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Test Plan and Report for Space Shuttle Launch Environment Testing of Bergen Cable Technology Safety Cable

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1.0 INTRODUCTION

Bergen Cable Technology (BCT) has introduced a new product they refer to as 'safety cable'. This product is intended as a replacement for lockwire when installed per Aerospace Standard (AS) 4536 (included in Appendix D). Installation of safety cable is reportedly faster and more uniform than lockwire. NASA / GSFC proposes to use this safety cable in Shuttle Small Payloads Project (SSPP) applications on upcoming Shuttle missions. To assure that BCT safety cable will provide positive locking of fasteners equivalent to lockwire, the SSPP will conduct vibration and pull tests of the safety cable.

2.0 TEST HARDWARE

Hardware to be used in the test includes the following items:

- BCT safety cable, 321 stainless steel, seven strand wire (0.030" diameter per manufacturer's literature - AS 3410 designates 0.035" nominal diameter).

- A test fixture consisting of a rectangular steel mass, match drilled and bolted to two Aluminum Association 8" x 5" I-beams, as shown in Figure 1, and in the mechanical drawings in Appendix C. Individual weights are as follows:

Component	Weight (lbs)
Test Mass	94.1
Nut bar #1	4.1
Nut bar #2	4.1
Nut bar #3	4.1
Nut bar #4	4.0
I-Beam #1	7.0
I-Beam #2	7.1
Total Comp. Wt.	124.5

  The weight of the assembled test fixture including test mass, two I-beams, four nut bars, all bolts securing the mass to the beams, and safety cable installed on the top bolts was approximately 127 lbs.

- A number of SSPP-supplied, flight certified, hardened bolts and appropriate countersunk washers of size 1/2", 3/8" and #10.

- An aluminum vibration table interface plate match drilled to the lower flange of the I-beams with Keenserts installed for bolting the I-beams.

The test fixture and safety cable wiring pattern are shown in Figures 1 and 2. Detailed drawings of the test fixture are included in Appendix C. All fasteners used in the test fixture will be torque striped to enable visual detection if the bolts rotate.

3.0 TEST OBJECTIVES

3.1 Vibration Test

The objective of the vibration test is to show that BCT safety cable is functionally equivalent to standard lockwire in all SSPP applications by conducting vibration tests at or beyond the General Environmental Verification Specifications for the STS.

3.2 Pull Test

AS 4536 states that the safety cable/ferrule assembly shall have a minimum pull-off load of 70 lbs. for 0.035" nominal diameter cable. The cable pull test of the BCT 0.030" diameter cable will verify that the BCT cable/ferrule assembly exceeds this minimum strength requirement. In addition, the pull test will verify the calibration of the BCT-supplied electronic cable pull-tester.

If the above objectives are achieved, SSPP intends to substitute BCT safety cable for standard lockwire to the maximum extent possible in all future SSPP payloads.

4.0 TEST SPECIFICATION

4.1 Vibration Test

Random vibration testing in three orthogonal axes will be conducted for 5 minutes in each axis. Vibration testing will use a test mass bolted to the top of a fixture which supports the mass 8 inches above the vibration table platform. Bolts attaching the mass to the fixture and securing the fixture to the vibration table interface plate will have safety cable installed.

Two series of tests will be run. In the first test sequence, each fastener will be torqued to values typically used for the fasteners in SSPP applications and safety cable will be installed per AS 4536. Specified torque values are shown in Table 1; actual values will be recorded in the supplied locations on the table. Bolts will be tightened in the numerical order shown in the Table.

For the second test sequence, each fastener will be loosened and then re-torqued to 25% of the values in the first test (see Table 2). Safety cable will again be installed per the manufacturer's specification and torque striping re-applied. Table 2 will be used to record actual torque values. Bolts will be tightened in the numerical order shown in Table 2.

For each test sequence the input vibration spectrum will be specified below:

Frequency (H_z)	ASD Level
50-500	0.1
500-2000	-3.0 db/oct
2000	0.025

Overall 10.9 G_{rms}

4.2 Pull Test

For the pull test, ten (10) randomly selected cables will be tested to failure on a Tinius-Olsen testing machine. To pull the cables on the Tinius-Olsen machine, two 1/4" thick aluminum plates will have 0.032" diameter holes drilled through their centers. These plates will be placed on the top and bottom anvils of the Tinius-Olsen pull test machine. A BCT safety cable will then be threaded through the holes in the aluminum plate and a securing ferrule crimped on using standard procedures as supplied by BCT. The cable will then be tested to failure and the tension at which the cable failed will be recorded. To provide statistical variance, a sample of ten (10) cables will be tested. See Figure 4 for details of the test setup.

5.0 TEST ORGANIZATION

The test will be conducted with support from GSFC Code 741 and Code 754. Code 754 and NSI will provide the facilities and necessary operating personnel for conducting the test and for acquiring and reducing the data. Code 754 will provide the Facility Engineer while Code 741 will provide the test plan and Test Engineer.

6.0 TEST FACILITIES

The test shall be performed in the Environmental Test Facility at the GSFC. The test facilities performance shall be verified and in calibration prior to the start of the test. The required test facilities and equipment are:

- Test fixture and mass (Code 741)
- Calibrated torque wrenches (Code 741)
- Vibration Table (Code 754)
- Photographic and video record of test set-up (Code 741)
- Accelerometer (Code 754)

7.0 TEST SET-UP

The test fixture with attached mass (see Attachments for detailed drawings) will be bolted directly to a shake table interface plate. The bottom of the test fixture will be drilled with through holes for each bolt. The interface plate between the test fixture and shake table will be supplied and match drilled by Code 754. Although this is a test of only the safety cable, one accelerometer will be mounted to the top of the test mass to monitor for a possible harmonic vibration. Figure 3 shows the reference bolt numbers for each bolt used in the test.

8.0 TEST DATA

Data required by Code 741 at the conclusion of the vibration test will be strip charts of the table vibration spectrum for all three test axes. This chart will plot power density (G^2/H_Z) vs. frequency (H_Z).

For the cable pull test, test data will be recorded directly from the Tinius-Olsen machine readout dial.

9.0 TEST SUMMARY AND RESULTS

9.1 Vibration Series One: Full Flight Torque Values

9.1.1 X-axis Test— As shown in the accompanying photographs and drawings, the test fixture was first attached to the vibration table interface plate. The interface plate was then bolted to the vibration table oriented such that the web of the fixture I-beams was parallel to the direction of motion of the vibration table. For reference purposes, this axis was designated 'X'.[1]

Each bolt identified in Table 1 was tightened in the sequence shown. Initially, each bolt was tightened to 1/2 the final value, then the sequence was repeated to the full specified torque. After completing the tightening sequence, safety cable was installed on the test bolts in the patterns shown in Figure 2a and each bolt was painted with a torque stripe. Final installation is documented in photographs included in Appendix B.

The vibration test was then started. Shake table power input levels were slowly increased to the maximum value specified in Section 4.1. This power input level was continued over the specified spectrum for five (5) minutes. The test fixture and cables were closely observed during the test to identify possible problems. No anomalies were observed during the test.

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[1] For ease of moving the fixture for testing of the different axes, the bolts attaching the fixture to the interface plate were not removed once torqued. Only the bolts securing the interface plate to vibration table were removed to allow rotation of the fixture for Y-axis testing and for moving the fixture to the Z-axis testing machine.

Following shutdown of the vibration table, each bolt was inspected for evidence of torque stripe cracking or safety cable loosening. No such evidence was found.

9.1.2 Y-axis Test— After completing the X-axis vibration test, the interface plate was unbolted from the shake table, rotated 90 degrees and re-bolted to the shake table. This orientation, with the fixture I-beam webs perpendicular to the shake table direction of motion, was designated 'Y'.

The vibration sequence was conducted again as described above. As expected, during the Y-axis vibration there was much more apparent motion of the test mass due to bending of the fixture I-beams.

After vibration table shutdown, the bolts were inspected and no movement of the bolts or loosening of the cables was noted.

9.1.3 Z-axis Test— For the Z-axis test, the interface plate was removed from the X-Y vibration table and installed on the vertical shake table. As noted above, loosening or removal of the test bolts was not required to accomplish this move. The vibration table drivers were set up by Code 754 in accordance with the specification in Section 2.1 and the test was started.

During the power ramp-up, an occasional audible 'ringing' was noted from the test fixture. When full power level was reached, the vibration table immediately shut down due to harmonic feedback. Code 754 increased by 50% the allowable G-level for the feedback monitor and the test was restarted. Once again, the table automatically shut down when full input power was reached. Code 754 again increased the allowable G-level to a maximum of 30g and restarted the test sequence. Again, upon reaching full input power, the table automatically shut down.

Inspection of the table monitor accelerometer data indicated that the audible ringing noted during the initial test sequence was at approximately 800 H_Z. Since this frequency was above the level deemed of greatest interest for this test, it was decided to modify the input vibration spectrum. For the Z-axis test only, the random vibration spectrum was changed to cut off frequencies above 500 H_Z. The test was then restarted and ran to completion without further shutdown of the table.

After completion of the Z-axis vibration, the bolts and cables were inspected and no problems or anomalies were noted.

9.2 Vibration Series Two: One-Quarter Flight Torque Values

Following completion of the Z-axis vibration at full flight torque values, the safety cables were cut and all bolts were loosened and removed. Breakaway torque values were recorded on Table 1.

All torque striping was removed from the bolts and the bolts were re-installed and torqued to approximately 25% of the flight values used above. Safety cables were again installed according to the pattern shown in Figure 2b.

The vibration sequences were run again starting with the Z-axis, then X and Y. Following vibration in each axis, the bolts, torque stripes and cables were observed for any evidence of bolt rotation or cable loosening. As in the full torque tests, no anomalies were noted. Actual torques values and breakaway torque values are recorded on Table 2.

TABLE 1
Test Sequence 1 Torque Values

Bolt #	Specified Torque (in-lb)	Actual Torque	Initials	Breakaway Torque
4 (1/2")	590	600	[illegible]	41 FP
5 (1/2")	600		[illegible]	37 FP
6 (1/2")	610		[illegible]	41 FP
11 (1/2")	575	600	[illegible]	40 FP
12 (1/2")	585		[illegible]	38 FP
10 (1/2")	565		[illegible]	39 FP
1 (1/2")	560	600	[illegible]	35 FP
2 (1/2")	570		[illegible]	41 FP
3 (1/2")	580		[illegible]	39 FP
13 (3/8")	290	290	[illegible]	20 FP
14 (3/8")	290		[illegible]	19 FP
15 (3/8")	290		[illegible]	20 FP
16 (3/8")	290		[illegible]	18 FP
9 (3/8")	300	290	[illegible]	19 FP
7 (3/8")	280		[illegible]	18 FP
8 (3/8")	290		[illegible]	18 FP
not wired { 20 (1/2")	590	600	[illegible]	38 FP
21 (1/2")	590		[illegible]	39 FP
22 (1/2")	590		[illegible]	40 FP
17 (3/8")	290	300	[illegible]	280 in-lb
18 (3/8")	290		[illegible]	310 in-lb
19 (3/8")	290		[illegible]	270 in-lb
23 (#10)	30	30	[illegible]	30 in-lb
24 (#10)	30		[illegible]	20 in-lb
25 (#10)	30		[illegible]	25 in-lb
26 (#10)	30	30	[illegible]	25 in-lb
27 (#10)	30		[illegible]	25 in-lb
28 (#10)	30		[illegible]	30 in-lb
not wired { 35 (1/2")	595		[illegible]	35 FP
36 (1/2")	605	600	[illegible]	36 FP
37 (1/2")	615		[illegible]	34 FP
32 (3/8")	280		[illegible]	290 in-lb
33 (3/8")	290	300	[illegible]	280 in-lb
34 (3/8")	300		[illegible]	290 in-lb
29 (#10)	30		[illegible]	25 in-lb
30 (#10)	30	30	[illegible]	25 in-lb
31 (#10)	30		[illegible]	25 in-lb
38 (#10)	30		[illegible]	20 in-lb
39 (#10)	30	30	[illegible]	25 in-lb
40 (#10)	30		[illegible]	20 in-lb
41-48 (3/8")		300	[illegible]	280-290 in-lb
49 (#10, control)		30	[illegible]	25 in-lb

BREAKWAY TORQUE WRENCHES

① ID M144041
CAL 26FEB92
DUE -26FEB93
Rng 0-175 FP

② ID-M16619
CAL-07 APR92
DUE 07 APR92
Rng - 0-150 in-lb

③ ID C66231
CAL 25 Feb 92
Due 25 Feb 92
Rng 0-300 in lb

Tighteng Torque wrenchs

① ID-M17125
CAL 14AUG 91
Due 14 AUG 92
Rng 30-200 in lb

② ID- M141331
CAL 14AUG 91
Due 14 Aug 92
Rng 150-1000 in lb

TABLE 2

Test Sequence 2 Torque Values

Bolt #	Specified Torque (in-lb)	Actual Torque	Initials	Breakaway Torque
4 (1/2")	140	140	MB	125 in-lb
5 (1/2")	150	150	↓	115 in-lb
6 (1/2")	150	150	↓	83 in-lb
11 (1/2")	145	145	MB	140 in-lb
12 (1/2")	145	↓	↓	130 in-lb
10 (1/2")	145	↓	↓	145 in-lb
1 (1/2")	140	140	MB	60 in-lb
2 (1/2")	140	140	↓	120 in-lb
3 (1/2")	140	140	↓	100 in-lb
13 (3/8")	70	70	MB	60 in-lb
14 (3/8")	70	70	↓	60 in-lb
15 (3/8")	70	70	↓	55 in-lb
16 (3/8")	70	70	↓	60 in-lb
9 (3/8")	70	70	MB	63 in-lb
7 (3/8")	70	70	↓	40 in-lb
8 (3/8")	75	75	↓	70 in-lb
20 (1/2")	140	140	MB	125 in-lb
21 (1/2")	140	140	↓	125 in-lb
22 (1/2")	140	140	↓	135 in-lb
17 (3/8")	75	75	MB	79 in-lb
18 (3/8")	75	75	↓	70 in-lb
19 (3/8")	75	75	↓	59 in-lb (#49) CNTR 8.5 in-lb.
23 (#10)	8	8	MB	8 in-lb
24 (#10)	8	8	↓	9 in-lb
25 (#10)	8	8	↓	9 in-lb
26 (#10)	8	8	↓	6 in-lb
27 (#10)	8	8	↓	8 in-lb
28 (#10)	8	8	↓	7 in-lb
35 (1/2")	140	140	MB	135 in-lb
36 (1/2")	140	140	↓	146 in-lb
37 (1/2")	150	150	↓	145 in-lb
32 (3/8")	75	75	MB	70 in-lb
33 (3/8")	75	75	↓	68 in-lb
34 (3/8")	75	75	↓	70 in-lb
29 (#10)	8	8	MB	5 in-lb
30 (#10)	8	8	↓	5 in-lb
31 (#10)	8	8	↓	6 in-lb
38 (#10)	10	10	MB	7.5 in-lb
39 (#10)	10	10	↓	7 in-lb
40 (#10)	10	10	↓	7.5 in-lb
41-48 (3/8")		75	RW	70 in-lb

3/8 CNTR 75-85 in-lb.

9.3 Safety Cable Pull Test

To verify the strength of the BCT safety cable/ferrule assembly, and as a check of the functioning of the BCT electronic testing machine (BCT part No. MPT-200A), a sample of ten (10) 321 stainless steel 0.030" safety cables were tested to failure on the GSFC Tinius-Olsen (T-O) Model AD test machine.

The BCT electronic tester measures the ultimate strength of a crimped cable/ferrule assembly and is used to verify proper operation of the crimp tool. Five tests of 0.030" safety cables were conducted on the electronic tester prior to starting the T-O pull test. The average crimped ferrule pull-off tension measured by the electronic tester was 100 lbs.

For the T-O pull test, each cable/ferrule assembly was threaded, in turn, through a 0.032" diameter hole in each of two 1/4" thick aluminum plates. These plates were placed on the top and bottom anvils of the T-O machine as shown in Figure 4. A crimped ferrule was then installed on the cable per AS 4536 and the cable/ferrule assembly was pulled to failure. Results of the ten pull tests are shown below.

SAMPLE	TENSION(lbs)	COMMENT
1	100.0	
2	103.0	
3	105.0	
4	102.0	
5	83.0	Due to operator error, only 1/2 of the ferrule length was crimped.
6	101.0	
7	101.0	
8	102.5	
9	103.5	
10	100.0	

Average - 100.1 lbs.

AS 4536 minimum specified value - 70 lbs.

Note: Eight of ten failures were at the factory-applied ferrule end of the safety cable.

10.0 CONCLUSIONS

Based on the results of the above tests, the following conclusions have been reached:

1. When installed according to the manufacturers' and AS 4536 specifications, 0.030" diameter 321 stainless steel safety cable is functionally equivalent to standard lockwire.

2. 0.030" diameter, 321 stainless steel BCT safety cable may be substituted for standard lockwire on any SSPP fasteners from size #10 up to 1/2" diameter.

