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ANALYSIS OF STS-3 GET AWAY SPECIAL (GAS) FLIGHT DATA AND VIBRATION SPECIFICATION FOR GAS PAYLOADS

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MARCH 1983

National Aeronautics and
Space Administration

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ILLUSTRATIONS

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TABLE

1. INTRODUCTION

During the Space Transportation System (STS)-3 mission, a Get Away Special (GAS) canister was flown. In order to determine the flight environment for GAS payloads, triaxial accelerometers and a microphone were installed inside the GAS canister. Data from these accelerometers and the microphone were analyzed and are provided in this report.

Also based on this flight data, vibration test specification for GAS payloads was developed and the recommended specification is presented here.

2. DATA ANALYSIS

The data used in this report were obtained from a microphone and accelerometers installed on the GAS canister in the STS-3 mission. The canister was located in bay 12 on the starboard side. The accelerometers were mounted on the top plate of the canister (Figure 1). The microphone was mounted inside the canister.

The GAS instrumentation recording system was designed to be turned on by an acoustic switch at the Space Shuttle Main Engine (SSME) ignition. It was turned on as designed, but the tape recorder signal conditioners did not stabilize until 2.5 seconds after Solid Rocket Booster (SRB) ignition.[1] This was established by identifying SRB separation on the GAS microphone channel (133.2 seconds GAS time) and relating this same event to Dynamic Acoustic and Thermal Environments (DATE) time of 127.5 seconds from SRB ignition (T = o). The internal GAS time was 5.7 seconds at SRB ignition and since SSME took place 5 seconds before SRB ignition, it was concluded that the GAS tape recorder system was turned on at SSME ignition. Useful data were not available until GAS time of about 8.2 seconds. GAS data were not collected at STS-3 landing.

2.1 MICROPHONE DATA

Data obtained from the microphone installed on the GAS canister were viewed on oscillographs for event identification and overall quality. As mentioned earlier, useful data were obtained from only 2.5 seconds after SRB ignition. The data were analyzed for three significant periods of flight, and one period to assess background noise. These periods are similar to those used in the DATE data analysis.[2] They are: $T_{+2.5}$ to T_{+12} including post-SRB ignition, liftoff, and a few seconds following liftoff; T_{+30} to T_{+55} including transonic noise; T_{+60} to T_{+84} period following transonic; and T_{+120} for background noise.

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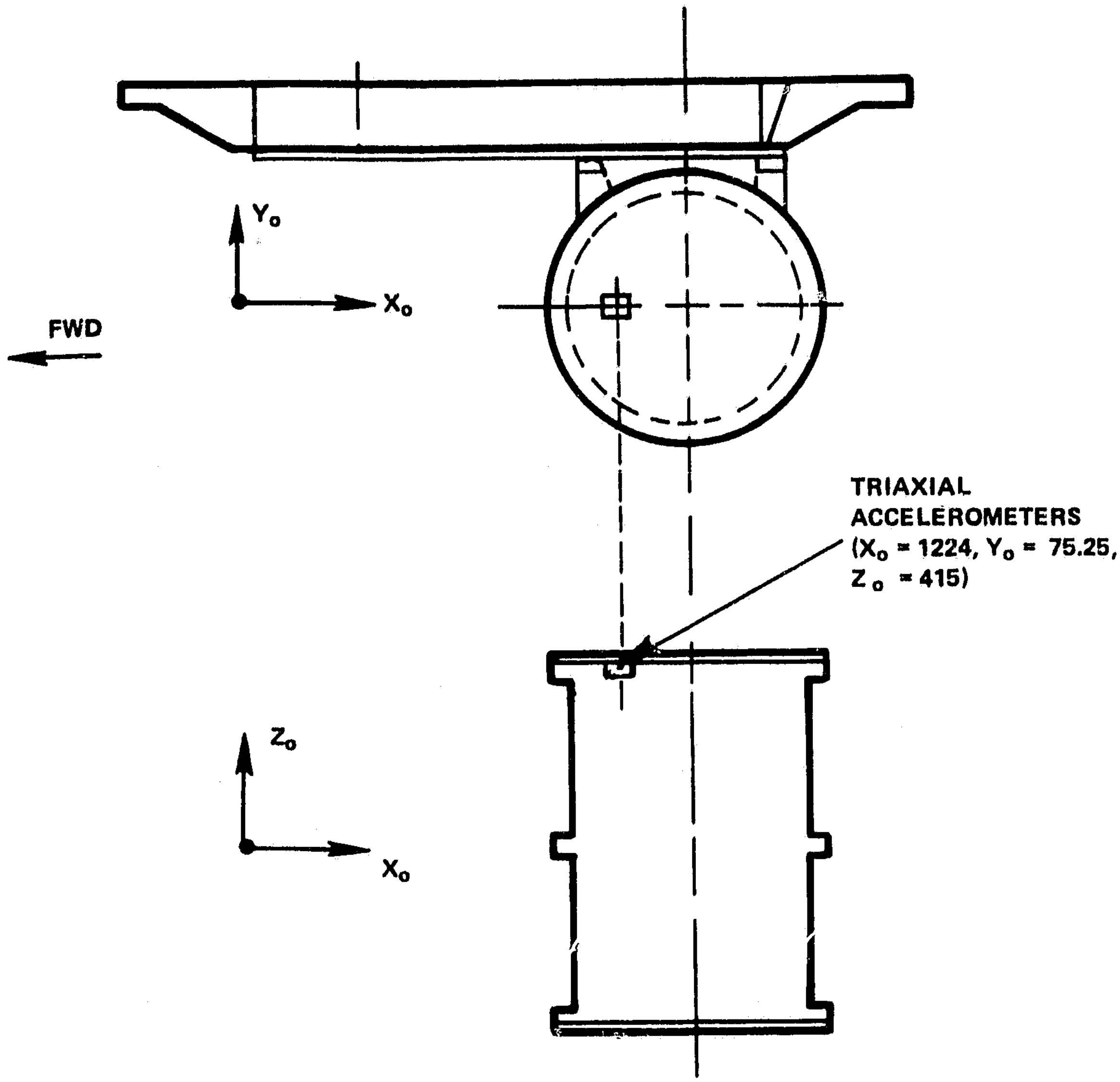

Figure 1. Location of Accelerometers on GAS Canister for STS-3 Flight, Bay 12

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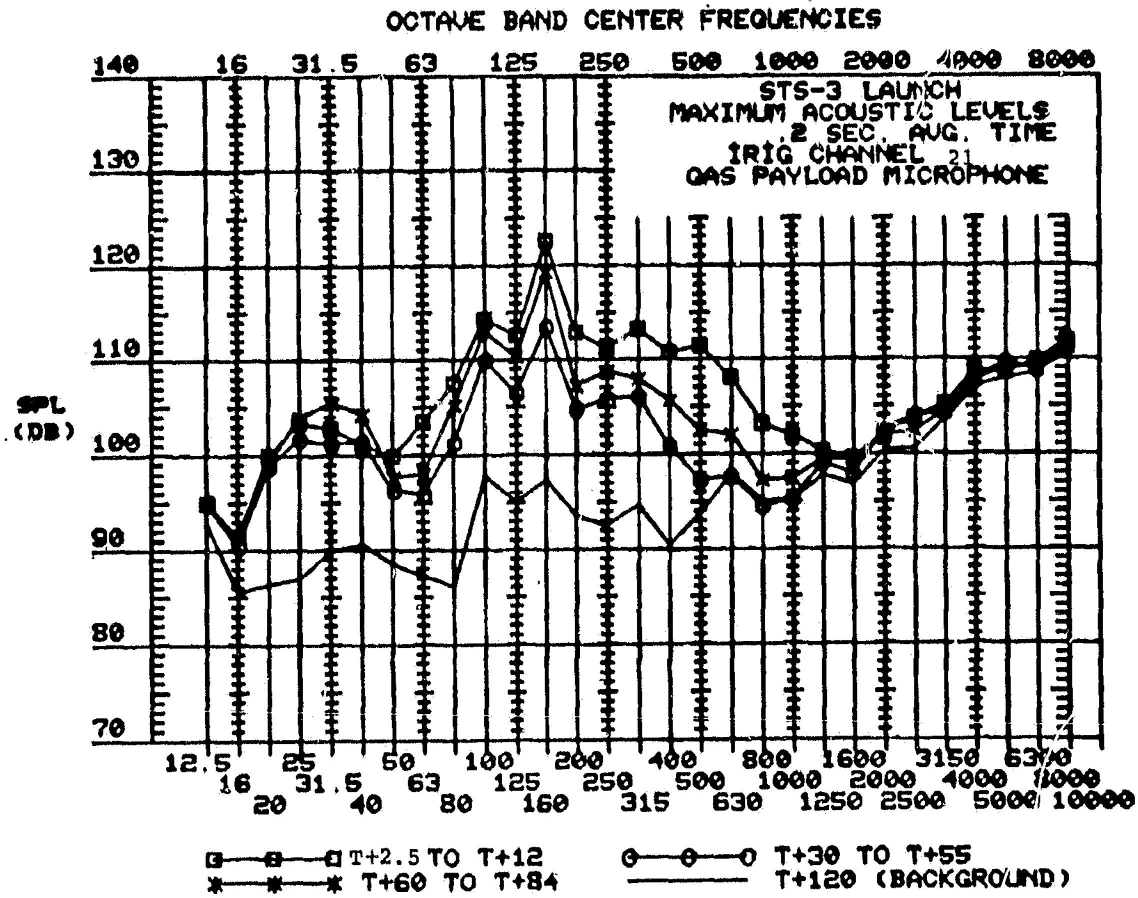

Figure 2. One-Third Octave Band SPL Plot

The microphone data were analyzed using an analog system. The one-third octave band plots for these periods are shown in Figure 2. The values plotted at each frequency represent the maximum observed for the considered interval. These data are also shown in Table 1. Time history plots for overall Sound Pressure Level (SPL) for frequency range 5 Hz to 8 kHz and 11 Hz to 8 kHz are shown in Figures 3 and 4, respectively. Time history plots for several individual octave bands are shown in Figures 5 through 11. For all three significant time periods shown in these figures, maximum SPL occurs at 160-Hz center frequency band (Figures 2 and 8).

