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DATA COLLECTION STANDARDS

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ISTA's requirements for measuring:

ATMOSPHERIC

SHOCKS/IMPACTS and DROPS

VEHICLE VIBRATION

The International Safe Transit Association (ISTA), through the help of industry subject matter experts, has established a set of distribution environment hazard data collection standards (DCS) for use in conjunction with the development of ISTA testing protocols. Ensuring that field data is captured in a consistent and meaningful manner is important in creating laboratory tests which reasonably and efficiently simulate real-world distribution hazards. Therefore, the objective of these standards is to create transparency into the type of data leveraged for the creation and maintenance of ISTA testing protocols, and to provide the ISTA community guidance on the measurement and collection of field data as needed.

ISTA also hopes these standards will encourage members of our community to collaborate with ISTA in growing our data warehouse and accelerating our global effort to optimize packaging for transit advancing both the environment and commerce.

We anticipate that the development of technology and alternative means of data collection will drive the need for these standards to be maintained and updated. As such, the DCS are intended to be living documents that will evolve over time. As part of this continued evolution, ISTA welcomes feedback from a broad audience. If you are a subject matter expert in one of these areas and would like to get involved in the future revisions, please reach out to ista@ista.org.

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DATA COLLECTION STANDARDS

ATMOSPHERIC

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Introduction

This document details ISTA's standard for measuring atmospheric conditions occurring in transport. The objective is to collect data that can be used in creating laboratory tests that reasonably and efficiently simulate real-world transportation atmospheric conditions. Data collection parameters for the following atmospheric elements are specified below:

1. Temperature
2. Pressure (Altitude) Environments[1]
3. Relative Humidity[2]

Document Scope

In scope items for this process guide are:

- Establishment of risk based thermal profiles
- Data gathering of ambient temperature and pressure data to create thermal profiles

Equipment

Recording equipment should be within manufacturer's calibration specifications. This is assured either by obtaining the Calibration or Certificate of Calibration or independent calibration to an NIST standard. The maximum recommended time interval for recording data is 30 minutes. Table 1 further specifies the recommended instrument recording parameters.

Parameter	Requirement	
Calibrated Accuracy:[3]	• Temperature: ○ ±1 °F (±0.5 °C) ≥ 0 °F (-18 °C) ○ ±1.8 °F (±1.0 °C) < 0 °F (- 18 °C) • Pressure: ± 3mbar • Relative Humidity: ±3%	
Range (Min/Max):[4]	**Typical -** Min -40°F (-40°C) & Max 160°F (71 °C) **Extreme -** Extreme altitudes may require a wider recording range	
Sample Recording Rate:[5]	Recommended	Maximum
	15 minutes (temperature, pressure, humidity)	30 minutes (temperature, pressure, humidity)
Date & Time Stamp	Required For Each Recorded Event	

Methodology (Documentation of Measurement Project and Variables)

It's important to understand the original intent of the measurement project as this helps with the review and analysis of the resulting data. The instrument setup, mounting, vehicle, vehicle lading, and other details must be thoroughly documented as they have direct impact on any resulting summary analysis and potential end-use of the environmental data.

- Project purpose (what are you trying to learn?)
- Instrument(s) used and their detailed setup(s)
- Vehicle routes (origin, destination, routing or service level, GPS tracking is strongly recommended)
- Data recorder calibration information
- Placement and placement orientation
- Vehicle and vehicle lading
- Photographs showing all aspects

Methodology (Instrument Placement)

Depending on the project, placement of the temperature recorders may or may not be within the scope of the project. Dedicated point-to-point shipments may give the practitioner the ability of selecting specific locations. For other projects, such as parcel, the placement will be on or as close to the surface of the shipper as practical. In some cases, transport vehicles have known locations where the environmental conditions are of comparably higher overall intensity. If that location is known, that's where the data recorders should be mounted. If that location is unknown as in parcel networks, multiple shippers used on separate shipments may be used in an effort to quantify the variability. Note that for conventional tractor-trailers and sea containers, the most severe environmental conditions are typically experienced near the ceiling and at the floor in the front and rear of the vehicle. Additionally, when possible, capturing external environmental data could be beneficial during analysis. The external data enables an understanding of correlation between outside conditions and inside the package and/or transport vehicles.

