LEAM Film Development Vibration
Test Report

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ILLUSTRATIONS

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1. PURPOSE

Since Parylene C, of which the present LEAM DVT sensor films are made, is stronger than Parylene N, of which the Pioneer dust detector sensor films were made, it was deemed reasonable to study whether or not the film support mesh used in the dust detector experiment could be eliminated. Removal of the mesh means less blockage of the particle impact area thus a higher probability of particle incidence.

Analysis of the problem showed that the critical loading of the film results from diaphragm pumping of air during vibration. The amplitude and the natural frequency of the film vibration is predominantly determined by the film's flexibility in tension and the mass of air that it moves. The mass of the film itself was assumed negligible compared to the mass of the air. Accurately determining the film's flexibility or the mass of the moving air was the weak link in the analysis; thus, a vibration test on several film samples was proposed. A secondary purpose of the vibration tests was to evaluate the necessity and effectivity of the urethane foam mounts which were used on the Pioneer experiment. In the Pioneer experiment a 4 lb/cu ft density urethane foam was used. It was anticipated that due to the small mass of the film frame, softer foam (lower density) would be more effective. Hard mounts, if shown to be adequate, had the advantage of "fixing" the dimension between the front and rear films, thus improving the over-all accuracy of the particle velocity measurements.

2. SCOPE

The test program used three film frames having different thicknesses of a parylene and gold film laminate with one of the three laminates supported by copper mesh. For the tests each film frame was sandwiched between two grid grames using either soft or hard support mounts. One series of tests was run on each of the two non-mesh supported film laminates, one film frame supported with soft mounts, and the other with hard mounts. The film frame with the mesh support for the laminate was subjected to two series of tests, one in an assembly using soft mounts, and the other assembled using hard mounts.

All test articles were subjected to both sinusoidal sweeps and random vibration excitations in an axis normal to the film frames.

3. OBJECTIVES

The objectives of the test were to measure, or observe, and record the following:

a. Film natural frequency

b. Frame natural frequency

c. Input acceleration

d. Film frame strain

4. EQUIPMENT DESCRIPTION

4.1 TEST ARTICLES

The basic test articles consisted of the LEAM front film and grid assembly (P/N 2347037) with variations in the mountings and film laminates within this assembly. Four articles were tested:

4.1.1 Article No. 1

P/N 2347037-105 - This assembly had the 2347007-5 film laminate (1000 Å parylene, 400 Å gold) on the film frame assembly (without support mesh) sandwiched between the two grid frame assemblies using rigid spacers.

4.1.2 Article No. 2

P/N 2347037-7 - This assembly had the 2347007-7 film laminate (2000 Å parylene 400 Å gold 1000 Å parylene overcoat) on the film frame assembly sandwiched between the two grid frame assemblies using 2 lb/cu ft molded urethane foam spacers (one piece).

4.1.3 Article No. 3

P/N 2347037-3 (except for foam density and thickness) - This assembly had the 2347007-3 film laminate (mesh support, 1000 Å parylene 400 Å gold) on the film frame assembly sandwiched between the two grid frame assemblies using 2 lb/cu ft fabricated urethane spacers (three rings, uniform pore size, no surface skins). See Figure in Table 6-1.

4.1.4 Article No. 4

P/N 2347037-103 - This assembly had the 2347007-3 film laminate (with support mesh, see No. 3) on the film frame assembly sandwiched between the two grid frame assemblies using rigid spacers.

4.2 VIBRATION FIXTURE AND INSTRUMENTATION

The test set-up is shown in Figure 4-1. The test articles were hard mounted at their four corners to the shaker plate through use of a 6-in.-square, 1-in.-thick aluminum plate with four 1.6-in. high, 3/4-in. diameter aluminum standoffs. The instrumentation consisted of: an accelerometer mounted on the fixture to monitor input acceleration; two strain gages mounted on the center of the film frame (wired to add); and a strobe light used to determine visually the resonances of the films and frames during sinusoidal sweeps. (Accelerometers could not be mounted on the frames due to their large mass relative to the frame mass.) Pictures of the test set-up are shown in Figure 4-2.

4.3 TEST EQUIPMENT

The following test equipment was used:

1. Strain Gage; W.T. Bean; Model BAE-15-062 AA-120
2. Accelerometer; ENDEVCO; Model 2221 D, S/N VR 59
3. X-Y Recorder; F.C. Moseley; Model 20 R, S/N 110
4. Log Converter; F.C. Moseley; Model 7561 A, S/N 00266
5. True RMS Voltmeter; Bruel and K. Jaer; Model 2409, S/N 72900
6. Tape Recorder; Sanborn; Model 3900, S/N 186
7. Oscillograph; Minn. Honeywell; Model 1108, S/N 11-941
8. Carrier Amplifier; Minn. Honeywell; Model 1198, S/N 3862
9. Accelerometer Amplifier; ENDEVCO; Model 2702
10. Charge Amplifier; ENDEVCO; Model 2614 C, S/N X078
11. Vibration System; M.B. Electronics; Model C10E-T35, S/N 484.

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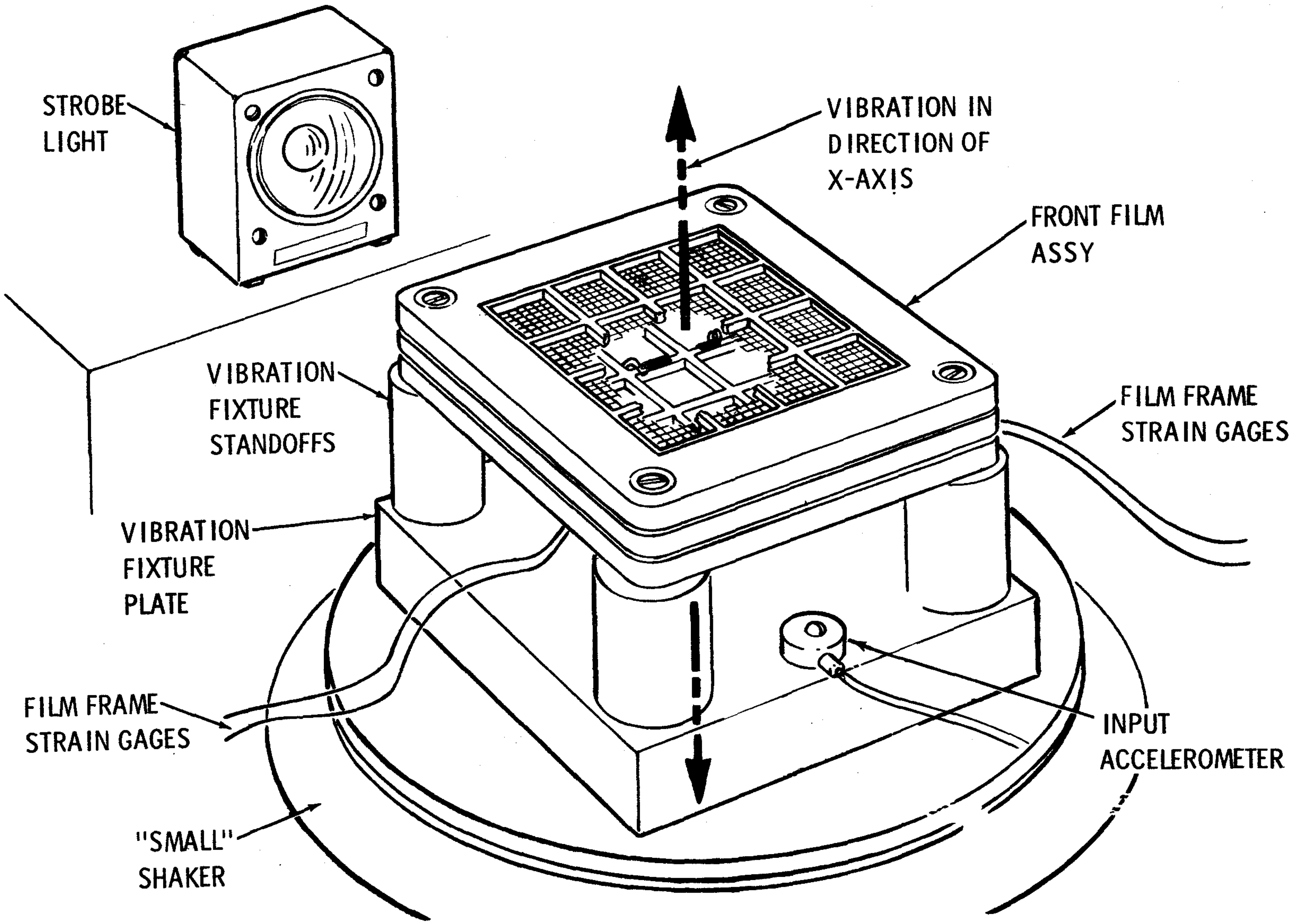


