# CHAPTER 6

# ENVIRONMENT AND LOADS

## 6.1 Summary

This chapter introduces the natural environment of launch site, thermal environment during Payload operation, electromagnetic environment during launch preparation and LV flight, as well as thermal environments, mechanical environments (vibration, shock & noise) during LV flight.

## 6.2 Pre-launch Environments

### 6.2.1 Natural Environment

LM-2C can be launched in the three launch sites, JSLC, XSLC & TSLC. The natural environmental data in these three sites concluded by long-term statistic research. The environmental data in JSLC are emphasized as listed below.

- Temperature statistic result for each month at JSLC.

| Month | Highest (°C) | Lowest (°C) | Mean (°C) |
|---|---|---|---|
| January | 14.20 | -32.40 | -11.20 |
| February | 17.70 | -33.10 | -6.20 |
| March | 24.10 | -21.90 | 1.90 |
| April | 31.60 | -13.60 | 11.10 |
| May | 38.10 | -5.60 | 19.10 |
| June | 40.90 | 5.00 | 24.60 |
| July | ***42.80*** | 9.70 | 26.50 |
| August | *40.60* | 7.70 | 24.60 |
| September | 36.40 | -4.60 | 17.60 |
| October | 30.10 | -14.50 | 8.30 |
| November | 22.10 | -27.50 | -1.70 |
| December | 16.00 | ***-34.00*** | -9.60 |

- The relative humidity at launch site is 35~55%. The dry season is all over the year, the average annual rainfall is 44mm.

### 6.2.2 Payload Processing Environment

Payload will be checked, tested in Payload Processing Buildings (BS2 and BS3) and then transported to the launch pad for launch. The environment impacting Payload includes 3 phases: (1) Processing in BS2 and BS3; (2) Transportation from BS3 to launch pad; (3) preparation on launch tower.

#### 6.2.2.1 Environment of Payload in Processing Building

The satellite will be tested and fueled in the BS2 and BS3 which are equipped with air conditioning system. The temperature, humidity and cleanness can be guaranteed in the whole process. Refer to chapter 7.

#### 6.2.2.2 Environment of Payload during Transportation to Launch Tower

After finishing fairing encapsulation in BS3, the fairing/payload combination will be transported to launch pad. The environment for Payload during transportation can be assured by temperature-control measures (such as thermal blanket). The environmental parameters in fairing are as follows:

Temperature: 10°C~25°C
Relative humidity: 30%~60%
Cleanliness: 100,000 level

#### 6.2.2.3 Air-conditioning inside Fairing at Launch Pad

The fairing air-conditioning system, shown in **Figure 6-1**, will be started after the payload was mated to the launch vehicle. The typical air-conditioning parameters inside the fairing are as follows:

Temperature: 15°C~22°C
Relative Humidity: 30%~45%
Cleanliness: 100,000 level
Air Flow Rate: 23~91kg/min

The air-conditioning is shut off at L-45 minutes and would be recovered in 40 minutes if the launch aborted.

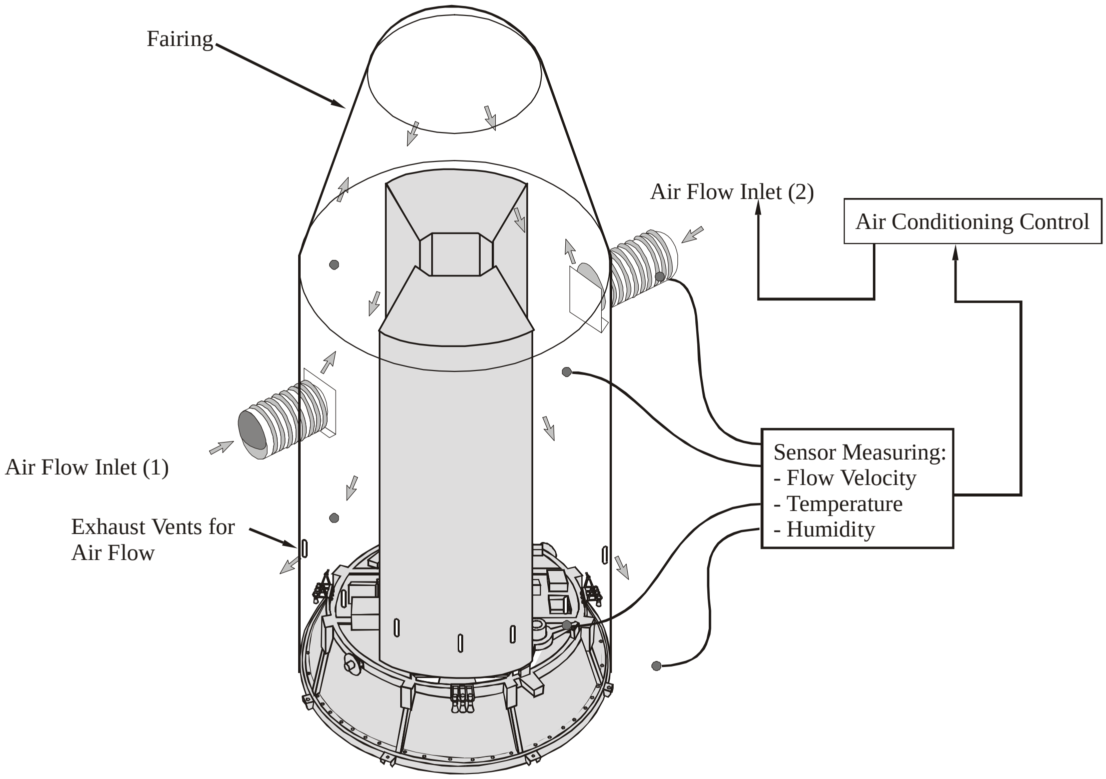


**Figure 6-1 Fairing Air-conditioning on the Launch Tower**

The SC battery cooling system can also be provided with the following typical parameters:

| | |
|---|---|
| Temperature: | 10°C~16°C |
| Relative Humidity: | 30%~60% |
| Cleanliness: | 100,000 level |
| Air Flow Rate: | >1.36kg/min |
| Relative pressure: | <35Kpa |