In order to ascertain attenuation of sound by the GAS canister, the response of a Development Flight Instrumentation (DFI) microphone (V08Y9403A, location X_o = 1306, Y_o = 12, Z_o = 400) nearest to the GAS canister was examined. The time history plot of overall SPL for this microphone is shown in Figure 12. This figure shows that the post-SRB SPL for this microphone is about

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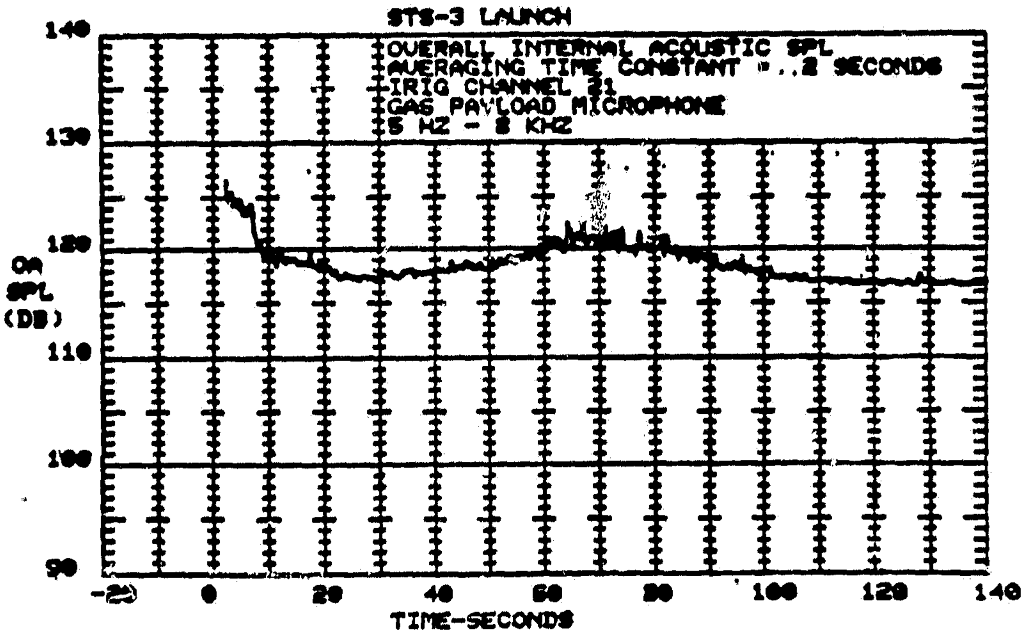
Table 1
One-Third Octave Band SPL

STS-3 LAUNCH MAXIMUM ACOUSTIC LEVELS 0.2 SEC. AVG. TIME
IRIG CHANNEL 21 GAS PAYLOAD MICROPHONE

FREQUENCY	T+2.5 TO T+12	T+30 TO T+55	T+60 TO T+84	T+120 (BLKGRD)
5-8000 HZ	126.7	119.3	122.6	116.8
11-8000HZ	126.3	119.3	122.6	116.6
12.5	95.0	95.0	95.1	92.7
16.	91.5	90.6	91.3	85.6
20.	100.	98.9	99.3	86.4
25.	103.4	101.7	104.	87.0
31.5	102.9	101.3	105.5	89.9
40.	101.1	101.5	104.4	90.6
50	100.	96.4	97.7	88.5
63	103.6	96.0	98.1	87.3
80	107.5	101.4	105.3	86.1
100	114.4	110.	113.	97.8
125	112.6	106.5	110.4	95.2
160	122.6	113.6	119.5	97.4
200	112.9	104.8	107.3	93.6
250	111.3	105.9	108.8	92.6
315	113.3	106.2	108.1	94.8
400	110.7	100.9	105.8	90.6
500	111.6	97.4	102.6	93.8
630	108.1	97.8	102.1	98.0
800	103.3	94.6	97.3	95.1
1000	102.	95.4	97.5	95.2
1250.	100.4	99.2	99.5	97.9
1600.	99.6	98.0	99.6	96.9
2000.	102.2	102.6	102.	100.4
2500.	103.9	104.	102.5	100.7
3150.	105.2	104.6	104.5	103.7
4000.	108.9	107.8	107.8	107.2
5000.	108.6	109.8	109.1	108.1
6300.	109.9	108.8	109.2	108.6
8000.	112.	111.6	111.2	110.8

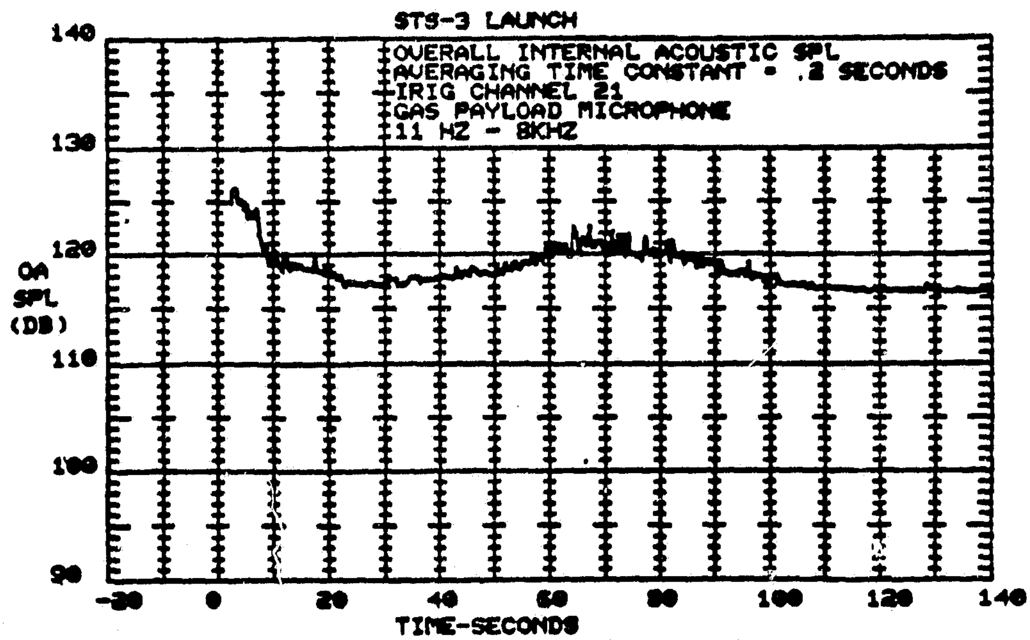
SUM OF SPL AT T+120 = 116.1



IRIG CHANNEL 21 21.
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR LIN-LIN (5 HZ-8000HZ)

T+2.5 TO T+12 =	126.7 DB	T+30 TO T+55 =	119.3 DB
T+60 TO T+84 =	122.6 DB	T+120 (BKGRD) =	116.8 DB

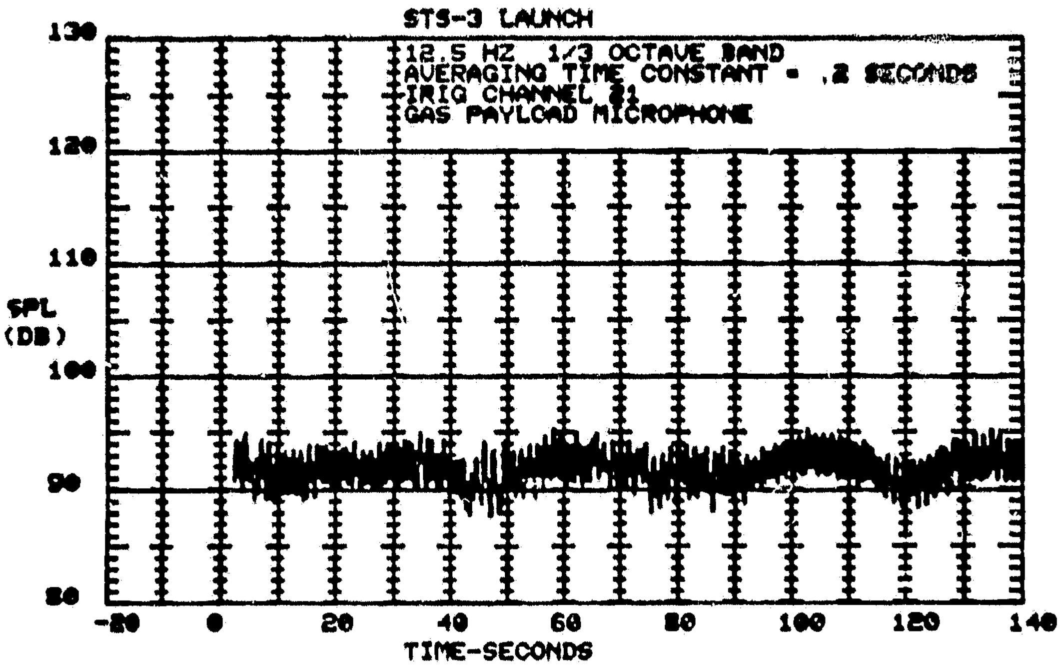
Figure 3. Overall SPL Time History (5 Hz to 8 kHz)



IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR LIN-LIN (11 HZ-8000HZ)

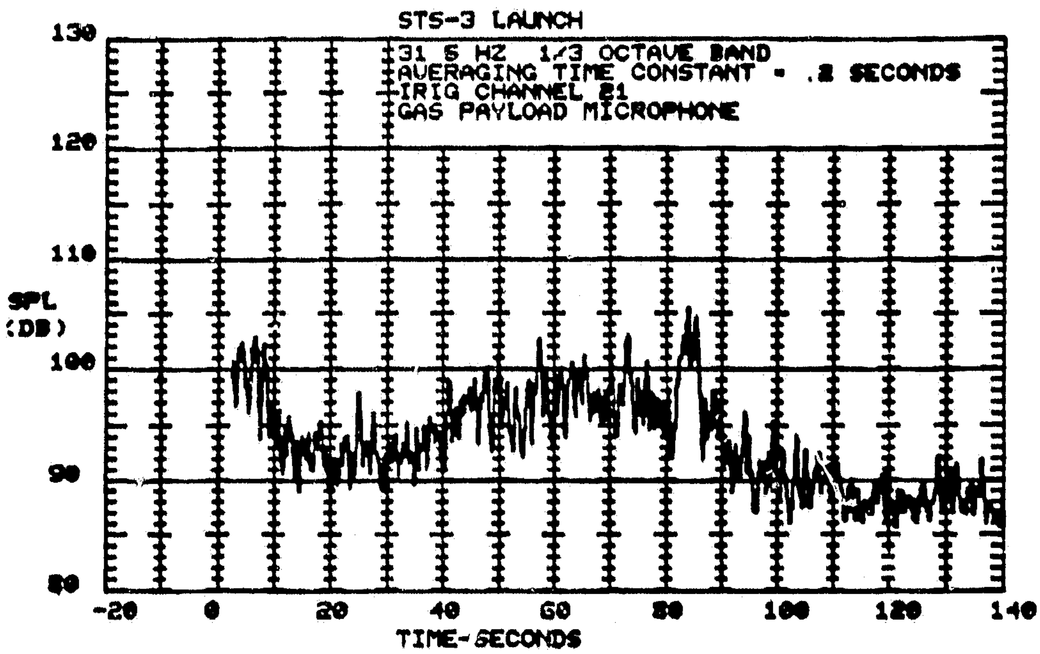
T+2.5 TO T+12 =	126.3 DB	T+30 TO T+55 =	119.3 DB
T+60 TO T+84 =	122.6 DB	T+120 (BKGRD) =	116.6 DB

Figure 4. Overall SPL Time History (11 Hz to 8 kHz)