Figure 4-1 Vibration Test Setup

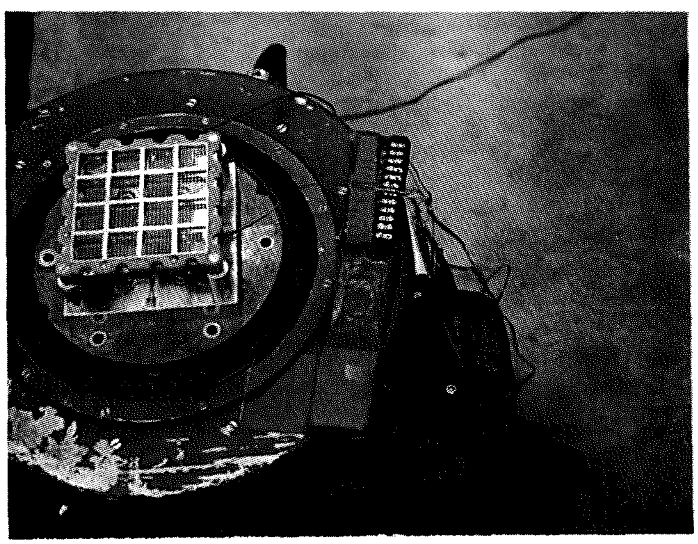


Figure 4-2 Test Setup Photographs

5. TEST DATA

The following test data were recorded either visually or on magnetic tape:

1. Film frame strain vs. frequency
2. Input acceleration vs. frequency
3. Linear distance between frames before and after tests
4. Film condition before and after test
5. Film frame resonant frequency
6. Film resonant frequency.

Polaroid photographs were taken before and after each test run.

6. TEST METHODS AND RESULTS

6.1 TEST LEVELS

Each of the four test articles was subjected to the following vibration inputs:

1. Sinusoidal sweep, 0-100-0 Hz, 9G peak (Figure 6-1)
2. Random, 40 to 150 Hz, .08 g^2/Hz Max PSD (Figure 6-2)
3. Random, 100 to 1000 Hz, .06 g^2/Hz Max PSD (Figure 6-3)
4. Random, 100 to 1000 Hz, .10 g^2/Hz Max PSD (Figure 6-3)
5. Sinusoidal sweep, 0-2000-0 Hz, 1G peak.

The sweep rate for the sinusoidal vibration was 3/4 octave/min, and the duration of each random vibration was 1 min.

