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The Foxboro Company Foxboro, Massachusetts, U.S.A. 02035 • Telephone (617) 543-8750

February 10, 1976

Transmittal Letter: Product Engineering Report No. PERS 75-113; Seismic Qualification Report on SPEC 200 Nests and Nest-Mounted Modules --- as extracted from Department 383 Test Report No. T3-1077

The attached report presents information on SPEC 200 nests and nest-mounted modules per Department 383 Test Report No. T3-1077. Excluded from the report are data, etc. on other SPEC 200 devices which are no longer applicable on the basis that these devices have been extensively redesigned since test T3-1077 was run.

The following comments apply to specific statements of Section 4.0, Observations and Conclusions:

Paragraph 1 - The mechanical integrity of the 2ANU nests has been established to be satisfactory with the use of all metal locking hardware per Test Report No. T4-1025.

Paragraph 2 - Integrator power drivers, 2AO-IPD-R's, are not considered to be useable on applications where chattering of the mercury-wetted relays during seismic would be a problem. In such cases, 2AO-IPD-A's should be used.

Paragraph 3 - The "output spikes" during seismic, as reported in 3.a, can be disregarded since it has been established that these resulted from intermittent electrostatic effects produced by oscillatory motion of signal leads between the Test Items on the seismic table and output monitoring test equipment which was located several feet from the seismic table. (See Test Report No. T5-6089)

Relative to statement 3.b. the number and arrangement of cable clamps now used for the wiring in the vicinity of relay socket for K1 is expected to prevent recurrence of the problem (breaking of two of forty-two leads to relay sockets on two units tested). It should be kept in mind that this failure occurred at the 10.0g level towards the end of three series of single frequency tests which had subjected the equipment to more than 1000 sine beats. Tests at the 3.5g and 5.0g levels were performed without incident.

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With respect to paragraph 4.e. the suitcase jumpers have been replaced by a spring clip with higher retention force and lower mass. The spring clip captures a male pin mounted upon the board, and is not free to "rock" under vibration as was the suitcase jumper.

With respect to paragraph 4.g. control of alignment of retaining clips on the cards relative to the corresponding holes in the 2AP modules will assure retention of the cards within the modules under seismic vibration.

Other one-of-a-kind component failures referred to in Paragraph 3 are regarded to be random failures.

J. C. Childs

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Staff Engineer
Nuclear Power Products and Standards

jd

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Report No. PERS 75-113
REV. 1

Seismic Qualification Report
on SPEC 200 Nests &
Nest-Mounted Modules
----- as extracted from -----

Department 383 Test Report No. T3-1077

SEISMIC VIBRATION TESTING
OF SPEC 200 CONTROL EQUIPMENT

Tests Performed at Acton Environmental
Testing Corporation, Acton, Mass.
July-August, 1973

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LIST OF ILLUSTRATIONS

NOTE: REV. 1 - add data on mini-nest Sections 2.0, 5.3 & Diagram No. 3; revise headings of 5.1.A, .B, .C, .D, .E & 5.2.A, .B, .D, .E; add Sections 5.2.C, .F, .G, .H for clarification; Section 5.2.A.4 - correction: ±25% error in vertical rather than side-to-side direction. (10 FEB 76)

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1.0 Summary

This report presents information extracted from Test Report No. T3-1077 on the performance of SPEC 200 nests and nest-mounted modules during and after seismic vibration tests.

Excluded from this report are performance data included in the original report on SPEC 200 display devices and power supplies. The deleted information no longer is pertinent inasmuch as the devices tested have since been extensively redesigned.

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2.0 Test Items

The test items were those designated for potential application on nuclear power generating stations as Class IE equipment.

The test items were broken down into three groups, each group containing two identical systems, or "loops", as below:

Group No. 1: Loop Nos. 1 & 2 which contain the following instruments:

(2)	2AX+DP10	Power Dist. Modules
(2)	2AI-P2V	Temperature Converters
(2)	2AI-T2V	Temperature Converters
(2)	2AO-V2I	Converters
(2)	2AI-I2V	Converters
(2)	2AP+MUL	Multiplier/Dividers
(2)	2AP+SUM	Summers
(2)	2AP+SQE	Square Root Converters
(2)	2AC-D+A5+RM	Controllers with Removable Manual
(1)	2ARPS	Multinest Power Supply (#1)
(2)	2ANU	Nests

Group No. 2: Loops Nos. 3 & 4 which contain the following instruments:

(2)	2AX+DP10	Power Dist. Modules
(2)	2AP+SSL	Signal Selectors
(2)	2AP+SGC	Signal Characterizers
(2)	2AP+SLM	Signal Limiters
(2)	2AP+INT-S	Square Root Integrators
(2)	2AP+ALM-AS	Absolute Alarms
(2)	2AO-IPD-R	Integrator Power Driver
(2)	2AO-L2C-R	Contact Output Isolator
(2)	2AO-L2C-A	Contact Output Isolator
(1)	2ARPS	Multinest Power Supply (#2)
(2)	2ANU	Nests

Group No. 3:

(2)	230SM	Control Stations
(2)	210S+DSP	Indicators
(2)	220-2FS+DSP	Recorders
(2)	235SA+DSP	Manual Stations
(8)	2AK-F2C0	Cables
(2)	2AX+DSC	Signal Dist. Modules
(1)	2AX+DP10	Power Dist. Modules
(6)	2AX+DSP	Signal Dist. Modules
(2)	202S-05	Shelves
(1)	2ANU-M	Mini-Nest

The arrangement of these units in their respective nests and loops or shelf is shown on the following four pages.

