

Test Methods for Evaluating Material Compatibility in Compressed Hydrogen Applications - Polymer

GTR no. 13 Phase 2 IWG

Bert Hobein, Ford Motor Company

Representing: CSA CHMC 2 committee

Topics of Presentation

- Polymer Compatibility
- CSA CHMC 2 Scope
- CSA CHMC 2 Content
- Next Steps

Compressed Hydrogen Material Compatibility - Polymers

Do we need a hydrogen compatibility methodology for polymer materials?

- Polymers are necessary and provide critical functions in hydrogen systems and failures in these functions can result in severe incidents
- Stakeholders acknowledge there is a lack of test methods for evaluating polymer properties in hydrogen applications for determining design robustness
- Industry would benefit from clear expectations in evaluating their materials
- Confirmation of compatibility should occur on a material level rather than developing components based on legacy materials or trial testing

Recommended feature for design of a hydrogen fuel system (per GTR no. 13):

“The materials used should be compatible with gaseous or liquid hydrogen, as appropriate.”

Focus topics for Phase 2 are expected to include:

“Requirements for material compatibility and hydrogen embrittlement;”

CHMC 2 Scope



ANSI/CSA CHMC 2-2018

Test methods for evaluating material compatibility in compressed hydrogen applications - **Polymers**



Complimentary to U.S. Department of Energy National Laboratories. Distribution Prohibited.

Title

*CHMC 2 – Test Methods for Evaluating Material Compatibility in Compressed Hydrogen Applications – **Polymers***

Scope

*This standard provides **uniform test methods** for evaluating material compatibility with compressed hydrogen applications. **The results of these tests are intended to provide a basic comparison of materials** performance in applications utilizing compressed hydrogen. This standard is not intended to replace sound engineering judgment; additional testing considerations may be necessary to fully qualify the design of a component manufactured for use in certain hydrogen applications.*

This standard applies to polymer materials only.

CHMC 2 Content – Development Plan

- ✓ **STEP 1:** Agree to high priority tests for polymer compatibility in hydrogen
- ✓ **STEP 2:** Develop high priority test methods for CHMC 2
 - » Assign sub-group with expertise to formulate method (may vary per application)
 - » Identify existing standards for high priority tests
 - » Evaluate if existing are sufficient to reference
 - » Provide test method recommendation to full committee
- ✓ **STEP 3:** Insert test methods into document and complete supporting sections
 - » Review test methods by full committee
 - » Determine additional material considerations and rating scale
 - » Develop other sections in the document (see CHMC 1 structure)
 - » Prepare document for public review & ballot

We have a draft
CHMC 2
document
complete and
ready for review

CHMC 2 Content – STEP 1: Agree to high priority tests



ANSI/CSA CHMC 2-2018

Test methods for evaluating material compatibility in compressed hydrogen applications - **Polymers**

Contents

0. Introduction
 1. Scope
 2. Reference Publications
 3. Definitions
 4. General Requirements
 5. Test Methods
 6. Material Qualifications
- Annex

We have the polymer compatibility tests identified per industry and FMEA input

CHMC 2 Test Methods

- 5.1 Hydrogen Permeability
- 5.2 Physical Stability
- 5.3 Material Property Changes
- 5.4 Dynamic Frictional Wear
- 5.5 Material Contamination
- 5.6 Hydrogen Static Exposure, Cycling, and Aging

CHMC 2 Content – STEP 2: Develop test methods



ANSI/CSA CHMC 2-2018

Test methods for evaluating material compatibility in compressed hydrogen applications - **Polymers**



Complimentary to U.S. Department of Energy National Laboratories. Distribution Prohibited.

CHMC 2 Test Method

→ Describe test purj

1.1 Apparatus

→ Describe test equ

1.2 Test environm

→ Describe pressur

1.3 Specimen Prep

→ Describe test sam

1.4 Test Procedure

→ Describe test step

1.5 Reporting

→ Describe test rest

CHMC 2 Test Method: Physical Stability of Polymers in Hydrogen Environments Density or Specific Gravity Measurements of Polymers

Test Purpose

This test method gives the details of the procedure to evaluate the density changes of specimens of elastomeric or solid polymeric materials due to swelling or shrinking upon exposure to hydrogen environments. Dimensional and density measurements will be made prior to and after conditioning in the designated test gas (in this case hydrogen).

