COTS ENCLOSURES ENVIRONMENTAL CHARACTERIZATION TEST REPORT

Prepared by:

Naval Surface Warfare Center
Crane Division
300 Highway 361
Crane, Indiana 47522

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EXECUTIVE SUMMARY

The Naval Sea Systems Command (PMS-428) tasked the Crane Division, Naval Surface Warfare Center (NSWC) to perform environmental tests on 6U VME convection cooled and conduction cooled enclosures provided by various vendors. A limited market survey was conducted to locate Commercial-Off-The-Shelf (COTS) equipment which could potentially satisfy rotary wing aircraft environmental requirements. Products were selected based on product availability and vendor willingness to participate in the tests. Products were chosen to represent a range of robustness from low end convection cooled to high end conduction cooled enclosures. The goal was to ***characterize*** the environmental responses of these COTS equipments and to determine potential suitability for use in a military rotary wing aircraft environment. The testing was conducted at the Crane Division, NSWC between 30 October 1995 and 6 November 1996. The following tests were performed:

1. Electromagnetic Environmental Effects (E^3).
2. Thermal design.
3. Airborne noise.
4. Temperature/altitude.
5. Vibration and shock.
6. Humidity.

The results of these tests are presented herein.

Jon Homme
By direction

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SECTION 1

INTRODUCTION

1.1 SCOPE

The Naval Sea Systems Command (PMS-428) tasked the Crane Division, Naval Surface Warfare Center (NSWC) to perform environmental characterization tests on 6U VME enclosures and modules provided by various vendors. The objective was to determine the potential suitability of using Commercial-Off-The-Shelf (COTS) equipment in a military rotary wing aircraft environment. The testing was conducted at the Crane Division, NSWC between 30 October 1995 and 6 November 1996. The following tests were performed:

1. Electromagnetic Environmental Effects (E^3).
2. Thermal design.
3. Airborne noise.
4. Temperature/altitude.
5. Vibration and shock.
6. Humidity.

NOTE: This test report is the summation of an extensive data set obtained during characterization tests. Detailed data sheets and plots are available for review by authorized parties. To obtain additional information, contact Jon Homme, Code 6022, Crane Division, NSWC, 300 Highway 361, Crane, Indiana 47522, phone 812-854-2212.

1.2 EQUIPMENT IDENTIFICATION

1.2.1 Vendor 1 Enclosure. Convection enclosure, 6U VME, 15 module slots, 350 watts power supply.

1.2.2 Vendor 2 Enclosure. Convection enclosure, 6U VME, 20 module slots, 640 watts power supply.

1.2.3 Vendor 3 Enclosure. Convection enclosure, 6U VME, 13 module slots, 622 watts power supply.

1.2.4 Vendor 4 Enclosure. Conduction enclosure, 6U VME, 10 module slots, 155 watts power supply.

1.2.5 Vendor 5 Module. Convection module, 6U VME, CPU type, extended temperature ranges (-40° to +85°C), quantity 2 (one of which was conformal coated).

1.2.6 Vendor 6 Module. Conduction module, 6U VME, CPU type, ruggedized, quantity 2.

We acknowledge that the sample size of 6U VME products tested does not represent every commercial vendor/product available in the marketplace. We also recognize the fact that the commercial marketplace is constantly changing, and commercial products are continually being improved. However, the conclusions presented in this report are based on the market survey, the vendors' responses, and the products tested in this limited sample.

1.3 SUMMARY/CONCLUSIONS

1.3.1 Convection cooled enclosures.

A summary of the findings for the convection cooled enclosures is provided in Table I.

TABLE I. Convection cooled enclosures findings summary.

CONVECTION COOLED ENCLOSURES	
TEST	FINDINGS
TEMPERATURE/ALTITUDE	POWER TRAIN ASSEMBLIES FAILED/MALFUNCTIONED
VIBRATION	POWER TRAIN ASSEMBLIES FAILED SHOCK ISOLATORS, ON BOTH EXTERNAL SHOCK TRAYS AND INTERNAL CARD CAGE (WIRE ROPE TYPE) FAILED MECHANICAL FASTENERS ON VME MODULES AND ON ENCLOSURE ACCESS PANELS VIBRATED LOOSE/OUT
E^3	CONDUCTED AND RADIATED EMISSIONS OUT OF SPECIFICATION
HUMIDITY	MINOR CORROSION ON VME MODULES AND ENCLOSURE
THERMAL DESIGN	INSUFFICIENT/MARGINAL AIRFLOW BETWEEN A NUMBER OF VME MODULES ON 1 OF 3 ENCLOSURES

1.3.1.1 Convection cooled enclosures conclusions.

Based on the findings for the convection enclosures shown in Table I, the following conclusions were made:

a. Power train assemblies require wider temperature operating ranges, enhanced EMI power line conducted emissions suppression, and vibration resistance.

b. The enclosures' vibration damping systems are inadequate and need to be re-assessed.

c. The enclosures require improved shielding to attenuate EMI radiated emissions.

d. The minor corrosion observed during humidity testing did not affect electrical performance and is not considered an area of concern.

e. Thermal responses were adequate on two of the three enclosures tested. Adequate air flow should be verified on any enclosure selected.

f. The deficiencies observed in the above findings should be able to be mitigated by careful selection of subassemblies and additional engineering tailored for the rotary wing aircraft environment.

1.3.1.2 Additional observations for the convection cooled enclosures.

The same two convection cooled 6U VME modules were used during all the tests of the three convection cooled enclosures. The modules survived the following environments:

a. Eight series of vibration tests (including some catastrophic enclosure failures).

b. Three temperature/altitude tests.

c. One humidity test.

d. Six radiated susceptibility tests.

Therefore, it was concluded that the extended temperature 6U VME modules are acceptable for use in a rotary wing aircraft environment.

1.3.2 Conduction cooled enclosure.

A summary of the findings for the conduction cooled enclosure is provided in Table II.

TABLE II. Conduction cooled enclosure findings summary.

CONDUCTION COOLED ENCLOSURE	
TEST	FINDINGS
E^3	CONDUCTED AND RADIATED EMISSIONS OUT OF SPECIFICATION
HUMIDITY	MINOR CORROSION ON CONNECTORS
THERMAL DESIGN	COLD WALL TEMPERATURES FOR HIGH TEMPERATURE ENVIRONMENTS EXCEED GENERALLY ACCEPTED GUIDELINES

1.3.2.1 Conduction cooled enclosure conclusions.

Based on the findings for the conduction enclosure shown in Table II, the following conclusions were made:

a. Power train assemblies require enhanced power line conducted emissions suppression.

b. The enclosure requires improved shielding to attenuate EMI radiated emissions.

c. The minor corrosion observed during humidity testing did not affect electrical performance and is not considered an area of concern.

d. Thermal response was marginal for the enclosure tested. The testing showed that the enclosure cold wall temperatures would be approximately 7 - 12°C above the maximum recommended 85°C for the 6U VME conduction modules tested when operating in a 55°C environment. Operating for short periods of time marginally above 85°C would probably be acceptable. The reliability reduction would need to be determined by looking at the amount of time the module was operated above the maximum recommended temperature.

e. The deficiencies observed in the above findings are not as severe as for the convection enclosures, and they should be able to be mitigated by careful selection of subassemblies and additional engineering tailored for the rotary wing aircraft environment.

1.3.2.2 Additional observations for the conduction cooled enclosure.

The same two conduction cooled 6U VME modules were used in all the tests of the conduction cooled enclosure. The modules survived the shock, vibration, temperature/altitude, humidity, and radiated susceptibility tests. Therefore, it was concluded that the extended temperature 6U VME conduction modules are acceptable for use in a rotary wing aircraft environment.

SECTION 2

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3) TESTING

2.1 INTRODUCTION/OBJECTIVE

The purpose of the testing was to determine the level of emissions conducted onto the power leads of the COTS enclosures and the level of emissions radiated by the COTS enclosures. Test procedures and requirements were in accordance with MIL-STD-461C, 461D, 462, and 462D.

2.2 EQUIPMENT TESTED AND LOADING

E^3 tests were performed on the three convection enclosures supplied by Vendors 1, 2, and 3 and the conduction enclosure supplied by Vendor 4. The three convection enclosures were populated with two CPU convection modules supplied by Vendor 5 and VME load modules set to provide 50% power loading. The conduction enclosure was populated with two CPU conduction modules supplied by Vendor 6, providing a 19% power loading.

2.3 TEST EQUIPMENT

Terminal monitor	Wyse, model WY-85, P/N 00-085-05
Regulated power supply	Lambda, model LES-F-03-OV
Shielded test chamber	Echoshield 24' x 24' x 10' (100dB)
Computer	Hewlett-Packard, model HP9836
Electromagnetic interference test measurement software	Hewlett-Packard, model HP85869
Spectrum analyzer	Hewlett-Packard, model 8566B
Current transformer	Electrometrics, model PCL-11
Current transformer	Electrometrics, model PCL-30
Line stabilization capacitor	Solar Electronics, model 6518-106R
RF preselector	Hewlett-Packard, model 85685A

VARIAC	Staco, Inc., model 3PN2210
Isolation transformer	Topaz, model 91001-12
Line impedance stabilization network	TEGAM, model 95300-50
Plotter	Hewlett-Packard, model 7475A
Antenna	EMCO, model 3301B
Antenna	Electrometrics, model BIA-30
Antenna	Electrometrics, model LCA-30
Antenna	Electrometrics, model LPA-30
Antenna	Instruments for Industry, model EFG-2
Oscillator	Hewlett-Packard, model HP651B
Signal generator	Hewlett-Packard, model HP8640B
Amplifier	Amplifier Research, model 150L
Amplifier	Amplifier Research, model 50W1000

2.4 TEST PROCEDURES

MIL-STD-461C, requirement CE01: Procedures of MIL-STD-462, method CE01, part 2 (aircraft) and part 5 (surface ship).

MIL-STD-461C, requirement CE03: Procedures of MIL-STD-462, method CE03, part 2 (aircraft) and part 5 (surface ship).

MIL-STD-461C, requirement RE02: Procedures of MIL-STD-462, method RE02, part 2 (aircraft) and part 5 (surface ship), with the following exceptions: The ambient electric field measured was greater than the maximum specified in paragraph 4.2.1.1 of MIL-STD-462. Due to equipment unavailability, the procedure given to measure emissions in the presence of high ambient fields was not performed. The ranges that this exception applies to is the following: 20 MHZ to 70 MHz, at 128.17 MHz, 132.53 MHz, and 226.51 MHz.

MIL-STD-461C, requirement RS03: Procedures of MIL-STD-462, method RS03, part 2 (aircraft) and part 5 (surface ship).

MIL-STD-461D, requirement CE101: Procedures of MIL-STD-462D, method CE101 (surface ship, submarine, and ASW aircraft)..

MIL-STD-461D, requirement CE102: Procedures of MIL-STD-462D, method CE102.

MIL-STD-461D, requirement RE102: Procedures of MIL-STD-462D, method RE102, with the following exceptions: (1) The height of the ground plane above the floor was 100 cm instead of 80 cm to 90 cm specified in figure RE02-2 of MIL-STD-461D. (2) Due to equipment unavailability, a log-periodic antenna was substituted for the antenna described in paragraph 2 of MIL-STD-462D, method RE102 in the frequency range of 200 MHz to 1 GHZ. (3) The ambient electric field measured was greater than the maximum specified in paragraph 4.4 of MIL-STD-462D for the following ranges: 40 MHz - 50 MHz, at 110 MHz and at 120 MHz. (4) The RF absorber material described in figure 1 of MIL-STD-462D is not available and therefore was not used.

2.5 TEST RESULTS

Vendor 1 convection enclosure: Passed 9 of 12 tests run.
Failed 3 of 12 tests run (RE02 aircraft, CE03 surface ship, and RE02 surface ship).

Vendor 2 convection enclosure: Passed 5 of 12 tests run.
Failed 7 of 12 tests run (CE03 aircraft, CE01 surface ship, CE03 surface ship, RE02 surface ship, CE101 surface ship & submarine, CE101 ASW aircraft, and CE102).

Vendor 3 convection enclosure: Passed 8 of 12 tests run.
Failed 4 of 12 tests run (CE03 aircraft, CE03 surface ship, RE02 surface ship, and RE102).

Vendor 4 conduction enclosure: Passed 7 of 12 tests run.
Failed 5 of 12 tests run (CE03 aircraft, RE02 aircraft, CE03 surface ship, RE02 surface ship, and RE102).

A summary of the tests run and the results for each vendor is shown in Table III.

2.6 CONCLUSIONS

a. Convection and conduction cooled enclosures require additional shielding to attenuate radiated emissions.

b. Power supply and EMI filter selection for both convection and conduction cooled enclosures must consider EMI conducted emission requirements.

TABLE III. E^3 test results summary.