## 6.2.3 Electromagnetic Environment

### 6.2.3.1 On-board Radio Equipment

Characteristics of on-board radio equipment are shown below:

| EQUIPMENT | FREQUENCY (MHz) | POWER (W) | susceptibility (dBW) | Polarization | Antenna position |
|---|---|---|---|---|---|
| Telemetry Transmitter 1 | 2200~2300 | 10 | | linear | Stage-2 Inter-tank section |
| Telemetry Transmitter 2 | 2200~2300 | 3x2 | | linear | SD |
| Beacon | 5300~5400(down)<br>5650~5850(up) | 1.5 | -110 | | Stage -2 Inter-tank section |
| Transponder | Rec.5550~56500. 8us,800bit | 0.8μs, 800bit | -91 | linear | Stage -2 Inter-tank section |
| Beacon | 2750~2800 | 1 | | linear | Stage-2 Inter-tank section |
| Telemetry command Receiver | 600~700 | | -129 | linear | Stage-2 Inter-tank section |

### 6.2.3.2 Electromagnetic Radiation Reduction

The payload is shielded by the launch tower and fairing. The electromagnetic strength is reduced 12dB at 0.1~10GHz comparing to the outside environment.

### 6.2.3.3 LV Electromagnetic Radiation and Susceptibility

The energy levels of launch vehicle electromagnetic radiation and susceptibility are measured at SC/LV separation plane. They are shown in **Figure 6-2** to **Figure 6-5**.

