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Manual of Tests and Criteria

Eighth revised edition

Amendment 1

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INTRODUCTION

The "Manual of Tests and Criteria" contains criteria, test methods and procedures to be used for the classification of dangerous goods according to the provisions of the *"United Nations Recommendations on the Transport of Dangerous Goods*, *Model Regulations"*, as well as of chemicals presenting physical hazards according to the *"Globally Harmonized System of Classification and Labelling of Chemicals (GHS)"*. It therefore also supplements national or international regulations which are derived from the Model Regulations or the GHS.

Originally developed by the Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods, which adopted a first version in 1984, the Manual of Tests and Criteria has been regularly updated and amended. Currently, the updating is done under the auspices of the Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals, which replaced the original committee in 2001.

At its twelfth session (6 December 2024), the Committee adopted a set of amendments to the eighth revised edition of the Manual, which were circulated as document ST/SG/AC.10/52/Add.2 and are listed in this publication. They address mainly:

- Changes to sections 11, 12, 18 and 25 and a new appendix 12 addressing Koenen tube test specifications and test procedures;

- Changes to section 31 for alignment of the definitions of flammable components and heat of combustion with special provision 63 in the *Model Regulations;*

- Changes to subsection 38.3 addressing lithium cells and batteries and the definition of rupture;

- The review of sub-section 51.4 for further improvement of the burning rate test criteria and method of assessing results; and

- A new section 42 containing a test method to prove the fire resistance of fibre reinforced plastics service equipment for portable tanks.

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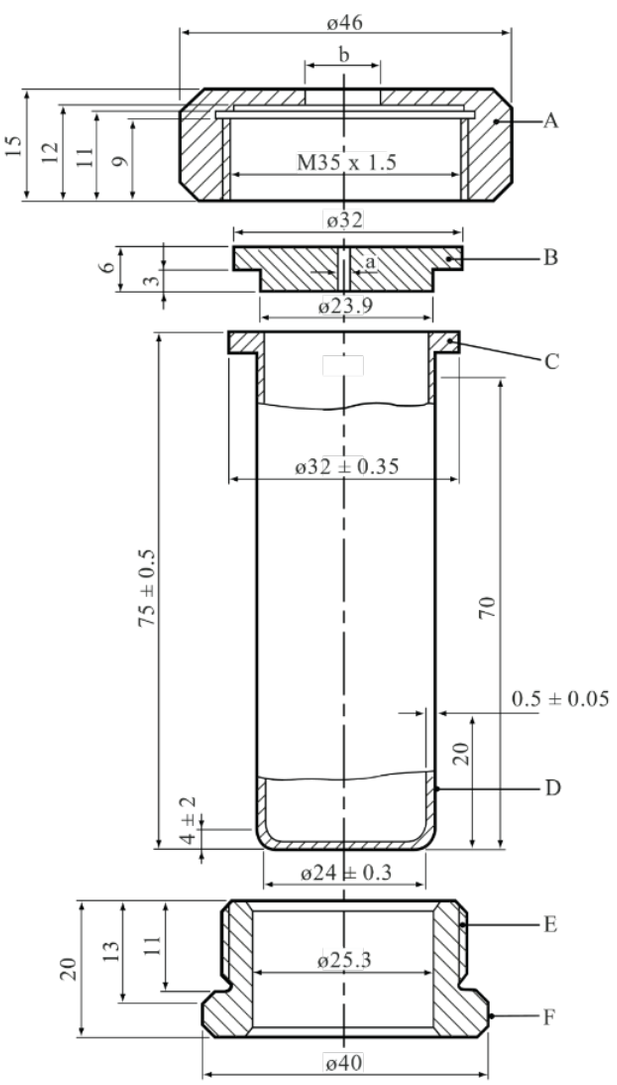
AMENDMENTS TO THE EIGHTH REVISED EDITION

SECTION 10

The amendments to paragraph 10.3.2.2 and figures 10.2 and 10.7 a) in the French version do not apply to the English text.