AXIS: X
SWEEP RATE: 3/4 OCT/MIN
SWEEP: 5-100-5 Hz

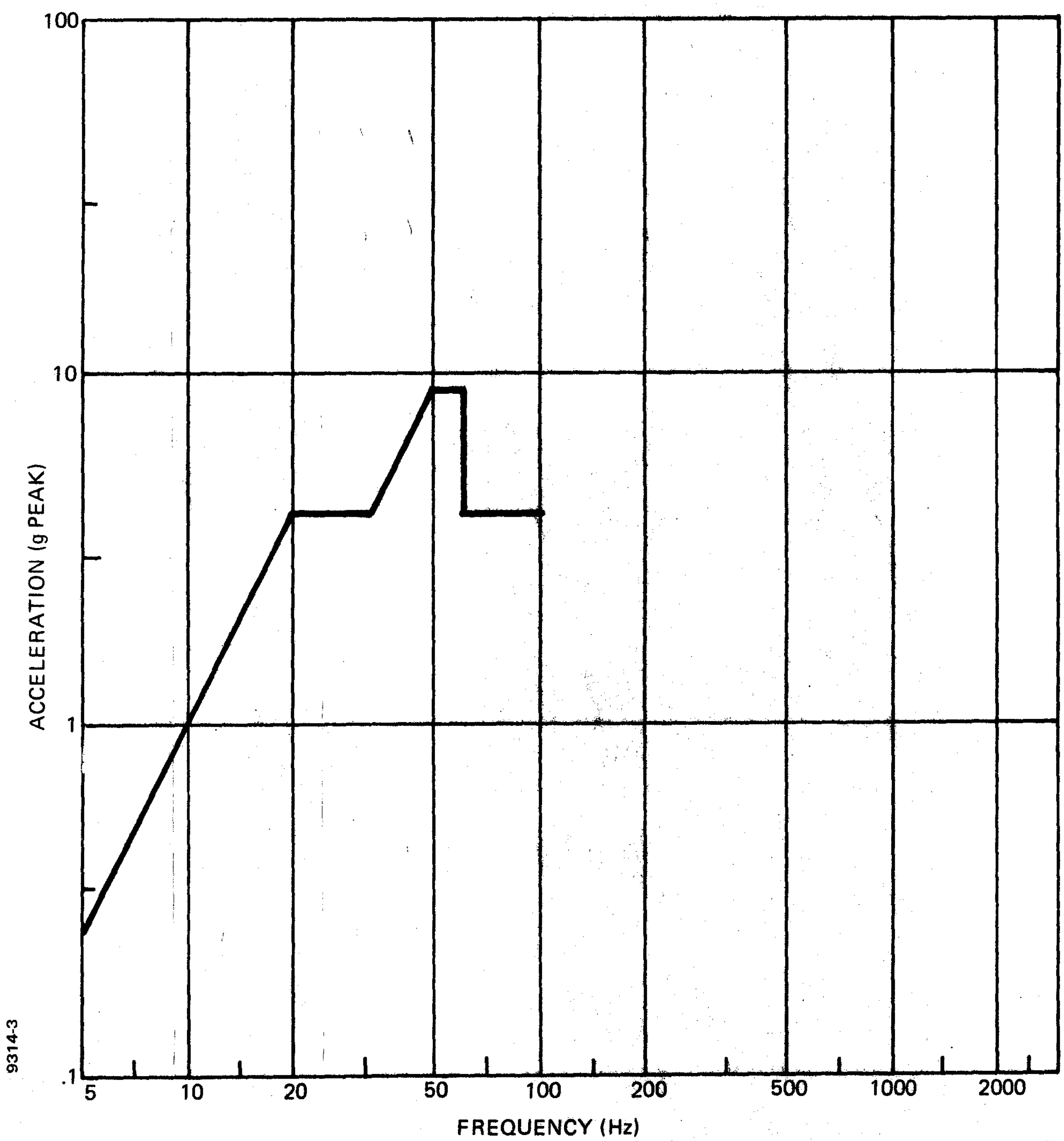


Figure 6-1 Sinusoidal Vibration Levels

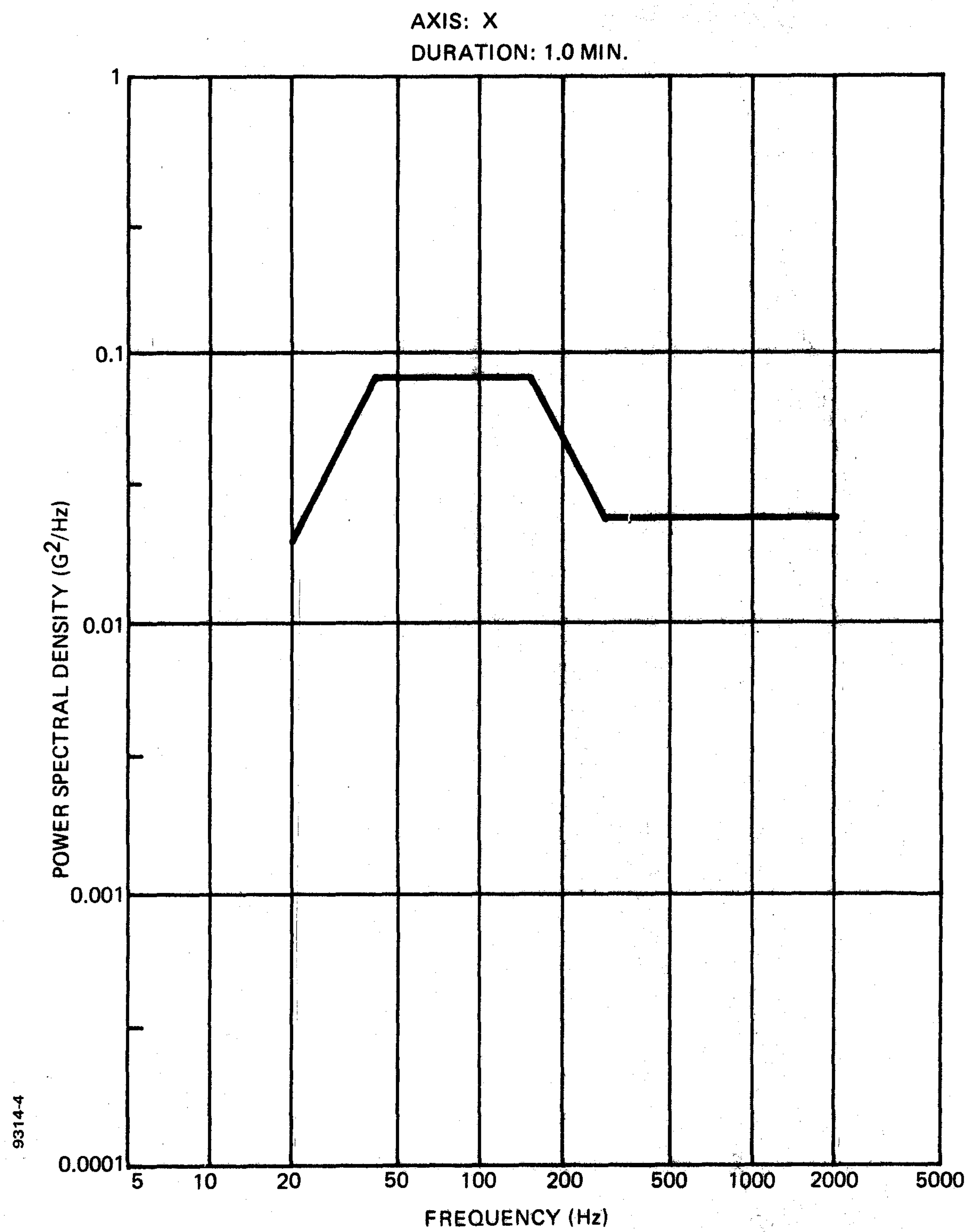
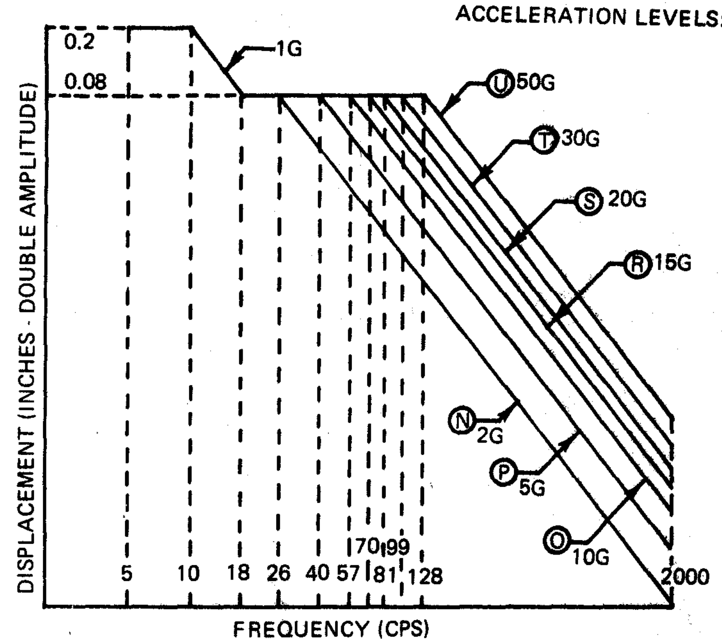


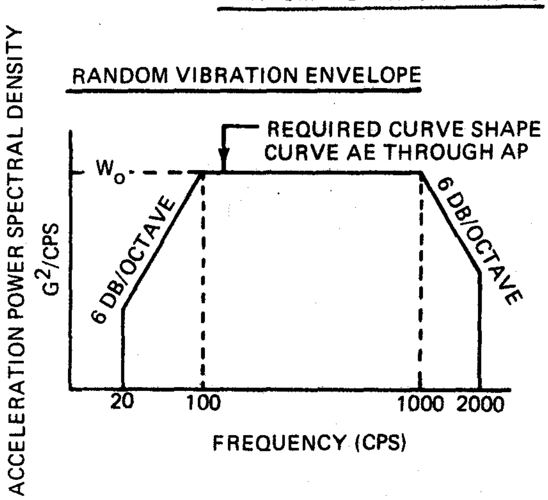
Figure 6-2 Random Vibration Levels (Acceptance)

SINUSOIDAL VIBRATION CURVES

ACCELERATION LEVELS: ± G (PEAK)



RANDOM VIBRATION CURVES



RANDOM VIBRATION TEST LEVELS

TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY W_o (G^2/CPS)	COMPOSITE G-RMS MINIMUM
AE	0.02	5.4
AF	0.04	7.6
AG	0.06	9.3
AH	0.10	12.0
AJ	0.20	16.9
AK	0.30	20.7
AL	0.40	23.9
AM	0.60	29.3
AN	1.00	37.9
AP	1.50	46.4

NOTE: COMPOSITE G-RMS $= \left[\int_{f_1}^{f_2} W(f)df \right]^{1/2}$

WHERE f_1 AND f_2 ARE THE LOWER AND UPPER TEST FREQUENCY LIMITS, RESPECTIVELY, W(f) IS THE ACCELERATION POWER SPECTRAL DENSITY IN G^2/CPS UNITS.