TEST IDENTIFICATION		VENDOR 1 ENCLOSURE RESULT	VENDOR 2 ENCLOSURE RESULT	VENDOR 3 ENCLOSURE RESULT	VENDOR 4 ENCLOSURE RESULT
STANDARD	TEST METHOD				
MIL-STD-461C, PART 2	CE01 AIRCRAFT	PASS	PASS	PASS	PASS
	CE03 AIRCRAFT	PASS	FAIL	FAIL	FAIL
	RE02 AIRCRAFT	FAIL	PASS	PASS	FAIL
	RS03 AIRCRAFT	PASS	PASS	PASS	PASS
MIL-STD-461C, PART 5	CE01 SURFACE SHIP	PASS	FAIL	PASS	PASS
	CE03 SURFACE SHIP	FAIL	FAIL	FAIL	FAIL
	RE02 SURFACE SHIP	FAIL	FAIL	FAIL	FAIL
	RS03 SURFACE SHIP	PASS	PASS	PASS	PASS
MIL-STD-461D	CE101 SURFACE SHIP & SUBMARINE	PASS	FAIL	PASS	PASS
	CE101 ASW AIRCRAFT	PASS	FAIL	PASS	PASS
	CE102	PASS	FAIL	PASS	PASS
	RE102	PASS	PASS	FAIL	FAIL

SECTION 3

THERMAL DESIGN TESTING

3.1 INTRODUCTION/OBJECTIVE

For the convection enclosures, an objective was to determine the air flow rates between the VME modules. The air flow rates in conjunction with the interior air temperatures provide a good indication of the cooling capabilities of the enclosures. For both the convection enclosures and the conduction enclosure tested, thermal surveys were performed to provide temperature rise data and temperature stabilization times.

3.2 EQUIPMENT TESTED AND LOADING

The air flow tests were performed on the three convection enclosures supplied by vendors 1, 2, and 3. For the air flow tests the card cages were fully populated with commercial VME load modules with their power setting shut off. The thermal survey (temperature rise and stabilization tests) was performed on the three convection enclosures supplied by vendors 1, 2, and 3 and the one conduction enclosure supplied by vendor 4. The convection enclosures were tested with two CPU convection modules supplied by vendor 5 and located in the first and last slots. The remaining slots were populated with commercial VME load modules, which were set to provide a total power loading of 75%. The conduction enclosure was tested with two CPU conduction modules supplied by vendor 6, one commercial VME load module, and a custom load module, which provided a total power loading of 72%. The conduction CPU modules were located in slots 2 and 3. The commercial VME load module was located in slot 5 and the custom load module was located in slot 7.

3.3 TEST EQUIPMENT

Constant temperature anemometer	TSI Inc., Model 1750
Thermal anemometry probe	TSI Inc., Model 1266
Thermal anemometry probe	TSI Inc., Model 1266
Probe switch box	TSI Inc., Model 1141-12
Dual output DC power supply	Hewlett-Packard, Model 6234A
Digital multimeter	Fluke, Model 75

Data logging system	Fluke, Model 2280B
Scanning thermometer system	Keithley, Model 740
Thermocouples	Omega Engineering, Type T

3.4 TEST PROCEDURES

The air flow was measured at the entrance and exit air paths between each module using a thermal anemometry system. For the thermal survey, thermocouples were placed: (1) in the inlet and outlet cooling air paths; (2) on microprocessor case of CPU modules; (3) on card cages; (4) on power supplies; and (5) on exterior surfaces of enclosures.

3.5 TEST RESULTS

The results of the air flow testing for the three convection enclosures is shown in Tables IV, V, and VI and in Figures 1, 2, and 3. Vendor 1 convection enclosure temperature stabilization occurred in approximately 2 hours and 5 minutes (at room temperature of 20.5 -21.8 °C). Temperature rise data for Vendor 1 convection enclosure is shown in Table VII. Vendor 2 convection enclosure temperature stabilization occurred in approximately 1 hours and 30 minutes (at room temperature of 20.1 -22.3 °C). Temperature rise data for Vendor 2 convection enclosure is shown in Table VIII. Vendor 3 convection enclosure temperature stabilization occurred in approximately 35 minutes (at room temperature of 20.3 -21.7 °C). Temperature rise data for Vendor 3 convection enclosure is shown in Table IX. Vendor 4 conduction enclosure temperature stabilization occurred in approximately 3 hours and 55 minutes (at room temperature of 21.6 -25.4 °C). Temperature rise data for Vendor 4 conduction enclosure is shown in Table X. All enclosures functioned correctly throughout the duration of the thermal surveys.

3.6 CONCLUSIONS

3.6.1 Convection cooled enclosures. Air flow rates of 300 ft/min or more is desirable for air cooled 6U VME modules operating in high temperature environments (+55°C to +71°C). Lower flow rates may be acceptable for some modules in limited applications. Enclosure internal air temperature at the entrance of the module is also a factor. For the purpose of the air flow testing reported herein, air flow rates of less than 200 ft/min are considered unacceptably low, rates of 200-299 ft/min marginally acceptable, and rates of 300 and above to be acceptable. The highest measured rate of the two measured (entrance and exit) for each card cage slot was used for rating each convection enclosure as follows:

Vendor 1 convection enclosure: 15 of 15 card cage slots acceptable air flow.

Vendor 2 convection enclosure: 9 of 20 card cage slots acceptable air flow.
1 of 20 card cage slots marginally acceptable air flow.
10 of 20 card cage slots unacceptable air flow.

Vendor 3 convection enclosure: 13 of 13 card cage slots acceptable air flow.

3.6.2 Conduction cooled enclosure. The Vendor 4 conduction enclosure kept the chassis cold wall at 37.2°C above ambient room temperature next to the module in slot 2 and 41.9°C above ambient room temperature next to the module in slot 3. These temperature rises translate to cold wall temperatures of 92.2°C and 96.9°C at an ambient of 55°C, which is the maximum continuous operating temperature for MIL-STD-5400, Class 1B equipment. Since a typical maximum recommended cold wall temperature for conduction cooled modules is 85°C, the Vendor 4 conduction enclosure would be unacceptable for high reliability in a continuous 55°C ambient operating environment.

TABLE IV. Vendor 1 enclosure air velocity data.

VENDOR 1 ENCLOSURE AIR VELOCITY TEST DATA TEST DATE: 8 JAN 96			
LOCATION OF AIRFLOW INSTRUMENTED MODULE (CARD SLOT #)	AIRFLOW AT ENTRANCE (FT/MIN)①	AIRFLOW AT EXIT (FT/MIN)①	AIRFLOW AVERAGE (FT/MIN)
1	500	186	343
2	486	244	365
3	353	234	294
4	318	207	263
5	430	255	343
6	371	295	333
7	313	234	274
8	481	255	368
9	387	300	344
10	630	244	437
11	565	255	410
12	392	198	295
13	559	229	394
14	346	186	266
15	361	138	250

① AIRFLOW DATA CORRECTED TO STANDARD CONDITIONS (29.92 INCHES H_g, 70°F).

TABLE V. Vendor 2 enclosure air velocity data.

VENDOR 2 ENCLOSURE AIR VELOCITY TEST DATA TEST DATE: 5 JAN 96			
LOCATION OF AIRFLOW INSTRUMENTED MODULE (CARD SLOT #)	AIRFLOW AT ENTRANCE (FT/MIN)①	AIRFLOW AT EXIT (FT/MIN)①	AIRFLOW AVERAGE (FT/MIN)
1	172	164	168
2	90	134	112
3	65	102	84
4	95	82	89
5	89	82	86
6	335	121	228
7	381	213	297
8	775	278	527
9	720	167	444
10	270	125	198
11	55	138	97
12	182	164	173
13	416	173	295
14	161	177	169
15	545	190	368
16	645	150	398
17	90	144	117
18	88	159	124
19	492	183	338
20	406	87	247

① AIRFLOW DATA CORRECTED TO STANDARD CONDITIONS (29.92 INCHES H_g, 70°F).

TABLE VI. Vendor 3 enclosure air velocity data.

VENDOR 3 ENCLOSURE AIR VELOCITY TEST DATA TEST DATE: 9 JAN 96			
LOCATION OF AIRFLOW INSTRUMENTED MODULE (CARD SLOT #)	AIRFLOW AT ENTRANCE (FT/MIN)①	AIRFLOW AT EXIT (FT/MIN)①	AIRFLOW AVERAGE (FT/MIN)
1	172	546	359
2	282	531	407
3	366	611	489
4	455	580	518
5	588	653	621
6	678	668	673
7	1000	660	830
8	1075	595	835
9	1140	587	864
10	1370	595	983
11	1420	692	1056
12	1355	634	995
13	330	223	277

① AIRFLOW DATA CORRECTED TO STANDARD CONDITIONS (29.92 INCHES H_g, 70°F).

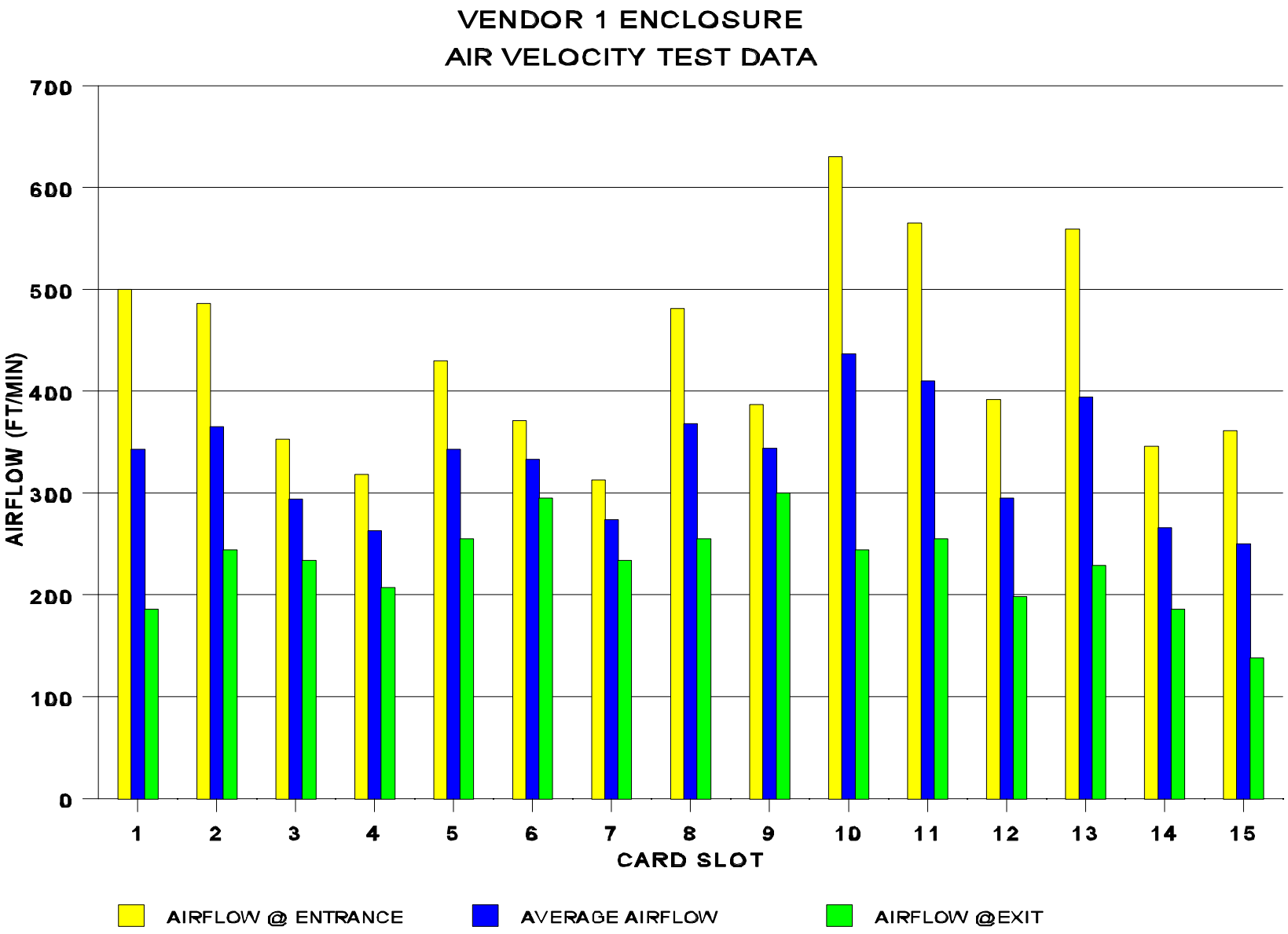

FIGURE 1. Vendor 1 enclosure air velocity data graph.

