER - COMBUSTIBLE FIBERS - NEW FIBERS - ORGANIC - BORON NITRIDE	LANGLEY LEWIS AMES LANGLEY LEWIS LANGLEY LANGLEY LEWIS LANGLEY

LARC PROGRAM OVERVIEW

- I. FIBER COATINGS
 - A. INORGANIC
 - B. ORGANIC
 - C. COATING TECHNIQUES
- II. GRAPHITE FIBER
 - A. NEW FABRICATION PROCESSES
 - B. MODIFY EXISTING FIBER
- III. NONGRAPHITE FIBERS
- IV. HYBRIDS
 - A. LAMINATES
 - B. MATRICES
- V. ALTERNATE MATRIX COMPOSITES

FIBER MODIFICATIONS

RPI

APPROACHES

- o ALTER CRYSTALLINE STRUCTURE THROUGH PROCESSING
- o EXPLORE C-B-N SYSTEM
- o INVESTIGATE BN COATING

STATUS

- o APPARATUS TO MEASURE CONDUCTIVITY AND STRENGTH BEING CONSTRUCTED
- o PRELIMINARY RESULTS SHOW PITCH FIBERS HAVING $R = 10^7 - 10^8 \text{ OHM/CM}$

HIGH RESISTIVITY INTERCALATED GRAPHITE FIBERS

OBJECTIVE: DETERMINE THE FEASIBILITY OF SIGNIFICANTLY INCREASING THE ELECTRICAL RESISTIVITY OF GRAPHITE FIBERS WITHOUT DEGRADING MECHANICAL PROPERTIES

APPROACH: TREAT FIBERS WITH STRONG ACIDS TO INTERCALATE WITH OXYGEN, FLUORINE, NITROGEN, SULFUR, OR OTHERS

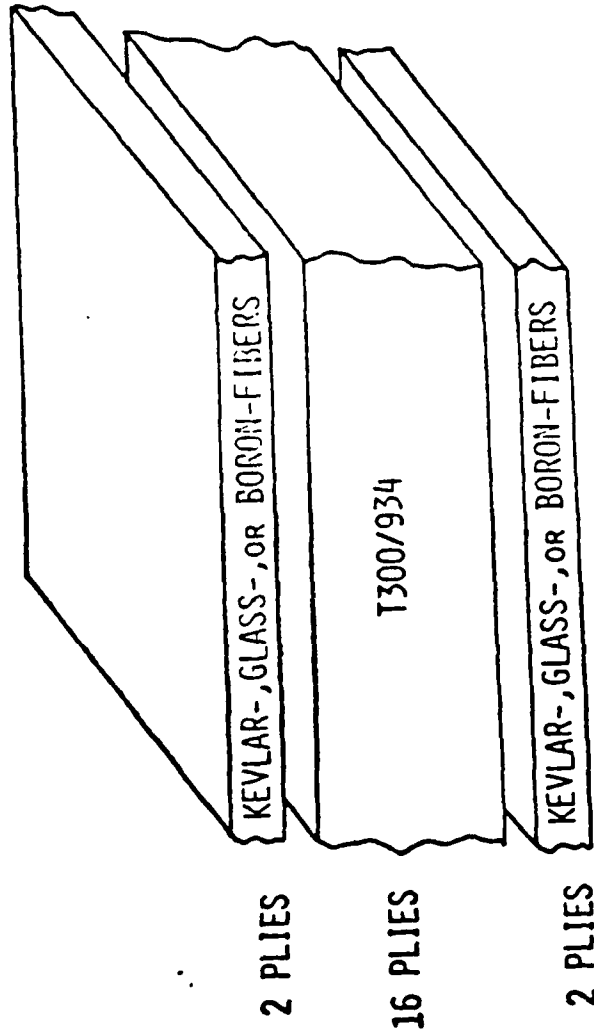
STATUS

- o WORK IS UNDERWAY AT THE UNIVERSITY OF PA AND FT. BELVOIR
- o PRESENT EMPHASIS IS ON GRAPHITE-OXYGEN SYSTEM
- o RESISTIVITY OF GY-70 AND TYPE P FIBERS HAS BEEN INCREASED BY 9000 X
- o MECHANICAL PROPERTY TESTS ARE BEING SET UP
- o SAMPLES ARE BEING PREPARED FOR CHEMICAL ANALYSIS

NEAR TERM ACTIVITIES:

- o EXPERIMENTS WITH T-300, AS, AND CELION FIBERS
- o THERMAL STABILITY TESTS

7.6 x 7.6 cm x 20 PLIES, 934 EPOXY RESIN FABRICATED IN



SUMMARY OF STATUS

- OBTAINED A FACTOR OF 10^6 INCREASE IN RESISTANCE OF FIBER WITH SiO_2 COATING
- FIBER RESISTIVITY INCREASED BY 9000X THROUGH INTERCALATION WITH OXYGEN
- HYBRIDS OF GLASS AND BORON FILAMENTS SIGNIFICANTLY REDUCE AMOUNT OF GRAPHITE FIBERS RELEASED ON IMPACT OF BURNED SPECIMENS
- PRELIMINARY RESULTS SHOW PITCH FIBERS HAVING $R = 10^7 - 10^8 \text{ OHM/CM}$

REFERENCES

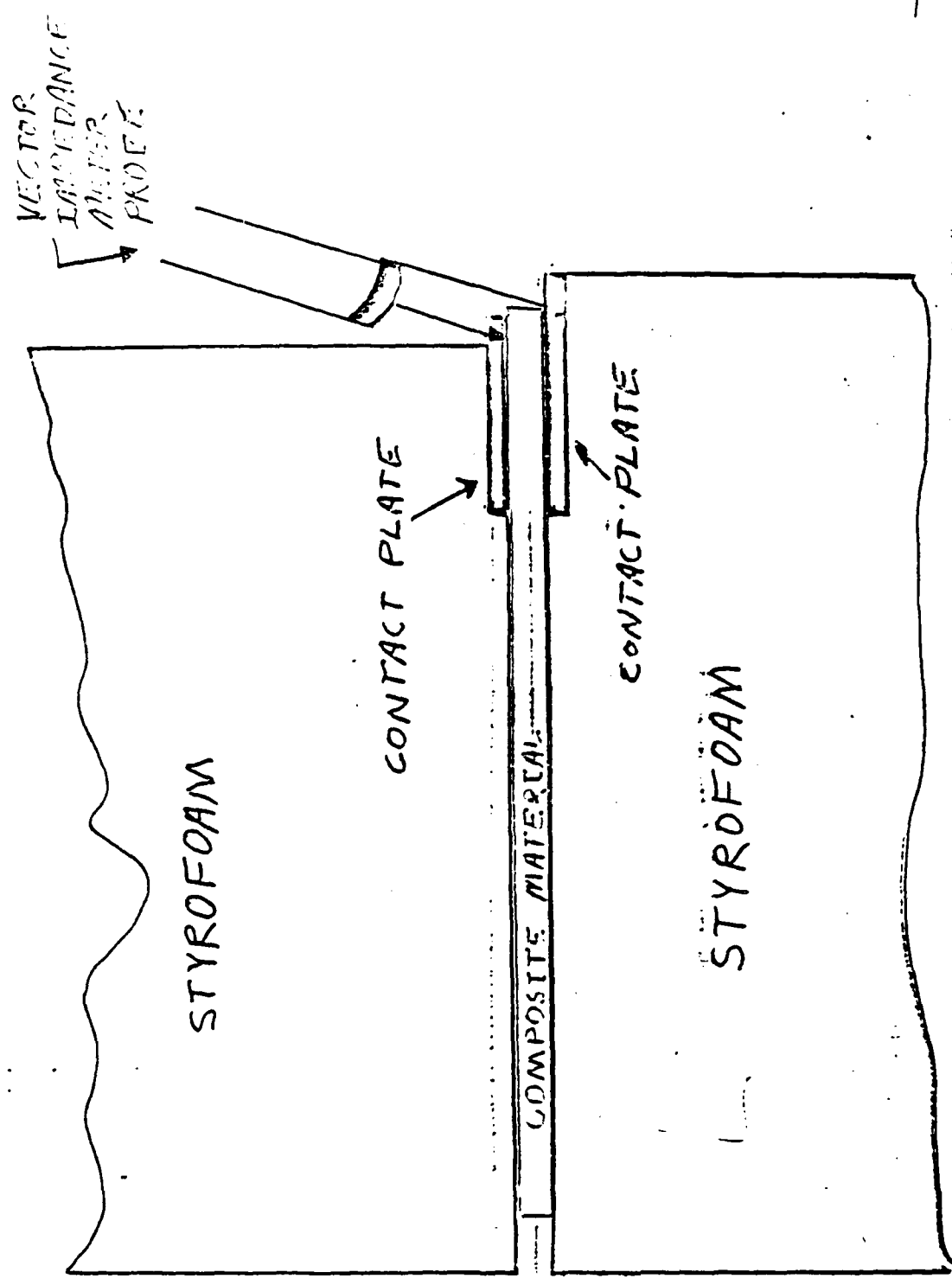
1. "A REPORT OF OBSERVED EFFECTS ON ELECTRICAL SYSTEMS OF AIRBORNE CARBON/GRAPHITE FIBERS." NASA TM 78652, JAN 1978.
2. "CARBON FIBER STUDY" COMPILED BY INTERGOVERNMENTAL COMMITTEE NASA TM 78718, MAY 1978.
3. "MODIFIED COMPOSITE MATERIALS WORKSHOP" COMPILED BY DENNIS L. DICUS, NASA TM 78761, JULY 1978.
4. "PRELIMINARY BURN AND IMPACT TESTS OF HYBRID POLYMERIC COMPOSITES" BY S.S. TOMPKINS AND W.D. BREWER, NASA TM 78762, JULY 1978.