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Figure 6-3 Random Vibration Levels (Design Limit)

The first two vibration inputs are the experiment acceptance levels as obtained from Reference 1. Vibration inputs 3 and 4 are more severe than experiment qualification levels and were obtained from MIL-STD-810B, Figure 514.1-23 curves AG and AH, respectively. The last vibration input was a resonance search. Vibration input 3 was used only for test articles 1 and 2.

6.2 TEST LOG

The following data was recorded during the testing of the test articles:

6.2.1 Test of Article No. 1: Monday, 7 December 1970

During handling before test the film frame had eight of the 1 x 1 film windows broken, as shown in Figure 6-4. No resonances are observed during the 0-100-0 Sinusoidal Sweep. Sharp film resonances are observed at 350, 480, 600, 860, 1140, and 1250 Hz during the 0-2000 sinusoidal sweep. The film frame exhibited resonances at 400 and 500 Hz. The 350-Hz film resonance appears to be the largest in amplitude. The strain gage output for the resonance search is shown as Figure 6-5.

Film failures occurred during the 0.08 g^2/Hz Max PSD (five windows at the start and one window at about 30 sec), and the 0.10 g^2/Hz Max PSD random vibration tests, as shown on Figure 6-4. One film window survived all tests.

6.2.2 Test of Article No. 2: Tuesday, 8 December 1970

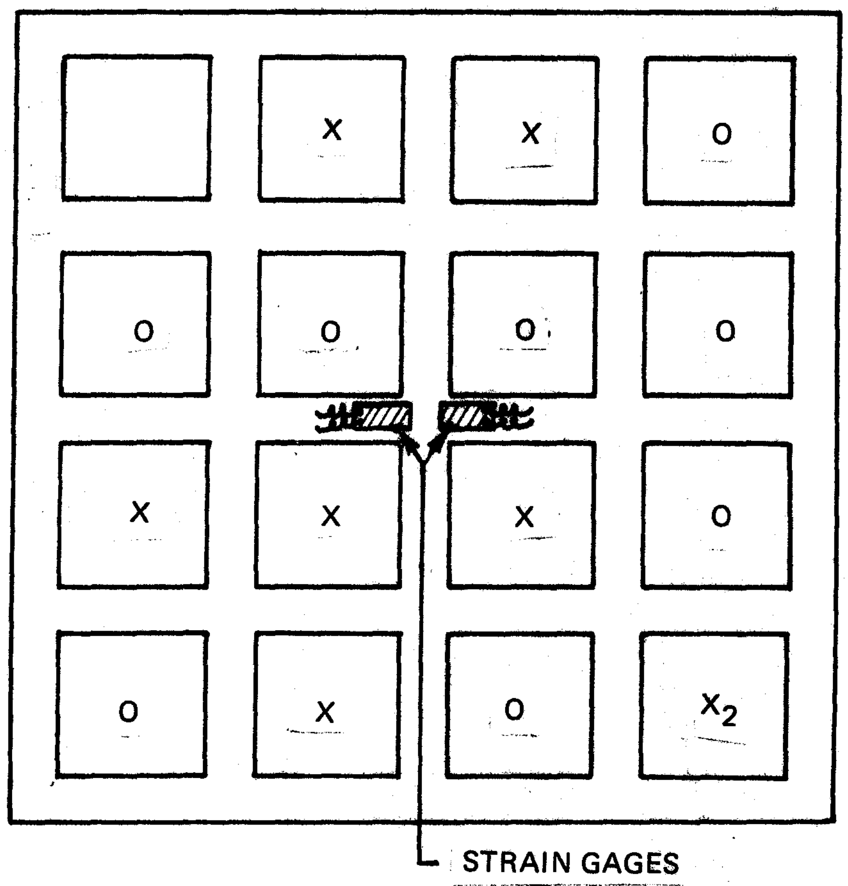
The film frame had two 1 x 1 film windows broken prior to testing, as shown in Figure 6-6. Film resonances are observed at 340, 730, and 800 Hz. Film frame resonances were observed at 350 and 700 Hz. The strain gage output for the resonance search is shown as Figure 6-7.

Film failures occurred during the 0.08 g^2/Hz Max. PSD and the 0.10 g^2/Hz Max. PSD random vibration tests, as shown on Figure 6-6. Six film windows survived all tests.

6.2.3 Test of Article No. 3: Monday, 11 January 1971

The film frame had fourteen 1/8 x 1/8 film windows broken prior to testing, as shown in Figure 6-8. While observing the film motion with the strobe light, it could not be determined whether the 1/8 x 1/8 film windows

FILM VIBRATION TEST OF 12-7-'70



LEGEND:

O : WINDOWS BROKEN BY HANDLING BEFORE TEST
X : WINDOWS FAILED DURING TEST (NO SUBSCRIPT INDICATES FAILURE AT FIRST RANDOM; SUBSCRIPT 2 INDICATES FAILURE AT THRID RANDOM TEST)

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Figure 6-4 Film Failures - Article No. 1

VIBRATION LEVELS

TEST ITEM: SINE
TEST DATE: 12-08-70 HARD MOUNT

FRAME PART NO. 2347037-105
INPUT: 1 G INPUT
RESPONSE AXIS: VERT.