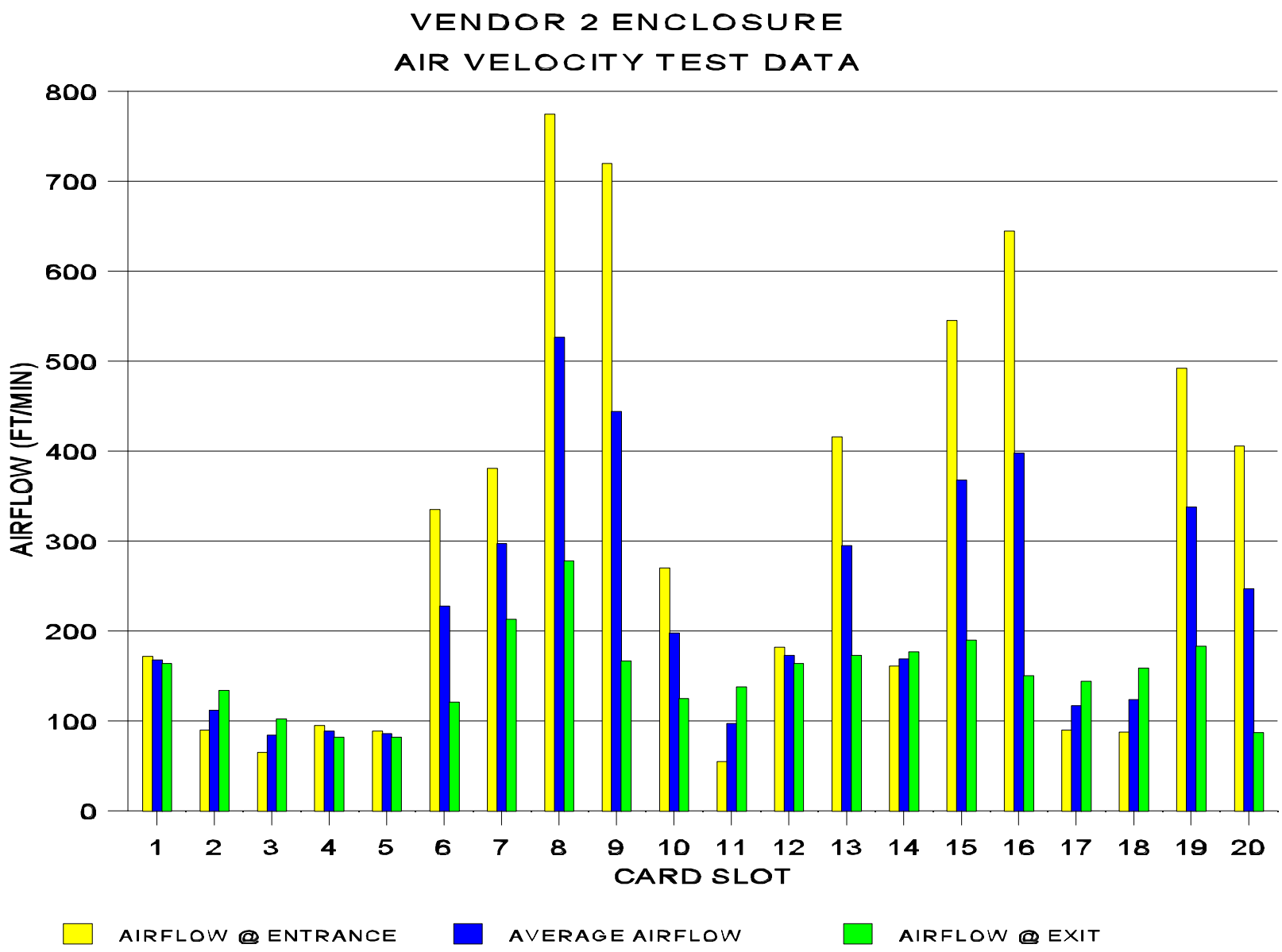

FIGURE 2. Vendor 2 enclosure air velocity data graph.

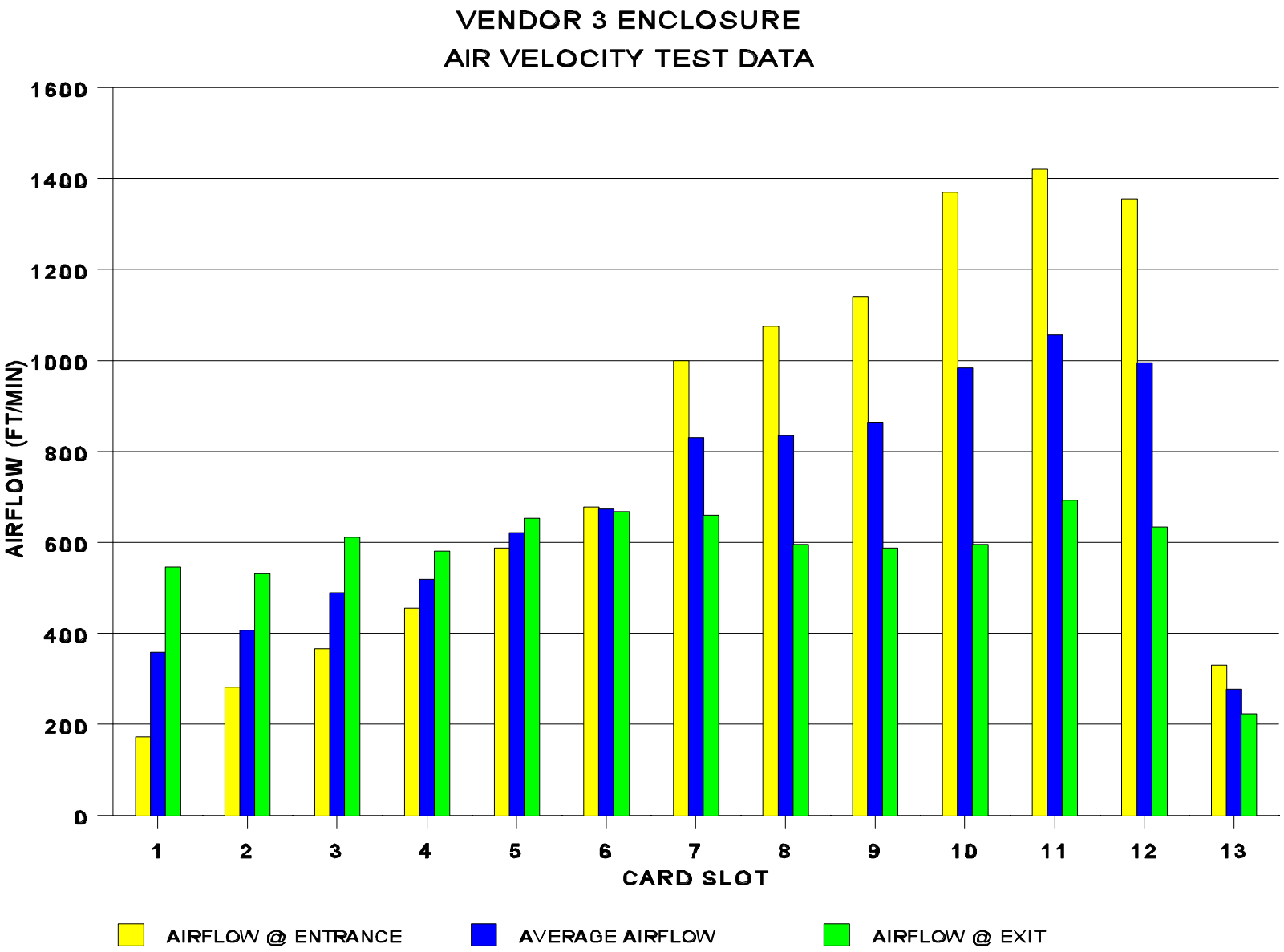

FIGURE 3. Vendor 3 enclosure air velocity data graph.

TABLE VII. Vendor 1 enclosure thermal survey summary.

VENDOR 1 ENCLOSURE THERMAL DATA	
Power supply rating	350 W
Power dissipated during test	264 W
Fans	42 W
CPU cards	30 W
Load cards	192 W
VME card capacity	15
No. of cards installed during test	15
Enclosure inlet to outlet air temperature rise	8.1°C
Slots 1-2 entrance air temperature rise	11.0°C
CPU card in slot 1:	
Measured microprocessor* case temperature rise	24.4°C
Calculated microprocessor case temperature at maximum ambient of 55°C	79.4°C
CPU card in slot 15:	
Measured microprocessor* case temperature rise	22.8°C
Calculated microprocessor case temperature at maximum ambient of 55°C	77.8°C
Power Supply mounting plate:	
Measured temperature rise	14.9°C
Calculated temperature at maximum ambient of 55°C	69.9°C
External Enclosure temperature rise:	
Front panel	5.5°C
Rear panel	7.7°C
Top panel	1.4°C

* Motorola microprocessor P/N MC68030RC25B

TABLE VIII. Vendor 2 enclosure thermal survey summary.

VENDOR 2 ENCLOSURE THERMAL DATA	
Power supply rating	640 W
Power dissipated during test	480 W
CPU cards	30 W
Load cards	450 W
Fans	AC power
VME card capacity	20
No. of cards installed during test	20
Inlet to outlet air temperature rise	7.6°C
Slots 1-2 entrance air temperature rise	2.1°C
CPU card in slot 1:	
Measured microprocessor* case temperature rise	11.7°C
Calculated microprocessor case temperature at maximum ambient of 55°C	66.7°C
CPU card in slot 20:	
Measured microprocessor* case temperature rise	19.1°C
Calculated microprocessor case temperature at maximum ambient of 55°C	74.1°C
Power supply case temperature rise:	
Measured temperature rise	13.6°C
Calculated temperature at maximum ambient of 55°C	68.6°C
External Enclosure temperature rise:	
Front panel	2.9°C
Rear panel	7.9°C
Top panel	10.5°C

* Motorola microprocessor P/N MC68030RC25B

TABLE IX. Vendor 3 enclosure thermal survey summary.

VENDOR 3 ENCLOSURE THERMAL DATA	
Power supply rating	622 W
Power dissipated during test	478 W
Fans	100 W
CPU cards	30 W
Load cards	348 W
VME card capacity	13
No. of cards installed during test	13
Inlet to outlet air temperature rise	5.3°C
Slots 1-2 entrance air temperature rise	3.3°C
CPU card in slot 1:	
Measured microprocessor* case temperature rise	13.3°C
Calculated microprocessor case temperature at maximum ambient of 55°C	68.3°C
CPU card in slot 13	
Measured microprocessor* case temperature rise	11.4°C
Calculated microprocessor case temperature at maximum ambient of 55°C	66.4°C
Power supply case temperature rise:	
Measured right side power supply	10.4°C
Calculated temperature at maximum ambient of 55°C	65.4°C
Measured left side power supply	4.0°C
Calculated temperature at maximum ambient of 55°C	59.0°C
External Enclosure temperature rise:	
Front panel	4.1°C
Rear panel	3.3°C
Right power supply heat sink	30.5°C
Calculated temperature at maximum ambient of 55°C	85.5°C
Left power supply heat sink	11.8°C
Calculated temperature at maximum ambient of 55°C	66.8°C

* Motorola microprocessor P/N MC68030RC25B

TABLE X. Vendor 4 enclosure thermal survey summary.

VENDOR 4 ENCLOSURE THERMAL DATA	
Power supply rating	155 W
Power dissipated during test	111 W
CPU cards	30W
VME convection load card	17 W
Conduction load card	64 W
VME card capacity	10
No. of conduction cards installed during test	3
CPU card in slot 2:	
Measured VME Interface Controller* chip case temperature rise above room temperature	46.2°C
Measured VME Interface Controller* chip case temperature rise above adjacent card guide (chassis cold wall)	9.0°C
Calculated VME Interface Controller chip case temperature at maximum ambient of 55°C	101.2°C
CPU card in slot 3:	
Measured VME Interface Controller* chip case temperature rise above room temperature	51.4°C
Measured VME Interface Controller* chip case temperature rise above adjacent card guide (chassis cold wall)	9.5°C
Calculated VME Interface Controller chip case temperature at maximum ambient of 55°C	106.4°C
Slot 1 card guide (chassis cold wall):	
Measured temperature rise above room temperature	37.2°C
Calculated temperature rise at maximum ambient of 55°C	92.2°C**
Slot 4 card guide (chassis cold wall):	
Measured temperature rise above room temperature	41.9°C
Calculated temperature rise at maximum ambient of 55°C	96.9°C**

TABLE X. Vendor 4 enclosure thermal survey summary - continued.