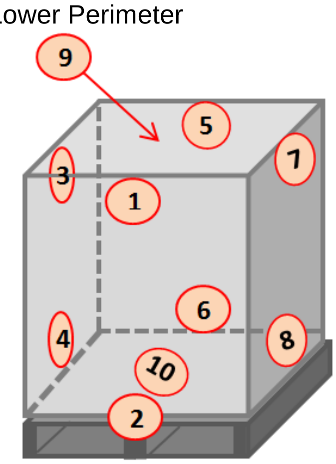
Pressure recorders may be placed within the package. Redundant recorders may be appropriate, but complete data from one recorder will reflect the entire shipment.

Individual Package: (non-dedicated shipment)

- **Locations**:
  - The sensor should be as close to the outside of the package as possible.
- **Number of Units & Locations:**
  - Minimum of One (1) sample[6]
  - Suggestion – Utilize two (2) or more units within the individual package. Redundancy ensures information capture during unforeseen issues. Recommended placement for two units would be one on the highest surface and one on the lowest surface.

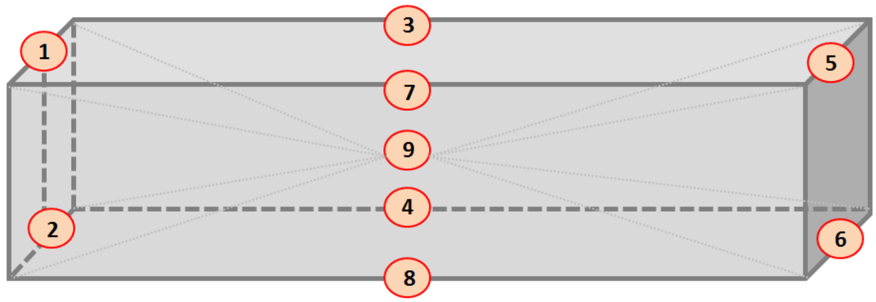
Unit Load: (non-dedicated shipment)

- Locations: Centered within the Unit Load, Upper Perimeter & Lower Perimeter
- Number of Units:
  - Minimum Three (3) - Centered (left to right) on the front vertical wall with one sensor at the highest location (near the ceiling – location 5) and one sensor at the lowest location (near the floor – location 6) & Centered (left to right) on the rear vertical wall (cargo doors) with one sensor at the highest location (near the ceiling – location 1) and one sensor at the lowest location (near the floor – location 2)



Inside a Vehicle: (dedicated shipment)

- **Number of Units & Locations:**
  - Minimum Four (4) - Centered (left to right) on the front vertical wall with one sensor at the highest location atop the pallet. (near the ceiling – location 5) and one sensor at the lowest location (near the floor – location 6) & Centered (left to right) on the rear vertical wall (cargo doors) with one sensor at the highest location (near the ceiling – location 1) and one sensor at the lowest location (near the floor – location 2)



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[1] Collecting Environmental elements beyond Temperature such as **Pressure (Altitude)** could be of interest in some parcel situations where parcels are known to be placed in an unpressurized feeder aircraft. If products or packaging materials are not susceptible to pressure and / or it is known that the parcel will not be placed into an unpressurized feeder aircraft then known pressure elements could be used such as commercial air transport has an 8,000 foot pressure limit and in North America trucks traveling over the Loveland Pass in Colorado will experience an altitude of 11,990 foot.

[2] Collecting Environmental elements beyond Temperature such as **Humidity** could be of interest to understand the effects it has on product characteristics and packaging performance such as the ability to compromise strength of corrugated board. Humidity however, for some products has shown to not be an issue such as drug products either tablets or capsules because of the rigorous testing requirements for primary container/closure systems (40C/75%RH for 3 months) or in the case of injectables that are in glass or highly impermeable plastic. Understanding the characteristics of the packaging and product in question are critical and if unknown, it is advisable to gather data on this environmental element for testing within a laboratory.