D. Swink
NSWC/Dahlgren

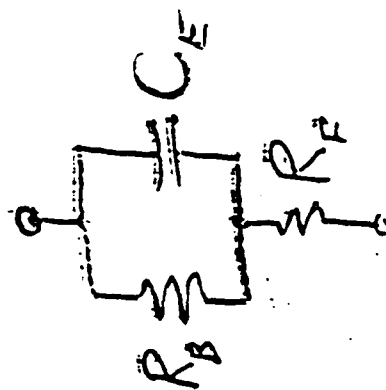
MEASUREMENT TECHNIQUES

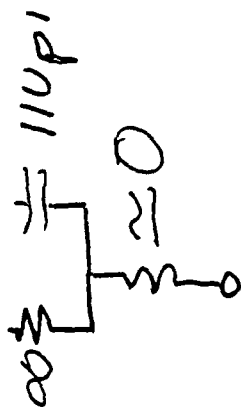
TYPE	YIELDS
MODE-STIRRED CHAMBER	SHIELDING EFFECTIVENESS
CONTACT IMPEDANCE	MATERIAL / JOINT MODEL

CONTACT IMPEDANCE MEASUREMENT



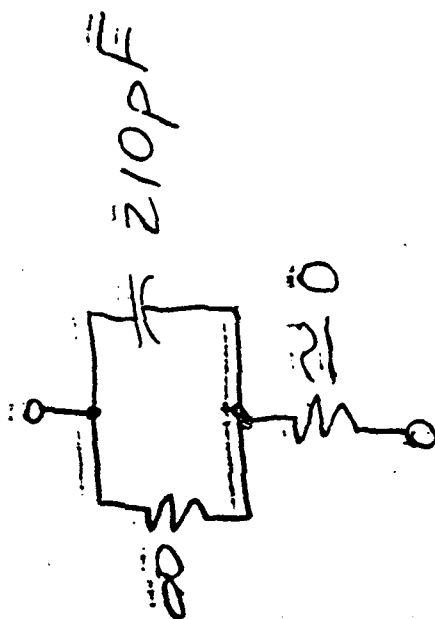
LOW FREQUENCY MODEL





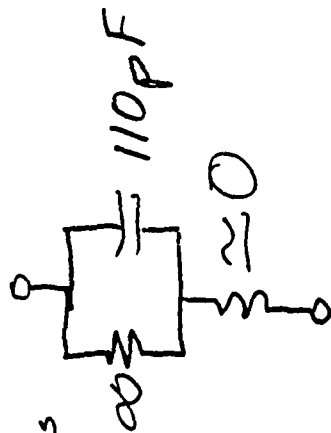
(assuming)

1.4" contact plates



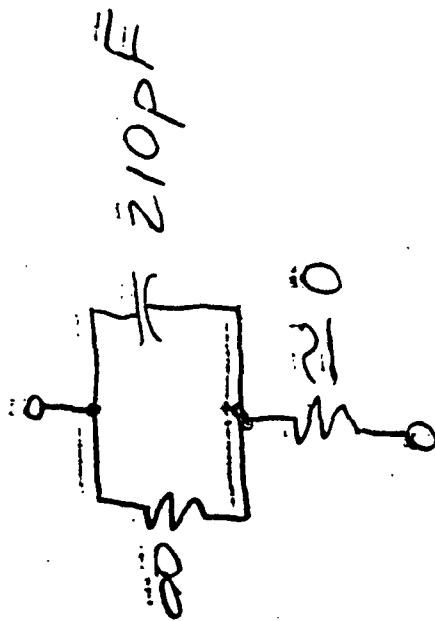
T-300, 1/4" Thick

1" contact plates



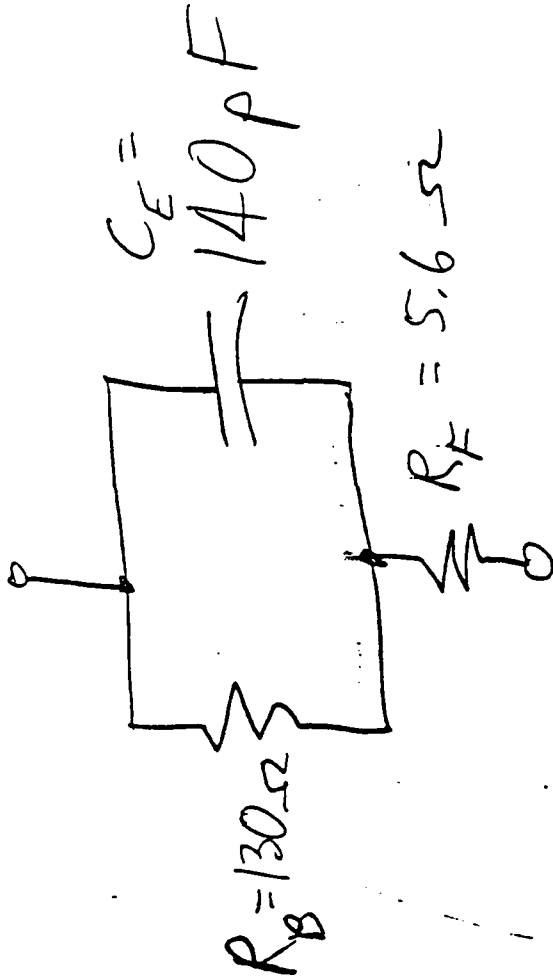
$t \approx 6\text{ mils}$
(assuming $\epsilon_r \approx 3$)