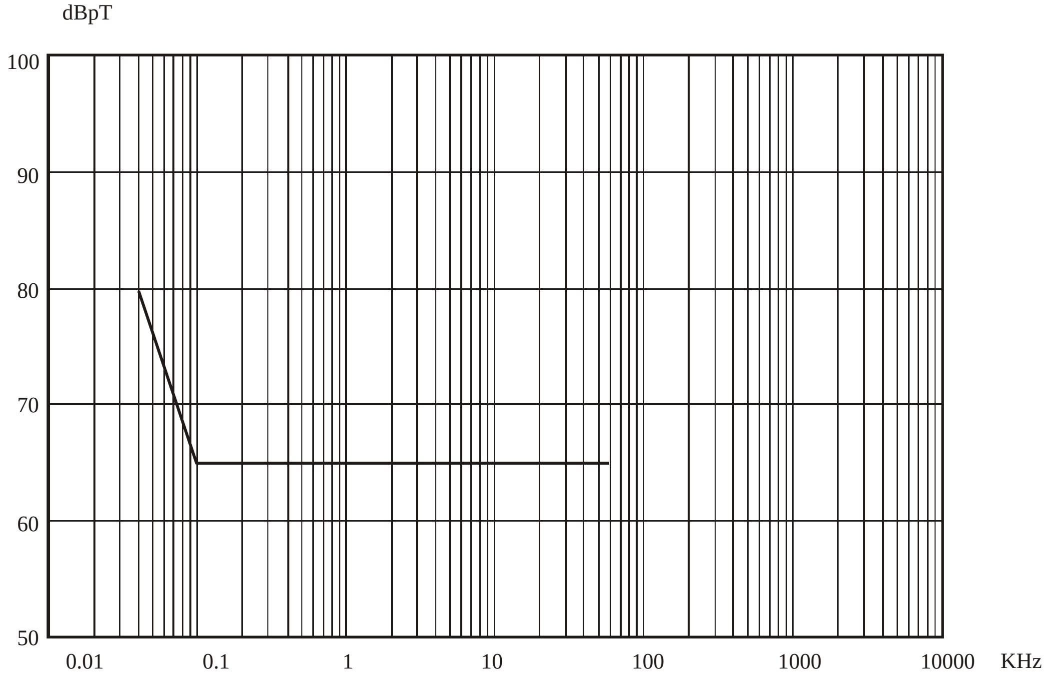


Figure 6-2 Narrow Band Magnetic Emission from LM-2C

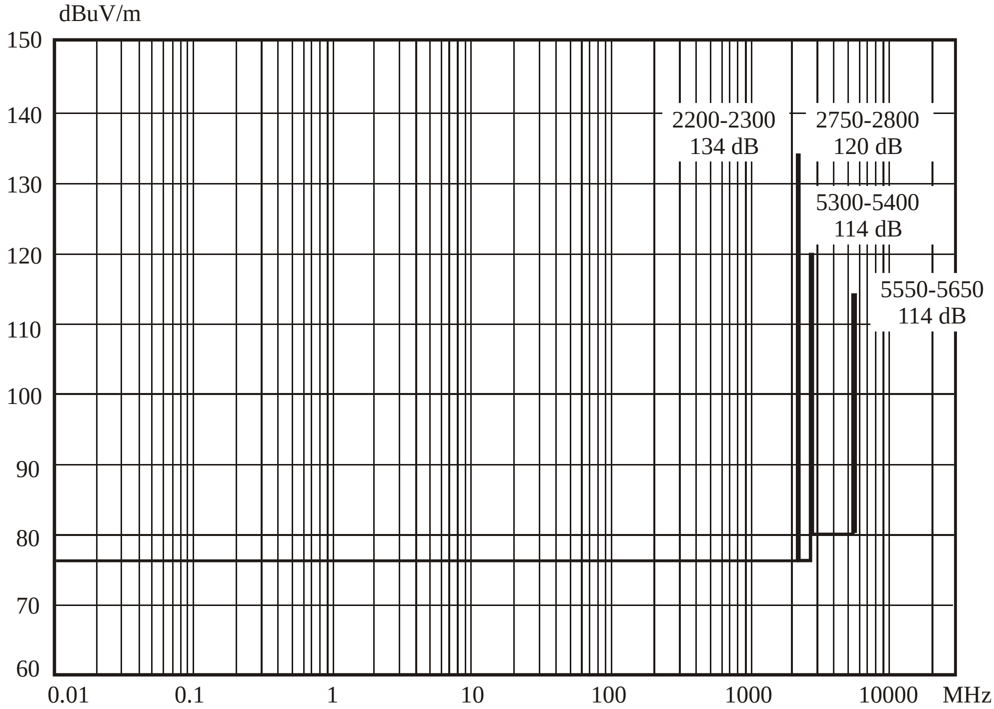


Figure 6-3 Narrow Band Electric Field Radiation from LM-2C

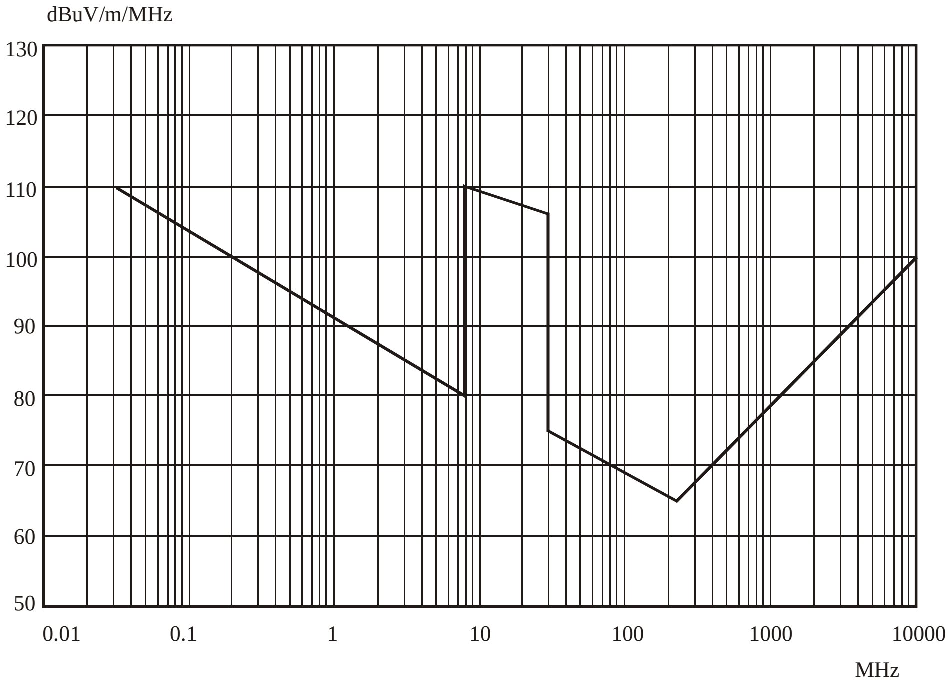


**Figure 6-4 Broad Band Electric Field Radiation from LM-2C**

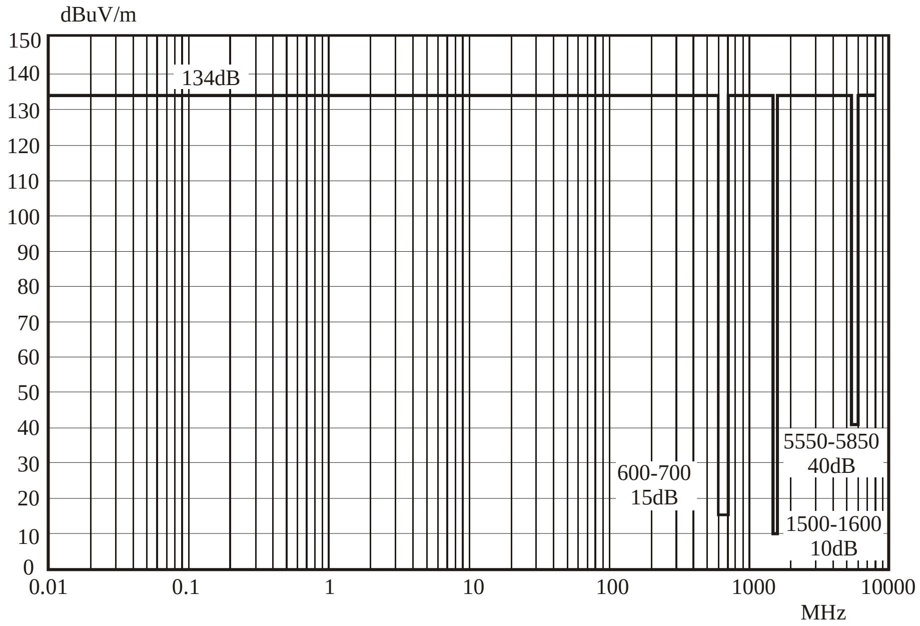


**Figure 6-5 Permissive Electric Field Radiation from LM-2C**

#### 6.2.3.4 EMC Analysis among Payload, LV and Launch Site

To conduct the EMC analysis among Payload, LV and launch site, both Payload and LV sides should provide related information to each other. The information provided by CALT are indicated in the **Figure 6-2** to **6-5** in this chapter**,** while the information provided by SC side are as follows:

a. Payload RF system configuration, characteristics, working period, antenna position and direction, etc.
b. Values and curves of the narrow-band electric field of intentional and parasitic radiation generated by Payload RF system at Payload/LV separation plane and values and curves of the electromagnetic susceptibility accepted by Payload.

CALT will perform the preliminary EMC analysis based on the information provided by SC side, and both sides will determine whether it is necessary to request further information according to the analysis result.

#### 6.2.3.5 Usage of SC RF Equipment

SC side and CALT will coordinate the RF working time phase during launch campaign and LV flight.

