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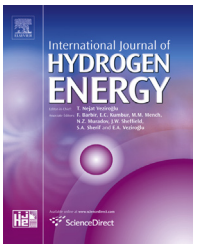

IPHE regulations codes and standards working group – Type IV COPV round robin testing☆

M. Maes [a], L. Starritt [a], J.Y. Zheng [b], K. Ou [b], J. Keller [c,*,1]

[a] NASA White Sands Test Facility, United States
[b] Zhejiang University, China
[c] Zero Carbon Energy Solutions, Inc., Consultant U.S. DOE, Fuel Cell Technology Office, Safety Codes and Standards Program, United States

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ABSTRACT

This manuscript presents the results of a multi-lateral international activity intended to understand how to execute a cycle stress test as specified in a chosen standard (GTR, SAE, ISO, EIHP …). The purpose of this work was to establish a harmonized test method protocol to ensure that the same results would be achieved regardless of the testing facility. It was found that accurate temperature measurement of the working fluid is necessary to ensure the test conditions remain within the tolerances specified. Continuous operation is possible with adequate cooling of the working fluid but this becomes more demanding if the cycle frequency increases. Recommendations for future test system design and operation are presented.

Test measurement protocol requirements

Background

Typically, the purpose of any pressure cycle test is to test the tank for cyclic fatigue, under expected service conditions. The three currently proposed hydraulic pressure test cycle documents, (the EIHP rev 12b [1], SAE J2579 rev 2 draft [2], and the Global Technical Regulation (GTR) [3]) are very similar with one significant exception relevant to type IV tanks. The EIHP specifies the lower pressure limit to be ≤2 MPa. The GTR and SAE J2579 rev 2 draft specify the lower limit to be (2 ± 1) MPa which, is consistent with the automobile controlled lower limit of 2 MPa. In addition, no ramp rate for pressurization or depressurization is supplied by any of the proposed tests in the standards or the GTR, with the exception that the overall cycle frequency cannot exceed 10 cycles/min.

Purpose

The suggested test measurement protocol developed by the RCSWG was established to provide a test measurement

☆ Product of IPHE RCSWG: Brazil, China, European Commission, France, Italy, Germany, Japan, New Zealand, Norway, Russia, South Africa, United Kingdom, United States.

* *Corresponding author.*
E-mail address: Jay.Keller@ZCES-Inc.com (J. Keller).
[1] Previously with Sandia National Laboratories.

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Nomenclature

Acronym	
BPR	Backpressure regulators
°C	Degrees centigrade
COPV	Composite overwrapped pressure vessel
EIHP	European Integrated Hydrogen Project
GTR	Global Technical Regulation
HDPE	High-density polyethylene
HVAC	Heating ventilation and air conditioning
IPHE	International partnership for hydrogen and fuel cells in the economy
L	Liter
Min	Minutes
MPa	Mega pascal (1.0×10^6 Pa)
NASA	National Aeronautics and Space Administration
NWP	Normal working pressure which is the same as normal service pressure
RCSWG	Regulations codes and standards working group of the IPHE
RR	Round robin
s	Seconds
SAE	Society of automotive engineers
TMMP	Test measurement method protocol
WSTF	White Sands Test Facility

method protocol (TMMP) for use in this round robin (RR). An outcome of this RR is a test method measurement protocol that when applied around the world, consistency in the test measurements could be assured. It is the goal of the RCSWG that test measurement methodologies developed and proven as a result from performing this internationally harmonized protocol would be applied to the relevant test requirements in the international standards and regulations such as the European Integrated Hydrogen Project (EIHP) CGH2R rev 12b (EIHP rev 12b), SAE J2579 rev 2 draft, and the Global Technical Regulation (GTR) for Hydrogen Fueled Vehicles (ECE-TRANS-WP29-GRSP-2012-12e). It is important to note that a qualifying test sequence is not specified, nor was the goal or objective for the round robin campaign because it is out of scope for the RCSWG to:

- Execute a qualifying test sequence,
- Qualify laboratories to execute test sequences,
- Or design test sequences.

With these ideas in mind, requirements were drafted and distributed to the RCSWG and the two test locations for review and concurrence.

Measurement protocol requirements

The proposed TMMP for hydraulic cycling test as agreed by the RCSWG and test locations required the following, in part or whole:

- The static pressure in the tank is to cycle between a specified minimum and maximum value until failure or a specific number of cycles have been executed whichever occurs first.
- The temperature of the fluid in the tank is to be monitored and controlled.
- The temperature of the outside surface of the tank (the skin) is to be monitored and controlled
- The temperature of the ambient is to be monitored and controlled.
- The cycle rate must not exceed 10/min
- The working fluid must be a non-corrosive liquid

Pressure cycle test systems can be constructed either open ended or closed-ended loop for the working fluid. Fig. 1 shows configurations for a closed-ended test, Fig. 2 shows configurations for open ended test. In this work the tanks tested had end-bosses on both ends, so the dead-ended tank configuration was achieved by putting a plug in one of the end-bosses.

Below are the requirements on the parameters that were to be measured and controlled during the hydraulic cycling test. These were the recommended practices that were suggested by the RCSWG.

- The static pressure in the tank is measured so no dynamic effects will influence the measurement during both pressurization and depressurization.
- The working fluid temperature in the tank should be measured in several places to understand any temperature variations that might occur—if this is not possible then the temperature of the metal boss at both ends should be made to approximate the internal fluid temperature.
- The temperature of the ambient air is to be measured and controlled
- The temperature of the skin is to be measured
- The data acquisition should be at a rate no slower than 10 Hz.
- The pressure measurement accuracy should be no less than 0.1% full scale (FS)
- Temperature accuracy ±1 °C

Following some iteration among the RCSWG and with input collected from the Chinese and the U.S. test locations, the suggested TMMP was improved and final requirements given to each test location are documented below. As testing continued some of these requirements were relaxed because of experimental difficulty or it was recognized that it was not necessary for the purpose of this program. The variation of these requirements will be discussed later.

- Pressure range, low: $1 \leq P \leq 3$ MPa, high: 125% NWP $\leq P \leq$ 125% NWP + 1 MPa
- Dwell time ≥0 s at the minimum pressure
- Dwell time ≥1.5 s at the maximum pressure
- Ambient temperature is to be (20 ± 5) °C
- Cycle frequency is to be ≤6/min
- The temperature of the hydraulic fluid within the container is monitored and maintained at the specified temperature: (20 ± 5) °C
- Measurements to ±1 °C on:
  - The metal end boss, both ends
  - The skin

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