[3] Current Industry Best Practice

[4] Army Regulation (AR 70-38) "RESEARCH, DEVELOPMENT, TEST AND EVALUATION OF MATERIEL FOR EXTREME CLIMATIC CONDITIONS"

[5] In the past, excel files (.xls) had a limit of 65.536 lines and this was one of the reasons to not collect the T and RH information each minute, taking as example a trip of 30 days if was collected the information each minute we would have 43.200 points very close to the excel limit. In the new format ".xlsx" (excel 2007, 2010 and 2013) the number of lines increased to 1.048.576, but the problem still persisted due to the data loggers use the format csv and when exported to excel. The software will split the data between the sheets, each 65.536 lines and it will be a lot of work to handle with this data.

The other reason is that the data will need to be paired down to accommodate climatic chamber software & memory limitations. It is concerning to have equipment trying to modify the temperature each minute during several days, take in consideration the maintenance required after a few months of usage.

A third reason would be the memory of the data logger(.cvs), they will be full very quickly if you collect in each minute. A common limit of the equipment is 16.382 readings, this is not a coincidence with the .xls excel limit, the first two lines usually are used for text information.

Using this data logger collecting the information each minute they will be full in 11 days. If we increase the data collection to each 5 min the memory will take now 56 days to be full and stop recording.

[6] ISTA 7E Thermal Lane Study – Six (6) data loggers were used in the collection of data for the ISTA 7E thermal profiles and through analysis of this data showed that one (1) data logger is sufficient as there was no significant difference between all 6 sides**.**

ista DATA COLLECTION STANDARDS

SHOCKS/IMPACTS and DROPS

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Introduction

This document details ISTA's requirements for measuring **Shocks/Impacts and Drops** occurring during distribution. The ISTA Technical Division acknowledges that there can be an overlap when recording and analyzing low intensity shocks vs. high intensity vibration. The objective of this DCS is to collect data and record responses to environmental stimuli that can be used in creating laboratory shock tests which reasonably and efficiently simulate real-world distribution shocks. If your intent is to study the low intensity shock inputs by attaching recording equipment fixed to the vehicle or device being recorded you should reference the Vibration DCS.

Documentation of Measurement Project and Variables

It's important to understand the original intent of the measurement project as this helps with the review and analysis of the resulting data. The instrument setup, mounting, vehicle, vehicle lading, and other details must be thoroughly documented as they have direct impact on any resulting summary analysis and potential end-use of the shock data.

- Instrument(s) used and their detailed setup(s)
- Data recorder calibration information
- Mounting and mounting orientation
- Related equipment
- Vehicle and vehicle lading
- Vehicle routes, speeds, road/rail/air conditions, etc.
- Photographs showing all aspects
- Project intent (what are you trying to learn?)
- Additional Considerations with Rail Switching
  - "Bullet" Car
    - Type, suspension, draft gear
    - Lading, blocking and bracing
    - Recorder mounting
    - Impact speeds
  - "Target" Car
    - Type, suspension, draft gear
    - Lading, blocking and bracing
    - Brakes on or off
    - Slack pushed or pulled
- Additional Considerations with Pallet Marshaling
  - Lift truck type, weight capacity, configuration
  - Pallet type, condition
  - Load, weight, configuration, unitization method
  - Impact speeds
  - Obstacles types and details
  - Angles of impact

Documentation of Measurement Project and Variables - Continued

It is critically important to have enough data to support a robust statistical analysis. Significant drops and impacts during distribution are largely unpredictable – some shipments may experience few and/or low-severity shocks, while others may experience quite high numbers and levels. There must be enough data to statistically determine what might be "typical" for a substantial majority of situations.