Power supply:	
Measured temperature rise	34.9°C
Calculated temperature at maximum ambient of 55°C	89.9°C
External Enclosure temperature rise:	
Front panel	33.8°C
Calculated temperature at maximum ambient of 55°C	88.8°C
Top panel	33.4°C
Calculated temperature at maximum ambient of 55°C	88.4°C
Rear side (average)	35.2°C
Calculated temperature at maximum ambient of 55°C	90.2°C
Left panel next to slot 2	34.1°C
Calculated temperature at maximum ambient of 55°C	89.1°C
Right side next to slot 2	35.9°C
Calculated temperature at maximum ambient of 55°C	90.9°C

*Motorola VME Interface Controller P/N CA91C078-33MG

**The CPU modules installed in enclosure are designed to operate at a maximum cold wall temperature of 85°C.

SECTION 4

AIRBORNE NOISE TESTING

4.1 INTRODUCTION/OBJECTIVE

The purpose of the airborne noise testing was to determine the noise levels generated by the cooling fans of the convection enclosures, and to determine if the noise levels were within the requirements of the Airborne Low Frequency Sonar (ALFS) AN/UYS-2A requirements document HDWALF0310 dated 17 January 1994. HDWALF0310 requires that the measured sound levels of the UUT be less than 80 dB (A) on air exhaust side and 70 dB (A) on the other 5 sides.

4.2 EQUIPMENT TESTED AND LOADING

Airborne noise tests were performed on the three convection enclosures supplied by Vendors 1, 2, and 3. The enclosures were populated with two CPU convection modules supplied by Vendor 5 and VME load modules set to provide 50% power loading.

4.3 TEST EQUIPMENT

Sound level meter (SLM) with microphone	Bruel and Kjaer, Type 2236
Sound level calibrator	Bruel and Kjaer, Type 4231
Spectrum Analyzer	Hewlett-Packard, Model 3561A
Temperature-Humidity chart recorder	Dickson, Model TH4
Acoustic chamber	Industrial Acoustics, 40 dB, 15' x 12' x 9'

4.4 TEST PROCEDURES

The UUT was placed on a wooden table located in the acoustic chamber. Data was collected for all six sides of the UUT. For each set of data, the microphone was positioned one meter from the UUT, perpendicular to the applicable side of the unit. The UUT was powered-on during data

collection (except during ambient data collection). A-weighted and Linear (L) weighted measurements were recorded from readings on the sound level meter. Octave measurements of band centers 31.5 Hz to 8000 Hz were recorded on the spectrum analyzer.

4.5 TEST RESULTS

Broadband airborne noise measurements were taken in dB referenced to 20 micro-Pascal (μPa) on both A and L-weighted scales. This is called Sound Pressure Level and referred to as SPL. The actual A-weighted dB levels for each side is shown in the shaded area of the Airborne Noise Data chart for Vendor 1 enclosure (see Table XI), Vendor 2 enclosure (see Table XII), and Vendor 3 enclosure (see Table XIII). The requirements that the SPL on the A-weighted scale be less than 80 dB on the air exhaust side and 70 dB on the other sides were met for all three convection enclosures tested. Additional airborne noise data was taken for reference and is also shown in the Airborne Noise Data charts for each vendor enclosure. This additional data was recorded on the spectrum analyzer in dBV for 9 data points representing octave band centers of 31.5 Hz to 8000 Hz for each microphone location. Readings in dBV represent the output of the spectrum analyzer, which processed the voltage signals from the sound level meter. The raw dBV data was converted to SPL referenced to 20 μPa. The speech interference level (SIL) was calculated from the octave band data.

4.6 CONCLUSIONS

COTS enclosures can meet the Airborne Noise requirements that the SPL on the A-weighted scale be less than 80 dB on the air exhaust side and 70 dB on the other sides.

TABLE XI. Vendor 1 enclosure airborne noise data.

VENDOR 1 ENCLOSURE

AIRBORNE NOISE DATA

TEST DATE: 07 NOV 95

MICROPHONE LOCATION	SPECTRUM ANALYZER TRACE IDENTIFICATION	SOUND LEVEL METER READING		OCTAVE BAND CENTERS (HZ)									SIL
		A-WGT	L-WGT	31.5	63	125	250	500	1000	2000	4000	8000	
FRONT SIDE (AMBIENT)	CBA (dBV)			-53.0	-69.0	-80.3	-91.7	-96.0	-97.6	-96.5	-94.7	-93.4	
	CBA (SPL)	21.0	56.7	54.3	38.3	27.0	15.6	11.3	9.7	10.8	12.5	13.9	10.6
FRONT SIDE (AIR INTAKE)	M1F (dBV)			-53.1	-60.1	-65.6	-45.8	-51.7	-55.4	-57.0	-62.6	-70.6	
	M1F (SPL)	59.3	64.5	54.2	47.2	41.7	61.5	55.6	51.9	50.3	44.7	36.7	52.6
RIGHT SIDE	M1R (dBV)			-57.4	-58.8	-62.0	-46.5	-53.9	-61.6	-65.9	-71.5	-81.4	
	M1R (SPL)	56.2	63.3	49.8	48.5	45.2	60.8	53.4	45.7	41.4	35.8	25.9	46.8
BACK SIDE (AIR EXHAUST)	M1B (dBV)			-60.1	-60.9	-61.0	-50.9	-52.1	-61.3	-62.4	-68.4	-78.2	
	M1B (SPL)	54.7	60.5	47.2	46.4	46.3	56.4	55.2	46.0	44.8	38.9	29.1	48.7
LEFT SIDE	M1L (dBV)			-52.4	-59.4	-63.5	-47.1	-52.1	-59.0	-63.9	-70.0	-80.3	
	M1L (SPL)	57.3	63.7	54.9	47.8	43.8	60.2	55.2	48.3	43.4	37.3	27.0	49.0
TOP SIDE	M1T (dBV)			-60.4	-61.0	-56.0	-47.4	-51.6	-59.7	-63.8	-69.9	-80.3	
	M1T (SPL)	56.9	63.1	46.9	46.3	51.3	59.8	55.7	47.6	43.5	37.4	27.0	48.9
BOTTOM SIDE	M1U (dBV)			-60.0	-62.3	-52.3	-46.6	-52.8	-61.9	-66.6	-72.7	-82.9	
	M1U (SPL)	55.2	63.0	47.2	45.0	55.0	60.7	54.5	45.4	40.6	34.6	24.4	46.9

TABLE XII. Vendor 2 enclosure airborne noise data.

VENDOR 2 ENCLOSURE

AIRBORNE NOISE DATA

TEST DATE: 07 NOV 95

MICROPHONE LOCATION	SPECTRUM ANALYZER TRACE IDENTIFICATION	SOUND LEVEL METER READING		OCTAVE BAND CENTERS (HZ)									SIL
		A-WGT	L-WGT	31.5	63	125	250	500	1000	2000	4000	8000	
FRONT SIDE (AMBIENT)	CBA2 (dBV)			-61.6	-73.5	-76.3	-90.4	-95.5	-97.7	-96.7	-94.9	-93.5	
	CBA2 (SPL)	20.6	52.1	45.7	33.8	31.0	16.8	11.8	9.5	10.6	12.4	13.8	10.6
FRONT SIDE (AIR INTAKE)	AR1F (dBV)			-52.9	-59.3	-50.9	-46.6	-51.2	-54.8	-58.3	-63.6	-69.7	
	AR1F (SPL)	58.4	64.4	54.3	48.0	56.4	60.7	56.1	52.5	49.0	43.7	37.6	52.5
RIGHT SIDE (AIR EXHAUST)	AR1R (dBV)			-57.1	-55.3	-53.4	-48.9	-52.5	-55.3	-56.0	-59.3	-66.0	
	AR1R (SPL)	58.2	63.4	50.2	52.0	53.9	58.4	54.8	51.9	51.3	48.0	41.3	52.7
BACK SIDE	AR1B (dBV)			-59.0	-55.3	-51.3	-49.1	-51.0	-55.0	-56.9	-60.4	-66.5	
	AR1B (SPL)	58.5	63.7	48.3	52.0	56.0	58.2	56.3	52.3	50.4	46.9	40.8	53.0
LEFT SIDE (AIR EXHAUST)	AR1L (dBV)			-51.2	-54.1	-51.7	-43.9	-46.6	-49.1	-49.5	-53.1	-57.5	
	AR1L (SPL)	64.2	67.9	56.1	53.2	55.6	63.3	60.7	58.2	57.8	54.2	49.8	58.9
TOP SIDE	AR1T (dBV)			-60.5	-62.4	-45.7	-42.8	-49.7	-55.8	-54.9	-60.0	-67.2	
	AR1T (SPL)	60.3	67.3	46.8	44.9	61.6	64.5	57.6	51.5	52.4	47.3	40.1	53.8
BOTTOM SIDE	AR1U (dBV)			-60.8	-63.5	-48.7	-43.7	-49.7	-56.0	-58.2	-63.7	-69.6	
	AR1U (SPL)	59.0	66.4	46.5	43.8	58.6	63.6	57.6	51.3	49.0	43.6	37.7	52.6

TABLE XIII. Vendor 3 enclosure airborne noise data.

VENDOR 3 ENCLOSURE

AIRBORNE NOISE DATA

TEST DATE: 25 JAN 96

MICROPHONE LOCATION	SPECTRUM ANALYZER TRACE IDENTIFICATION	SOUND LEVEL METER READING		OCTAVE BAND CENTERS (HZ)									SIL
		A-WGT	L-WGT	31.5	63	125	250	500	1000	2000	4000	8000	
FRONT SIDE (AMBIENT)	CBA (dBV)			-65.8	-69.7	-86.1	-92.5	-95.1	-97.8	-96.4	-95.3	-93.8	
	CBA (SPL)	<20.0	56.5	41.5	37.6	21.2	14.8	12.2	9.6	10.9	12.0	13.5	10.9
FRONT SIDE (AIR INTAKE)	P1F (dBV)			-62.3	-59.7	-54.4	-50.6	-41.4	-42.5	-49.0	-51.7	-54.2	
	P1F (SPL)	68.4	69.9	45.0	47.6	53.0	56.7	65.9	64.8	58.4	55.6	53.1	63.0
RIGHT SIDE	P1R (dBV)			-64.1	-63.4	-56.4	-50.8	-49.6	-50.0	-53.2	-55.8	-70.0	
	P1R (SPL)	61.4	63.8	43.2	43.9	50.9	56.5	57.8	57.3	54.2	51.6	37.3	56.4
BACK SIDE (AIR EXHAUST)	P1B (dBV)			-62.1	-59.4	-55.7	-53.6	-49.5	-51.6	-49.8	-50.3	-61.8	
	P1B (SPL)	63.4	64.5	45.2	48.0	51.7	53.7	57.8	55.7	57.5	57.1	45.6	57.0
LEFT SIDE	P1L (dBV)			-65.7	-66.4	-56.9	-53.3	-44.7	-53.6	-54.3	-57.9	-70.7	
	P1L (SPL)	62.1	64.9	41.7	41.0	50.4	54.0	62.6	53.7	53.0	49.5	36.7	56.4
TOP SIDE	P1T (dBV)			-68.2	-64.2	-46.8	-48.0	-51.2	-50.0	-52.9	-56.5	-68.7	
	P1T (SPL)	62.0	65.8	39.1	43.2	60.6	59.3	56.1	57.3	54.5	50.8	38.6	56.0
BOTTOM SIDE	P1UT (dBV)			-65.9	-64.1	-50.1	-48.1	-50.6	-51.4	-55.2	-56.2	-67.6	
	P1UT (SPL)	61.2	64.9	41.5	43.2	57.2	59.3	56.7	55.9	52.2	51.1	39.7	54.9

SECTION 5

TEMPERATURE/ALTITUDE TESTING

5.1 INTRODUCTION/OBJECTIVE

The tests were performed to characterize the temperature/altitude responses of the COTS enclosures. Two stages of testing were planned. The first stage temperature/altitude cycle was moderately severe, but much less than a full mil-spec requirement. Upon successful completion of the first stage testing, a mil-spec cycle, based on MIL-T-5422F, was to be run. After the first two convection enclosures tested (Vendor 1 and Vendor 3) failed the first stage testing and concerns about test times and scheduling arose, the original test plans were modified for the remaining two enclosures. The third convection enclosure (Vendor 2) was tested only to its commercial rating. The conduction enclosure (Vendor 4) was tested only to the MIL-T-5422F requirements.

5.2 EQUIPMENT TESTED AND LOADING

Temperature/Altitude tests were performed on the three convection enclosures supplied by Vendors 1, 2, and 3 and the conduction enclosure supplied by Vendor 4. The three convection enclosures were populated with two CPU convection modules supplied by Vendor 5 and VME load modules set to provide 75% power loading. The conduction enclosure was populated with two CPU conduction modules supplied by Vendor 6, providing a 19% power loading.

