COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS AND ON THE GLOBALLY HARMONIZED SYSTEM OF CLASSIFICATION AND LABELLING OF CHEMICALS

Sub-Committee of Experts on the Transport of Dangerous Goods

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MISCELLANEOUS PROPOSALS OF AMENDMENTS TO THE MODEL REGULATIONS ON THE TRANSPORT OF DANGEROUS GOODS

Impact testing of UN Portable tanks and MEGCs

Proposal to change Sections 6.7.2.19.2, 6.7.3.15.1, 6.7.4.14.1 and 6.7.5.12.1

Submitted by the expert from Canada

Background

The current requirements in the UN Model Regulations in relation to impact testing of portable tanks and MEGCs were adopted by the Sub-Committee in December, 1995 (ST/SG/AC.10/C.3/21/Add.1 and ST/SG/AC.10/C.3/22/Add.1). At that time, the Sub-Committee agreed that the Model Regulations would include a list of standards relevant to a “4g” impact test as an interim measure. For a permanent solution, it was the view of the Sub-Committee that reference to a single international standard in the Model Regulations would enhance consistency between test facilities throughout the world. The Sub-Committee noted that the ISO TC 104 Committee overseeing the ISO 1496-3 Standard on freight containers had convened a work group to consider incorporating an impact test for tank containers into that standard.

The list of standards on impact testing that appeared in the 10th edition of the Model Regulations remains unchanged in the 13th edition, except for the reference to the Canadian Standard. The new Canadian Standard adopted in the 13th edition, includes a completely new impact test protocol that is the subject of this paper.

Testing issues and developments

The ability of tank and MEGC containers transporting dangerous goods to withstand impacts encountered in the rail transport environment has been an ongoing concern for the Canadian competent authority. Requirements for impact testing have been included in the Canadian Transportation of Dangerous Goods Regulations for many years, certainly before 1995. Tank containers are forbidden from rail transport in Canada unless their capability to withstand impacts has been proven by testing. The “TC Impact Approved” mark is used to identify tank containers that are in compliance with a design that has been successfully tested at a test facility approved by the Canadian competent authority.

Tank container impact testing procedures involve subjecting a prototype container, loaded to maximum capacity, to an impact of prescribed severity. Following the test impact, verification for deleterious deformation of the container is carried out to determine if the design has passed or failed.

Ensuring that an impact of the required severity is consistently applied in testing has traditionally been a great challenge. Experience with other standards demonstrated that testing in different parts of the world was not being carried out with consistent impact severity. Vehicle speeds are not reliable in defining impact severity due to differences in railway coupler cushioning, while measured “g” loads can vary markedly depending on the way test data is sampled and on placement of the measurement devices (load cells) on the structure.

Between 1995 and 1998, the Canadian competent authority sponsored research and industry surveys to determine a reliable and universally applicable method for quantifying impact severity under test conditions. The method chosen as a result of these studies involves measurement of acceleration (rather than load) at the container corners. The collected acceleration vs time data for a test impact is then reduced mathematically to a plot called the “Shock Response Spectrum” (SRS). A test is considered valid if the SRS plot at least equals the minimum specified SRS severity. The National Standard of Canada CGSB 43.147-2002, now incorporates this new test protocol, and in the 13th edition of the UN Recommendations this standard replaced the previous Canadian impact test requirement.

Under the new protocol, the method of creating the impact is irrelevant. Impact forces may be created with the tank container mounted on a moving railway vehicle and impacting a stationary obstacle, or with the tank container stationary and being impacted by a moving mass of any kind. The test method is therefore applicable in any part of the world, regardless of railway vehicles with different running gear or indeed regardless of the impact method. As far as the impact severity, the minimum SRS severity reflects the severity that had been required by the previous Canadian standard (the CSA B620-87) that involved an impact from a speed of 12.8 km/h into a stationary string of railway vehicles (nominally “4g”).

The major rail impact test facilities in the world located in Canada, the United States, France and South Africa have been applying the SRS test protocol since 2001. The method is now well proven and has been improved with the benefit of this experience.

A single international standard

Canadian representatives proposed the SRS impact test method to the ISO TC104/SC2 and its working group 4. ISO deliberations on this matter began in 1996. Although the proposal was very favourably received, benefited from wide consultation and achieved consensus support, no standard has yet been published nor is it imminent.

While progress toward an ISO standard seems in danger of stalling, the pressing need for a single impact test protocol for tank containers and MEGCs, as identified by this Sub-Committee in 1995, remains. The documents listed in the current Model Regulations describe test methods that differ from one another in severity and therefore yield results that cannot be compared between methods. This situation is causing confusion for tank manufacturers and in some cases has caused manufacturers the burden of needless duplicate testing. In addition, the old test protocols suffer from the shortcomings that have been discussed and that the SRS method was developed to resolve.