### 6.2.4 Contamination Control

The molecule deposition on Payload surface is less than $2mg/m^2$/week. The total mass loss is less than 1%. The volatile of condensable material is less than 0.1%.

## 6.3 Flight Environment

The mechanical environment for Payload is at Payload/LV interface. The pressure environment and thermal environment is just for typical fairing.

### 6.3.1 Pressure Environment

When the launch vehicle flies in the atmosphere, the fairing air-depressurization is provided by 12 vents (total venting area 350cm$^2$) opened on the lower cylindrical section. The typical design range of fairing internal pressure is presented in **Figure 6-6**. The maximum depressurization rate inside fairing will not exceed 6.0 kPa/sec.

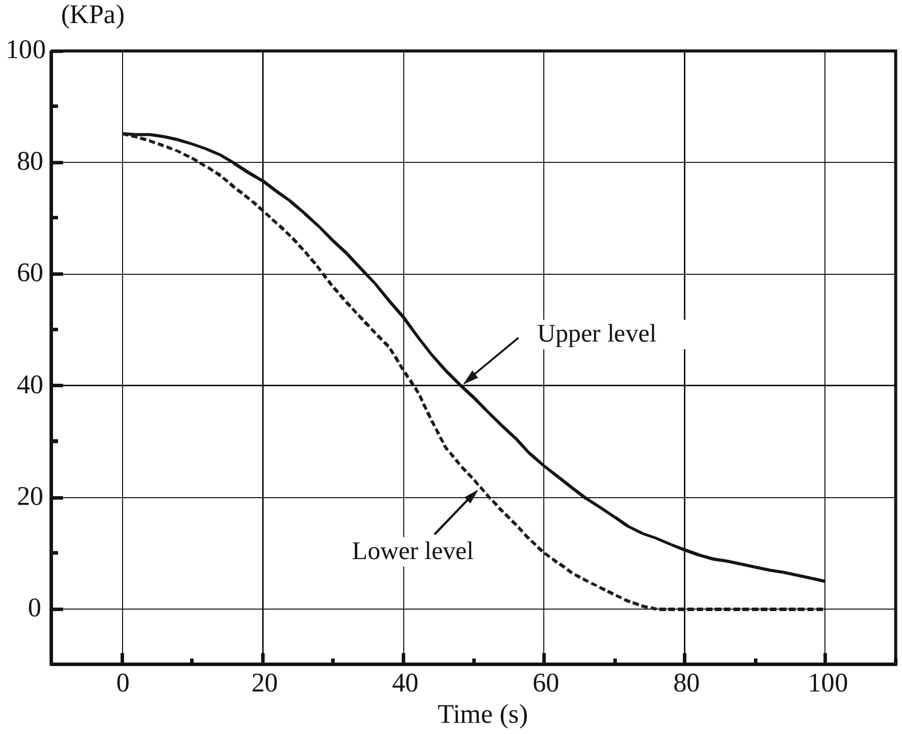


**Figure 6-6 Fairing Internal Pressure vs. Flight Time**
**(Maximum Pressure depressurization rate Vs. time is 6.0kPa/sec.)**

### 6.3.2 Thermal environment

The radiation heat flux density and radiant rate from the inner surface of the fairing is shown in **Figure 6-7**.

The free molecular heating flux at fairing jettisoning shall be lower than 1135W/m$^2$. After fairing jettisoning, the thermal effects caused by the sun radiation, Earth infrared radiation and albedo will also be considered. The specific affects will be determined through the Payload/LV thermal coupling analysis by CALT.

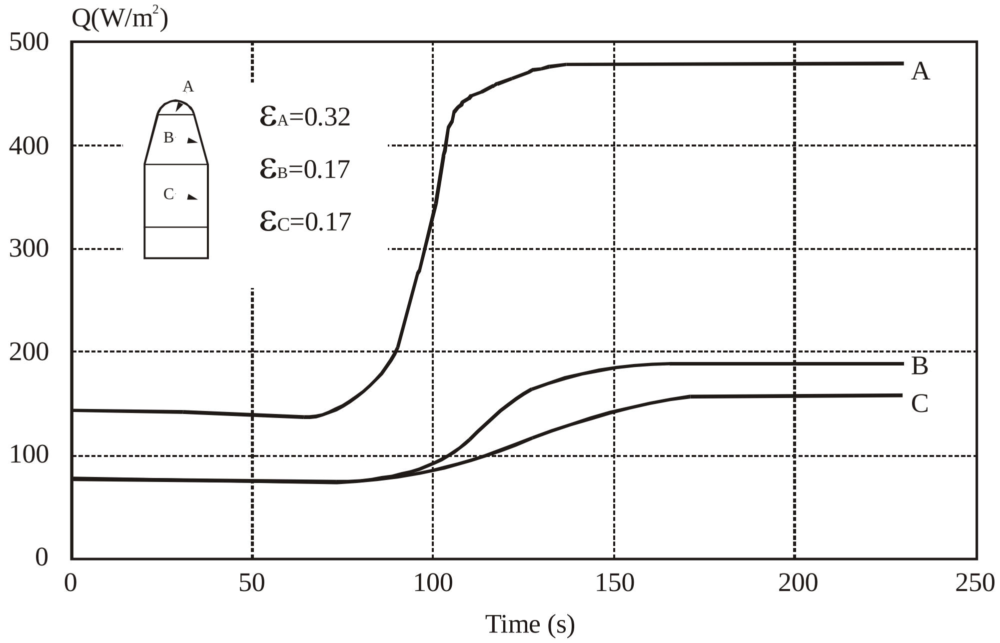


**Figure 6-7 Radiation Heat Flux Density and Radiant Rate on the Inner Surface of Each Section of the Fairing**

### 6.3.3 Static Acceleration

#### 6.3.3.1 Longitudinal Static Acceleration

The longitudinal static acceleration is caused by the LV engine thrust and aerodynamic foresees. The acceleration is usually given in longitudinal static over load. The maximum overload is 4.6g for first stage flight and 6.7g for second stage flight, which could be varied slightly to different payloads.

