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MODEL IUS

TITLE IUS Program: Shock Analyses and Shock Tests

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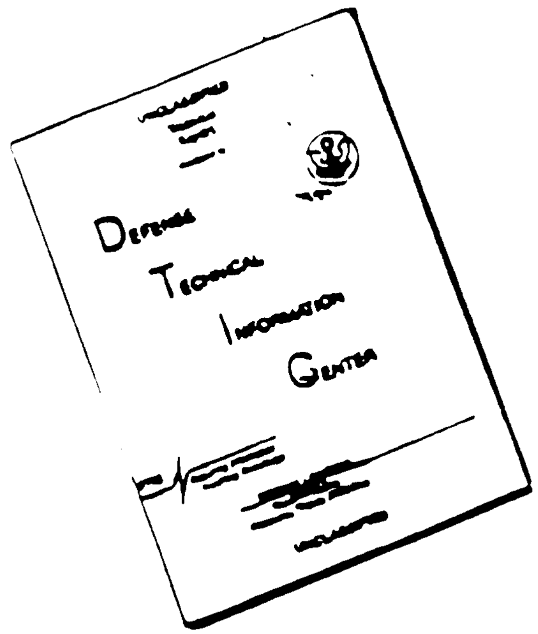

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ABSTRACT

This volume of D290-75303-2 contains shock analysis and shock test results performed in support of the Inertial Upper Stage (IUS) program.

KEY WORDS

analysis
flight data
IUS
pyroshock
shock
shock spectra
test data

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TABLE OF CONTENTS

1.0 INTRODUCTION

Since the original release of Volume 1 in February 1982, additional shock analyses and tests have been performed to support the IUS program. The purpose of this volume is to serve as a repository for these additional analyses and test results.

2.0 TITAN/IUS SEPARATION SHOCK

Separation shock testing of the TITAN/IUS (T34D/DTV) provided pyroshock data throughout the IUS vehicle. These data have been evaluated to show the attenuation of shock through the IUS structure. The evaluation results are presented in this section.

TEST NO 1

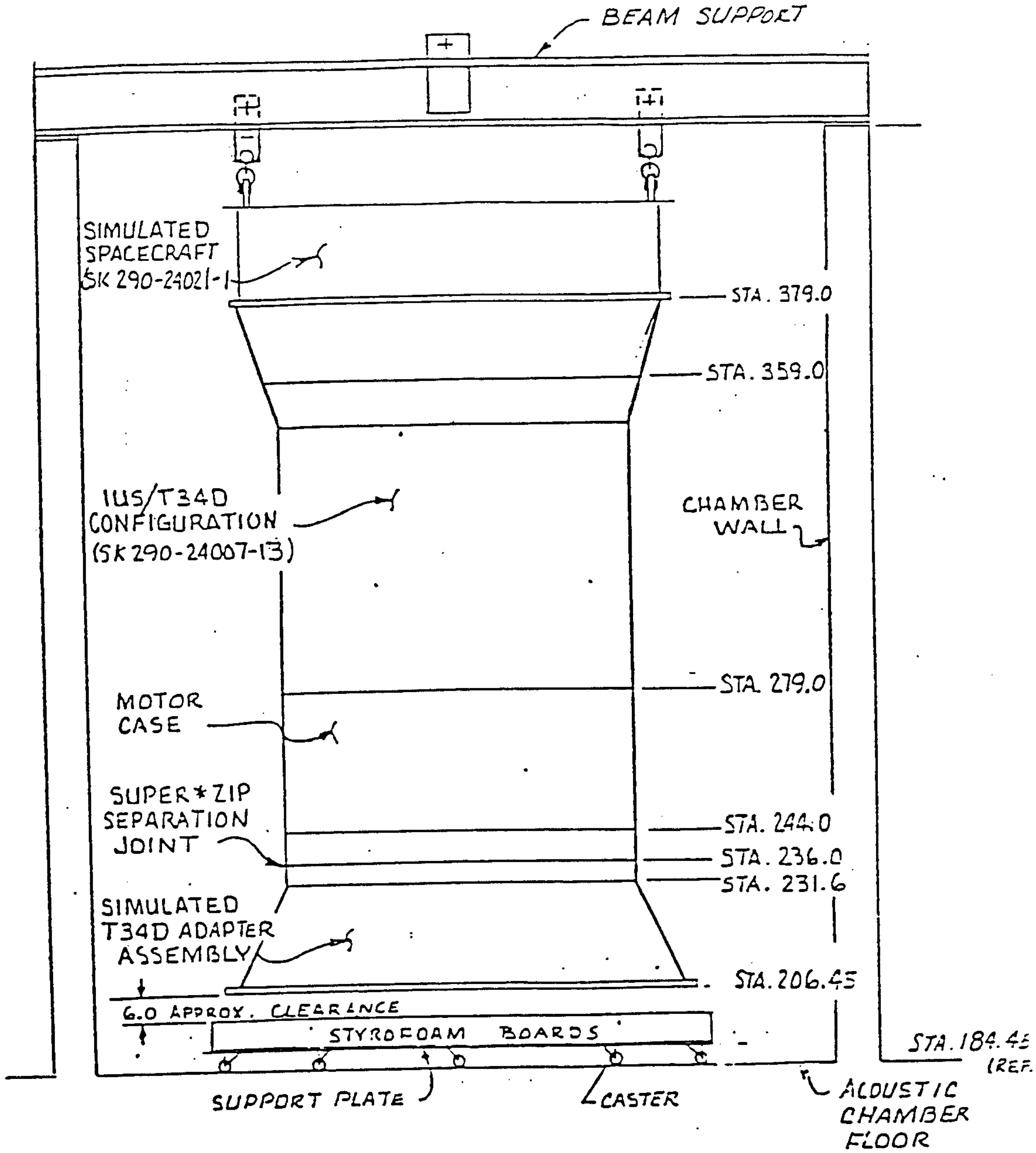

FIGURE 1

TEST SETUP - TITAN/IUS (T34D/DTV) SEPARATION SHOCK TEST

(1)

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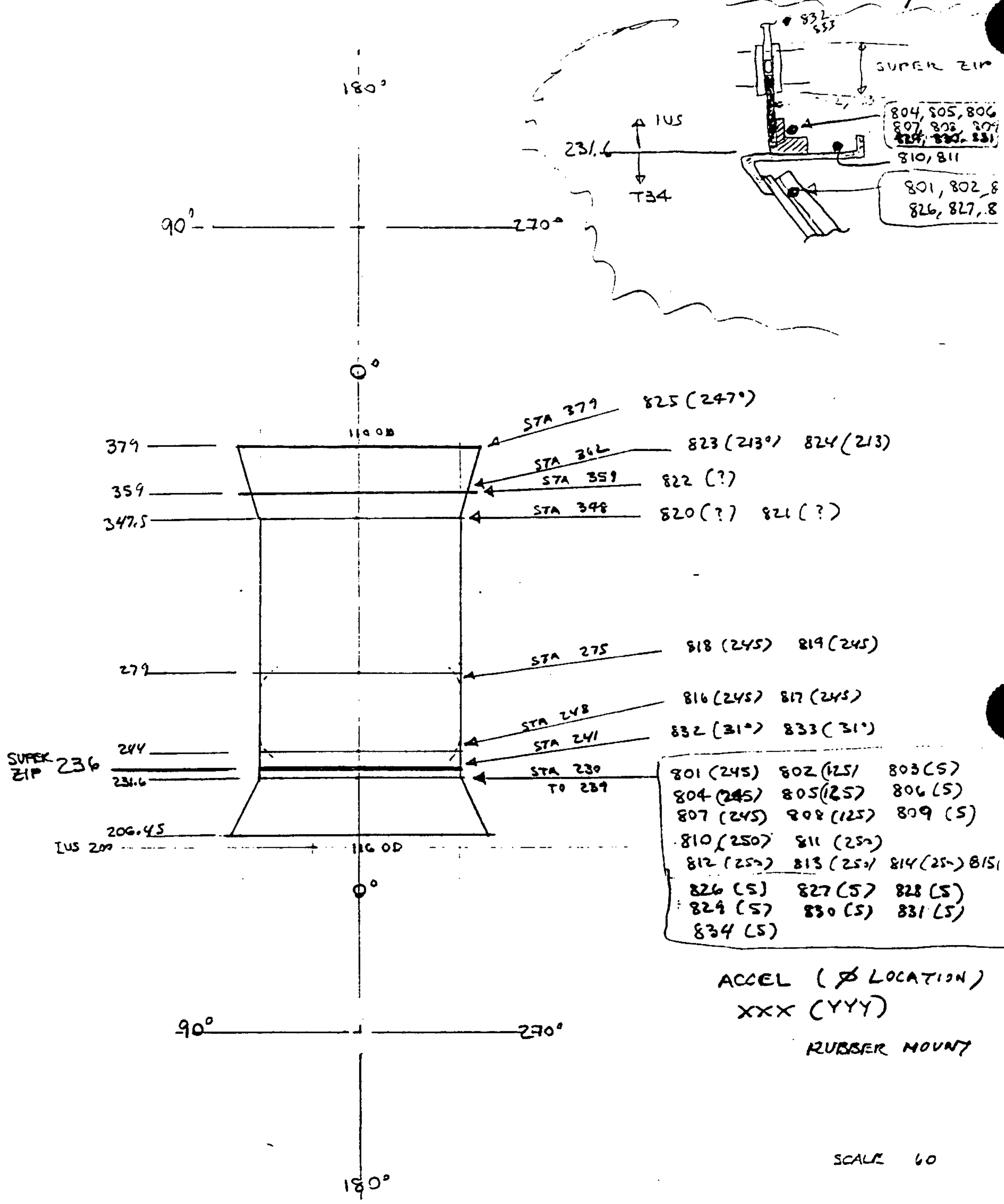
TITAN / IUS SEPARATION SHOCK TEST INSTRUMENTATION SUMMARY

TPR 2-5693-7800-117 3 JAN 79

JB 4/13/79



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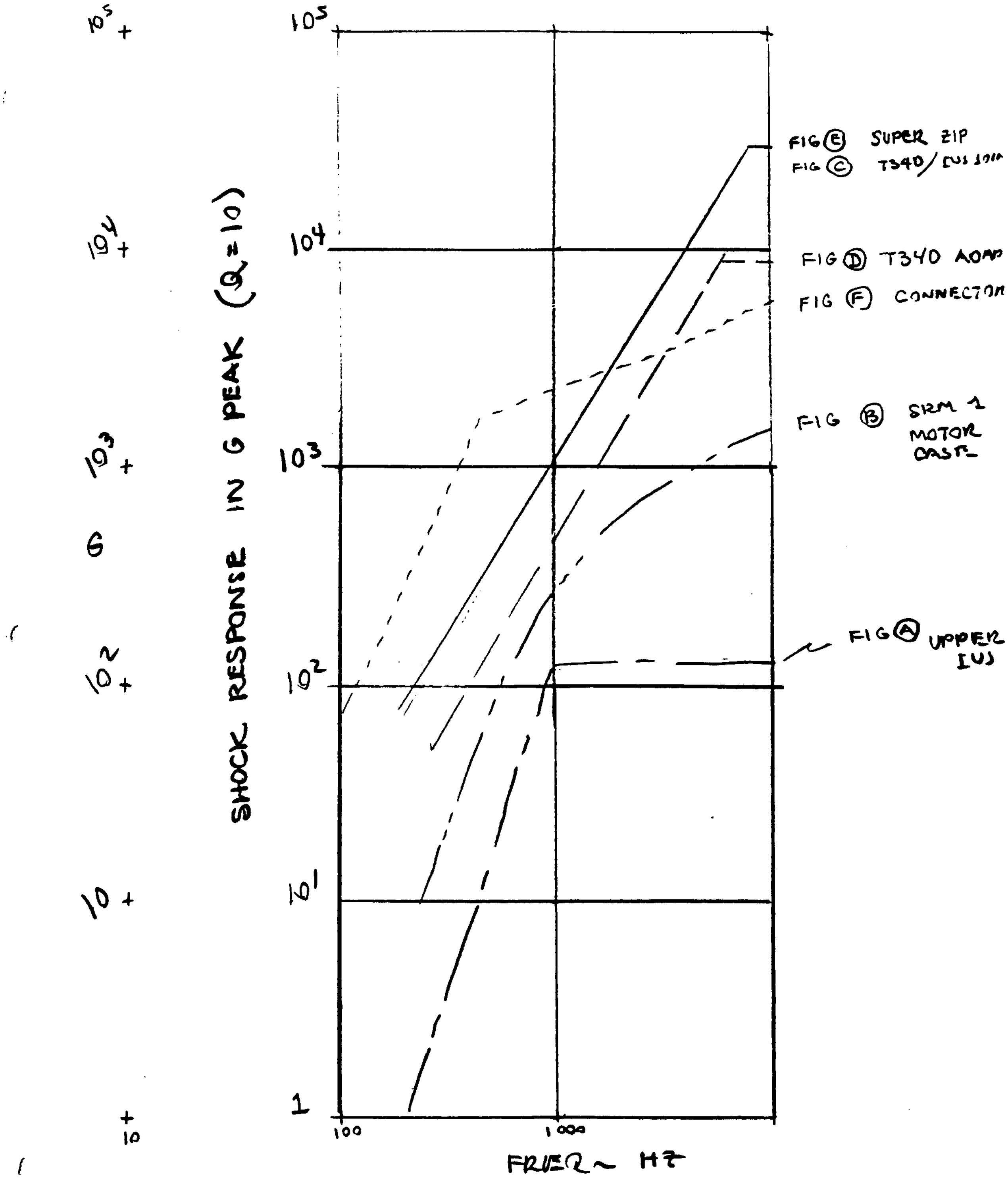
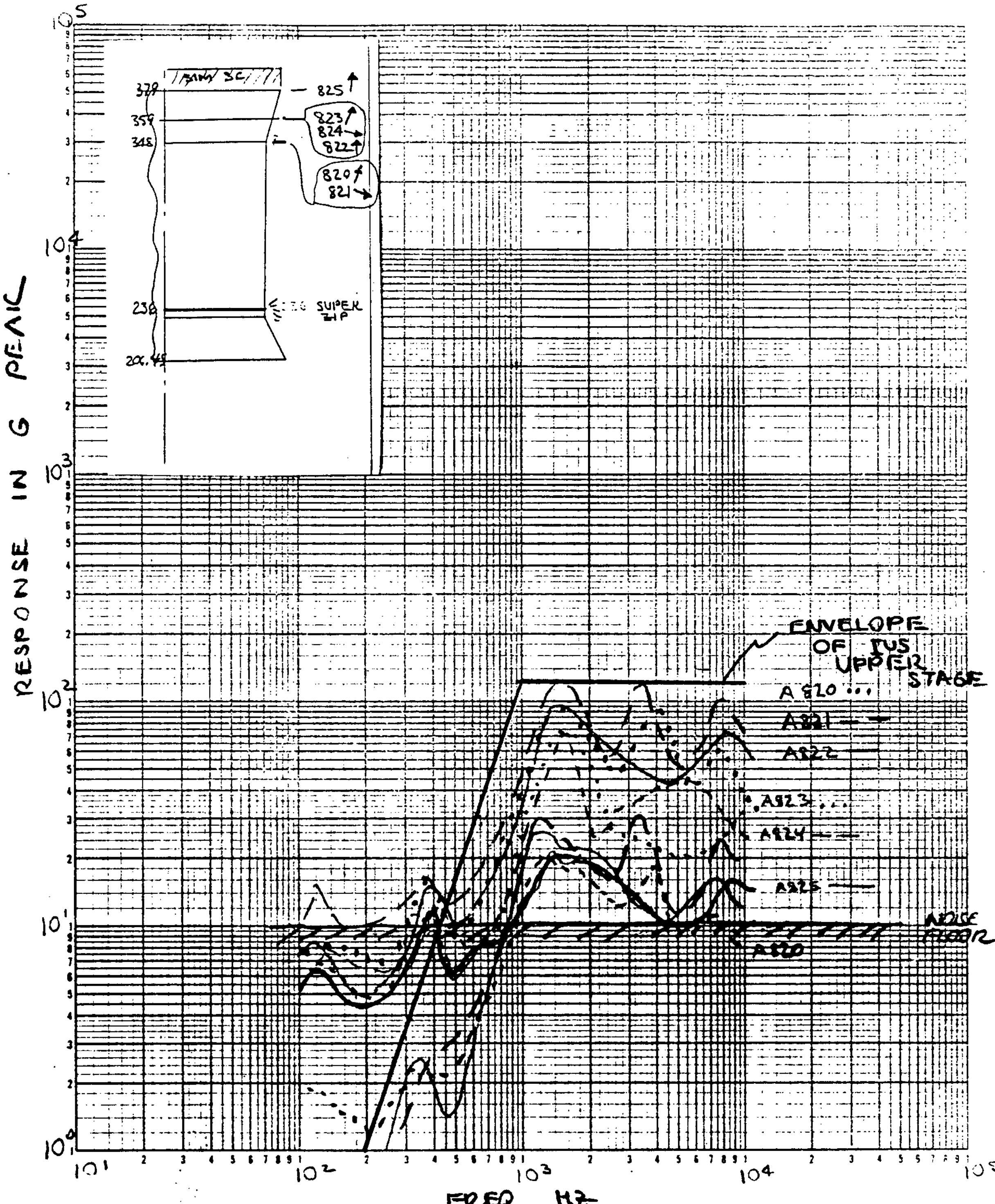


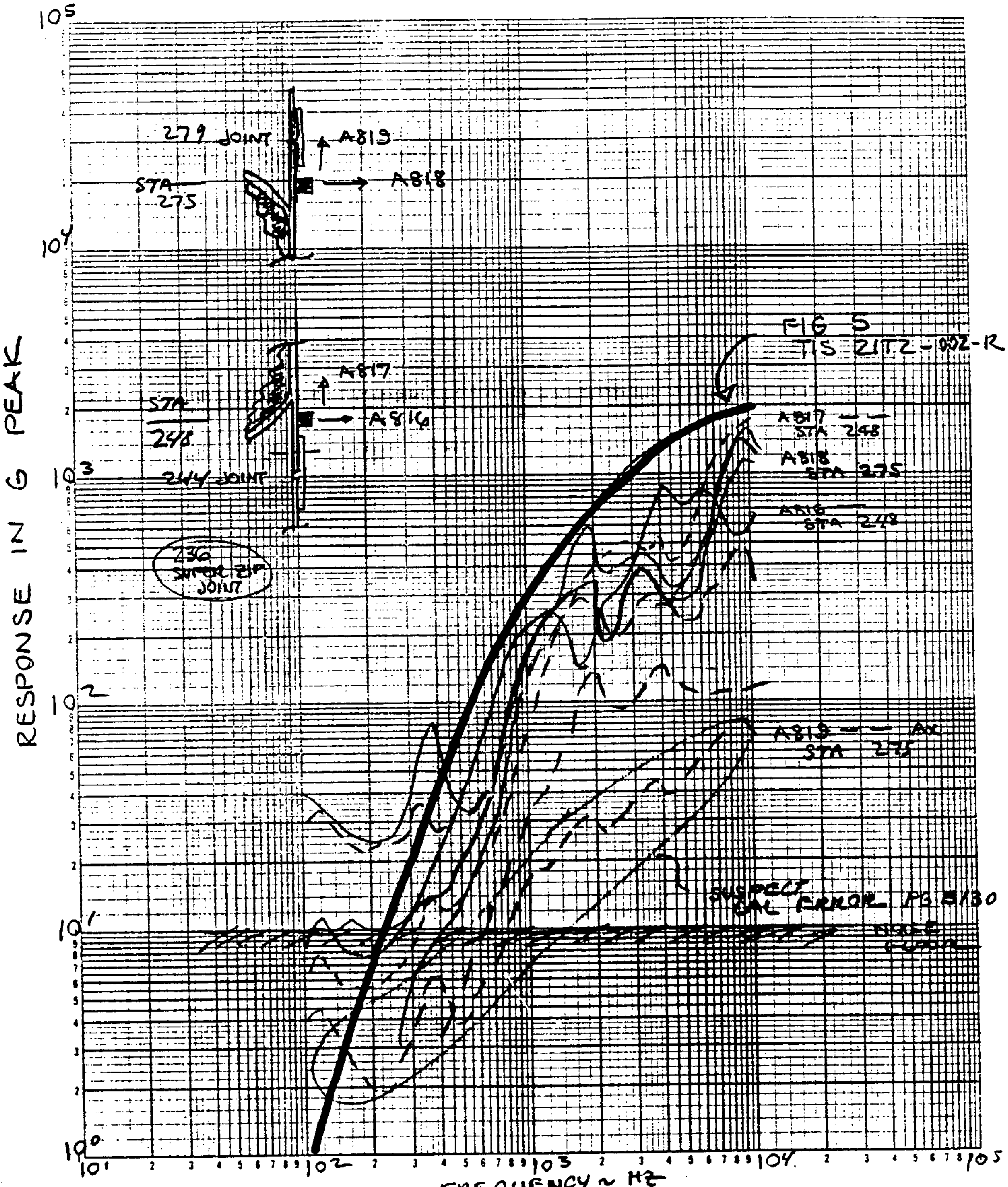
SUMMARY OF SHOCK ENVELOPED T34D/IUS SEPARATION PYROTECH.
4/30/79

(3)



CALC	C/S	4/13/79	FIG (A) TPR 2-5693-7800-117 RESPONSE OF UPPER IUS TO T34D/IUS SEPARATION, SUPER ZIP
CHECK			
APPD			
APPD			

SHEET (4)

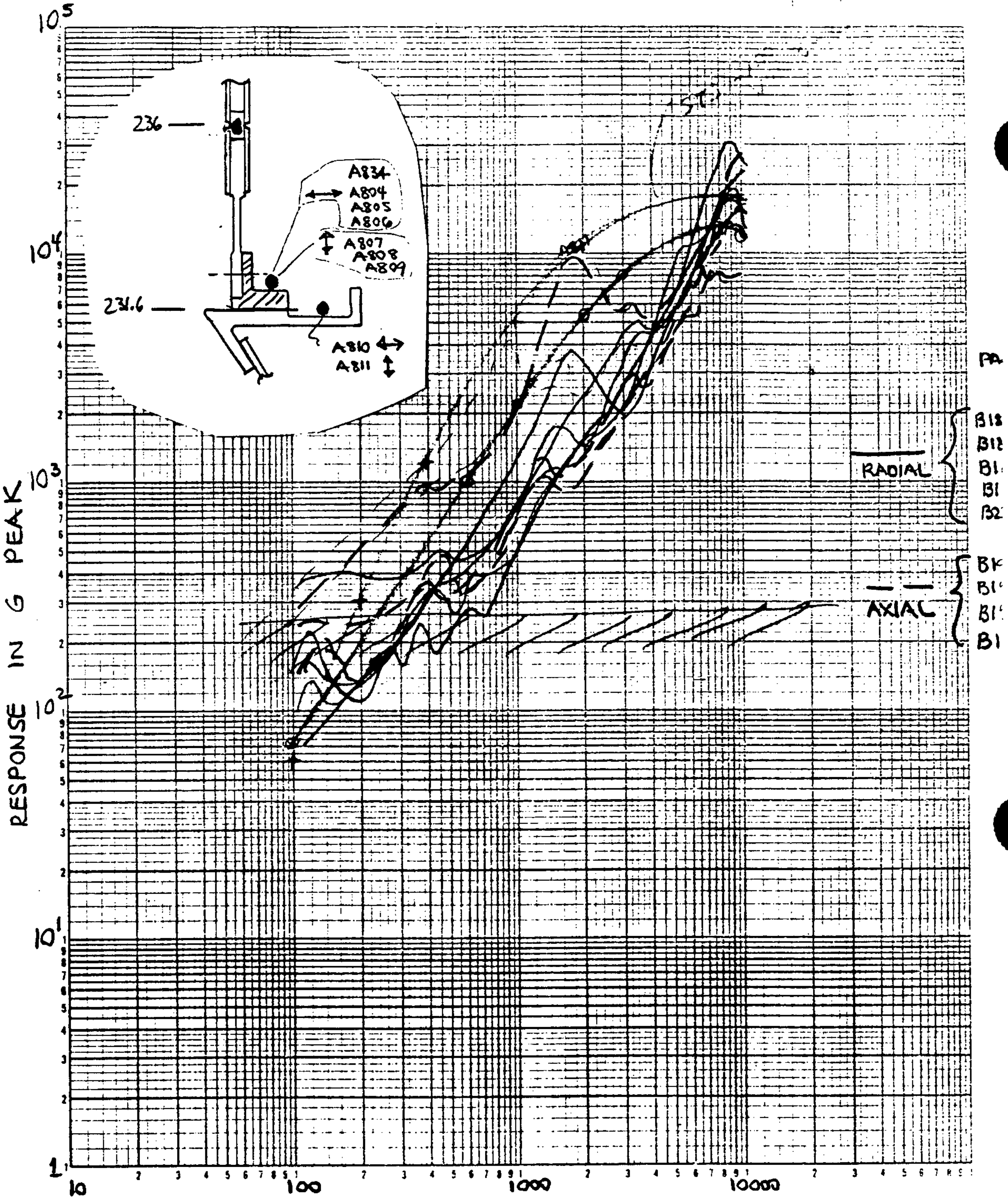


TPR 2-5693-7800-117

CALC	[illegible]	4/13/79	FIG (B) RESPONSE OF SRM 1 MOTOR CASE TO T34D/ IUS SEPARATION
CHECK			
APPD			
APPD			

SHEET (5)

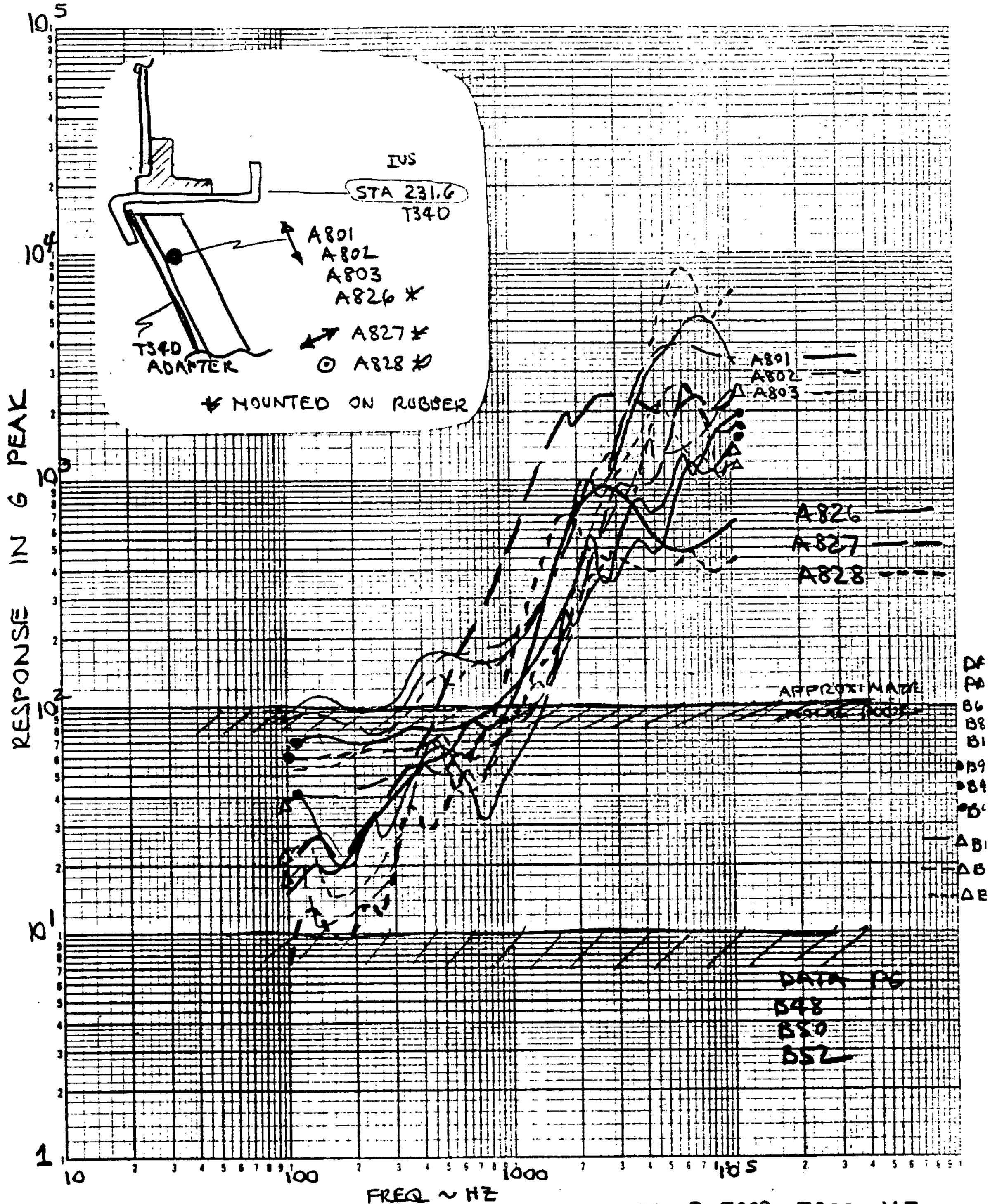
12



TPR 2-5693-7800-117

CALC	CB	4/27/79		FIG (C) RESPONSE OF STRUCTURE NEAR T34D/IUS JOINT TO T34D/IUS SEPARATION
CHECK				
APPD				
APPD				

SHEET (6)



TPR 2-5693-7800-117

CALC	CJB	4/22/79		FIG D RESPONSE OF T34D ADAPTER TO T34D/IUS SEPARATION
CHECK				
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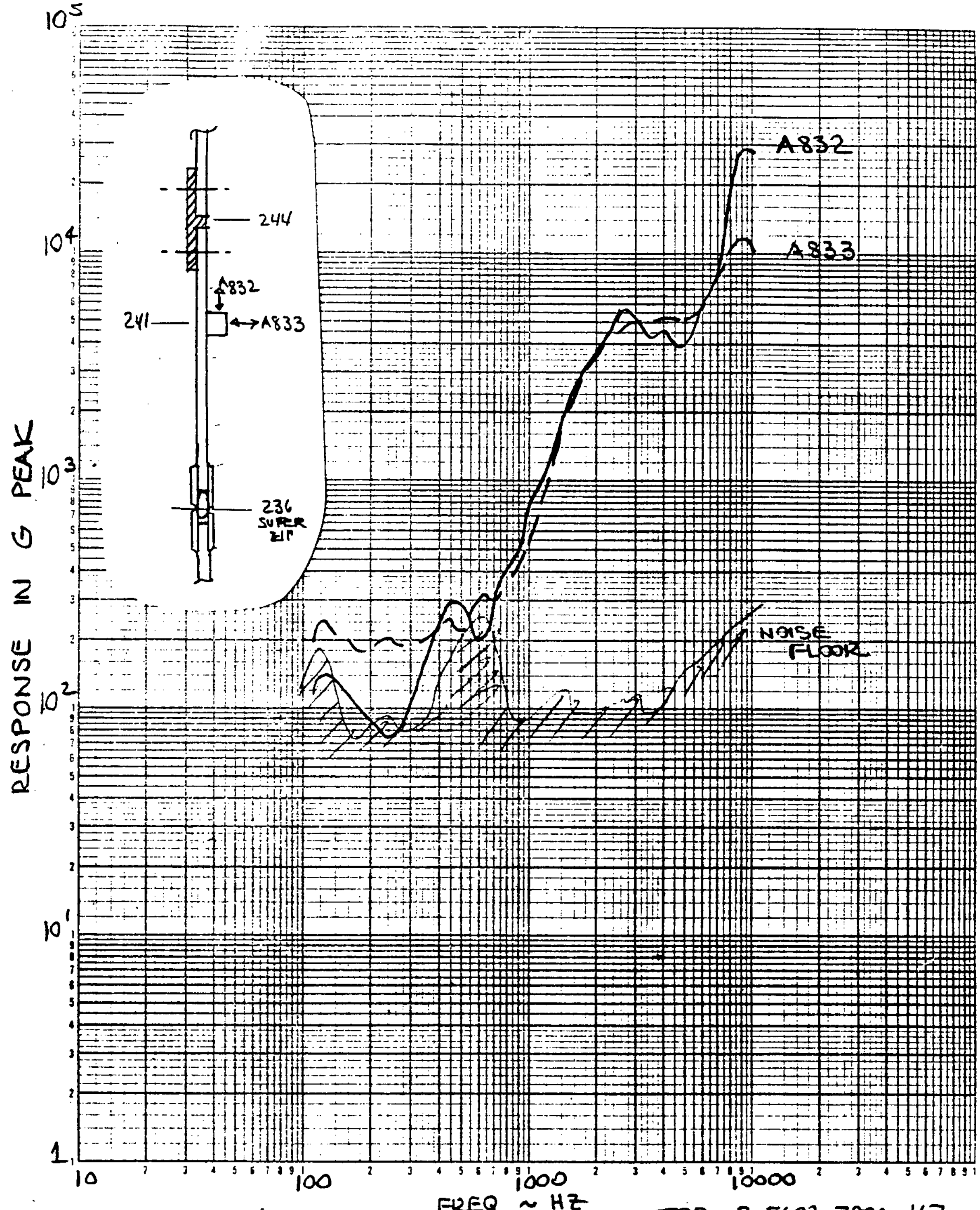
SHEET 7

FORM X4151 REV. 6.68



TPR 2-5693-7800-117

CALC	O Beck	4/27/79	FIG (E) STRUCTURE RESPONSE WITHIN 5 INCHES OF SUPER ZIP
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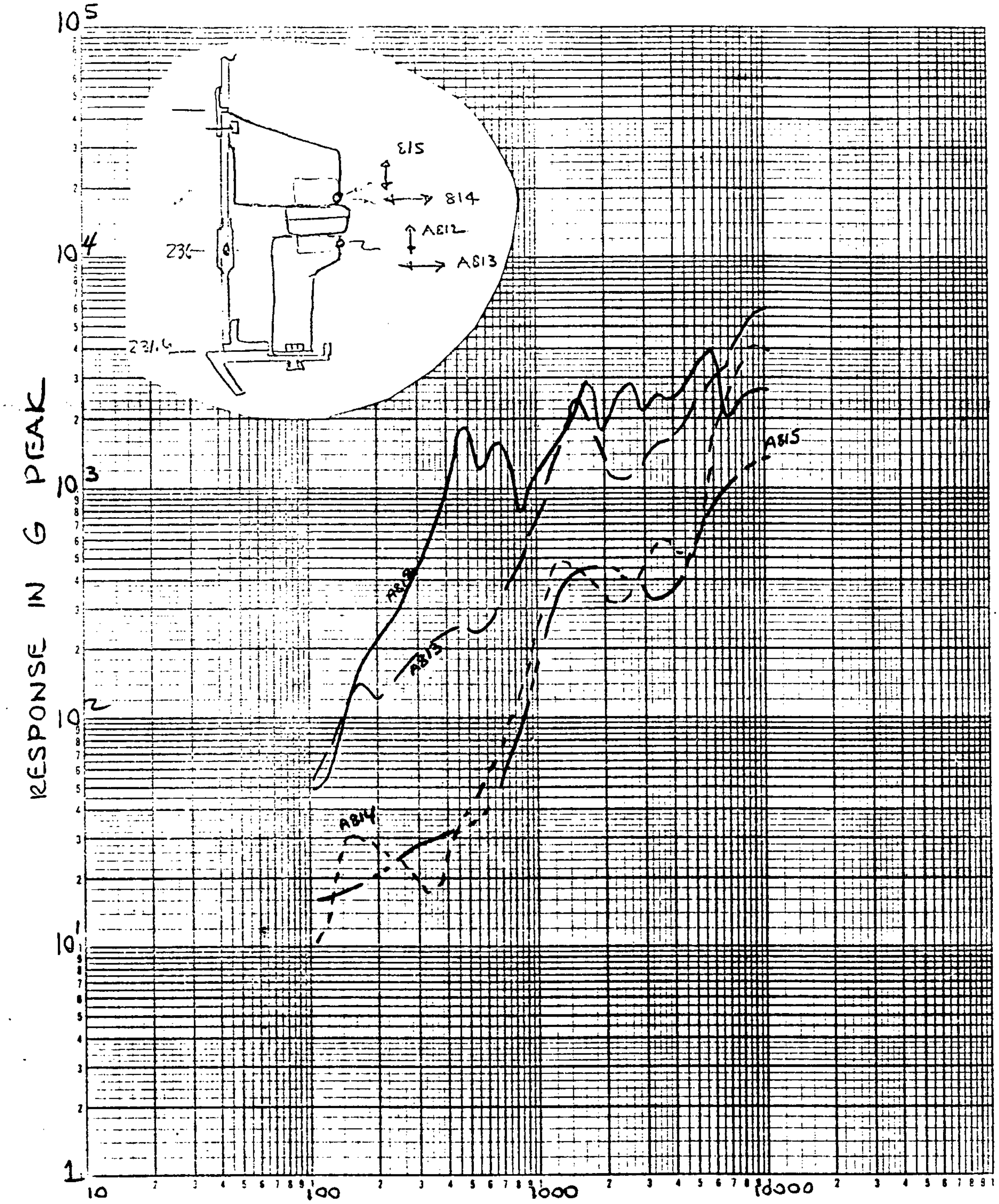
SHEET (8)



TPR 2-5693-7800-117

CALC	CB	1/30/79	FIG (F) RESPONSE OF CONNECTORS TO T34D/IUS SEPARATION
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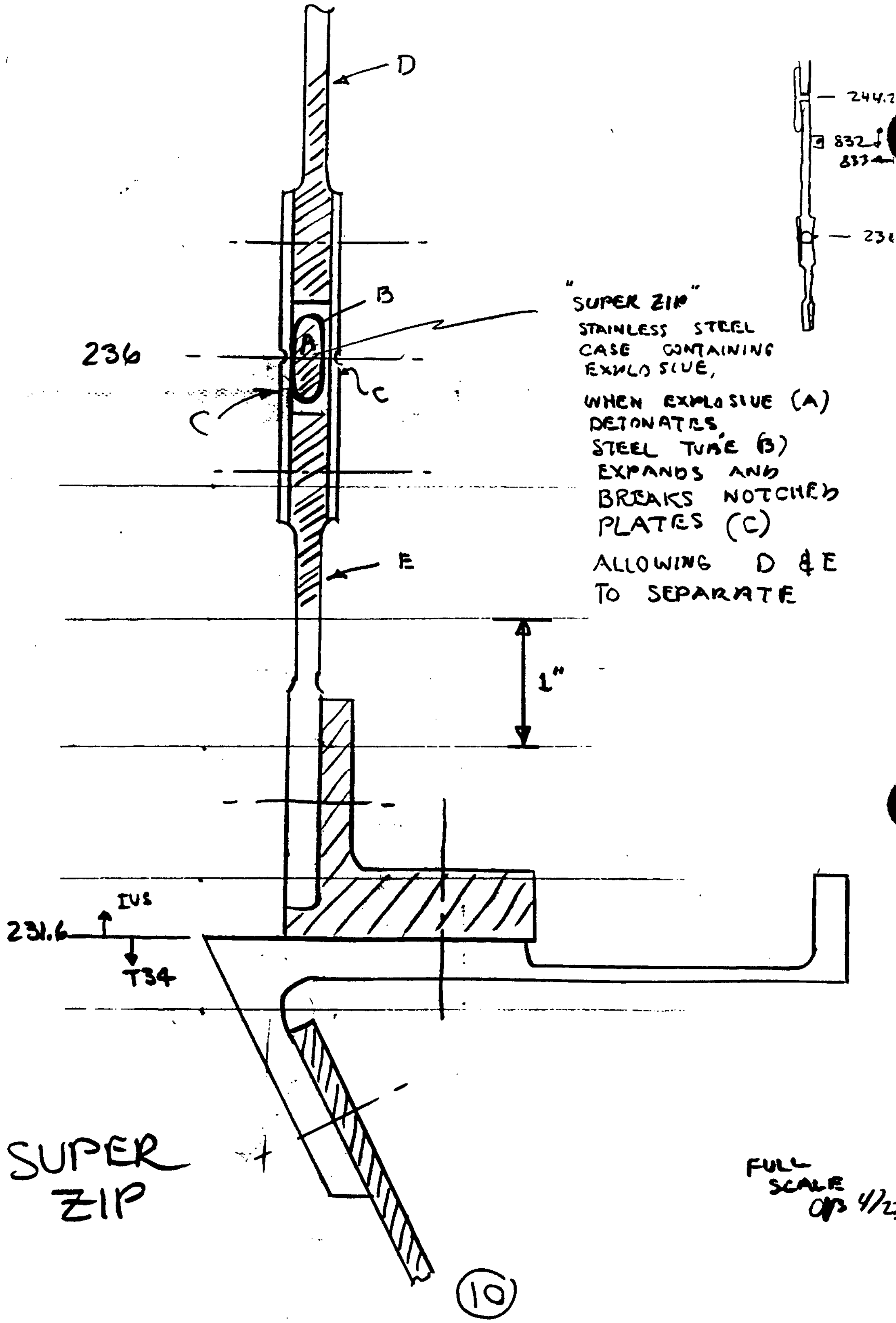
APPD			
APPD			

SHEET 9


D
B
A
236
C
C
E
1"
IUS
231.6
T34
"SUPER ZIP"
STAINLESS STEEL CASE CONTAINING EXPLOSIVE,
WHEN EXPLOSIVE (A) DETONATES, STEEL TUBE (B) EXPANDS AND BREAKS NOTCHED PLATES (C)
ALLOWING D & E TO SEPARATE
SUPER ZIP
10
FULL SCALE

4

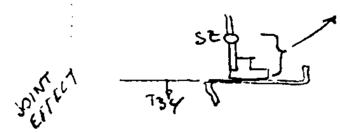
BOEING

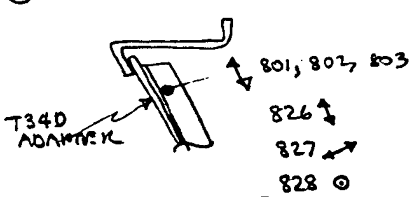
Beck 4/13/79

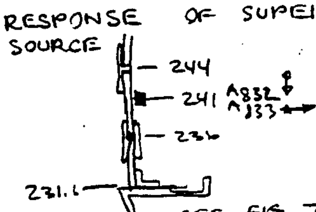
TITAN/IUS SEPARATION SHOCK TEST DATA PLOTS

TPR 2-5693-7800-117
TESTED 11/10/78 THRU 11/21/78

FIG	PLOT DESCRIPTION	DATA TO BE PLOTTED: ACCEL	STA	AXIS	PAGE
FIG (A)	RESPONSE OF IUS STAGE 2 AND UPPER PART OF STG 1 TO T34D/IUS SEPARATION	A825	379	A	B46 ✓
		A824	362	R	B44 ✓
		A823	362	A	B42 ✓
		A822	359	A	B40, B136, B213
		A821	348	R	B38, B134, B21[illegible]
		A820	348	A	B36, B132, B2[illegible]
FIG (B)	RESPONSE OF SRM 1 MOTOR CASE TO T34D/IUS SEPARATION. SEE FIG 5 OF TIS 21T2-002-R	A816	248	R	–, B124 ✓, B20[illegible]
		A817	248	A	–, B126 ✓, B20[illegible]
		A818	275	R	B32 ✓, B128, B2[illegible]
		A819	275	A	B34, B130, B2[illegible]
FIG (C)	RESPONSE OF STRUCTURE BETWEEN SUPER ZIP AND T34D I/S JOINT. SEE FIG 4 OF TIS 21T2-002-R	A804	233	R	B185
		A805	233	R	B187
		A806	233	R	B189
		A807	233	A	B191
		A808	233	A	B193
		A809	233	A	B195
		~~A829~~	~~232~~	A	~~B221~~ NOT PLOT
		~~A830~~	~~232~~	R	~~B223~~
		~~A831~~	~~232~~	T	~~B225~~
		A834	232	R	B231
		~~A810~~	~~232~~	~~R~~	B197
		A811	232	A	B199
FIG (D)	RESPONSE OF T34D ADAPTER. SEE FIG 3 OF TIS 21T2-002-R	A801	229.5	∥ TO ADAPT	B6 ✓, B94 ✓, B179
		A802	229.5	"	B8 ✓, B96 ✓, B18[illegible]
		A803	229.5	"	B10 ✓, B98 ✓, B18[illegible]
		A826	230	"	B48 ✓, B138, B21[illegible]
		A827	230	⊥ TO ADAPT	B50, B140, B21[illegible]
		A828	230	TANG.	B52, B142, B21[illegible]
FIG (E)	RESPONSE OF SUPER ZIP SOURCE. SEE FIG 7 OF TIS 21T2-002-R	A832	241	A	~~B150~~ B227
		A833	241	R	~~B152~~ B229







8 ACCEL ON RUBBER

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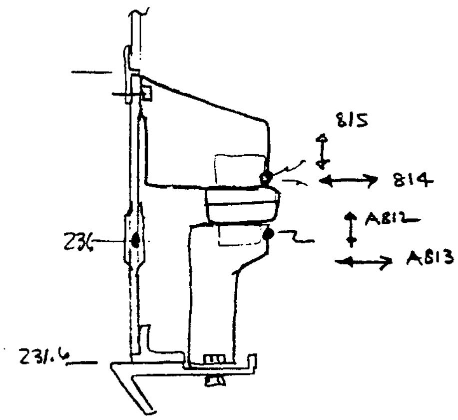
TITAN / IUS SEPARATION SHOCK DATA PLOTS (CONTINUED)

4/30/79

TPR 2-5693-7800-117 Test 11/10/78 THRU 11/29/

PLOT DESCRIPTION	DATA TO BE PLOTTED				
	ACCEL	STA	AXIS	PAGE	
FIG (F) RESPONSE OF CONNECTORS	A812	237	A	B-28	B-116
	A813	237	R	B-30	B-118
	A814	239	R	—	B-120
	A815	239	A	—	B-122



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3.0 IUS PYROTECHNIC SHOCK REDUCTION STUDY

In 1981 the Air Force authorized a special study relative to pyrotechnic shock at the IUS/spacecraft interface. There are two parts to the study: (1) definition of the shock environment at the interface; (2) evaluation of shock reduction techniques. The study results are presented in this section.

BOEING

July 29, 1981
2-3612-IUS-445

To: W. N. Morton

Subject: Special Study FSD 81-003, "IUS Pyrotechnic Shock Reduction, Stage I/II Separation

The final report on the subject special study (CDRL 193A2, dated 10 July 1981) was delivered to data management on July 15, 1981.

S. M. Church

C. Beck

FINAL REPORT

SPECIAL STUDY FSD-81-003

"IUS Pyrotechnic Shock Reduction, Stage I/II Separation"

10 July 1981

(CDRL 193A2)

CONTRACT F04701-78-C-0040

Principal Investigator C. J. Beck 7/15/81
C. J. Beck

Supervisor S. M. Church
S. M. Church

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LIST OF FIGURES

SUMMARY

The pyrotechnic shock environment induced by firing of the IUS Stage 1 and Stage 2 separation nuts was measured on the IUS Qualification Test Vehicle (QTV) in May 1981. The Baseline Shock Environment at the IUS/Spacecraft Interface is defined in Figure 2-14.

The shock induced by the Stage 1 and Stage 2 nuts is similar above 1000 Hz. Stage 2 nuts induce higher shock levels over limited frequency ranges below 1000 Hz. This phenomena is discussed in Section 2.2.

Five shock reduction techniques were evaluated. Only two of the five techniques are judged to be effective in reducing shock. Development tests are required to determine the magnitude of shock reduction. Paragraph 4.0 presents conclusions from the shock evaluation study.

1.0 INTRODUCTION

The purpose of this report is to present the results of the IUS Pyrotechnic Shock Reduction Study conducted by Boeing during the period 6 April 1981 thru 10 July 1981. The study was authorized under Special Study FSD-81-003, Contract F04701-78-C-0040.

There are two major parts to the study: (1) definition of the baseline shock environment based on measured shock data from the IUS QTV; (2) design evaluation of shock reduction techniques. Section 2 of this report presents the baseline shock environment and describes the techniques used to define the environment. Section 3 discusses the design evaluation results. Conclusions from the study are presented in Section 4.

2.0 BASELINE SHOCK ENVIRONMENT

One of the special study Statement of work tasks was to provide a baseline shock environment at the IUS/Spacecraft interface plane (IUS Station 379). This task was accomplished by placing accelerometers at the IUS/QTV 379 interface and recording the output from these accelerometers during the IUS Stage 1/2 separation event. The accelerometer output recordings were analyzed to obtain shock spectra for defining the baseline shock environment. The following paragraphs provide details of the process used to define the baseline.

2.1 TEST DESCRIPTION

2.1.1 Test Configuration

The test configuration consisted of the IUS QTV Second Stage and Interstage and the IUS Support System, Figure 2-1. The IUS Second Stage (ESS) was supported at four points by steel cables sized to provide a vertical mode frequency of about 50 Hz. The cables were attached to eyebolts fastened to the IUS thru the interface attach holes at IUS Station 379. The eyebolts were located at azimuths 33°, 112.5°, 213° and 292.5°. This configuration simulated an unloaded IUS/Spacecraft Interface. The test configuration is more fully described in D290-10316-21, QTV, Pyro Shock/Separation Test Procedures.

2.1.2 Instrumentation

Twenty-four accelerometers were located on the IUS 379 interface as illustrated in Figure 2-2. The accelerometers were oriented in the axial, radial and tangential directions at each of the 8 interface attach points.

2.1.3 Test Procedure

Three pyro shock/separation tests were performed. The shock environment induced by firing the IUS Stage 1/2 separation nuts was recorded during each separation test using the instrumentation described in 2.1.2. The separation nut firing was initiated thru the IUS computers. The 8 Stage 1 nuts fired first followed by the 8 Stage 2 nuts.

2.1.4 Data Reduction

The outputs from the interface accelerometers were recorded on magnetic tape. Time histories of the shock pulse were obtained from the tape recordings. Figure 2-3 shows typical time histories. The first shock event is the result of the Stage 1 separation nut firing. The second shock event is the result of the Stage 2 nut firing. A shock spectrum analysis was performed for each shock event. Figure 2-4 shows a typical shock spectrum.

2.2 DATA EVALUATION

2.1.1 Data Validity

The time histories and shock spectra from each accelerometer were reviewed to determine data validity. The data validity is summarized in Figure 2-5.

2.2.2 Data Envelopes

The shock spectra were enveloped to evaluate the configuration effects on the interface shock environment. Figures 2-6, 2-7 and 2-8 show comparisons of the shock levels induced by the Stage 1 and Stage 2 nuts for the axial, radial and tangential directions. These comparisons indicate the shock induced by Stage 1 and Stage 2 events are similar but there appear to be significant differences (greater than 3db) at specific frequency ranges. These differences are tabulated below.

DIRECTION	FREQUENCY RANGE (Hz)	DIFFERENCE	MAX
Axial	330 to 1200	STG 2 > 1	7db
Axial	1800 to 2700	STG 2 > 1	3db
Axial	7500 to 10000	STG 2 > 1	6db
Radial	120 to 600	STG 1 > 2	6db
Radial	600 to 2300	STG 2 > 1	6db
Radial	2300 to 10000	STG 1 > 2	5db
Tangential	100 to 450	STG 1 > 2	3db
Tangential	450 to 1250	STG 2 > 1	6db
Tangential	3200 to 4500	STG 1 > 2	3db

The differences are called apparent because they are less than the data spread which is about 10db. Comparisons of peak responses at selected frequencies were conducted to determine if one of the stages consistently induced a higher shock response. These comparisons are shown on Figures 2-9 thru 2-12.

Shock spectra statistics were calculated for selected frequencies where spectral peaks were noted. The calculations are based on the 95%/50% statistics discussed in paragraph 3.19 of MIL-STD-1540A. A tabulation of the statistic calculations and an explanation of the calculation procedure are contained in Figure 2-13.

The statistics of Figure 2-13 were obtained by combining the valid data from all eight interface attach points for all three tests for a given axis. This technique was used because the 8 second stage longerons are identical and the separation nuts which create the shock are identical. The longerons are the primary transmission path from the shock source (separation nut) to the shock instrumentation at the spacecraft/IUS interface. Therefore each shock spectra is assumed to be part of the same population.

2.3 RESULTS

The baseline shock environment is shown in Figure 2-14. The baseline is the envelope of all the QTV data. The special study goal is also shown on Figure 2-14. Note that the measured baseline environment is less than the goal except for two frequency ranges.

Figures 2-15 thru 2-17 show the data envelopes for the axial, radial and tangential directions.

The shock spectra used to define the baseline is contained in the IUS QTV Qualification Test Report, 22B5-005R.

3.0 SHOCK REDUCTION EVALUATION

The other major part of this special study consisted of shock reduction technique evaluation. Five shock reduction techniques were evaluated. The following paragraphs describe the results and conclusions from these evaluations.

3.1 REVERSE FIRING ORDER

3.1.1 Concept

Pyrotechnic shock tests on the DSCS/IUS showed that the spacecraft shock environment induced by firing the IUS stage 1/2 separation nuts is a function of the IUS 1/2 joint configuration. The spacecraft environment increased when the IUS fixed nut (Stage 2 side) was fired with the 1/2 joint open, Figure 3-1. In the current design, the torqued nut (Stage 1 side) fires first followed by the fixed nut 40 milliseconds later. The stages are separated (joint open) when the fixed nuts fire. Reversing the firing order of the separation nuts will cause the fixed nut to fire with the 1/2 joint closed, thereby minimizing the shock induced in the spacecraft.

3.1.2 Design Approach

Four designs were considered for reversing the firing order of the separation nuts. In order to understand the design approaches, it is necessary to discuss the operation of the existing separation system. Figure 3-2 shows the components of the separation system. The A system fires the Stage 1 nuts and system B fires the Stage 2 nuts. The firing signal command is generated in Computer A and is fed thru SCU A (Signal Conditioning Unit) to PSU A (Pyro Switching Unit). The firing signal from PSU A travels thru the pyro staging connector at the Stage 1/2 interface to the separation nuts located on Stage 1. Forty milliseconds after the firing signal is generated in Computer A a signal is generated in Computer B to fire the Stage 2 nuts. If all Stage 1 nuts have fired the stages will be separated (joint open) when the Stage 2 nuts fire.

The four design approaches considered for reversing the separation nuts firing order are:

1) modify software to cause Computer B signal to precede Computer A;

2) modify software to reverse computer command order and to shorten delay time (40 ms to 20 ms);

3) modify software to reverse computer command order and redesign pyro staging connector;

4) reverse electrical conductors from PSUs to separation nuts.

The Avionics Design organization recommended approach 4). A detailed discussion of the approaches is contained in Appendix A.

3.1.3 Evaluation

Reversing firing order of the nuts is feasible. However, evaluation of the IUS QTV shock test results described in paragraph 2.2.2 indicates that the interface shock levels induced by firing the Stage 1 nuts (Stage 1/2 joint closed) and the Stage 2 nuts (Stage 1/2 joint open) do not differ significantly above 1000 Hz. Therefore, reversal of separation nuts firing order is not an effective technique for reducing the interface shock environment.

3.2 INHIBIT FIRING

3.2.1 Concept

Inhibiting firing of the Stage 2 nuts after the Stage 1 nuts fire will cause the shock to occur with the Stage 1/2 joint closed. The DSCS/IUS shock test indicated that lower shock levels occur at the IUS/DSCS interface if the Stage 1/2 joint is closed when the nuts fire (see Figure 3-1).

3.2.2 Design Approach

The design approach is to add a Stage 1/2 separation switch in series with each enable switch in the PSU. If the Stage 1 separation nut fires and stage separation occurs, the separation switch will open and disable the circuit so that the Stage 2 nut cannot fire. Appendix A contains a detailed description of the design approach.

3.2.3 Evaluation

Inhibiting firing of the Stage 2 nuts is feasible. However, this design approach is not expected to be effective in reducing the interface shock environment for the reason explained in paragraph 3.1.3.

3.3 SIMULTANEOUS FIRING

3.3.1 Concept

Simultaneous firing of the Stage 1 and Stage 2 separation nuts will cause the shock to occur with the Stage 1/2 joint closed. The shock at the interface will be reduced because of the closed joint configuration.

3.3.2 Evaluation

This reduction technique is not feasible for the following reasons:

1) the present firing system cannot perform simultaneous firing without major redesign (see Appendix A);

2) firing both nuts simultaneously could theoretically double the shock level;

3) the closed joint shock environment does not differ significantly from the open joint environment (see paragraph 3.1.3).

3.4 SHOCK ISOLATION

3.4.1 Concept

If the primary shock source is assumed to be internal to the separation nut, then shock isolation of the nut from the IUS structure should reduce the interface shock environment.

3.4.2 Design Approach

Figure 3-3 shows the design approach for isolating the nut from the IUS structure. Only the Stage 2 nut was considered for isolation, since the Stage 1 nut is effectively isolated by the crush washer between the nut and the structure.

3.4.3 Evaluation

This concept is feasible; however, the amount of shock reduction would have to be determined by development testing. Also the isolator effect on the structural integrity of the joint would have to be determined. The requirement for structural integrity could possibly negate the shock reduction capability of this concept.

3.5 INTERFACE SHOCK ATTENUATION

3.5.1 Concept

Shock attenuation can be obtained thru structural joints. The IUS/spacecraft joint could be configured to optimize the shock reduction between the IUS and the spacecraft.

3.5.2 Design Approach

Figure 3-4 shows the design approach for attenuating the shock from the IUS to the spacecraft. Laboratory tests conducted by Martin Marietta Corporation[1] indicate that high frequency shock can be attenuated across a load carrying structural joint by using multiple metal inserts. Their studies show that up to 10 db reductions can be achieved at frequencies above 1500 Hz.

3.5.3 Evaluation

This concept is feasible but is subject to verification by test and analysis as discussed in paragraph 3.4.3.

4.0 CONCLUSIONS

The conclusions from the shock reduction evaluation follow.

a) Reversing firing order of Stage 1/Stage 2 separation nuts is not an effective technique for shock reduction.

b) Inhibiting firing of the Stage 2 nuts is not an effective technique for shock reduction.

c) Simultaneous firing of IUS Stage 1 and Stage 2 nuts is not an effective technique for shock reduction.

d) Shock isolation of the IUS Stage 2 separation nuts is feasible, but development testing is required to determine the amount of reduction. Structural analysis is required to determine the structural integrity of the isolated joint.

e) Shock attenuation thru the IUS/Spacecraft interface joint is feasible, but development testing and structural analysis is required to validate the concept.

The Baseline Shock Environment is less than the Special Study Goal except for two frequency ranges, see Figure 2-14. Cost estimates and schedules were not obtained for any of the shock reduction techniques since the Baseline Environment essentially meets the Special Study Goal.

1 "Methods of Attenuating Pyrotechnic Shock", Shock and Vibration Bulletin No. 42, Part 4, January 1972.

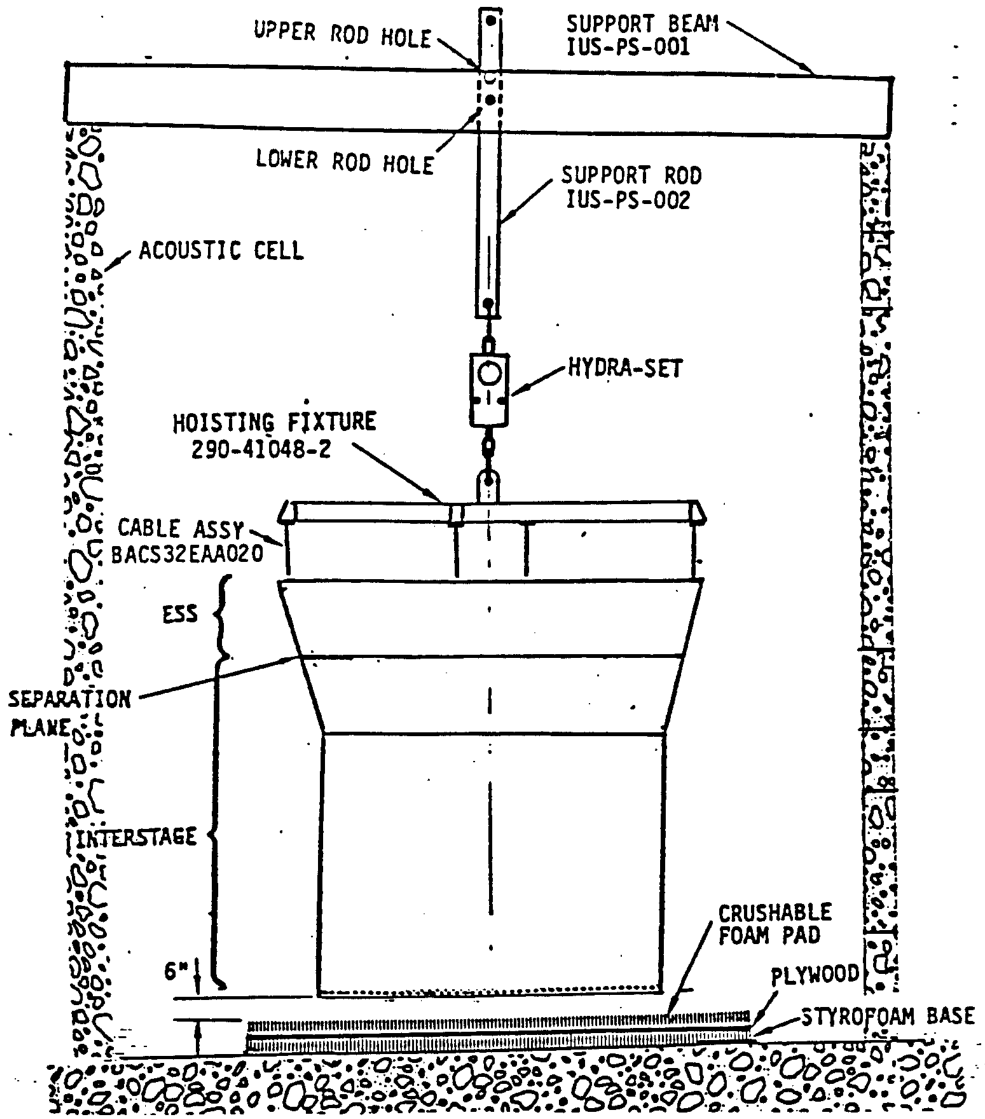

FIGURE 2-1 IUS QTV TEST CONFIGURATION

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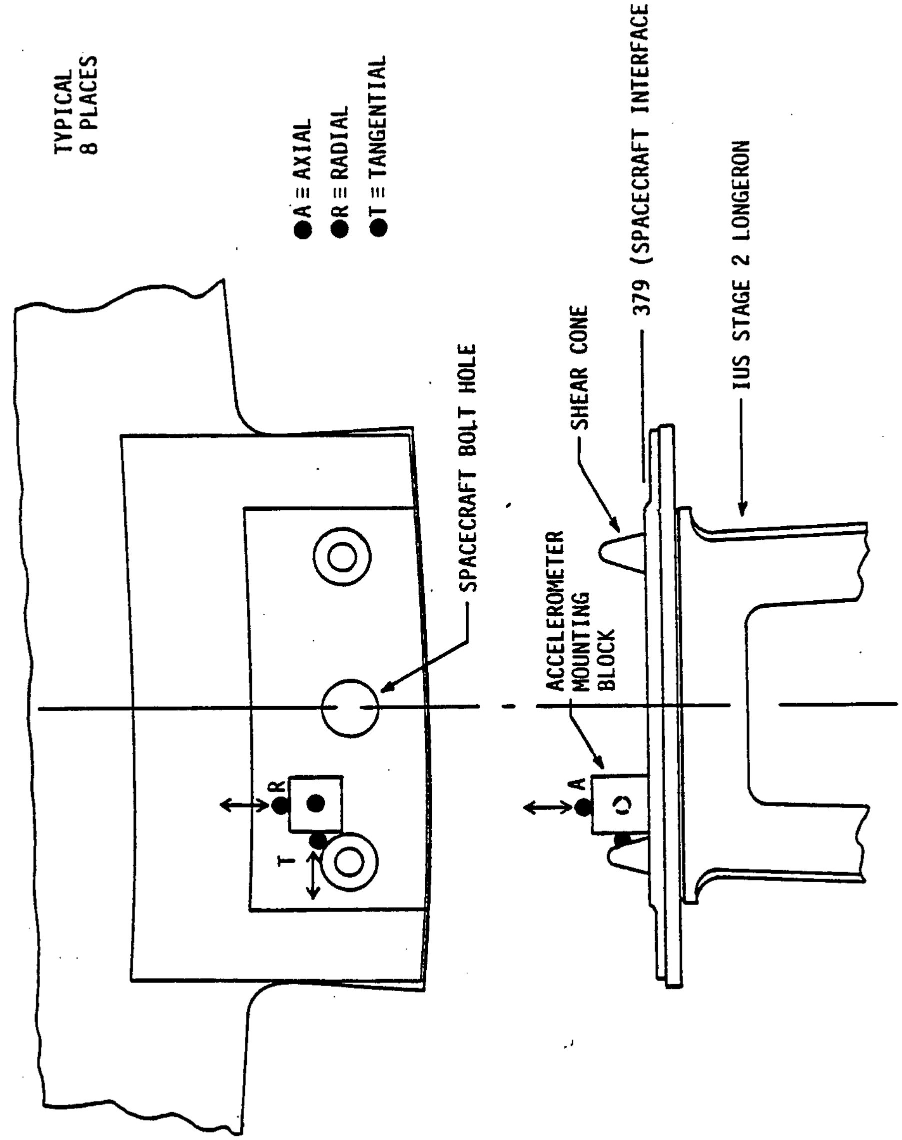
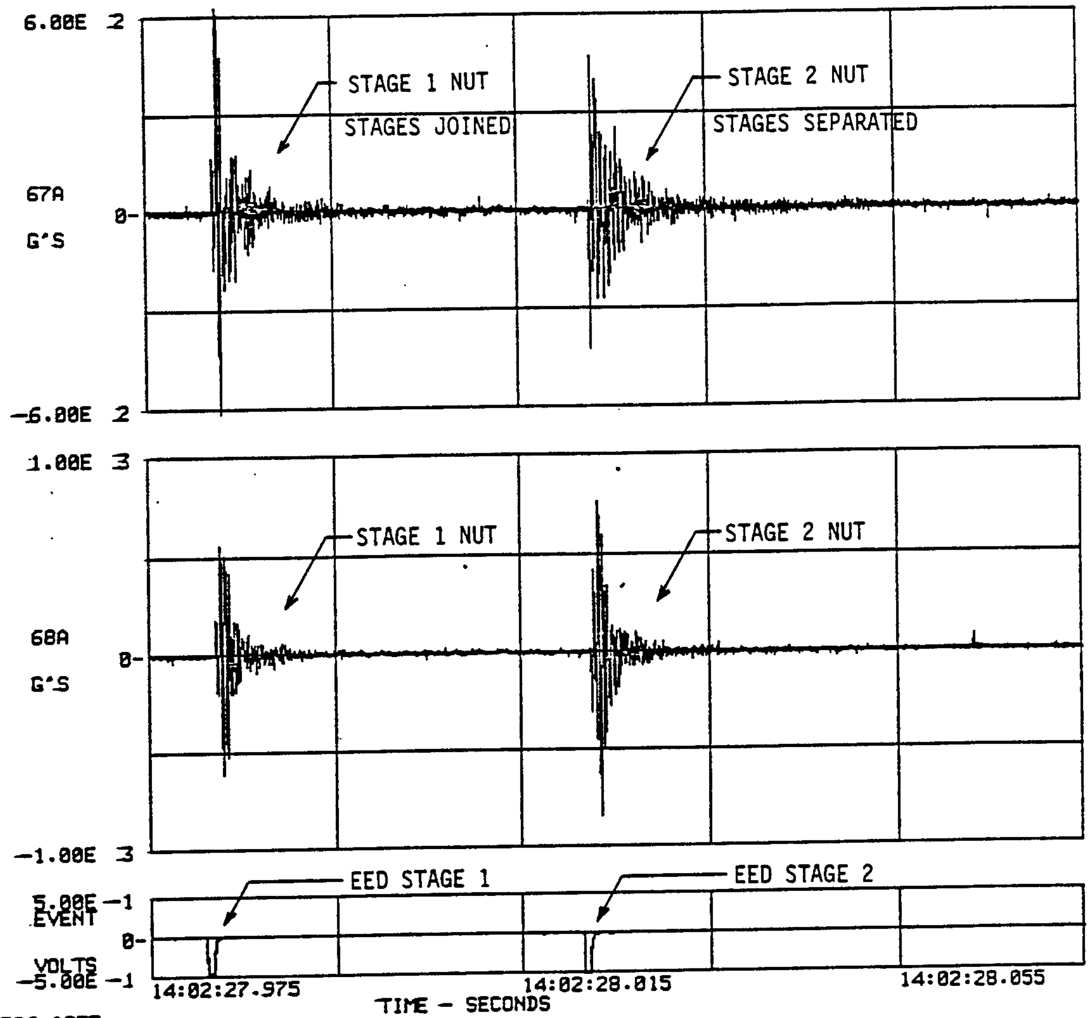


FIGURE 2-2 IUS QTV'INTERFACE INSTRUMENTATION



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CALC	MJC 5/06/81		IUS QTV PYRO-SHOCK TEST (NO S&A) SEPARATION TEST NO. 2
CHECK	TMT 5/7/81		
APPD			
APPD			

FIGURE 2-3 SHOCK TIME HISTORIES

12

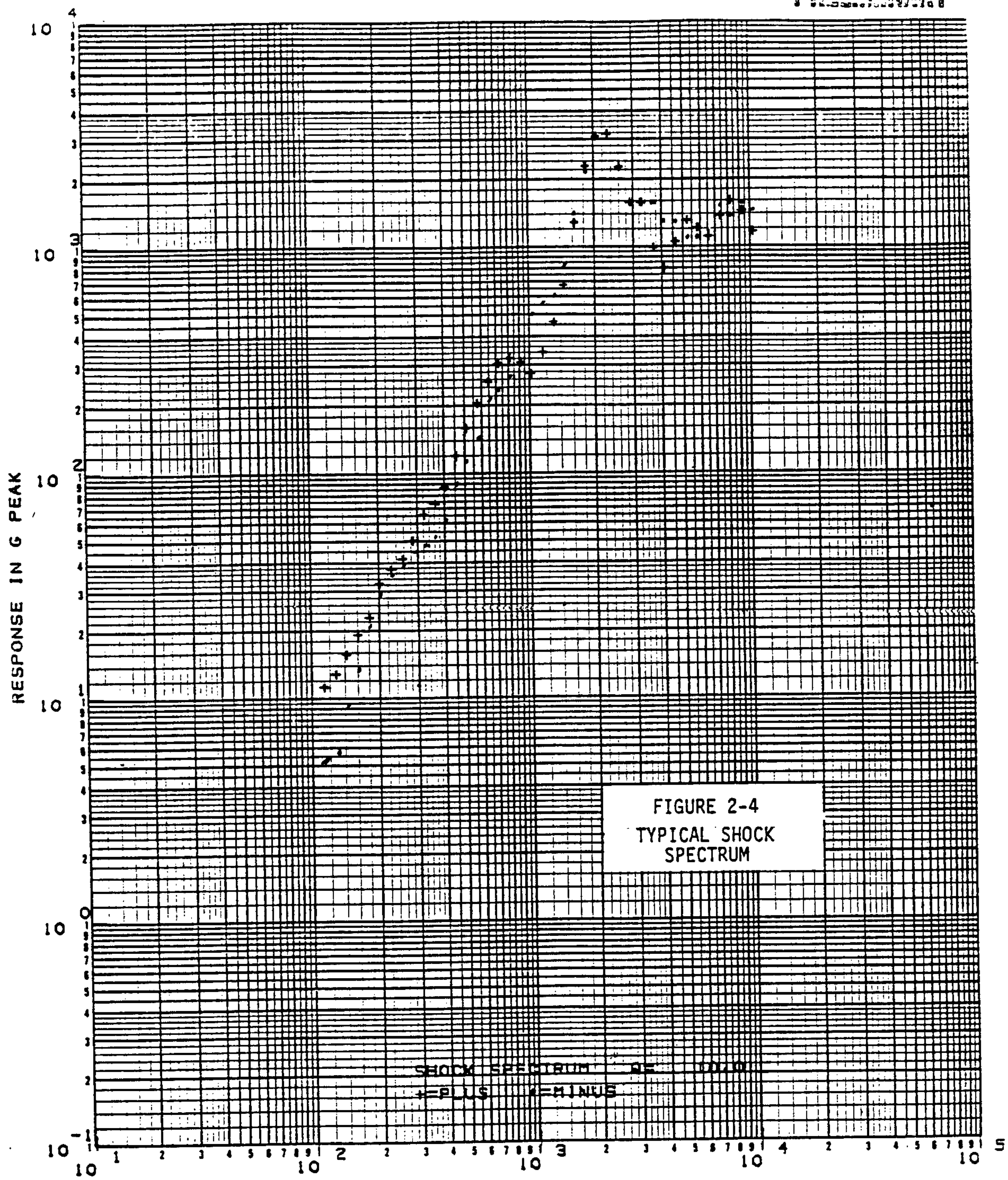

FIGURE 2-4
TYPICAL SHOCK SPECTRUM

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APPD					ACCELEROMETER NO 68A

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13

FORM X6151 orig. 6 68

LONGERON (ACCEL.)	AXIS	TEST 1 STG 1	TEST 1 STG 2	TEST 2 STG 1	TEST 2 STG 2	TEST 3 STG 1	TEST 3 STG 2
33° (61)	A	●	●	O	O	●	●
	R	●	●	●	●	●	●
	T	●	●	●	●	●	●
67.5° (62)	A	●	●	●	●	●	●
	R	●	●	●	●	●	●
	T	●	●	O	O	●	●
112.5° (63)	A	●	●	●	●	●	●
	R	●	●	●	●	●	●
	T	●	●	●	●	●	●
147° (64)	A	●	●	●	●	●	●
	R	●	●	●	●	●	●
	T	●	●	●	●	●	●
213° (65)	A	●	●	●	●	●	●
	R	●	●	●	●	O	O
	T	●	●	O	O	O	O
247.5° (66)	A	●	●	●	●	●	●
	R	●	●	●	●	●	●
	T	●	●	O	O	●	●
292.5° (67)	A	●	●	●	●	●	●
	R	●	●	●	●	●	●
	T	●	●	●	●	●	●
327° (68)	A	O	O	●	●	●	●
	R	O	O	●	●	●	●
	T	●	●	●	●	●	●

● VALID

O NOT VALID

TEST #1 15 MAY 81

TEST #2 6 MAY 81

TEST #3 11 MAY 81

FIGURE 2-5 DATA VALIDITY SUMMARY

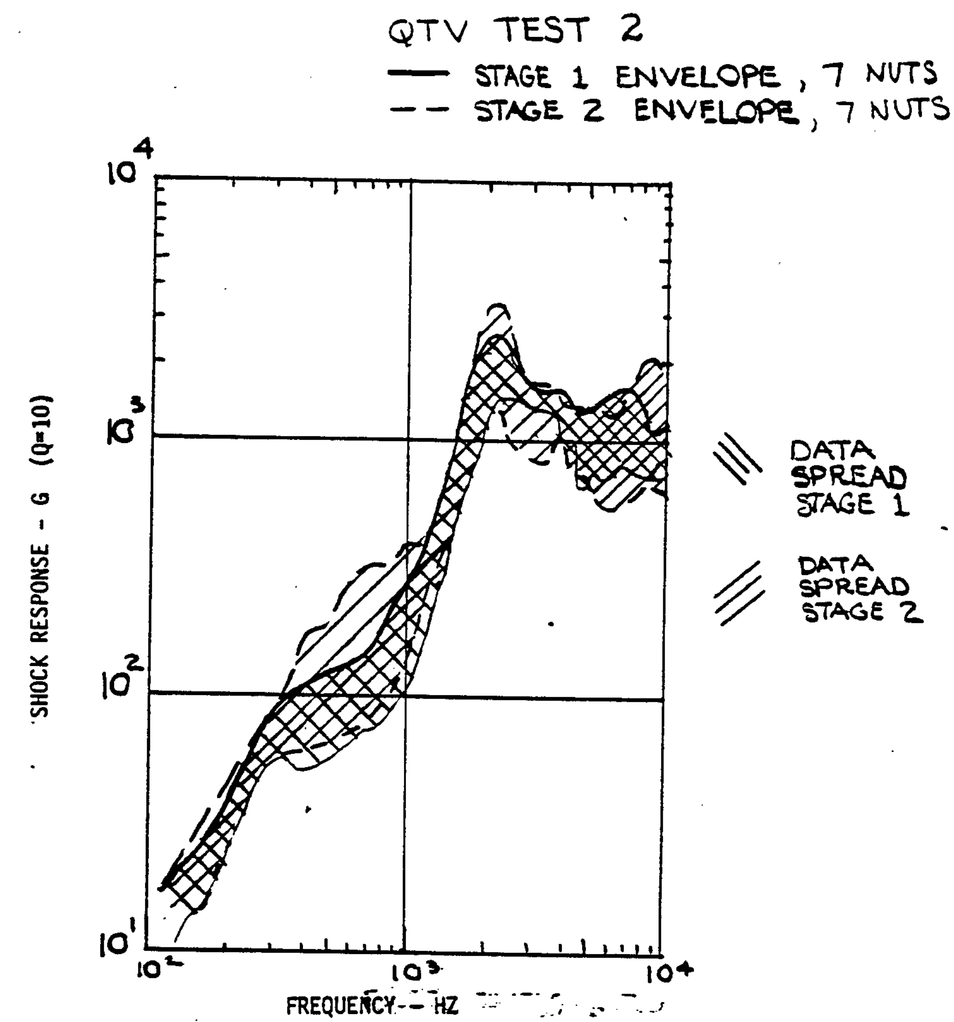


FIGURE 2-6
STA 379 AXIAL
STAGE 1 NUT vs. STAGE 2 NUT
QTV TEST 2

15

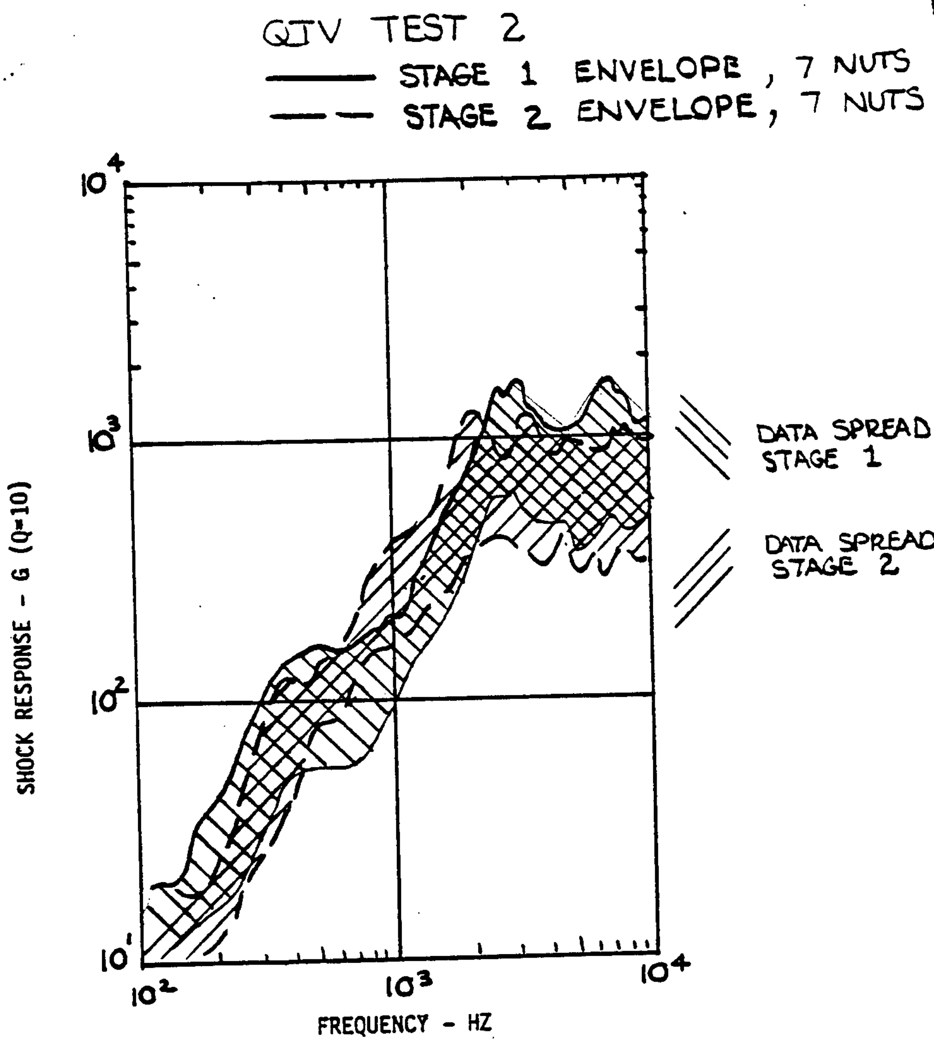


FIGURE 2-7
STA 379 RADIAL
STAGE 1 NUT vs. STAGE 2 NUT
QTV TEST 2

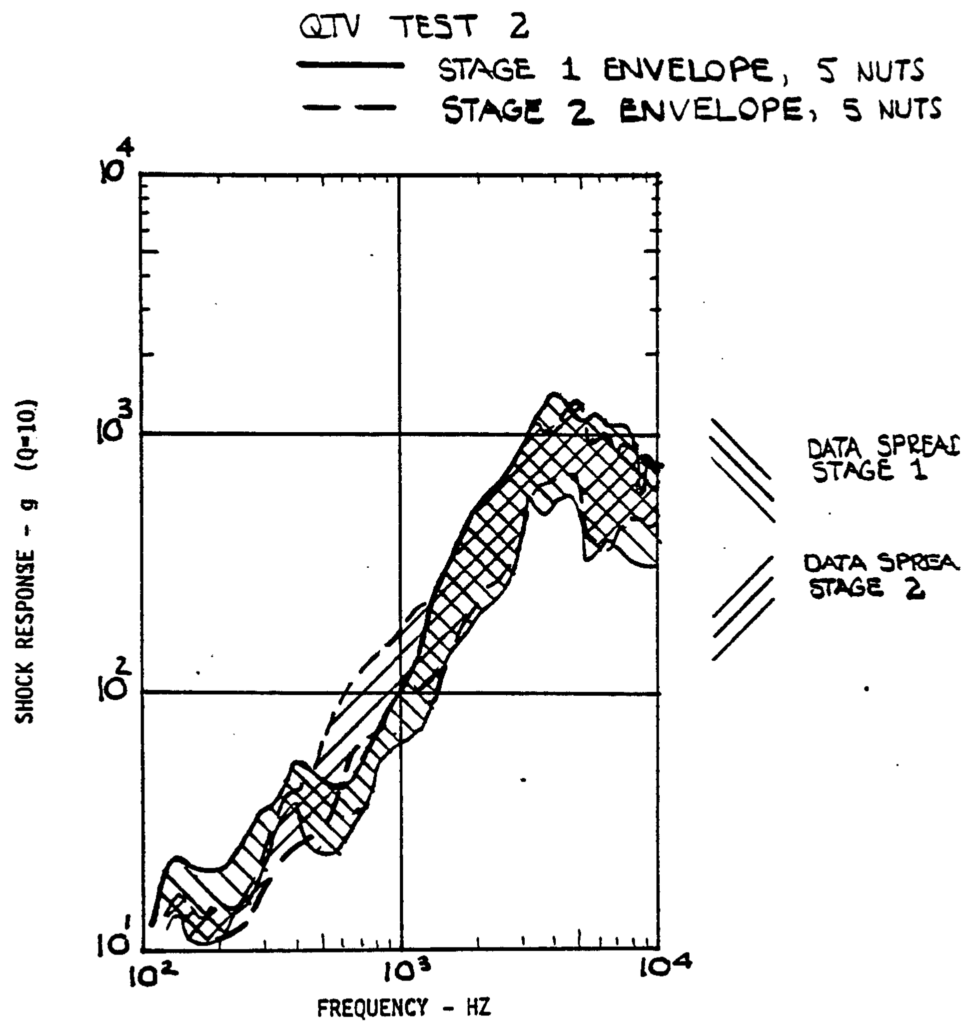
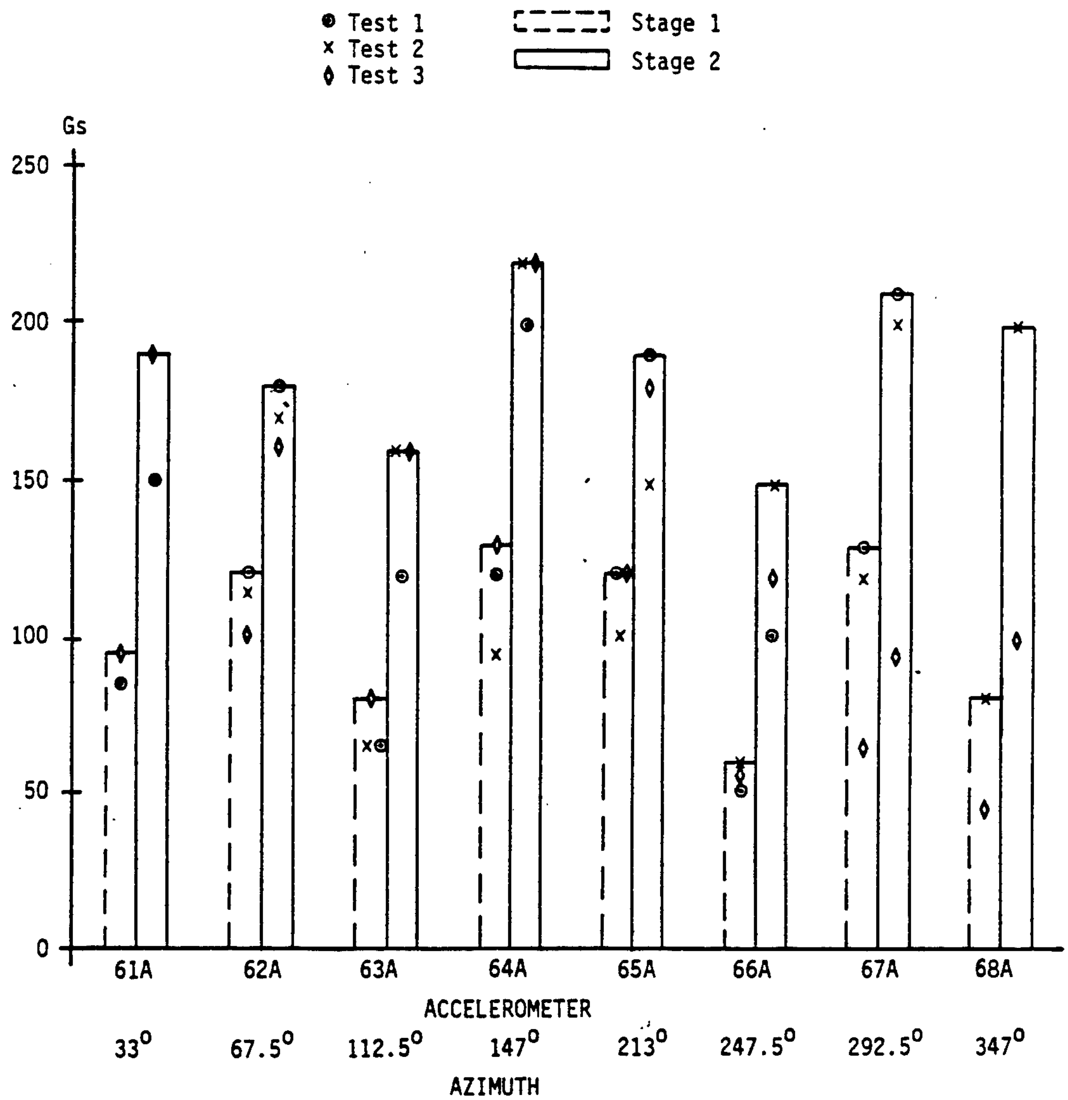


FIGURE 2-8
STA 379 TANGENTIAL
STAGE 1 NUT vs. STAGE 2 NUT
QTV TEST 2

17

Figure 2-9

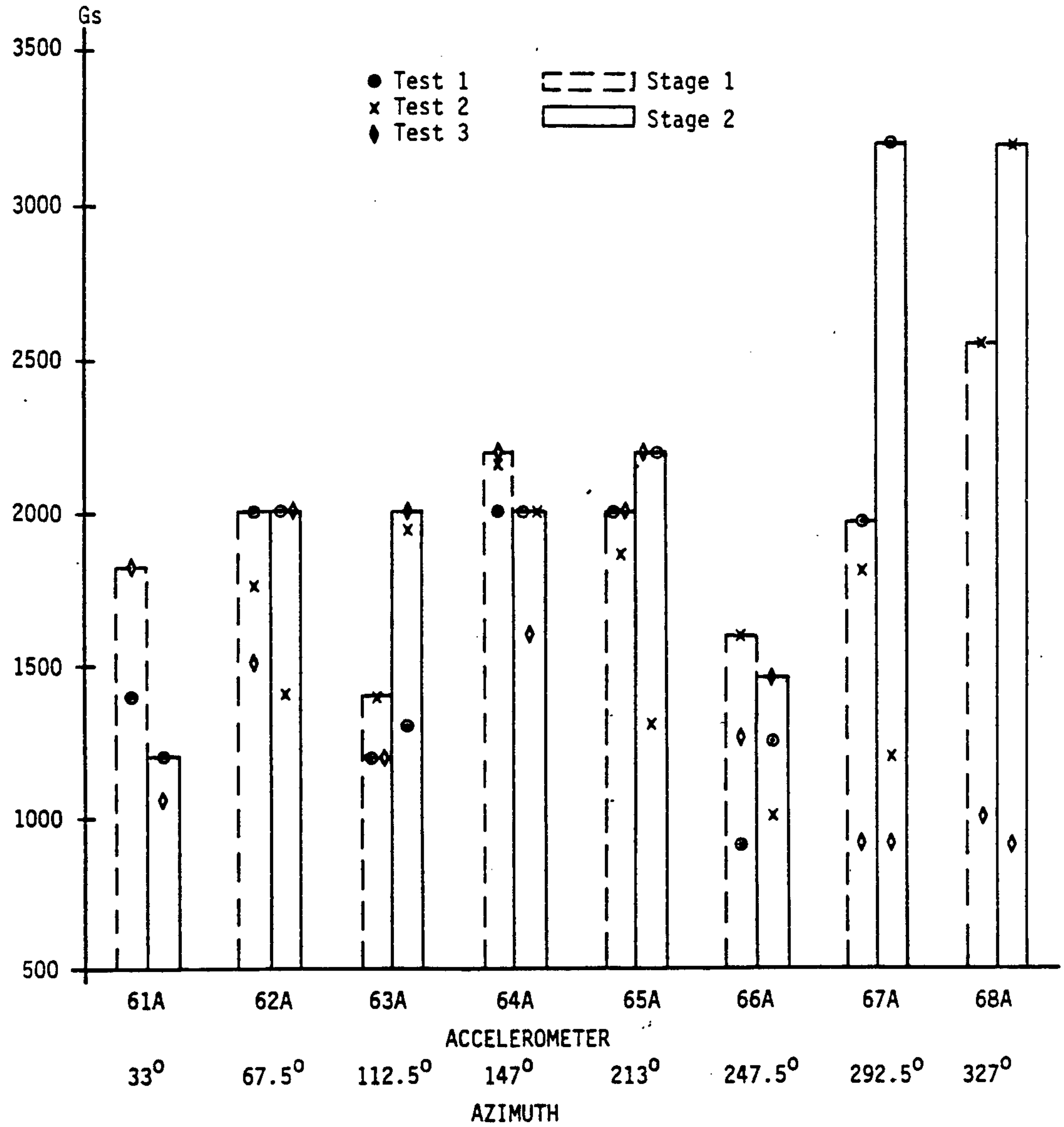
379 INTERFACE
MAXIMUM SHOCK SPECTRA
f = 556 Hz
AXIAL



BOEING

Figure 2-10

379 INTERFACE
MAXIMUM SHOCK SPECTRA
f = 2226 Hz
AXIAL

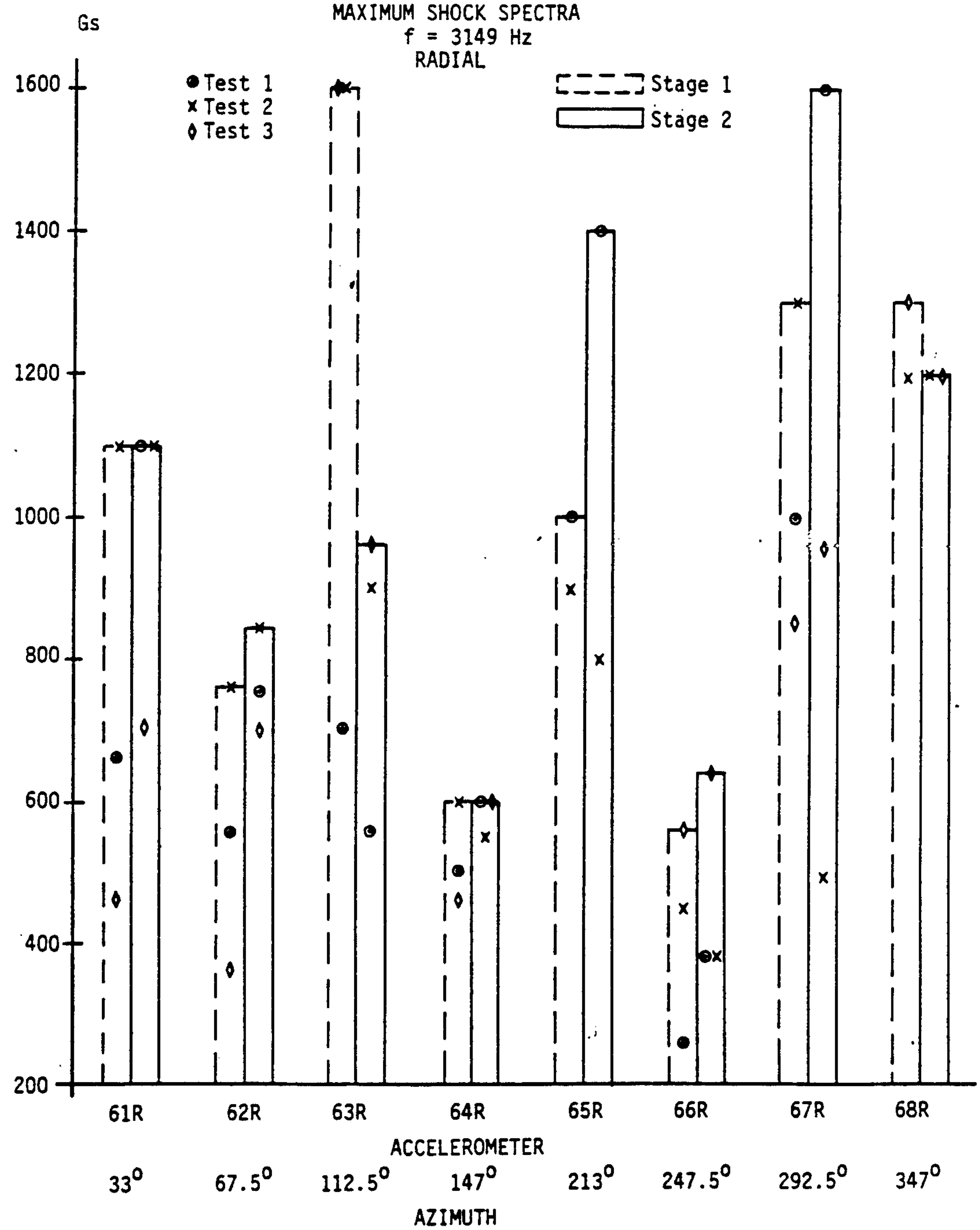


19

DO 6000 2140 ORIG. 4/71

Figure 2-11

379 INTERFACE
MAXIMUM SHOCK SPECTRA
f = 3149 Hz
RADIAL



DO 6000 2140 ORIG. 4/71

Figure 2-12

379 INTERFACE
MAXIMUM SHOCK SPECTRA
f = 7070Hz
RADIAL

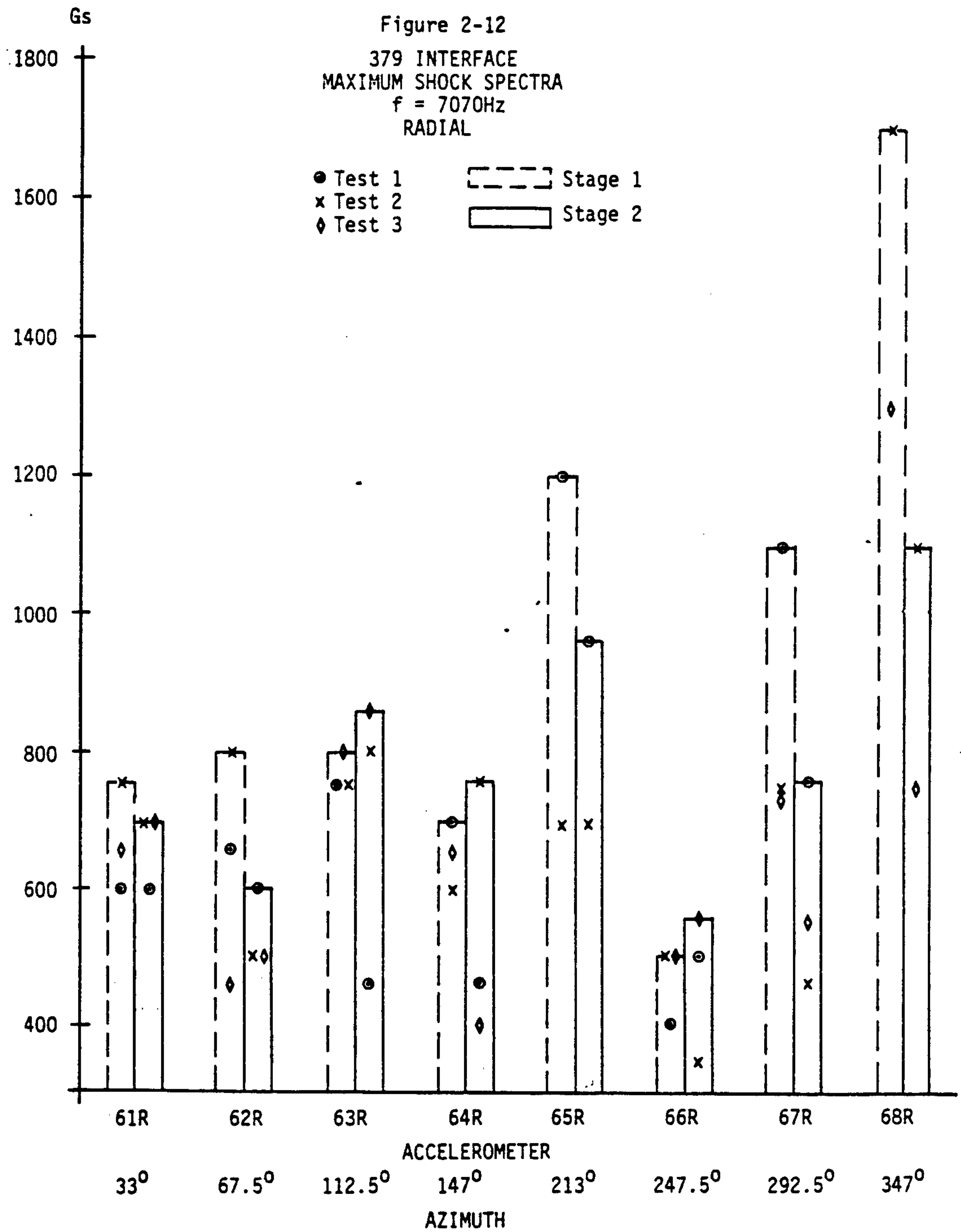


FIGURE 2-13

TABULATION OF QTV SHOCK STATISTICS 379 INTERFACE

AXIS	FREQ (Hz)	P95/50* (GS)	$\bar{X}$ (GS)	S (GS)	MAX (GS)	MIN (GS)	N	NO. OF EVENTS >P95/50
Axial	556	211	128	50	220	45	44	3
	1113	436	281	94	650	140	44	2
	2226	2559	1675	536	3200	900	44	2
	3149	1649	1116	323	1700	500	44	2
	7070	1811	1067	451	2000	400	44	4
Radial	556	159	115	26	190	60	44	3
	1113	440	266	105	500	120	44	3
	2226	1285	774	310	2000	340	44	1
	3149	1419	830	357	1600	260	44	3
	7070	1133	706	259	1700	350	44	3
	8908	1025	653	225	1200	300	44	3
Tang	556	66	40	15	80	15	40	4
	1113	231	138	56	280	65	40	2
	3967	1313	803	309	1400	360	40	2
	7070	1228	665	341	2200	300	40	2

* $P95/50 = \bar{X} + K_N S$

P95/50 = Ninety-fifth percentile with 50 percent confidence based on a one sided tolerance limit. Reference paragraph 3.19 of MIL-STD-1540A.