SECTIONS 11 and 12

Figures 11.5.1.1 and 12.5.1.1 Replace by the following (*the title and the legend applicable to each figure remain unchanged)*:



SECTION 11

11.1.1 In the first sentence, replace “Is it an explosive substance?” by “Does the substance have explosive properties?”.

11.5.1.2.1 In the first paragraph, second sentence, at the end, add a reference to the following new footnote [1]: “[1] *Tubes manufactured from sheet steel not meeting these specifications may be used provided conditions (a) to (d) are met and the tubes are qualified as having the required limiting diameters listed in A12.3 of appendix 12.*”. Renumber subsequent footnotes accordingly.

In (a), replace “26.5 ± 1.5 g” by “27.5 ± 3 g”.

Amend (d) to read as follows:

“(d) The bursting pressure as determined by dynamic load through a liquid shall be 29 ± 4 MPa (i.e., the pressure-measuring device should be able to measure a pressure rise from 5 to 35 MPa). The pressure rise rate should be not less than 100 MPa/s, e.g. calculated from the pressure rise from 5 to 25 MPa. The "Dynamic burst pressure test procedure" is described in A12.2 of appendix 12.”

11.6.1.3.1 In the fifth sentence, replace “weight” by “mass”.

SECTION 12

12.1.1 In the first sentence, replace “inclusion” by “acceptance”.

12.5.1.2.1 In the first paragraph, second sentence, at the end, add a reference to the following new footnote [1]: “[1] *Tubes manufactured from sheet steel not meeting these specifications may be used provided conditions (a) to (d) are met and the tubes are qualified as having the required limiting diameters listed in A12.3 of appendix 12.*”. Renumber subsequent footnotes accordingly.

In (a), replace “26.5 ± 1.5 g” by “27.5 ± 3 g”.

Amend (d) to read as follows:

“(d) The bursting pressure as determined by dynamic load through a liquid shall be 29 ± 4 MPa (i.e. the pressure-measuring device should be able to measure a pressure rise from 5 to 35 MPa). The pressure rise rate should be not less than 100 MPa/s, e.g. calculated from the pressure rise from 5 to 25 MPa. The "Dynamic burst pressure test procedure" is described in A12.2 of appendix 12.”

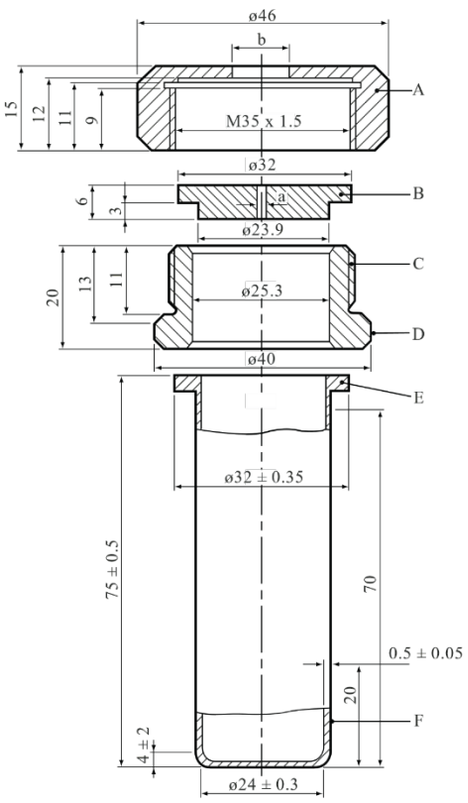
12.6.1.3.1 In the fifth sentence, replace “weight” by “mass”.

SECTION 13

The amendments to paragraphs 13.4.1.3.1, 13.4.2.2.2, 13.4.2.3.3 and 13.4.3.2.2 in the French and Spanish versions do not apply to the English text.

SECTION 18

Figure 18.6.1.1 Replace by the following (the title and the legend remain unchanged):



18.6.1.2.1 In the first paragraph, second sentence, at the end, add a reference to the following new footnote 1: "[1] Tubes manufactured from sheet steel not meeting these specifications may be used provided conditions (a) to (d) are met and the tubes are qualified as having the required limiting diameters listed in A12.3 of appendix 12.". Renumber subsequent footnotes accordingly.