Also, since it may be difficult to accurately calculate "Equivalent Free-Fall Drop Height" (EFFDH) or damage potential from an acceleration-vs.-time record, a large quantity of data will help to ensure that any individual data point with its inherent uncertainty will have a reduced influence on the overall conclusions reached. A minimum of 30 one-way trips is recommended for each set of variables to be explored, and of course more trips produce higher confidence. Additionally, in trying to determine the "typical" pulses for lab simulation, it is important to perform at least several tests under each set of variables and conditions.

Instrument Mounting

The ideal situation is to mount a field data recorder solidly near the impact point. It is important to remember that any structure between the instrument mounting location and the location best representing dynamic inputs could adversely affect the data.

For means of gathering drop data, it is important to solidly mount the recording device in a shipping container that is comprised of a non-resonant structure. Typically, the test package consists of an outer corrugated box, resilient interior cushioning, and non- resonant wood or metal structure "simulated product" with the recorder mounted at its center.

Mounting the recorder on or inside an actual product may result in undesired "noise" (from responses of product components) on the data. It is important to know the coefficient of restitution of the package when dropped, for use in subsequent data analysis. This can be determined from laboratory drop tests. The package coefficient of restitution may change when impact orientation and drop height level change. So, the package coefficient of restitution should be measured and reported for various impact orientations and drop heights.

Instrument Recording Setup – Shock/Impact

The measurement of shock pulses requires an instrument that records full-waveform events and is capable of capturing a sufficient amount of time to contain the entire pulse. Sampling rate should be done fast enough so that it is relative to the pulse duration and characteristics. This will enable an accurate picture of the entire pulse. It is also important to level triggering with pre-trigger recording as well as to date & time stamping every pulsed recorded.

Acceleration peaks can exceed 200g for severe conditions and can be as low as around 1 g (average) for cushioned rail car impacts. Significant frequency content can be as low as 0.5 Hz. and extend to 500 Hz. or more. Additionally, pulse durations can range from under 10 msec. for pallet marshaling to over 600 msec. for cushioned rail car impacts. To cover these extremes and provide data necessary for the creation of laboratory simulation tests, a recorder must be capable of the following setup conditions and parameter ranges. Narrow ranges are acceptable if only one application (rail switching or pallet marshaling) is being captured.

Instrument Recording Setup – Shock/Impact - Continued

Instrument setup requirements are as follows:

Instrument Setup – Shock/Impact								
Event Recording	Event Record Time	Date & Time Stamp	Acceleration Range	Pre-trigger record time	Signal Trigger Level	Low-Pass Filtering	Sampling Rate	Frequency Response
Full-waveform	20 msec. to 2000 msec.[1]	Each recorded event	10 g or less to 200 g[2] or greater	20% of event duration[3]	0.1 g or less[4]	20 Hz to 500 Hz[5]	2000 samples/ sec./ channel or greater[6]	0.5 Hz[7] to 500 Hz

- Signal trigger recording:
    - Memory Allocation - 85%
    - Signal Pre-Trigger – 20%
    - Data Retention Mode – Max Overwrite

Instrument Recording Setup – Drop

There are many similarities to the Shock/Impact application for Drop application. Both applications utilize measurement of acceleration verses time pulses. The biggest difference is that drop height is not measured directly but rather it is calculated from acceleration information. The desired data should be analyzed in the terms of "Equivalent Free-Fall Drop Height" (EFFDH).

The measurement of shock pulses requires an instrument that records full-waveform events and is capable of capturing a sufficient amount of time to contain the entire pulse. Sampling rate should be done fast enough so that it is relative to the pulse duration and characteristics. This will enable an accurate picture of the entire pulse. It is also important to level triggering with pre-trigger recording as well as to date & time stamping every pulsed recorded.

Shock pulses to be measured can range from under 10g to over 100g in amplitude, and from under 10 msec. to over 50 msec. in duration, depending upon the design and performance of the test package. To cover these extremes and provide data necessary for the creation of laboratory simulation tests, a recorder must be capable of the following setup conditions and parameter ranges (narrower ranges may be workable for specific situations).