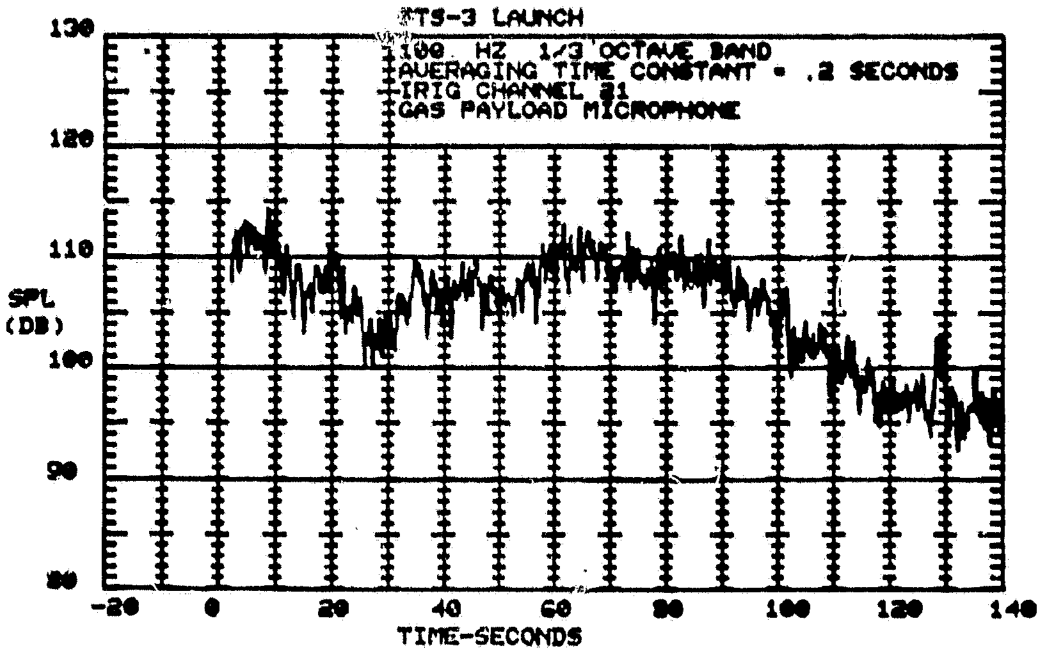
IRIG CHANNEL 21 21.
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 12.5 HZ CENTER FREQUENCY
T+2.5 TO T+12 = 95.0 DB T+30 TO T+55 = 95.0 DB
T+60 TO T+84 = 95.1 DB T+120 (BKGRD) = 92.7 DB

Figure 5. 12.5-Hz One-Third Octave Band Plot



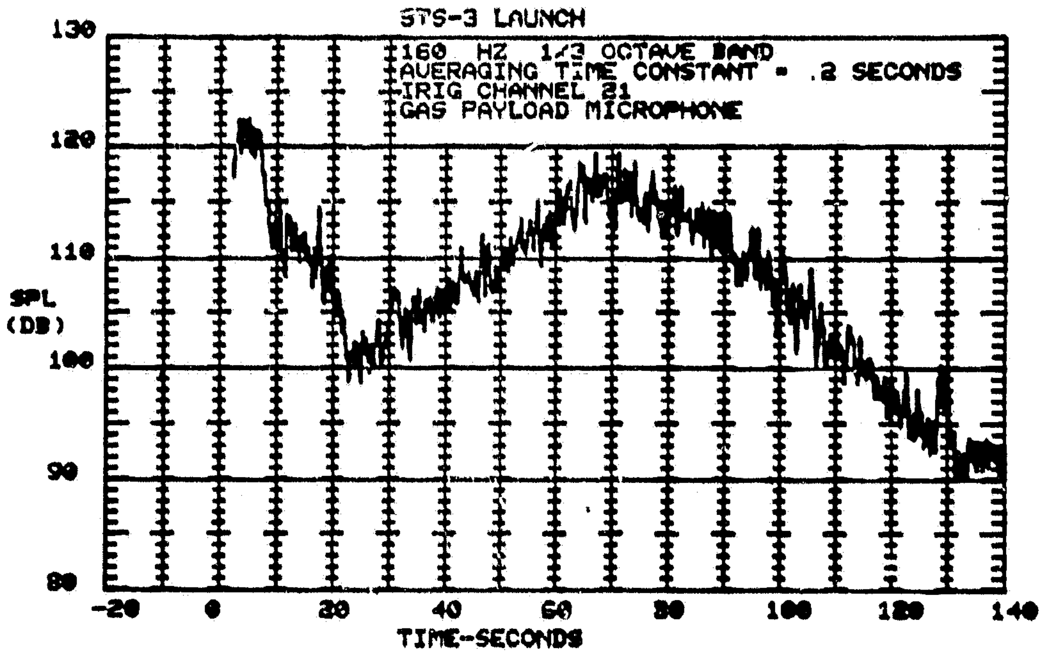
IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 31.5 HZ CENTER FREQUENCY
T+2.5 TO T+12 = 102.9 DB T+30 TO T+55 = 101.3 DB
T+60 TO T+84 = 105.5 DB T+120 (BKGRD) = 89.9 DB

Figure 6. 31.5-Hz One-Third Octave Band Plot



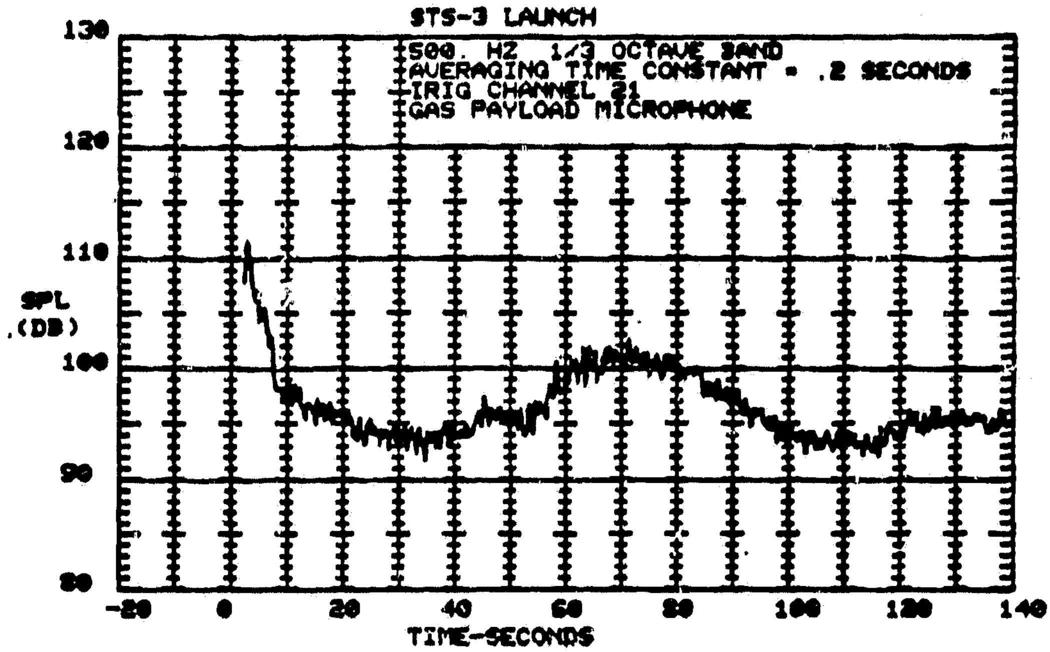
IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
T+2.5 SPL (DB) FOR 100. HZ CENTER FREQUENCY
T=6 TO T+12 = 114.4 DB T+30 TO T+55 = 110. DB
T+60 TO T+84 = 113. DB T+120 (BKGRD) = 97.8 DB

Figure 7. 100-Hz One-Third Octave Band Plot



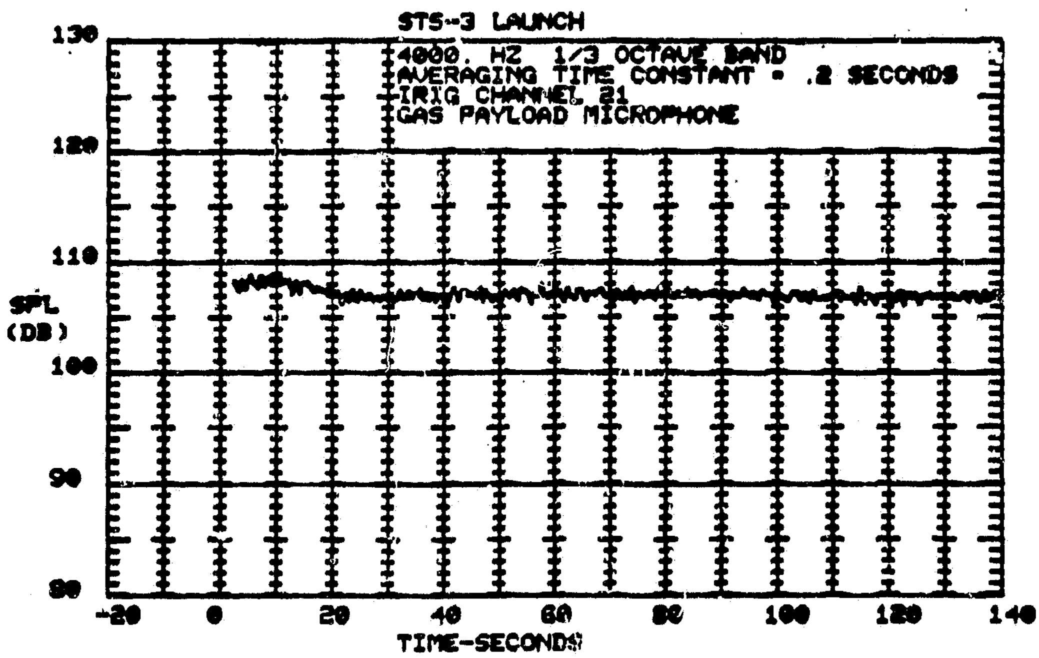
IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 160. HZ CENTER FREQUENCY
T+2.5 TO T+12 = 122.6 DB T+30 TO T+55 = 113.8 DB
T+60 TO T+84 = 119.5 DB T+120 (BKGRD) = 97.4 DB

Figure 8. 160-Hz One-Third Octave Band Plot



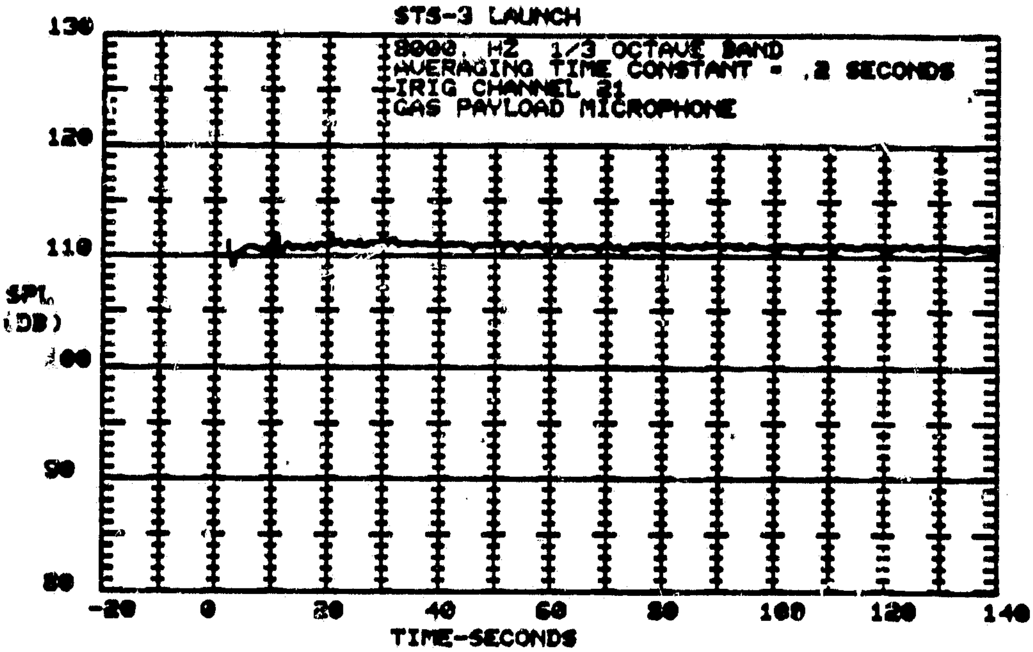
IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 500. HZ CENTER FREQUENCY
T+2.5 TO T+12 = 111.0 DB T+30 TO T+55 = 97.4 DB
T+60 TO T+84 = 102.0 DB T+120 (BKGRD) = 93.8 DB

Figure 9. 500-Hz One-Third Octave Band Plot



IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 4000. HZ CENTER FREQUENCY
T+2.5 TO T+12 = 108.9 DB T+30 TO T+55 = 107.3 DB
T+60 TO T+84 = 107.2 DB T+120 (BKGRD) = 107.2 DB

Figure 10. 4000-Hz One-Third Octave Band Plot



IRIG CHANNEL 21 21
GAS PAYLOAD MICROPHONE
PEAK SPL (DB) FOR 8000. HZ CENTER FREQUENCY
T+2.5 TO T+12 = 112. DB T+30 TO T+55 = 111.6 DB
T+60 TO T+84 = 111.2 DB T+120 (BKGRD) = 110.8 DB

Figure 11. 8000-Hz One-Third Octave Band Plot

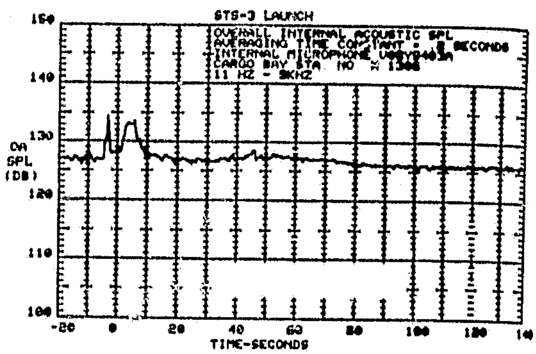


Figure 12. Overall SPL for Microphone V08Y9403A (DFI)[2]

133.5 dB in comparison to 126.3 dB (Figure 4) for the GAS microphone. Therefore, this shows that the GAS canister provides a significant amount of sound attenuation.