In (a), replace "26.5 ± 1.5 g" by "27.5 ± 3 g, tubes to be used in one test sequence shall not differ in mass by more than 1 g".

Amend (d) to read as follows:

"(d) The bursting pressure as determined by dynamic load through a liquid shall be 29 ± 4 MPa (i.e., the pressure-measuring device should be able to measure a pressure rise from 5 to 35 MPa). The pressure rise rate should be not less than 100 MPa/s, e.g. calculated from the pressure rise from 5 to 25 MPa. The "Dynamic burst pressure test procedure" is described in A12.2 of appendix 12."

18.8.1.2.1 In the fourth sentence, at the end, add ", e.g. by use of a syringe, piping bag, or pastry bag where the viscosity of the sample allows".

18.8.1.2.2 In the first sentence, replace "0.51 mm" by "0.50 to 0.51 mm" and replace "5.5 Ω m^{-1}" by "5.50 to 5.75 Ω·m^{-1}".

18.8.1.2.3 At the end, add "and a Type-K thermocouple to measure the gas temperature".

18.8.1.3.3 At the end, add the following two new sentences: "The test should be started after the gas temperature drops to room temperature or the gas pressure has stabilised. The value of the pressure transducer is then recorded as the initial pressure.".

SECTIONS 21 and 22

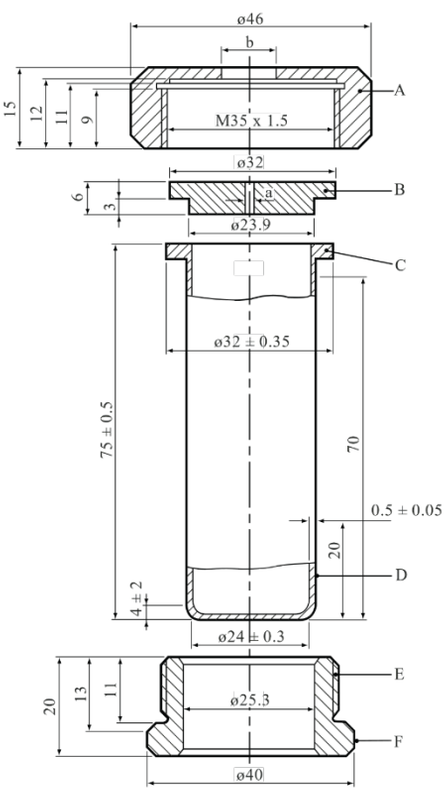
21.4.1.2 and 22.3.1 The amendments to the Spanish version do not apply to the English text.

SECTION 23

23.4.1.3.1 The amendment to the fourth sentence in the French version does not apply to the English text. In the fifth sentence, replace “weight” by “mass”.

SECTION 25

Figure 25.4.1.1 Replace by the following (the title and the legend remain unchanged):



25.4.1.2.1 In the first paragraph, second sentence, at the end, add a reference to the following new footnote 1: “[1] Tubes manufactured from sheet steel not meeting these specifications may be used provided conditions (a) to (d) are met and the tubes are qualified as having the required limiting diameters listed in A12.3 of appendix 12.”. Renumber subsequent footnotes accordingly.

In (a), replace “26.5 ± 1.5 g” by “27.5 ± 3 g”.

Amend (d) to read as follows:

“(d) The bursting pressure as determined by dynamic load through a liquid shall be 29 ± 4 MPa (i.e. the pressure-measuring device should be able to measure a pressure rise from 5 to 35 MPa). The pressure rise rate should be not less than 100 MPa/s, e.g. calculated from the pressure rise from 5 to 25 MPa. The "Dynamic burst pressure test procedure" is described in A12.2 of appendix 12.”

SECTION 26

26.4.1.2.1 In the third sentence, replace “weight” by “mass”.

SECTION 28

28.4.2.2.2.3 In the second sentence, replace “weight” by “mass”.

SECTION 31

31.1.3 In the definition for “*Flammable components*”, delete the second sentence.

31.3.3 Amend the existing sentence to read: “The chemical heats of combustion shall be determined either by reference to published scientific literature, through calculation or by using suitable calorimetric test methods (e.g. ASTM D 240 and NFPA 30B).”.