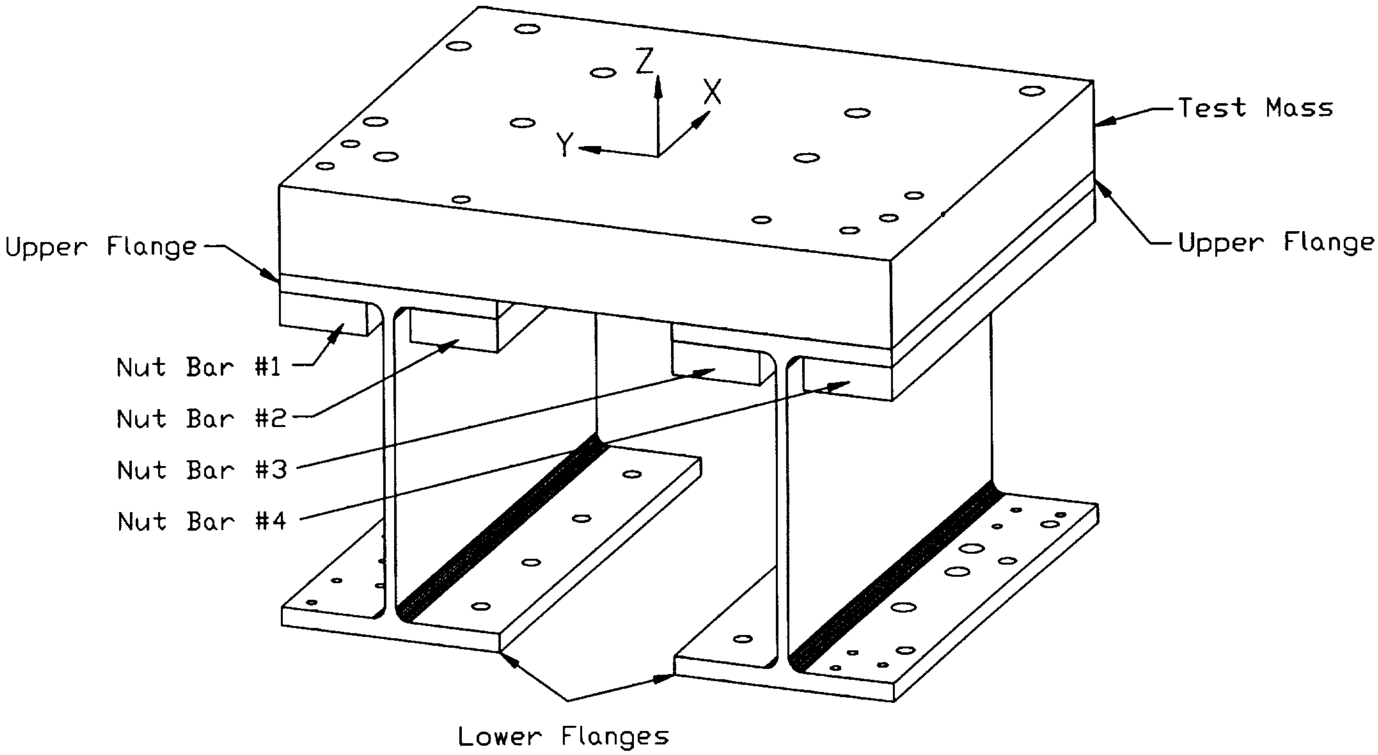

Figure 1: Test Fixture

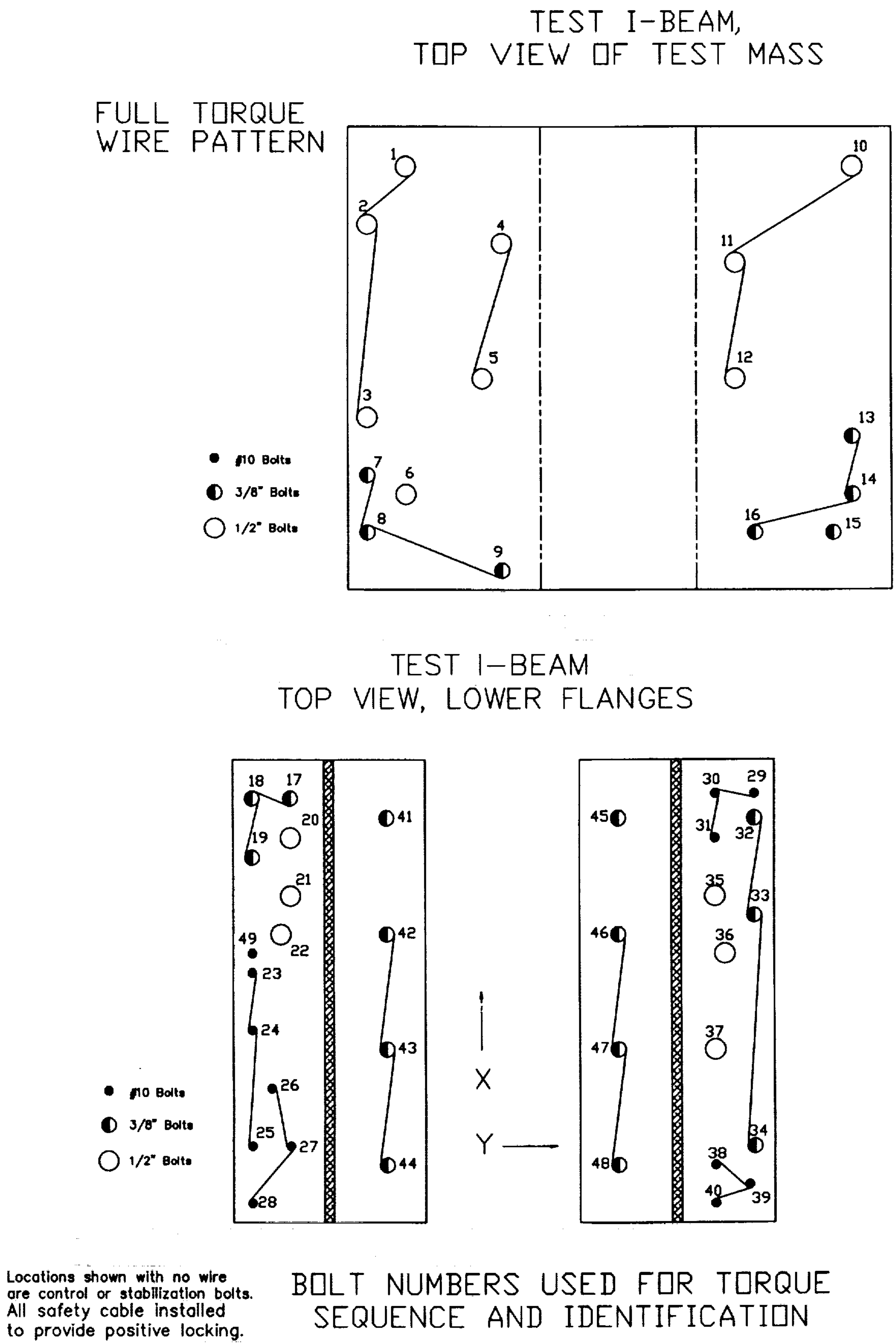

Figure 2a: Test Fixture, Wire Pattern, Full Torque Test

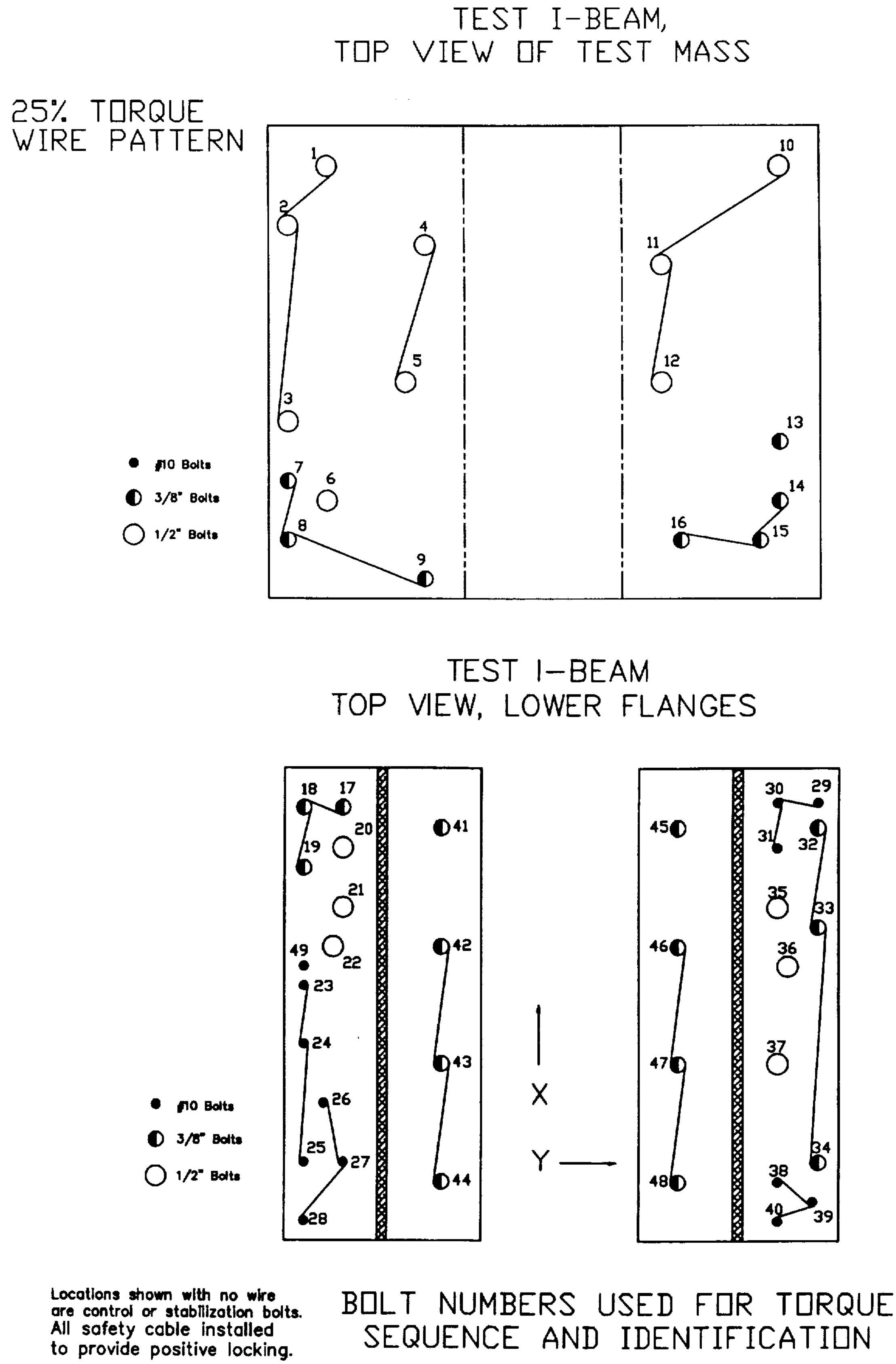

Figure 2b: Test Fixture, Wire Pattern, One Quarter Torque Test

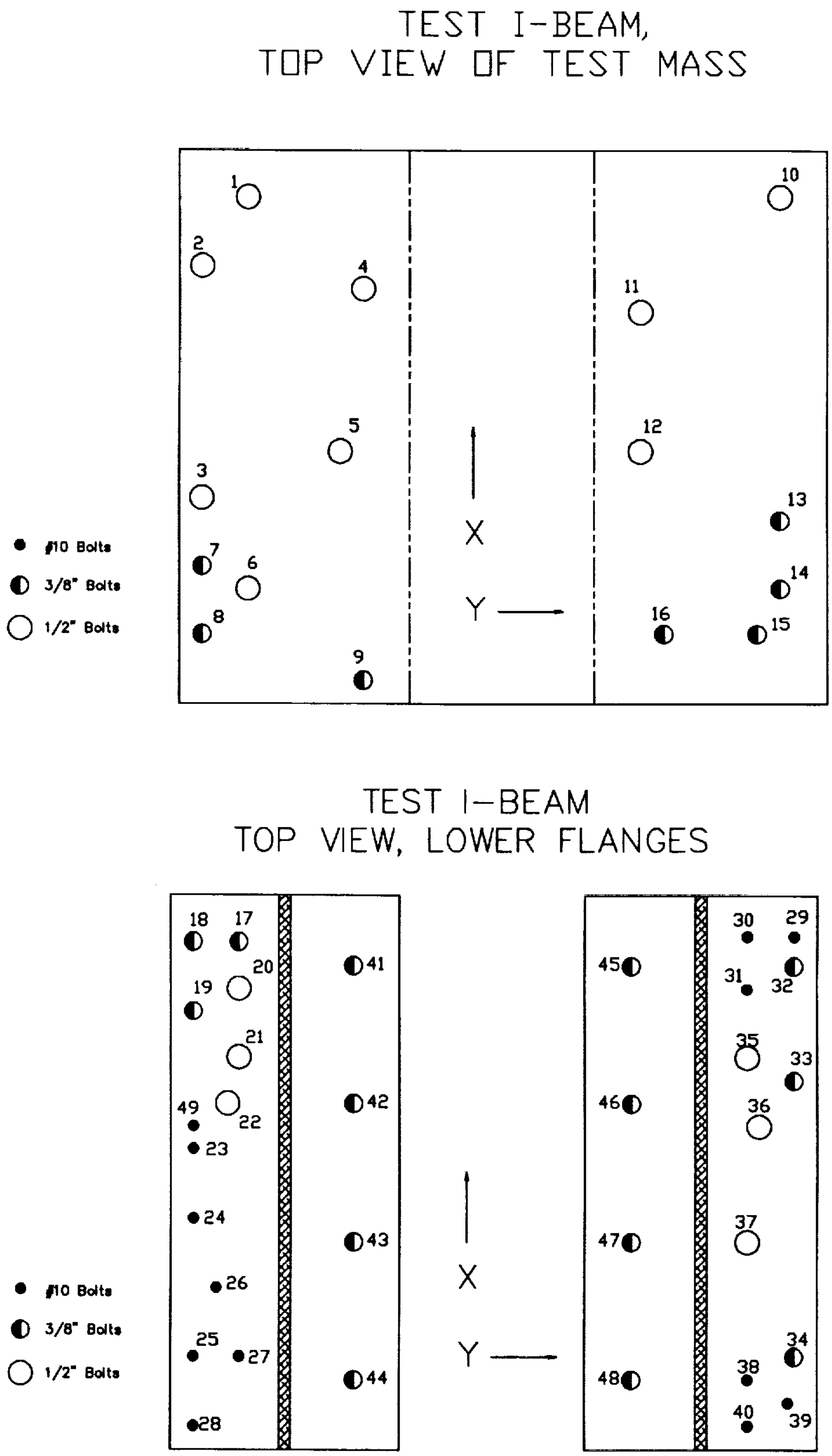

Figure 3: Test Fixture, Bolt Numbers

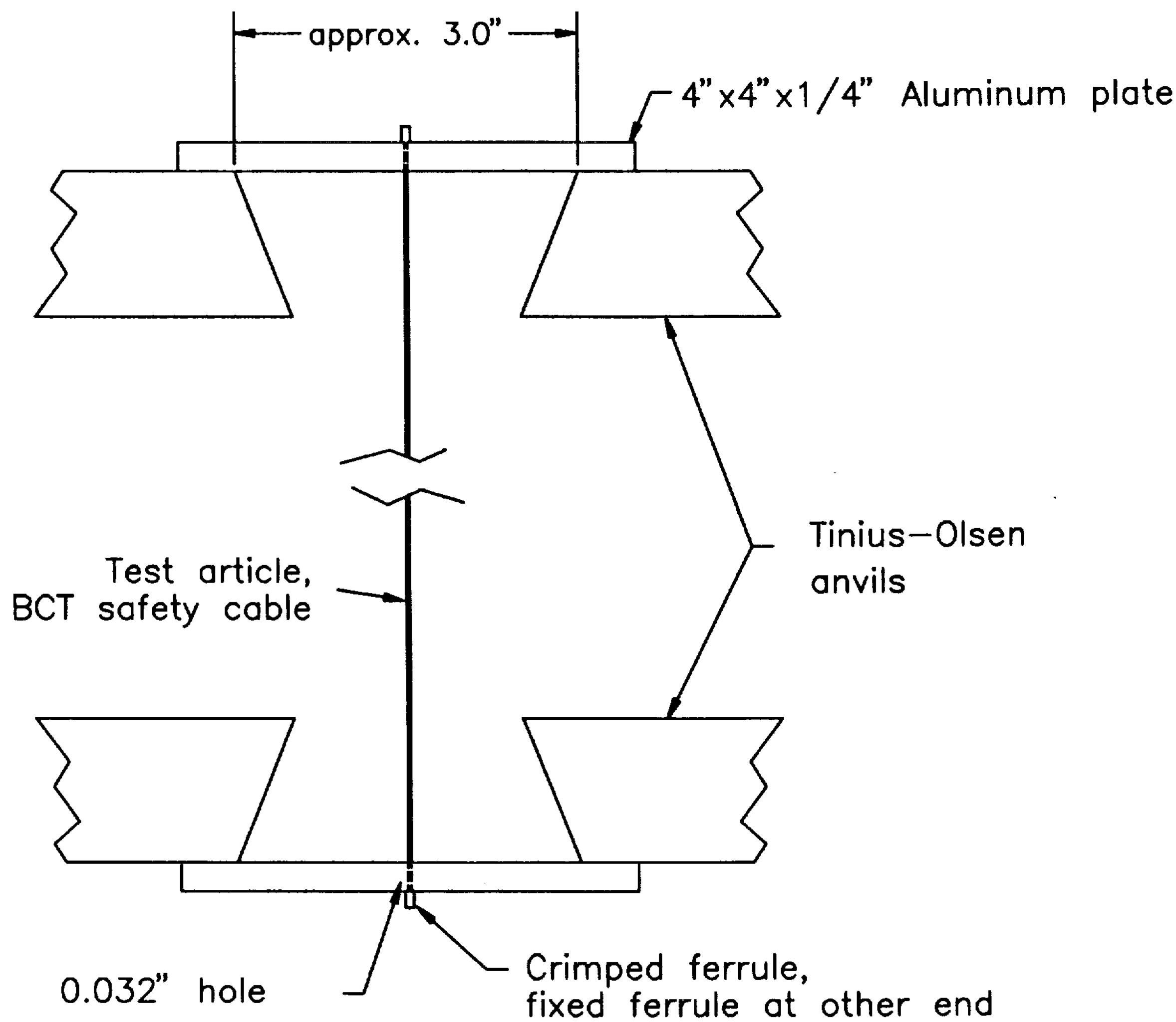

Figure 4: Pull Test Setup

APPENDIX A

Vibration Test Report

Data Analysis Review Summary

HITCHHIKER Bergen safety Cable						
TAR: 8815						
Test Date: 5/13-5/14/92						
Run Number:		Run 4		Run 8		Run 13
Test Description:		10.9 grms Random		10.9 grms Random		7.1 grms Random
Axis		X Axis		Y Axis		Z Axis
Freq. Range:		10-2000 Hz		10-2000 Hz		10-500 Hz
		(5 minutes)		(5 minutes)		(5 minutes)
Sample Rate:		6400 s/sec		6400 s/sec		1600 s/sec
A.A. Filter:		2500 Hz		2500 Hz		625 Hz
Resolution:		6.25 Hz		6.25 Hz		1.5625 Hz
File Name:		hh_bct_04.ati		hh_bct_08.ati		hh_bct_13.ati
Channel	Sensitivity	PSD Overall Level	Sensitivity	PSD Overall Level	Sensitivity	PSD Overall Level
Input Monitor	30 g/v	9.791 grms	100 g/v	9.979 grms	100 g/v	6.310 grms
Response X	100 g/v	21.513 grms	100 g/v	0.744 grms	100 g/v	0.923 grms
Response Y	100 g/v	2.692 grms	100 g/v	8.788 grms	100 g/v	0.236 grms
Response Z	100 g/v	15.146 grms	100 g/v	3.361 grms	100 g/v	7.927 grms
Run Number:		Run 15		Run 17		Run 19
Test Description:		7.1 grms Random		10.9 grms Random		10.9 grms Random
Axis		Z Axis		X Axis		Y Axis
Freq. Range:		10-500 Hz		10-2000 Hz		10-2000 Hz
		(5 minutes)		(5 minutes)		(5 minutes)
Sample Rate:		1600 s/sec		6400 s/sec		6400 s/sec
A.A. Filter:		625 Hz		2500 Hz		2500 Hz
Resolution:		1.5625 Hz		6.25 Hz		6.25 Hz
File Name:		hh_bct_15.ati		hh_bct_17.ati		hh_bct_19.ati
Channel	Sensitivity	PSD Overall Level	Sensitivity	PSD Overall Level	Sensitivity	PSD Overall Level
Input Monitor	30 g/v	6.232 grms	100 g/v	9.849 grms	100 g/v	9.792 grms
Response X	100 g/v	0.585 grms	300 g/v	17.687 grms	100 g/v	0.624 grms
Response Y	100 g/v	0.266 grms	100 g/v	5.264 grms	300 g/v	8.366 grms
Response Z	100 g/v	9.143 grms	100 g/v	18.443 grms	100 g/v	2.699 grms

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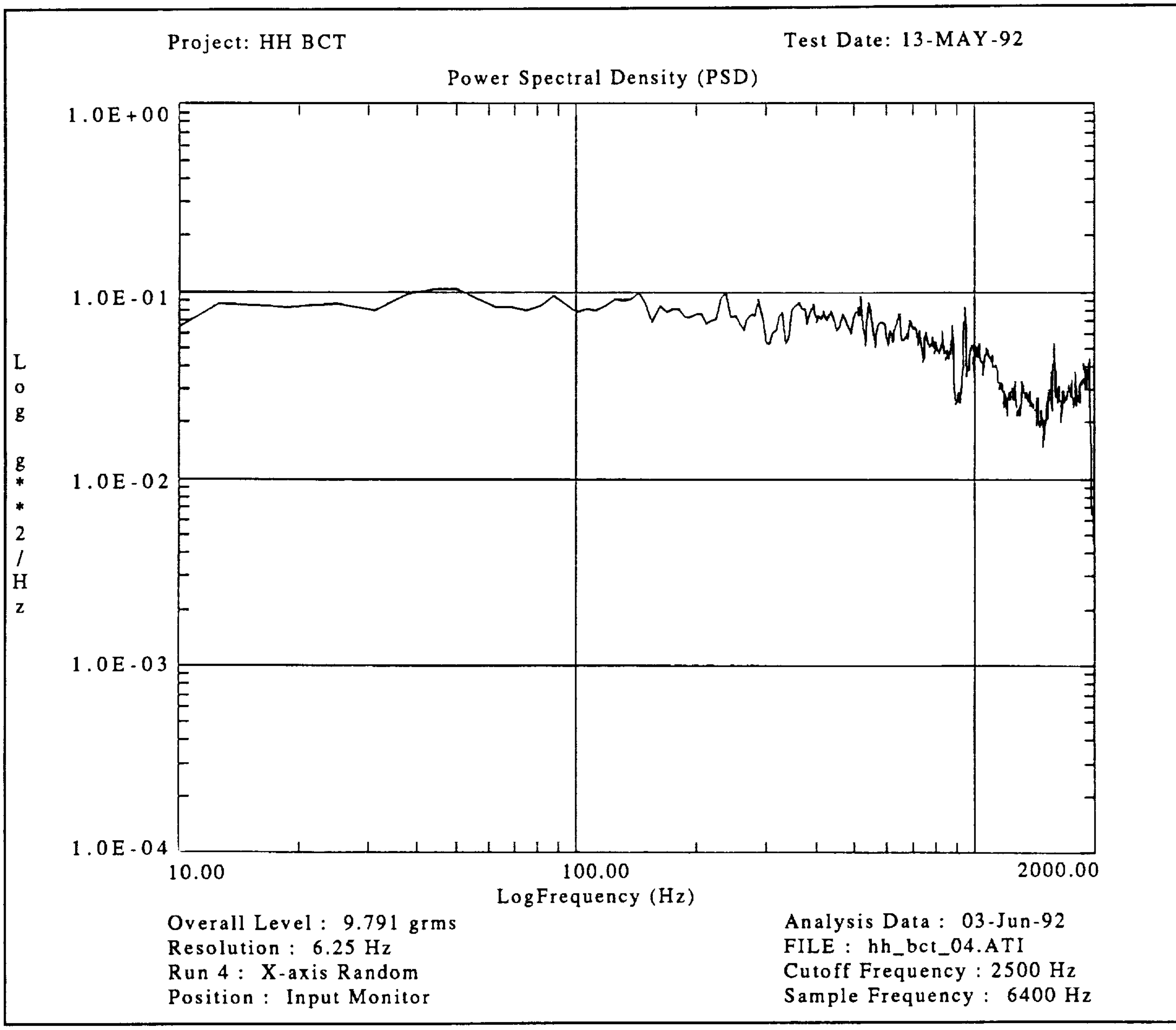
<u>Test Block Data</u>

Run 4 (X Axis)
10.9 G_{rms} Random Vibration
10-2000 H_Z Input
Full Torque on Bolts



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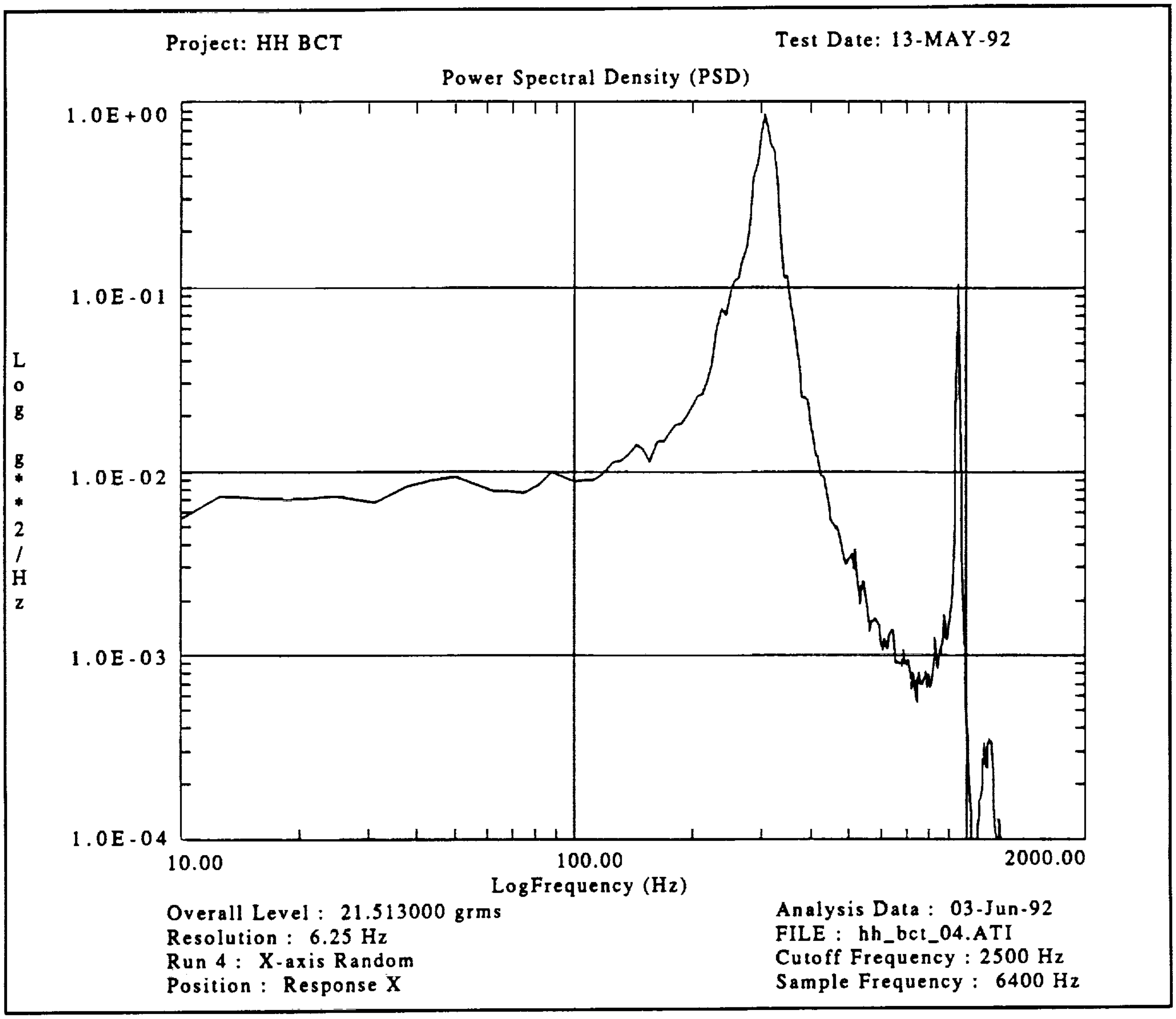
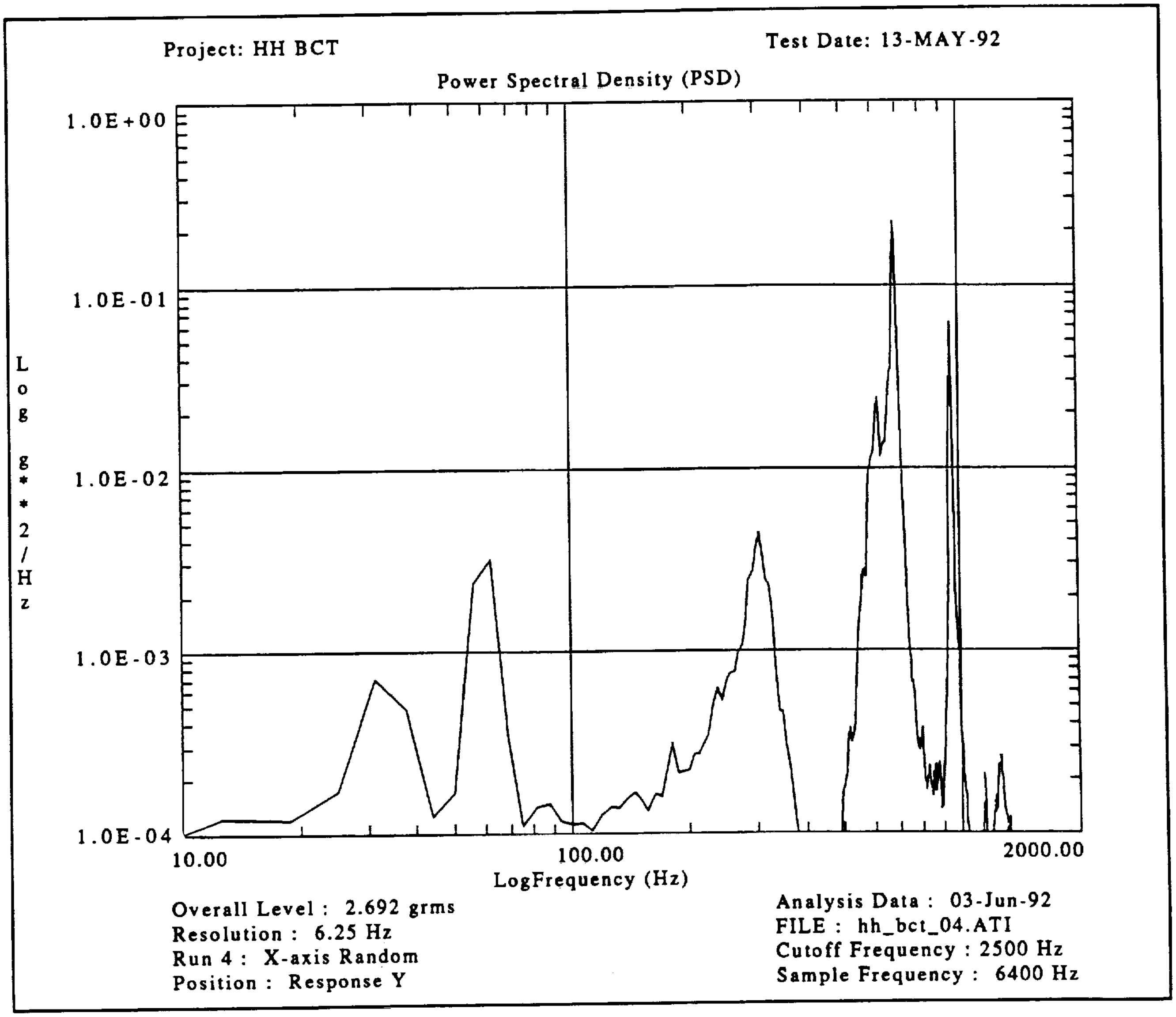
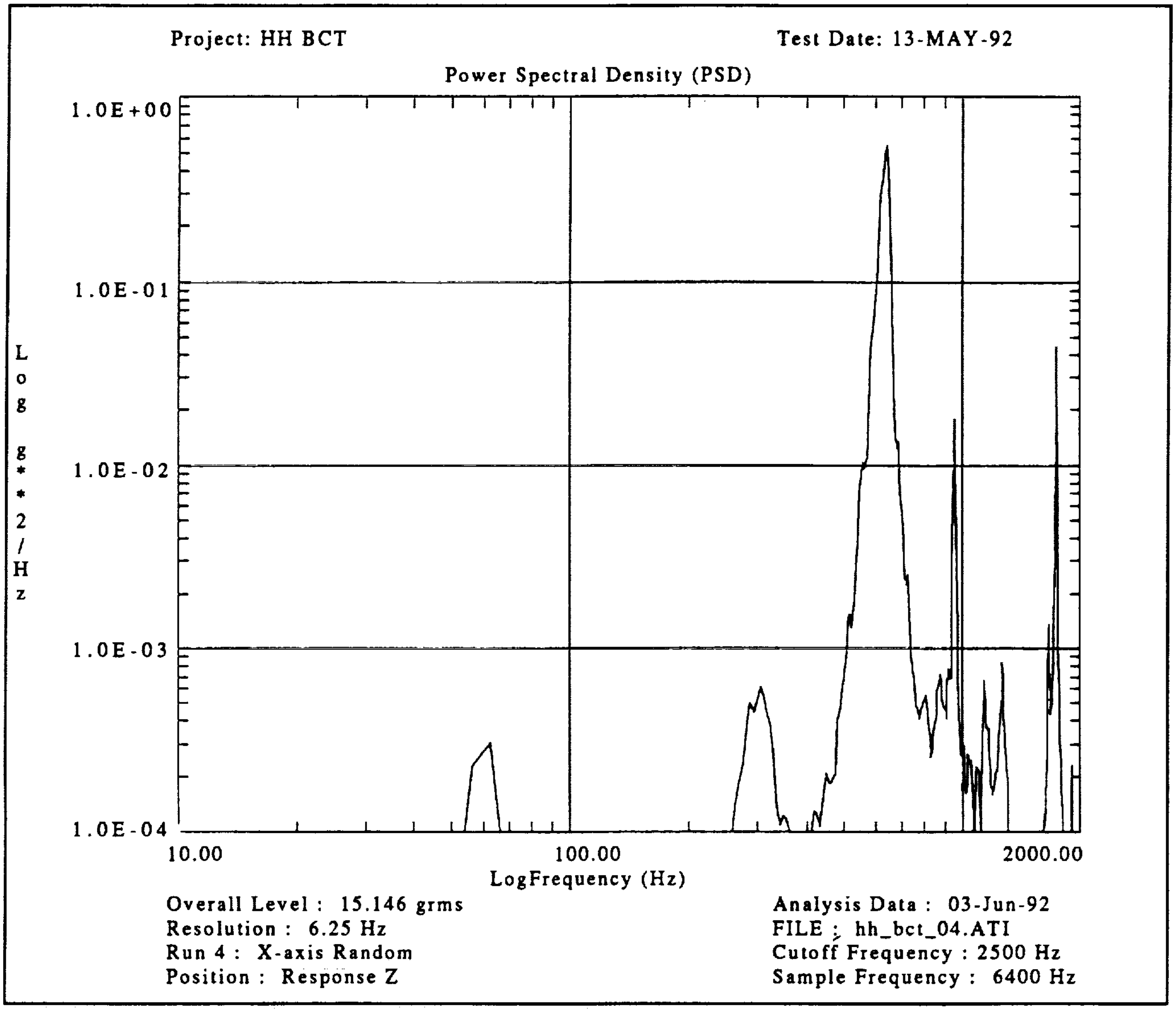