5 3 TEST EQUIPMENT

Terminal monitor	Wyse, model WY-85, P/N 00-085-05
Regulated power supply	Lambda, model LES-F-03-OV
Temperature/Altitude chamber	Russell, model RH 84-10-10
Data logging system	Fluke, model 2280B
Thermocouples	Omega Engineering, Type T

5.4 TEST PROCEDURES

The enclosures were subjected to the temperature/altitude profiles referenced as follows:

Vendor 1 enclosure: see Table XIV.
Vendor 2 enclosure: see Table XV.
Vendor 3 enclosure: see Table XVI.
Vendor 4 enclosure: see Table XVII.

The profiles run for Vendors 1 through 3 enclosures were based on commercial type requirements and were less than the full mil-spec requirements. The profile run for Vendor 4 enclosure was a slightly modified MIL-T-5422F requirement, equipment class 1B of MIL-E-5400. Table XVIII compares the full mil-spec requirements verses the actual profile run for Vendor 4 enclosure.

5.5 TEST RESULTS

The results of the temperature/altitude testing for the four enclosures is summarized in Table XIX. The temperature/altitude chamber profile and the temperature responses of the power supply and CPU module microprocessor case for each enclosure is shown in Figures 4 through 7.

Vendor 1 convection enclosure. The power supply for Vendor 1 convection enclosure became unstable (intermittent processing of data) at -13°C as the chamber was being lowered to -40°C from ambient. It continued to remain unstable until its temperature rose above -13°C as the chamber was being driven from -40°C to 0°C. The unit passed the altitude tests (5,000; 10,000; and 15,000 feet) at 0°C. When the chamber was at 43.1°C (being driven to 50°C) the power supply failed. The temperature of the power supply at failure was 62.8°C.

Vendor 2 convection enclosure. Vendor 2 convection enclosure operated without failure throughout the temperature/altitude profiles subjected to it, which included a low temperature of 0°C at altitudes of 5,000; 10,000; and 15,000 feet and a high temperature of 50°C at altitudes of 5,000; 10,000; and 15,000 feet.

Vendor 3 convection enclosure. Vendor 3 convection enclosure passed low temperature testing down to -40°C and the altitude testing (5,000; 10,000; and 15,000 feet) at -40°C. As the chamber temperature was being increased, the unit power supply shut down when it reached 20.3°C (chamber at 13.0°C). Unit was rebooted at approximately 30°C and functioned correctly, until chamber temperature was stabilized at 55°C and altitudes were increased. Unit passed the 5,000 feet altitude test at 55°C, then the power supply became unstable 5 minutes into the 10,000 feet altitude test. The power supply temperature was at 64.7°C.

Vendor 4 conduction enclosure. Vendor 4 conduction enclosure passed the modified MIL-T-5422F temperature and altitude profiles it was subjected to. Included were: (1) low temperature tests at -40°C at altitudes of 5,000; 10,000; and 15,000 feet; (2) frost tests; and (3) high temperature tests at 85°C at altitudes of 5,000; 10,000; and 15,000 feet.

5.6 CONCLUSIONS

The convection cooled enclosures tested for temperature/altitude revealed weaknesses in the power train assemblies, including power supplies, circuit breakers, and switches. More robust power train assemblies need to be selected. The conduction cooled enclosure, with conduction modules and backplane, was adequate to survive the MIL-T-5422F temperature/altitude testing.

TABLE XIV. Vendor 1 enclosure - chamber temperature/altitude profile and UUT power status.

TIME (HOURS:MIN)	CHAMBER STATUS/EVENT	UUT POWER STATUS
00:00	AMBIENT	ON
00:00-04:00	MOVE TO 0°C	ON
04:00-06:00	STABILIZE AT 0°C	ON
06:00-10:00	MOVE TO -10°C	ON
10:00-12:00	STABILIZE AT -10°C	ON
12:00-16:00	MOVE TO -20°C	ON
16:00-18:00	STABILIZE AT -20°C	ON
18:00-22:00	MOVE TO -30°C	ON
22:00-24:00	STABILIZE AT -30°C	ON
24:00-28:00	MOVE TO -40°C	ON
28:00-30:00	MOVE TO 0°C	ON/OFF*
30:00-30:30	STABILIZE AT 0°C	ON/OFF*
30:30-30:45	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT 0°C	ON
30:45-31:00	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT 0°C	ON
31:00-31:15	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT 0°C	ON
31:15-31:30	RELEASE VACUUM AT 0°C	ON
31:30-35:30	MOVE TEMPERATURE TO AMBIENT	ON
35:30-39:30	STABILIZE AT AMBIENT	ON

39:30-41:30	MOVE TO +40°C	ON
41:30-45:30	STABILIZE AT +40°C	ON
45:30-47:30	MOVE TO +50°C	ON

*UUT manually cycled on/off prior to altitude test in attempt to maintain power supply and CPU at 0°C.

TABLE XV. Vendor 2 enclosure - chamber temperature/altitude profile and UUT power status.

TIME (HOURS:MIN)	CHAMBER STATUS/EVENT	UUT POWER STATUS
00:00	AMBIENT	ON
00:00-04:00	MOVE TO 0°C	ON
04:00-05:00	STABILIZE AT 0°C	ON/OFF*
05:00-05:15	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT 0°C	ON
05:15-05:30	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT 0°C	ON
05:30-05:45	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT 0°C	ON
05:45-06:00	RELEASE VACUUM AT 0°C	ON
06:00-09:00	MOVE TEMPERATURE TO AMBIENT	ON
09:00-10:00	STABILIZE AT AMBIENT	ON
10:00-14:00	MOVE TO +40°C	ON
14:00-22:00	STABILIZE AT +40°C	ON
22:00-26:00	MOVE TO +50°C	ON
26:00-27:00	STABILIZE AT +50°C	ON
27:00-27:15	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT +50°C	ON
27:15-27:30	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT +50°C	ON
27:30-27:45	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT +50°C	ON
27:45-28:00	RELEASE VACUUM AT +50°C	ON
28:00-29:00	MOVE TO AMBIENT	ON

*UUT off 30 minutes at test time 4:30-5:00.

TABLE XVI. Vendor 3 enclosure - chamber temperature/altitude profile and UUT power status.

TIME (HOURS:MIN)	CHAMBER STATUS/EVENT	UUT POWER STATUS
00:00	AMBIENT	ON
00:00-04:00	MOVE TO 0°C	ON
04:00-05:00	STABILIZE AT 0°C	ON
05:00-09:00	MOVE TO -10°C	ON
09:00-10:00	STABILIZE AT -10°C	ON
10:00-14:00	MOVE TO -20°C	ON
14:00-15:00	STABILIZE AT -20°C	ON
15:00-19:00	MOVE TO -30°C	ON
19:00-20:00	STABILIZE AT -30°C	ON
20:00-24:00	MOVE TO -40°C	ON
24:00-25:00	STABILIZE AT -40°C	ON
25:00-25:15	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT -40°C	ON
25:15-25:30	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT -40°C	ON
25:30-25:45	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT -40°C	ON
25:45-26:00	RELEASE VACUUM AT -40°C	ON
26:00-32:00	MOVE TEMPERATURE TO AMBIENT	ON
32:00-33:00	STABILIZE AT AMBIENT	ON
33:00-42:00	MOVE TO +40°C	ON

42:00-43:00	STABILIZE AT +40°C	ON
43:00-45:00	MOVE TO +55°C	ON
45:00-46:00	STABILIZE AT +55°C	ON
46:00-46:15	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT +55°C	ON
46:15-46:30	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT +55°C	ON

TABLE XVII. Vendor 4 enclosure - chamber temperature/altitude profile and UUT power status.

TIME (HOURS:MIN)	CHAMBER STATUS/EVENT	UUT POWER STATUS
00:00	AMBIENT	OFF
00:00-04:00	MOVE TO -40°C	OFF
04:00-06:00	STABILIZE AT -40°C	OFF
06:00-07:00	UUT ON/OFF TESTS AT -40°C	ON 5 MIN - OFF 15 MIN (3 X)
07:00-07:15	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT -40°C	ON
07:15-07:30	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT -40°C	ON
07:30-07:45	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT -40°C	ON
07:45-08:00	RELEASE VACUUM AT -40°C	OFF
08:00-12:00	MOVE TO -10°C	OFF
12:00-14:00	STABILIZE AT -10°C	OFF
14:00-14:30	UUT FROST TESTS AT -10°C	ON/OFF*
14:30-18:30	MOVE TO +85°C	OFF
18:30-20:30	STABILIZE AT +85°C	OFF
20:30-24:30	SOAK AT +85°C	OFF
24:30-28:30	MOVE TO +55°	OFF
28:30-30:30	STABILIZE AT +55°	OFF
30:30-34:30	OPERATE UUT AT +55°	ON
34:30-34:45	PULL VACUUM EQUIVALENT TO 5000 FT ALTITUDE AT +55°C	ON

34:45- 35:00	PULL VACUUM EQUIVALENT TO 10,000 FT ALTITUDE AT +55°C	ON
35:00- 35:15	PULL VACUUM EQUIVALENT TO 15,000 FT ALTITUDE AT +55°C	ON
35:15- 35:30	RELEASE VACUUM AT +55°C	OFF
35:30- 37:30	MOVE TO +71°C	OFF
37:30- 49:30	STABILIZE AT +71°C	OFF
39:30- 40:00	OPERATE UUT AT +71°C	ON
40:00- 44:00	MOVE TO AMBIENT	OFF

*Open chamber door allowing frost to form on UUT. Leave door open long enough for the frost to melt but not long enough to allow moisture to evaporate. Close chamber door, and turn on UUT to check operational status. Turn UUT on and off at least 3 times.

TABLE XVIII. Vendor 4 enclosure - comparison of full MIL-T-5422F temperature/altitude profiles vs. actual profiles run.

FULL MIL-T-5422F	ACTUAL RUN
OPERATE UUT 15 MINUTES AT -40°C AT 15,000 FT ALTITUDE.	OPERATE UUT 15 MINUTES AT -40°C AT EACH ALTITUDE OF 5,000 FT; 10,000 FT; AND 15,000 FT.
SOAK UUT AT +85°C FOR 16 HRS.	SOAK UUT AT +85°C FOR 4 HRS
OPERATE UUT AT 55°C FOR 4 HRS AT ATMOSPHERIC. RAISE TO +71°C AND OPERATE 4 HRS AT ATMOSPHERIC.	OPERATE UUT AT +55°C FOR 4 HRS AT ATMOSPHERIC, DRAW ALTITUDES OF 5,000; 10,000; AND 15,000 FOR 15 MINUTES AT EACH ALTITUDE. RAISE TO +71°C AND OPERATE UUT 30 MINUTES AT ATMOSPHERIC.
OPERATE UUT AT +55°C FOR 4 HRS AT 15,000 FT. RAISE TO +71°C AND OPERATE 30 MINUTES AT 15,000 FT.	NOT PERFORMED.

TABLE XIX. Temperature/Altitude test results summary.

TEST	VENDOR 1 ENCLOSURE	VENDOR 2 ENCLOSURE	VENDOR 3 ENCLOSURE	VENDOR 4 ENCLOSURE
OPERATE @ -40°C	FAIL: POWER SUPPLY UNSTABLE BELOW -13°C, CHAMBER @ -26 to -40 to -24°C	N/A	PASS	PASS
OPERATE @ -40°C,5000 FT	N/A	N/A	PASS	PASS
OPERATE @ -40°C,10,000 FT	N/A	N/A	PASS	PASS
OPERATE @ -40°C,15,000 FT	N/A	N/A	PASS	PASS
FROST TESTS @ -10°C	N/A	N/A	N/A	PASS
OPERATE @ 0°C	PASS	PASS	PASS	N/A
OPERATE @ 0°C,5000 FT	PASS	PASS	N/A	N/A
OPERATE @ 0°C,10,000 FT	PASS	PASS	N/A	N/A
OPERATE @ 0°C,15,000 FT	PASS	PASS	N/A	N/A
OPERATE: -40°C to AMBIENT	SEE FAILURE CITED ABOVE @ -40°C	N/A	FAIL: POWER SUPPLY SHUT DOWN @+20.3°C, CHAMBER @ +13°C	N/A
OPERATE @ +50°C	FAIL: POWER SUPPLY SHUT DOWN @+62.8°C, CHAMBER @+43.1°C BEING DRIVEN TO +50°C	PASS	PASS	PASS
OPERATE @ +50°C,5000 FT	N/A	PASS	N/A	N/A
OPERATE @ +50°C,10,000 FT	N/A	PASS	N/A	N/A
OPERATE @ +50°C,15,000 FT	N/A	PASS	N/A	N/A
SOAK 4 HRS @ +85°C (UUT OFF)	N/A	N/A	N/A	DONE
OPERATE @ +55°C	N/A	N/A	PASS	PASS
OPERATE @ +55°C,5000 FT	N/A	N/A	PASS	PASS

OPERATE @ +55°C,10,000 FT	N/A	N/A	FAIL: POWER SUPPLY BECAME UNSTABLE @ +64.7°C	PASS
OPERATE @ +55°C,15,000 FT	N/A	N/A	N/A	PASS
OPERATE @ +71°C	N/A	N/A	N/A	PASS