N = Number of events

$\bar{X}$ = Average of N events

S = Standard Deviation

KN ≈ 1.65 for $N \geq 40$

The P95/50 value was calculated using shock response values in GS read from the shock spectra.

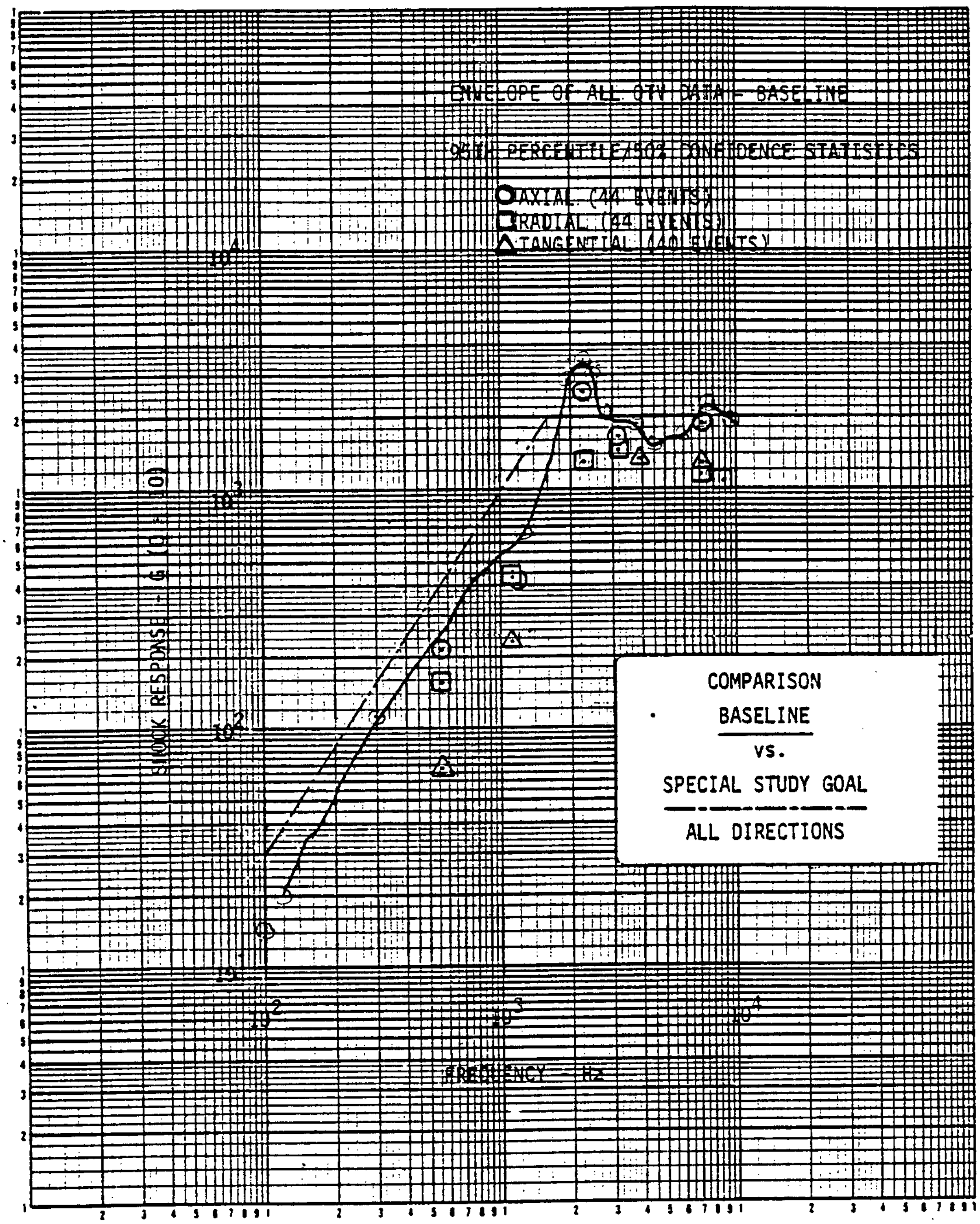


FIGURE 2-14

CALC	CBeck	9/24/81			IUS INDUCED SHOCK ENVIRONMENT BASELINE IUS/SPACECRAFT INTERFACE
CHECK					
APPD					
APPD					

SHEET
23

FORM X6151 orig. 6-68

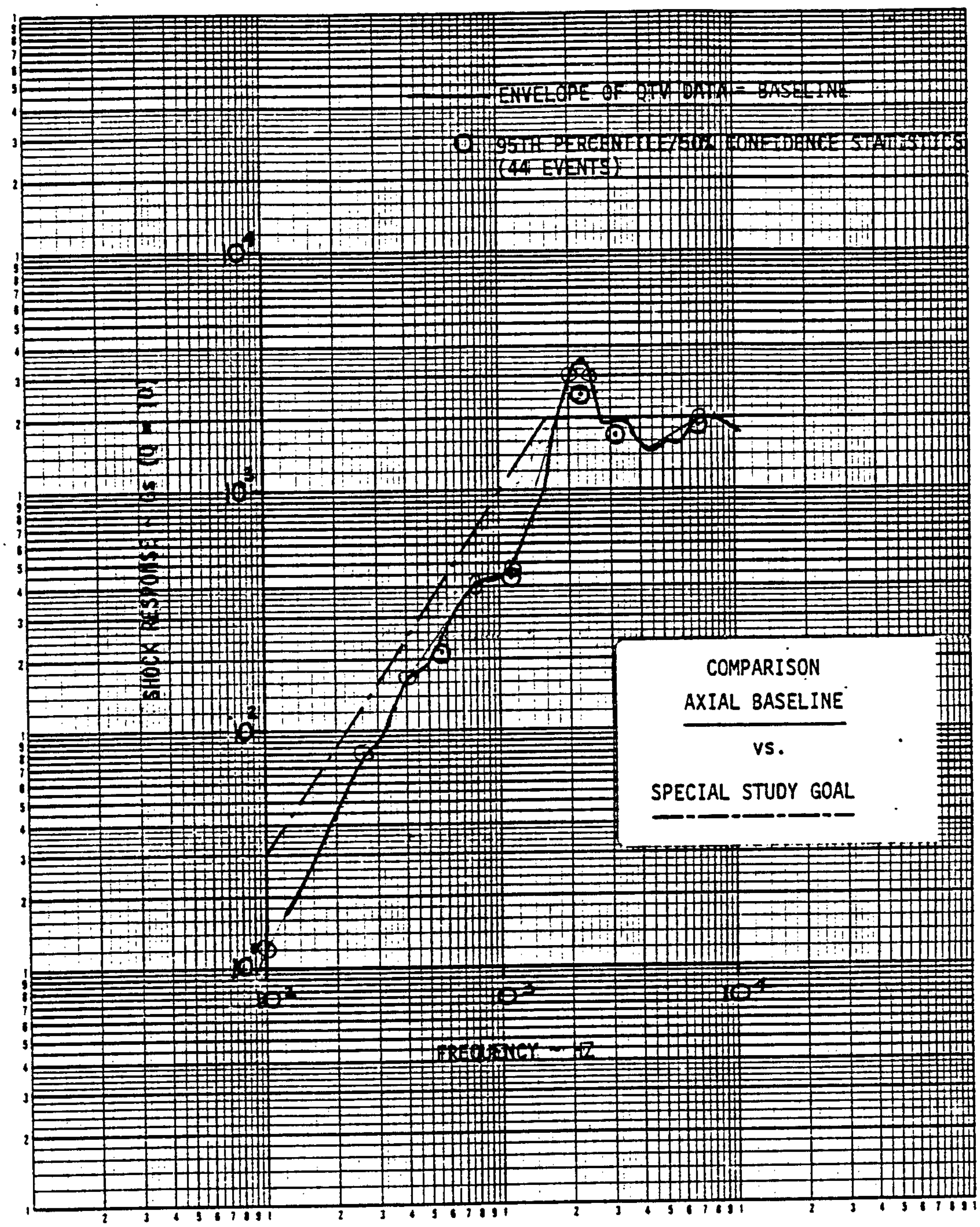


FIGURE 2-15

CALC	C/Sock 9/12/81			IUS INDUCED SHOCK ENVIRONMENT IUS/SPACECRAFT INTERFACE AXIAL DIRECTION
CHECK				
APPD				
APPD				

SHEET
24

FORM X6151 orig. 6/68

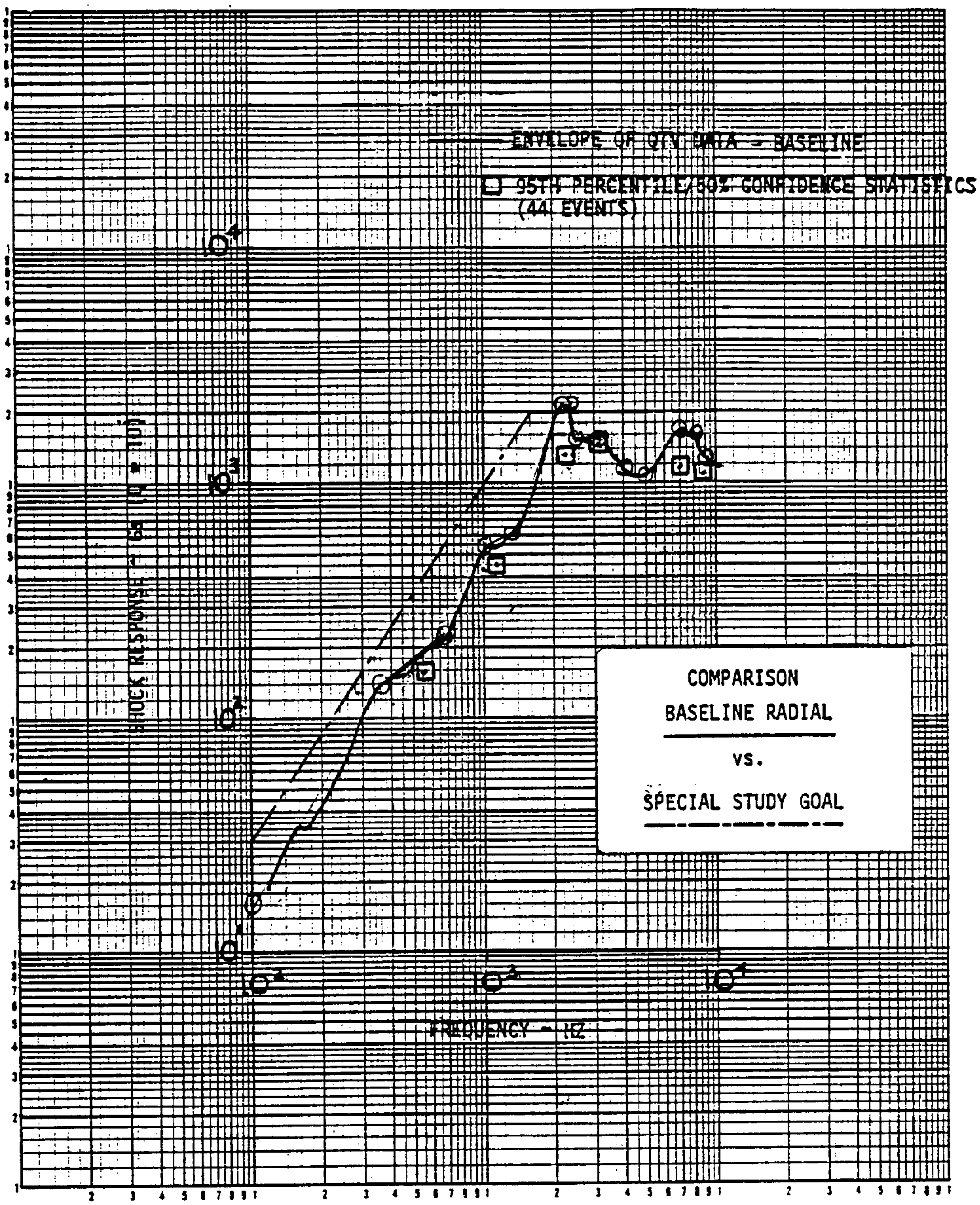


FIGURE 2-16

				IUS INDUCED SHOCK ENVIRONMENT IUS/SPACECRAFT INTERFACE RADIAL DIRECTION
CALC	C Beck	6/12/3		
CHECK				
APPD				
APPD				

SHEET
25

FORM X6151 orig. 6/68

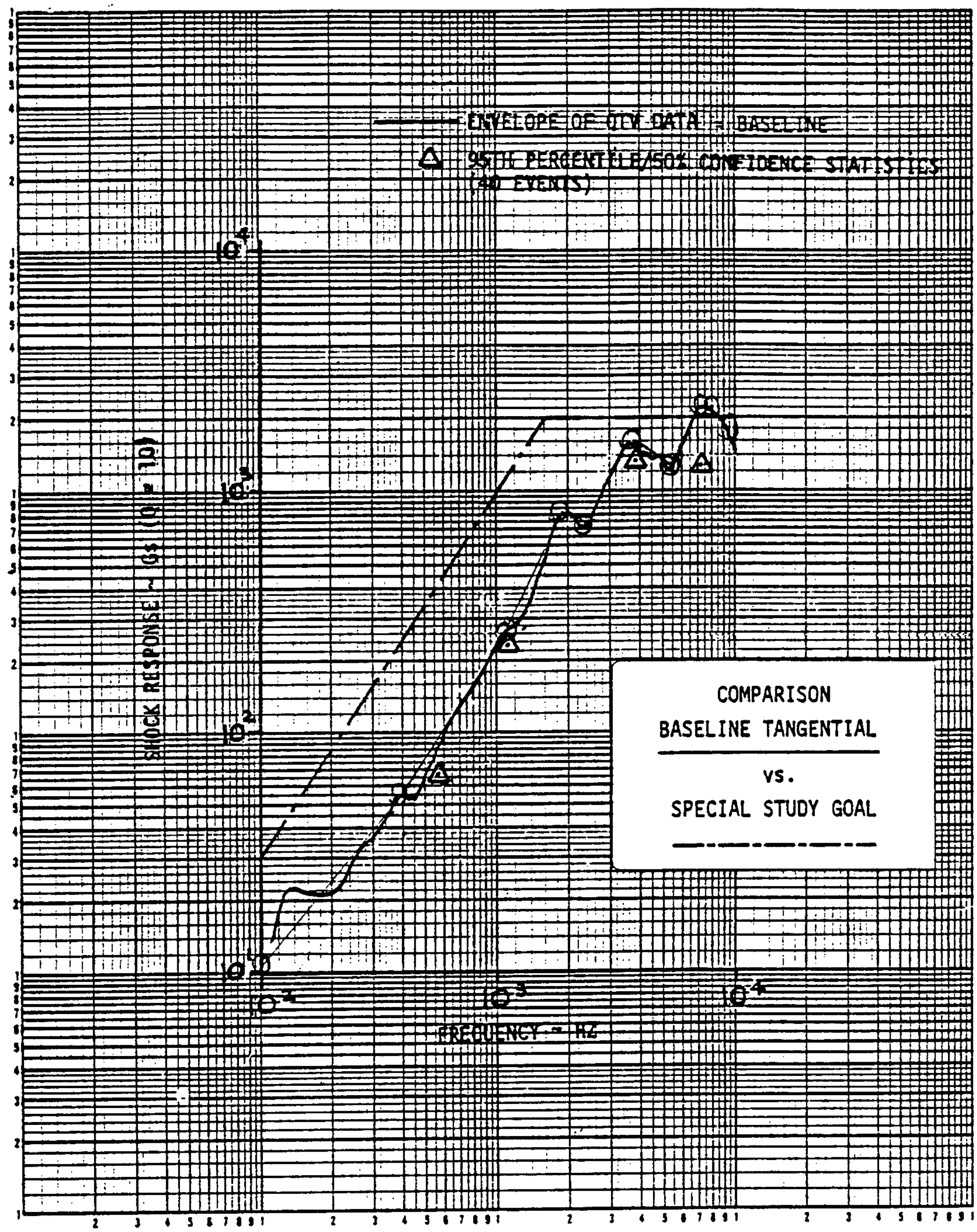


FIGURE 2-17

CALC	-B	6/24/81		IUS INDUCED SHOCK ENVIRONMENT IUS/SPACECRAFT INTERFACE TANGENTIAL DIRECTION
CHECK				
APPD				
APPD				

SHEET
26

FORM X6151 orig. 6/68

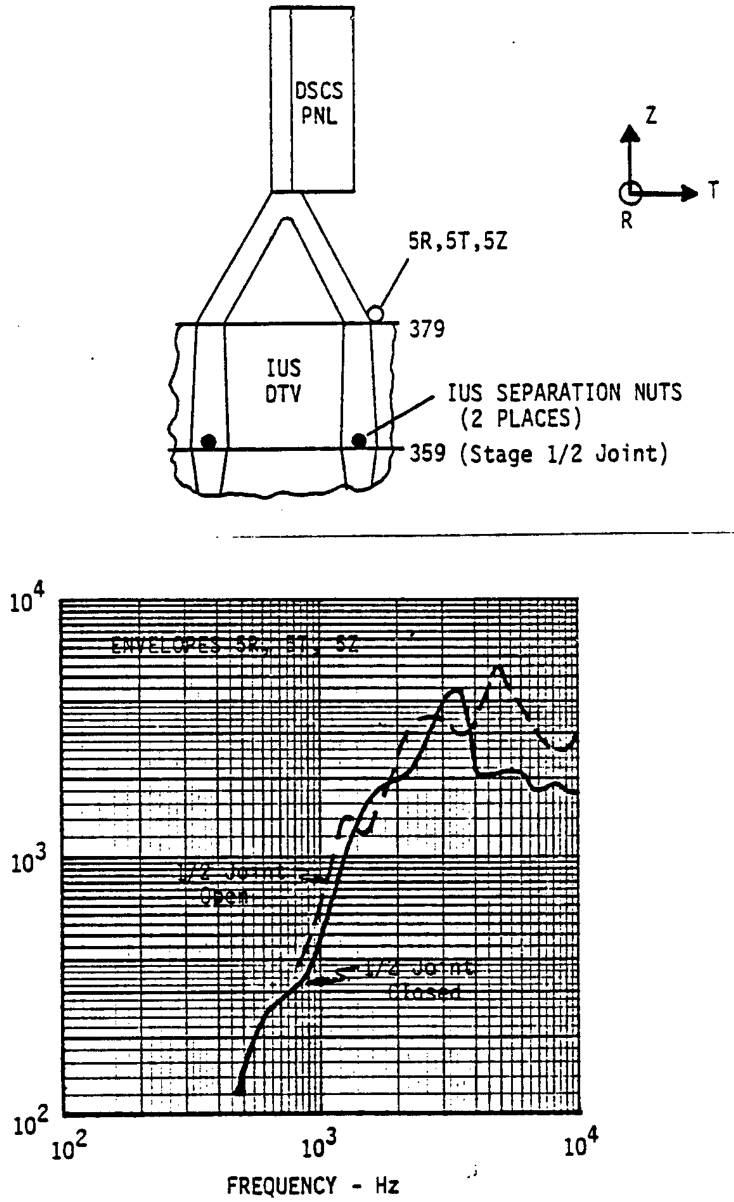


FIGURE 3-1

COMPARISON OF SHOCK LEVELS
IUS STAGE 1/2 JOINT OPEN AND CLOSED
DSCS/IUS TEST, OCTOBER 1980

27

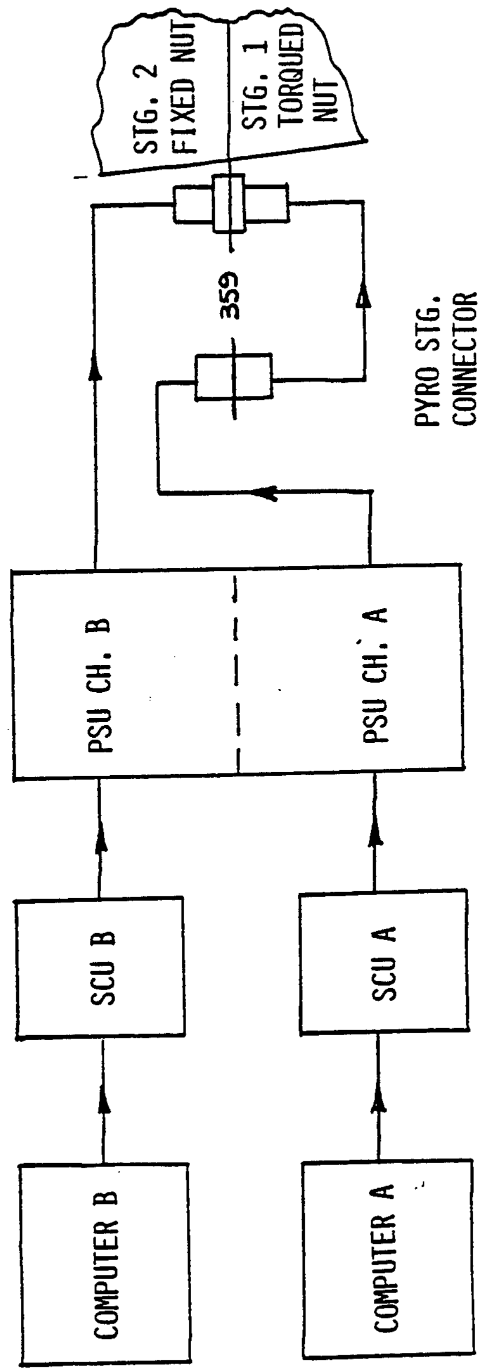
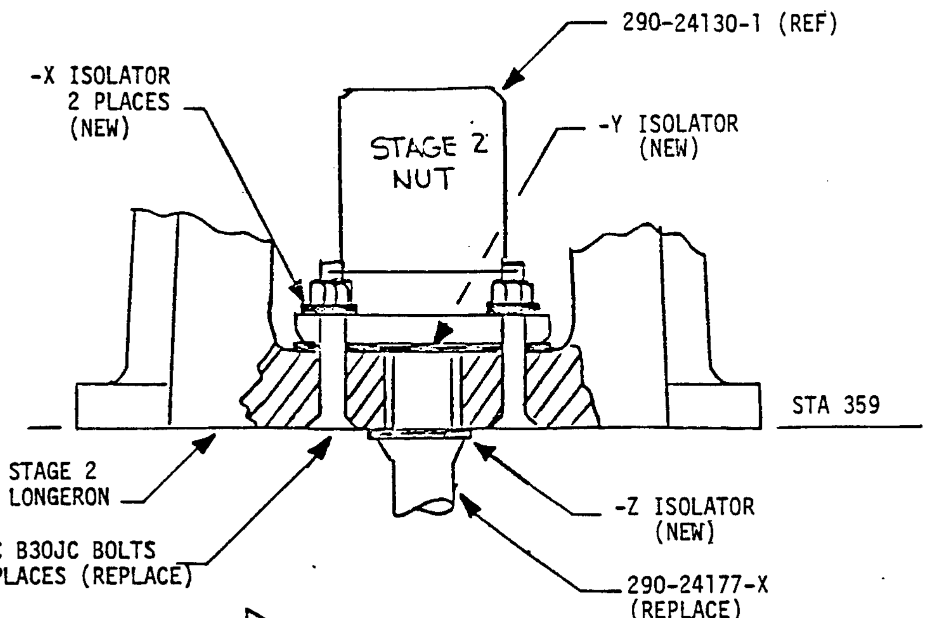


FIGURE 3-2
IUS STAGE 1-2 SEPARATION SYSTEM SCHEMATIC

28

FIGURE 3-3
STAGE 2 NUT ISOLATION DESIGN



MATERIAL LIST [*]

CATEGORY	PART NO.	QTY [*]	DESCRIPTION
NEW	-X	2	Isolating washer assy .75 OD, .38 ID, [1] thick Material [1]
NEW	-Y	1	Isolating washer assy 2 OD, 1 ID, [1] thick Material [1]
NEW	-Z	1	Isolating washer assy 1.5 OD, 1 ID, [1] thick Material [1]
REPLACE	290-24177-X	1	Similar to 290-24177-1, increase length
REPLACE	BACB30JC	2	Increased length

[*] Quantity per longeron, 8 sets per vehicle

[1] Thickness & Matl TBD based on development test. Assume 2 alum, 2 steel (.05 in/layer)

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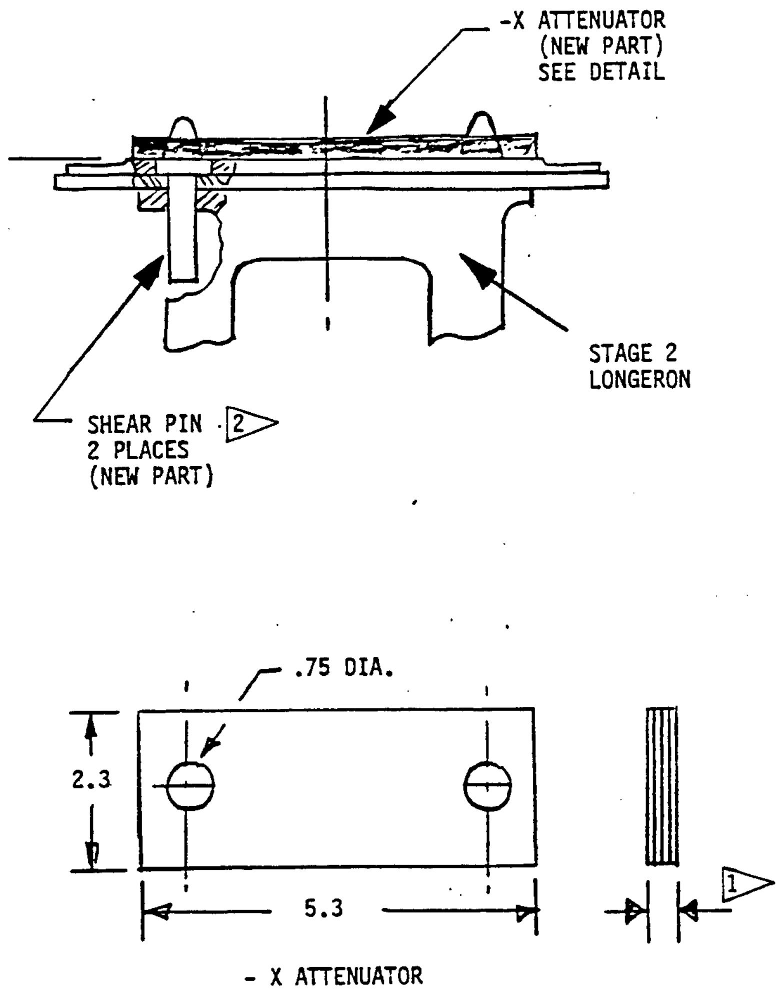
TYPICAL INSTALLATION
8 LOCATIONS/IUS



1 ATTENUATOR THICKNESS TBD BASED ON DEVELOPMENT TEST. ASSUME 2 LAYERS STEEL, 2 LAYERS ALUMINUM (APPROX. 0.05 IN/LAYER) FOR PRICING.

2 SIMILAR TO 290-24187

FIGURE 3-4
INTERFACE ATTENUATOR DESIGN

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APPENDIX

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Technique #1

Reverse firing order of IUS Stage I/II separation device

Electrical conductors from channels A and B of the PSU for detonation of the EED bridgewires in the Stage I/II separation nuts must be reversed or a software change is required to change the order of firing the explosive nuts. It is recommended that the conductors be reversed.

A development test is required to verify that the electrical conductors to the torque nuts (interstage side) will not break before the fire pulse to the bridgewires is accomplished. If the EED in the torque nuts cannot be detonated, this technique would result in a Stage I/II separation circuit that had a potential single point failure. The probability of this failure occurring is 348×10^{-6}. This is unacceptable.

If a break in the conductors does occur before the firing pulse can be issued to the torque nuts on the stage I side, then the staging connector design must be changed to increase the connector separation time.** Shortening the delay time between fire pulses from channels A and B is not considered feasible. To make the delay between pulses 20ms, as has been suggested, would require making changes in two software modules. First, the two pulses must be changed to issue from the same 40ms time frame. Second, the priority interrupt logic must be modified to give the stage I/II separation command (M16) priority over antenna switching command (M37). Software should be consulted on this. This change is believed to be extensive.

Manufacturing Description

IUS Wire Harness PEI 290E63A: Revise wire harness W152 to reroute 8 TSP #20 wires from P144 to P145 and reroute 8 TSP #20 from P145 to P145. (Note: For completed wire harness W152 a total of 16 TSP #20 wire pairs must be removed and replaced)

Materiel Parts List

Development and qualification of new pyro staging connectors similar to 280-33019-103 and 280-33019-104 and replace J289 on wire harness W152 and P289 on wire harness W154 with the new pyro connectors.

*Note: The need for a pyro staging connector change will require an analysis by Dynamics to determine if the connector pins separate from the socket before the fire pulse detonates the torque nuts on the Stage I side of the Stage I/II interface, and possibly a development test to verify the analysis findings.

** See page 36 of this report.

Technique #2 - Inhibit firing of the fixed nut IUS Stage I/II

Firing only those fixed nuts (ESS side) where the torque nuts (interstage side) did not open the Stage I/II joint.

Stage I/II Separation System Description:

Implementation of technique number 2 can be accomplished by adding a stage I/II separation switch in series with each enable switch in the PSU that is used to enable the fire circuit for an explosive bridgewire in a stage I/II separation nut. This requires eight separation switches; one each for the explosive bridgewire in each fixed nut of the separation device. Each separation switch is a DPDT switch.

One set of the normally open contacts is used for the fire circuit and is used to disable that particular circuit. If the stage I separation nut has fired and the stage I/II has separated, the switch will open and disable the circuit.

Another set of the normally closed contacts in each of the eight switches are connected in series and connected to the SCU measurement processor to verify that stage separation has been accomplished and to provide LRU fault isolation data in the event of a failure in this system.

See Figure 1 for system block diagram, Figure 3 for an electrical schematic and Figure 2 for a layout of the added electrical components (Stages I/II separation switches).

Features:

No avionics LRU changes

Minimum software change - one discrete for telemetry downlink in channel B

Modest stage 2 electrical wire harness change

8 new separation switches required for stages I/II separation indication.

Manufacturing Description:

Modify wire harness PEI 290E63A as follows:

Add a total of 32 TSP #20 wires via the use of 8 plugs (P/N 280-33010-24SN) interfacing with 8 new separation switch assemblies (similar to P/N 290-27408-1)

NOTE: The above wires will be utilized to interconnect the SCU, PSU, separation switch and pyro staging connector J289.

Materiel Parts List:	Qty/Vehicle
Separation Switch 280-41012-101	8
Connector 280-33012-24PN	8
Connector 280-33010-24SN	8

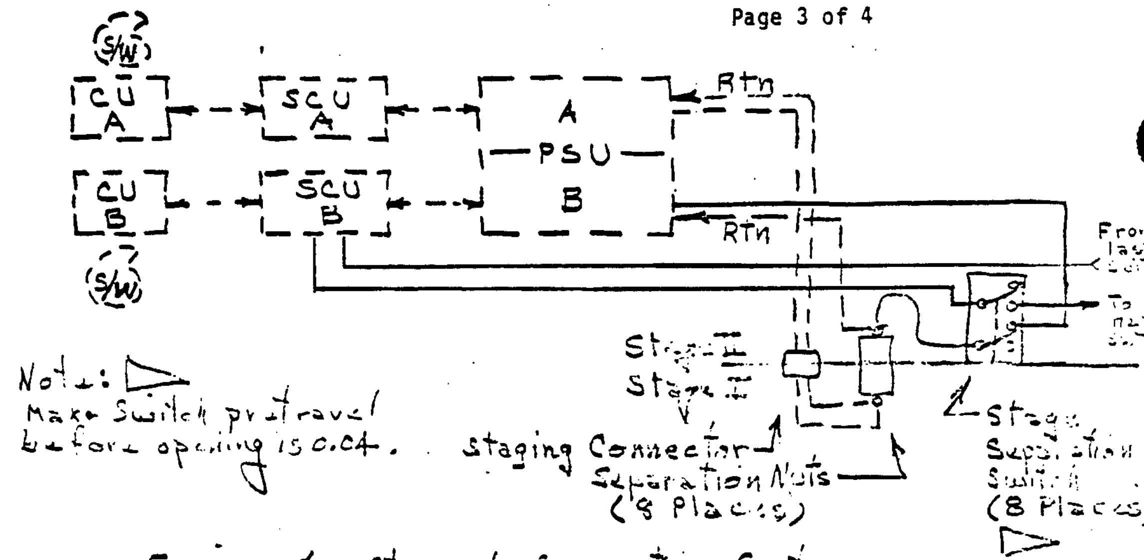


Figure 1 - Stage I/II Separation System

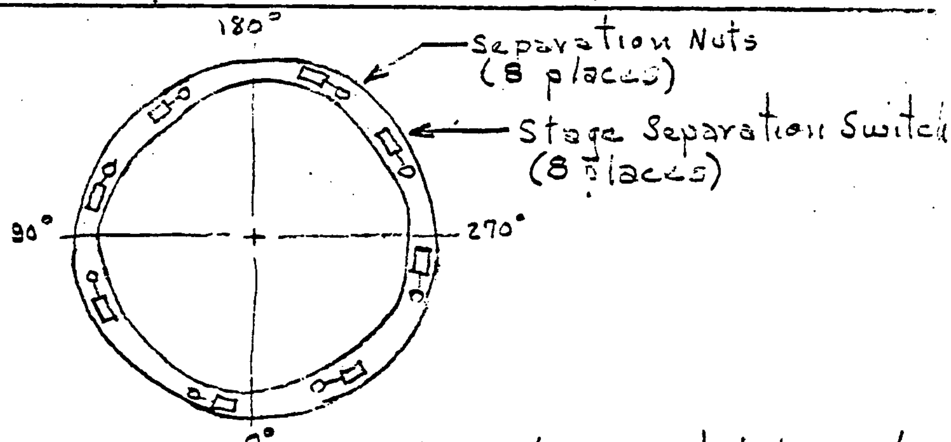
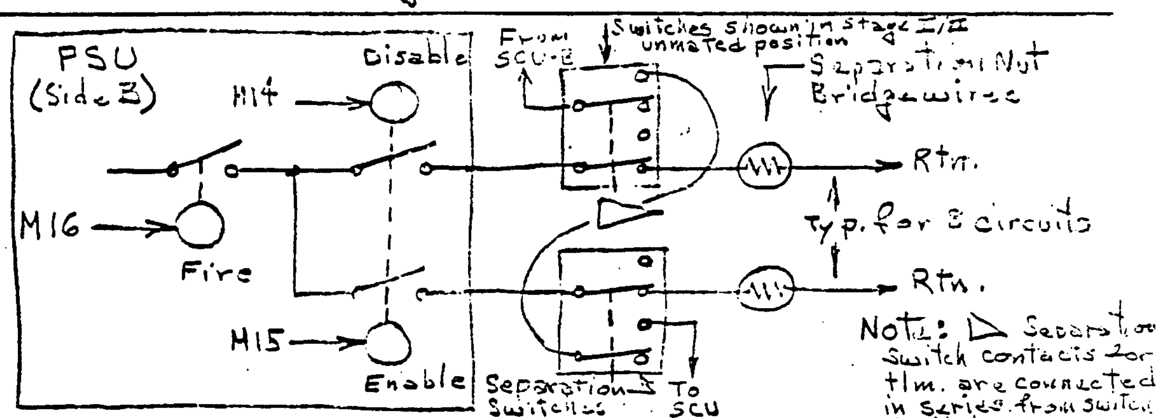


Figure 2 - Stages I/II Separation Switch Layout
(Stage II Side of Interface)



34 Figure 3 - Stage I/II Separation System Electrical Schematic

Technique #3 - Simultaneous firing of the 16 separation devices, IUS Stages I/II

System cannot perform simultaneous firing of the nuts on both sides of the separation device without a major redesign. The variation in tolerance build up in time between each avionics channel from fire command initiation until execution, and limitations in queing between channels to issue "simultaneous" commands from each channel prevent a simultaneous firing. The closest that issuance of Commands from each channel can be with respect to each other is 5 milliseconds.

Technique #4 - Shock isolation on IUS Stage I/II separation devices

Mechanical solution - no avionics impact

Technique #5 - Attenuate shock at IUS/Spacecraft interface

Mechanical solution - no avionics impact

BOEING

April 27, 1981
2-3944-0010-375

To:	S. M. Church	8K-89
	[redacted]	[redacted]
	Larry Judd	8K-85
	Tom McNasser	8K-84
	Jerry Hyde	8A-83
	Les Adams	8A-83
	Don Hurley	8K-89
	Dave O'Harrow	8K-89
	W. D. Newton	8W-02
	Tom Cunningham	8A-77
	Curt Gnagy	8K-89
	Don Cooper	8A-80
	Max Dodd	8K-61
cc:	C. H. Price	8R-38
	R. S. Winters	8K-89

Subject: Pyro Shock Reduction, Special Study FSD-81-003, Technique No. 1, Reverse Firing Order

Reversing the firing order of the separation nuts to reduce the pyro shock would appear to introduce a single point failure with respect to Stage 1/2 separation. The firing pulse is carried through the pyro staging connector P/J 289 located at Station 359.0 and azimuth 118.5°. A tolerance analysis of the pin/socket engagement shows that with a .226 separation of Stage 1/2 the pins are disengaged from the sockets. This would not be a problem provided all of the fixed, Stage 2, nuts fired properly. However, if the nut at 292.5° did not fire and the separation of pyro connector had occurred, the Stage 1 nut would not fire and separation could not be achieved.

The relationship of the staging connectors, push off springs and separation nuts are shown in Figure 1. It would appear that this relationship, combined with a maximum delay of the second firing pulse, could produce a "hinge" action about the separation nut at 292.5° producing .226 separation at P/J 289 (included angle of .127°).

If this problem can be resolved, response to the assigned tasks follows:

TASK 1) "Identify design changes, drawing and documentation changes required to implement shock reduction technique."

Revise the ESS assembly drawings to incorporate a new wire harness installation, creating a new part number. This new part number would then require changes to 16 additional engineering drawings and documents. This assumes the part number of the IUS vehicle would change.

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TASK 2) "Identify analyses and/or tests required to verify design change. If tests are required, provide a test outline including test configuration."

An analysis must be performed to verify the stud is "captured" by the bolt catcher when the free nut is fired. Figure 2 shows the separation interface prior to staging, Figure 3 shows the interface just prior to firing stage 1 separation nut.

A test would have to be run using an ESS and interstage longeron to verify the actual shock reduction. This would require the procurement of Separation Nuts (290-24130-1 and 290-24130-2) and preload washers (290-24325-1) and the fabrication of studs (290-24177-1) and spacers (290-24225-1).

TASK 3) "Evaluate impact of design change on IUS qualification."

Impact dependent upon Task 2 analysis and test.

TASK 4) "Provide a manpower estimate and schedule for accomplishing design change and associated analyses."

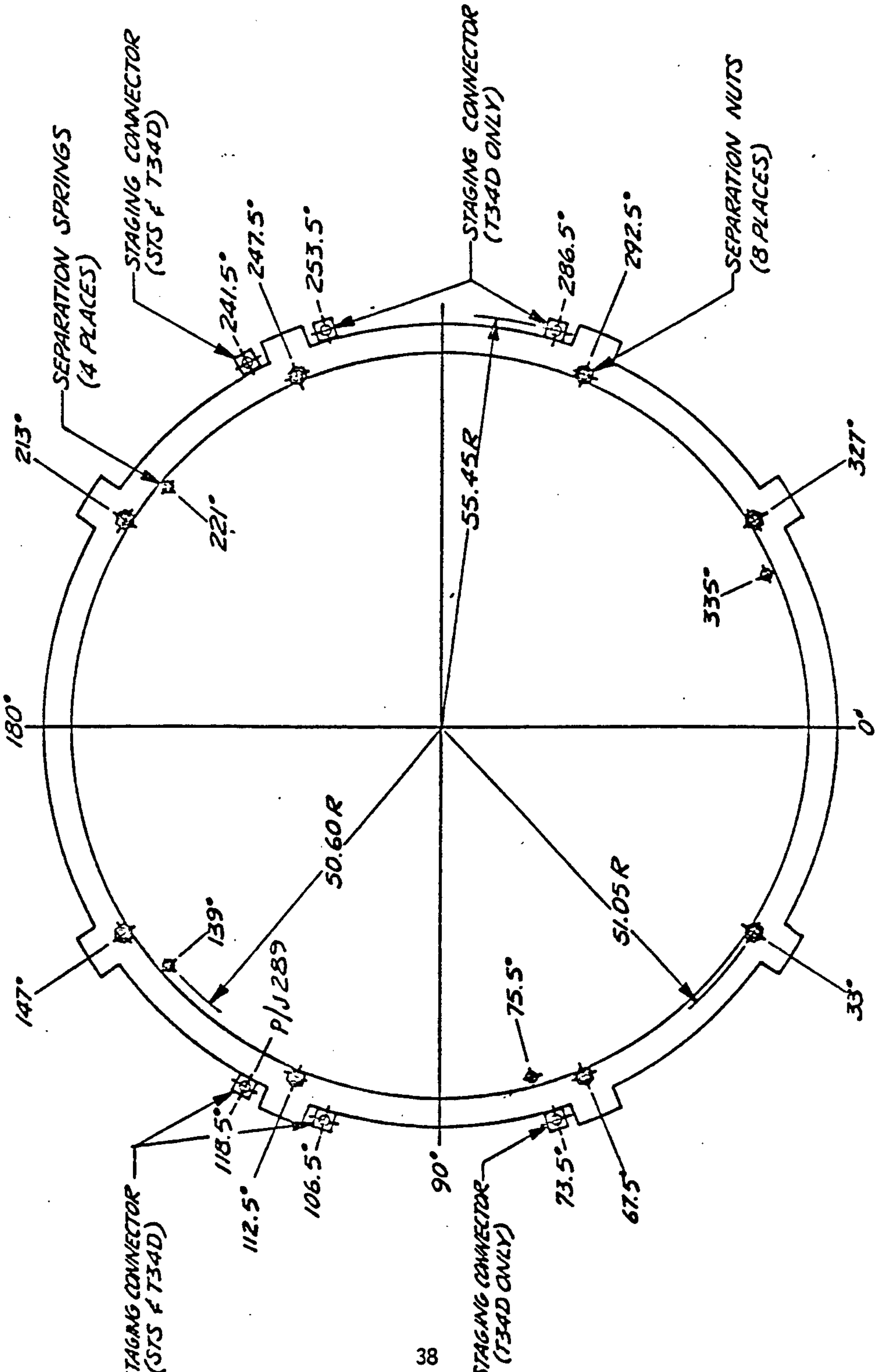
This change would require approximately 6.1 M/M of engineering budget and could be incorporated into the engineering drawings within approximately 6 months after authorization.

Prepared by G. V. Hard 4/20/81
G. V. Hard

Approved by A. D. Watson 4/21/81
A. D. Watson

Attachment

STAGE I - II SEPARATION



38

FIGURE 1

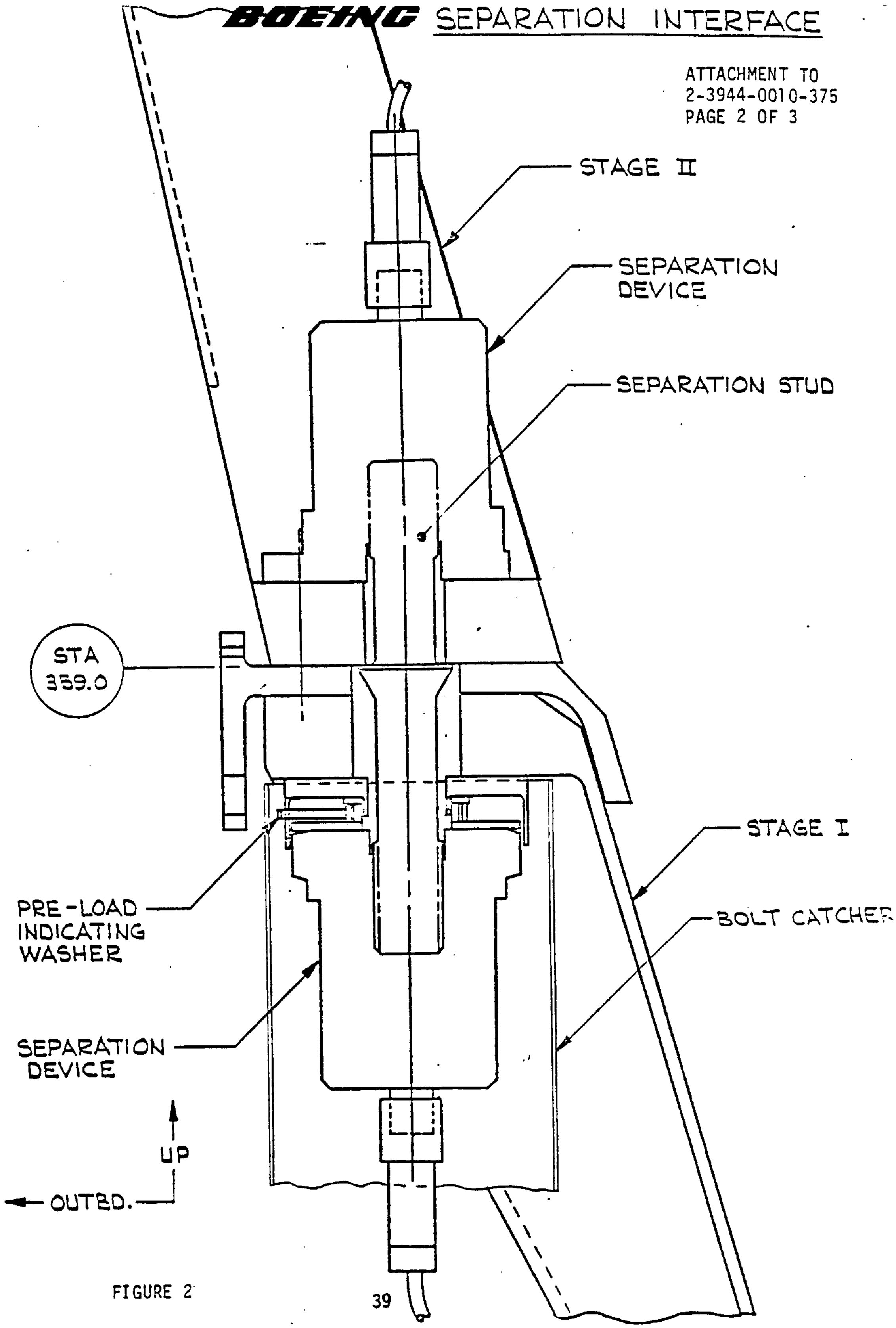

BOEING SEPARATION INTERFACE
STAGE II
SEPARATION DEVICE
SEPARATION STUD
STA 359.0
STAGE I
BOLT CATCHER
PRE-LOAD INDICATING WASHER
SEPARATION DEVICE
UP
OUTBD.

FIGURE 2

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SEPARATION INTERFACE - REVERSE FIRING

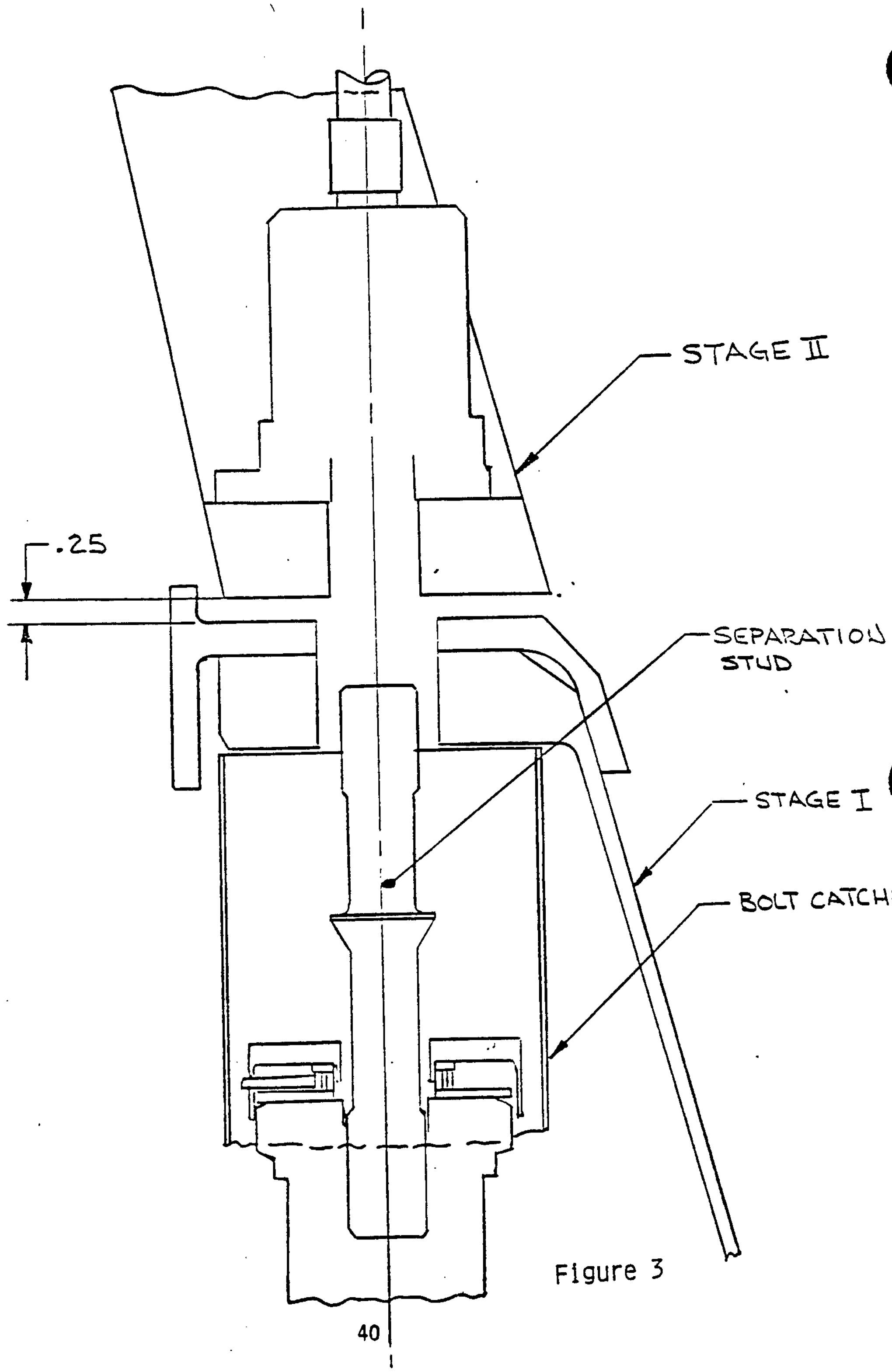


Figure 3

40

4.0 ASE PIN PULLER SHOCK

Measurements of pyrotechnic shock generated by activation of pin pullers on the ASE are presented in this section.

BOEING

October 7, 1982
2-3612-IUS-716

To: E. L. Cowgill 8A-78

cc: B. T. Takatsuka 8R-37

Subject: ASE AFTA and Umbilical Pin Puller Shock Test

Comparisons of pin puller shock test data and the corresponding component qualification levels are presented in Figures 1 to 17.* These comparisons show that there are no exceedances of the acceptance levels for any component at any frequency.

The data for the Right Hand AFTA at Pivot Bracket support (Accel's 8X, 8Y, 8Z), the Isolated PCU (N13) (Accel's 14X, 14Y, 14Z) and the Controller (N18) (Accel's 18N, 18T, 18X) and the Right Hand AFTA (Accel 44X) are the envelopes of three tests. The data for the WBDI (Accel's 17X, 17Y, 17Z) and the DC-DC Converter (Accel's 42X, 42N, 42T) are the result of only one test. For the WBDI, a margin in excess of 30 dB exists for each axis at all frequencies. For the DC-DC Converter, a margin exists in excess of 20 dB at all frequencies.

Comparisons of data taken on the Forward-Aft ASE Trunnion and the Aft-Aft ASE Trunnion and the Orbiter ICD are presented in Figures 18 to 20 and 21 to 23 respectively. The data is an envelope of the three tests made. No exceedances of the ICD limit exist at any frequency.

Comparisons of envelopes of the data taken on the IUS trunnion ring during the umbilical pin puller test and envelopes of the separation nut source shock data taken during the QTV qualification test are presented in Figures 24 to 26. The separation nut source shock was measured at the 292.5° longeron. The comparisons show that the separation nut shock is significantly more severe than the shock resulting from umbilical release. The IUS vehicle components are qualified for shock separation of eight separation nuts. All IUS vehicle components are therefore qualified with satisfactory margins for the umbilical release shock environment.

* These data were obtained during the ASE Mechanical Functional Test, Test Report 22B5-038R.

Prepared by R. F. Hain
R. F. Hain

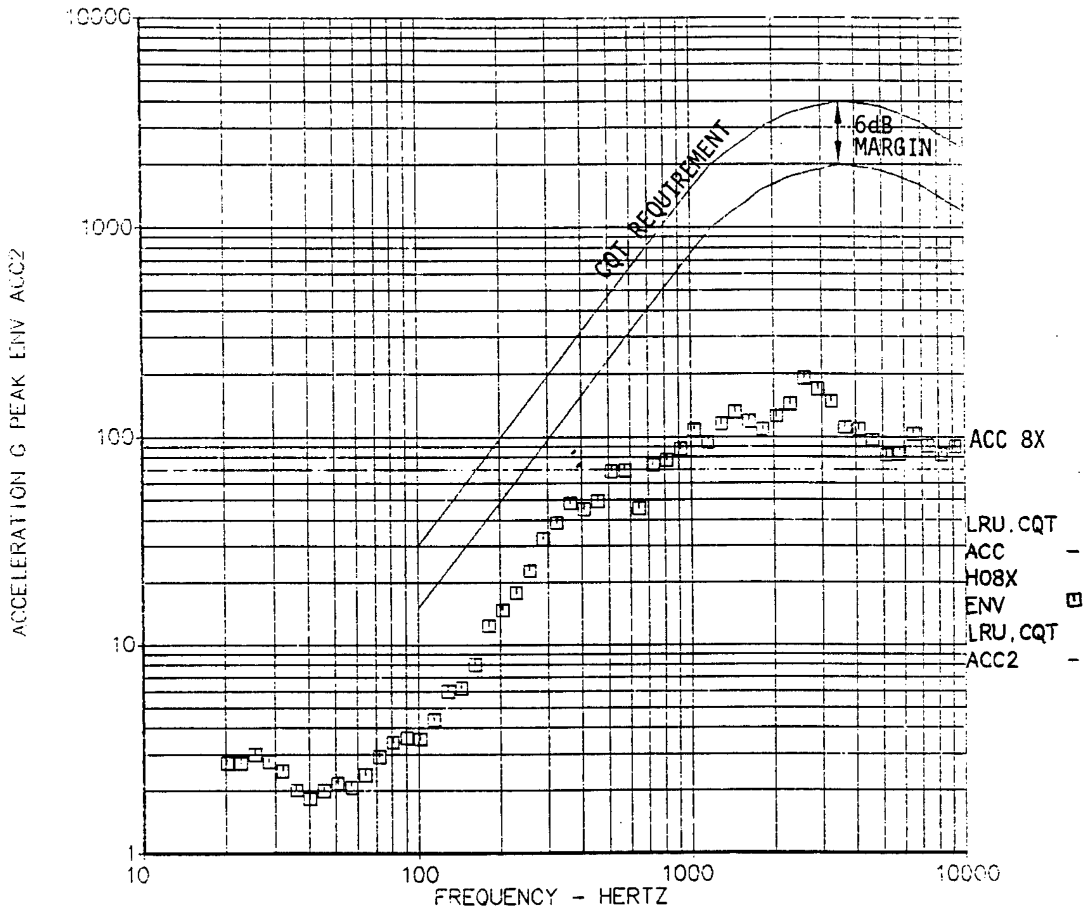
AWS

Approved by S. M. Church 10/7/82
S. M. Church

Attachment

FIGURE 1

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

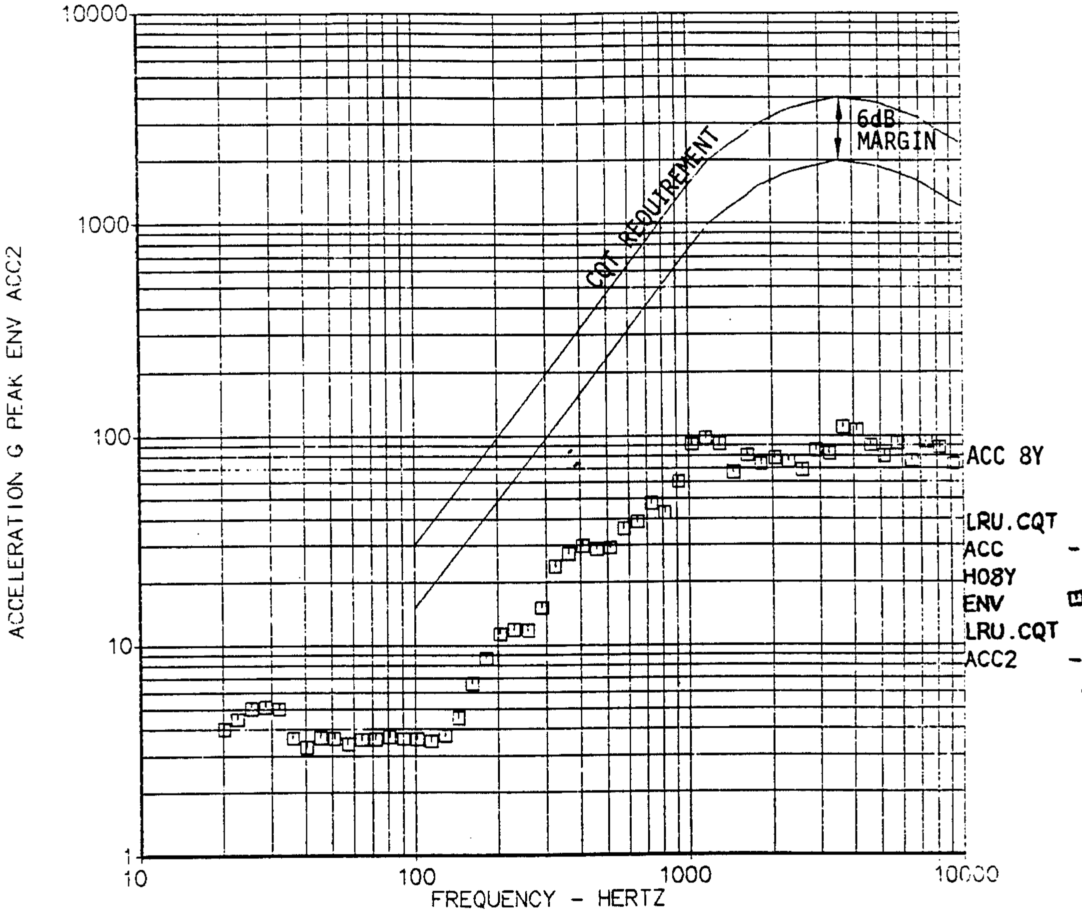


25-MAY-82 17:40:13

CALC	25MAY82	REVISED	DATE	RH AFTA PIVOT BRKT	
CHECK					
APPD.					
APPD.				THE BOEING COMPANY	PAGE

FIGURE 2

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

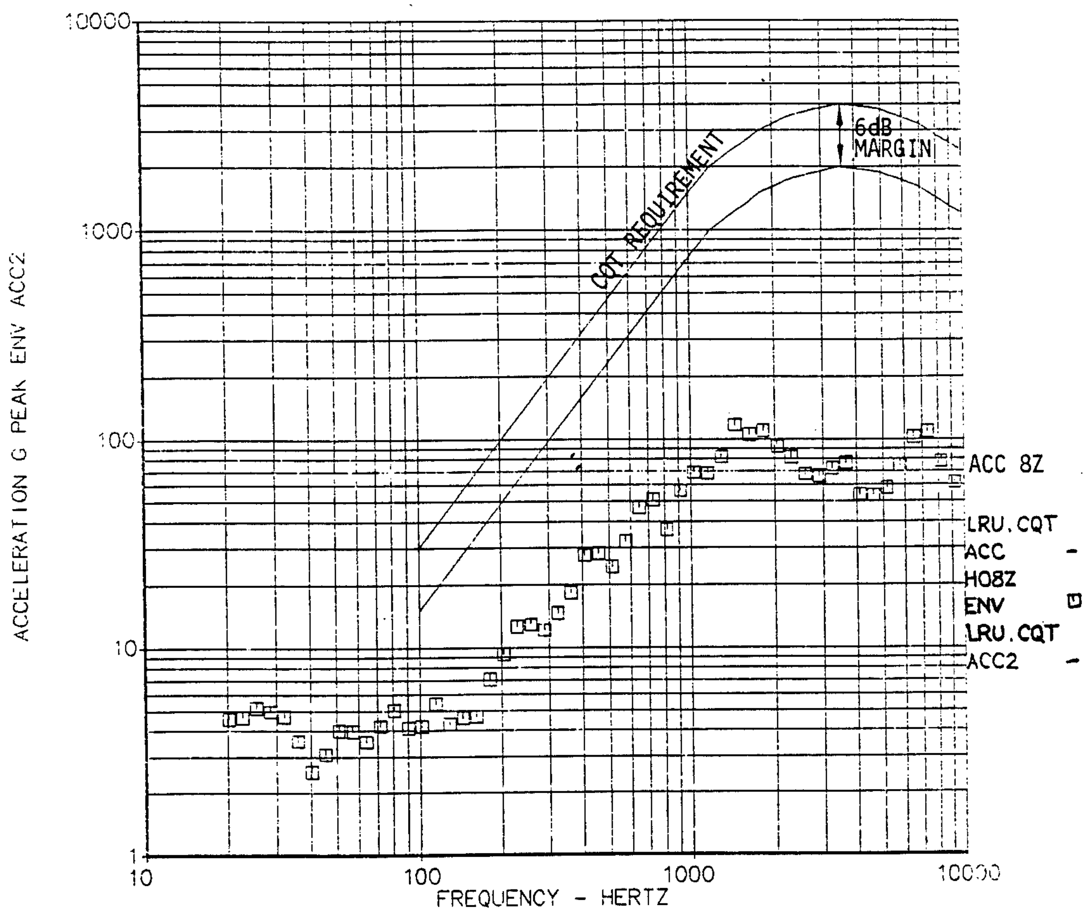


25-MAY-82 17:40:59

CALC		25MAY82	REVISED	DATE	RH AFTA PIVOT BRKT	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE

FIGURE 3

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

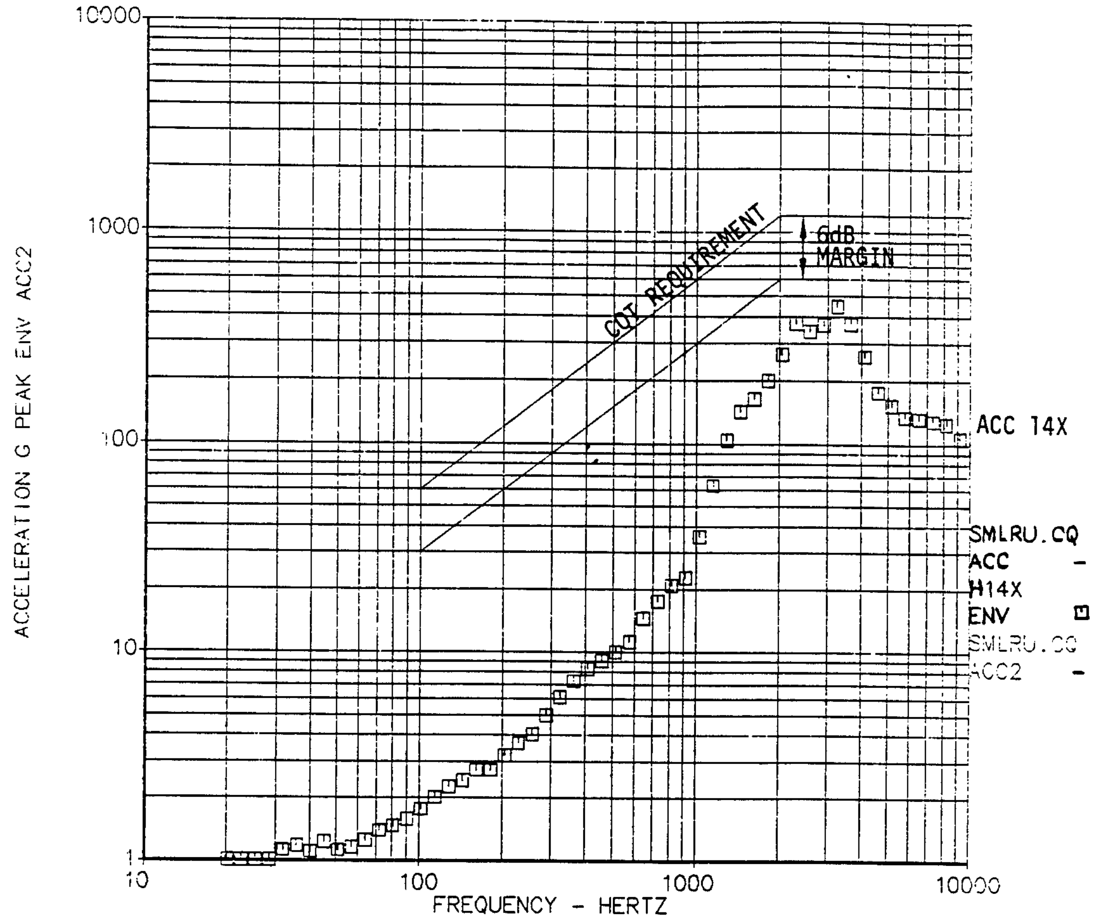


25-MAY-82 17:41:46

CALC		25MAY82	REVISED	DATE	RH AFTA PIVOT BRKT	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE

FIGURE 4

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

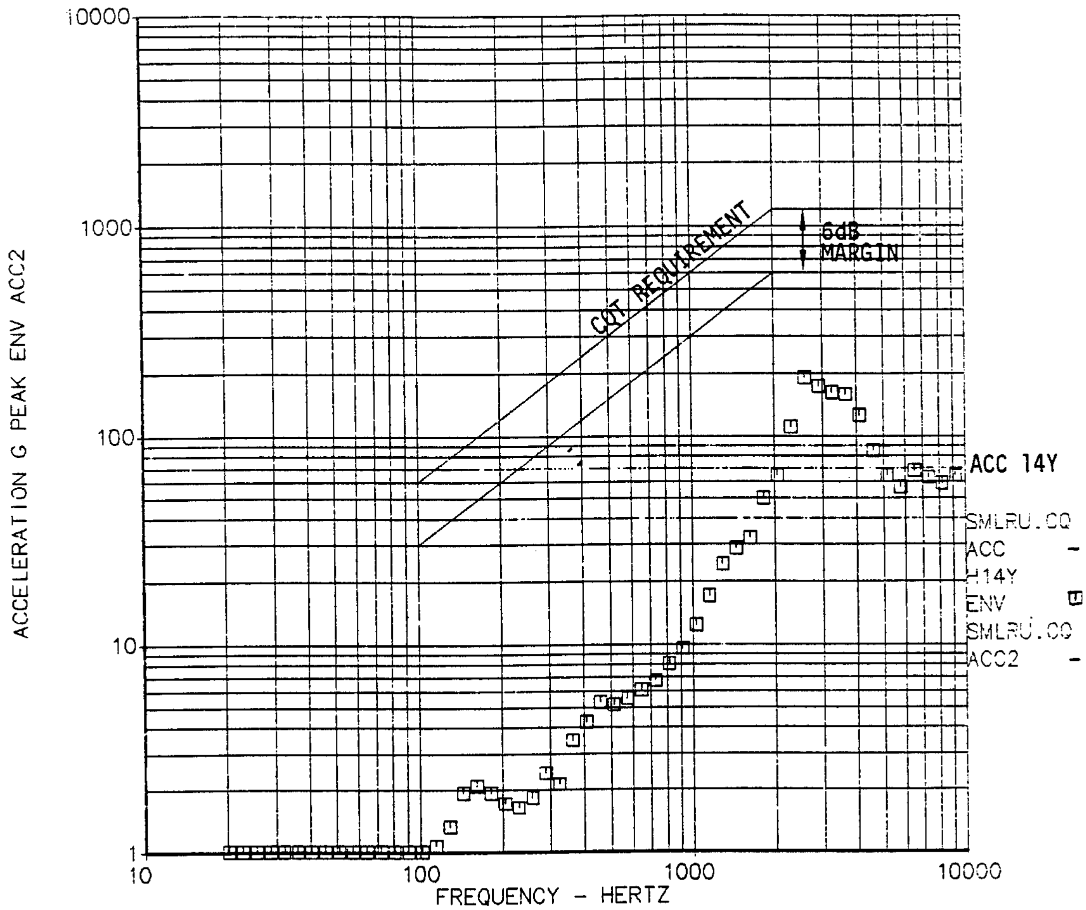


25-MAY-82 17:42:59

CALC		25MAY82	REVISED	DATE	PCU (N13) OUTBOARD (ISOLATED)
CHECK					
APPD.					
APPD.					THE BOEING COMPANY
					PAGE

FIGURE 5

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

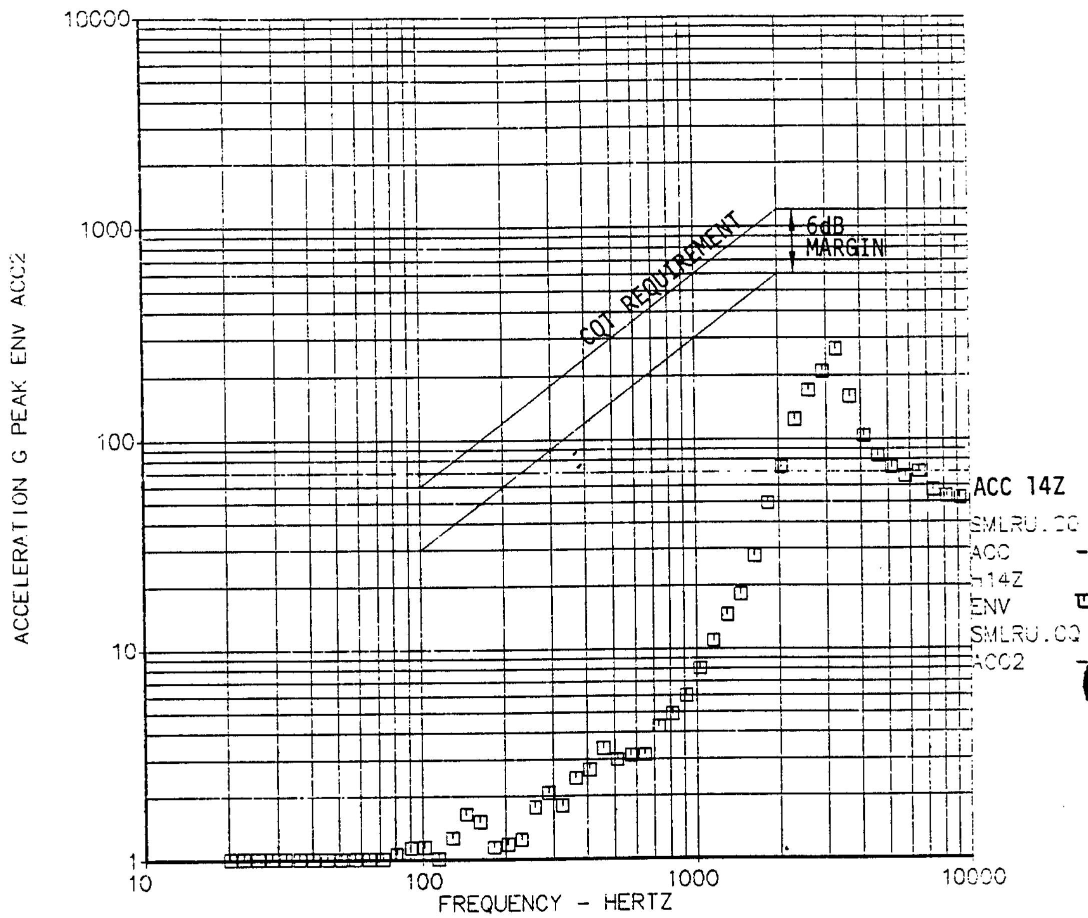


25-MAY-82 17:43:40

CALC		25MAY82	REVISED	DATE	PCU (N13) OUTBOARD (ISOLATED)	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE

FIGURE 6

Statistics for 3 Shock Spectra (Q=10)
PINPULLER



25-MAY-82 17:44:14

CALC		25MAY82	REVISED	DATE	PCU (N13) OUTBOARD (ISOLATED)
CHECK					
APPD.					
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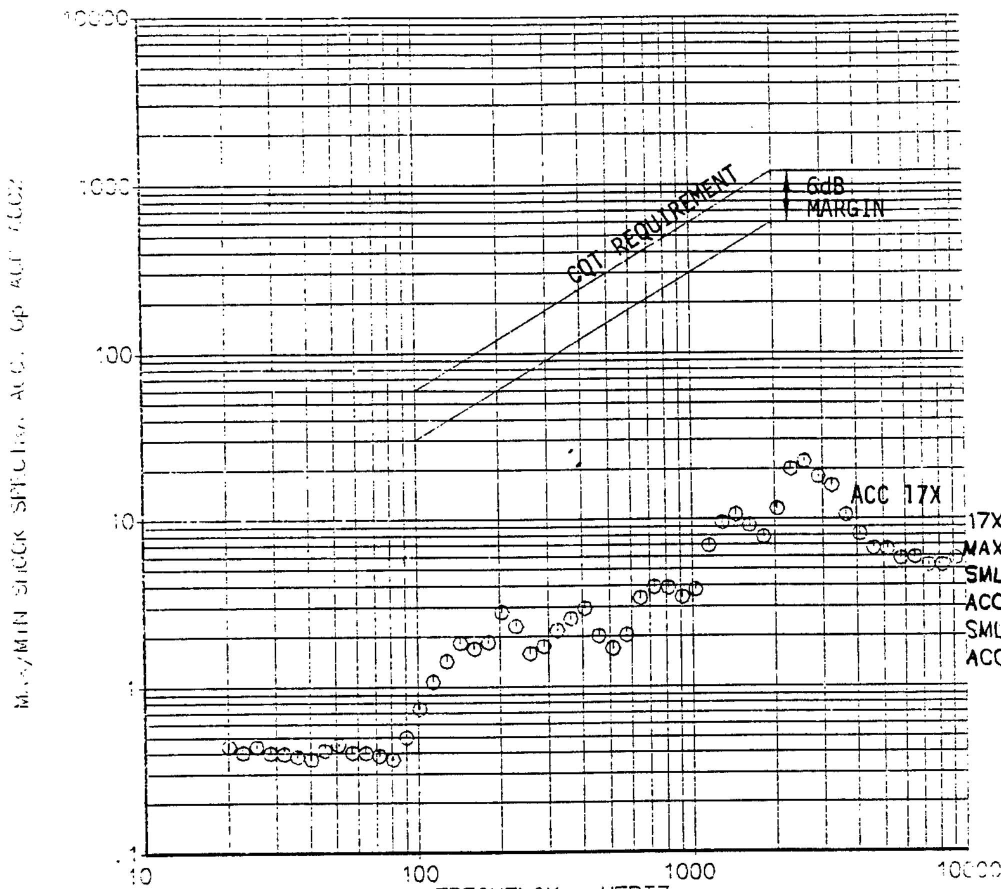
Attachment to
2-3612-IUS-71

FIGURE 7

SHOCK SPECTRA (Q = 10)
H17X ASE AFTA PINPULLER SHOCK #1



26-MAY-82 10:28:31

CALC	26MAY82	REVISED	DATE	WBDI (N8) (ISOLATED)	
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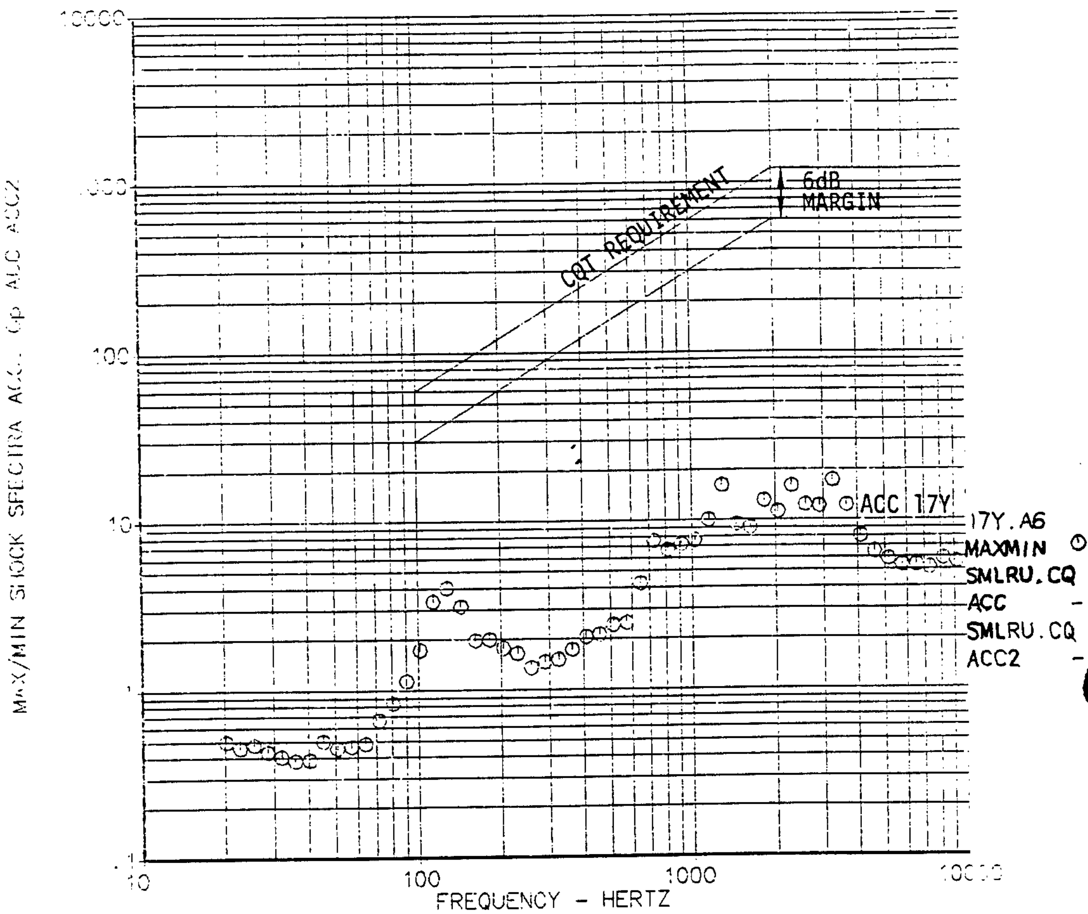
FIGURE 8

SHOCK SPECTRA (Q = 10)
H17Y ASE AFTA PINPULLER SHOCK #1



26-MAY-82 10:31:06

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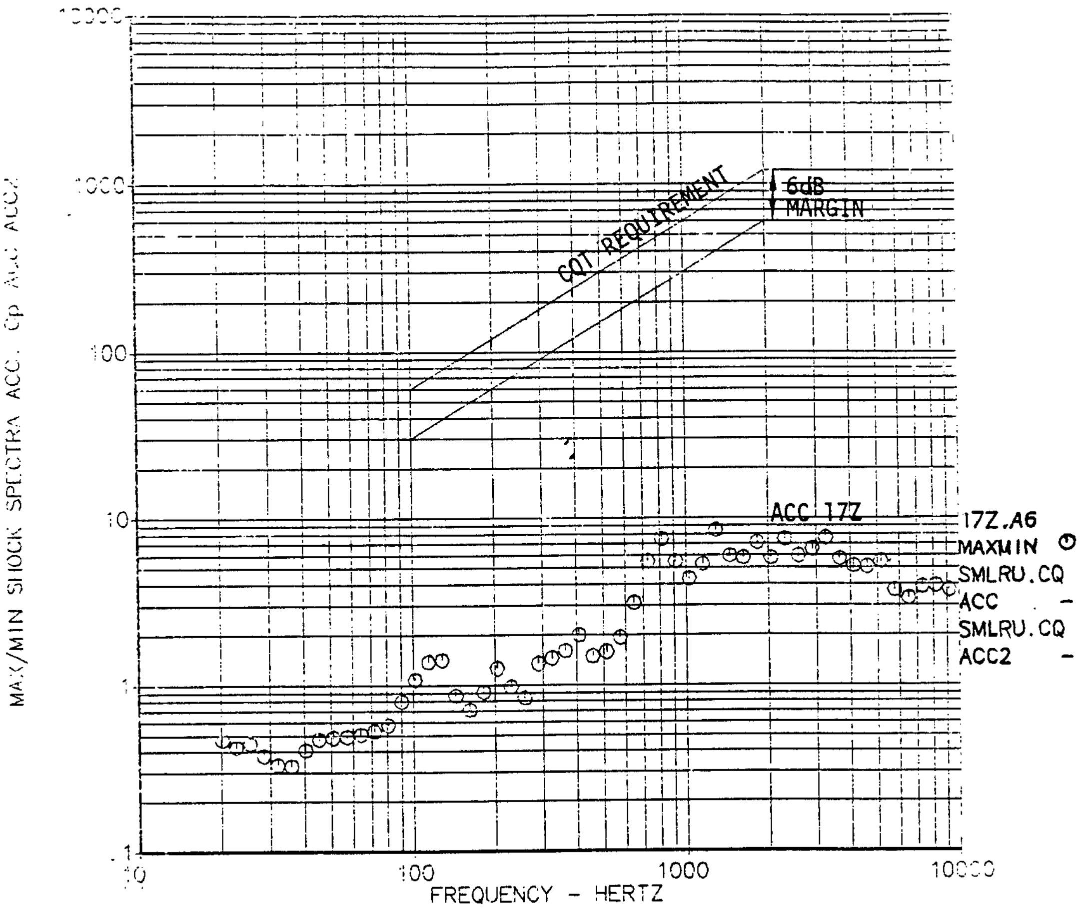
FIGURE 9

