ANSI/CSA CHMC 1-2014

Test methods for evaluating material compatibility in compressed hydrogen applications - Metals

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ANSI/CSA CHMC 1-2014
January 2014

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Approved on January 07, 2014 by ANSI
Published in January 2014 by CSA Group
A not-for-profit private sector organization
5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6

To purchase standards and related publications, visit our Online Store at ***shop.csa.ca***
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ISBN 978–1–77139–428–4

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Preface

This is the first edition of ANSI/CSA CHMC 1-2014, *Test methods for evaluating material compatibility in compressed hydrogen applications - Metals*. It supersedes the previous CSA CHMC 1-2012 edition published in 2012.

This Standard was prepared by the CSA Technical Advisory Group on Standards for Test Methods for Evaluating Material Compatibility in Compressed Hydrogen Applications, under the jurisdiction of the Automotive Technical Committee and the Strategic Steering Committee U.S. Advisory Council on Alternative Energy on Standards, and had been formally approved by the Technical Committee(s), and American National Standards Institute.

Interpretations: The Strategic Steering Committee on Standards for Alternative Energy has provided the following direction for the interpretation of standards under its jurisdiction: "The literal text shall be used in judging compliance of products with the safety requirements of this Standard. When the literal text cannot be applied to the product, such as for new materials or construction, and when a relevant committee interpretation has not already been published, CSA's procedures for interpretation shall be followed to determine the intended safety principle."

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

2) *This standard contains SI (Metric) corresponding to the yard/pound quantities, the purpose being to allow the standard to be used in SI (Metric) units. (Standard for use of the International System of Units (SI): The Modern Metric System, IEEE/ASTM SI I0 or ISO 80000-1:2009 Quantities and units– Part 1: General are used as a guide in making metric conversion from yard/pound quantities.) If a value for a measurement and a corresponding value in other units are stated, the first stated value is to be regarded as the requirement. The given corresponding value may be approximate. If a value for a measurement and a corresponding value in other units are both specified as a quoted marking requirement, the first stated unit, or both shall be provided.*

3) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*

4) *This publication was developed by consensus, which is defined by CSA Policy governing standardization – Code of good practice for standardization as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity." It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this publication.*

5) *This Standard is subject to periodic review, and suggestions for their improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to* ***inquiries@csagroup.org*** *and include "Proposal for change" in the subject line:*

a) *Standard designation (number)*
b) *relevant clause, table, and/or figure number;*
c) *wording of the proposed change; and*
d) *rationale for the change.*

6) *To submit a request for interpretation of this Standard, please send the following information to* ***inquiries@csagroup.org*** *and include "Request for interpretation" in the subject line:*

a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
b) *provide an explanation of circumstances surrounding the actual field condition; and*
c) *where possible, phrase the request in such a way that a specific "yes" or "no" answer will address the issue.*

Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization and are available on the Current Standards Activities page at ***standardsactivities.csa.ca****.*

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History of the development of ANSI/CSA CHMC 1

Note: *This history is informative and is not part of the standard.*

In September 2002, CSA met with the U.S. Department of Energy, Renewable Fuels Group in Washington, D.C. to discuss standards development opportunities in the hydrogen technology area. During this meeting, DOE requested that CSA provide a proposal relating to the development of hydrogen technology standards and codes in the United States.

Industry recognized that an important consideration in the successful commercialization of hydrogen gas as a vehicle fuel was the issue of codes and standards, pertaining to both fueling stations and vehicle fuel system components. CSA undertook the goal of establishing a program for the development of an organized family of coordinated standards that addresses hydrogen gas vehicles and fueling stations.

Industry and CSA recognized there was no comprehensive standard that provided methods for evaluating suitability of materials for use in hydrogen environments.

The development of such a standard was necessary based on industry needs and feedback:

a) There were no comprehensive standard available for material suitability in hydrogen applications.
b) Automotive OEMs driving the application of hydrogen as a fuel for vehicles expressed concern over solutions in demonstration projects in the field.

The focus of the Test Method for Evaluating Material Compatibility in Compressed Hydrogen Applications standard established 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 the targeted testing which may be necessary to qualify the design of a component manufactured for use in hydrogen applications.

This standard applies to metallic materials only.

CSA has positioned itself as a leader in the fuel cell, hydrogen and natural gas sectors as a Standards Developing Organization (SDO). CSA is aggressively updating and developing national standards, and is playing a major role in the promulgation of US technologies nationally. As US TAG Administrator to IEC TC 105 for Fuel Cell Technologies and as US TAG members of ISO TC 197 and ISO TC 22 / SC 25, CSA is facilitating US technology internationally. CSA organized committees to address technical issues in the development of standards which would affect future expansion of the hydrogen industry.

The ANSI/CSA CHMC 1 Test Method for Evaluating Material Compatibility in Compressed Hydrogen Applications standard was processed as an American National Standard in accordance with procedures of the American National Standards Institute (ANSI).