Instrument setup requirements are as follows:

Instrument Setup - Drop								
Event Recording	Event Record Time	Date & Time Stamp	Acceleration Range	Low-Pass Filtering	Pre-Trigger Record Time	Signal Trigger Level	Sampling Rate	Frequency Response
Full-waveform	500 msec. to 2000 msec.[1]	Each recorded event	Up to 200g [1]	20 Hz to 250 Hz[8]	0.5 sec or greater [1]	0.1 g or less[1]	2000 samples/ sec./ channel or greater[1]	2 Hz[1] to 500 Hz

- Signal trigger recording:
    - Memory Allocation - 85%
    - Signal Pre-Trigger – half second or more before the pulse, to permit evaluation of pre-impact motions
    - Data Retention Mode – Max Overwrite

- Additional recording requirements:
    - A minimum of 30 one-way shipments are required.[9]

Shock/Impact Information and Examples[1]

Example 1 – Measurement of Pallet Marshalling Shock Pulses

A field data recorder is mounted solidly to the structure of a pallet. The pallet is loaded with packaged-products in a typical unitized configuration. This test item is handled with a fork lift and is "bumped" into various obstacles.

Possible Variables: Type of fork lift, type of pallet, type of load on pallet, unitization method, fork lift speeds, obstacles (other pallets, poles, solid walls.), angles of impact, etc. Document all variables for each recording.

Descriptions/Photos/Videos: Recorder mounting and mounting orientation, fork-lifts, pallets, loads, speeds, obstacles. Videos of typical test runs could be extremely valuable.

Instrument Recording Setup

The setup can vary according to specific conditions, but the following represents a reasonable starting point. It is recommended that a few preliminary tests under each set of conditions be conducted and analyzed to arrive at an optimum setup.

- Acceleration range: 50g
- Event record time: 50 msec.
- Threshold triggering from data
- Trigger level: 2 g
- Pre-trigger record time: 10 msec.
- Sampling rate: 2000 samples/sec./channel
- Low-pass filter cutoff frequency: 500 Hz.

Data Reporting

- Full-waveform display of each shock pulse with peak g, duration, and velocity change
- Test conditions (description of variables) for each shock pulse
- As appropriate, determination of "typical" shock pulses for each set of conditions and variables

Example 2 – Measurement of Railcar Coupling Impacts

A field data recorder is mounted solidly to the floor or base structure of a railcar, near the end to be impacted. The car is loaded with product in a typical configuration. The car is then coupled to other cars at varying speeds.

Possible Variables: Type of rail car, car's draft gear type (standard, cushioned), lading (weight, type, blocking/bracing), coupling speeds, type and condition of impacted car (type of car, draft gear type, lading, brakes on/off, slack pulled/pushed), etc. Document all variables for each recording.

Descriptions/Photos/Videos: Recorder mounting and mounting orientation, railcars, lading, conditions, etc. Videos of typical test runs could be extremely valuable.

Instrument Recording Setup:

The setup can vary according to specific conditions, but the following represents a reasonable starting point for cushioned draft gear cars. It is recommended that a few preliminary tests under each set of conditions be conducted and analyzed to arrive at an optimum setup.

- Acceleration range: 20g
- Event record time: 1500 msec.
- Threshold triggering from data
- Trigger level: 1 g (see Appendix D)
- Pre-trigger record time: 200 msec.
- Sampling rate: 500 samples/sec./channel
- Low-pass filter cutoff frequency: 100 Hz.

