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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

Twenty-sixth session, 29 November-3 December 2004
Item 4 of the provisional agenda

NEW PROPOSALS OF AMENDMENT TO THE RECOMMENDATIONS ON THE TRANSPORT OF DANGEROUS GOODS

Impact Testing of UN Portable Tanks and MEGCs
Proposal to change clauses 6.7.2.19.1, 6.7.3.15.1, 6.7.4.14.1, and 6.7.5.12.1 and the Manual of Tests and Criteria

Transmitted by the expert from Canada

Background

1. 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 of 1995 (ST/SG/AC.10/C.3/21/Add 1 and ST/SG/AC.10/C.3/22/Add 1 and ST/SG/AC/1/C.3/22). 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.

2. The list of standards on impact testing that appeared in the 10th edition of the Model Regulations remains unchanged in the 13th edition, save for 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

1. 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 Canada. Requirements for impact testing were included in the Canadian Transportation of Dangerous Goods Regulations before 1995. Tank containers are forbidden for rail transport in Canada unless a prototype has been subjected to and has successfully passed impact testing. The “TC Impact Approved” mark is used to identify tanks containers of a design that has been successfully tested at a test facility approved by the Canadian competent authority.

2. 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.

3. Ensuring that an impact of the required severity is consistently applied in testing has traditionally been a great challenge. Experience has 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 the type and placement of the measurement devices (load cells or accelerometers) on the container structure.

4. 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.

5. Under the new SRS 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/hr into a stationary string of railway vehicles (nominally a “4g” impact).

A Single International Standard

1. As well as being adopted as a Canadian National 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.

2. 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 the methods. This situation is causing confusion for tank manufacturers and in some cases has burdened manufacturers with 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.

3. The major rail impact test facilities in the world, in Canada, United States of America, France and South Africa, have been applying the new SRS test protocol since 2001. The method is now well proven and has been improved with the benefit of this experience. The SRS test protocol proposed by this paper is consistent with the method in the National Standard of Canada, with the proposal tabled at the ISO, and is currently being applied by the world's major container impact testing facilities. It incorporates all improvements resulting from nearly four years of use.

Proposal

1. It is proposed that the new impact test protocol for MEGCs and tank containers attached to this paper, be added to the Manual for Tests and Criteria as Part IV, Section 39.

2. It is further proposed that the existing text and lists of standards in sections 6.7.2.19.1, 6.7.3.15.1, and 6.7.4.14.1, of the UN Model Regulations be deleted and replaced with the following:

   "Portable tanks meeting the definition of "container" in the CSC shall not be used unless they are successfully qualified by subjecting a representative prototype of each design to the Dynamic, Longitudinal Impact Test prescribed in the Manual for Tests and Criteria, Part IV, Section 39."

3. It is further proposed that the existing text and list of standards in section 6.7.5.12.1 of the UN Model Regulations be deleted and replaced with the following:

   "MEGCs meeting the definition of "container" in the CSC shall not be used unless they are successfully qualified by subjecting a representative prototype of each design to the Dynamic, Longitudinal Impact Test prescribed in the Manual for Tests and Criteria, Part IV, Section 39."

* * *

Annex

Dynamic, Longitudinal Impact Test for Portable Tanks and MEGC's

1. General

A representative prototype of each design of portable tank and MEGC meeting the definition of "container" under the International Convention for Safe Containers, 1972, as amended (CSC), shall be subjected to and shall satisfy the requirements the dynamic, longitudinal impact test. Testing shall be conducted by facilities approved for this purpose by the Competent Authority.

2. Permitted Design Variations

The following variations in container design from an already tested prototype are permitted without 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;

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 most unfavourable specified values of mechanical properties for that grade, meet or exceed the results of the design calculation for the existing grade; and

ii. the alternate grade is permitted by the welding procedures specification.