SHOCK SPECTRA (Q = 10)
#17Z ASE AFTA PINPULLER SHOCK #1



26-MAY-82 10:33:41

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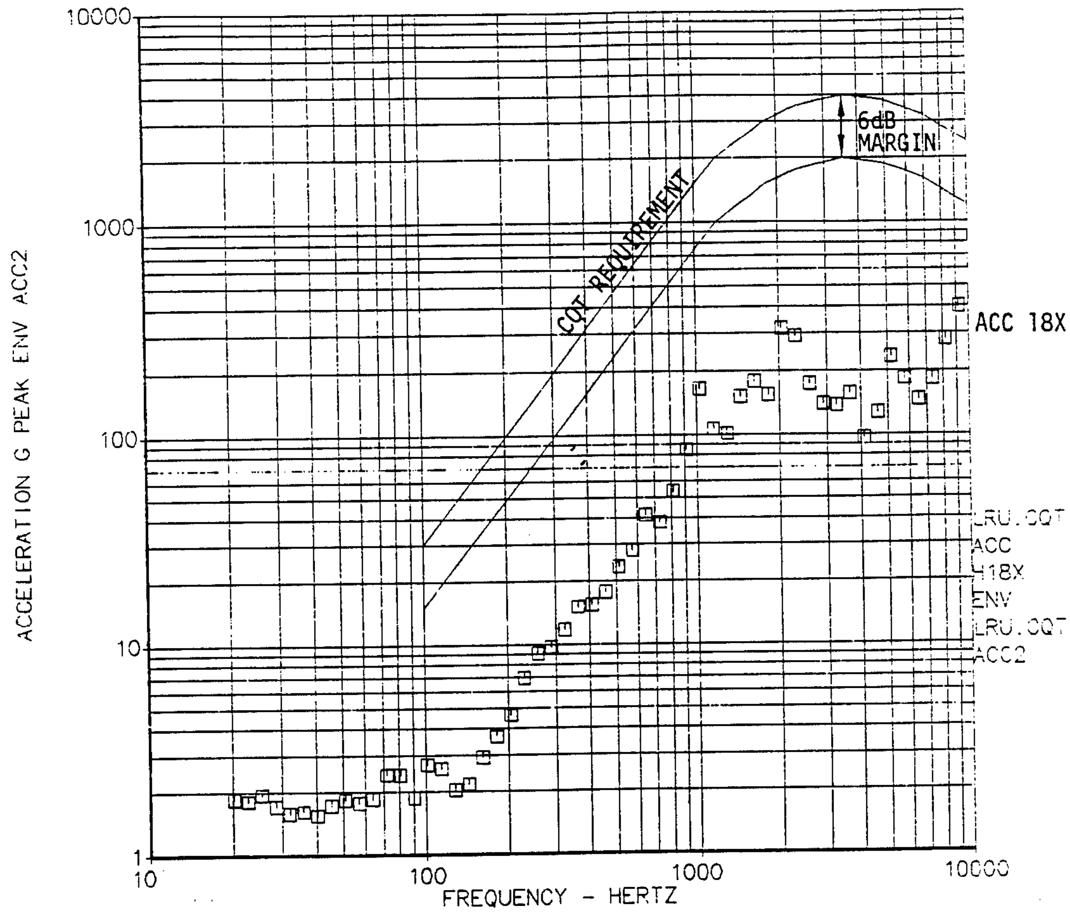
FIGURE 10

Statistics for 3 Shock Spectra (Q=10)
PINPULLER



25-MAY-82 17:46:29

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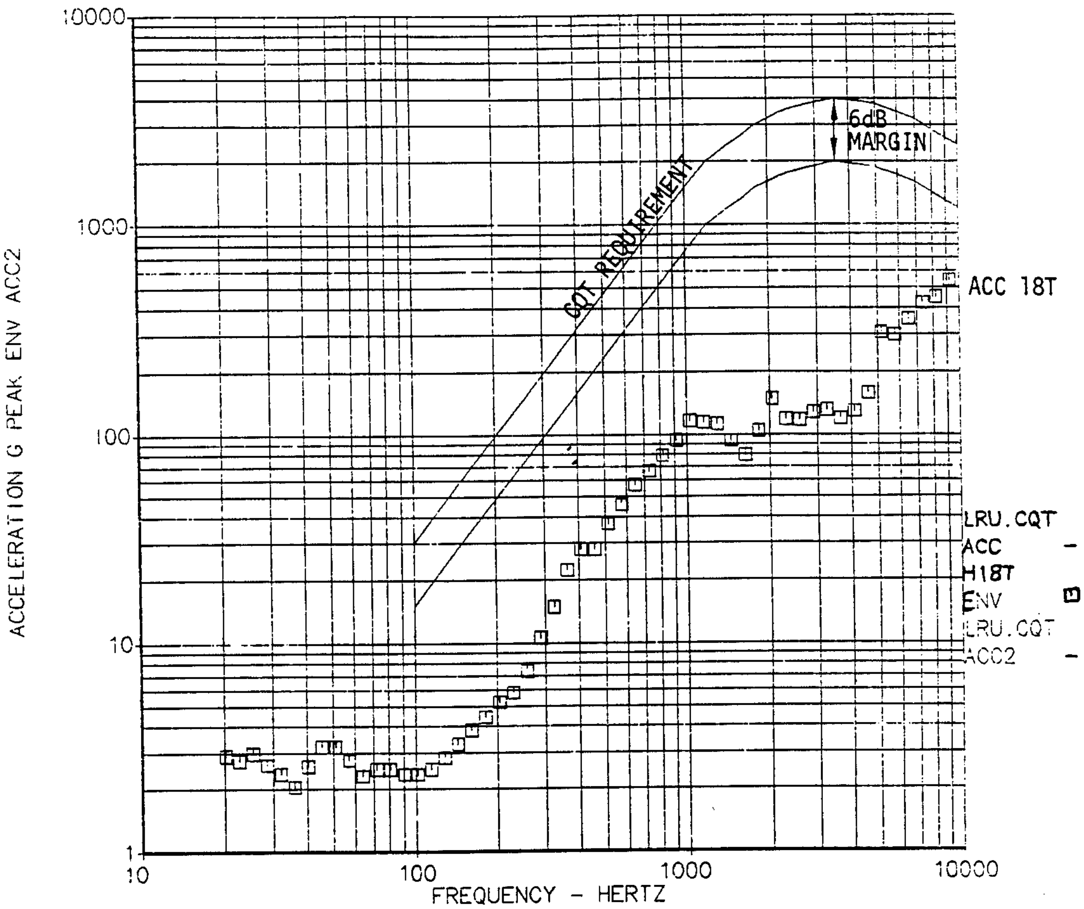
FIGURE 11

Statistics for 3 Shock Spectra (Q=10)
PINPULLER



25-MAY-82 17:45:41

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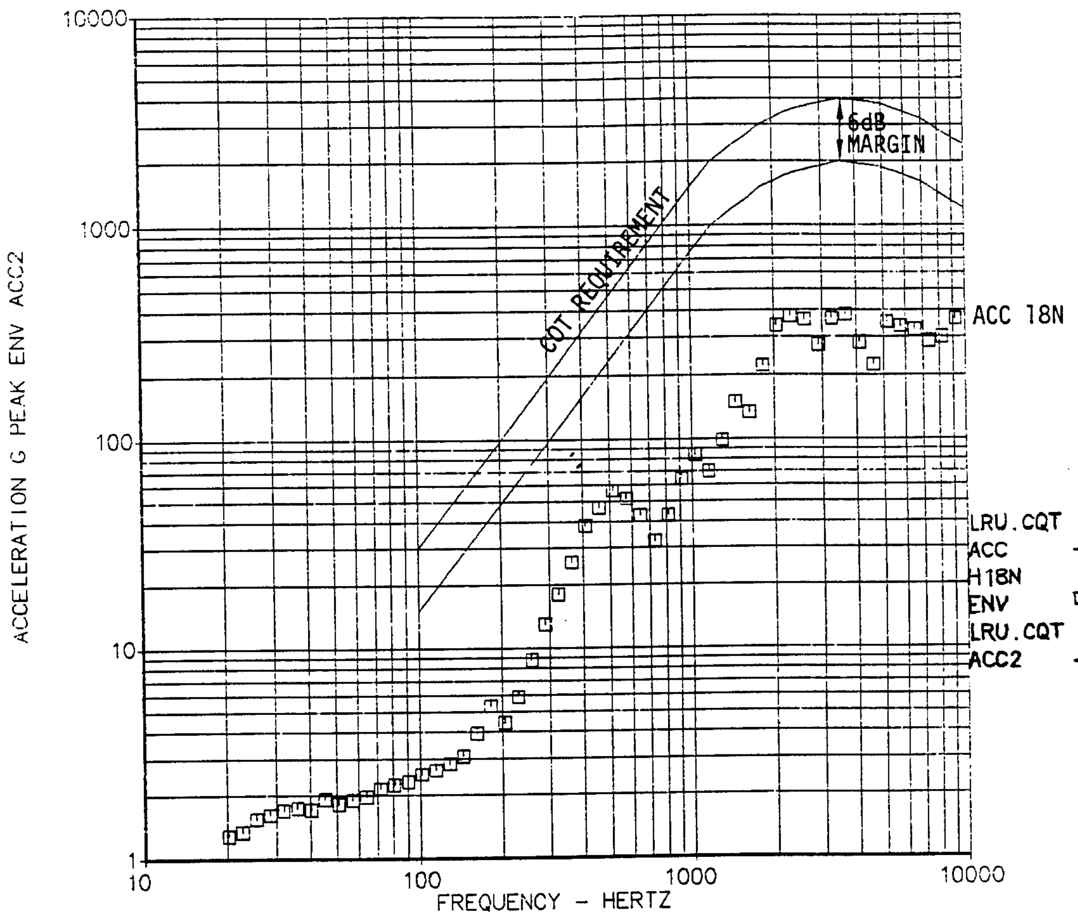
FIGURE 12

Statistics for 3 Shock Spectra (Q=10)
PINPULLER



25-MAY-82 17:44:59

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FIGURE 13 INTENTIONALLY OMITTED

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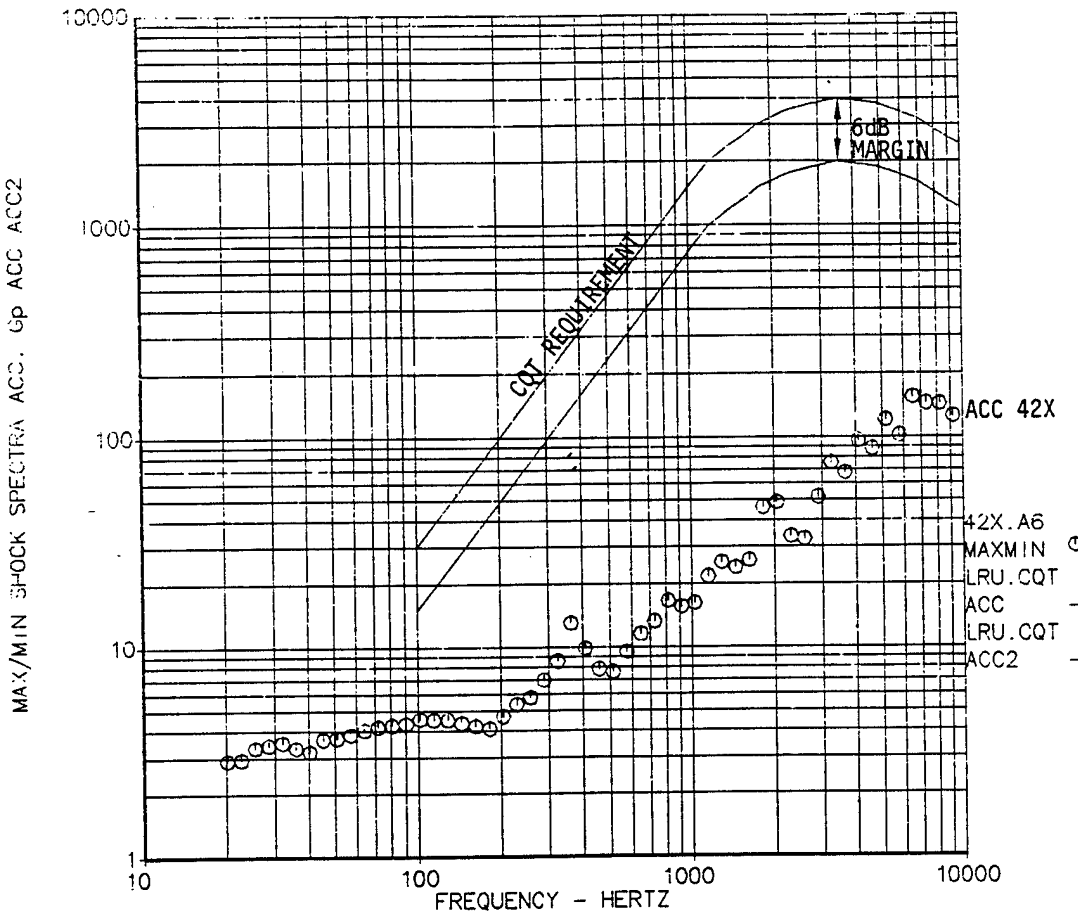
FIGURE 14

SHOCK SPECTRA (Q = 10)
H42 ASE AFTA PINPULLER SHOCK



26-MAY-82 15:01:21

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FIGURE 15

SHOCK SPECTRA (Q = 10)
H42 ASE AFTA PINPULLER SHOCK

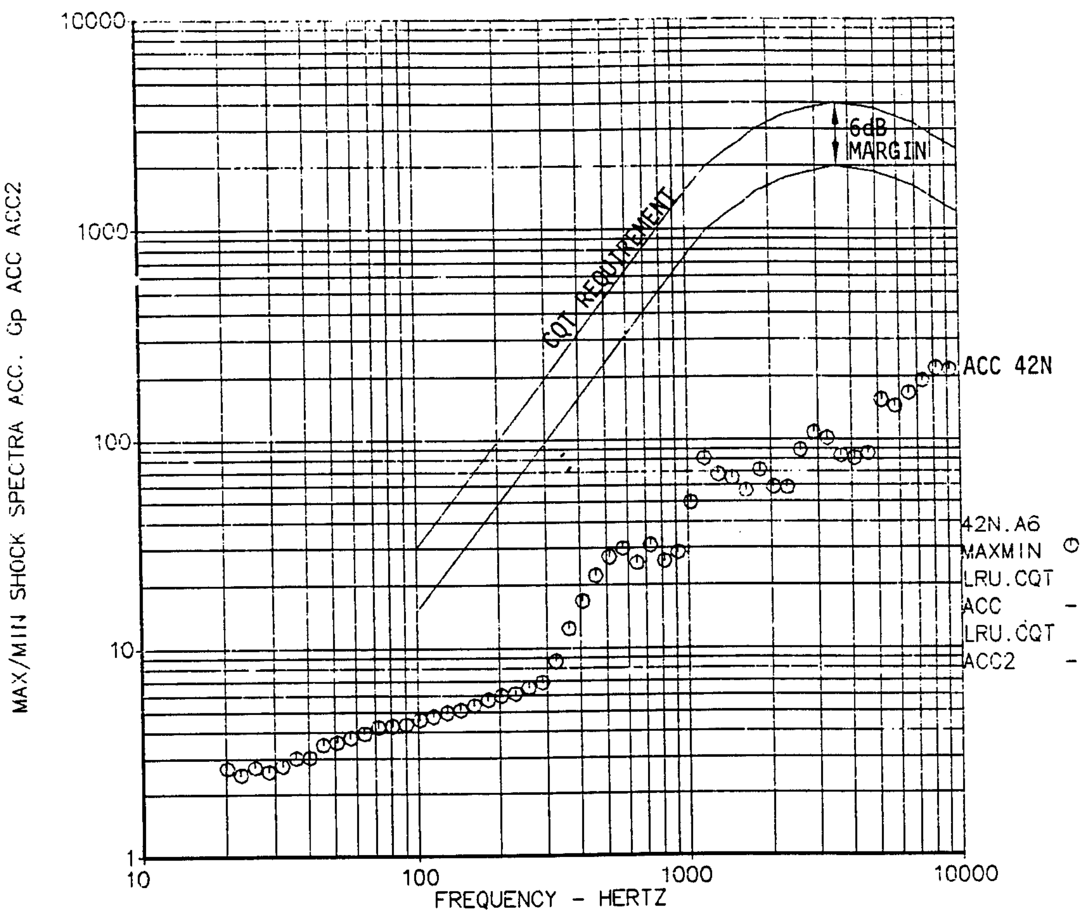

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FIGURE 16

SHOCK SPECTRA (Q = 10)
H42 ASE AFTA PINPULLER SHOCK

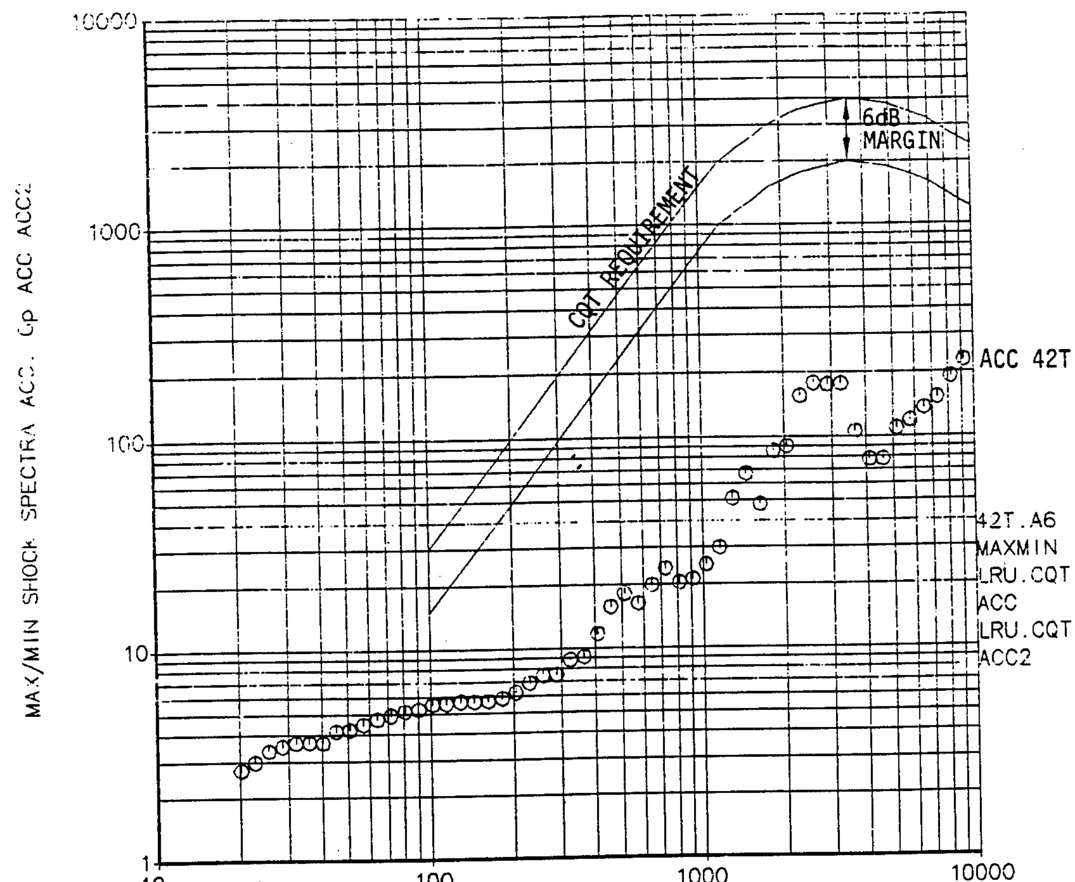

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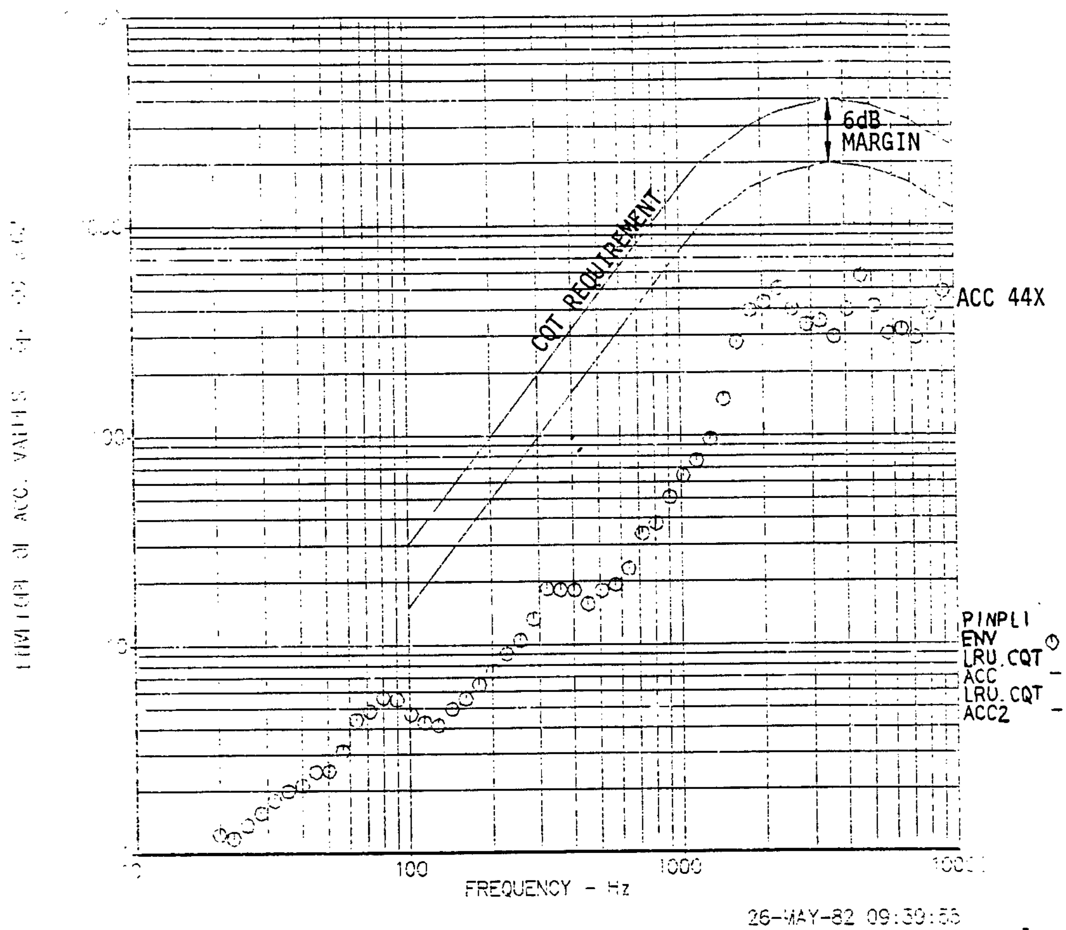
FIGURE 17

Statistics for 3 Shock Spectra (Q=10)
PINPULLER

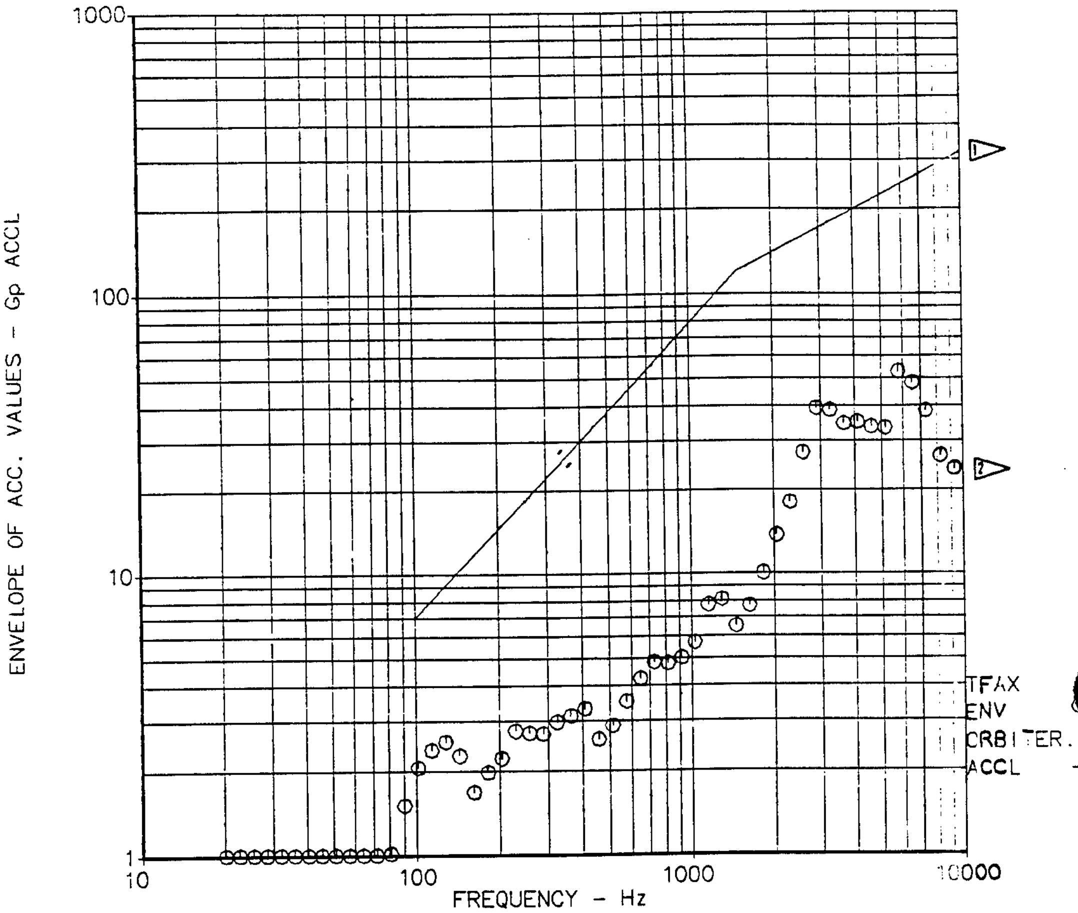


AFTA BODY, RH

THE BOEING COMPANY

FIGURE 18

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



1 Orbiter ICD

2 Response of Accelerometer 9X

CALC		4OCT82	REVISED	DATE	TRUNNION, FWD-AFT ASE	ACC. 9X
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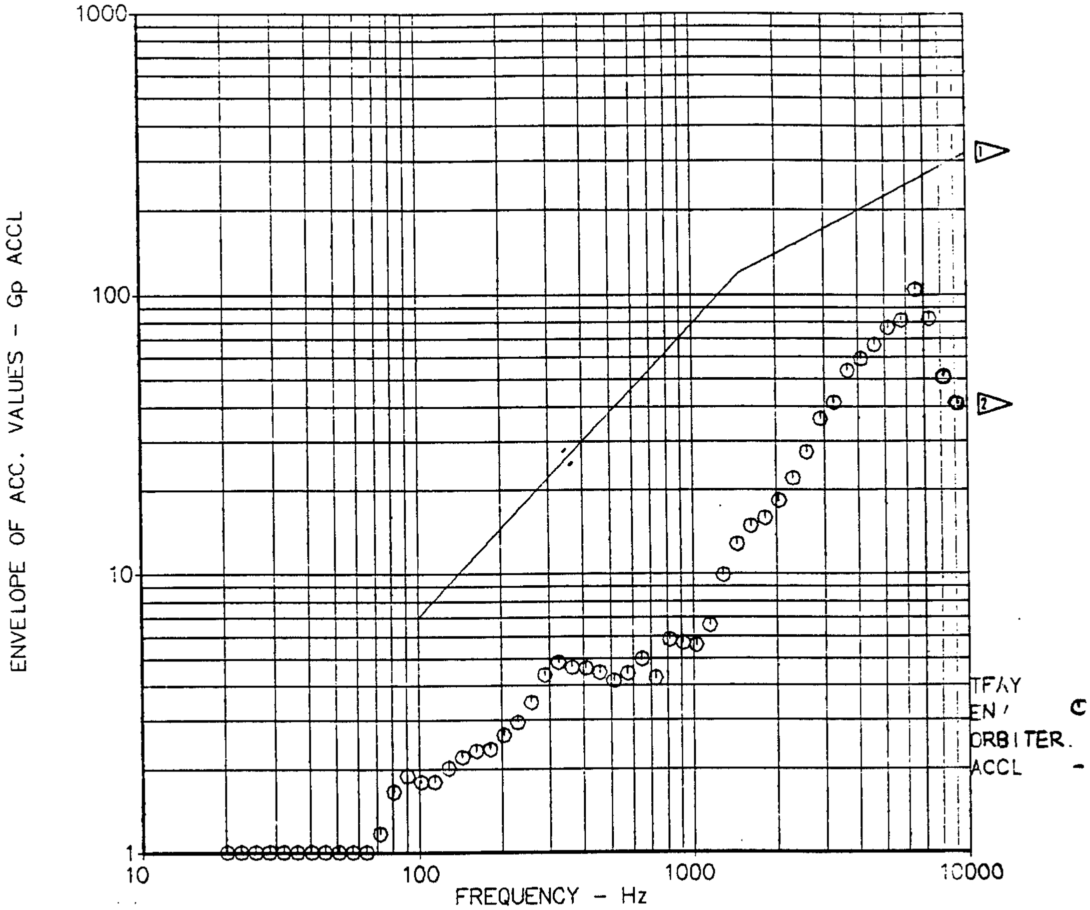
FIGURE 19

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



4-OCT-82 15:46:35

1 Orbiter ICD

2 Response of Accelerometer 9Y

CALC		4OCT82	REVISED	DATE	TRUNNION, FWD-AFT ASE	ACC. 9Y
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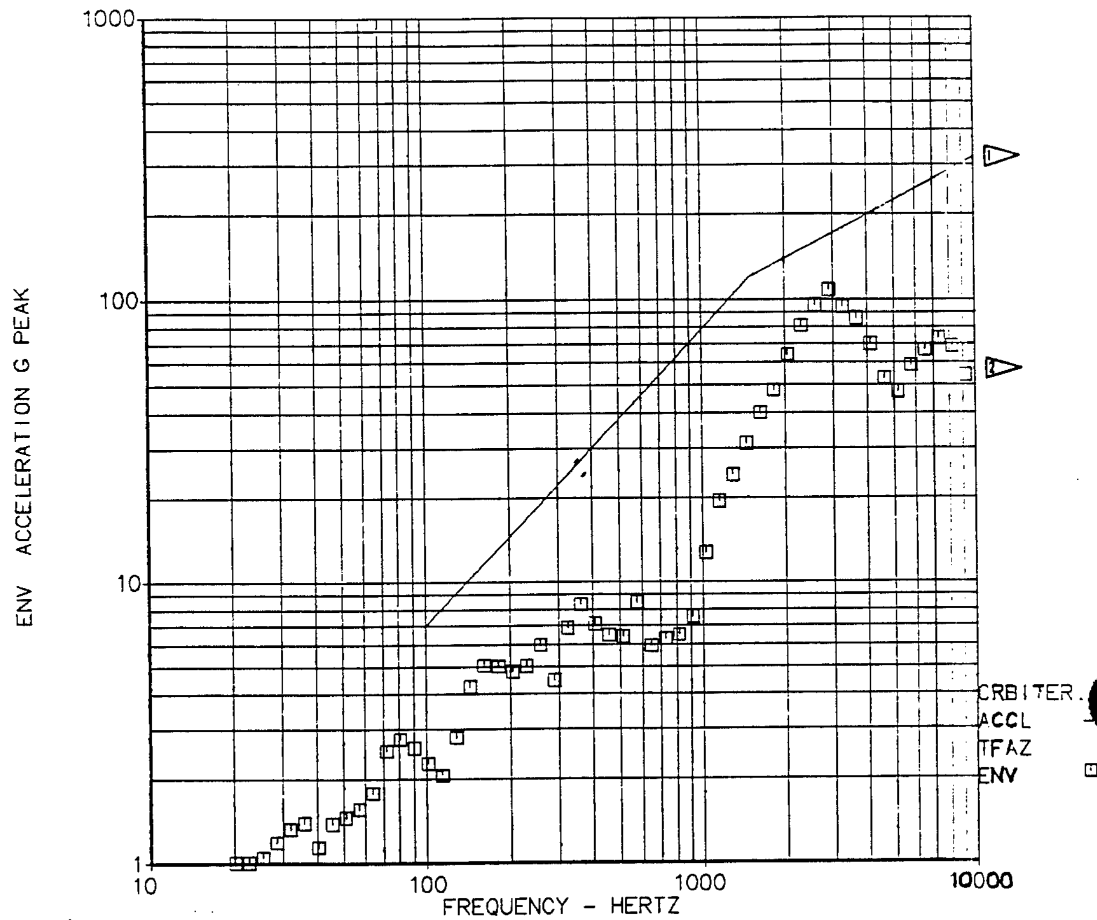
FIGURE 20

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



4-OCT-82 15:50:53

1. Orbiter ICD
2. Response of Accelerometer 9Z

CALC		4OCT82	REVISED	DATE	TRUNNION, FWD-AFT ASE	ACC. 9Z
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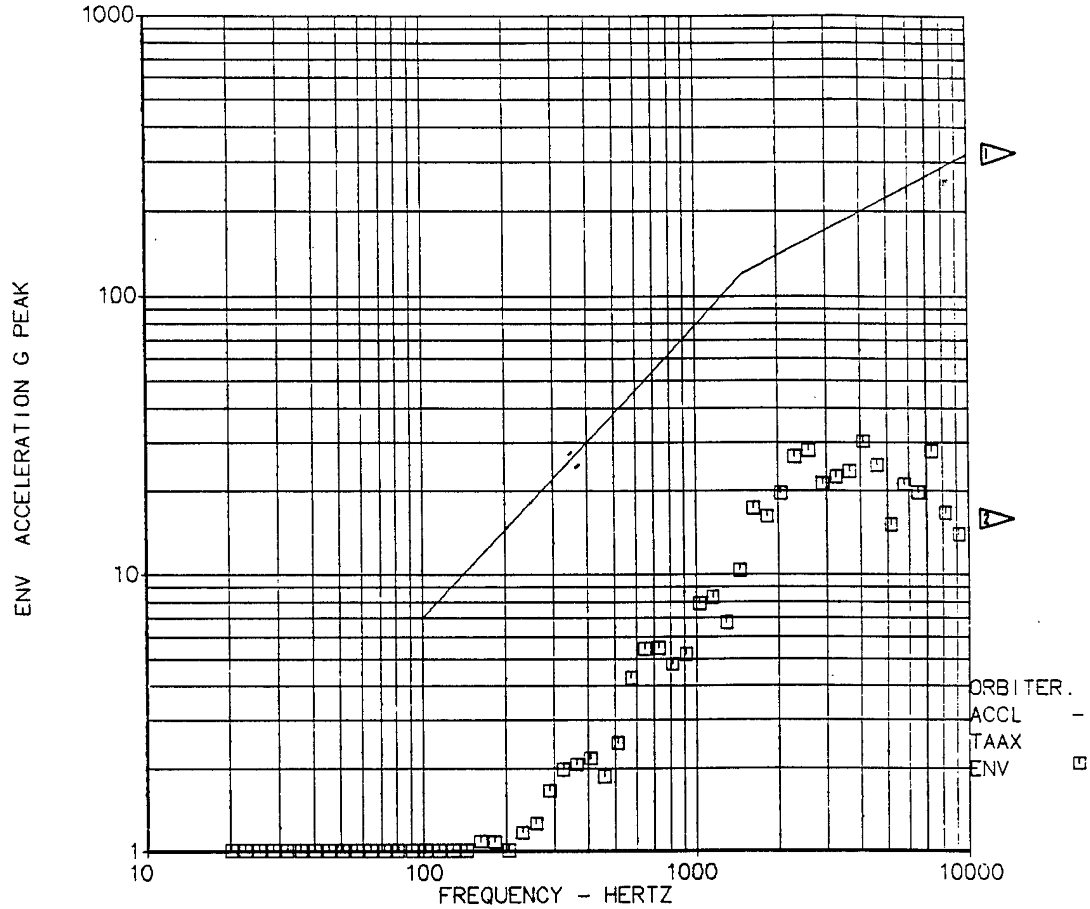
FIGURE 21

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



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1 Orbiter ICD

2 Response of Accelerometer 10X

CALC	40CT82	REVISED	DATE	TRUNNION, AFT-AFT ASE	ACC. 10X
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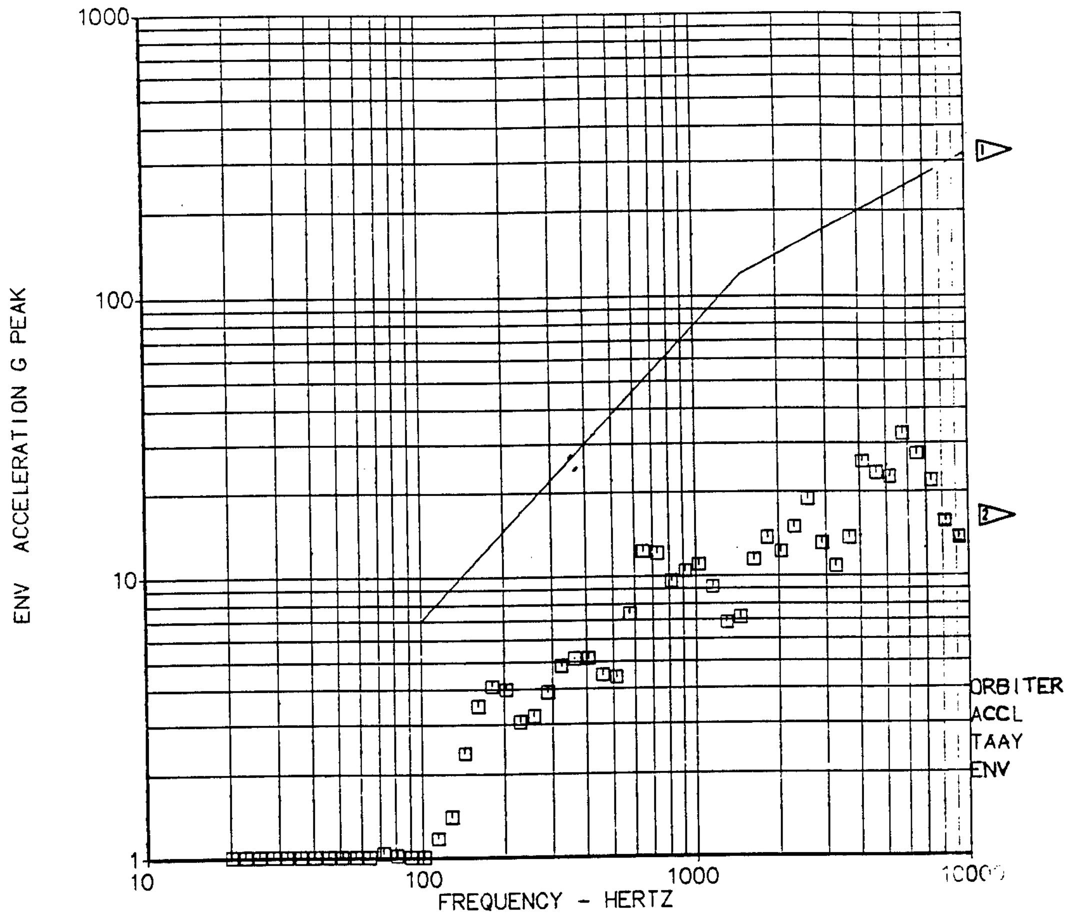
FIGURE 22

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



1 Orbiter ICD

2 Response of Accelerometer 10Y

CALC		4OCT82	REVISED	DATE	TRUNNION, AFT-AFT ASE	ACC. 10Y
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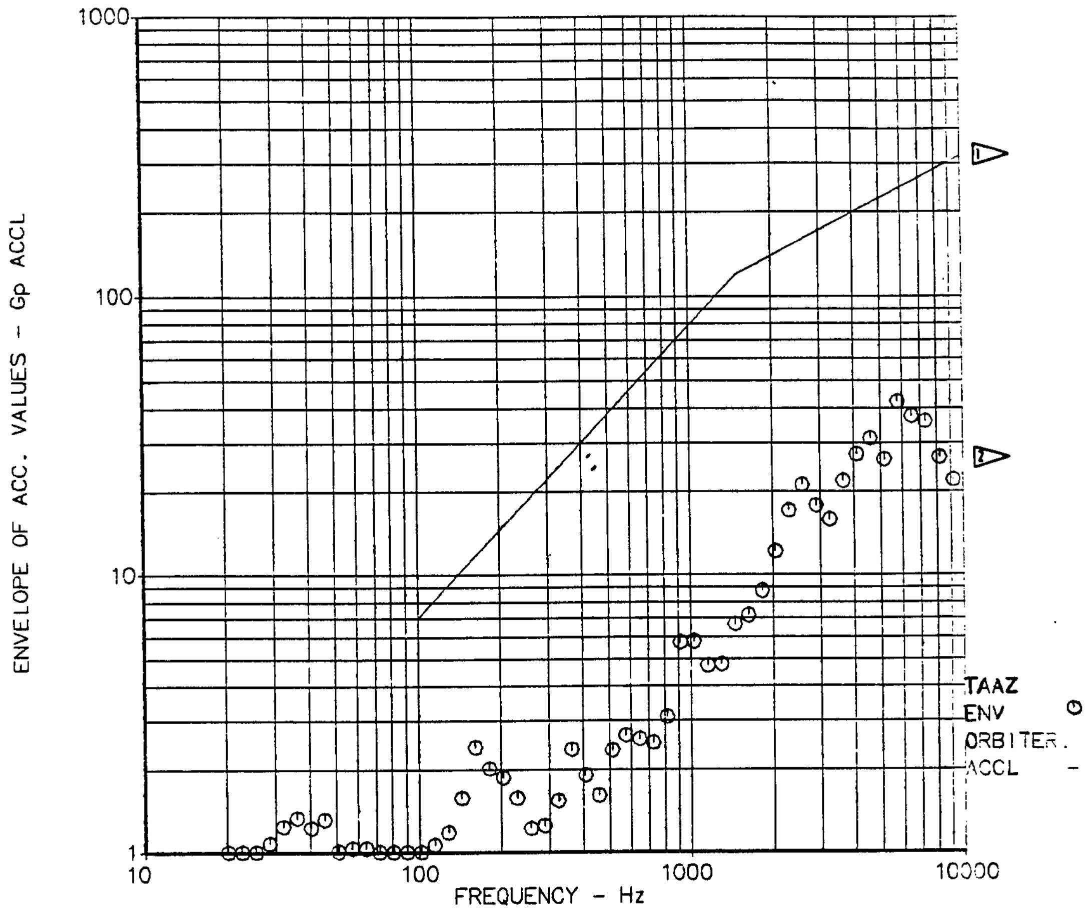
FIGURE 23

Statistics for 3 Shock Spectra (Q=10)
ASE AFTA PINPULLER SHOCK TEST



4-OCT-82 15:55:20

1 Orbiter ICD

2 Response of Accelerometer 10Z

CALC		4OCT82	REVISED	DATE	TRUNNION, AFT-AFT ASE	ACC. 10Z
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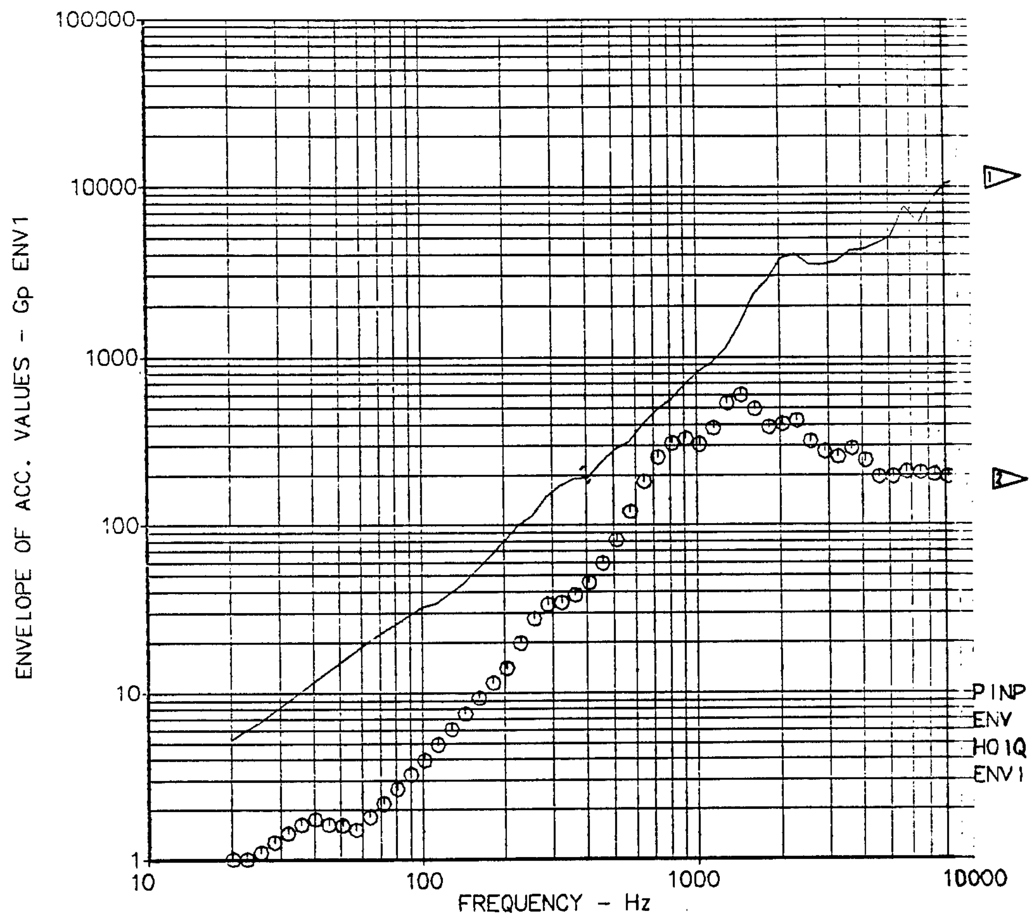
FIGURE 24

Statistics for 2 Shock Spectra (Q=10)
PINPULLER SHOCK TEST



1 Envelope of Accelerometer H01A from QTV Shock Test

2 Envelope of Accelerometer H27A from Umibilical Pin Puller Shock Test

CALC	5OCT82	REVISED	DATE	IUS TRUNNION RING	ACC. H01A
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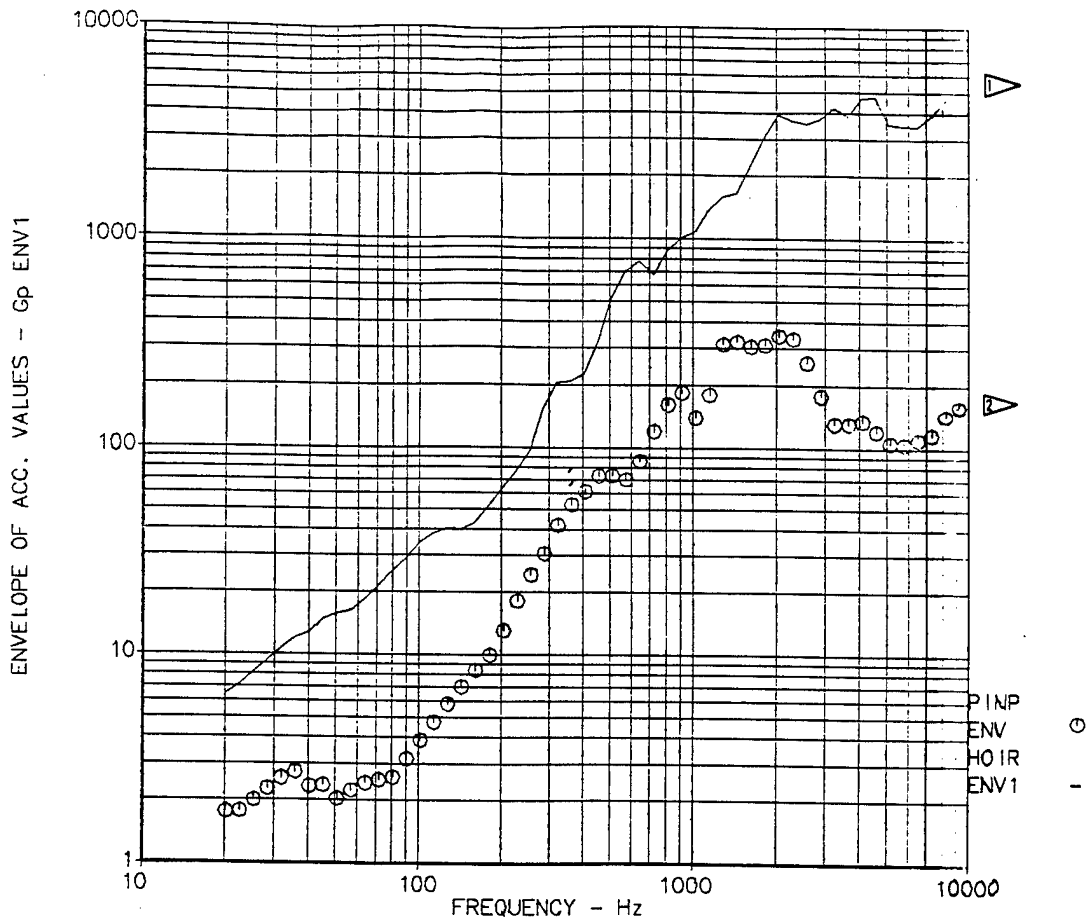
FIGURE 25

Statistics for 2 Shock Spectra (Q=10)
PINPULLER SHOCK TEST



6-OCT-82 09:45:

1 Envelope of Accelerometer H01R from QTV Shock Test

2 Envelope of Accelerometer H27R from Umbilical Pin Puller Shock Test

CALC		6OCT82	REVISED	DATE	IUS TRUNNION RING	ACC. H01R
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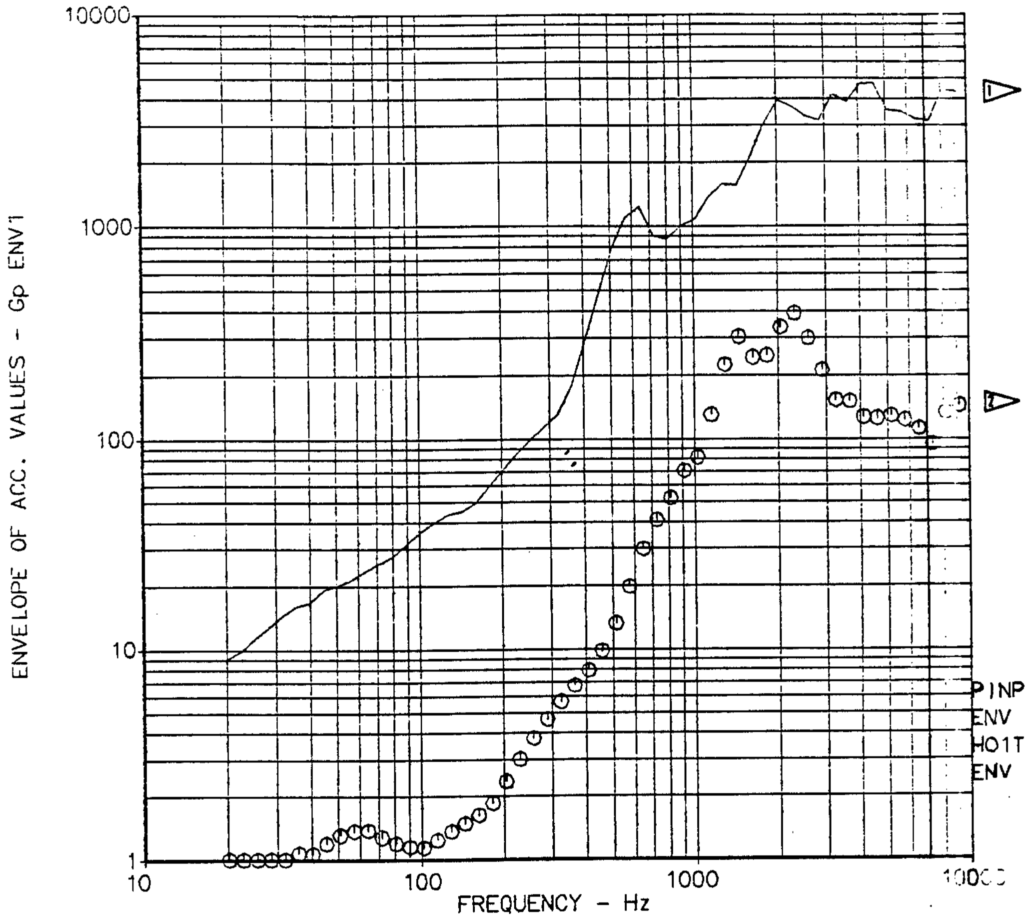
FIGURE 26

Statistics for 2 Shock Spectra (Q=10)
PINPULLER SHOCK TEST



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1 Envelope of Accelerometer H01T from QTV Shock Test

2 Envelope of Accelerometer H27T from Umbilical Pin Puller Shock Test

CALC	6OCT82	REVISED	DATE	IUS TRUNNION RING	ACC. H01T
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5.0 STAGING BOLT SHOCK

Pyrotechnic shock data from an IUS staging bolt separation test are presented in this section. The purpose of the test was to determine the effects of firing both separation nuts simultaneously.

BOEING

2-3612-IUS-020/84
31 January 1984

To:	S.M. Church	8K-89
	R.F. Hain	8K-89
	F.W. Spann	8F-81
cc:	A.D. Watson	8R-37
	E.H. Ralph	8R-37

Subject: Evaluation of Pyrotechnic Shock Data

The following is a summary of findings from evaluation of pyrotechnic shock data obtained during the Staging Bolt Separation Test conducted in July 1983.

1. Single nut and simultaneous nut firing produce similar shock spectra.
2. Shock response did not consistently attenuate with distance.
3. The shock response was a function of the nut fired (fixed or free).
4. Measured axial shock response was greater than the PIDS allowable for the fixed nut firings and the 2 nut joint free firings.

The measured shock spectra are in the enclosure.

Clark Beck

Clark Beck

Enclosure (Addressees only)

ENCLOSURE TO
2-3612-IUS-020/84
68 Pages

EVALUATION OF PYROTECHNIC SHOCK DATA IUS STAGING BOLT SEPARATION TEST, JULY 1983

by Clark Beck
23 Jan 1984

Introduction

This report presents an evaluation of pyrotechnic shock data from an IUS Staging Bolt Separation Test. The test was conducted in July 1983 at the Boeing Kent Space Center.

The purpose of the test was to determine the effect on the nuts and stud dynamics when both separation nuts fire simultaneously in a Stage 1/Stage 2 separation of the ESS and interstage, see Appendix A.

Six accelerometers were attached to the test article at two locations. The accelerometer outputs were recorded during the separation event and subsequently reduced to acceleration shock spectra. The presentation and evaluation of the shock spectra are discussed in this report.

Test Setup/Instrumentation

A schematic of the test setup and accelerometer locations is shown in Figure 1.

Test Conditions

Ten tests were conducted:

5 single nut firings,
4 fixed nuts,
1 free nut;

5 simultaneous (fixed and free) nut firings,
3 longerons not clamped,*
2 longerons clamped*.

* Refer to Figure 1. The normal longeron configuration is when the longerons are held together by the separation stud connection. When either nut is fired the interstage longeron would move to the left. For runs 3 and 7 the longerons were held together by an additional clamp preventing movement of the interstage longeron when the nuts were fired.

1

The following table presents the run number/test configuration correlation.

Test No.	Nuts Fired	Longeron Condition	VAX Ext. Code (1)
1	1 (Fixed)		1N1
2	2		2N2
3	2	Clamped	2N3
4	2		2N4
5	2		2N5
6A	1 (Free)		16A
6B	1 (Fixed)		16B
7	2	Clamped	2N7
8	1 (Fixed)		1N8
9	1 (Fixed)		1N9

(1) See Section entitled VAX Files

Data Analysis

The outputs from the 6 accelerometers were recorded on magnetic tape for each of the 10 tests. Recording system calibrated for ± 2000 gs.

Time histories of each of the shock pulses are shown in Appendix B.

Shock spectra were obtained using the Hewlitt Packard HP 5451C analyzer. Composite spectra of both the positive and negative spectra were obtained for each pulse. The shock response values were calculated for a Q of 10 (5% of critical damping) at 1/6 octave frequency intervals.

The HP analyzer output was recorded on a magnetic tape for further analysis on the VAX 11/780.

The HP output was loaded into the VAX computer using the following identifiers for the spectra.

H a b c . d e f

a & b = accelerometer number
01 or 01

2

e = accelerometer direction
A = Axial
R = Radial
T = Tangential

d = number of nuts fired

e = N or run number 6

f = run number,
1, 2, 3, 4, 5, 6A, 6B, 7, 8, 9

Example H01A.1N1

Accelerometer 1, axial, single nut firing, run 1.

VAX Files

The shock spectra are contained in a file named

SEPNUT.GGP; 1 19 Jul 1983
Directory Structures:[CJB]

H01A.1N1	01A.1N8	01A.1N9	01A.2N2	01A.2N3
01A.2N4	01A.2N5	01A.2N7	01R.1N1	01R.1N8
01R.1N9	01R.2N2	01R.2N3	01R.2N4	01R.2N5
01R.2N7	01T.1N1	01T.1N8	01T.1N9	01T.2N2
01T.2N3	01T.2N4	01T.2N5	01T.2N7	02A.1N1
02A.1N8	02A.1N9	02A.2N2	02A.2N3	02A.2N4
02A.2N5	02A.2N7	02R.1N1	02R.1N8	02R.1N9
02R.2N2	02R.2N3	02R.2N4	02R.2N5	02R.2N7
02T.1N1	02T.1N8	02T.1N9	02T.2N2	02T.2N3
02T.2N4	02T.2N5	02T.2N7	01A.16A	01A.16B
01R.16A	01R.16B	01T.16A	01T.16B	02A.16A
02A.16B	02R.16A	02R.16B	02T.16A	02T.16B

Data Evaluation

The 60 shock time histories in Appendix B were reviewed and judged to be valid. The wave forms looked reasonable, the peak values were less than the 2000g calibration value and the minimum peak values were at least 10% of the calibration value.

3

Figures 2, 3 and 4 contain the shock spectra at location 1 for the single fixed nut firing, axial, radial, tangential. Note the data spread below 500 Hz for axial and radial compared to tangential. Reason for data spread is not readily apparent.

Figures 5, 6 and 7 contain the shock spectra at location 2 for the single fixed nut firing, three directions. Note shock is attenuated between location 1 and 2 except for the axial direction.

Figures 8, 9 and 10 compare single nut firing spectra near nut and at top of longeron (20 inches from nut). Attenuation is noted above 200 Hz for the radial and tangential directions. However, magnification is apparent in the axial direction. Figures 8A, 9A and 10A show the same comparison for a 2 nut firing.

Figures 11, 12 and 13 contain the shock spectra at location 1 for the 2 nut firing, three directions. Tests were run with the separation joint free and clamped. The clamp-free configuration made a significant difference in axial response as shown in Figure 11.

Figures 14, 15, and 16 show the shock spectra at location 2 for the 2 nut firing, three directions. Tests were run with the separation joint free and clamped. A significant difference in axial response was noted between clamp and free as shown in Figure 14.

Figures 17, 18 and 19 show the difference between single and 2 nut firing, three directions at location 1. Figures 20, 21 and 22 shows the difference for location 2.

Figures 23 through 25 shows the effect of firing the fixed nut as compared to the free nut at location 1. Figures 26 through 28 show the fixed/free effect at location 2.

Figures 29 and 30 compare shock level as a function of direction for location 1 and location 2, single fixed nut firing Figures 31 and 32 compare shock level as a function of direction for location 1 and location 2, single free nut firing. Figures 33 and 34 compare shock level as a function of direction for locations 1 and 2, simultaneous nut firing, free joint Figures 35 and 36 compare shock level as a function of direction for locations 1 and 2, simultaneous nut firing, clamped joint.

Note that the axial response for the single fixed nut is similar to the 2 nut free joint. Likewise the single free nut has axial response similar to the 2 nut clamped joint. The single fixed nut/free joint responses demonstrate higher levels than free nut/joint clamped up to a frequency of 400 Hz. These level differences are attributed to the apparent dynamic system mass differences. The fixed nut/joint free configurations is a lighter dynamic system hence a higher first resonant mode and higher responses at higher frequencies.

Conclusions

1. Single nut firings and 2 nut simultaneous firings produce similar shock spectra. See Figures 17 through 22.

2. The shock response did not consistently demonstrate attenuation with distance. See Figures 8 through 10 and 8A through 10A.

3. The shock response was a function of the nut fired. Differences in the order of 10 dB were noted in the axial dirction. The higher levels were caused by the fixed nut. See Figures 23 through 25. Similar differences were observed between the separation joint free and clamped. See Figures 11 and 14.

   These response differences are attributed to the difference in effective mass of the dynamic system.

4. The measured axial shock response exceeded the PIDS (Prime Item Development Spec) allowable for the fixed single nut firings and the 2 nut free joint firings. See Figures 29 through 36. The high axial levels are a function of the test configuration. The "above spec" levels are not anticipated on the IUS vehicle. See Special Study FSD-81-003 dated 10 July 1981.

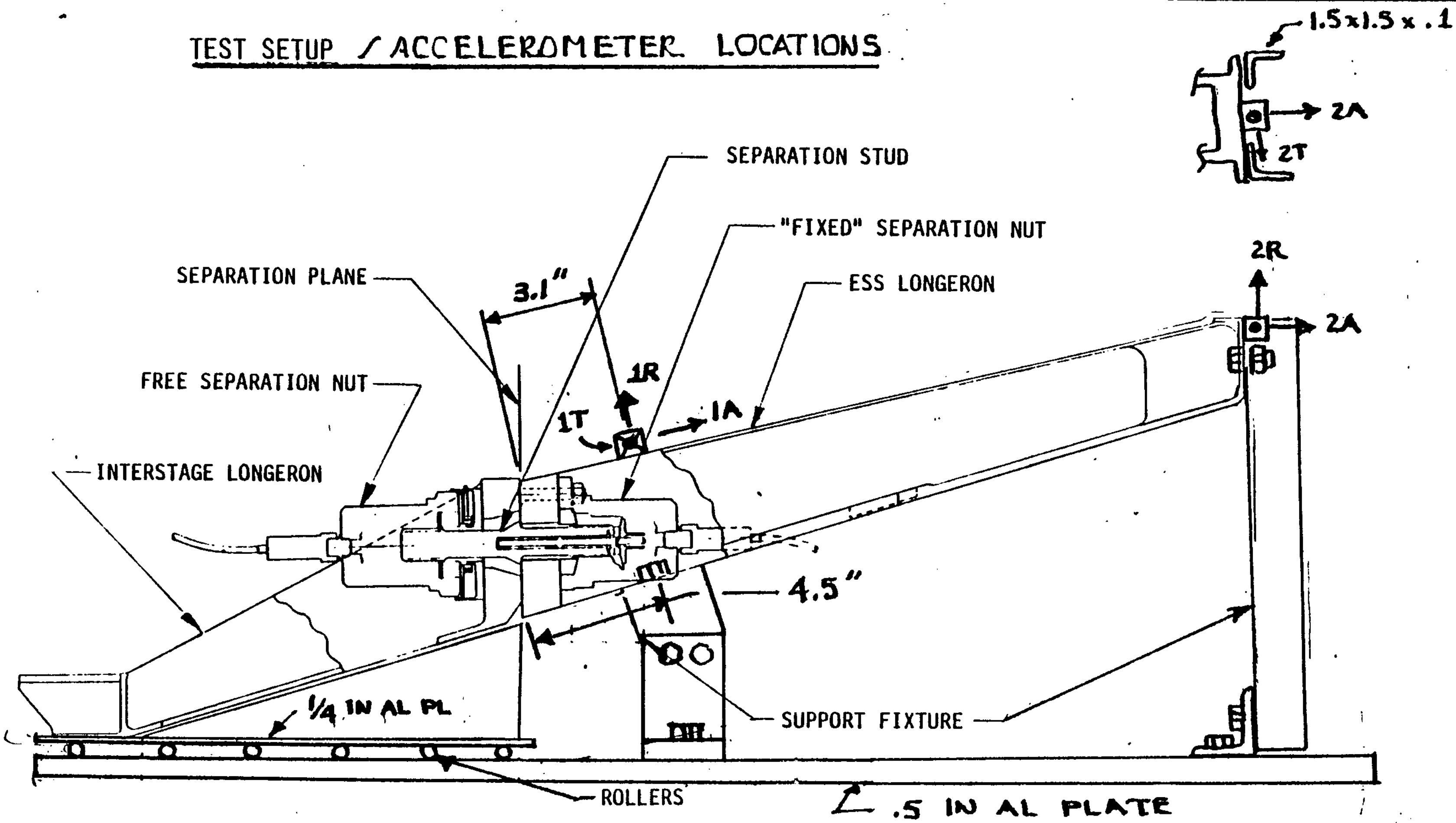
5. There was higher than expected data range below 300 Hz for the radial direction, single fixed nut firing. See Figure 3.

INERTIAL UPPER STAGE

SIMULTANEOUS FIRING OF SEPARATION NUTS

FIGURE 1

TEST SETUP / ACCELEROMETER LOCATIONS



6

A. D. Watson July 13, 1983
REVISED CJ Beck 1/23/84

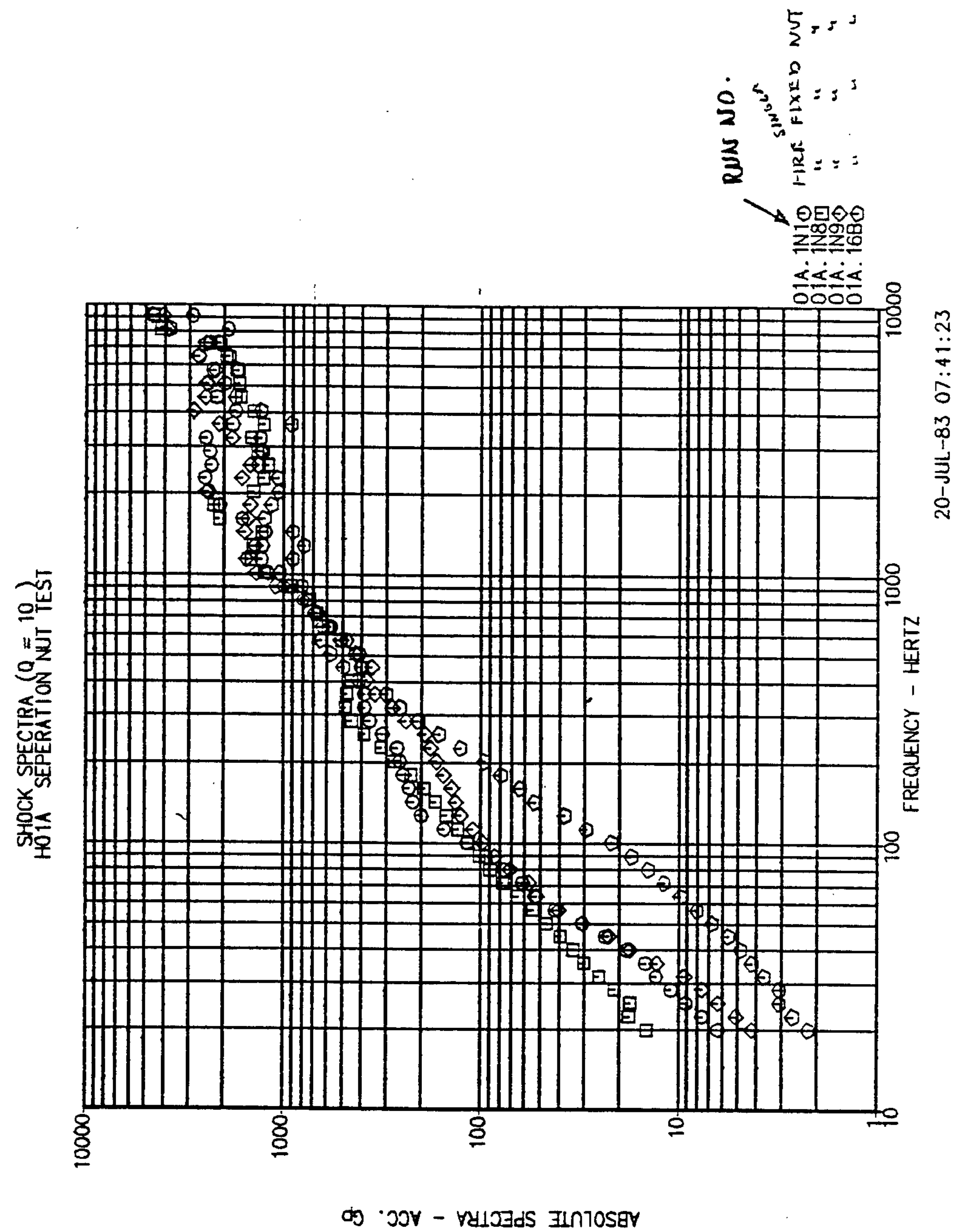


FIGURE 2 SINGLE FIXED NUT FIRING LOCATION 1 AXIAL

7

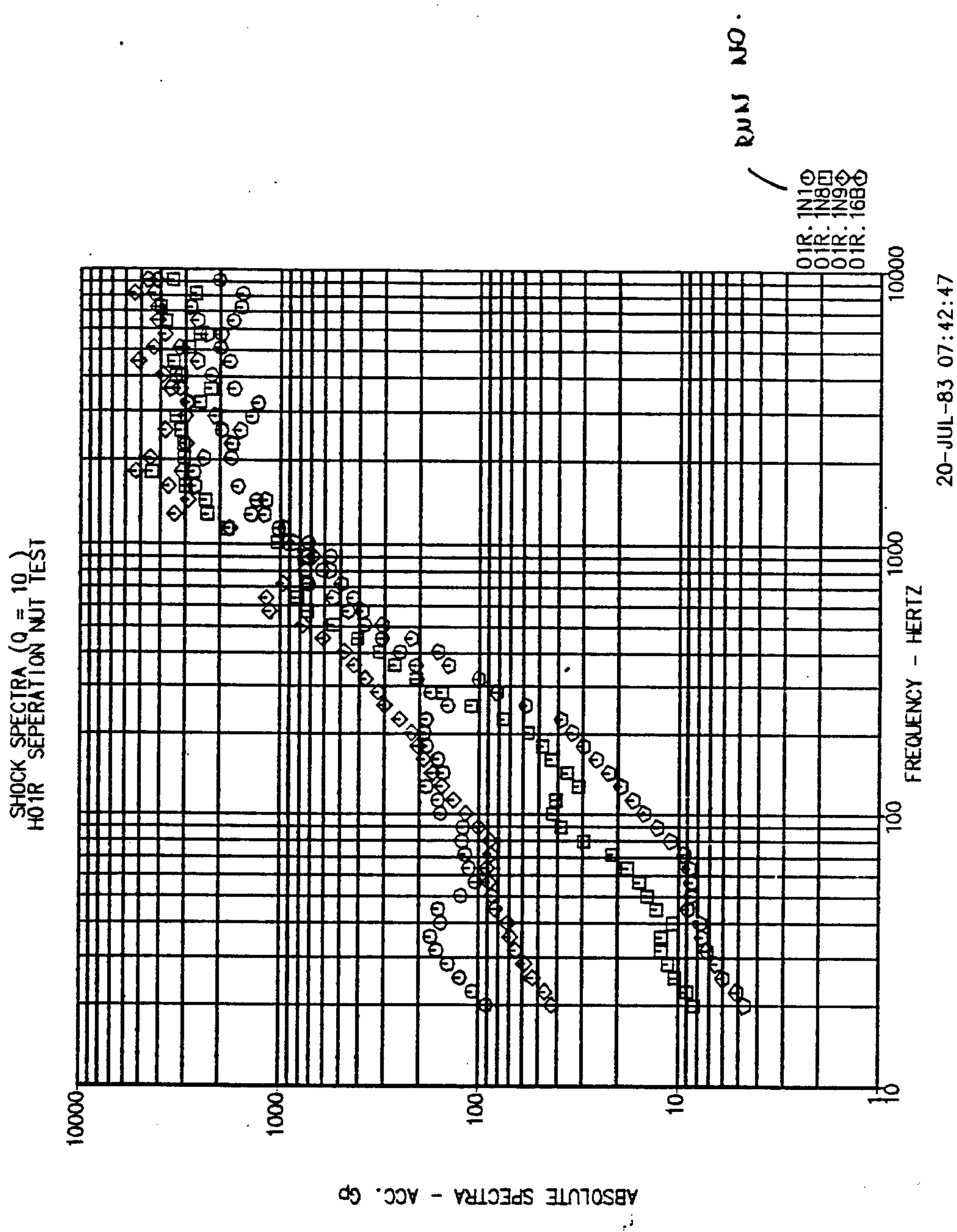


FIGURE 3 SINGLE FIXED NUT FIRING
LOCATION 1 RADIAL

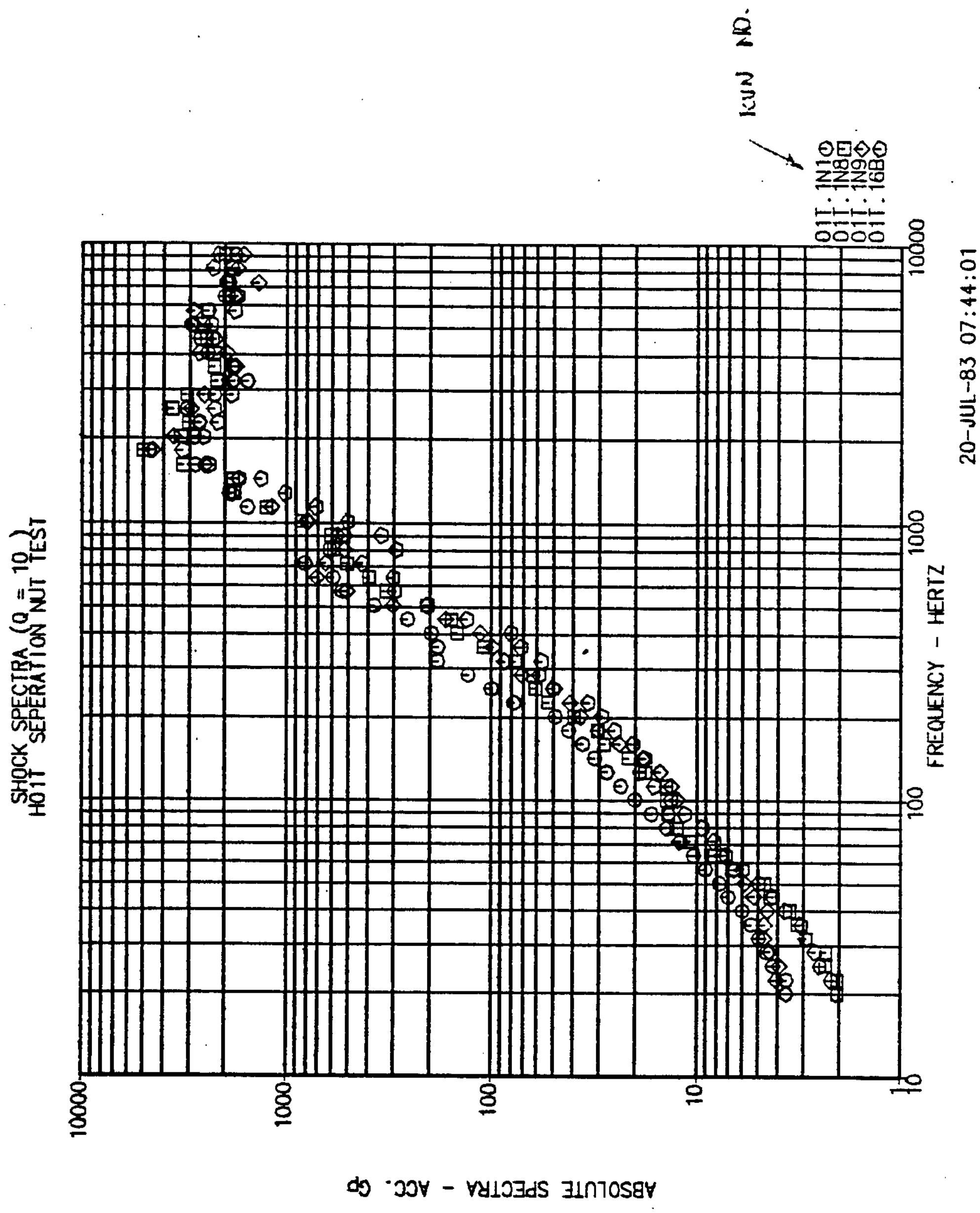


FIGURE 4 SINGLE FIXED NUT
LOCATION 2 TANGENTIAL

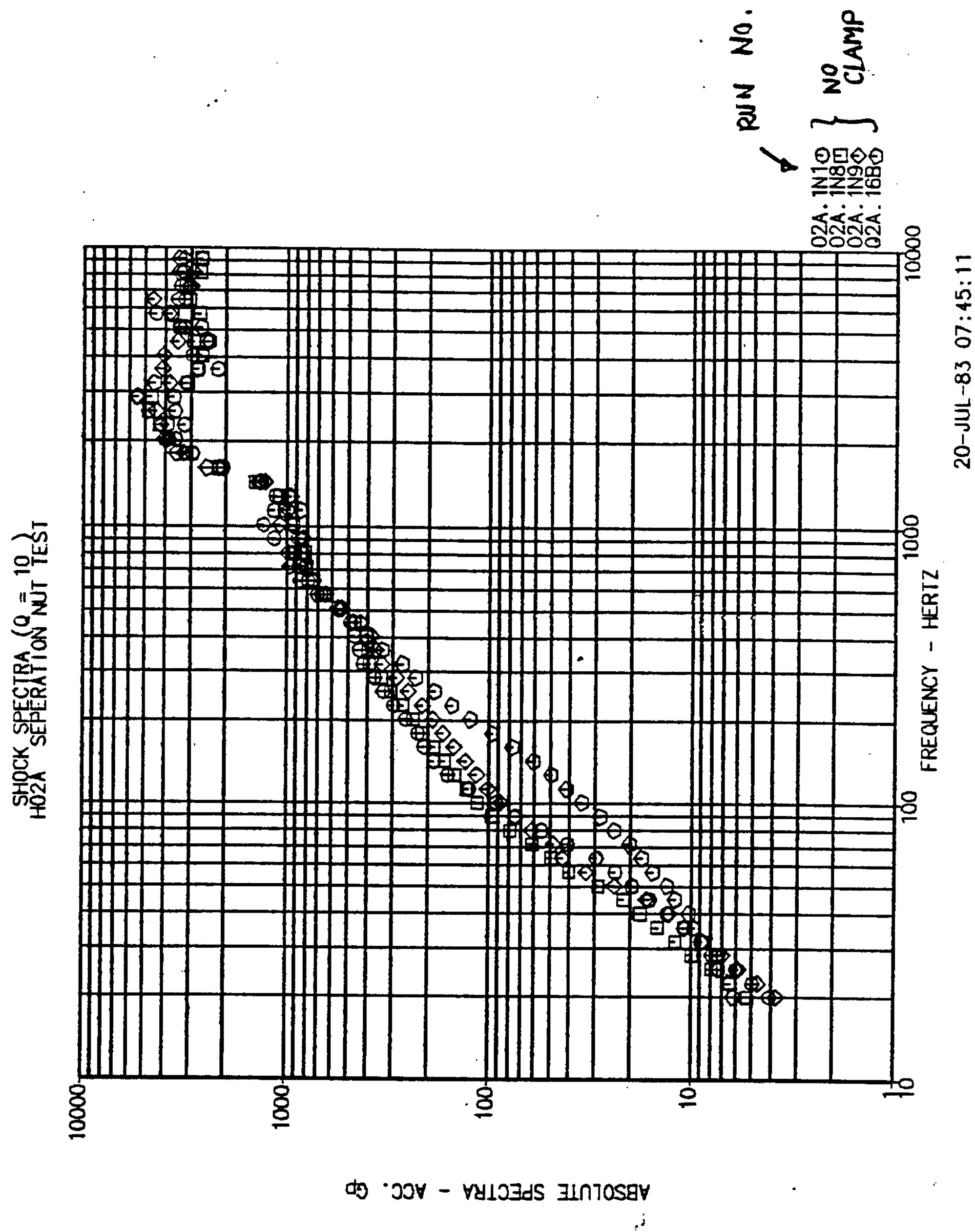


FIGURE 5 SINGLE FIXED NUT FIRING LOCATION 2 AXIAL

10

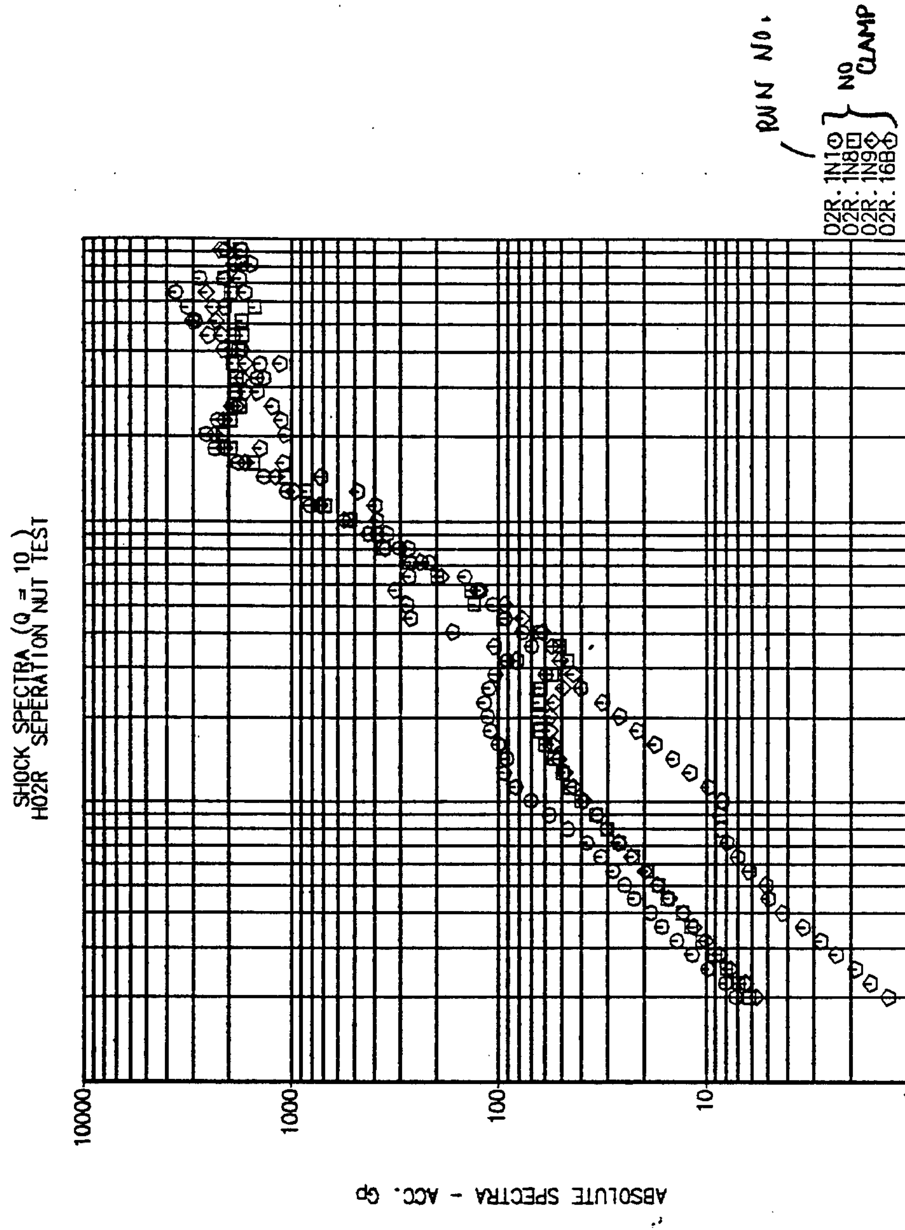


FIGURE 6 SINGLE FIXED NUT FIRING LOCATION 2 RADIAL

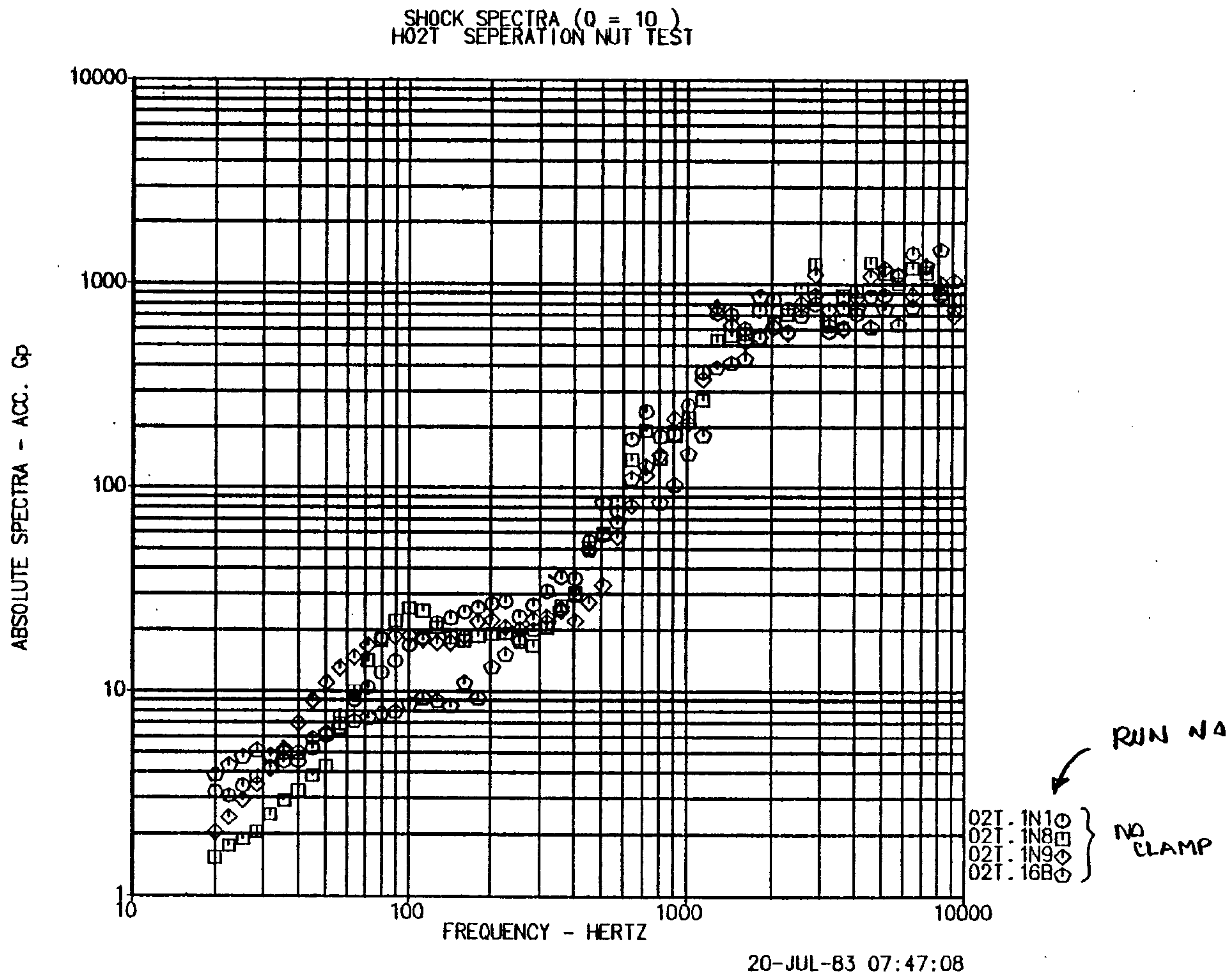


FIGURE 7 SINGLE FIXED NUT FIRING
LOCATION 2 TANGENTIAL

12

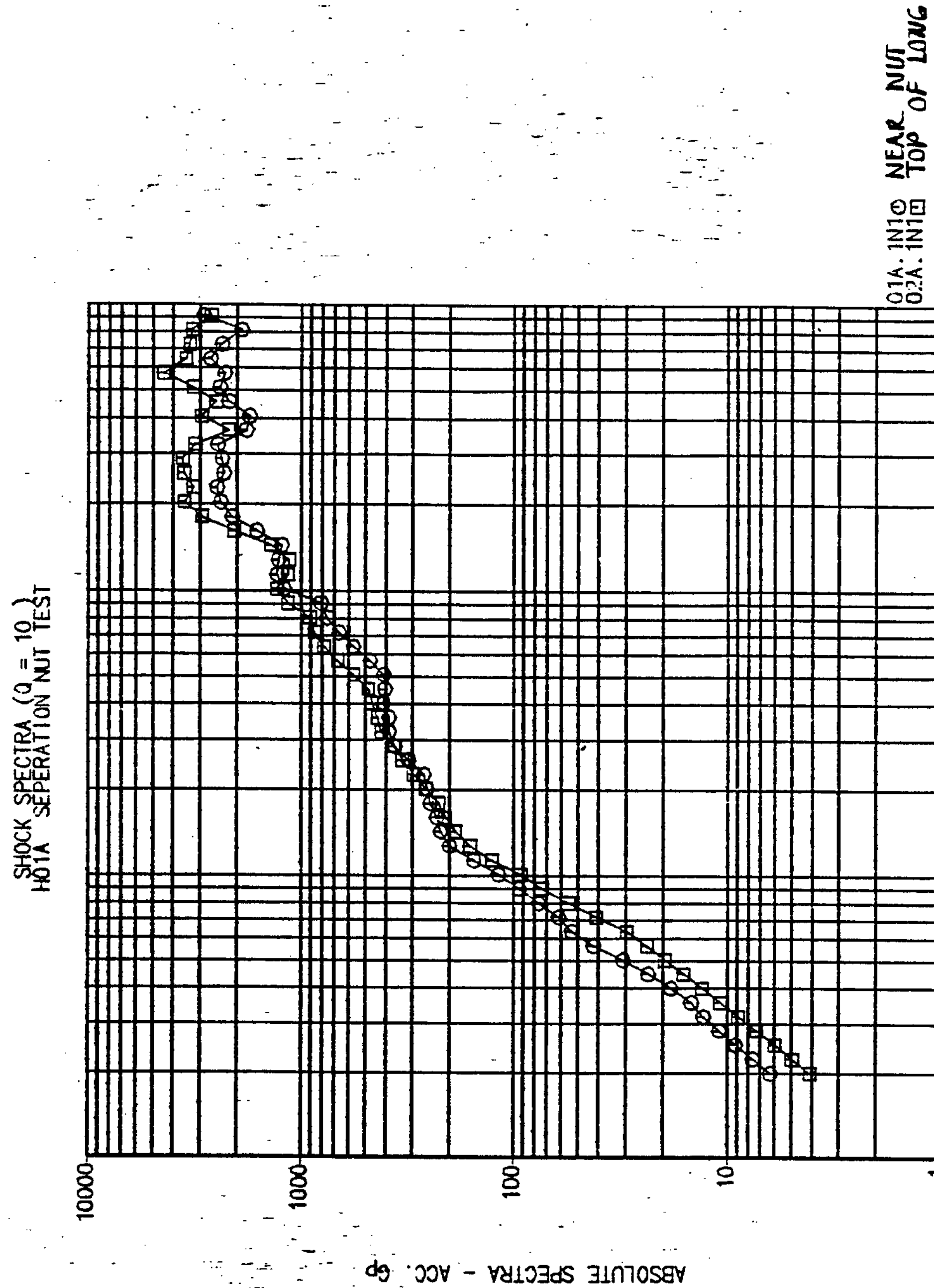


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FIGURE 8 ATTENUATION EVALUATION
LOCATION 1 AND 2 AXIAL
SINGLE FIXED NUT FIRING