NEST LOADING FOR SPEC 200 SEISMIC TEST

Loops 1 & 2

NEST NO. 1

2AI-P2V	2AI-T2V	2AO-V2I	2AI-I2V	OPEN	OPEN	2AI-I2V	2AO-V2I	2AI-T2V	2AI-P2V	2AX+DP10

NEST NO. 2

2AP+MUL	2AP+SUM	2AC+SQE	2AC+D+RM	2AC+A5	2AC+D+RM	2AC+A5	2AC+SQE	2AP+SUM	2AP+MUL	2AX+DP10

Loops 3 & 4

NEST NO. 3

2AP+SSL	2AP+SGC	2AP+SLM	2AP+ALM-AS	2AP+INT-S	2AP+INT-S	2AP+ALM-AS	2AP+SLM	2AP+SGC	2AP+SSL	2AX+DP10

NEST NO. 4

2AO-IPD	2AO-L2C-R	2AO-L2C-R	2AO-L2C-A	OPEN	OPEN	2AO-L2C-A	2AO-L2C-R	2AO-L2C-R	2AO-IPD	2AX+DP10

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Diagram No. 1
Group 1 Configuration for Seismic Testing
Test No. T3-1077 July-August, 1973

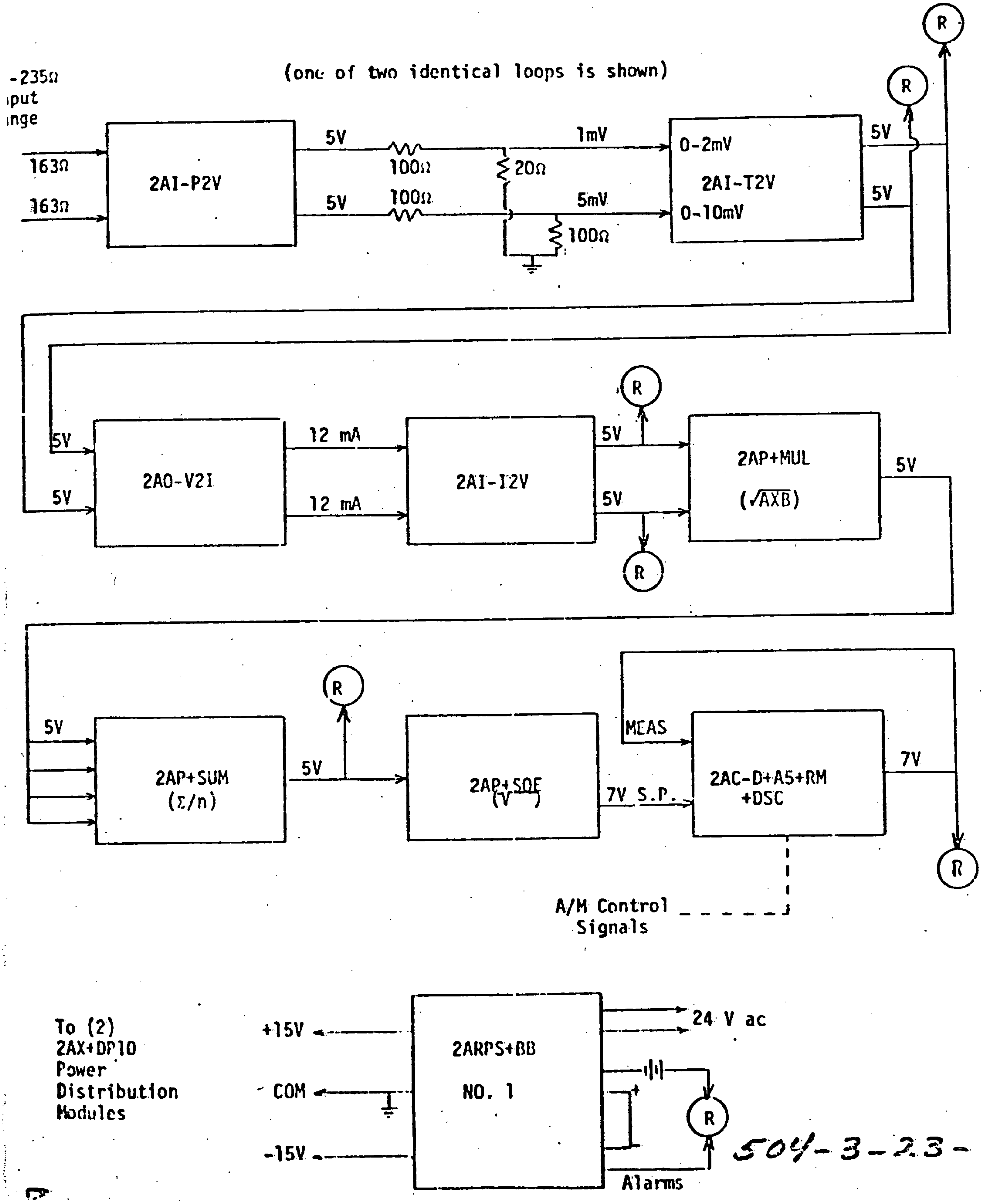

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Diagram No. 2
Group 2 Configuration for Seismic Testing
Test No. T3-1077 July-August, 1973

(one of two identical loops is shown)