2.2 ACCELEROMETER DATA

The accelerometers installed on the GAS canister for STS-3 flight, have frequency response as shown in Figure 13. In order to retrieve the accelerometer data up to 2000 Hz, equalization of the data was required. This was achieved by passing the accelerometer data through a resistor and a capacitor (R-C) circuit having a frequency response as shown in Figure 14.

The circuit was verified using a random noise input signal (Figure 15). The input signal was first low pass filtered (Figure 16) to simulate the STS-3 GAS accelerometer frequency response. The signal was then passed through the equalization circuit and the equalized signal (Figure 17) was compared with the original signal (Figure 15). This shows that the equalization circuit brought the signal back, very close to its original state. (The details of this technique are given in reference 3.)

The disadvantage of passing the GAS accelerometer data through the equalization circuit is that the background noise between 1000 to 2000 Hz becomes amplified. The other limitation of the accelerometer data is due to the maximum obtainable frequency of the Inter-Range Instrumentation Group (IRIG) channels (Figure 18). The maximum intelligence frequency of the IRIG channels 18 (Z-axis), 19 (Y-axis), and 20 (X-axis) are 1050 Hz, 1395 Hz, and 1860 Hz, respectively. These maximum frequencies limit the usable frequency range of the GAS accelerometer data.

Equalized accelerometer data were analyzed to produce instantaneous time histories, rms time histories, and Power Spectral Density (PSD) plots. The instantaneous time histories and rms time histories are shown in Figures 19 through 21, and Figures 22 through 24, respectively. The instantaneous time histories show the peak g levels to be about 6, 8, and 3.5, for X-, Y-, and Z-axes, respectively. The PSD plots for X-, Y-, and Z-axes were obtained for four time periods, $T_{+2.5}$ to $T_{+7.5}$, T_{+58} to T_{+66}, T_{+77} to T_{+85}, and T_{+116} to T_{+124}. They are given in Figures 25 through 36. These time period selections were based on examination of the data on the oscillographs. The PSD plots show that for all three axes, the maximum overall grms occurs during the period following liftoff. SSME influence on the overall grms levels is not known because it is not included in the data.

3. VIBRATION SPECIFICATIONS FOR GAS PAYLOADS

The GAS canister for STS-3 flight was instrumented to obtain data

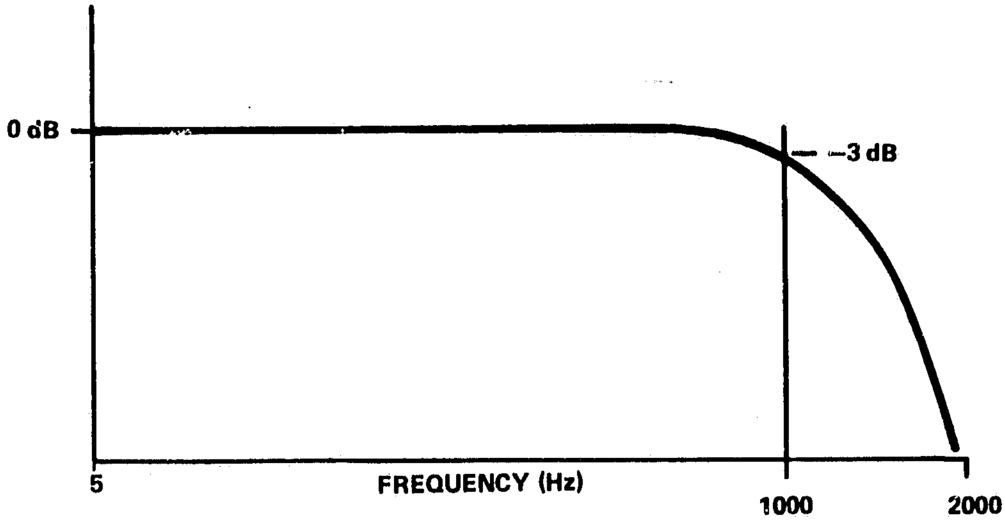


Figure 13. Frequency Response of GAS Accelerometers

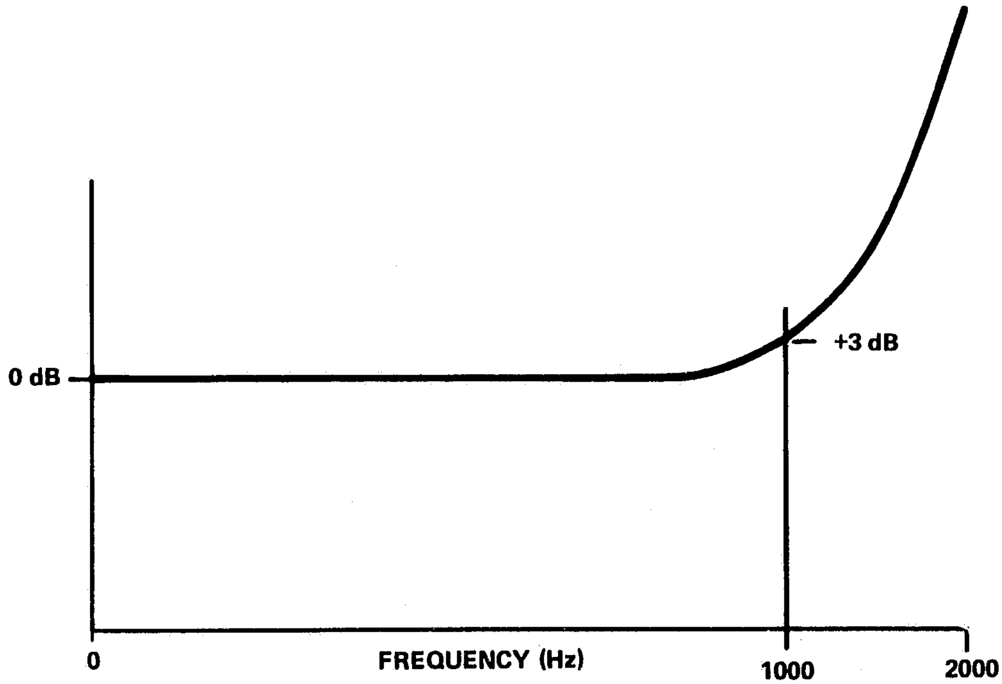


Figure 14. Frequency Response of Equalization Circuit

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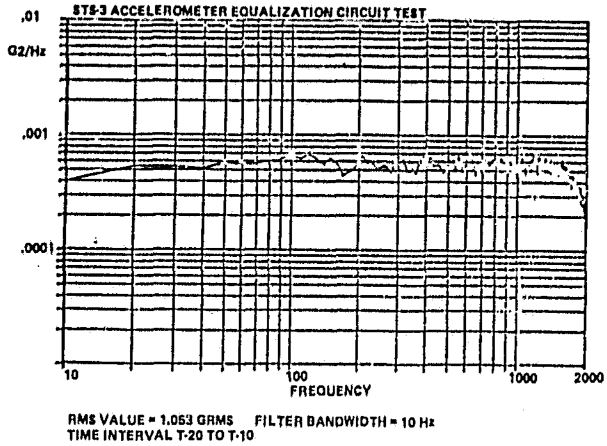