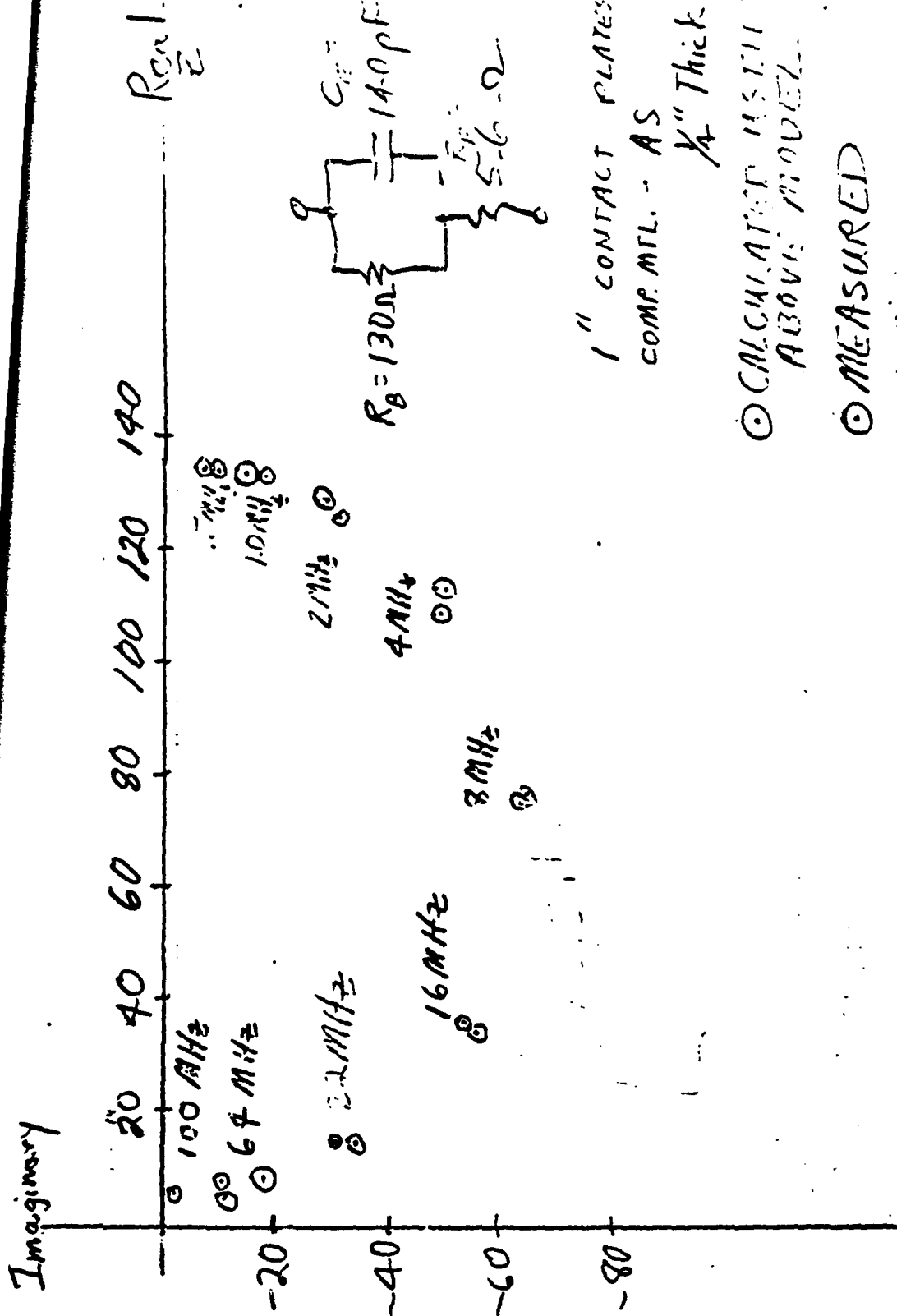
1.4" contact plates

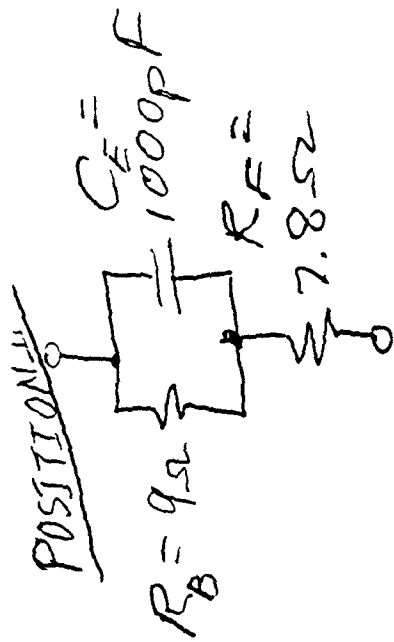
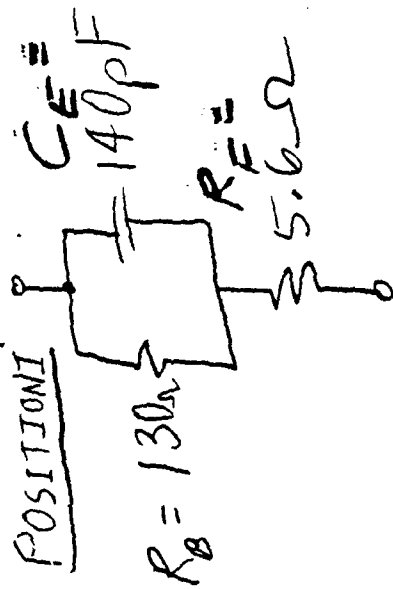


AS $\frac{1}{4}$ " Thick

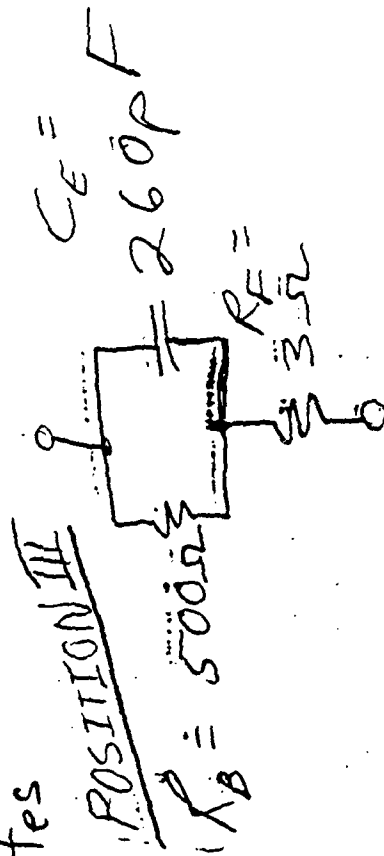
1" contact
plates







1.4" Plates



Rom Prehoda
NSWC/Dahlgren

PURPOSE

Develop Information, Methods or Techniques
that can be used by.

1. ELECTRONIC SYSTEMS DESIGNERS

2. EVALUATION ENGINEERS

REPORT OF INVESTIGATION

ANALYTICAL

ANALYTICAL & EXPERIMENTAL METHODS TO:

