
NON-TRADITIONAL VIBROACOUSTIC TEST ASPECTS IN MIL-STD-1540E*

by

S. RUBIN, Consultant to The Aerospace Corporation.

©2005 The Aerospace Corporation

* Military Standard – Test Requirements for Launch, Upper-Stage, and Space Vehicles, Aerospace Corp. TR-2004(8583)-1, 31 Jan 2004

OUTLINE

- **Topics covered in appended Notes (Section 10.2)**
 - **Statistical basis for test level**
 - **Acceleration of acceptance life in traditional qual & protoqual**
 - **General requirements for qual or protoqual**
 - **Two-phase qual and protoqual**
 - **Damage-based analysis of flight vibroacoustic data**
 - **Threshold Response Spectrum for shock significance**
- **Flightproof test strategy**

10.2.1 Statistical Basis for Test Level

- **Flight-to-flight variability (lognormal with $\sigma = 3$ dB)**
- **Level is function of probability and confidence**
- **Acceptance at P95/50 is 4.9 dB above mean**
- **Qualification at P99/90**
 - 6 dB margin over acceptance in advance of flight
 - With multi-flight data, statistical basis can be used
- **Proto-qualification at 3 dB over acceptance (7.9 dB above mean)**
 - Exceeded once in 230 flights with 50% confidence
 - P91/90 compares to P99/90 for qualification

10.2.2 Acceleration of Acceptance Life Testing

- **Baseline model for time acceleration factor**
 - High-cycle fatigue; $S^b N = C$ with $b = 4$ as a conservative value
 - Linear Response (e.g., +6 dB causes doubling of response)
 - 4X life to be demonstrated by qualification (2X by protoqual)
 - Each minute at 6-dB margin over acceptance demonstrates life for 4 minutes of repeated acceptance testing
 - Each minute at 3-dB margin demonstrates a limit of only 1 min.
- **2 minutes of a 3-minute qual is considered an accelerated acceptance life test**
 - Limits acceptance of flight units to 8 minutes max for $M = 6$ dB
 - If b can be increased to 6, limit becomes 32 minutes
- **1 min. of 2-minute proto-qual is accelerated acceptance**
 - For $b = 4$, limit is 1 minute; $b = 6$, limit is 2 minutes

10.2.4 Two-Phase Qual & Protoqual

- **Phase I: Test for acceptance life at acceptance level for 4 times the to-be-allowed limit on flight hardware**
- **Phase II: Test for flight using the qual or protoqual spectrum**
- **Approach avoids the conservatism involved in the acceleration of the acceptance life test in traditional qual and protoqual**
 - No assumption needed on mechanism limiting life
 - No assumption of linearity of response
- **Two-phase testing is required for units on vibration isolators when acceptance does not include the isolators**
- **Example for qual or proto-qual based on an 8 min. acceptance limit**
 - 32 min. at acceptance, followed by 1 min. at margin for flight

10.2.5 Damage-Based Analysis of Flight Data

- Traditional maximax analysis can lead to excessively conservative test requirements
- Basis and examples of a damage-based analysis contained in journal article
 - DiMaggio, Sako, Rubin, *Analysis of Nonstationary Vibroacoustic Flight Data Using a Damage-Potential Basis*, AIAA Journal of Spacecraft & Rockets, vol. 40, no. 5, Sep-Oct 2003, pp.682-689
 - Demo of use in *VISPERS* in today's last presentation
- Recommended for use in addressing qualification adequacy when maximax *PSD* of flight data indicates excess re *MPE*

10.2.6 Threshold Response Spectrum for Shock Significance

- **Shock considered insignificant if SRS level ≤ 0.8 times frequency in Hz (≤ 50 in./sec response velocity)**
 - Not for particularly vulnerable units (e.g., crystals, ceramic chips)
- **Also, clearly insignificant if peak response to random vibration test exceeds SRS**
 - Generally conservative for any type of vulnerability
 - Basis provided (does not assume a 3-sigma peak)
 - Example for $Q = 10$ & 1-min. vibration: random more severe than 50 in./sec when
$$PSD > 0.24 \text{ g}^2/\text{Hz} \text{ at } 100 \text{ Hz} \text{ \& } > 1.92 \text{ g}^2/\text{Hz} \text{ at } 1000 \text{ Hz}$$

FLIGHTPROOF STRATEGY (Sec. 5.2)

- **Each flight unit undergoes acceptance testing at the protoqual level, but for the acceptance duration**
 - Concept similar to proof testing of pressure vessels
 - Removes from protoqual the acceptance life aspect for follow-on units
 - Baseline: P95/50 + 3 dB for 1 minute
 - Enhanced level for repeated acceptance should be evaluated
- **Essentially each unit is considered one-of-a-kind**
 - Clearly appropriate when like flight units have unique features
- **Risk due to lack of formal demonstration of remaining life**
 - Development testing should be used to gain confidence about life
 - Lesser risk than taken for flight of protoqual unit (tested at same level for 2 minutes)
 - However, risk accepted for all flightproof items
 - Risk traded against additional capability demonstrated for sensitivity to unit-to-unit variability