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 21.513000 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_04.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 2.692 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_04.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 15.146 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_04.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz

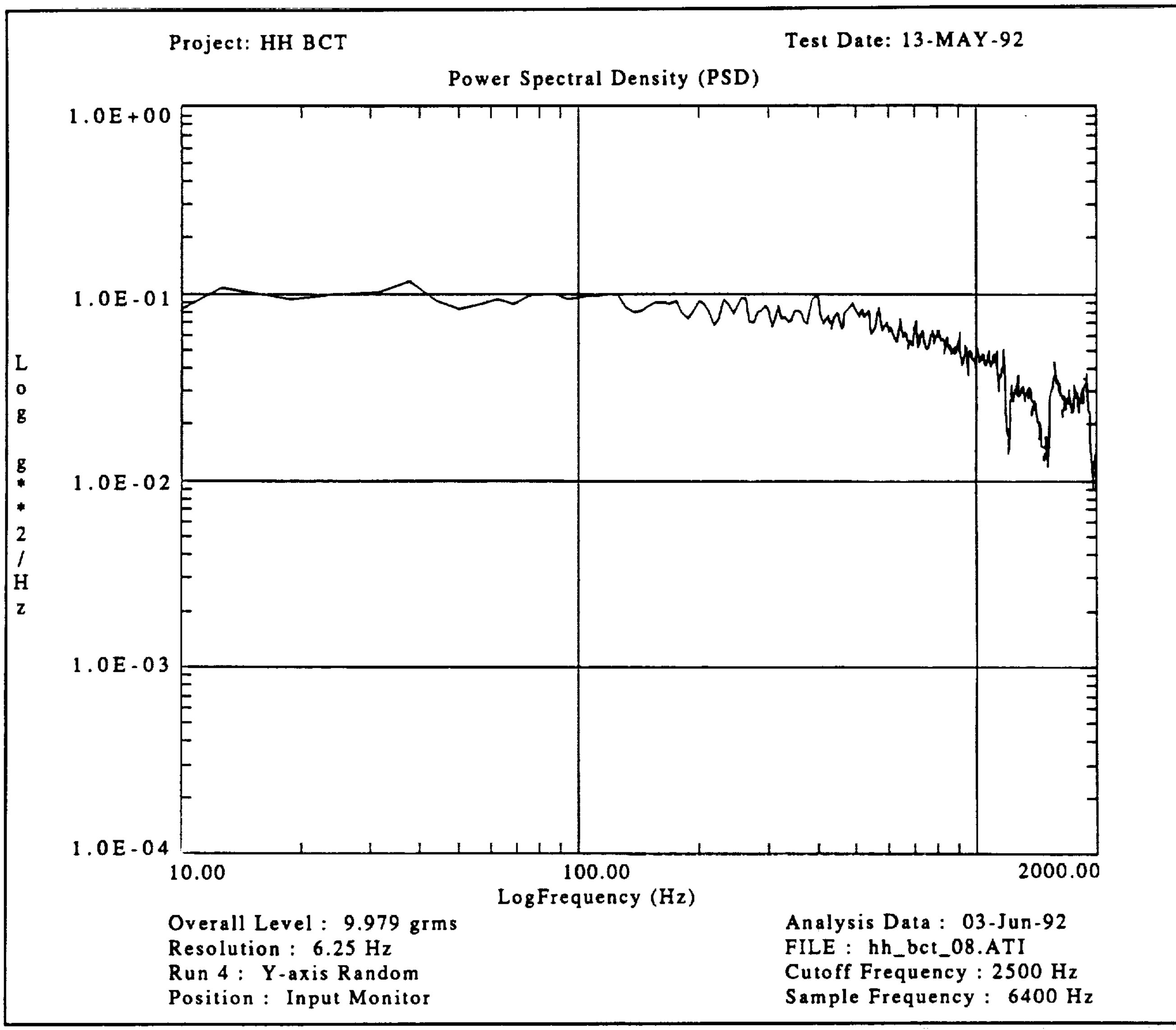
Test Block Data

Run 8 (Y Axis)

10.9 G_{rms} Random Vibration

10-2000 H_Z Input

Full Torque on Bolts



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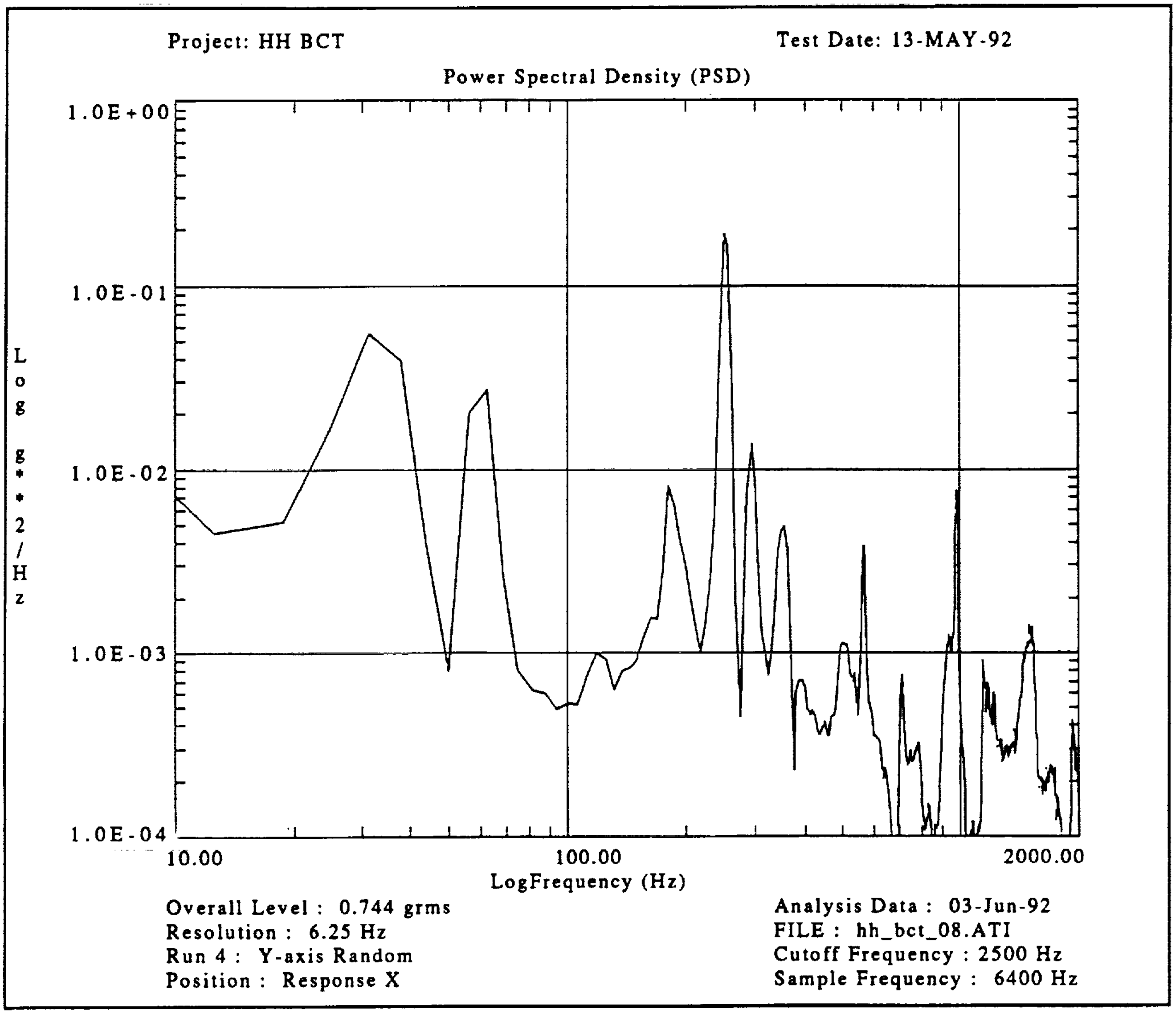
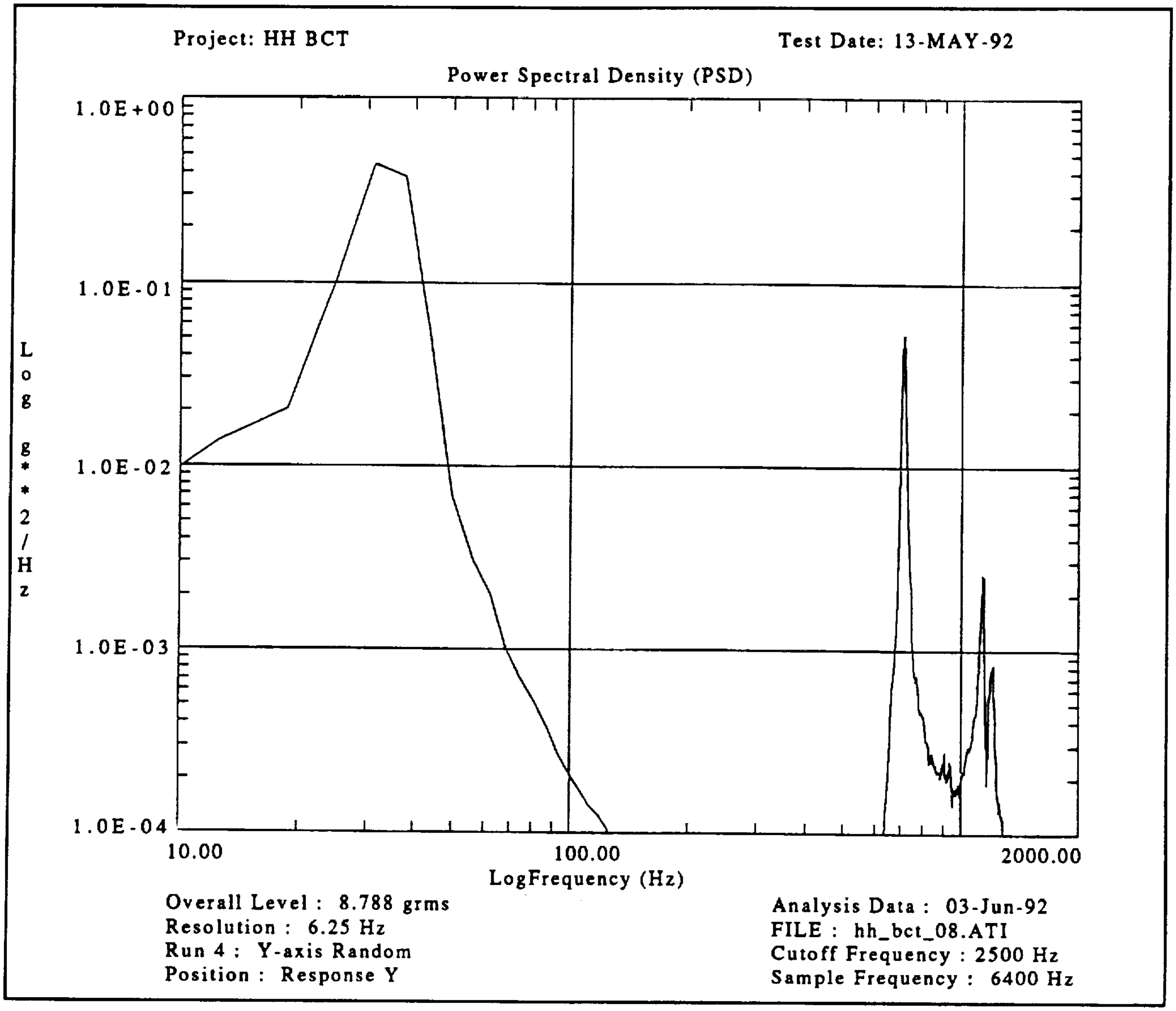
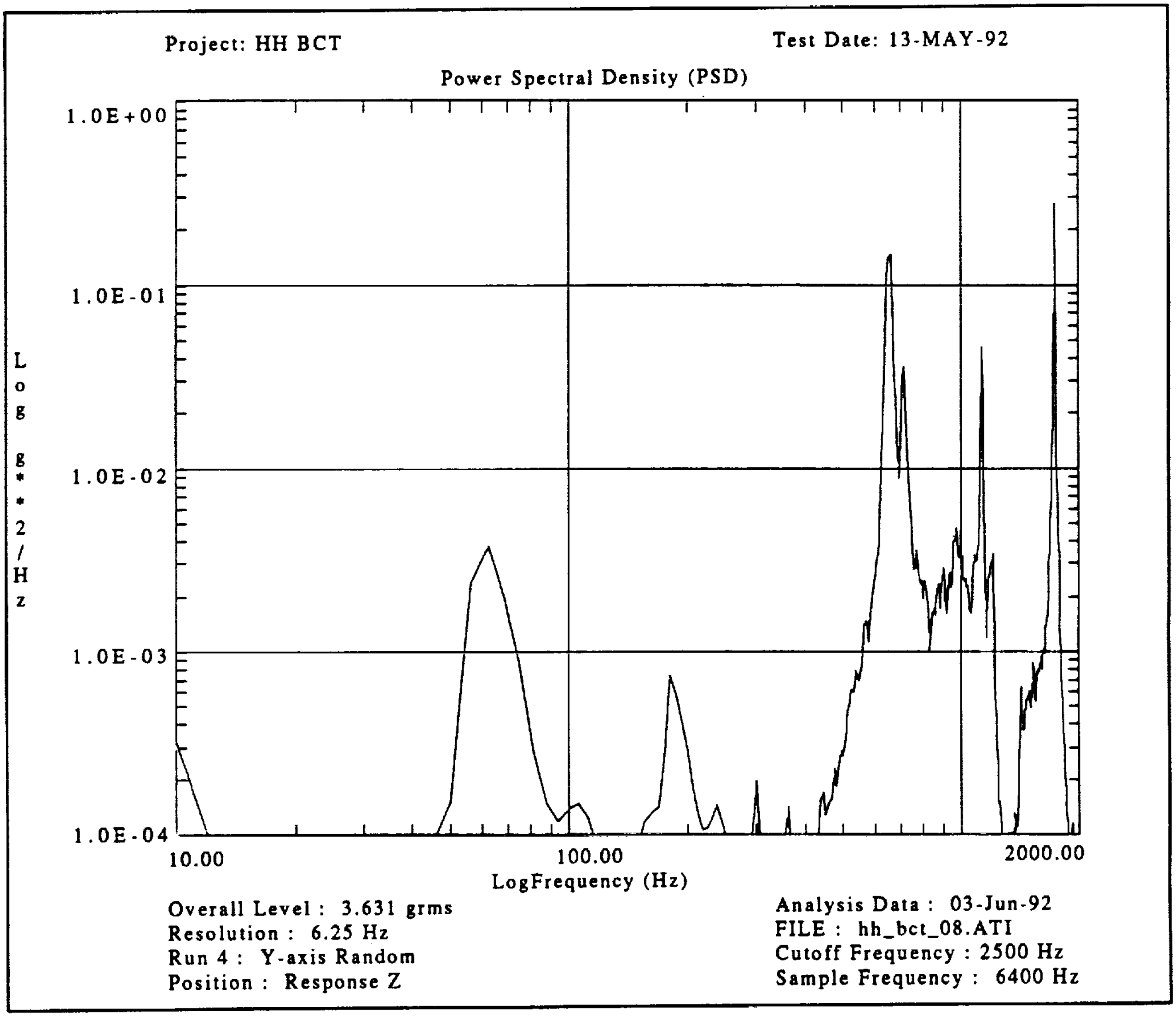


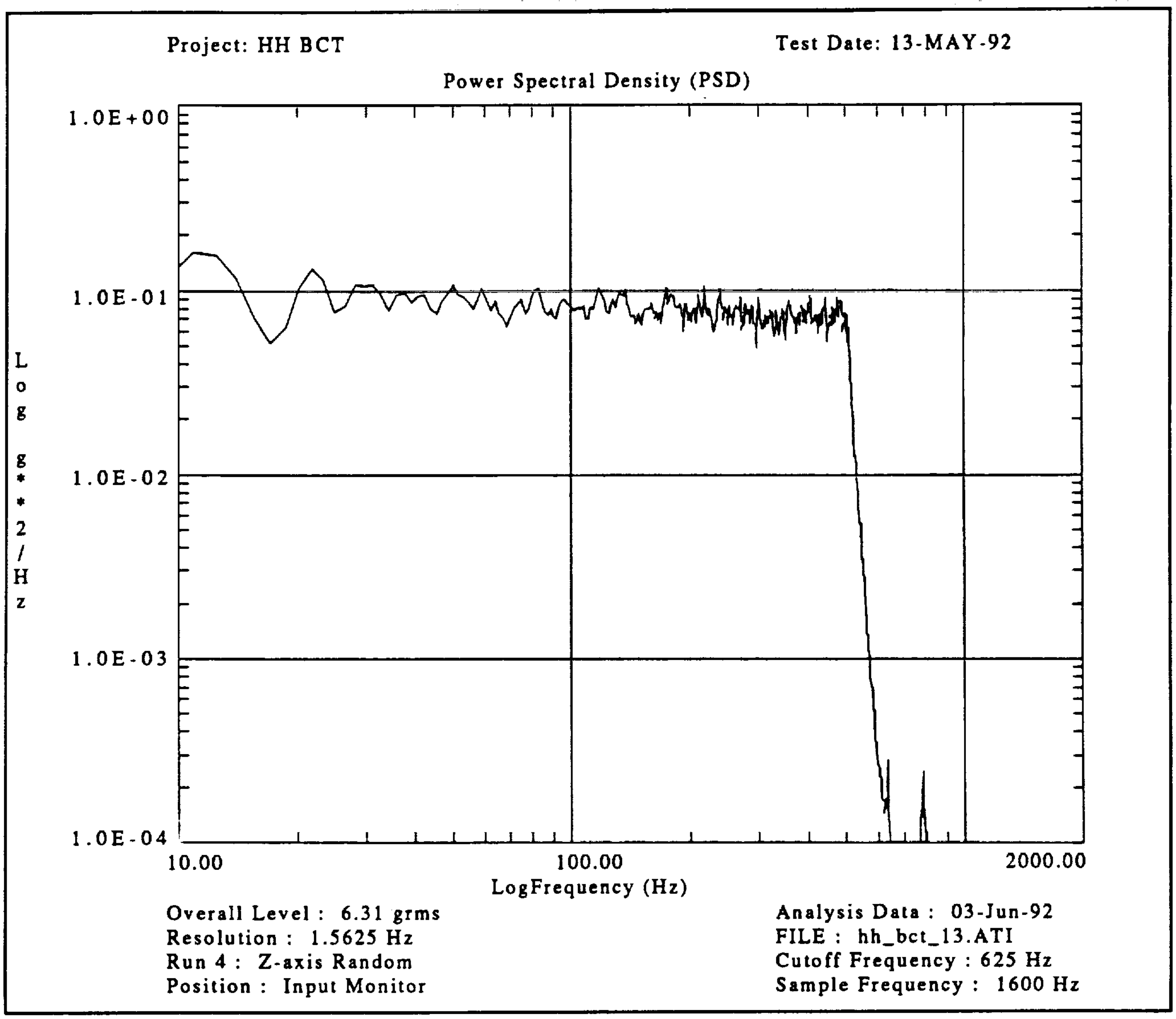
Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.744 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_08.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 8.788 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_08.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 3.631 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_08.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz

Test Block Data

Run 13 (Z Axis)
7.1 G_{rms} Random Vibration
10-500 H_Z Input
Full Torque on Bolts