Figure 15. PSD of Random Noise Input Signal

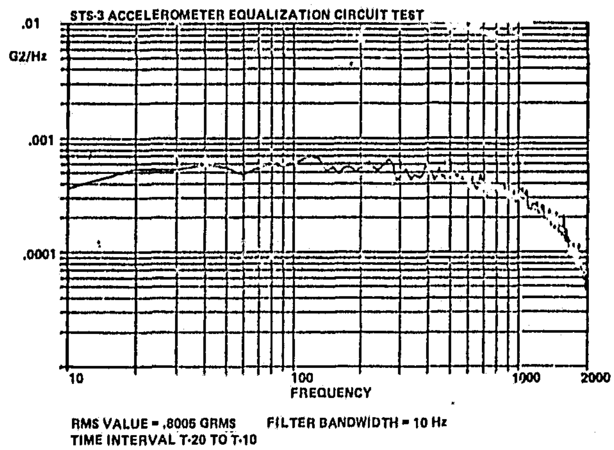

Figure 16. PSD of Filtered Input Signal

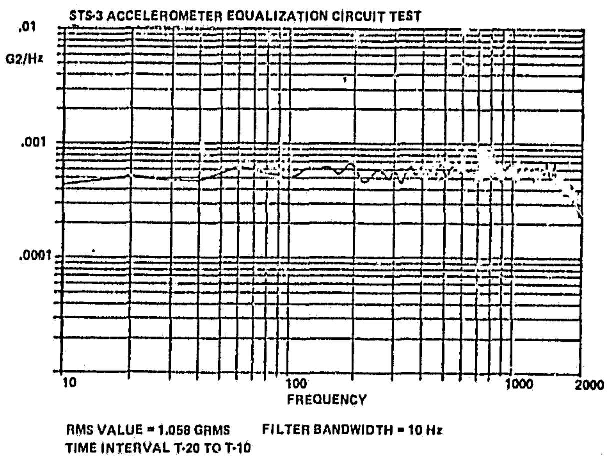

Figure 17. PSD of Equalized Signal

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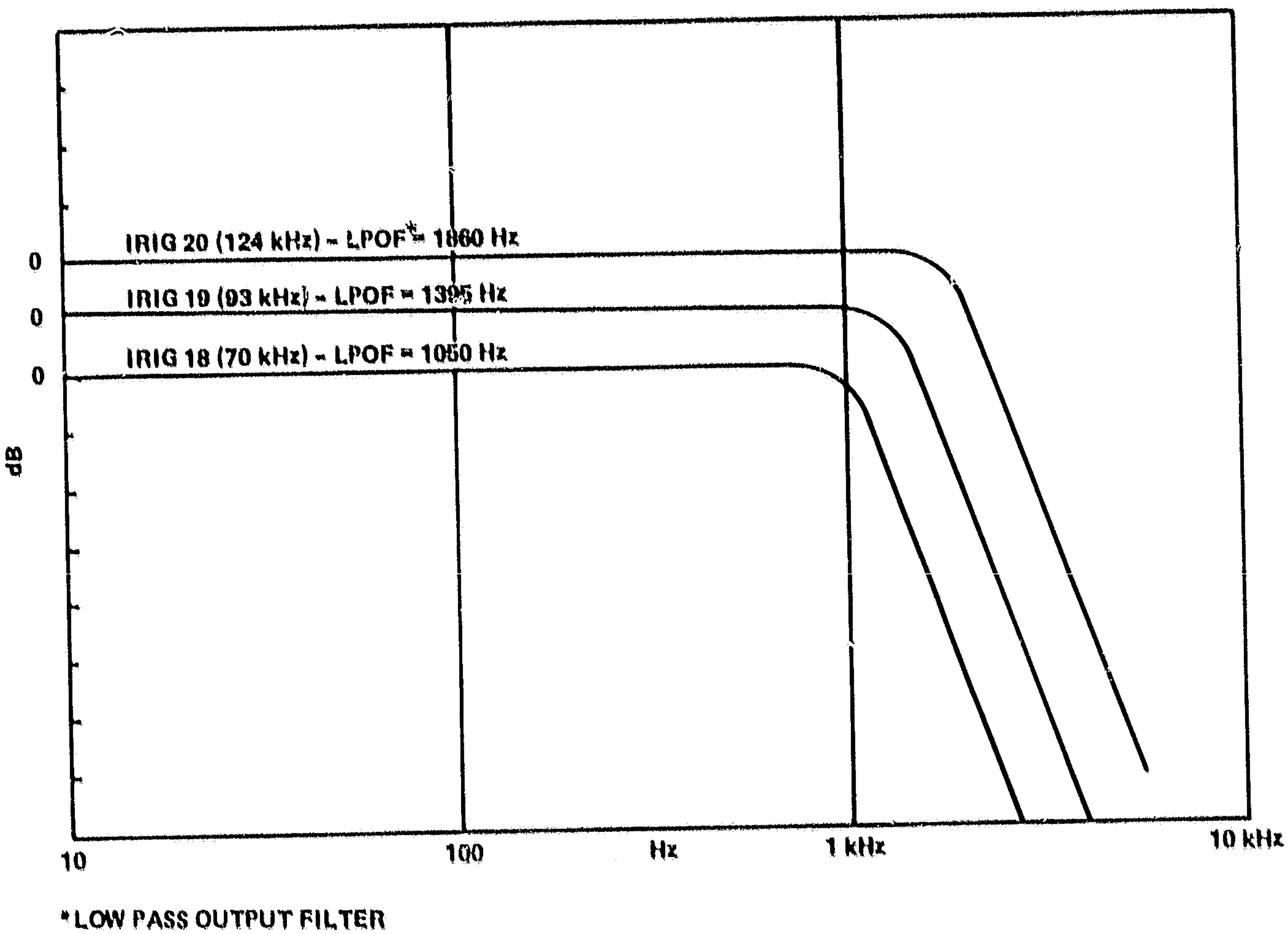

Figure 18. Frequency Response of IRIG Channels

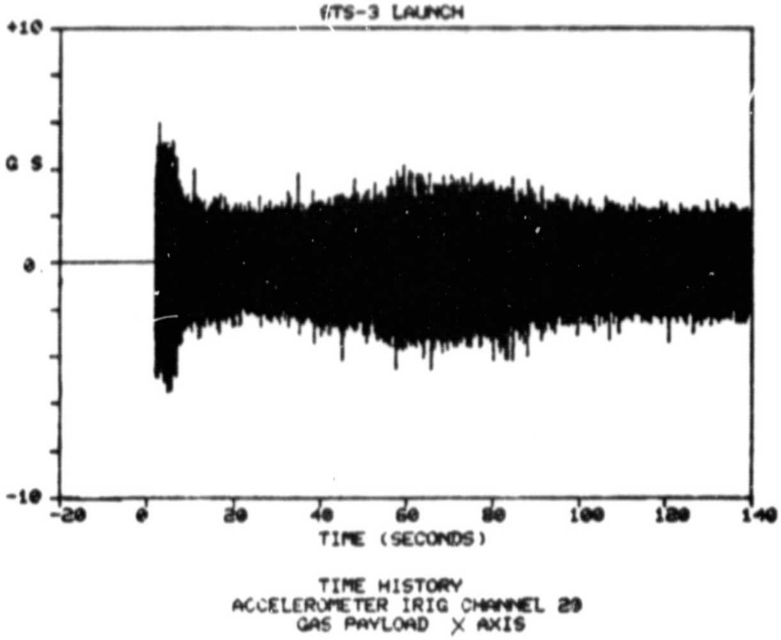

Figure 19. Instantaneous Time History (X-axis)

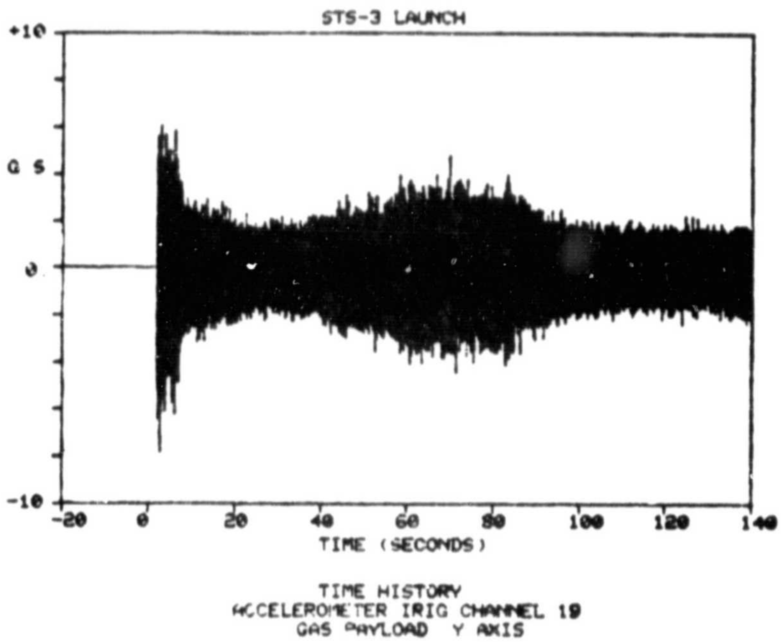

Figure 20. Instantaneous Time History (Y-axis)

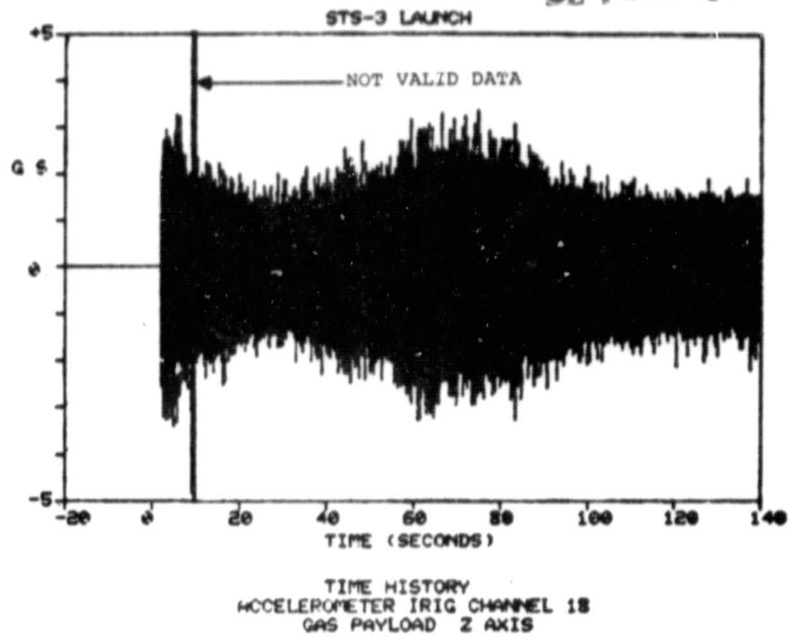

Figure 21. Instantaneous Time History (Z-axis)

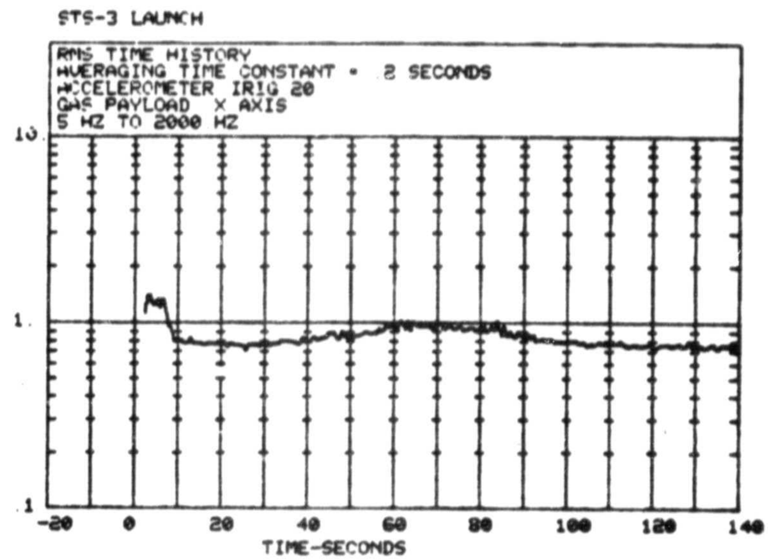

Figure 22. RMS Time History (X-axis)

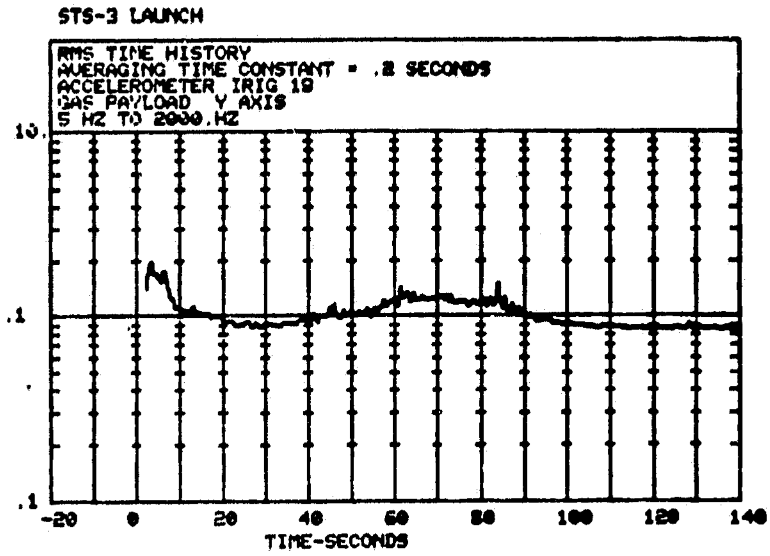

Figure 23. RMS Time History (Y-axis)

