PART IV

TEST METHODS CONCERNING TRANSPORT EQUIPMENT

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SECTION 40

INTRODUCTION TO PART IV

40.1 Purpose

40.1.1 Part IV of the Manual presents the United Nations schemes for dynamic and longitudinal impact testing of portable tanks and MEGCs (see section 41 of this Manual and 6.7.2.19.1, 6.7.3.15.1, 6.7.4.14.1 and 6.7.5.12.1 of the Model Regulations).

40.2 Scope

40.2.1 The test methods of this Part should be applied when required by the Model Regulations.

SECTION 41

DYNAMIC LONGITUDINAL IMPACT TEST FOR PORTABLE TANKS AND MULTIPLE-ELEMENT GAS CONTAINERS (MEGCs)

41.1 General

41.1.1 This test method is intended to prove the ability of portable tanks and MEGCs to withstand the effects of a longitudinal impact, as required by 6.7.2.19.1, 6.7.3.15.1, 6.7.4.14.1 and 6.7.5.12.1 of the Model Regulations.

41.1.2 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 of the dynamic longitudinal impact test. Testing shall be conducted by facilities approved for this purpose by the competent authority.

41.2 Permitted design variations

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

41.2.1 *Portable tanks*

(a) A reduction of no more than 10% or an increase of no more than 20% in capacity, resulting from variations in diameter and length;

(b) A decrease in maximum permissible gross mass;

(c) An increase in thickness, independent of design pressure and temperature;

(d) A change to the grade of material of construction provided that the permitted yield strength meets or exceeds that of the tested portable tank;

(e) A change in location of, or a modification to, nozzles and manholes.

41.2.2 *MEGCs*

(a) A decrease in the initial maximum design temperature, not affecting thickness;

(b) An increase in the initial minimum design temperature, not affecting thickness;

(c) A decrease in the maximum gross mass;

(d) A reduction in capacity not exceeding 10% resulting only from variations in diameter or 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 allowable working pressure, or maximum working pressure, not affecting thickness;

(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 specifications.

41.3 Test apparatus

41.3.1 Test platform

The test platform may be any suitable structure capable of 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 four devices, in good condition, for securing the container-under-test in accordance with ISO 1161:1984 (Series 1 Freight containers – Corner fittings – Specification); and

(c) equipped with a cushioning device to provide a suitable duration of impact.

41.3.2 Impact creation

41.3.2.1 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.

41.3.2.2 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.

41.3.3 Measuring and recording system

41.3.3.1 Unless otherwise specified, the measuring and recording system shall comply with ISO 6487:2002 (Road vehicles – Measurement techniques in impact tests – Instrumentation).

41.3.3.2 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 3 000 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 1 000 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.

41.3.4 ***Procedure***

41.3.4.1 Filling the container-under-test may be undertaken before or after mounting on the test platform, as follows:

(a) Portable tanks: The tank shall be filled with water or any other non-pressurized substance to approximately 97% of the tank 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.

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

41.3.4.3 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 its corner fittings so as to restrain its 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.

41.3.4.4 An impact shall be created (see 41.3.2) such that for a single impact the as tested Shock Response Spectrum (SRS, see 41.3.5.1) 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 Hz to 100 Hz. Repeated impacts may be required to achieve this result but the test results for each impact shall be considered individually;

41.3.4.5 Following an impact described in 41.3.4.4, 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.

41.3.5 *Processing and analysis of data*

41.3.5.1 *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 41.3.5.2;

(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:

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

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.

41.3.5.2 *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.

41.3.6 ***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.

41.3.7 ***Alternate test severity validation method for portable tanks with frame length of 20 feet***

41.3.7.1 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 41.3.7.2; and

(b) Second and third impact at a speed higher than 95 % of the critical speed referred to in 41.3.7.2.

41.3.7.2 The alternate validation method described in 41.3.7.1, 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.

41.3.8 ***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;

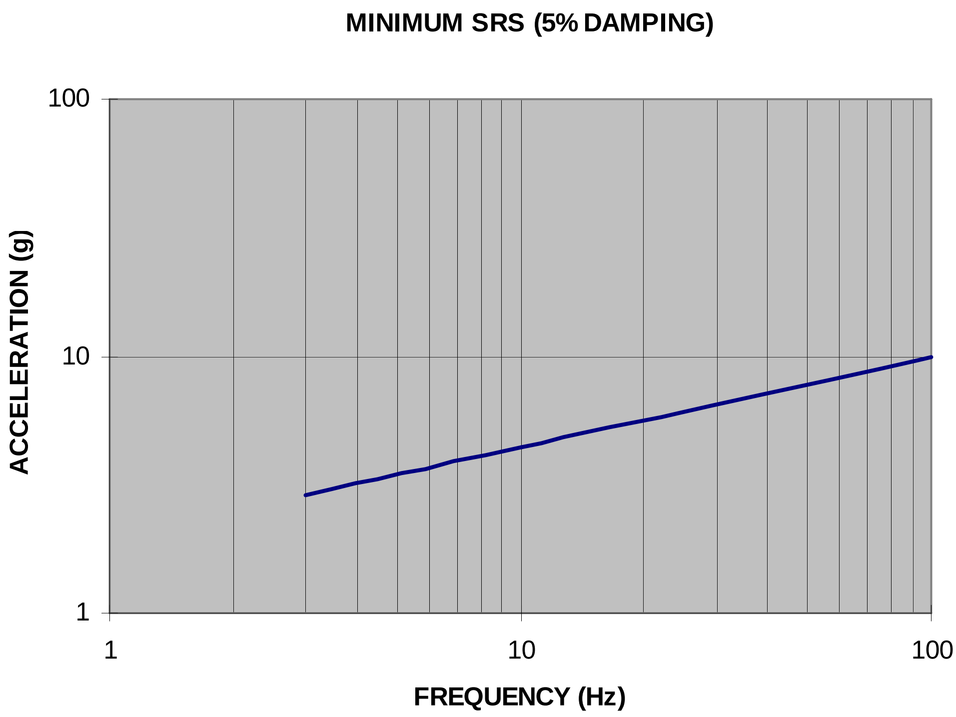
(d) Test platform mass;

(e) Impact velocity;

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

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

Figure 41.1: Minimum SRS Curve



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

Table 41.1: 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