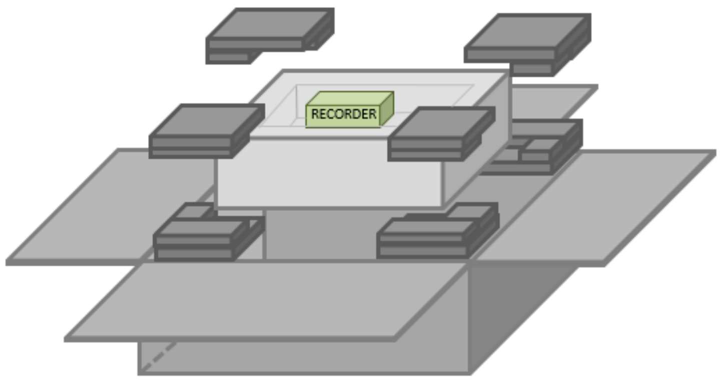
Example 2 – CONTINUED

Data Reporting:

- Full-waveform display of each shock pulse with peak and dwell g, duration, and velocity change
- Test conditions (description of variables) for each shock pulse
- As appropriate, determination of "typical" shock pulses for each set of conditions and variables

Drop Information and Example

A field data recorder is mounted solidly to the structure of a rigid and non-resonant simulated product, which is placed in a cushioned package, or placed inside a rigid, cushioned container. Although there are many possibilities, below is a configuration which has been used successfully.



The package is shipped by various carriers, routes, and levels of service.

Possible Variables: Package configuration, size and weight of package, package markings, handling methods and situations, carriers, routes, levels of service. Document all variables for each shipment.

Descriptions/Photos: Recorder mounting, all details of simulated or dummy package, package markings. The package coefficient of restitution should be measured and reported for various impact orientations and drop heights.

Drop Information and Example - Continued

Instrument Recording Setup

The setup can vary according to specific conditions and package configurations, but the following represents a reasonable starting point. It is recommended that a few preliminary tests (perhaps in the laboratory) be conducted and analyzed to arrive at an optimum setup.

- Acceleration range: 100g
- Event record time: 1200 msec.
- Threshold triggering from data
- Trigger level: 5 g (see Appendix D)
- Pre-trigger record time: 800 msec.
- Sampling rate: 2000 samples/sec./channel
- Low-pass filter cutoff frequency: 500 Hz.

Example 2 – CONTINUED

Data Reporting

- Availability of full-waveform display of each shock pulse, 3-axis
- Calculated drop height for each significant event and method of calculation, separated by one-way trips
- Orientation at impact for each significant event, and method of calculation
- Number of significant events for each one-way trip

Notes on Threshold Triggering from Data

The selection of a triggering level (threshold) is important. If set too high, large events (usually of great interest) may be missed. If set too low, measurement "noise" and/or unwanted data may record – at the very least a nuisance to be addressed, and at the worst filling instrument memory with useless information. Trigger level can often determine the *amount* of data which will be recorded.

The trigger level recommendations given in this document are generally good starting points, but should be evaluated based on specific situations. It is always recommended that instrument setups be verified with a limited number of preliminary tests before beginning a large-scale measurement project, and this is particularly true of triggering level. Additional details are given below.

Example 1 – Measurement of Pallet Marshalling Shock Pulses

Set the trigger level *high* enough so that normal fork lift movement, without the load being "bumped" into the various obstacles, does not cause event recording.

Set the trigger level *low* enough so that the most gentle "bump" (lowest fork lift speed, softest obstacle, most flexible pallet, etc.) is properly recorded.

Example 2 – Measurement of Railcar Coupling Impacts

Set the trigger level *high* enough so that normal railcar movement, prior to the coupling impact, does not cause event recording.

Set the trigger level *low* enough so that the gentlest coupling impact (lowest car speed, softest cushioned draft gear, softest configuration of impacted car, etc.) is properly recorded.

Note: since normal car movement may involve accelerations of 0.1g or more, and cushioned draft gear impact pulses may be only 1g or less, the trigger level may need to be set very precisely.

Drop Determination

Set the trigger level *high* enough so that package movement *without* significant drops/impacts (transport vibration, conveyors, carts, etc.) does not cause event recording.

Set the trigger level *low* enough so that the most gentle drops/impacts desired (often defined as drops or equivalent drops above a few inches or centimeters) are properly recorded.