DEVELOP EFFECTIVE TEST TECHNIQUES

DEVELOP ANALYTICAL PREDICTION TECHNIQUES

DETERMINE THE VALIDITY BY COMPARING RESULTS

OF ACOUSTIC CHAMBER MEASUREMENTS

ACCEPTABILITY CRITERIA

PROVIDE VALID INFORMATION

PROVIDE TIMELY IMPACT

GENERATE USER CONFIDENCE

APPLY TO 100 KHZ - 12 GHZ FREQUENCY RANGE

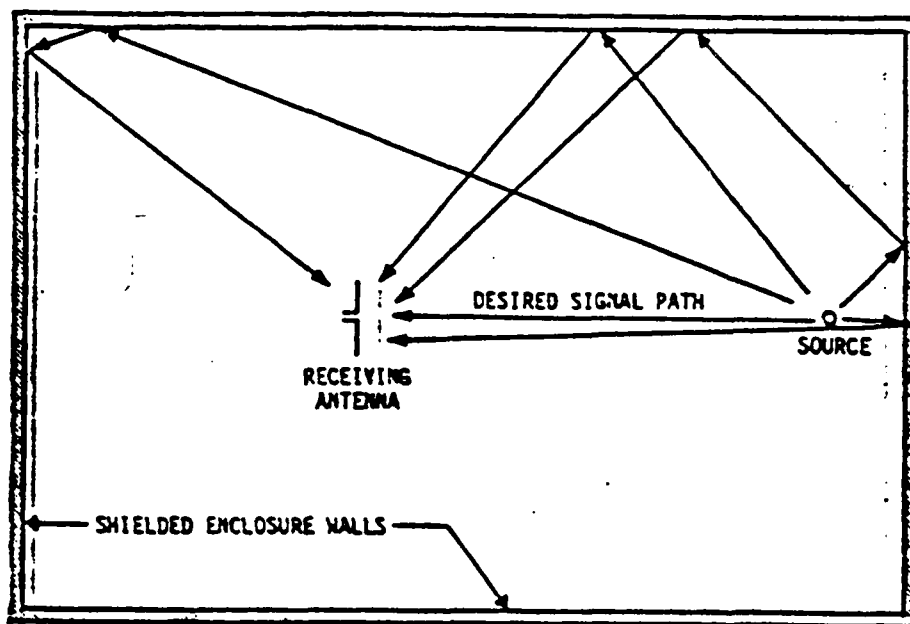


FIGURE 1: Multiple Signal Paths in Shielded Enclosure

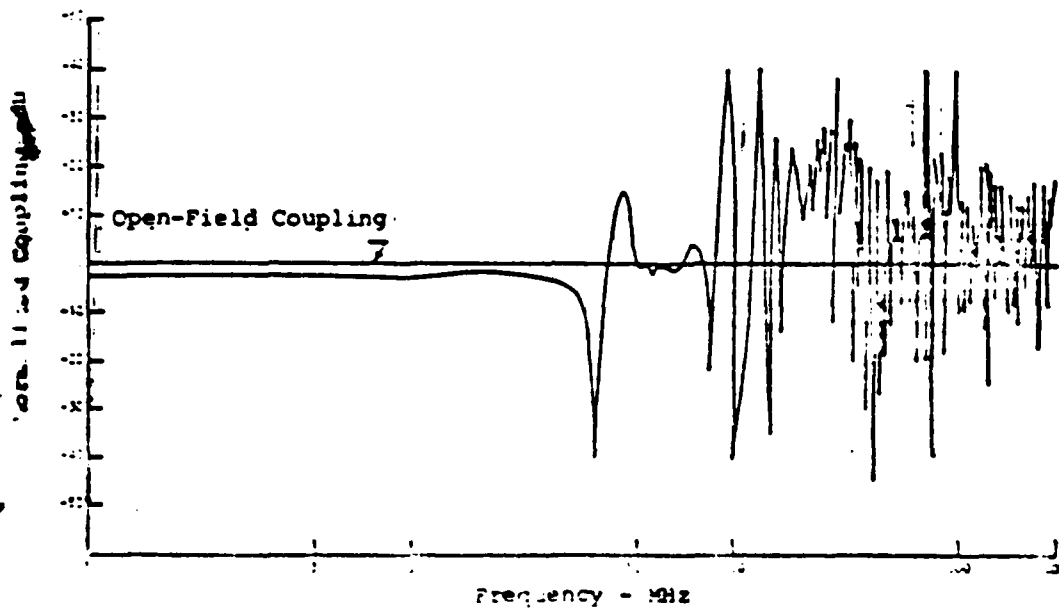
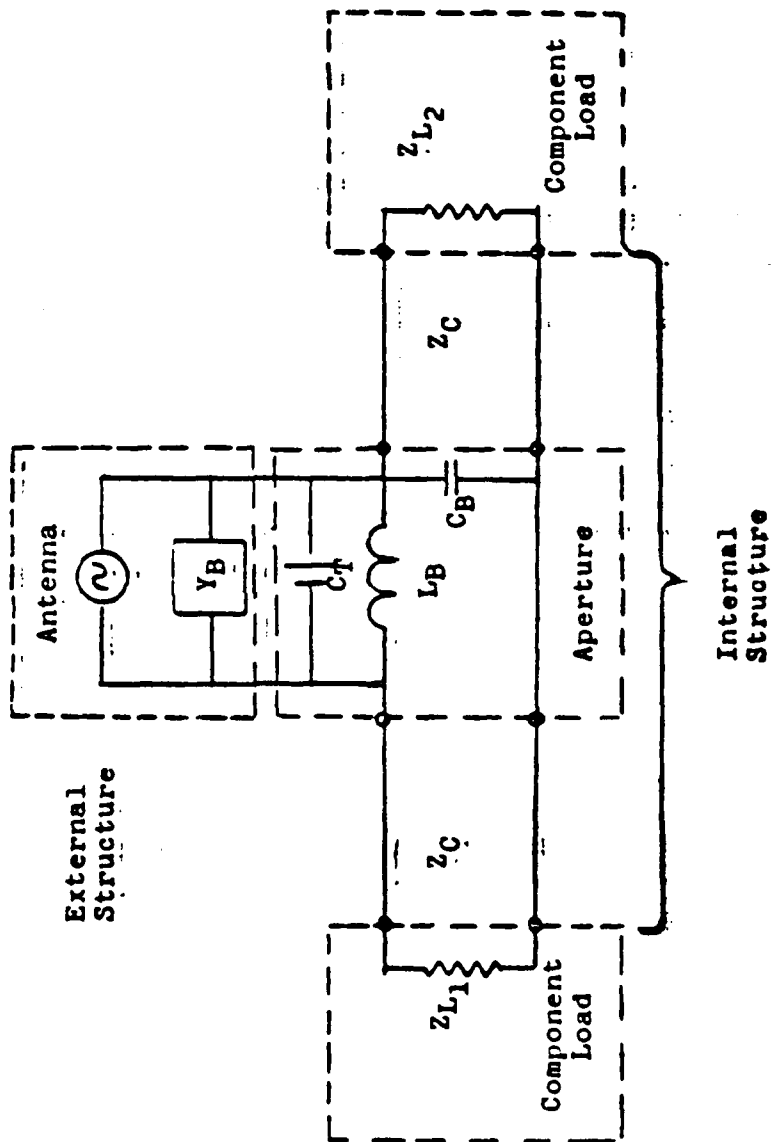
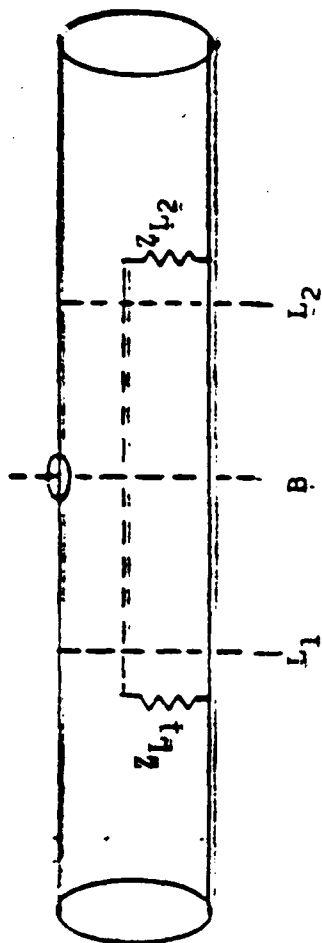
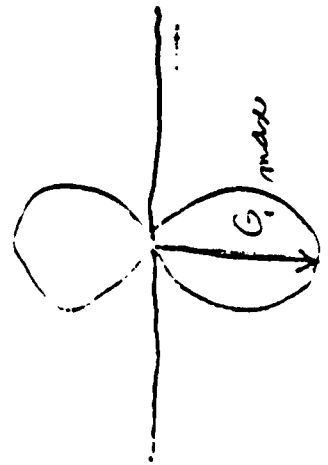
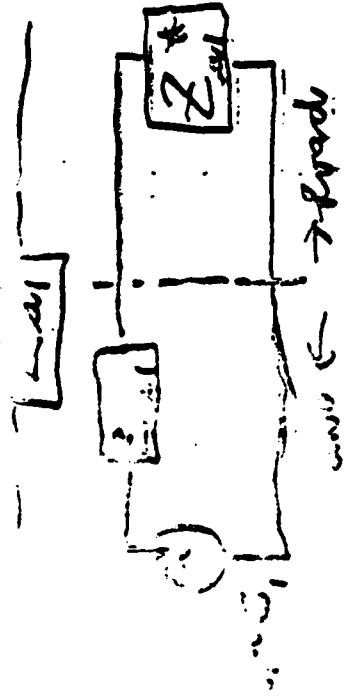
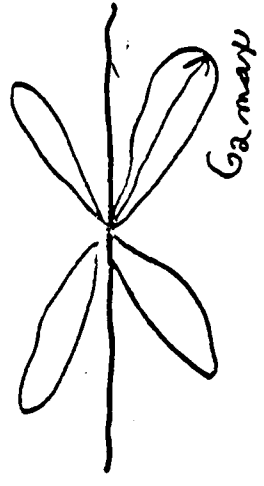
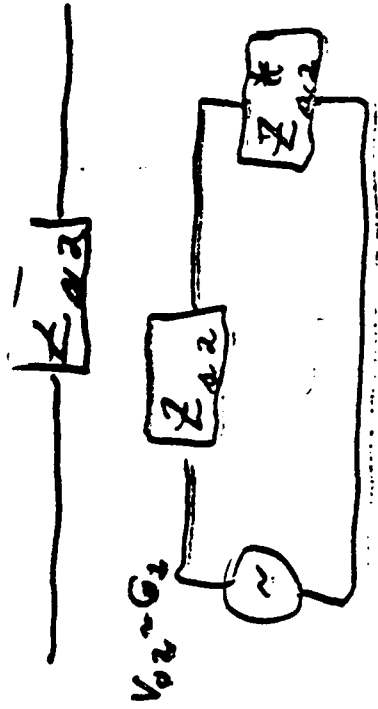
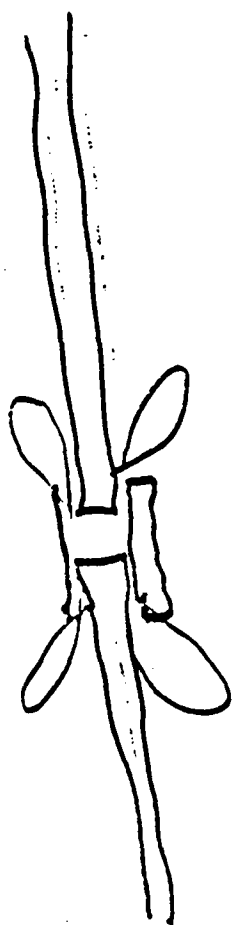
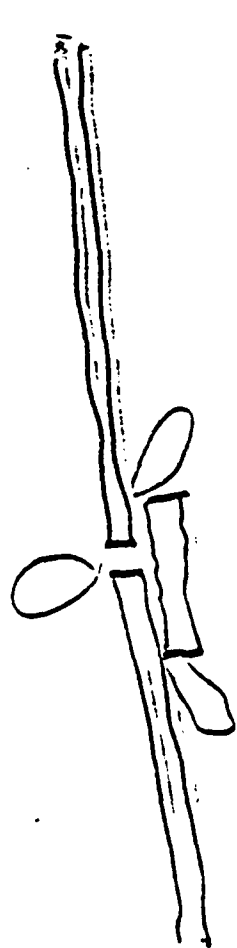


