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SIGNATURE *J. M. Proietti for*
 R. L. Chandler, RDT Standards Writer

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RDT Standard

DESIGN BASIS FOR FUEL
AND IRRADIATIONS
EXPERIMENT RESISTANCE TO
SHOCK AND VIBRATION IN
TRUCK TRANSPORT

FEBRUARY 1975

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DESIGN BASIS FOR FUEL AND IRRADIATIONS EXPERIMENT RESISTANCE TO SHOCK AND VIBRATION IN TRUCK TRANSPORT

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DESIGN BASIS FOR FUEL AND IRRADIATIONS EXPERIMENT RESISTANCE TO SHOCK AND VIBRATION IN TRUCK TRANSPORT

1. SCOPE

This standard specifies minimum design values for shock and vibration in highway transport, by truck or tractor-trailer, for fuel and irradiation experiments when package weight exceeds one ton. Shock values correspond to normal transport over rough roads and to minor accidents causing only body damage to the vehicle. Vibration values correspond to normal transport; any large amplitude vibration resulting from a minor accident is treated as shock. The standard includes recommended methods of application to the design of packaging and tiedown systems.

1.1 Applicability. This standard is applicable to evaluating effects of shock and vibration during truck transport of packages weighing more than one ton and containing fuel and irradiations experiments. These may include unirradiated fuel pins and subassemblies, instrumented test trains, and other devices with fissile or radioactive content. The standard is intended for application in cases where damage in shipment would cause unacceptable cost penalty or programmatic delay.

2. APPLICABLE DOCUMENT

The following document is part of this standard to the extent specified.

2.1 RDT Standard.

RDT F 8-11T Fuel Shipping Container Tiedown for Truck Transport

3. DEFINITIONS

3.1 Truck. A single-chassis vehicle or a tractor-trailer combination.

3.2 Package. The container or cask which is attached to the vehicle for transport, including the contents. It specifically includes fuel elements and fuel assemblies in addition to the outer packaging in which the material is shipped.

3.3 Air Suspension. Air suspension is available on tractors, trailers, and single-chassis trucks. A tractor-trailer combination in which the trailer is of the air-suspension type and the tractor is of the "Velvet-Ride" type is considered an air-suspension vehicle. When either the tractor or the trailer is spring-mounted, the combination is considered spring-mounted. For a "Velvet-Ride" single-chassis vehicle, the shock and vibration values for spring mounting are assumed.

3.4 Amplitude. Amplitude of vibration designates either maximum acceleration or maximum displacement, depending on the context. For sine wave or simple harmonic vibration, the maximum displacement from the mean is given by Equation 1:

$$X_m = \frac{A_m}{(2\pi f)^2} \quad (1)$$

where

X_m = maximum displacement (ft)
 A_m = maximum acceleration (ft/sec²)
 f = frequency (Hz).

If acceleration is expressed as number (N) of g's so that $A_m = N$ times g, the X_m is approximately $0.8 N/f^2$.

3.5 Damping. Damping is resistance to vibration which causes the vibration wave to decay after a shock and which limits the amplitude of response to forced vibration input. The resistance may be present in various forms, including internal friction. For a spring-mass system, the degree of damping is commonly expressed as a fraction of critical damping, which, in turn, is defined as two times the square root of the quantity (spring rate times mass). The inherent resistance of mechanical systems, including shipping containers and contents, is nearly always at least 3% of critical damping and usually more than 5%.

The symbol ζ (Greek zeta) is used for fraction of critical damping.

3.6 Gaussian Probability Distribution. The density function is given by Equation 2:

$$P(x) = \frac{1}{\sqrt{2\pi} \sigma} \exp \left[-\frac{1}{2} \left(\frac{x}{\sigma} \right)^2 \right] \quad (2)$$

where

$P(x)$ = density function
 x = random acceleration amplitude
 σ = standard deviation (which for this distribution is the root mean square value).

3.7 Rayleigh Probability Distribution. The density function is given by Equation 3:

$$P(x) = \frac{x}{\beta^2} \exp \left[-\frac{1}{2} \left(\frac{x}{\beta} \right)^2 \right] \quad (3)$$

where

β = the most probable value of x or the mode of the distribution.

3.8 Instantaneous Vibration. If the vibration trace, with amplitude as the ordinate and time as the abscissa, is analyzed for frequency (i.e., a specified frequency is a frequency range of small band width), and, further, if any given amplitude is considered a barrier, then for a given frequency, the number of instantaneous vibrations of given amplitude during a selected time interval is the number of times the trace crosses that barrier. This is not equal to twice the number of peaks exceeding the amplitude because between an upward crossing and the next downward crossing there may be many peaks whose valleys are all above the specified amplitude.

4. DESCRIPTION OF DATA

Magnitude of shock and amplitude of vibration are given in terms of acceleration experienced by the bed of the truck.

The shock wave is approximately sinusoidal and rapidly decaying. Duration of the pulse is given for a full wave rather than a half wave because, for the type of shock being considered, there is no net change of velocity or of displacement in the reference frame.

The instantaneous vibrations with amplitude as the variable are found to have a probability distribution which is approximately Gaussian or normal. The design values for the 3-sigma limits of this distribution are given in 6.1. The number of peaks exceeding a given amplitude is influenced by the spectrum, but generally has a distribution between the Gaussian and the Rayleigh, with the latter being the limiting case for an idealized situation (see 8.1). Usually more than 99% of the peaks fall within the 3-sigma limit given in 6.1. Infrequent peaks of greater amplitude at any frequency are considered to be shock.