Note: The design of the cushioned package determines what accelerations are transmitted to the recorder. Stiff cushions will transmit higher accelerations and will require higher trigger levels; softer cushions will transmit lower accelerations and will require lower trigger levels.

[1] Recommendation sited from Field Data Acquisition and Basic Requirements by Bill Kipp, September 2009.

[2] 200g is a high enough acceleration range to accurately capture high level Shock/Impact events while also maintaining the fidelity and resolution to accurately represent the low level events.

[3] Reasoning for level here

[4] A signal trigger level of 0.1g or less allows the data recorder to capture data anytime the targeted transport vehicle is in motion.

[5] Recommendation sited from Field Data Acquisition and Basic Requirements by Bill Kipp, September 2009.

[6] Sampling rate should be at least 2.5x the maximum frequency.

[7] Long duration pulses may have rectangular shapes and an issue of "droop" during recording can occur. To limit "droop" errors to about 10-15%, utilize $F_{LC} \leq 300$ / Pulse Duration. Approximate Fundamental Frequency = 300 / 600 msec. = 0.5 Hz

[8] Recommendation sited from Field Data Acquisition and Basic Requirements by Bill Kipp, September 2009.

[9] Recommendation sited from Analysis of Field Shock/Drop Data and Creation of Laboratory; Bill Kipp, October 2009.

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DATA COLLECTION STANDARDS

VEHICLE VIBRATION

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Introduction

This document details ISTA's requirements for measuring vibrations generated by transport vehicles. It does not relate to measuring response vibrations experienced by packed-products inside the transport vehicle. The objective is to collect data that can be used in creating laboratory vibration tests which reasonably and efficiently simulate real-world transportation vibrations. Data collection parameters for the following vibration simulation techniques are specified below:

1. ISTA (General Simulation)
2. Kurtosis Control
3. Modulated Intensity
    a. Statistical Vibration Synthesis (SVS)
    b. Constructed Probability Spectra (CPS)

Documentation of Measurement Project and Variables

It's important to understand the original intent of the measurement project as this helps with the review and analysis of the resulting data. The instrument setup, mounting, vehicle, vehicle lading, and other details must be thoroughly documented as they have direct impact on any resulting summary analysis and potential end-use of the PSD Spectra.

- Instrument(s) used and their detailed setup(s)
- Data recorder calibration information
- Mounting configuration, mounting location, and mounting orientation
- Vehicle type and vehicle lading (especially number of axles, suspension type, gross vehicle mass limit, payload mass, vehicle dimensions (length, wheel base, load dimension and location))
- Vehicle routes (map detailing speeds, road types, road/rail/air conditions, and transport modes)
- Photographs showing relevant aspects. (vehicle and instrument mounting)
- Project intent (what are you trying to learn?)

Instrument Mounting

The ideal situation is to mount a field data recorder solidly to the vehicle chassis. When not possible the field data recorder should be mounted to the vehicle floor where it meets the chassis of the vehicle to be measured. If this is not possible, then the recorder should be mounted to an intermediate fixture with resonant frequencies well above the recorded frequency range of interest and directly and firmly mounted to the floor or frame structure. Avoid mounting the sensor on thin or light components of the vehicle. It is not possible to adequately measure vehicle vibrations with a recorder mounted in a package.

In some cases, transport vehicles have known locations where the vibration is of comparably higher overall intensity. If that location is known, that's where the data recorders should be mounted. If that location is unknown, multiple data recorders should be used in an effort to identify worst-case conditions. Note that for conventional, single tractor-trailers, the most severe vibration is typically experienced in the extreme rear of the trailer.

Instrument Recording Setup

Modern field data recording instruments have the ability to measure transit vibration through "time triggering" and/or "signal triggering". Time triggering wakes the data recorder at set intervals to record events of a user specified length. Signal triggering wakes the data recorder to record vibration events at a user specified acceleration level. Signal triggering at a low acceleration level (0.1g or less) requires a data recorder with large amounts of storage capacity for extended collection periods.