This is the first edition of the ANSI/CHMC 1 Test Methods for Evaluating Material Compatibility in Compressed Hydrogen Applications - Metals, was approved by CSA Technical Committee on Automotive Alternative Energy on October 28, 2013, and the American National Standards Institute, Inc. on January 07, 2014.

Previous editions of this standard are as follows: CSA CHMC-1-2012

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Test methods for evaluating material compatibility in compressed hydrogen applications - Metals

0 Introduction

Pressurized hydrogen gas environments may alter the mechanical properties of virtually all common structural metal alloys. The manifestations of the effects of hydrogen environment on mechanical properties are qualitatively similar for all relevant structural metals and alloys – hydrogen reduces the resistance to crack initiation and crack growth, and reduces ductility. Quantitatively, the magnitude of this reduction is strongly dependent on a large number of variables related to the material, the environment and the mechanical loading conditions.

The test methods described in this standard are intended to provide an assessment of the influence of gaseous hydrogen on a given metallic alloy's tensile ductility and resistance to sub-critical crack growth under quasi-static or cyclic loading. These test methods may be used to determine the compatibility of a given metallic material with gaseous hydrogen within a specified window of material and environmental variables.

This standard is divided into three parts; together these three parts determine the compatibility of a given material with compressed hydrogen gas environments Clause 4 – *General Requirements* defines the specific environmental variables within which the material will be qualified; specifically these variables are temperature, hydrogen gas pressure and hydrogen gas purity. Clause 5 – *Test Methods* provides specific methods for conducting mechanical property measurements in gaseous hydrogen. Test results generated using Clause 5 of this document are valid only within the bounding conditions of temperature, hydrogen gas pressure, and hydrogen gas purity, as described in Clause 4. Clause 6 – *Material Qualification* provides procedures for qualification of the material based on the results generated from Clause 5. Clause 6 provides three separate pathways by which the compatibility of the material with hydrogen may be quantified

1 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 metallic materials only.

If the value for measurement as given in this standard is followed by an equivalent value in other units, the first stated value is to be regarded as the specification.

All references to pressure throughout this standard are to be considered gauge pressures, unless otherwise specified.

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2 Reference publications

ASTM International (American Society for Testing and Materials)

ASTM G142-98 (Reapproved 2011)
"Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both"

ASTM G129-00 (Reapproved 2006)
"Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking."

ASTM E8/E8M 11
"Standard Test Methods for Tension Testing of Metallic Materials"

ASTM E1823-13
"Standard Terminology Relating to Fatigue and Fracture Testing"

ASTM E1820 – 11e2
"Standard Test Method for Measurement of Fracture Toughness"

ASTM E647-13e1
"Standard Test Method for Measurement of Fatigue Crack Growth Rates"

ASTM E1012-12e1
"Standard Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application"

ASTM E466-07
"Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials"

ASTM E606/E606M-12
"Standard Practice for Strain-Controlled Fatigue Testing"

ASTM E739 -10
"Standard Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (ε-N) Fatigue Data"

CGA

CGA G-5.3 – 2011
"Commodity Specification for Hydrogen" Fifth Edition

3 Definitions

Batch — all material resulting from a single mill heat and subjected to the same processing. Material from different product forms (bar, sheet, etc), material from different mill heats (e.g. any materials not covered by same mill certification), and any material to which additional processing steps have been applied that alter the microstructure or properties of the metal including, but not limited to, heat treating, rolling, drawing, forging, etc., will not be considered as part of the same batch.

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Crack length, a — lineal dimension used to calculate fracture mechanics parameters, measured from the load line of the specimen to the crack tip.

Fatigue crack growth rate, da/dN — increment of crack extension per fatigue cycle.

Force ratio, R — the ratio of the minimum and maximum force applied in the fatigue cycle. $R=P_{min}/P_{max}=K_{min}/K_{max}$

Frequency, f — the number of times the complete fatigue loading cycle is repeated per second.

J_{IH} — Elastic plastic threshold value of the J-integral determined near the onset of crack extension in gaseous hydrogen environments determined using the 0.2 mm offset intersect method.

K_{IH} — Linear elastic threshold stress intensity factor for crack initiation in gaseous hydrogen environments.

Maximum stress intensity factor, K_{max} — the stress intensity factor associated with the largest applied load during the fatigue cycle.

Minimum stress intensity factor, K_{min} — the stress intensity factor associate with the smallest applied load during the fatigue cycle.

Stress intensity factor, K — amplitude of the stress singularity ahead of a crack tip in a homogenous, linear elastic body.

Stress intensity factor range, ΔK: K_{max}-K_{min} — the range of stress intensity factor applied during a fatigue cycle.

Waveform — refers to the shape of the fatigue cycle when plotted as load (or force or stress intensity factor) versus time.

4 General requirements

4.1 Hydrogen gas purity

4.1.1 Significance

High purity hydrogen gas environment is necessary to ensure that meaningful results are achieved using the test procedures in Clause 5.

4.1.2 Source gas

The purity of the hydrogen gas used to fill the test chamber shall be consistent with CGA G-5.3 grade L or of greater purity.

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