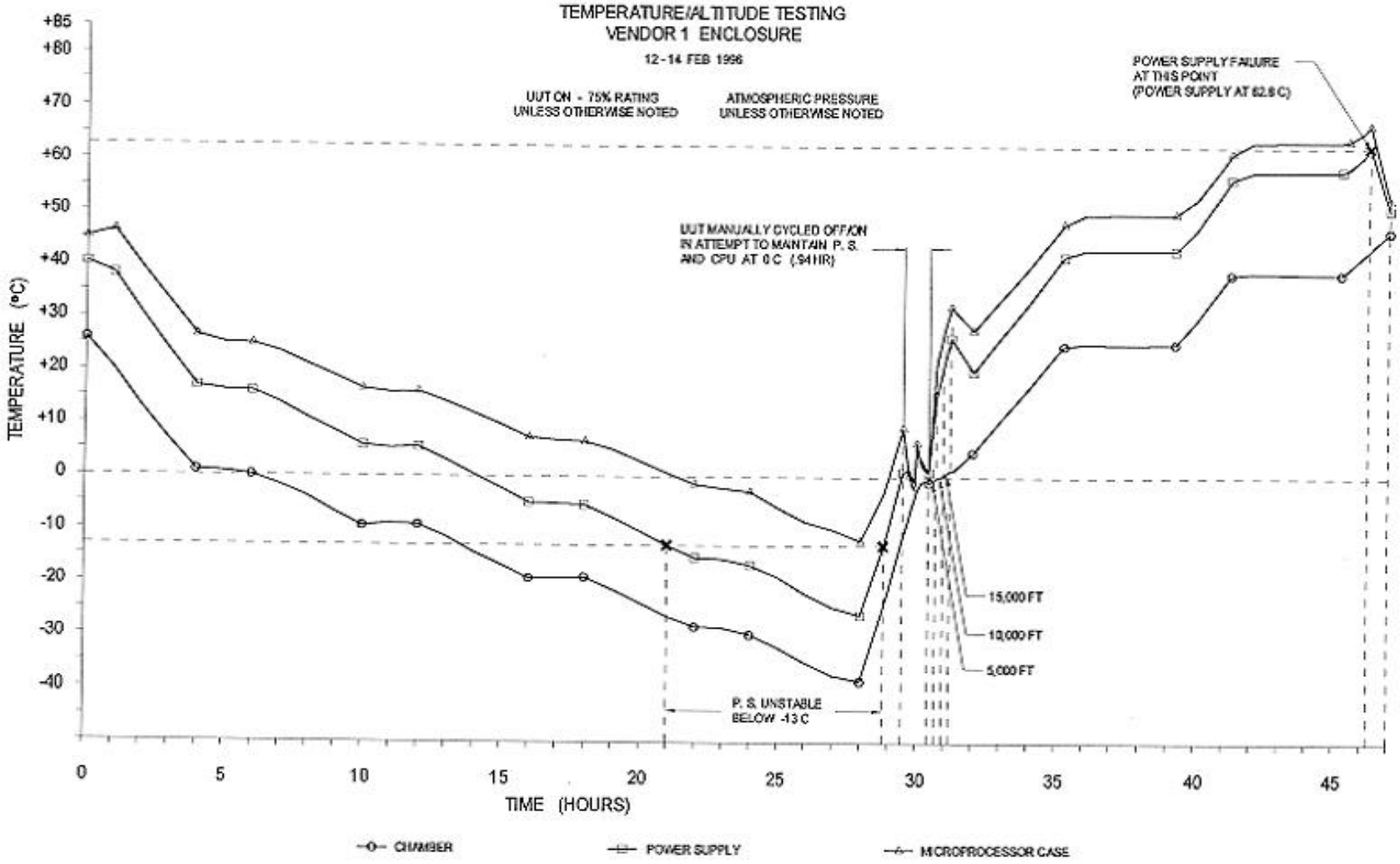

FIGURE 4. Vendor 1 enclosure temperature/altitude profiles.

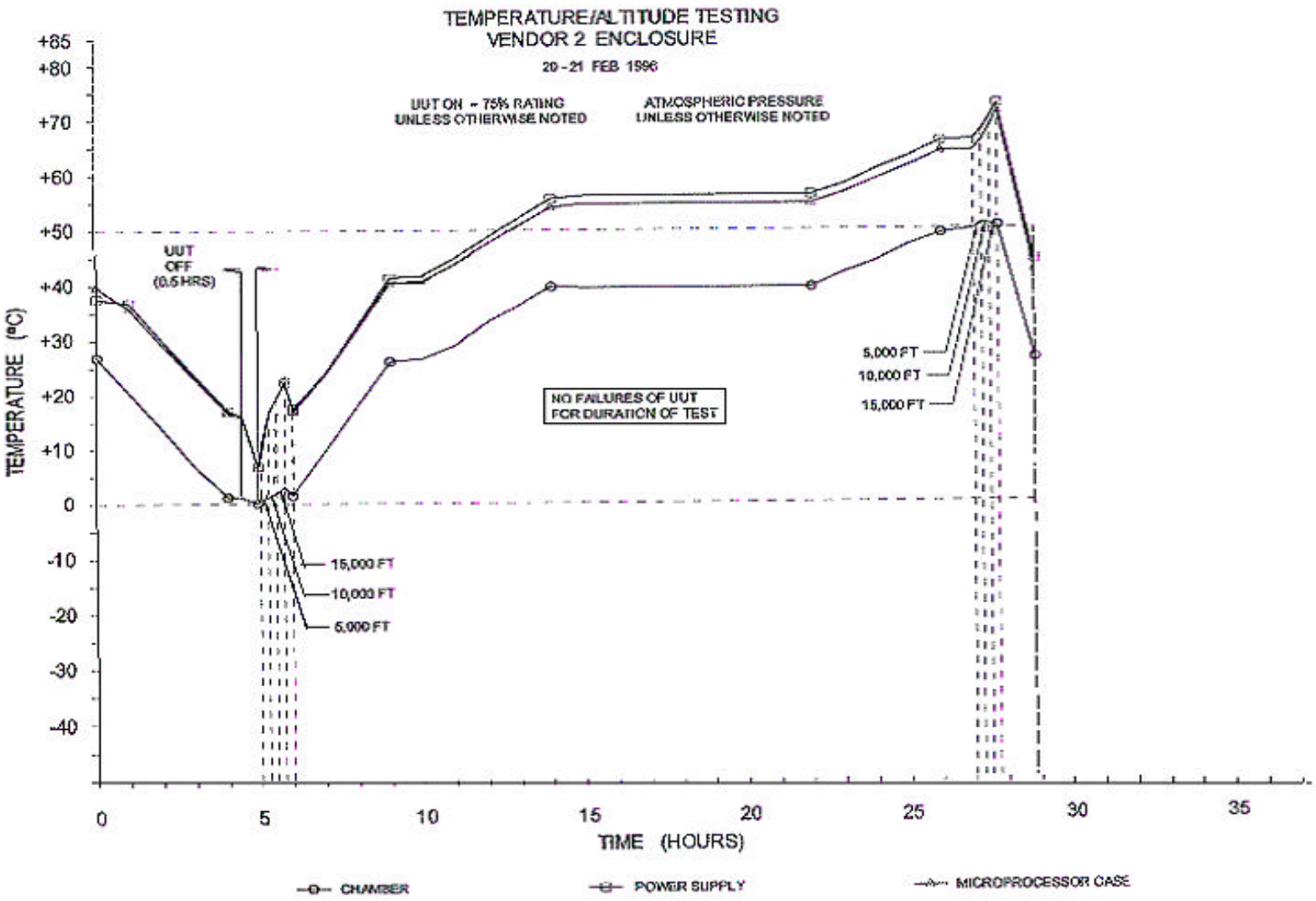

FIGURE 5. Vendor 2 enclosure temperature/altitude profiles

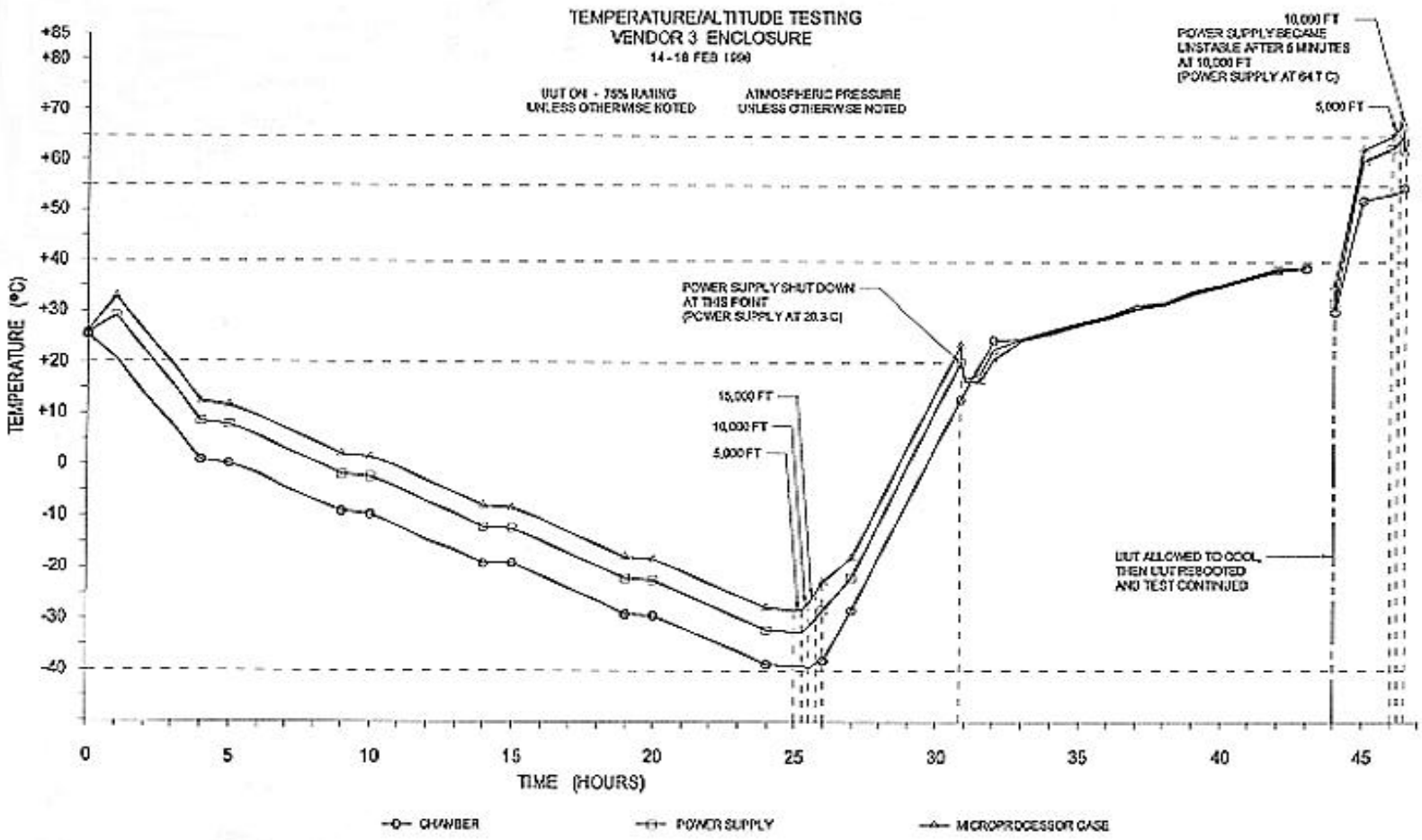

FIGURE 6. Vendor 3 enclosure temperature/altitude profiles.