3. Test apparatus

3.1 Test platform

The test platform may be any suitable structure capable of achieving and sustaining without significant damage a shock of the prescribed 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. equipped with 4 devices, in good condition, for securing the container-under-test in accordance with ISO 1161; and

c. equipped with a cushioning device to provide 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 consists of two or more railway vehicles connected together, each railway vehicle shall be equipped with cushioning devices. Free play between the vehicles shall be eliminated and 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 and recording 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 shall be rigidly attached to the container-under-test at the outer end or side face of the two adjacent bottom corner fittings closest to the impact source. The accelerometers shall be aligned so as to measure the acceleration in the longitudinal axis of the container. 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. A means of measuring the velocity of the moving test platform or the moving mass at the moment of impact;

c. An analogue-to-digital data acquisition system capable of recording the shock disturbance as an acceleration versus time history at a minimum sampling frequency of 1000 Hz. The data acquisition system shall incorporate 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 minimum roll off rate of 40 dB/octave; and

d. A means of storing the acceleration versus time histories in electronic format so that they can be subsequently retrieved and analysed.

3.4 Procedure

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

a. Portable Tanks- The tank shall be filled with water or any other non-pressurized substance to approximately 97% of the tank's volumetric capacity. The tank shall not be pressurized during the test. If for reasons of overload it is not desirable to fill to 97% of capacity, the tank shall be filled so that the mass of the container-under test(tare and product) is as close as practicable to its maximum rated mass (R).

b. MEGCs.- Each element shall be filled with an equal quantity of water or any other non-pressurized substance. The MEGC shall be filled so that its mass is as close as practicable to its maximum rated mass (R) but in any event, to no more than 97% of its volumetric capacity. The MEGC shall not be pressurized during the test. Filling a MEGC is not required when its tare mass is equal to or higher than 90% of R.

3.4.2 The mass of the container, as tested, shall be measured and recorded.

3.4.3 The container-under-test shall be oriented in a manner that will result in the most severe test. The container shall be mounted on the test platform, as close as possible to the impacting end and secured using all four of it's corner fittings so as to restrain it's movement in all directions. Any clearance between the corner fittings of the container-under-test and the securing devices at the impacting end of the test platform shall be minimised. In particular, impacting masses shall be free to rebound after impact;

3.4.4 An impact shall be created (see section 3.2) such that for a single impact the as tested Shock Response Spectrum (SRS, see section 3.5.1) curve at both corner fittings at the impacting end equals or exceeds the minimum SRS curve shown in Figure 1 at all frequencies within the range from 3 Hertz to 100 Hertz. Repeated impacts may be required to achieve this result but the test results for each impact shall be considered individually;

3.4.5 Following an impact described in 3.4.4, the container-under-test shall be examined and the results recorded. To satisfy the test, the container shall show no leakage, permanent deformation or damage that would render it unsuitable for use, and shall be in conformity with the dimensional requirements regarding handling, securing and transfer from one means of transport to another.

3. 5 Processing and Analysis of data

3.5.1 Data reduction system

a. The acceleration versus time history data from each channel shall be reduced 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 shall be recorded for each of the specified frequency break points. The data reduction shall follow the following criteria:

   i. If required, the corrected impact acceleration versus time history data shall be scaled using the procedure outlined in section 3.5.2.
   ii. The acceleration versus time history data shall comprise the period commencing 0.05 seconds prior to the start of the impact event and the 2.0 seconds thereafter;
   iii. The analysis shall span the frequency range of 2 to 100 Hz and calculation of the shock response curve points shall be performed at a minimum of 30 frequency break points per octave. Each break point in the range shall constitute a natural frequency; and
   iv. A damping ratio of 5% shall be used in the analysis.

b. Calculation of the test shock response curve points shall be made as described below. For each frequency break point:

   i. A matrix of relative displacement values shall be calculated using all data points from the shock input acceleration versus 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. A matrix of relative accelerations shall be calculated using the displacement values obtained in step i 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. The maximum absolute acceleration value from the matrix generated in step ii for the frequency break point under consideration shall be retained. This value becomes the SRS curve point for this particular frequency break point. Step i shall be repeated for each natural frequency until all natural frequency break points have been evaluated.

iv. The test shock response spectrum curve shall be generated.