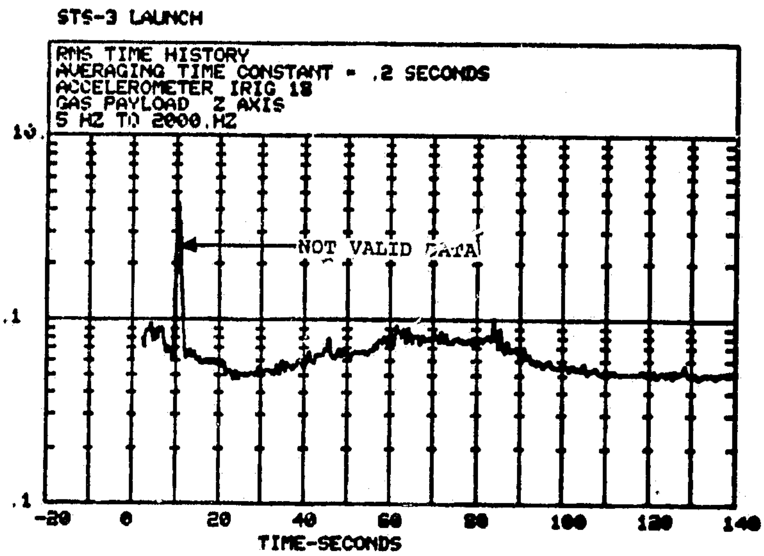

Figure 24. RMS Time History (Z-axis)

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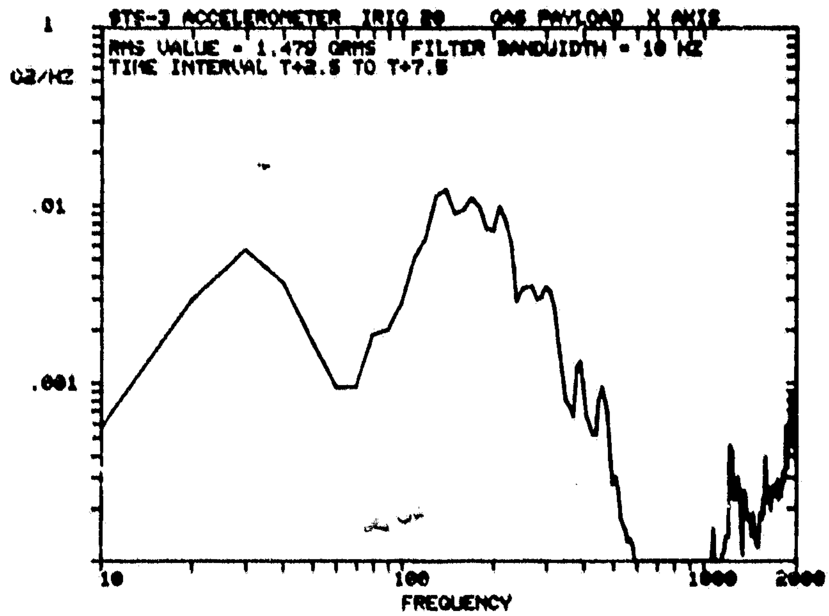

Figure 25. X-axis PSD ($T_{+2.5}$ to $T_{+7.5}$)

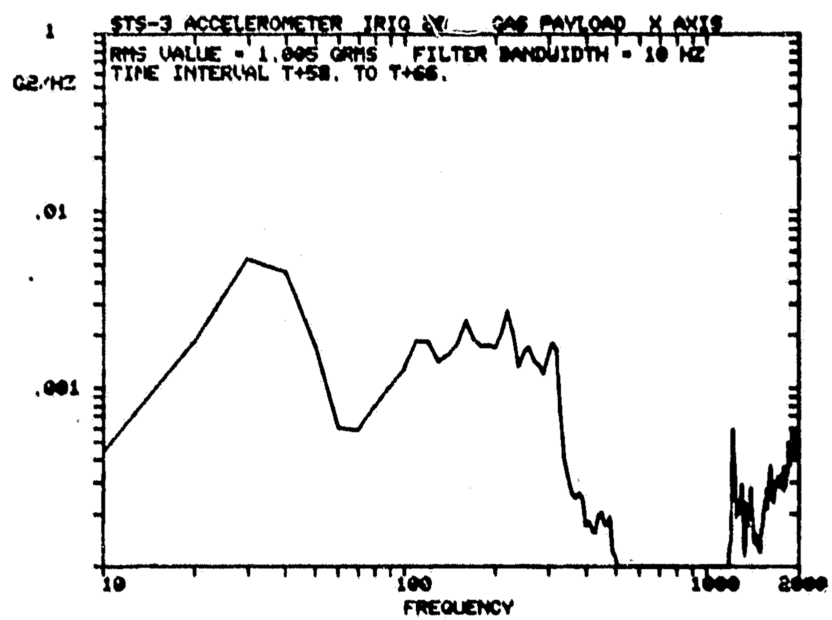

Figure 26. X-axis PSD (T_{+58} to T_{+66})

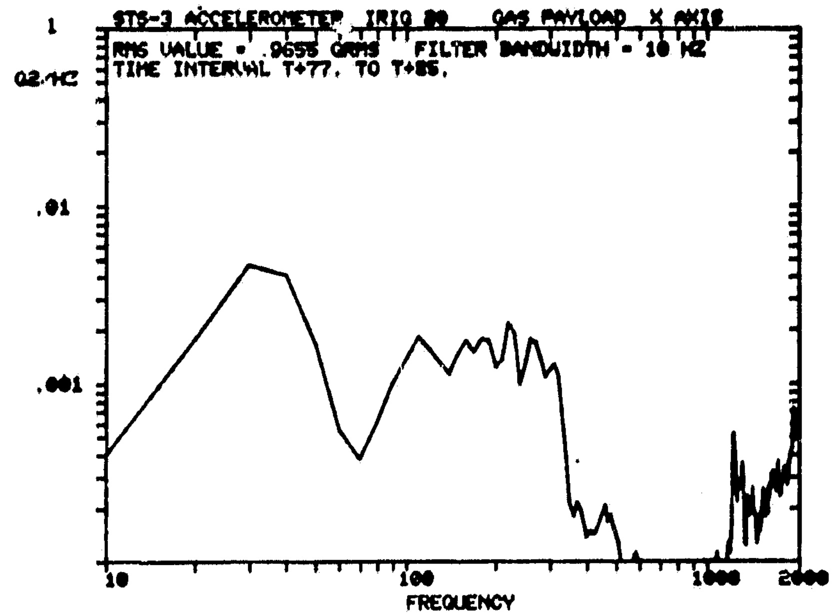

Figure 27. X-axis PSD (T_{+77} to T_{+85})

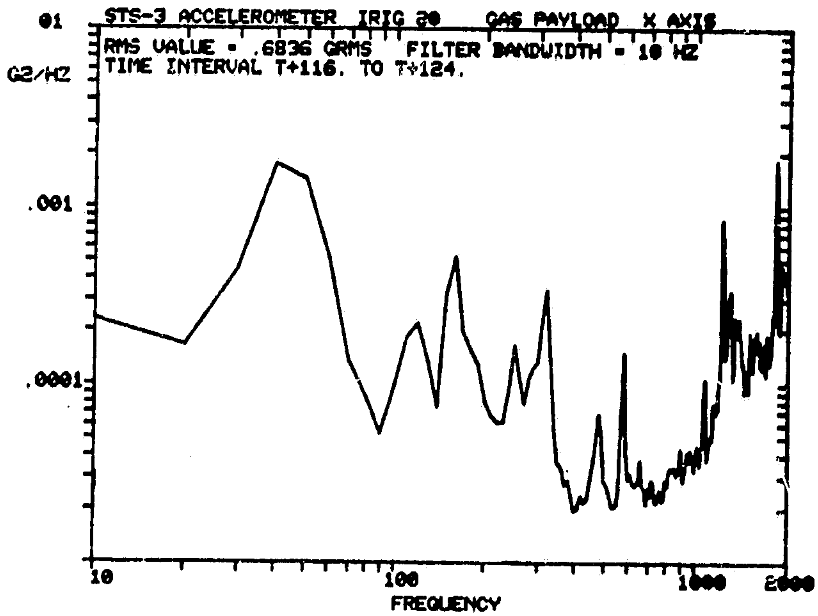

Figure 28. X-axis PSD (T_{+116} to T_{+124})

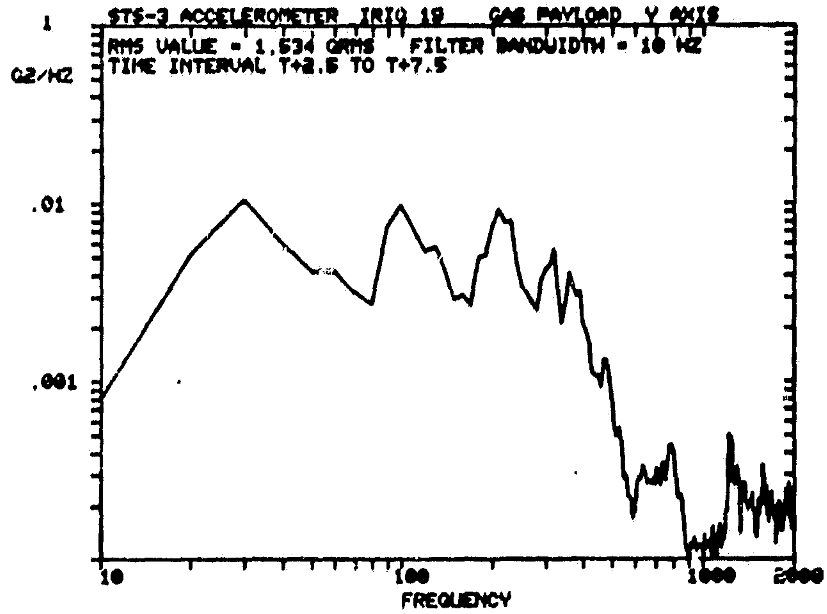

Figure 29. Y-axis PSD ($T_{+2.5}$ to $T_{+7.5}$)

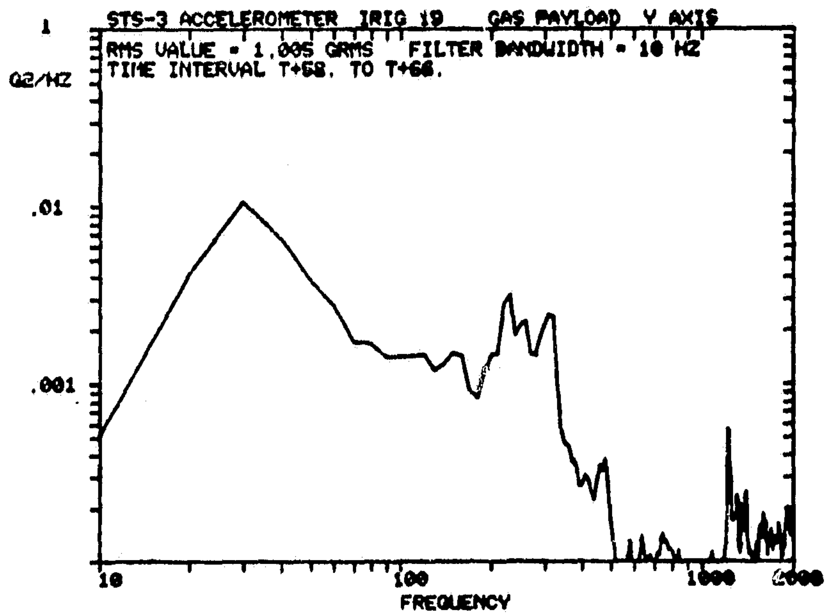

Figure 30. Y-axis PSD (T_{+58} to T_{+66})