13

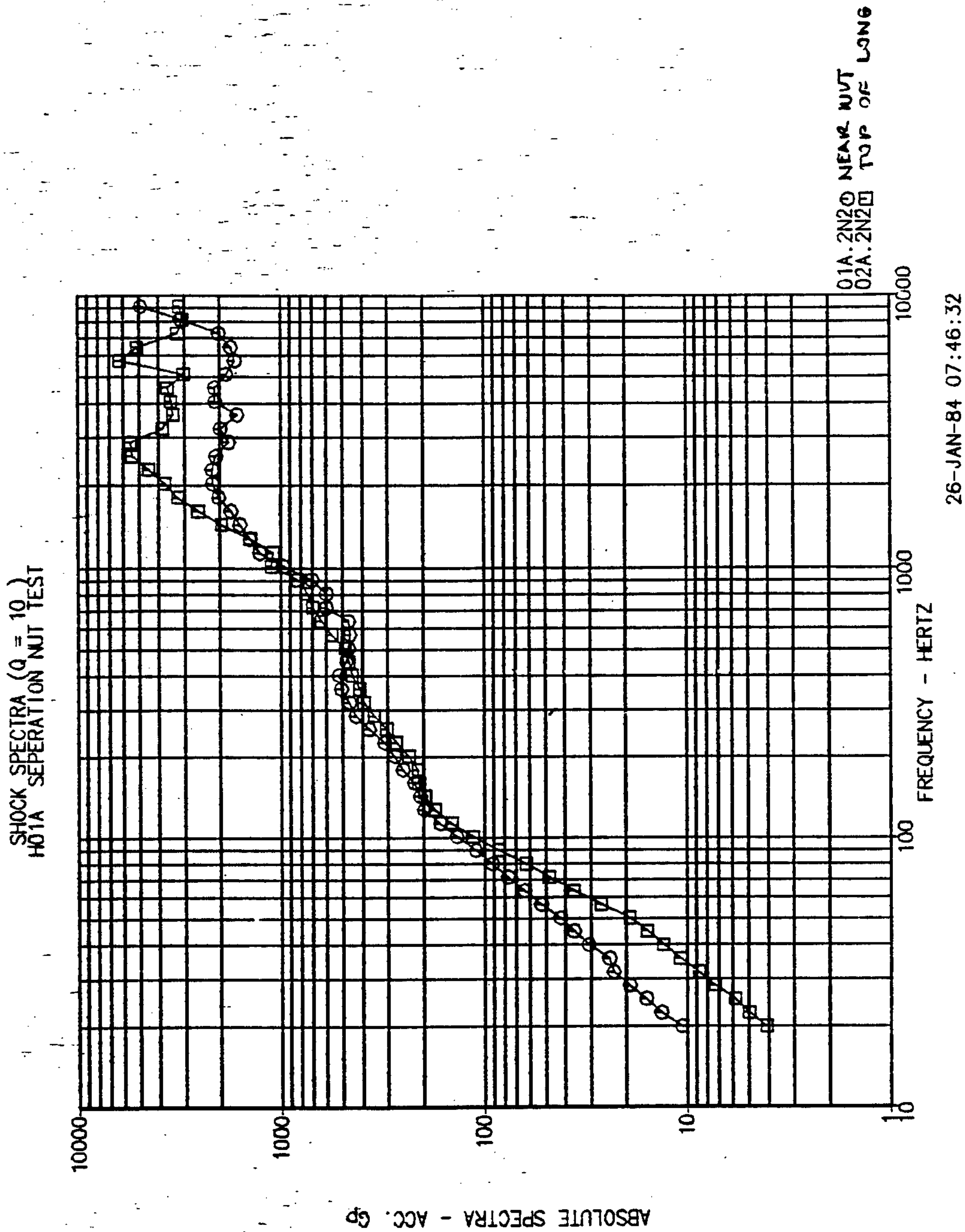


FIGURE 8A ATTENUATION EVALUATION
LOCATION 1 AND 2 AXIAL
2 NUT FIRING

14

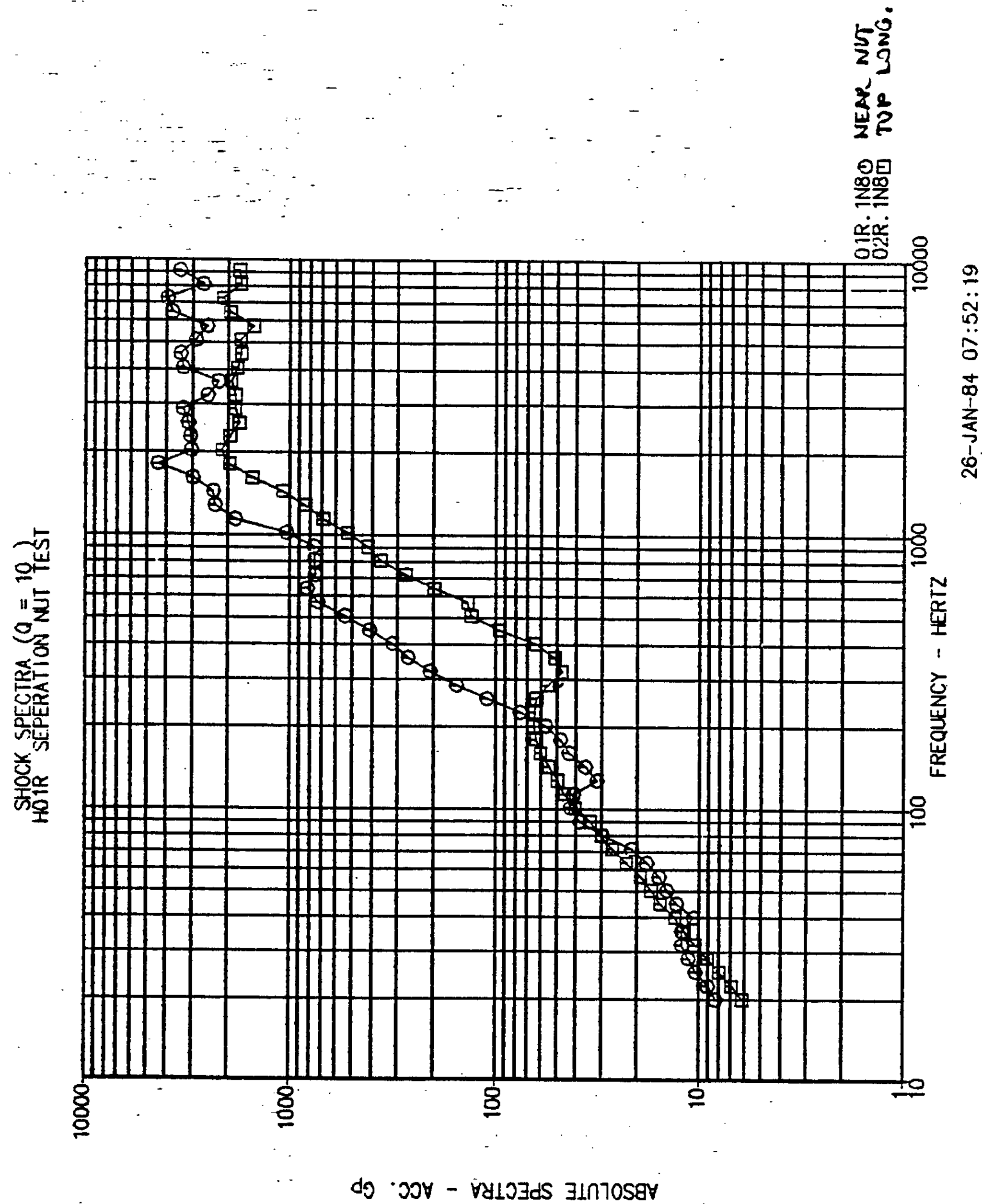


FIGURE 9 ATTENUATION EVALUATION
LOCATION 1 & Z RADIAL
SINGLE FIXED NUT FIRING

15

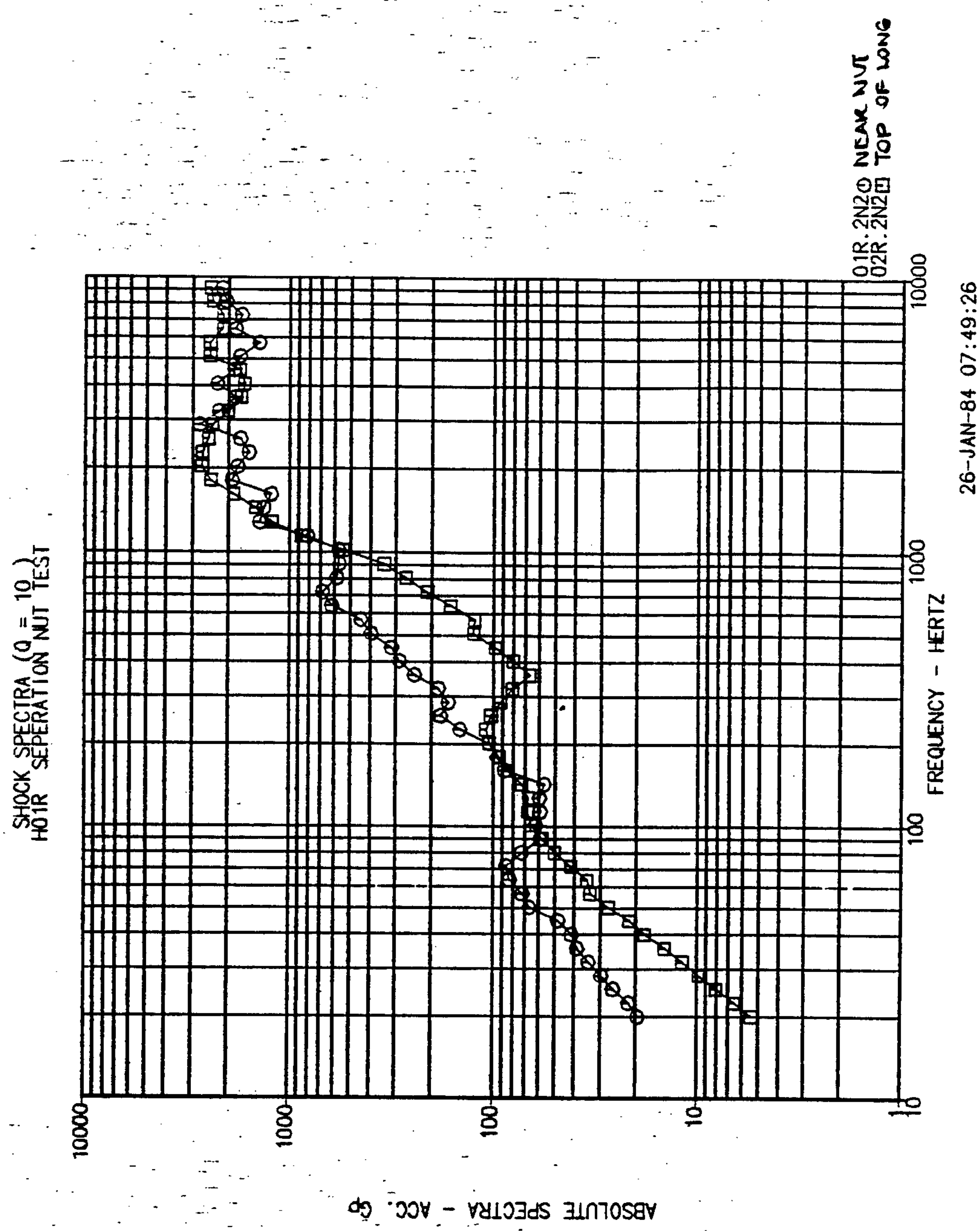


FIGURE 9A ATTENUATION EVALUATION LOCATION 1 AND 2 RADIAL 2 NUT FIRING

16

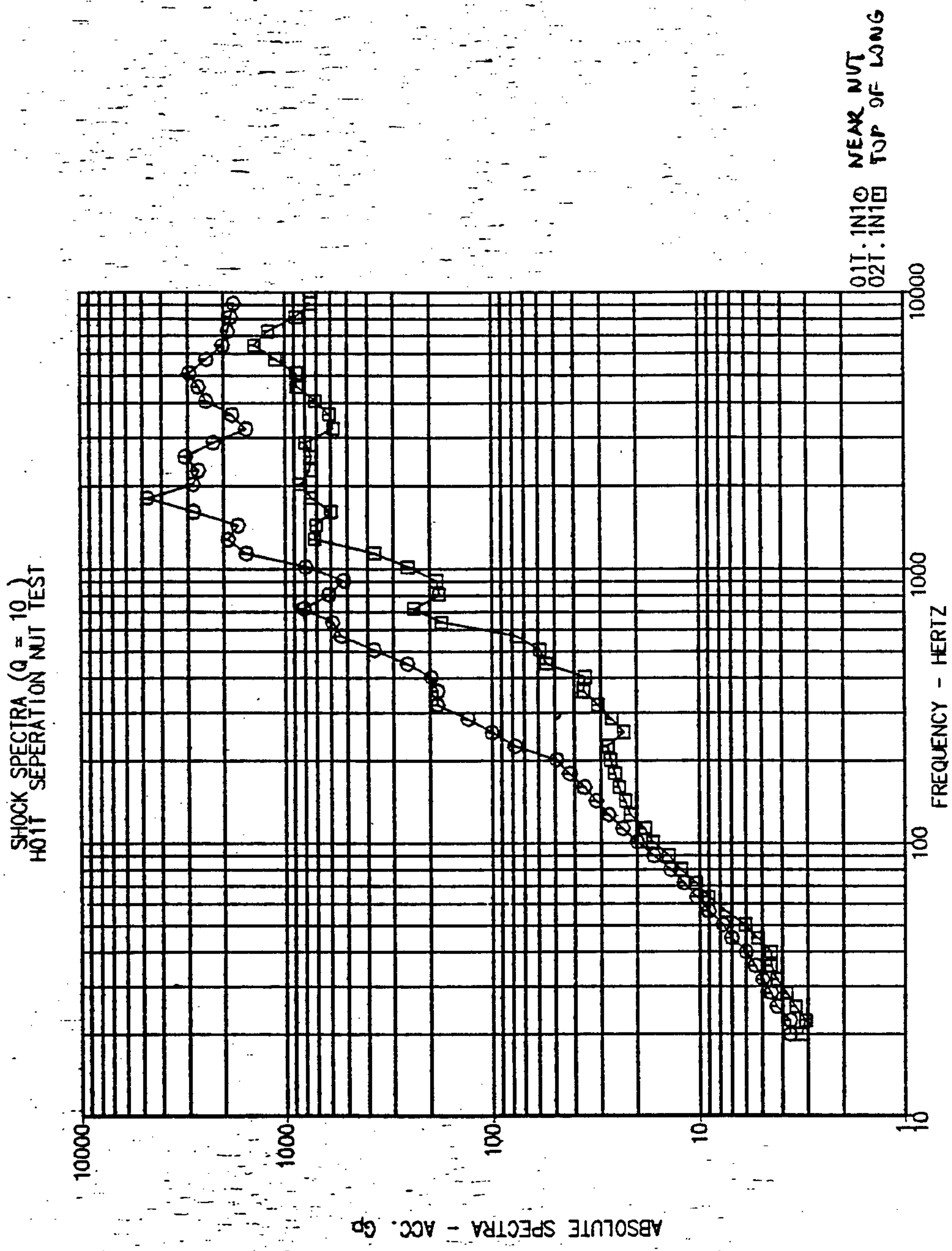


FIGURE 10 ATTENUATION EVALUATION
LOCATION 1 & 2 TANGENTIAL
SINGLE FIXED NUT FIRING

17

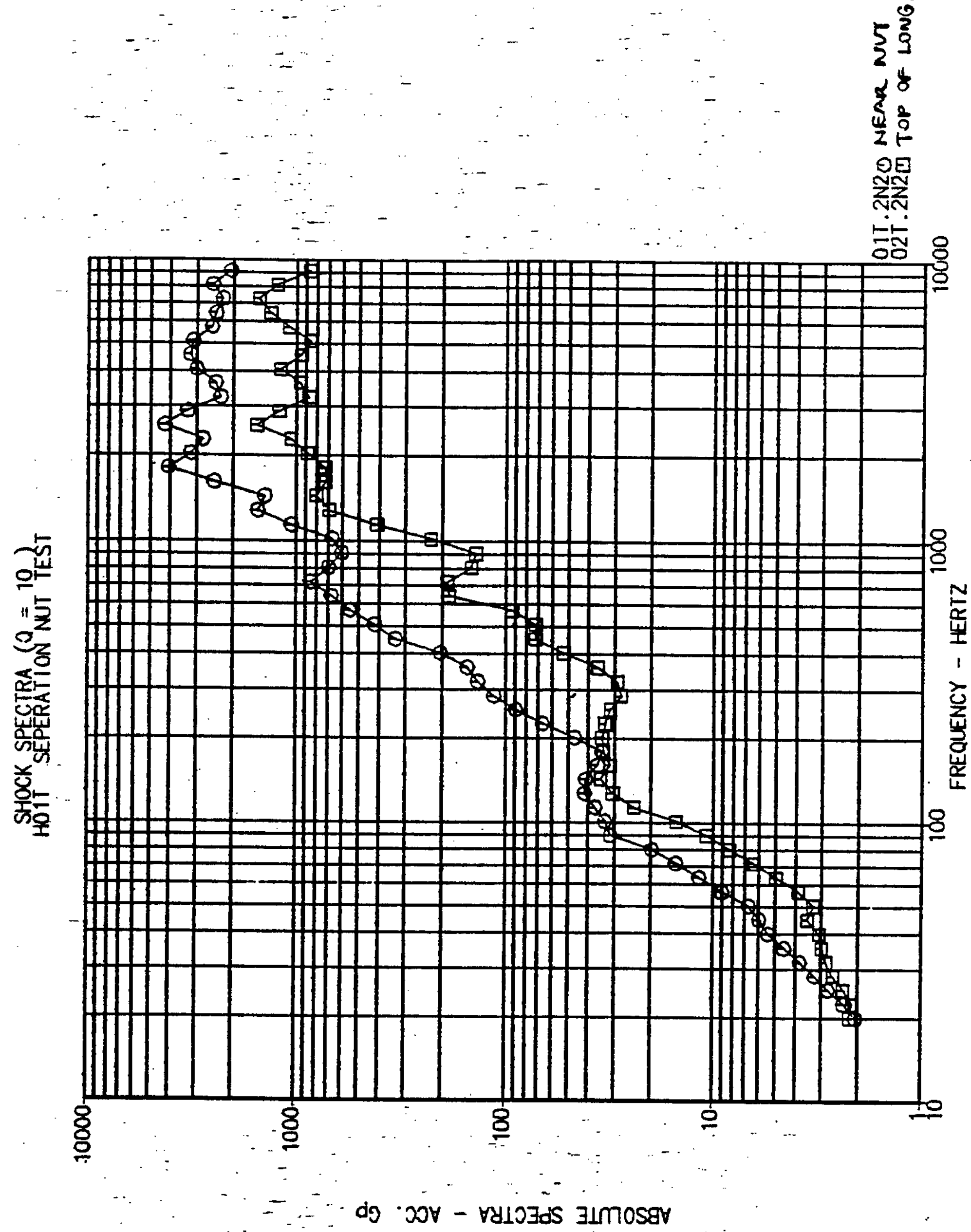


FIGURE 10A ATTENUATION EVALUATION LOCATION 1 AND 2 TANGENTIAL 2 NUT FIRING

18

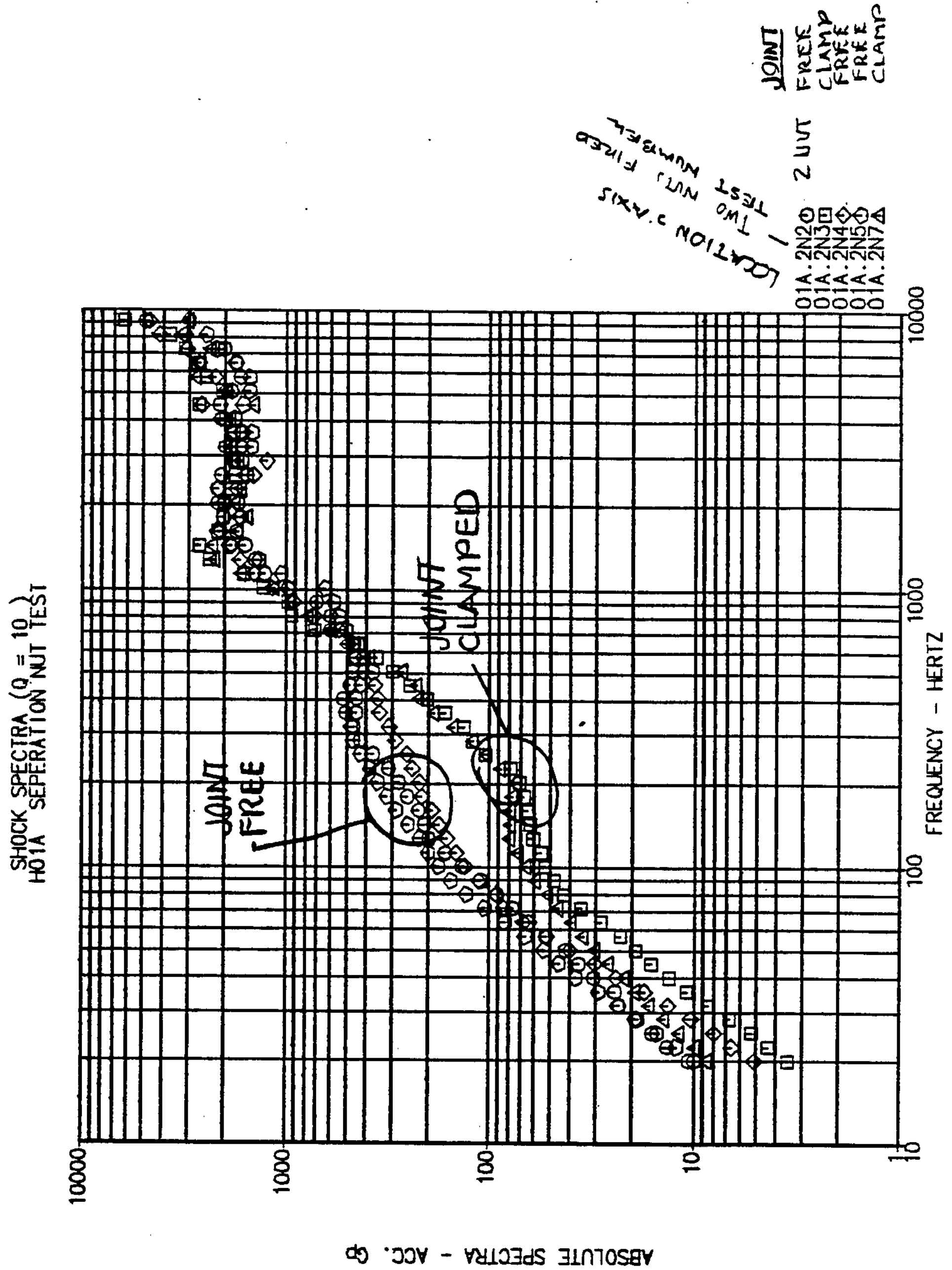


FIGURE 11 2 NUT FIRING
LOCATION 1 AXIAL
JOINT FREE & CLAMPED

19

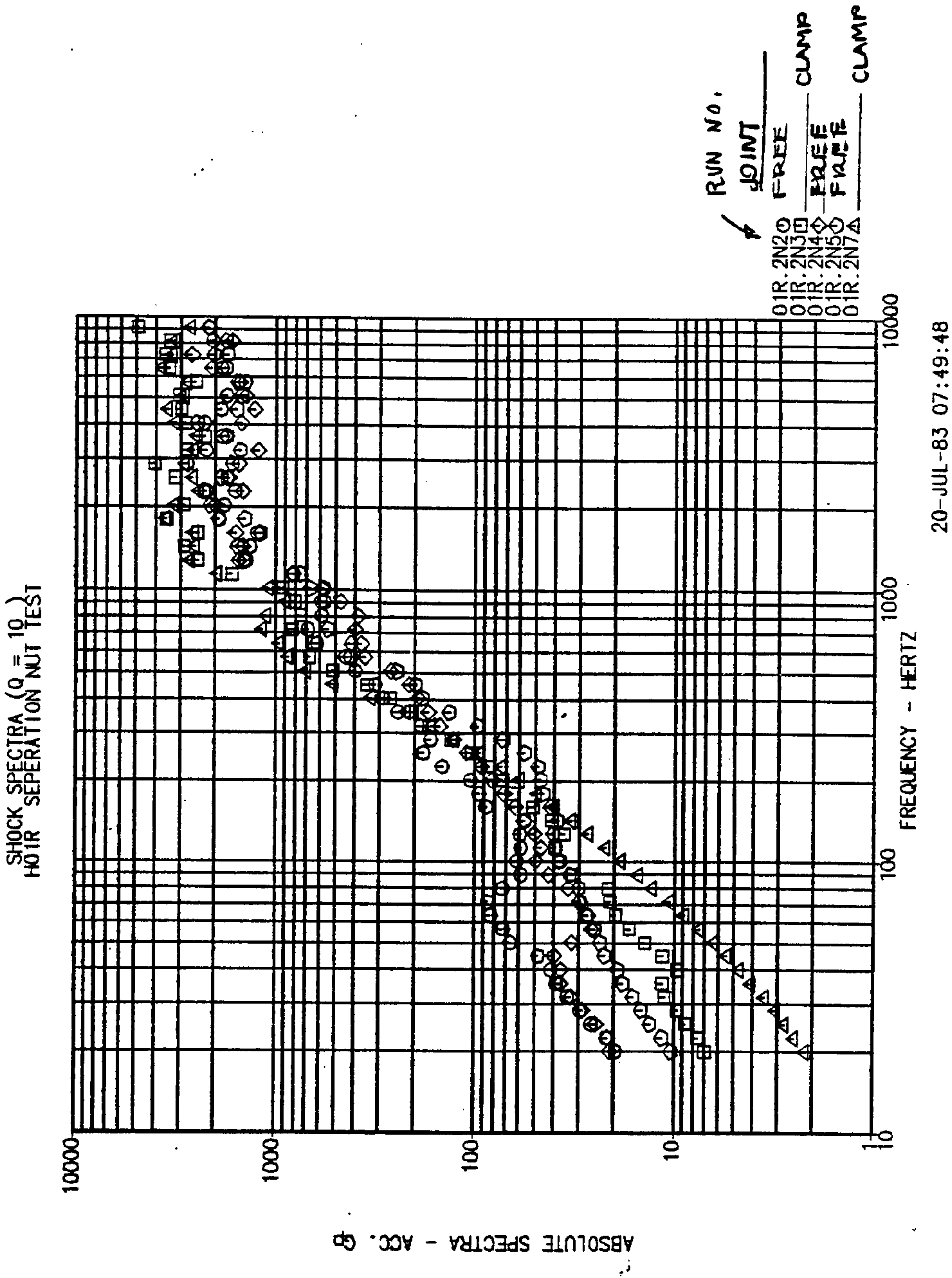


FIGURE 12 2 NUT FIRING
LOCATION 1 RADIAL
JOINT FREE & CLAMPED

20

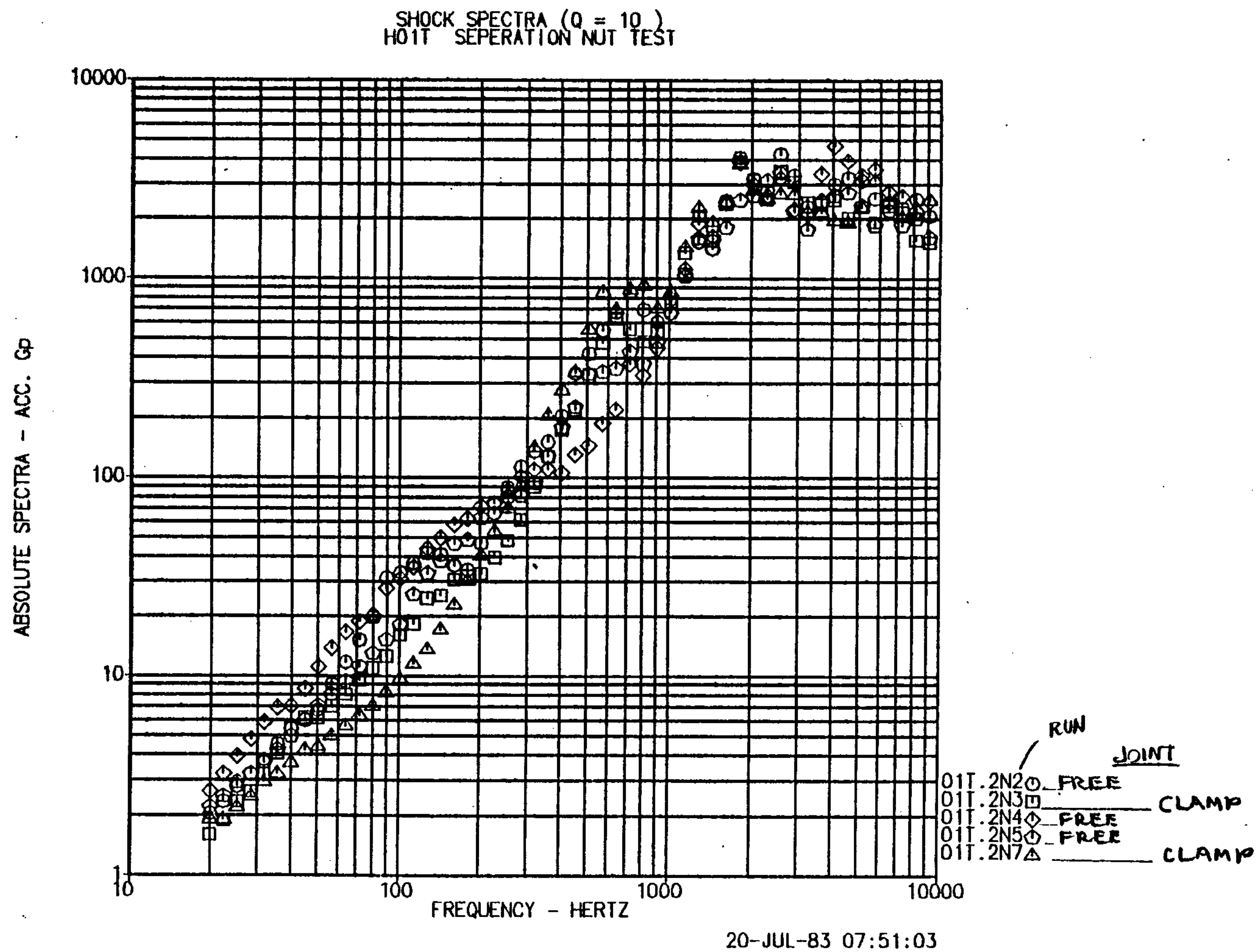


FIGURE 13 2 NUT FIRING
LOCATION 1 TANGENTIAL
JOINT FREE & CLAMPED

21

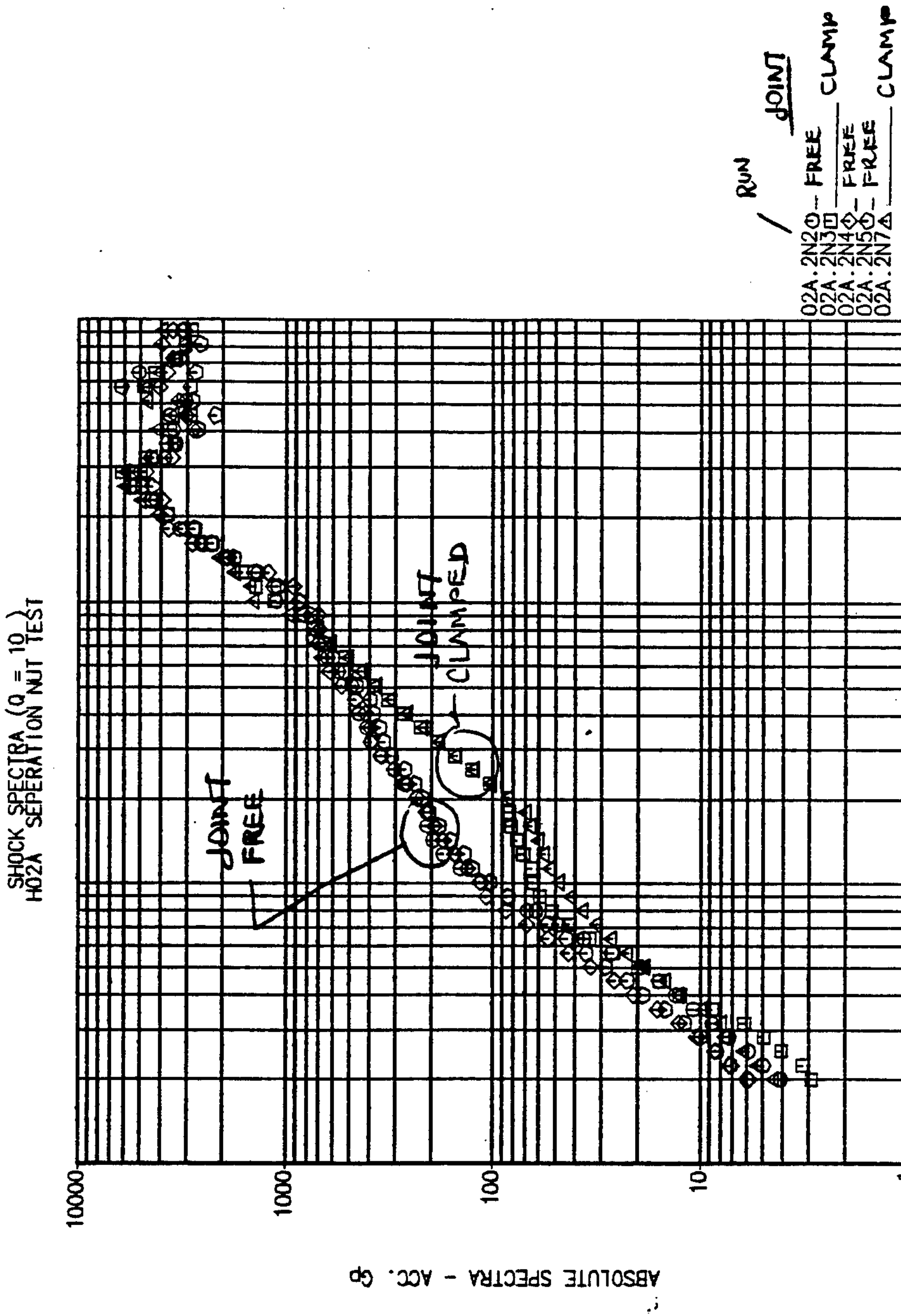


FIGURE 14 2 NUT FIRING
LOCATION 2 AXIAL
JOINT FREE & CLAMPED

22

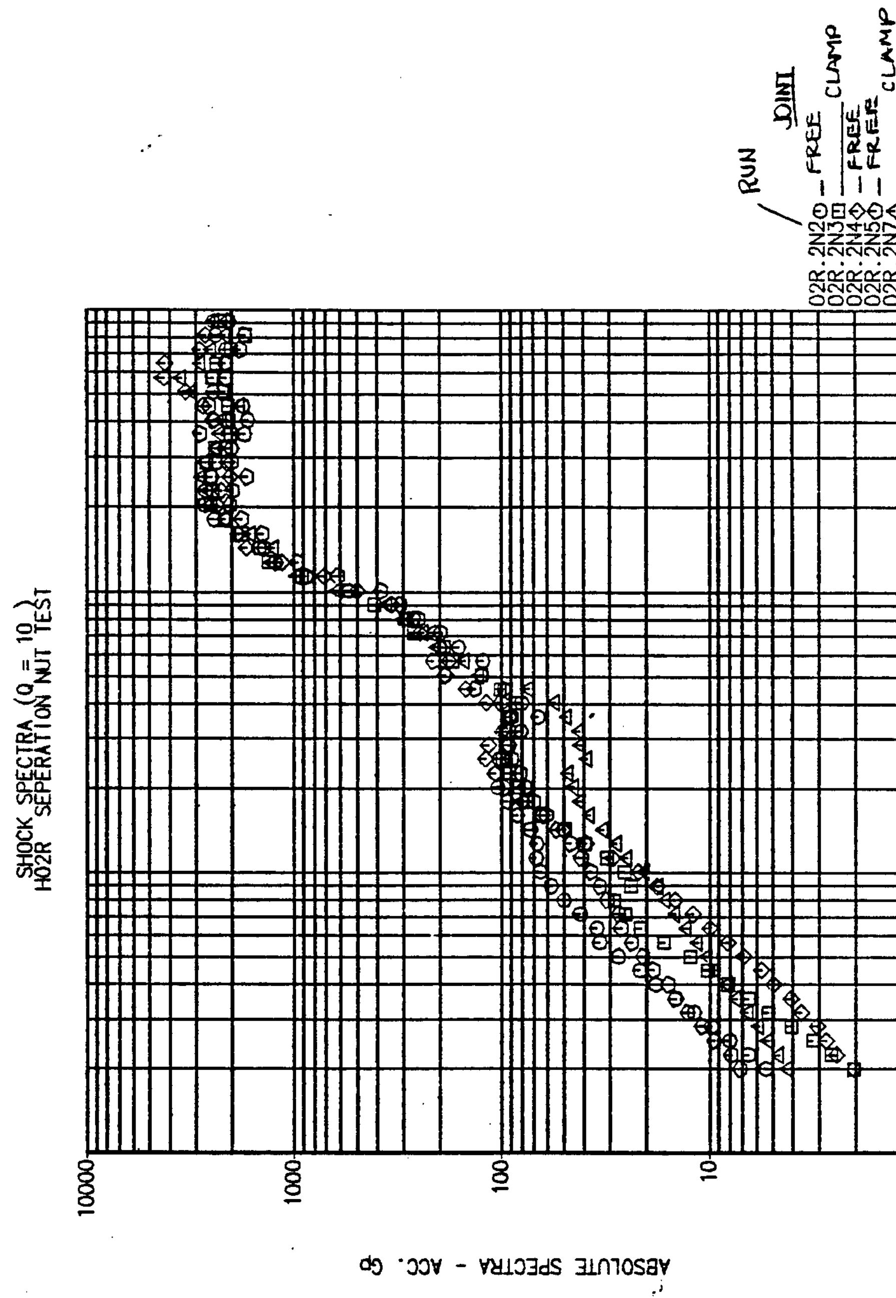


FIGURE 15 Z NUT FIRING LOCATION Z RADIAL JOINT FREE & CLAMPED

24

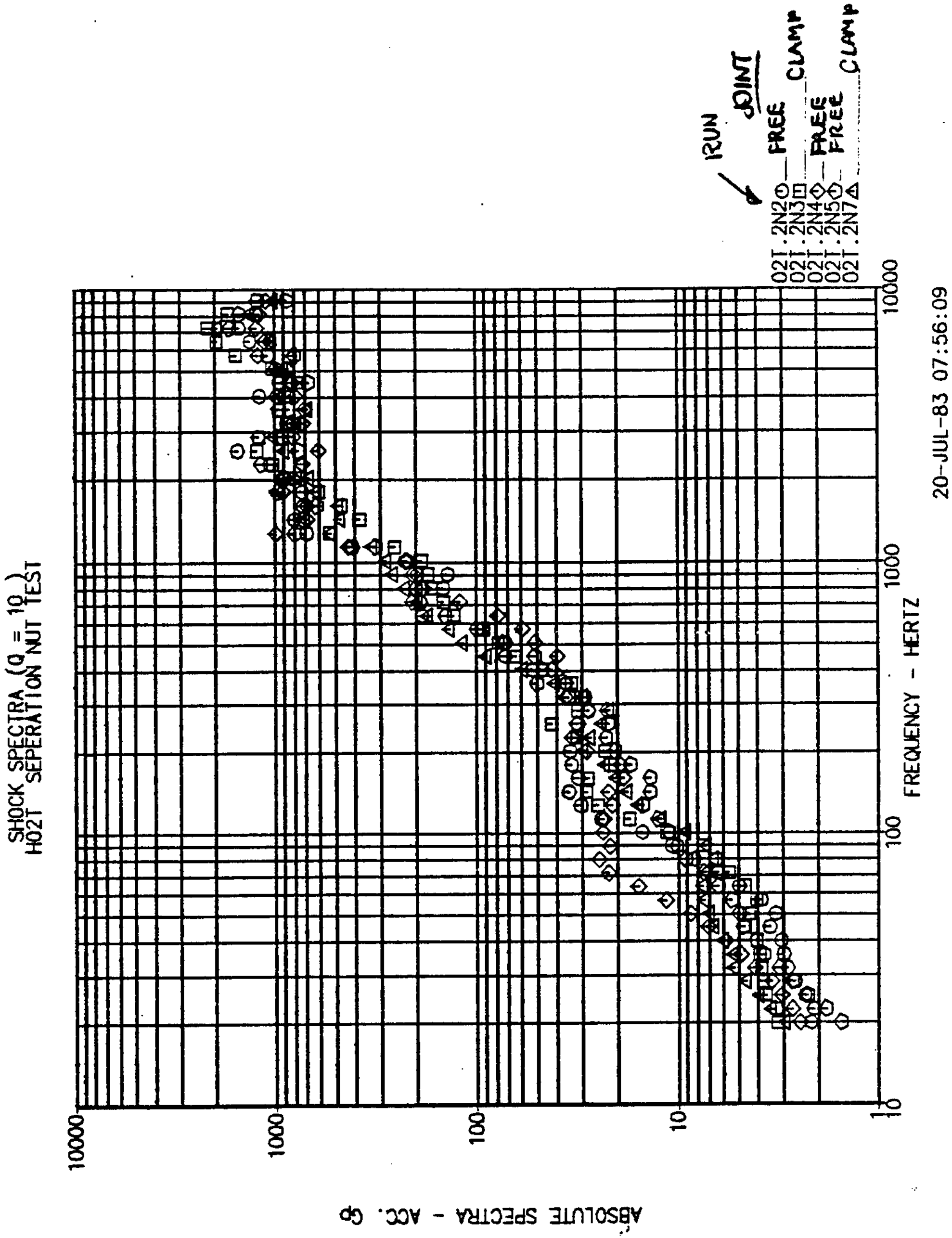
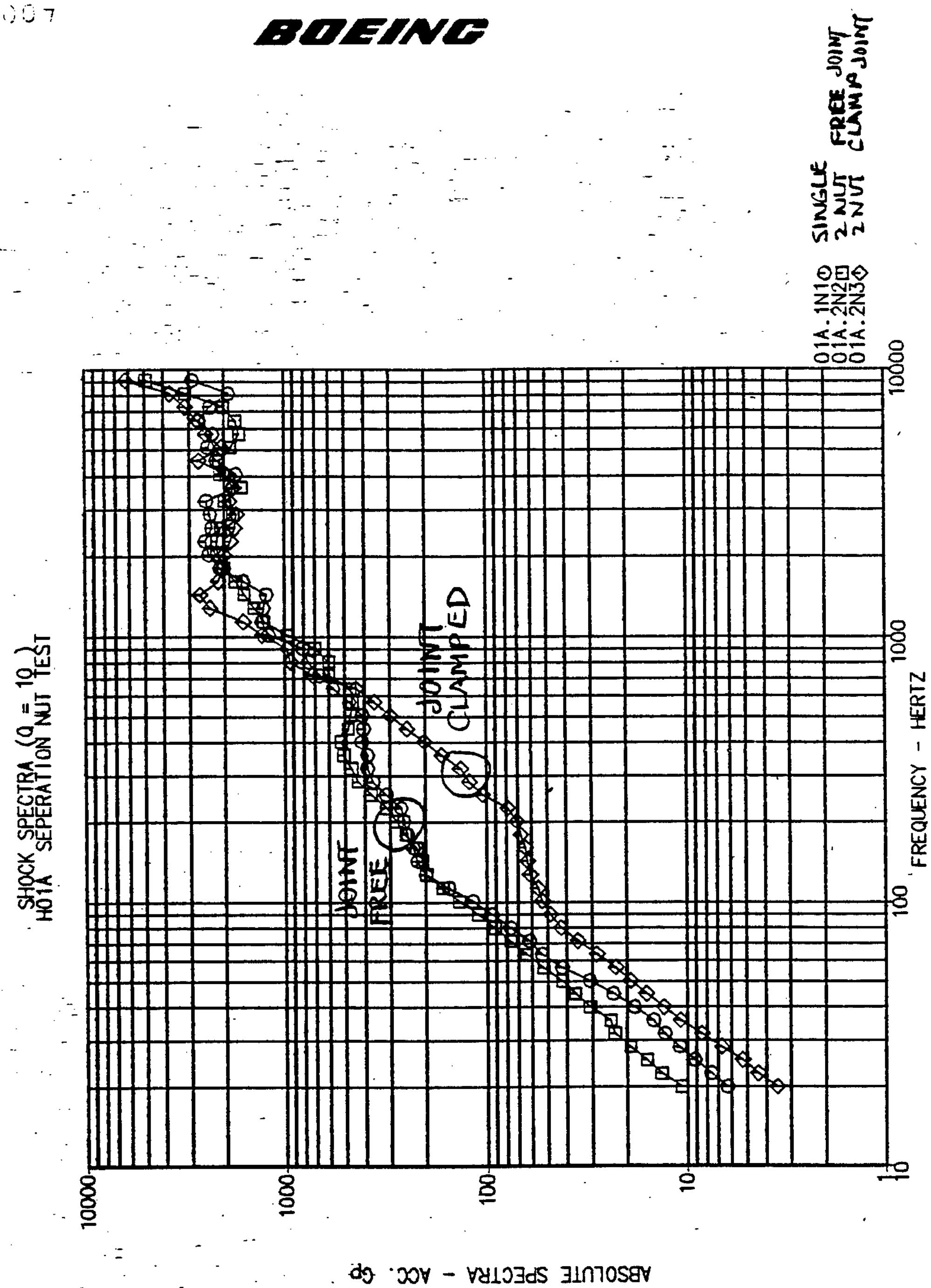


FIGURE 16 2 NUT FIRING
LOCATION 2 TANGENTIAL
JOINT FREE & CLAMPED

25



26-JAN-84 07:39:57

FIGURE 17 SINGLE VS. 2 NUT SHOCK
LOCATION 1 AXIAL
JOINT FREE AND CLAMPED

26

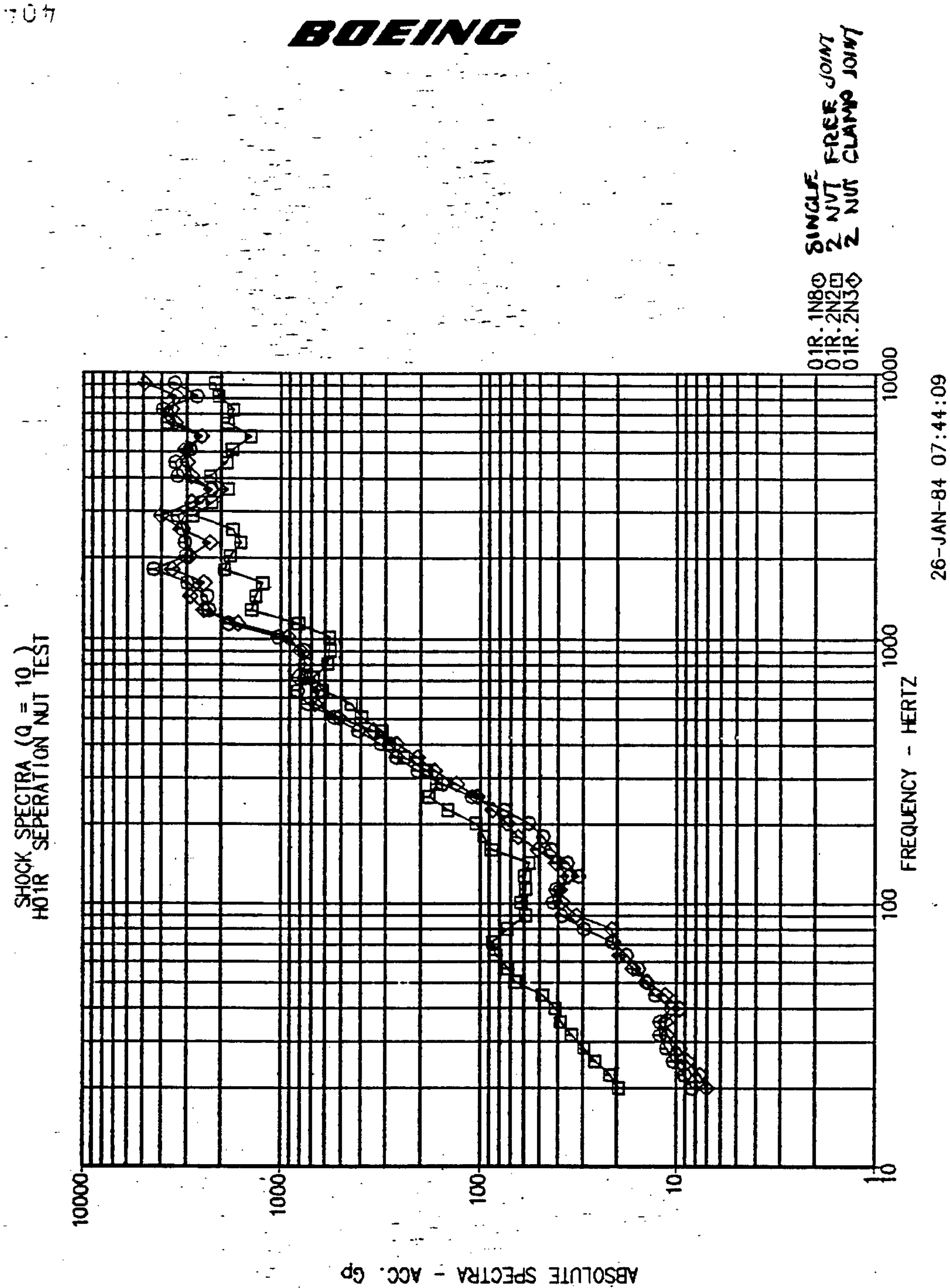


FIGURE 18 SINGLE VS. 2 NUT SHOCK LOCATION 1 RADIAL JOINT FREE AND CLAMPED

27

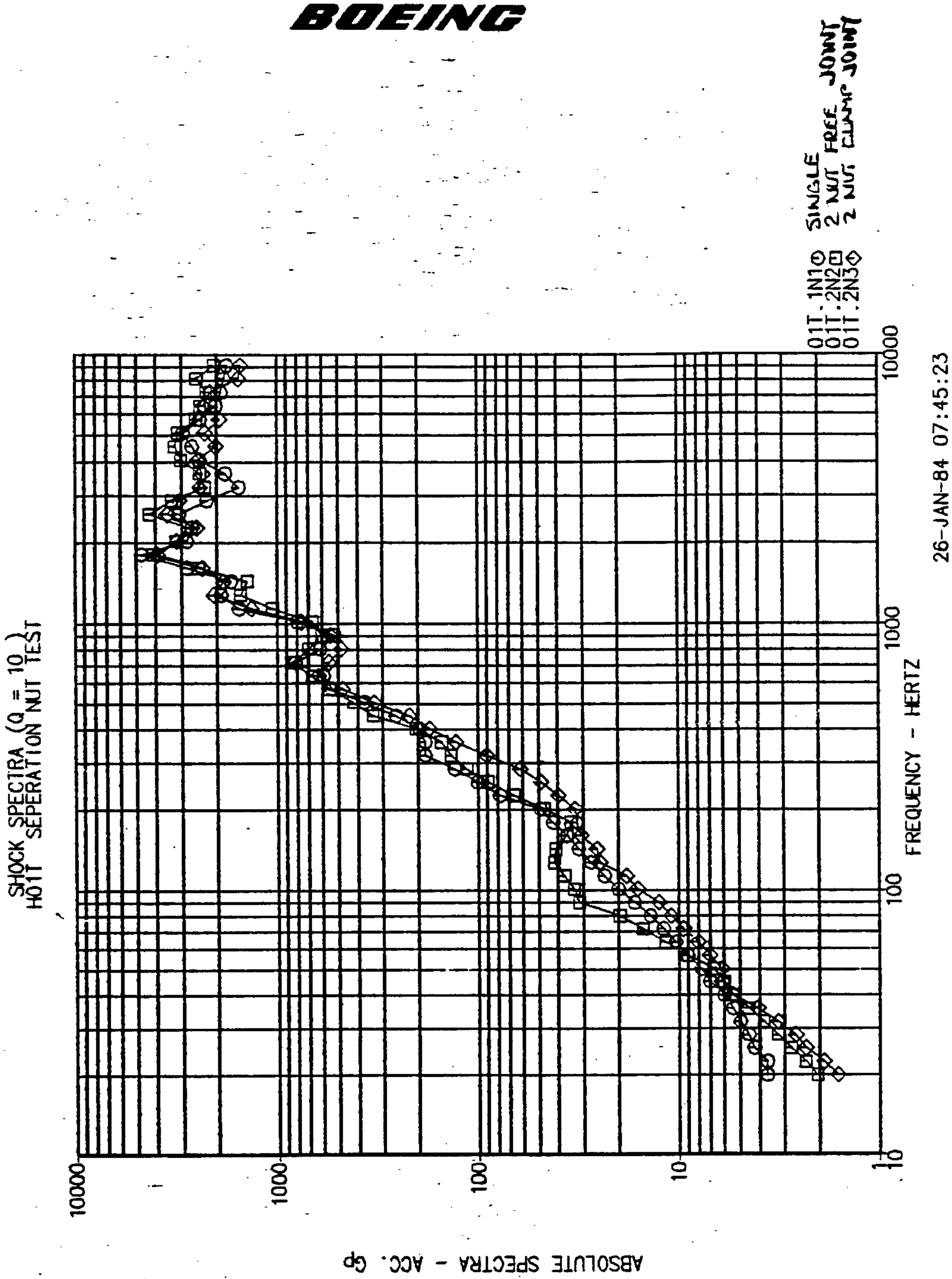


FIGURE 19 SINGLE VS. 2 NUT SHOCK
LOCATION 1 TANGENTIAL
JOINT FREE & CLAMPED

28

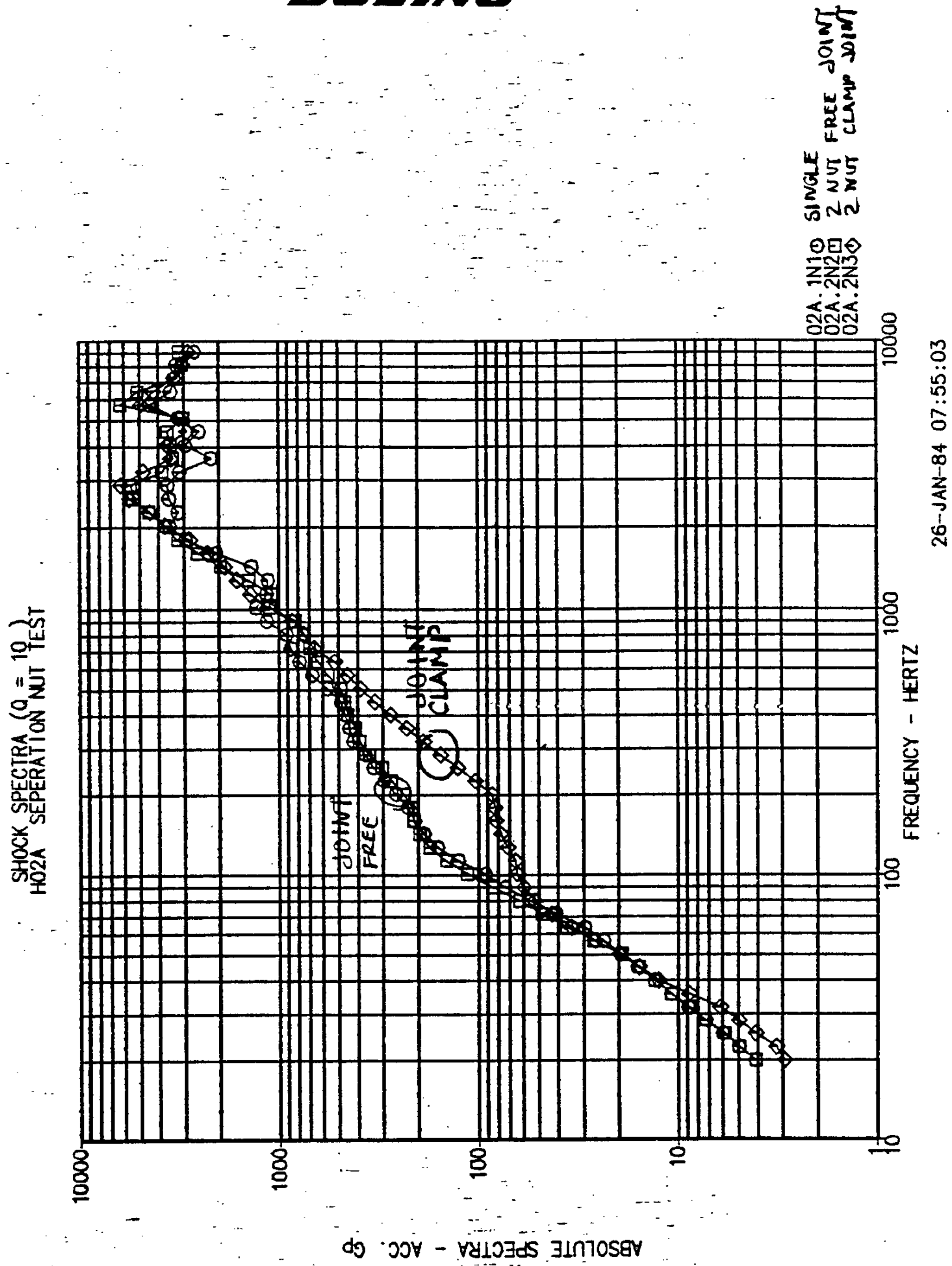


FIGURE 20 SINGLE VS. 2 NUT SHOCK
LOCATION 2 AXIAL
JOINT FREE AND CLAMPED

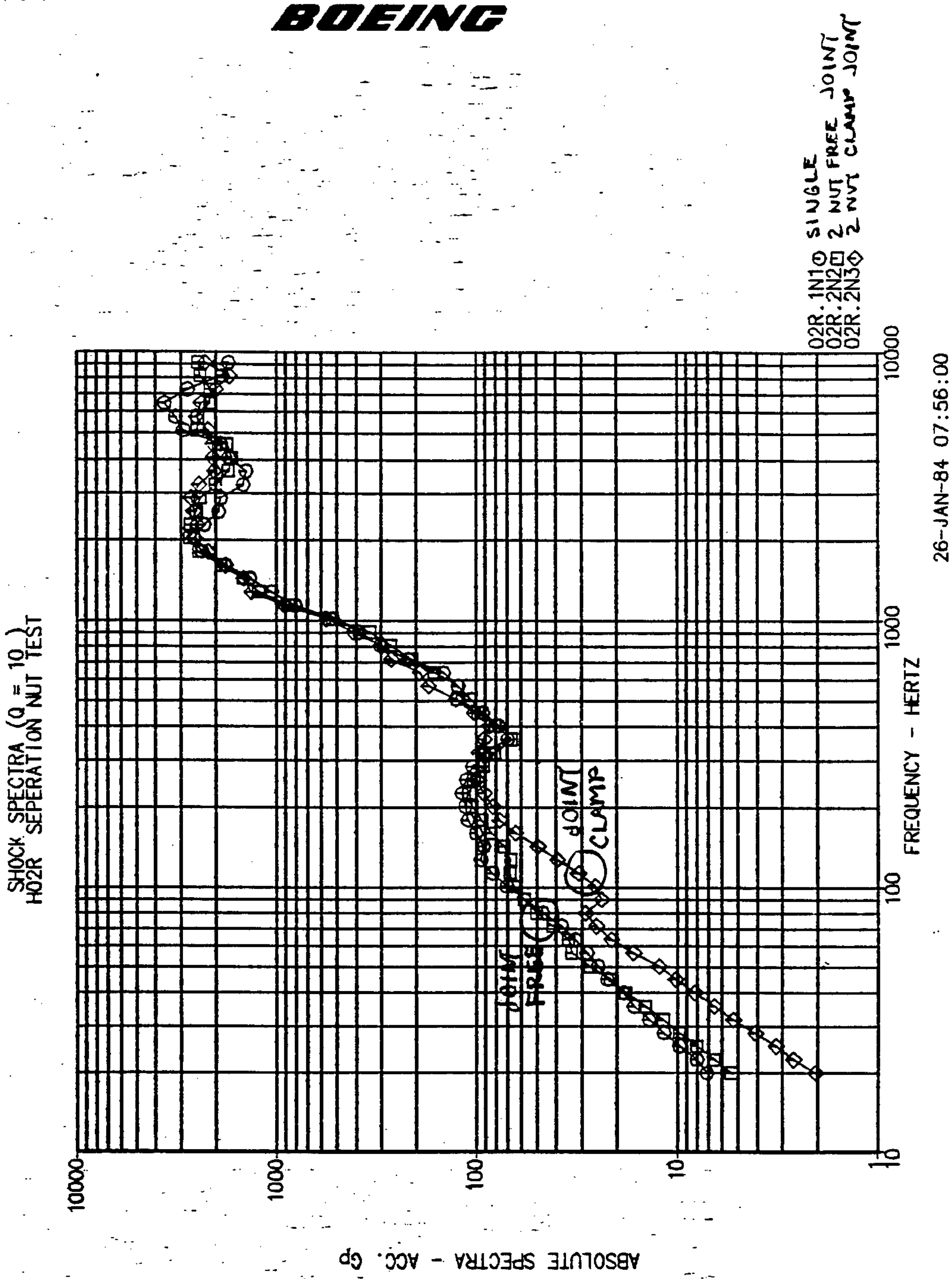


FIGURE 21 SINGLE VS. 2 NUT SHOCK
LOCATION 2 RADIAL
JOINT FREE AND CLAMPED

30

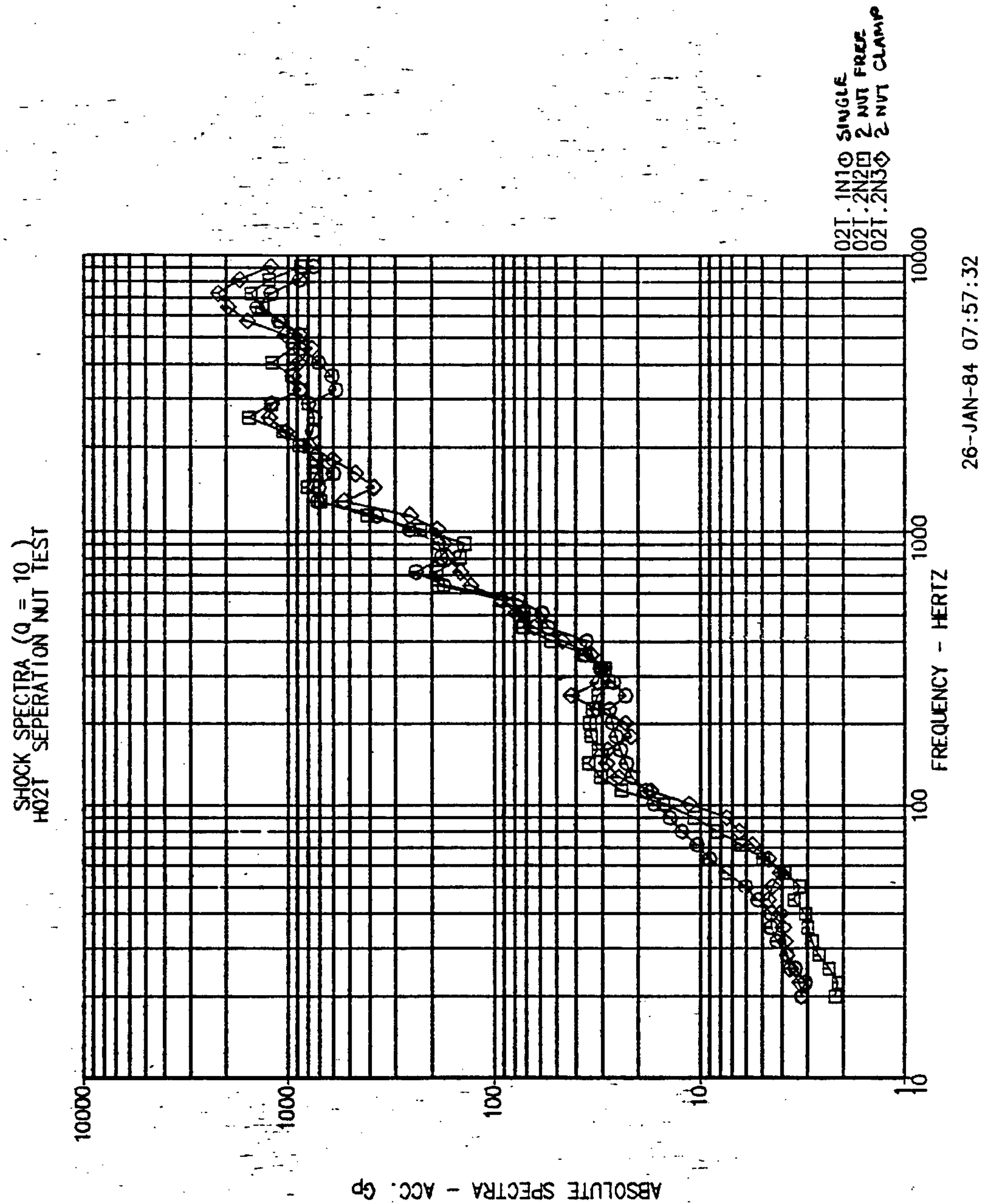


FIGURE 22 SINGLE VS. 2 NUT SHOCK
LOCATION 2 TANGENTIAL
JOINT FREE AND CLAMPED

31

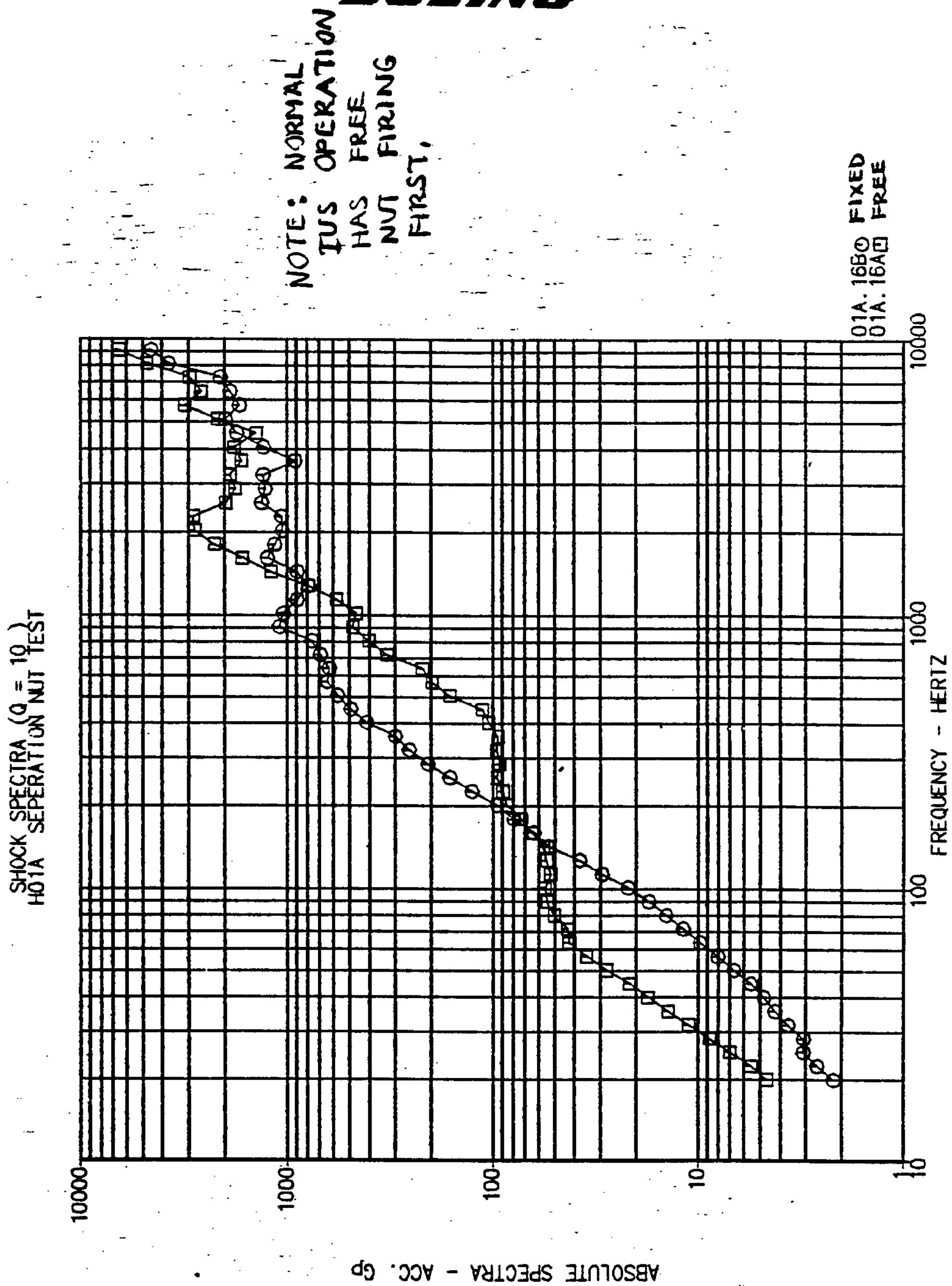


FIGURE 23 SINGLE NUT FIRING
FIXED NUT VS. FREE NUT
LOC. 1. AXIAL

32

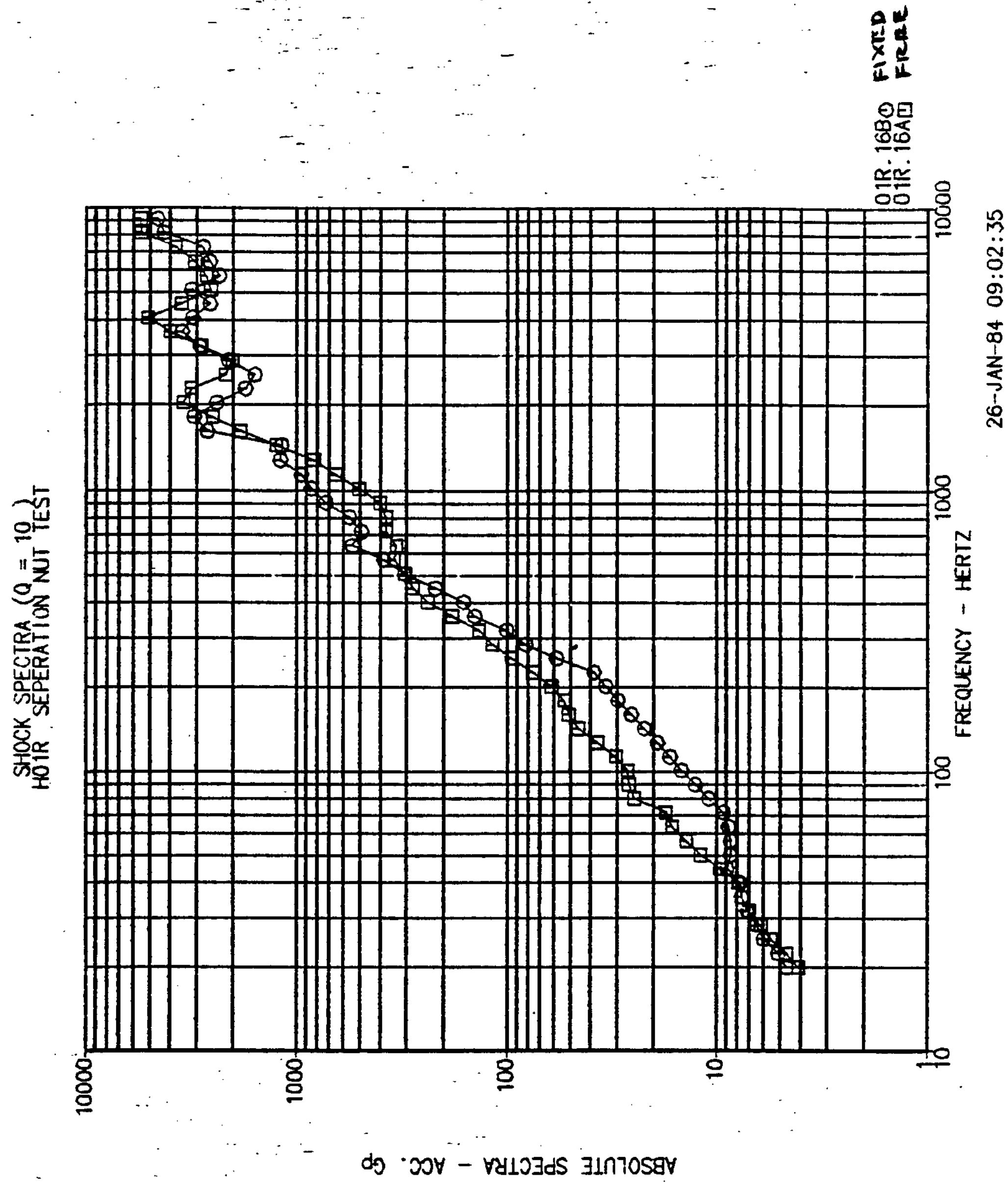


FIGURE Z4 SINGLE NUT FIRING
FIXED NUT VS. FREE NUT
LOC. 1 RADIAL

33

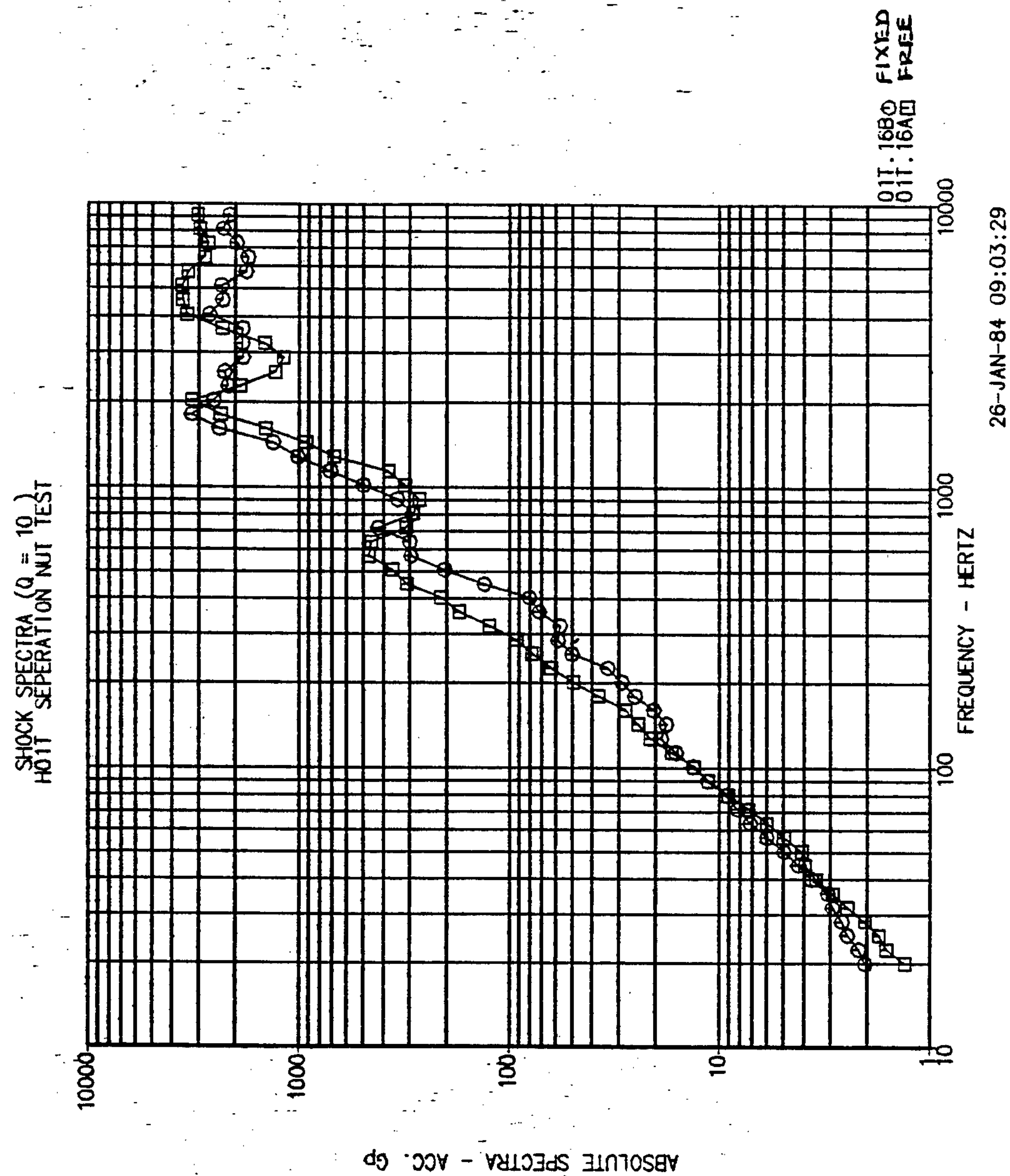


FIGURE 25 SINGLE NUT FIRING
FIXED NUT VS. FREE NUT
LOC. 1. TANGENTIAL

34

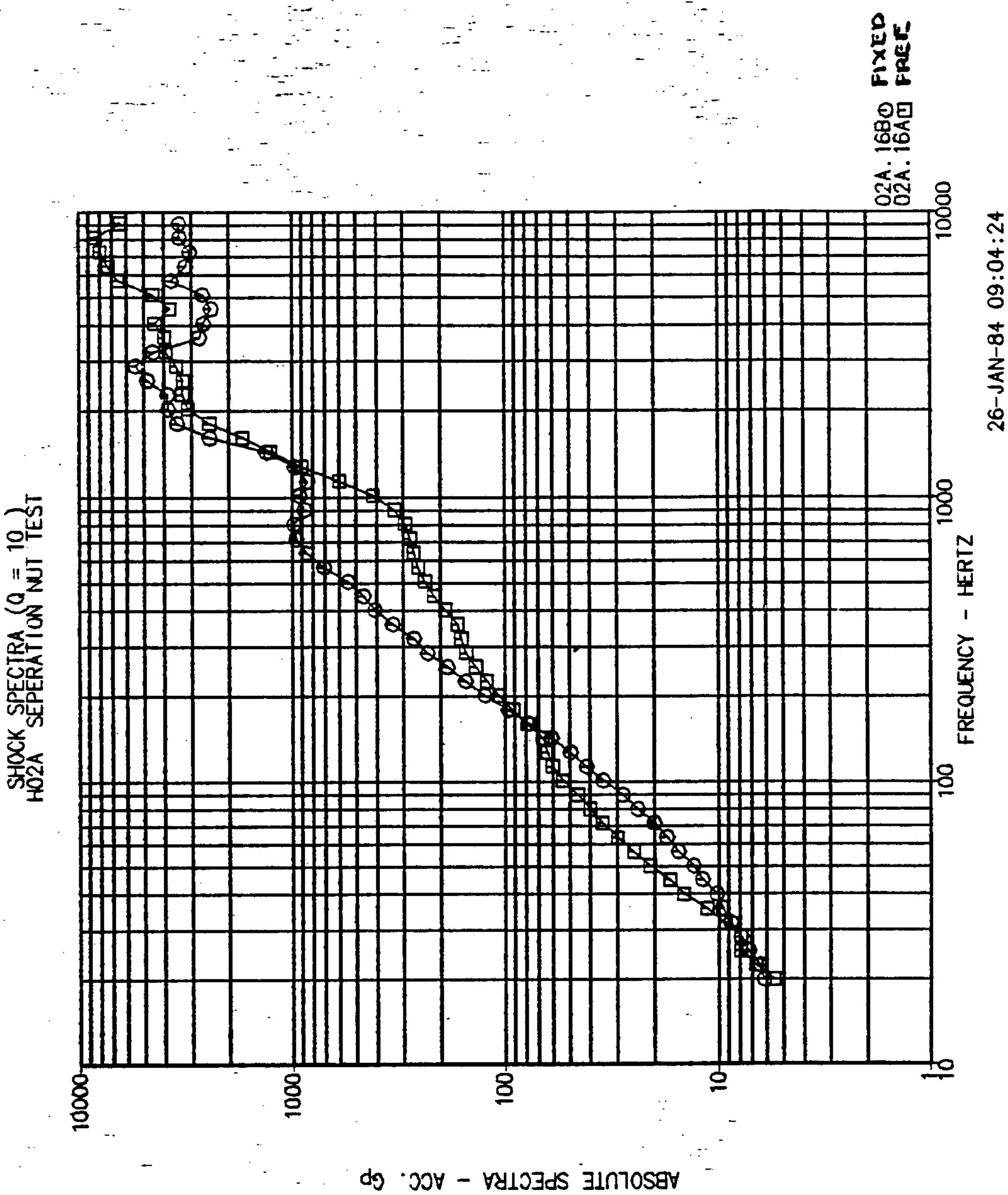


FIGURE 26 SINGLE NUT FIRING
FIXED NUT VS. FREE NUT
LOC. 2 AXIAL

35

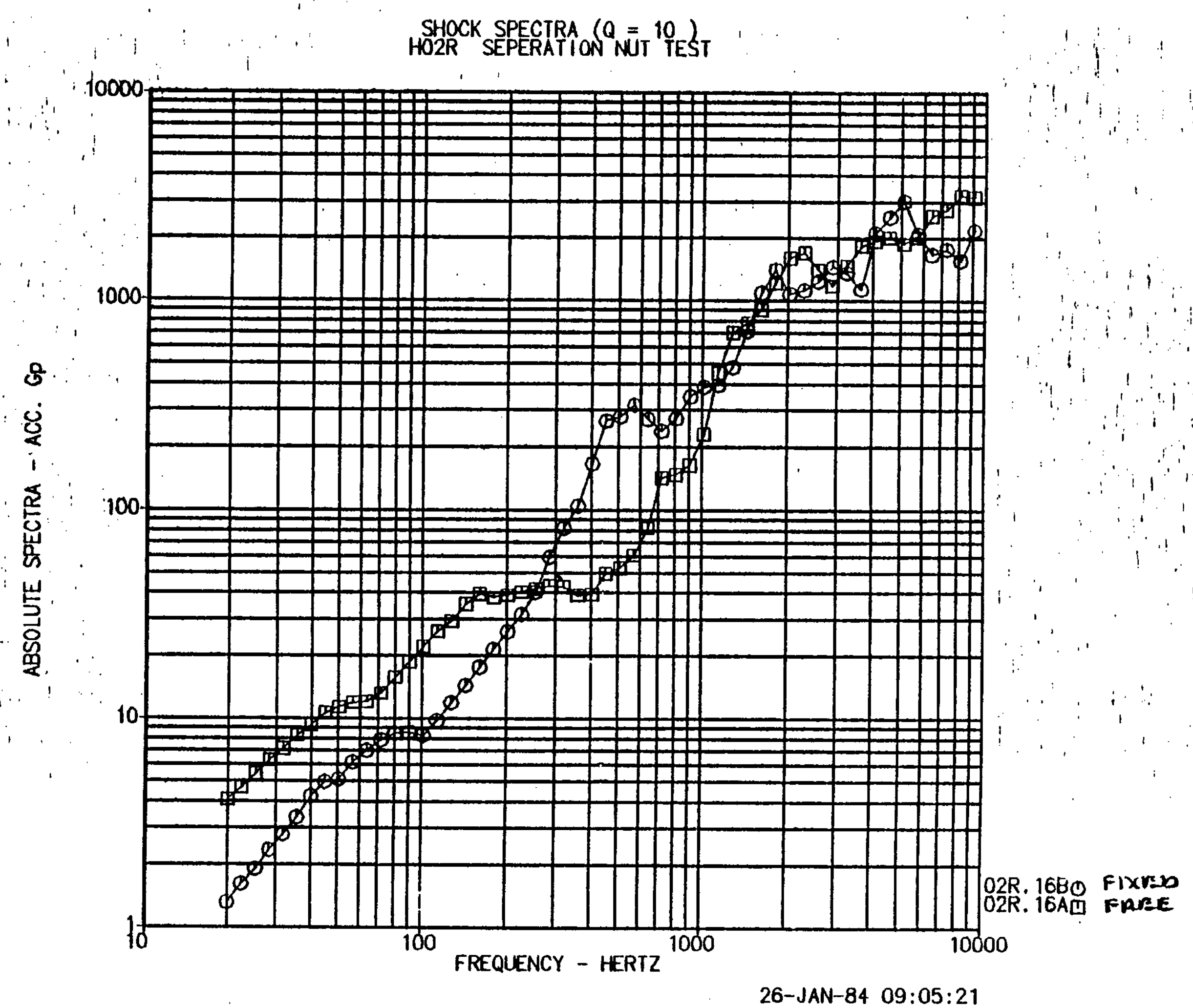


FIGURE 27 SINGLE NUT FIRING
FIXED NUT VS. FREE NUT
LOC. 2 RADIAL

36

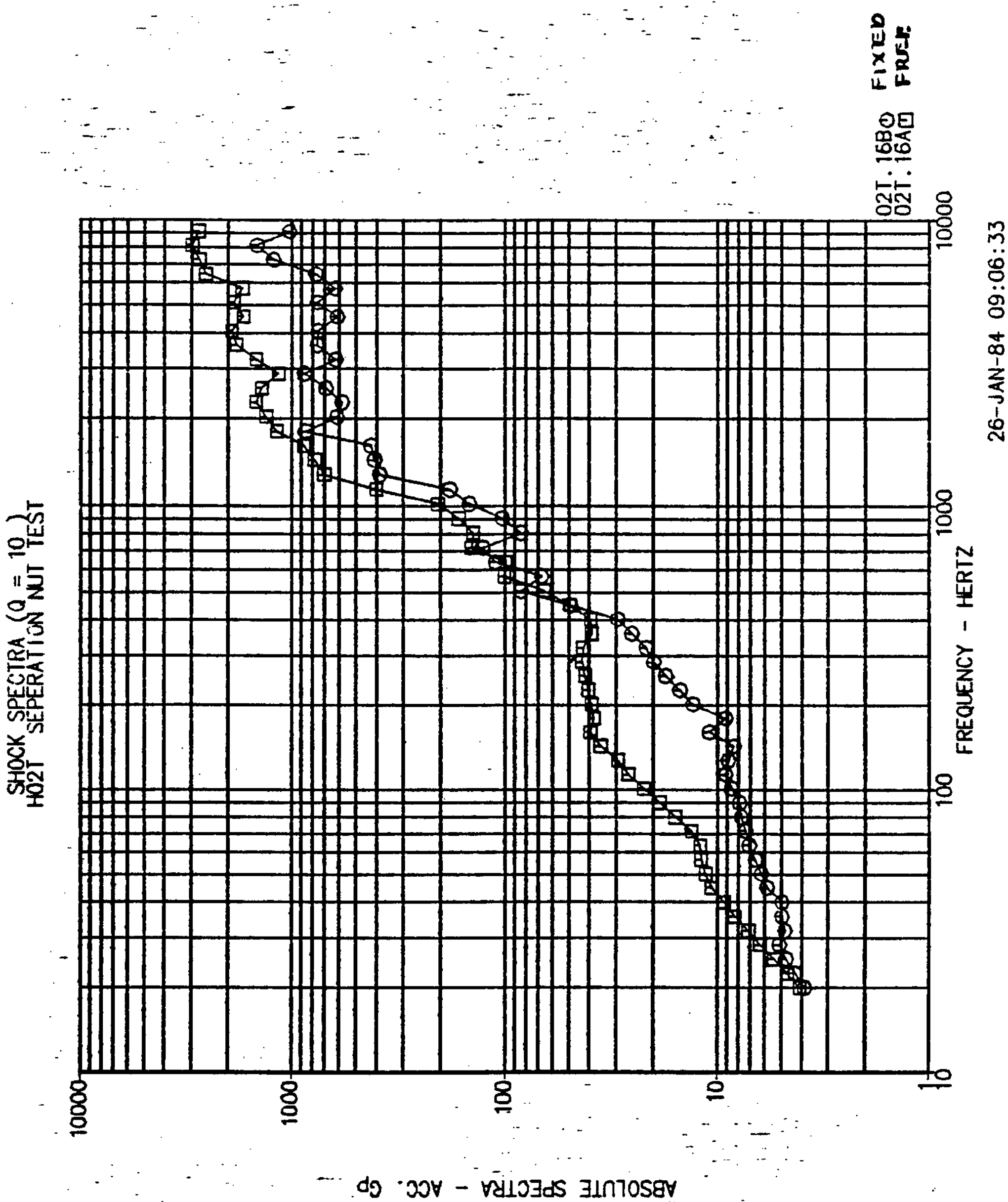


FIGURE 28 SINGLE NUT FIRING
FIXED NUT VS. FREE
LOC. 2. TANGENTIAL

37

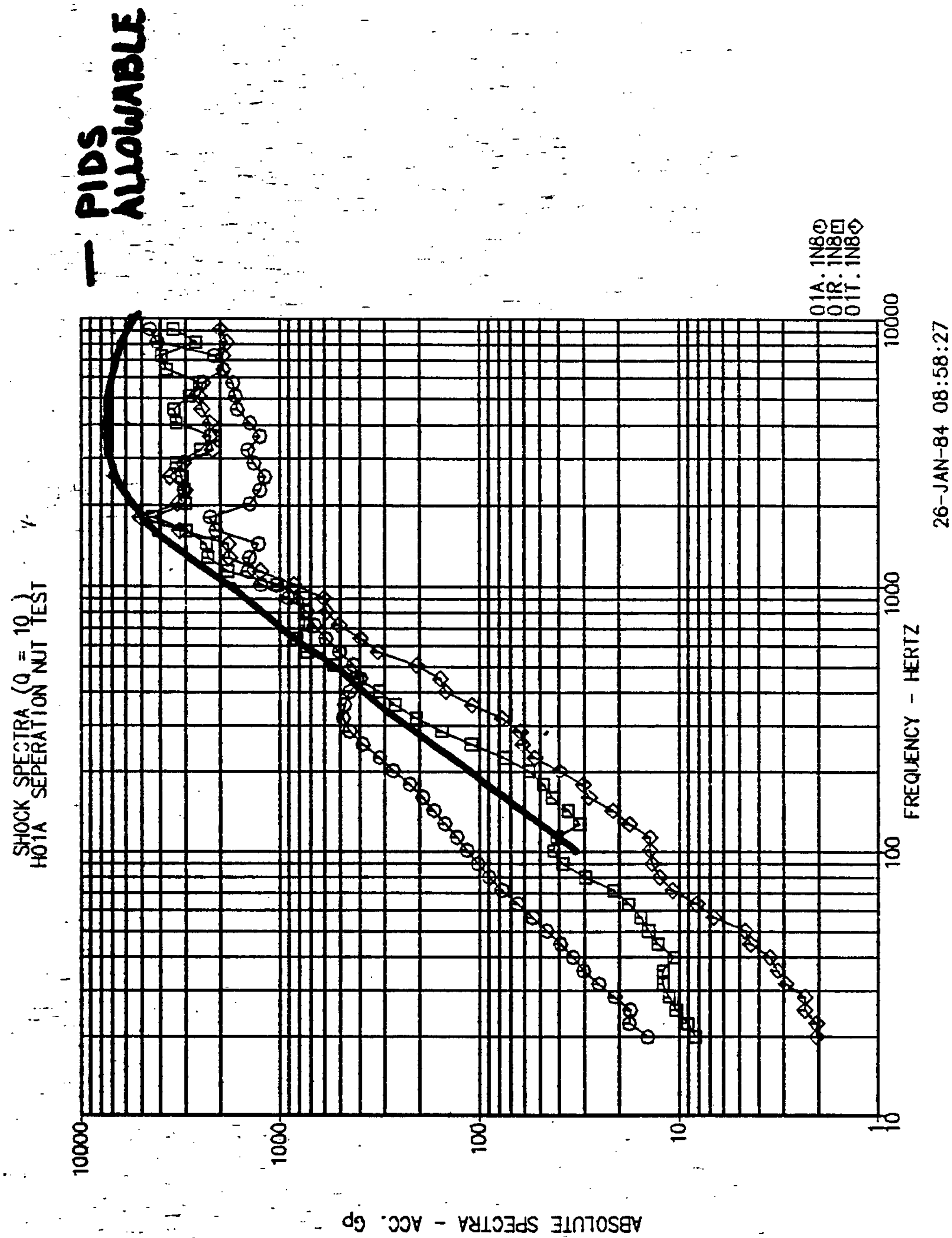


FIGURE 29 DIRECTION COMPARISON
AXIAL VS. RADIAL VS. TANGENTIAL
LOCATION 1 SINGLE FIXED NUT

38

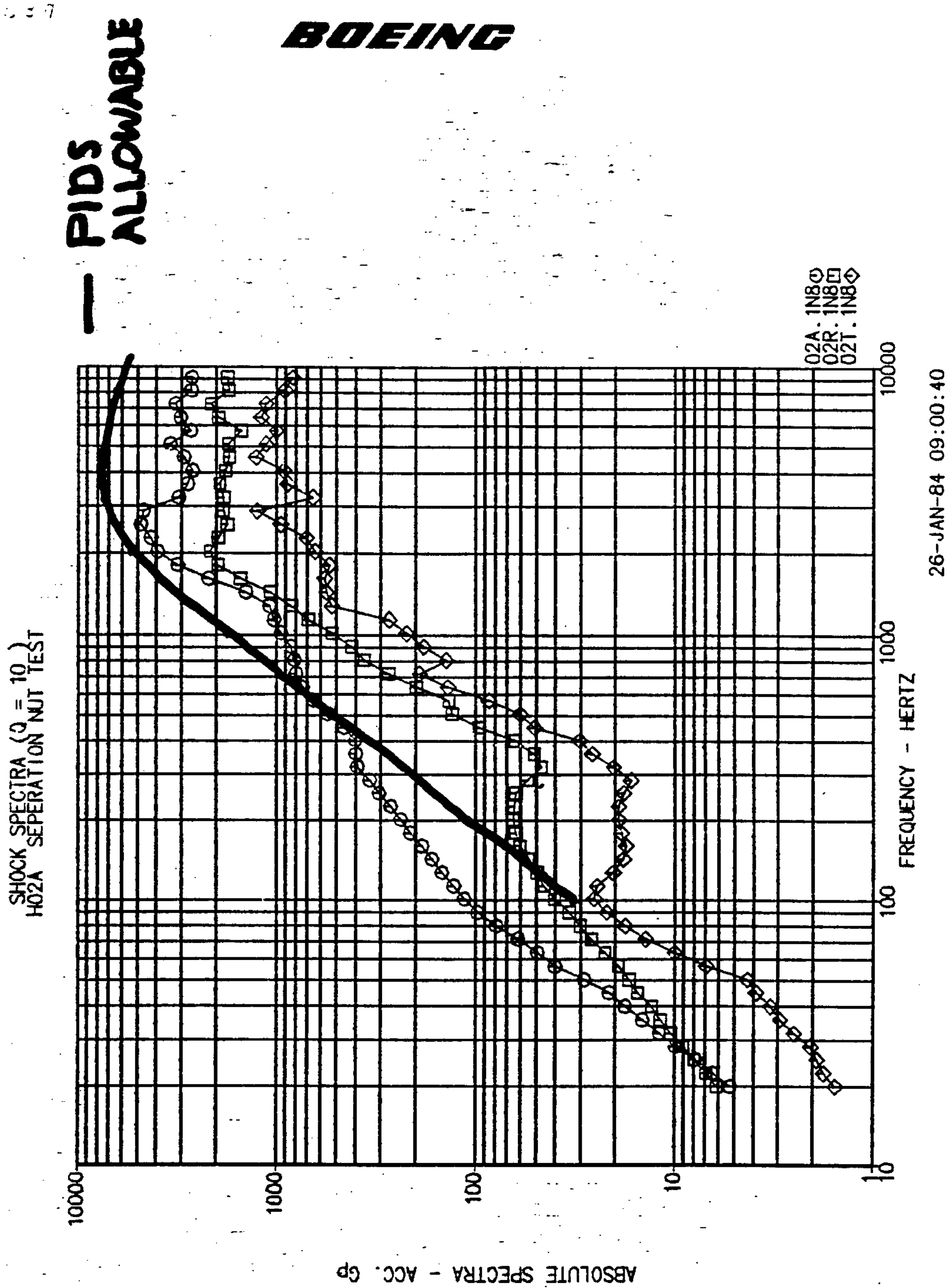


FIGURE 30 DIRECTION COMPARISON
AXIAL VS. RADIAL VS. TANGENTIAL
LOCATION 2 SINGLE FIXED NUT

39

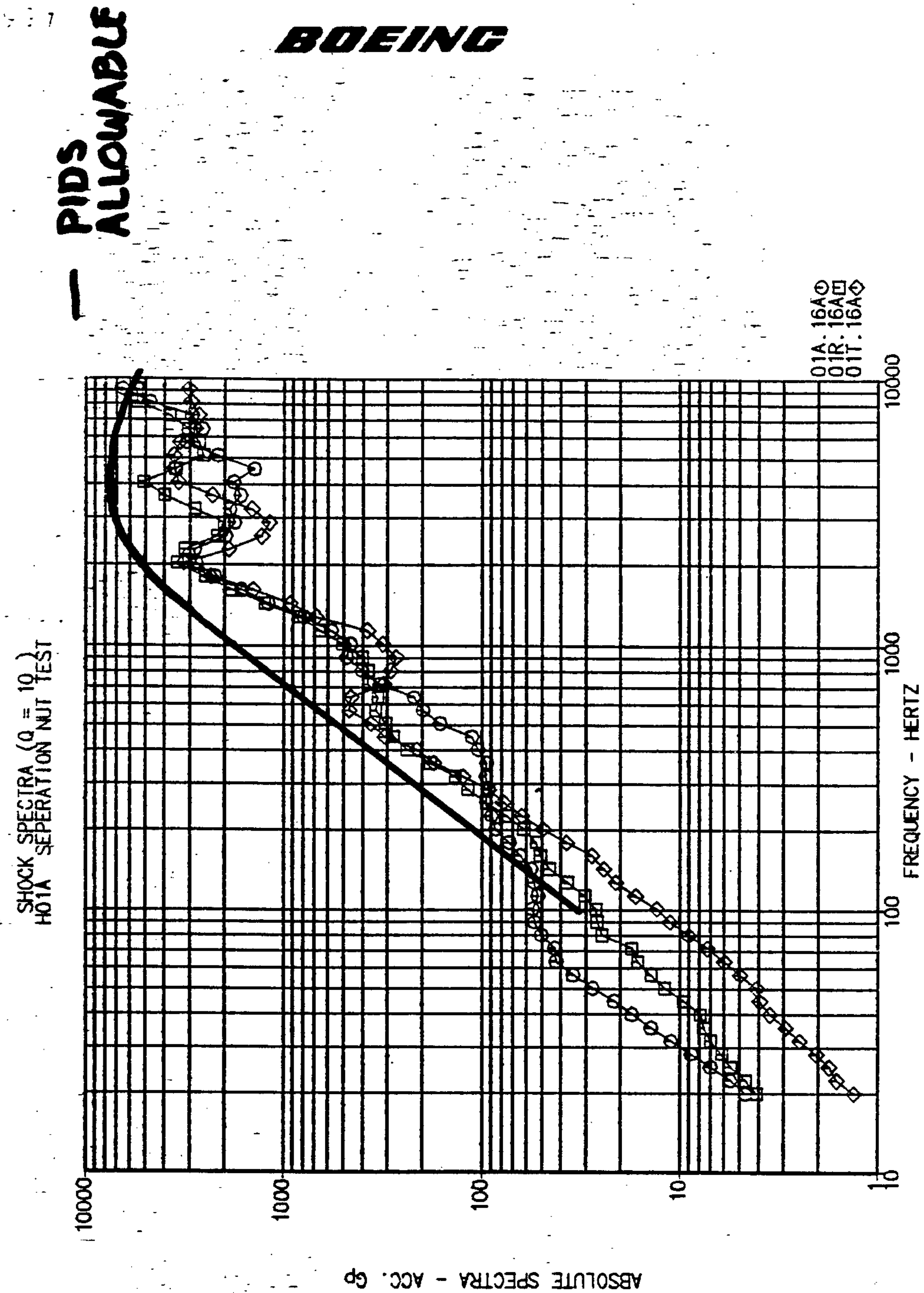


FIGURE 31 DIRECTION COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION 1, SINGLE FREE NUT