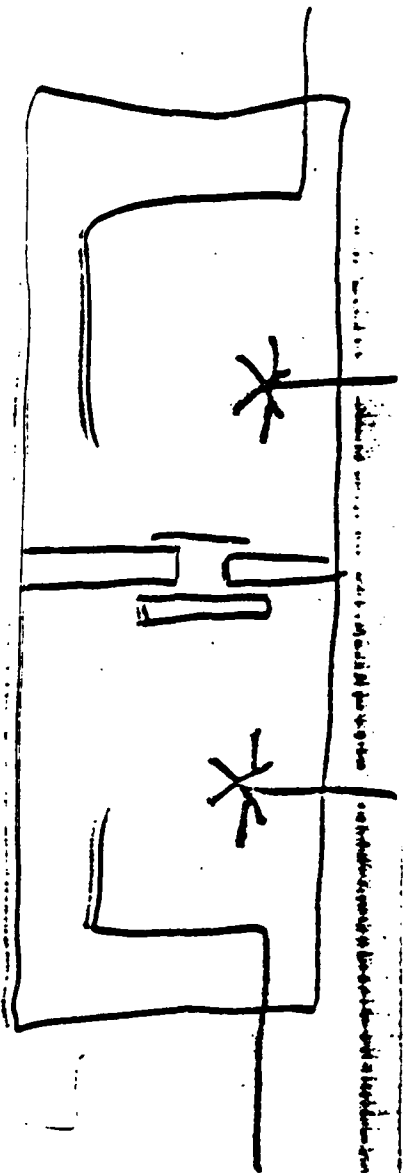
FIGURE 2: Coupling Between Antennas in Shielded Enclosure



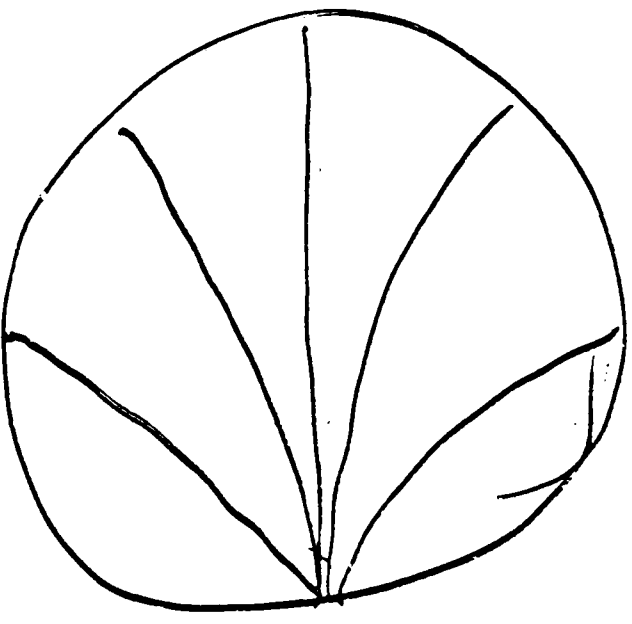


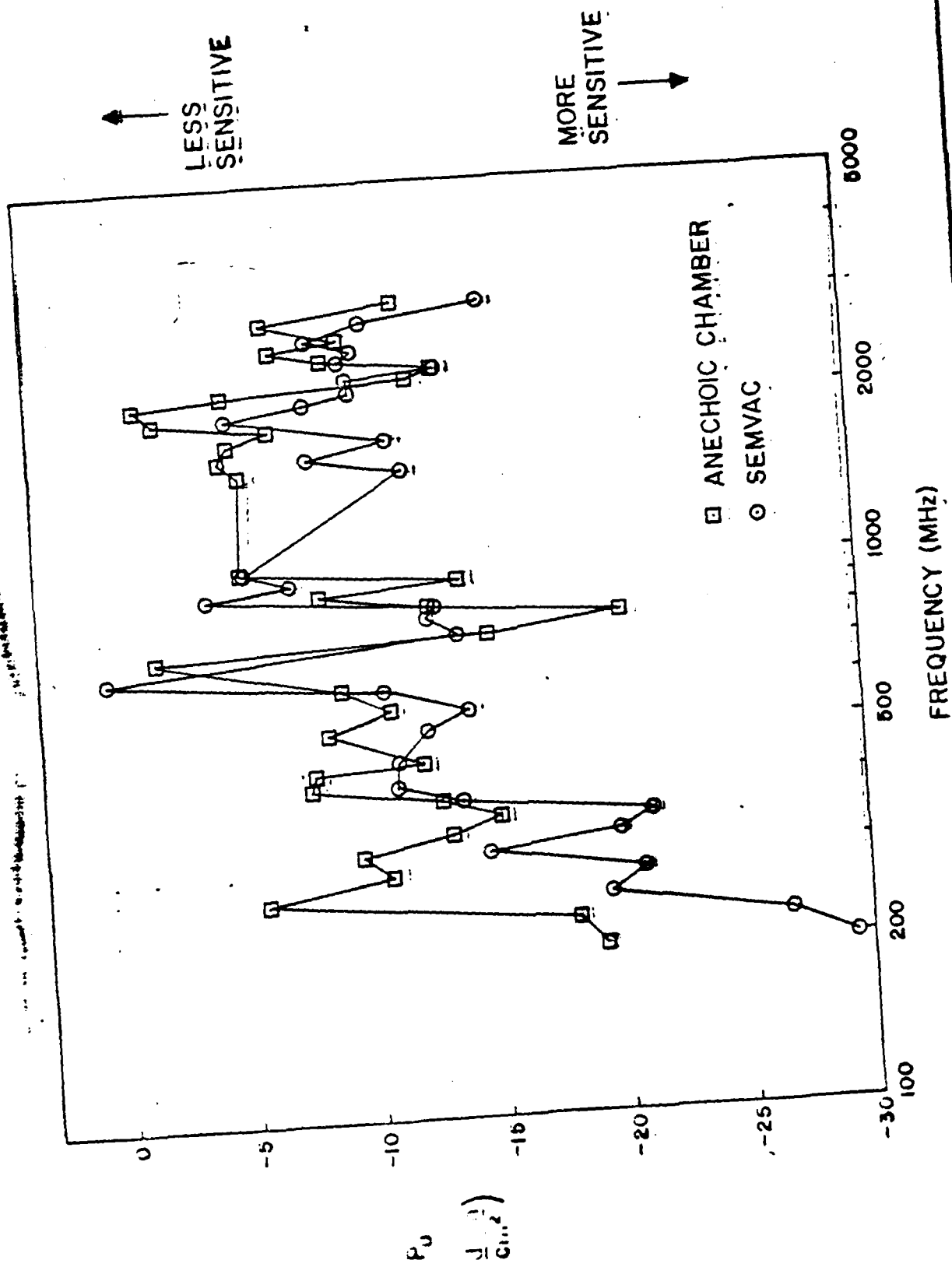
$$\begin{aligned}
 G_{1max} &\neq G_2_{max} \\
 P_{1max} &\neq P_2_{max} \\
 \underline{G_1} &\equiv G_2 \\
 \underline{P_1} &\equiv P_2
 \end{aligned}$$