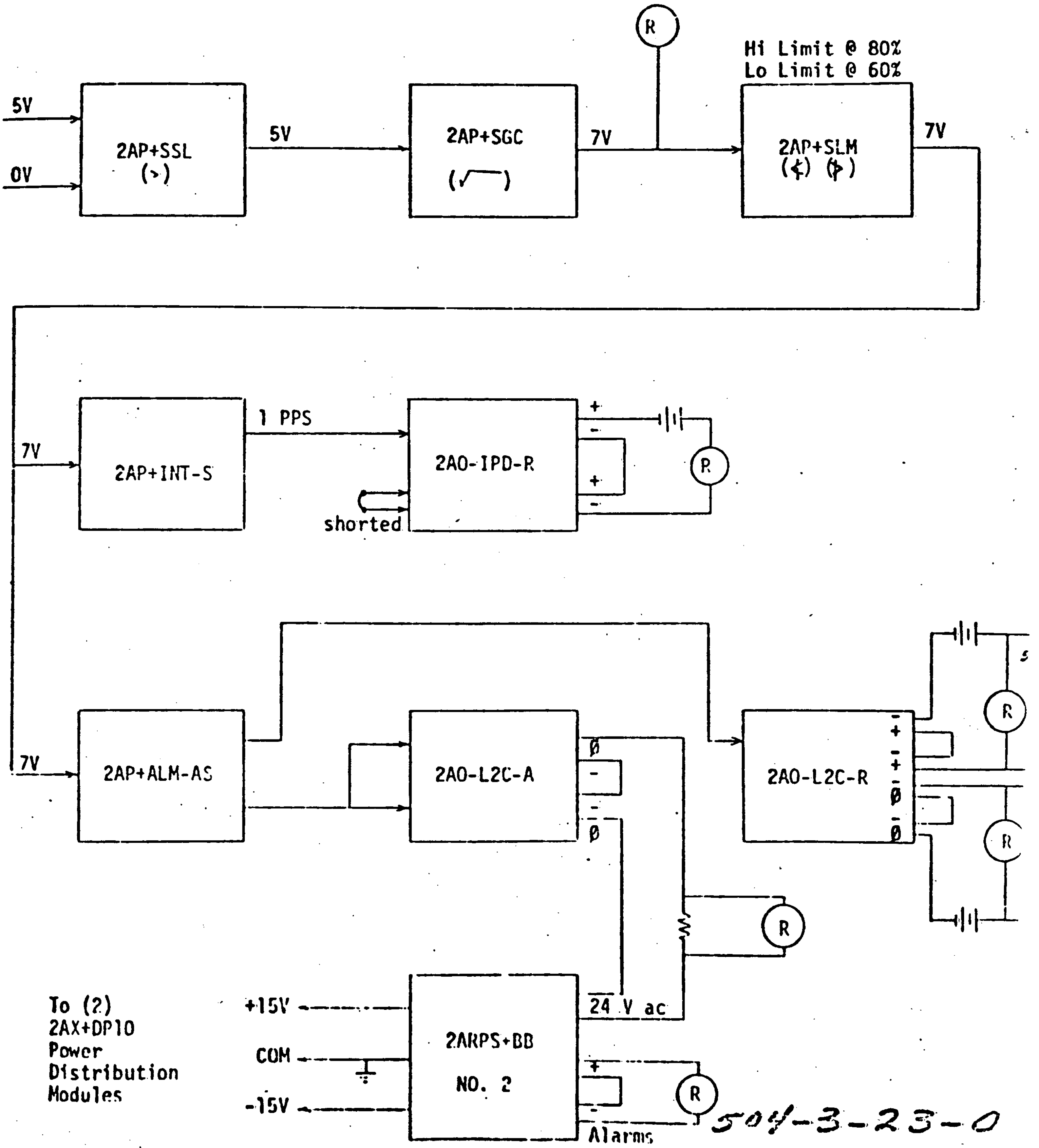

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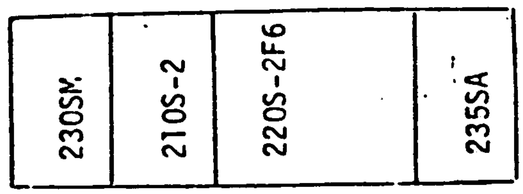
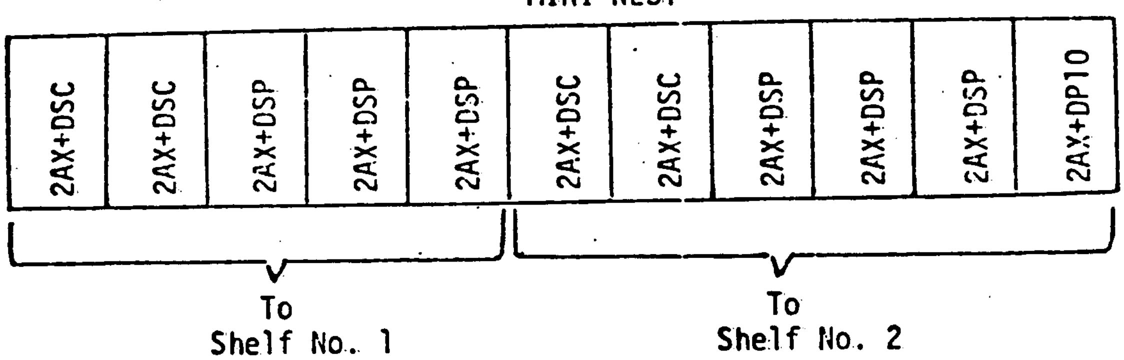
Diagram No. 3
SHELF & MINI NEST LOADING
FOR SPEC 200 SEISMIC
TEST

SHELF (TWO IDENTICAL SHELVES)