Proposal for comment

The purpose of this paper is to ask the Sub-Committee for comments on the appropriateness of replacing the current text in sections 6.7.2.19.2, 6.7.3.15.1, 6.7.4.14.1 and 6.7.5.12.1 with a reference to the impact test protocol attached. The attached test protocol is consistent with the method in the National Standard of Canada, with the proposal under consideration by ISO, and is currently being applied by the world’s major impact testing facilities. It contains all improvements resulting from more than three years of use. The Expert from Canada is of the opinion that the test protocol should be included in the Manual of Tests and Criteria so that the reference in the sections mentioned above would be to the applicable section in the Manual..

Dynamic, longitudinal impact test for portable tanks and MEGCs

1. General

A representative prototype of each design of portable tank and MEGC meeting the definition of "container" under the CSC, shall be subjected to and shall satisfy the requirements of the dynamic, longitudinal impact test.

2. Permitted design variations

The following variations in container design from an already tested prototype are permitted without requiring additional testing:

(a) A decrease in the initial maximum design temperature;

(b) An increase in the initial minimum design temperature;

(c) A decrease in the maximum gross mass;

(d) A reduction in capacity resulting only from variations in diameter and length;

(e) A change of location or a modification to nozzles and manholes provided that:

  (i) an equivalent level of protection is maintained; and

  (ii) the most unfavourable configuration is used for the purpose of the tank strength calculations.

(f) An increase in the number of baffles and surge plates;

(g) An increase in wall thickness provided the thickness stays within the range permitted by the welding procedures specifications;

(h) A decrease of the maximum service pressure, maximum allowable working pressure, or maximum working pressure, as the case may be;

(i) An increase in the insulation system effectiveness from using:

  (i) a greater thickness of the same insulating material; or

  (ii) the same thickness of a different insulating material having better insulation properties.

(j) A change to the service equipment provided that the untested service equipment:

  (i) is located at the same place and meets or exceeds the same performance specification as the existing equipment; and

  (ii) is approximately of the same size and mass as the existing equipment; and

(k) The use of a different grade of the same type of material for the construction of the shell or frame, provided that

  (i) the results of the design calculations for the different grade, using the lowest specified values of mechanical properties of that grade, meet or exceed the results of the design calculation for the existing grade;

(ii) the alternate grade is permitted by the welding procedures specification; and

(iii) the alternate grade is compatible with the dangerous goods intended for transport.

3 Test apparatus

3.1 Test platform

The test platform may be any suitable structure having securing devices in accordance with ISO 1161, which is capable of achieving and sustaining without permanent damage the prescribed shock severity with the container-under-test mounted securely in place. The test platform shall be:

(a) configured so as to allow the container-under-test to be mounted as close as possible to the impacting end;

(b) fitted with 4 securing devices in good condition;

(c) equipped with a cushioning device providing a suitable duration of impact;

3.2 Impact creation

3.2.1 The impact shall be created by:

(a) the test platform striking a stationary mass; or

(b) the test platform being struck by a moving mass.

3.2.2 When the stationary mass consist of two or more railway vehicles coupled together, each railway vehicle shall be equipped with cushioning devices and any free play between the vehicles shall be eliminated. In addition, the brakes on each of the railway vehicles shall be set.

3.3 Measuring and recording system

3.3.1 Unless otherwise specified, the measuring system shall comply with ISO 6487.

3.3.2 The following equipment shall be available for the test:

(a) Two accelerometers with a minimum amplitude range of 200 ’g’, a maximum lower frequency limit of 1 Hz and a minimum upper frequency limit of 3000 Hz. Each accelerometer is to be rigidly attached to the outer end or side face of the two adjacent bottom corner fittings closest to the impact source and aligned in such a way as to measure the acceleration in the longitudinal axis. The preferred method is to attach each accelerometer to a flat mounting plate by means of bolting and to bond the mounting plates to the corner fittings;

(b) Method of measuring the impact velocity;

(c) Analogue-to-digital data acquisition system capable of recording the shock disturbance as an acceleration-time history at a minimum sampling frequency of 1 kHz and incorporating a low-pass anti-aliasing analogue filter with a corner frequency set to a minimum of 200 Hz and a maximum of 20% of the sampling rate and a having a minimum roll off rate of 40 dB/octave; and

(d) Method of permanently storing in electronic format the acceleration-time histories so that they can be subsequently retrieved and analyzed.

3.4 Procedure

3.4.1 Water Filling

Filling the container-under-test may be undertaken before or after mounting on the test platform;

(a) Portable Tanks: Fill the tank with a quantity of water or any other non-pressurized product to approximately 97% volumetric capacity, ensuring that it is not pressurized during the test. However, if for reasons of overload it is not desirable to fill to 97% of the capacity, then the test mass of the container (tare and product) must be as close as possible to R.