SECTION 32

32.3.2.1 Amend the first sentence to read as follows: “This subsection presents the *Model Regulations* scheme for the classification of liquid desensitized explosives as flammable liquids (see paragraph 2.3.1.4 of the *Model Regulations*; for the *GHS* see subparagraph 2.17.1.2 (b) of the *GHS*).”.

SECTION 33

33.3.1 Amend the first sentence to read as follows: “This subsection presents the *Model Regulations* scheme for the classification of desensitized explosives as flammable solids of Division 4.1 (see subsection 2.4.2.4 of the *Model Regulations*; for the *GHS* see sub-paragraph 2.17.1.2 (a) of the *GHS*).”

SECTION 37

37.4.1.3 and 37.4.1.4.1 The amendment to the Spanish version does not apply to the English text.

SECTION 38

38.3.2.2 In (c), replace “would” by “might”.

In the note, at the end of (e), delete “and”, at the end of (f), replace the period by “; and” and add a new g to read as follows:

“(g) Repairing, refurbishing, or remanufacturing including replacement of parts with non-original spares, replacement of parts of a different specification, or in a manner that would result in a deviation from the manufacturer’s tested type.”

38.3.2.3 Add a new note under the definition of “*Rupture*” to read as follows:

“***NOTE:*** *In the case of a battery that is not fully enclosed by its casing and the cells are exposed by design prior to the tests, "exposure" means an increased visibility of components that are exposed beyond that of the original design of the battery.*”

38.3.4.5.2 In the first paragraph, first sentence, replace “on the external case” by “on the external case or on an internal cell”. In the second paragraph, replace “the cell or battery external case temperature” by “the measured temperature”.

38.3.4.5.3 Replace “external” by “measured”.

38.3.4.6.3 In the first paragraph under the note, at the end of the first sentence, add “, each having sufficient surface area to ensure the crushing force is applied evenly across the entire surface of the cell”.

SECTION 40

40.1.1 After “schemes for”, add ”:”, transfer the rest of the text to a new indent (a) and, at the end, replace the full stop with “; and”. Add a new (b) as follows:

“(b) the requirements to the fire resistance test of service equipment made from fibre reinforced plastic (FRP) for portable tanks (see section 42 of this *Manual* and 6.9.2.7.1.5 and 6.9.3.5.2 (d) of the *Model Regulations*).”

SECTION 42

Add a new section 42 to read as follows:

“**SECTION 42**

FIRE RESISTANCE TEST OF FIBRE REINFORCED PLASTICS (FRP) SERVICE EQUIPMENT FOR PORTABLE TANKS

42.1 General

42.1.1 This test method is intended to prove the fire resistance of FRP service equipment for portable tanks which meet the requirements of 6.7.2 or 6.9.2 of the *Model Regulations*.

42.1.2 The representative prototype of FRP service equipment meeting the definition of 6.9.3.1 of the *Model Regulations* shall be subjected to and satisfy the requirements of the fire resistance test. The fire resistance test shall be conducted by test facilities approved by the competent authorities.

42.2 Definitions

Test specimen means an instance of FRP service equipment including gate and seal assemblies subjected to the fire resistance test.

Relevant definitions of standard ISO 21843:2018 and chapters 6.7.2, 6.9.2 and 6.9.3 of the *Model Regulations* are applicable to this section.