Acceleration peaks can exceed 20g for severe conditions. Significant frequency content can be as low as 1 Hz. and extend to 250 Hz. or more. To cover these extremes and provide data necessary for the creation of laboratory simulation tests, a recorder must be capable of the following setup conditions and parameter ranges. Instrument setup requirements are as follows:

Instrument Setup Parameters							
Event Recording	Event Record Time	Date & Time Stamp	Acceleration Range	Pre-trigger record time	Signal Trigger Level	Sampling Rate	Low-pass Filtering Cutoff
Full-waveform	2000 msec. or greater[1]	Each recorded event	50 g[2]	10% of event duration[3]	0.1 g to 0.5 g depending on trip duration[4]	500 samples/ sec./channel is absolute minimum. 1000 samples/ sec./ channel or greater is preferred[5]	1.6 x F_i[6]

- Signal trigger recording:
  - Memory Allocation - 50%
  - Signal Pre-Trigger – 50%
  - Data Retention Mode – Max Overwrite

- Time trigger recording:
  - Wakeup Interval – No more frequently than 1 sample every 60 seconds, except when recording shorter journeys when a more frequent sample rate maybe possible and preferable.[7]
  - Data Retention Mode – Fill Stop

Additional Considerations

1. Measuring single trips, or single routes may only provide a snap-shot - not a statistically valid measurement - of a target distribution environment
2. Multi-mode routes should not be treated as a single data set but should be analyzed by mode
3. High intensity events (e.g. where peak G values are >> 1) may be high frequency structural responses to load shift. These should be examined for frequency content (e.g. by examining the PSD for that event in question). A dominance of high frequency will suggest a response rather than an input and such events should be removed from the data set.

[1] Be aware that if you increase your frame duration you will reduce the number of recorded events and therefore affect the statistics of the overall spectrum and smooth out some transient events.

[2] 50g is a high enough acceleration range to accurately capture high level vibration events while also maintaining the fidelity and resolution to accurately represent the low level events.

[3] The lower the trigger the less the pre-trigger needs to be.

[4] A signal trigger level of 0.1g or less allows the data recorder to capture data anytime the targeted transport vehicle is in motion.

[5] Sampling rate should be at least 2.5x the maximum frequency. 200 Hz is typically the highest frequency found in today's industry standard PSD spectra. Historical measurements/studies have shown that a 500/samples/sec./channel sampling rate provides for analysis bandwidth that is appropriate for cargo transport vehicles/containers, such as trucks, railcars, and aircraft.

[6] The cut-off frequency of the low-pass filter is the frequency at which the signal is attenuated by 30% (-3 dB). It is therefore important to set the low-pass filter cut-off frequency to at least 1.6 times the highest frequency of interest (F_i) (no more than 5 % attenuation). For example, if the highest frequency of interest is 125 Hz, the low-pass filter cut-off frequency should be at least 1.6 x 125 = 200 Hz.

[7] The average PSD and rms distribution can be estimated with an uncertainty of ± 10% with data representing at least 3% of the journey length. Refer to Rouillard, V. & Lamb, M. (2008). On the Effects of Sampling Parameters When Surveying Distribution Vibrations. *Packaging Technology and Science*, *21*, 467-477 for further information.

Examples of the suggested approach for calculation are as follows:

1. Desired frequency resolution for the PSD: D_F (e.g. 1/2 Hz)
2. Duration of each event: $T_E=1/D_F$ (2 seconds)
3. Applying a minimum of 3% for the journey, the wake-up interval can be calculated as follows: $T_W=T_E/0.03$ (= 2/0.03 = 67 seconds)

1. Desired frequency resolution for the PSD: D_F (e.g. 1/4 Hz)
2. Duration of each event: $T_E=1/D_F$ (4 seconds)
3. Applying a minimum of 3% for the journey, the wake-up interval can be calculated as follows: $T_W=T_E/0.03$ (= 4/0.03 = 133 seconds)