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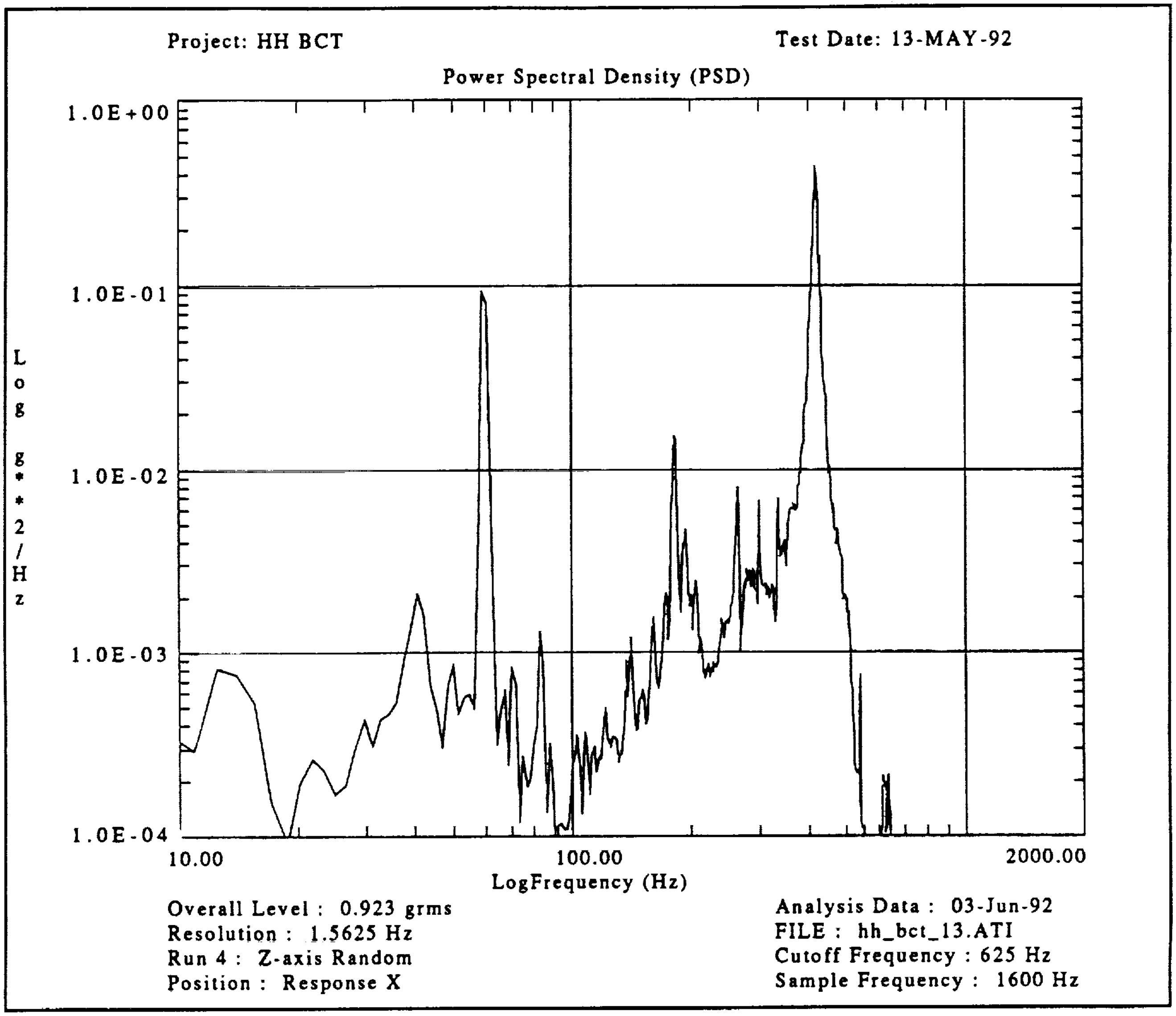
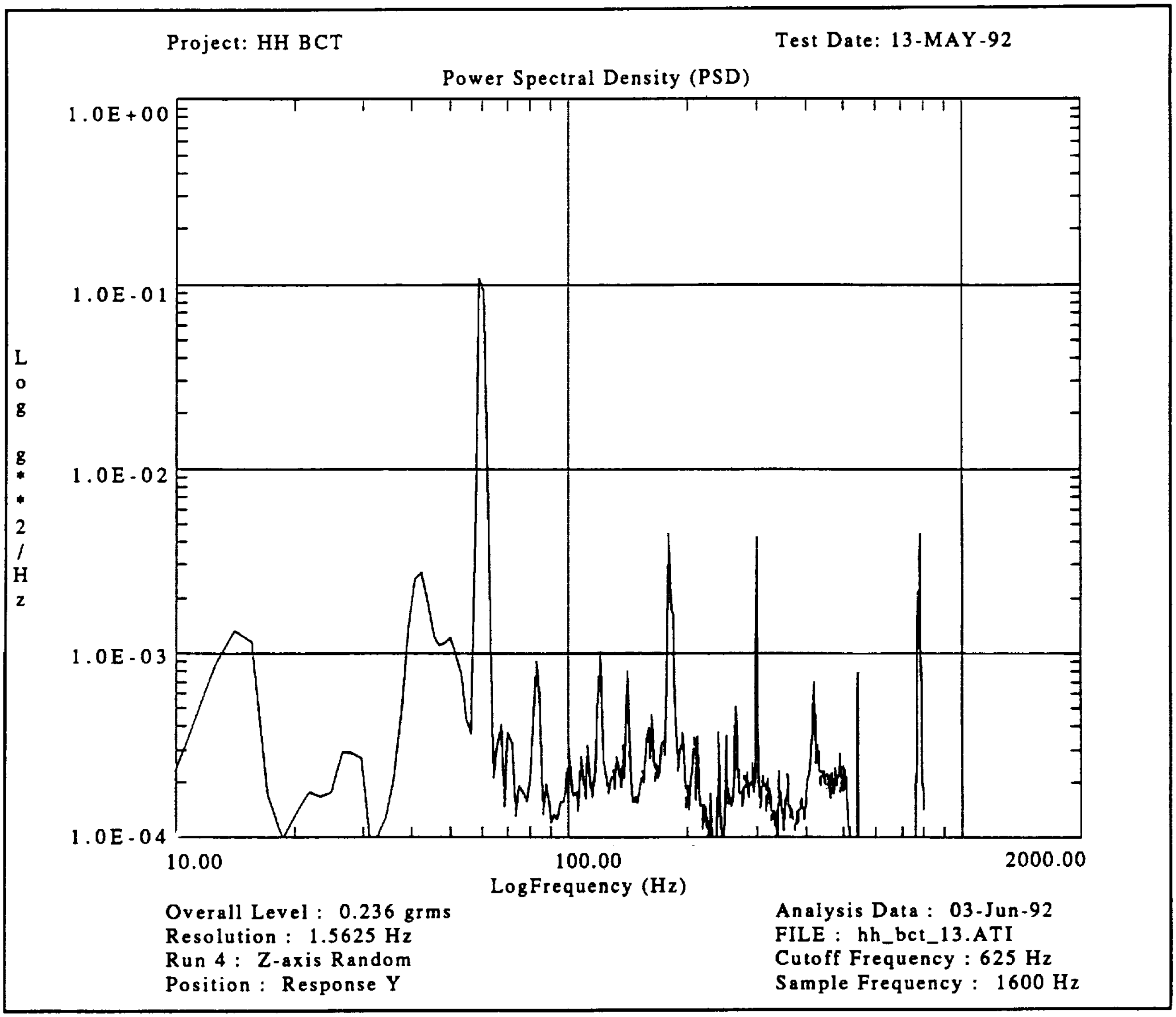
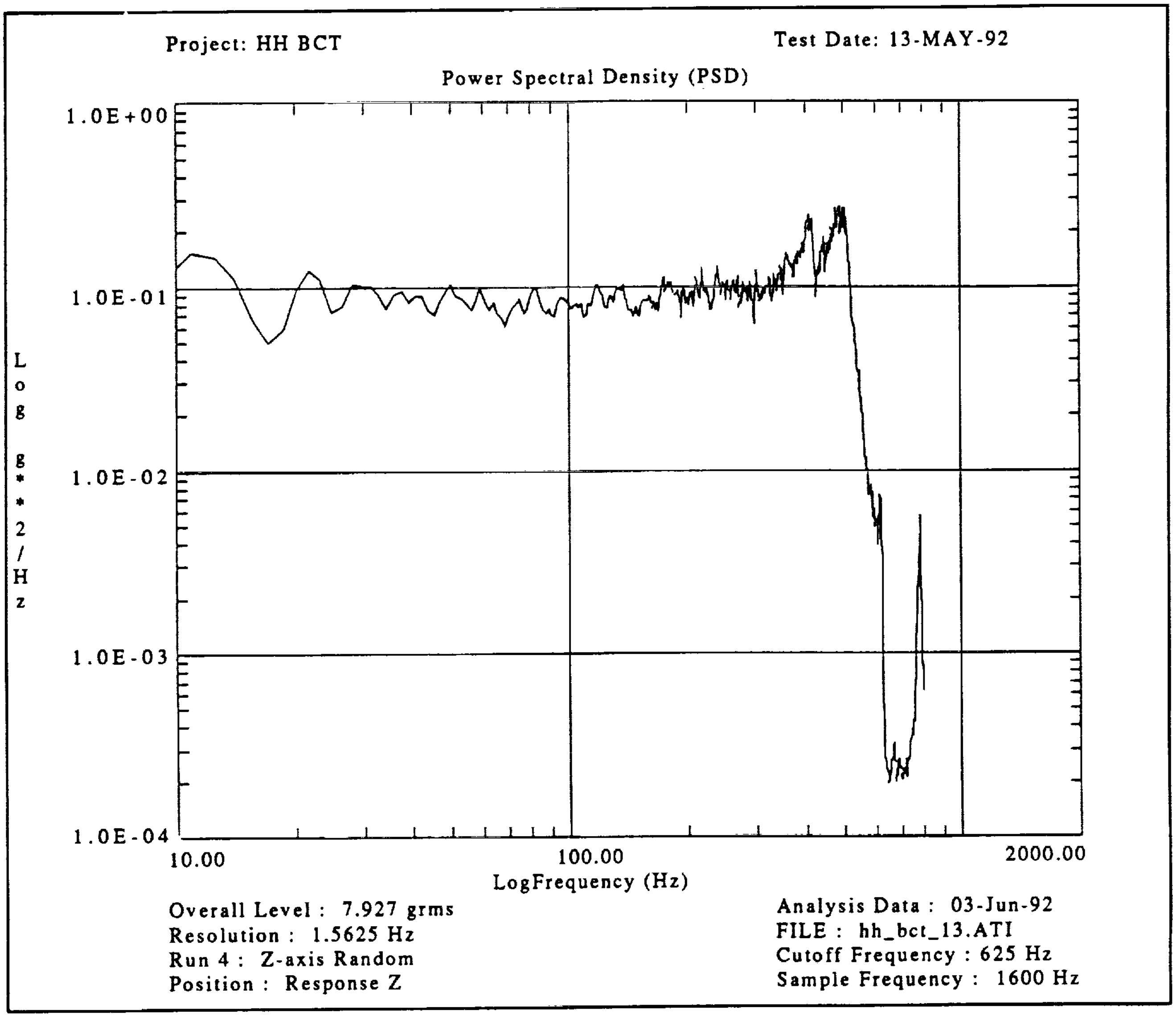
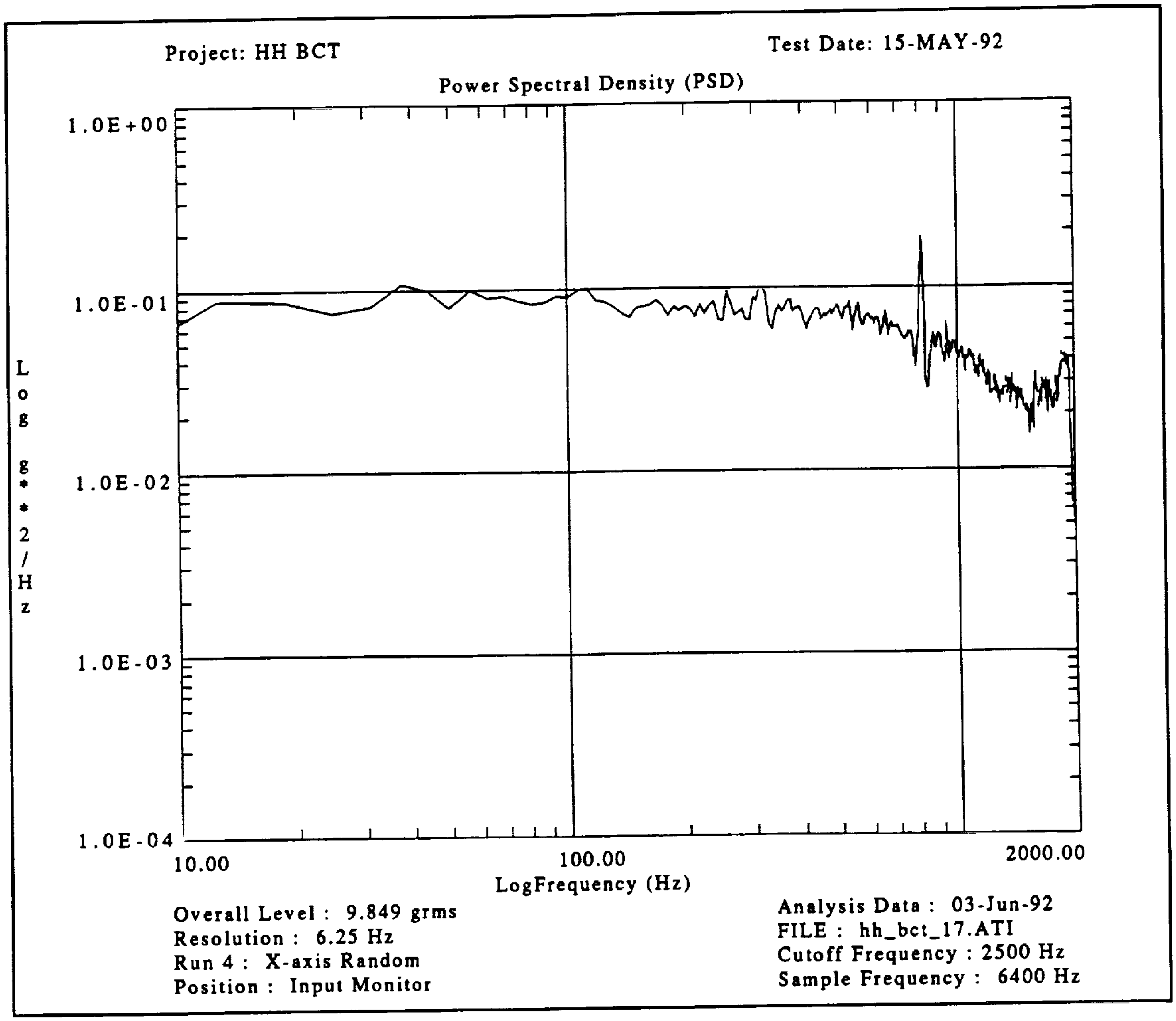

Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.923 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_13.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.236 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_13.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz


Project: HH BCT
Test Date: 13-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 7.927 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_13.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz

Test Block Data

Run 17 (X Axis)
10.9 G_{rms} Random Vibration
10-2000 H_Z Input
One-Quarter Torque on Bolts



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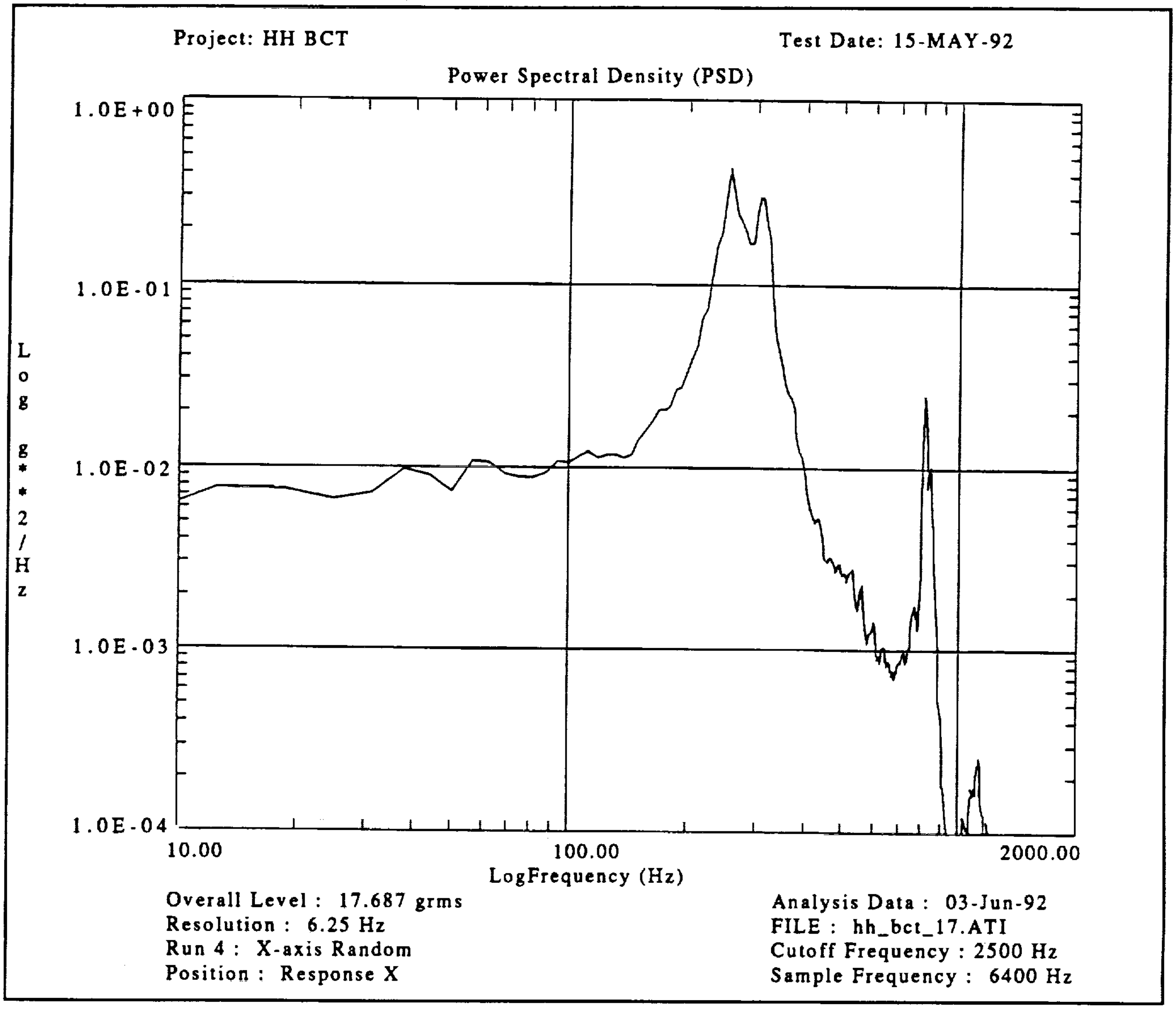
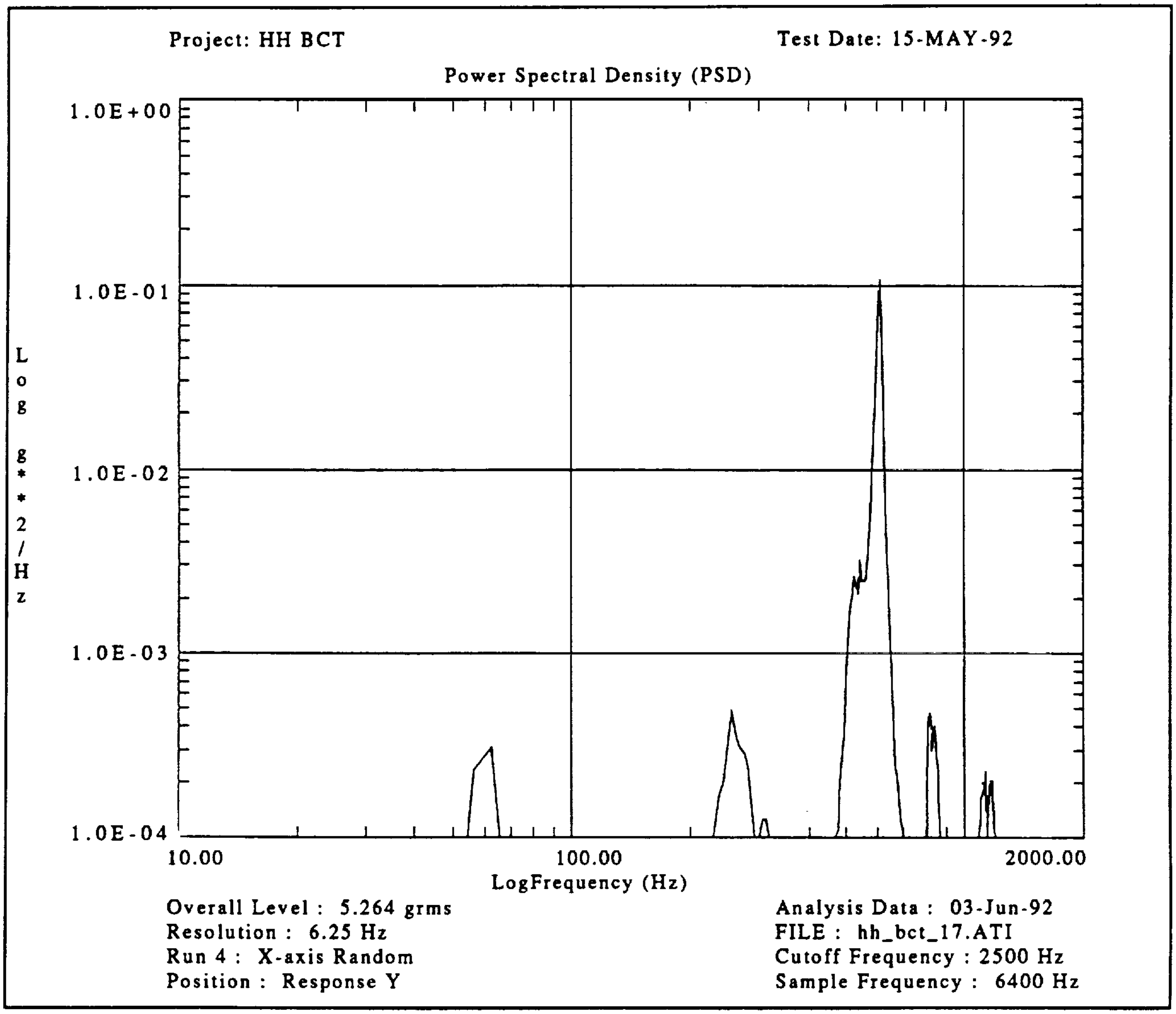
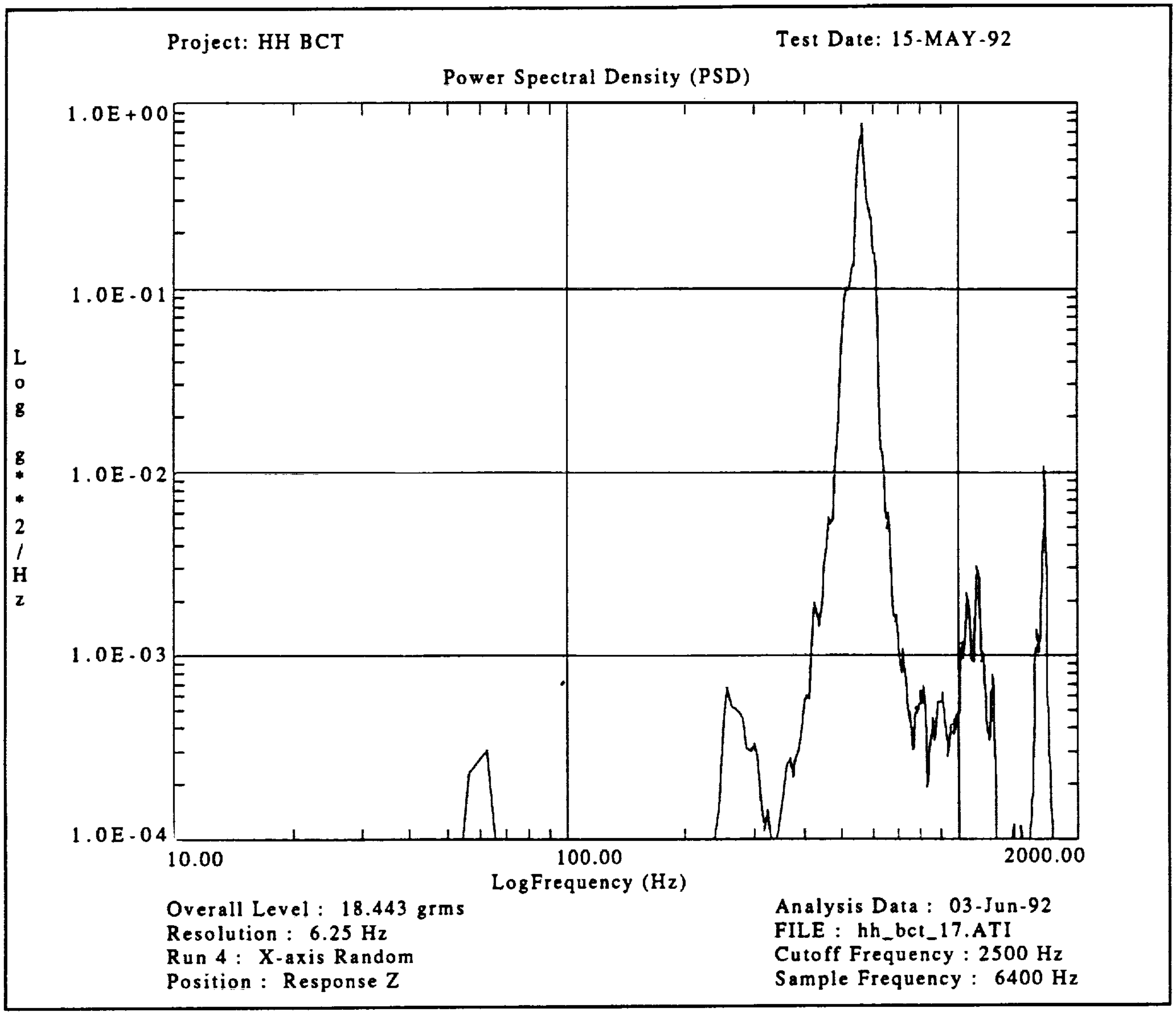

Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 17.687 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_17.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz



Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 5.264 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_17.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 18.443 grms
Resolution : 6.25 Hz
Run 4 : X-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_17.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz

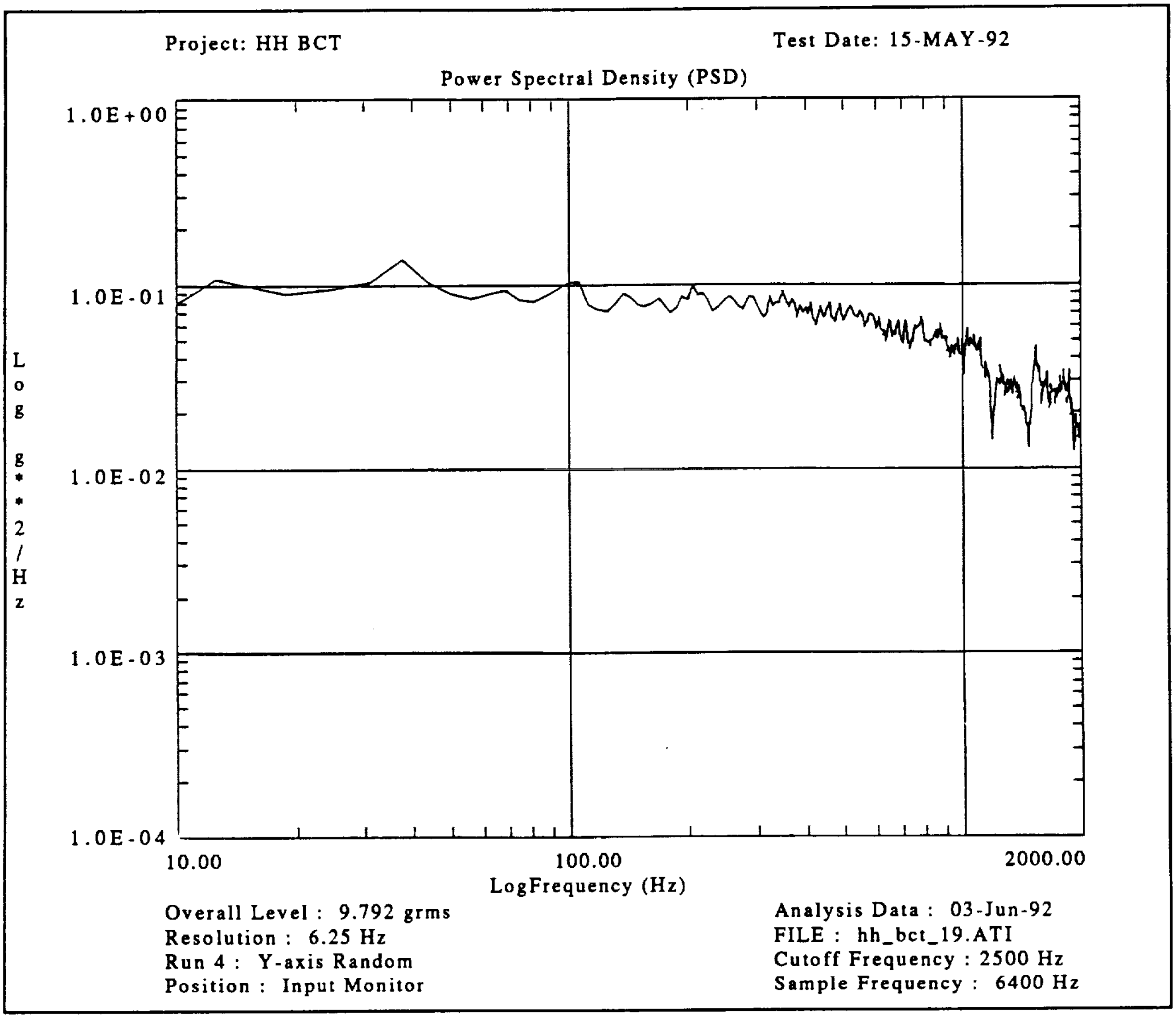
Test Block Data

Run 19 (Y Axis)

10.9 G_{rms} Random Vibration

10-2000 H_z Input

One-Quarter Torque on Bolts



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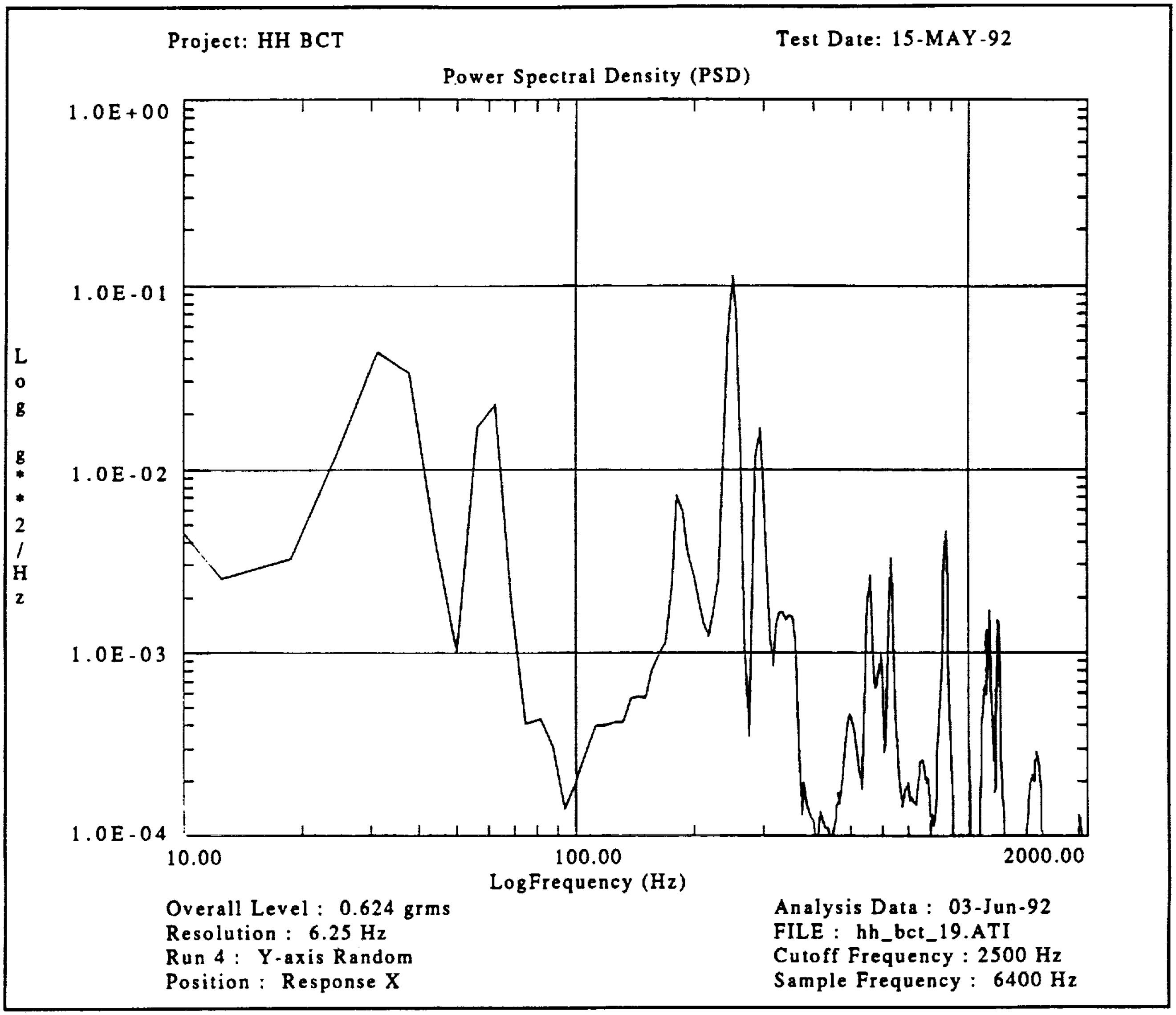
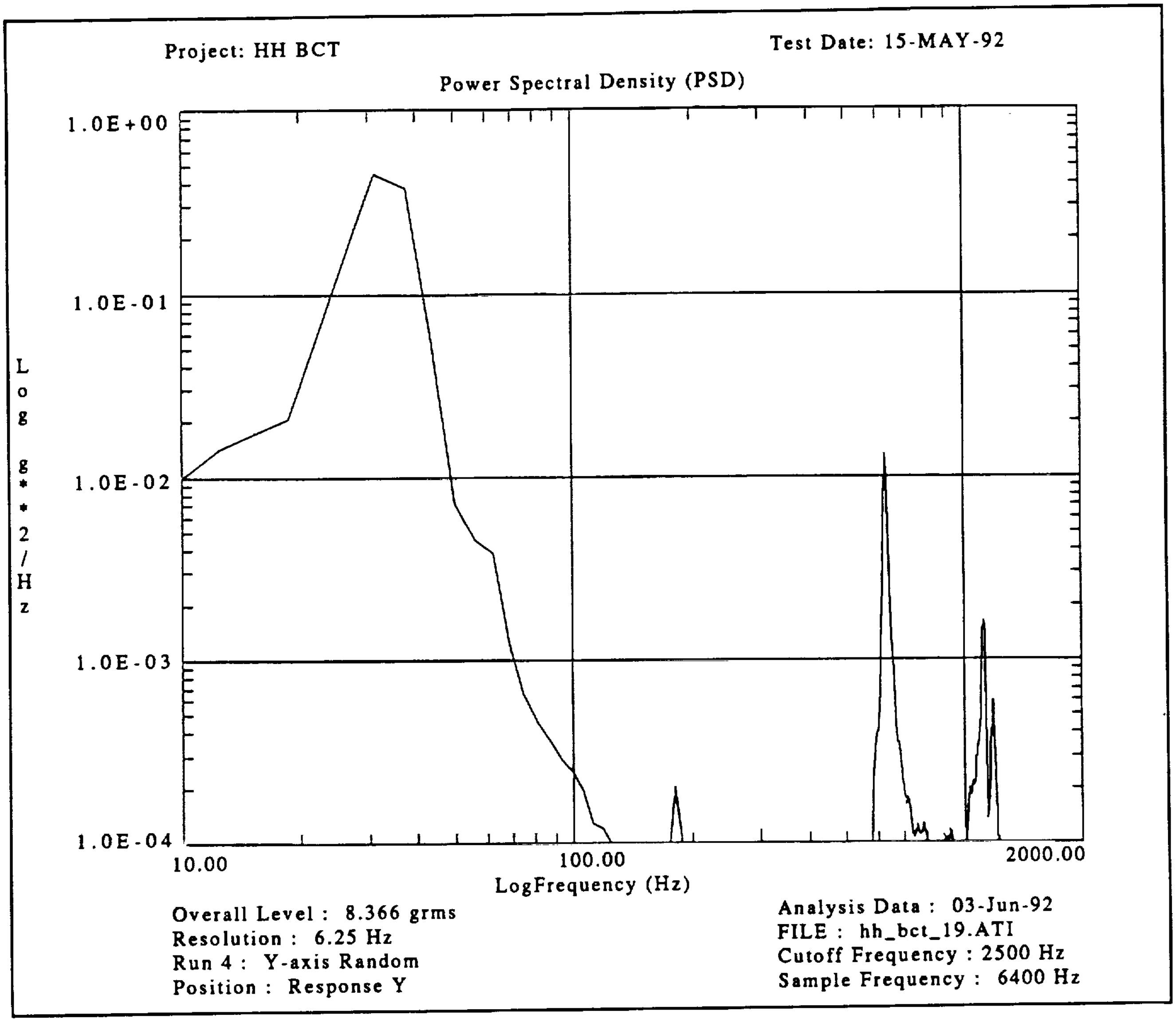
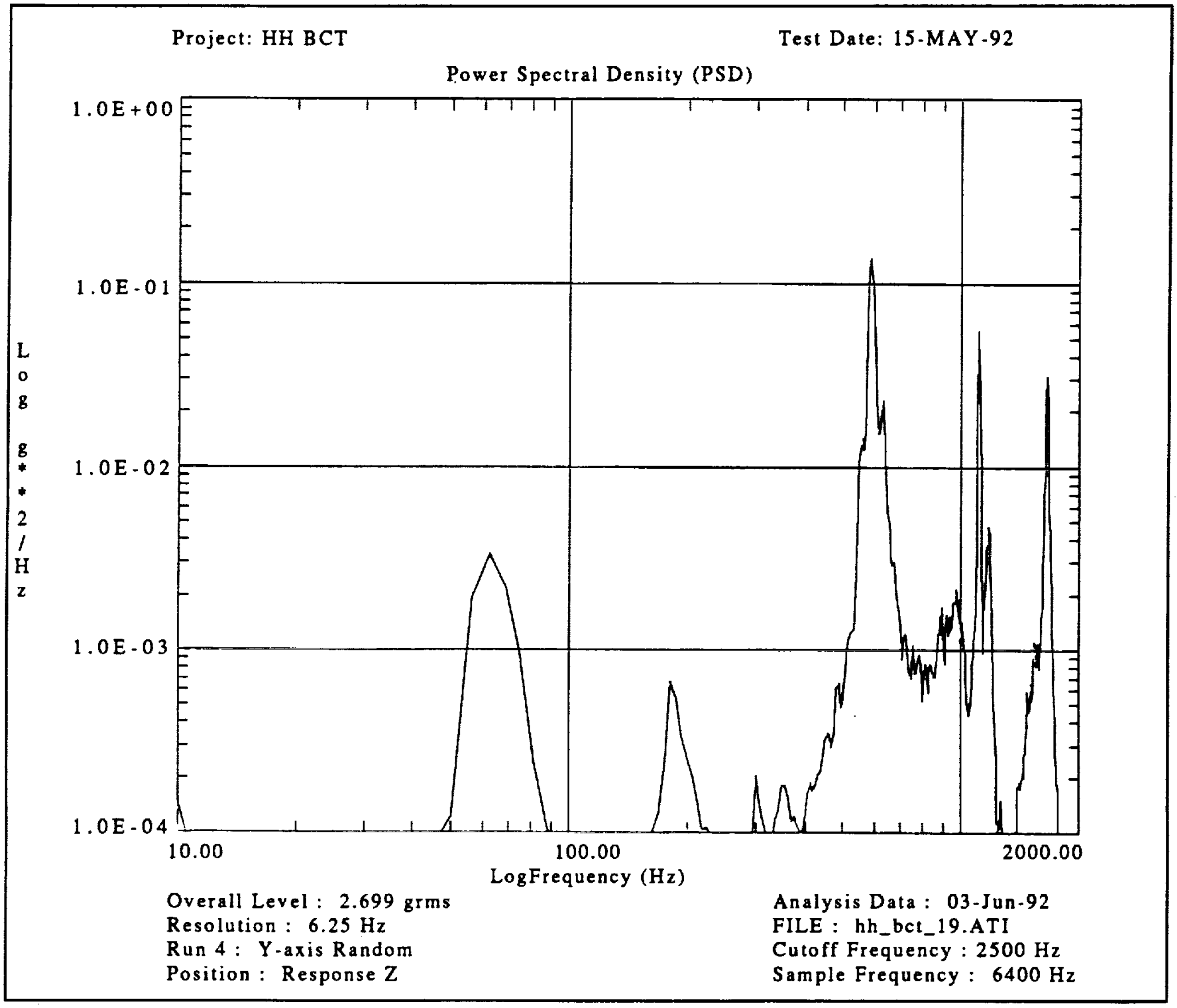


Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.624 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_19.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g*2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 8.366 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_19.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz


Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 2.699 grms
Resolution : 6.25 Hz
Run 4 : Y-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_19.ATI
Cutoff Frequency : 2500 Hz
Sample Frequency : 6400 Hz

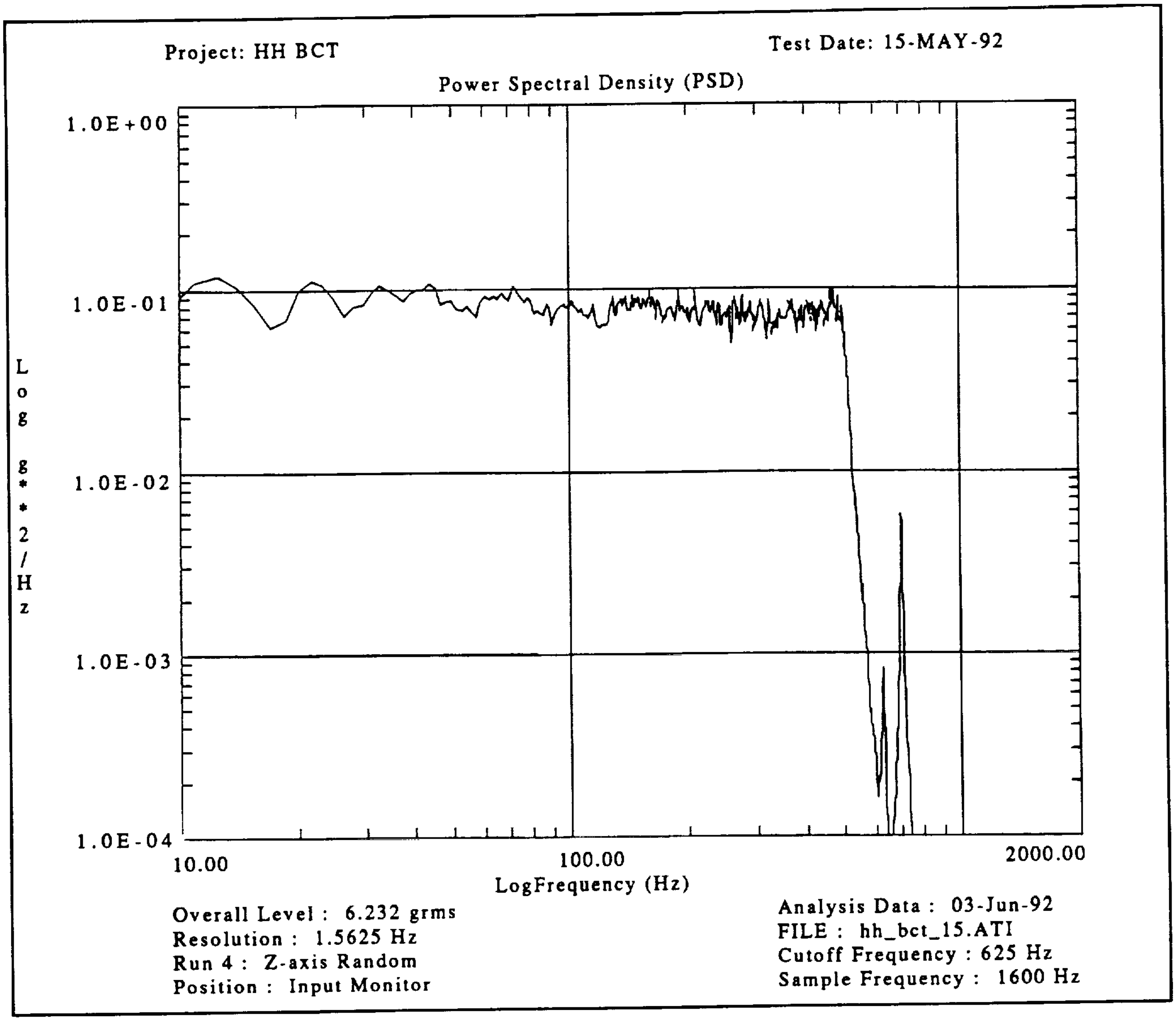
Test Block Data

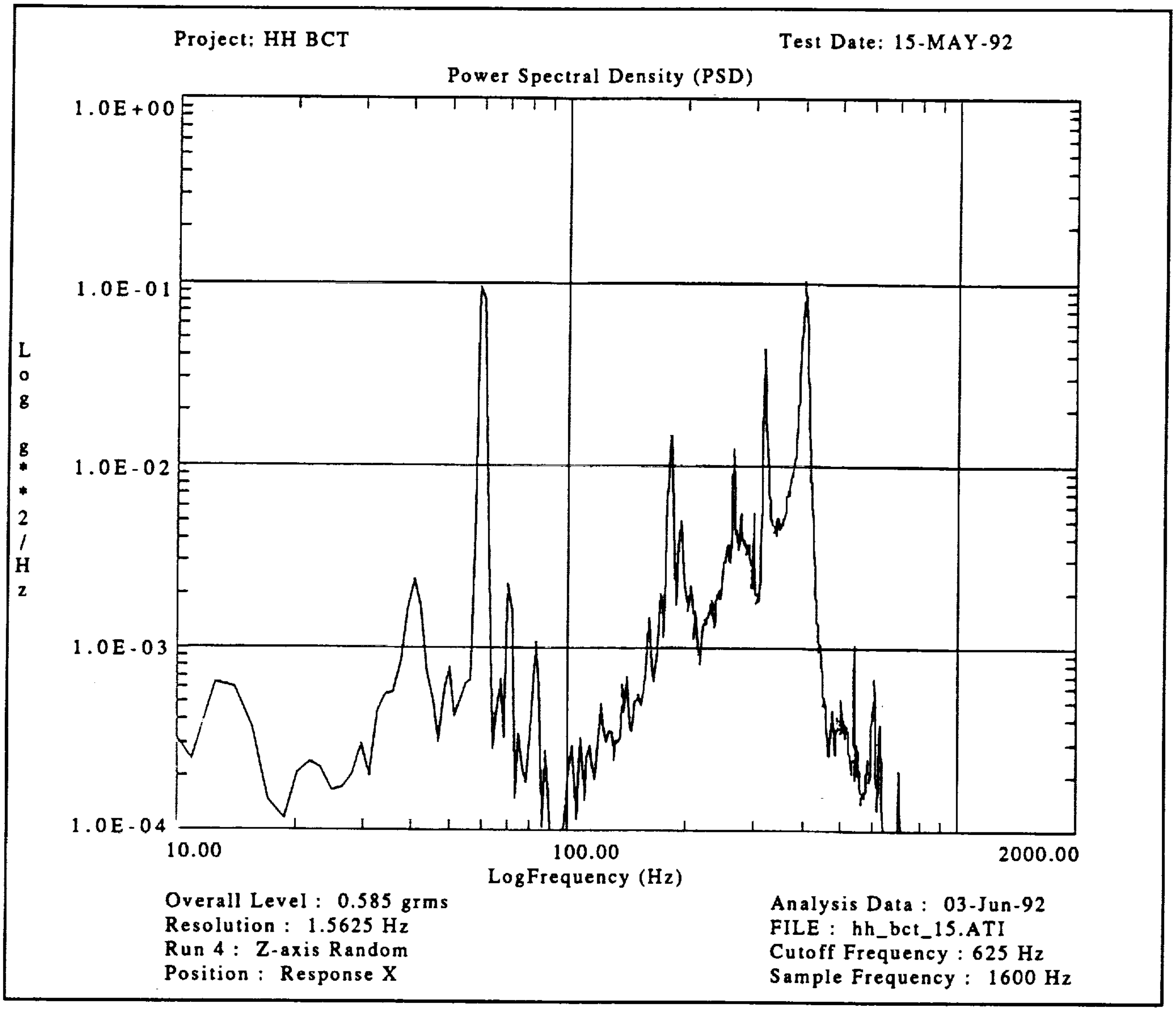
Run 15 (Z Axis)