MINI NEST



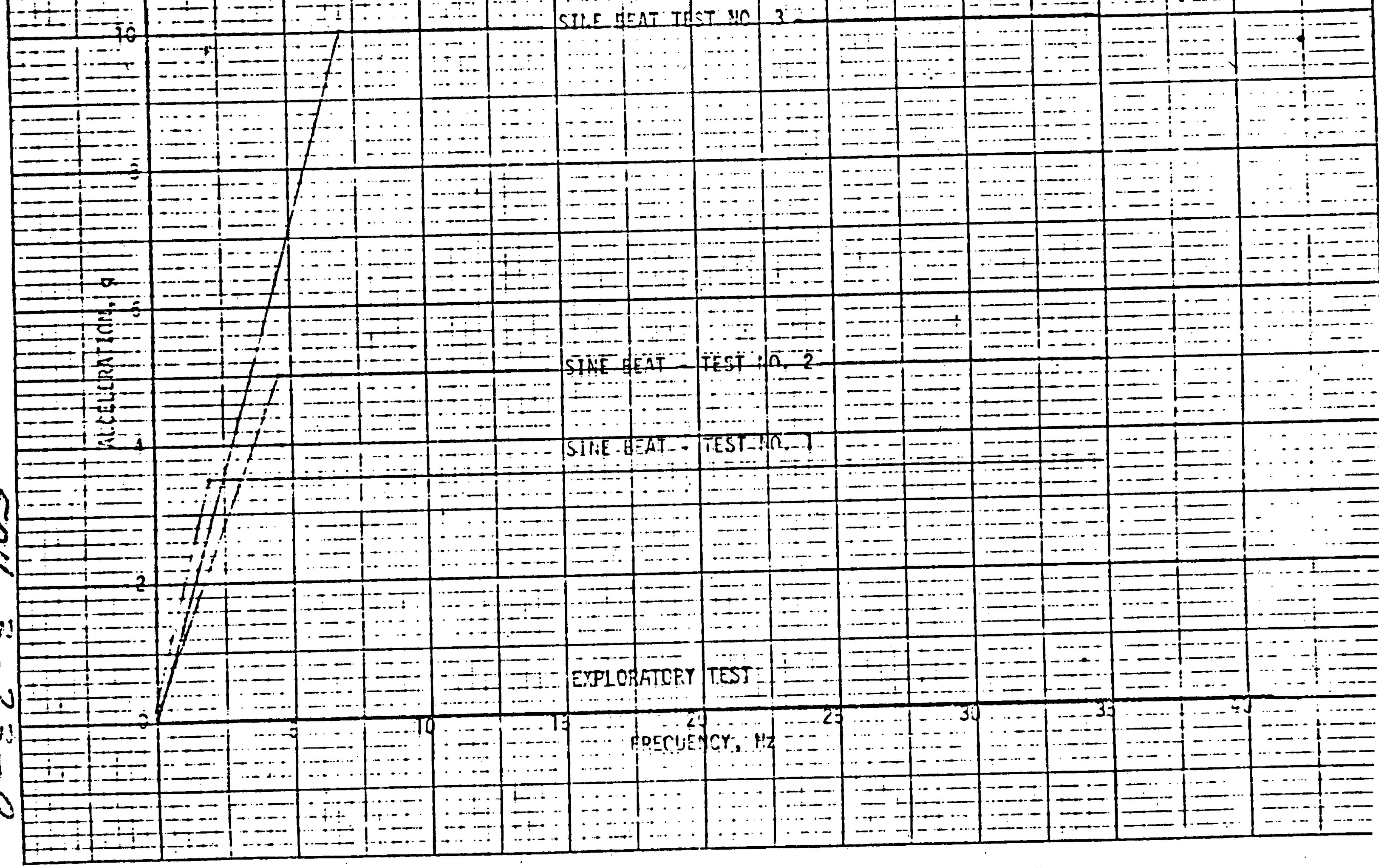
3.0 Test Objective

To determine the ability of SPEC 200 Control Equipment to perform without loss of function under the seismic vibration conditions specified herein.

Since the criteria for acceptable performance under seismic vibration very with application requirements, they are not included in this document.

A sequence of tests were conducted on each equipment group in which a resonance search at 0.4g's, 1-35 Hz was followed by "sine beat" tests at peak accelerations of 3.5, 5.0 and 10.0g's, 1-35 Hz (see Figure Nos. 1 & 2).