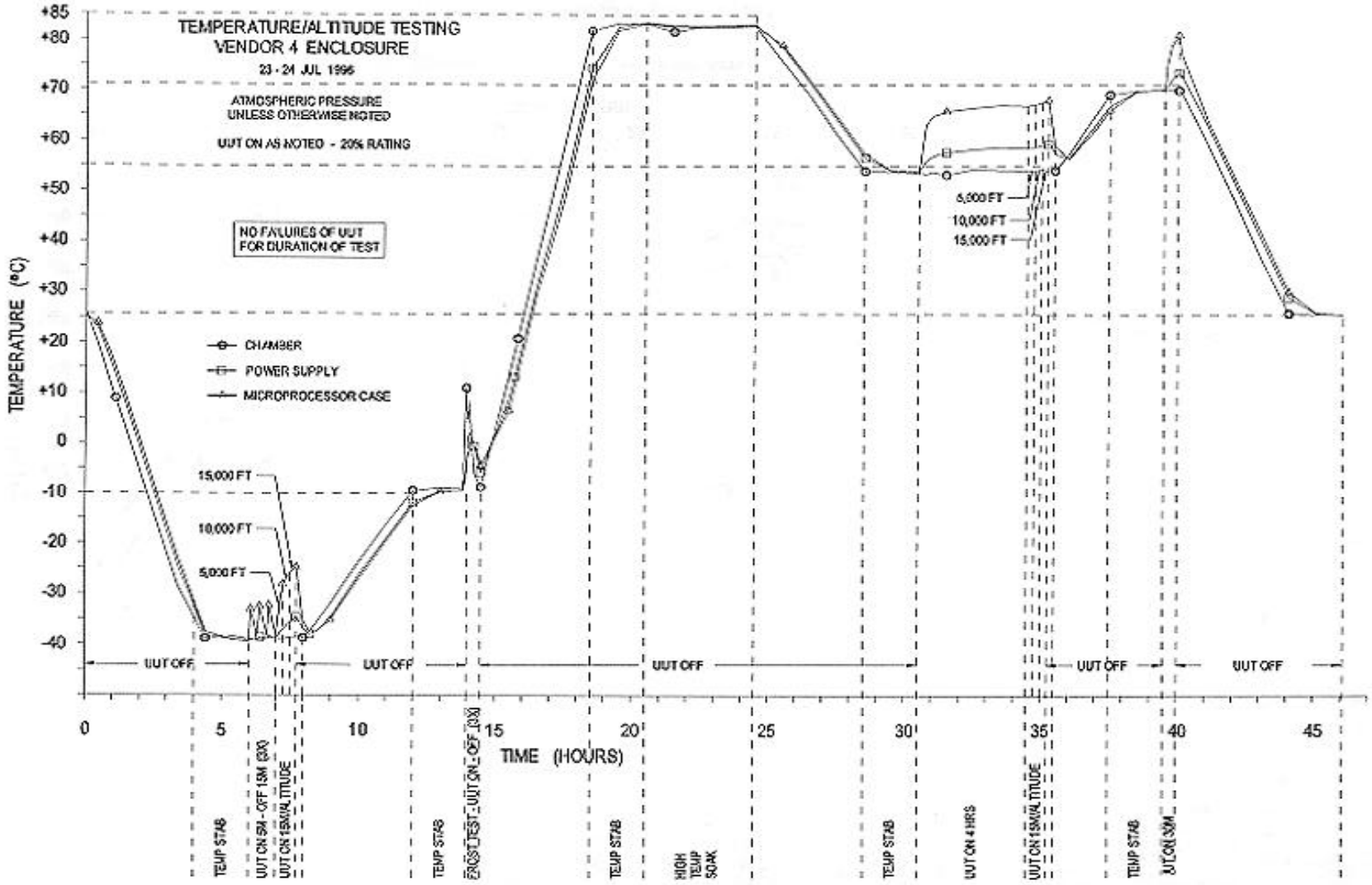

FIGURE 7. Vendor 4 enclosure temperature/altitude profiles.

SECTION 6

VIBRATION AND SHOCK TESTING

6.1 INTRODUCTION/OBJECTIVE

The purpose of the vibration testing was to determine the ability of the enclosures to pass the helicopter sinusoidal vibration requirements of MIL-E-5400T and the sine-on-random vibration requirements of MIL-STD-810E for the UH-60 helicopter. The purpose of the shock testing was to determine the ability of the enclosures to pass the functional shock test of MIL-STD-810E for flight equipment.

6.2 EQUIPMENT TESTED AND LOADING

Vibration tests were performed on the three convection enclosures supplied by vendors 1, 2, and 3 and the one conduction enclosure supplied by Vendor 4. Shock tests were performed on the conduction enclosure. The three convection enclosures were populated with two CPU convection modules supplied by Vendor 5 and VME load modules set to provide 75% power loading. The conduction enclosure was populated with two CPU conduction modules supplied by Vendor 6, providing a 19% power loading.

6. 3 TEST EQUIPMENT

Terminal monitor	Wyse, model WY-85, P/N 00-085-05
Regulated power supply	Lambda, Model LES-F-03-OV
Vibration exciter	Unholtz-Dickie, model T-4000 Unholtz-Dickie Model T-1000
Vibration amplifier	Unholtz-Dickie, model MA460 Unholtz-Dickie Model TA-160-170
Vibration control system	Spectral Dynamics, model SD415, SD400A Spectral Dynamics Model SD1201-1 GEN-RAD 57055
Power supplies	Raytheon, model DCR40-20A Endevco, model 109

Charge amplifiers	Unholtz-Dickie, model D22PMOPTS,L Endevco, model 104
Accelerometers	Endevco, model 7702-50 Endevco, model 2224C Endevco, model 2226C
Test fixture	NSWC Crane drawing 12255-96400058 (no rev) NSWC Crane drawing 12255-75QE0285, Rev A

6.4 TEST PROCEDURES

Sinusoidal vibration tests (resonance survey, resonance dwell, and cycling tests) based on MIL-STD-5422F, Procedure I. See Figure 8 for the vibration level used for the resonance dwell and cycling tests.

Sine on random vibration test per MIL-STD-810E, Method 514.4, Procedure I, Category 6, tailored for the UH-60 helicopter (see Figure 9 for the required vibration profile). NOTE: The low amplitude (0.11 g) sine tone at 4.3 Hz was not run due to vibration equipment limitations at this low frequency.

Shock test per MIL-STD-810E, Method 516.4, Procedure I (see Figure 10 for the required shock response spectrum).

6.5 TEST RESULTS

Vendor 1 convection enclosure. The enclosure as originally supplied by the manufacturer failed the Z-Axis (side-to-side) sinusoidal cycling test. After repair/modification, the manufacturer was given three more attempts to pass vibration testing. After three cycles of repair/modification and retesting, the enclosure was not able to pass the vibration testing. The card cage wire rope isolators failed in two of the four attempts, with the power supply failing in all four attempts. The shock testing was planned for each axis following the vibration testing per axis. Since the enclosure was not able to pass the vibration testing on any axis attempted, none of the shock testing planned was done. A summary of the axes tested, the tests performed, and the failures is provided in Table XX.

Vendor 2 convection enclosure. The enclosure as originally supplied by the manufacturer failed the Z-Axis (side-to-side) sine-on-random test. Failed items were the shock mounts and power supply. After repair/modification by the manufacturer, the unit was tested again, starting with the Y-Axis (vertical). During the resonance survey, the power supply failed. A summary of the axes tested, the tests performed, and the failures is provided in Table XXI.

Vendor 3 convection enclosure. The enclosure as originally supplied by the manufacturer failed the Z-Axis (side-to-side) sine-on-random test, following successful completion of the resonance dwells and the sinusoidal cycling test. Failed items were the shock mounts and power supply. After repair/modification by the manufacturer, the unit was tested again, starting with the Y-Axis (vertical). The unit again failed the sine-on-random test, after successfully passing the resonance dwells and sinusoidal cycling test. This failure was attributed to the power supply. A summary of the axes tested, the tests performed, and the failures is provided in Table XXII.

Vendor 4 conduction enclosure. The enclosure passed all 3 axes (front-to-back; side-to-side; and vertical) vibration and shock tests it was subjected to.

6.6 CONCLUSIONS

The convection cooled enclosures shock/vibration isolators could not withstand the rotary wing aircraft sinusoidal/sine-on-random vibration profiles. Failures of the shock/vibration isolators resulted in failures of power train assemblies, which included power supplies, circuit breakers, and switches. Even after multiple failures of the shock/vibration isolators and the power train assemblies, the convection modules continued to function properly. Shock/vibration isolation systems need to be improved in order to meet rotary wing aircraft requirements. The conduction cooled enclosure, with conduction modules and backplane, was adequate to survive the rotary wing aircraft shock and vibration requirements.

TABLE XX. Vendor 1 enclosure vibration testing summary.

	VENDOR 1 ATTEMPT 1	VENDOR 1 ATTEMPT 2	VENDOR 1 ATTEMPT 3	VENDOR 1 ATTEMPT 4
AXIS	Z (SIDE-TO-SIDE)	Z (SIDE-TO-SIDE)	Y (VERTICAL)	Y (VERTICAL)
TESTS PERFORMED	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (FAILED)	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (PASSED) 3. SINE-ON-RANDOM (FAILED)	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (FAILED)	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (FAILED)
FAILURES	1. CARD CAGE WIRE ROPE ISOLATORS 2. POWER SUPPLY	1. POWER SUPPLY	1. CARD CAGE WIRE ROPE ISOLATORS 2. POWER SUPPLY	1. POWER SUPPLY

TABLE XXI. Vendor 2 enclosure vibration testing summary.

	VENDOR 2 ATTEMPT 1	VENDOR 2 ATTEMPT 2
AXIS	Z (SIDE-TO-SIDE)	Y (VERTICAL)
TESTS PERFORMED	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (PASSED) 3. SINE-ON-RANDOM (FAILED)	1. FAILED DURING RESONANCE SURVEY.
FAILURES	1. SHOCK MOUNTS 2. POWER SUPPLY	1. POWER SUPPLY

TABLE XXII. Vendor 3 enclosure vibration testing summary.

	VENDOR 3 ATTEMPT 1	VENDOR 3 ATTEMPT 2
AXIS	Z (SIDE-TO-SIDE)	Y (VERTICAL)
TESTS PERFORMED	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (PASSED) 3. SINE-ON-RANDOM (FAILED)	1. RESONANCE DWELLS (PASSED) 2. SINUSOIDAL CYCLING (PASSED) 3. SINE-ON-RANDOM (FAILED)
FAILURES	1. SHOCK MOUNTS 2. POWER SUPPLY	1. POWER SUPPLY

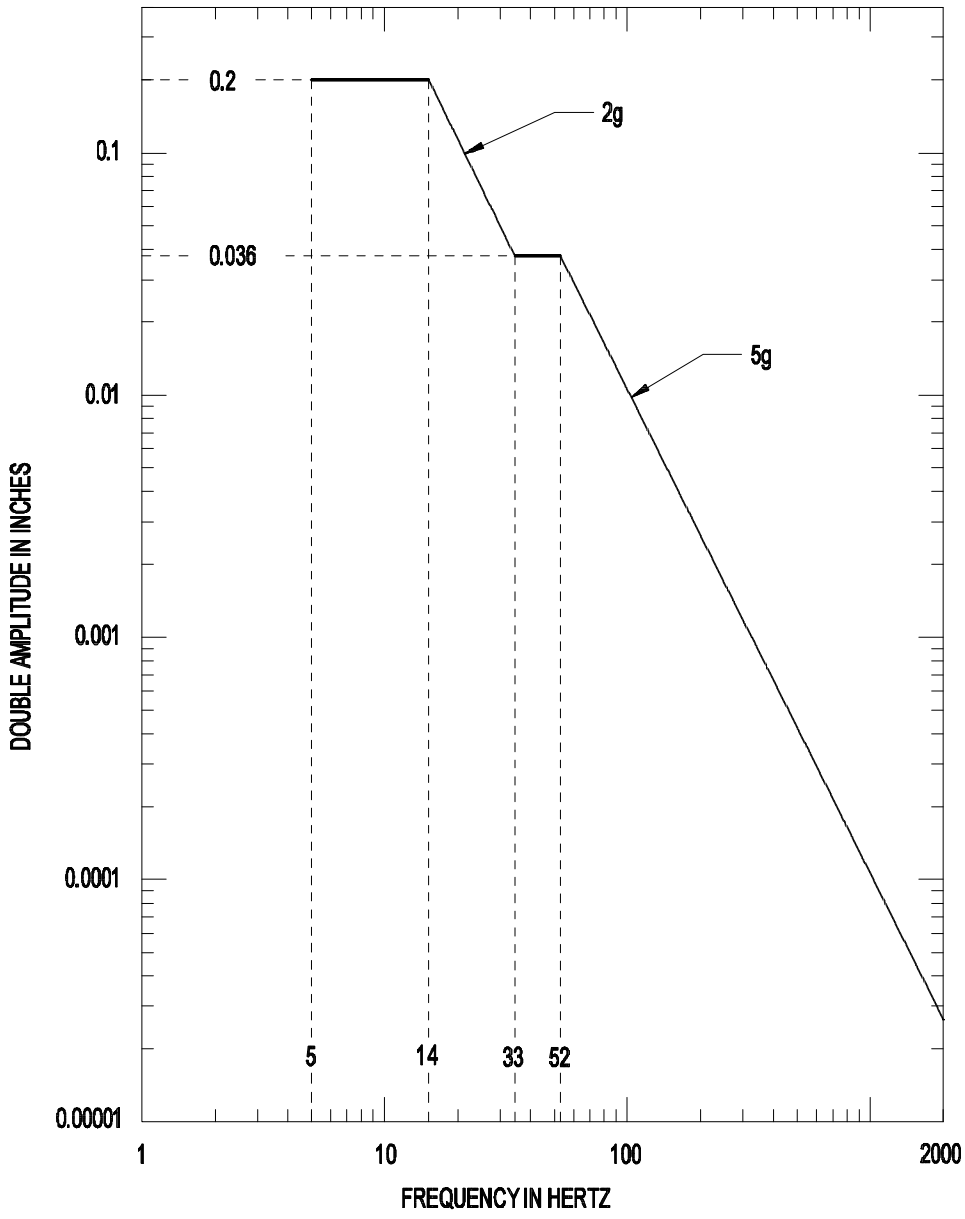

FIGURE 1. Vibration level for resonance dwell and cycling tests.