### 6.3.3.2 Lateral Static Acceleration

The lateral static acceleration is caused by the LV maneuver and aerodynamic foresees. The maximum overload will not exceed 0.4g during the whole flight, which also could be varied slightly to different payloads.

### 6.3.4 Dynamic Environment

The LV suffers engine thrust, aerodynamic forces (including buffeting during transonic phase, wind aloft, etc.), various separation forces (such as stage-1/stage-2 separation, fairing jettisoning, SC/LV separation, etc.) during powered flight phase. It is also affected by disturbances caused by engine jet and transonic acoustic noise. According to the acting forces and LV responses, the dynamic environment can be divided into sinusoidal vibration, random vibration, shock and acoustic.

### 6.3.4.1 Sinusoidal Vibration

The sinusoidal vibration mainly occurs in the processes of engine ignition and shut-off, transonic flight and stage separations. The sinusoidal vibration (zero-peak value) at Payload/LV interface is shown below.

| Direction | Frequency Range (Hz) | Amplitude or Acceleration | |
|---|---|---|---|
| | | Two-stage LM-2C | LM-2C/CTS |
| Longitudinal | 5 – 10 | 2 mm | 2.5mm |
| | 10 – 100 | 0.8g | 1.0 g |
| Lateral | 5 – 10 | 1.5mm | 1.75mm |
| | 10-100 | 0.6g | 0.7g |

### 6.3.4.2 Random Vibration

The Payload random vibration is mainly generated by noise and reaches the maximum at the lift-off and transonic flight periods.

The random vibration Power Spectral Density and the total Root-Mean-Square (RMS) values at Payload/LV separation plane in three directions are given in the table below.

| Frequency Range (Hz) | Power Spectral Density | Total RMS Value |
|---|---|---|
| 20 - 150 | +3dB/octave. | 6.94 g |
| 150 - 800 | 0.04 $g^2$/Hz | |
| 800 - 2000 | -6 dB/octave. | |

### 6.3.4.3 Acoustic Noise

The flight noise mainly includes the engine noise and aerodynamic noise. The maximum acoustic noise Payload suffers occurs at the moment of lift-off and during the transonic flight phase. The values in the table below are the maximum noise levels in fairing.

| Central Frequency of Octave Bandwidth (Hz) | Acoustic Pressure Level (dB) |
|---|---|
| 31.5 | 118 |
| 63 | 131 |
| 125 | 134.5 |
| 250 | 135 |
| 500 | 133.5 |
| 1000 | 127 |
| 2000 | 122 |
| 4000 | 118 |
| 8000 | 114 |
| Total Acoustic Pressure Level | 140 |

0 dB referenced to $2\times10^{-5}$ Pa.

### 6.3.4.4 Shock Environment

The maximum shock Payload suffers occurs at the Payload/LV separation. Different separation mechanism and preload forces will affect the separation shock significantly. The typical shock response spectrum at Payload/LV separation plane is shown bellow.

| Frequency Range (Hz) | Response Acceleration (Q=10) |
|---|---|
| 100-1500 | +9.0 dB/octave. |
| 1500-6000 | 4000 g |

## 6.4 Load Conditions for Payload Design

### 6.4.1 Frequency Requirement

To avoid the Payload resonance with launch vehicle, the primary frequency of Payload structure should meet the following requirement (under the condition that the Payload is rigidly mounted on the LV separation plane.):

***The frequency of the lateral main mode>12Hz***
***The frequency of the longitudinal main mode >35Hz***

*Whereas:*
*For Two-stage LM-2C, payload here means the SC.*
*For LM-2C/CTS, payload here means the SC plus CTS.*

### 6.4.2 Loads Applied for Payload Structure Design

During LV flight, the Payload suffers four cases: the transonic phase or Maximum Dynamic Pressure phase, the first stage engines shut down, the first and second stage separation, and the second stage main engines shut down. Therefore, the following limit loads at SC/LV separation plane corresponding to different conditions in flight are recommended for Payload design consideration.

| Flight Condition | Longitudinal Acceleration(g) | | | Lateral Acceleration(g) |
|---|---|---|---|---|
| | Static | Dynamic | Combined | |
| Transonic and MDP | +2.2 | ±0.4 | +2.6 | 1.0 |
| Stage-1 shut down | +4.6 | ±1.0 | +5.6 | 0.6 |
| Stage-1/2 separation | +0.8 | ±3.0 | +3.8/-2.2 | 0.8 |
| Stage-2 shut down | +6.7 | ±0.5 | +7.2 | 0.4 |

**Notes:**

- Usage of the above table:

  **Payload design loads** = **Limit loads** × **Safety factor ***

  ***** The safety factor is determined by the Payload designer. (CALT suggests ≥1.25).
- The direction of the longitudinal loads is the same as the LV longitudinal axis.
- The lateral load means the load acting in any direction perpendicular to the longitudinal axis.
- Lateral and longitudinal loads occur simultaneously.
- "+" means compress in axial direction.
- The loads are acting on the separation plane.

### 6.4.3 Coupled Load Analysis

The Payload manufacturer should provide the Payload mathematical model to CALT for Coupled Loads Analysis (CLA). CALT will predict the Payload maximum dynamic response by coupled load analysis. The detailed data exchange requirements and special technical specifications will be coordinated by SC side and LV side.。 The Payload manufacturer should confirm that the Payload could survive from the predicted environment and has adequate safety margin.

## 6.5 Payload Qualification and Acceptance Test Specifications

### 6.5.1 Static Test (Qualification)

The main Payload structure must pass static qualification tests without damage. The test level must be not lower than Payload design load required in **Paragraph 6.4.2**.