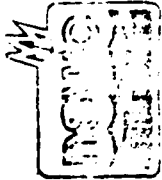
absolute
relative





George Bechtold

NSWC/WO



OBJECTIVE:

DETERMINE THE EMP SHIELDING EFFECTIVENESS OF A GRAPHITE/EPOXY COMPOSITE PANEL

APPROACH:

- TESTS WERE MADE IN A 20 KV/TH FIELD PRODUCED BY THE NSWC SIMULATOR
- THE TEST OBJECT CONSISTED OF AN ALUMINUM CYLINDER WITH A COMPOSITE PANEL MOUNTED ON THE SURFACE
- THE INTERNAL H FIELD, E FIELD, AND THE CURRENT AND VOLTAGE ON AN INTERNALLY MOUNTED WIRE WERE MEASURED
- COMPARISONS WERE MADE WITH AN ALUMINUM PANEL AND WITH NO PANEL INSTALLED

MEASUREMENTS OF COMPOSITE PANELS
MOUNTED ON AN ALUMINUM CYLINDER ★

G. W. BECHTOLD

P. E. HUNTER

L. LIBELO

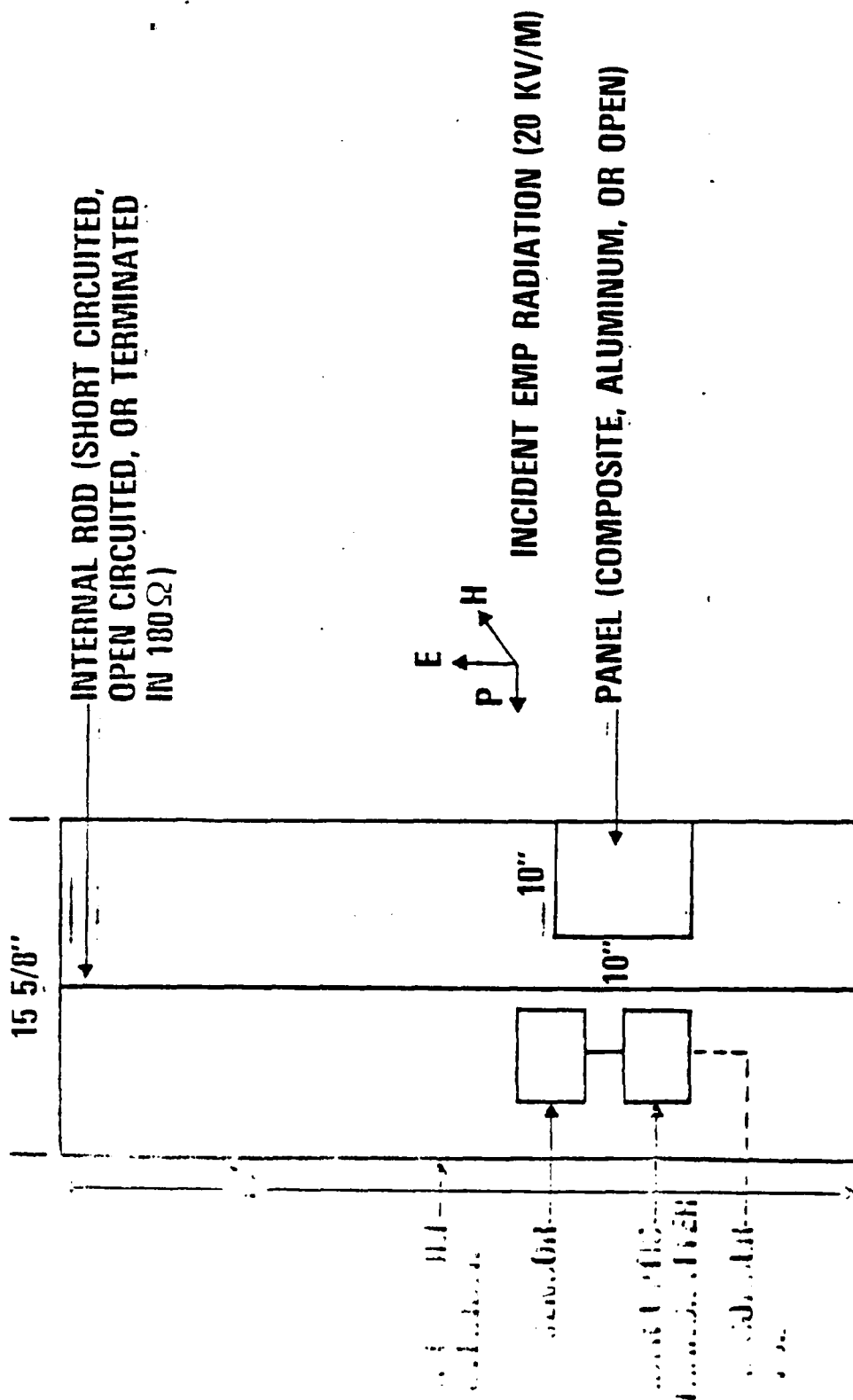
★ ORIGINATOR: NAVAL AIR SYSTEMS COMMAND

2

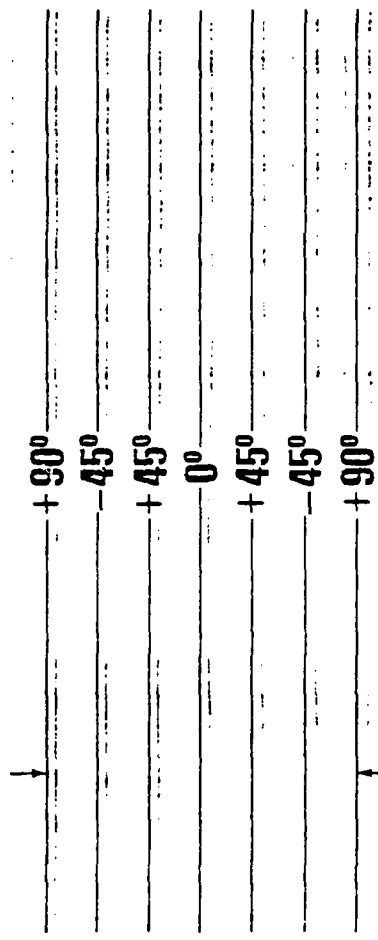
EMP MEASUREMENTS OF COMPOSITE PANELS MOUNTED ON AN ALUMINUM CYLINDER

- **MEASUREMENTS WERE MADE IN THE
NSWC EMP SIMULATOR**
- **RESPONSE OF ALUMINUM, COMPOSITE
AND OPEN PANELS ARE COMPARED**
- **MEASUREMENT TECHNIQUES ARE
DISCUSSED**

