International Civil Aviation Organization

DGP-WG/12-WP/13
7/9/12

WORKING PAPER

DANGEROUS GOODS PANEL (DGP)
MEETING OF THE WORKING GROUP OF THE WHOLE

Montréal, 15 to 19 October 2012

Agenda Item 2: Development of recommendations for amendments to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284) for incorporation in the 2015-2016 Edition
2.4: Part 4 — Packing Instructions
2.8: Part 8 — Provisions Concerning Passengers and Crew

FUEL CELL INDUSTRY UPDATE

(Presented by FCHEA)

SUMMARY

This paper provides an update to the ICAO DGP regarding DGP/23-WP/44, including progress on Amendment 1 to IEC 62282-6-100.

Action by the DGP-WG is in paragraph 2.

1. INTRODUCTION

1.1 In DGP/23–WP/44 and associated flimsies, and during DGP/23, the FCHEA brought forward Amendment 1 to IEC 62282-6-100 Edition 1, as issued for enquiry (CD-V) balloting at the time. As discussed previously, Amendment 1 provides critical clarifications and improvements to IEC 62282-6-100.

1.2 As noted in paragraph 2.5.4 of the DGP/23 Report (DGP/23-WP/102), the voting period for the enquiry stage of Amendment 1 ended on 3 March 2012. This presented practical problems with removing the square brackets placed around Amendment 1 during DGP/23, both relative to scheduling of the review of the DGP/23 report by the Council, and in terms of Amendment 1 being approved by the DGP members and published without change from the enquiry stage.

1.3 This working paper provides a comprehensive update on the status of Amendment 1, which was approved during the enquiry stage, but also modified in response to comments prior to circulation for final approval. Final approval is expected, but still pending with a voting period closing on 14 September 2012. This amendment provides enhancements in safety over and above the safety provided through IEC 62282-6-100; therefore, the DGP is herein requested to reference this Amendment 1, along with IEC 62282-6-100, via an addendum to the ICAO Technical Instructions.

2. UPDATE ON AMENDMENT 1

2.1 Amendment 1 was approved during the enquiry (CD-V) stage, with a large majority of voting member countries voting to approve the document. Two voting member countries (Germany and Japan) submitted negative votes, and comments were submitted by five voting member countries (Egypt, Germany, Japan, Spain, and the United States). Consequently, the Amendment could not proceed directly to publication following the enquiry stage.

2.2 The technical experts on the IEC committee spent considerable time working together and with interested regulators to review and address all comments submitted during the enquiry stage prior to completing the final draft international standard (FDIS), which is currently out for a two-month voting period, ending 14 September 2012.

2.3 As a result of this work, several technical changes were included in the FDIS document, a summary of which is included in paragraph 3, below. For ease of reference, an annotated version of the FDIS is attached, including a redline of all changes relative to the previous version reviewed by the DGP, and explanatory comments providing rationale for the changes made.

2.4 Voting on the final draft international standard for Amendment 1 closes on 14 September 2012. FCHEA will provide the DGP with an update including voting results and estimated date of publication of Amendment 1 as soon as possible once voting is complete. Preliminary voting results indicate that positive votes with no further comments have already been submitted to the IEC by at least Canada, France, Japan, the United Kingdom, and the United States. It should be also noted that experts in these countries have positively confirmed that any prior concerns with the enquiry stage document have now been addressed in the FDIS.

2.5 The FCHEA would further like to thank the members of the DGP who generously gave their time to review and comment on the proposed changes to Amendment 1, both throughout the editorial process as well as during the FDIS circulation.

3. DISCUSSION OF CHANGES IN AMENDMENT 1 (FDIS)

3.1 Amendment 1 to 62282-6-100 Edition 1 was circulated 13 July 2012 for final draft international standard balloting and comments by member countries until 14 September 2012. A copy as circulated for final vote is attached (105/402/FDIS) as Appendix A. A redline document comparing the FDIS of Amendment 1 to the document as circulated for enquiry stage balloting (and previously reviewed by the DGP) is attached as Appendix B.

3.2 A brief summary outlining the major items in Amendment 1, as circulated for FDIS vote, and in particular the major changes from the enquiry stage, and supporting rationale follows.

3.2.1 The FDIS employs a universal approach to assessing whether or not any bubbles observed during leakage testing are attributable to dangerous goods outside the fuel cartridge. This new approach utilizes the point source gas loss detection test to ensure no leakage of dangerous goods to the environment, and more correctly stipulates that it is bubbles due to hydrogen leakage that result in failure of the hydrogen leakage tests for Annexes E and F. The approach replaces the previously proposed approach from the enquiry stage circulation of Amendment 1, which utilized the impermissible hydrogen gas loss test following leakage testing for used cartridges.

3.2.2 The revised procedure ensures and improves safety, while avoiding false failures that may result from presence of non-hazardous materials (e.g. water vapour, surface tension, etc.). The proposed text dictating the new procedure for checking for hydrogen leakage includes text as follows:

a) the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.

b) if bubbles are observed, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.

c) if point source testing is performed, hydrogen leakage measurement in accordance with paragraph a) shall be repeated one hour after completion of the point source test. If bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure E.2 and Figure E.3.

3.2.3 Passing criteria and procedures for each type test throughout Annexes E and F have now also been modified as illustrated in the attached document to avoid confusion around which tests are to be performed when. Significant text and new figures were added to Amendment 1 to address a number of inconsistencies and ambiguities between the text and figures in IEC 62282-6-100, which could lead to incorrect or unsafe application of the standard.

3.2.4 Figures in Annexes E and F have now been updated to clearly reflect the improved leakage and gas loss testing procedures to be implemented following each type test. These modifications further improve the safety of the standard by improving consistency, correcting minor errors, and removing ambiguities.

3.3 As previously detailed to the DGP in the Addendum to DGP/23-WP/44, Amendment 1 continues to address a number of errors and ambiguities within IEC 62282-6-100, resulting in a stronger, safer standard. T hese amendments provide clarification and improve consistency in terminology, measurement methods, and test procedures used throughout the standard, and address issues with clarity and legibility of markings on very small cartridges.

4. ACTION BY THE DGP-WG

4.1 The FCHEA would like to request that the DGP review the FDIS of Amendment 1 to IEC 62282-6-100. In consideration of the foregoing rationale, the DGP is asked to consider referencing Amendment 1 in addition to IEC 62282-6-100 by way of the following amendments to the ICAO Technical Instructions:

a) at Packing Instructions 216, 375, 496, and 874, under additional packing requirements, modify the fourth point as follows:

— On passenger aircraft, each fuel cell system and each fuel cell cartridge must conform to IEC 62282-6-100 Ed. 1, including Amendment 1, or a standard approved by the appropriate authority of the State of Origin.

b) at Table 8-1. Provisions for dangerous goods carried by passengers or crew, item 20, modify restrictions d) and h) as follows:

— each fuel cell and each fuel cell cartridge must conform to IEC 62282-6-100 Ed. 1, including Amendment 1, and must be marked with a manufacturer's certification that it conforms to the specification. In addition, each fuel cell cartridge must be marked with the maximum quantity and type of fuel in the cartridge;

— interaction between fuel cells and integrated batteries in a device must conform to IEC 62282-6-100 Ed. 1. , including Amendment 1, Fuel cells whose sole function is to charge a battery in the device are not permitted;

4.2 Further, in light of the important clarifications to and enhanced safety afforded by Amendment 1 to IEC 62282-6-100, implementation of these changes at the earliest possible time is considered essential to further enhance the safety associated with the transport of fuel cell cartridges and systems by aircraft. Therefore, the DGP is also invited to consider implementing these changes by way of an Addendum to the 2013-2014 Technical Instructions.

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APPENDIX A

FINAL DRAFT INTERNATIONAL STANDARD (FDIS) FOR AMENDMENT 1 TO IEC 62282-6-100 (105/402/FDIS)

105/402/FDIS

FINAL DRAFT INTERNATIONAL STANDARD
PROJET FINAL DE NORME INTERNATIONALE

	Project number Numéro de projet **IEC 62282-6-100 A1 Ed.1**	
	IEC/TC or SC CEI/CE ou SC **105**	Secretariat / Secrétariat **Germany**
☒ Submitted for parallel voting in CENELEC Soumis au vote parallèle au CENELEC	Distributed on / Diffusé le **2012-07-13**	Voting terminates on / Vote clos le **2012-09-14**
Also of interest to the following committees Intéresse également les comités suivants ISO TC 197		Supersedes document Remplace le document 105/348/CDV 105/391A/RVC
Functions concerned Fonctions concernées ☒ Safety / Sécurité ☐ EMC / CEM ☐ Environment / Environnement ☐ Quality assurance / Assurance de la qualité		

Titre

Amendement 1 à la CEI 62282-6-100: Technologies des piles à combustible – Partie 6-100: Systèmes à micro-piles à combustible – Sécurité

Title

IEC 62282-6-100 A1: Amendment 1 to IEC 62282-6-100: Fuel cell technologies – Part 6-100: Micro fuel cell power systems – Safety

ATTENTION
VOTE PARALLÈLE
CEI – CENELEC

L'attention des Comités nationaux de la CEI, membres du CENELEC, est attirée sur le fait que ce projet finale de Norme internationale est soumis au vote parallèle.
Les membres du CENELEC sont invités à voter via le système de vote en ligne du CENELEC.

ATTENTION
IEC – CENELEC
PARALLEL VOTING

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this final draft International Standard (DIS) is submitted for parallel voting.
The CENELEC members are invited to vote through the CENELEC online voting system.

Introductory note to the FDIS provided by the TC 105 WG 8 convenor:

The explanations below were deemed necessary in order to explain any potential concern that voting countries might have over the increased size of A1 compared to the CDV version. The increased size of A1 was necessary in order to resolve consensus issues about A1 with the experts of WG 8. There is no new technical material in the proposed A1. We needed to provide clarity in order to satisfy those concerned experts.

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The previously proposed approach from the CDV circulation of Amendment 1, to utilize the impermissible hydrogen gas loss test following leakage testing for used cartridges, has been replaced with a universal approach to assessing whether or not any bubbles observed during hydrogen leakage testing are attributable to hazardous hydrogen gas outside the fuel cartridge. This new approach utilizes the point source gas loss detection test to ensure no leakage of hazardous materials to the environment, and more correctly stipulates that it is bubble due to hydrogen leakage that result in failure of the hydrogen leakage tests for Annexes E and F. The proposed text dictating the new procedure for checking for hydrogen leakage includes text as follows:

a. *The measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.*

b. *If bubbles are observed, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.*

c. *If point source testing is performed, hydrogen leakage measurement in accordance with paragraph (a) shall be repeated one hour after completion of the point source test. If bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure E.2 and Figure E.3.*

Passing criteria for each type test throughout Annexes E and F have now also been modified as illustrated in the attached document to avoid any potential confusion around which tests are to be performed when.

FOREWORD

This amendment has been prepared by IEC technical committee 105: Fuel cell technologies.

The text of this amendment is based on the following documents:

FDIS	Report on voting
105/XX/FDIS	105/XX/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The National Committees are requested to note that for this publication the stability date is 2015.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

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2 Normative references

Add the following reference:

ISO 7010:2003, *Graphical symbols – Safety colours and safety signs – Safety signs used in workplaces and public areas*

6.1 General

Replace the existing text of 6.1 with the following new text:

All micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall be accompanied by appropriate safety information (instructions, warnings, or both) communicating the intended safe transportation, use, storage, maintenance and disposal of the product, including warnings regarding adequate ventilation for storage.

If space does not permit all markings on the fuel cartridge, markings corresponding to a) through f) in 6.2 may be on the smallest unit package, or on a package insert. The fuel cartridge shall also be marked with the appropriate signal word (“CAUTION”, “WARNING” or “DANGER”) and the general warning sign (W001 specified in ISO 7010:2003) plus the text:

"(See accompanying Warning Information.)".

E.3 Terms and definitions

Add, after E.3.5, the following new terminological entry:

E.3.6
fuel cartridge
removable article that contains fuel and supplies fuel or hydrogen to the micro fuel cell power unit or internal reservoir, not to be refillable by the user

E.3.11
leakage

Replace the definition of terminological entry E.3.11 with the following:

accessible fuel, hazardous fuel byproducts, electrolyte or hazardous liquid fuel outside the micro fuel cell power system, micro fuel cell power unit or fuel cartridge as described in E.7.2.1

E.3.43
impermissible hydrogen gas loss

Replace the definition of terminological entry E.3.43 with the following:

hydrogen gas escaping non-operating micro fuel cell power system, micro fuel cell power unit, or fuel cartridge greater than or equal to 0,0032 g/h

E.3.52
hydrogen leakage

Replace the definition of terminological entry E.3.52 with the following:

accessible hazardous hydrogen gas outside containment system, including fuel cartridge, fuel management and internal reservoir (see E.7.2.2)

E.3.53
positive pH indication of liquid borohydride fuel and by product

Delete this entry (number, term and definition).

E.7.2.2 Hydrogen leakage measurement from fuel cartridges and measurement procedures

Replace the existing text of E.7.2.2, with the following new text:

a) For fuel cartridges containing Class 8 (corrosive) borohydride compounds, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.

b) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.

c) If point source testing is performed, hydrogen leakage measurement in accordance with paragraph (a) shall be repeated one hour after completion of the point source test. If

bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure E.2 and Figure E.3.

E.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

Replace the existing text of E.7.2.3, with the following new text:

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure E.4 as follows.

a) Perform hydrogen emission testing in accordance with E.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen gas loss shall be less than 0,0032 g/h. If transient emission rates greater than 0,016 g/h are observed during hydrogen emission testing, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed. See Table E.7.

b) Perform hydrogen emission testing in accordance with E.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table E.7.

Figure E.2 – Fuel cartridge leakage test flow chart for vibration, drop, compressive loading – Replaces Figure 2

Replace the existing Figure E.2, together with its title, with the following:

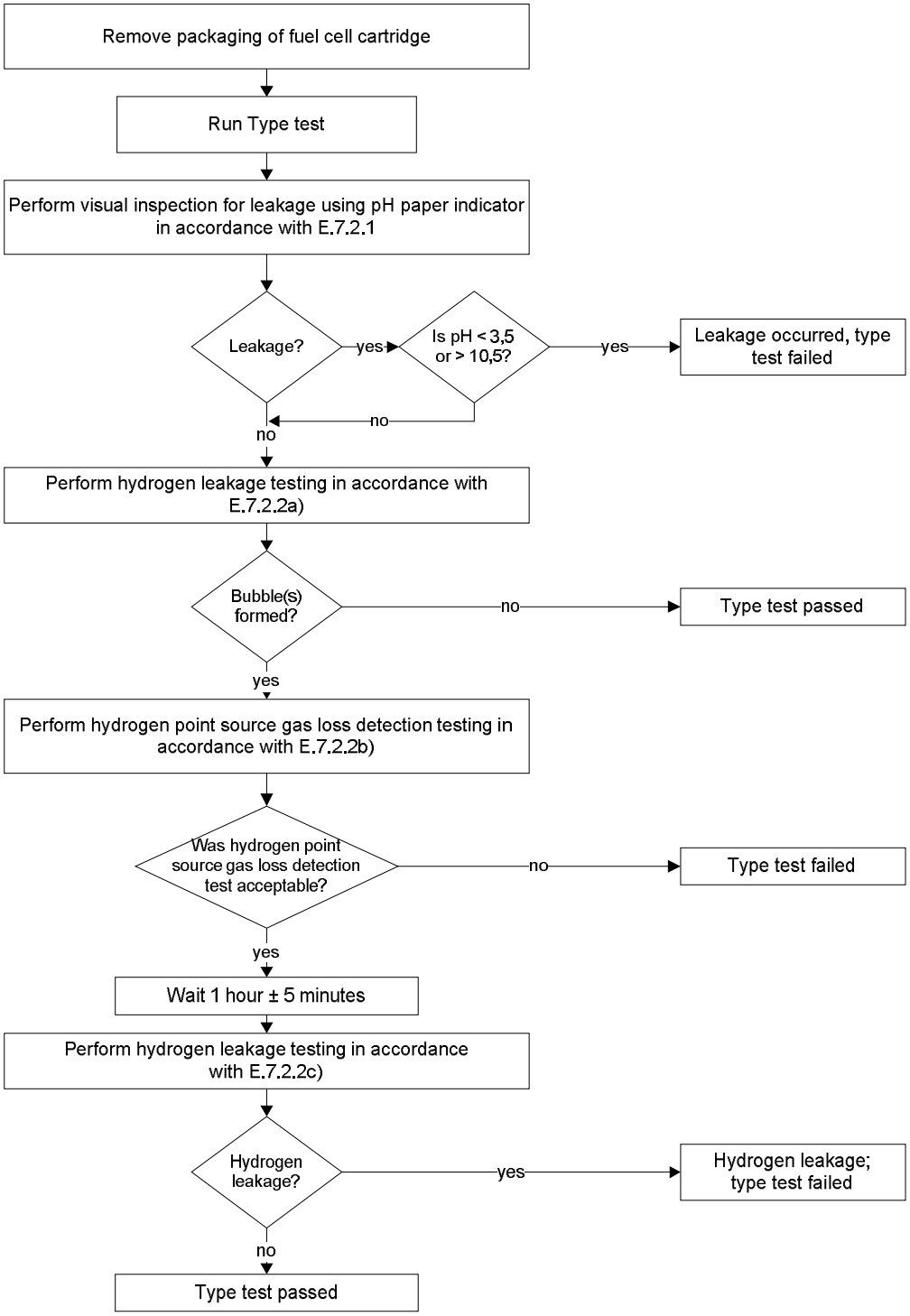


Figure E.2 – Fuel cartridge leakage and hydrogen leakage and test flow chart for vibration, drop, compressive loading – Replaces Figure 2

Figure E.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Replace the existing Figure E.3, together with its title, with the following:

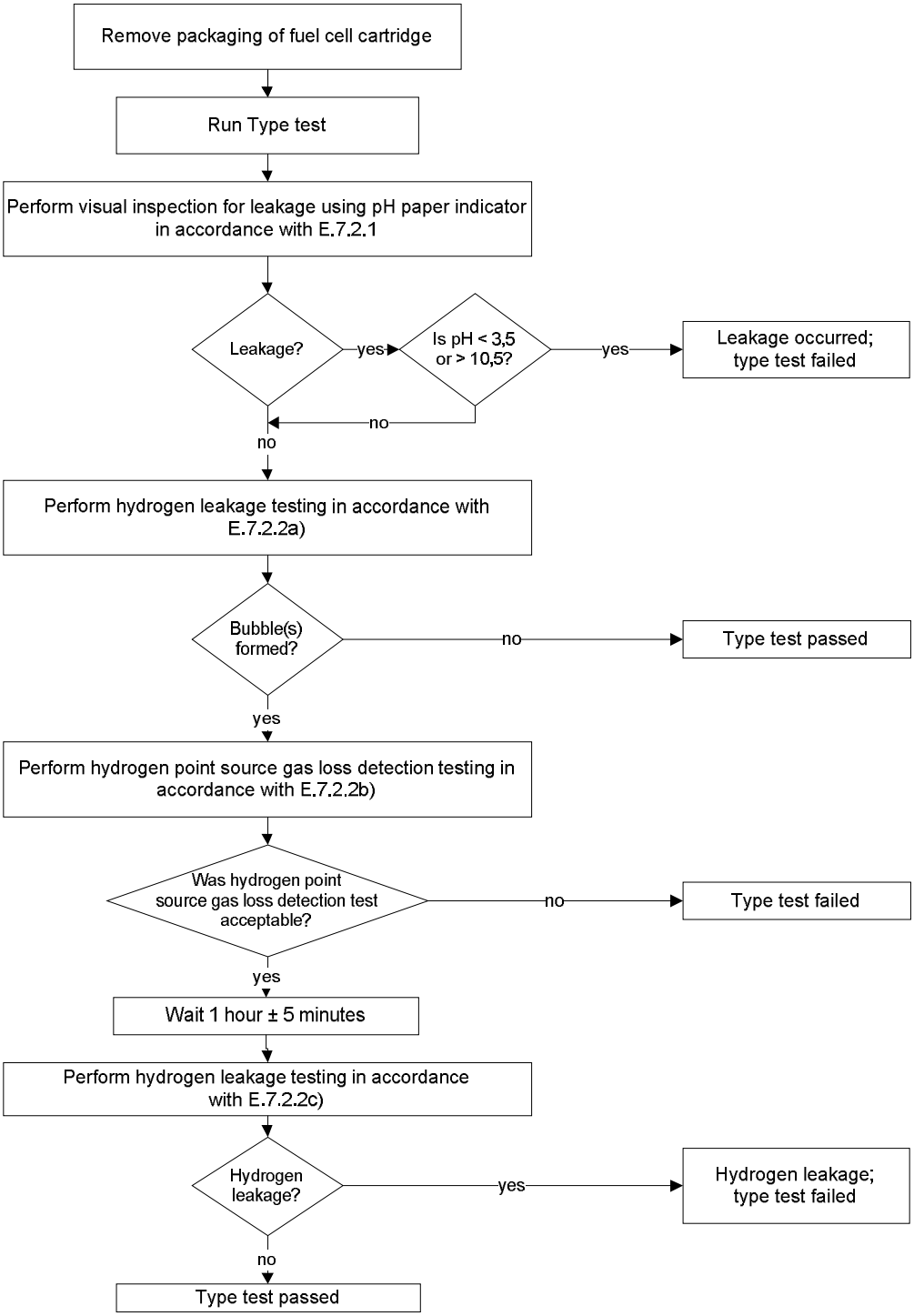


Figure E.3 – Fuel cartridge leakage and hydrogen leakage test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Figure E.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Replace, the existing Figure E.4, together with its title, with the following:

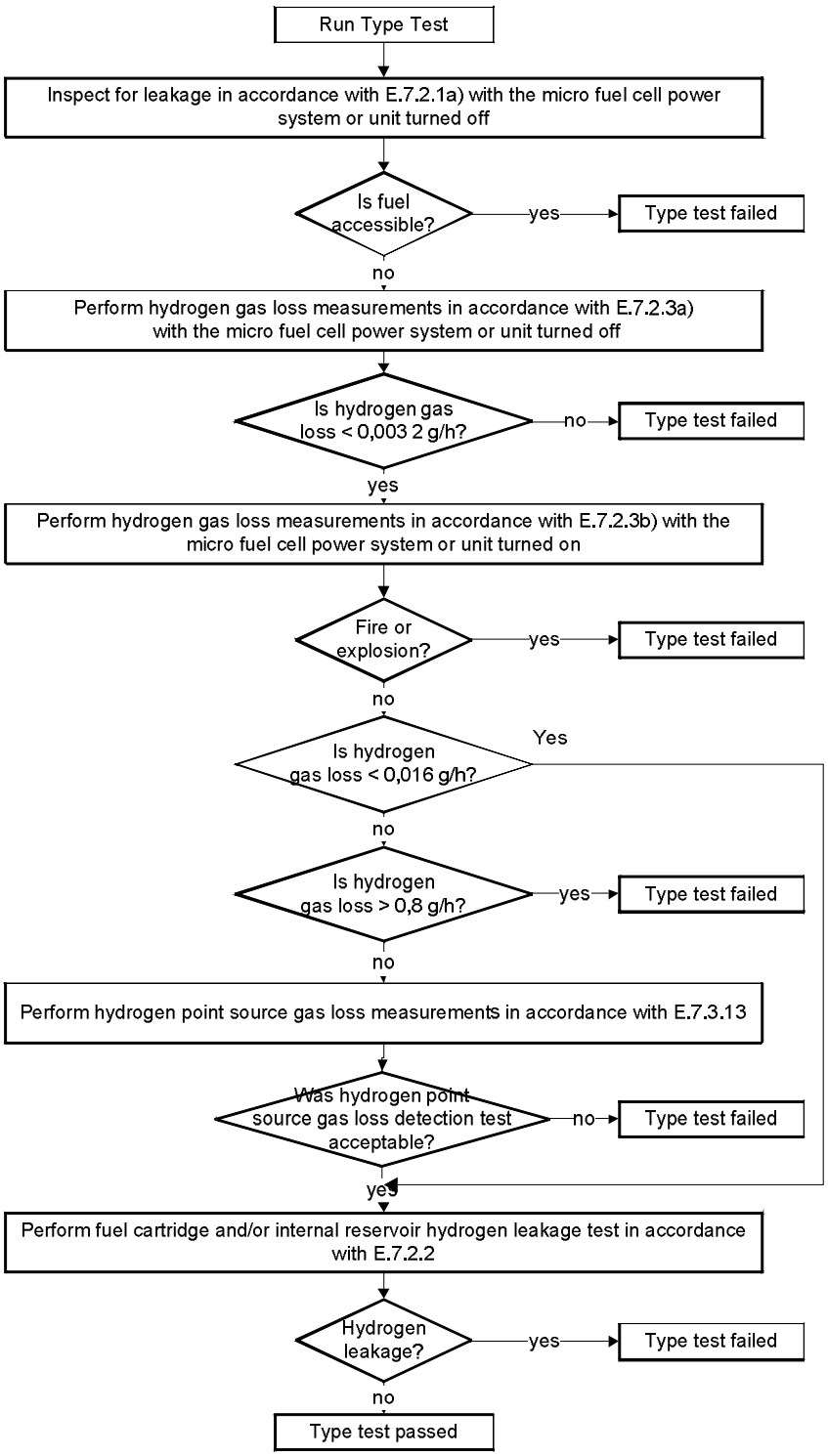


Figure E.4 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Figure E.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

Replace, the existing Figure E.5, together with its title, with the following:

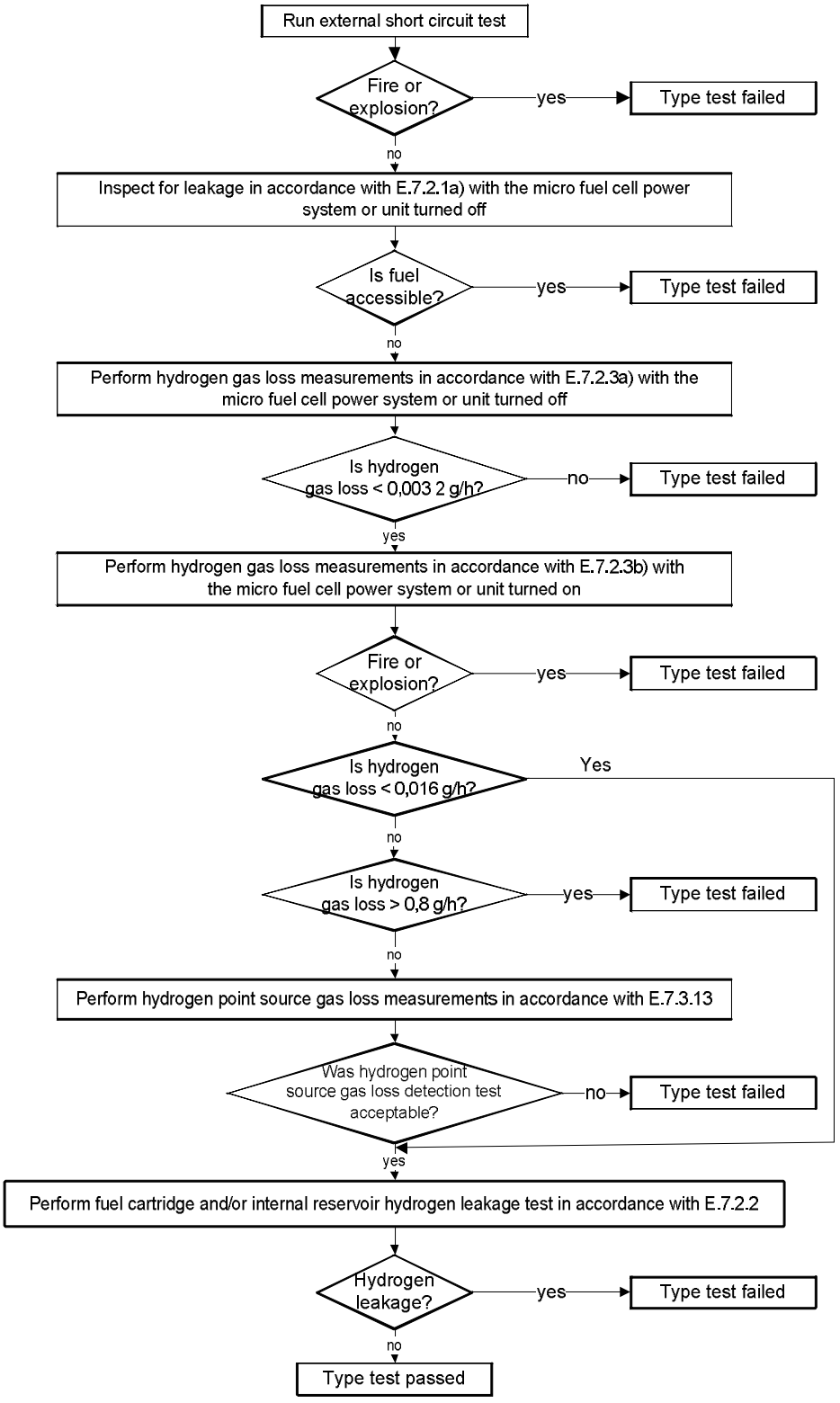


Figure E.5 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for external short-circuit test – Replaces Figure 5

Figure E.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

*Replace, in the title of Figure E.6, the word "*mass*" with "*hydrogen gas*".*

Figure E.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

*Replace, in the title of Figure E.7, the word "*mass*" with "*hydrogen gas*".*

E.7.3.1.3 Fuel cartridge low external pressure test

Replace, under item c), the existing text of point 5) with the following new text:

5) Check for hydrogen leakage as described in E.7.2.2. See Figure E.16.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h) for the fuel cartridge and micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2.

E.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See B.7.3.1.3 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

E.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See B.7.3.1.4 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

E.7.3.2 Vibration test

Replace, under item c), the existing text of point 6) with the following new text:

6) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss

testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge perform hydrogen leakage measurements in accordance with E.7.2.2.

iv) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked following E.7.3.3, in accordance with E.7.3.3 c) 9(iii).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge and micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.3 Temperature cycling test

Replace, under item c), the existing text of points 9) and 10) with the following new text:

9) Perform the following leakage tests:

i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.3.

ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge and the micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.4 High temperature exposure test

Add, under item c), at the end of point 4), the following new text:

See Figure E.3.

Delete, under item c), the entirety of point 5).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

E.7.3.5 Drop test

Replace, under item c), the existing text of points 7), 8), and 9) with the following new text:

7) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

   iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause E.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

E.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

Replace, under item c), the existing text of point 6) with the following new text:

6) Perform the following leakage tests:

   i) Perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

   ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.6.2 Fuel cartridge

Add, under item c), at the end of point 5), the following new text:

See Figure E.2.

Delete, under item c), the entirety of point 6).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

E.7.3.7 External short-circuit test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

   Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

NOTE The external short circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

E.7.3.9 Long-term storage

Replace, under item c), the existing text of point 7) with the following new text:

7) Perform leakage tests in accordance with E.7.2.1 and hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.9.

Add, under item c), the following new item 8):

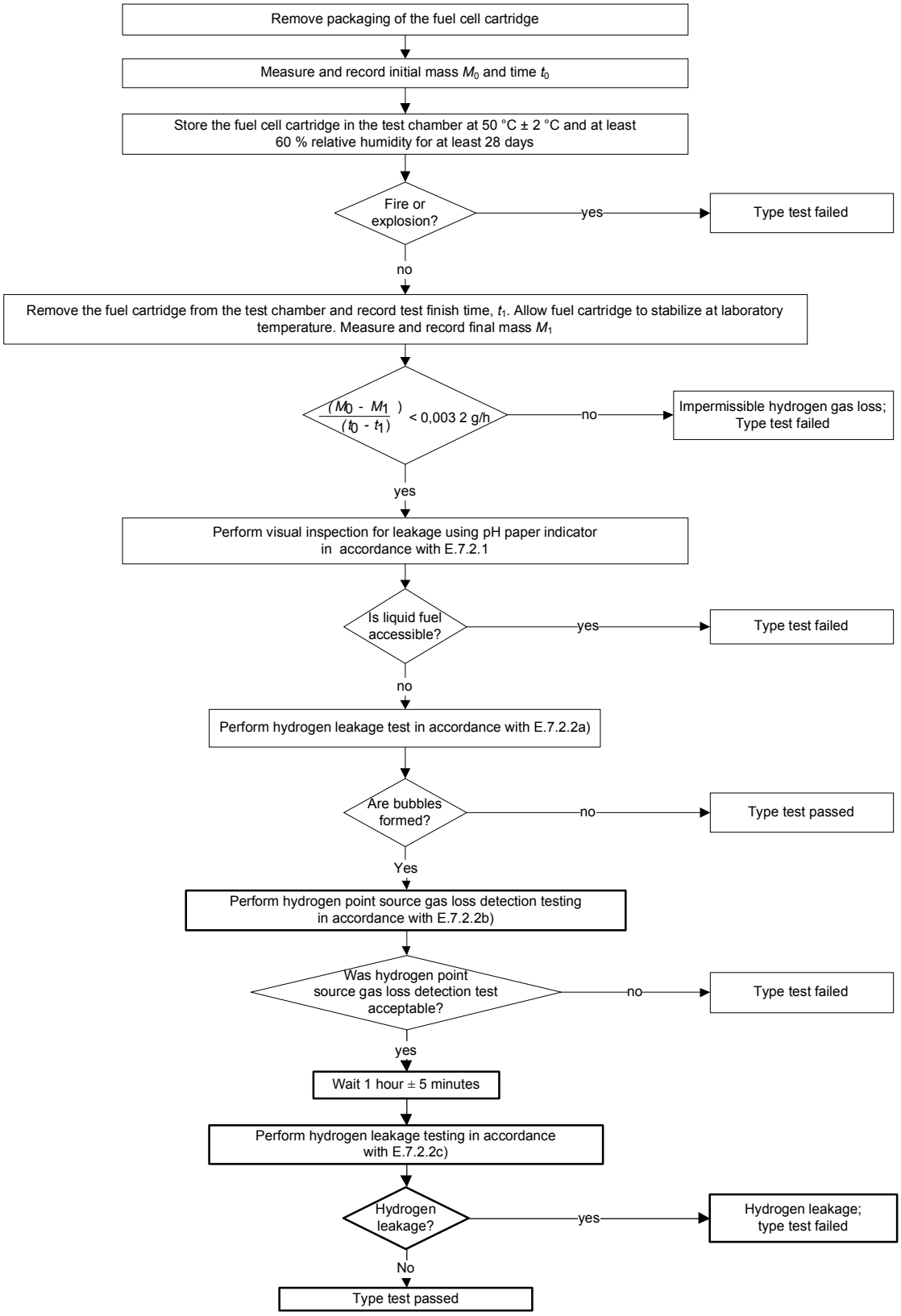
8) See B.7.3.9 for alternative methods to measure and calculate impermissible hydrogen gas loss.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h). The hydrogen concentration in the temperature test chamber shall not exceed 25 % LFL at any time during the test. Hydrogen leakage shall meet the no hydrogen leakage of Subclause E.7.2.2. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

Figure E.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

Replace the existing Figure E.9 with the following:



E.7.3.10 High-temperature connection test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

Delete, under item c), the entirety of point 14).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c once, following all 10 connection-disconnection cycles (in step 13), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.1.2 Satellite cartridge

Delete, under item c), the entirety of point 12).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c after each set of 10 connection-disconnection cycles (in step 10), rather than repeat at each disconnection step (e.g. steps 1, 2, 4, 6, 8). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.2 Micro fuel cell power unit

Replace, under item c), the existing text of point 30) with the following new text:

30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte

or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c after each set of 10 connection-disconnection cycles (in step 14 and step 29), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10, 11, 16, 19, 21, 23, 25, and 26). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Emissions must meet passing criteria of E.7.3.12 for operational and non-operating systems.