40

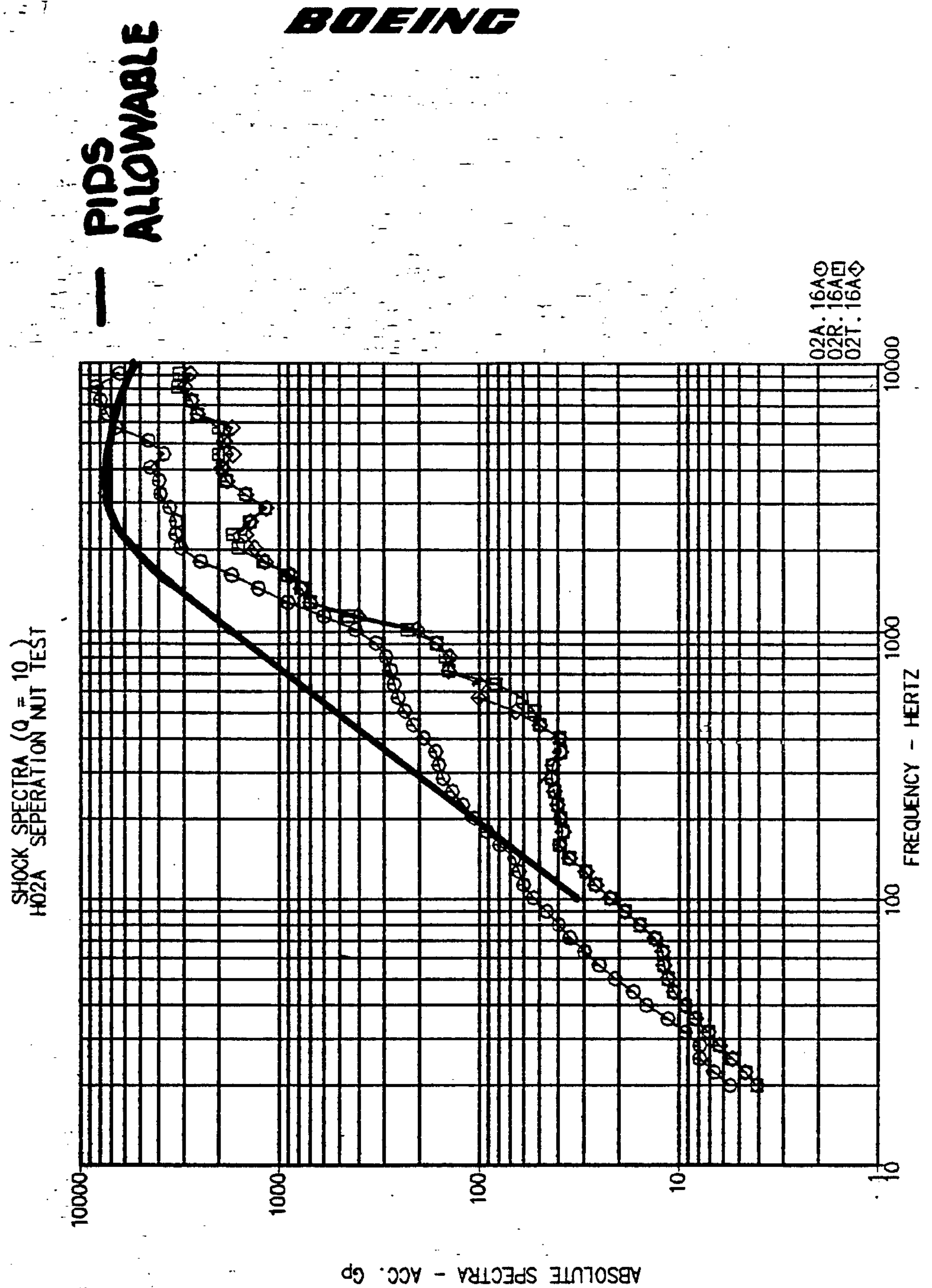


FIGURE 32 DIRECTION COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION Z. SINGLE FREE NUT

41

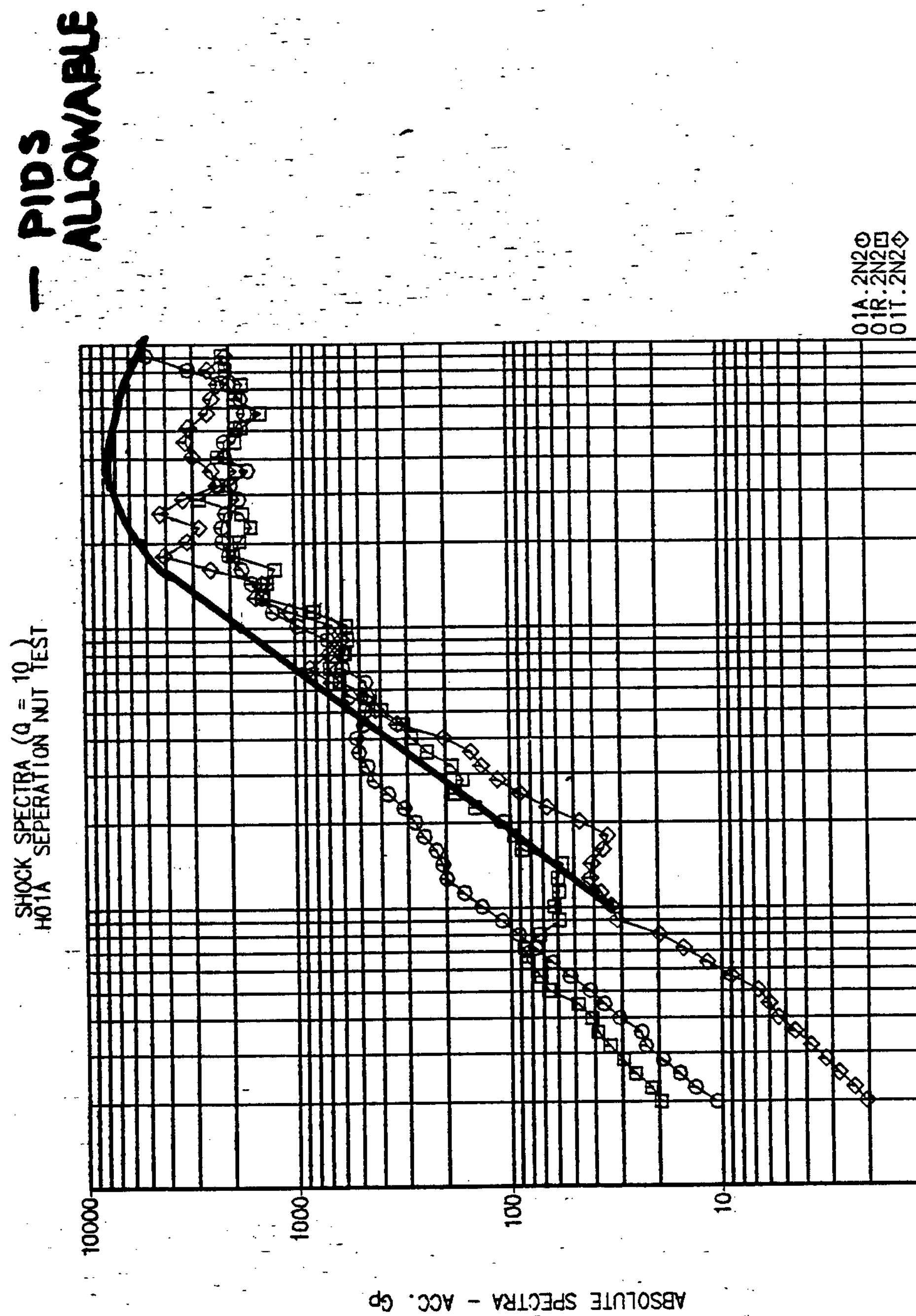


FIGURE 33 DIRECTIONAL COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION 1, 2 NUTS FIRED, JOINT FREE

42

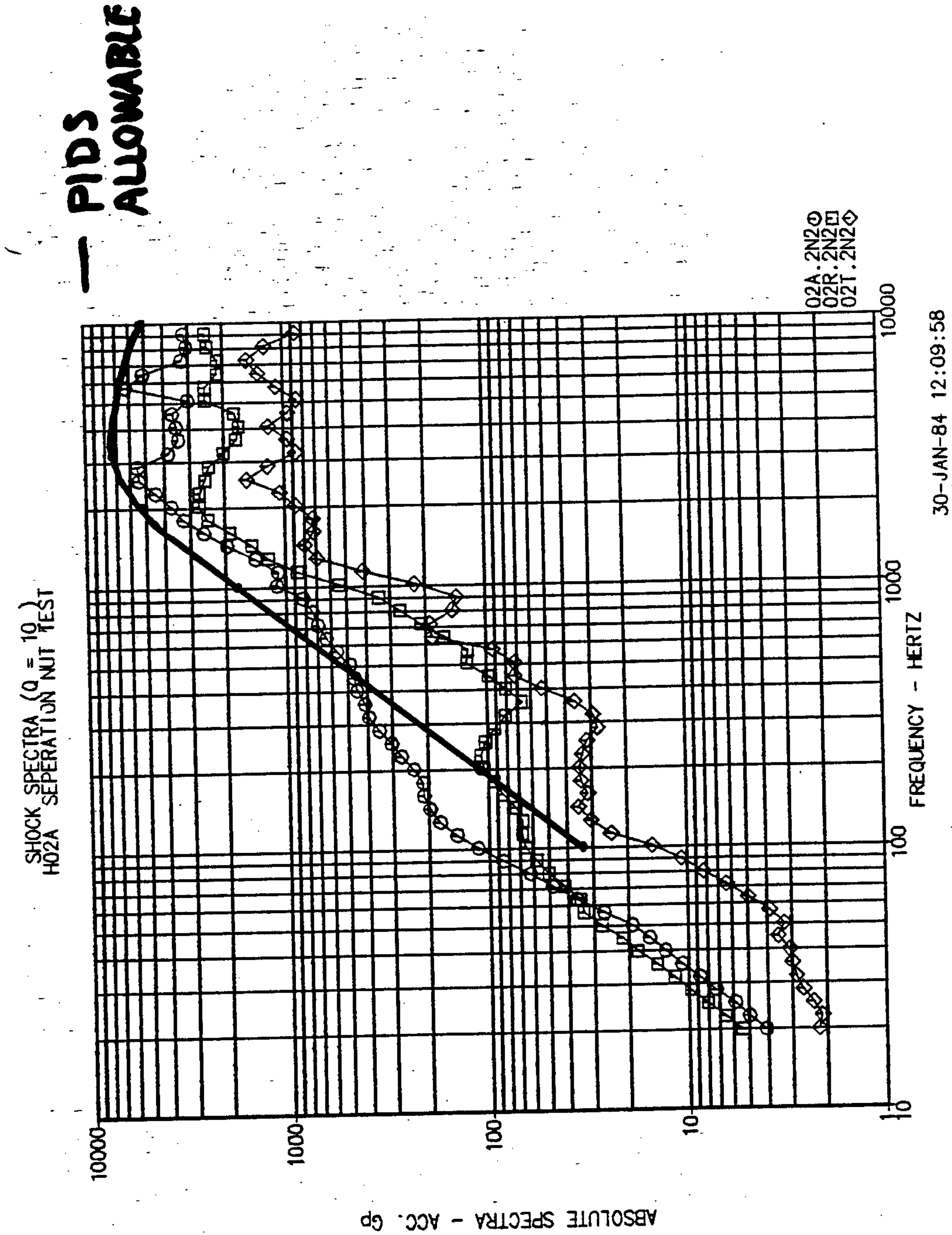


FIGURE 34 DIRECTION COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION 2, 2 NUTS FIRED, JOINT FREE

43

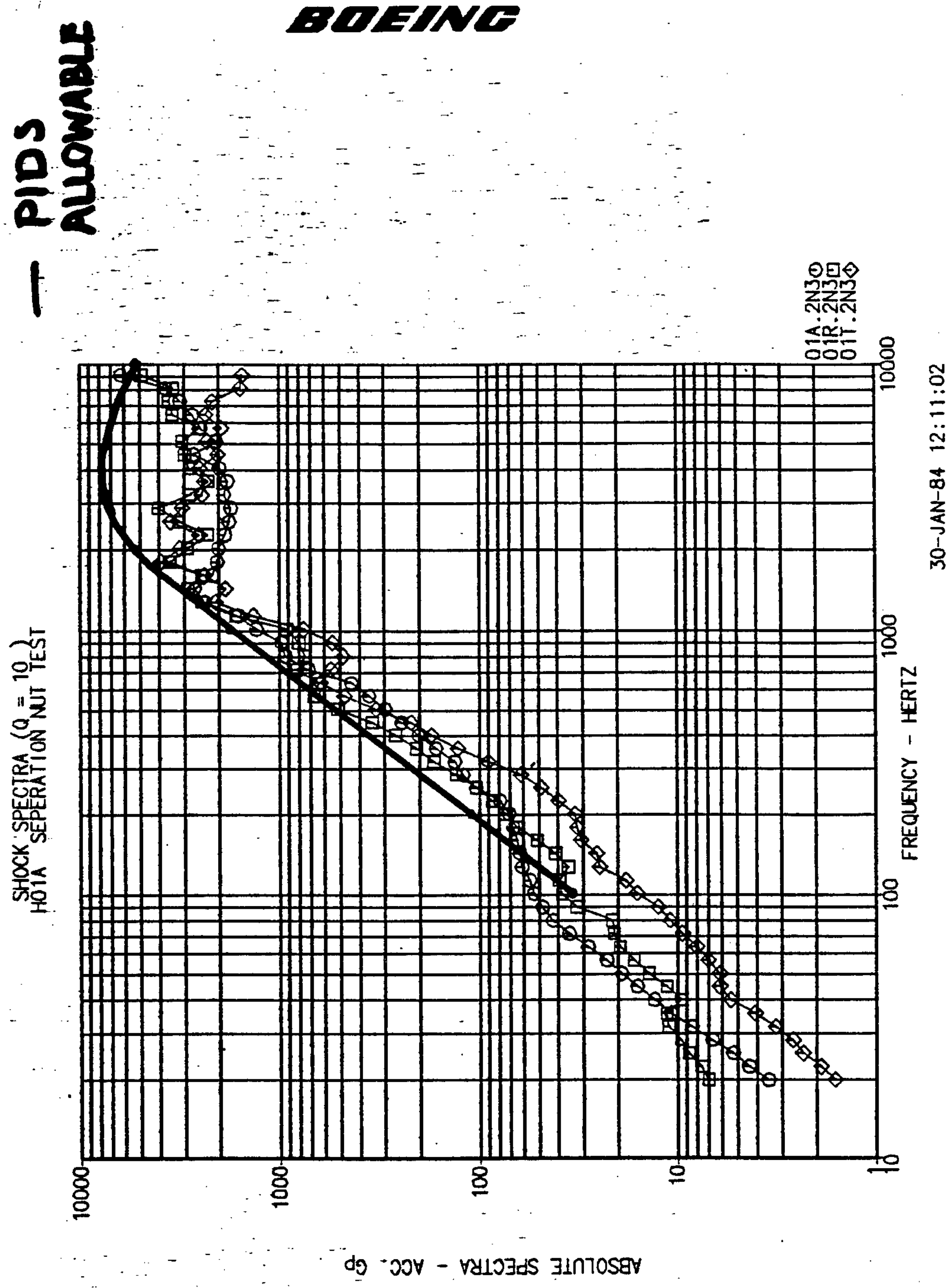


FIGURE 35 DIRECTION COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION 1, 2 NUTS FIRED, JOINT CLAMPED

44

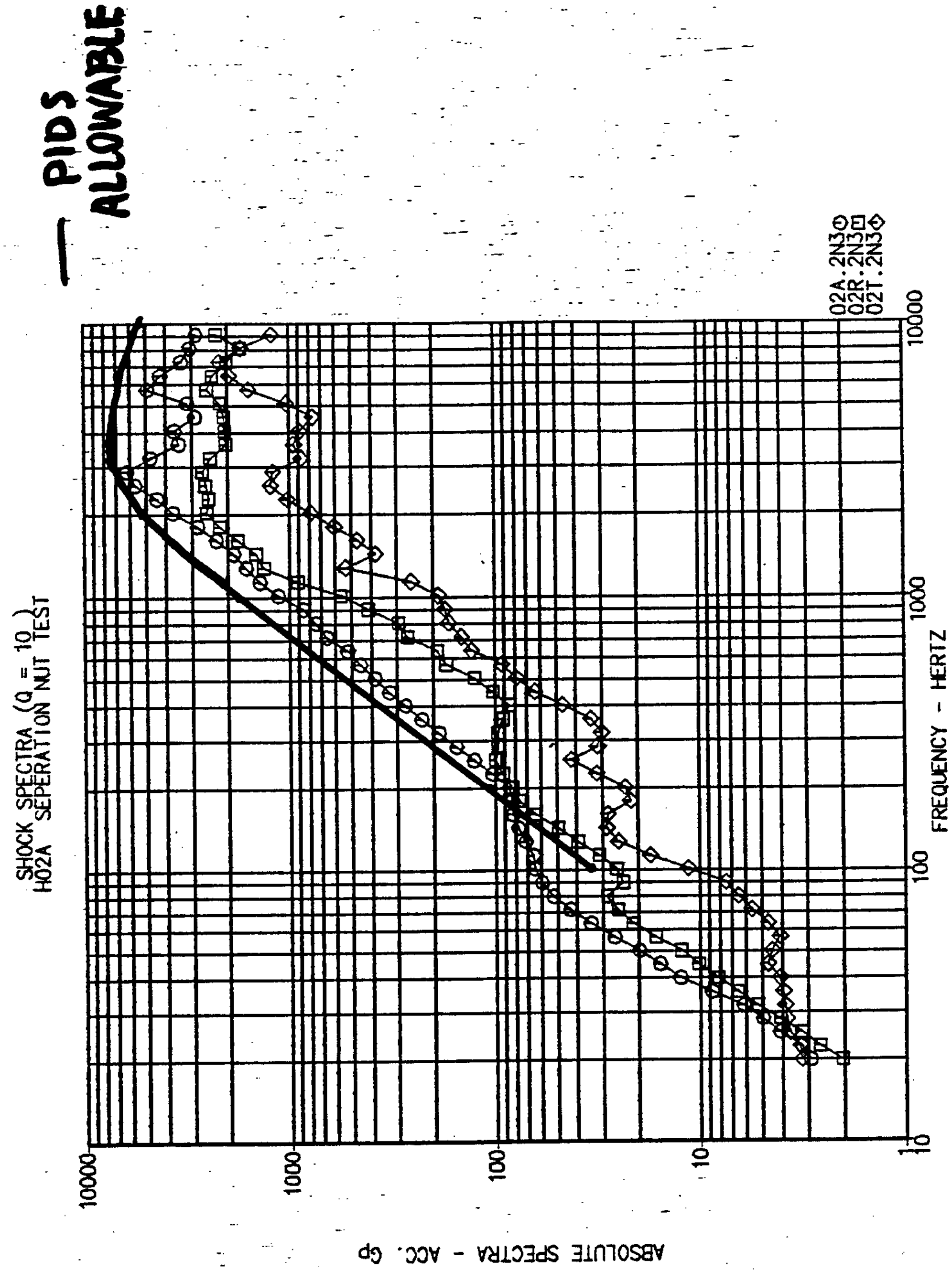


FIGURE 36 DIRECTION COMPARISON
AXIAL, RADIAL, TANGENTIAL
LOCATION 2, 2 NUTS FIRED, JOINT CLAMPED

45

IUS-STS SINGLE POINT SEPARATION TEST,

SIMULTANEOUS SEPARATION NUT FIRINGS

OBJECTIVE:

To determine the effect on the (2) Nuts and Stud Dynamics of simultaneously electrically firing both Separation Nut - Initiators in a simulated Stage 1/Stage 2 Separation of the ESS and Interstage.

CONFIGURATION:

A single longeron of the STS/ESS and the Interstage shall be assembled as closely as possible to resemble a single location of the IUS Stage 1/Stage 2 structural interface in accordance with Figure 1 (reference SK290-24921).

The separation joint shall include the proper material, spacing, shear cone, and stud bore configuration per Figure 1 to demonstrate the operating function of the Separation Nuts and Stud.

INSTRUMENTATION:

Instrumentation shall include two high speed cameras (4000 and 500 frames per second capability) located to optimize observation of the separation event. Triggering of the cameras should be synchronized with the Initiator firing to capture the total separation event. One camera shall be focused to record movement of the Lock (Indicator) pins of both nuts to a maximum extent possible to record and compare the function time sequencing of both nuts. (When functioned, the Lock pin projects .4 inches from the cylinder end.)

Other instrumentation shall be two triaxial accelerometers to record pyrotechnic shock of the separation event. Accelerometer location and type shall be as shown in Figure 2. Accelerometer range shall be plus or minus 3000 g's peak. The transducer output shall be recorded on magnetic tape. Time histories will be required for each shock from each accelerometer. The data shall be reduced as shock spectra for each shock from each accelerometer using the HP shock analyzer. The HP output shall be recorded on a VAX compatible tape for Structures Technology evaluation.

CRITERIA:

Success criteria are the recording of the total separation event of each test, as defined in Table 1. Photographic coverage is required to record the movement of the Lock Pins using a single time-sequenced film, also the motion of the Stud and Structure in separating. The shock data requirement shall be as specified previously under instrumentation.

REQUIREMENTS:

Test Location and Operation shall be in accordance with SOP 339. Test configuration shall be as shown in Figure 2.

APPENDIX A PAGE A1

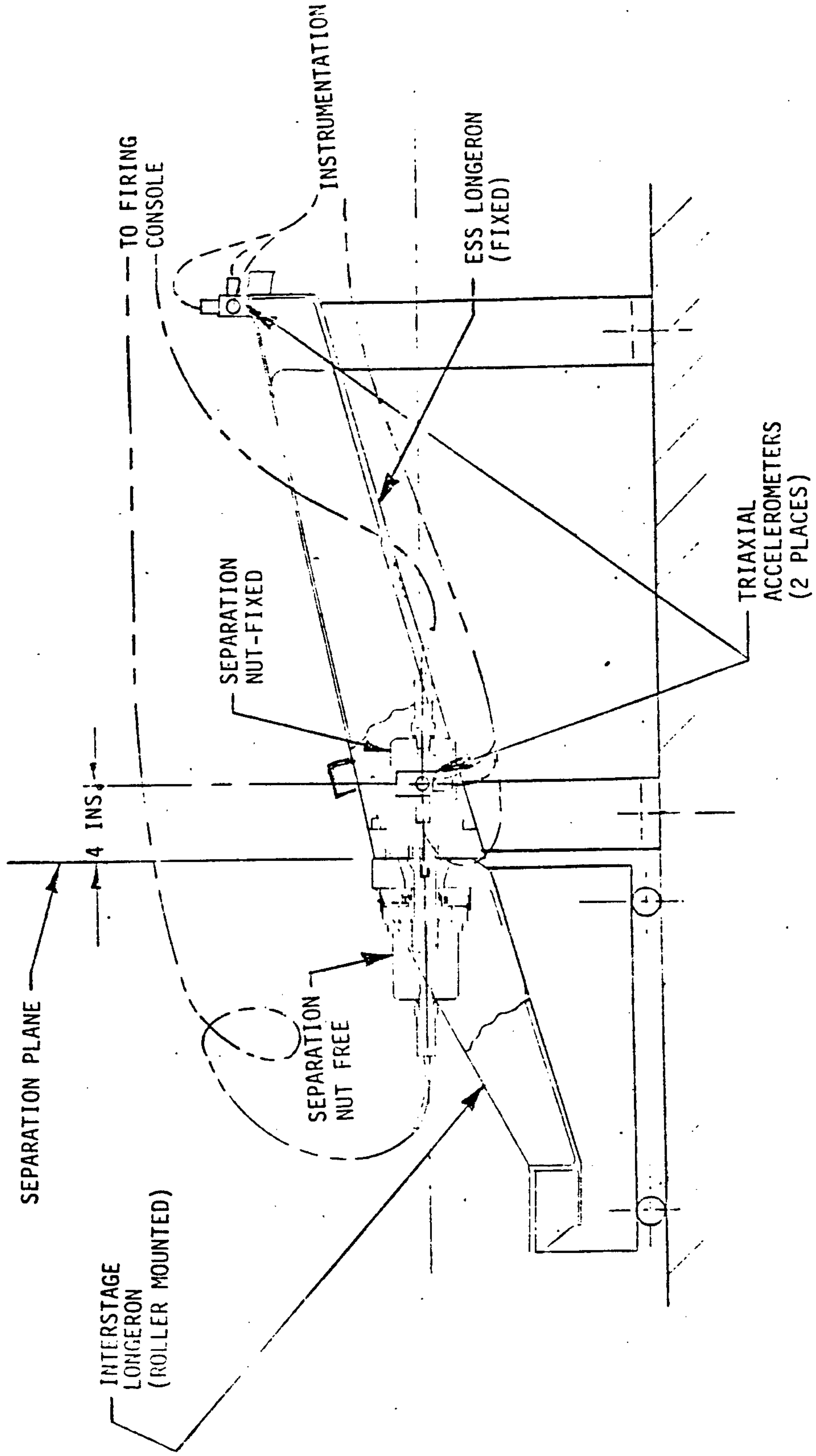


FIGURE 2 IUS-STS SINGLE POINT SEPARATION TEST - SIMULTANEOUS SEPARATION NUT FIRINGS

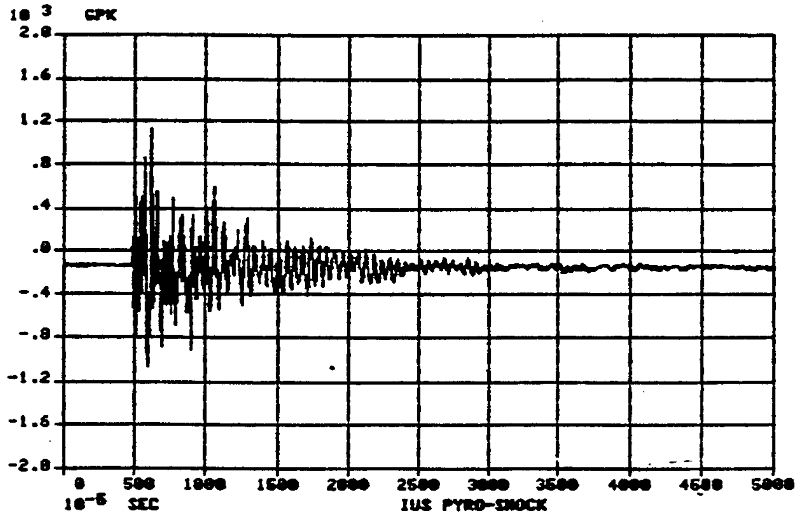
A2

TEST NO.	[illegible]	TEST CONFIGURATION.	SPECIAL OBJECTIVES (INCLUDE IN OVERALL OBJECTIVES)	REMARKS.
1	FIRE FIXED [illegible] INITIATOR	BASIC CONFIG. [illegible] FIGURE 2.	ESTABLISH COMPARATIVE PYRO-SHOCK BASELINE	
2	SIMULTANEOUSLY FIRE BOTH NUT INITIATORS.	AS 1. ABOVE.	RECORD COMPARATIVE NUT-FUNCTION TIME	FILM INDICATOR PIN MOVEMENT (BOTH NUTS)
3	AS 2. ABOVE	AS 1. ABOVE EXCEPT LONGERONS CLAMPED TOGETHER.	RECORD SEPARATION DYNAMICS.	(DITTO)
4	AS 2. ABOVE	AS 1. ABOVE	(DITTO)	(DITTO)
5	AS 2. ABOVE	AS 1. ABOVE	(DITTO)	(DITTO)
6	[illegible] ABOVE	AS 3. ABOVE	(DITTO)	(DITTO)
7	[illegible]	AS 3. ABOVE	(DITTO)	(DITTO)
8	AS 1 ABOVE	AS 1 ABOVE	(DITTO)	(DITTO)
9	AS 1 ABOVE	AS 1 ABOVE	(DITTO)	(DITTO)

TABLE 1 IUS-STS SINGLE POINT SEPARATION - SIMULTANEOUS SEPARATION-NUT FIRING TESTS

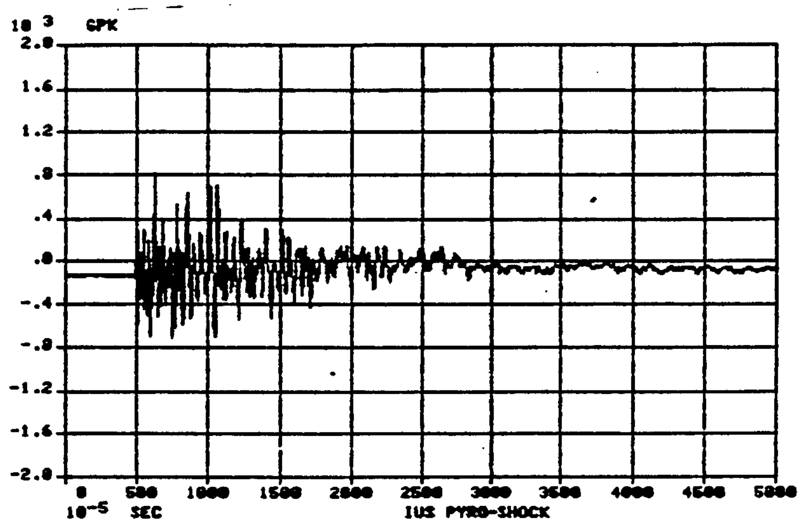
A3

IUS STAGING BOLT SEPARATION TEST RUN 1 ACCEL 1A 7/14/83
TRANSIENT CAPTURE



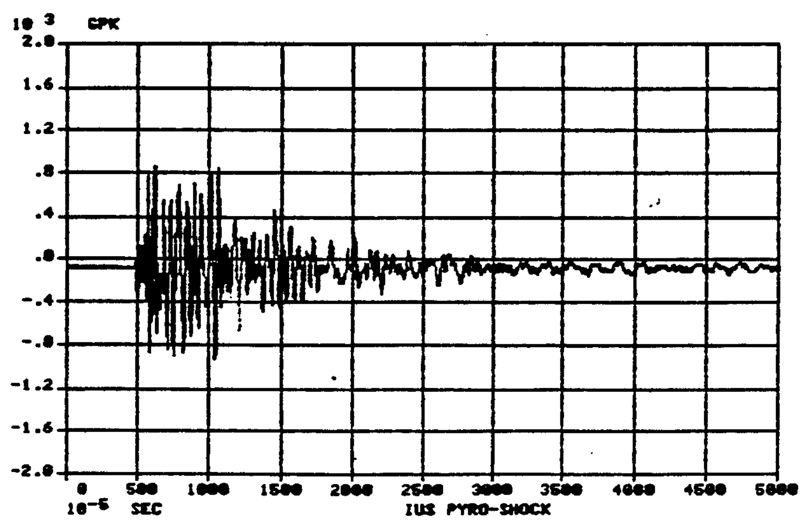
1A

IUS STAGING BOLT SEPARATION TEST RUN 1 ACCEL 1R 7/14/83
TRANSIENT CAPTURE



1R

IUS STAGING BOLT SEPARATION TEST RUN 1 ACCEL 1T 7/14/83
TRANSIENT CAPTURE

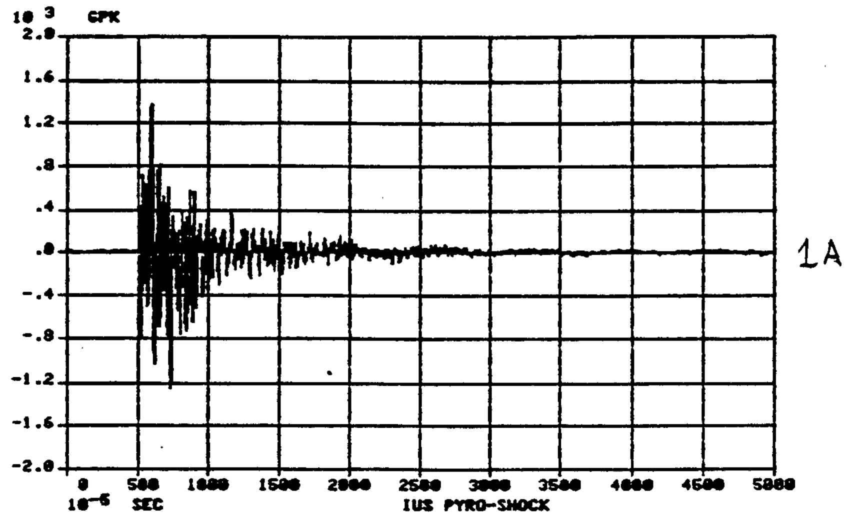


1T

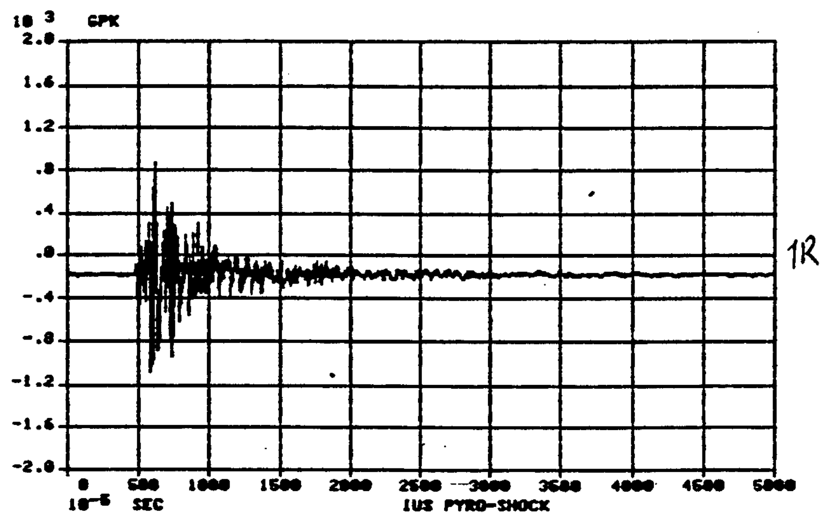
RUN 1
ACCEL
1A
1R
1T

APPENDIX B
B1

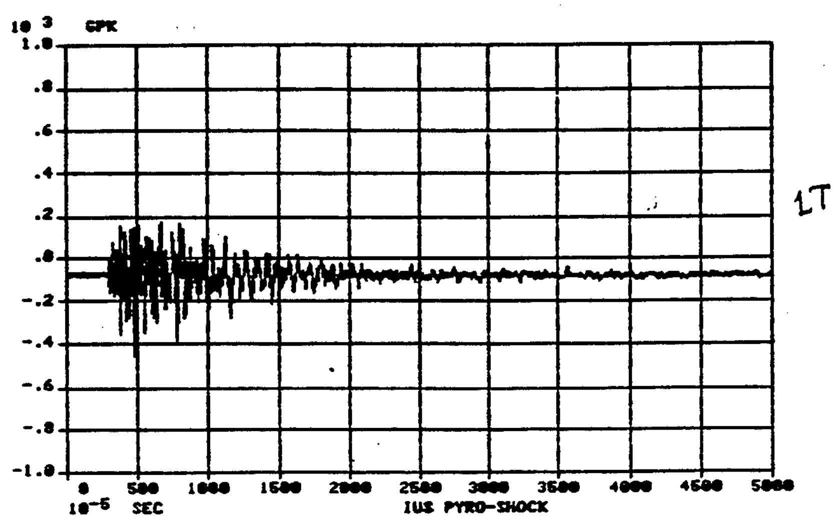
IUS STAGING BOLT SEPARATION TEST RUN 1 ACCEL 2A 7/14/83
TRANSIENT CAPTURE



IUS STAGING BOLT SEPARATION TEST RUN 1 ACCEL 2R 7/14/83
TRANSIENT CAPTURE



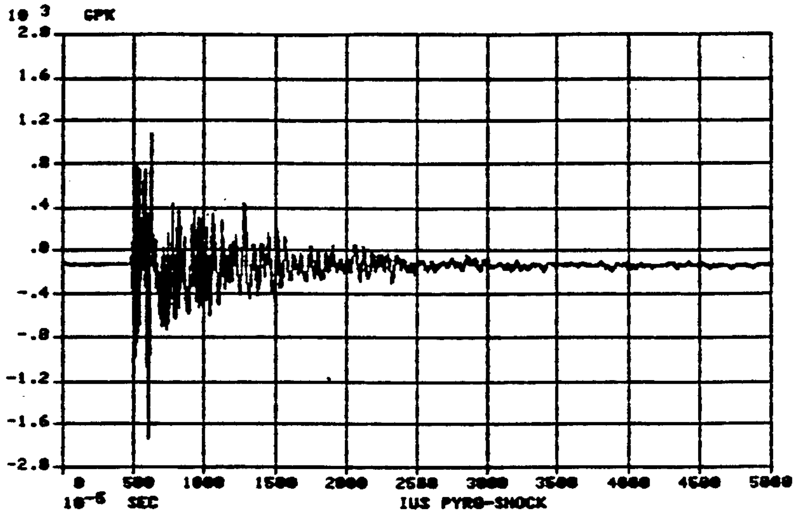
IUS SATAGING BOLT SEPARATION TEST 7/14/83 RUN 1 2T
TRANSIENT CAPTURE



RUN 1
ACCEL -
2A
2R
2T

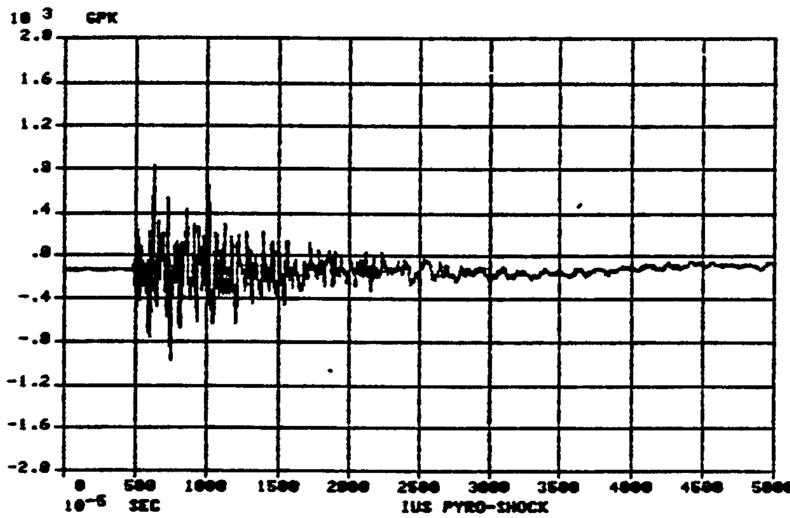
B2

IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL 1A 7/14/83
TRANSIENT CAPTURE



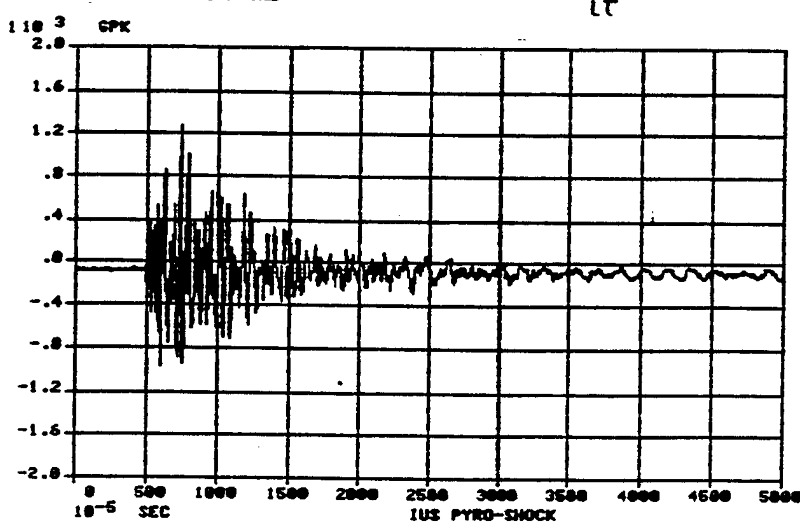
1A

IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL 1R 7/14/83
TRANSIENT CAPTURE



1R

IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL ~~1Q~~ 1T 7/14/83
TRANSIENT CAPTURE



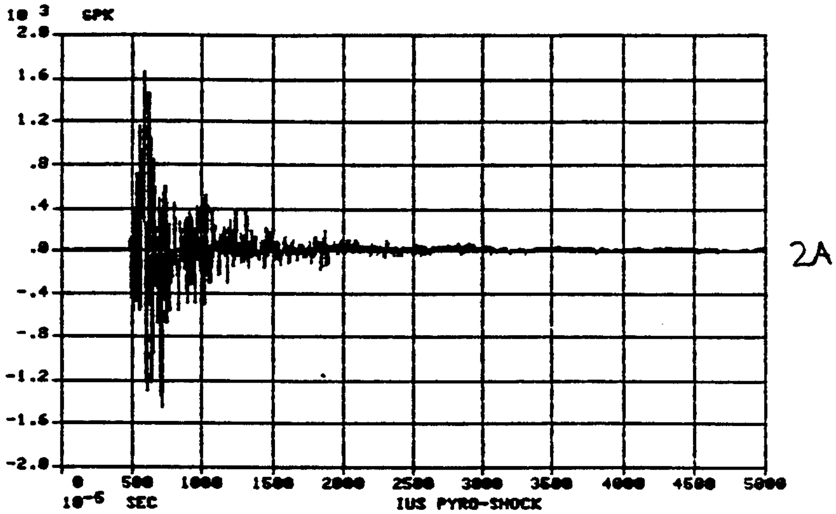
1T

RUN 2
ACCEL
1A
1R
1T

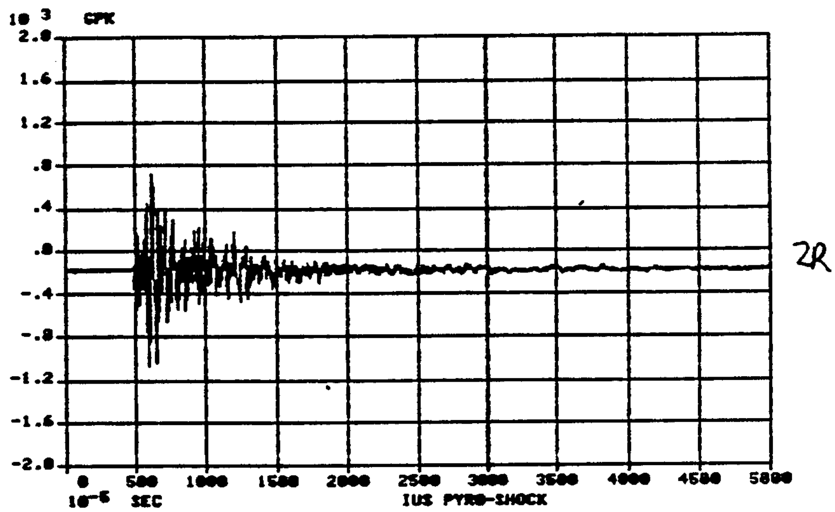
B3

BOEING

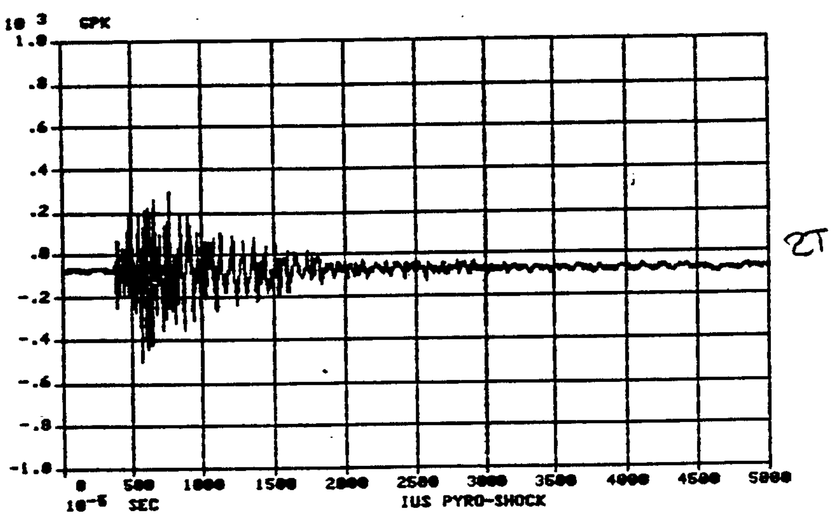
IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL 2A 7/14/83
TRANSIENT CAPTURE



IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL 2R 7/14/83
TRANSIENT CAPTURE

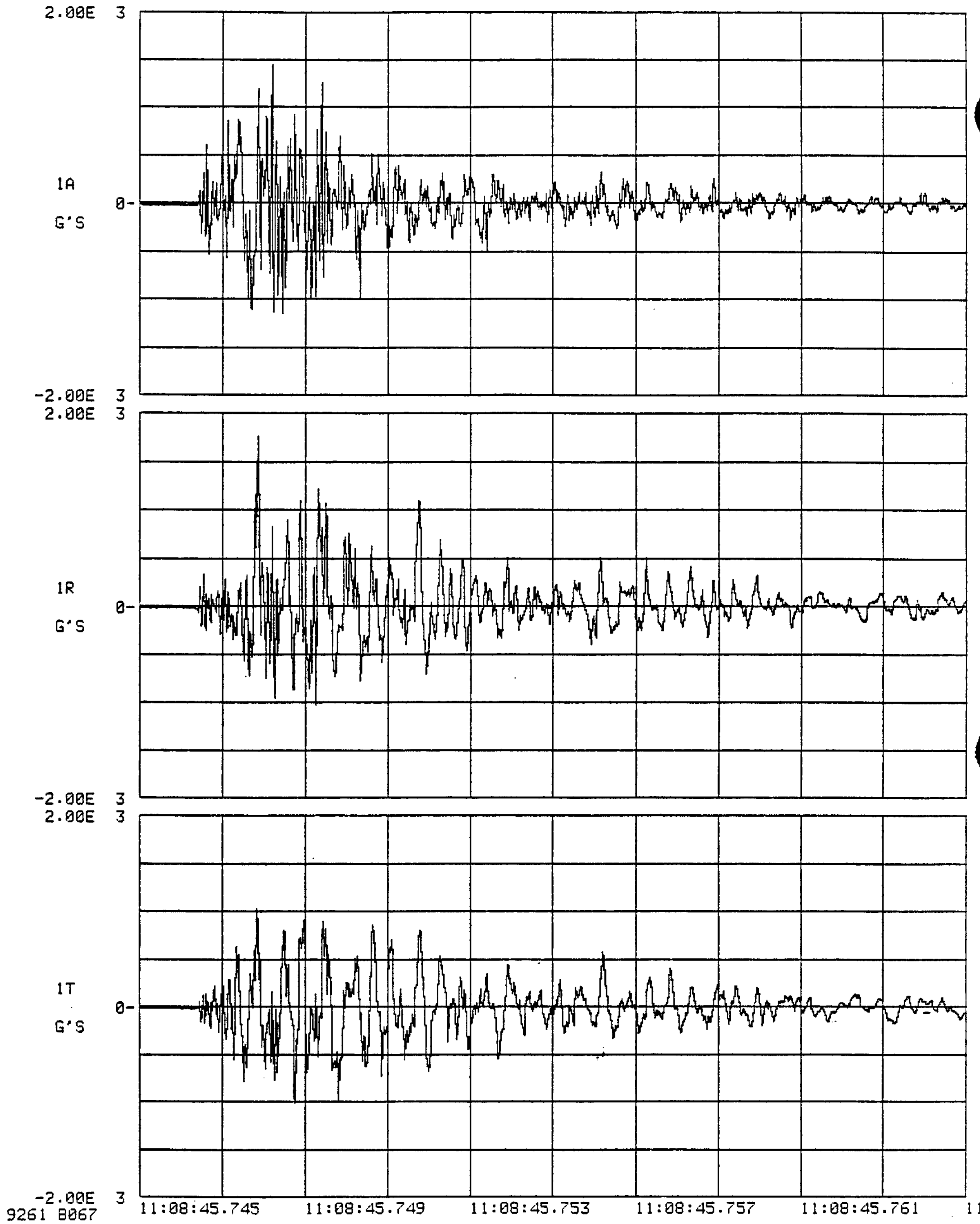


IUS STAGING BOLT SEPARATION TEST RUN 2 ACCEL 2T 7/14/83
TRANSIENT CAPTURE



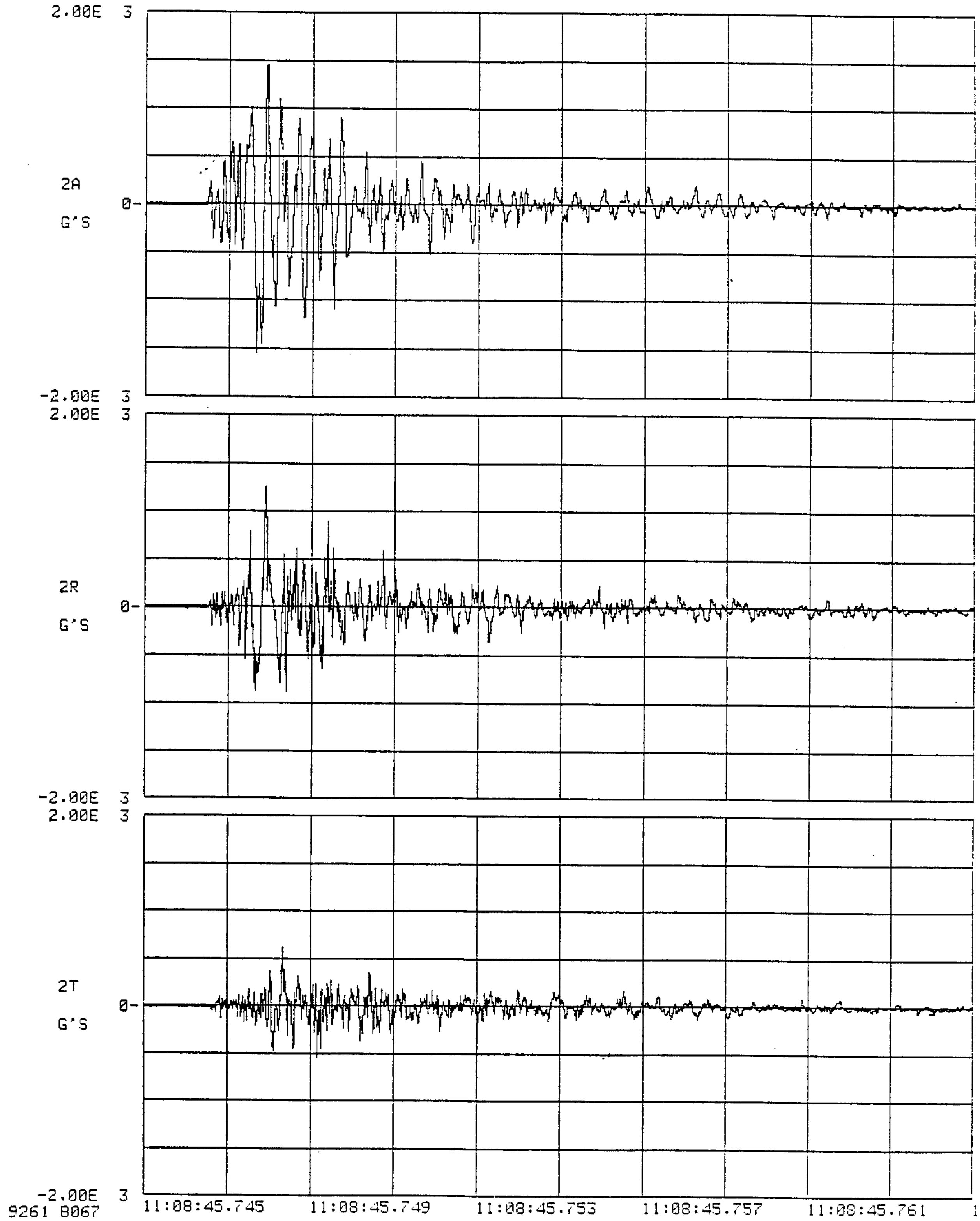
RUN 2
ACCEL
2A
2R
2T

B4



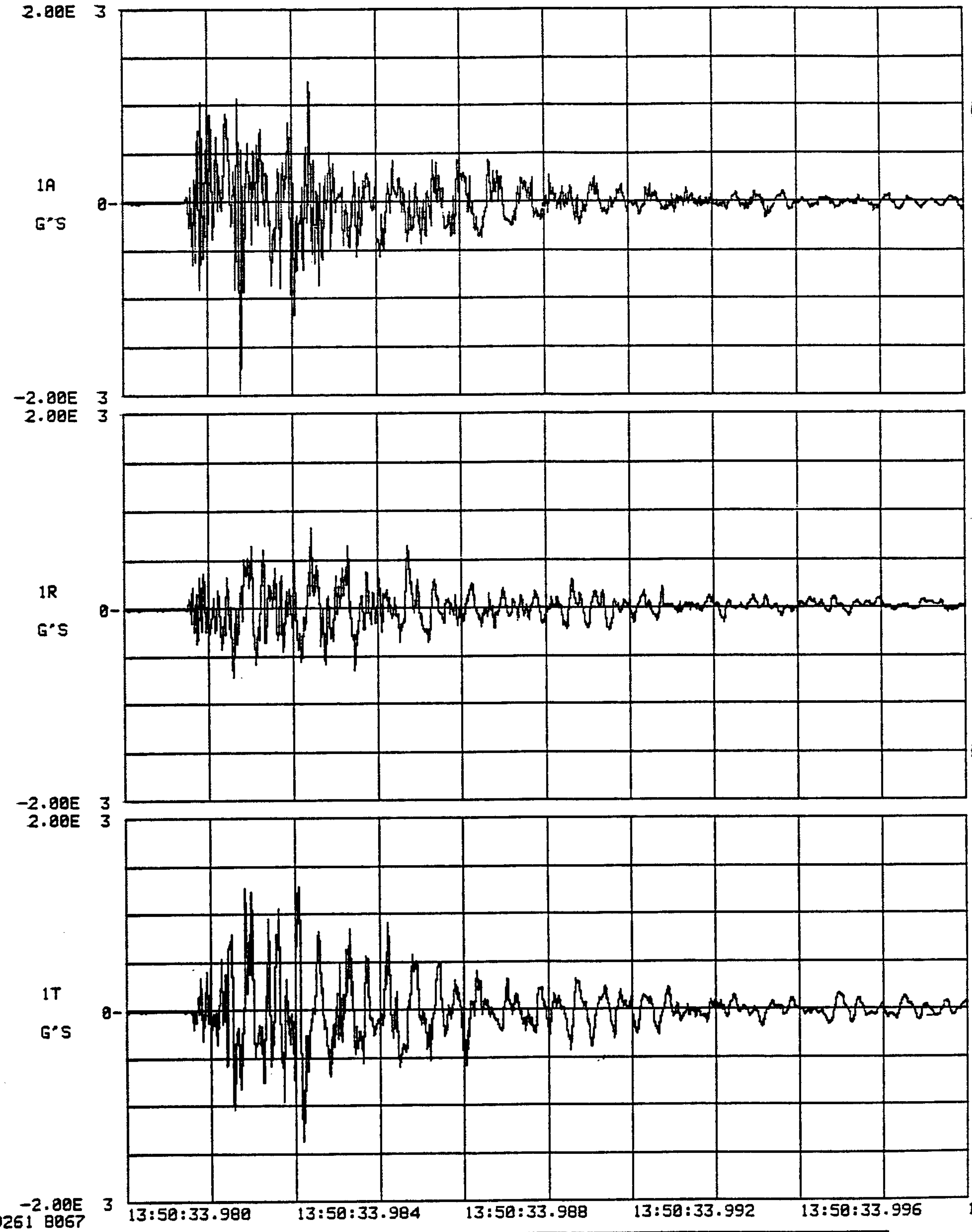
CALC	MED 8/01/83		IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83		RUN NO. 3 1A 1R 1T
APPD			
APPD			

B5



CALC	MED 8/01/83		IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83		
APPD			RUN NO. 3
APPD			

B6



9261 B067

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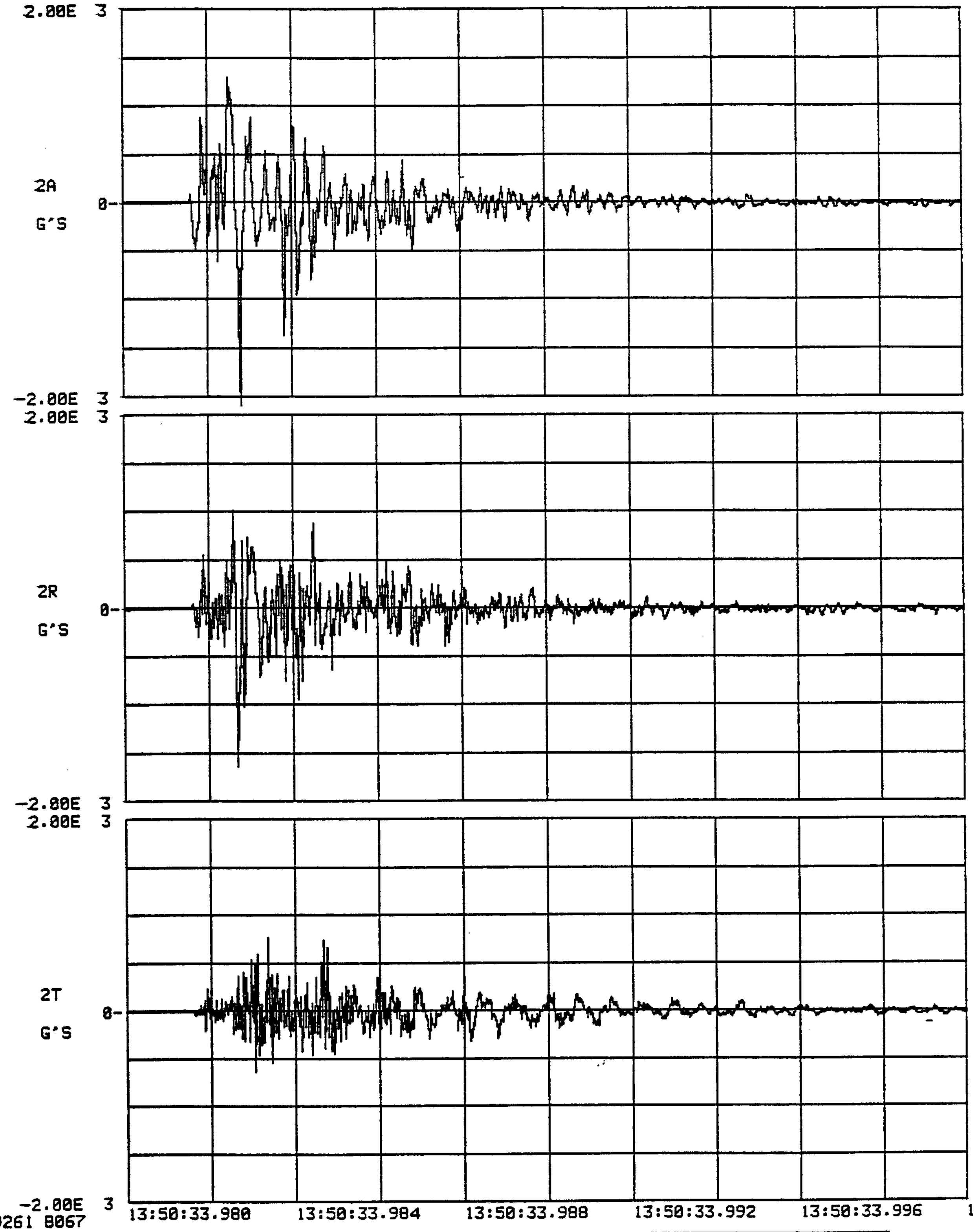
CHECK	[illegible]		
APPD			RUN NO. 4
APPD			

B7



9261 B067

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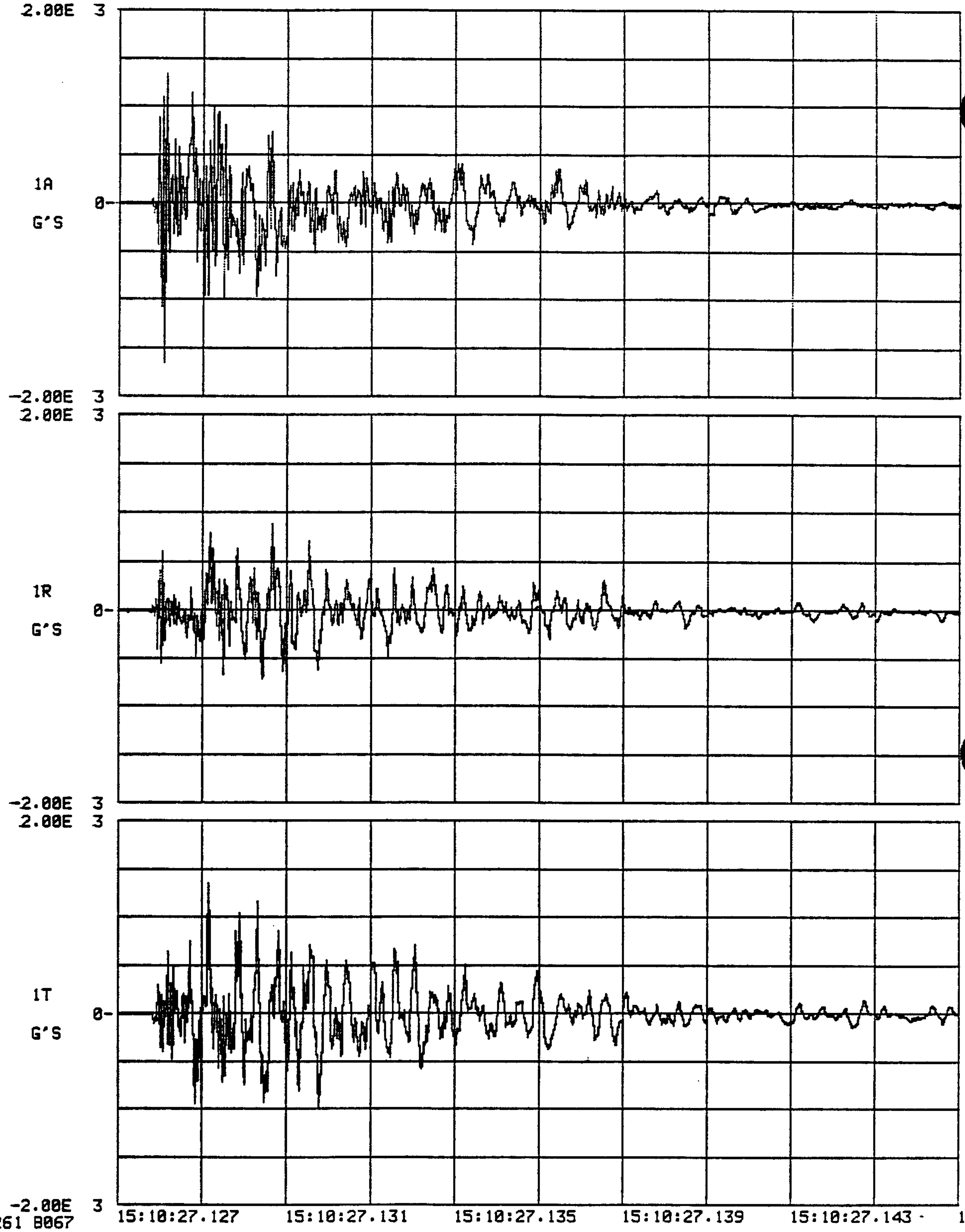
CHECK	TMT 8/2/83		RUN NO. 4
APPD			
APPD			

BOEING



9261 B067

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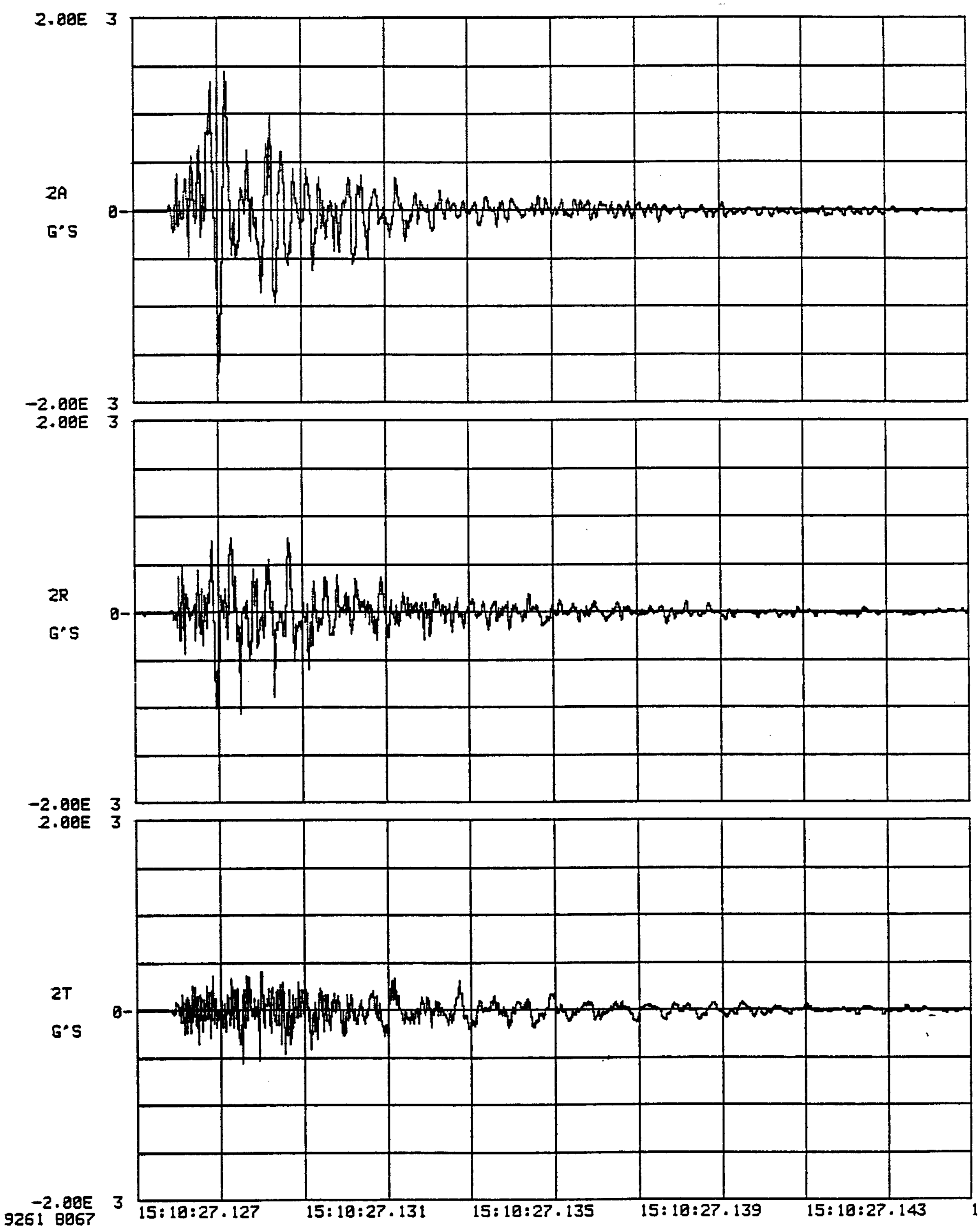
CHECK	TMF 8/3/83		
APPD			RUN NO. 5
APPD			

B9

BOEING



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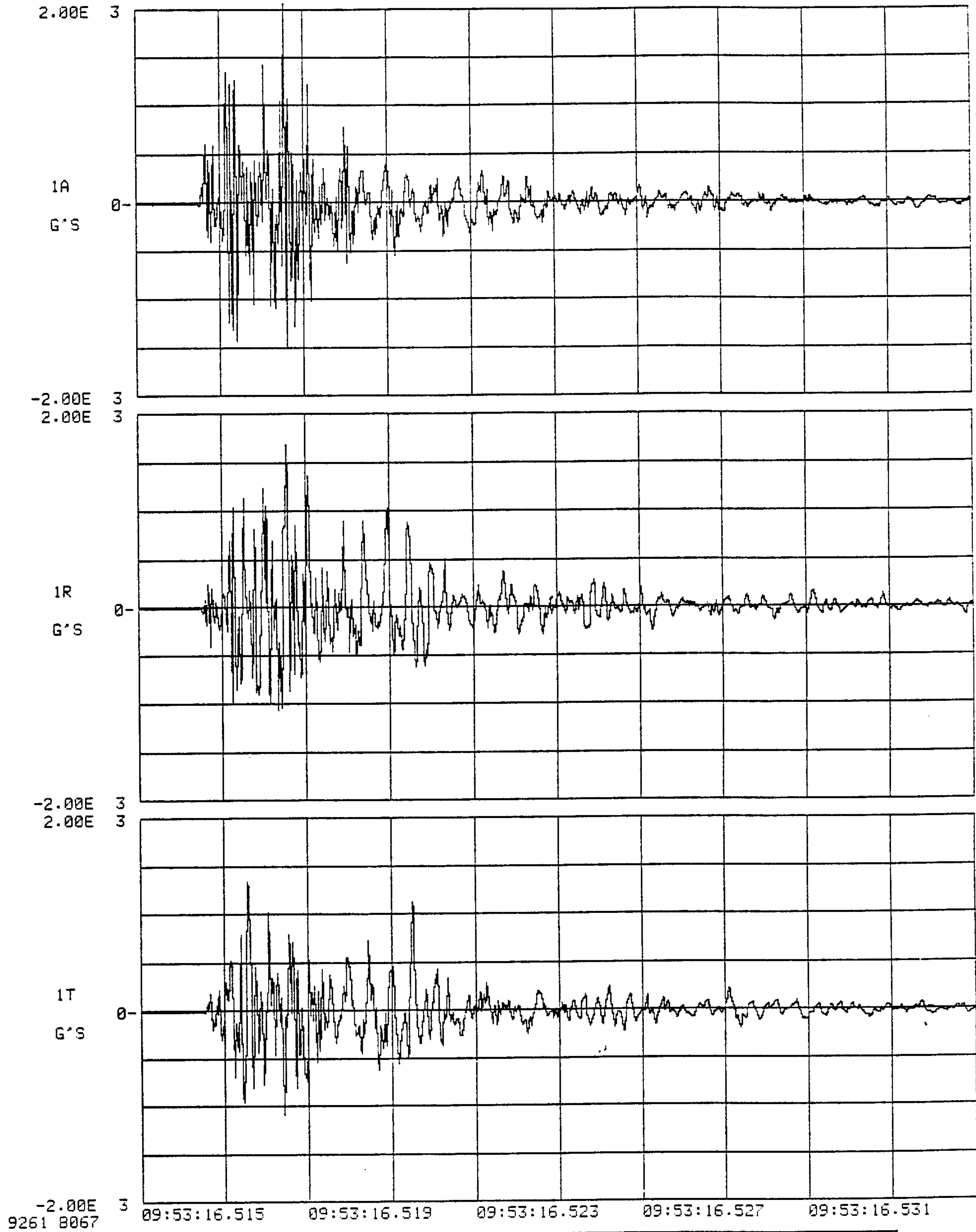
CHECK	TMT 8/2/83		RUN NO. 5
APPD			
APPD			

B10



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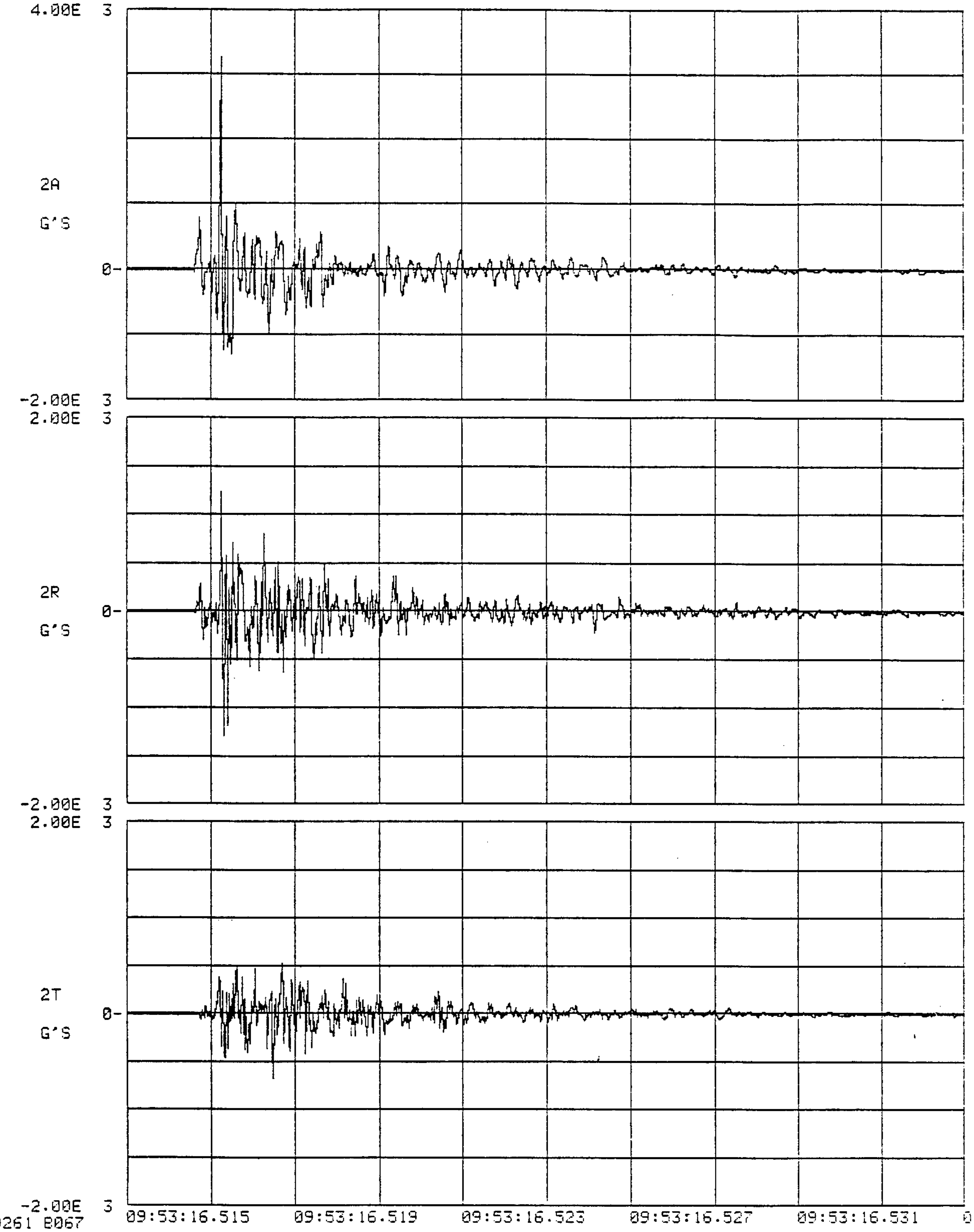
CHECK	TMT 8/2/83		
APPD			RUN NO. 6A
APPD			

B11



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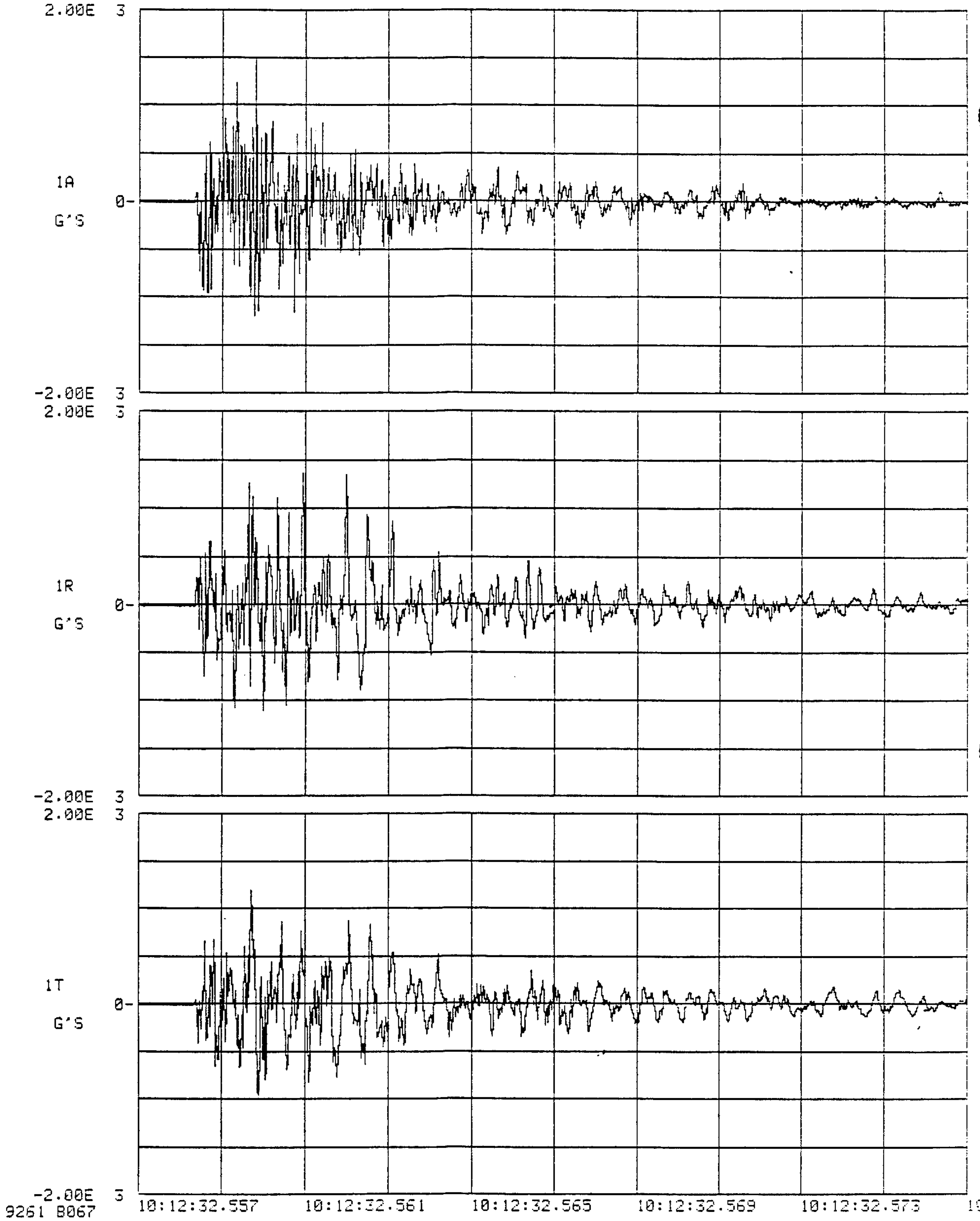
APPD			
APPD			

B12



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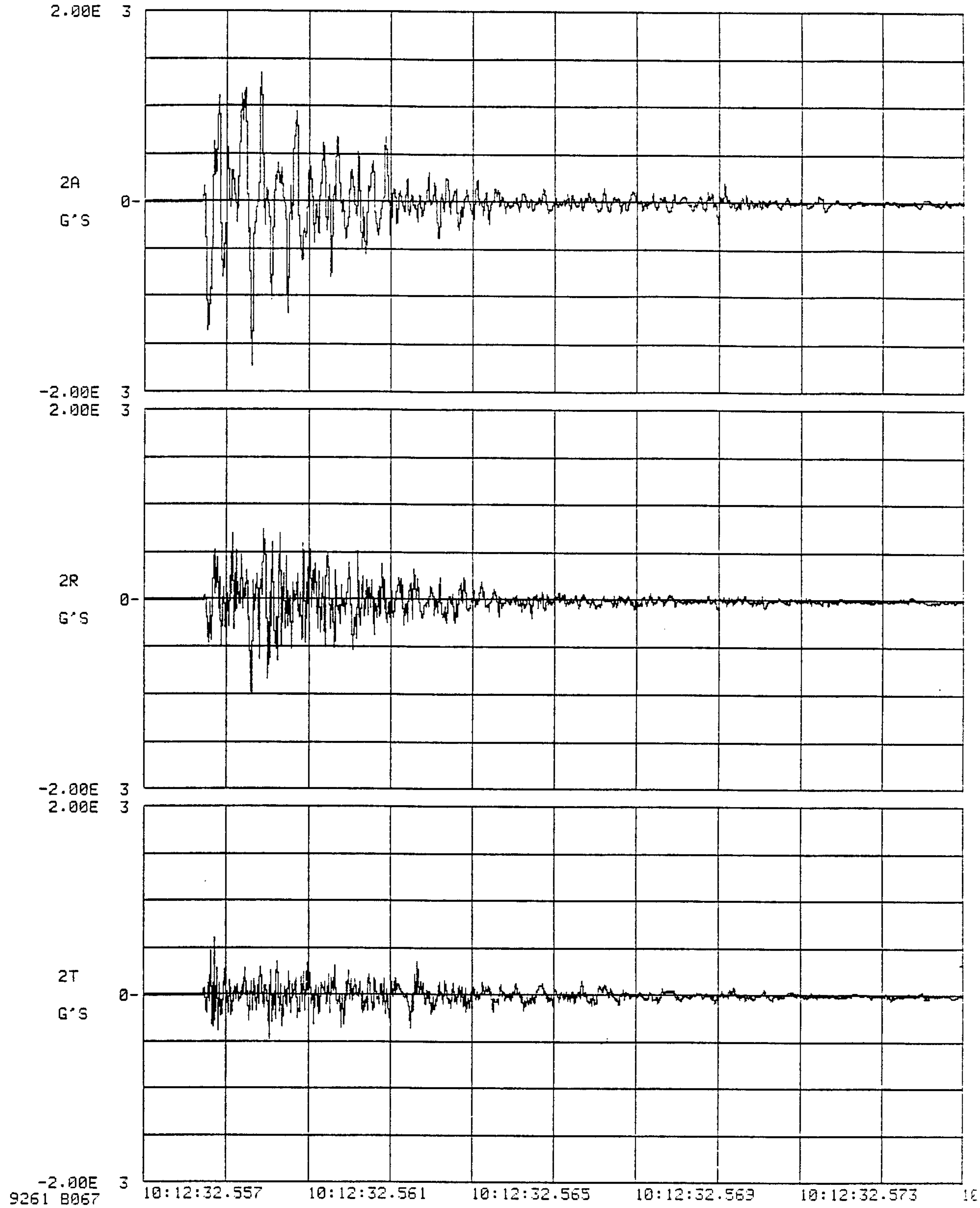
APPD			
APPD			