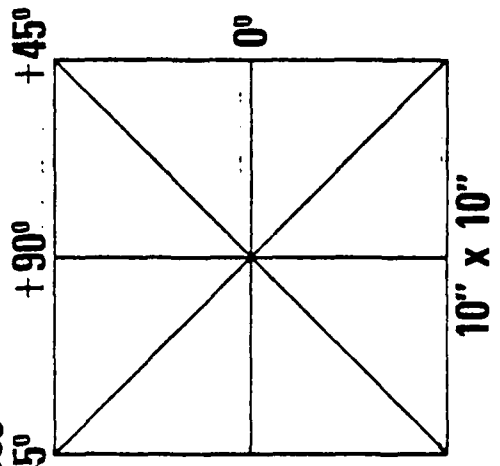
SHIELDING EXPERIMENT



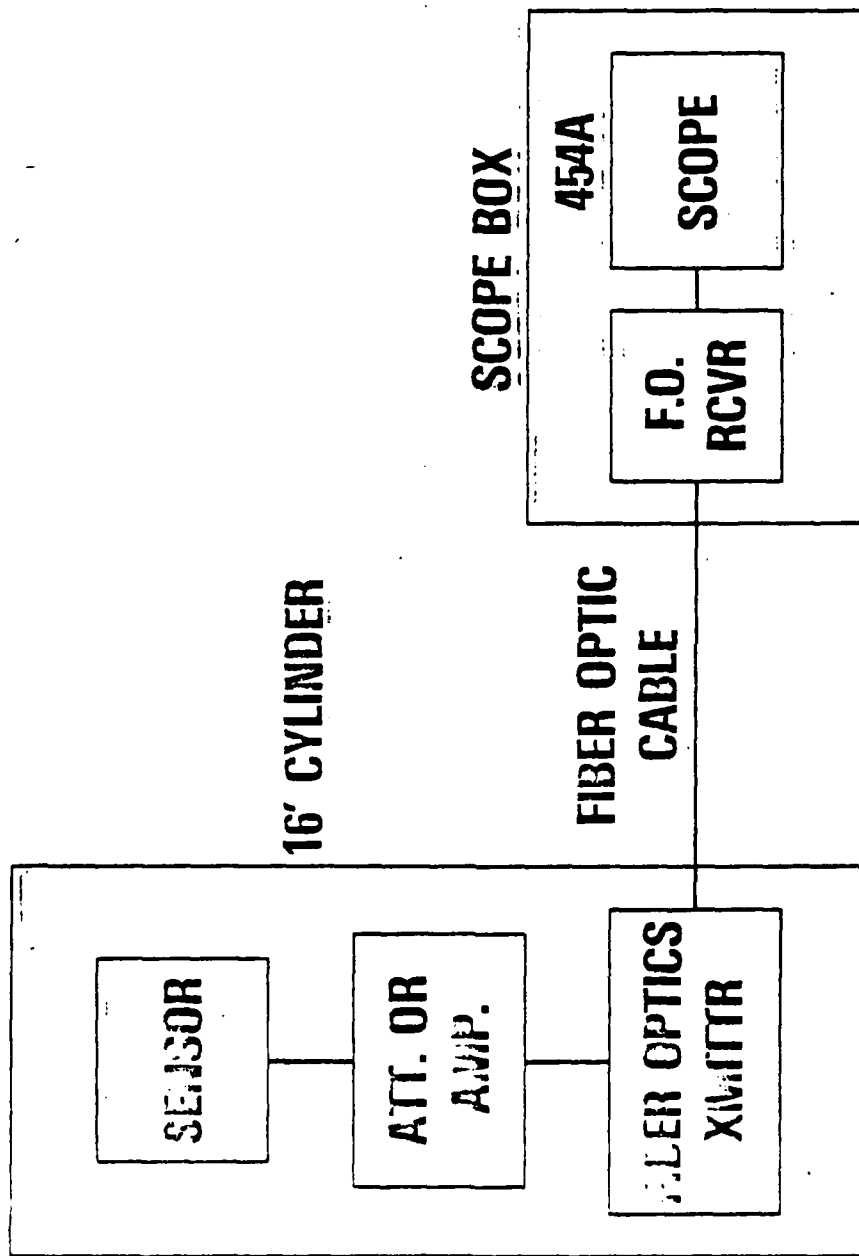
7 PLY COMPOSITE PANEL CONSTRUCTION



THICKNESS 0.038"

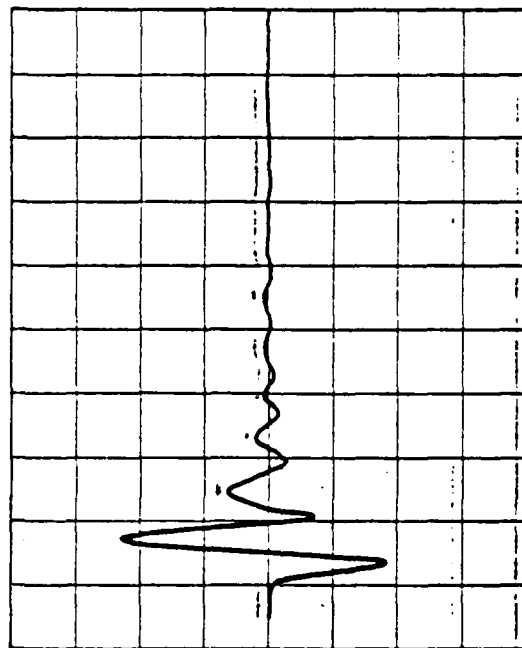


INSTRUMENTATION DIAGRAM

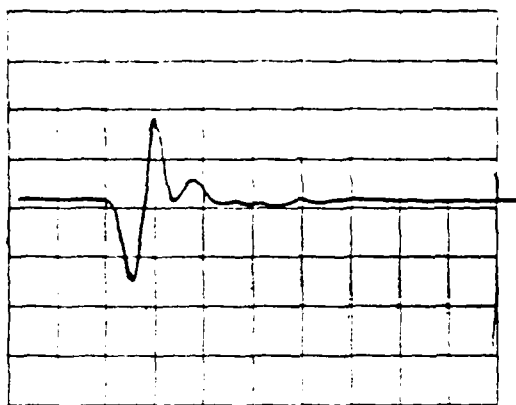




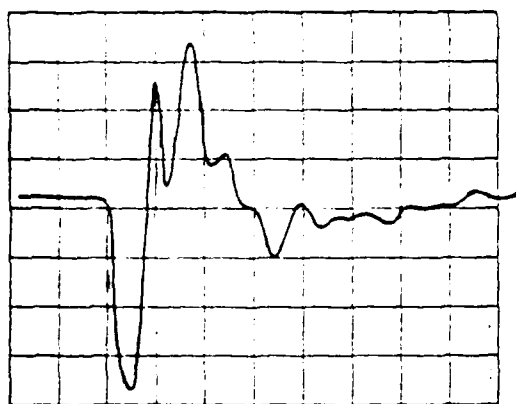
SKIN CURRENT AT THE CENTER OF THE CYLINDER