Table E.7 – Emissions limits – Replaces Table 7

Replace the existing table with the following:

Emissions	**"DEVICE – ON"** **Concentration limit** [a] based on TWA values for "DEVICE – ON" test condition	**"DEVICE – ON"** **Permissible emissions rate in 10 m^3 ACH volume** [b]	**Impermissible gas loss**[c] **(including "DEVICE – OFF")**
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m^3	0,8 g/h total 0,016 g/h from single point leak[f]	0,003 2 g/h total
Formaldehyde[d]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h
CO	0,029 g/m^3	0,290 g/h	0,290 g/h
CO_2	9 g/m^3	60 g/h[e]	60 g/h[e]
Volatile organic carbon compounds[e]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h

a The concentration limits for CO and CO_2 in this table are the mg/m^3 equivalent of the TWA and STEL exposure limits.

b The "DEVICE – ON" emission rate limit was based on 10 m^3 ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m^3. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per-person volume is over 20 m^3, so a product of 10 is conservative. A further factor of safety of 10 has been added for hydrogen in this specific case.

c The “impermissible hydrogen gas loss” criteria for non-operating micro fuel cell power systems has been chosen based on a scenario of micro fuel cell power systems in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m^3, or approximately 10 cubic feet. The criterion has been prescribed so that a hydrogen concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

d WHO guideline limit is 0,000 1 g/m^3. Background levels are 0,000 03 g/m^3. The emission limit cannot push the background level above the guideline limit.

e A seated human adult has a CO_2 emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO_2 concentration does not reach the WHO 8 h concentration limit of 9 g/m^3. In an environment with 10 m^3 ACH, this limits the contribution from the fuel cell to 60 g/h.

f The allowable flammable hydrogen emission level that will not support a standing flame is 3 standard ml/min, which is equivalent to 0,016 g/h. (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M/N. Swain, Codes and Standards Analysis, 2001 (USA)).

Figure E.16 – Fuel cartridge leakage test flow chart for external pressure test

Replace, the existing Figure E.16, together with its title, with the following:

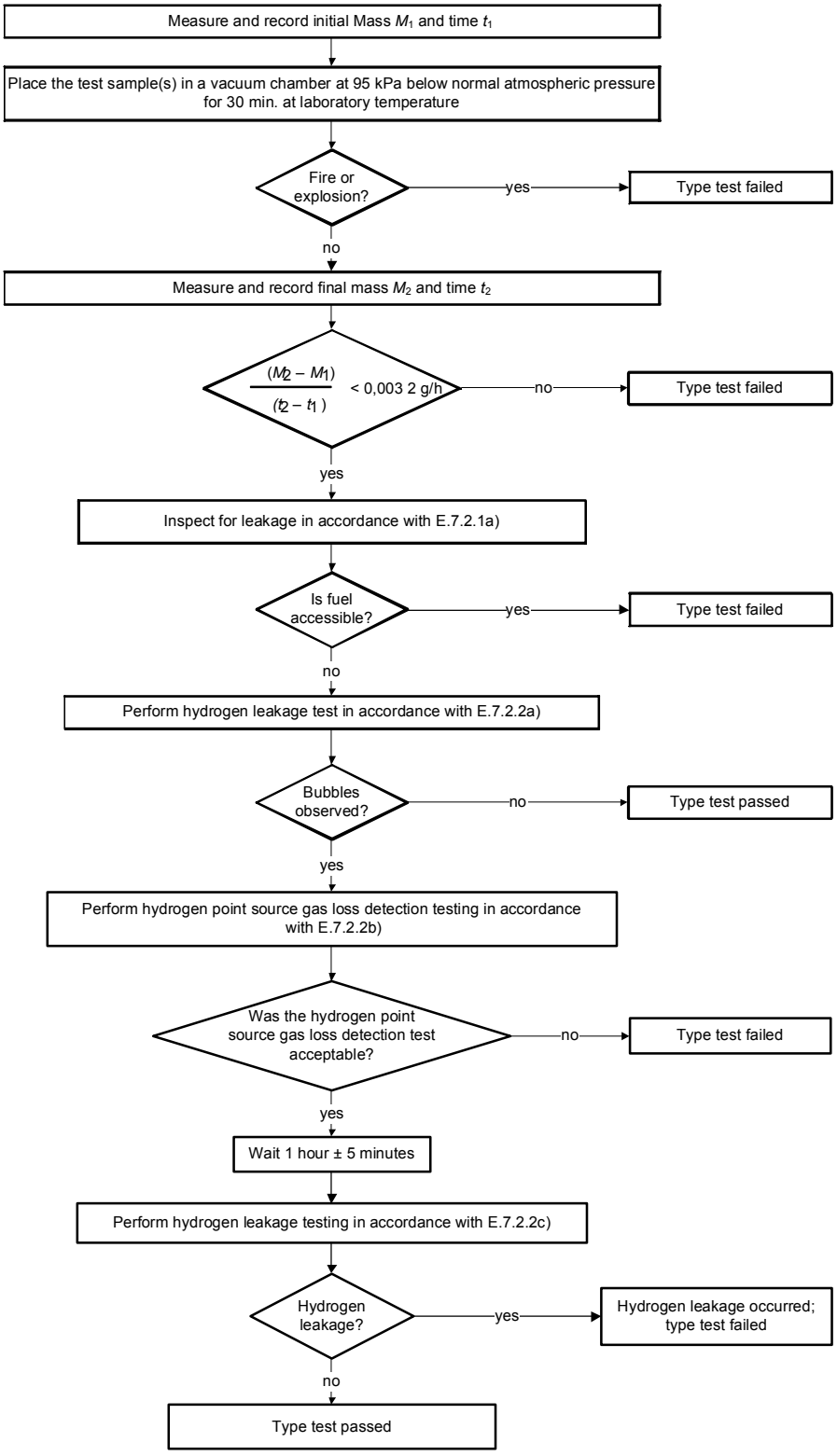


Figure E.16 – Fuel cartridge leakage test flow chart for low external pressure test

E.7.3.13 Hydrogen point source gas loss detection test

Add, at the end of item a), the following new text:

or a fuel cartridge.

*Replace, under item c), all occurrences of the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

*Replace, under item d), in steps 2, 3, 4, 5, 6, 7, 10, and 12, the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

*Replace, under item e), all occurrences of the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

F.3 Terms and definitions

Add, after F.3.5, the following new terminological entry to replace 3.6:

F.3.6
fuel cartridge
removable article that contains fuel and supplies fuel or hydrogen to the micro fuel cell power unit or internal reservoir, not to be refillable by the user

F.3.11
leakage

Replace the definition of terminological entry F.3.11 with the following:

accessible fuel, hazardous fuel byproducts, electrolyte or hazardous liquid fuel outside the micro fuel cell power system, micro fuel cell power unit or fuel cartridge as described in F.7.2.1

F.3.42
impermissible hydrogen gas loss

Replace the definition of terminological entry F.3.42 with the following:

hydrogen gas escaping non-operating micro fuel cell power system, micro fuel cell power unit, or fuel cartridge greater than or equal to 0,0032 g/h

F.3.51
hydrogen leakage

Replace the definition of terminological entry F.3.51 with the following:

accessible hazardous hydrogen gas outside containment system, including fuel cartridge, fuel management and internal reservoir (see F.7.2.2)

F.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

F.7.2.1 Leakage test and measurement procedure

Replace the existing text under item b), with the following new text:

1) For fuel cell cartridges containing solid, water reactive borohydride fuel, a water immersion test shall be shall be performed following each type test. The entire fuel

cartridge containing solid borohydride fuel is immersed in at least one meter of laboratory temperature water for 30 min.

2) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed to ensure no release of hazardous material to the environment.

3) If point source testing is performed, the water immersion test of step 1 shall be repeated one hour after completion of the point source test. If bubbles due to leakage are observed, the fuel cartridge fails the leakage test. See Figure F.2 and Figure F.3.

F.7.2.2 Hydrogen leakage measurement from fuel cartridges and/or fuel management systems and measuring procedures

Replace the existing text of F.7.2.2, with the following new text:

a) For fuel cartridges containing Class 4.3 (water reactive) borohydride, the measurement of hydrogen leakage shall be done following each type test as follows:

   1) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.

   2) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.

   3) If point source testing is performed, hydrogen leakage measurement in accordance with step 1 shall be repeated one hour after completion of the point source test. If bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure F.2 and Figure F.3.

   4) Measurement of hydrogen leakage may be performed simultaneously with the leakage test of F.7.2.1.

b) If the fuel cartridge is of the type that is refillable by the manufacturer (automated or by trained technicians), it shall be filled to its rated capacity prior to testing. If the fuel cartridge is not refillable, it shall be tested in the condition in which it completed the type test in question. The fuel cartridge shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel cartridge.

c) For micro fuel cell power systems or micro fuel cell power units with a fuel management system that contains hydrogen gas above ambient pressure, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel management system. The fuel management system shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel management system.

d) Both for fuel cartridges containing Class 4.3 (water reactive) borohydride, and for fuel management systems containing hydrogen, no hydrogen leakage is allowed. Testing for hydrogen leakage with a liquid leak detector (bubble forming) solution is acceptable only if no bubbles due to hydrogen leakage are observed.

F.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems, and micro fuel cell power units and measuring procedures

Replace the existing text of F.7.2.3 with the following new text:

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure F.4 as follows:

a) Perform hydrogen emission testing in accordance with F.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen gas loss shall be less than 0,0032 g/h. If transient emission rates greater than 0,016 g/h are

observed during hydrogen emission testing, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed. See Table F.7.

b) Perform hydrogen emission testing in accordance with Subclause F.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table F.7.

Figure F.2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

Replace the existing Figure F.2, together with its title, with the following:

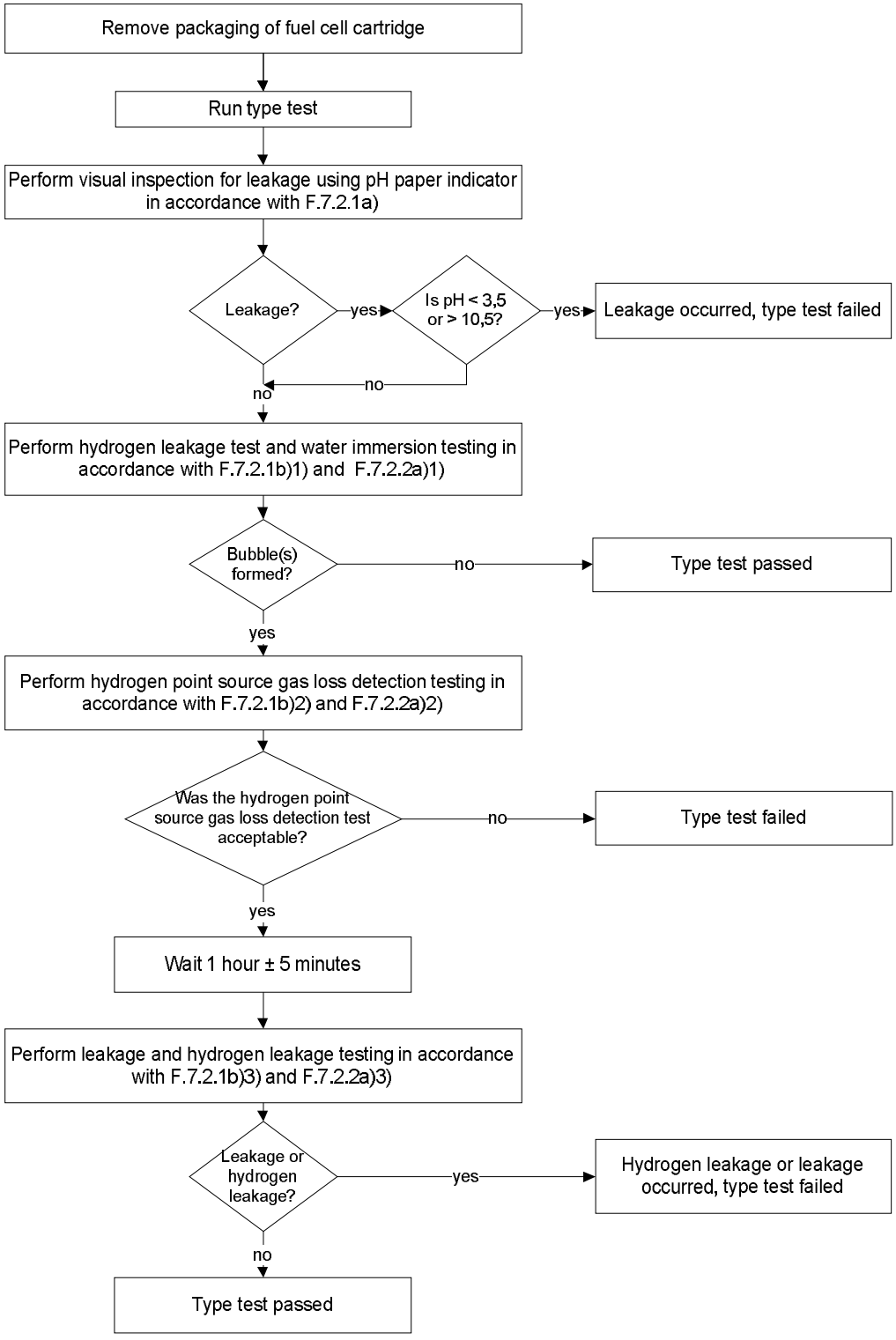


Figure F.2 – Fuel cartridge leakage and hydrogen leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

Figure F.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Replace the existing Figure F.3, together with its title, with the following:

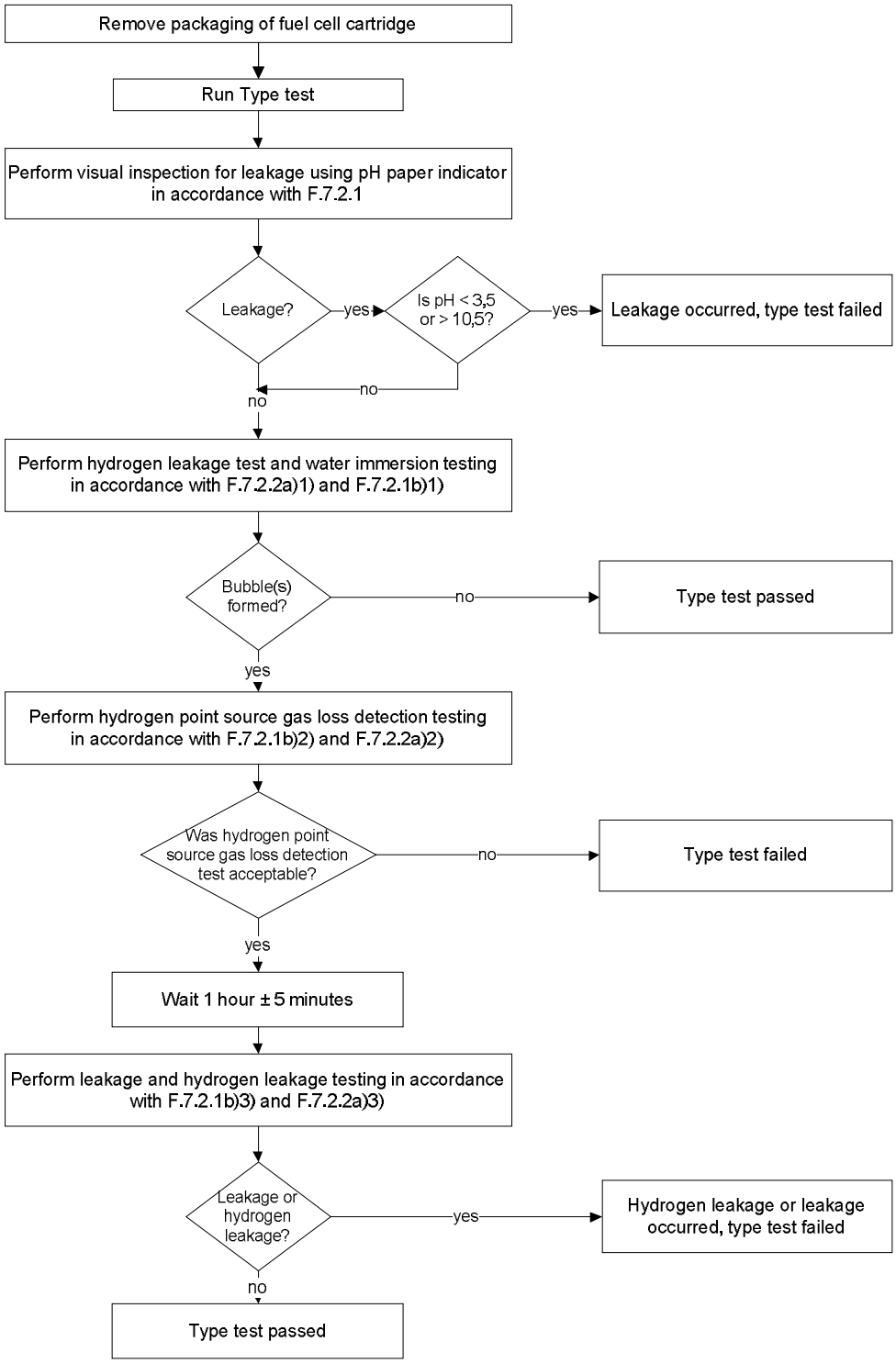


Figure F.3 – Fuel cartridge leakage and hydrogen leakage test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Figure F.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Replace, the existing Figure F.4, together with its title, with the following:

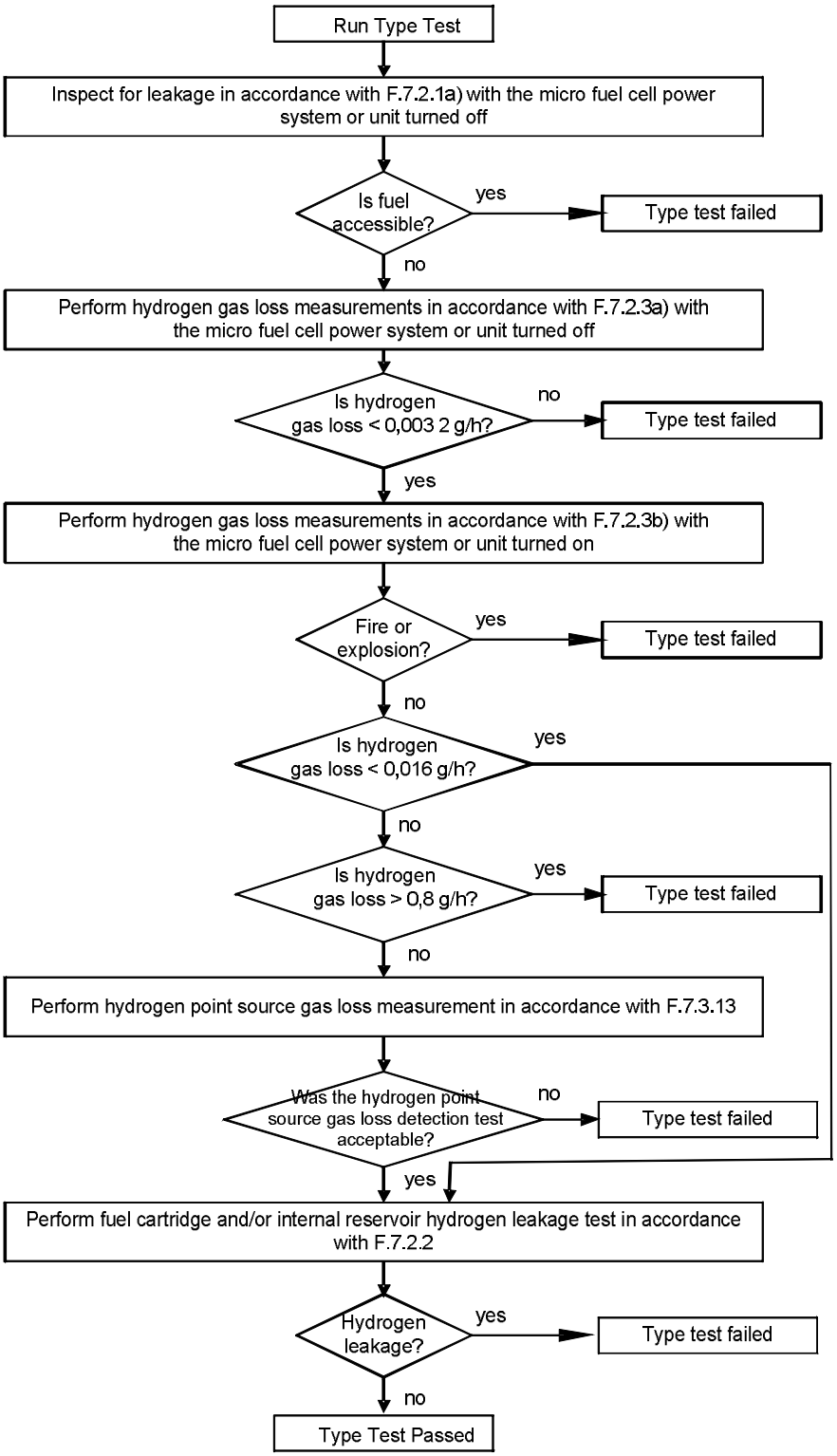


Figure F.4 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Figure F.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

Replace, the existing Figure F.5, together with its title, with the following:

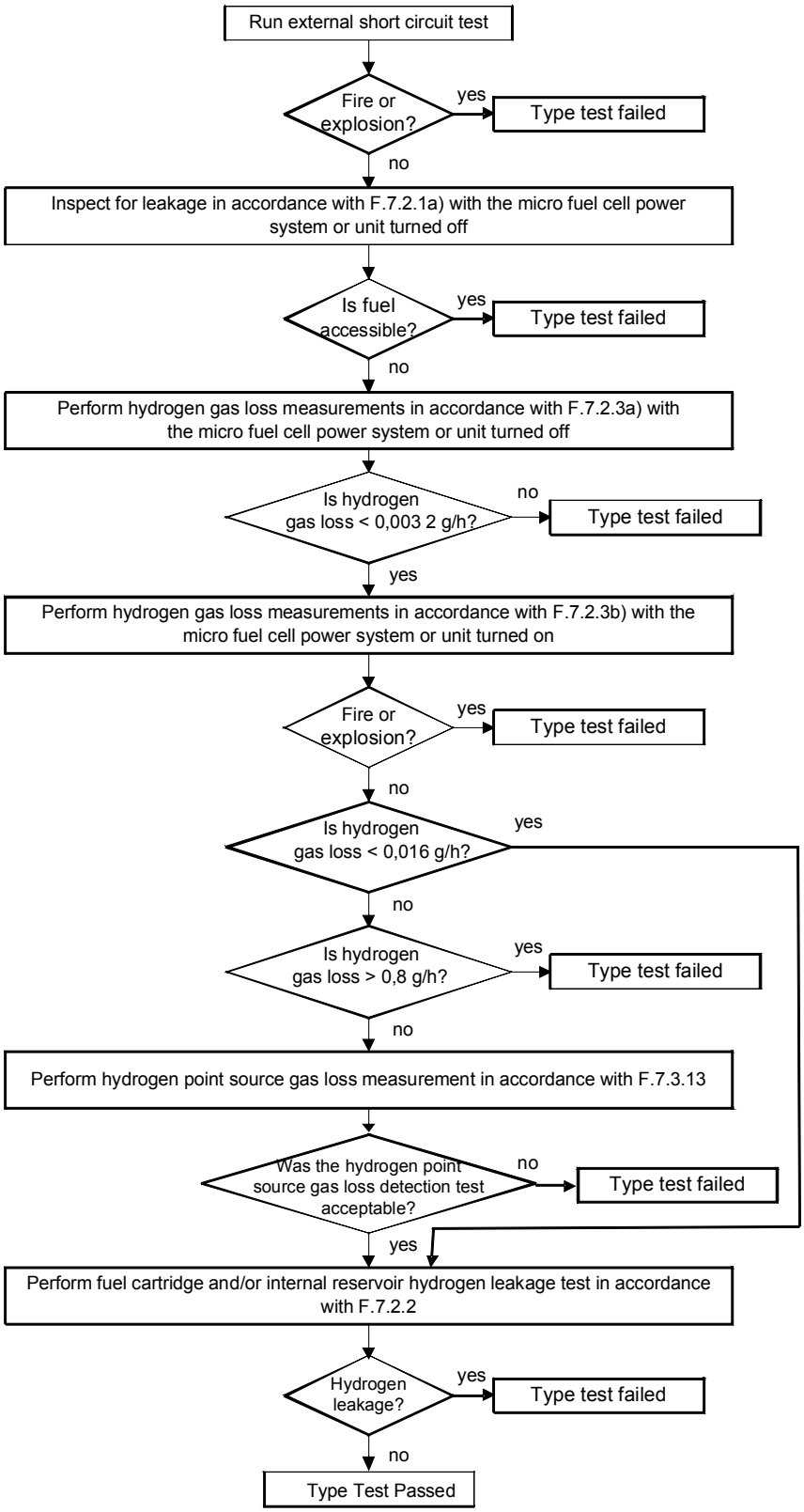


Figure F.5 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for external short-circuit test – Replaces Figure 5

Figure F.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

*Replace, in the title of Figure F.6, the word "*mass*" with "*hydrogen gas*".*

Figure F.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

*Replace, in the title of Figure F.7, the word "*mass*" with "*hydrogen gas*".*

F.7.3.1.3 Fuel cartridge low external pressure test

Replace, under item c), the existing text of point 4) with the following new text:

4) Check for hydrogen leakage as described in F.7.2.2. See Figure F.14.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss, no hydrogen leakage and no Class 4.3 (water reactive) fuel or liquid fuel component leakage. See Figure F.14. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3 (less than 0,0032 g/h). Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator and with the water immersion test as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See B.7.3.1.3 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

F.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See B.7.3.1.4 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

F.7.3.2 Vibration test

Replace, under item c), the existing text of points 6), 7), and 8) with the following new text:

6) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge perform hydrogen leakage measurements in accordance with F.7.2.2.

iv) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked following F.7.3.3, in accordance with F.7.3.3 c) 9) iii).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit Emissions shall meet the passing criteria in F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.3 Temperature cycling test

Replace, under item c), the existing text of points 9) and 10) with the following new text:

9) Perform the following leakage tests:

i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.3.

ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.4 High temperature exposure test

Add, under item c), at the end of point 3), the following new text:

See Figure F.3.

Delete, under item c), the entirety of point 4).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.5 Drop test

Replace, under item c), the existing text of points 6), 7), and 8) with the following new text:

6) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1(a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

   iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

F.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

Replace, under item c), the existing text of point 5) with the following new text:

5) Perform the following leakage tests:

   i) Perform visual inspection for leakage using pH paper in accordance with F.7.2.1(a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

   ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually

using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.6.2 Fuel cartridge

Add, under item c), at the end of point 5), the following new text:

See Figure F.2.

Delete, under item c), the entirety of point 6).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.7 External short-circuit test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of F.7.3.12, the emission test is acceptable.

NOTE The external short circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

F.7.3.9 Long-term storage test

Replace, under item c), the existing text of point 7) with the following new text:

7) Perform leakage tests in accordance with F.7.2.1 and hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.9.

Replace, under item c), the existing text of point 8) with the following new text:

8) See B.7.3.9 for alternative methods to measure and calculate impermissible hydrogen gas loss.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. The hydrogen concentration in the chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the cartridge shall not exceed 0,0032 g/h at any time during the test. Fire, flame and explosion shall be checked using cheesecloth, infrared camera, or other suitable methods.

Figure F.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

Replace the existing Figure F.9, together with its title, with the following:

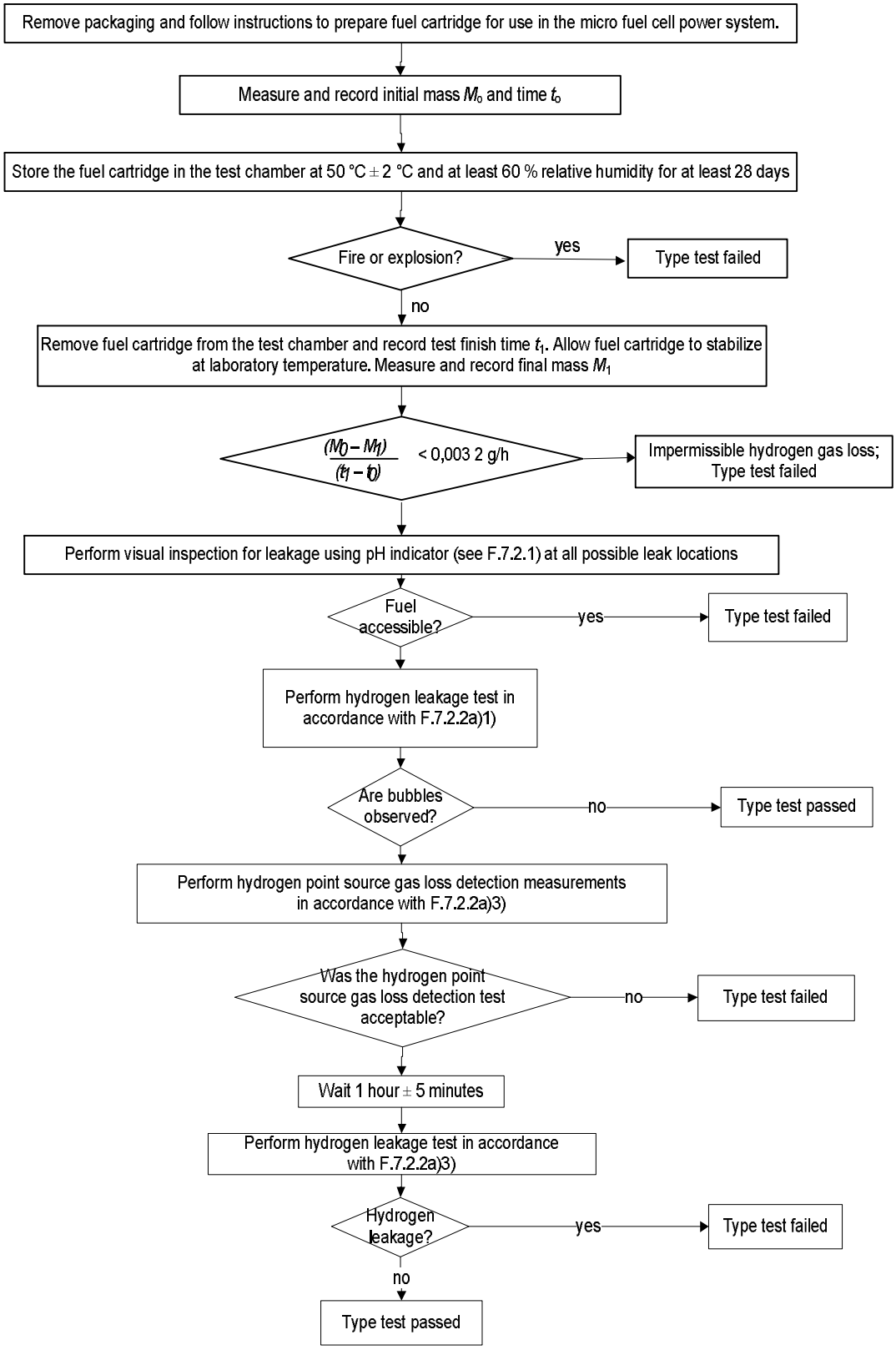


Figure F.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

F.7.3.10 High temperature connection test

Delete, under item c), point 4), the words “and water immersion test”.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occur, the test is acceptable. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.11 Connection cycling tests

F.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

Delete, under item c), the entirety of point 14).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1, For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with Subclauses F.7.2.2a)3) and F.7.2.1b)3) once, following all 10 connection-disconnection cycles (in step 13), rather than repeat at each disconnection step (e.g. steps 1, 4, 6, 8, 10).

F.7.3.11.1.2 Satellite cartridge

Delete, under item c), the entirety of point 12).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with F.7.2.2a)3) and F.7.2.1b)3) after each set of 10 connection-disconnection cycles (in step 10), rather than repeating at each disconnection step (e.g. steps 1, 2, 4, 6, 8).

F.7.3.11.2 Micro fuel cell power unit

Replace, under item c), the existing text of point 30) with the following new text:

30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3. Emissions must meet passing criteria of Subclause F.7.3.12 for operational and non-operating systems. For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with F.7.2.2a)3) and F.7.2.1b)3) after each set of 10 connection-disconnection cycles (in step 14 and step 29), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10, 11, 16, 19, 21, 23, 25, and 26).

Table F.7 – Emissions limits – Replaces Table 7

Replace the entire existing table with the following:

Emissions	"DEVICE – ON" Concentration limit [a] based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m^3 ACH volume [b]	Impermissible gas loss[c] (including "DEVICE – OFF")
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m^3	0,8 g/h total 0,016 g/h from single point leak[f]	0,0032 g/h total
Formaldehyde[d]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h
CO	0,029 g/m^3	0,290 g/h	0,290 g/h
CO_2	9 g/m^3	60 g/h[e]	60 g/h[e]
Volatile organic carbon compounds[e]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h

a The concentration limits for CO and CO_2 in this table are the mg/m^3 equivalent of the TWA and STEL exposure limits.

b The "DEVICE – ON" emission rate limit was based on 10 m^3 ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m^3. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per-person volume is over 20 m^3, so a product of 10 is conservative. A further factor of safety of 10 has been added for hydrogen in this specific case.

c The “impermissible hydrogen gas loss” criteria for non-operating micro fuel cell power systems has been chosen based on a scenario of micro fuel cell power systems in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m^3, or approximately 10 cubic feet. The criterion has been prescribed so that a hydrogen concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

d WHO guideline limit is 0,000 1 g/m^3. Background levels are 0,000 03 g/m^3. The emission limit cannot push the background level above the guideline limit.

e A seated human adult has a CO_2 emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO_2 concentration does not reach the WHO 8 h concentration limit of 9 g/m^3. In an environment with 10 m^3 ACH, this limits the contribution from the fuel cell to 60 g/h.

f The allowable flammable hydrogen emission level that will not support a standing flame is 3 standard ml/min, which is equivalent to 0,016 g/h. (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, Codes and Standards Analysis, 2001 (USA)).