5. SHOCK ENVIRONMENT

5.1 Primary Response of Vehicle Bed. The minimum design values for shocks at the bed of the truck in normal transport and minor accidents are given in Table 1. The acceleration pulse is considered to be one complete cycle of simple harmonic motion with any duration up to 0.5 second. This duration with 2 g maximum corresponds to about ± 5 -in. displacement of the

bed relative to the suspension system, because in normal transport the force on the bed is applied through the suspension system.

Table 1. Peak Shock Accelerations

Direction	Acceleration (g)	
	Spring Mounted	Air Suspended
Vertical up	3	2
Vertical down	2	1.5
Longitudinal	2	1.5
Lateral	1	1

5.2 Package Response. Acceleration of the package or parts thereof in response to shock depends on the natural frequency and on the time duration and shape of the shock pulse. Analysis of data from actual shock events (see 8.2) yields the values shown in Table 2 for 3% of critical damping and for the vertical axis when the package (or some part) is free to vibrate at the natural frequency shown.

Table 2. Response to Shock

Natural Frequency of Package or Part (Hz)	Maximum Vertical Response (g)	
	Spring Mounted	Air Suspended
2	3	2
3	5	3
4-12	7	4
>12	10	6

Similar analysis is not available for the horizontal axes; however, response acceleration is approximately proportional to the input acceleration so that 100% of the vertical values may be assumed for the longitudinal axis and 50% of the vertical values may be assumed for the lateral axis.

For damping greater than 3% of critical, the response may be taken as inversely proportional to the 0.2 power of ζ for values of ζ up to approximately 0.25 (see 8.2).

6. VIBRATION ENVIRONMENT

6.1 Bed of Truck. Design values for the 3-sigma limits of amplitude for all frequencies from 1 Hz to 500 Hz are:

Spring-mounted truck	0.5 g
Air-suspension truck	0.3 g

These values are based on observations for the vertical axis. Vibration in the horizontal plane is normally less severe; hence the same values are conservatively recommended for the longitudinal and lateral directions.

Frequencies less than 1 Hz with amplitudes as great as the design values are rarely if ever encountered because of restrictions of the suspension systems. From limited data, a design value of 1 g is specified and appears conservatively high for frequencies greater than 500 Hz.

6.2 Package Response. Vibration of any part of the package whose vibration input is that of the bed of the truck depends on the natural frequency and degree of damping for that part. If the vibration input were at the resonant frequency f_n and of fixed amplitude g , the response would be the same number of g 's for all values of f_n . The random input of normal transport results in a response which is greater at higher frequencies (see 8.3). This response is approximated by Equation 4:

$$g_{\text{response}} = g_{\text{input}} \sqrt{\frac{\pi f_n}{4\zeta}} \quad (4)$$

For the 3-sigma limits of input given in 6.1 for f_n from 1 Hz to 500 Hz, and for $\zeta = 0.03$, this reduces to:

$$g_{\text{response}} \sim 2.5 \sqrt{f_n} \text{ for spring-mounted truck}$$

$$g_{\text{response}} \sim 1.5 \sqrt{f_n} \text{ for air-suspension truck.}$$

7. APPLICATION OF DATA

7.1 Shock. The maximum shock is an infrequent occurrence which the shipment must withstand. Forces which are transmitted to the package or contents may be greater or less than those corresponding to acceleration at the bed of the truck, depending on the method of mounting and other mechanical features. For example, a flexible mounting could attenuate the acceleration or it could cause a magnified response; a floating attachment with fixed stops could cause a secondary shock greater than the primary shock.

The package shall be rigidly attached to the vehicle, unless there are special considerations (such as thermal expansion) necessitating vibration mounts or a flexible or floating attachment. In all cases to the extent

applicable, RDT F 8-11 shall be complied with. When the package is rigidly attached, as for example in the tiedowns described in RDT F 8-11, the shock of the vehicle bed is transmitted directly to the package contents. Any component which is free to deflect and thus to vibrate, and which would not satisfactorily withstand the amplitude of vibration determined in accordance with 5.2, shall be provided with suitable shock isolation, damping or restraint.

When the package is supported on vibration mounts, the entire package shall be considered to experience the response shown in 5.2. In this case, the response of the package is the input for the contents. Because of complexity of the system and incompleteness of input data, available experimental evidence and analytical techniques may not be adequate for evaluation of the secondary response of components which are free to vibrate; in such cases, the matter shall be referred to the purchaser for consideration of the need for tests or design modification.

Maximum shock values in the three principal directions can occur almost simultaneously. However, if for calculation of stresses the maximum inertial loads based on the accelerations of 5.2 are conservatively applied as static loads, the different directions may be considered to be independent.

7.2 Vibration. Fatigue effects of the random vibration can be approximated by a constant input amplitude of 75% of the 3-sigma limit (see 8.4). Thus for assessment of impairment of strength or fatigue failure, a constant input not less than 75% of the 3-sigma limit of 6.1 shall be assumed at the natural frequencies of those parts of the package of concern, and for the expected period of transport. For calculative assessment, response as shown in 6.2 shall be taken into account for determination of the need for additional damping or vibration isolation. A value of 0.03 for ζ shall be assumed unless there is a basis for a higher value.

Response data are not available for parts which (because they are attached to other vibrating parts) do not have a direct input from the bed of the vehicle. In such situations, calculative assessment is not feasible and experimental techniques or actual transport tests should be applied as needed.

8. REFERENCES

The first four references refer to specific items in this standard. The remaining references are provided to supply the user with additional background information.

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