42.3 Test method

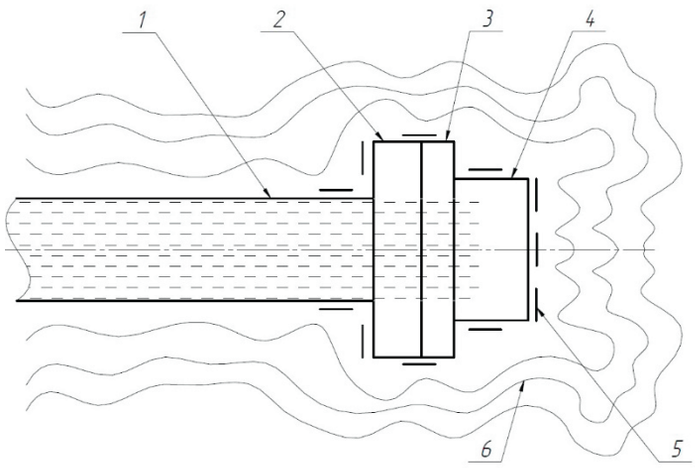
42.3.1 The fire resistance test is carried out for the test specimen installed in a closed position, filled with water with initial temperature of 20 ±5°C under maximum allowable working pressure (MAWP, 6.7.2.1 of the *Model Regulations*), and exposures to flame for at least 30 minutes. Pressure relief devices are subjected to pressure, which is 10% below nominal pressure set to discharge (6.7.2.9.2 of the *Model Regulations*). The test specimen shall be completely engulfed in the flame including the gate and seal assemblies. The general test scheme is given in figure 42.3.1. If the test specimen is a part of equipment which is not intended to be the outermost closure in a multi-closure system (such as a valve), then the test specimen may be equipped with a blind flange, at its outermost interface which would otherwise be exposed to flame during the test.

42.3.2 The fire exposure parameters shall comply with paragraph 6.9.2.7.1.5.1 of the *Model Regulations*. The fire shall be equivalent to a theoretical fire with a flame temperature of 800 °C, emissivity of 0.9 and a minimum net heat flux of 75 kW/m² calibrated according to ISO 21843:2018.

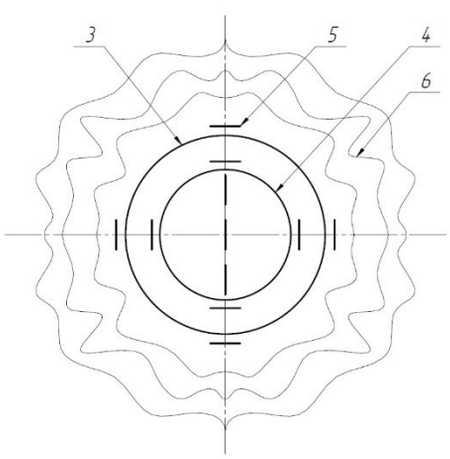
42.3.3 The intensity of heat exposure shall be measured using temperature and heat flux sensors in accordance with the requirements of ISO 21843-2018.

42.3.4 After the fire exposure and cooling the test specimen is subjected to leakproofness test under MAWP.

Figure 42.3.1: Fire resistance test scheme



A



B

(A) Side view	(B) End-face view
(1) Pressure system with water supply	(2) Fixture to join the test specimen to the pressure system
(3) Flange of the test specimen	(4) Test specimen
(5) Temperature and heat flow measuring system	(6) Flame

42.4 Test apparatus

42.4.1 *General requirements*

42.4.1.1 The fire resistance test bed shall include:

(a) a fire chamber with dimensions sufficient to accommodate the test specimen and the temperature and heat flux measuring system;

(b) a fuel supply and combustion system;

(c) a pressure system with water supply ((1) in figure 42.3.1);

(d) a fixture to join the test specimen to the test bed ((2) in figure 42.3.1); and

(e) a temperature and heat flux measuring system ((5) in figure 42.3.1) according to ISO 21843:2018.

42.4.1.2 The specific types of testing equipment can be modified and supplemented in accordance with the requirements of the testing laboratory.

42.4.1.3 The test bed facilities shall not expose the test specimen to external influences that can affect the test results.

42.4.1.4 The heat regime shall be provided by burning liquid fuel or gas.

42.4.1.5 The test bed shall ensure uniform flame coverage of the test specimen.

42.4.1.6 The firing chamber shall provide a horizontal gap between any part of the test specimen and its own shell of at least 150 mm.

42.4.1.7 The fire source (nozzles) shall be at least 150 mm away from the test specimen and temperature sensors and shall provide sufficient power to ensure that the test specimen is completely engulfed in flame.