Figure F.14 – Fuel cartridge leakage test flow chart for low external pressure test

Replace, the existing Figure F.14, together with its title, with the following:

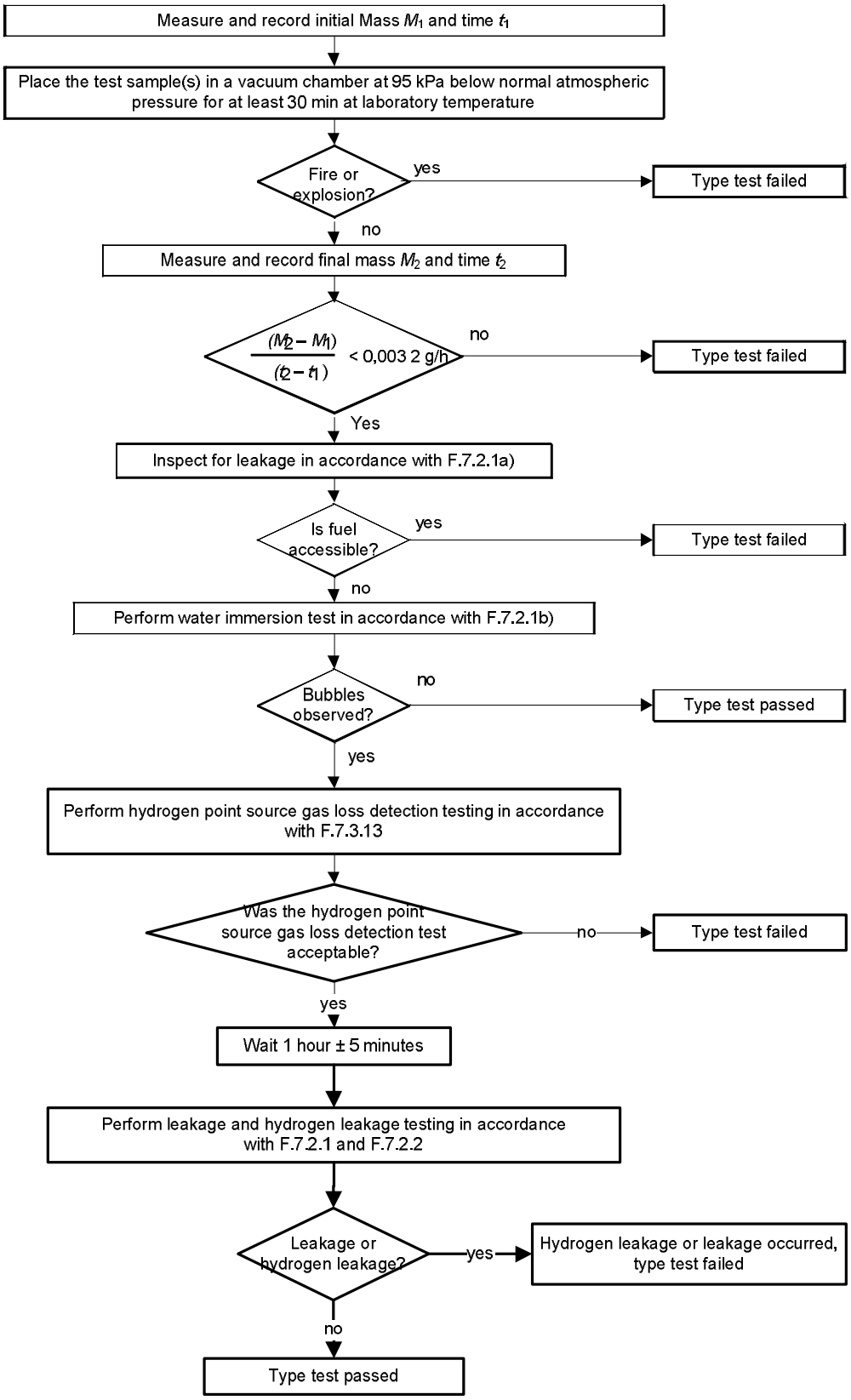


Figure F.14 – Fuel cartridge leakage test flow chart for external pressure test

F.7.3.13 Hydrogen point source gas loss detection test

Add, at the end of point a), the following new text:

or a fuel cartridge.

*Replace, under item c), all occurrences of the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

*Replace, under item d), in steps 2, 3, 4, 5, 6, 7, 10, and 12, the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

*Replace, under item e), all occurrences of the existing text "*micro fuel cell power system or unit*" with the new text "*test sample*".*

Bibliography

Add the following reference:

SWAIN, M.R. and SWAIN, M.N. Codes and Standards Analysis. Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535, 2001.

_____

APPENDIX B

COMPARISON OF FINAL DRAFT INTERNATIONAL STANDARD (FDIS) AND ENQUIRY STAGE VERSIONS OF AMENDMENT 1 TO IEC 62282-6-100

Amendment 1 to IEC 62282-6-100: FUEL CELL TECHNOLOGIES –

Part 6-1: Micro fuel cell power systems – Safety

FOREWORD

This amendment has been prepared by IEC technical committee 105: Fuel cell technologies.

The text of this amendment is based on the following documents:

FDIS	Report on voting
105/XX/FDIS	105/XX/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The National Committees are requested to note that for this publication the stability date is 2015.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

Deleted: edition 1.¶
This amendment provides the

Deleted: technical changes with respect to the previous edition

Deleted: This amendment has been drafted in accordance with the ISO/IEC Directives, Part 2.¶

Deleted: maintenance result

2 Normative references

Add the following reference:

ISO 7010:2003, *Graphical symbols – Safety colours and safety signs – Safety signs used in workplaces and public areas*

6.1 General

Replace the existing text of 6.1 with the following new text:

All micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall be accompanied by appropriate safety information (instructions, warnings, or both) communicating the intended safe transportation, use, storage, maintenance and disposal of the product, including warnings regarding adequate ventilation for storage.

If space does not permit all markings on the fuel cartridge, markings corresponding to a) through f) in 6.2 may be on the smallest unit package, or on a package insert. The fuel cartridge shall also be marked with the appropriate signal word ("CAUTION", "WARNING" or "DANGER") and the general warning sign (W001 specified in ISO 7010:2003) plus the text:

"(See accompanying Warning Information.)".

E.3 Terms and definitions

Add, after E.3.5, the following new terminological entry:

E.3.6
fuel cartridge
removable article that contains fuel and supplies fuel or hydrogen to the micro fuel cell power unit or internal reservoir, not to be refillable by the user

E.3.11
leakage

Replace the definition of terminological entry E.3.11 with the following:

accessible fuel, hazardous fuel byproducts, electrolyte or hazardous liquid fuel outside the micro fuel cell power system, micro fuel cell power unit or fuel cartridge as described in E.7.2.1

E.3.43
impermissible hydrogen gas loss

Replace the definition of terminological entry E.3.43 with the following:

hydrogen gas escaping non-operating micro fuel cell power system, micro fuel cell power unit, or fuel cartridge greater than or equal to 0,0032 g/h

E.3.52
hydrogen leakage

Replace the definition of terminological entry E.3.52 with the following:

accessible hazardous hydrogen gas outside containment system, including fuel cartridge, fuel management and internal reservoir (see E.7.2.2)

Comment [A1]: Added to remove ambiguity regarding content of mandatory warning information.

Deleted: ¶
<#>General¶
Add at the end this text to this subclause

Deleted: cell

Deleted: corresponding (

Deleted: safety alert symbol

Comment [A2]: Moved from below to match IEC word order, no change of content.

Moved (insertion) [1]

Deleted: used

Deleted: fuel

Deleted: unused

E.3.53
positive pH indication of liquid borohydride fuel and by product

Delete this entry (number, term and definition).

E.7.2.2 Hydrogen leakage measurement from fuel cartridges and measurement procedures

Replace the existing text of E.7.2.2, with the following new text:

a) For fuel cartridges containing Class 8 (corrosive) borohydride compounds, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.

b) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.

c) If point source testing is performed, hydrogen leakage measurement in accordance with paragraph (a) shall be repeated one hour after completion of the point source test. If bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure E.2 and Figure E.3.

E.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

Replace the existing text of E.7.2.3, with the following new text:

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure E.4 as follows.

a) Perform hydrogen emission testing in accordance with E.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen gas loss shall be less than 0,0032 g/h. If transient emission rates greater than 0,016 g/h are observed during hydrogen emission testing, hydrogen point source gas loss detection testing in accordance with E.7.3.13 shall be performed. See Table E.7.

b) Perform hydrogen emission testing in accordance with E.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table E.7.

Moved up [1]: fuel cartridge¶

Comment [A3]: New procedure to check for leakage from all cartridges.

Revised procedure ensures no release of hazardous materials to the environment, while avoiding false failures that may result from presence of non-hazardous materials (e.g. water vapour, surface tension, etc), through use of the point source gas loss testing in combination with bubble testing.

Deleted: and used fuel cartridges and measuring procedures"¶
¶
Add the following immediately after the existing item b ¶
¶
For used fuel cartridges

Deleted: used

Deleted: cartridge

Comment [A4]: Deletion of reference to used cartridges in light of change in test procedure for all cartridges (see E.7.2.2).

Additions to text address omission in standard regarding treatment of transient emission rates higher than the average allowable emission rates. Further clarification includes requiring point source gas loss testing in instances where transient emission rates exceed average limits, instead of stating that point source testing is not applicable, as the standard previous stated, providing an enhanced level of safety.

Deleted: measurement is for used

Deleted: cartridge only. Hydrogen point source testing in accordance with E.7.3.13 is not applicable.

Deleted: not exceed

Figure E.2 – Fuel cartridge leakage test flow chart for vibration, drop, compressive loading – Replaces Figure 2

Replace the existing Figure E.2, together with its title, with the following:

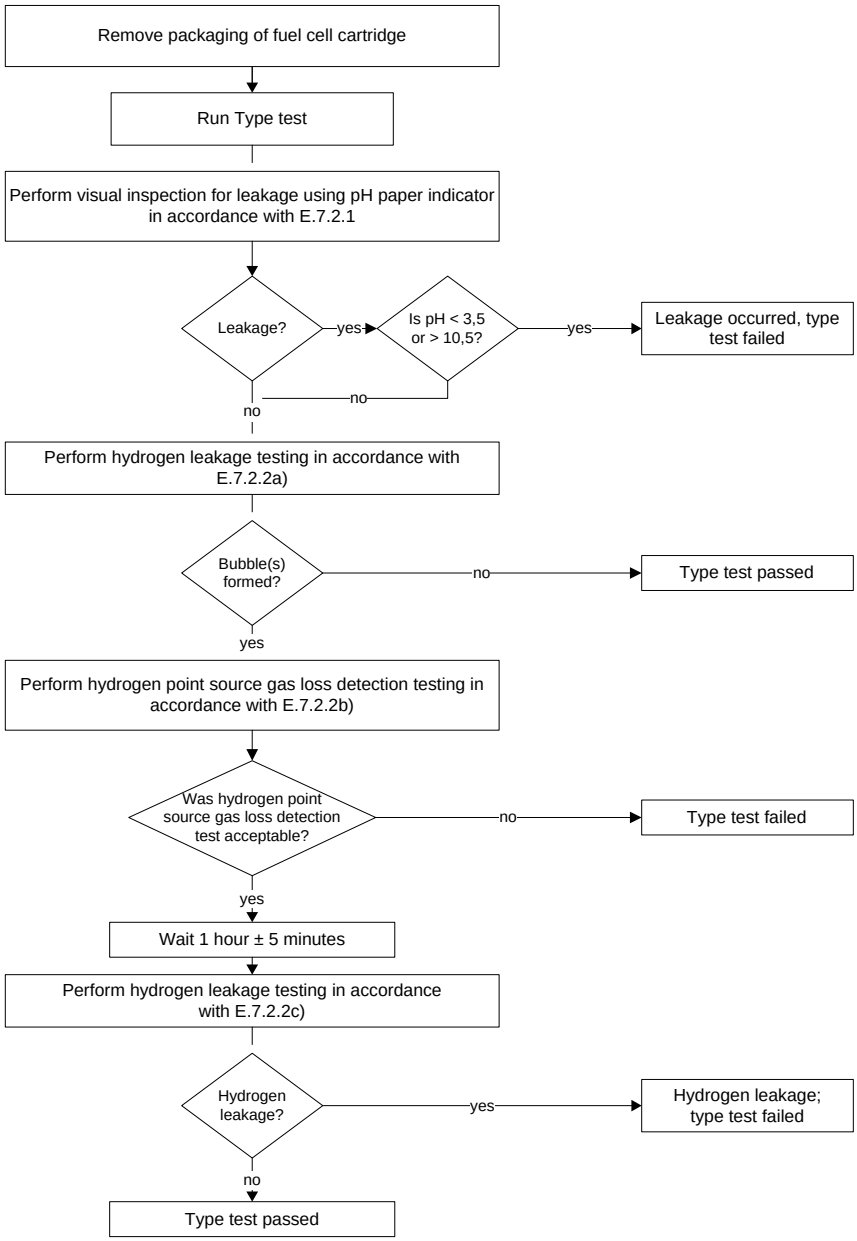


Figure E.2 – Fuel cartridge leakage and hydrogen leakage and test flow chart for vibration, drop, compressive loading – Replaces Figure 2

Deleted: , hydrogen leakage and used fuel cartridge hydrogen gas loss

Comment [A5]: NOTE; Figure E.2 changed from CD-V to FDIS to reflect new procedures in E.7.2.2

Deleted: *entire*

Figure E.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Deleted: used fuel cartridge hydrogen gas

Comment [A6]: NOTE; Figure E.3 changed from CD-V to FDIS to reflect new procedures in E.7.2.2

Replace the existing Figure E.3, together with its title, with the following:

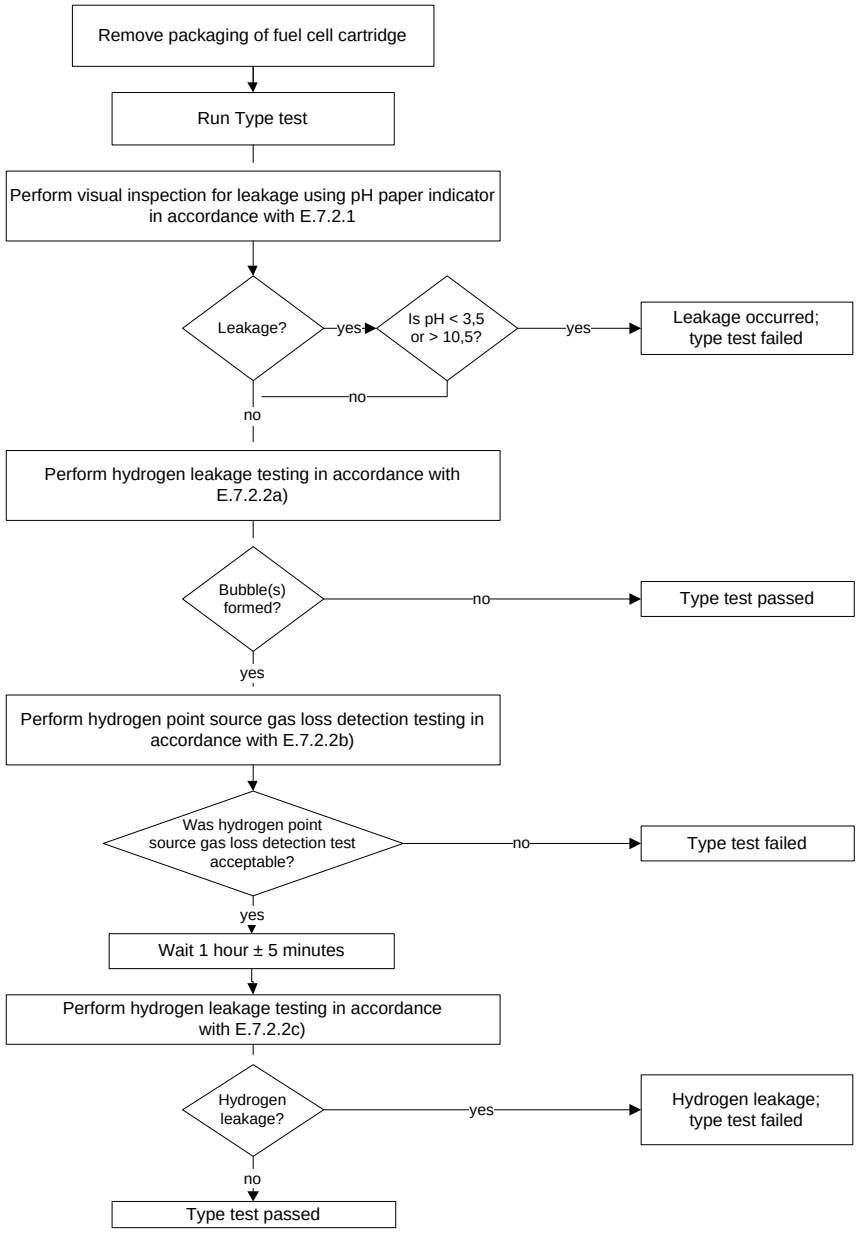


Figure E.3 – Fuel cartridge leakage and hydrogen leakage test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Figure E.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Replace, the existing Figure E.4, together with its title, with the following:

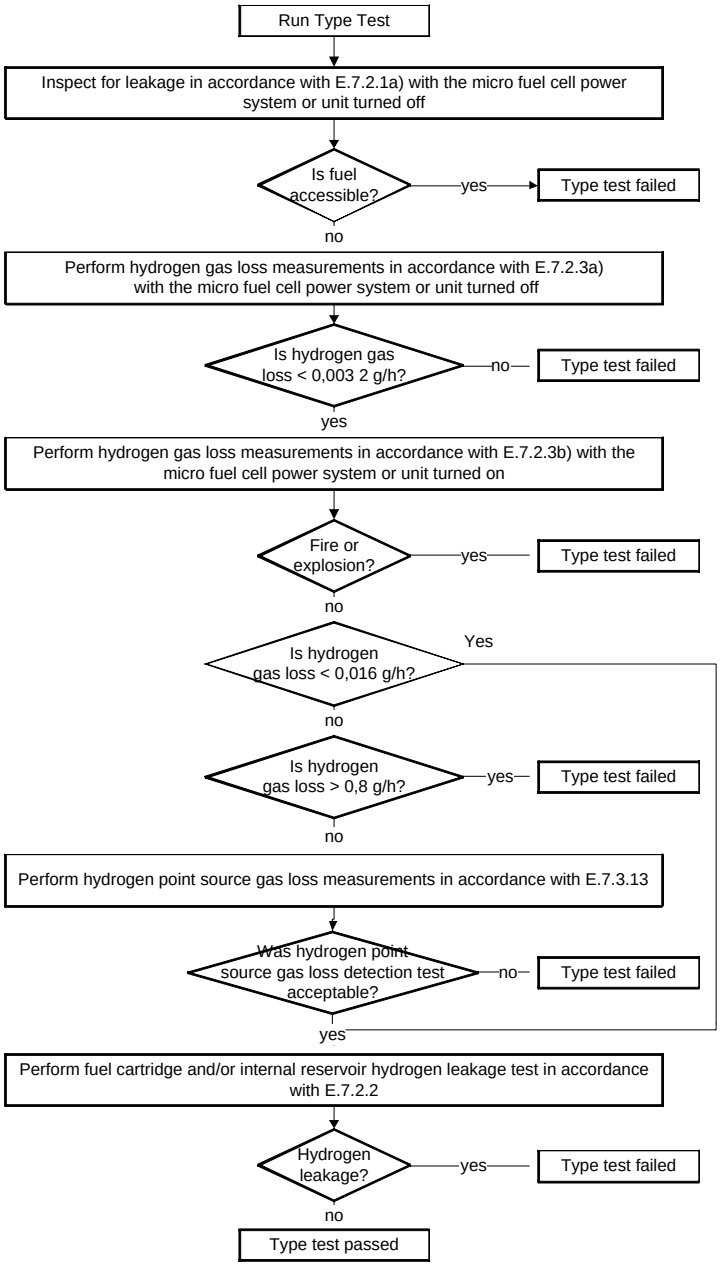


Figure E.4 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Comment [A7]: Figure E.4 newly replaced in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies.