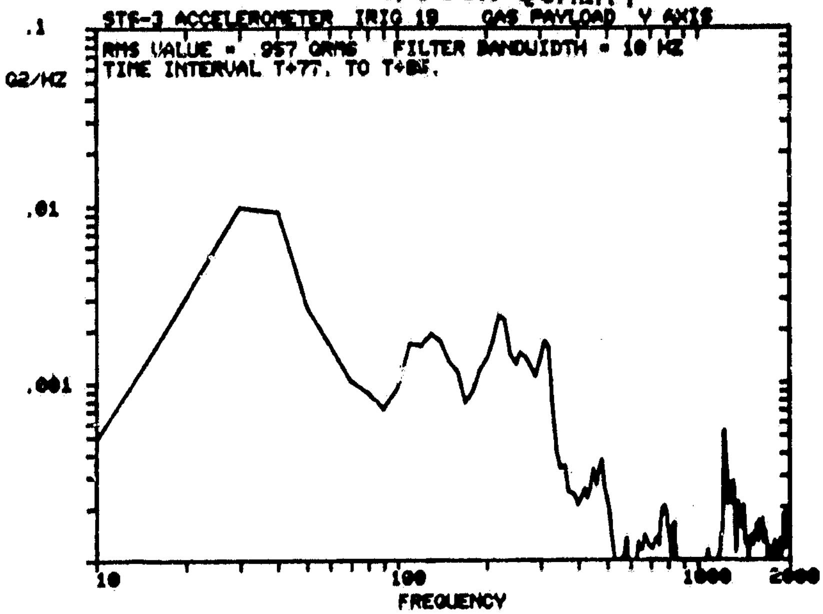

Figure 31. Y-axis PSD (T_{+77} to T_{+85})

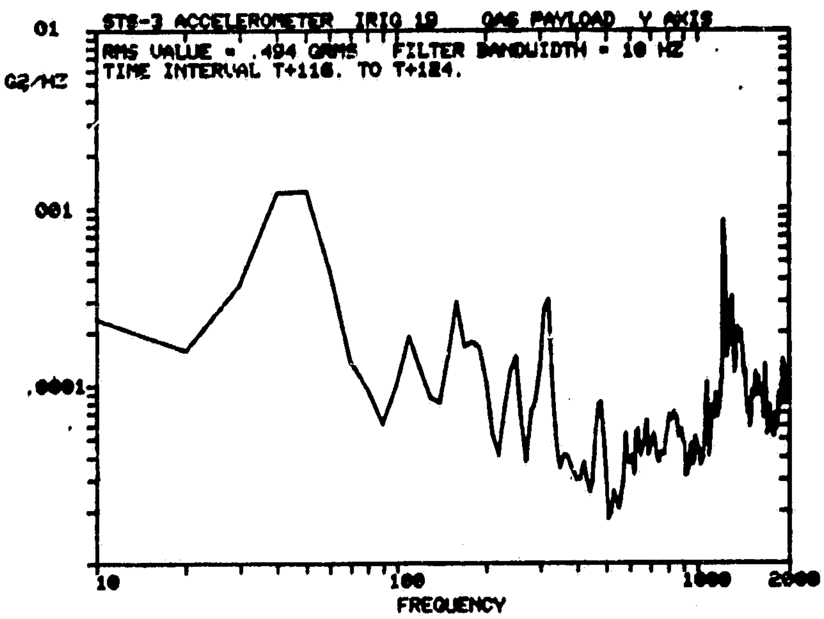

Figure 32. Y-axis PSD (T_{+116} to T_{+124})

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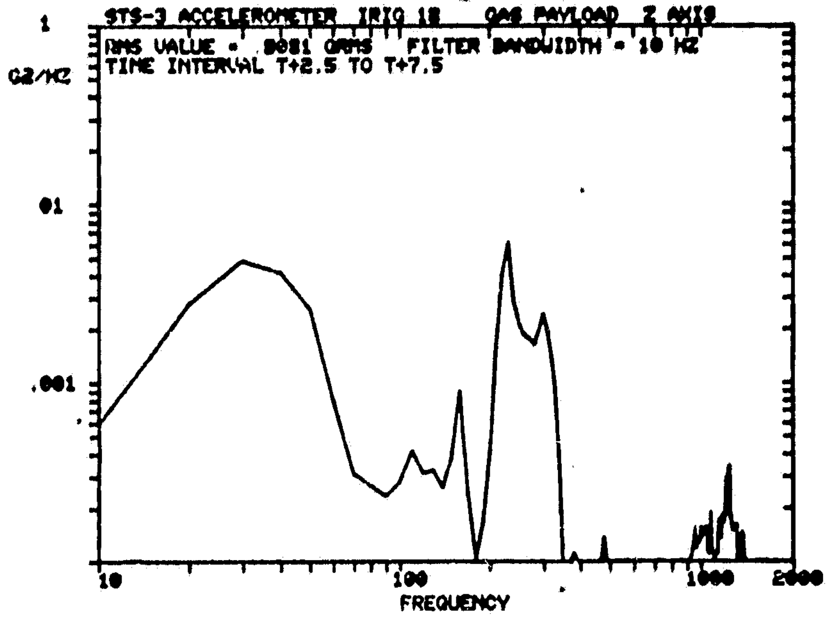

Figure 33. Z-axis PSD ($T_{+2.5}$ to $T_{+7.5}$)

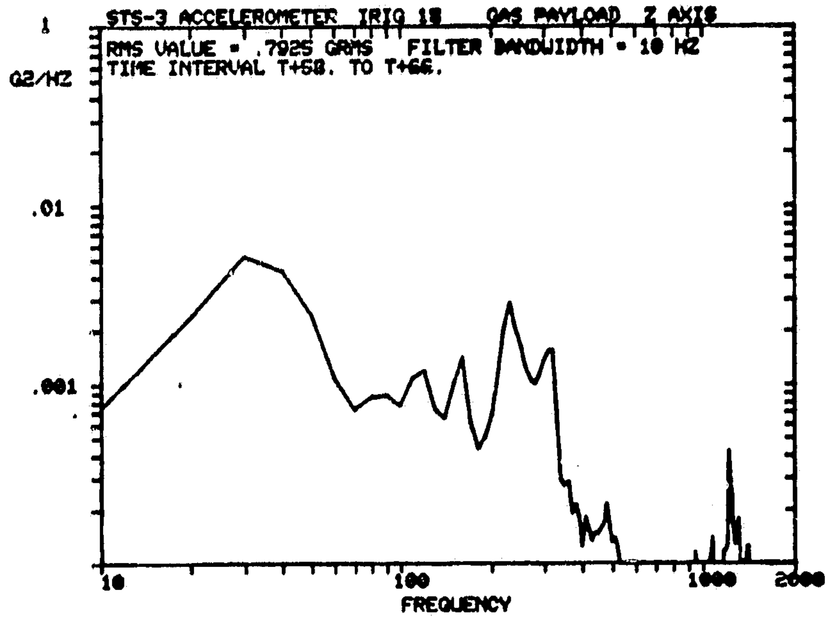

Figure 34. Z-axis PSD (T_{+58} to T_{+66})

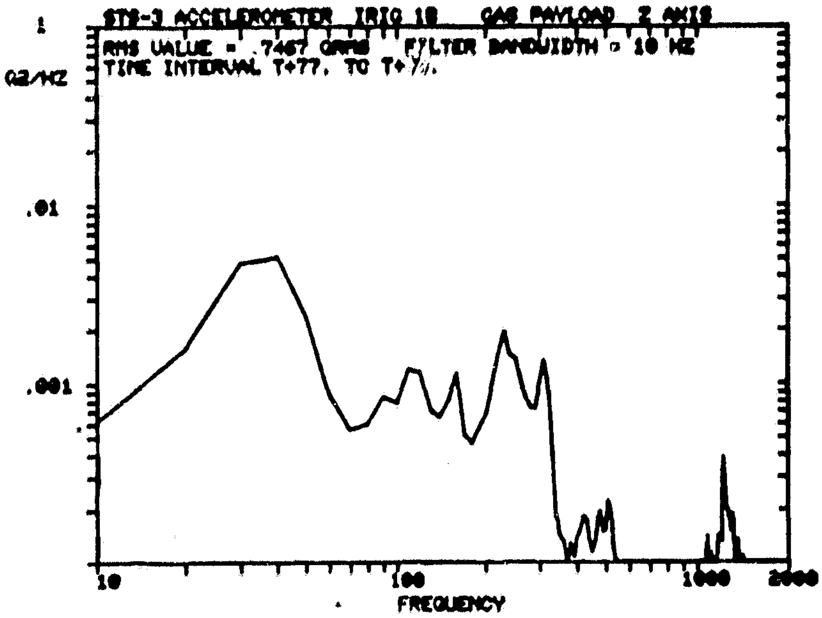

Figure 35. Z-axis PSD (T_{+77} to T_{+85})

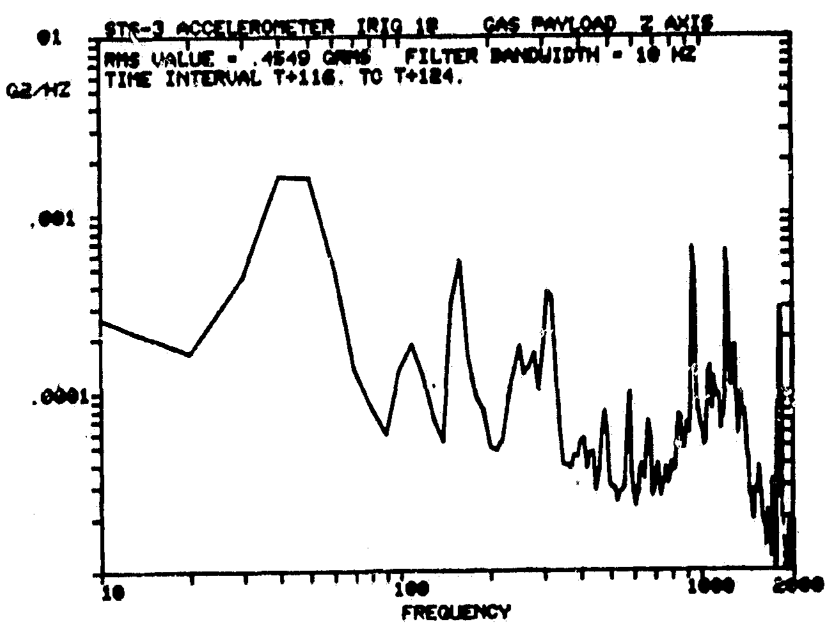

Figure 36. Z-axis PSD (T_{+116} to T_{+124})

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which can be used to develop vibration specifications for GAS payloads. However, accelerometer responses shown in the previous section do not include the SSME. In the development of specifications, one must consider the worst case. Therefore, it is necessary to estimate SSME environment. For that purpose, the responses of nearby DATE accelerometers V08D9273/4A (X_o = 1187, Y_o = 14, and Z_o = 428) were considered (Figure 37). As can be seen from this figure, the X-axis grms following SSME ($T_{-3.8}$ to $T_{-3.3}$ seconds) is only 1.04 times higher than grms following liftoff ($T_{+2.8}$ to $T_{+4.8}$ seconds), and grms at landing is quite low. Whereas for Z-axis accelerometer, grms following SSME ($T_{-3.8}$ to $T_{-3.3}$ seconds) is 1.19 times higher than grms following liftoff ($T_{+2.8}$ to $T_{+4.8}$ seconds). Again, at landing, the grms level is quite low. Thus based on the DATE data, landing loads can be ignored, and to account for SSME, the grms level should be raised by a factor of 1.19.