FIGURE NO. 1
SEISMIC QUALIFICATION TEST
PEAK ACCELERATION VERSUS FREQUENCY
TEST NO. T3-1077 AUGUST 1973



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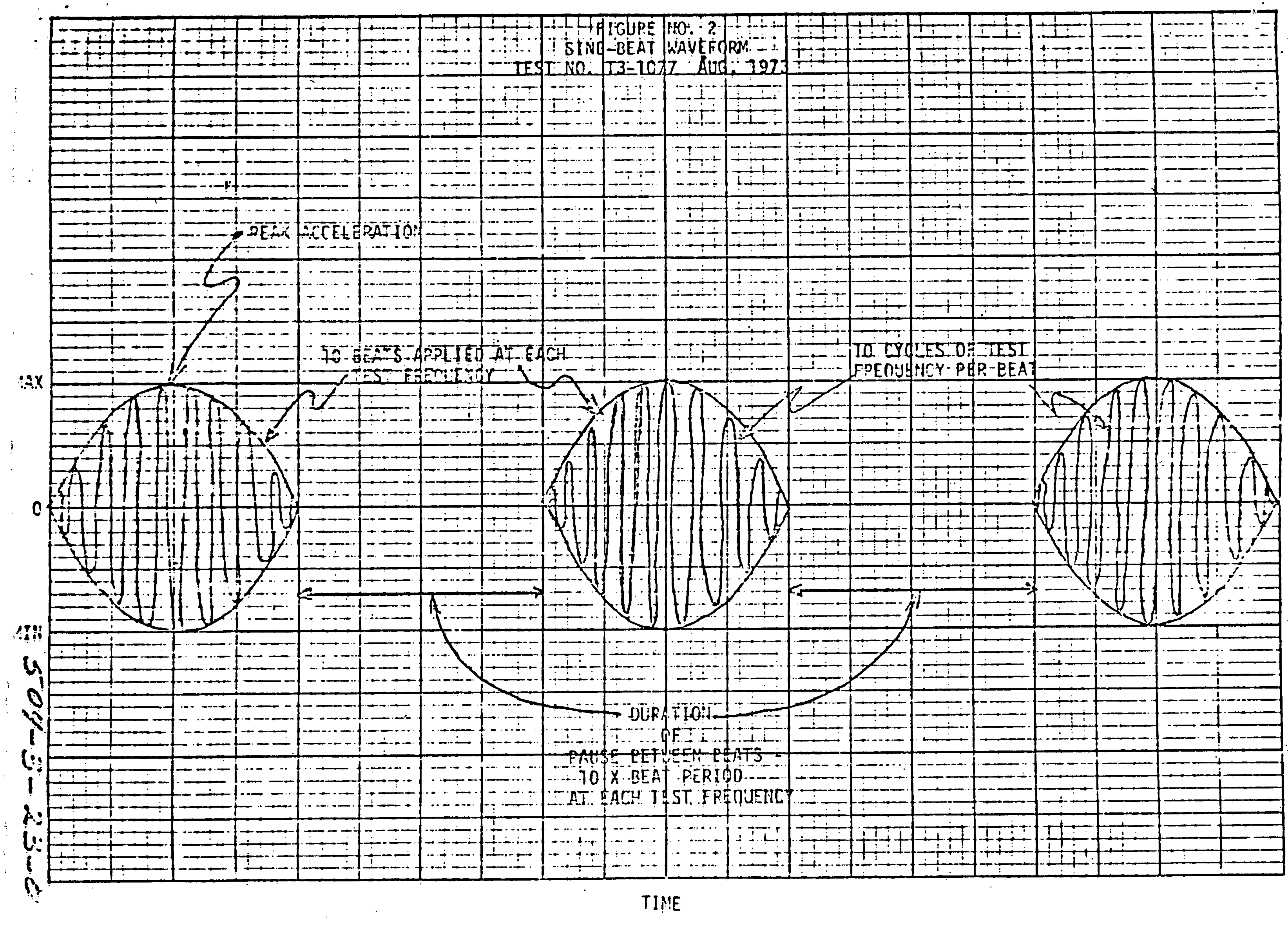
FIGURE NO. 2
SINE-BEAT WAVEFORM
TEST NO. T3-1077 AUG. 1973
PEAK ACCELERATION
10 BEATS APPLIED AT EACH TEST FREQUENCY
10 CYCLES OF TEST FREQUENCY PER BEAT
MAX
0
MIN
DURATION OF PAUSE BETWEEN BEATS = 10 X BEAT PERIOD AT EACH TEST FREQUENCY
TIME