7.1 G_{rms} Random Vibration

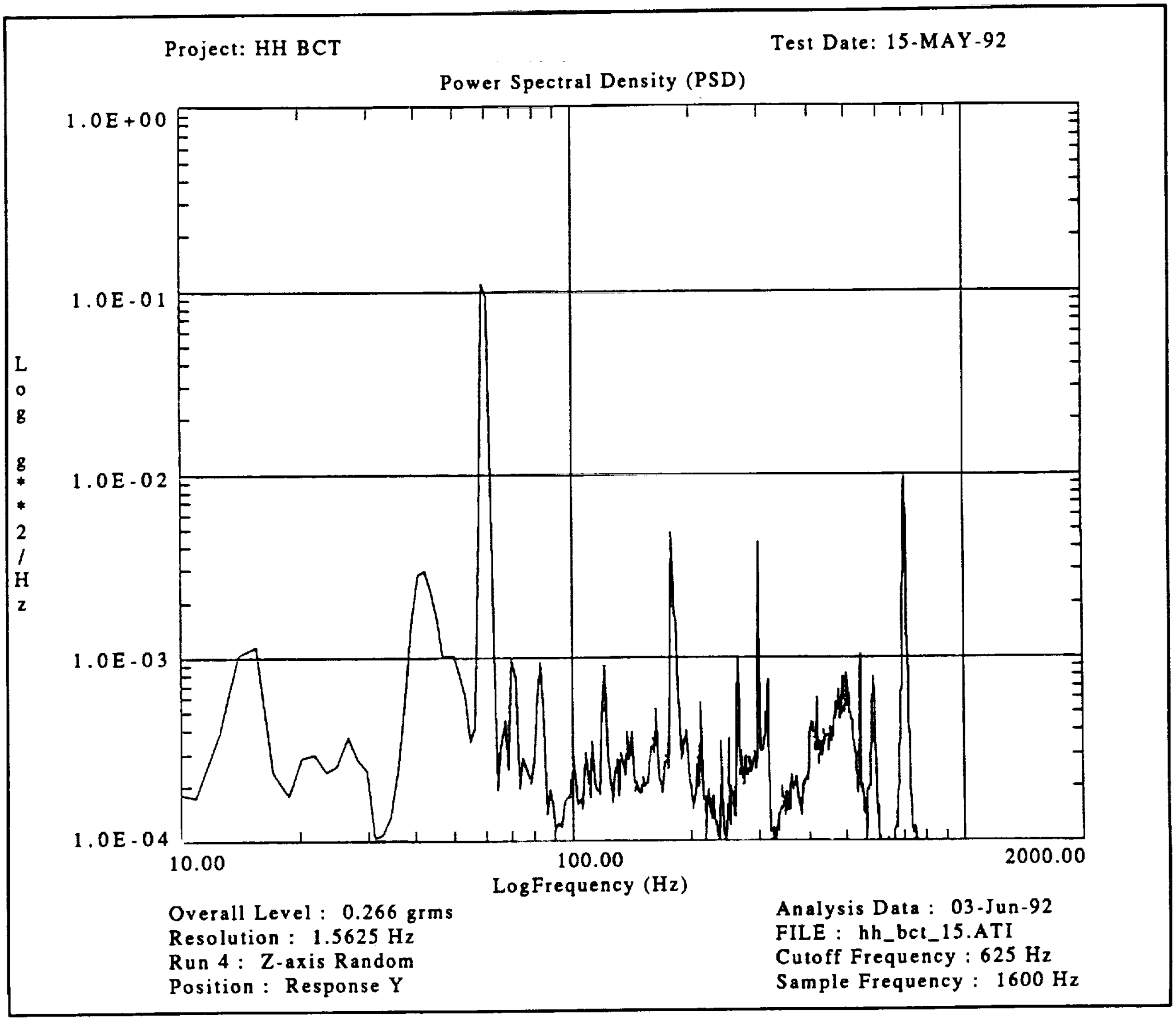
10-500 H_Z Input

One-Quarter Torque on Bolts

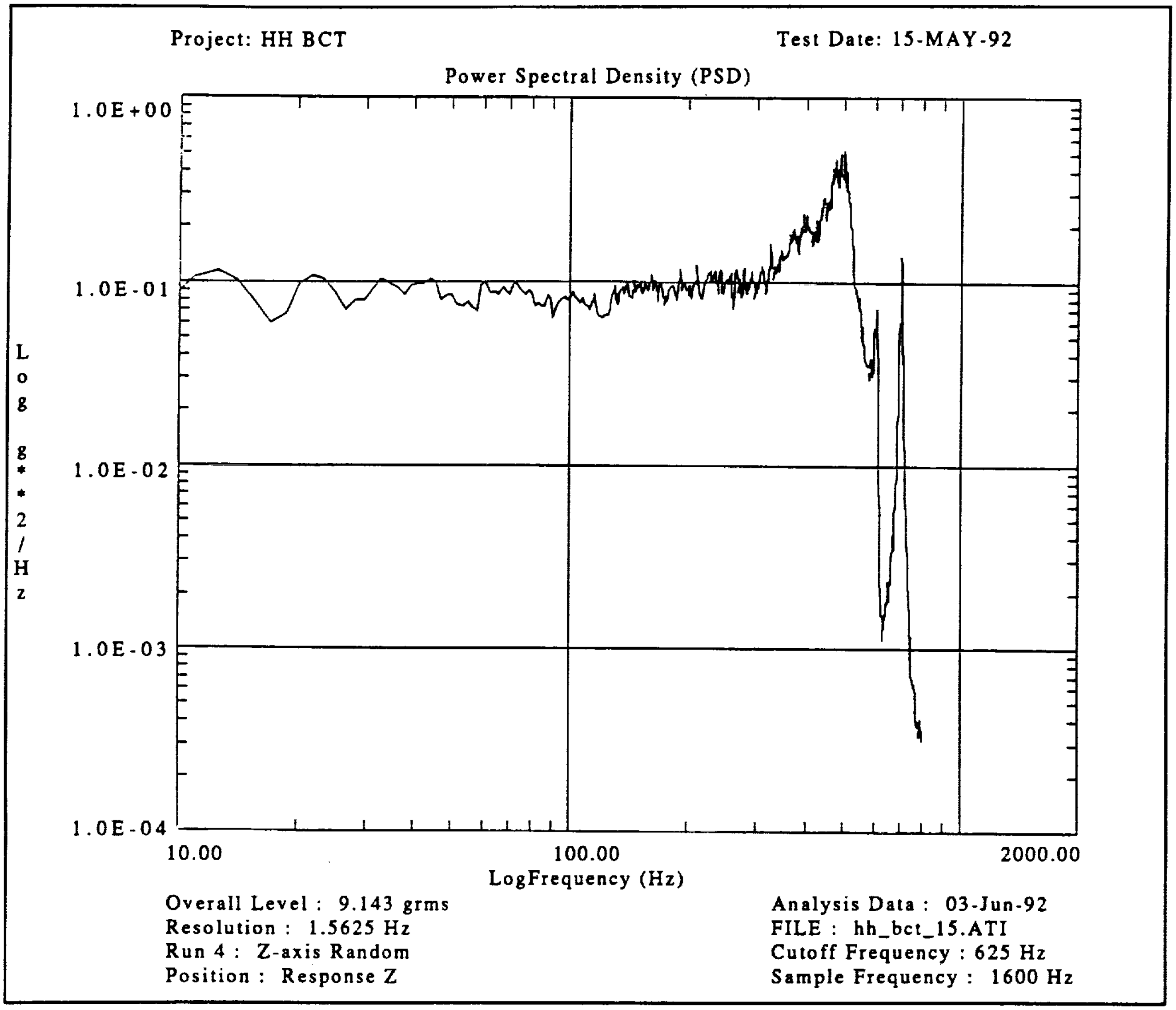

Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 6.232 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Input Monitor
Analysis Data : 03-Jun-92
FILE : hh_bct_15.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz



Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.585 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response X
Analysis Data : 03-Jun-92
FILE : hh_bct_15.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz



Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 0.266 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response Y
Analysis Data : 03-Jun-92
FILE : hh_bct_15.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz


Project: HH BCT
Test Date: 15-MAY-92
Power Spectral Density (PSD)
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
Log g**2/Hz
10.00
100.00
2000.00
LogFrequency (Hz)
Overall Level : 9.143 grms
Resolution : 1.5625 Hz
Run 4 : Z-axis Random
Position : Response Z
Analysis Data : 03-Jun-92
FILE : hh_bct_15.ATI
Cutoff Frequency : 625 Hz
Sample Frequency : 1600 Hz

APPENDIX B

Vibration Test Photographs

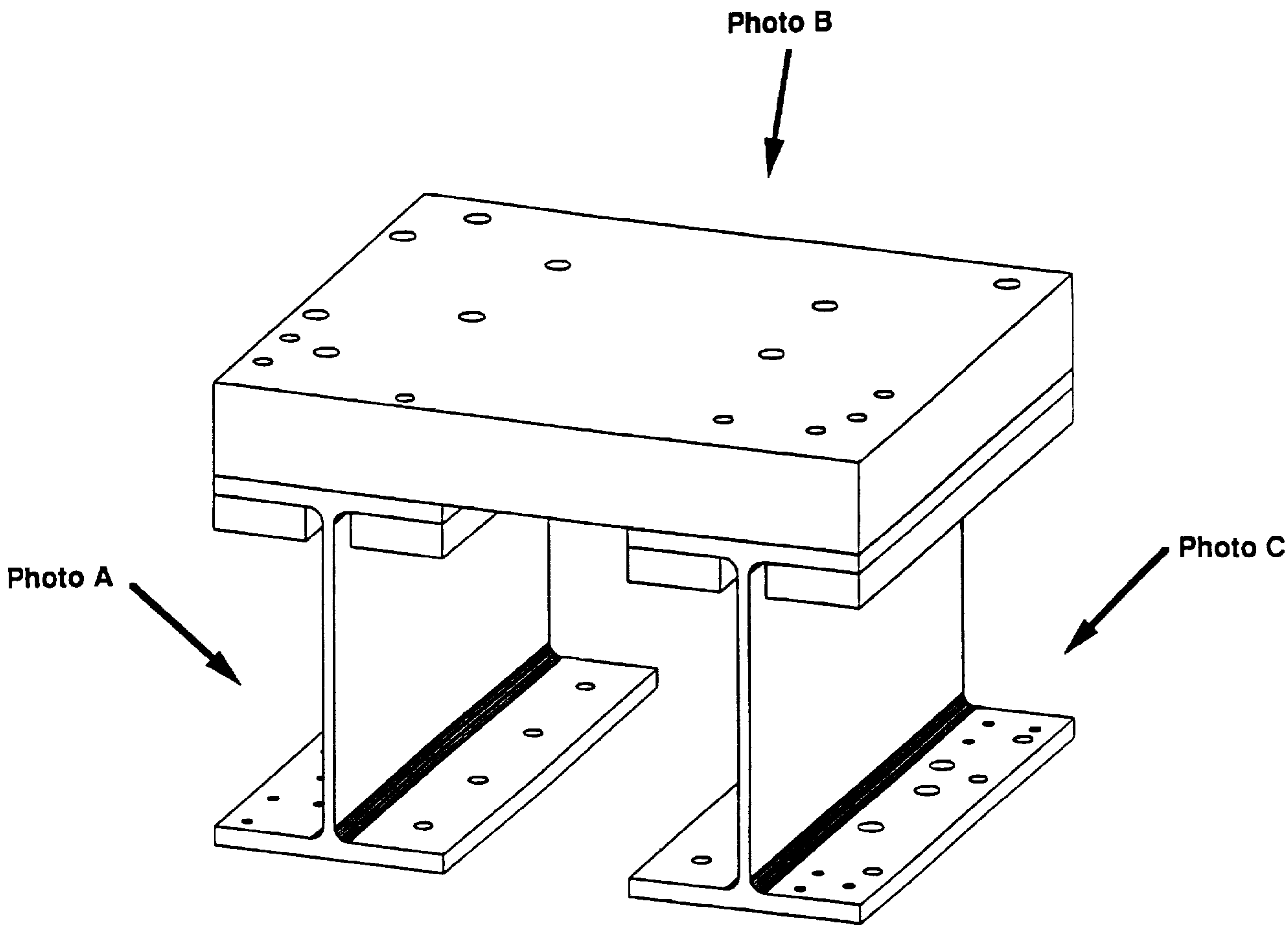


Photo B
Photo A
Photo C

Photo A

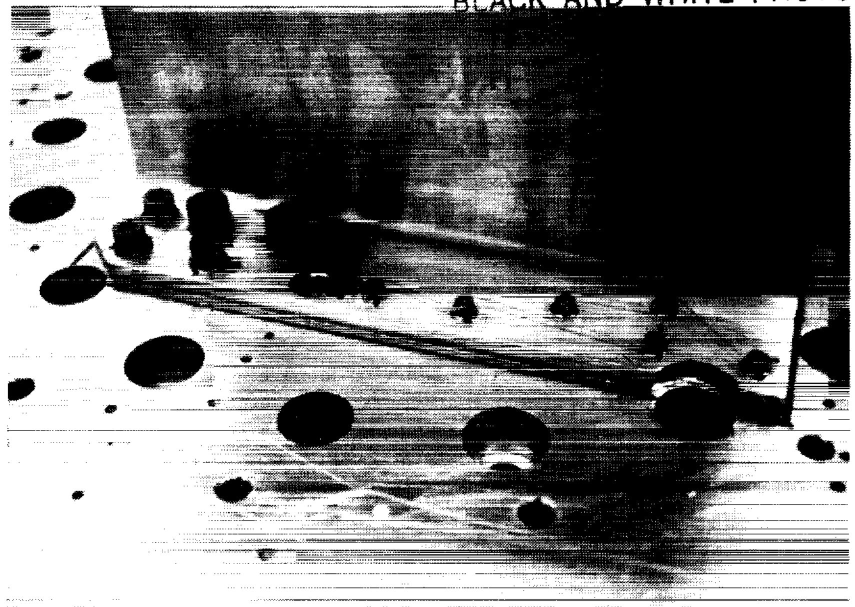


Photo B

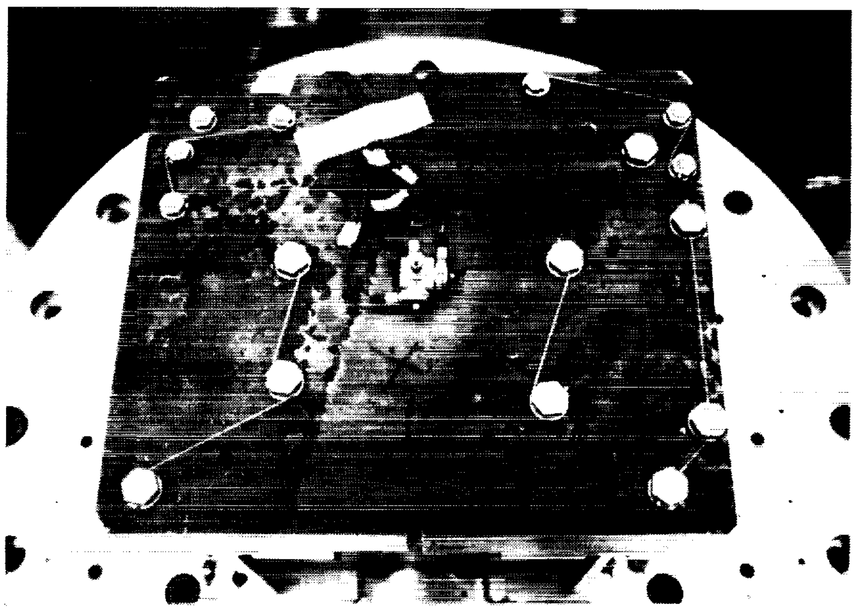
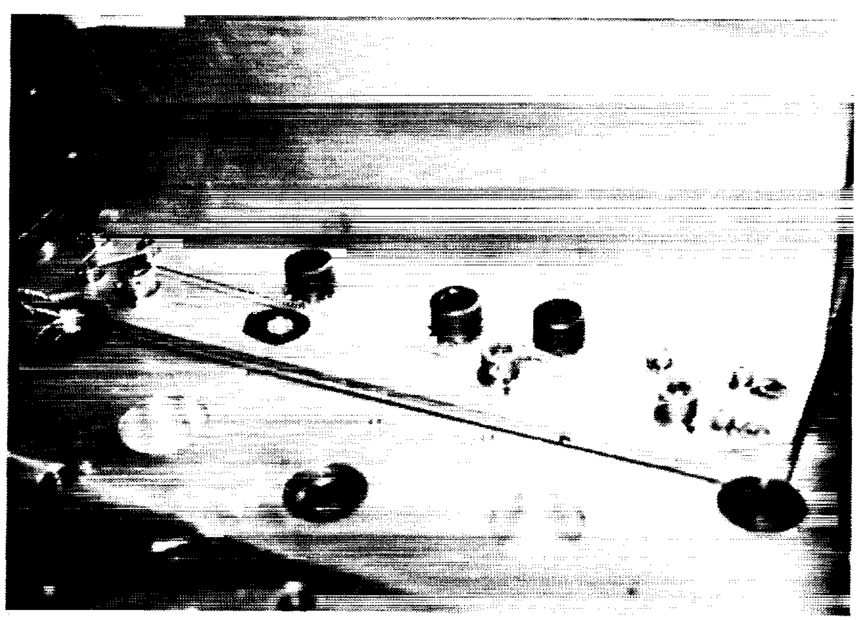
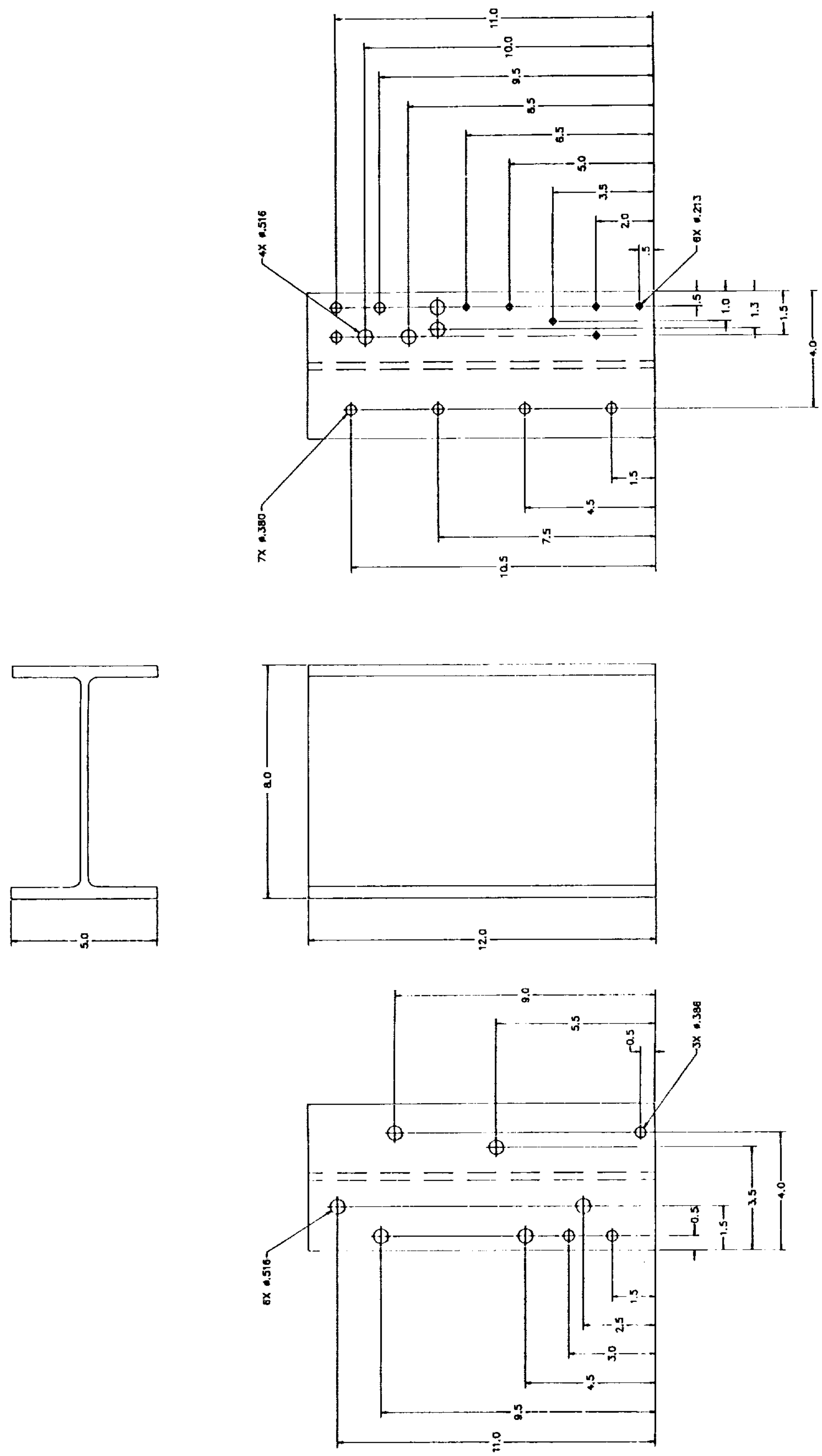