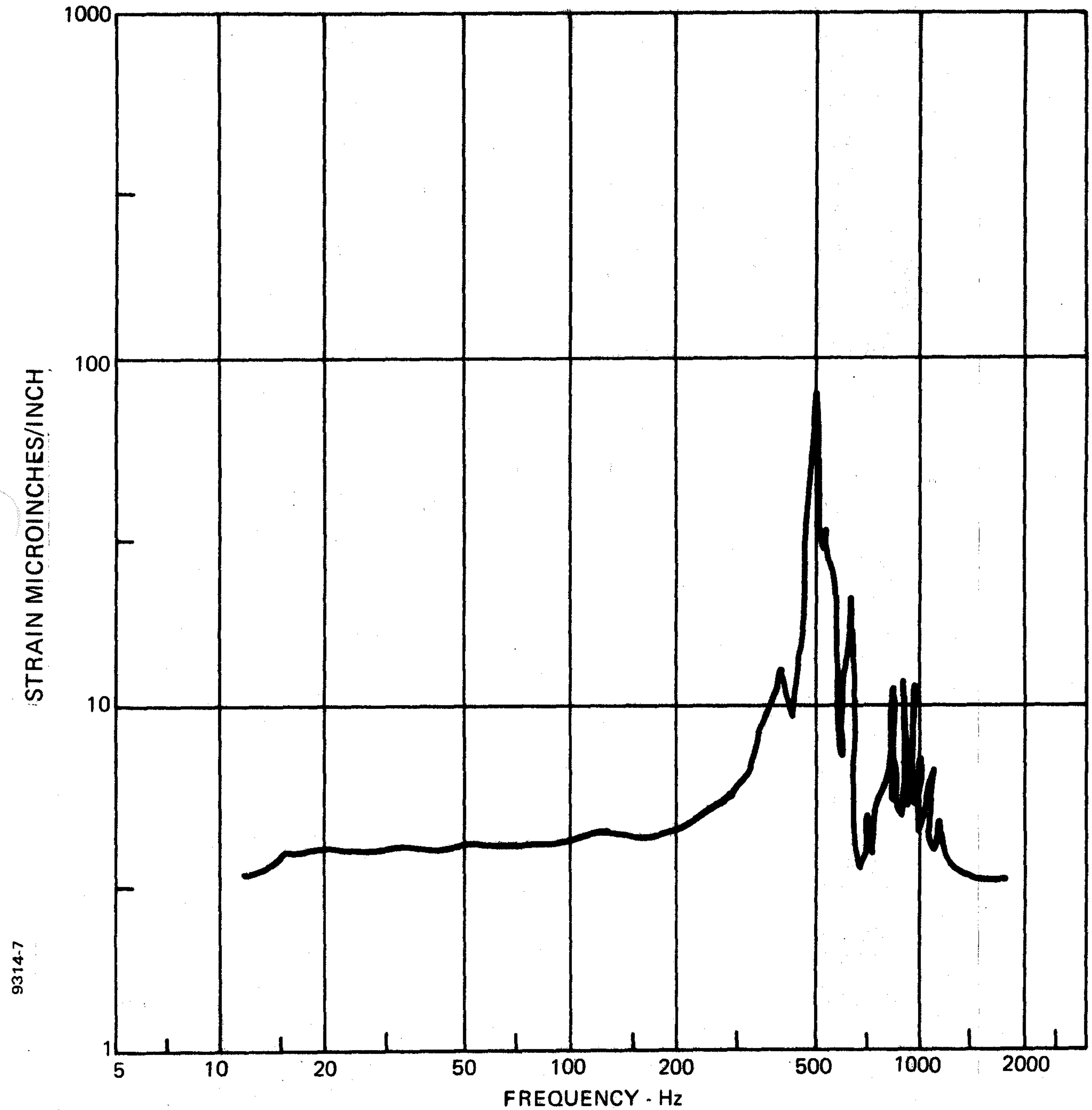
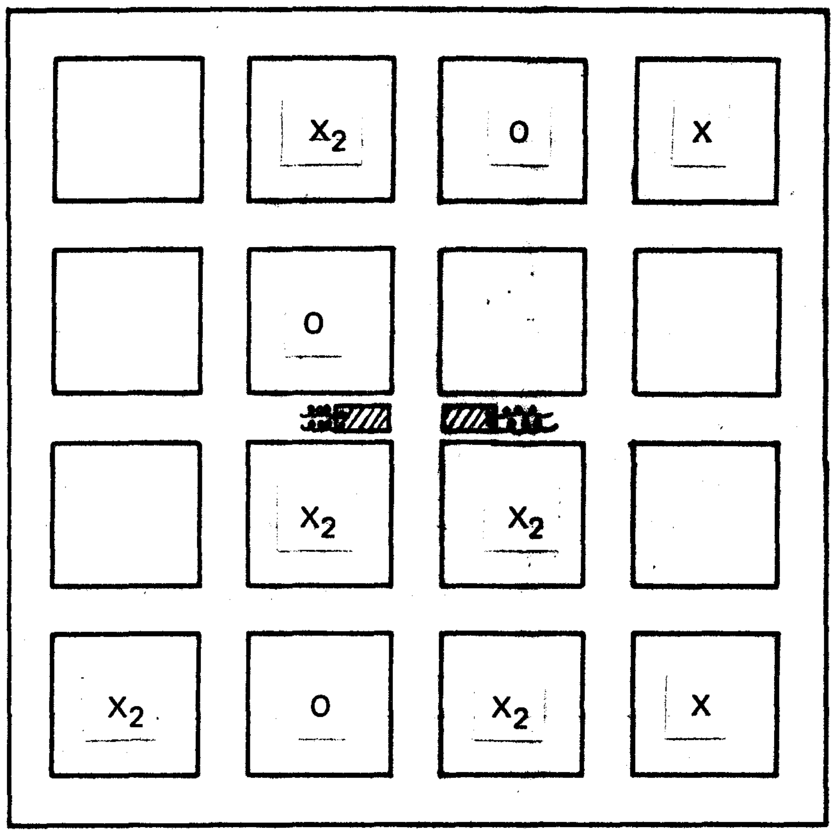


Figure 6-5 Strain Gage Output - Article No. 1

Figure 6-6 Film Failures - Article No. 2

FILM VIBRATION TEST OF 12-8-70



LEGEND:

O : WINDOWS BROKEN BY HANDLING BEFORE TEST
X : WINDOWS FAILED DURING TEST (NO SUBSCRIPT INDICATES FAILURE AT FIRST RANDOM; SUBSCRIPT 2 INDICATES FAILURE AT THIRD RANDOM TEST)

Figure 6-6 Film Failures - Article No. 2

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VIBRATION LEVELS

TEST ITEM: LEAM NO. 2 - SINE FRAME PART NO. 2347037-7
TEST DATE: 12-08-70 SOFT MOUNT INPUT AXIS: VERT.
RESPONSE AXIS: 1 G-INPUT