42.4.1.8 The fuel supply and combustion system shall be controlled.

42.4.2 *Requirements of the measuring system*

42.4.2.1 During the test the following parameters shall be measured:

(a) temperature and heat flux on the surface of the test specimen;

(b) internal pressure during fire and cooling (pressure gauge records);

(c) leakproofness of the test specimen.

42.4.2.2 The general scheme of installation of the test specimen and temperature and heat flow sensors is shown in figure 42.3.1. Measurement errors shall not be more than:

± 3 % when measuring pressures;

± 5 % when measuring temperature and heat flux;

± 2 % when measuring time.

42.5 Test procedure

42.5.1 The temperature and heat flux sensors shall be installed and calibrated according to ISO 21843:2018.

42.5.2 Before the test, the test specimen and attachments shall be completely filled with water.

42.5.3 After the system is completely filled with water, the system shall be loaded with MAWP at a temperature of 20 °C. Then the leakproofness of the test specimen and pipelines shall be checked.

42.5.4 The fuel supply to the burners shall be opened, ignited and the flame be adjusted with a control valve. The fire parameters shall be maintained in accordance with 42.3.2 at least for 30 minutes. The temperature and heat flux are recorded every 30 seconds with separate records for each sensor during the test.

42.5.5 The fuel supply shall be turned off after the test (at least 30 minutes).

42.5.6 The test specimen shall be removed after complete cooling (wall temperature less than 50 °C). Then the test specimen shall be subjected to leakproofness test at MAWP.

42.5.7 At least 3 "open-closed" cycles (if any) shall be performed for pressure relief devises.

42.6 Performance criteria

The test specimen shall demonstrate leakproofness under MAWP after fire exposure. At least 3 “open-closed” cycles (if any) shall be performed for pressure relief devises. If this condition is met, the test specimen is considered to have passed the fire resistance test.

42.7 Test report

The test report shall contain:

(a) the name of the organization conducting the tests;

(b) the name of the manufacturer of the FRP service equipment;

(c) the date of the fire resistance tests;

(d) a description of the FRP service equipment, including dimensions, weight, diameter of the gate section, body and lid materials, seal material, marking;

(e) a recording of the controlled parameters according to 42.4.2.1 and the results of their processing and analysis;

(f) the results of visual observations;

(g) a description of the damage or failure (if any);

(h) the start time of the test (i.e., the ignition of the burners);

(i) the conclusion on the compliance or non-compliance of the FRP service equipment with the requirements of 42.6.

42.8 Safety requirements

As the fire resistance test of the FRP service equipment is potentially dangerous, the safety of personnel shall be assured. Considering the possibility of damage and failure of the test, protective screens and other appropriate means to protect personnel shall be used."

SECTION 51

51.3.2 Delete subparagraphs (a) and (c) and renumber remaining subparagraphs accordingly.

51.4.1.2 In (b), delete "Division 1.1".

51.4.4.1 In (a), second sentence, replace "radiation level" by "irradiance" and replace "maximum level (*Imax*)" by "maximum irradiance (*Imax*). The total burning time *t* is the time span between the starting point and the end point of the fire".

Delete (c) and renumber subsequent subparagraphs accordingly.

In (c) (old (d)), before "burning time", add "total".

51.4.4.2 In (a), second sentence, delete "percent" and replace "radiation level" by "radiation energy".

In (c), last sentence, replace "of the radiation intensities I_t [W/m^2]" by "of the irradiance I_t [kW/m^2]".

In (d), first sentence replace "radiation level" by "irradiance" and in the second sentence delete "to 1 %".

Amend (e) to read as follows:

"(e) $I_{relevant}$ is obtained from the maximum of the smoothed and corrected curve of the measured heat radiation. $I_{calculated}$ is the average value of the radiation obtained by converting the integrated area in a rectangle of equal area during the same total burning time (see figure 51.4.1);"

In (g), last paragraph, first sentence, after "*f*", add "is".

51.4.4.3 Replace "is classified in the hazard class "explosives"" by "is not classified as a desensitized explosive and should be classified as an explosive in accordance with chapter 2.1 of the *GHS*".