Photo C



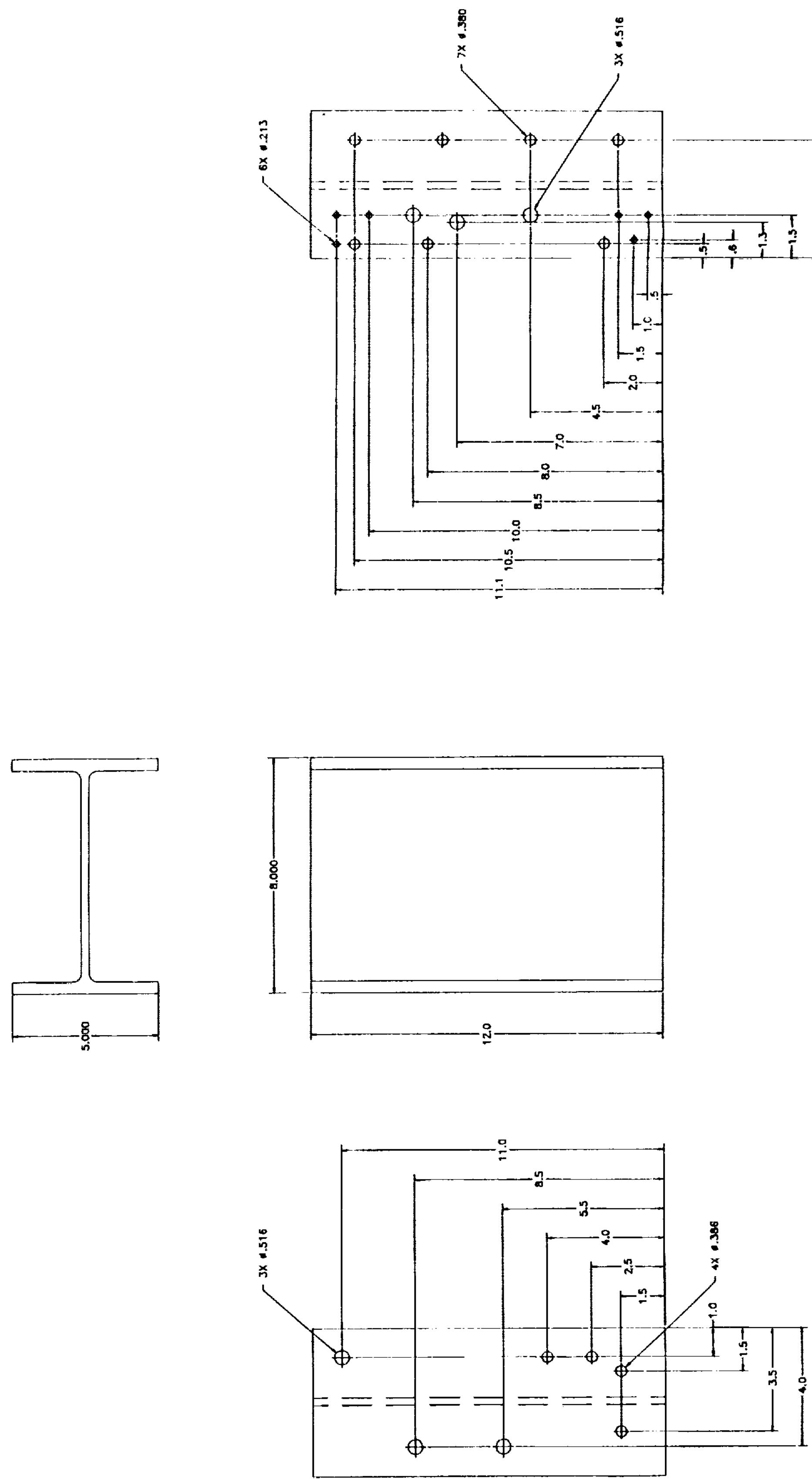
APPENDIX C

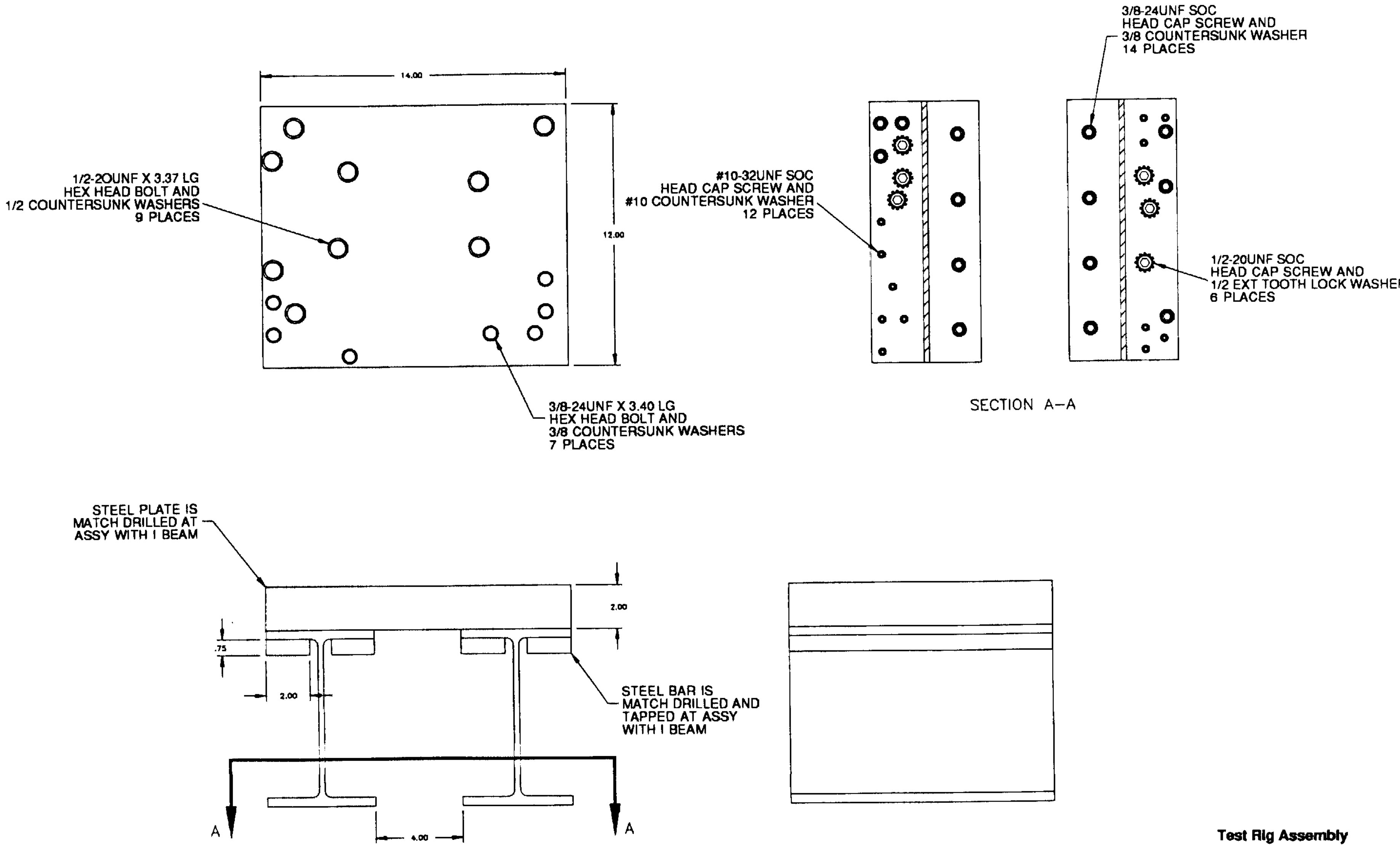
Test Fixture Mechanical Drawings


4X ⌀.516
6X ⌀.213
7X ⌀.380
11.0
10.0
9.5
8.5
6.5
5.0
3.5
2.0
.5
1.0
1.3
1.5
4.0
4.5
7.5
10.5
8.0
12.0
5.0
9.0
5.5
0.5
3X ⌀.388
6X ⌀.516
3.5
2.5
3.0

I-Beam #1

I-Beam #2





Test Rig Assembly

APPENDIX D
Draft Proposed Aerospace Standards

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE STANDARD

SAE AS4536

Submitted for recognition as an American National Standard

SAFETY CABLE KIT PROCUREMENT SPECIFICATION AND REQUIREMENTS FOR USE

PRELIMINARY

1. SCOPE:

1.1 Purpose:

This procurement specification covers aircraft quality safety cable kits consisting of safety cables and ferrules made from corrosion and heat resistant steels and a nickel base alloy of the type identified under the Unified Numbering system as follows:

a. UNS S30400 - corrosion and heat resistant steel (AMS 5697)
b. UNS S32100 - corrosion and heat resistant steel (AMS 5689)
c. UNS N06600 - nickel base alloy (AMS 5687)

The requirements for installation practices are also specified.

1.2 Field of Application:

For use in aerospace systems for securing fasteners and other utility parts which may have the potential of coming loose during operation. This standard excludes those devices which have integral locking features incorporated into the item being locked.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this specification to the extent specified herein. The latest issue of all SAE Technical Reports shall apply.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 5687 - Alloy Wire, Corrosion and Heat Resistant, 74Ni - 15.5Cr - 8.0Fe, Annealed

AMS 5689 - Steel Wire, Corrosion and Heat Resistant, 18Cr - 10.5Ni - 0.40Ti, Solution Heat Treated

AMS 5697 - Steel Wire, Corrosion Resistant, 19Cr - 9.5Ni, Solution Heat Treated

AS3509 - Cable, Safety, Kit - Nickel Alloy, UNS N06600

AS3510 - Cable, Safety, Kit - Corrosion and Heat Resistant Steel, UNS S32100

AS3511 - Cable, Safety, Kit - Corrosion Resistant Steel, UNS S30400

2.1.2 Military Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-2073-1 DOD Material Procedures for Development and Application of Packaging Requirements

Available from Commander, Defense Logistics Services Center, ATTN: DLSC-JBB, Federal Center, Battle Creek, MI 49016.

2.1.3 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E4 - Standard Practices for Load Verification of Testing Machines

ASTM E8 - Tension Testing of Metallic Materials

2.2 Definitions:

STRAND: A group of wires helically wound around a core wire in left-hand direction or right hand direction.

CABLE: A group of strands helically twisted together in a right-hand direction without a core.

DEFECTIVE: A defective is a unit of product which contains one or more defects.

DIAMETER: The diameter of wire strand and cable is the diameter of the circumscribing circle, or across diametrically opposite wires.

FERRULE/END FITTING: Metal sleeve used for crimping onto the cable to maintain tension in the cable.

LAY: The helical form taken by the wires in the strand and by the strands in the cable is characterized as the lay (or twist) of the wires in a strand, or strands in a cable, respectively. In a right-hand lay, the wires of the strand are the same direction as the thread on a right-hand screw, and a left-hand lay the strands or wires lay in the opposite direction.

LENGTH OF LAY (or pitch): The distance parallel to the axis of the strand, in which a wire makes one complete turn about the axis.

PING: Ping is an audible sound given off as a result of an individual wire breaking in the wire strand.

PRODUCTION INSPECTION LOT: Shall be all finished parts of the same part number, made from a single heat of alloy, heat treated at the same time to the same specified condition, produced as one continuous run, and submitted for vendor's inspection at the same time.

PULL-OFF LOAD: The force required to pull the cable out of either the ferrule or cable end fitting.

SAFETY CABLE: An inseparable assembly consisting of a length of cable and an end fitting affixed to one end of the cable.

SAFETY CABLE ASSEMBLY: An assembly consisting of a ferrule affixed to the safety cable.

TERMINATION POINT: The point at which the cable end fitting or ferrule attach to the cable.

WIRE: Each individual cylindrical element is designated as a wire.

3. TECHNICAL REQUIREMENTS:

3.1 Material:

Unless otherwise specified on the part drawing, the material for the cable, end fitting, and ferrule shall be as in Table 1 for the specified procurement specification dash number:

TABLE 1 - Material

Procurement Specification Designation	Cable End Fitting and Ferrule	Material
AS4536-1	AMS 5687	Nickel Base Alloy
AS4536-2	AMS 5689	Corrosion and Heat Resistant Steel
AS4536-3	AMS 5697	Corrosion and Heat Resistant Steel

3.2 Design:

Finished safety cable shall conform to AS3509, AS3510, or AS3511.

3.3 Construction:

3.3.1 Wire Properties: Tensile strength of wire and wire sizes shall be such that the cable will be capable of meeting the requirements of this specification.

3.3.1.2 Preforming of Wires: The individual wires comprising a strand shall be shaped into the exact helical position they will have in the finished strand or cable, so that if the strand or cable is cut, the measured diameter of the cable at the un-fused cut ends shall not increase by more than 0.006 inch.

3.3.1.3 Splicing and Joining: There shall be no wire splices in the finished strand or cable.

3.3.2 Type of Construction:

3.3.2.1 Strand 1 X 7: The 0.020 inch nominal diameter cable shall be a strand of wires having 1 X 7 construction, consisting of a layer of 6 wires laid around a center core wire in a left-hand direction. The length of lay shall be not more than 0.25 inch nor less than 0.20 inch.

3.3.2.2 Cable 3 X 7: The 0.032 inch nominal diameter cable shall consist of 3 strands of 7 wires each, laid together without a core. Each strand shall consist of a layer of 6 wires laid around a center core wire in a left-hand direction. The 3 strands shall be laid together in a right-hand direction. The length of the lay of the 6 outer wires in each strand shall not exceed 70 percent of the lay of the finished cable. The length of lay of the finished cable shall be not more than 0.25 inch nor less than 0.18 inch.

3.3.3 Safety Cable:

3.3.3.1 The 0.020 inch nominal diameter safety cable comprises the following:

a. One strand of wires, 1 X 7 construction as in 3.3.2.1.
b. Fitting end, as specified on part drawing, crimped onto strand at one end.
c. Free end of strand is fused by brazing or welding.
d. Ferrule, as specified on part drawing, to be crimped onto the free end of the strand at installation.

3.3.3.2 The 0.032 inch nominal diameter safety cable comprises the following:

a. Three strands of wires, 3 X 7 construction as in 3.3.2.2.
b. Fitting end, as specified on part drawing, crimped onto cable at one end.
c. Free end of cable is fused by brazing or welding.
d. Ferrule, as specified on part drawing, to be crimped onto the free end of the cable at installation.

3.3.3.3 The length of the safety cable shall be as specified on the part drawing in 3 inch increments, 6 inch minimum length, tolerance ± 0.5 inch.

3.4 Performance:

3.4.1 Breaking Strength: Strength of 0.020 inch nominal diameter cable as in 3.3.2.1 and of the 0.032 inch nominal diameter cable as in 3.3.2.2 shall be not less than the minimum breaking strength specified in Table 2, for the applicable material, and determined in accordance with ASTM E8.

3.4.2 Stretch Limits: When tested in accordance with 3.4.2.1, the stretch limit in the cable shall be as follows:

a. The 0.020 inch nominal diameter cable as in 3.3.2.1 shall not exceed one percent when it is loaded to 60 percent of the minimum breaking strength as specified in Table 2.

b. The 0.032 inch nominal diameter cable as in 3.3.2.2 shall not exceed 1.5 percent when it is loaded to 60 percent of the minimum breaking strength as specified in Table 2.

3.4.2.1 Stretch Test: For each size and material, one specimen from each sample of wire strand or cable, taken from the production inspection lot, shall be tested to determine the percent stretch. The length of the wire strand or cable specimen to be tested shall not be less than 24 inches. The amount of stretch shall be determined on a tension testing machine in accordance with ASTM E8. The specimen shall be loaded to one percent of the minimum breaking strength specified in Table 2 to straighten the wire strand or cable. While the specimen is under tension, a gage length not less than 10 inches shall be marked on the specimen between the end fittings of the testing machine. The specimen shall then be loaded to 60 percent of the minimum breaking strength and measured for elongation under load. From this data, the percent stretch can be read directly or calculated using equation 1:

% Stretch = (100) (elongation under load) / (original length) (Eq 1)

3.4.3 Test Load: Each wire strand or cable shall carry 80 percent of its respective minimum breaking load, as specified in Table 2, without any failures. The test loading shall be made using the same specimen used in the stretch test. Load the speciment to one percent of the breaking strength, then increase the loading to 80 percent of the minimum breaking strength of the wire strand or cable and applied for five seconds. At the end of the test, the specimen shall be removed and the entire specimen be completely unwound and each individual wire inspected. A suitable electronic device capable of detecting the breaking of individual wires during testing may be used instead of unwinding the wires from the specimen. The failure of any wire shall be cause for rejection.

3.4.3.1 Use of Electronic Device for First Wire Break Test: The load shall be increased to 80 percent on the test specimen. If no ping is heard, the specimen has passed the test. If one or more pings are heard, the specimen will be unraveled and the broken wires shall confirm failure of the specimen. If no broken wires are found, the specimen has passed the test.

3.4.4 Pull-Off Test: The crimped fitting end on the safety cable shall withstand a pull-off load not less than that specified in Table 3, determined in accordance with ASTM E8.

TABLE 2 - Construction & Physical Property of Cables

Material	Nom Cable Dia inch (mm)	Tolerance on Dia Plus Only inch (mm)	Con-struct-tion	Breaking Strength Minimum LbF (N)
AMS 5687	0.020 (0.508)	0.006 (0.152)	1 X 7	75 (333.6)
AMS 5689	0.020 (0.508)	0.006 (0.152)	1 X 7	70 (311.4)
AMS 5697	0.020 (0.508)	0.006 (0.152)	1 X 7	70 (311.4)
AMS 5687	0.032 (0.813)	0.006 (0.152)	3 X 7	116 (516.0)
AMS5689	0.032 (0.813)	0.006 (0.152)	3 X 7	110 (489.3)
AMS 5697	0.032 (0.813)	0.006 (0.152)	3 X 7	110 (489.3)

3.5 INSTALLATION:

3.5.1 Maximum Span: The maximum span of safety cable between two termination points shall be six inch (152.4 mm) unless otherwise specified.

3.5.2 Installation Defects: Any cable defect (nick, fray, kink, or any other mutilation of the safety cable) found prior to, during, or subsequent to installation, at or between termination points, is not acceptable.

3.5.3 Installation Holes: In all cases the safety cable must be installed through the holes specified on the part drawing.

3.5.4 Safety Cable/Ferrule Reuse: Safety cable and ferrule shall be new upon each application. Reuse is not acceptable.

3.5.5 Installation: Various examples of safety cable installation are shown in Figures 1 to 3. All possible combinations are not shown. Unless otherwise specified in the application engineering drawing, safety cable shall be installed in two or three bolt patterns with two bolt patterns being the preferred method when safety cable is applied to an even number of fasteners. Although every possible combination is not shown, any combination must adhere to the basic rules outlined in this specification.

3.5.5.1 Hose and Electrical Requirements: Hose and electrical coupling nuts shall have safety cable installed in the same manner as tube coupling nuts.

3.5.6 Crimp Requirements (Pull-Off Load): The ferrule shall be crimped to the cable by any suitable mechanical means. The safety cable assembly must be capable of meeting the minimum crimp requirements in Table 3.

TABLE 3 - Safety Cable Minimum Crimp Requiremsnts
(Pull-Off Load)

Nominal Cable Diameter inch (mm)	Minimum Pull-Off Load LbF (N)
0.020 (0.510)	30 (133.4)
0.032 (0.813)	70 (311.4)

3.5.7 Detailed Installation:

3.5.7.1 Hole Alignment: Undertorquing or overtorquing to obtain proper alignment of the holes is not permitted.

3.5.7.2 Adjacent Units: It is recommended that safety cable be installed in such a manner that any tendency for a fastener to loosen will be counteracted by an additional tension on the cable. The recommended practice for installation is to avoid sharp turns; in excess of 90 degrees, as the cable is threaded through the fasteners. This will produce installed safety cable with either positive or neutral pull.

3.5.7.3 Cable Flex Limits: After installing, the maximum cable flex limits between termination points shall be no greater than that specified in Figure 4 and Table 7.

3.5.7.4 Excess Cable: After installing safety cable, excess cable from crimped ferrule shall be cut off. The maximum allowable length of cable extending beyond the ferrule shall be .031 in (0.79 mm).

3.6 Quality: Kits of safety cables, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the parts. Cut end of cable shall not contain frayed strands of wire.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of parts shall supply all samples for vendor's test and shall be responsible for performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the parts conform to the requirements of this specification.

4.2 Responsibility for Compliance:

The manufacturer's system for parts production shall be based on preventing product defects, rather than detecting the defects at final inspection and then requiring corrective action to be invoked. An effective manufacturing in-process control system shall be established, subject to the approval of the purchaser, and used during the production of parts.

4.3 Production Acceptance Tests:

The purpose of production acceptance tests is to check, as simply as possible, using a method which is inexpensive and representative of the part usage, with the uncertainty inherent in random sampling, that the parts comprising a production inspection lot satisfy the requirements of this specification.

4.3.1 Tests to determine conformance to all technical requirements of this specification are classified as acceptance tests and shall be performed on each production inspection lot. A summary of acceptance tests is specified in Table 4.

4.4 Acceptance Tests Sampling:

4.4.1 Material: One sample of wire, from which safety cable kit was made, from each heat of alloy.

4.4.2 Non-Destructive Tests - Visual and Dimensional: A random sample shall be selected from each production inspection lot in accordance with Table 5.

4.4.3 Destructive Tests: A random sample shall be selected from each production inspection lot; the size of the sample shall be as specified in Table 6, except the sample for the Stretch Test as in 3.4.2.1 and the Test Load as in 3.4.3 shall be a specimen as specified in 3.4.2.1.

4.4.4 Acceptance Quality: Of random samples tested, acceptance quality shall be based on zero defectives.

4.5 Reports:

The vendor of safety cable kits shall furnish with each shipment a report stating that the chemical composition of the kits conforms to the applicable material specification, showing the results of performance tests, and stating that the kits conform to the other technical requirements. This report shall include the purchase order number, AS4536, lot number, contractor or other direct supplier of material, part number, nominal size, and quantity.

4.6 Rejected Lots:

If a production inspection lot is rejected, the vendor of the parts may perform corrective action to screen out or rework the defective parts, and resubmit for acceptance tests inspection as in Table 4. Resubmitted lots shall be clearly identified as re-inspected lots.

5. PREPARATION FOR DELIVERY:

5.1 Packaging and Identification:

5.1.1 Kits having different part numbers shall be packed in separate containers.

5.1.2 Each container of parts shall be marked to show not less than the following information:

KIT, SAFETY CABLE, NICKEL ALLOY (or CRES, as applicable)
AS4536
PART NUMBER
LOT NUMBER
PURCHASER ORDER NUMBER
QUANTITY
MANUFACTURER'S IDENTIFICATION

5.1.3 Safety cable kits shall be suitably protected from abrasion and chafing during handling, transportation, and storage.

5.1.4 Containers of kits shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

5.1.5 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-2073-1, industrial packaging, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGEMENT:

A vendor shall mention this specification in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Parts not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Direct U.S. Military Procurement:

Purchase documents should specify the following:

Title, number, and date of this specification
Part number of parts desired
Quantity of parts desired
Level A packaging, if required (see 5.1.5)

8.2 Key Words:

Kit, Safety Cable; Procurement Specification.