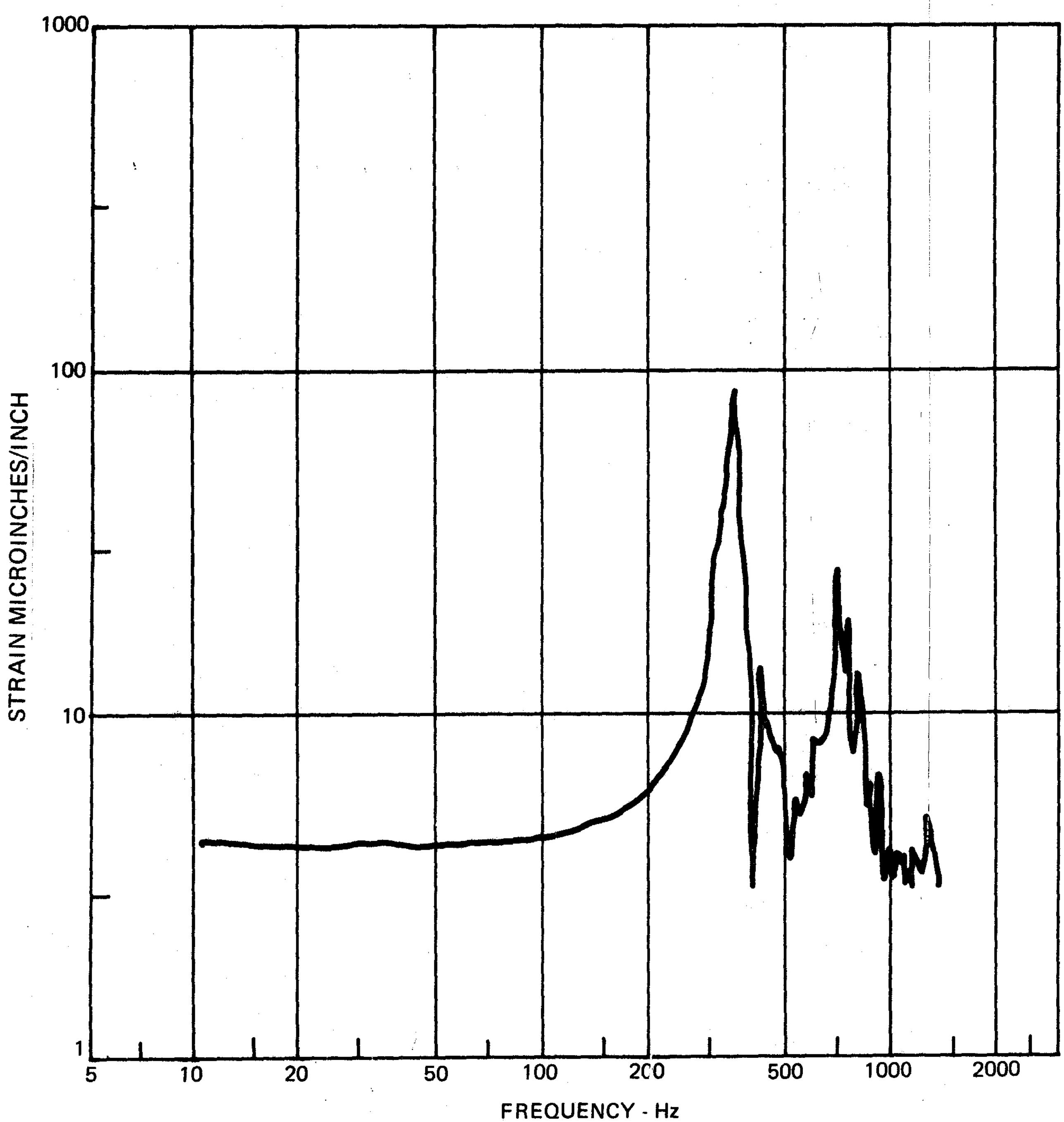


Figure 6-7 Strain Gage Output - Article No. 2

were vibrating individually or the whole 1 x 1 array was vibrating as a unit. Film resonances are observed at 476, 500, 680, 740, 800, and 1200 Hz. The strain gage output for the resonance search is shown as Figure 6-9.

No film failures occurred during this test.

Measurements, as shown in Table 6-1, were taken before and after the vibration testing to determine memory characteristics of the foam mounts.

6.2.4 Test of Article No. 4: Monday, 11 January 1971

The film frame for this test was that used in the test of Article No. 3. The film frame had fourteen 1/8 x 1/8 film windows broken prior to testing, as shown in Figure 6-8. Film resonances were observed at 460, 560, 700, 800, and 1150 Hz. The strain gage output for the resonance search is shown as Figure 6-10.

Thirteen 1/8 x 1/8 film windows failed during the 0.10 Max. PSD random vibration test, as shown on Figure 6-8.

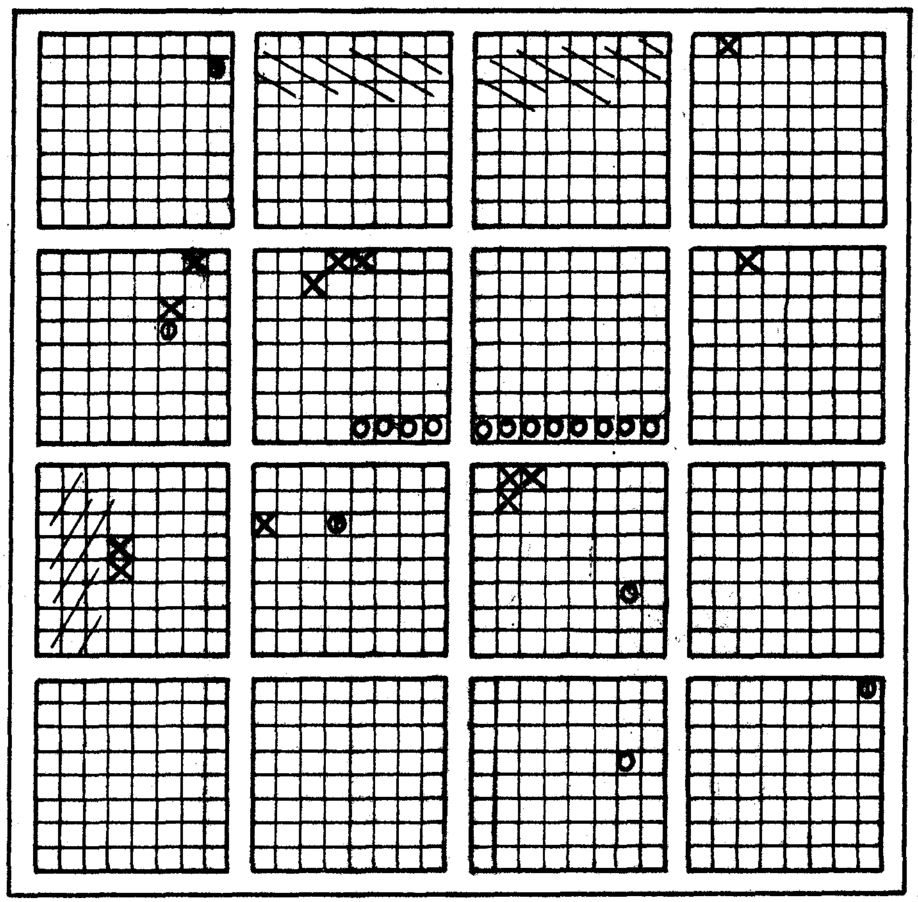
7. TEST RESULTS DISCUSSION

7.1 SUMMARY OF RESULTS

A summary of the test is shown as Table 7-1. No film failures occurred during testing of Article No. 3, which has the mesh support and soft mounts. The film without the grid mesh support, Articles No. 1 and No. 2, could not withstand the random vibration levels used for this test. When the film frame was hard mounted, the supported films (Article No. 4) withstood the 0.08 g^2/Hz Max. PSD random vibration, but 1 percent of the film windows failed at the highest level tested, 0.10 g^2/Hz Max. PSD. The effectiveness of the urethane foam mounts was proved when the supported films thus mounted, Article No. 3, withstood even the 0.1 g^2/Hz peak random vibration. As shown by the strain gage output, the highest hard mounted frame transmissibility (at 420 Hz) was 38.3, while the soft mounted frame transmissibility was 5.83 (at 185 Hz) -- a reduction by a factor of 6.6 or 16.4 db.

No appreciable change in film frame to grid frame separation distances was noted due to the soft mounts; i.e., the 2 lb/cu ft urethane foam has adequate memory characteristics after vibration.

FILM VIBRATION TEST 1-11-'71



LEGEND:

O : WINDOWS BROKEN BY HANDLING BEFORE START OF TEST
⦶ : WINDOWS BROKEN BY HANDLING DURING MOUNT CHANGE
⊖ : WINDOWS BROKEN BY HANDLING AFTER FIRST SINUSOIDAL
X : WINDOWS BROKEN DURING QUALIFICATION VIBRATION TEST
HASH MARKS INDICATE FILM WRINKLES DUB TO FRAME WARPING.

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Figure 6-8 Film Failures - Articles No. 3 and No. 4

VIBRATION LEVELS

TEST ITEM:	LEAM #3	FRAME PART NO. 2347037-3		
TEST DATE:	11 JAN 71	SOFT MOUNT	INPUT:	1 G INPUT
		1 G RUN	RESPONSE AXIS:	VERT.