An examination of the data presented in the earlier section shows that the GAS accelerometer responses are maximum following liftoff ($T_{+2.5}$ to $T_{+7.5}$ seconds), and the X-, Y-, and Z-axes accelerations are 1.479, 1.534, and 0.808 grms, respectively (Figures 25, 29, and 33). Also, these figures show that the maximum g^2/Hz level for these responses is approximately 0.015.

As it is desirable to have the same specifications for all three axes, the vibration specifications for GAS payloads are based on the maximum g^2/Hz of 0.015. To compensate for the fact that these data do not include SSME, 0.015 g^2/Hz is multiplied by 1.19^2 (1.19 on grms). In addition, in order to account for flight-to-flight variations and other uncertainties, this level is raised by a factor of 2. This provides the maximum g^2/Hz level as 0.042. Also, this g^2/Hz level is considered necessary to account, as per Goddard Space Flight Center test policy recommendations, for good workmanship demonstration.[4]

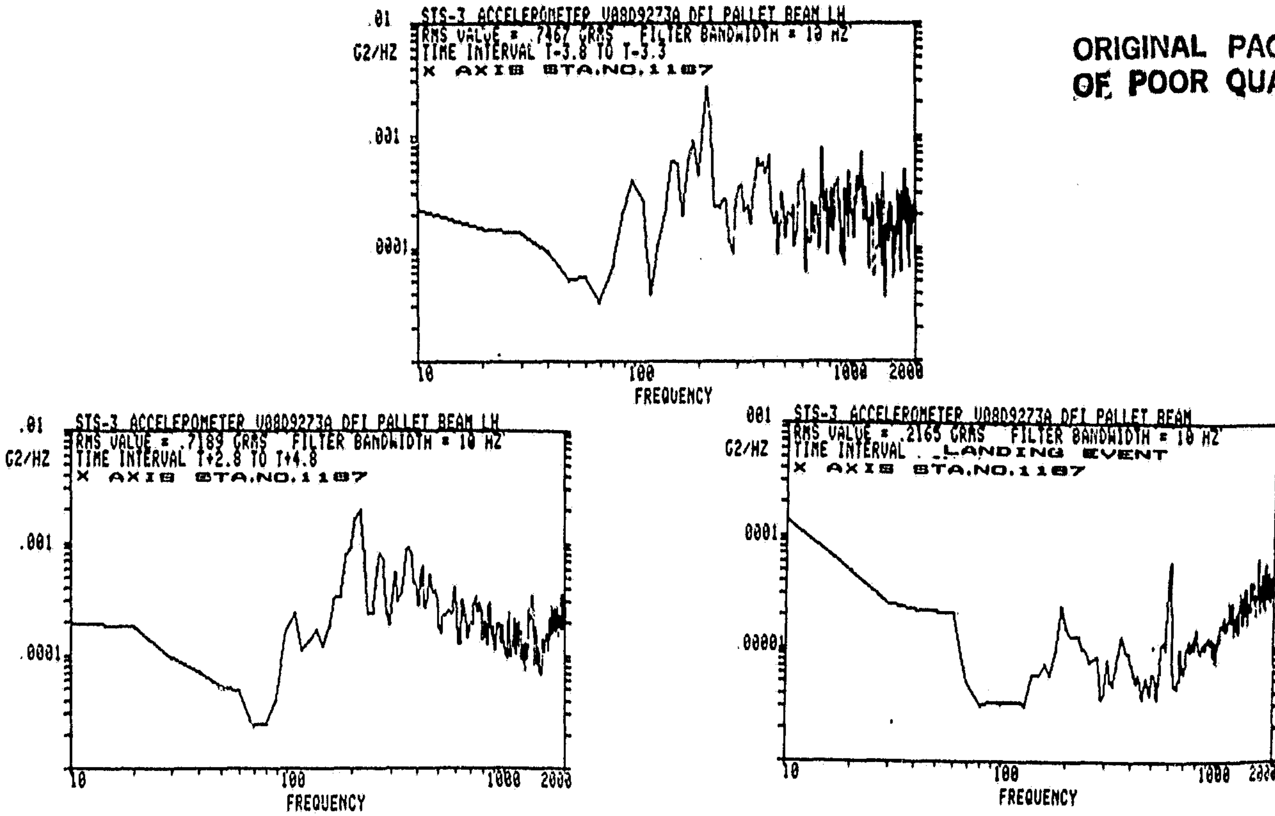
The PSD plots in the previous section show that the higher energy levels are approximately bounded by 20 to 500 Hz frequencies. Based on the above discussions, the following levels are recommended for flight vibration specifications of GAS payloads:

20 - 30 Hz	+6 dB/octave
30 - 500 Hz	0.042 g^2/Hz
500 - 2000 Hz	-6 dB/octave
overall level =	6 grms

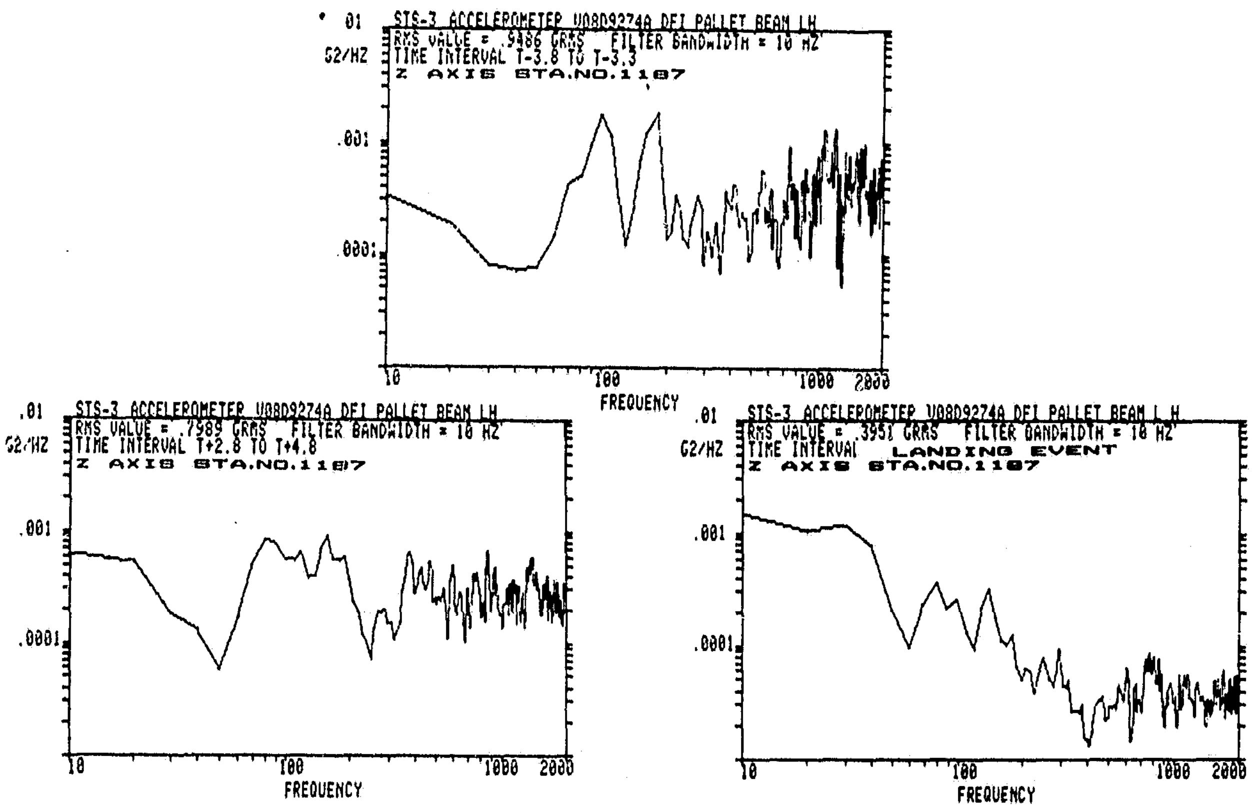
40 seconds/mission/axis

This specification and its comparison with STS-3 flight data is shown in Figure 38.

In the Interface Control Document (ICD) for shuttle orbiter/GAS interfaces, the vibration level specified for medium-sized canis-



a) X-axis Accelerometer V08D9273A



b) Z-axis Accelerometer V08D9274A

Figure 37. DATE Accelerometer Responses[2]

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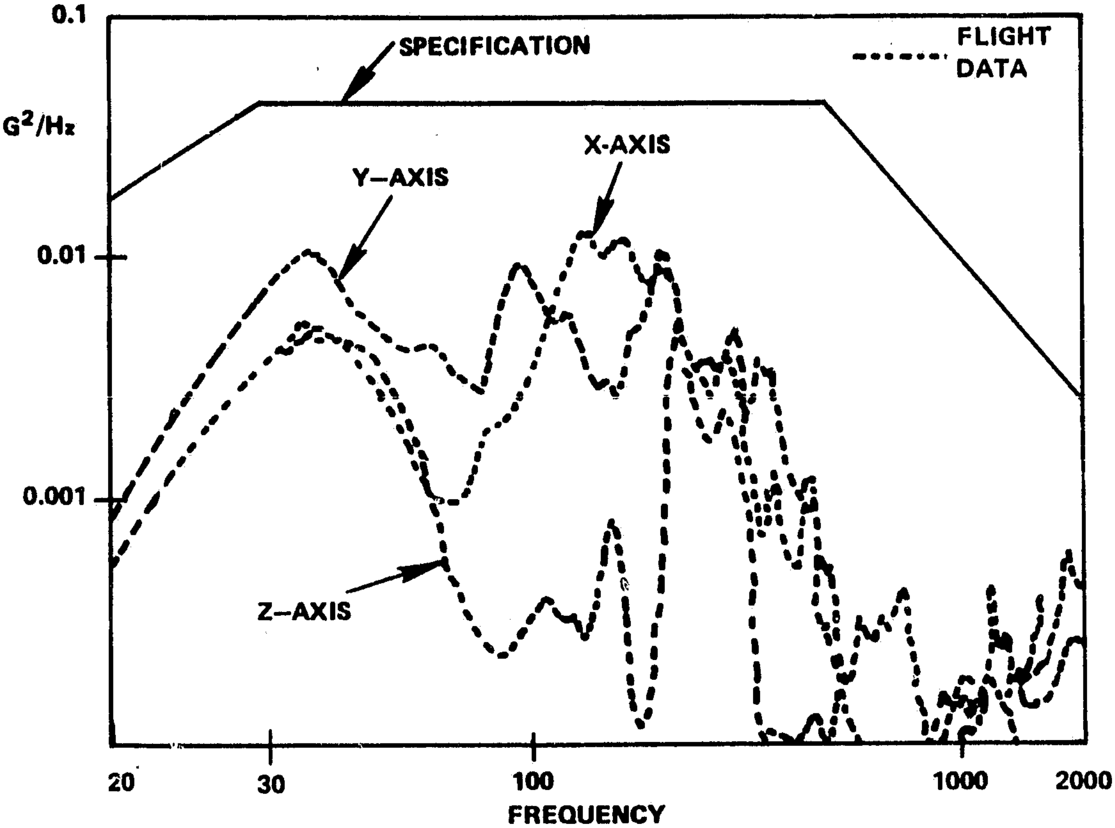

Figure 38. Flight Vibration Specifications for GAS Payloads and Comparison with Flight Data.

ters, 500 lbs. (226.8 kg), is 5.1 grms.[5] The 6 grms level recommended here for GAS payloads is larger than this level. This is in line with the observation made in earlier vibration tests.[6] These tests showed that the g levels observed on the canisters were larger than the input g levels at the mounting interface.

4. REFERENCES

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