4.0 Observations & Conclusions

In general all of the input/output and computing cards performed well, even at 10g's. Exceptions are stated below, along with other observations and comments. In reviewing these several exceptions, the endurance testing aspect of the test sequence should be kept in mind, from the standpoint that these occurrences took place among 38 functioning modules, each of which was subjected to more than 1000 ten-cycle sine beats of vibration.

1. The mechanical integrity of the 2ANU nests and mounting hardware appears to be adequate at 3.5g's, but it is evident that additional measures must be taken for use at 5.0g and 10g levels.

   The nylon bushings on the mounting screws of the 2ANU nests and Power Supply are too soft and can be distorted by vibration to the point where the mounting screws become loose allowing the nests and power supply to slide in these mounting slots and/or rack opening.

   The nest-to-rack mounting brackets on the nests containing 2AP modules as opposed to the nest containing the input/output modules held at acceleration levels of 5.0g's or less; but when tested at 10g acceleration level, the brackets flexed considerably (compounded by the problem listed above) causing one nest's brackets to develop cracks along the 90° bend.

   The following design modifications are suggested for consideration:

   a. The use of all-metal locking hardware for mounting the nests.

   b. Using holes instead of slots in the front of the mounting brackets in order to reduce the amount of side-play available.

   c. Repositioning of the bracket-to-nest fastening hardware closer to the front of the nest in order to reduce the amount of side-play available.

   d. Using a heavier-gauge steel for the mounting brackets.

   e. Alteration of the design of the "pressed nuts" in the nest into which the mounting screws for the mounting brackets go would be desirable. In the present design the mounting bracket is kept from mounting flush to the nest by the lip on the "pressed nut" body. This allows flexing and eventually leads to failure of the fastener at 5 and 10g levels.

2. The mercury-wetted relays of the two 2AO-IPD-R's frequently chattered at various frequencies during all of the sine beat tests, and occasionally during the resonant searches at 0.4g's.

3. Several one-of-a-kind problems were encountered. They are as follows:

   a. Output spikes of up to -15% were observed on the output of the 2AP+SUM summer and 2AC+A5 controller of loop 2, group 1 at 3.5g's in the horizontal plane. At 5g's these spikes began appearing on the outputs of all the loop 2 units, but did not occur at any time from any of the units at 10g's.

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4.0 Observations & Conclusions (Cont.)

No output spikes were observed in the other, identical group of equipment (loop 1, group 1) during testing.

b. Output A of the 2AO-L2C-R No. 2 failed at 20 Hz in the side-to-side plane @ 10g's. The fault was traced to two broken wires on the relay socket of K1.

c. The 2AP+ALM-A No. 2 failed at 28 Hz in the side-to-side plane @ 5g's. The fault was traced to operational amplifier, U2 (LM301A).

d. Diode CR2 (IN914) of the 2AP+SLM No. 1 failed (shorted) at 32 Hz in the vertical plane at 5g's. This caused the output to follow the low limit setting regardless of input signal level.

e. One suitcase jumper fell out of its position on the 2AP+SGC No. 2, at 10g's in the side-to-side plane, and all of the other suitcase jumpers were found to be partially withdrawn from their pins at the completion of testing.

f. At 3.5g's the alarm set point of one 2AP-ALM-AS shifted causing the output to fire.

g. Cards 2AX+INT No. 1 and 2AX+ALM No. 2, repeatedly came from their 2AP modules during 5g and 10g tests. This occurred because the retaining clips on the cards did not line up with the holes in the 2AP modules. After completion of testing, inspection revealed that many of the cards which did not come out were held by only one retaining clip.

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5.0 Test Results

5.1 Group No. 1 Instrument Calibration Shifts Due to Seismic Vibration Tests

Note: Data listed below was taken at points shown in Diagrams 1 & 2, and represents output shifts during each test of the total loop up to the point at which the data was taken. The values reported are with reference to data taken before each test.