51.4.4.5 In the last sentence, replace "is classified as an explosive (See chapter 2.1 of the GHS)." by "is not classified as a desensitized explosive and should be classified as an explosive in accordance with chapter 2.1 of the *GHS*".

Figure 51.4.1 Replace "*Dosis*" by "*dose*" (three times).

51.4.6 Replace "Burning time" by "Total burning time" and "Enthalpy of combustion" by "Heat of combustion".

References Add the following new reference at the end of the current list:

"[6] Organic Peroxides: Storage (Guideline for the labour-safe, environment-safe and fire-safe storage of organic peroxides), Hazardous Substances Publication Series 8:2011 (PGS 8:2011) version 1.0, December 2011."

APPENDIX 6

A6.4.1 In the first paragraph, second sentence, replace “4.2” by “A6.4.2”.

A6.5.1 Amend (b) to read as follows:

“(b) For a single organic substance or a homogeneous mixture of organic substances, the estimated SADT for a 50 kg package is greater than 75 °C or the exothermic decomposition energy is less than 300 J/g. A suitable method to estimate whether the SADT for a 50 kg package is greater than 75 °C is if:

(i) The first detected exothermic reaction (onset, detection limit maximum: 20 $W \cdot kg^{-1}$) in a screening DSC is not less than 175 °C for liquids or 200 °C for solids; or

(ii) The measured isothermal maximum heat flow at 75 °C is not greater than 100 $mW \cdot kg^{-1}$ for liquids or 50 $mW \cdot kg^{-1}$ for solids.

Calorimetric data should be obtained following the guidelines in section 20.3.3.3.

NOTE: *These screening rules can fail for substances showing strong autocatalytic behaviour in the decomposition. For such substances, further information is needed to determine if these simple screening rules apply to the particular substance (e.g., the effect of sample aging on the decomposition). Information concerning potential autocatalytic behaviour may be obtained from further calorimetric measurements (e.g., comparison of DSC measurements of tempered samples with fresh samples, or DSC scans with different scan rates). The onset temperature criteria or heat flow criteria should always be met for fresh and aged samples representing the anticipated duration of transport.*”

APPENDIX 7

A7.2.2 The amendment to the introductory paragraphs in the French version does not apply to the English version. In (d), replace “weighing” by “with a mass”.

APPENDIX 10

A10.3.2.2.1 In the first sentence, replace “weighing” by “with a mass”.

A10.3.4.4 In the first sentence, replace “less than 30 min” by “30 min or less”.

A10.3.5 Amend the table to read as follows:

Test time (min)	Result
25	+
30	+
35	–

APPENDIX 12

Add a new appendix 12 to read as follows:

"**APPENDIX 12**

KOENEN TUBE QUALIFICATION TEST PROCEDURES

A12.1 Introduction

The purpose of this appendix is to provide sufficient procedural details to:

(a) obtain accurate dynamic burst pressure test results for quality control of the steel tubes specified by the Koenen test procedures (A12.2); and

(b) qualify new tubes produced from alloys other than those specified in Koenen procedures by confirming they will give identical limiting diameter results for specified substances (A12.3).

A12.2 Dynamic burst pressure test procedure

A12.2.1 *Introduction*

A12.2.1.1 This procedure details the test method to determine whether Koenen tubes manufactured from a variety of manufacturers and manufacturing lots meet the dynamic burst pressure specifications in 11.5.1.2.1(d), 12.5.1.2.1(d), 18.6.1.2.1(d) and 25.4.1.2.1(d). The bursting pressure as determined by dynamic load through a liquid shall be 29 ± 4 MPa.

A12.2.1.2 Specific details of the Koenen apparatus are detailed in tests 1(b), 2(b), 8(c), and test method E.1.

A12.2.2 *Apparatus and materials*

The following items are required:

(a) Burst pressure apparatus (figure A12.1) designed to apply pressures of 35 MPa or greater using a non-corrosive liquid, and optionally capable of purging Koenen tube and apparatus of all air. The apparatus is equipped to accept a pressure transducer.