1.1 Apparatus

Test equipment will

- 1.1.1. A devic be used
- 1.1.2. A dens
- 1.1.2.1. Imm
- 1.1.2.2. comp
- 1.1.2.3. Sink shall
- 1.1.2.4. them
- 1.1.2.5. Sam
- 1.1.2.6. An a the s a mil
- 1.1.3. Sample 1 cm³ in
- 1.1.4. A stain for the

1.2 Test environm

The following s pressure and ter

- 1.2.1 The conditi hydrogen ga conditioning

Component
Hydrogen
CO + CO ₂
Nitrogen
Oxygen
THC
Water

Table 1. Comp

CHMC 2 Test Method: Physical Stability of Polymers in Hydrogen Environments

Test Purpose

This test method gives the details of the procedure to evaluate the change in dimensions and mass of specimens of elastomeric or rubbery materials due to swelling or shrinking upon exposure to hydrogen environments. Dimensional and mass measurements will be made prior to and after conditioning in the designated test gas.

1.1 Apparatus

Test equipment wi

- 1.1.1. A dev be us const
- 1.1.2. An ar the sf millic
- 1.1.3. A cut mm (
- 1.1.4. A sta for th

1.2 Test environm

The following pressure and t

- 1.2.1 The condi hydrogen, conditio

Component
Hydrogen
CO + CO ₂
Nitrogen
Oxygen
THC
Water

Table 1. Com

- 1.2.2 Pressure o psi) during
- 1.2.3 Temperat the end of

1.3 Specimen Pr

The following

We have test methods developed for each polymer compatibility test

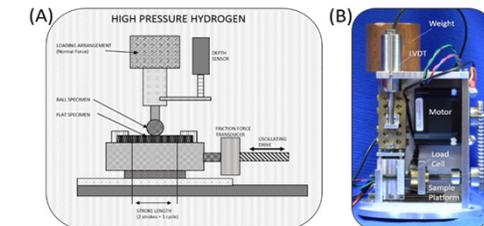
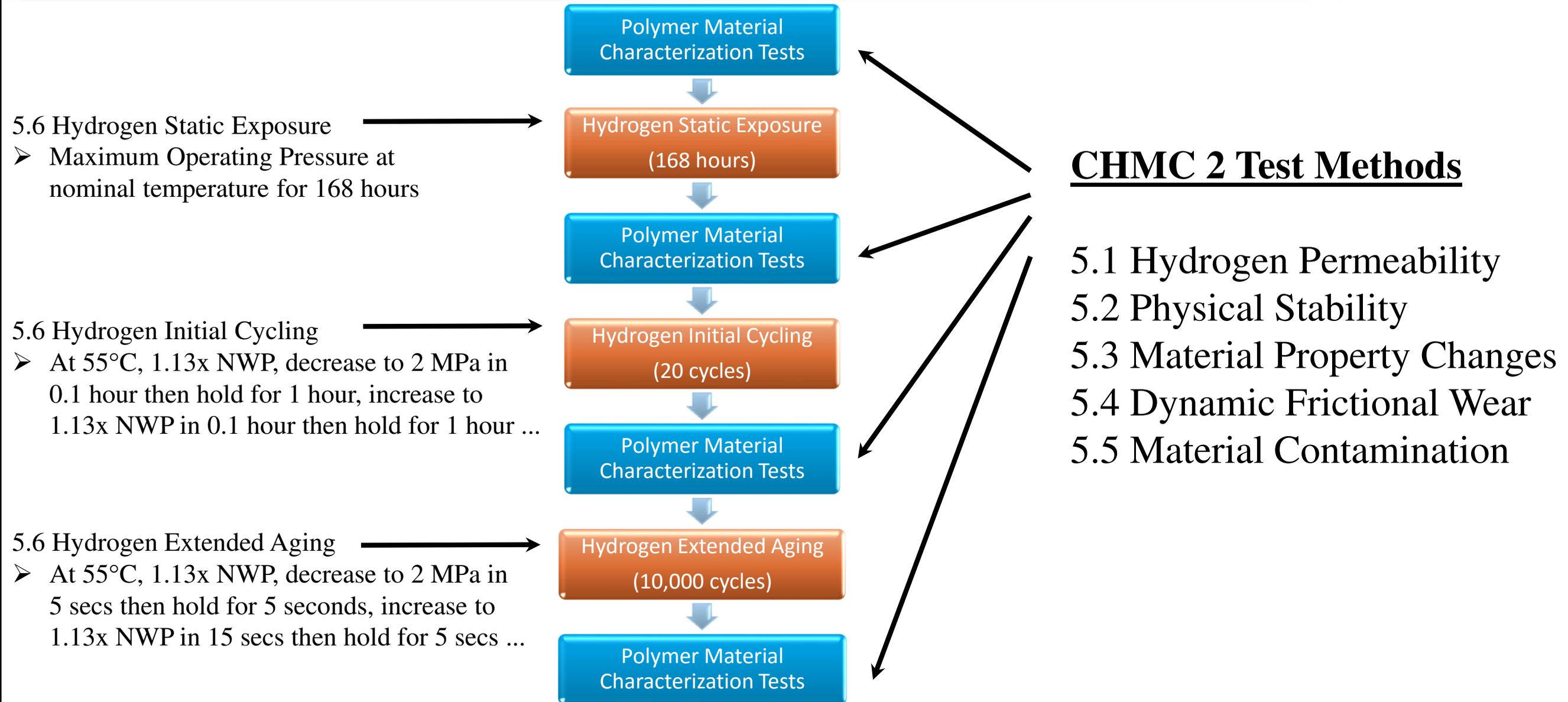