B13



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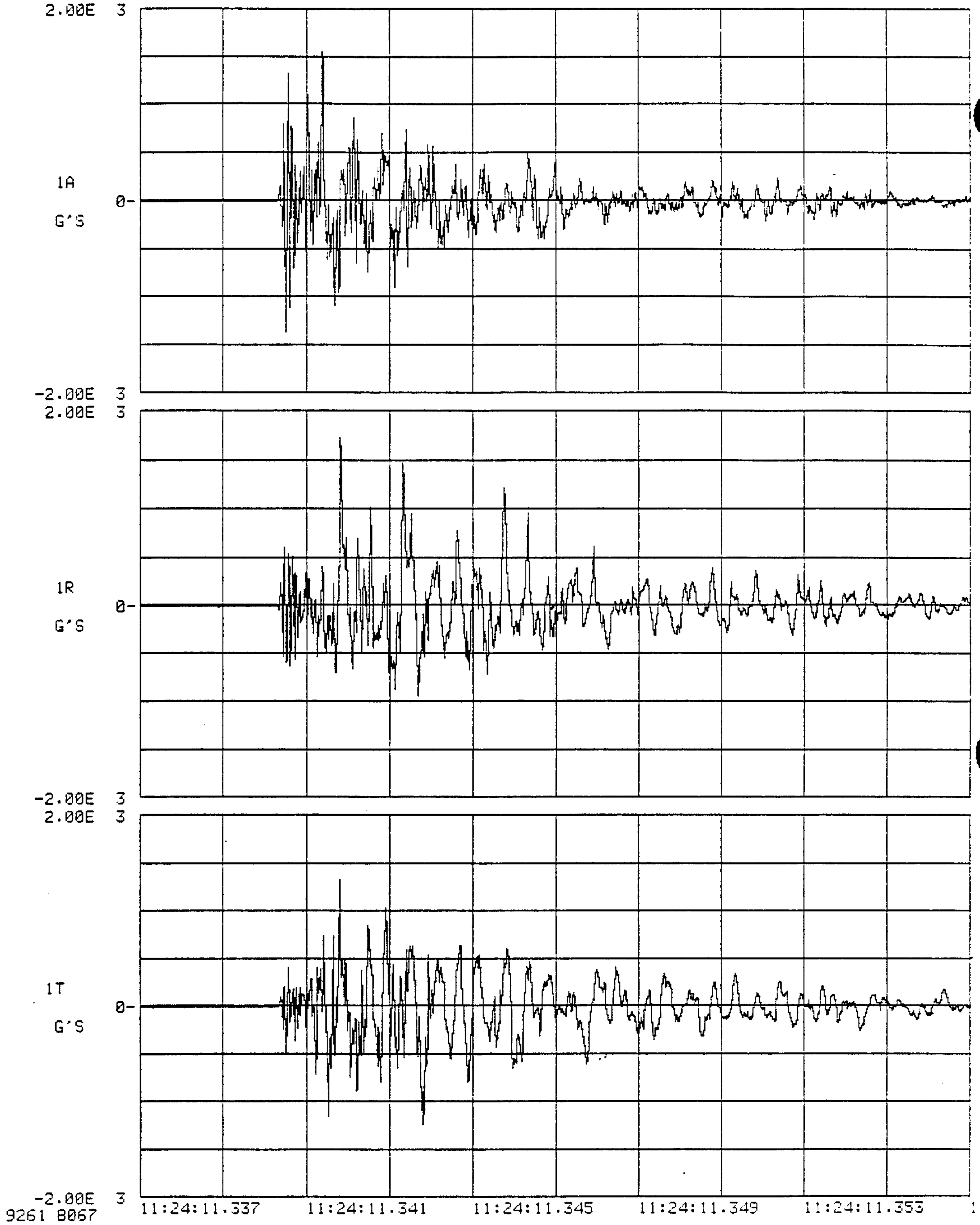
CHECK	TMT 8/2/83	RUN NO. 6B
APPD		
APPD		

B14



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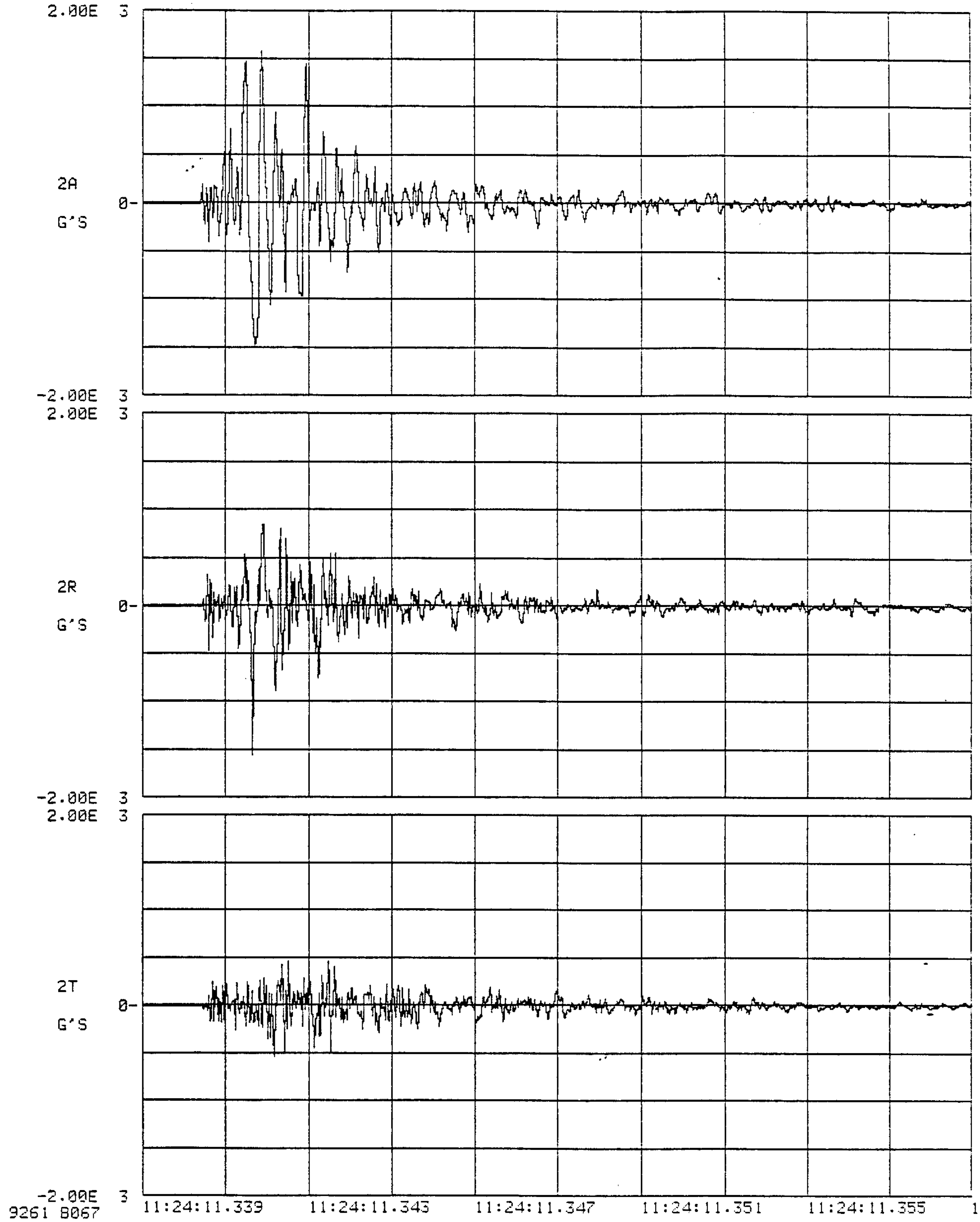
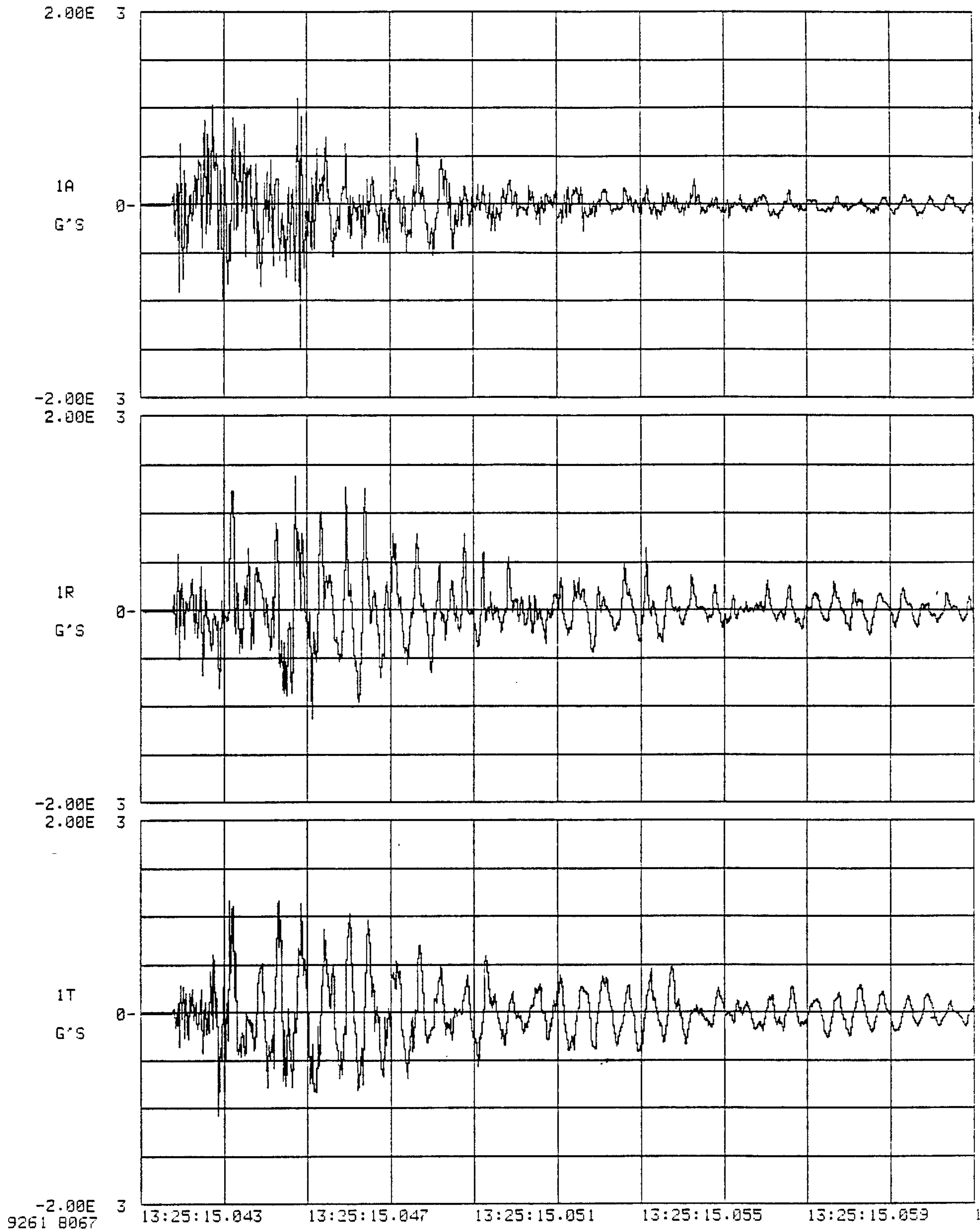
CHECK	TMT 8/2/83	
APPD		RUN NO. 7
APPD		

B15



CALC	MED 8/02/83	IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83	
APPD		RUN NO. 7
APPD		

B16



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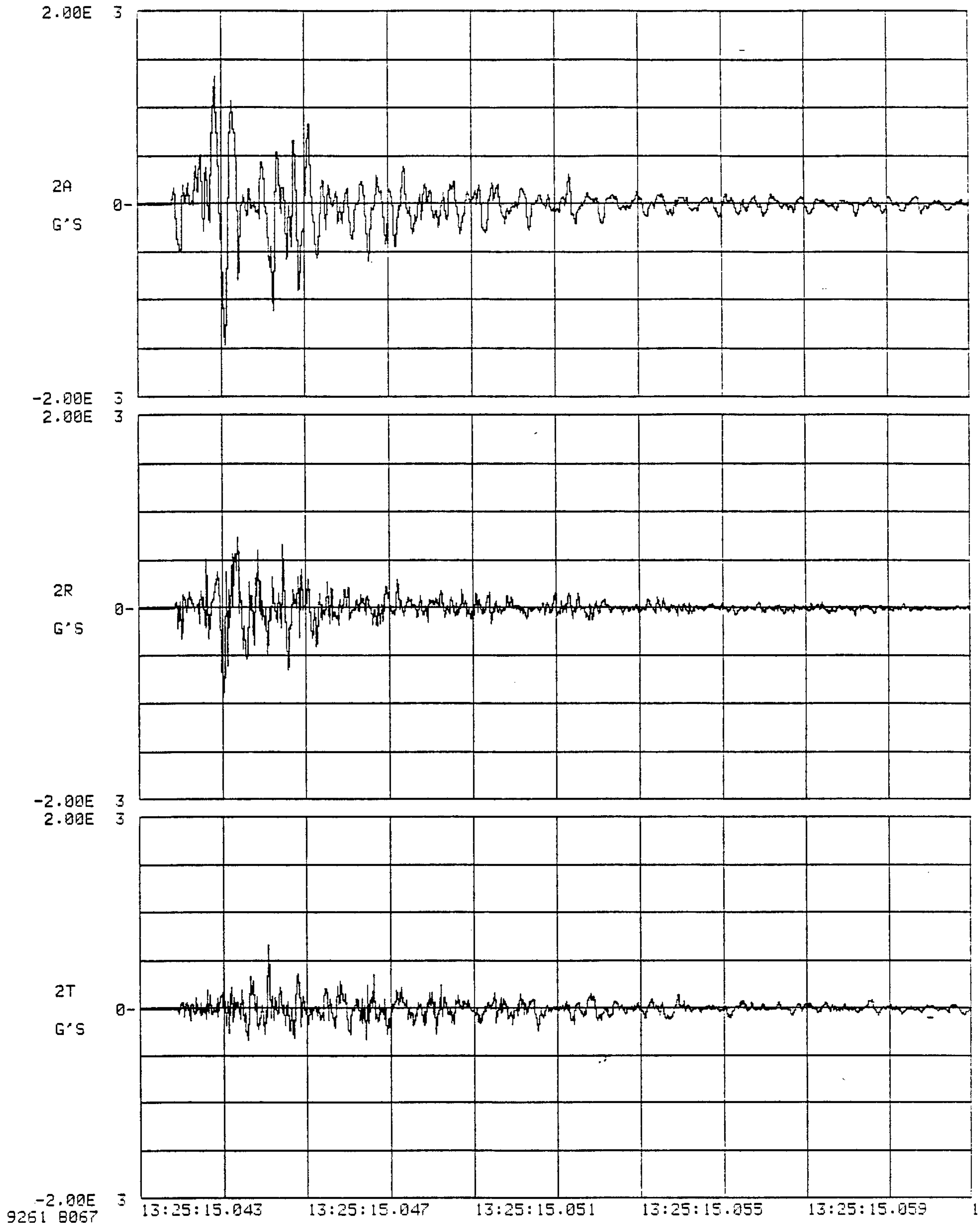
CHECK	TMT 8/2/83	
APPD		RUN NO. 8
APPD		

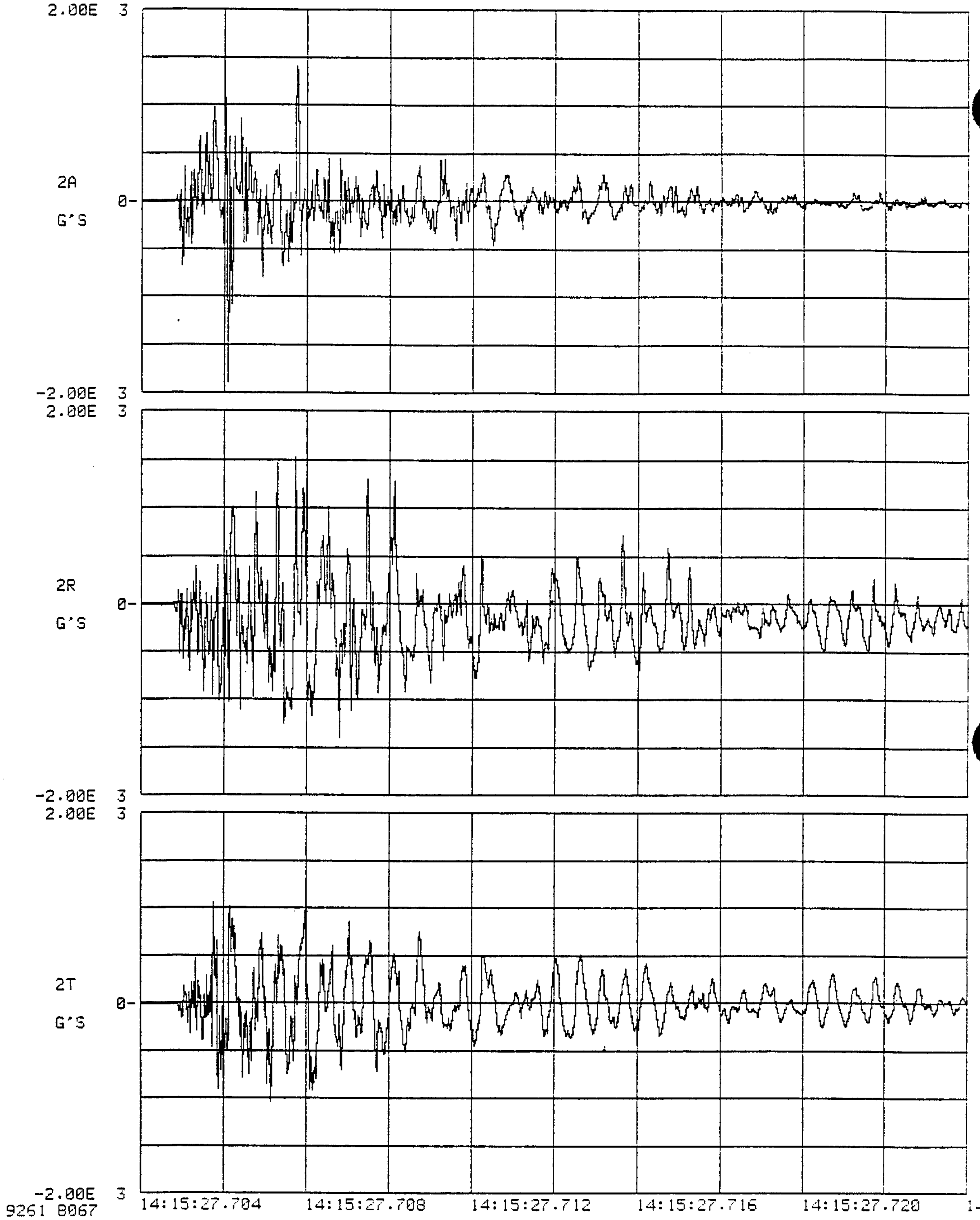
B17



9261 B067

CALC	MED 8/02/83		IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83		
APPD			RUN NO. 8
APPD			

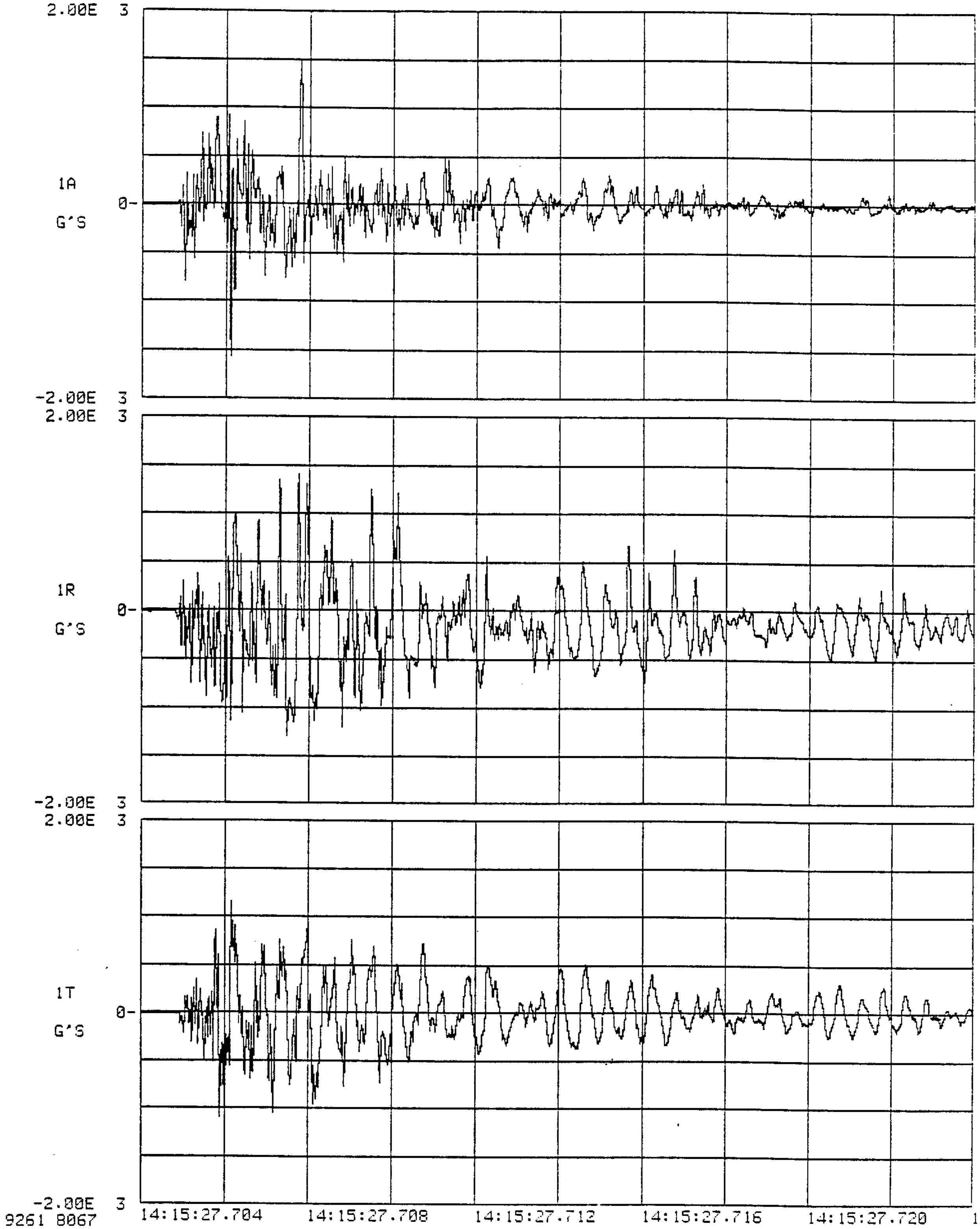
B18



CALC	MED 8/02/83		IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83		
APPD			RUN NO. 9
APPD			

B19

BOEING



CALC	MED 8/02/83		IUS STAGING BOLT SEPARATION TEST
CHECK	TMT 8/2/83		
APPD			RUN NO. 9
APPD			

B20

TYPICAL DATA DESCRIPTION SHEET

DIGITAL OSCILLOGRAM

DATE 8/ 1/83 TIME 15:14: 8

DIGITIZATION PARAMETERS

NUMBER OF CHANNELS 4
ACTUAL SAMPLING RATE 10000. SAMPLES/SEC/CH.
IRIG START TIME 11: 8:45.300
PLAYBACK RECORD RATIO 0.2500

ADC - NUMBER OF BITS 14
CALIBRATION LEVEL 0.707 VRMS
DATA DURATION 0.600 SECONDS

PLOT PARAMETERS

DATA IDENTIFICATION 9261 B067
NUMBER OF CHANNELS 3
IRIG START TIME 11: 8:45.745

PAPER SPEED 325.000 INCHES/SEC.
PLOT DURATION 0.020 SECONDS

CHANNEL ORIENTED PARAMETERS

PLOT TRACE POSITION BOT - TOP	ADC CHANNEL NUMBER	CHANNEL IDENT-IFCATION	SENSITIVITY VOLTS/ENG UNIT	CALIBRATION VOLTS/ COUNT	CALIBRATION LEVEL - VRMS	DC OFFSET VOLTS	ENG. UNIT TYPE
1	4	1T	5.00E -4 ✓	6.10E -4	7.07E -1	0.00E 0	G'S
2	3	1R	5.00E -4 ✓	6.10E -4	7.07E -1	0.00E 0	G'S
3	2	1A	5.00E -4 ✓	6.10E -4	7.07E -1	0.00E 0	G'S

Run no. 3

CAL

$$\frac{.707\ V_{rms}}{5\times10^{-4}\ \frac{V}{g}} = 1414\ g_{rms} \text{ or } 2000\ g/1\ \text{volt}$$

B21

6.0 DSP/IUS SHOCK EVALUATION

This section contains pyrotechic shock data generated by firing of the DSP spacecraft separation nuts. The spacecraft was attached to the IUS. The data were generated during a ground test. The shock levels were higher than anticipated. Additional tests were performed to demonstrate that the DSP shock did not damage IUS equipment. This testing was performed between October 1985 and February 1986.

BOEING

2-3612-IUS-014/86
18 March 1986

To:	S. M. Church	8C-72
	J. E. Honsberger	8A-33
cc:	M.V. Allain	8C-75
	F. G. Staples	8A-23
	A. D. Watson	8C-71

Subject: DSP/IUS Shock Evaluation

Reference: TRW 35.60.4-589; 18 February 1986; to HQ Space Division from D. Stager TRW; subject, Minutes of Second DSP/IUS Interface Shock/Tap Test Data Review

Attached is an evaluation of pyrotechnic shock data from the DSP/IUS separation test conducted in October 1985. The evaluation includes results from the tap test conducted in February 1986 and comparisons with data from other separation tests. The conclusion from this evaluation is: the IUS is compatible with the DSP separation shock.

This evaluation has been prepared in response to an action assigned during the reference meeting. This evaluation supersedes previous evaluations of DSP/IUS compatibility.

Clark Beck

Clark Beck

DSP 14/ IUS SHOCK TEST EVALUATION AND COMPATIBILITY REPORT

18 March 1986

SUMMARY

This report presents pyrotechnic shock spectra and analyses showing the IUS compatible with the shock environment caused by DSP separation. The shock spectra were obtained from the DSP/IUS separation test conducted in October 1985. The shock spectra were validated using acceleration mobility functions generated during a modal survey (tap test) conducted in February 1986. The shock spectra were also validated by comparison with spectra from 4 other spacecraft/IUS tests. The axial shock spectrum was increased based on the comparison.

1.0 INTRODUCTION

Purpose

The purpose of this report is to present pyrotechnic shock data generated by separation of the DSP 14 spacecraft from the IUS vehicle and to assess the compatibility of the IUS components with the DSP generated shock.

Background

The DSP 14/IUS separation shock test was conducted in October 1985 at TRW, reference 1. A preliminary evaluation of the test data by Boeing revealed that the measured shock exceeded the IUS allowable shock and 10 IUS components were not qualified for the DSP shock levels, reference 2. A final evaluation of the data by Boeing in December 1985 again showed that the DSP shock exceeded the IUS allowable and identified 10 IUS components that were not qualified for the DSP shock. The last evaluation questioned the applicability of the measured data because of the dissimilarity between the DSP data and data from other spacecraft /IUS shock tests, reference 3.

A meeting was held at TRW on January 16, 1986 to discuss the results of the October shock test, reference 4. A conclusion from this meeting was that some of the accelerometer locations and installations on the IUS had adversely affected the measured shock data. The axial accelerometer at IUS station 379 was particularly suspect. As a result of the meeting, a tap test (modal survey) was planned to evaluate the structural modes and transfer functions associated with the accelerometer installations. Boeing agreed to re-evaluate IUS component compatibility using the axial accelerometer data at station 375 in place of the station 379 axial data. The Boeing re-evaluation (reference 5) showed that one component was not compatible with the DSP shock and that 3 components were marginal.

The tap test was conducted at TRW during the week of February 3, 1986 (reference 6). A meeting was held at TRW on February 14 to discuss the results of the tap test, reference 7. The tap test did show that the shock levels were significantly influenced by the accelerometer installation. It was also concluded during this meeting that representative shock data were available from the October test for evaluation of IUS component compatibility. However, the DSP data must be validated by comparing it with shock data from other IUS/spacecraft shock tests. This report presents data and analyses used to evaluate the compatibility ofJUS components with DSP shock.

Scope

Section 2 of this report presents shock data forn the October 1985 test. The measured data are compared with the IUS allowable shock and the data characteristics are discussed. Section 3 contains a discussion of the tap test and findings from the test. Section 4 contains comparisons of the DSP shock data with shock data from other IUS/spacecraft tests. Rationale is provided to justify selection of representative DSP shock data. The compatibility of IUS components with the representative DSP shock data is assessed in Section 5. Section 6 presents final conclusions relative to DSP 14/IUS compatibility.

2.0 DSP 14/IUS TEST RESULTS

Introduction

A pyrotechnic shock test of the DSP 14 and IUS Equipment Support Section (ESS) was conducted at TRW in October 1985, reference 1. The pyrotechnic shock was generated when the one inch diameter separation nuts were fired on the DSP. The four separation nuts are located about 10 inches from the DSP/IUS interface plane. The ESS was attached to the test lab floor. The DSP was supported to simulate a zero g condition. The separation test was performed three times. Acceleration response was measured during each of the three tests. The IUS ESS was instrumented with 18 accelerometers.

Scope

This section presents the shock spectra envelopes at the DSP/IUS interface (IUS station 379) and on the IUS longerons four inches from the interface (IUS station 375). Comparisons of the DSP generated shock with the IUS allowable are provided.

IUS ESS Configuration

The IUS ESS configuration was the STV (Structural Test Vehicle). The STV structure is representative of flight vehicle structure. The STV ESS was supported by 8 steel pillars bolted to the test lab floor. Figure 2-1 is a sketch showing the relationship between the test articles.

IUS Instrumentation

Eighteen (18) accelerometers were located on the STV ESS. Six (6) of the accelerometers were on the IUS ring at the DSP/IUS interface (station 379) and 12 were on the IUS longerons four inches from the interface (station 375). Figure 2-2 contains a detailed description of the instrumentation.

Shock Spectra

Figures 2-3 and 2-4 show the DSP 14 induced shock spectra at IUS station 379 (DSP/IUS interface) and IUS station 375 (4 inches from the interface). The measured spectra are compared to the IUS allowable shock. Note that the DSP induced shock is higher than the IUS allowable below 1000 Hz. Also note the high shock level at station 379 and 500 Hz in the Z direction. At station 375 a high shock level occurs at 350 Hz in the tangential direction.

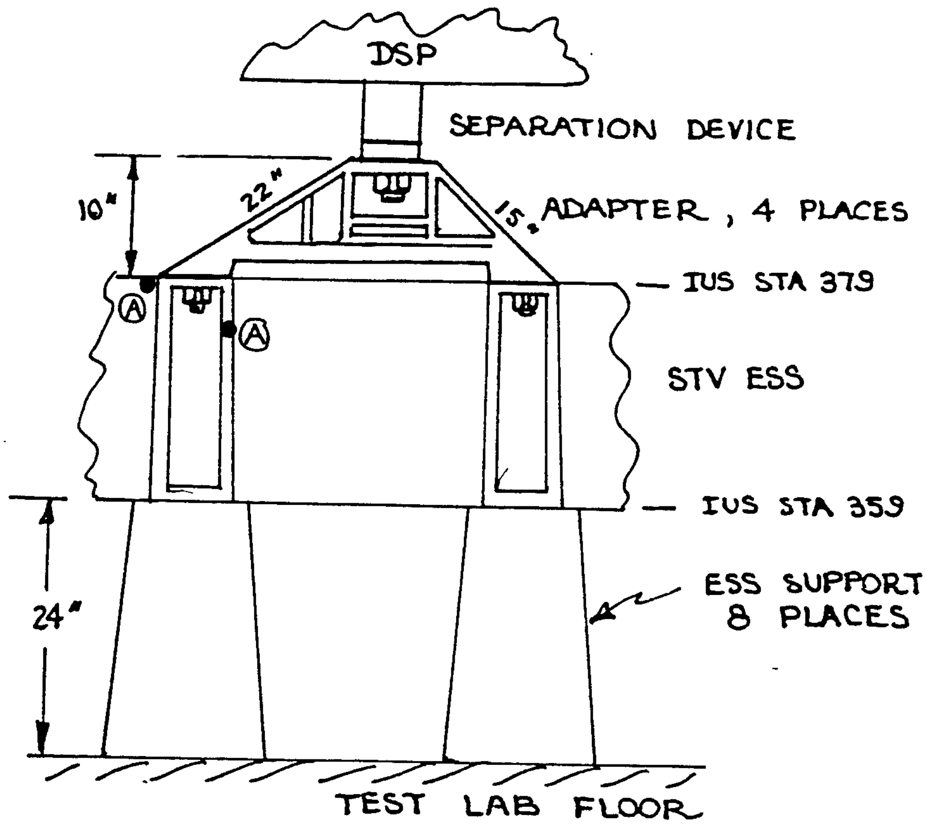
Suspect Measurements

The axial shock measured at station 379 and the tangential shock measured at station 375 were suspect because of the high shock levels at 500 Hz and 350 Hz. A review of the accelerometer installations showed that because of the accelerometer blockweight and location, it was probable that the high shock levels were the result of localized block-structure resonances. Figure 2-5 is a schematic representation of the suspected resonant modes.

Recommended Tap Test

Because of the high shock levels as well as the suspicion that the high levels were the result of local resonances involving the measurement blocks, a modal survey (tap test) was recommended (reference 4). The tap test was conducted in February 1986. The results of the tap test are discussed in Section 3.

FIGURE 2-1
TEST SETUP

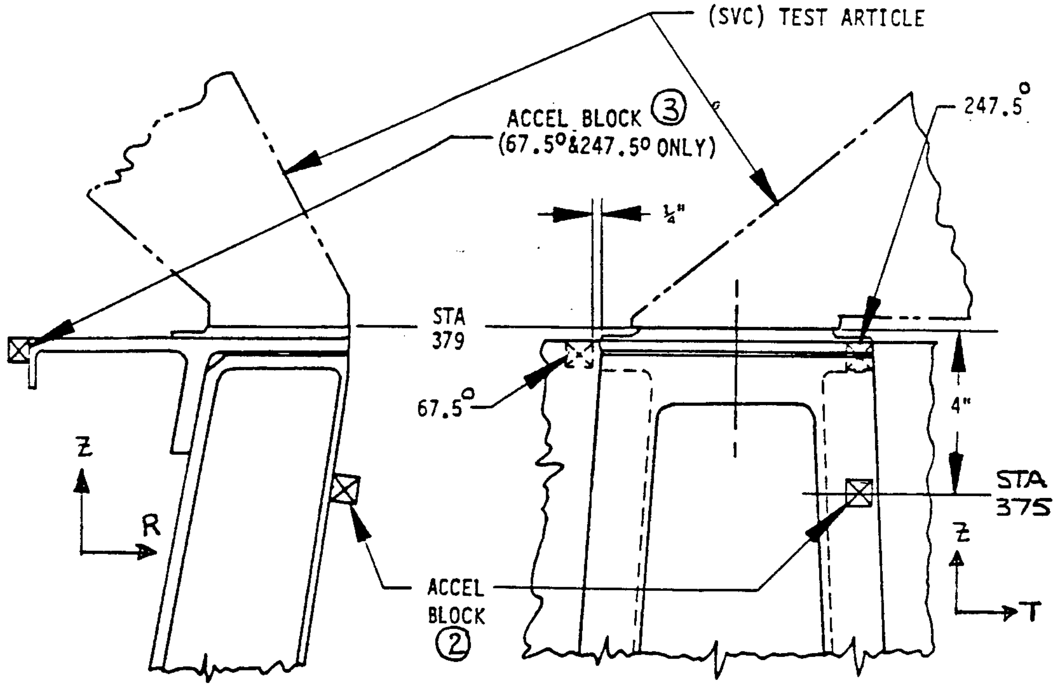


Ⓐ ACCELEROMETERS, SEE FIGURE 2-2

4

INTERFACE AZIMUTH (DEGREES)	IUS RING (379)			IUS LONGERON (375)		
	3R (RADIAL)	3T (TANGENTIAL)	3Z (AXIAL)	2R	2T	2Z
67.5°	101	102	103	107	108	109
247.5°	104	105	106	113	114	115
112.5°				110	111	112
292.5°				116	117	118

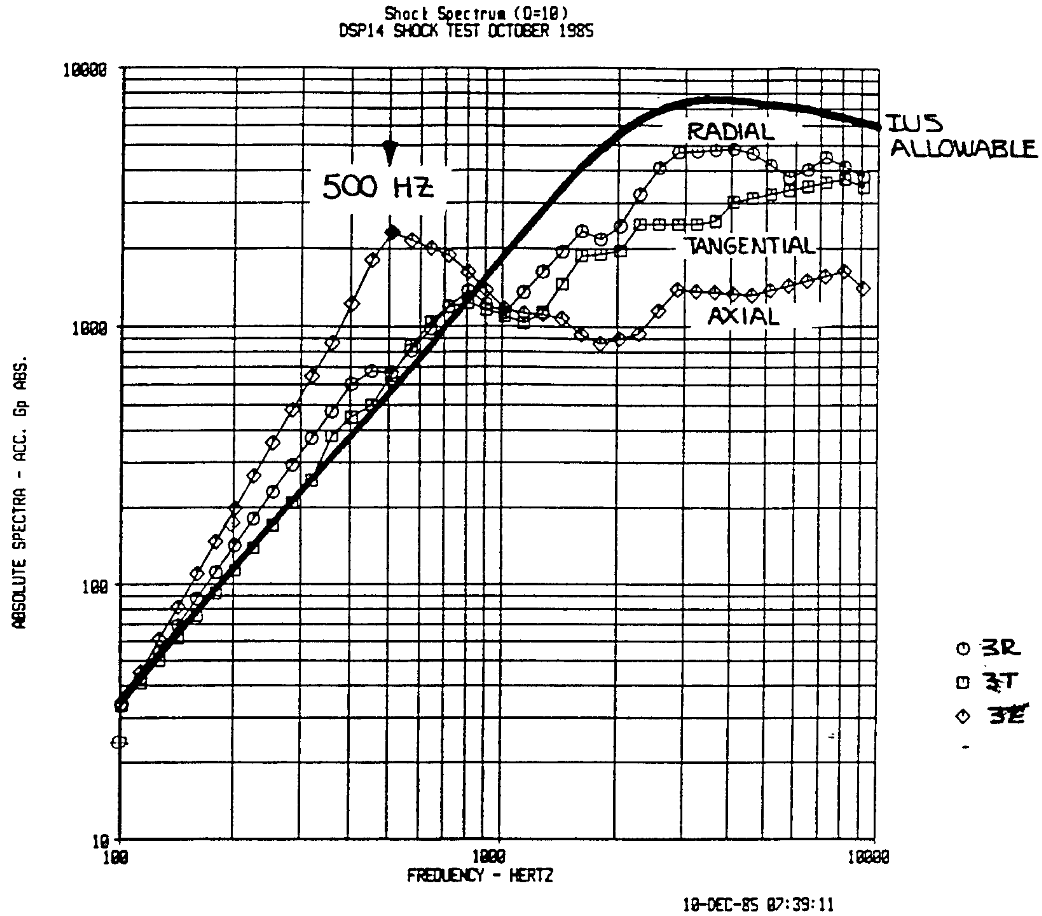
ACCELEROMETER LOCATIONS



TYPICAL
67.5°, 247.5°, 112.5° & 292.5°
(EXCEPT AS NOTED)

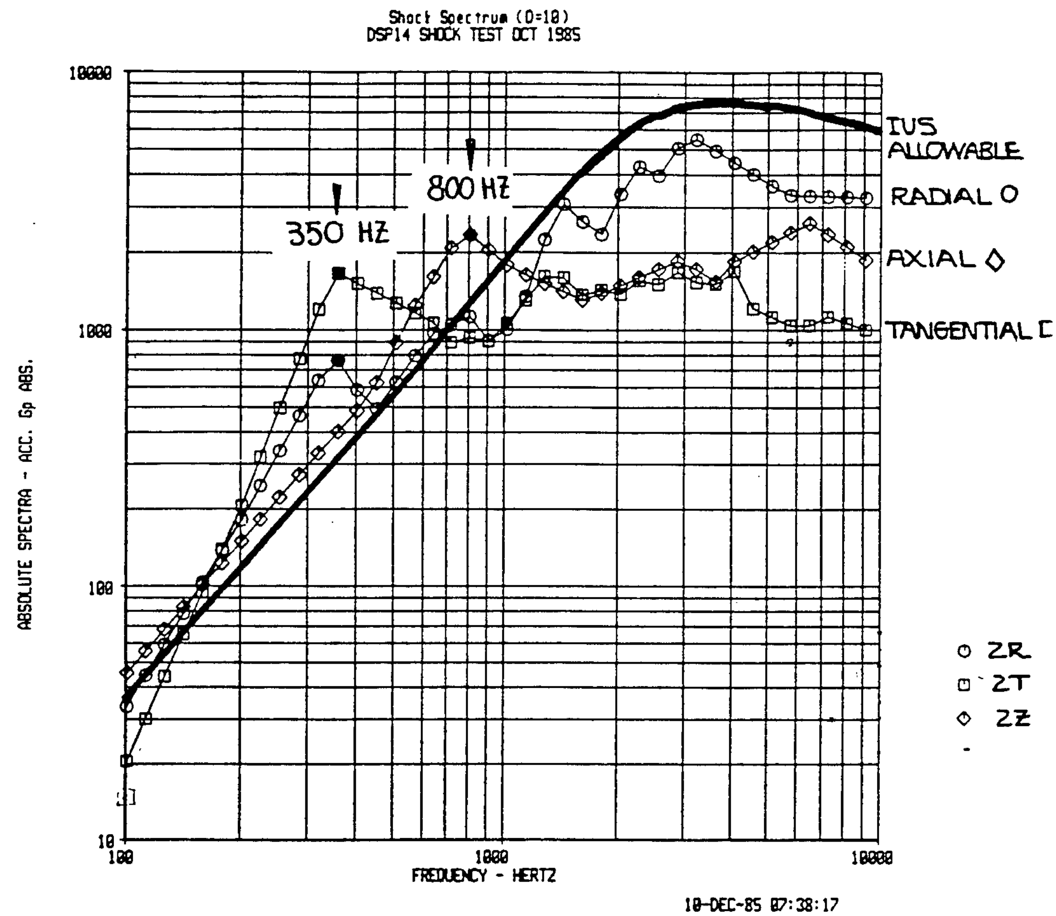
FIGURE 2-2
IUS INSTRUMENTATION

5



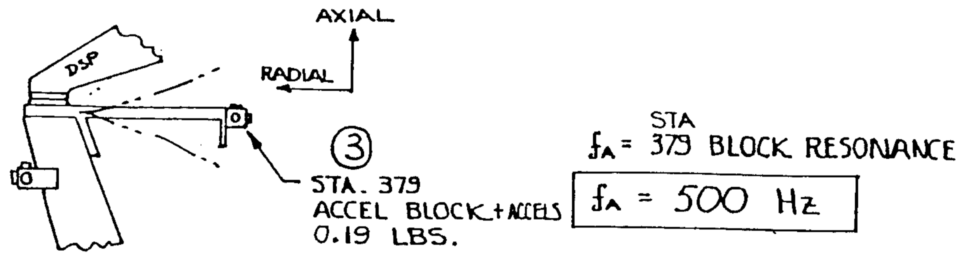
DSP 14 INDUCED SHOCK
AT DSP/IUS INTERFACE
IUS STATION 379 (LOCATION 3)

CALC	CB	10DEC85	REVISED	DATE	FIGURE 2-3	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 6



DSP 14 INDUCED SHOCK
ON IUS LONGERON, 4 INCHES
FROM DSP/IUS INTERFACE
<u>IUS STATION 375</u> (LOCATION 2)

CALC		10DEC85	REVISED	DATE	FIGURE 2-4	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 7



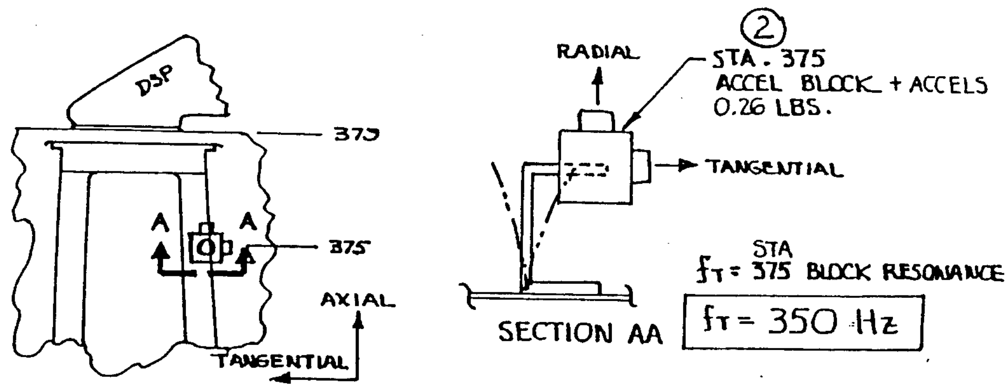


FIGURE 2-5
ACCELEROMETER BLOCK RESONANCES

8

3.0 TAP TEST RESULTS

Introduction

A tap test of the DSP 14 adapter and the IUS ESS was conducted at TRW in February 1986 (reference 6). The purpose of the test was: (1) to determine if the high shock levels were due to the accelerometer installation:(2) to provide transfer function information to aid in evaluating the shock level.

Two configurations were tested. Configuration 1 included the heavy measurement blocks and accelerometers used during the shock test. The heavy blocks were removed and replaced with lightweight accelerometers and blocks for configuration 2. Tap tests were conducted on each configuration and acceleration mobility plots were generated from the test measurements.

Scope

This section presents selected mobility plots showing the effect of accelerometer block installation on the structural response. Three accelerometer locations are selected which provide the best estimate of the shock delivered to the IUS.

Instrumentation

The instrumentation locations for configurations 1 and 2 are shown in figures 3-1 and 3-2. Locations 2 and 3 are of primary interest. Locations 2 and 3 were instrumented during the October 1985 shock test. The accelerometer installations at locations 2 and 3 were changed between configurations 1 and 2. The changes are shown in the following table.

LOCATION	IUS STATION	CONFIGURATION	INSTALLATION WEIGHT
2	375	1	0.26 lbs
2	375	2	0.03 lbs
3	379	1	0.19 lbs
3	379	2	0.03 lbs

Three accelerometers were installed at locations 2 and 3 for both configurations.

Data Description

The data from the tap tests consists of acceleration mobility graphs. A sample graph is shown in figure 3-3. The data were obtained by tapping the structure with a force sensing hammer and recording the hammer force time history along with the structure acceleration response time history. The ratio of the acceleration response to the force input was calculated to provide an acceleration mobility spectrum. The phase angle between the acceleration and force was also calculated and presented on the data graph.

One hundred eighty-five graphs are available from this test, reference 6. The data were obtained at the force-response locations shown in figures 3-1 and 3-2.

Mobility Evaluation

Acceleration mobility plots for locations 1,2 and 3 are shown in figures 3-4 through 3-12. The evaluation of each plot is discussed in the following paragraphs.

Figure 3-4 compares direct mobility measurements at locations 1T and 2T. The comparison shows a resonance at 330 Hz as suspected from the shock test data. When the lightweight installation (configuration 2) was tested, the resonance moved to 660 Hz. Note that the mobility at location 2T is 1 to 3 orders-of-magnitude greater than the mobility at location 1 (spacecraft/IUS interface). Location 1 is the desired location for the shock measurement since location 1 is a "hard point" and provides the best estimate of the shock delivered to the IUS.

An estimate of the difference between shocks measured at location 1T and 2T is obtained by comparing the transfer mobility and direct mobility. This comparison is shown in figure 3-5. The comparison shows the direct mobility at 1T for a frequency of 330 Hz is about 20 dB less than the transfer mobility at location 2T. Referring to figure 2-4, if the 1700 g shock level at 350 Hz is lowered by 20 dB, the result is a level of about 200 gs.

Figure 3-6 contains a comparison of the transfer mobility at location 3T and the direct mobility at location 1T. This comparison shows the mobilities are similar. Therefore, the shock measured at 3T should be similar to the shock measured at 1T. Figure 2-3 presents the shock measured at 3T during the October test. At 350 Hz the measured shock is 300 gs. The 300 g level is the same order of magnitude as the 200 g estimate discussed in the previous paragraph. The above analysis suggests that the shock measured at 3T provides a valid definition of the shock delivered to the IUS by the DSP in the tangential direction.

Figures 3-7 through 3-9 present mobility measurement comparisons for locations 1R, 2R and 3R. Figure 3-7 shows a 330 Hz resonance at location 2R for configuration 1. When the configuration 1 mounting block is replaced by configuration 2, the resonance moves to 1300 Hz. The mobility at 330 Hz for location 2R is 2½ orders-of-magnitude greater than the mobility of 1R. Location 2R does not provide a valid measurement of the shock delivered to the IUS.

An estimate of the 350 Hz shock level at 1R can be obtained by the use of figure 3-8. Figure 3-8 (shaded area) indicates that 2R responds about 10 dB higher than 1R when an excitation is applied at 1R. Therefore, the 350 Hz shock of 750 g measured at 2R (figure 2-4) is estimated to be 250 gs if measured at 1R.

Figure 3-9 shows the mobility relationships between location 1R and 3R. Below 500 Hz the mobility of the two locations are the same. Therefore, at 350 Hz, 3R will provide a good estimate of the shock at 1R. From figure 2-3 the shock at 350 Hz in the radial direction is 420 gs. This 420 g level is the same order-of-magnitude as the 250 g estimate discussed in the previous paragraph. The analysis of the data in figures 3-7 through 3-9 indicates that the shock measured at 3R provides a valid definition of the shock delivered to the IUS by the DSP in the radial direction.

Figures 3-10 through 3-12 contain mobility measurement comparisons for locations 1Z, 2Z and 3Z. Figure 3-10 shows a resonance at 500 Hz at 3Z. The mobility at 3Z is 2½ orders-of-magnitude greater than the 1Z mobility. Therefore, the 2200 g shock level measured at 3Z and 350 Hz (figure 2-3) is not valid. The resonance frequency shift from 500 Hz to 715 Hz due to the configuration change illustrates how the shock level is influenced by the accelerometer installation.

An estimate of the shock level at 1Z and 500 Hz can be obtained by correcting the 2200 g level from 3Z (figure 2-3) by the mobility ratio from figure 3-11. The mobility ratio at 500 Hz is 20 dB. Therefore, the shock level at 1Z and 500 Hz is estimated to be 220 g. Another estimate can be obtained from accelerometer 2Z. Figure 2-4 shows a shock level of 600 g at 500 Hz for 2Z.

Figure 3-12 compares the direct mobility at 1Z to the transfer mobility at 2Z. Comparing figures 3-11 and 3-12, you can see that 2Z is a better measurement location than 3Z in the 500 to 700 Hz range. However, 2Z will indicate higher shock levels than 1Z between 700 Hz and 1000 Hz because of the higher mobility (see shaded area in figure 3-12) and 2Z will have lower levels than 1Z between 1000 Hz and 2000 Hz. The analysis of the data in figures 3-10 through 3-12 indicates that the shock measured at 2Z is the best available definition of the shock delivered to the IUS by the DSP in the axial direction.

Selected Accelerometer Locations

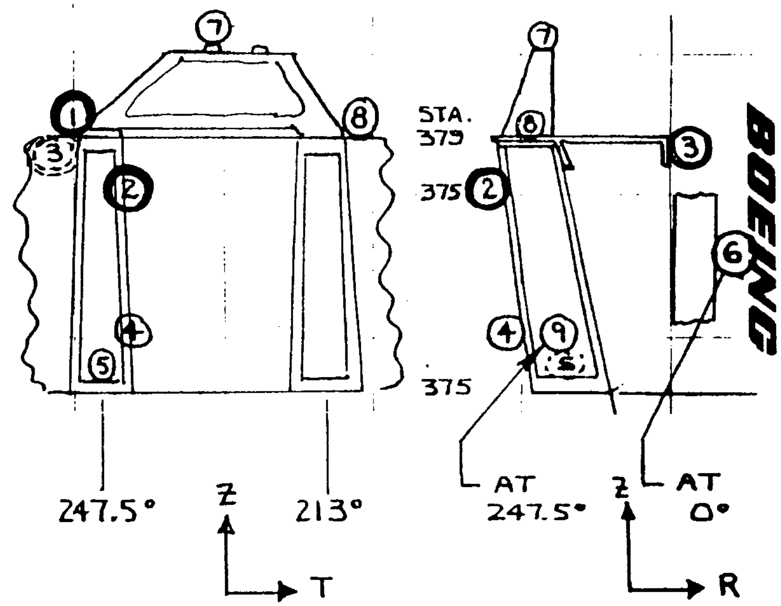
The shock spectra from accelerometer locations 2Z, 3R and 3T will be used to define the DSP induced pyrotechnic shock at the DSP/IUS interface, IUS station 379.

FIGURE 3-1 CONFIGURATION 1 MEASUREMENTS

RESPONSE MEASURE		1 Z	1 R	1 T	2 R	2 T	3 Z	3 R	4 R	4 T	5 Z	6 R	6 T	7 Z	8 Z	8 R	8 T	9 T
1	Z	⊙	⊙	⊙	⊙	⊙	⊙	⊙			⊙			⊙				
	R	⊙	⊙	⊙	⊙	⊙	⊙	⊙			⊙			⊙				
	T	⊙	⊙	⊙	⊙	⊙	⊙	⊙			⊙			⊙				
2	Z	⊙	⊙	⊙	⊙	⊙								⊙				
	R	⊙	⊙	⊙	⊙	⊙								⊙				
	T	⊙	⊙	⊙	⊙	⊙								⊙				
3	Z	⊙	⊙	⊙			⊙	⊙						⊙				
	R	⊙	⊙	⊙			⊙	⊙						⊙				
	T	⊙	⊙	⊙			⊙	⊙						⊙				
4	Z	⊙	⊙	⊙							⊙			⊙				
	R	⊙	⊙	⊙					⊙	⊙	⊙			⊙				
	T	⊙	⊙	⊙					⊙	⊙	⊙			⊙				
5	Z	⊙	⊙	⊙							⊙			⊙				
6	Z	⊙	⊙	⊙							⊙			⊙				
	R	⊙	⊙	⊙							⊙	⊙	⊙	⊙				
	T	⊙	⊙	⊙							⊙	⊙	⊙	⊙				
7	Z						⊙							⊙				
8	Z													⊙	⊙	⊙	⊙	
	R													⊙	⊙	⊙	⊙	
	T													⊙	⊙	⊙	⊙	
9	Z																	
	R																	
	T																	

(Column header: TRANSIENT FORCE INPUT)

• DATA TAKEN
⊙ DATA PLOTTED, 120 GRAPHS



PCB ACCELS ON 1/2" PHENOLIC CUBE EXCEPT LOCATIONS (2) AND (3)

(2) 1" x 1" x 1.7" AL BLOCK PLUS 3 ENDEVCO 2225

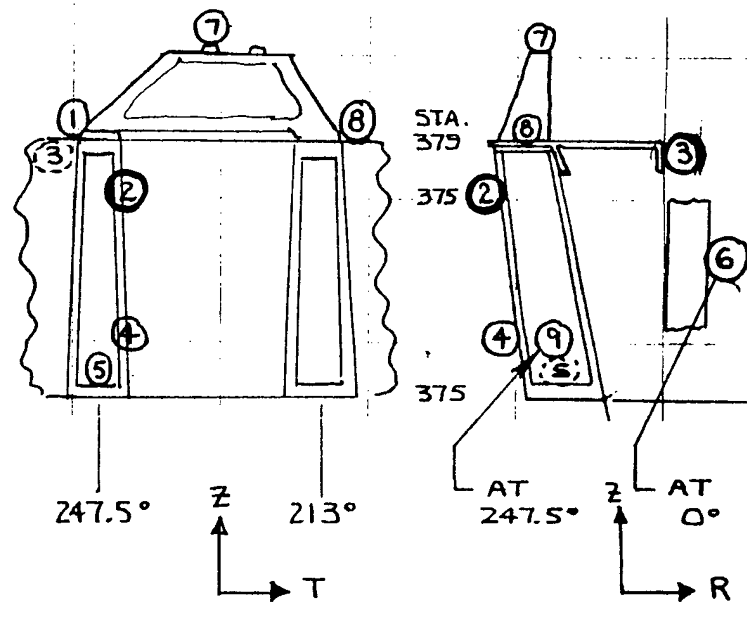
(3) 1" AL CUBE PLUS 3 ENDEVCO 2225

12

FIGURE 3-2 CONFIGURATION 2 MEASUREMENTS

RESPONSE MEASURE		TRANSIENT FORCE INPUT 1 Z	1 R	1 T	2 R	2 T	3 Z	3 R	4 R	4 T	5 Z	6 R	6 T	7 Z	8 Z	8 R	8 T	9 T
1	Z	◉	◉	◉	◉	◉								◉				◉
	R	◉	◉	◉	◉	◉								◉				◉
	T	◉	◉	◉	◉	◉								◉				◉
2	Z	◉	◉	◉	◉	◉					◉			◉				
	R	◉	◉	◉	◉	◉					◉			◉				
	T	◉	◉	◉	◉	◉					◉			◉				
3	Z	◉	◉	◉			◉	◉						◉				
	R	◉	◉	◉			◉	◉						◉				
	T	◉	◉	◉			◉	◉						◉				
4	Z																	
	R																	
	T																	
5	Z										◉							
6	Z																	
	R																	
	T																	
7	Z													◉				
8	Z																	
	R																	
	T																	
9	Z																	◉
	R																	◉
	T																	◉

• DATA TAKEN
◉ DATA PLOTTED, 65 GRAPHS



PCB ACCELS ON 1/2" PHENOLIC CUBE ALL LOCATIONS

BOEING

13

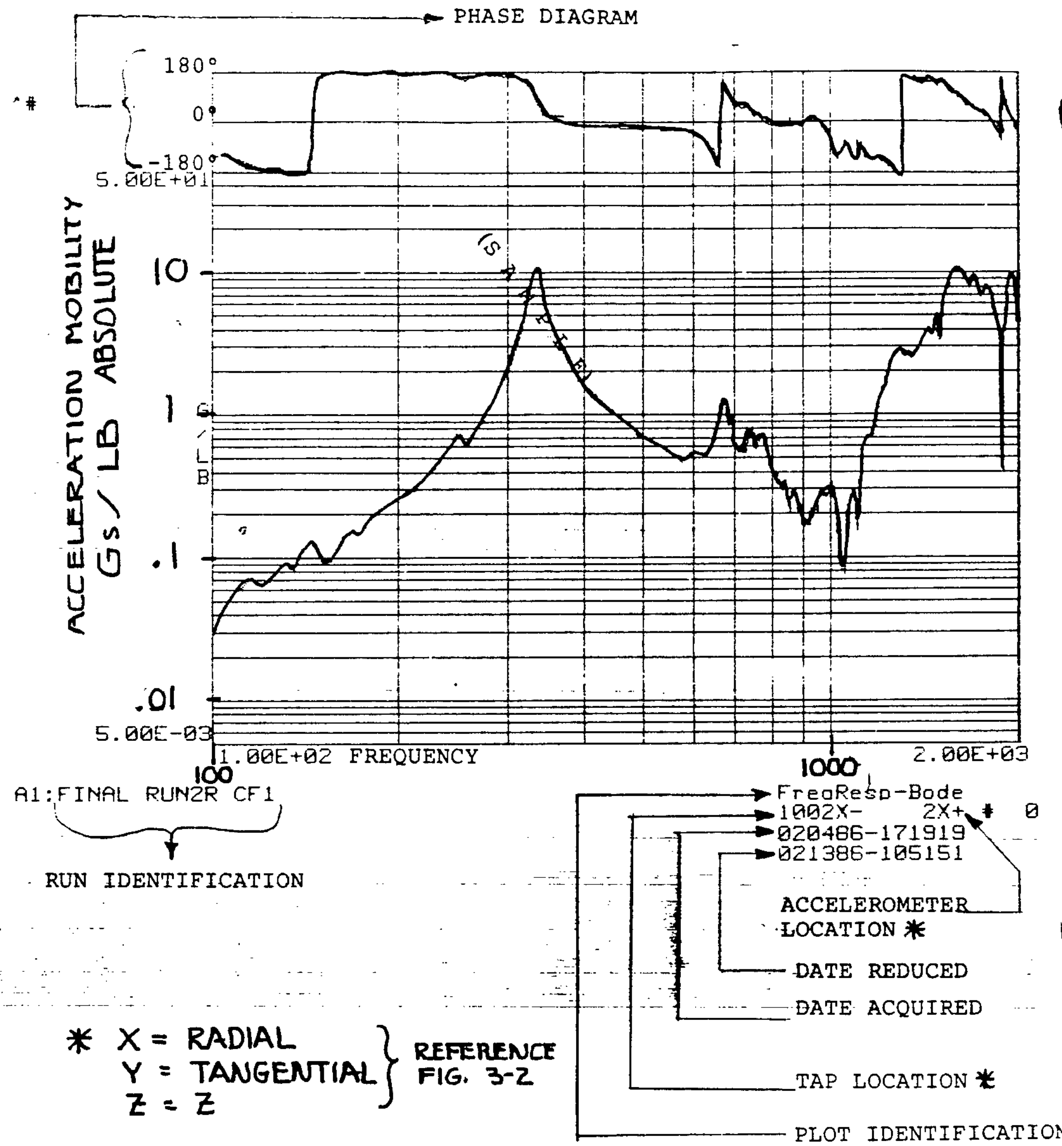


FIGURE 3-3
ACCELERATION MOBILITY GRAPH

14

LEGEND

1^{1T}_{1T} CONFIGURATION 1, RESPONSE 1T, FORCE 1T

1^{2T}_{2T} CONFIGURATION 1, RESPONSE 2T, FORCE 2T

2^{2T}_{2T} CONFIGURATION 2, RESPONSE 2T, FORCE 2T

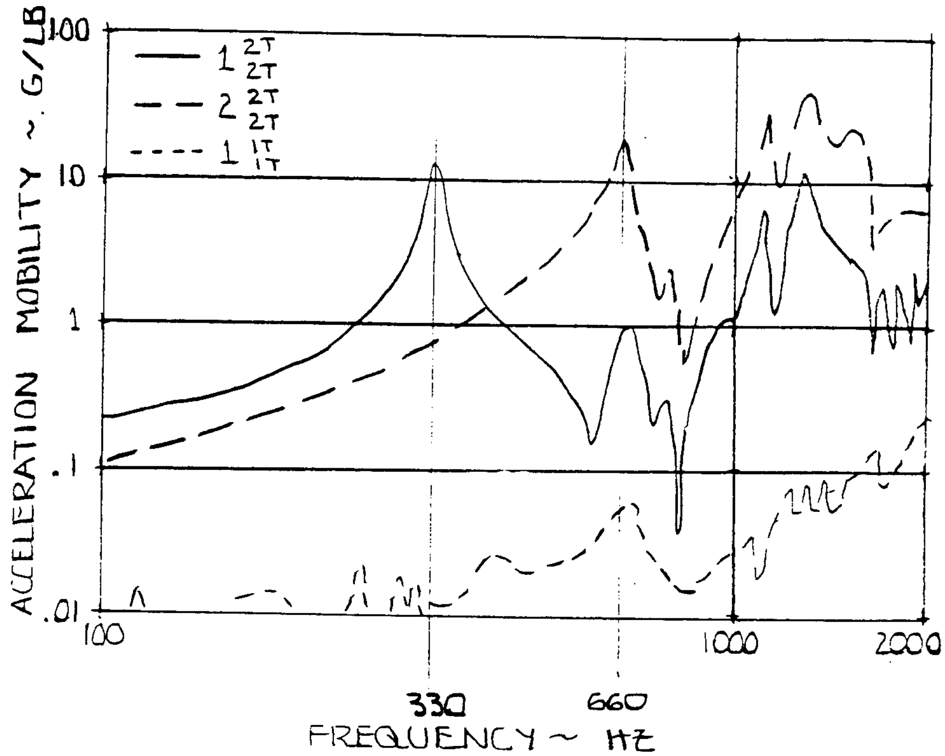


FIGURE 3-4

DIRECT MOBILITY LOCATIONS 1T AND 2T

15

LEGEND

1^{1T}_{1T} **CONFIGURATION 1, RESPONSE 1T, FORCE 1T**

1^{2T}_{1T} **CONFIGURATION 1, RESPONSE 2T, FORCE 1T**

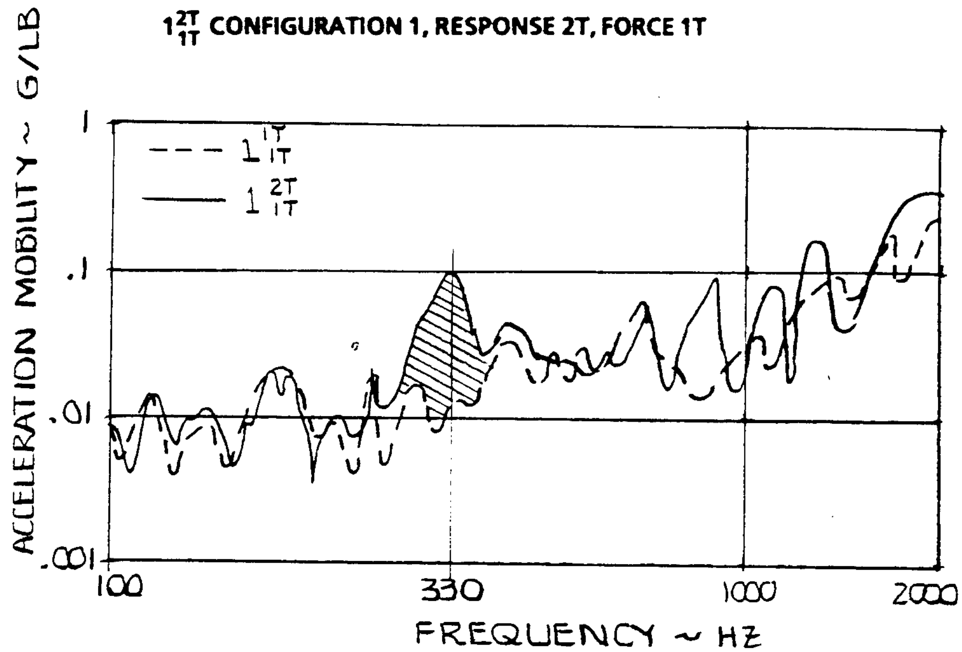


FIGURE 3-5

DIRECT/TRANSFER MOBILITY LOCATIONS 1T AND 2T

16

LEGEND

1^{1T}_{1T} CONFIGURATION 1, RESPONSE 1T, FORCE 1T

1^{3T}_{1T} CONFIGURATION 1, RESPONSE 3T, FORCE 1T

2^{3T}_{1T} CONFIGURATION 2, RESPONSE 3T, FORCE 1T

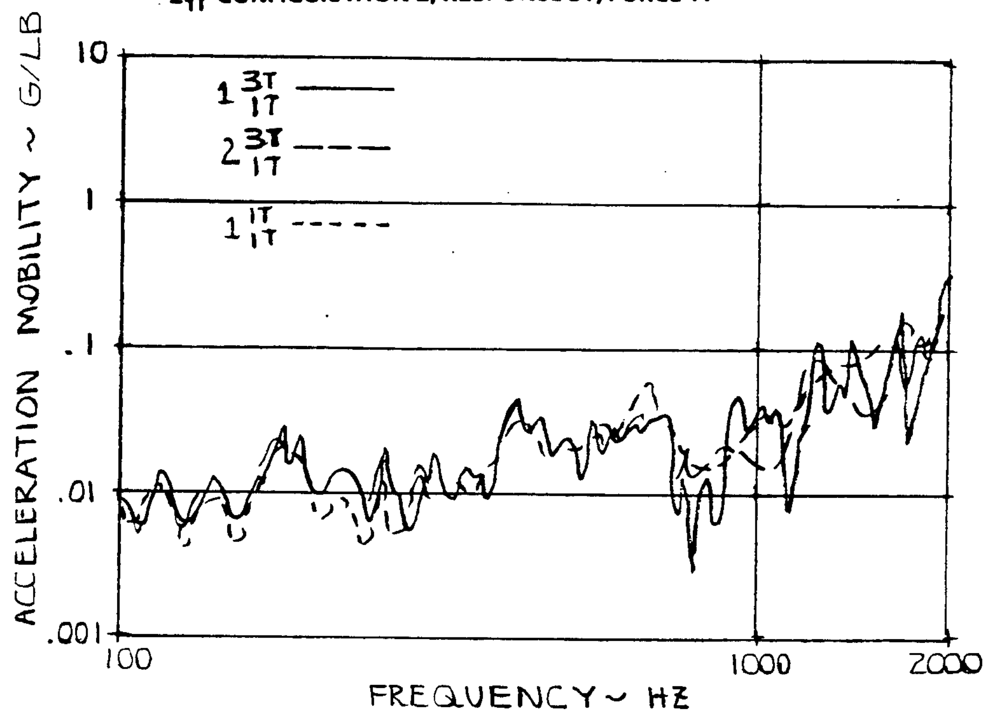


FIGURE 3-6

DIRECT/TRANSFER MOBILITY LOCATIONS 1T AND 3T

17

LEGEND

1^{1R}_{1R} CONFIGURATION 1, RESPONSE 1R, FORCE 1R

1^{2R}_{2R} CONFIGURATION 1, RESPONSE 2R, FORCE 2R

2^{2R}_{2R} CONFIGURATION 2, RESPONSE 2R, FORCE 2R

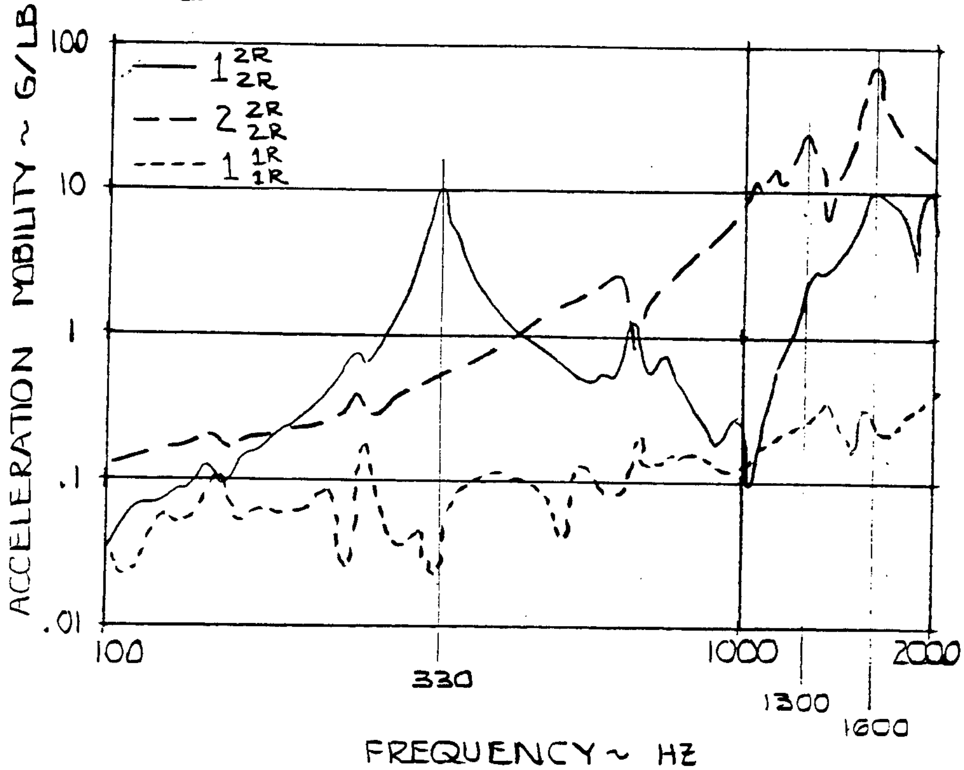


FIGURE 3-7

DIRECT MOBILITY LOCATIONS 1R AND 2R

18

LEGEND

1^{1R}_{1R} CONFIGURATION 1, RESPONSE 1R, FORCE 1R

1^{2R}_{1R} CONFIGURATION 1, RESPONSE 2R, FORCE 1R

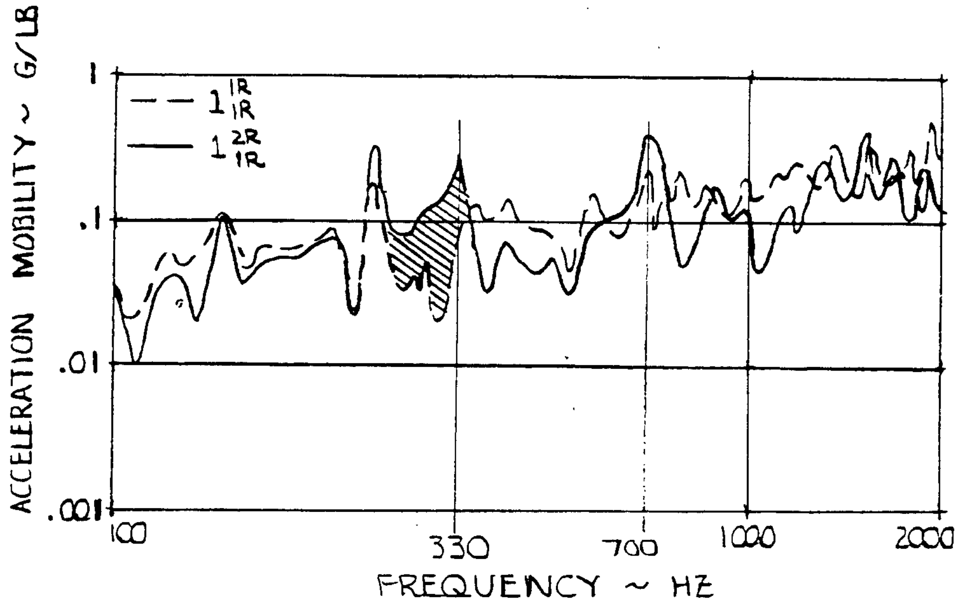


FIGURE 3-8

DIRECT/TRANSFER MOBILITY LOCATIONS 1R AND 2R

19

LEGEND

1^{1R}_{1R} CONFIGURATION 1, RESPONSE 1R, FORCE 1R

1^{3R}_{1R} CONFIGURATION 1, RESPONSE 3R, FORCE 1R

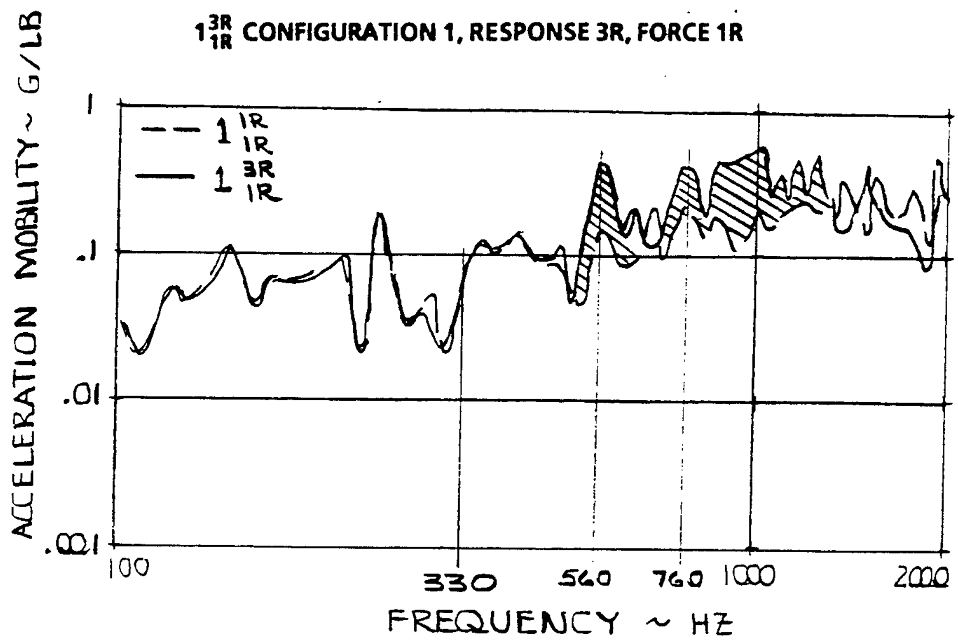


FIGURE 3-9

DIRECT/TRANSFER MOBILITY LOCATIONS 1R AND 3R

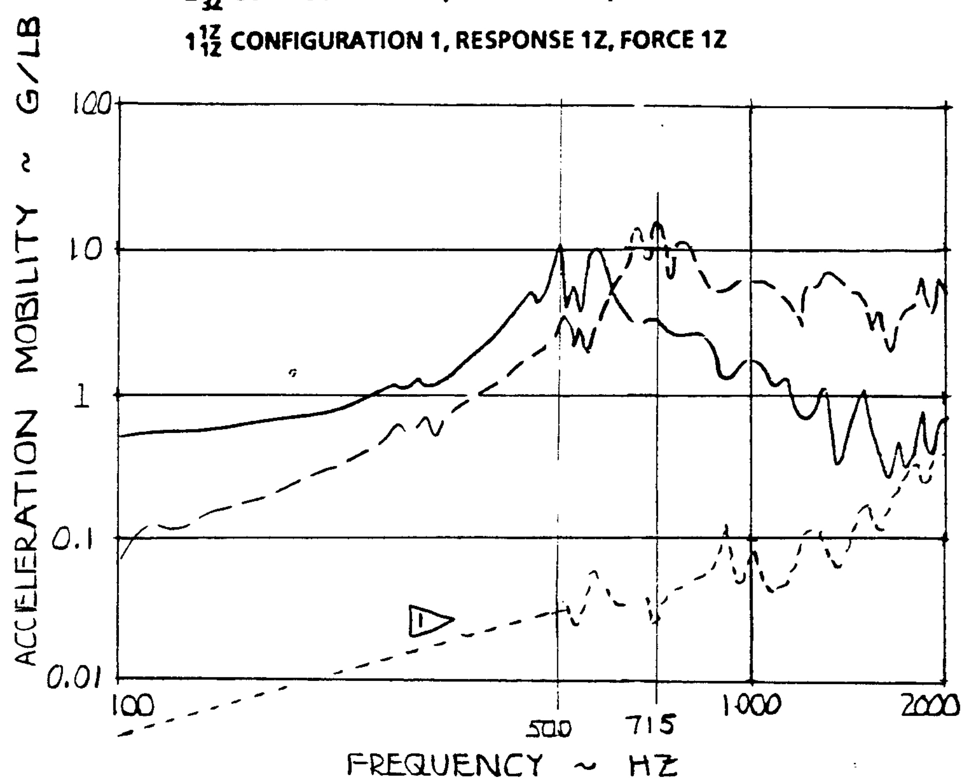
20

LEGEND

1^{3Z}_{3Z} CONFIGURATION 1, RESPONSE 3Z, FORCE 3Z

2^{3Z}_{3Z} CONFIGURATION 2, RESPONSE 3Z, FORCE 3Z

1^{1Z}_{1Z} CONFIGURATION 1, RESPONSE 1Z, FORCE 1Z



▷1 1^{1Z}_{1Z} MEASUREMENT APPEARS TO BE INVALID BETWEEN 100 HZ AND 500 HZ. SUSPECT LOW SIGNAL TO NOISE RATIO IN THIS RANGE. THE MOBILITY HAS BEEN ESTIMATED BY A 6 DB/OCTAVE SLOPE.

FIGURE 3-10

DIRECT MOBILITY LOCATIONS 1Z AND 3Z

21

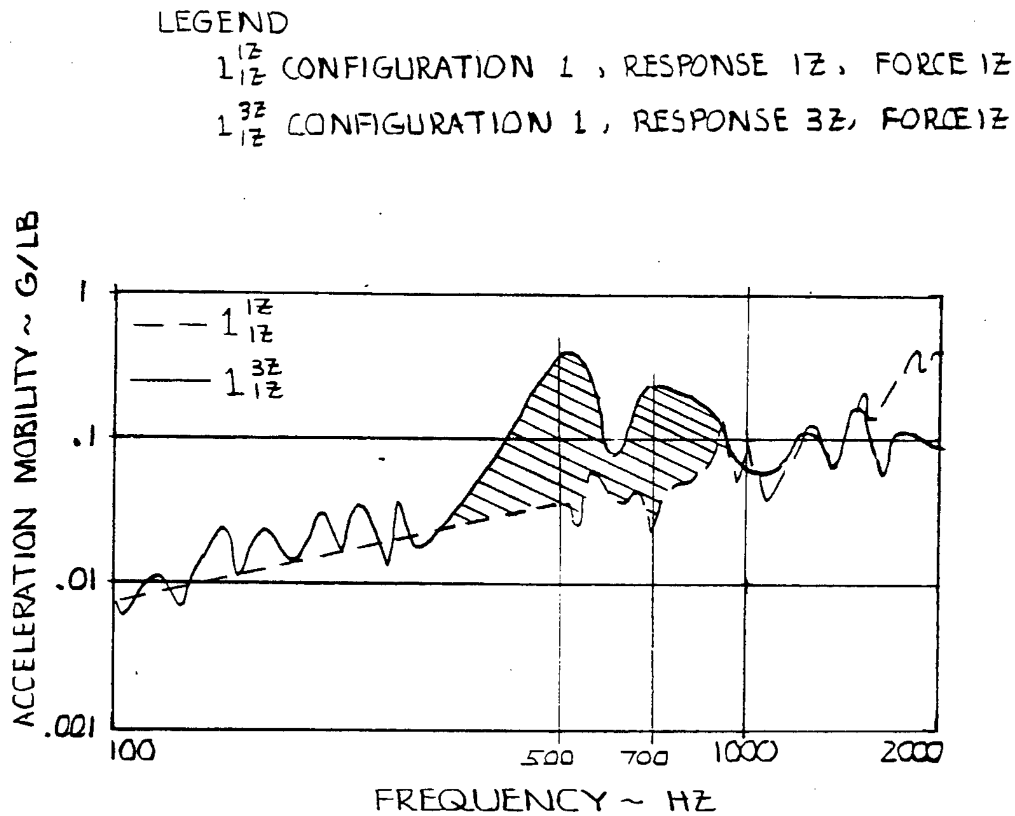


FIGURE 3-11

DIRECT/TRANSFER MOBILITY LOCATIONS 1Z AND 3Z

22

LEGEND

1_{1Z}^{1Z} CONFIGURATION 1, RESPONSE 1Z, FORCE 1Z

1_{1Z}^{2Z} CONFIGURATION 1, RESPONSE 2Z, FORCE 1Z

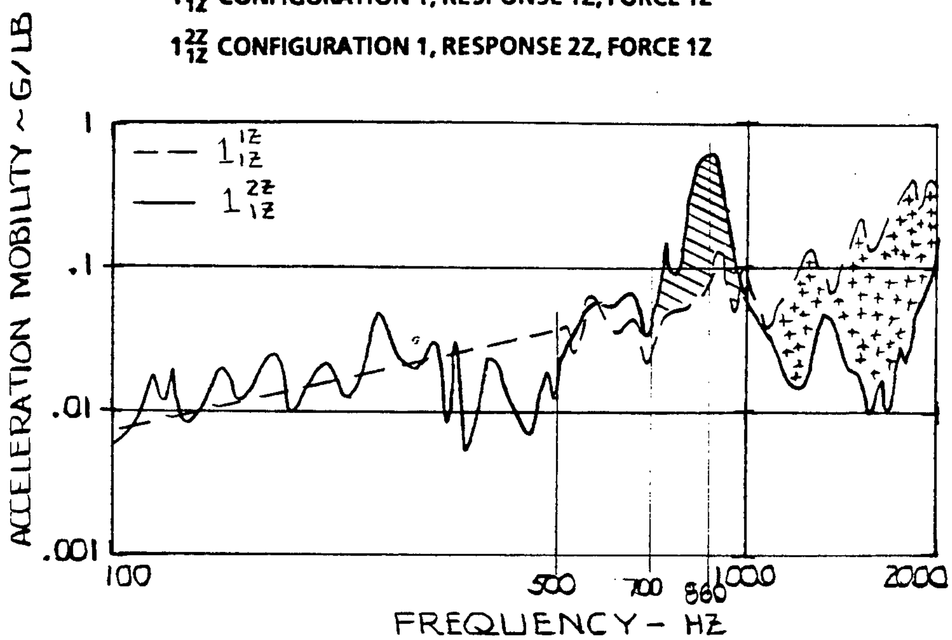


FIGURE 3-12

DIRECT/TRANSFER MOBILITY LOCATIONS 1Z AND 2Z

4.0 SHOCK DATA VALIDITY

Introduction

Three of the 6 shock measurement locations utilized during the DSP shock test were selected to define the shock delivered to the IUS. These locations were selected on the basis of mobility measurements described in section 3. Since the mobility data provide a qualitative evaluation of the shock data, another evaluation technique is desireable. Comparison of the DSP data with data from other IUS pyrotechnic shock tests was chosen as the other evaluation technique.

Scope

This section presents comparisons of DSP shock spectra with shock spectra obtained from 4 other pyrotechnic shock tests. The validity of the 3 selected DSP measurement locations are evaluated based on the comparisons.

DSP Shock Spectra

The 3 DSP shock spectra selected in Section 3 to describe the shock delivered to IUS are shown in Figures 4-1 thru 4-3.

Other Tests

The following table describes the 4 pyrotechnic shock tests which are compared with the DSP test.

DESIGNATION	CONFIGURATION	SHOCK SOURCE	MEASUREMENT LOCATION
S1	Spacecraft mounted on IUS ESS	Spacecraft separation nuts, 1/2"diameter	IUS/spacecraft interface
S2	Spacecraft mounted on IUS DTV	IUS separation nuts, 7/8"diameter	IUS/spacecraft interface
S3	Spacecraft mounted on TITAN AC-2	Spacecraft separation nuts, 1/2"diameter	TITAN /spacecraft interface
S4	IUS QTV without spacecraft	IUS separation nuts, 7/8"diameter	IUS/spacecraft interface ring

Shock Spectra Comparisons

Figures 4-4 thru 4-6 contain comparisons of the selected DSP shock spectra with spectra from 4 other tests. The three DSP spectra have the same general shape as the spectra from the 4 other tests, but the DSP shock levels are higher except for DSP location 2Z, figure 4-4. Location 2Z levels are lower between 1500 Hz and 4000 Hz. The mobility data shown in figure 3-12 indicates that lower levels can be expected from 2Z between 1000 Hz and 2000 Hz.

Conclusions

Shock levels at locations 3R and 3T (figures 4-2 and 4-3) are valid definitions of the shock delivered to the IUS by DSP. The shock level at location 2Z is valid below 1500 Hz and above 4000 Hz. Between 1500 Hz and 4000 Hz, the levels from tests S2 or S4 should be used (see figure 4-4).