3.5.2 Method for scaling measured acceleration versus time history values to compensate for under or over mass containers

Where the sum of the as-tested payload mass plus tare mass of the container-under-test is not the maximum rated mass of the container-under-test, a scaling factor shall be applied to the measured acceleration versus time histories for the container-under-test as follows:

The corrected acceleration-time values, Acc(t) $_{(corrected)}$, shall be calculated from the measured acceleration versus time values using 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 shall 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 test severity validation method for portable tanks with frame length of 20 feet

3.7.1 If the design of a tank container-under-test is significantly different from other containers successfully subjected to this test and the SRS curves obtained have correct features but remain below the minimum SRS curve, the test severity may be considered acceptable 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 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

At least the following data shall be recorded 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;

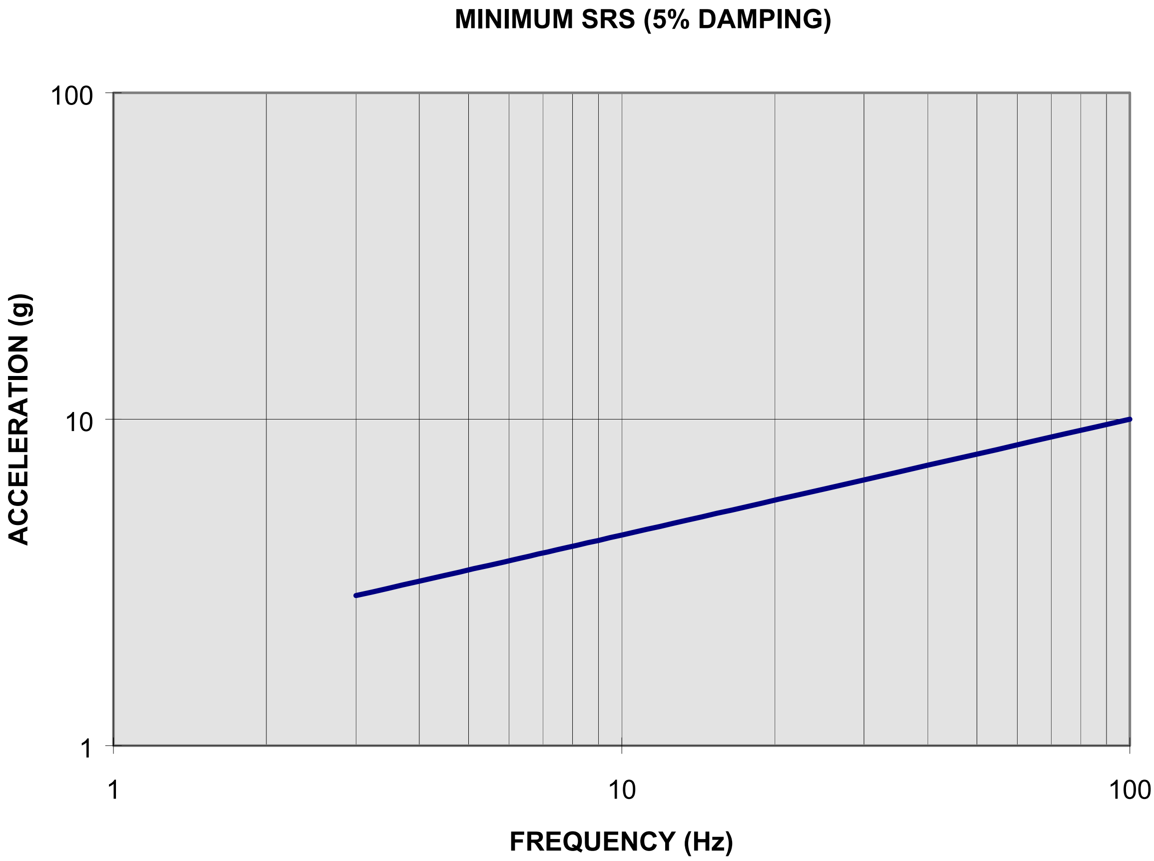
d. Test platform mass;

e. Impact velocity;

f. Direction of impact with respect to tank container; and

g. For each impact, an acceleration versus time history for each instrumented corner fitting.

Figure 1: Minimum SRS Curve



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

Table 1. 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