Figure E.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

Replace, the existing Figure E.5, together with its title, with the following:

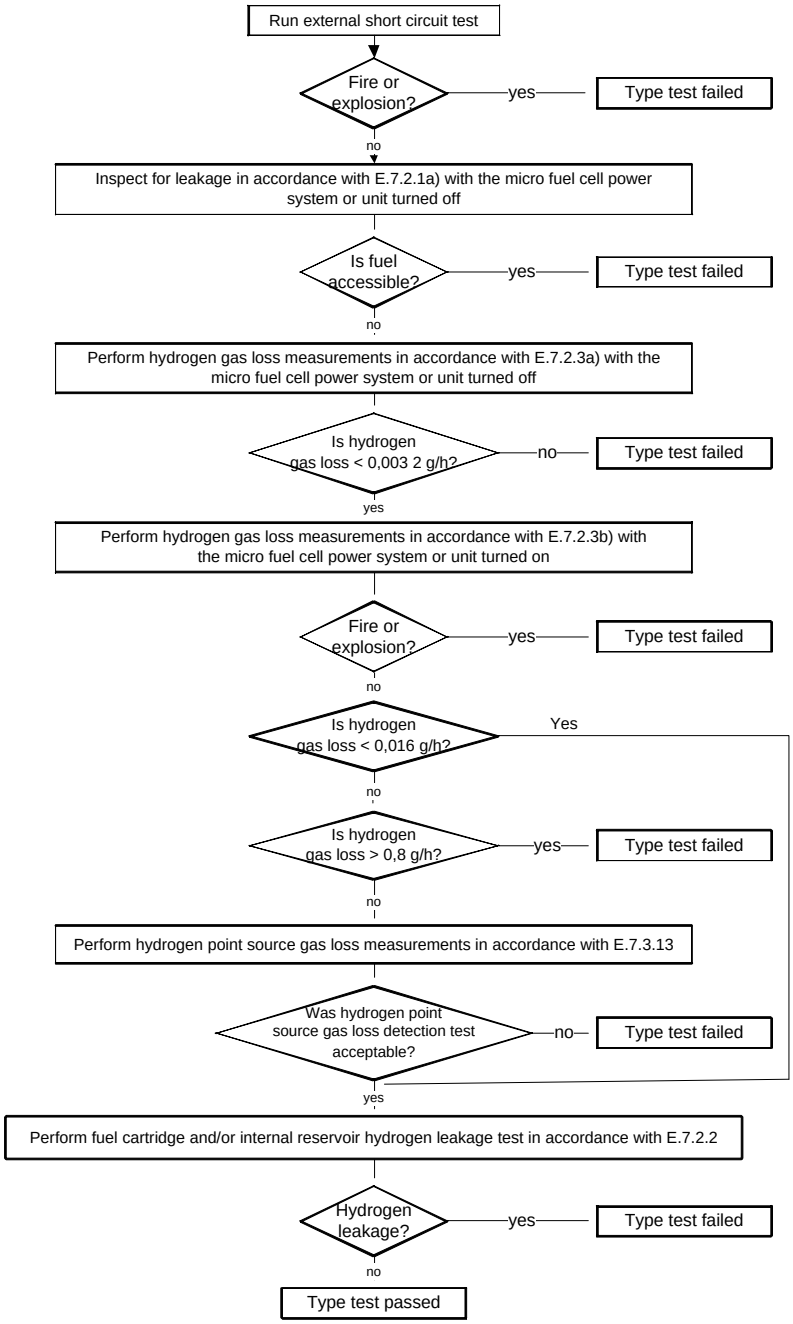


Figure E.5 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for external short-circuit test – Replaces Figure 5

Comment [A8]: Figure E.5 newly replaced in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies.

Figure E.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

Replace, in the title of Figure E.6, the word "mass" *with* "hydrogen gas".

Figure E.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

Replace, in the title of Figure E.7, the word "mass" *with* "hydrogen gas".

E.7.3.1.3 Fuel cartridge low external pressure test

Replace, under item c), the existing text of point 5) with the following new text:

5) Check for hydrogen leakage as described in E.7.2.2. See Figure E.16.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h) for the fuel cartridge and micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2.

E.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See B.7.3.1.3 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

E.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See B.7.3.1.4 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

E.7.3.2 Vibration test

Replace, under item c), the existing text of point 6) with the following new text:

6) Perform the following leakage tests:

i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.2.

ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss

Comment [A9]: Changes to E.7.3.1.3 through E.7.3.11.2 added in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies. The changes ensure that equivalent procedures and passing criteria are employed by all type tests throughout the standard. In particular:
•Consistent application of leakage and gas loss testing following each type test
•Consistent passing criteria
•Alignment between text in procedures and flow charts.

testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge perform hydrogen leakage measurements in accordance with E.7.2.2.

iv) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked following E.7.3.3, in accordance with E.7.3.3 c) 9(iii).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge and micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.3 Temperature cycling test

Replace, under item c), the existing text of points 9) and 10) with the following new text:

9) Perform the following leakage tests:

i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.3.

ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge and the micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.4 High temperature exposure test

Add, under item c), at the end of point 4), the following new text:

See Figure E.3.

Delete, under item c), the entirety of point 5).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

E.7.3.5 Drop test

Replace, under item c), the existing text of points 7), 8), and 9) with the following new text:

7) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with E.7.2.1, hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

   iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause E.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

E.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

Replace, under item c), the existing text of point 6) with the following new text:

6) Perform the following leakage tests:

i) Perform visual inspection for leakage using pH paper in accordance with E.7.2.1a, and then perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). See Figure E.4.

ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.6.2 Fuel cartridge

Add, under item c), at the end of point 5), the following new text:

See Figure E.2.

Delete, under item c), the entirety of point 6).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

E.7.3.7 External short-circuit test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

NOTE The external short circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

E.7.3.9 Long-term storage

Replace, under item c), the existing text of point 7) with the following new text:

7) Perform leakage tests in accordance with E.7.2.1 and hydrogen leakage measurements in accordance with E.7.2.2. See Figure E.9.

Add, under item c), the following new item 8):

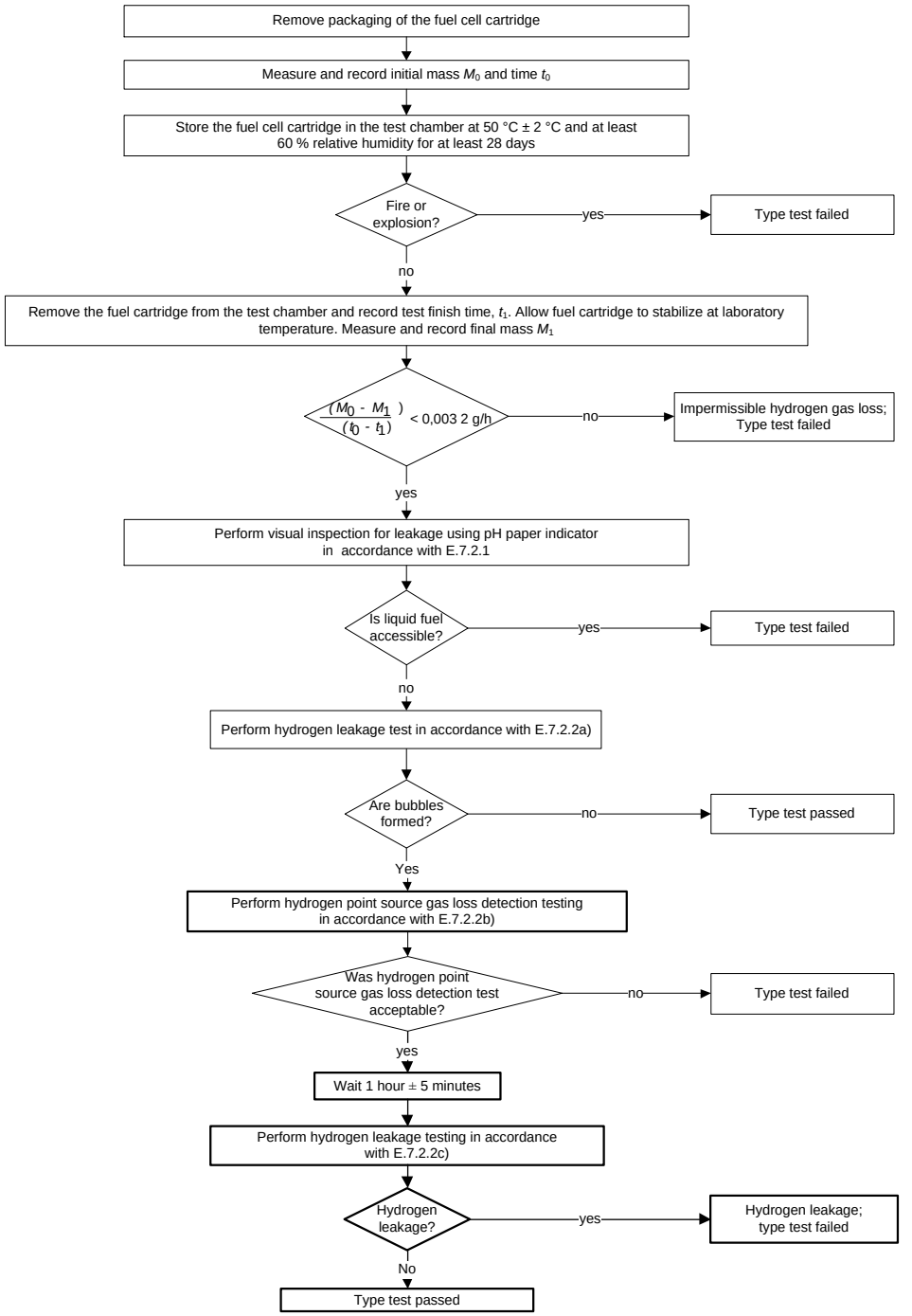
8) See B.7.3.9 for alternative methods to measure and calculate impermissible hydrogen gas loss.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h). The hydrogen concentration in the temperature test chamber shall not exceed 25 % LFL at any time during the test. Hydrogen leakage shall meet the no hydrogen leakage of Subclause E.7.2.2. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

Figure E.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

Replace the existing Figure E.9 with the following:



Comment [A10]: Figure E.9 modified to provide consistency with Figures E.2 and E.3 in light of revised leakage testing procedures.

E.7.3.10 High-temperature connection test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

Delete, under item c), the entirety of point 14).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c once, following all 10 connection-disconnection cycles (in step 13), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.1.2 Satellite cartridge

Delete, under item c), the entirety of point 12).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2 for the fuel cartridge; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c after each set of 10 connection-disconnection cycles (in step 10), rather than repeat at each disconnection step (e.g. steps 1, 2, 4, 6, 8). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11.2 Micro fuel cell power unit

Replace, under item c), the existing text of point 30) with the following new text:

30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform hydrogen gas loss testing in accordance with E.7.2.3 (including emission testing in accordance with E.7.3.12). If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with E.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH

indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause E.7.2.2, including after the fuel cartridge is installed in a micro fuel cell power system or unit and operated; for clarification, it is acceptable to perform the (second) hydrogen leakage test in accordance with E.7.2.2c after each set of 10 connection-disconnection cycles (in step 14 and step 29), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10, 11, 16, 19, 21, 23, 25, and 26). Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Emissions must meet passing criteria of E.7.3.12 for operational and non-operating systems.

Table E.7 – Emissions limits – Replaces Table 7

Replace the existing table with the following:

Emissions	"DEVICE – ON" Concentration limit [a] based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m^3 ACH volume [b]	Impermissible gas loss[c] (including "DEVICE – OFF")
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m^3	0,8 g/h total 0,016 g/h from single point leak[f]	0,003 2 g/h total
Formaldehyde[d]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h
CO	0,029 g/m^3	0,290 g/h	0,290 g/h
CO_2	9 g/m^3	60 g/h[e]	60 g/h[e]
Volatile organic carbon compounds[e]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h

a The concentration limits for CO and CO_2 in this table are the mg/m^3 equivalent of the TWA and STEL exposure limits.

b The "DEVICE – ON" emission rate limit was based on 10 m^3 ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m^3. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per-person volume is over 20 m^3, so a product of 10 is conservative. A further factor of safety of 10 has been added for hydrogen in this specific case.

c The "impermissible hydrogen gas loss" criteria for non-operating micro fuel cell power systems has been chosen based on a scenario of micro fuel cell power systems in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m^3, or approximately 10 cubic feet. The criterion has been prescribed so that a hydrogen concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

d WHO guideline limit is 0,000 1 g/m^3. Background levels are 0,000 03 g/m^3. The emission limit cannot push the background level above the guideline limit.

e A seated human adult has a CO_2 emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO_2 concentration does not reach the WHO 8 h concentration limit of 9 g/m^3. In an environment with 10 m^3 ACH, this limits the contribution from the fuel cell to 60 g/h.

f The allowable flammable hydrogen emission level that will not support a standing flame is 3 standard ml/min, which is equivalent to 0,016 g/h. (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M/N. Swain, Codes and Standards Analysis, 2001 (USA)).

Deleted: Non-operating system

Comment [A11]: Inclusion of "used fuel cartridge" removed from impermissible gas loss column in response to comments received on the CD-V.

Deleted: and used cartridge

Comment [A12]: Added to provide clarity and consistency with other annexes.

Comment [A13]: Added to provide clarity and consistency with other annexes.

Figure E.16 – Fuel cartridge leakage test flow chart for external pressure test

Comment [A14]: Figure E.16 modified to provide consistency with Figures E.2 and E.3 in light of revised leakage testing procedures.

Replace, the existing Figure E.16, together with its title, with the following:

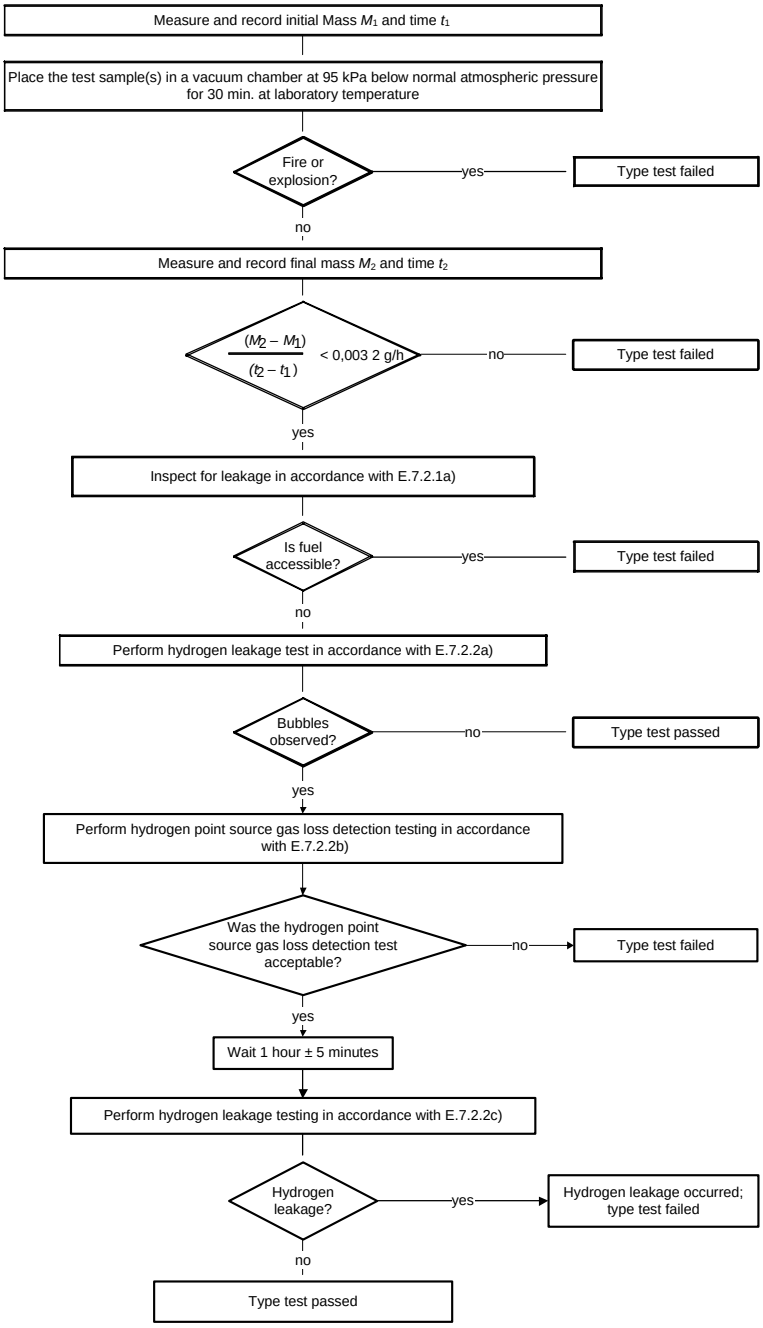


Figure E.16 – Fuel cartridge leakage test flow chart for low external pressure test

E.7.3.13 Hydrogen point source gas loss detection test

Add, at the end of item a), the following new text:

or a fuel cartridge.