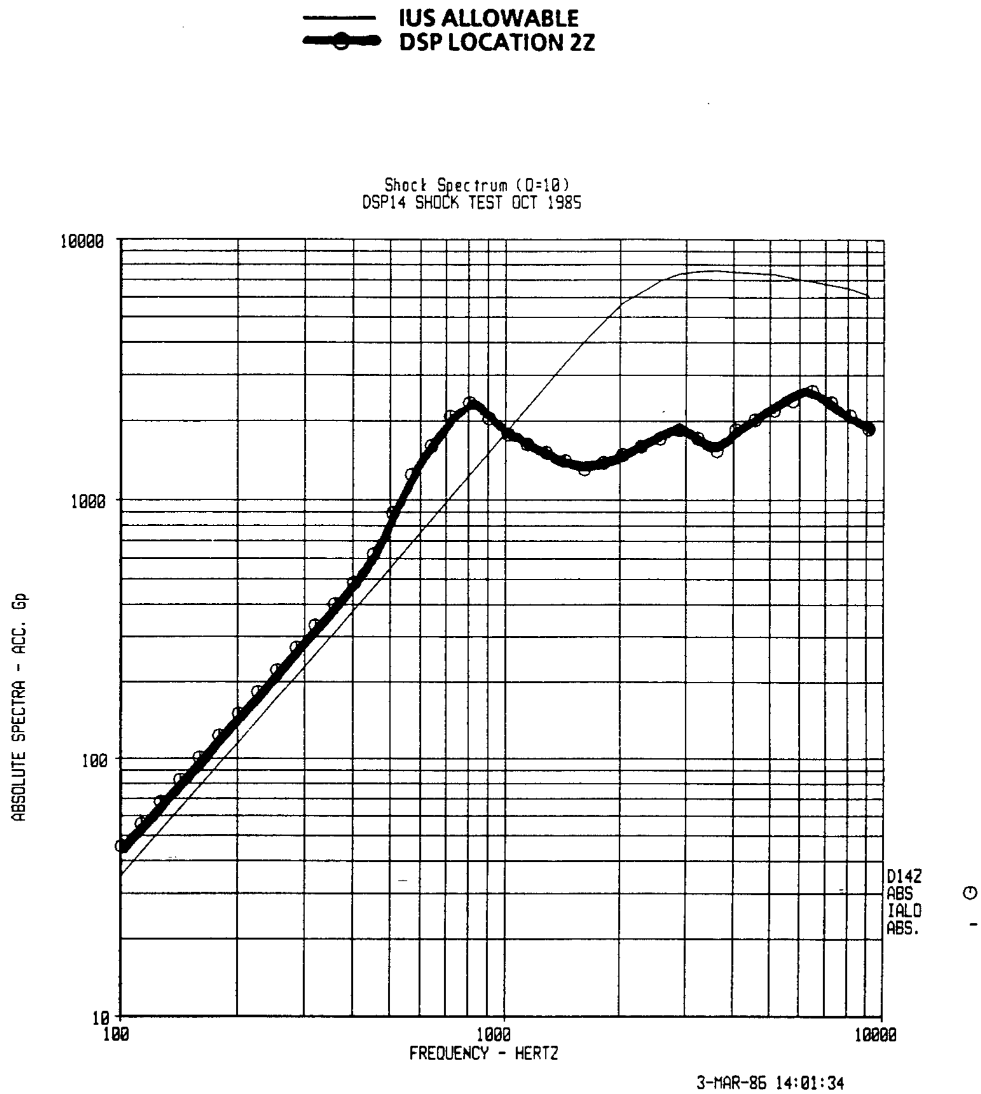


FIGURE 4-1
DSP 14 INDUCED SHOCK
AXIAL

CALC		3MAR86	REVISED	DATE		
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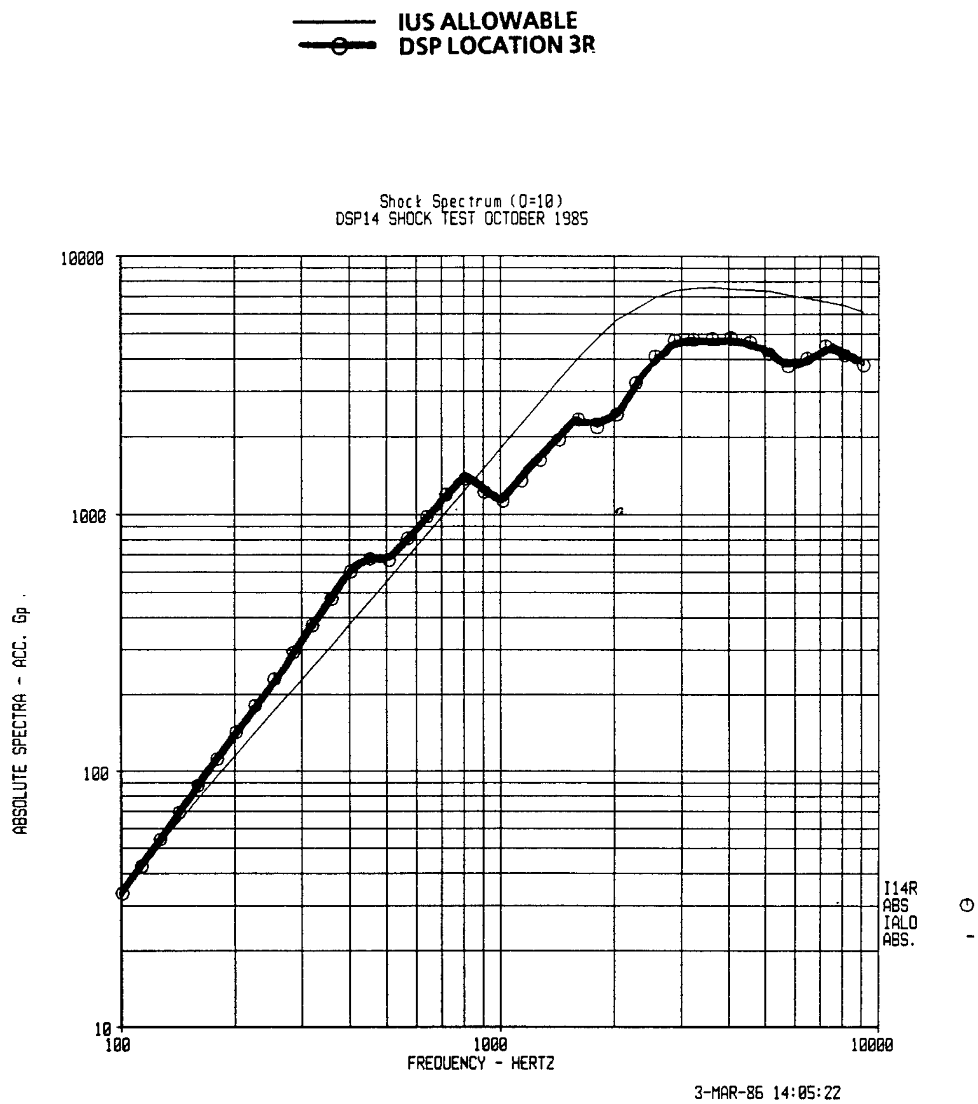

FIGURE 4-2
DSP 14 INDUCED SHOCK
RADIAL

CALC		3MAR86	REVISED	DATE		
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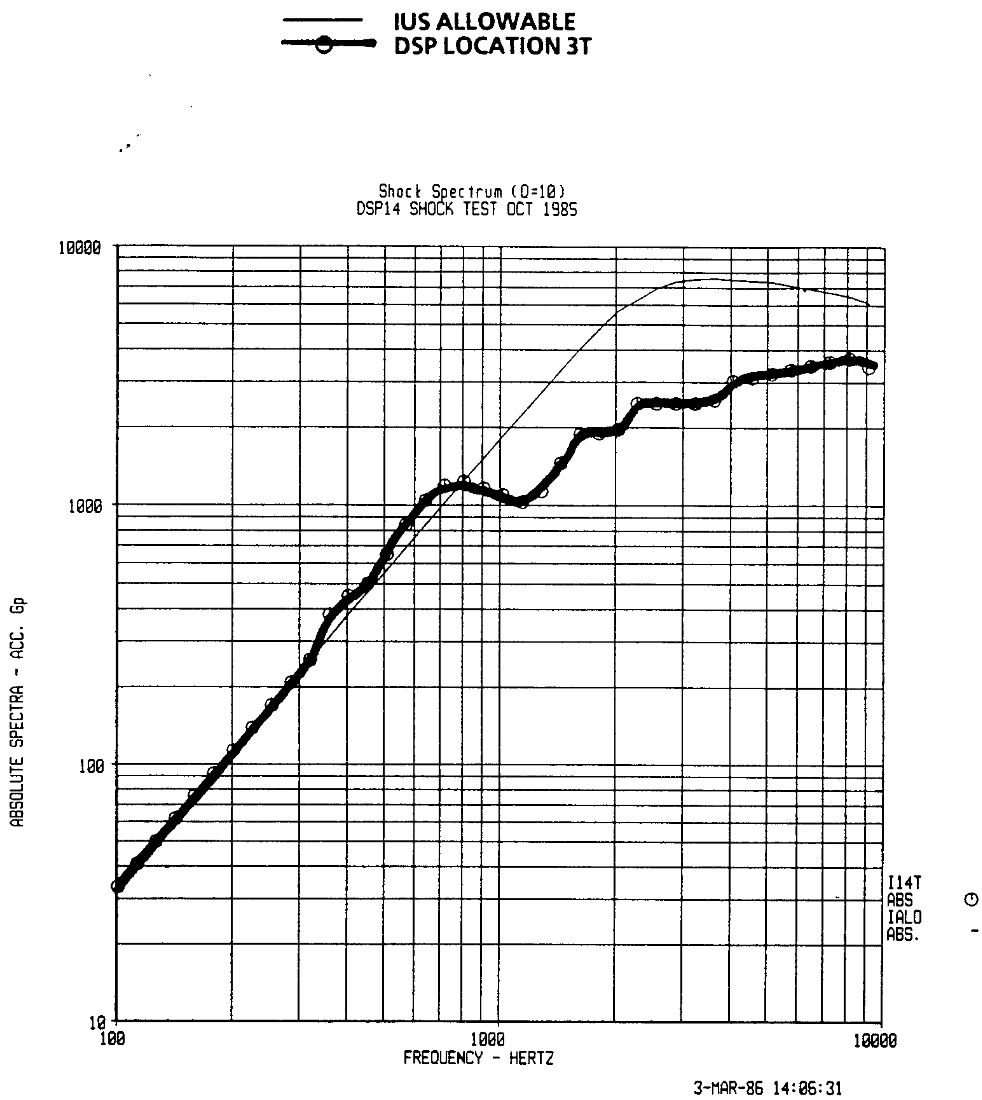

FIGURE 4-3
DSP 14 INDUCED SHOCK
TANGENTIAL

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APPD.					THE BOEING COMPANY	PAGE 28

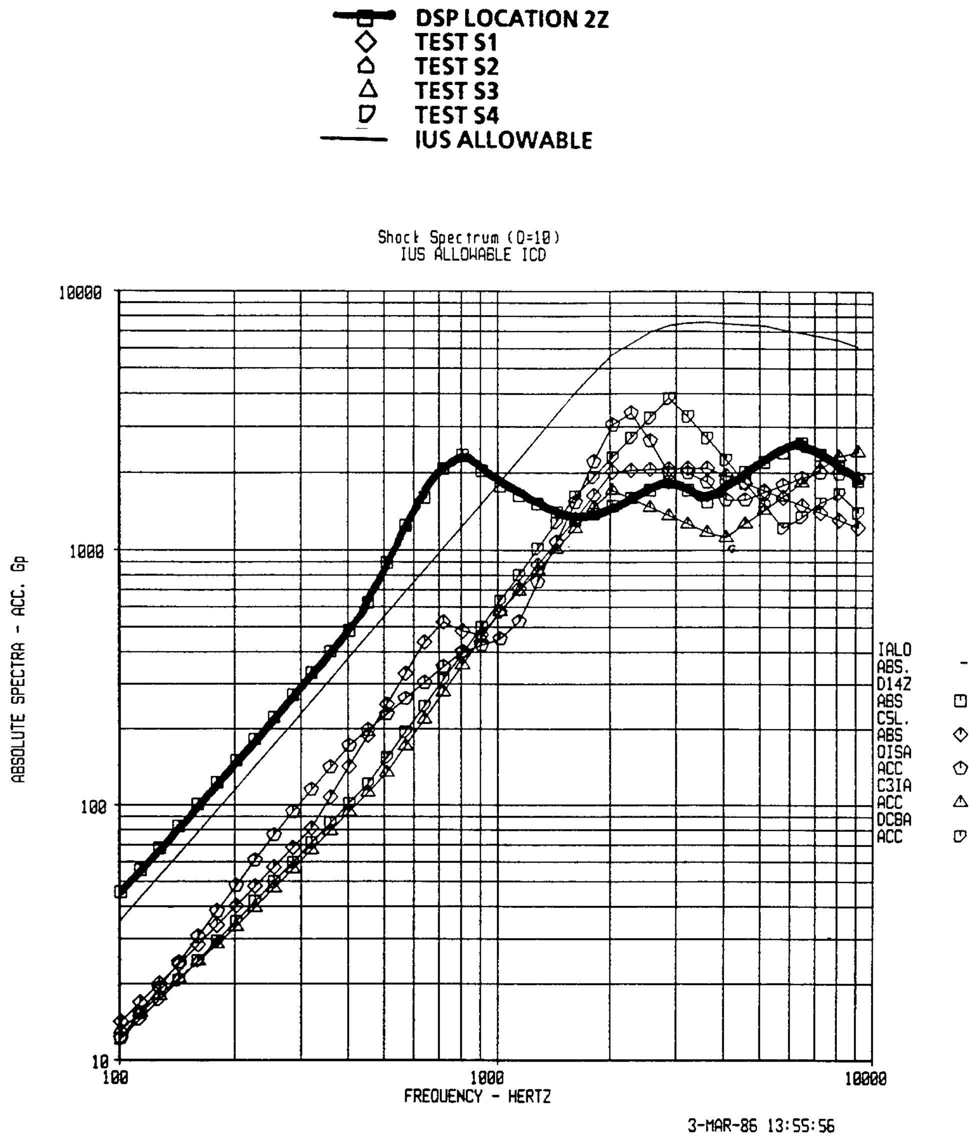

FIGURE 4-4
SHOCK SPECTRA COMPARISON
AXIAL

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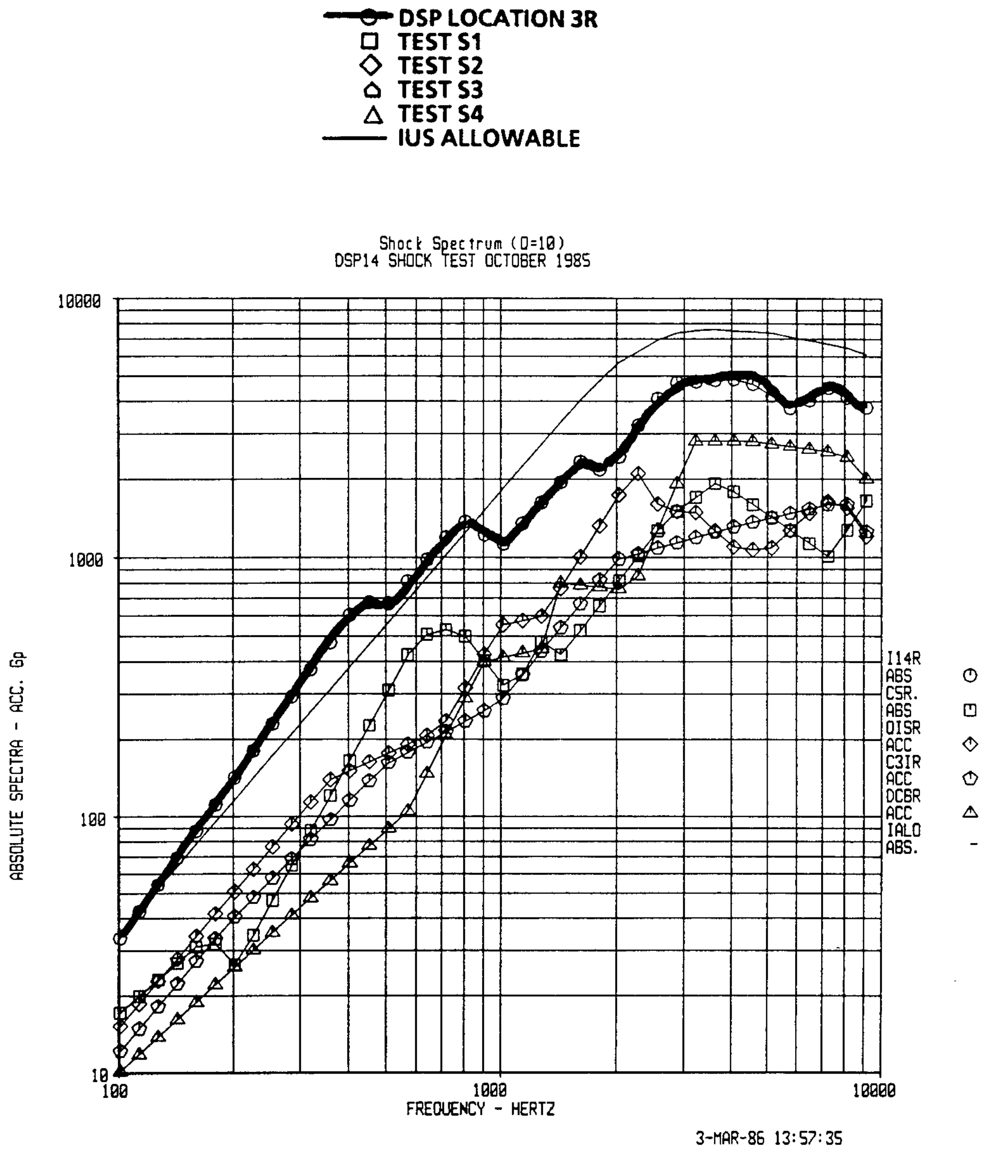

FIGURE 4-5
SHOCK SPECTRA COMPARISON
RADIAL

CALC		3MAR86	REVISED	DATE		
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APPD.					THE BOEING COMPANY	PAGE 30

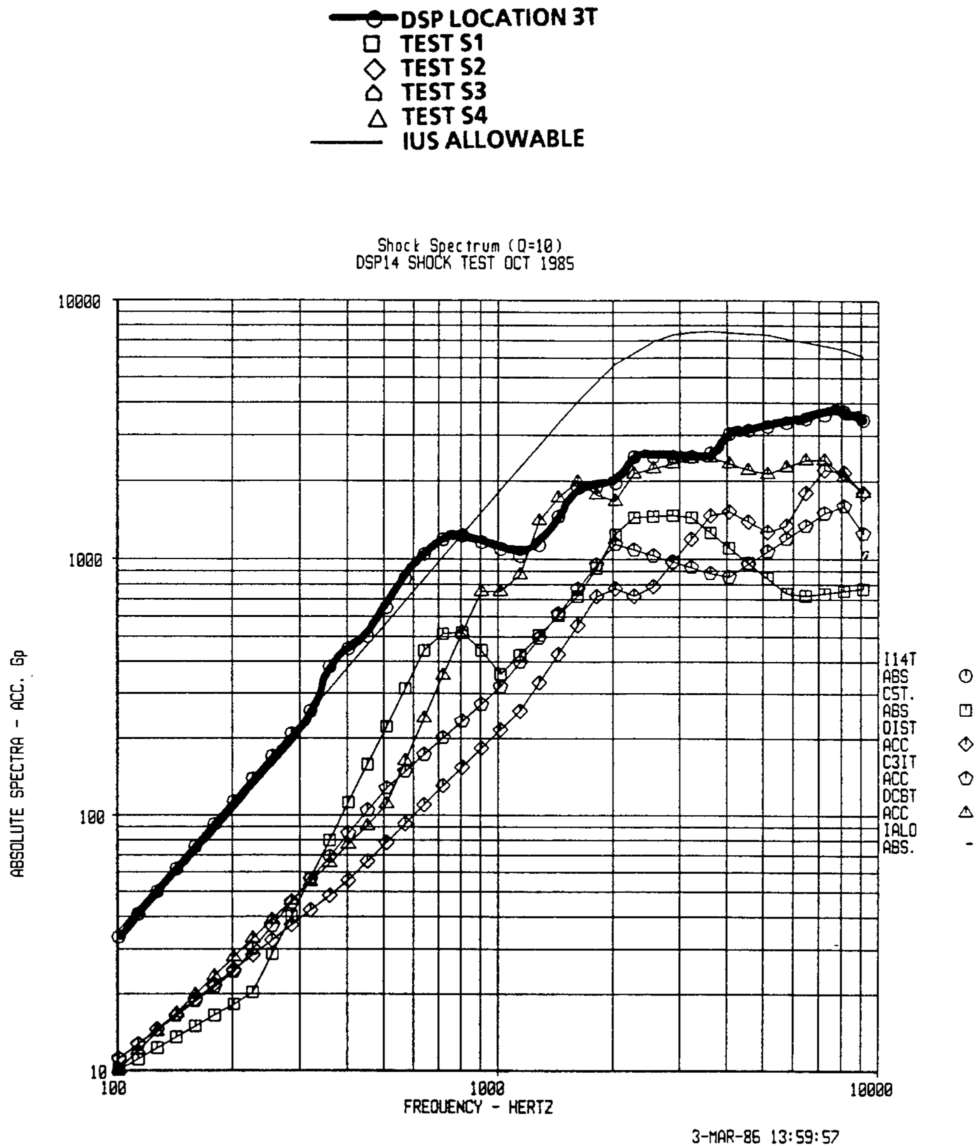

FIGURE 4-6
SHOCK SPECTRA COMPARISON
TANGENTIAL

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APPD.					THE BOEING COMPANY	PAGE 31

5.0 DSP/IUS COMPATIBILITY

Scope

This section presents the response of IUS components to the DSP separation shock. The IUS component response is compared to the component qualification level to determine if the components are compatible with the DSP shock. A compatibility assessment is presented.

Approach

The DSP shock values discussed in section 4 are used as the shock input to IUS. The selected DSP shock spectra are shown in figure 5-1. Note that the location 2Z spectrum has been increased in the 1000 Hz to 4000 Hz band as discussed in section 4.

The shock levels of figure 5-1 were multiplied by the appropriate functions representing the attenuation between the shock application point (IUS/DSP interface, station 379) and the IUS component. The product is the predicted component shock spectrum. This analysis procedure is discussed in reference 3.

Compatibility Assessment

Figures 5-2 thru 5-18 contain comparisons of the predicted DSP induced shock versus the IUS component qualification test level. The component is compatible with the shock if the component qualification level is a least 3 dB greater than the induced shock at all frequencies. The compatibility assessment results follow.

- 14 of the 17 components are compatible with the DSP shock

- The Medium Gain Antenna has less than a 3dB margin at 700 Hz and 2700 Hz, see figure 5-2. The antenna is compatible with the shock environment based on the rationale presented at the end of this section.

- The Omni Antenna has less than a 3 dB margin between 500 Hz and 800 Hz, see figure 5-3. The antenna is compatible with the shock environment based on the rationale presented at the end of this section.

- The Diplexer has less than a 3 dB margin at 300 Hz, see figure 5-7. The Diplexer is compatible with the shock environment based on the rationale presented at the end of this section.

Medium Gain Antenna and Omni Antenna Compatibility Rationale

The medium gain antenna and omni antenna are similar in shape and construction as illustrated in figure 5-19. The antennas are compatible with the shock environment for the following reasons.

1. The antennas are simple devices and are not susceptible to damage by pyrotechnic shock. This conclusion is supported by the requirements of MIL-STD-1540A and 1540B. Both of these documents indicate that component qualification tests of antennas are optional. MIL-STD-1540A states that component acceptance tests of antennas are optional while 1540B does not require antenna acceptance tests.

2. Since the antennas are similar, the qualification test levels are applicable to both antennas. The comparison of the combined qualification levels with the antenna environments shows a 3 dB margin at all frequencies, see figure 5-20.

3. The predicted axial shock response is greater than the maximum expected flight response because of the shock test measurement anomalies discussed in section 3 (see figure 3-12).

Diplexer Compatibility Rationale

The diplexer is compatible with the shock environment for the following reasons.

1. The diplexer is a rugged device and is not susceptible to pyrotechnic shock. Figure 5-21 contains an illustration of the diplexer.

2. The margin is less than 3 db over a narrow frequency band (280 Hz to 320 Hz) and the margin is at least 2.5 dB in this range.

6.0 CONCLUSIONS

1. Acceleration mobility measurements and comparisons with data from other shock tests show that shock levels measured at locations 3R and 3T provide valid definitions of the pyrotechnic shock delivered to IUS as a result of DSP separation. The axial shock spectra from location 2Z was modified to provide a higher environment than was measured during the test. The shock spectra are shown in figure 5-1.

2. The IUS components are compatible with the DSP induced shock presented in figure 5-1.

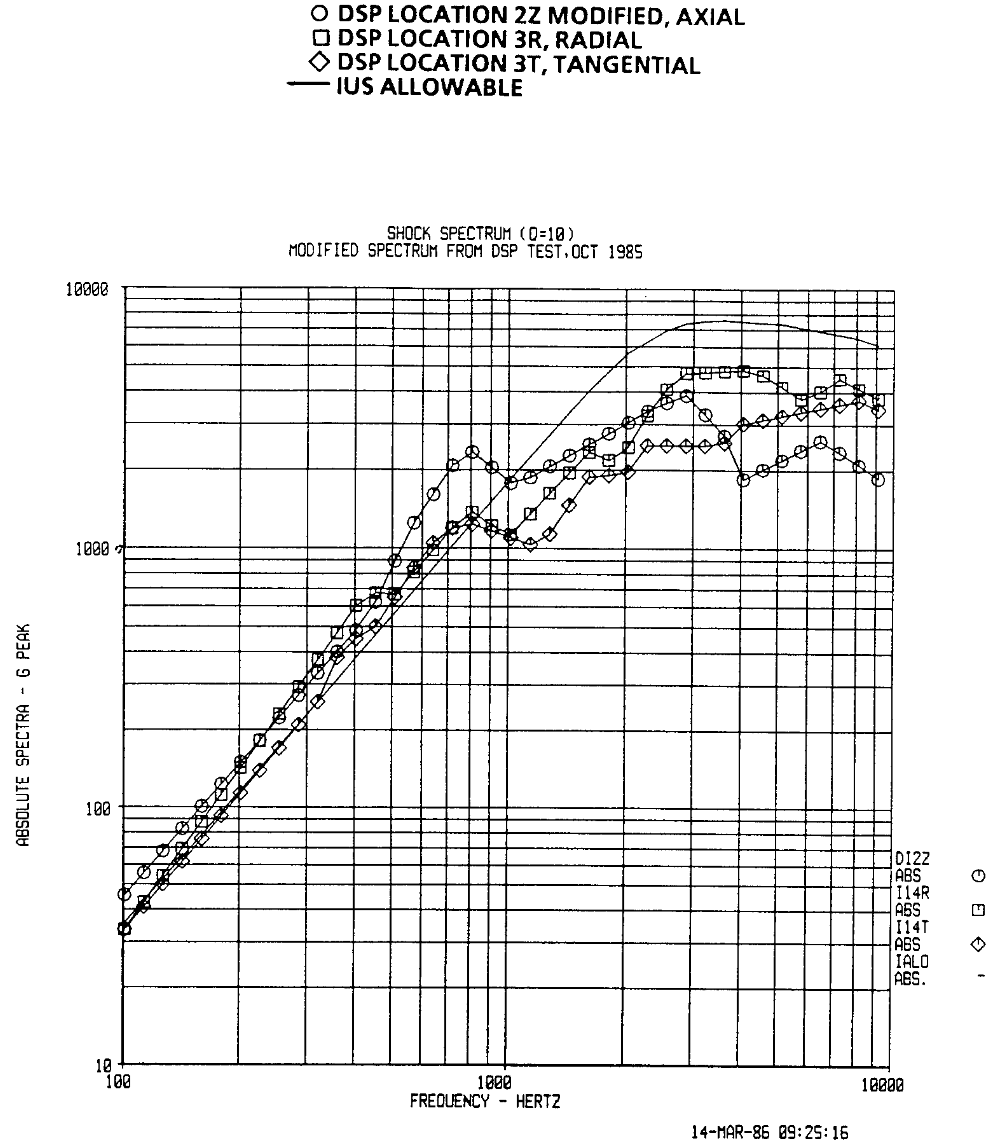

FIGURE 5-1
DSP INDUCED SHOCK
DSP/IUS INTERFACE, STATION 379

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——— ANTENNA QUALIFICATION TEST
— — — ANTENNA QUALIFICATION TEST MINUS 3 DB
○ ANTENNA RADIAL
□ ANTENNA TANGENTIAL
◇ ANTENNA AXIAL

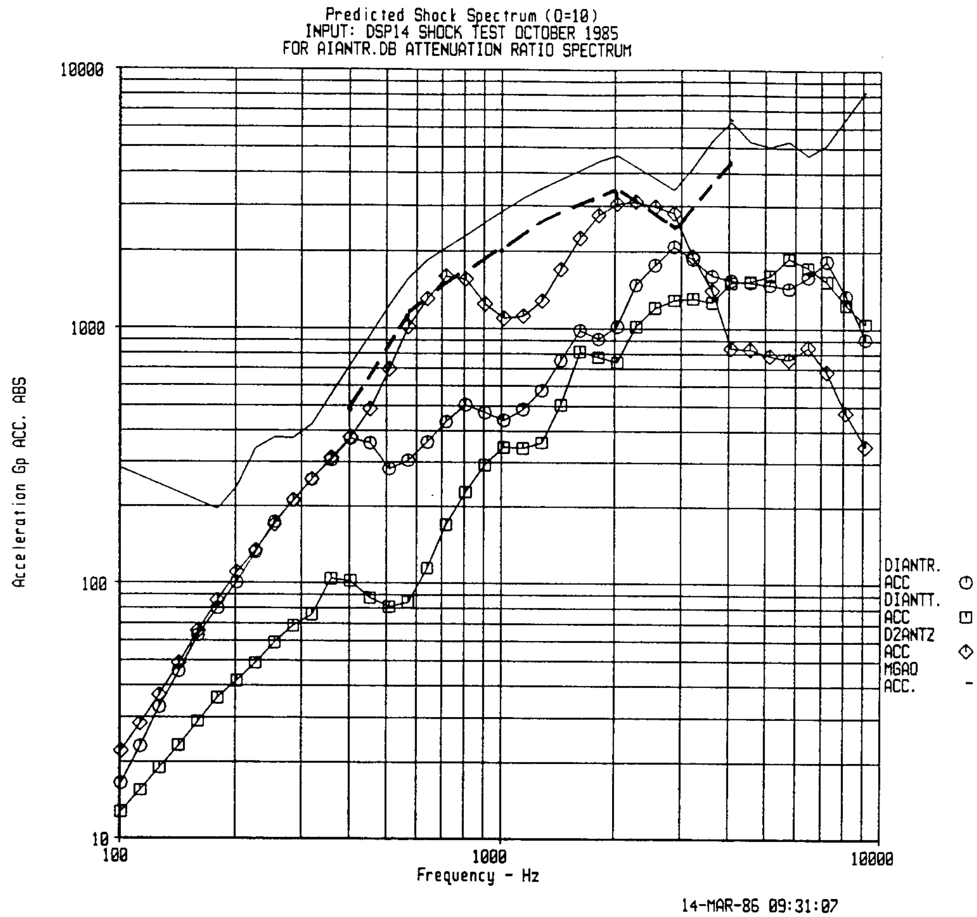

FIGURE 5-2
MEDIUM GAIN ANTENNA

CALC		14MAR86	REVISED	DATE		
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——— ANTENNA QUALIFICATION TEST
— — -- ANTENNA QUALIFICATION TEST MINUS 3 DB
O ANTENNA RADIAL
□ ANTENNA TANGENTIAL
◇ ANTENNA AXIAL

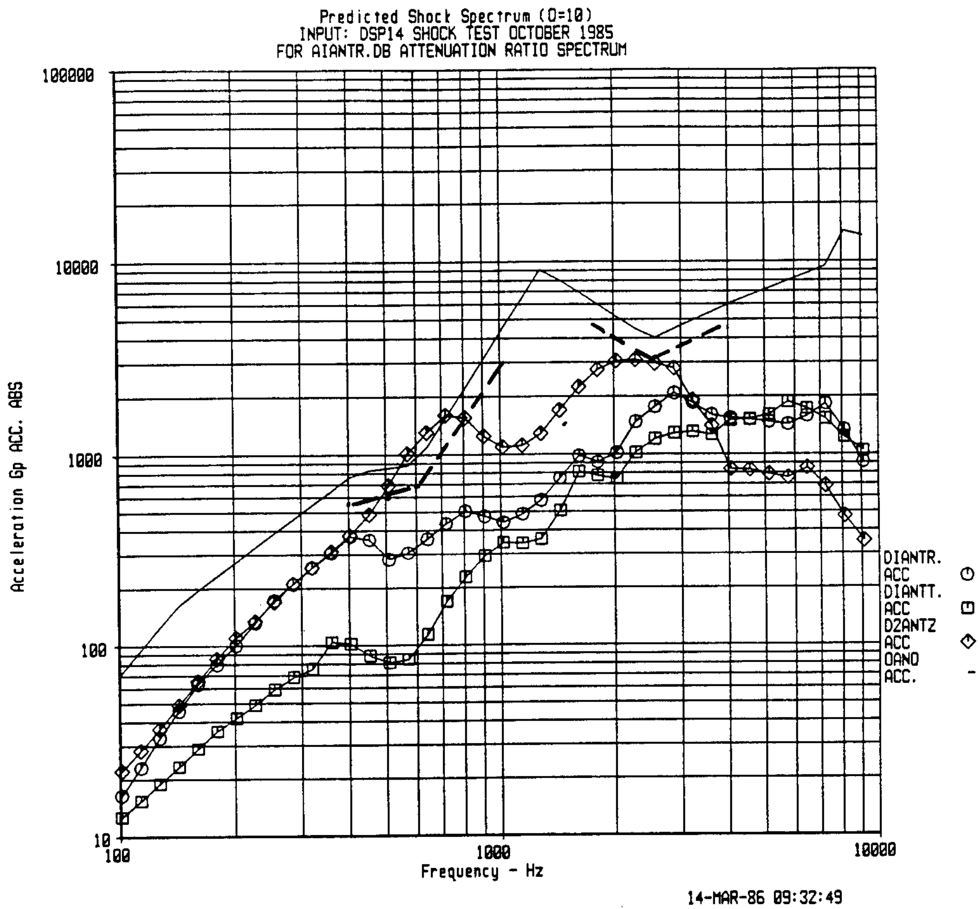

FIGURE 5-3
OMNI ANTENNA

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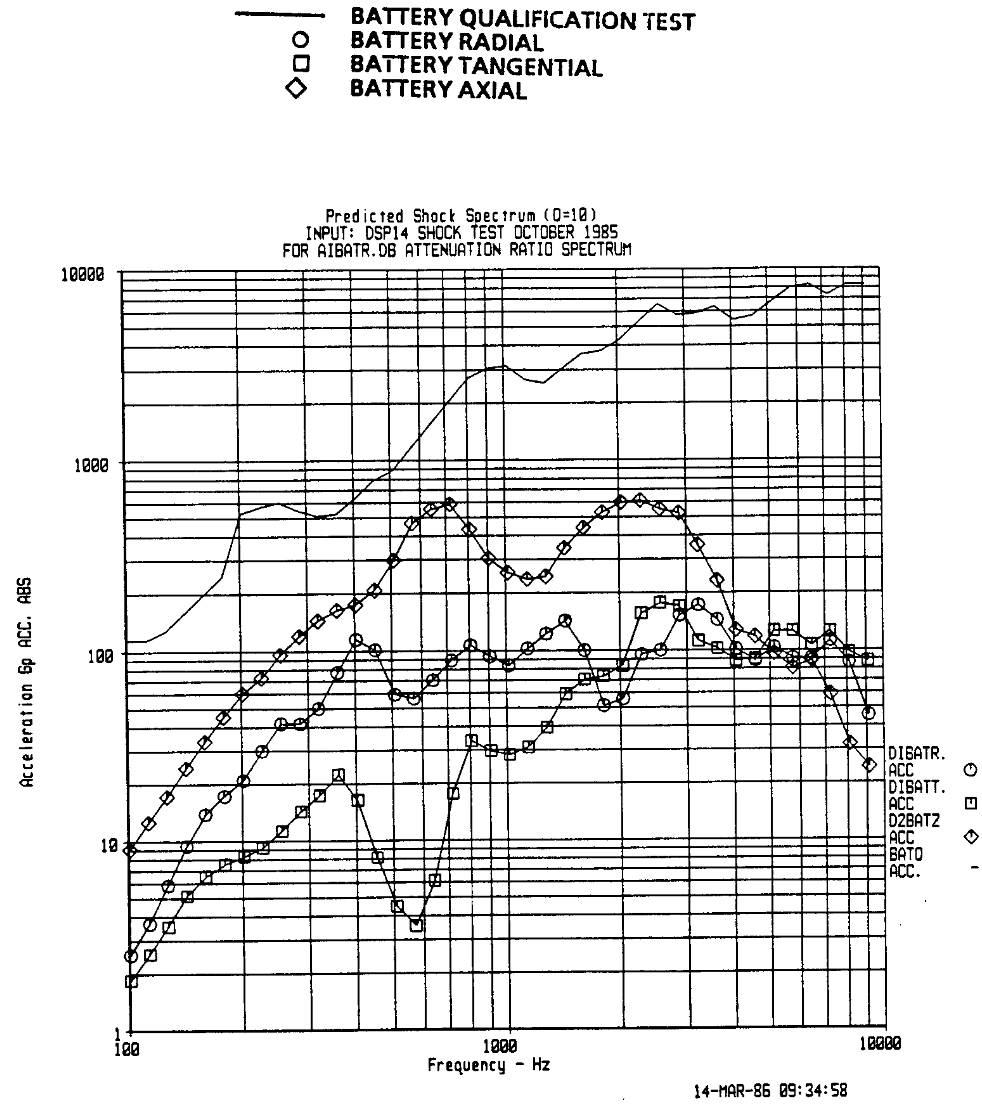

FIGURE 5-4

UTILITY BATTERY

CALC		14MAR86	REVISED	DATE		
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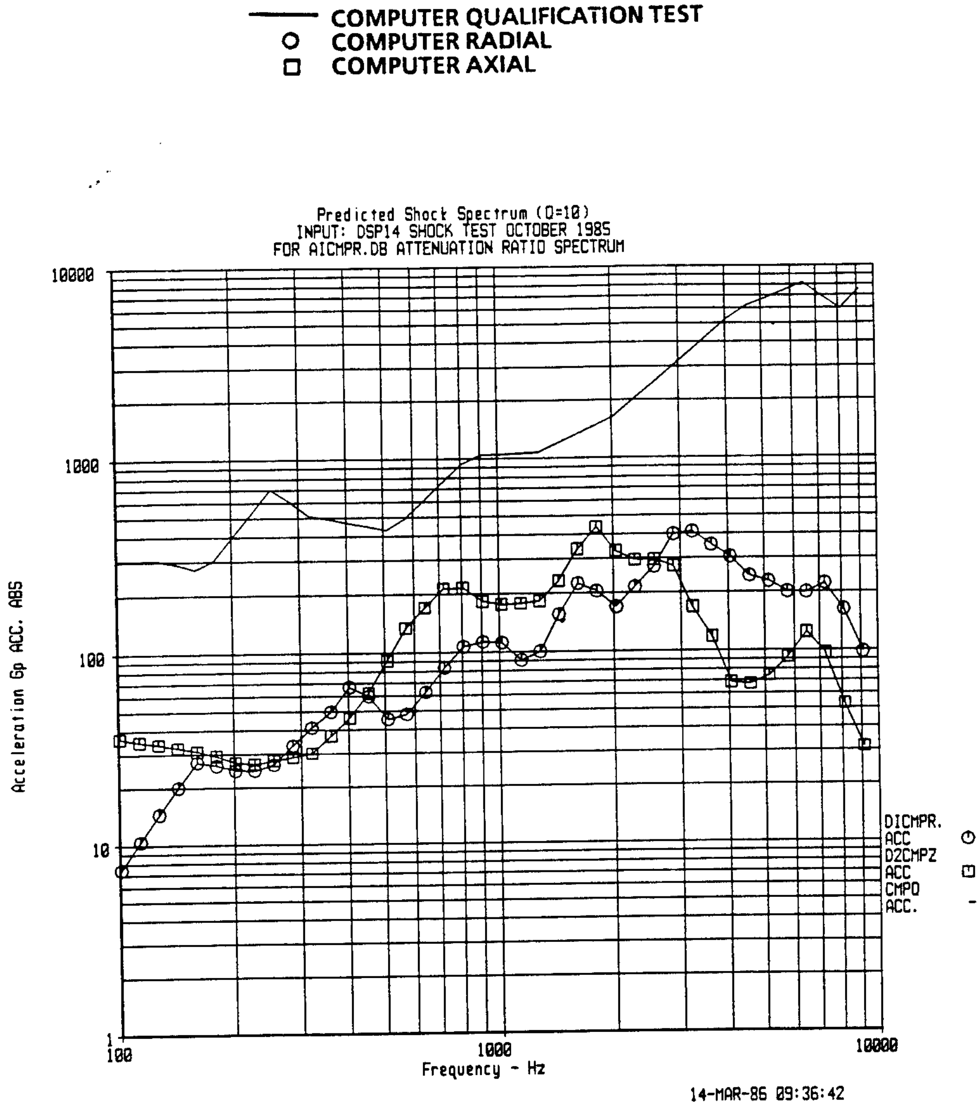

FIGURE 5-5
COMPUTER

CALC		14MAR86	REVISED	DATE		
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— DECRYPTOR QUALIFICATION REQUIREMENT
○ DECRYPTOR RADIAL
□ DECRYPTOR TANGENTIAL
◇ DECRYPTOR AXIAL

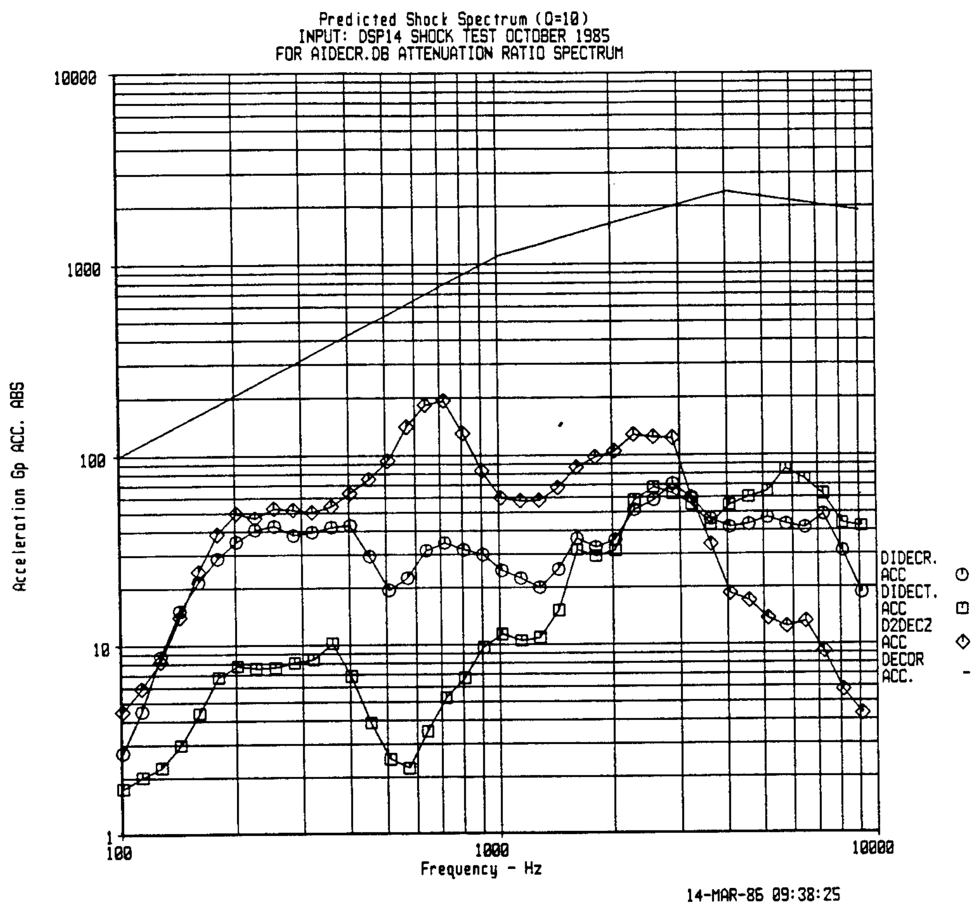

FIGURE 5-6
DECRYPTOR

CALC		14MAR86	REVISED	DATE		
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BOEING

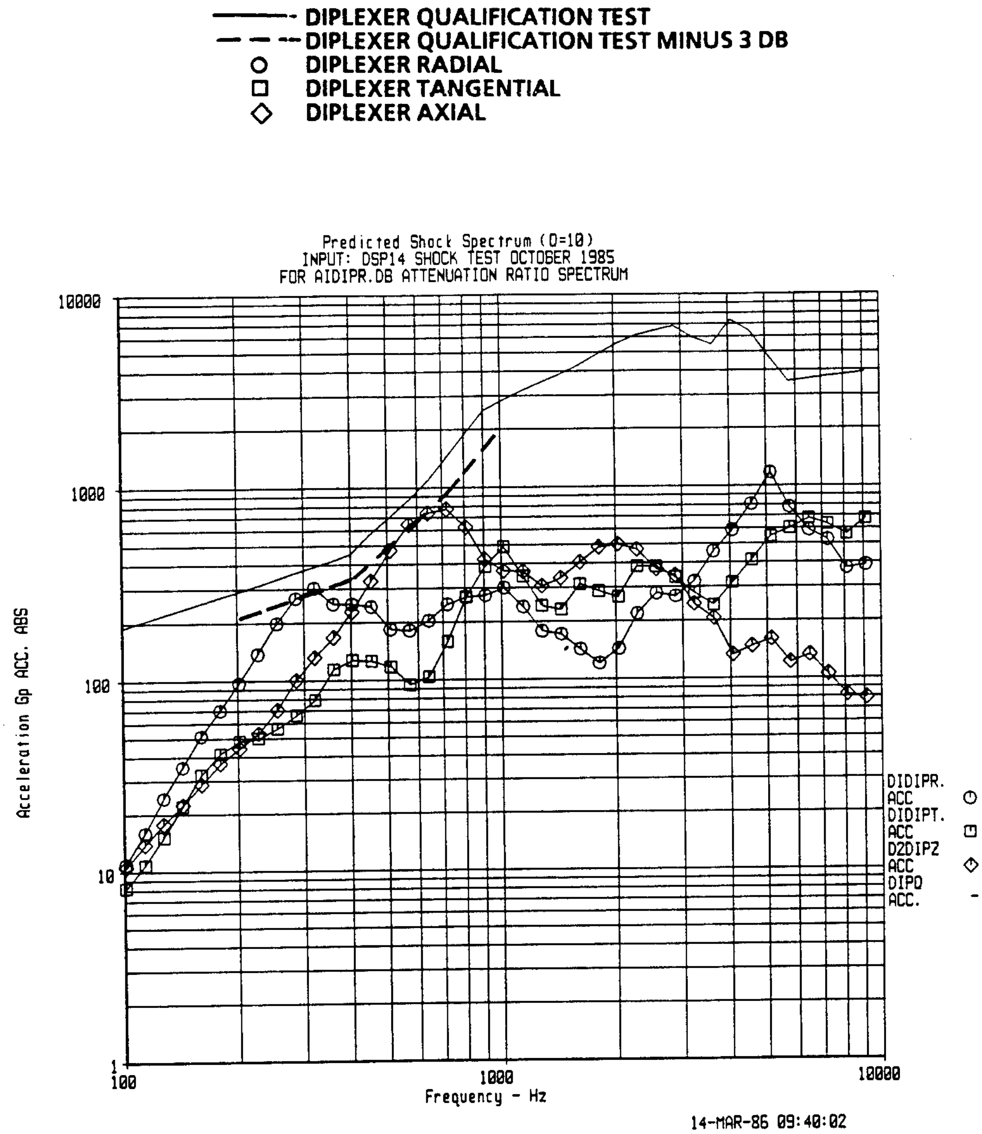

FIGURE 5-7
DIPLEXER

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BOEING

—— ENCRYPTOR QUALIFICATION REQUIREMENT
○ ENCRYPTOR RADIAL
□ ENCRYPTOR TANGENTIAL
◇ ENCRYPTOR AXIAL

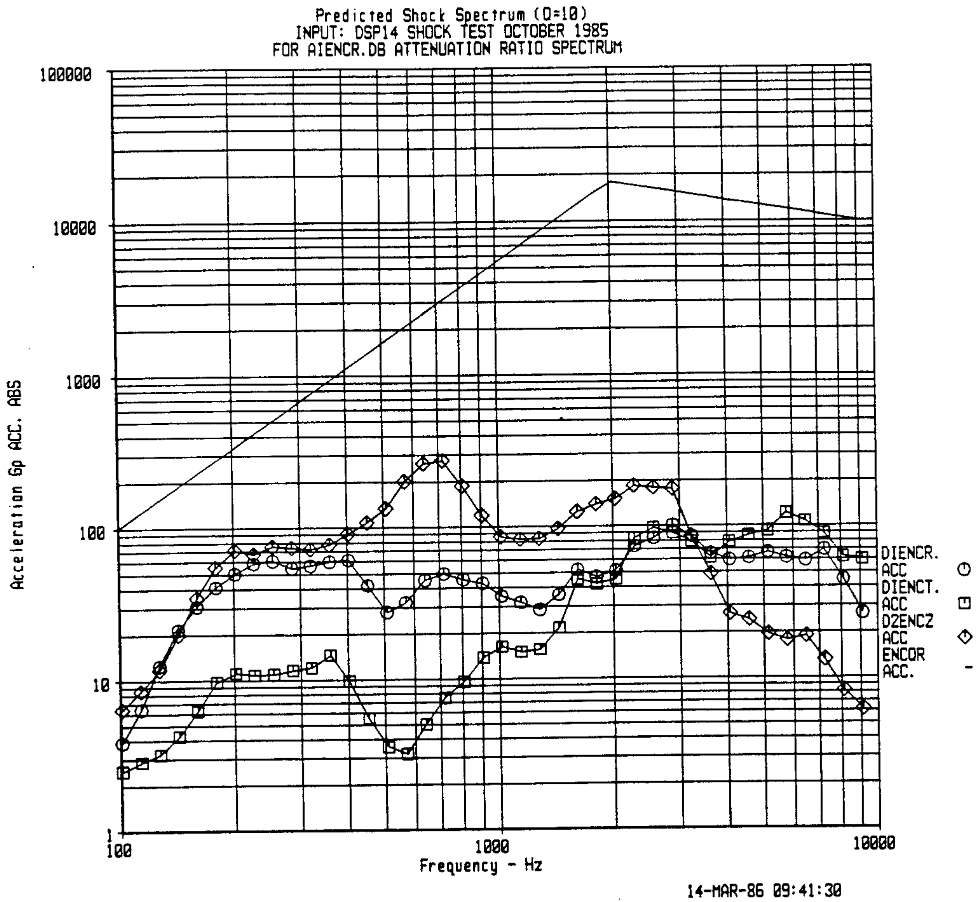

FIGURE 5-8
ENCRYPTOR

CALC		14MAR86	REVISED	DATE		
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BOEING

— IMU QUALIFICATION REQUIREMENT
○ IMU RADIAL
□ IMU TANGENTIAL
◇ IMU AXIAL

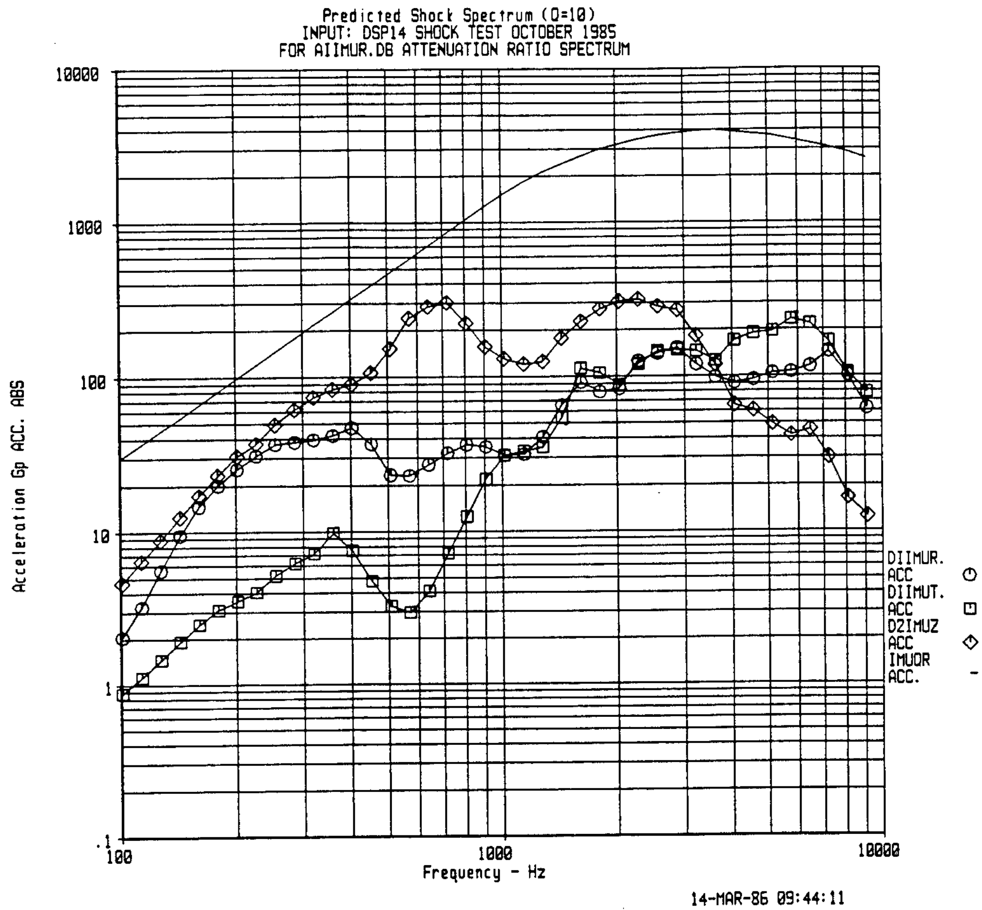

FIGURE 5-9
IMU

CALC		14MAR86	REVISED	DATE		
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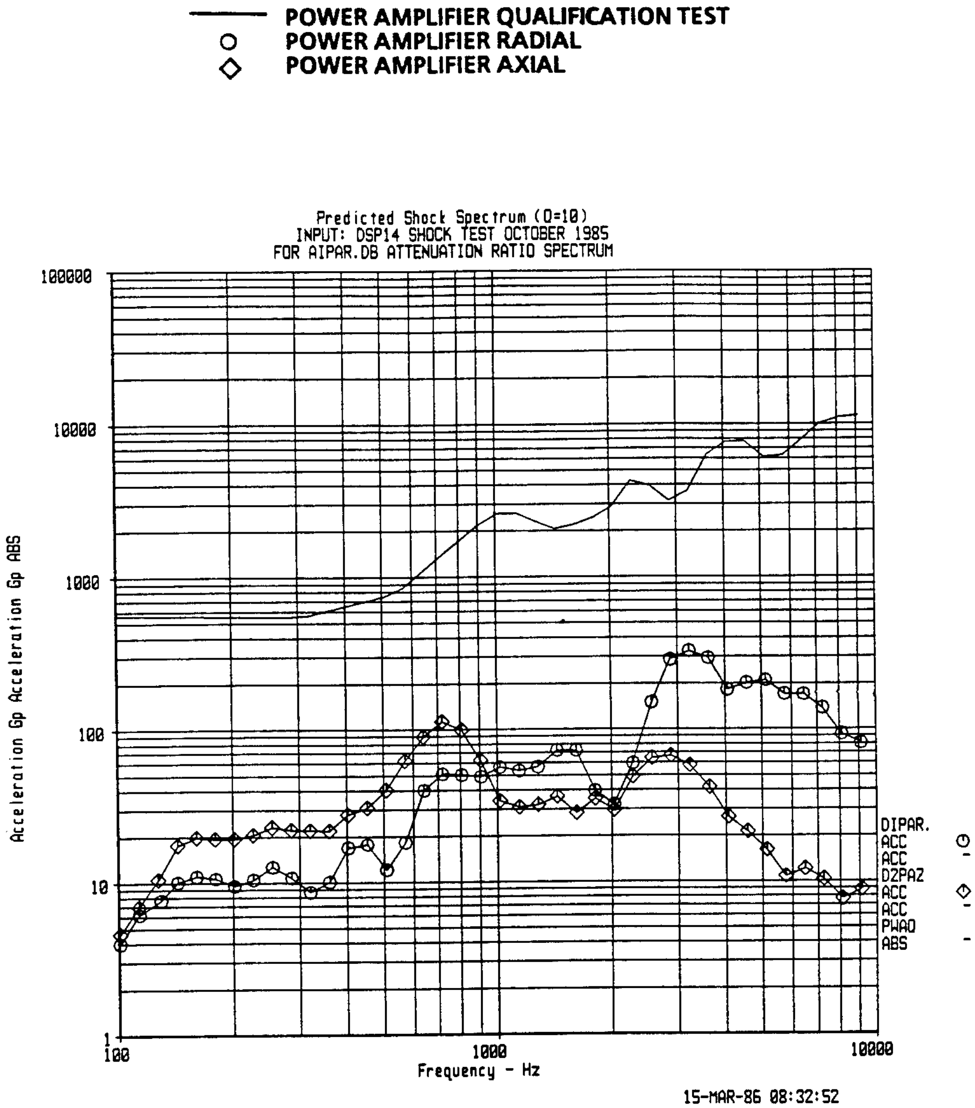

FIGURE 5-10
POWER AMPLIFIER

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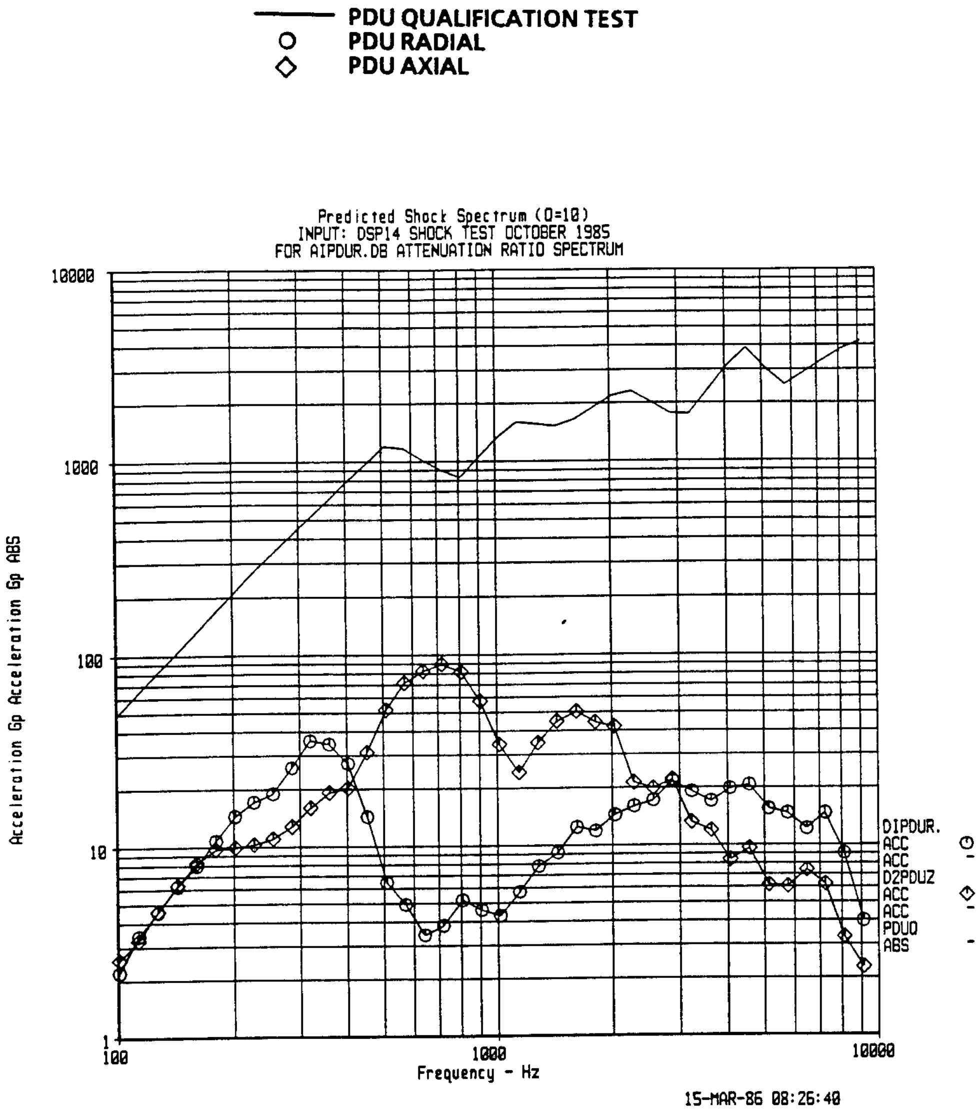

FIGURE 5-11
POWER DISTRIBUTION UNIT (PDU)

CALC		15MAR86	REVISED	DATE		
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APPD.					THE BOEING COMPANY	PAGE 44

——— RCS TANK QUALIFICATION TEST
○ RCS TANK RADIAL
□ RCS TANK TANGENTIAL
◇ RCS TANK AXIAL

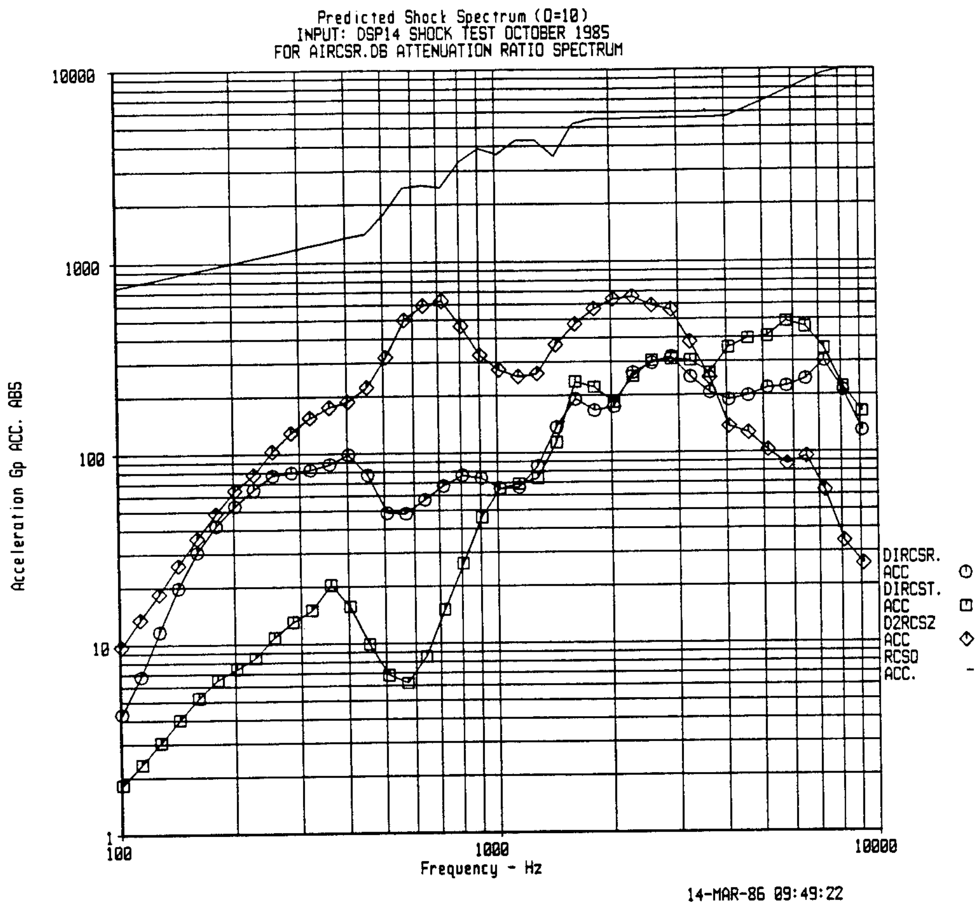

FIGURE 5-12
RCS TANK

CALC		14MAR86	REVISED	DATE	
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BOEING

———	RESISTOR BOARD ASSEMBLY QUALIFICATION TEST
○	RESISTOR BOARD ASSEMBLY RADIAL
□	RESISTOR BOARD ASSEMBLY TANGENTIAL
◇	RESISTOR BOARD ASSEMBLY AXIAL

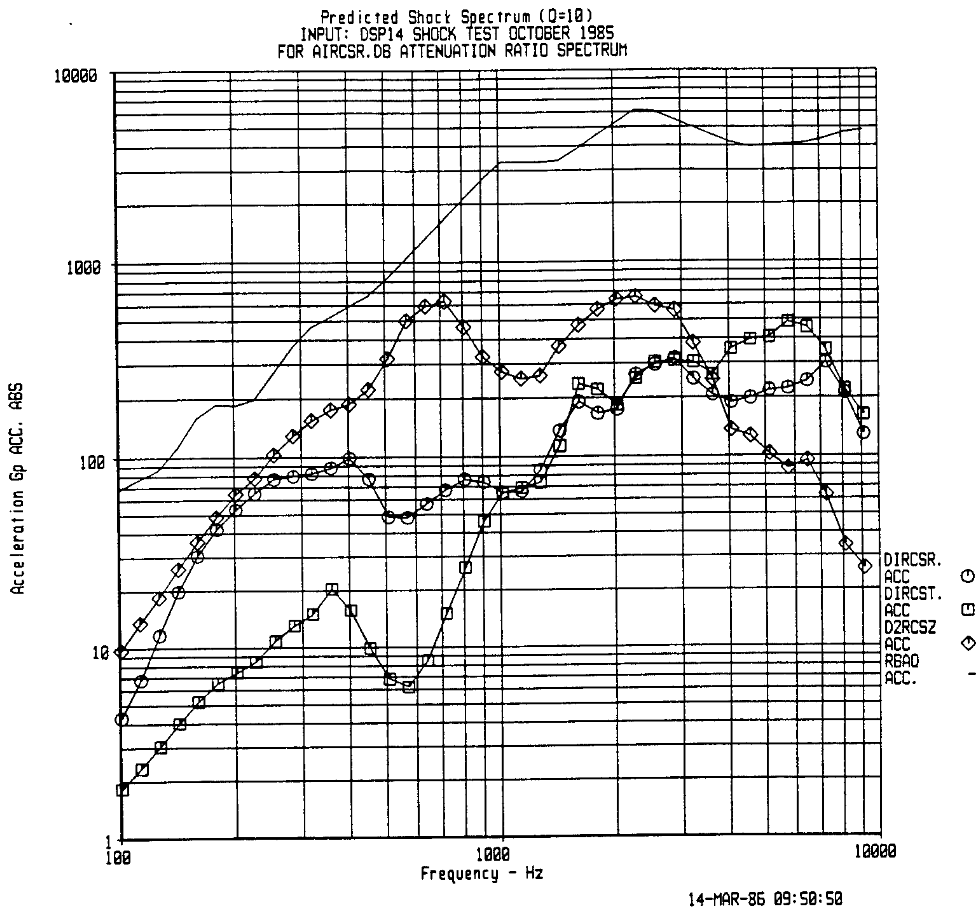

FIGURE 5-13
RESISTOR BOARD ASSEMBLY

CALC		14MAR86	REVISED	DATE		
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APPD.					THE BOEING COMPANY	PAGE 46

——— REM QUALIFICATION TEST
— — — REM QUALIFICATION TEST MINUS 3 DB
○ REM RADIAL
□ REM TANGENTIAL
◇ REM AXIAL

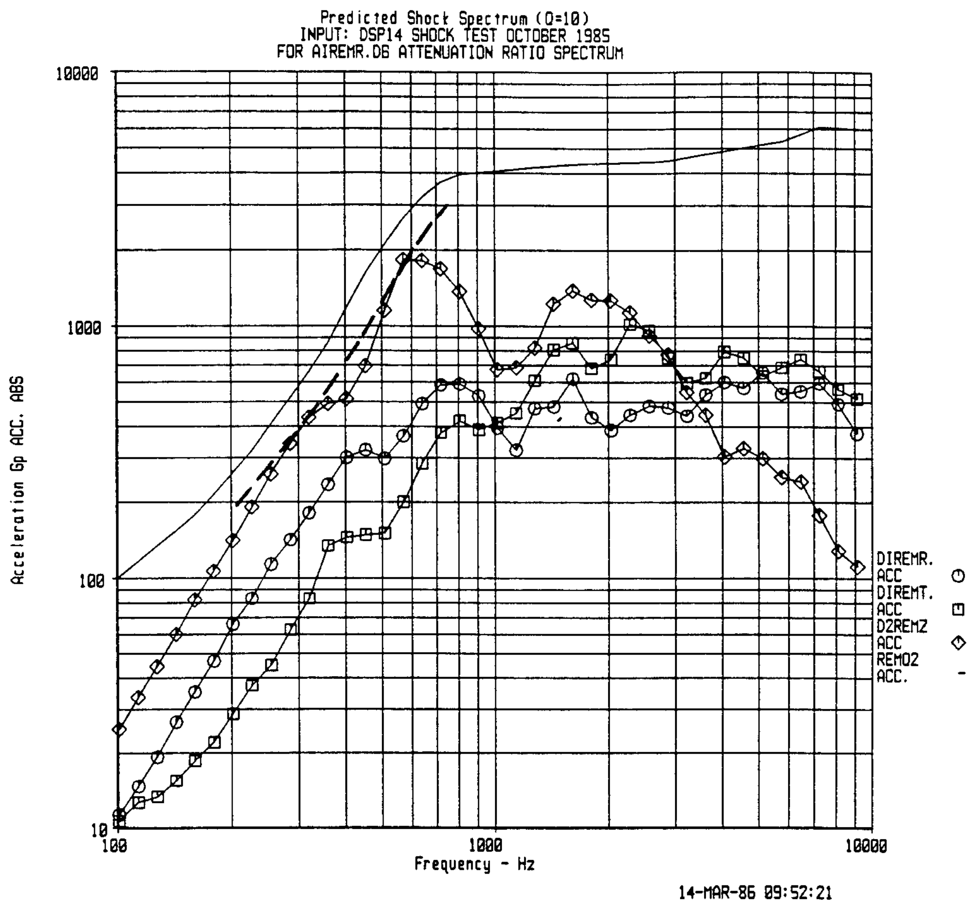

FIGURE 5-14
REM

CALC		14MAR86	REVISED	DATE		
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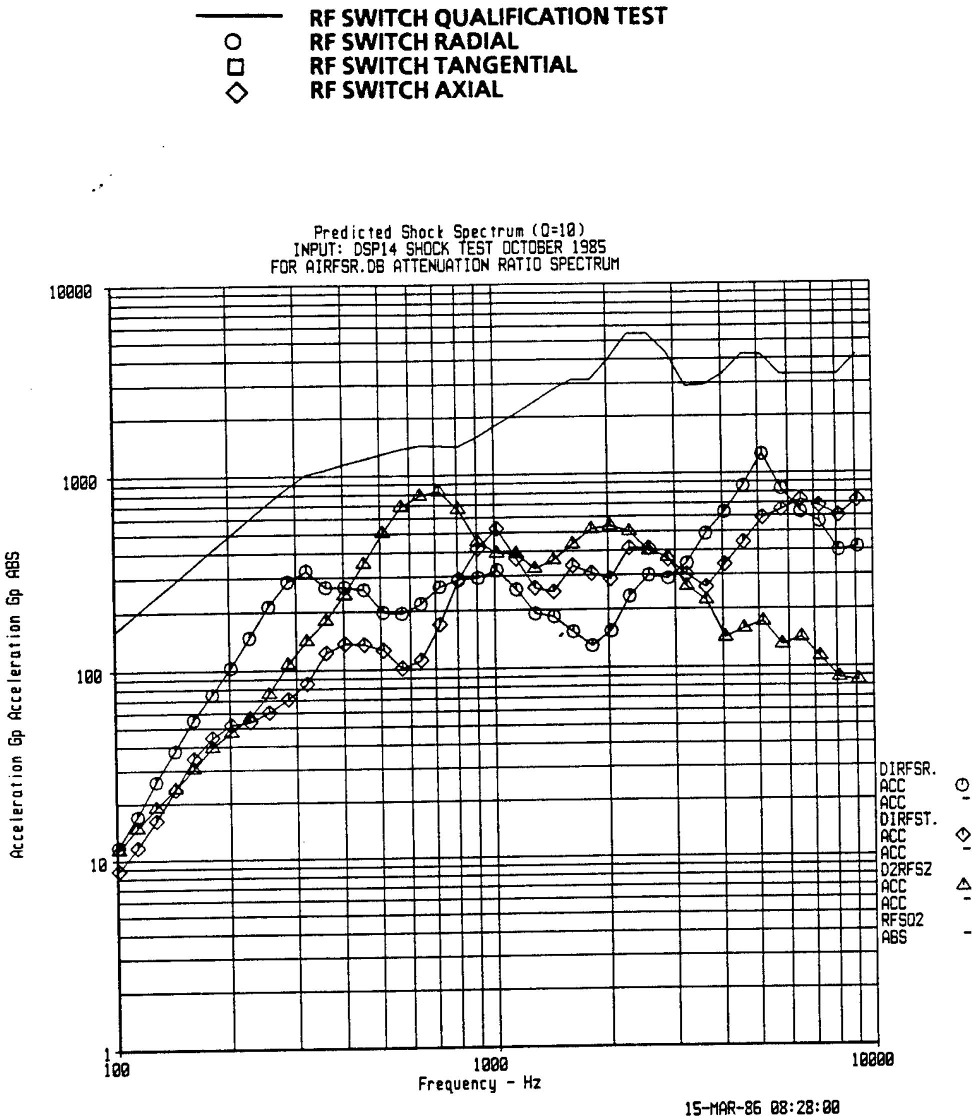

FIGURE 5-15
RF SWITCH

CALC		15MAR86	REVISED	DATE		
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APPD.					THE BOEING COMPANY	PAGE 48

——— SCU QUALIFICATION TEST
— — — SCU QUALIFICATION TEST MINUS 3 DB
○ SCU RADIAL
□ SCU TANGENTIAL
◇ SCU AXIAL

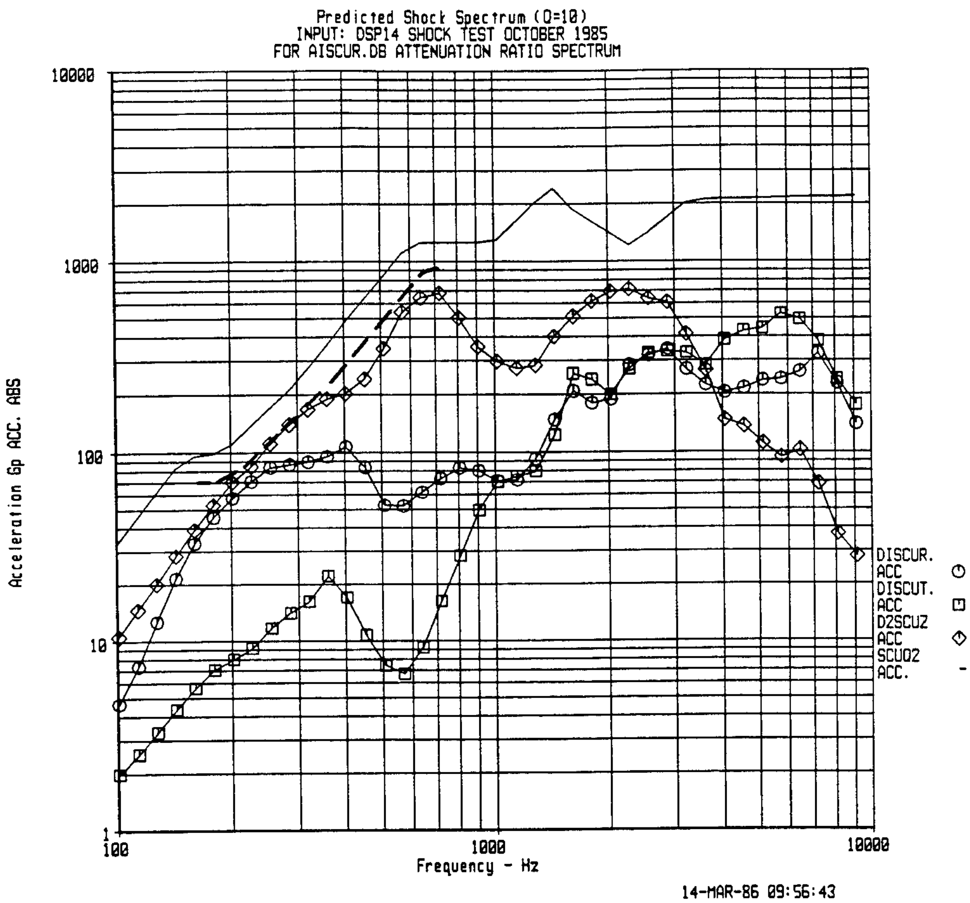

FIGURE 5-16
SCU

CALC		14MAR86	REVISED	DATE		
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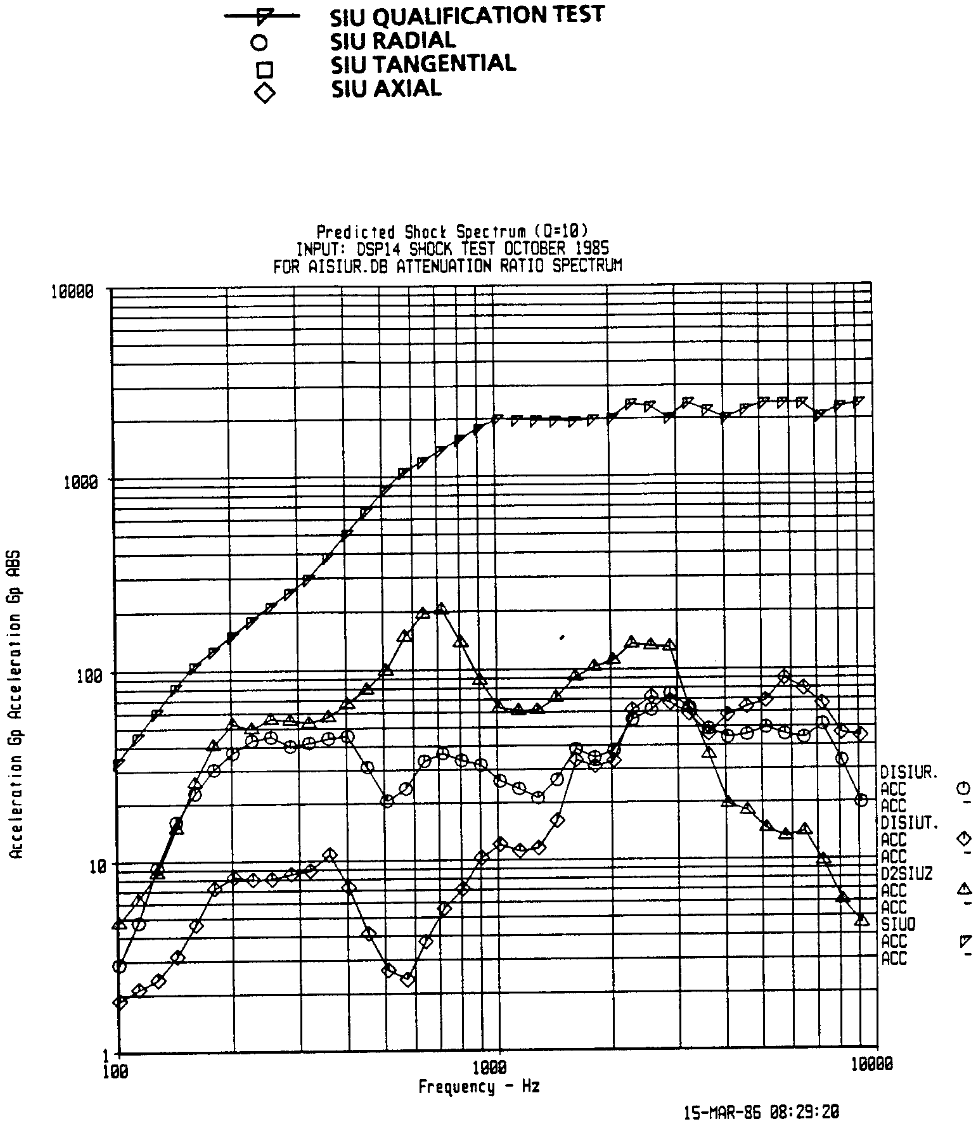

FIGURE 5-17
SIU

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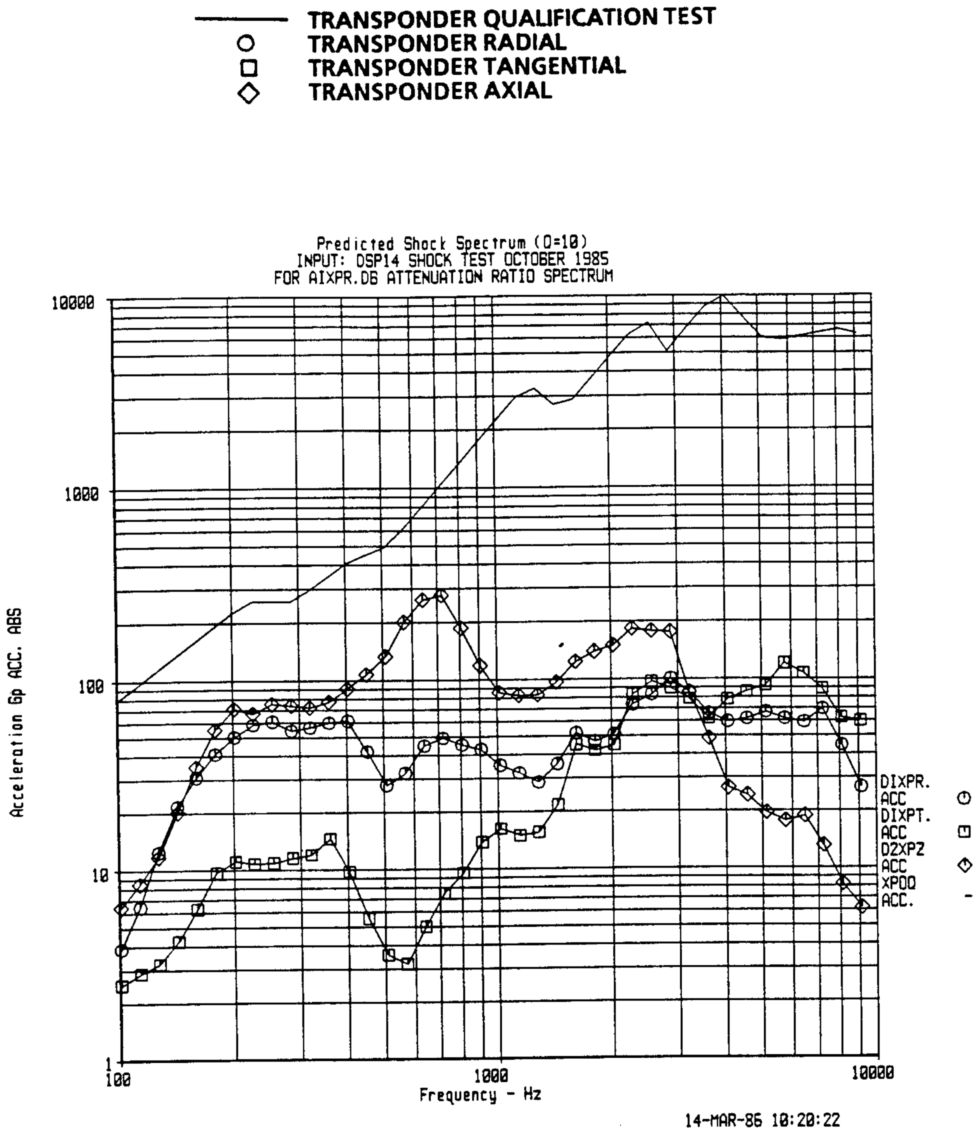

FIGURE 5-18
TRANSPONDER

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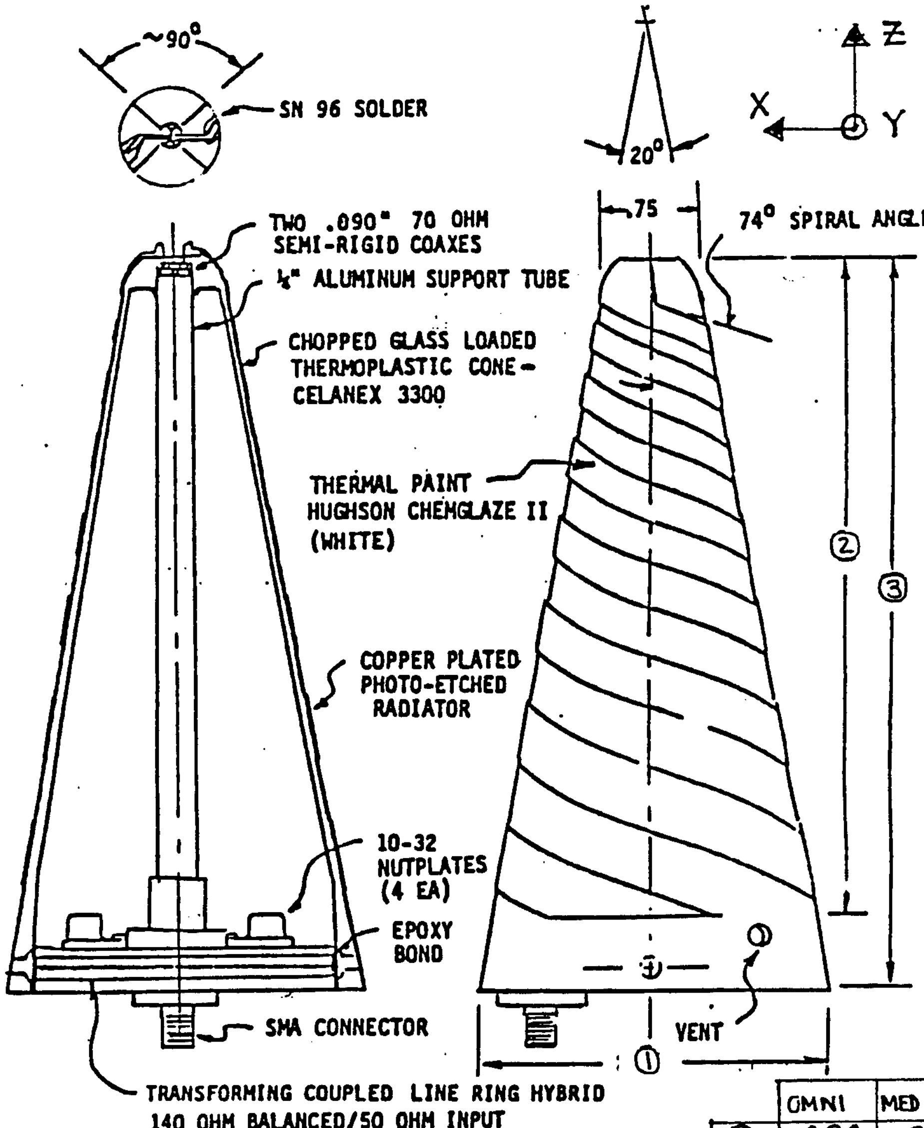

	OMNI	MED GAIN
①	3.94 in	2.43 in
②	9.7	4.58
③	10.2	5.08

Medium Gain Antenna shown, Omni Antenna construction similar

FIGURE 5-19 ANTENNA CONSTRUCTION

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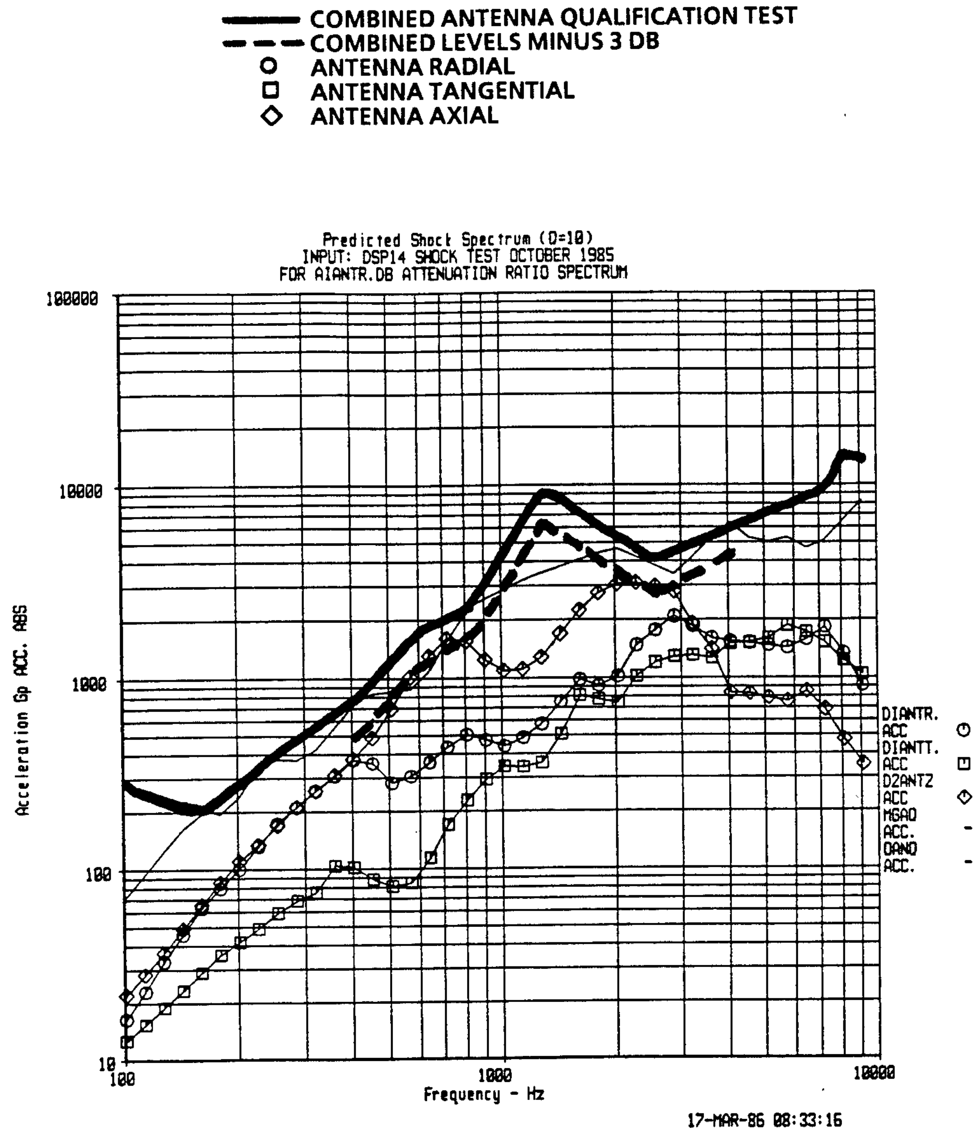

FIGURE 5-20
MEDIUM GAIN ANTENNA
OMNI ANTENNA

CALC		17MAR86	REVISED	DATE		
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APPD.					THE BOEING COMPANY	PAGE 53

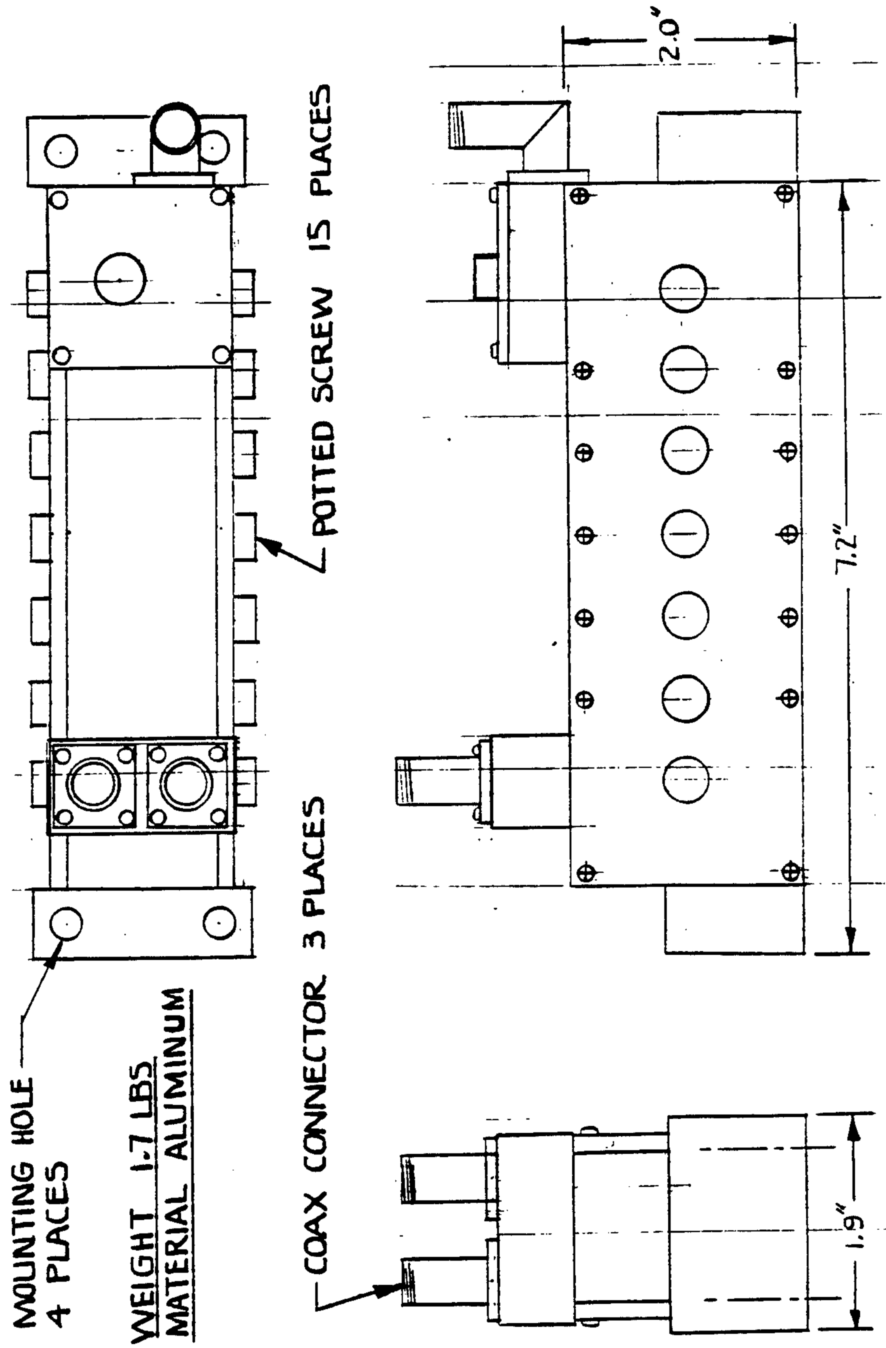
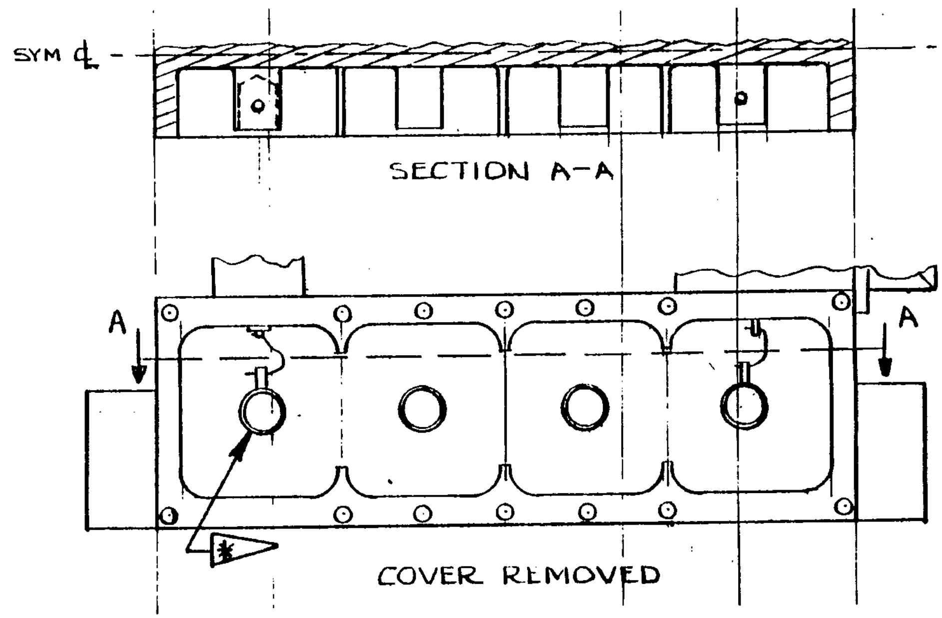


FIGURE 5-21
DIPLEXER CONSTRUCTION

54



* THE HOLLOW CYLINDERS, 8 PLACES, ARE MACHINED OUT OF AN ALUMINUM BLOCK.