### 6.5.2 Dynamic Environment Test

#### 6.5.2.1 Sine Vibration Test

During tests, the Payload must be rigidly mounted on the shaker. The tables below specifies the vibration acceleration level (zero - peak) of Payload qualification and acceptance tests at Payload/LV interface. (See **Figure 6-8a&b**).

| | | Frequency (Hz) | Test Load | |
|---|---|---|---|---|
| | | | Acceptance | Qualification |
| For LM-2C/CTS | Longitudinal | 5-10 | 2.5 mm | 4.0 mm |
| | | 10-100 | 1.0 g | 1.6 g |
| | Lateral | 5-10 | 1.75 mm | 3.0 mm |
| | | 10-100 | 0.7 g | 1.2 g |
| | Scan rate | | 4 Oct/min | 2 Oct/min |
| For Two-stage LM-2C | Longitudinal | 5-10 | 2.0 mm | 3.25 mm |
| | | 10-100 | 0.8 g | 1.3 g |
| | Lateral | 5-10 | 1.5 mm | 2.5 mm |
| | | 10-100 | 0.6 g | 1.0 g |
| | Scan rate | | 4 Oct/min | 2 Oct/min |

**Notes:**

- Frequency tolerance is allowed to be ±2%
- Amplitude tolerance is allowed to be ±10%
- Acceleration notching is permitted after consultation with CALT and concurred by all parties. Anyway, the coupled load analysis results should be considered , and the safety margin should be enough (CALT requires that safety factor $\geq 1.25$).

