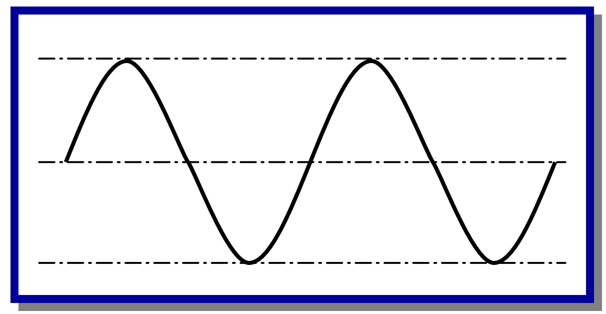
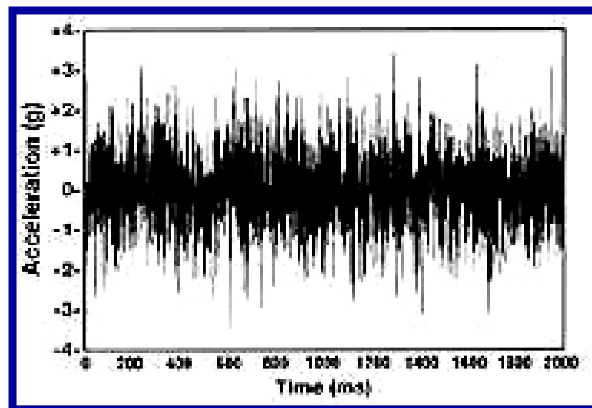
RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- GENERAL
  - Random Vibration: In direct contrast to the definition of 'standard' vibration, and as the name implies, random vibration has a different pattern. All frequencies, within the given limits, occur at the same time. However, the amplitude of any discrete frequency could be very large or very small at any given instant in time, within the capabilities of the test equipment available.





RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- GENERAL

SINUSOIDAL VIBRATION
- Oscillation
- Predictable
- Single Frequency(s)
- Pure Tone / Motion

RANDOM VIBRATION
- Oscillation
- Unpredictable Instantaneous Magnitudes
- All Frequencies at Once
- Statistics
- Spectral Density
- Probability Distribution
- White Noise / Static

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - Random Vibration: Oscillations whose instantaneous amplitudes occur, as a function of time, according to a 'normal' (Gaussian) curve.

  - Stationary Vibration: The condition of 'stationarity' for periodic vibration. That type of vibration for which properties, such as the Mean Magnitude, the RMS Magnitude, the Spectral Density, and the Probability Distribution of the Random Vibration Magnitude, are independent of time. Power Density: The usual way to describe random motion is in terms of its Power Spectral Density (PSD).

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - White Noise: A type of Random Vibration for which the Spectral Density has a constant value for all frequencies from zero to infinity.
  - Band-Limited White Noise: A type of Random Vibration for which the Spectral Density has a constant value over a specified frequency range.

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - Power Density: The Power Density W(f) of Random Vibration is the Mean-Square Magnitude per Unit Bandwidth of the output of an ideal filter with unity gain responding to the vibration as follows:

    $$W(f) = F(f)^2 RMS/\Delta f$$

    where by convention the bandwidth f is usually chosen to be 1Hz.

  - Power Density Spectrum: A graphical representation of values of power density W(f) displayed as a function of frequency. It represents the distribution of vibration energy with frequency.

BARRY CONTROLS

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - Normal Probability Distribution: Standardized form of the normal (or Gaussian) Probability Density, assuming a zero Mean Magnitude, is given by:

    $$P(F/\sigma) = (1/\sqrt{2\pi})e^{-1/2\,(F/\sigma)^2}$$

    where σ is the standard deviation or RMS magnitude of the variable F and $-\infty < F > \infty$. The normal probability distribution has been found to describe suitably the statistical distribution of the instantaneous magnitude of random vibration.