Replace, under item c), all occurrences of the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

Replace, under item d), in steps 2, 3, 4, 5, 6, 7, 10, and 12, the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

Replace, under item e), all occurrences of the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

F.3 Terms and definitions

Add, after F.3.5, the following new terminological entry to replace 3.6:

F.3.6
fuel cartridge
removable article that contains fuel and supplies fuel or hydrogen to the micro fuel cell power unit or internal reservoir, not to be refillable by the user

F.3.11
leakage

Replace the definition of terminological entry F.3.11 with the following:

accessible fuel, hazardous fuel byproducts, electrolyte or hazardous liquid fuel outside the micro fuel cell power system, micro fuel cell power unit or fuel cartridge as described in F.7.2.1

F.3.42
impermissible hydrogen gas loss

Replace the definition of terminological entry F.3.42 with the following:

hydrogen gas escaping non-operating micro fuel cell power system, micro fuel cell power unit, or fuel cartridge greater than or equal to 0,0032 g/h

F.3.51
hydrogen leakage

Replace the definition of terminological entry F.3.51 with the following:

accessible hazardous hydrogen gas outside containment system, including fuel cartridge, fuel management and internal reservoir (see F.7.2.2)

Comment [A15]: Modified to ensure test can be clearly applied to fuel cartridges in accordance with the new hydrogen leakage test procedures in E.7.2.2.

Comment [A16]: Moved from below to match IEC word order, no change of content.

Moved (insertion) [2]

Deleted: used

Deleted: fuel

Deleted: unused

F.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

F.7.2.1 Leakage test and measurement procedure

Replace the existing text under item b), with the following new text:

1) For fuel cell cartridges containing solid, water reactive borohydride fuel, a water immersion test shall be shall be performed following each type test. The entire fuel cartridge containing solid borohydride fuel is immersed in at least one meter of laboratory temperature water for 30 min.
2) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed to ensure no release of hazardous material to the environment.
3) If point source testing is performed, the water immersion test of step 1 shall be repeated one hour after completion of the point source test. If bubbles due to leakage are observed, the fuel cartridge fails the leakage test. See Figure F.2 and Figure F.3.

F.7.2.2 Hydrogen leakage measurement from fuel cartridges and/or fuel management systems and measuring procedures

Replace the existing text of F.7.2.2, with the following new text:

a) For fuel cartridges containing Class 4.3 (water reactive) borohydride, the measurement of hydrogen leakage shall be done following each type test as follows:
   1) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution or other equivalent means, such as a water immersion test, on all possible leak locations of the fuel cartridge.
   2) If bubbles are observed, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed to ensure no release of hazardous materials to the environment.
   3) If point source testing is performed, hydrogen leakage measurement in accordance with step 1 shall be repeated one hour after completion of the point source test. If bubbles due to hydrogen leakage are observed, the fuel cartridge fails the hydrogen leakage test. See Figure F.2 and Figure F.3.
   4) Measurement of hydrogen leakage may be performed simultaneously with the leakage test of F.7.2.1.
b) If the fuel cartridge is of the type that is refillable by the manufacturer (automated or by trained technicians), it shall be filled to its rated capacity prior to testing. If the fuel cartridge is not refillable, it shall be tested in the condition in which it completed the type test in question. The fuel cartridge shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel cartridge.
c) For micro fuel cell power systems or micro fuel cell power units with a fuel management system that contains hydrogen gas above ambient pressure, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel management system. The fuel management system shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel management system.
d) Both for fuel cartridges containing Class 4.3 (water reactive) borohydride, and for fuel management systems containing hydrogen, no hydrogen leakage is allowed. Testing for hydrogen leakage with a liquid leak detector (bubble forming) solution is acceptable only if no bubbles due to hydrogen leakage are observed.

Deleted: ¶
Annex F.3. Terms and definitions¶
Add at the end of Annex F.3. the following definition: ¶
¶
fuel cartridge¶

Moved up [2]: removable article that contains fuel and supplies fuel or hydrogen to the micro fuel cell power unit or internal reservoir, not to be refillable by the user

Comment [A17]: New procedures to check for leakage from all cartridges in F.7.2.1 and F.7.2.2.

Revised procedure ensures no release of hazardous materials to the environment, while avoiding false failures that may result from presence of non-hazardous materials (e.g. water vapour, surface tension, etc), through use of the point source gas loss testing in combination with bubble testing.

F.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems, and micro fuel cell power units and measuring procedures

Replace the existing text of F.7.2.3 with the following new text:

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure F.4 as follows:

a) Perform hydrogen emission testing in accordance with F.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen gas loss shall be less than 0,0032 g/h. If transient emission rates greater than 0,016 g/h are observed during hydrogen emission testing, hydrogen point source gas loss detection testing in accordance with F.7.3.13 shall be performed. See Table F.7.

b) Perform hydrogen emission testing in accordance with Subclause F.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table F.7.

Comment [A18]: Deletion of reference to used cartridges in light of change in test procedure for all cartridges (see F.7.2.1 and F.7.2.2).

Additions to text address omission in standard regarding treatment of transient emission rates higher than the average allowable emission rates. Further clarification includes requiring point source gas loss testing in instances where transient emission rates exceed average limits, instead of stating that point source testing is not applicable, as the standard previous stated, providing an enhanced level of safety.

Deleted: - Hydrogen gas loss measurements from

Deleted: and used fuel cartridges and measuring procedures"¶
¶
Add the following immediately after the existing item b), noting that new figures F.2 and F.3, from this amendment, apply:¶
¶
For used fuel cartridges

Deleted: used

Deleted: cartridge

Deleted: 2 and F.3

Deleted: measurement is for used fuel cartridge only. Hydrogen point source

Deleted: is not applicable. Hydrogen gas loss shall not exceed 0,0032 g/h.

Figure F.2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

Comment [A19]: NOTE; Figure F.2 changed from CD-V to FDIS to reflect new procedures in F.7.2.1 and F.7.2.2

Replace the existing Figure F.2, together with its title, with the following:

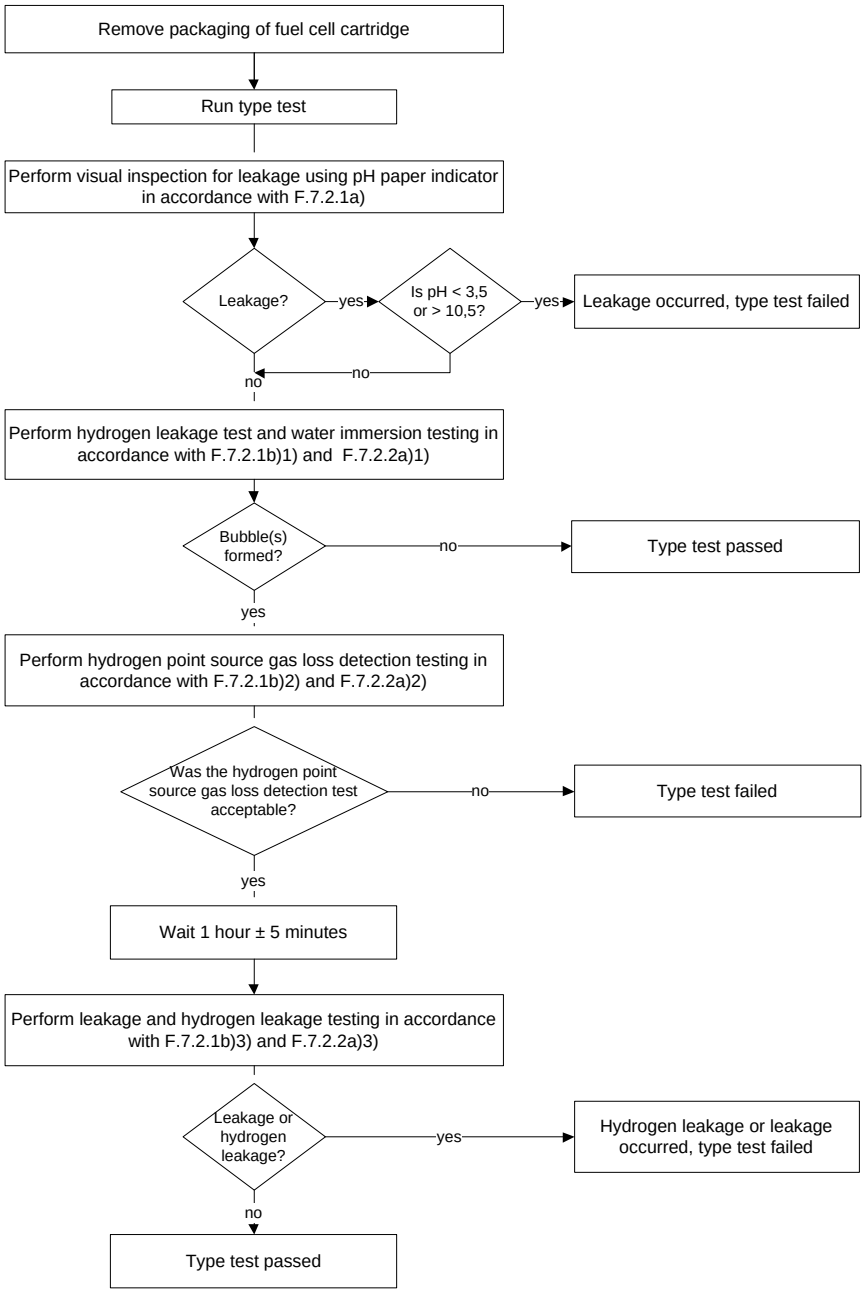


Figure F.2 – Fuel cartridge leakage and hydrogen leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

Deleted: , and used fuel cartridge hydrogen gas loss

Figure F.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Comment [A20]: NOTE; Figure F.3 changed from CD-V to FDIS to reflect new procedures in F.7.2.1 and F.7.2.2

Replace the existing Figure F.3, together with its title, with the following:

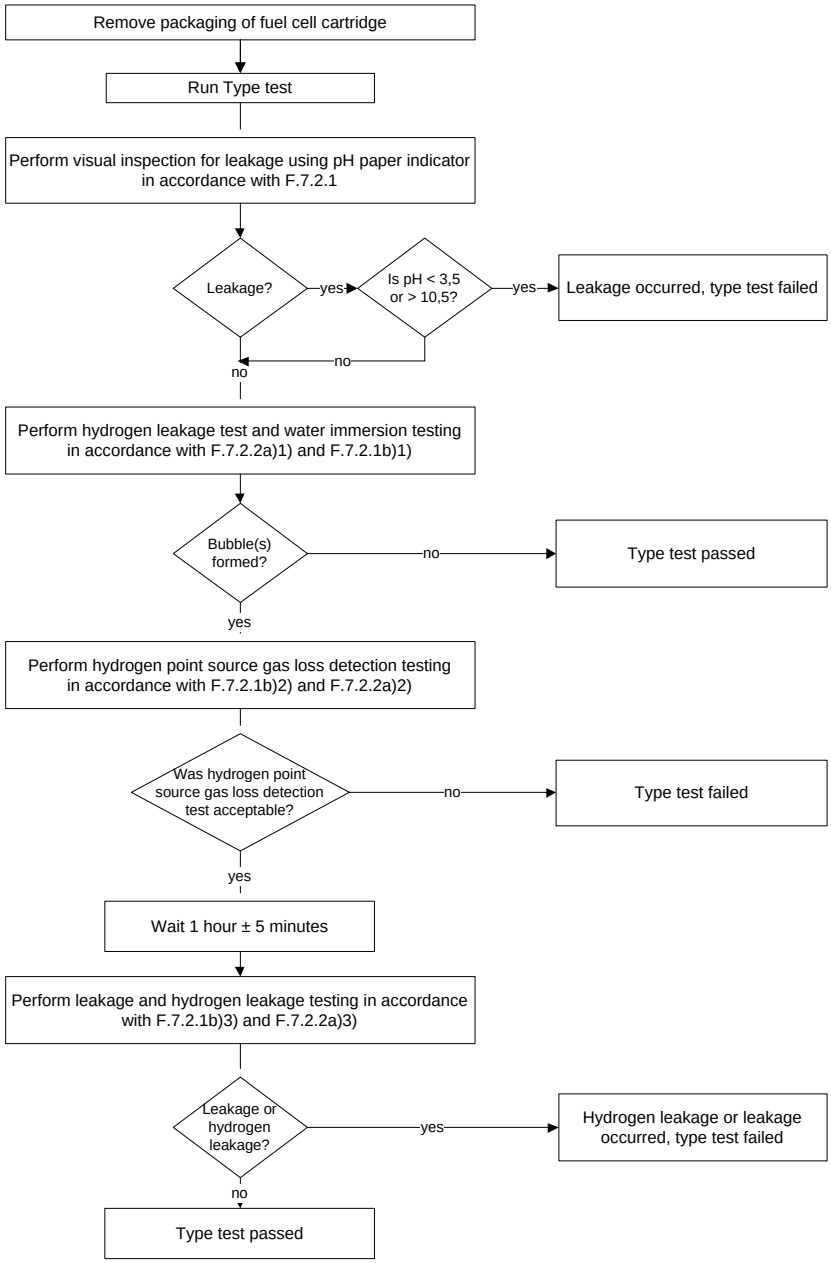


Figure F.3 – Fuel cartridge leakage and hydrogen leakage test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

Deleted: , and used fuel cartridge hydrogen gas loss

Figure F.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Replace, the existing Figure F.4, together with its title, with the following:

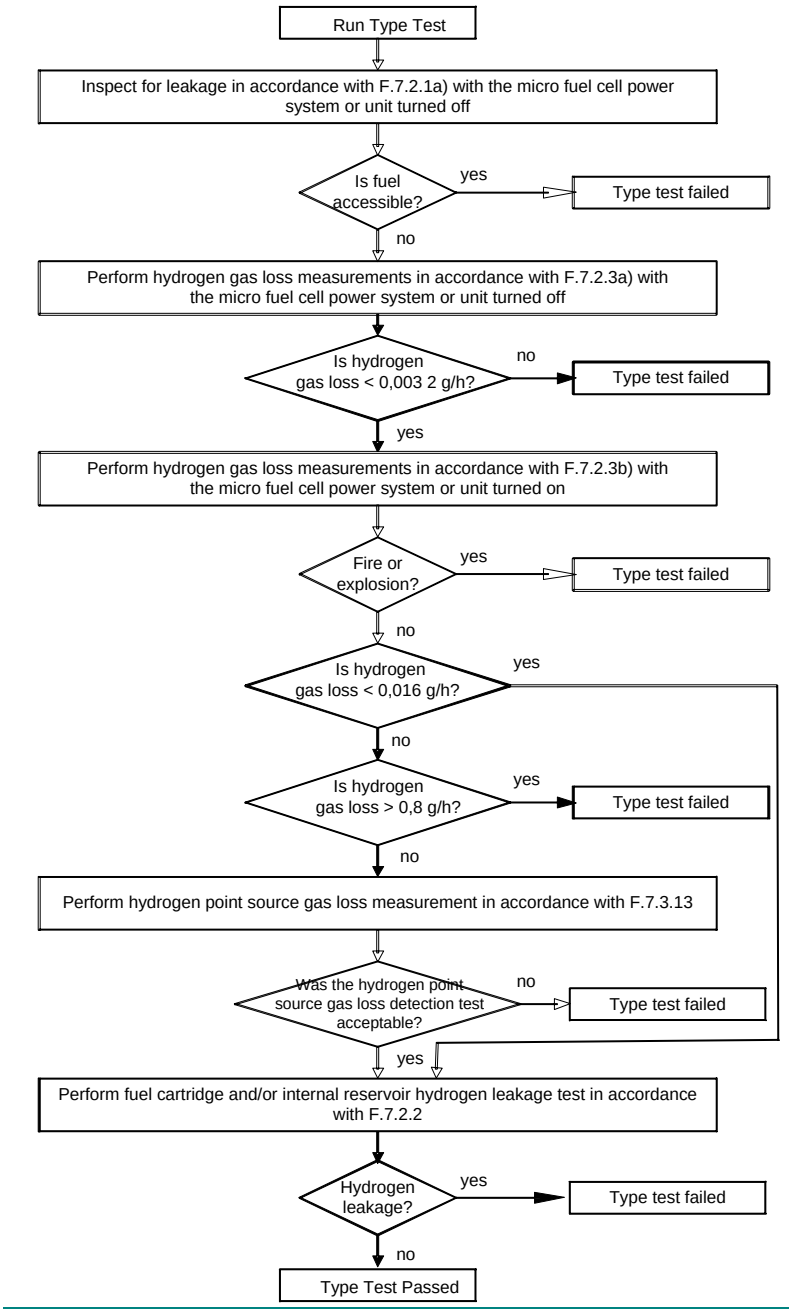


Figure F.4 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

Comment [A21]: Figure F.4 newly replaced in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies.