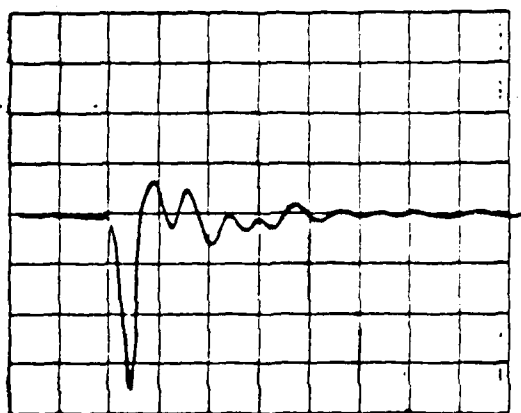
0.1 V/div
50 nS/div
CENTER OF
CYLINDER



-44 dB
ALL METAL

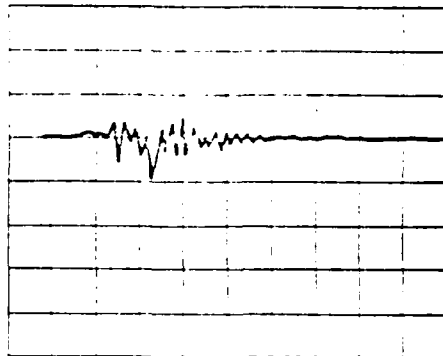


-34 dB
COMPOSITE PANEL

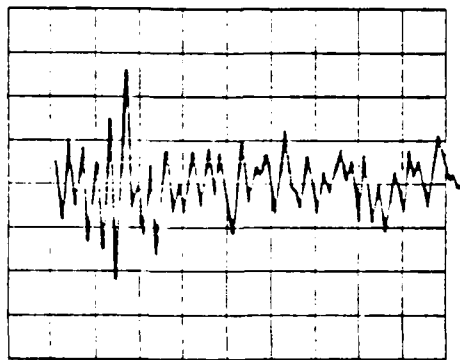


0 dB
LARGE METAL
PANEL REMOVED

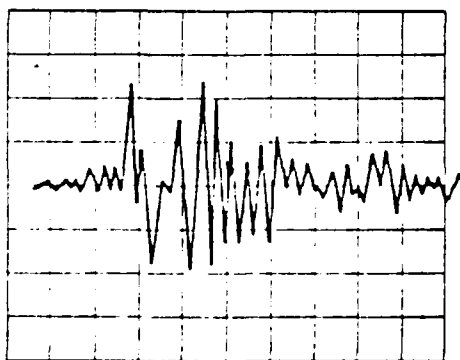
0 250 500
ns



-46 dB
ALL METAL



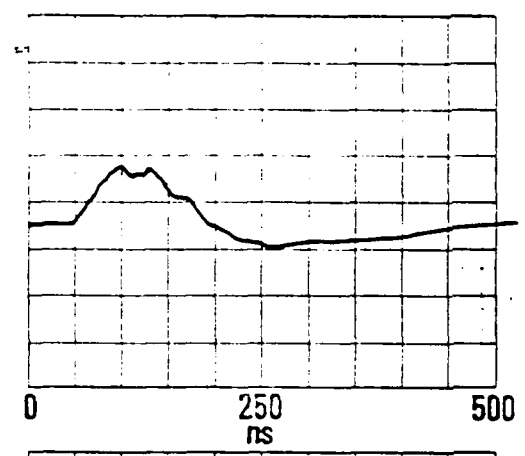
-34 dB
COMPOSITE
PANEL



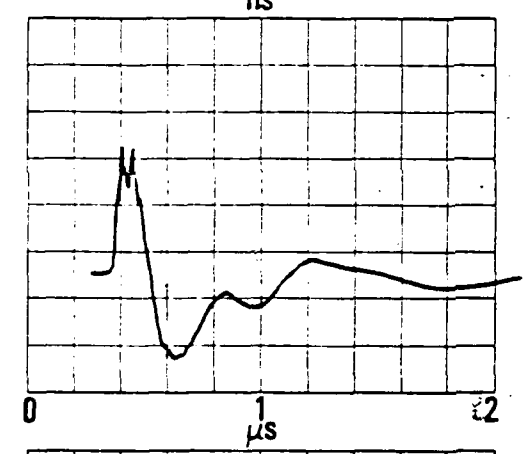
0 dB
LARGE METAL
PANEL REMOVED

0 100 200
ns

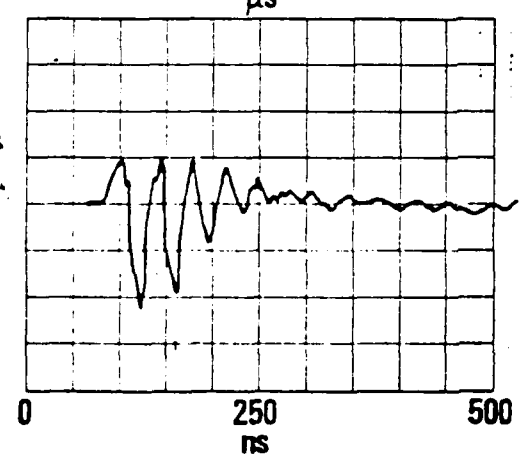
MEASUREMENT OF THE EFFECT OF POLARIZATION



BP 44
ALL METAL

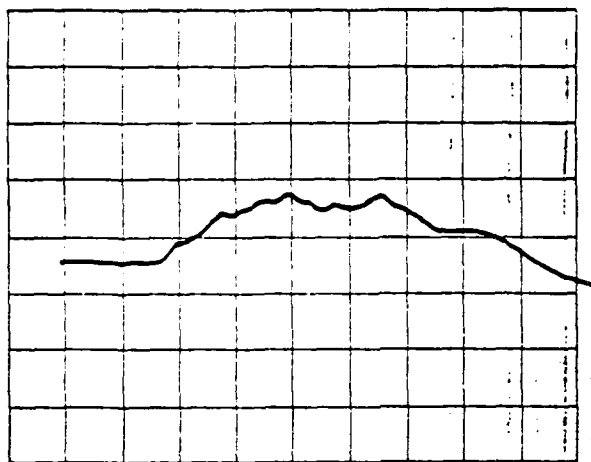


BP 32
COMPOSITE
PANEL

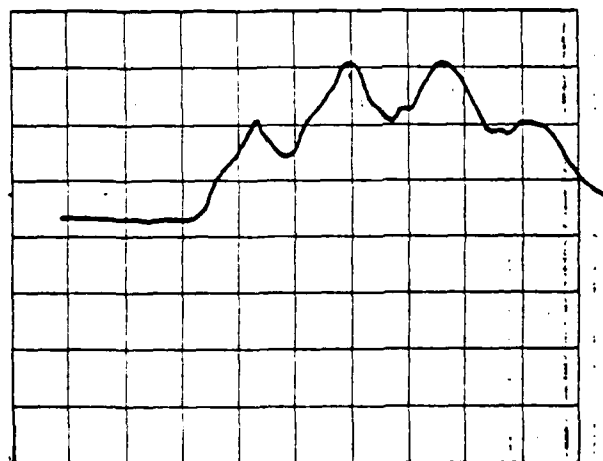


BP 10
LARGE METAL
PANEL REMOVED

COMPOSITE VS. ALUMINUM
TRANSMISSION
(VOLT POLARIZATION)



15 mV/div
20 nS/div
ALUMINUM
PANEL



10 mV/div
20 nS/div
COMPOSITE
PANEL

AD-A096 459

NAVAL AIR SYSTEMS COMMAND WASHINGTON DC

F/6 11/4

REPORT OF COMPOSITE MATERIAL AND METAL COMPOSITES JOINT WORKSHO--ETC(U)
1978

UNCLASSIFIED

NL

3 OF 3
AD A 096 459



END
DATE
FILMED
4-81
DTIC

SUMMARY OF DATA 16 FOOT CYLINDER SHIELDING

	AL PANEL	COMPOSITE PANEL
H FIELD	44 dB	34 dB
E FIELD	40 dB	
CURRENT ON WIRE	46 dB	34 dB
VOLTAGE ON WIRE	44 dB	32 dB



CONCLUSIONS

- COMPOSITE SHIELDING IS ≈ 12 dB WORSE THAN ALUMINUM AT EMP FREQUENCIES
- COMPOSITES EFFECT THE FREQUENCY CONTENT OF INTERVAL SIGNALS
- USING THE EXPERIMENTAL TECHNIQUES, COMPOSITE JOINTS CAN BE EVALUATED AT EMP FREQUENCIES

Gil Condon

General Electric

View Graphs Were Not Available

J. Roden

Syracuse Research Corporation

View Graphs Were Not Available

George Bechtold

NSWC/WO

Cliff Scouby

McDonnell Aircraft Corporation

View Graphs Were not Available