(b) MECGs: Fill each element with an equal quantity of water or any other non-pressurized product to 97% or less of their volumetric capacity, ensuring there is no pressure during the test. The test mass of the container must be as close as possible to R. Filling a MEGC with water is not required when its tare mass is equal to or higher than 90% of R.

3.4.2 Measure and record the as tested payload mass.

3.4.3 Orient the container-under-test so as to present it in a manner that will result in the most severe test and mount on the test platform, as close as possible to the impacting end and secured by the corner fittings. Ensure that any clearance between the corner fittings of the container-under-test and the securing devices at the impacting end of the test platform are minimised. In particular, ensure that impacting masses are free to rebound after impact;

3.4.4 Create an impact (see section 3.2) such that for a single impact the as tested Shock Response Spectrum (SRS) curve at both corner fittings equals or exceeds the minimum SRS shown in Figure 1 at all frequencies within the range from 3 Hz to 100 Hz. Repeated impacts may be required to achieve this result;

3.4.5 Examine the container-under-test for evidence of any faults and record the result.

3. 5 Analysis/processing of data

3.5.1 Data reduction system

(a) Reduce the acceleration time-history data from each channel to the shock response spectrum, ensuring that the spectra are presented in the form of equivalent static acceleration plotted as a function of frequency. The maximum absolute value acceleration peak will be recorded for each of the specified frequency break points, thus producing what is commonly referred to as the maximax acceleration shock response spectrum. The data reduction will follow the following criteria:

  (i) If required, the corrected impact acceleration time-history data will be generated using the procedure outlined in section 3.5.2;
  (ii) The time-history data will comprise the period commencing 0.05 s prior to the start of the impact event and the 2.0 s thereafter;
  (iii) The analysis will span the frequency range of 2 to 100 Hz with a minimum of 1/30 octave break points. Each break point, or bin in the range will constitute a natural frequency; and
  (iv) A damping ratio of 5% will be used in the analysis.

(b) Calculation of the test shock response curve data points must be made as described below. For each frequency bin:

(i) Calculate a matrix of relative displacement values using all data points from the shock input acceleration time history using the following equation:

$$\xi_i = -\frac{\Delta t}{\omega_d}\sum_{k=0}^{i}\ddot{X}_k e^{-\zeta\omega_n \Delta t(i-k)} \sin\left[\omega_d \Delta t(i-k)\right]$$

where:

Δt = time interval between acceleration values
ω_n = undamped natural frequency (in radians)
ω_d = damped natural frequency = $\omega_n\sqrt{1-\zeta^2}$
$\ddot{x}_k$ = k_{th} value of acceleration input data
ζ = damping ratio
i = integer number, varies from 1 to the number of input acceleration data points
k = parameter used in summation which varies from 0 to the current value of i

(ii) Calculate a matrix of relative accelerations using the displacement values obtained in step 1 in the following equation:

$$\ddot{\xi}_i = 2\zeta\omega_n\Delta t\sum_{k=0}^{i}\ddot{x}_k e^{-\zeta\omega_n\Delta t(i-k)}\cos\left[\omega_d\Delta t(i-k)\right] + \omega_n^2\left(2\zeta^2-1\right)\xi_i$$

(iii) Retain the maximum absolute acceleration value from the matrix generated in step 2 for the frequency bin under consideration. This value becomes the SRS curve point for this particular frequency bin. Repeat step 1 for each natural frequency until all natural frequency bins have been evaluated.

(iv) Generate the test shock response spectrum curve.

3.5.2 Method for scaling measured acceleration-time history values to compensate for under mass containers.

Where the sum of the as-tested payload mass plus tare mass of the container-under-test is less than the maximum rated mass of the container-under-test, apply a scaling factor to the measured acceleration-time histories for the container-under-test as follows:

Calculate the corrected acceleration-time values, Acc(t) $_{(corrected)}$, from the measured acceleration-time values by use of the following formula:

$$Acc(t)_{(corrected)} = Acc(t)_{(measured)} \times \frac{1}{\sqrt{1+\frac{\Delta M}{M1+M2}}}$$

Where:

Acc(t) $_{(measured)}$ = actual measured-time value;

M1= mass of the test platform, without the container-under-test;
M2= actual test mass (including tare) of the container-under-test;
R= the maximum rated mass (including tare) of the container-under-test;
ΔM = R - M2;
The test SRS values must be generated from the Acc(t) $_{(corrected)}$ values.

3.6 Defective instrumentation

If the acquired signal from one accelerometer is faulty the test may be validated by the SRS from the functional accelerometer after three consecutive impacts provided that the SRS from each of the three impacts meets or exceeds the minimum SRS curve.