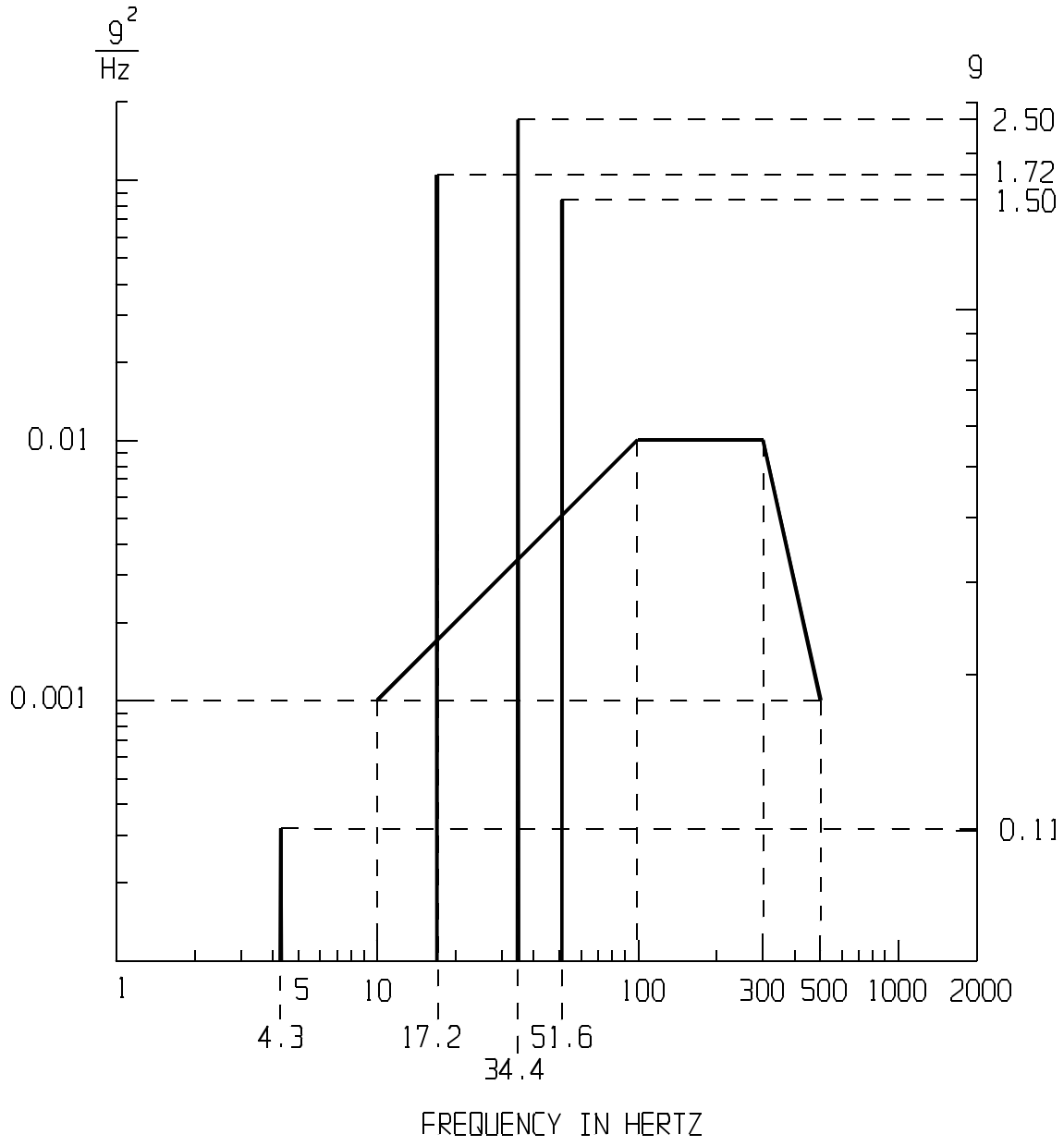

FIGURE 9. Sine on random vibration spectrum.

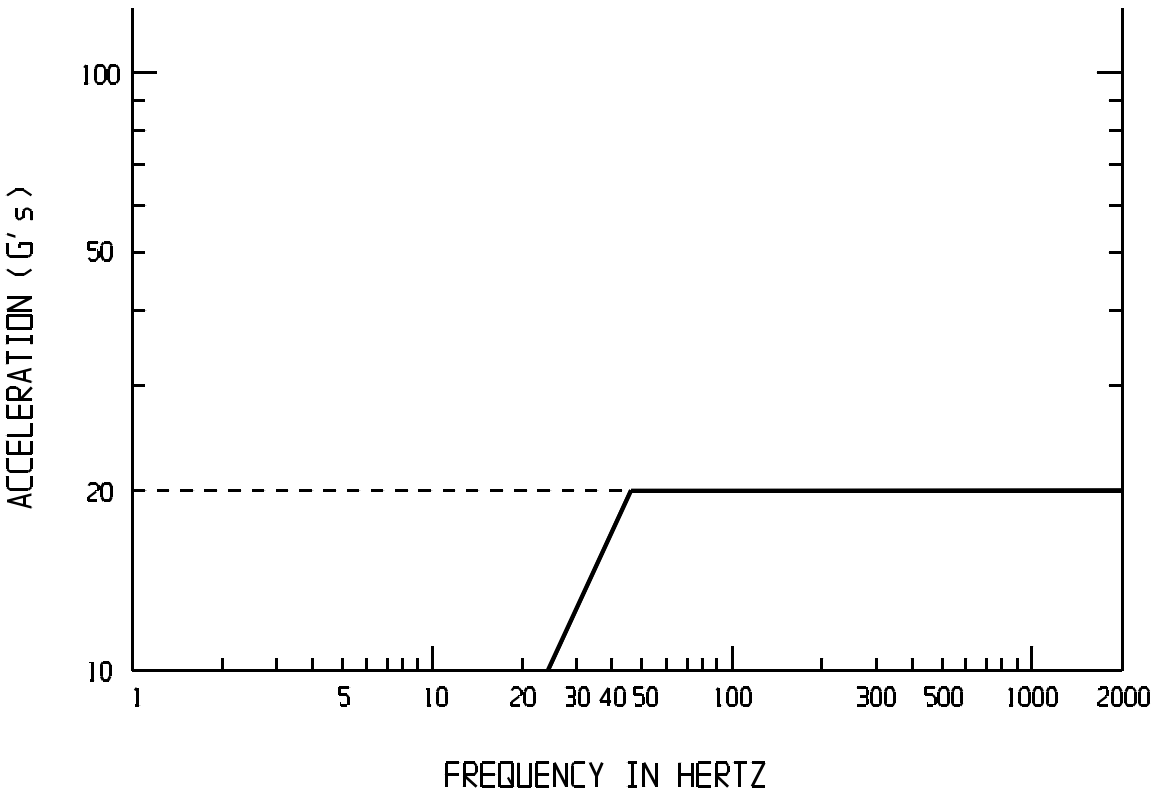
ACCELERATION (G's)
100
50
20
10
1
5
10
20
30
40
50
100
300
500
1000
2000
FREQUENCY IN HERTZ

FIGURE 10. Test shock response spectrum.

SECTION 7

HUMIDITY TESTING

7.1 INTRODUCTION/OBJECTIVE

The humidity test was the last test performed on the COTS equipment. The objective was to determine the effects of MIL-T-5422F humidity tests on the COTS equipment.

7.2 EQUIPMENT TESTED

Humidity tests were conducted on Vendor 3 convection enclosure with two CPU convection modules supplied by vendor 5. Also humidity tests were conducted on Vendor 4 conduction enclosure with two CPU conduction modules supplied by Vendor 6. The equipment was not powered during the humidity cycling.

7.3 TEST EQUIPMENT

Humidity chamber	Thermotron, model SM-32S
Terminal monitor	Wyse, model WY-85, P/N 00-085-05
Regulated power supply	Lambda, model LES-F-03-OV

7.4 TEST PROCEDURES

The enclosures, with the modules installed, were subjected to the MIL-T-5422F humidity cycle shown in Figure 11. After the 240 hour humidity cycle, each UUT was powered on, and processing was monitored for 15 minutes.

7.5 TEST RESULTS

7.5.1 Vendor 3 convection enclosure.

7.5.1.1 Operational status. The operational checkout, following the 240 hour humidity cycle, demonstrated that the enclosure and the CPU modules were functioning correctly.

7.5.1.2 Physical examination of parts/components.

Vendor 3 convection enclosure:

a. There was no entrapped moisture observed in the enclosure.
b. Corrosion was noted on the power supply backshell connectors.
c. Surface corrosion observed on inside, upper panel of disk drive compartment.
d. Small amount of rust on exposed edges of on/off breaker switch.

Vendor 5 convection modules:

a. Corrosion (rust and white powder) observed on mounting hardware.
   - screws/nuts attaching connectors to the PWB.
   - screws holding the PWB to the frame.
   - front panel mounting brackets.
b. Corrosion observed on battery leads.
c. Corrosion observed on exposed LED leads.

7.5.2 Vendor 4 conduction enclosure.

7.5.2.1 Operation status. The operational checkout, following the 240 hour humidity cycle, demonstrated that the enclosure and the CPU modules were functioning correctly.

7.5.2.2 Physical examination of parts/components.

Vendor 4 conduction enclosure:

a. There was no entrapped moisture observed in the enclosure.
b. Corrosion was noted on the DB-37 connectors.

Vendor 6 conduction modules:

Visual examination of the modules revealed no discernable corrosion or other deterioration.

7.6 CONCLUSIONS

Although some corrosion was observed on the electrical parts, it was considered of a minor nature, and did not affect the electrical operation of the enclosures and modules. The mounting hardware corrosion problems could be eliminated with the substitution of readily available parts utilizing corrosion resisting materials.

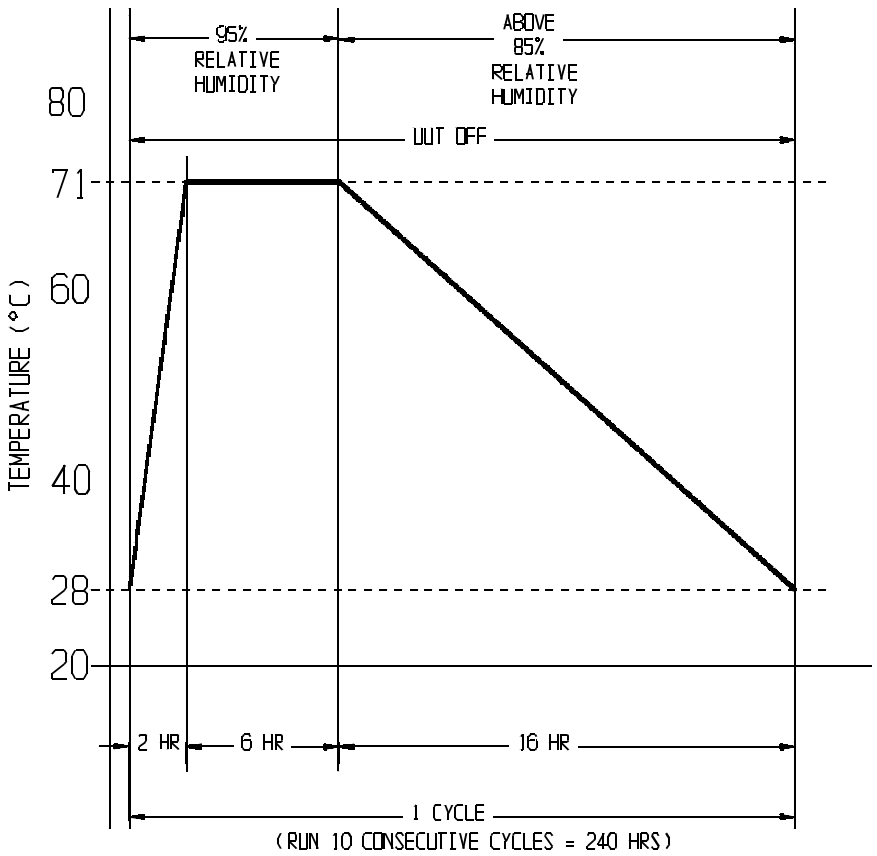

FIGURE 11. Humidity cycle.