Figure F.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

Replace, the existing Figure F.5, together with its title, with the following:

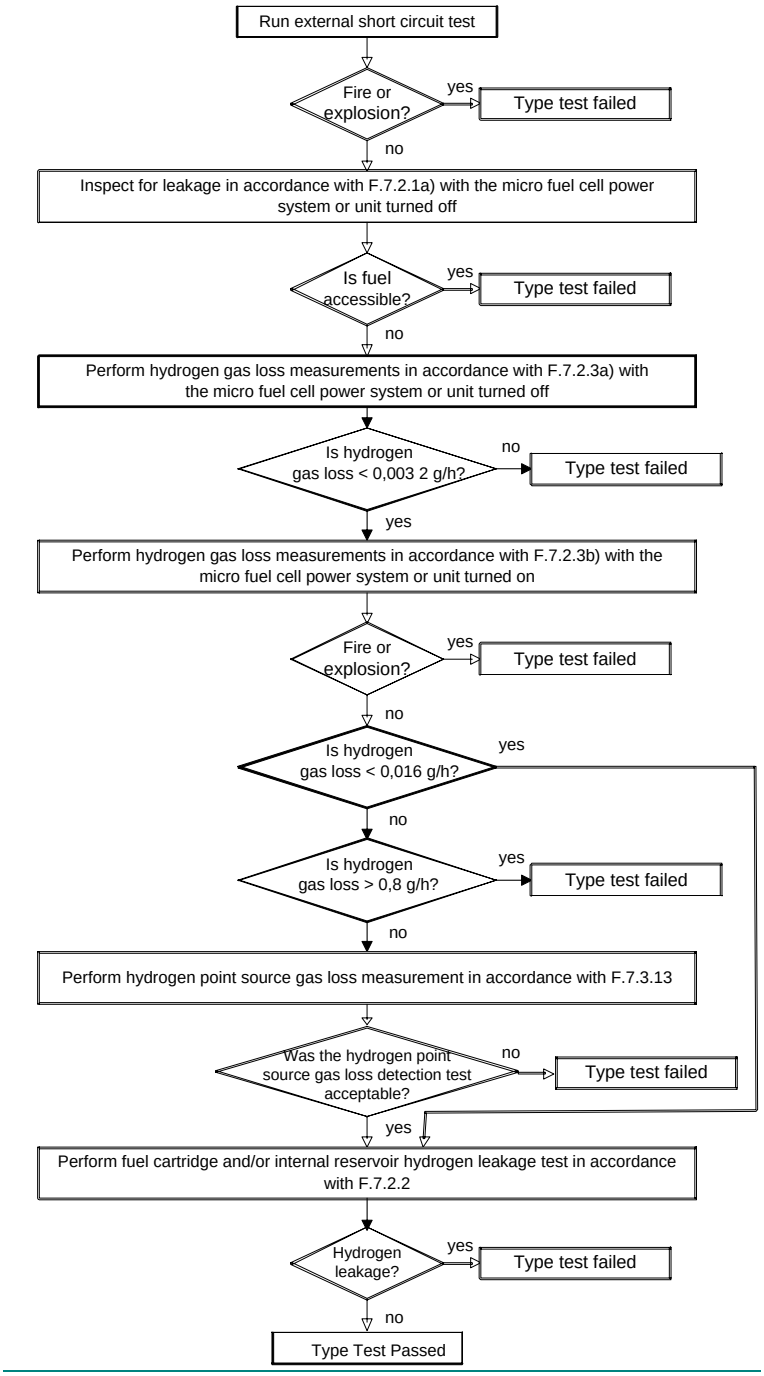


Figure F.5 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for external short-circuit test – Replaces Figure 5

Comment [A22]: Figure F.5 newly replaced in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies.

Figure F.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

Replace, in the title of Figure F.6, the word "mass" *with* "hydrogen gas".

Figure F.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

Replace, in the title of Figure F.7, the word "mass" *with* "hydrogen gas".

F.7.3.1.3 Fuel cartridge low external pressure test

Replace, under item c), the existing text of point 4) with the following new text:

4) Check for hydrogen leakage as described in F.7.2.2. See Figure F.14.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss, no hydrogen leakage and no Class 4.3 (water reactive) fuel or liquid fuel component leakage. See Figure F.14. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3 (less than 0,0032 g/h). Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator and with the water immersion test as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See B.7.3.1.3 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

F.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

Replace, under item c), the existing text of point 3) with the following new text:

3) For the micro fuel cell power system or unit, perform hydrogen gas loss measurements in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See B.7.3.1.4 for alternative methods to measure and calculate impermissible hydrogen gas loss during step 2.

F.7.3.2 Vibration test

Replace, under item c), the existing text of points 6), 7), and 8) with the following new text:

6) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

Deleted: " *in the Figure title*

Deleted: " *in the Figure title*

Comment [A23]: Changes to F.7.3.1.3 through F.7.3.11.2 added in FDIS to address inconsistencies between text and figures in the standard as published.

Changes are required to ensure consistent application of standard, and provide an increased level of safety by eliminating ambiguities and inconsistencies. The changes ensure that equivalent procedures and passing criteria are employed by all type tests throughout the standard. In particular:
- Consistent application of leakage and gas loss testing following each type test
- Consistent passing criteria
- Alignment between text in procedures and flow charts.

iii) If the micro fuel cell power system or unit contains a fuel cartridge perform hydrogen leakage measurements in accordance with F.7.2.2.

iv) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked following F.7.3.3, in accordance with F.7.3.3 c) 9) iii).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit Emissions shall meet the passing criteria in F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.3 Temperature cycling test

Replace, under item c), the existing text of points 9) and 10) with the following new text:

9) Perform the following leakage tests:

i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.3.

ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.4 High temperature exposure test

Add, under item c), at the end of point 3), the following new text:

See Figure F.3.

Delete, under item c), the entirety of point 4).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.5 Drop test

Replace, under item c), the existing text of points 6), 7), and 8) with the following new text:

6) Perform the following leakage tests:

   i) For the fuel cartridge, perform leakage tests in accordance with F.7.2.1, hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.2.

   ii) For the micro fuel cell power system or unit, perform visual inspection for leakage using pH paper in accordance with F.7.2.1(a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

   iii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

F.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

Replace, under item c), the existing text of point 5) with the following new text:

5) Perform the following leakage tests:

i) Perform visual inspection for leakage using pH paper in accordance with F.7.2.1(a), and then perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). See Figure F.4.

ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.6.2 Fuel cartridge

Add, under item c), at the end of point 5), the following new text:

See Figure F.2.

Delete, under item c), the entirety of point 6).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.7 External short-circuit test

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of F.7.3.12, the emission test is acceptable.

NOTE The external short circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

F.7.3.9 Long-term storage test

Replace, under item c), the existing text of point 7) with the following new text:

7) Perform leakage tests in accordance with F.7.2.1 and hydrogen leakage measurements in accordance with F.7.2.2. See Figure F.9.

Replace, under item c), the existing text of point 8) with the following new text:

8) See B.7.3.9 for alternative methods to measure and calculate impermissible hydrogen gas loss.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. The hydrogen concentration in the chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the cartridge shall not exceed 0,0032 g/h at any time during the test. Fire, flame and explosion shall be checked using cheesecloth, infrared camera, or other suitable methods.

Figure F.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

Comment [A24]: Figure F.9 modified to provide consistency with Figures F.2 and F.3 in light of revised leakage testing procedures.

Replace the existing Figure F.9, together with its title, with the following:

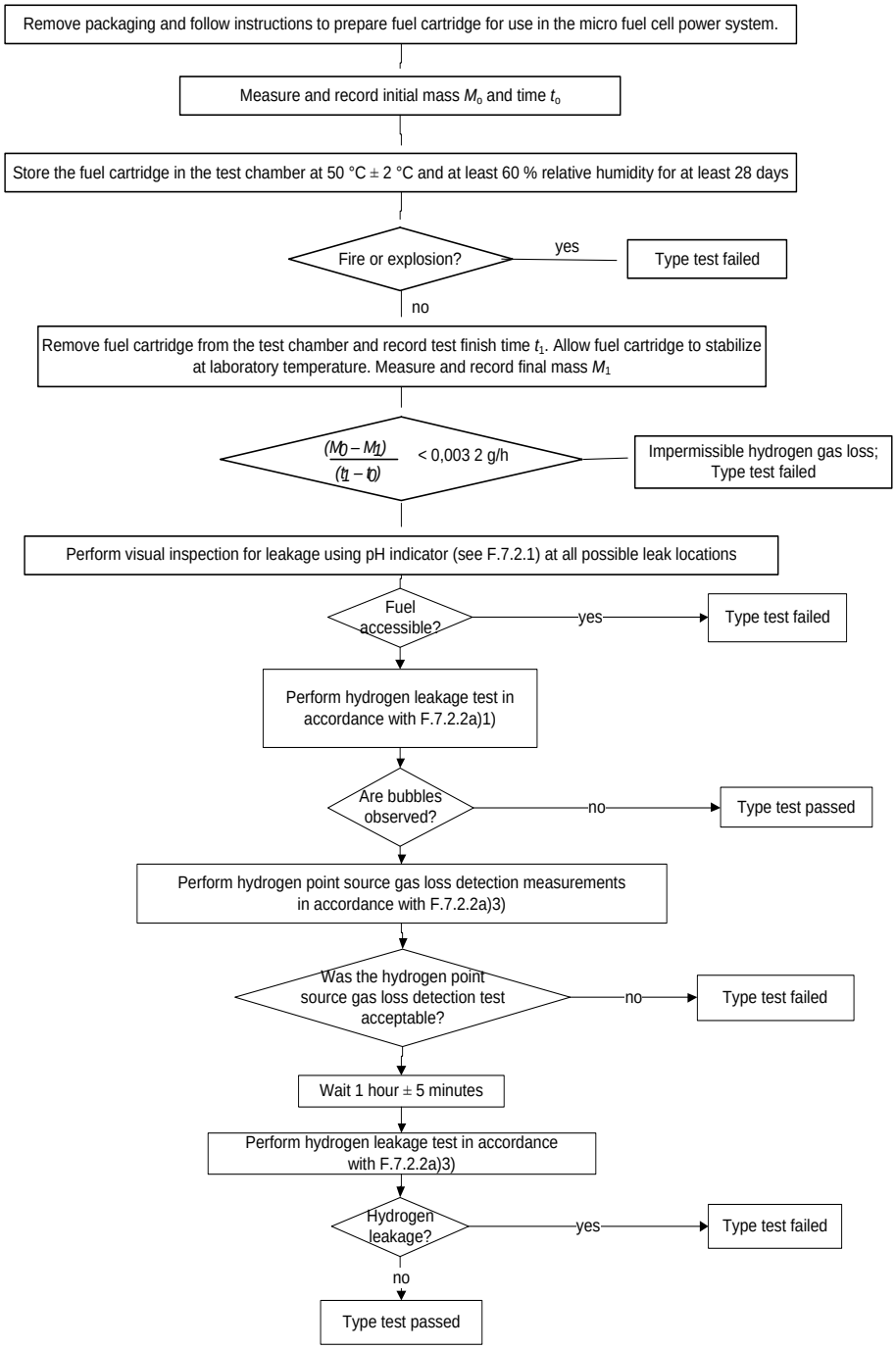


Figure F.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

F.7.3.10 High temperature connection test

Delete, under item c), point 4), the words "and water immersion test".

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occur, the test is acceptable. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.11 Connection cycling tests

F.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

Delete, under item c), the entirety of point 14).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1, For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with Subclauses F.7.2.2a)3) and F.7.2.1b)3) once, following all 10 connection-disconnection cycles (in step 13), rather than repeat at each disconnection step (e.g. steps 1, 4, 6, 8, 10).

F.7.3.11.1.2 Satellite cartridge

Delete, under item c), the entirety of point 12).

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with F.7.2.2a)3) and F.7.2.1b)3) after each set of 10 connection-disconnection cycles (in step 10), rather than repeating at each disconnection step (e.g. steps 1, 2, 4, 6, 8).

F.7.3.11.2 Micro fuel cell power unit

Replace, under item c), the existing text of point 30) with the following new text:

30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform hydrogen gas loss testing in accordance with F.7.2.3 (including emission testing in accordance with F.7.3.12). If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurements in accordance with F.7.2.2.

Replace the existing text of item d) with the following new text:

d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3. Emissions must meet passing criteria of Subclause F.7.3.12 for operational and non-operating systems. For clarification, it is acceptable to perform the (second) hydrogen leakage/water immersion test in accordance with F.7.2.2a)3) and F.7.2.1b)3) after each set of 10 connection-disconnection cycles (in step 14 and step 29), rather than repeat at each connection-disconnection step (e.g. steps 1, 4, 6, 8, 10, 11, 16, 19, 21, 23, 25, and 26).

Table F.7 – Emissions limits – Replaces Table 7

Replace the entire existing table with the following:

Emissions	"DEVICE – ON" Concentration limit [a] based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m^3 ACH volume [b]	Impermissible gas loss[c] (including "DEVICE – OFF")
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m^3	0,8 g/h total 0,016 g/h from single point leak[f]	0,0032 g/h total
Formaldehyde[d]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h
CO	0,029 g/m^3	0,290 g/h	0,290 g/h
CO_2	9 g/m^3	60 g/h[e]	60 g/h[e]
Volatile organic carbon compounds[e]	0,000 1 g/m^3	0,000 6 g/h	0,000 6 g/h

a The concentration limits for CO and CO_2 in this table are the mg/m^3 equivalent of the TWA and STEL exposure limits.

b The "DEVICE – ON" emission rate limit was based on 10 m^3 ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m^3. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per-person volume is over 20 m^3, so a product of 10 is conservative. A further factor of safety of 10 has been added for hydrogen in this specific case.

c The "impermissible hydrogen gas loss" criteria for non-operating micro fuel cell power systems has been chosen based on a scenario of micro fuel cell power systems in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m^3, or approximately 10 cubic feet. The criterion has been prescribed so that a hydrogen concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

d WHO guideline limit is 0,000 1 g/m^3. Background levels are 0,000 03 g/m^3. The emission limit cannot push the background level above the guideline limit.

e A seated human adult has a CO_2 emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO_2 concentration does not reach the WHO 8 h concentration limit of 9 g/m^3. In an environment with 10 m^3 ACH, this limits the contribution from the fuel cell to 60 g/h.

f The allowable flammable hydrogen emission level that will not support a standing flame is 3 standard ml/min, which is equivalent to 0,016 g/h. (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, Codes and Standards Analysis, 2001 (USA)).

Deleted: Non-operating system

Comment [A25]: Inclusion of "used fuel cartridge" removed from impermissible gas loss column in response to comments received on the CD-V.

Deleted: and used cartridge

Comment [A26]: Added to provide clarity and consistency with other annexes.

Comment [A27]: Added to provide clarity and consistency with other annexes.

Figure F.14 – Fuel cartridge leakage test flow chart for low external pressure test

Comment [A28]: Figure F.14modified to provide consistency with Figures F.2 and F.3 in light of revised leakage testing procedures.

Replace, the existing Figure F.14, together with its title, with the following:

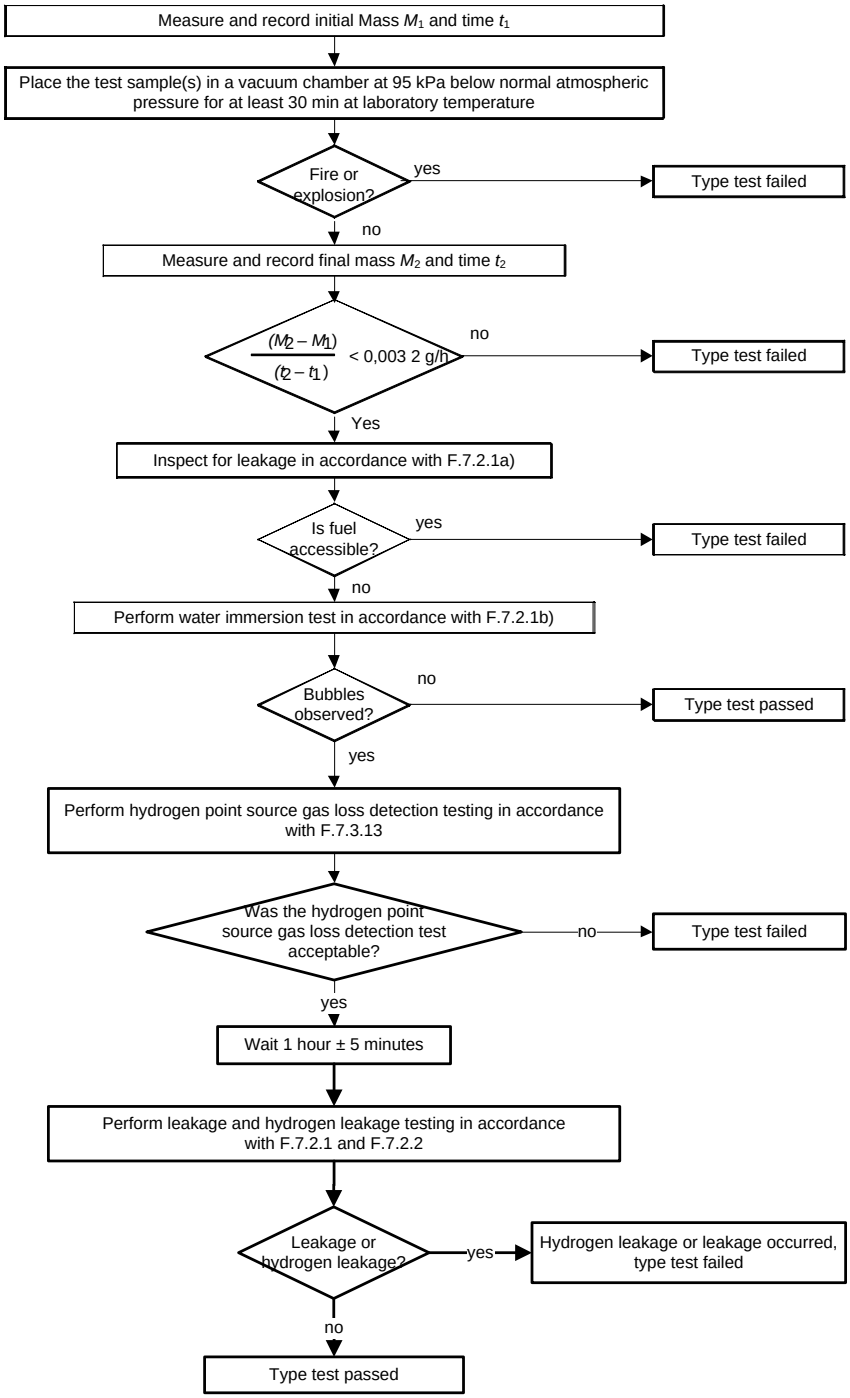


Figure F.14 – Fuel cartridge leakage test flow chart for external pressure test

F.7.3.13 Hydrogen point source gas loss detection test

Add, at the end of point a), the following new text:

or a fuel cartridge.

Replace, under item c), all occurrences of the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

Replace, under item d), in steps 2, 3, 4, 5, 6, 7, 10, and 12, the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

Replace, under item e), all occurrences of the existing text "micro fuel cell power system or unit" *with the new text* "test sample".

Bibliography

Add the following reference:

SWAIN, M.R. and SWAIN, M.N. Codes and Standards Analysis. Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535, 2001.

Comment [A29]: Modified to ensure test can be clearly applied to fuel cartridges in accordance with the new leakage test procedures in F.7.2.1 and F.7.2.2.