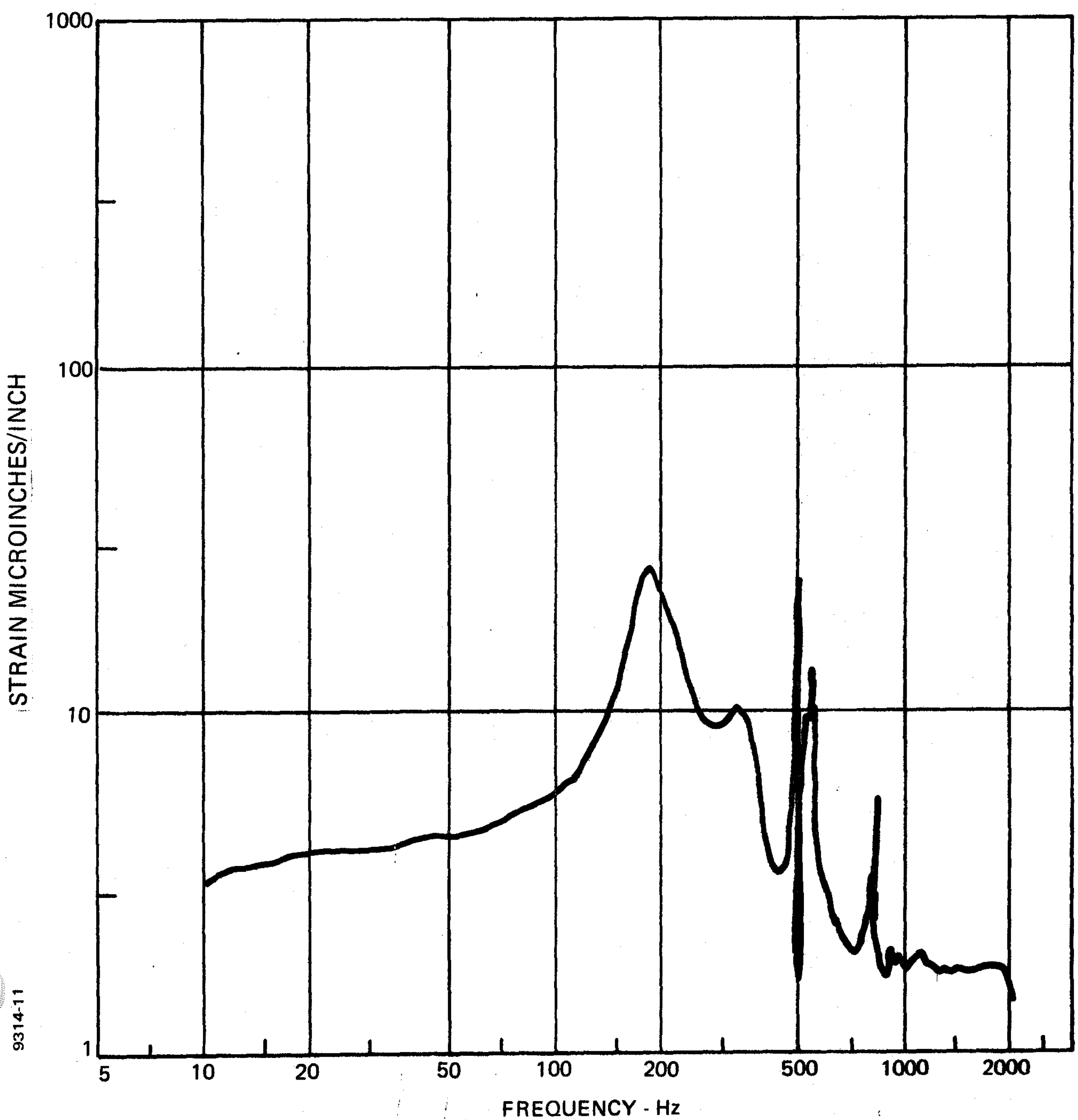
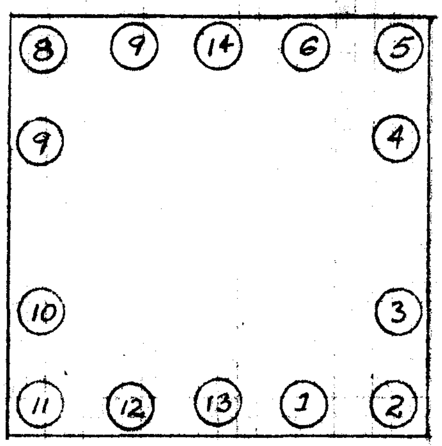
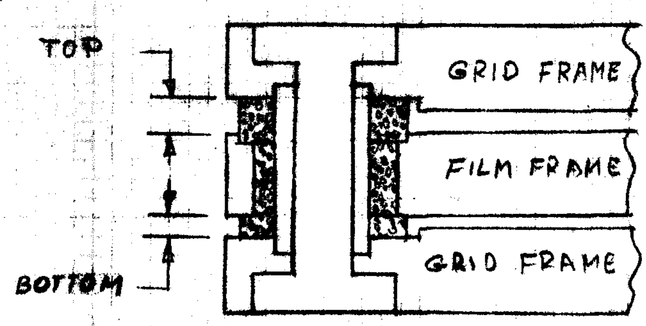


TABLE 6-1 SOFT MOUNT MEMORY MEASUREMENTS
Article #3





SOFT MOUNTED

	* Before Vibration			* After Vibration		
Pt#	Top	Bottom	Sum	Top	Bottom	Sum
2	.115	.089	.204	.106	.086	.192
5	.108	.078	.186	.103	.093	.196
8	.101	.100	.201	.101	.086	.197
11	.103	.098	.201	.108	.095	.203
13	.110	.058	.168	.105	.060	.165
14	.105	.065	.170	.094	.055	.149

RIGID MOUNTED

Pt#	Top	Bottom	Sum	Pt#	Top	Bottom	Sum
1	.098	.065	.163	7	.098	.060	.158
2	.132	.070	.202	8	.133	.078	.211
3	.097	.036	.133	9	.097	.035	.132
4	.099	.034	.133	10	.098	.034	.132
5	.135	.071	.206	11	.139	.070	.209
6	.098	.065	.163	12	.098	.065	.163

*Sinusoidal 0-2000 Hz

TEST ITEM:	LEAM NO. 4	RIGID	SERIAL NUMBER:	
TEST DATE:	1-11-71	MOUNT	INPUT:	1 G INPUT
			RESPONSE AXIS:	VERT.