55

FIGURE 5-21
DIPLEXER CONSTRUCTION
(CONTINUED)

REFERENCES

1. TRW letter 35.24-3-082;25 November 1985; to G. Staples BAC from E. Wheeler TRW; subject, Transmittal of Results of DSP-1/IUS Pyro Shock Tests.

2. Boeing memo 2-3612-IUS-061/85; 10 December 1985; to F. G. Staples from S. M. Church; subject, Evaluation of DSP 14 Separation Shock Data.

3. Boeing memo 2-3612-IUS-062/85; 20 December 1985; to F. G. Staples from S. M. Church; subject, Final Evaluation of IUS Response to DSP 14 Pyrotechnic Shock.

4. TRW letter 35.60.4-585; 10 February 1986; to HQ Space Division from D. C. Stager, TRW; subject, Minutes of DSP Separation Shock Test Data Review Interface Meeting.

5. Boeing memo 2-3612-IUS-005/86; 21 January 1986; to F. G. Staples from S. M. Church; subject, Additional Evaluation of IUS Response to DSP 14 Pyrotechnic Shock.

6. TRW memo BHW.86-L421.043; 21 February 1986; to L. A. Barney from B. H. Wendler; subject, DSP-1 IUS/ESS Adapter Modal Tap Test Results.

7. TRW letter 35.60.4-589; 18 February 1986; to HQ Space Division from D. C. Stager, TRW; subject, Minutes of Second DSP/IUS Interface Shock/Tap Test Data Review.

7.0 TITAN 4 PAYLOAD FAIRING SHOCK

Pyrotechnic shock measurements were obtained on the IUS during separation of the TITAN 4 payload fairing. The test results are presented in this section.

BOEING

2-3612-IUS-058/88
Revision A
7 July 1988

TO:	F. G. Staples	8A-23
CC:	D. B. Benson	8A-79
	G. V. Hard	8C-71
	K. F. Ryan	8A-12
	C. A. Slater	8A-23
	P. H. Stern	8C-72
	T. T. Do	Aerospace, M4-910
	R. C. Zaller	Aerospace, M5-552

SUBJECT: TITAN 4 Payload Fairing Shock Data, ECP 2246

An evaluation of final data from the TITAN 4 payload fairing separation test at AEDC is attached. The pyrotechnic shocks associated with the payload fairing separation are compared with the ICD shock envelope. The IUS is compatible with the TITAN 4 induced shock.

Clark Beck
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773-0327

W. C. Gustafson
W. C. Gustafson
IUS Dynamics

Attachment

EVALUATION OF TITAN 4 PAYLOAD FAIRING SEPARATION
PYROTECHNIC SHOCK

by Clark Beck
7 July 1988

INTRODUCTION

A TITAN 4 Payload Fairing separation test was conducted at AEDC in January 1988. This document contains an evaluation of shock data measured on the IUS during the test. The measured shock data are compared with the interface maximum shock envelope from ICD-TIV/IUS-10102.

IUS MEASUREMENTS

Seven accelerometers were installed on the IUS Pathfinder near the separation joint between IUS and TITAN. The accelerometer locations are shown in figure 1.

SHOCK DATA

The shock data are from 2 separation tests; normal separation and force margin separation. Data were obtained for the unlatch event and the separation event associated with each separation test. The shock data consists of time histories and response shock spectra from each of the 7 IUS accelerometers. The data were reduced by Calspan Corporation at AEDC. The data were transmitted to Boeing by Martin Marietta Denver on 6 July 1988.

DATA EVALUATION

The shock spectra from all accelerometers were enveloped for each shock event (total of 4 events). The envelopes are shown in figure 2 and are compared to the interface maximum shock envelope from ICD-TIV/IUS-10102. The highest levels were recorded on accelerometers I1R and I4R. The shock spectrum from accelerometer I7L was not included in the data envelope for the force margin separation test. The shock spectrum was not considered valid because of a plus 20g bias noted in the acceleration time history.

The accelerometers were calibrated to measure shocks in the 6000g to 10000g range. The acceleration levels measured on IUS were less than 100gs.

Figures 3 and 4 show a comparison of the shock levels from the TITAN 4 test with the levels from the T34D test conducted in 1979.

CONCLUSIONS

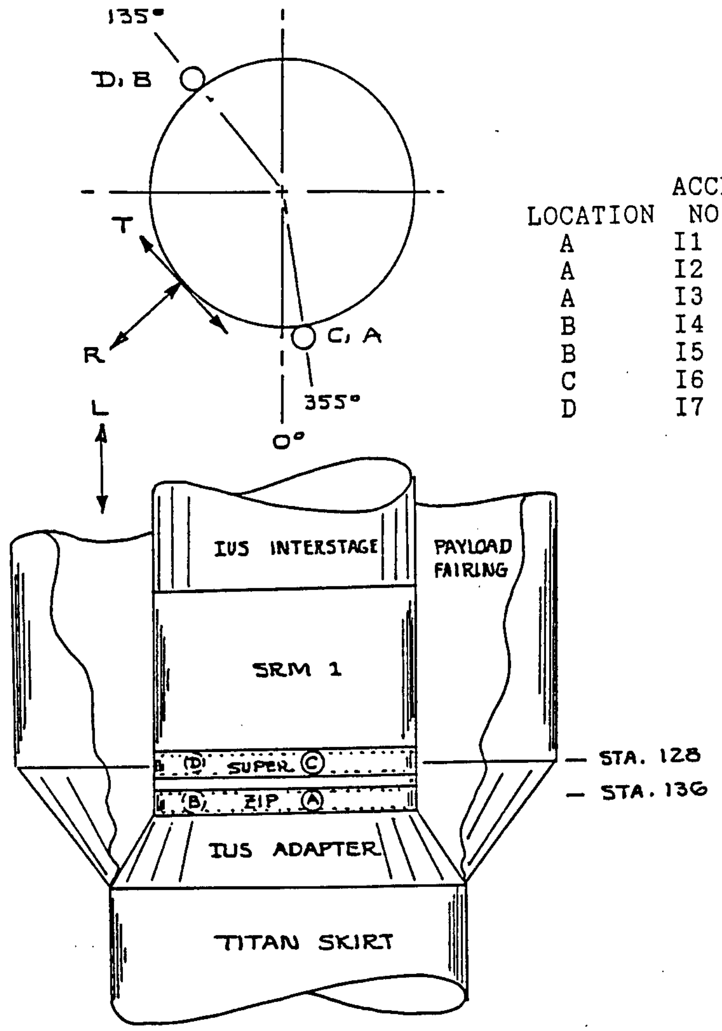
The shock levels measured on IUS during the TITAN 4 payload fairing separation test are less than the ICD envelope except for the 100 Hz to 150 Hz frequency range. The normal payload fairing separation envelope was greater than the ICD envelope over the 100 to 150 Hz range. The validity of the measured levels are questionable in this frequency range since the measured levels are near the noise level of the data.

The payload fairing separation event produces higher shock levels than the unlatch event.

The TITAN 4 shock levels are less than the levels measured during the T34D fairing separation test in 1979.

The IUS is compatible with the TITAN 4 induced shock caused by payload fairing separation.

Attachment to 2-3612-IUS-058/88
Revision A
Page 3



LOCATION	ACCELEROMETER NO.	AXIS	STA.	AZIMUTH
A	I1	R	136	355
A	I2	T	136	355
A	I3	L	136	355
B	I4	R	136	135
B	I5	L	136	135
C	I6	L	128	355
D	I7	L	128	135

FIGURE 1
IUS ACCELEROMETER LOCATIONS
TITAN 4 PAYLOAD FAIRING SEPARATION TEST
JANUARY 1988

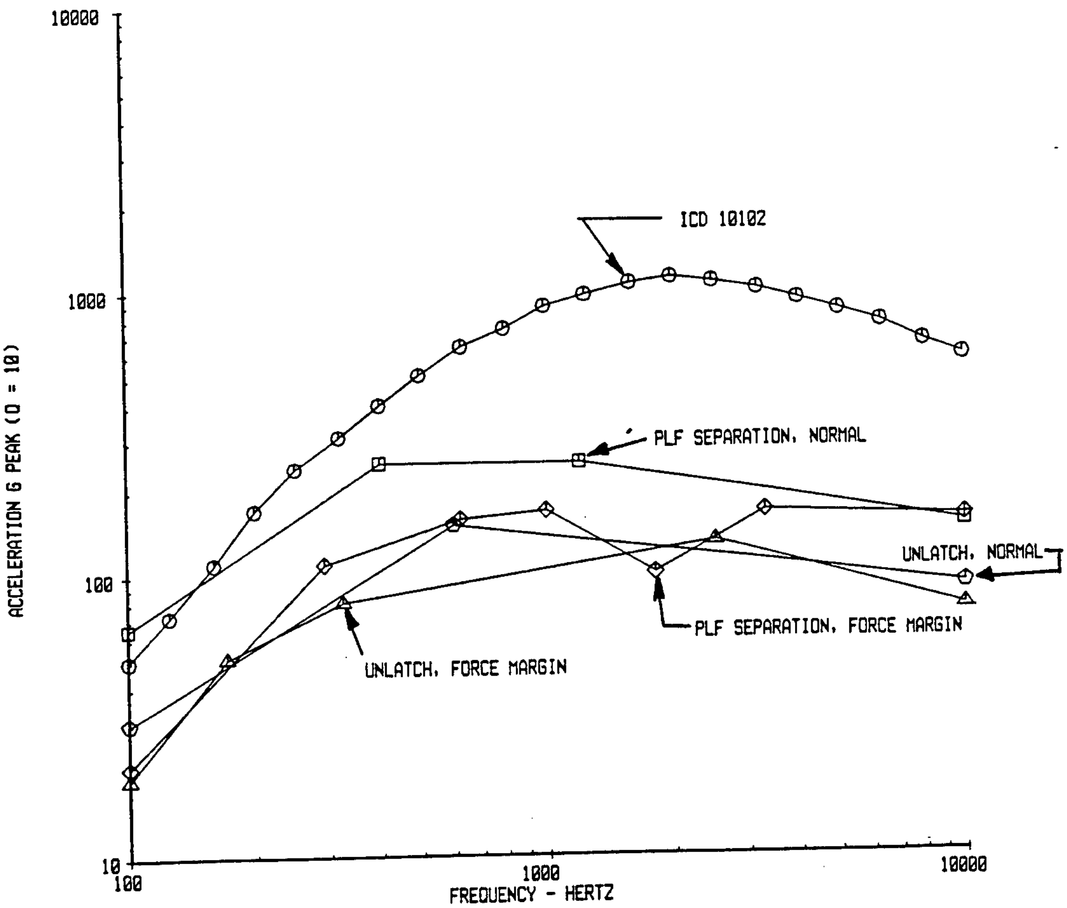


FIGURE 2
COMPARISON
TITAN 4 UNLATCH AND PAYLOAD FAIRING SEPARATION
ICD-TIV/IUS-10102

Attachment to 2-3612-IUS-058/88
Revision A
Page 5

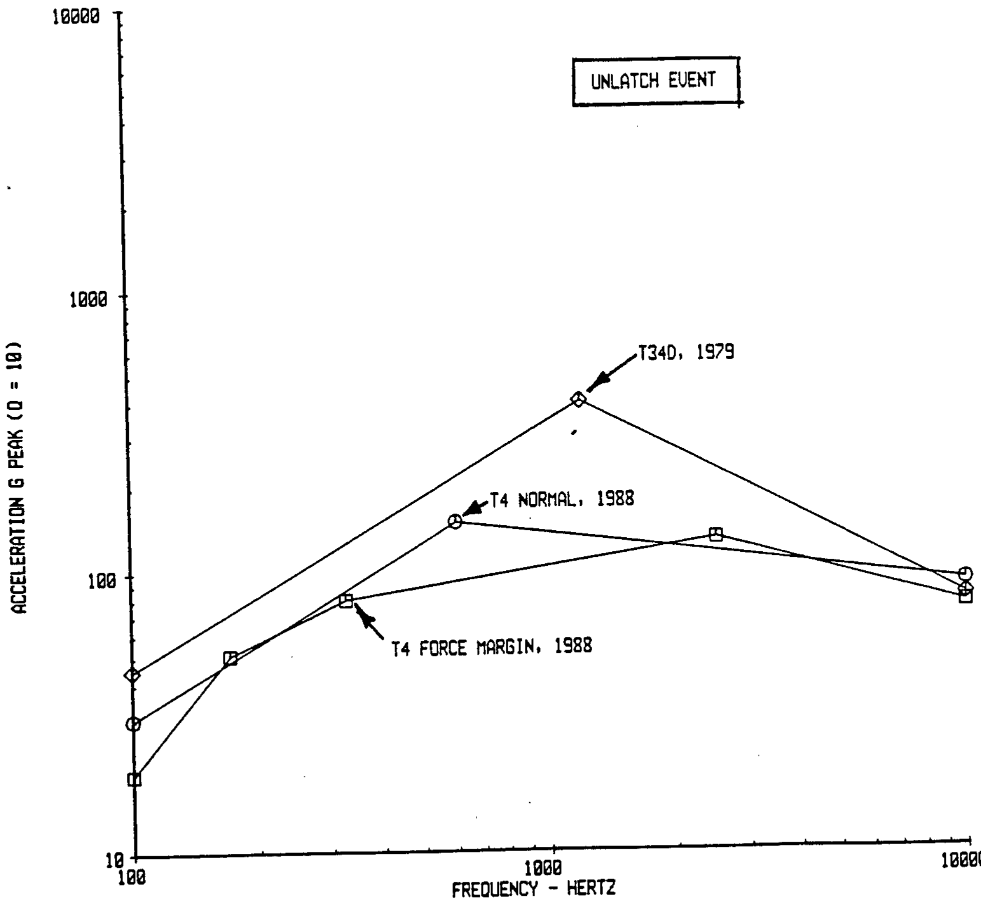


FIGURE 3
COMPARISON UNLATCH EVENT
TITAN 4 VERSUS T34D

BOEING

Attachment to 2-3612-IUS-058/88
Revision A
Page 6

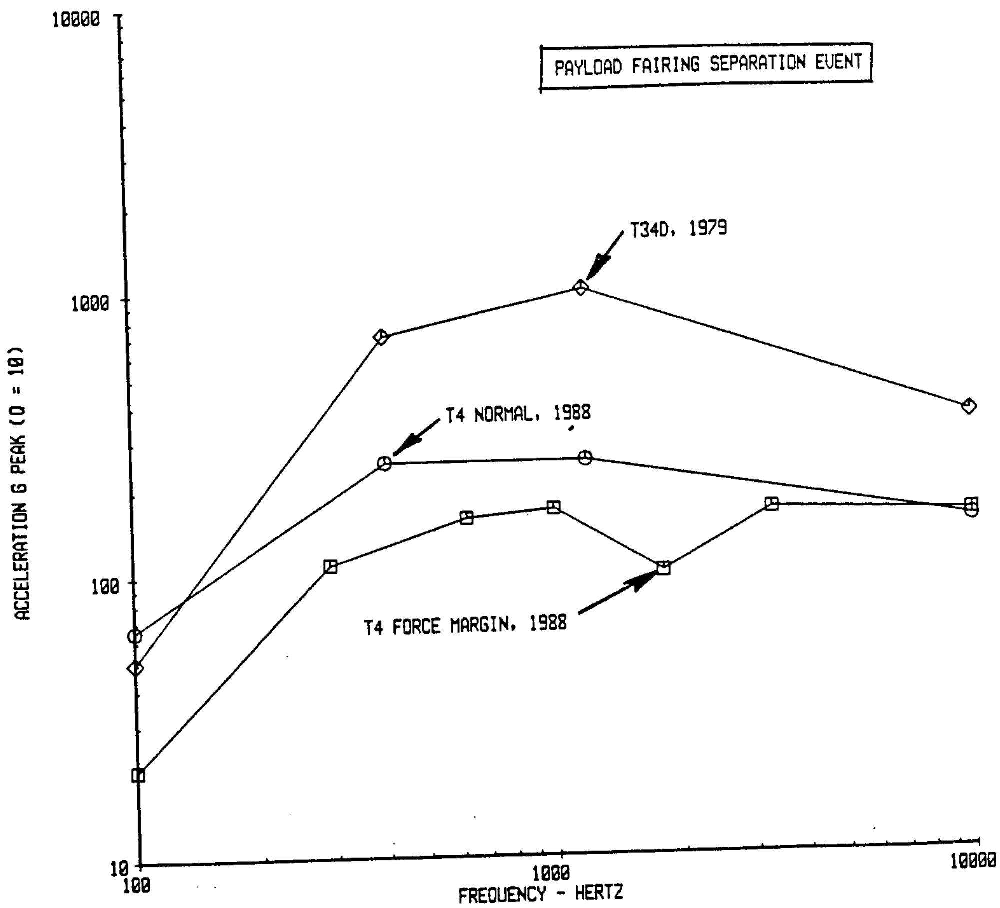


FIGURE 4
COMPARISON PAYLOAD FAIRING SEPARATION EVENT
TITAN 4 VERSUS T34D

8.0 SEPARATION NUT SHOCK

The IUS stage 1/2 separation nuts were modified in 1988. Vibration and shock testing of the modified nuts was performed. This section presents the test results.

2-3612-IUS-249/88
22 December 1988

TO: A. D. Watson 8C-71

CC: T. M. Howell 8C-71
P. H. Stern 8C-72
M. H. Louie Aerospace, M5-552
T. T. Do Aerospace, M4-910

SUBJECT: Results of Separation Nut Vibration and Shock Testing

REFERENCE: Boeing Drawing 290-24807, Test Configuration IUS Stage 1/2 Separation Nut Vibration/Shock, 12/16/88.

SUMMARY

Vibration and shock testing was conducted on IUS stage 1/2 separation nuts during the period 19 December 1988 through 21 December 1988 at Kent Space Center. The reference contains the test plan. The separation nuts were modified by removing the retainer ring. The nuts with retainer ring removed successfully passed qualification vibration testing. The pyrotechnic shock levels generated by firing the IUS stage 1/2 separation nuts are not significantly different for nuts with or without the retainer ring installed.

TEST ARTICLE

The test articles were IUS stage 1/2 separation nuts. The separation nuts were manufactured by Hi Shear Corporation. Some of the nuts tested did not have the retainer ring installed. The retainer ring is shown on page 4. A fixed nut and a free nut were used in the test. An instrumented stud and a crush washer installation were also part of the test article. A comprehensive description of the test article is contained in the reference.

TEST CONFIGURATIONS

Vibration

The fixed and free nuts without the retainer ring were installed on the test fixture shown on page 5. A schematic of the test installation and the test axes is shown on page 6. The stud holding the 2 nuts together was instrumented with a strain gage to measure the load in the stud. The free nut was tightened until the load in the stud was 21,000 pounds. A single accelerometer was placed on the test fixture to control the vibration input.

Pyrotechnic Shock

The fixed and free nut were installed on the same test fixture used for vibration. A schematic showing the test installation and test axes is shown on page 7. Three accelerometers were mounted on a 1 inch aluminum cube. The cube was attached to the test fixture using an adhesive and a bolt.

Eight (8) configurations were tested. The fixed nut was fired for all configurations. The configurations are identified by a run number.

Runs 1, 3, 5	Fixed nut (S/N 60911) without retainer ring, free nut (S/N 52976) installed, stud load 42,000 pounds.
Runs 2, 4, 6	Fixed nut (S/N 60911) with retainer ring, free nut (S/N 52976) installed, stud load 42,000 pounds.
Run 7	Fixed nut (S/N 53124) without retainer ring, free nut removed, stud hand tight.
Run 8	Fixed nut (S/N 53124) with retainer ring, free nut removed, stud hand tight.

TEST PROCEDURE

Vibration

The vibration test was conducted at qualification test levels for 3 minutes in each test axis. The output of the control accelerometer was recorded throughout the test. An acceleration power spectral density plot was obtained from the recorded data and compared to the qualification test requirement. The position of the lock pin was measured before and after vibration in each test axis. The lock pin is shown on page 4.

Pyrotechnic Shock

The pyrotechnic shock test was conducted by firing the fixed nut and recording the output from each of the three accelerometers. The accelerometer outputs were recorded. A time history of the response to the shock was made for each accelerometer. An acceleration shock response spectrum (Q=10) was obtained from each time history.

TEST RESULTS

Vibration

The qualification test levels were applied at the correct level (43.3 grms) for the proper duration (3 minutes) in each of the three test axes. Pages 8, 9 and 10 show the applied acceleration power spectral density in each test axis. The nut assembly was still intact following the vibration test and measurements indicate the lock pin did not move during the test. Therefore, the nuts without the retainer ring successfully passed the vibration test.

Pyrotechnic Shock
The shock spectra for a given direction varied from test to test. However, the variation is within the range associated with measured pyrotechnic shock spectra. Figures 11, 12 and 13 contain comparisons of the shock spectra for each direction.

The shock spectra and time histories from each of the test runs is shown on the following pages. Note that the time history of the firing current is presented with each data set.

Run 1	pages 14 through 20
Run 2	pages 21 through 27
Run 3	no data obtained
Run 4	pages 28 through 34
Run 5	pages 35 through 41
Run 6	pages 42 through 48
Run 7	pages 49 through 55
Run 8	pages 56 through 62

CONCLUSIONS
The IUS stage 1/2 separation nut with retainer ring removed successfully completed qualification vibration testing.

The pyrotechnic shock levels generated by firing the IUS stage 1/2 separation nuts are not significantly different for nuts with or without the retainer ring installed.

Clark Beck
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773-0327

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for W. C. Gustafson
IUS Dynamics

Page 1 of 62 pages

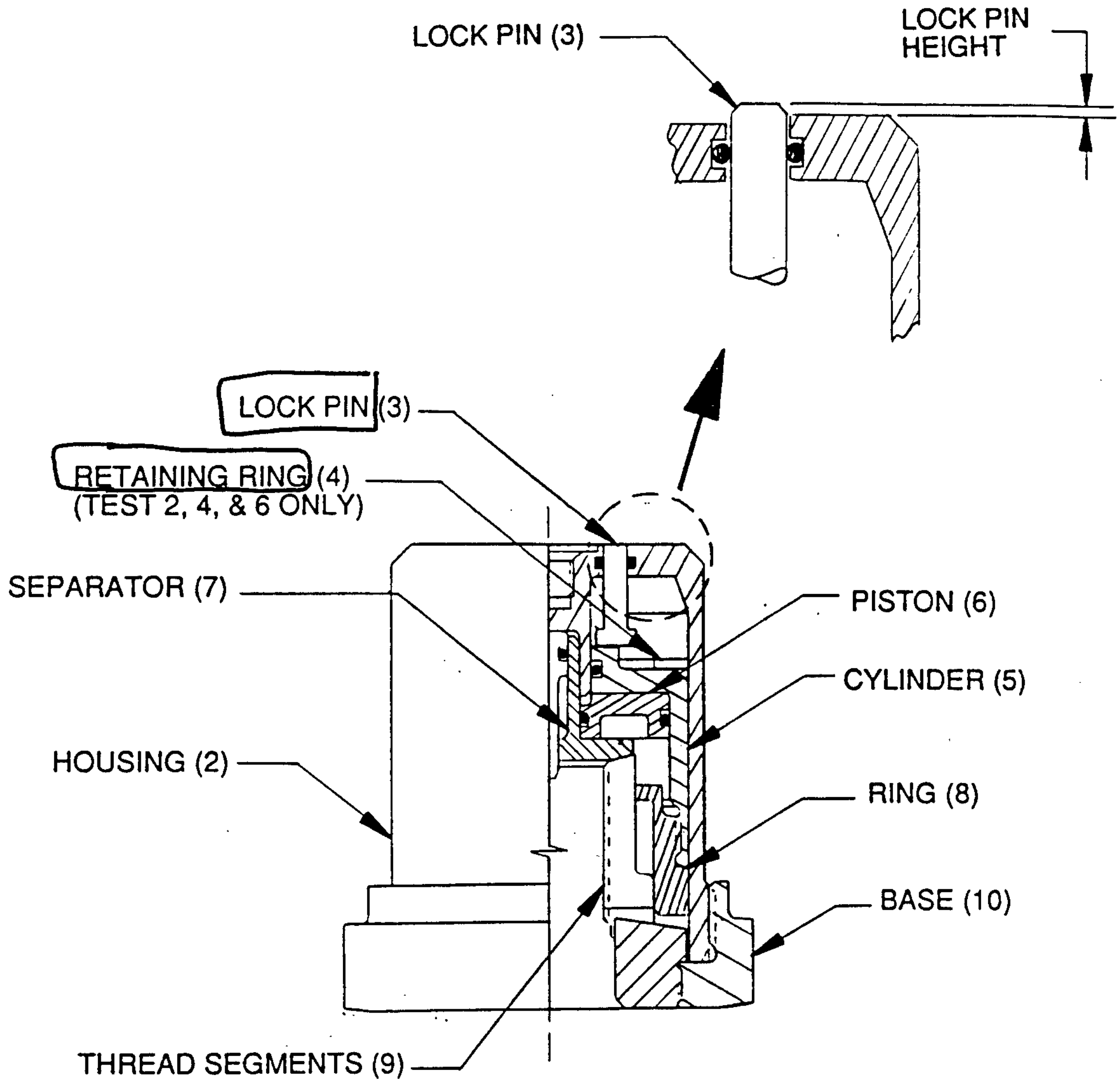
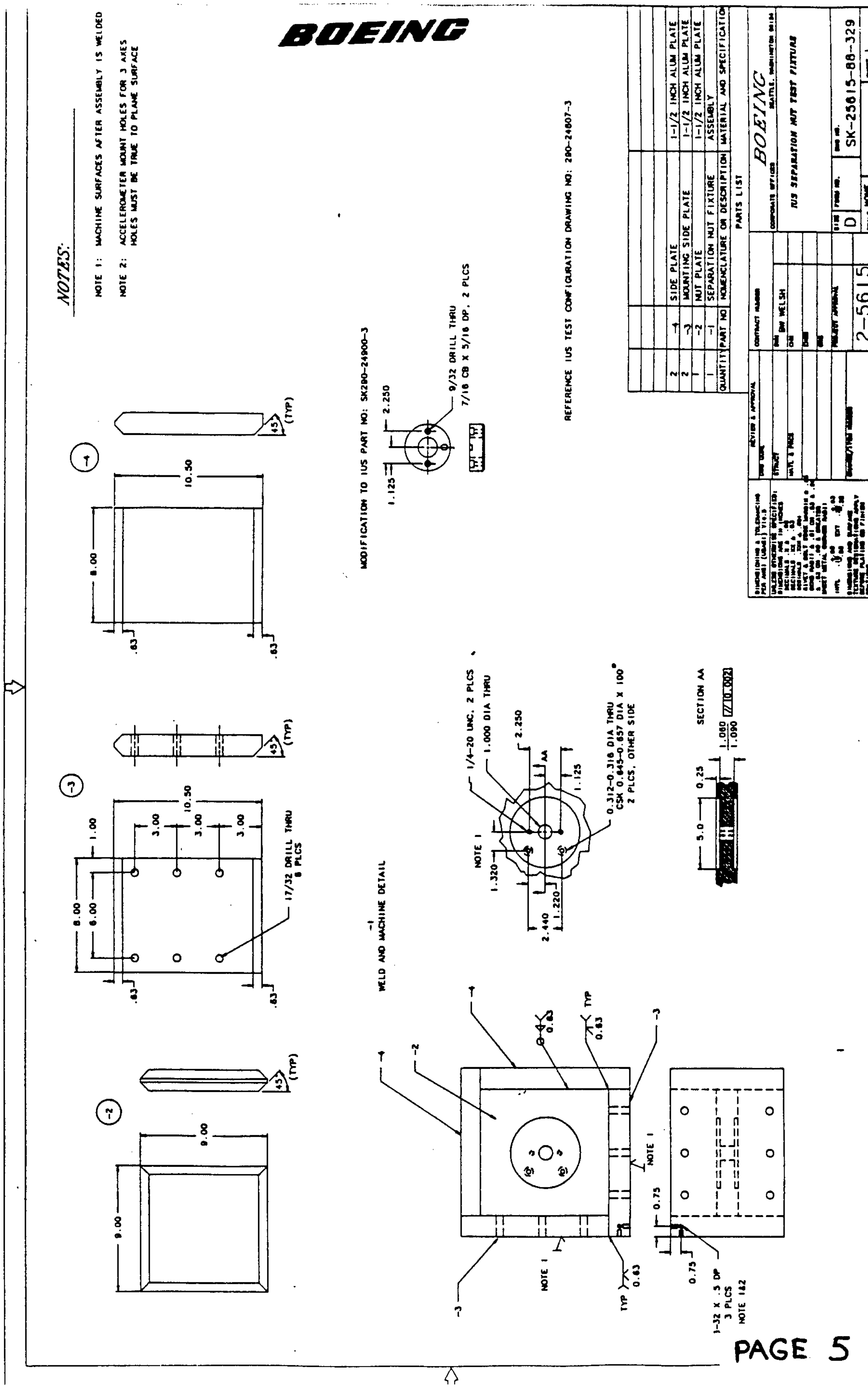


FIGURE 5

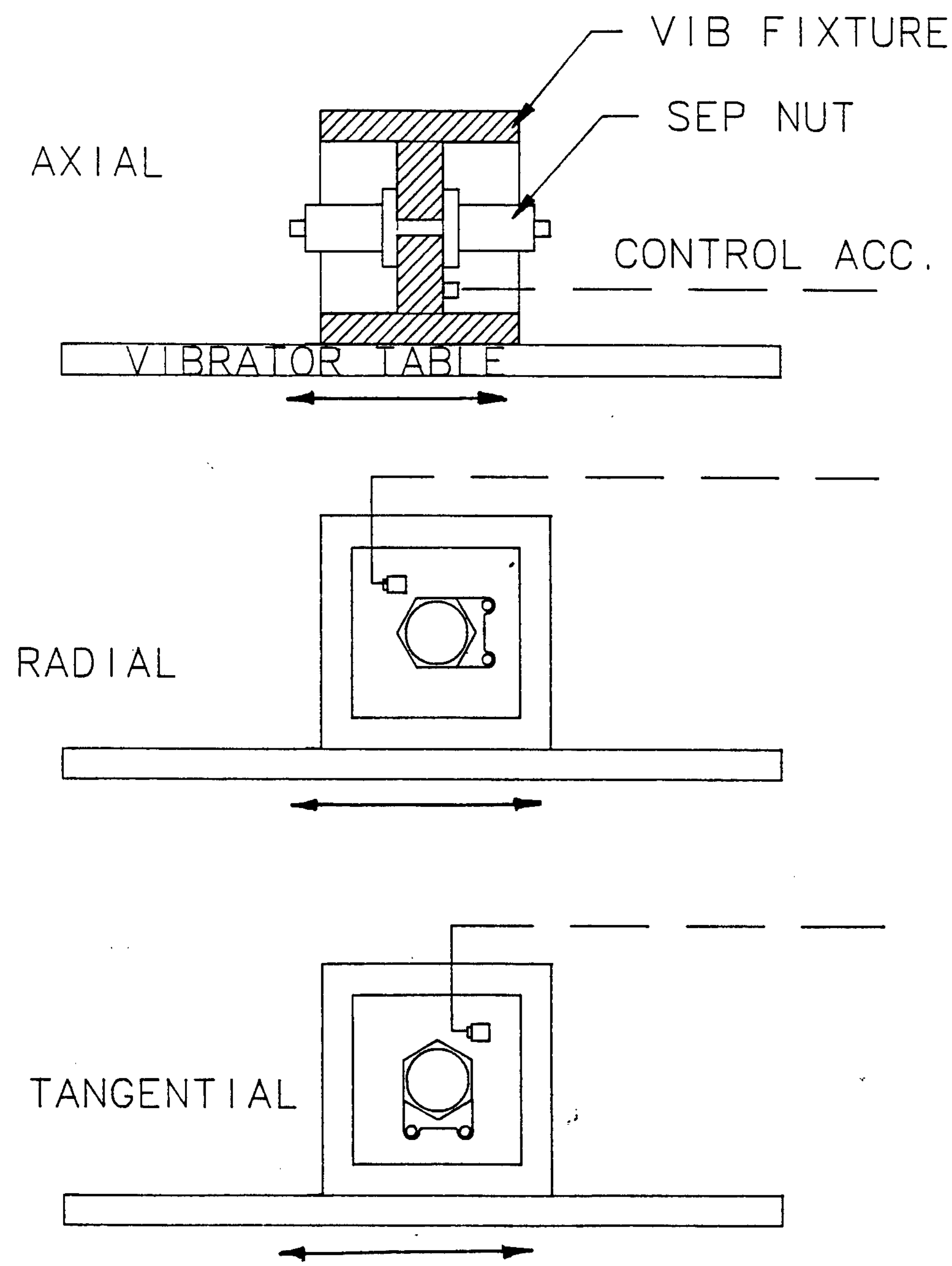
ASSEMBLED SEPARATION DEVICE

SIZE	FSCM NO	DWG NO	REV
A			
SCALE		SHEET 4	

18

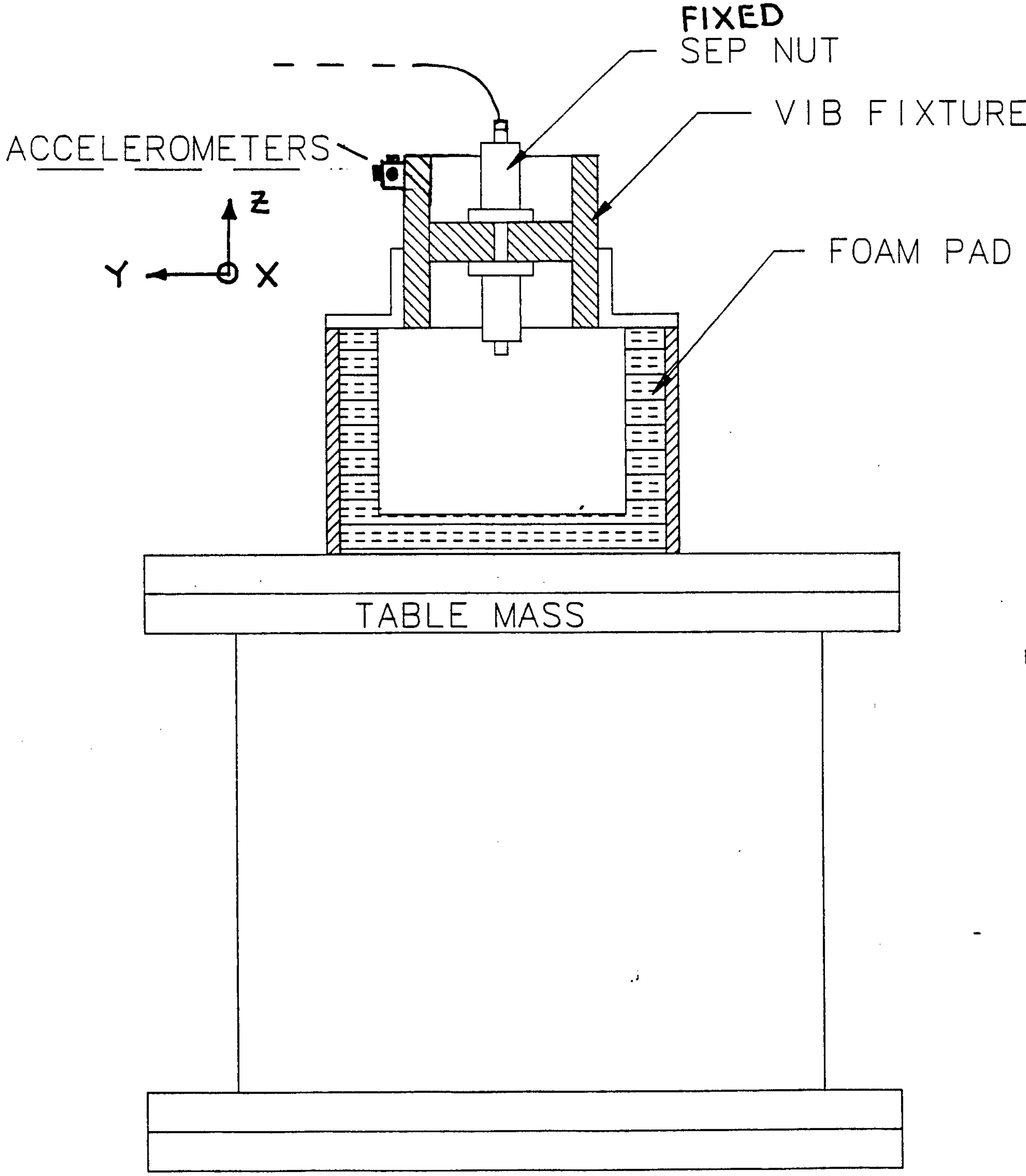

BOEING
NOTES:
NOTE 1: MACHINE SURFACES AFTER ASSEMBLY IS WELDED
NOTE 2: ACCELEROMETER MOUNT HOLES FOR 3 AXES HOLES MUST BE TRUE TO PLANE SURFACE
MODIFICATION TO IUS PART NO: SK290-24900-3
9/32 DRILL THRU 7/16 CB X 5/16 DP, 2 PLCS
REFERENCE IUS TEST CONFIGURATION DRAWING NO: 290-24807-3
1/4-20 UNC, 2 PLCS
1.000 DIA THRU
0.312-0.316 DIA THRU CSK 0.645-0.657 DIA X 100° 2 PLCS, OTHER SIDE
SECTION AA
17/32 DRILL THRU 6 PLCS
-1 WELD AND MACHINE DETAIL
1-32 X .5 DP 3 PLCS NOTE 1&2
2 -4 SIDE PLATE 1-1/2 INCH ALUM PLATE
2 -3 MOUNTING SIDE PLATE 1-1/2 INCH ALUM PLATE
1 -2 NUT PLATE 1-1/2 INCH ALUM PLATE
1 -1 SEPARATION NUT FIXTURE ASSEMBLY
QUANTITY PART NO NOMENCLATURE OR DESCRIPTION MATERIAL AND SPECIFICATION
PARTS LIST
BW WELSH
BOEING SEATTLE, WASHINGTON
IUS SEPARATION NUT TEST FIXTURE
D 2-5615 SK-25615-88-329
PAGE 5

IUS SEPARATION NUT TEST
VIBRATION TEST SET-UP

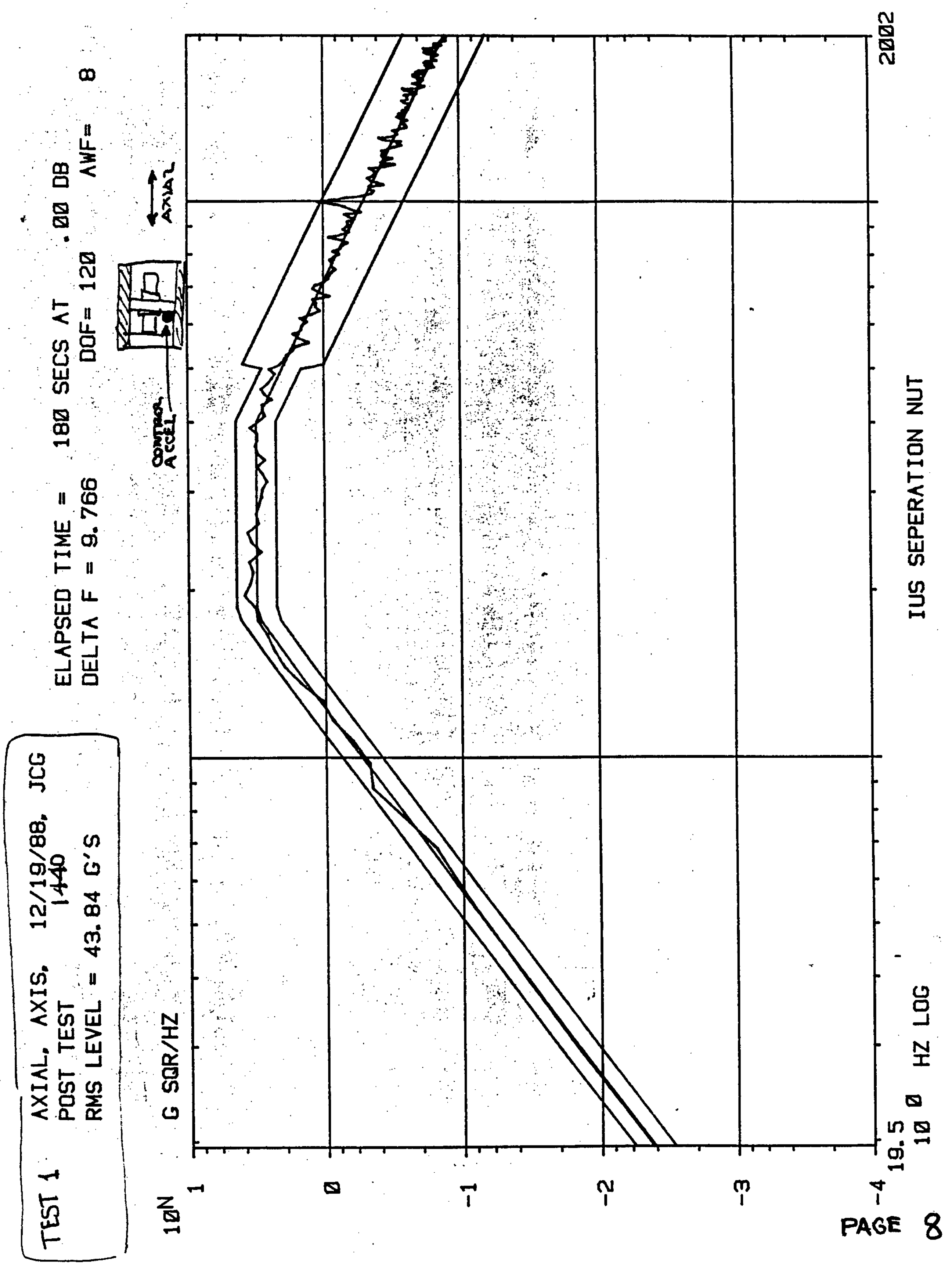


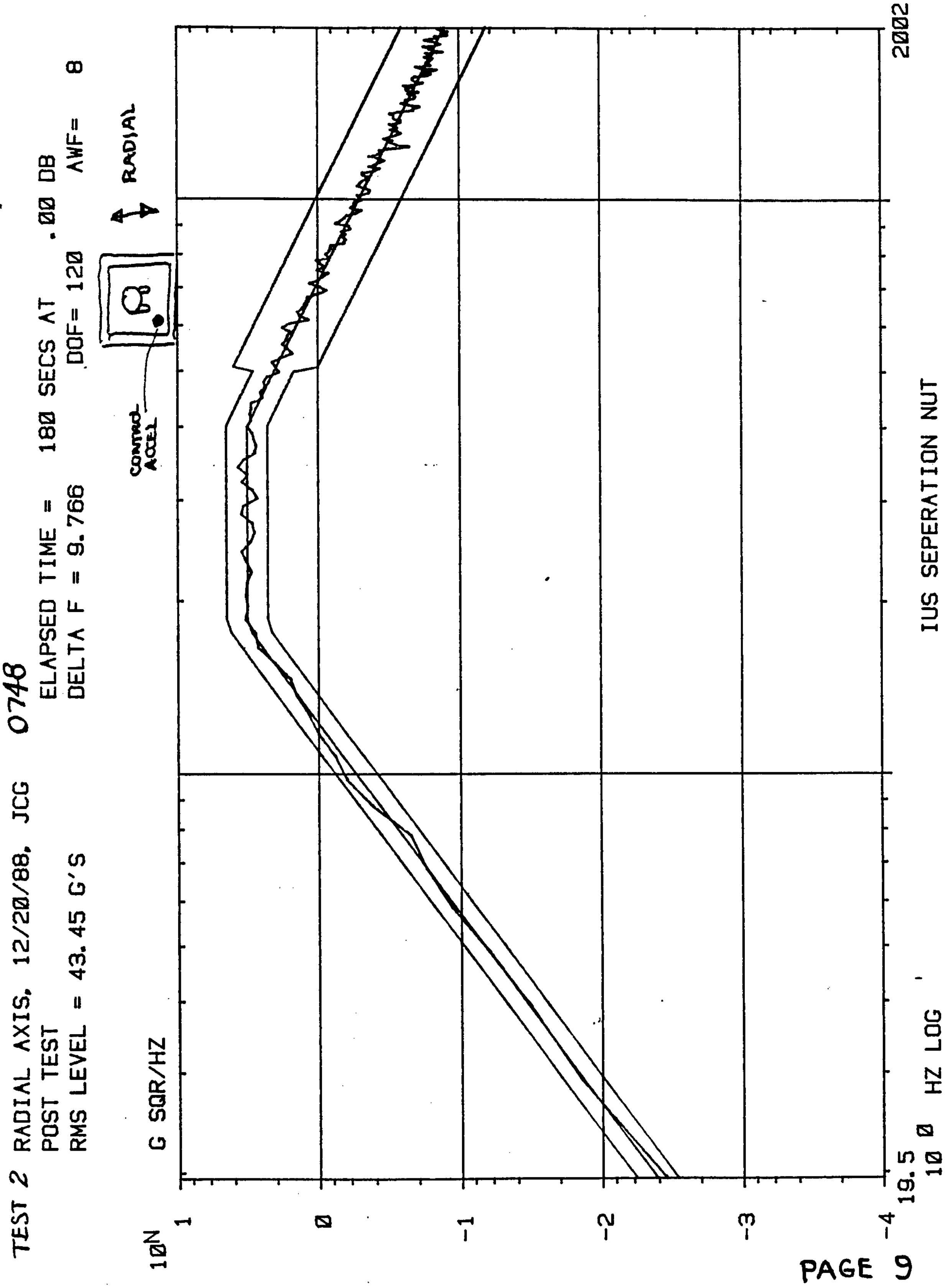
PAGE 6

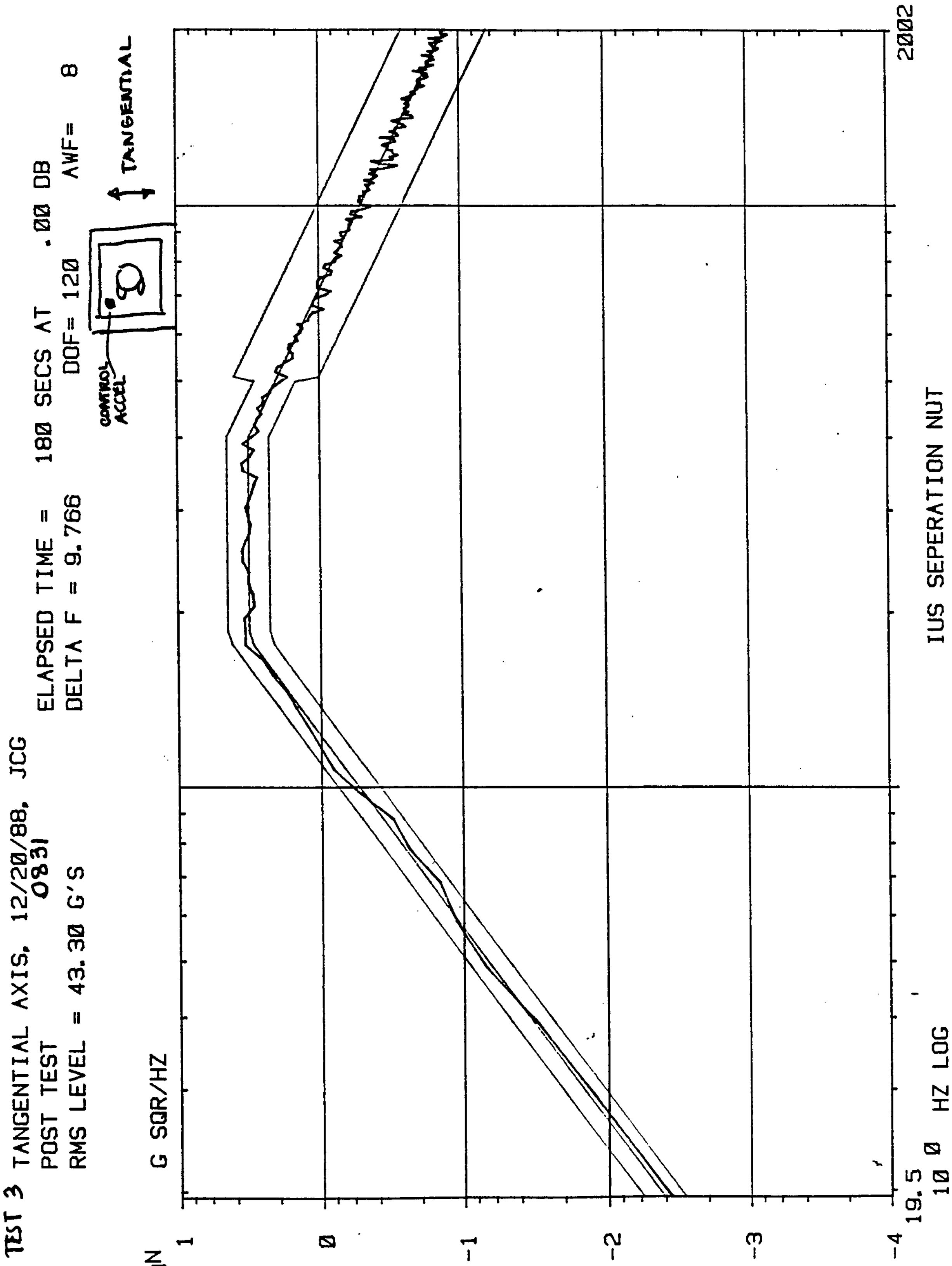
IUS SEPARATION NUT TEST
PYRO-SHOCK TEST SET-UP



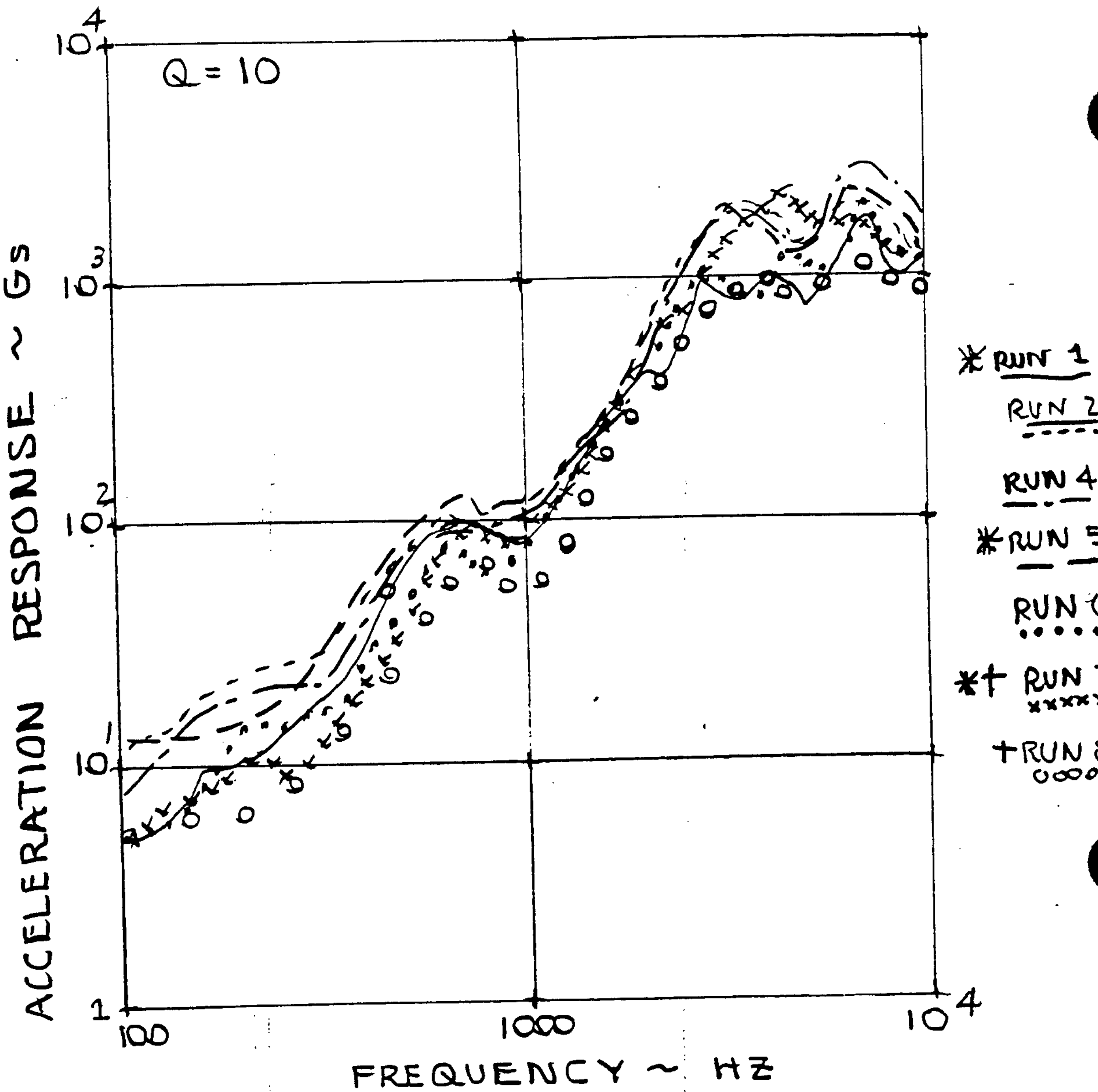
PAGE 7


TEST 1
AXIAL, AXIS, 12/19/88, JCG
1440
POST TEST
RMS LEVEL = 43.84 G'S
ELAPSED TIME = 180 SECS AT .00 DB
DELTA F = 9.766 DOF= 120 AWF= 8
CONTROL ACCEL
AXIAL
G SQR/HZ
10N
1
0
-1
-2
-3
-4
19.5
10 0 HZ LOG
2002
IUS SEPERATION NUT
PAGE 8


TEST 2 RADIAL AXIS, 12/20/88, JCG
0748
POST TEST
ELAPSED TIME = 180 SECS AT .00 DB
RMS LEVEL = 43.45 G'S
DELTA F = 9.766
DOF= 120
AWF= 8
RADIAL
CONTROL ACCEL
G SQR/HZ
10N
1
0
-1
-2
-3
-4
19.5
10 0
HZ LOG
2002
IUS SEPERATION NUT
PAGE 9


TEST 3 TANGENTIAL AXIS, 12/2Ø/88, JCG
0831
POST TEST
RMS LEVEL = 43.3Ø G'S
ELAPSED TIME = 18Ø SECS AT .ØØ DB
DELTA F = 9.766 DOF= 12Ø AWF= 8
G SQR/HZ
1ØN
1
Ø
-1
-2
-3
-4
19.5
1Ø Ø HZ LOG
2ØØ2
IUS SEPERATION NUT
TANGENTIAL
CONTROL ACCEL

PAGE 10

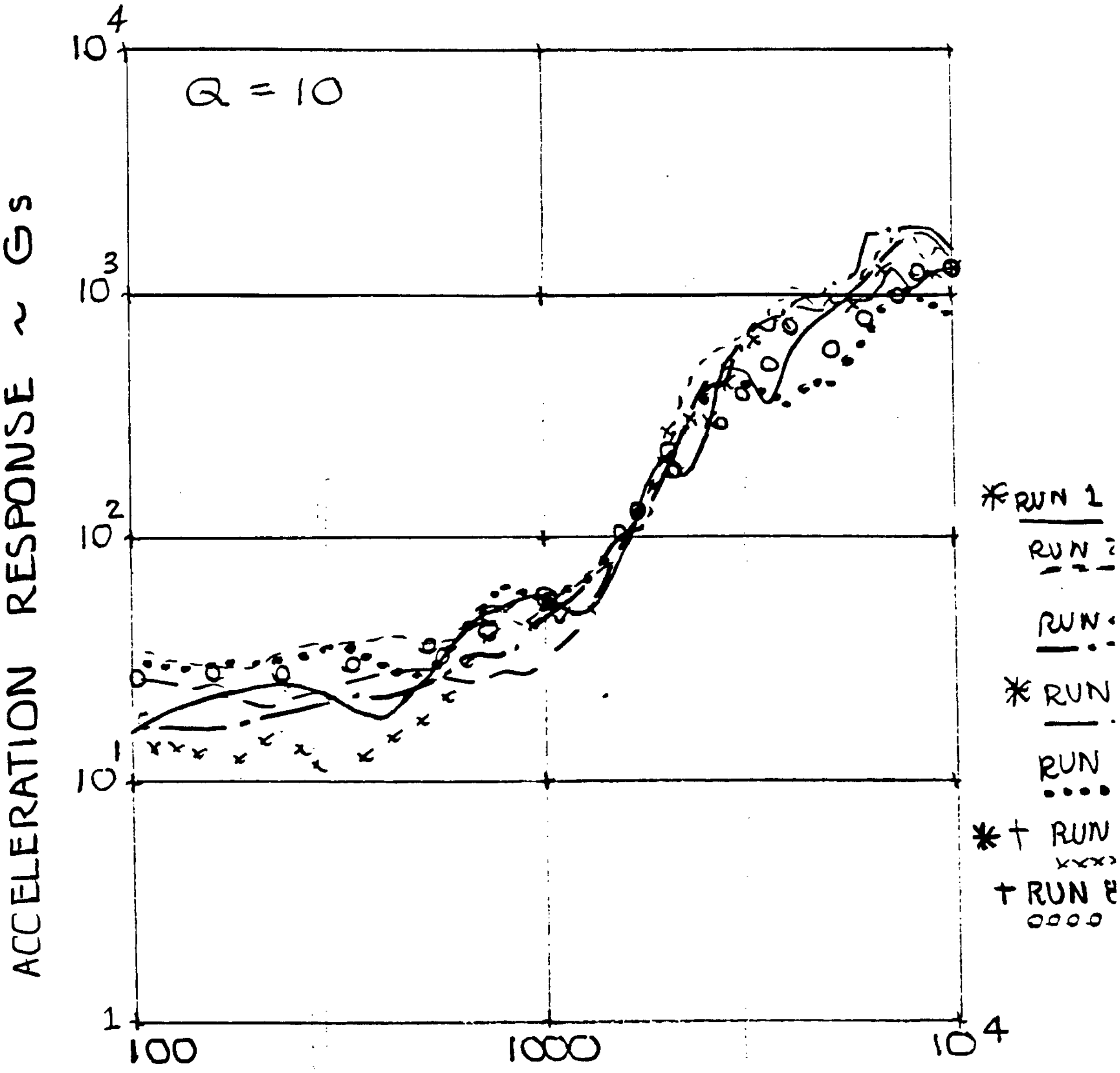


* WITHOUT RETAINER   + FREE NUT REMOVED

SHOCK SPECTRUM COMPARISONS
IUS STAGE 1/2 SEPARATION NUTS
MEASUREMENT IX

PAGE 11

CJB
22 DEC 88

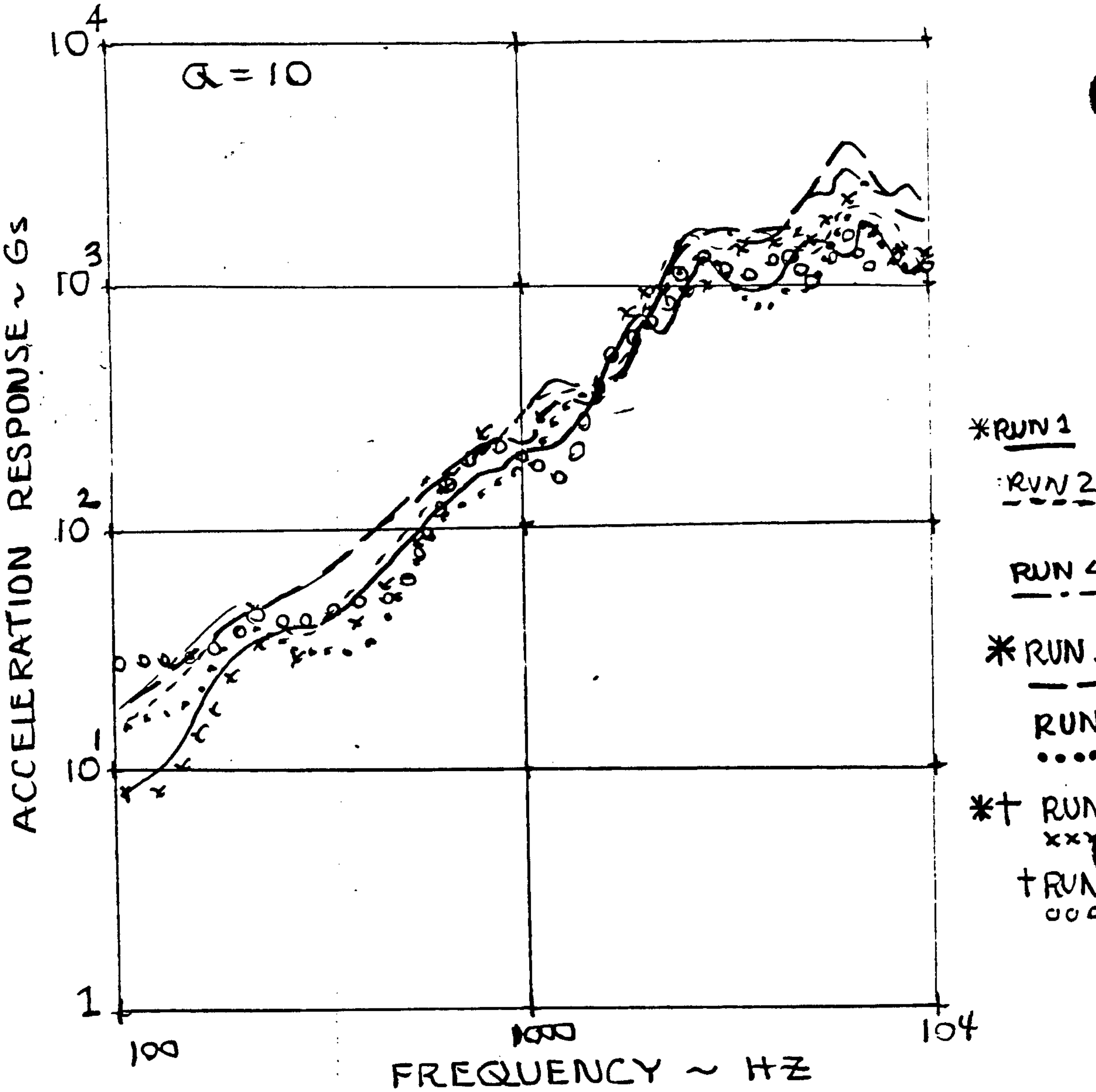


* WITHOUT RETAINER † FREE NUT REMOVED

SHOCK SPECTRUM COMPARISONS
IUS STAGE 1/2 SEPARATION NUTS
MEASUREMENT 1Y

PAGE 1.

CJB
22 DEC 88



* WITHOUT RETAINER + FREE NUT REMOVED

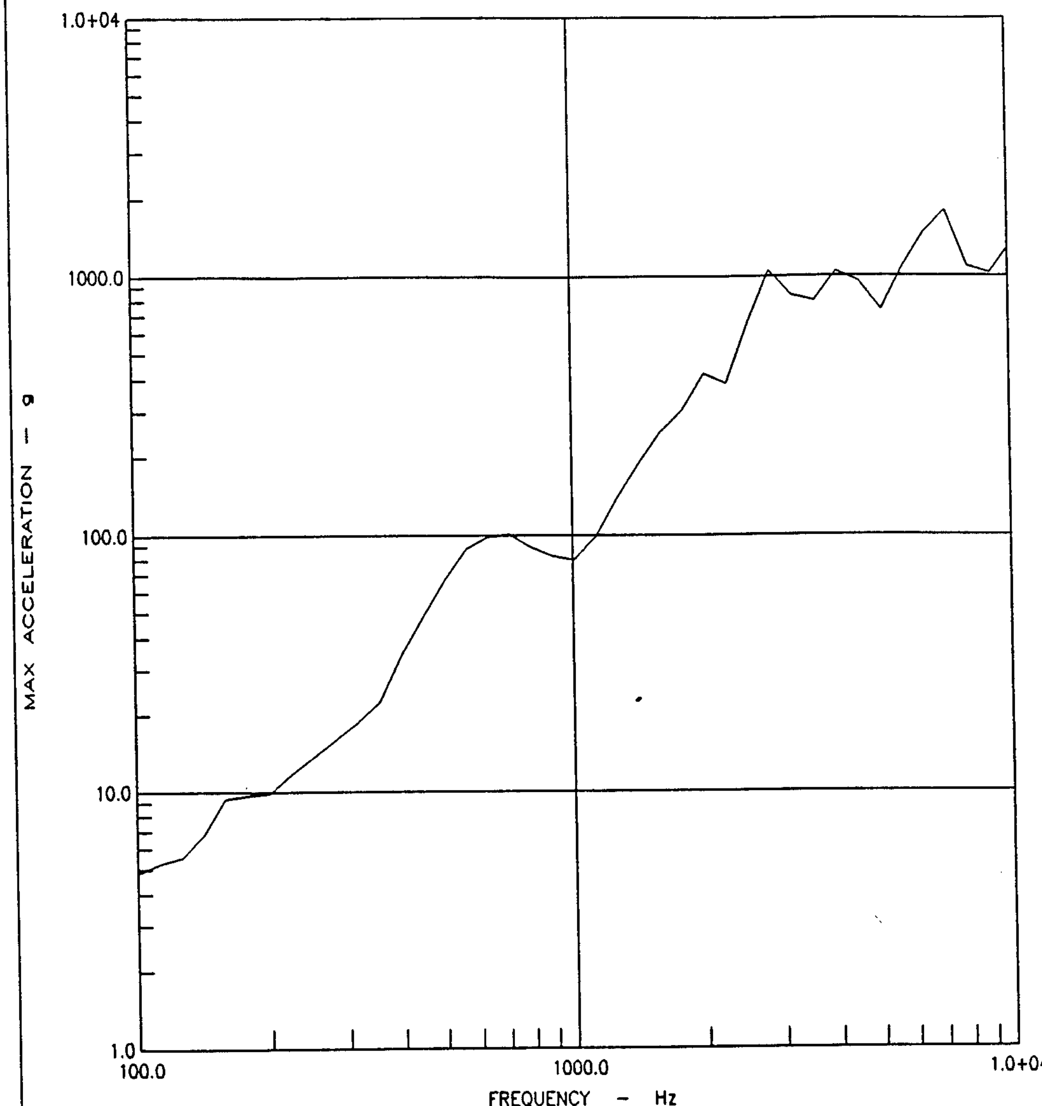
SHOCK SPECTRUM COMPARISONS
IUS STAGE 1/2 SEPARATION NUT
MEASUREMENT 1Z

PAGE

22 DEC 1988

CJB

SHOCK SPECTRA



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CHANNEL NUMBER: 1

DATA TYPE: ABS MAX
Q: 10.000

RUN NUMBER: 1

DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS

CALC		12/21/88	IUS PYRO SHOCK TEST FIXED NUT W/O RETAINER STUD 42K	
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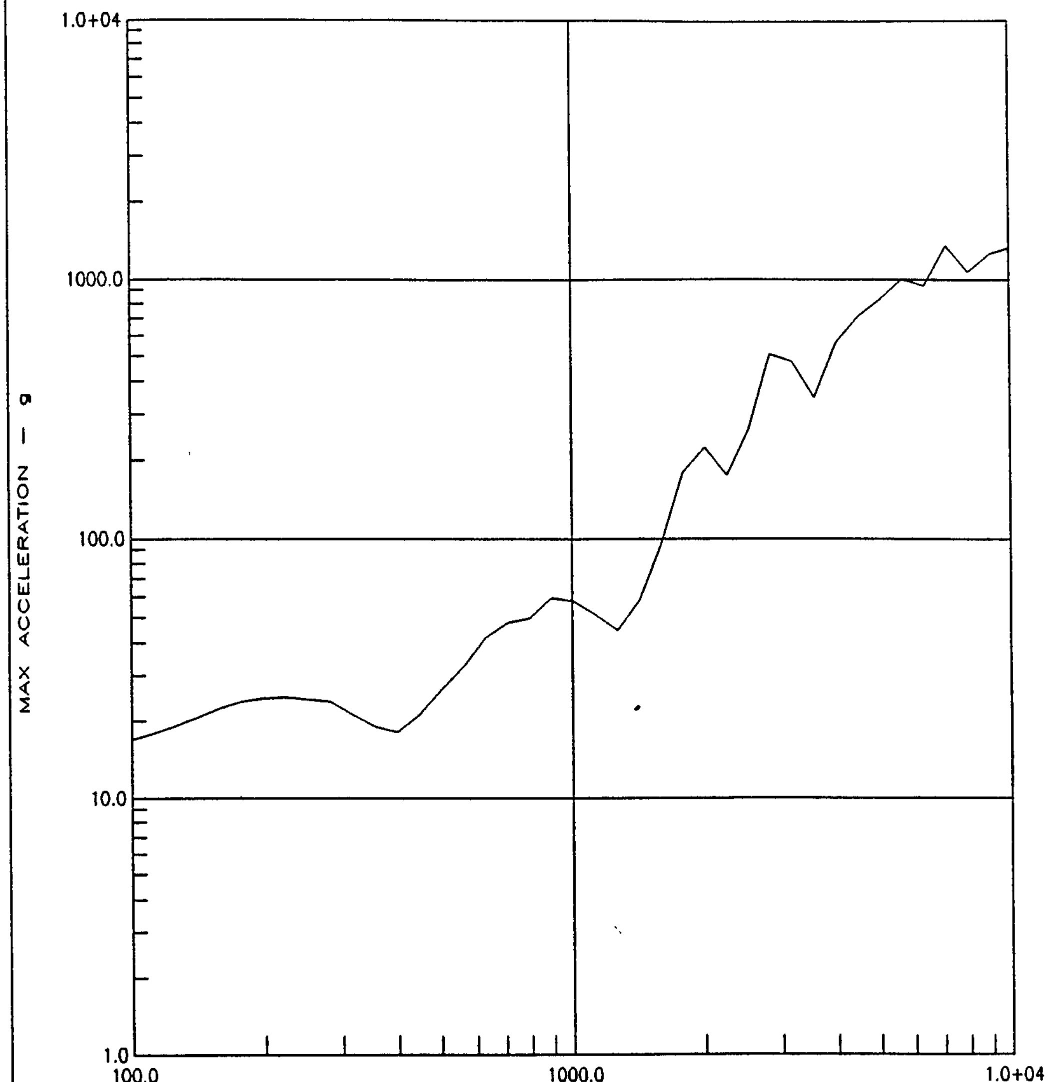
CHECK				
APPD	GB	12/21/88		SHEET 14

SHOCK SPECTRA



CHANNEL NAME: A1Y
CHANNEL NUMBER: 2

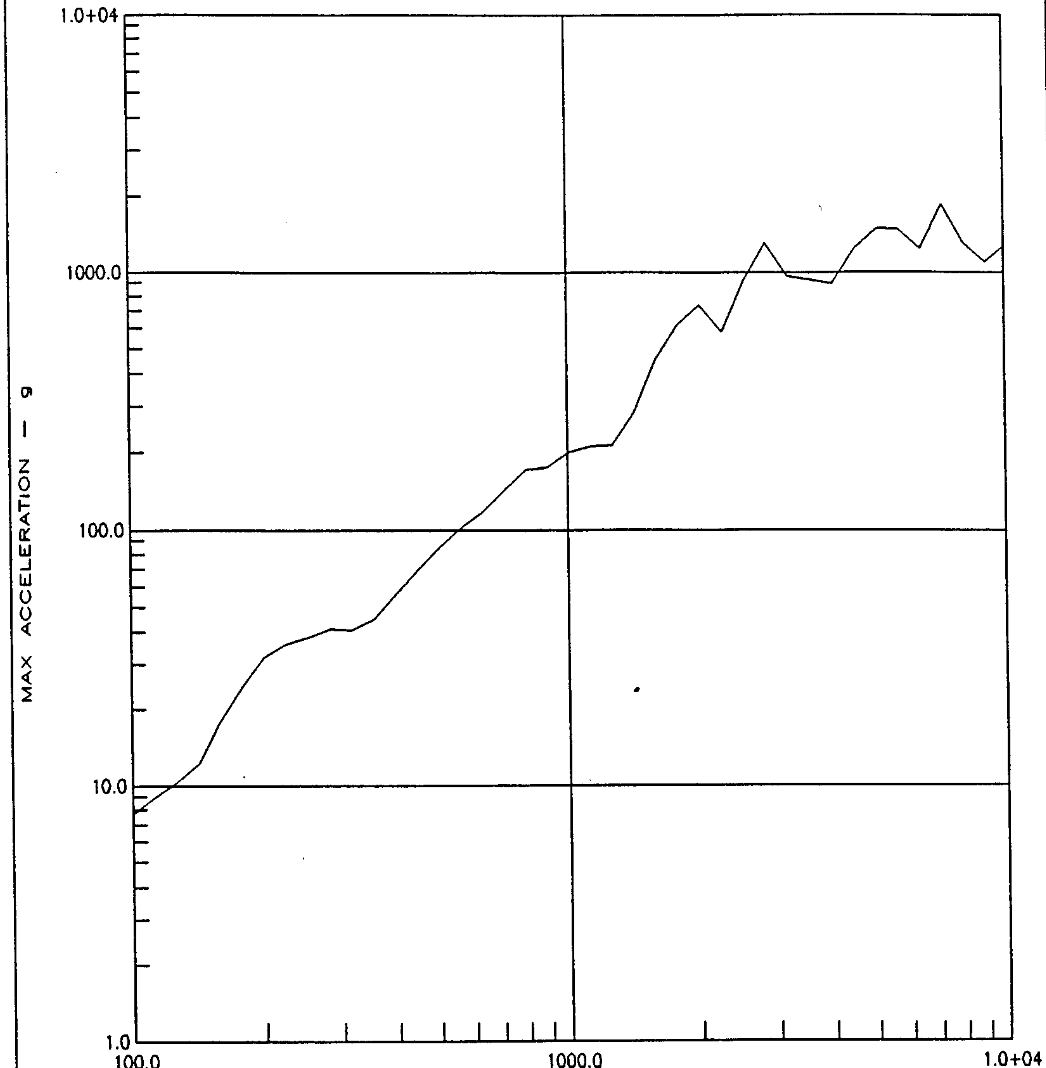
DATA TYPE: ABS MAX
Q: 10.000

RUN NUMBER: 1

DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS

CALC		12/21/88	IUS PYRO SHOCK TEST	
		10:49:27	RUN 1 FIXED NUT W/O RETAINER STUD 42K	
CHECK				
APPD	CJB	12/21/88		SHEET 15

SHOCK SPECTRA



CHANNEL NAME: A1Z
CHANNEL NUMBER: 3

DATA TYPE: ABS MAX
Q: 10.000

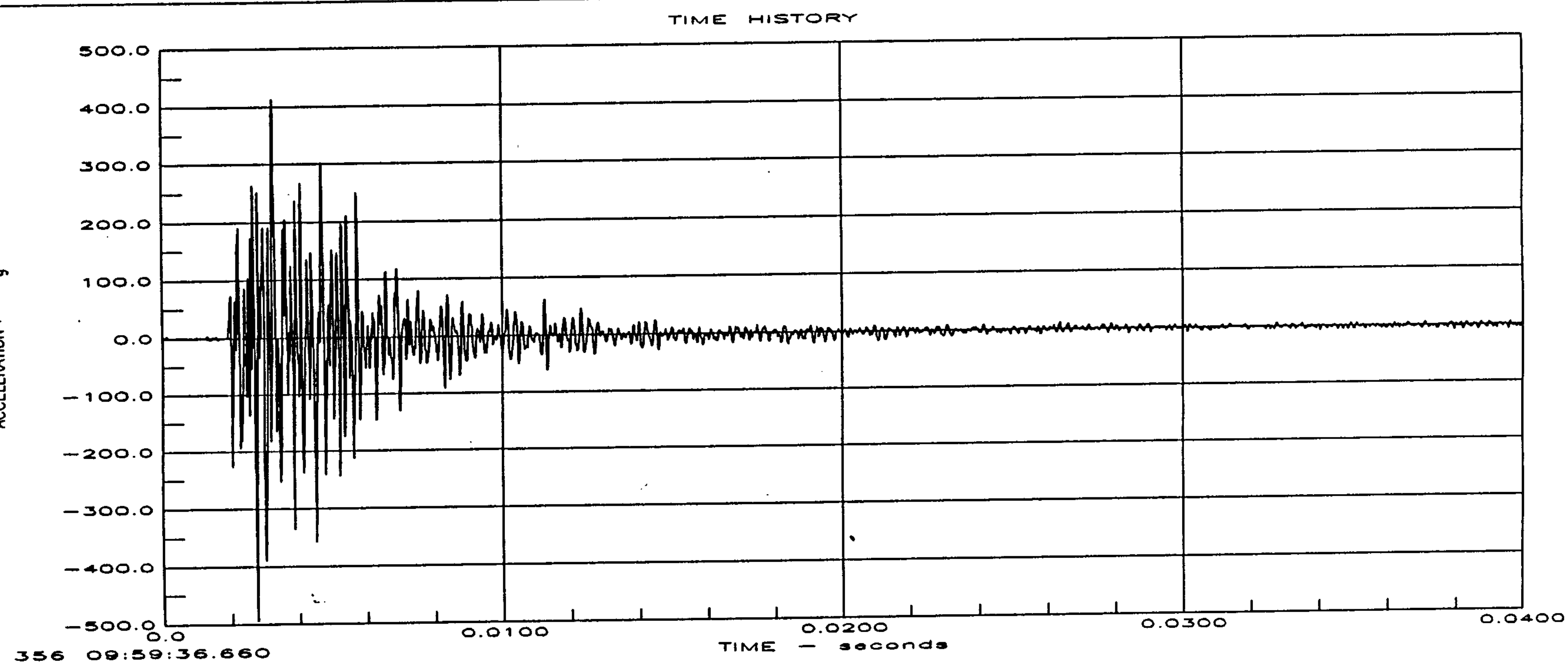
RUN NUMBER: 1

DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS

CALC		12/21/88	IUS PYRO SHOCK TEST
		10:48:02	RUN 1 FIXED NUT W/O RETAINER STUD 42K
CHECK			
APPD	VB	12/21/88	SHEET 16

The BOEING Company

Environmental Test Laboratories



CHANNEL NAME: A1X
CHANNEL NUMBER: 1
CHANNEL UNITS: G

DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS

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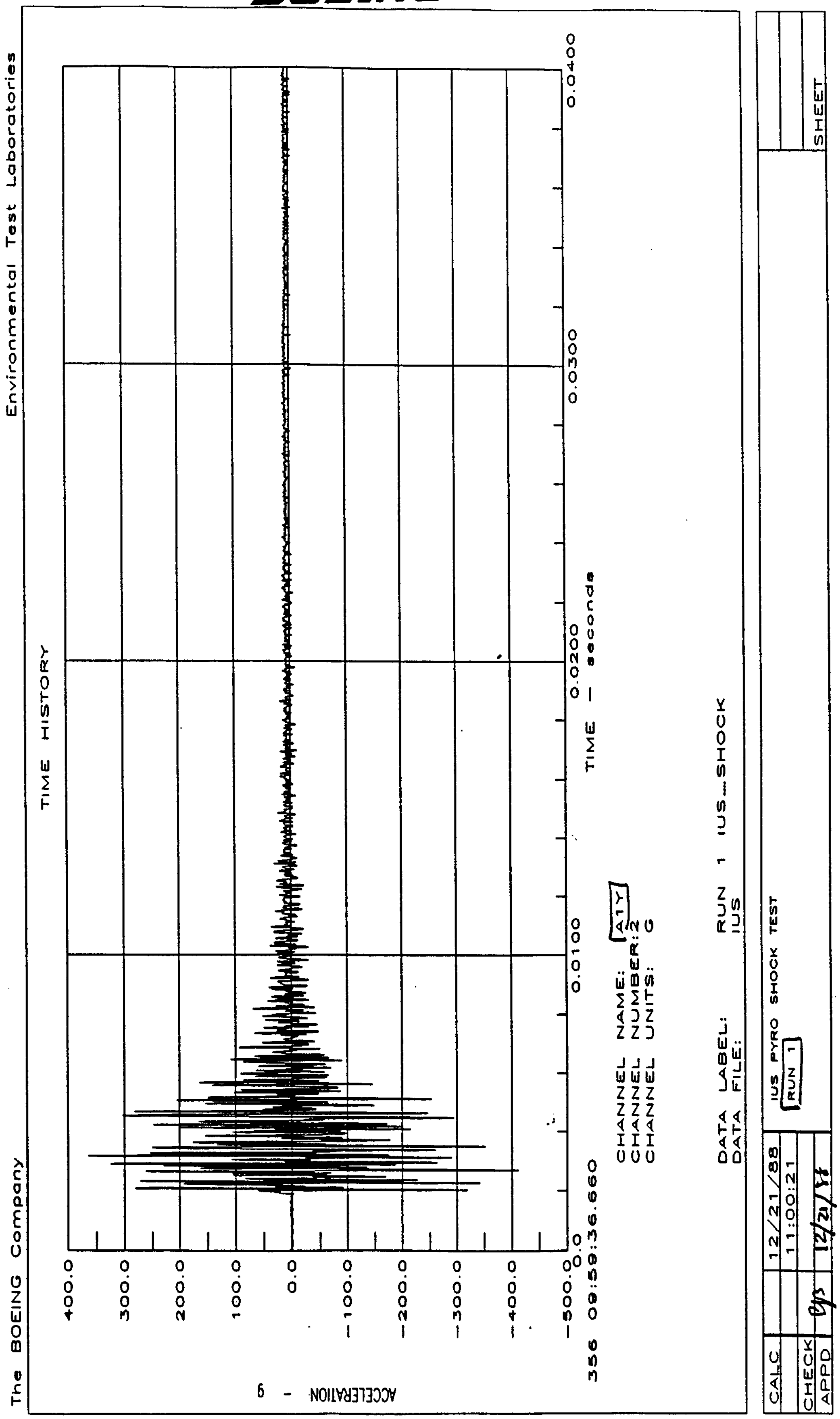
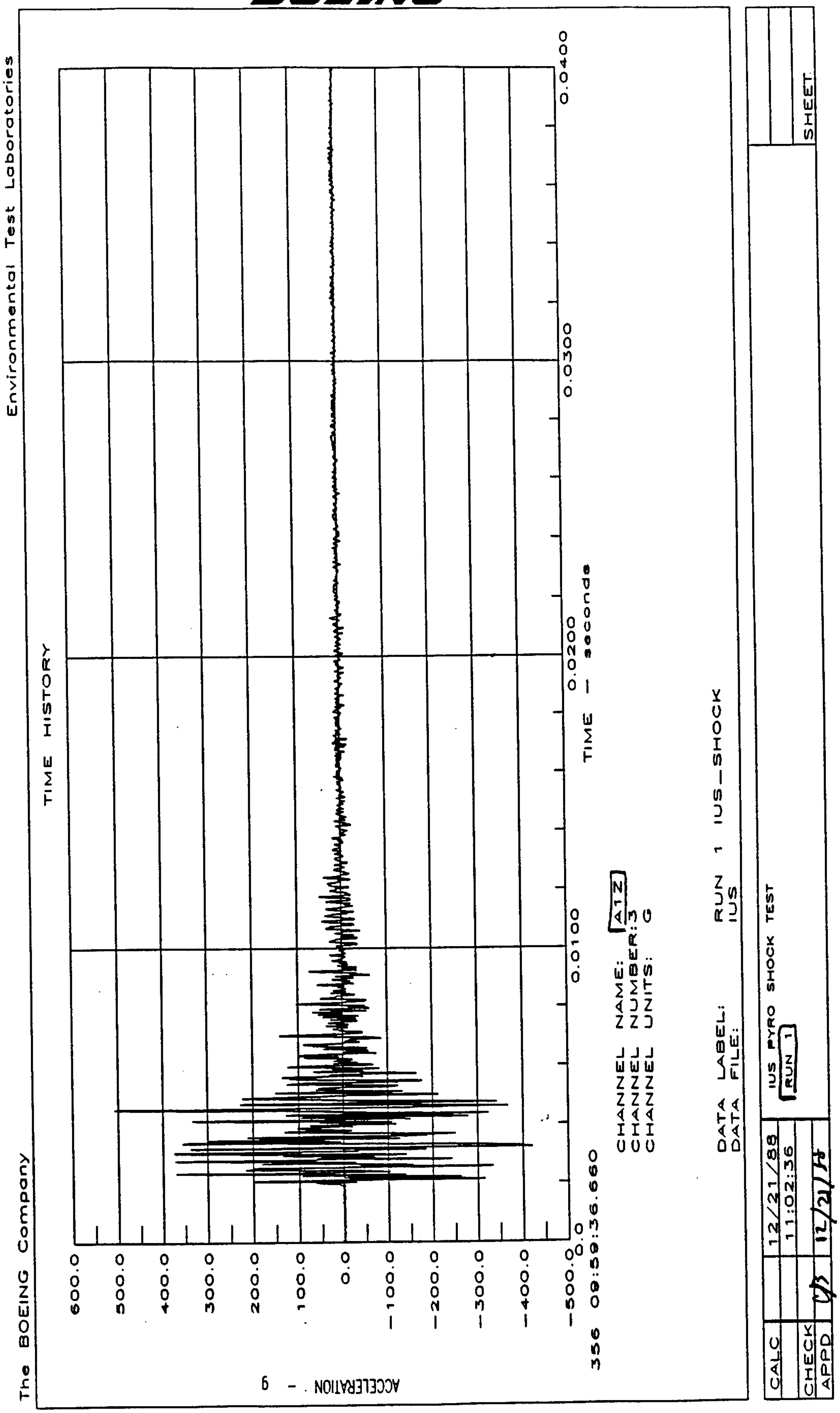
CHECK			
APPD	CJ3	12/21/88	SHEET

BOEING

17


The BOEING Company
Environmental Test Laboratories
TIME HISTORY
ACCELERATION - g
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
356 09:59:36.660
0.0
0.0100
0.0200
0.0300
0.0400
TIME — seconds
CHANNEL NAME: A1Y
CHANNEL NUMBER: 2
CHANNEL UNITS: G
DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS
CALC 12/21/88
11:00:21
CHECK
APPD 12/21/88
IUS PYRO SHOCK TEST
RUN 1
SHEET

18


The BOEING Company
Environmental Test Laboratories
TIME HISTORY
ACCELERATION - g
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400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
0.0
0.0100
0.0200
0.0300
0.0400
TIME - seconds
356 09:59:36.660
CHANNEL NAME: A1Z
CHANNEL NUMBER:3
CHANNEL UNITS: G
DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS
CALC
CHECK
APPD
12/21/88
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12/21/88
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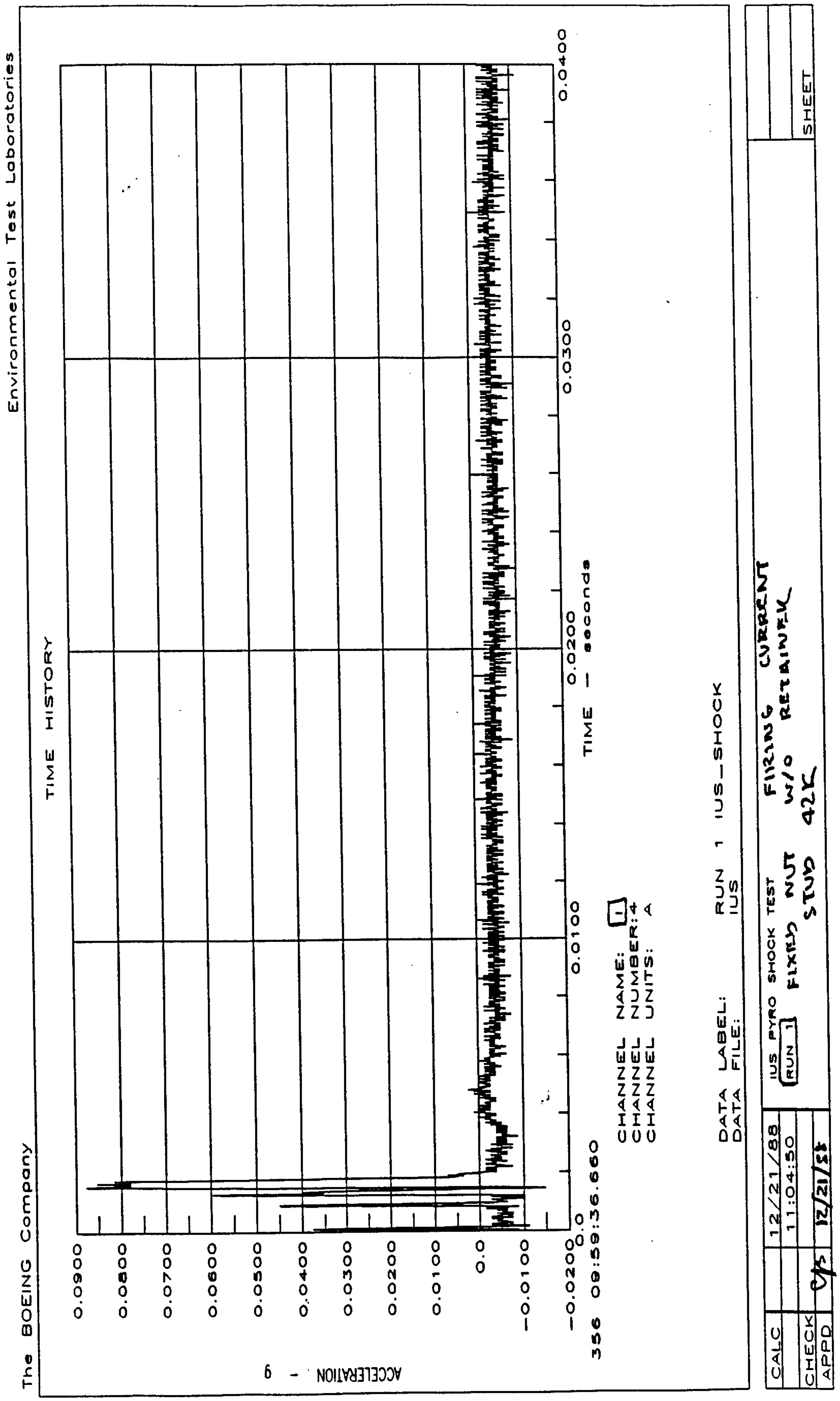
RUN 1
SHEET

19


The BOEING Company
Environmental Test Laboratories
TIME HISTORY
ACCELERATION - g
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0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0
-0.0100
-0.0200
0.0
0.0100
0.0200
0.0300
0.0400
TIME — seconds
356 09:59:36.660
CHANNEL NAME: 1
CHANNEL NUMBER: 4
CHANNEL UNITS: A
DATA LABEL: RUN 1 IUS_SHOCK
DATA FILE: IUS
IUS PYRO SHOCK TEST
RUN 1
FIXED NUT STUD
FIRING CURRENT W/O RETAINER
42K
CALC 12/21/88 11:04:50
CHECK
APPD 12/21/88
SHEET

20

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