3.7 Alternate validation method for portable tanks with frame length of 20 feet

3.7.1 If the design of a container-under -test is significantly different from other containers successfully subjected to this test, the test platform being used is a railway vehicle, and the SRS curves obtained have correct features but remain below the minimum SRS, the test may be validated if three successive impacts are performed as follows:

(a) First impact at a speed higher than 90% of the critical speed referred to in 3.7.2; and

(b) Second and third impact at a speed higher than 95% of the critical speed referred to in 3.7.2.

3.7.2 The alternate validation method described in 3.7.1, shall be used only if the platform's "critical speed" had been determined beforehand. The critical speed is the speed where the platform's (railway vehicle) coupler cushioning devices reach their maximum travel and energy absorption capacity beyond which the minimum SRS curve is normally obtained or exceeded. The critical speed shall have been determined from a minimum of five documented tests on five different tank containers. Each such test shall have been performed using the same equipment, measuring system and procedure.

3.8 Recording of data

Record at least the following data in the application of this procedure:

(a) Date, time, ambient temperature, and location of test;

(b) Container tare mass, maximum rated mass, and as-tested payload mass;

(c) Container manufacturer, type, registration number if applicable, certified design codes and approvals if applicable;

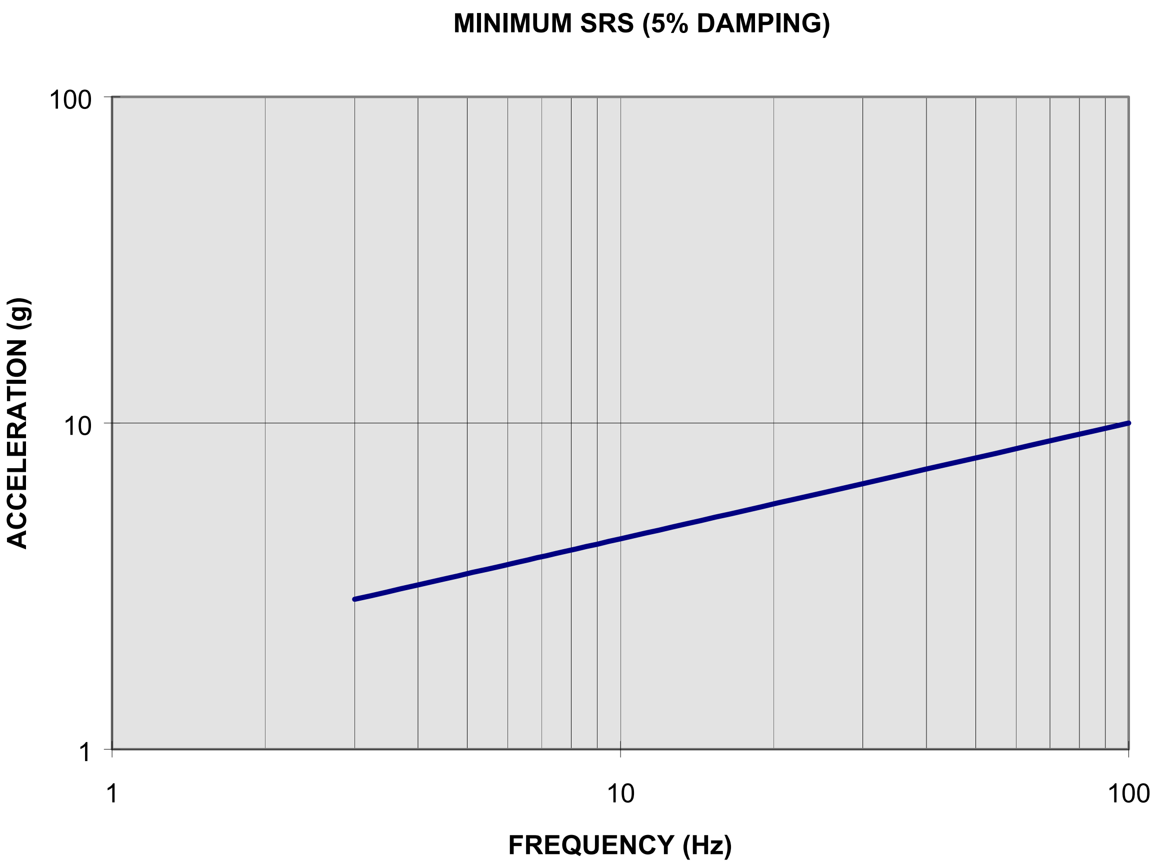
(d) Test platform mass;

(e) Impact velocity;

(f) Direction of impact with respect to tank container; and

(g) For each impact, an acceleration-time history for each instrumented corner fitting shall be recorded.

Figure 1: Minimum SRS Curve



Equation for generating the above Minimum SRS Curve: $ACCEL = 1.95\ FREQ^{0.355}$

Table D1. Tabular representation of some data points for the minimum SRS curve above.

FREQUENCY (Hz)	ACCELERATION (g)
3	2.88
10	4.42
100	10.0