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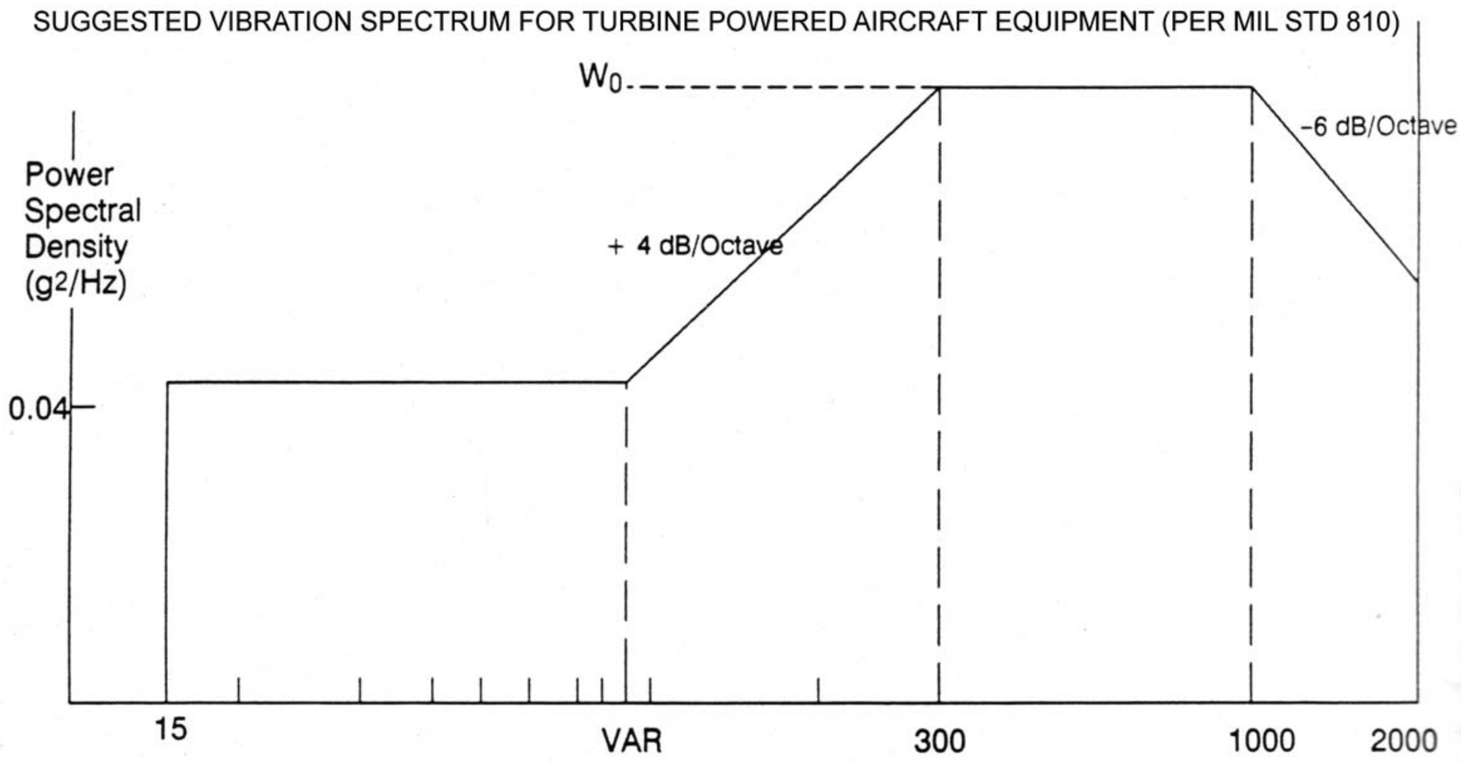
RANDOM VIBRATION

TYPICAL RANDOM VIBRATION SPECTRA



HUTCHINSON

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - f = frequency (Hz)
  - f_1 = lower limit of frequency band (Hz)
  - f_2 = upper limit of frequency band (Hz)
  - f_n = natural frequency (Hz)
  - G = gravitational constant
  - S_f = input power spectral density (G2 / Hz)
  - Tr = resonant transmissibility
  - X = instantaneous input displacement

RANDOM VIBRATION

DEFINITIONS AND TERMINOLOGY APPLICABLE TO VIBRATION ISOLATION MOUNTING SYSTEMS

- SPECIFIC
  - X_{RMS} = root-mean-square input displacement (inches)
  - $\ddot{X}$ = instantaneous inputs acceleration (g's)
  - $\ddot{X}_{RMS}$ = root-mean-square input accelerations (g's)
  - Y = response displacement (inches)
  - $\ddot{Y}_{RMS}$ = G_{RMS} = root-mean-square response acceleration (g's)
  - Y_O = peak response displacement (inches)
  - $\ddot{Y}_O$ = peak response acceleration (g's)
  - Y_{RMS} = RMS response displacement (inches)

BARRY CONTROLS

RANDOM VIBRATION

ANALYZING RANDOM VIBRATION IN PREPARATION OF SELECTING VIBRATION ISOLATION MOUNTS

- PERFORMANCE LIMITS
  - Performance limits are calculated based on the following relationship:

$$G_{RMS} = \frac{(Y/3)fn^2}{9.8} \; ; \; Sf = G_{RMS}^2 / (\pi/2)\, fn\, Tr$$

  - It should be further noted that the limiting criteria is one of displacement capability within the mount and thereby its ability, when snubbing, under "3 Y_{RMS}" excursion peaks.

RANDOM VIBRATION

ANALYZING RANDOM VIBRATION IN PREPARATION OF SELECTING VIBRATION ISOLATION MOUNTS

- WORK SHEET; 1
  - Required Data:
    - Resonant Frequency: ______ Hz.*
    - Resonant Transmissibility: ______ T*
    - Acceleration Spectral Density ______ G^2/Hz
      (In region of isolator resonance)

*Assumes that the Fn of the isolator is within the test spectra.