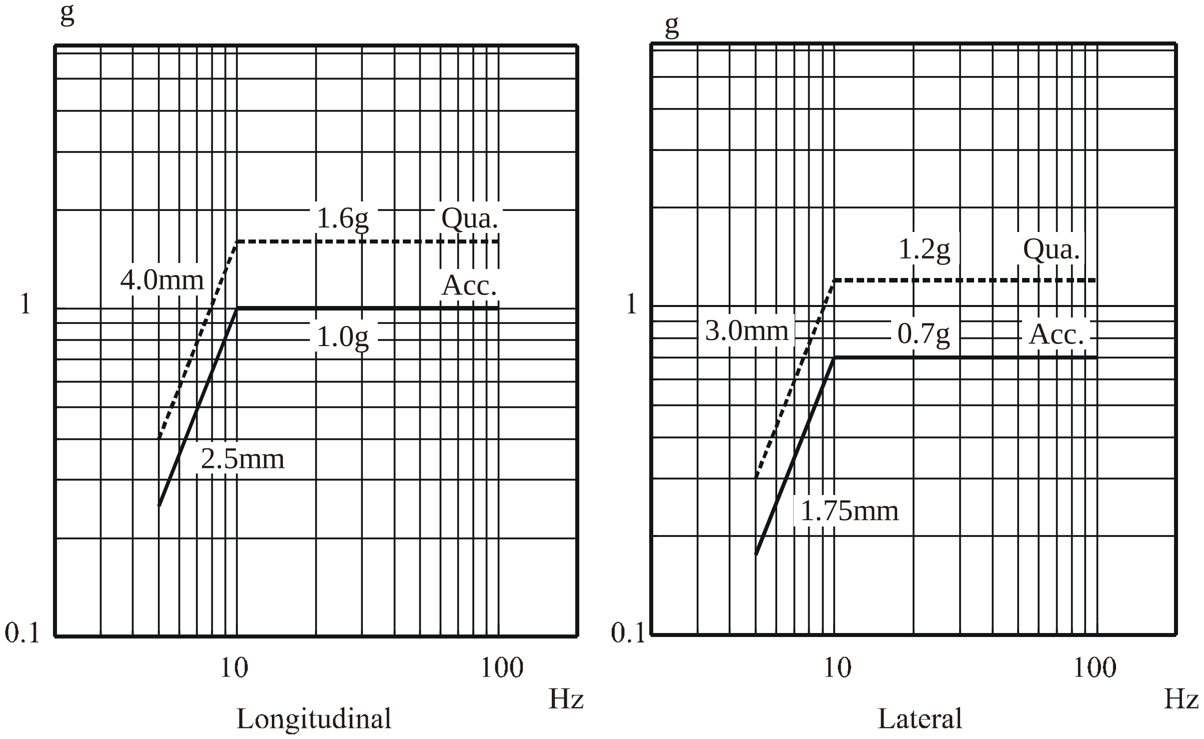


**Figure 6-8a Sinusoidal Vibration Test in Longitudinal & lateral directions (For LM-2C/CTS)**

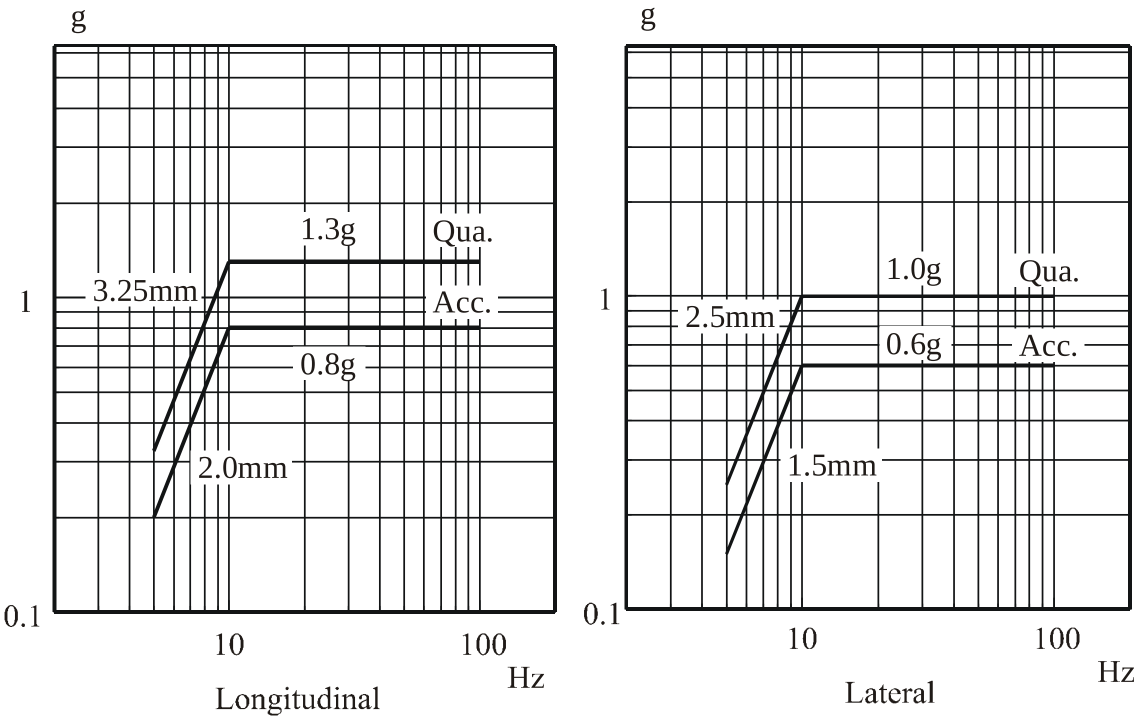


**Figure 6-8b Sinusoidal Vibration Test in Longitudinal & lateral directions (For Two-stage LM-2C)**

### 6.5.2.2 Random Vibration Test

During tests, the Payload structure must be rigidly mounted onto the shaker. The table below specifies the Payload qualification and acceptance test levels at Payload/LV interface. (See **Figure 6-9**).

| Frequency (Hz) | Acceptance | | Qualification | |
|---|---|---|---|---|
| | Spectrum Density | Total rms (Grms) | Spectrum Density | Total rms (Grms) |
| 20 - 150 | +3 dB/oct | 6.94 g | +3 dB/oct | 10.41 g |
| 150 - 800 | 0.04 $g^2$/Hz | | 0.09 $g^2$/Hz | |
| 800 - 2000 | -6 dB/octave. | | -6 dB/octave | |
| Duration | 1 min. | | 2 min. | |

**Notes:**

- Tolerances of ±3.0 dB for power spectral density and ±1.5 dB for total rms values are allowed.
- The random test can be replaced by acoustic test.

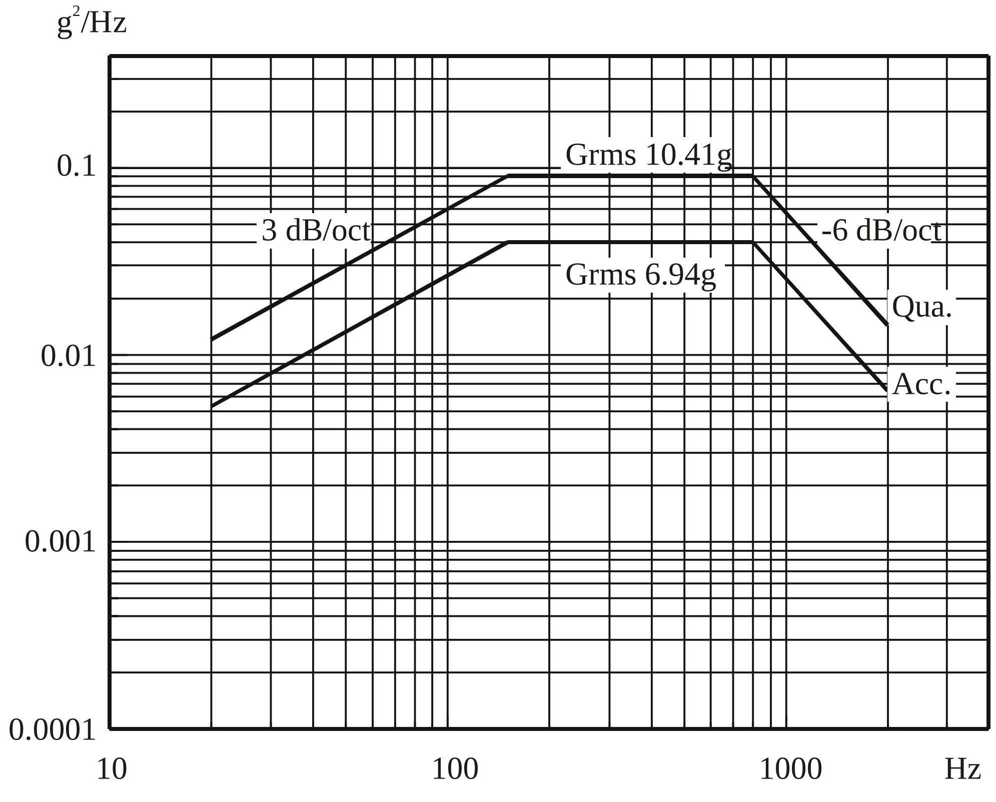


**Figure 6-9 Random Vibration Power Spectrum Density Test Conditions (For Two-stage LM-2C and LM-2C/CTS in All Directions)**

### 6.5.2.3 Acoustic Test

The acceptance and qualification test levels are given in the following table (also see **Figure 6-10**).

| Central Octave Frequency (Hz) | Acceptance Sound Pressure Level (dB) | Qualification Sound Pressure Level (dB) | Tolerance (dB) |
|---|---|---|---|
| 31.5 | 122 | 126 | -2/+4 |
| 63 | 128 | 132 | -1/+3 |
| 125 | 134 | 138 | |
| 250 | 139 | 143 | |
| 500 | 135 | 139 | |
| 1000 | 130 | 134 | |
| 2000 | 125 | 129 | |
| 4000 | 120 | 124 | -6/+4 |
| 8000 | 116 | 120 | |
| Total Sound Pressure Level | 142 | 146 | -1/+3 |

0 dB is equal to $2\times10^{-5}$ Pa.