A. 2AI-P2V and 2AI-T2V Converters

1. Resonance Search @ 0.4g's

	50% Point Shift, %			
	Unit No. 1		Unit No. 2	
Plane	A	B	A	B
Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5
Vertical	<0.5	<0.5	<0.5	<0.5

2. Sine Beat Test @ 3.5g's

Vertical	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5
Side-to-Side	<0.5	<0.5	<0.5	<0.5

3. Sine Beat Test @ 5g's

Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5*	<0.5*
Vertical	<0.5	<0.5	<0.5	<0.5

*Although the dc output shifts due to this test were less than 0.5%, spikes of 14 and 13% for Sections A and B respectively were noted during the test.

4. Sine Beat Test @ 10g's

Vertical	<0.5	<0.5	<0.5	<0.5
Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5

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5.0 Test Results (Cont.)

5.1 (Cont.)

B. 2AO-V21 and 2A1-12V Converters

1. Resonance Search @ 0.4g's

Plane	50% Point Shift, %			
	Unit No. 1		Unit No. 2	
	A	B	A	B
Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5
Vertical	<0.5	<0.5	<0.5	<0.5

2. Sine Beat @ 3.5g's

Vertical	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5
Side-to-Side	<0.5	<0.5	<0.5	<0.5

3. Sine Beat @ 5.0g's

Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5*	<0.5*
Vertical	<0.5	<0.5	<0.5	<0.5

*Although the dc output shifts due to this test were less than 0.5%, spikes of 24 and 23% for Sections A and B respectively were noted during the test.

4. Sine Beat @ 10g's

Vertical	<0.5	<0.5	<0.5	<0.5
Side-to-Side	<0.5	<0.5	<0.5	<0.5
Front-to-Back	<0.5	<0.5	<0.5	<0.5

C. 2AP+MUL Multiplier/Divider and 2AP+SUM Summer

1. Resonance Search @ 0.4g's

Plane	50% Point Output Shift, %	
	Unit No. 1	Unit No. 2
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5
Vertical	<0.5	<0.5

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5.0 Test Results (Cont.)

5.1 (Cont.)

C. 2AP+MUL Multiplier/Divider and 2AP+SUM Summer (Cont.)

2. Sine Beat Test @ 3.5g's

Plane	50% Point Shift, % Unit No. 1	Unit No. 2
Vertical	<0.5	<0.5*
Front-to-Back	<0.5	<0.5*
Side-to-Side	<0.5	<0.5

*Although the dc output shifts due to this test were less than 0.5%, spikes of 12 and 15% for the Vertical and Front-to-Back planes respectively were noted during the test.

3. Sine Beat Test @ 5.0g's

Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5*
Vertical	<0.5	<0.5

*Although the dc output shifts due to this test were less than 0.5%, spikes of -14% were noted during the test.

4. Sine Beat Test @ 10g's

Vertical	<0.5	<0.5
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5

D. 2AP+SQE Square Root Converter and 2AC-D+A5+RM+DSC Controller

1. Resonance Search @ 0.4g's

Plane	70% Point Output Shift, % Unit No. 1	Unit No. 2
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5
Vertical	<0.5	<0.5

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5.0 Test Results (Cont.)

5.1 (Cont.)

D. 2AP+SQE Square Root Converter and 2AC-D+A5+RM Controller (Cont.)

2. Sine Beat Test @ 3.5g's

Plane	70% Point Output Shift, % Unit No. 1	Unit No. 2
Vertical	<0.5	0.5*
Front-to-Back	<0.5	0.5*
Side-to-Side	<0.5	0.5

*Although the dc output shifts due to this test were <0.5, spikes of 4 and 7% for the Side-to-Side and Vertical plane respectively were noted during this test.

3. Sine Beat Test @ 5.0g's

Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5*
Vertical	<0.5	<0.5

*Although the dc output shifts due to this test were <0.5, spikes of 6% were noted during this test.

4. Sine Beat Test @ 10g's

Vertical	<0.5	<0.5
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5

E. 2AX+DP10 Power Distribution Modules

The power distribution modules functioned properly throughout all tests.

5.2 Group No. 2 Instrument Calibration Shifts due to Seismic Vibration Tests

Note: All of the shifts listed below are the shifts for that particular test (the value reported is referenced to data taken before each test). Listed in the order of testing.

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5.0 Test Results (Cont.)

5.2 (Cont.)

A. 2AP+SSL Signal Selector and 2AP+SGC Signal Characterizer

Plane	70% Point Output Shift, % Unit No. 1	Unit No. 2
1. Resonance Search @ 0.4g's		
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5
Vertical	<0.5	<0.5
2. Sine Beat Test @ 3.5g's		
Vertical	<0.5	<0.5
Front-to-Back	<0.5	<0.5
Side-to-Side	<0.5	<0.5
3. Sine Beat Test @ 5.0g's		
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5
Vertical	<0.5	<0.5
4. Sine Beat Test @ 10g's		
Vertical	<0.5	<0.5
Side-to-Side	<0.5	<0.5
Front-to-Back	<0.5	<0.5

B. 2AO-IPD-R Integrator Power Driver

1. The outputs of both power drivers chattered during resonance search, and sine beat tests at 3.5, 5.0 and 10g's.

C. 2AP+INT-S Square Root Integrator

As shown in Diagram No. 2, the 2AP+INT-S square root integrator and the 2AO-IPD-R integrator power driver were monitored in a series configuration. As stated above, the output of the power drivers chattered during applied vibration at all levels.