TABLE 4 - Summary of Acceptance Tests

Characteristic	Req. Para.	Sample Size	Test Method
Non-Destructive Tests			
Design & Dimensions	3.2	Table 6	Conventional measuring methods
Construction	3.3	Table 6	Visual
Quality	3.6	Table 6	Visual
Destructive Tests			
Material Composition	3.1	4.4.1	Per material specification
Breaking Strength	3.4.1	Table 7	ASTM E 8
Stretch Limits	3.4.2	3.4.2.1	ASTM E 8
Test Load	3.4.3	3.4.2.1	ASTM E 8
Pull-Off Test	3.4.4	Table 7	ASTM E 8

TABLE 5 - Sampling Data

Non-Destructive Tests Visual and Dimensional	
Production Inspection Lot Size	Sample Size
2 to 15	2
16 to 50	3
51 to 150	5
151 to 500	8
501 to 3200	13
3201 to 35,000	20
35,001 to 500,000	32
500,000 and over	50

TABLE 6 - Sampling Data

Destructive Tests, Performance Tests	
Production Inspection Lot Size	Sample Size
Up to 500	3
501 to 3200	5
3201 to 35,000	8
35,001 and over	13

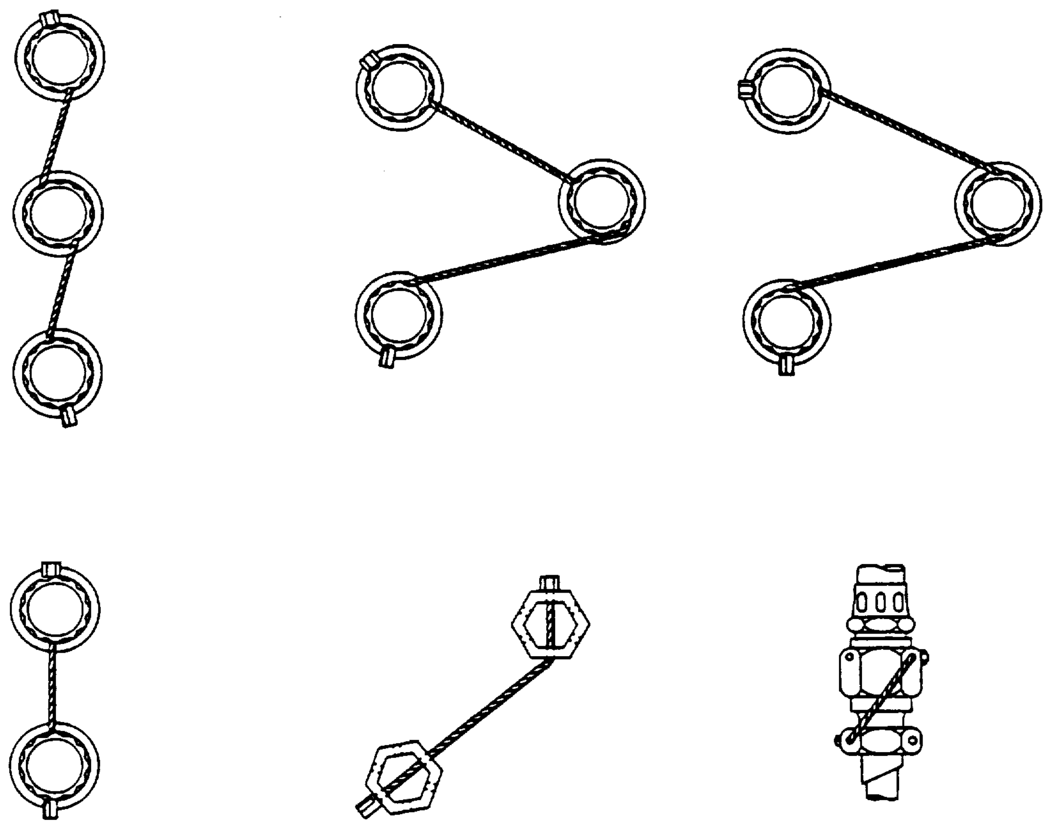


FIGURE 1 - STANDARD HARDWARE

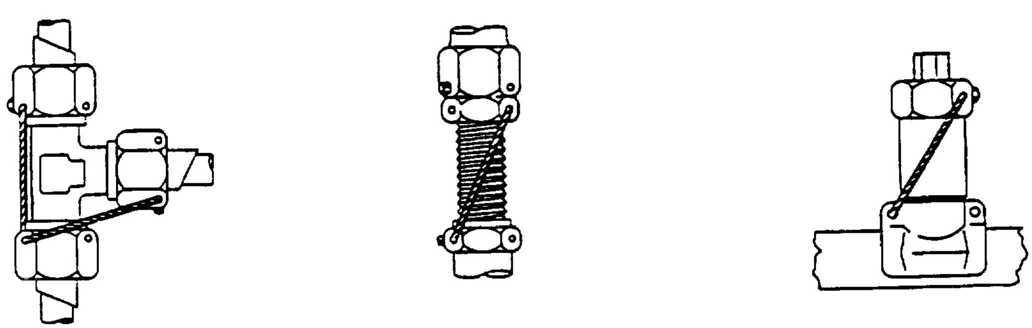


FIGURE 2 - TUBE COUPLINGS

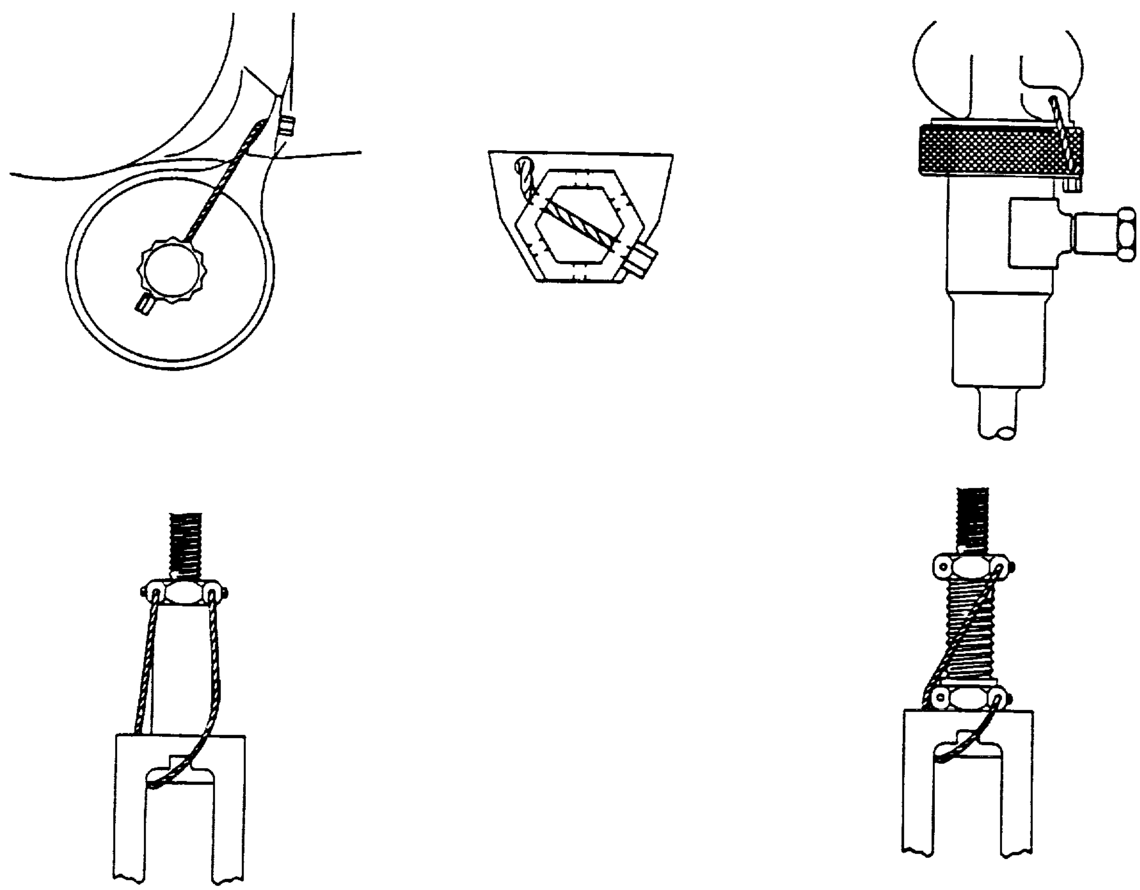
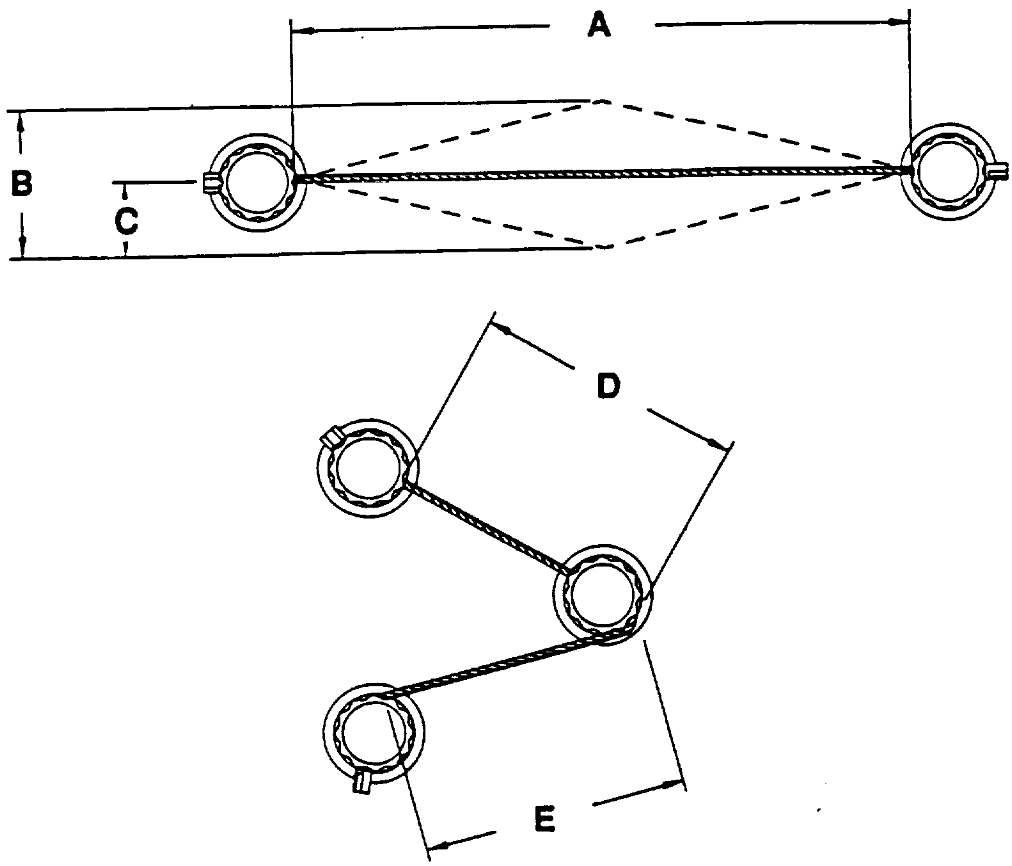


FIGURE 3 - OTHER APPLICATIONS



For Three Bolt Patterns
A = D + E

FIGURE 4 - SAFETY CABLE FLEX LIMITS

TABLE 7 - Flex Limits, Dimensions

A inch (mm)	B inch (mm)	C inch (mm)
0.5 (12.7)	0.125 (3.18)	0.062 (1.59)
1.0 (25.4)	0.250 (6.35)	0.125 (3.18)
2.0 (50.8)	0.375 (9.52)	0.188 (4.76)
3.0 (76.2)	0.375 (9.52)	0.188 (4.76)
4.0 (101.6)	0.500 (12.70)	0.250 (6.35)
5.0 (127.0)	0.500 (12.70)	0.250 (6.35)
6.0 (152.4)	0.625 (15.88)	0.312 (7.94)

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GENERAL STANDARDS FOR AEROSPACE PROPULSION SYSTEMS

AS3509

FEDERAL SUPPLY CLASS
5340

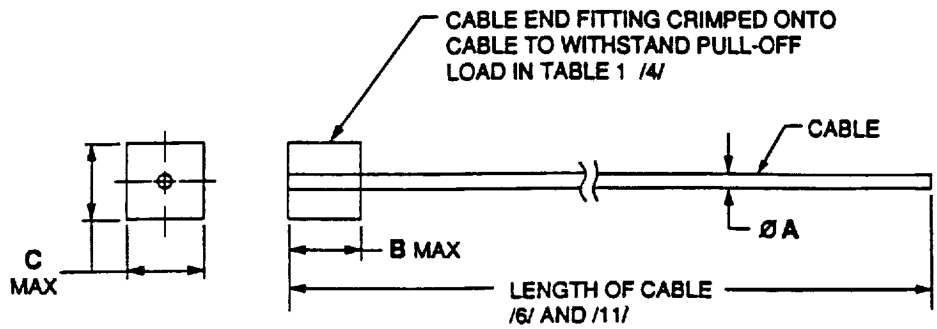

FIGURE 1 - SAFETY CABLE-END FITTING AND CABLE ASSEMBLY

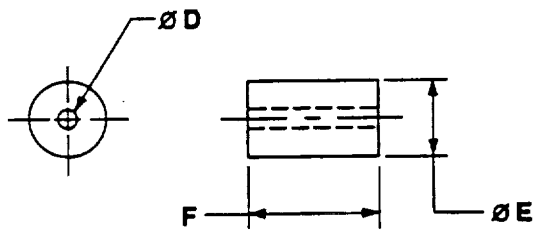

FIGURE 2 - FERRULE

TABLE 1 - DIMENSIONS

PART NUMBER	A /5/	B MAX	C MAX	D
AS3509 - 01XXL	.020 - .026 (0.510 - 0.660)	.135 (3.429)	.085 (2.159)	.029 - .032 (0.737 - 0.813)
AS3509 - 02XXL	.032 - .038 (0.813 - 0.965)	.135 (3.429)	.125 (3.175)	.043 - .049 (1.092 - 1.245)

	E	F	CABLE TYPE	MINIMUM PULL-OFF LOAD
AS3509 - 01XXL	.089 - .091 (2.261 - 2.311)	.087 - .095 (2.210 - 2.413)	STRAND 1X7	30 (133.4)
AS3509 - 02XXL	.104 - .106 (2.642 - 2.692)	.156 - .164 (3.962 - 4.166)	CABLE 3X7	70 (311.4)

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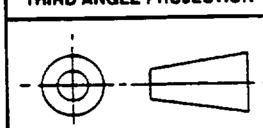
THIRD ANGLE PROJECTION



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AEROSPACE STANDARD

CABLE, SAFETY, KIT
NICKEL ALLOY, UNS N06600

AS3509

SHEET 1 OF 2

FEDERAL SUPPLY CLASS
5340

AS3509

NOTES:

1. MATERIAL: CABLE, END FITTING, AND FERRULE - AMS 5687, NICKEL ALLOY WIRE, (UNS N06600 CRES WIRE).

2. PROCUREMENT SPECIFICATION: AS4536-1.

3. INSTALLATION IN ACCORDANCE WITH AS4536.

/4/ CABLE END FITTING SHAPE OPTIONAL, HOWEVER, MUST BE WITHIN SPECIFIED ENVELOPE.

/5/ CUT END OF CABLE OR STRAND SHALL BE FUSED TO PREVENT UNRAVELING AND CAN BE UP TO .006 INCH (0.152 MM) ABOVE ACTUAL MEASURED DIAMETER.

/6/ LENGTH OF CABLE SHALL BE IN 3.0 INCH (76.2 MM) INCREMENTS; MINIMUM LENGTH AT 6.0 INCH (152.4 MM), MAXIMUM LENGTH AT 24.0 INCH (609.6 MM), +/-.50 (12.7 MM).

7. MARK PART NUMBER AND MANUFACTURER IDENTIFICATION PER AS478 CLASS N.

8. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M.

9. DIMENSIONS ARE IN INCHES, PARENTHESIS ARE IN MILLIMETERS.

10. PULL-OFF LOAD IN POUND-FORCE, PARENTHESIS IN NEWTONS.

/11/ EXAMPLE OF KIT PART NUMBER: FOR .032 INCH (0.889 MM) NOMINAL DIAMETER SAFETY CABLE AND FERRULE, 9.0 INCH (228.6 MM) LONG.

AS3509 - 0209L

DOCUMENT NUMBER (AS3509)

9.0 INCH (228.6 MM) LENGTH OF CABLE (9L)

SAFETY CABLE ASSEMBLY Ø A PER TABLE 1 (02)

12. DO NOT USE UNASSIGNED PART NUMBERS.

13. AS AND AMS ARE SAE PUBLICATIONS.

14. ANSI Y14.5M IS AN AMERICAN NATIONAL STANDARDS INSTITUTE PUBLICATION.

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AEROSPACE STANDARD	AS3509
CABLE, SAFETY, KIT NICKEL ALLOY, UNS N06600	SHEET 2 OF 2

AS3510

FEDERAL SUPPLY CLASS
5340

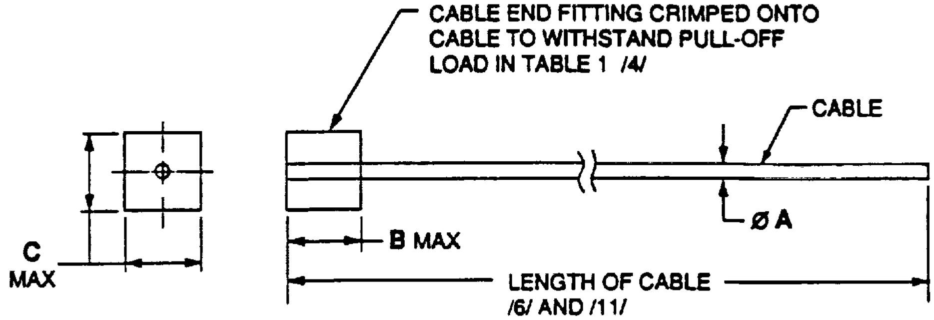

FIGURE 1 - SAFETY CABLE-END FITTING AND CABLE ASSEMBLY

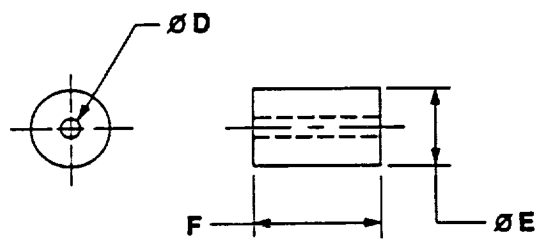

FIGURE 2 - FERRULE

TABLE 1 - DIMENSIONS

PART NUMBER	A /5/	B MAX	C MAX	D
AS3510 - 01XXL	.020 - .026 (0.510 - 0.660)	.135 (3.429)	.085 (2.159)	.029 - .032 (0.737 - 0.813)
AS3510 - 02XXL	.032 - .038 (0.813 - 0.965)	.135 (3.429)	.125 (3.175)	.043 - .049 (1.092 - 1.245)

	E	F	CABLE TYPE	MINIMUM PULL-OFF LOAD
AS3510 - 01XXL	.089 - .091 (2.261 - 2.311)	.087 - .095 (2.210 - 2.413)	STRAND 1X7	30 (133.4)
AS3510 - 02XXL	.104 - .106 (2.642 - 2.692)	.156 - .164 (3.962 - 4.166)	CABLE 3X7	70 (311.4)

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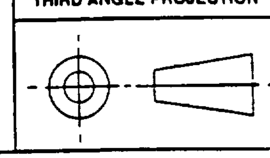
THIRD ANGLE PROJECTION



CUSTODIAN: SAE E-25, GENERAL STANDARDS FOR AEROSPACE PROPULSION SYSTEMS

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AEROSPACE STANDARD

CABLE, SAFETY, KIT - CORROSION, AND HEAT RESISTANT STEEL, UNS S32100

AS3510

SHEET 1 OF 2

FEDERAL SUPPLY CLASS
5340

NOTES:

1. MATERIAL: CABLE, END FITTING, AND FERRULE - AMS 5689 CRES WIRE, (UNS S32100 CRES WIRE).
2. PROCUREMENT SPECIFICATION: AS4536-2.
3. INSTALLATION IN ACCORDANCE WITH AS4536.

/4/ CABLE END FITTING SHAPE OPTIONAL, HOWEVER, MUST BE WITHIN SPECIFIED ENVELOPE.

/5/ CUT END OF CABLE OR STRAND SHALL BE FUSED TO PREVENT UNRAVELING AND CAN BE UP TO .006 INCH (0.152 MM) ABOVE ACTUAL MEASURED DIAMETER.

/6/ LENGTH OF CABLE SHALL BE IN 3.0 INCH (76.2 MM) INCREMENTS; MINIMUM LENGTH AT 6.0 INCH (152.4 MM), MAXIMUM LENGTH AT 24.0 INCH (609.6 MM), +/-.50 (12.7 MM).

7. MARK PART NUMBER AND MANUFACTURER IDENTIFICATION PER AS478 CLASS N.
8. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M.
9. DIMENSIONS ARE IN INCHES PARENTHESIS ARE IN MILLIMETERS.
10. PULL-OFF LOAD IN POUND-FORCE, PARENTHESIS IN NEWTONS.

/11/ EXAMPLE OF KIT PART NUMBER: FOR .032 INCH (0.889 MM) NOMINAL DIAMETER SAFETY CABLE AND FERRULE, 9.0 INCH (228.6 MM) LONG.

AS3510 - 0209L

DOCUMENT NUMBER (AS3510)

9.0 INCH (228.6 MM) LENGTH OF CABLE (09L)

SAFETY CABLE ASSEMBLY Ø A PER TABLE 1 (02)

12. DO NOT USE UNASSIGNED PART NUMBERS.
13. AS AND AMS ARE SAE PUBLICATIONS.
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	AEROSPACE STANDARD	AS3510
	CABLE, SAFETY, KIT - CORROSION, AND HEAT RESISTANT STEEL, UNS S32100	SHEET 2 OF 2

FEDERAL SUPPLY CLASS
5340

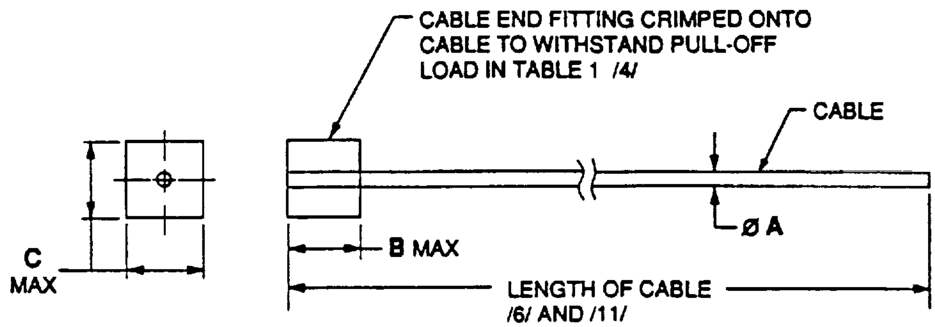

FIGURE 1 - SAFETY CABLE-END FITTING AND CABLE ASSEMBLY

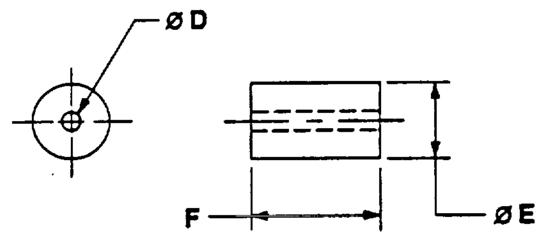

FIGURE 2 - FERRULE

TABLE 1 - DIMENSIONS

PART NUMBER	A /5/	B MAX	C MAX	D
AS3511 - 01XXL AS3511 - 02XXL	.020 - .026 (0.510 - 0.660) .032 - .038 (0.813 - 0.965)	.135 (3.429) .135 (3.429)	.085 (2.159) .125 (3.175)	.029 - .032 (0.737 - 0.813) .043 - .049 (1.092 - 1.245)

	E	F	CABLE TYPE	MINIMUM PULL-OFF LOAD
AS3511 - 01XXL AS3511 - 02XXL	.089 - .091 (2.261 - 2.311) .104 - .106 (2.642 - 2.692)	.087 - .095 (2.210 - 2.413) .156 - .164 (3.962 - 4.166)	STRAND 1X7 CABLE 3X7	30 (133.4) 70 (311.4)

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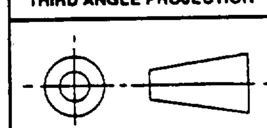
THIRD ANGLE PROJECTION



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AEROSPACE STANDARD

CABLE, SAFETY, KIT - CORROSION RESISTANT STEEL, UNS S30400

AS3511

SHEET 1 OF 2

FEDERAL SUPPLY CLASS
5340

AS3511

NOTES:

1. MATERIAL: CABLE, END FITTING, AND FERRULE - AMS 5697 CRES WIRE, (UNS S30400 CRES WIRE).
2. PROCUREMENT SPECIFICATION: AS4536-3.
3. INSTALLATION IN ACCORDANCE WITH AS4536.

/4/ CABLE END FITTING SHAPE OPTIONAL, HOWEVER, MUST BE WITHIN SPECIFIED ENVELOPE.

/5/ CUT END OF CABLE OR STRAND SHALL BE FUSED TO PREVENT UNRAVELING AND CAN BE UP TO .006 INCH (0.152 MM) ABOVE ACTUAL MEASURED DIAMETER.

/6/ LENGTH OF CABLE SHALL BE IN 3.0 INCH (76.2 MM) INCREMENTS; MINIMUM LENGTH AT 6.0 INCH (152.4 MM), MAXIMUM LENGTH AT 24.0 INCH (609.6 MM), +/-.50 (12.7 MM).

7. MARK PART NUMBER AND MANUFACTURER IDENTIFICATION PER AS478 CLASS N.
8. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M.
9. DIMENSIONS ARE IN INCHES PARENTHESIS ARE IN MILLIMETERS.
10. PULL-OFF LOAD IN POUND-FORCE, PARENTHESIS IN NEWTONS.

/11/ EXAMPLE OF KIT PART NUMBER: FOR .032 INCH (0.889 MM) NOMINAL DIAMETER SAFETY CABLE AND FERRULE, 9.0 INCH (228.6 MM) LONG.

AS3511 - 0209L

DOCUMENT NUMBER

9.0 INCH (228.6 MM) LENGTH OF CABLE

SAFETY CABLE ASSEMBLY Ø A PER TABLE 1

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AEROSPACE STANDARD

CABLE, SAFETY, KIT - CORROSION RESISTANT STEEL, UNS S30400

AS3511

SHEET 2 OF 2

REPORT DOCUMENTATION PAGE

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5. FUNDING NUMBERS
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John Ralph

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Goddard Space Flight Center
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J. Ralph: Interstel, Inc., 8000 Virginia Manor Road, Suite 180, Beltsville, Maryland.

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13. ABSTRACT *(Maximum 200 words)*

Bergen Cable Technology (BCT) has introduced a new product they refer to as "safety cable." This product is intended as a replacement for lockwire when installed per Aerospace Standard (AS) 4536 (included in Appendix D of this document). Installation of safety cable is reportedly faster and more uniform than lockwire. NASA/GSFC proposes to use this safety cable in Shuttle Small Payloads Project (SSPP) applications on upcoming Shuttle missions. To assure that BCT safety cable will provide positive locking of fasteners equivalent to lockwire, the SSPP will conduct vibration and pull tests of the safety cable.

14. SUBJECT TERMS
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