Test Duration:

- Acceptance test: 1.0 minute
- Qualification test: 2.0 minutes

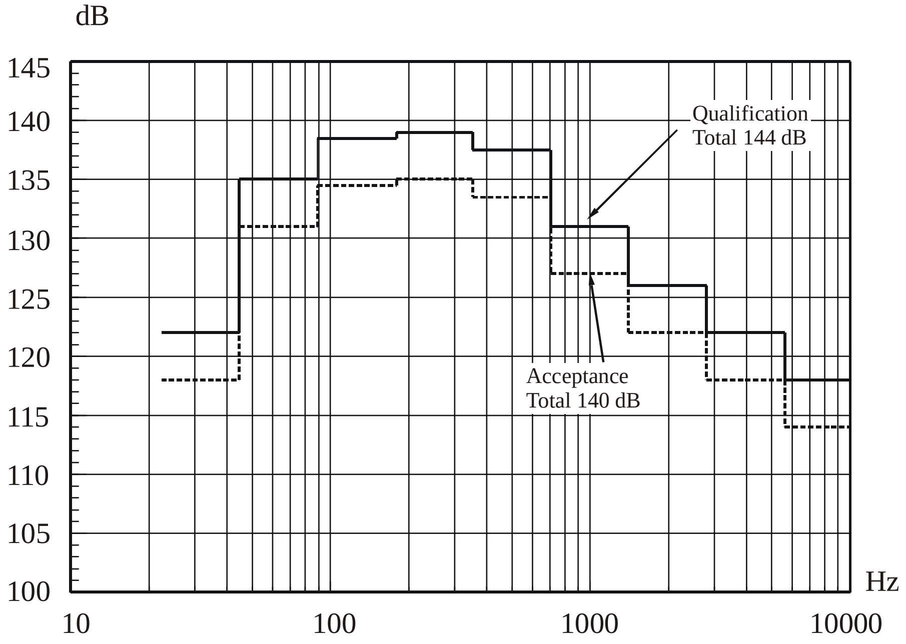
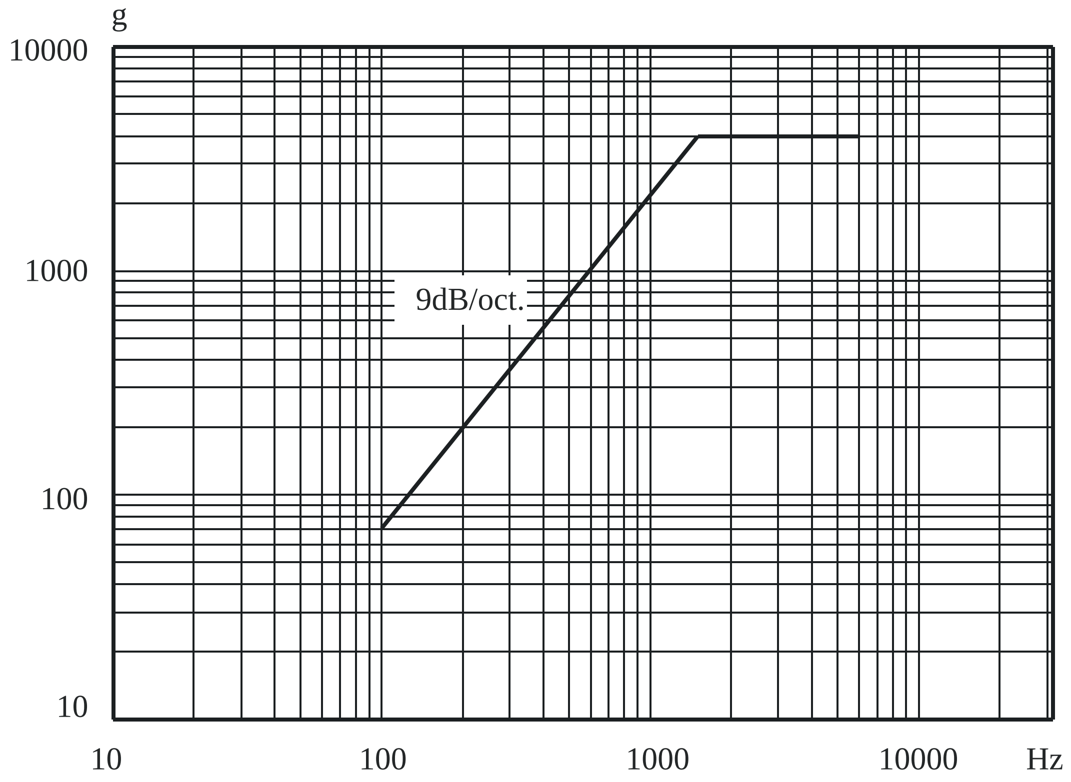


Figure 6-10 Payload Acoustic Test

### 6.5.2.4 Shock Test

The shock test level is specified in **Paragraph 6.3.4.4**. Such test shall be performed once for acceptance, and twice for qualification. A ±6.0dB tolerance in test specification is allowed. However, the test strength must be applied so that in the shock response spectral analysis over 1/6 octave on the test results, 30% of the response acceleration values at central frequencies shall be greater than or equal to the values of test level. (See **Figure 6-11**)

The shock test can also be performed through Payload/LV separation test by using of flight Payload, payload adapter, and separation system. Such test shall be performed once for acceptance, and twice for qualification.



| Frequency Range (Hz) | Shock Response Spectrum (Q=10) |
|---|---|
| 100~1500 | 9.0 dB/oct. |
| 1500~6000 | 4000g |

Figure 6-11 Shock Response Spectrum at Payload/LV Separation Plane