(b) A static pressure transducer. Any pressure-measuring device may be used provided it is calibrated with a measuring range above the allowable Koenen tube burst pressures detailed in 11.5.1.2.1 (d), 12.5.1.2.1 (d), 18.6.1.2.1 (d), or 25.4.1.2.1 (d) and has a response time capable of detecting pressure changes at which they will occur during testing.

(c) A data acquisition (DAQ) system. Used to collect static pressure data with acquisition rate of suitable speed and resolution to accurately assess tube burst pressure. A minimum sampling rate of 10 kHz should be used to ensure peak pressure is captured with accuracy.

(d) A Koenen tube collar meeting the specifications detailed in figures 11.5.1.1, 12.5.1.1, 18.6.1.1.

(e) A modified orifice for hydraulic testing. The modified orifice allows connection of the Koenen tube to the burst pressure apparatus.

A12.2.3 *Procedure*

A12.2.3.1 The burst pressure testing apparatus is set up to introduce the test liquid. The pressure transducer and data acquisition system are attached (see figure A12.1) and tested to verify proper functioning and capability to accurately measure and record pressures above the maximum burst pressures specified in 11.5.1.2.1 (d), 12.5.1.2.1 (d), 18.6.1.2.1 (d), or 25.4.1.2.1 (d).

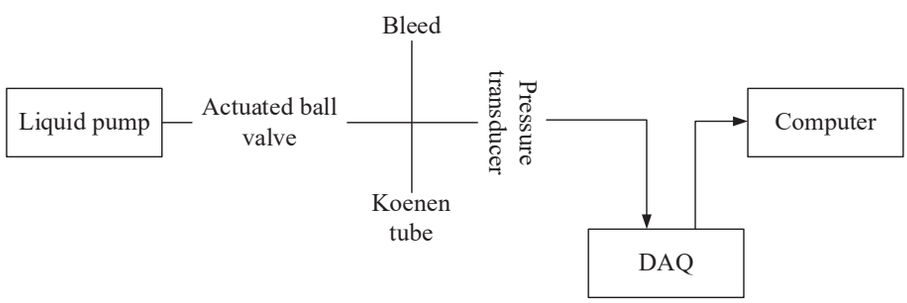
A12.2.3.2 The Koenen tube is labelled and inserted into the threaded collar with the modified orifice plate on top of the tube, then the collar nut is tightened to provide an effective seal.

A12.2.3.3 The modified orifice plate is connected to the burst pressure apparatus and placed in a protective area, then connections verified against leaks. As a best practice it is recommended at this step that the entire system is purged of air under vacuum, followed by closure of the vacuum valve and examination for constant pressure. The actuated ball-valve is closed to prevent premature pressurization of the Koenen tube, after which the supply line to the closed valve is charged with the pump to approximately 35 MPa. The ball-valve is opened remotely and gauge pressure at which tube bursts is recorded.

A12.2.4 *Test criteria and method of assessing results*

The test results are interpreted in terms of whether the peak pressure recorded by the transducer before rupture of the Koenen tube falls within the required pressure range. The result is considered negative ("-") if the peak pressure is 29 ± 4 MPa and the lot from which the tested tubes were selected is considered to be qualified as meeting the Koenen test burst pressure specifications.

Figure A12.1: Burst pressure apparatus setup



A12.3 Required limiting diameters for use of alternative tube alloys

A12.3.1 *Introduction*

Tubes manufactured from sheet steel alloys other than those listed in 11.5.1.2.1, 12.5.1.2.1, 18.6.1.2.1 and 25.4.1.21 may be used provided that the each of the limiting diameters listed in A12.3.2 are met.

Table A12.1: Required limiting diameters

Substance	Limiting diameter (mm)
Guanidine nitrate	1.5
Ammonium nitrate powder	1
Tert-butyl peroxybenzoate	3.5
Diluted tert-butyl peroxybenzoate with 50 % isododecane by weight	1 [a]

[a] *For a type "A" effect.*

NOTE: *The detailed protocol used to determine the limiting diameters given in the table above is available from the national contacts for test details in Germany, United Kingdom or United States of America (see appendix 4).*"