RANDOM VIBRATION

ANALYZING RANDOM VIBRATION IN PREPARATION OF SELECTING VIBRATION ISOLATION MOUNTS

- WORK SHEET; 1b
  - Calculations:
    - G_{RMS} Value: ______ G's
      (From Barry Slide Rule)
    - Displacement (RMS):

$$\delta\, rms = \left(\frac{3.13}{fn}\right)^2 G_{RMS} = \left(\frac{3.13}{\quad}\right)^2 \_\_\_\_\_ = \_\_\_\_\_ \text{ inches}$$

FIND FIND RESULT

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RANDOM VIBRATION

ANALYZING RANDOM VIBRATION IN PREPARATION OF SELECTING VIBRATION ISOLATION MOUNTS

- WORK SHEET; 1c
  - Calculations:
    - Required Isolator Displacement (necessary):

δ necessary = 3 δ rms = 3 (   ) = ______ inches

- Why 3 δ ? Because at 1 δ the percentage of probability of actual deflection to snub is excessively high; i.e.; > 30%. At 3 δ the percentage of probability of actual deflection is < 0.3%.

HUTCHINSON

RANDOM VIBRATION

DETERMINING DISPLACEMENT REQUIRED FOR MOUNTING AN AIRBORNE ELECTRONIC PACKAGE

- WORK SHEET; 2
  - Exercise: Determining Necessary Displacement of Mounts
    - Givens: Supported Mass = Airborne electronic package
      Mounting interface = Soft mount
      Mount fn = 30Hz
      Mount Tr = 3.0
      Input Power Spectral Density = 0.06 G^2/Hz in area of mount resonance.

RANDOM VIBRATION

DETERMINING DISPLACEMENT REQUIRED FOR MOUNTING AN AIRBORNE ELECTRONIC PACKAGE

- WORK SHEET; 2b
  - Exercise: Determine Necessary Displacement of Mounts
    - Solution With Givens of:
      - fn = 30Hz
      - Tr = 3.0
      - Sf = 0.06 G^2/Hz
    - Calculate G_{RMS}:

$$\sqrt{(\pi/2)(3.0(30)(0.06))} = 2.91\ G_{RMS}$$

RANDOM VIBRATION

DETERMINING DISPLACEMENT REQUIRED FOR MOUNTING AN AIRBORNE ELECTRONIC PACKAGE

- WORK SHEET; 2c
  - Exercise: Determine Necessary Displacement of Mounts
    - Calculate RMS displacement (Y_{RMS}):

$$Y_{RMS} = (9.8)(2.91)/(30)^2 = 0.032 \text{ inches}$$

    - Multiply by probability factor of 3:

$$(3)(.032) = .096 \text{ inches}$$

  - Solution: Displacement requirement is .096 inches

RANDOM VIBRATION

DETERMINING SUITABILITY OF A PRE-SELECTED MOUNT WITH AN AIRBORNE EQUIPMENT PACKAGE

- WORK SHEET; 3
  - Exercise: Determine Suitability of Pre-Selected Mount (S series)
    - Givens:
      - Pre-selected mount = Barry S Series
      - Fragility level = 10 G's
      - Random input = 0.03 G^2 Hz
      - Range = 0.5 - 100 Hz
    - Solution:
      - S mount specs: fn = 7 Hz & Tr = 4; Sf = 0.03 G2/Hz
      - Given: Sf = 0.03 G^2/Hz
      - Given: Fragility level = 10 g's

RANDOM VIBRATION

DETERMINING SUITABILITY OF A PRE-SELECTED MOUNT WITH AN AIRBORNE EQUIPMENT PACKAGE

- WORK SHEET; 3b
  - Exercise: Determine Suitability of Pre-Selected Mount (S series)
    - Solution:
      - Calculate G_{RMS}: G_{RMS} = 1.15 G's
    - Probability theory indicates that there is a 0.3% chance of exceeding a 3 G_{RMS} acceleration level. A 3 G_{RMS} level is 3.45 G's as compared with the fragility level of 10 G's so the design is considered quite safe.

BARRY CONTROLS

RANDOM VIBRATION

DETERMINING SUITABILITY OF A PRE-SELECTED MOUNT WITH AN AIRBORNE EQUIPMENT PACKAGE

- WORK SHEET; 3c
  - Exercise: Determine Suitability of Pre-Selected Mount (S series)
    - Solution (cont.):
    - However, further calculation shows that the response displacement is:
      - $9.8\ G_{RMS}/fn^2 = 9.8(1.15)/49 = 0.23$ inches

      and that a deflection capability of 3 times that or 0.69 inches is required. Since the S mount does not have this deflection capability an alternative mounting solution must be sought. In all probability, a custom solution will be required for this application.