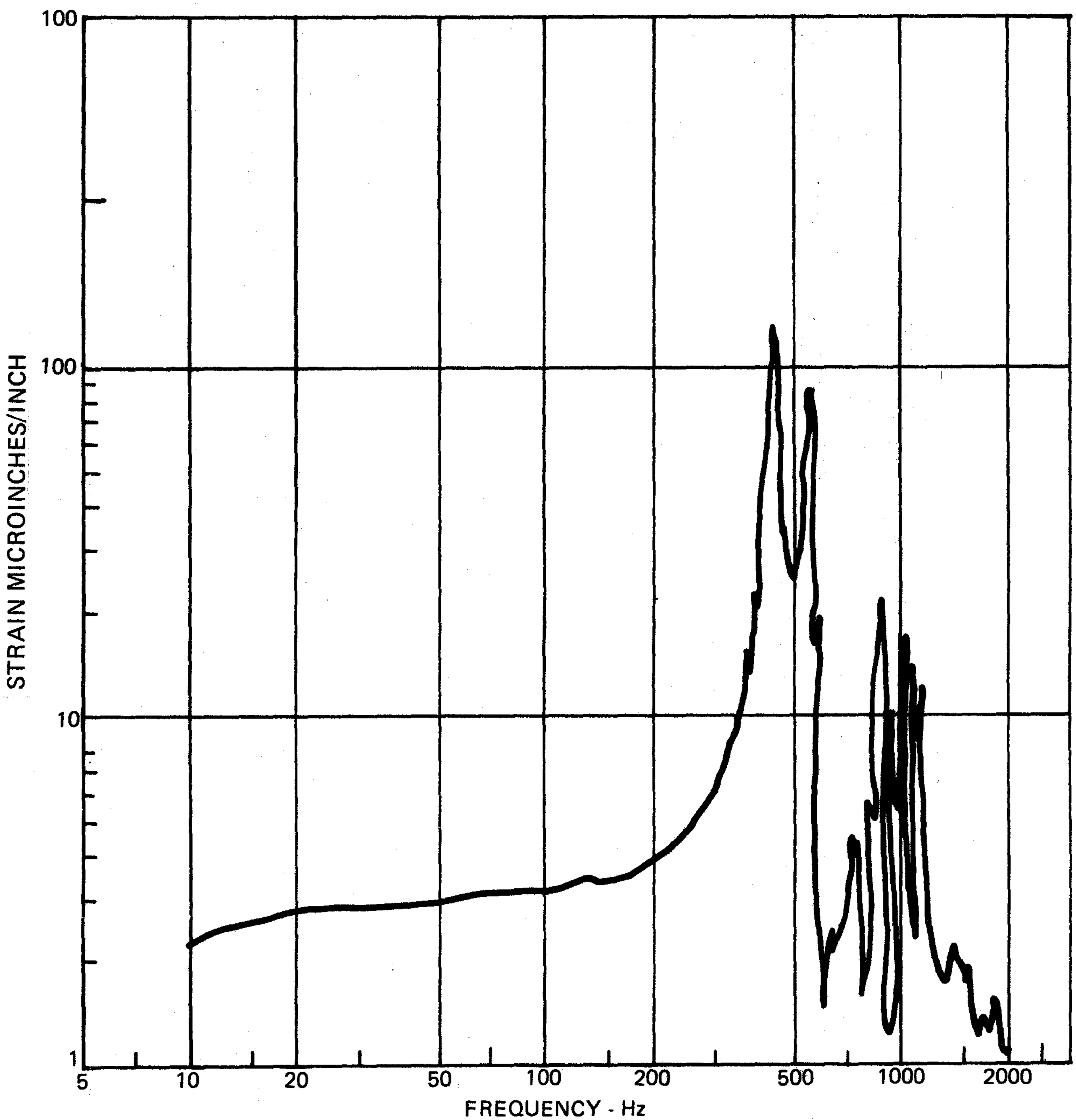


Figure 6-10 Strain Gage Output - Article No. 4

TABLE 7-1 TEST SUMMARY

Article	Support Mesh	Sinusoidal Sweep 5-100-5 Hz	Sinusoidal Sweep 0-2000 Hz	Random According to Fig 6-2	Random According to Fig 6.3 (Curve AG)	Random According to Fig 6.3 (Curve AH)	Type of Film Frame Mount
1	No	Yes	Yes	Yes	Yes	Yes	Rigid
Window Failures		None	None	6	None	1	
2	No	Yes	Yes	Yes	Yes	Yes	Soft-Molded Foam
Window Failures		None	None	2	None	5	
3	Yes	Yes	Yes	Yes	No	Yes	Soft-Fabricated Foam
Window Failures		None	None	None		None	
4	Yes	Yes	Yes	Yes	No	Yes	Rigid
Window Failures		None	None	None		13	

7.2 SELECTION OF LEVELS

Design limit vibration levels at the LEAM/ALSEP interface points are those listed in Reference 2 (ATM 964). However, since the LEAM transmissibilities are not yet defined and also since one of the purposes of this test is to define film failure levels, higher levels with broader frequency distribution (see Section 6.1) were chosen for this test.

7.3 FILM SUPPORT MESH

The film support mesh was shown to be beneficial in two ways:

1. It increased the natural frequency of the individual film panels, moving it away from the high PSD frequencies.

2. It increased the film's load carrying capacity. It is believed the film failures resulted from air loads; and since the film strength is a function of peripheral length while the air load is a function of film's area, the decrease in film window size increased the film's load carrying capacity.

7.4 FLEXIBLE FILM FRAME MOUNTS

As the strain gage outputs of the two soft mounted tests show, the molded foam used in Article No. 2 acted mainly as a spring, with little damping; whereas the fabricated foam used in Article No. 3 acted as both a spring and a damper. Examination of the two varieties of foam suggests that the difference was due to density and uniformity.

The molded mounts were cast at Bendix and had the appearance of bread, i.e., various sizes of closed air bubbles surrounded by rather thick walls and a heavier skin at the surface. The fabricated mounts were made out of a large, commercially cast, bun which was first slit into flat stock. This foam had the appearance of soap foam, i.e., uniform lattice with thin walls. Many of the walls are apparently broken, allowing throttled air flow - the property which probably effects damping - more than the hysteresis of the urethane. Moreover, although the two varieties of foam were ostensibly of the same density, the molded foam was obviously more dense than the fabricated one.

Film frame separation distances from the grid frames in the three-frame sandwich assembly were measured before and after vibration to determine whether vibration will dislocate the front film frame with respect to the support structure, thus changing the distance between front and rear films. These measurements are recorded in Table 6-1. The differences are on the same order as the accuracy of measurement, and show that the foam has adequate memory, i.e., little permanent set.

It should be noted that with constant film separation (the parameter which determines particle velocity), as much as 12 percent velocity error can be introduced by trajectory angle within the angular resolution of the sensor - a considerably larger error than the possible separation change can contribute.

7.5 FILM FAILURES

While most of the unsupported windows failed at the start of the causal vibration, the failures of the mesh-supported windows were randomly distributed in both time and location within the frame. This can be credited either to fatigue or the long period acceleration peaks that result from summation of random vibration frequency components. However, since failures did not consistently coincide with points of prestress as indicated by film wrinkles, fatigue is not likely.

The stress wrinkles appeared when the film frame was assembled with the rigid mounts (prior to mounting it on the test fixture). These wrinkles suggest that either the frame was warped at installation of the film strips or it was warped in the assembly. No ill effects, however, were observed due to the warpage.

8. CONCLUSIONS AND RECOMMENDATIONS

1. A support mesh is required to support the 1 x 1 film "windows" in order to withstand design limit random vibrations. Grid P/N 2347935 will suffice.

2. Isolators will be used to mount the film frame in the sensor assembly. Polyester flexible urethane foam mounts designed to the following specifications are adequate:

a. 2 lb/cu ft density

b. 60 P.P.I. pore density

d. Closed Cell (as foamed)

d. Fabricated from a large bun for uniformity

e. 3.1-sq in. total support area (1.55 sq in. each side)

f. 35 percent nominal initial compression.

9. REFERENCES

1. TL 9712-56, "Array E Subpack 1 Subsystem Dynamic Environment", J. Maszatics, 15 October 1970.

2. ATM-964, " ALSEP Array E Component, Non-Operating Vibration Specifications, " J. Maszatics, 2 February 1971.