It is concluded that the 2AP+INT-S performed satisfactorily during seismic testing on the bases (1) that both units continued to function satisfactorily before and after all tests, and (2) that the chattering in the output of the 2AO-IPD-R during vibration was attributed to performance of its mercury wetted relays.

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5.0 Test Results (Cont.)

5.2 (Cont.)

D. 2AO-L2C-R Contact Isolators

1. The outputs of both contact isolators operated properly throughout all tests.

E. 2AO-L2C-A Contact Isolators

1. The outputs of both contact isolators operated properly throughout all tests.

F. 2AP+SLM Signal Limiters

1. Signal Limiter #1 failed at 33 Hz in the vertical plane at 5g's, causing the output to follow the low limit setting regardless of input signal level. The fault was traced to diode CR2, which was shorted.

2. Signal Limiter #2 functioned properly throughout all tests.

G. 2AP+ALM-AS Absolute Alarms

Other than the problems of a single alarm set point shift of 2AP+ALM-AS (#2) at the 3.5g level, and of interruption of performance during testing of the same card due to misalignment of its retention clips (per Section 4.g) no malfunction of the 2AP+ALM-AS was observed.

H. 2AX+DP10 Power Distribution Modules

The power distribution modules functioned properly throughout all tests.

5.3 Group No. 3 Mini-Nest and Shelf-Mounted Displays

A. Shelf-Mounted Displays

As stated under Summary, Page 3, performance of display devices has been excluded from this report inasmuch as these devices have since been extensively redesigned.

B. 2AX+DP10 Power Distribution Modules

The power distribution modules functioned properly throughout all tests.

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5.0 Test Results (Cont.)

5.3 (Cont.)

C. 2AX+DSC Signal Distribution Modules

The signal distribution modules functioned properly throughout all tests.

D. 2AX+DSP Signal Distribution Modules

The signal distribution modules functioned properly throughout all tests.

E. 2ANU-M Mini-Nest

Mechanical integrity of the mini-nest was maintained throughout all tests.

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6.0 Test Procedure

6.1 Test Mounting

Mounting fixture design was such as to insure an input transmissibility of 1 to the test unit.

6.2 Test Monitoring

The test items were operational with outputs checked and monitored before, during and after each test to confirm performance.

Accelerometers were attached to the test fixture and on the test item at various locations for determining mechanical response.

6.3 Exploratory Test

Using a sinusoidal input signal of 0.4g, a continuous frequency sweep from 1-35 Hz was run in each of the three major mutually-perpendicular axes independently. Natural frequencies were noted and included in the subsequent tests. The sweep rate was 8 cycles/min. See Figure No. 1.

6.4 Sine Beat Test

This test consisted of amplitude modulated sinusoids at frequencies from 1 to 35 Hz with a peak acceleration corresponding to that for which the device was to be qualified. The sine beats consisted of a sinusoid at the frequency and amplitude of interest, as shown in Figure No. 2. For this test, the test period for each frequency was 10 beats with a pause between beats of ten times the beat period. The test levels apply to the three mutually perpendicular axes, run independently. See Figure Nos. 1 & 2.

6.0 Test Procedure (Cont.)

6.5 Sequence of Tests

6.5.1 Group No. 1

Test No.	Test	Plane	Acceleration
1	Resonance Search	Side-to-Side	0.4g's
2	Resonance Search	Front-to-Back	0.4g's
3	Resonance Search	Vertical	0.4g's
4	Sine Beat	Vertical	3.5g's
5	Sine Beat	Front-to-Back	3.5g's
6	Sine Beat	Side-to-Side	3.5g's
7	Sine Beat	Side-to-Side	5.0g's
8	Sine Beat	Front-to-Back	5.0g's
9	Sine Beat	Vertical	5.0g's
10	Sine Beat	Vertical	10g's
11	Sine Beat	Side-to-Side	10g's
12	Sine Beat	Front-to-Back	10g's

6.5.2 Group No. 2

13	Resonance Search	Front-to-Back	0.4g's
14	Resonance Search	Side-to-Side	0.4g's
15	Resonance Search	Vertical	0.4g's
16	Sine Beat	Vertical	3.5g's
17	Sine Beat	Side-to-Side	3.5g's
18	Sine Beat	Front-to-Back	3.5g's
19	Sine Beat	Front-to-Back	5g's
20	Sine Beat	Side-to-Side	5g's
21	Sine Beat	Vertical	5g's
22	Sine Beat	Vertical	10g's
23	Sine Beat	Side-to-Side	10g's
24	Sine Beat	Front-to-Back	10g's

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