Figure 1. (A) Schematic of the in situ tribometer to measure friction and wear in a high-pressure hydrogen environment.

CHMC 2 Content – STEP 2: Develop test methods



CHMC 2 Content – STEP 3: Complete draft document

We have a material compatibility rating scale in section 6 to compare results.

Our focus in this version is uniform test methods for basic comparison and do not include acceptance criteria.

Therefore, we expect the CHMC 2 to be used to guide the design and material selection for polymer compatibility rather than including in the GTR as a specific requirement.

Evaluation Tests	Reference Clause	Material Compatibility Rating										
		10	9	8	7	6	5	4	3	2	1	0
Break Through Time, min	Clause 5.1 Permeability	**	>960	>480-≤960	>240-≤480	>120-≤240	>30-≤120	>10-≤30	>5-≤10	>2-≤5	>1-≤2	≤1
Permeation Rate	Clause 5.1 Permeability	≤0.9	**	>0.9-9	**	>9-90	**	>90-900	**	>900-9000	**	>9000
Weight Change, %	Clause 5.2 Physical Stability	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.5	>1.5-2.0	>2.0-3.0	>3.0-4.0	>4.0-6.0	>6.0	**
Thickness Change, %	Clause 5.2 Physical Stability	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.5	>1.5-2.0	>2.0-3.0	>3.0-4.0	>4.0-6.0	>6.0	**
Volume Change, %	Clause 5.2 Physical Stability	0-2.5	>2.5-5.0	>5.0-10.0	>10.0-20.0	>20.0-30.0	>30.0-40.0	>40.0-50.0	>50.0-70.0	>70.0-90.0	>90.0	**
Mechanical Property Retained, %	Clause 5.3 Material Property Changes	≥97	94-<97	90-<94	85-<90	80-<85	75-<80	70-<75	60-<70	50-<60	>0-<50	0
Hardness Change	Clause 5.3 Material Property Changes	0-2	>2-4	>4-6	>6-9	>9-12	>12-15	>15-18	>18-21	>21-25	>25	**
Coefficient of Friction Retained, %	Clause 5.4 Dynamic Wear	≥97	94-<97	90-<94	85-<90	80-<85	75-<80	70-<75	60-<70	50-<60	>0-<50	0
Wear Rate Retained, %	Clause 5.4 Dynamic Wear	≥97	94-<97	90-<94	85-<90	80-<85	75-<80	70-<75	60-<70	50-<60	>0-<50	0

CHMC 2 – Next Steps

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Committee Meeting (4 th Wednesday of Month)	X	X	X	X	X	X	X	X	X						
STEP 2: Test Methods - Working Group Effort	█														
Prepare support sections - Chair / CSA Effort	█														
STEP 3: Merge Content - Full committee review				█			█	█	█	█					
CHMC 2 CSA DOC PREP - internal quality review - editorial team review											█				
INDUSTRY REVIEW											◆				
PUBLIC REVIEW											█	█			
EDITING per comments													█		
BALLOT														◆	█
BALLOT DISPOSITION															█