

SAFETY COMPLIANCE VERIFICATION OF FUEL CELL ELECTRIC VEHICLE EXHAUST

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GTR 13

Regulated Hydrogen Levels in FCEV Exhaust

GTR-13 is the underlying document regulating FCEV Safety

GTR No. 13

- International agreement on hydrogen FCEV safety
- Basis for the national regulations
 - United States: FMVSS (DOT)
 - Canada: CMVSS (Transport Canada, TC)
 - To harmonize national vehicle safety standards to a common international template
- Contracting parties are to start the adoption process
- Requirements must be verifiable
 - Include electrical and hydrogen safety requirements

Section 5.2.1.3.2: Vehicle Exhaust System

At the vehicle exhaust system's point of discharge, the hydrogen concentration level shall:

- Not exceed 4 per cent average by volume during any moving three-second time interval during normal operation including start-up and shutdown;
- And not exceed 8 per cent at any time (para. 6.1.4. test procedure)

It was also stipulated that the analyzer have a response time (t_{90}) of 300 ms or faster

NOTE: A means to verify compliance is necessary to enforce a requirement
The NREL FCEV Exhaust Gas Analyzer

ECCC Vehicle Emission Program

History

- The Vehicle Emissions Testing Laboratory was established in 1971
- Provided Testing for the New Vehicle Surveillance Compliance Audit test program administered by Transport Canada

Role ERMS / ECCC Now

- Conducts compliance audit testing for vehicles and engines sold in Canada administered by ECCC.
 - Four light-duty in-house Chassis Cells with Dynamometers
- Collaborates with Transport Canada to investigate new technologies and fuels for safety and regulatory developments and to inform policies
- R&D for mobile emission reducing technologies and fuels
- NRCan publishes energy consumption, fuel consumption and CO2 emission rate performance data on all vehicles sold in Canada, including EVs.



ECCC is responsible for verification of FCEV emission requirements.



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Requirements for an FCEV Exhaust Gas Analyzer

H₂ Sensing element for the Prototype FCEV Exhaust Analyzer

Required

- Range of 0 to 10 vol% Hydrogen
- $t_{90} < 300$ ms
- Not significantly impacted by likely interferences (physical & chemical)

Desirable

- Integratable into FCEV exhaust (and test systems for vehicle exhaust measurements)
- Convenient user Interface



Commercial Thermal Conductivity Sensor

- Low-cost hydrogen sensor
- Fast response ($t_{90} < 250$ ms)
 - Verified at JRC & NREL
- Linear to 10 vol% (measurement range to 100 vol%)
- Minimal effects from changes in T & RH
- Low power, miniature size

The NREL Sensor Laboratory has been developing a prototype FCEV Exhaust Gas Analyzer based upon a commercial thermal conductivity (TC) Sensor

Brief Project History

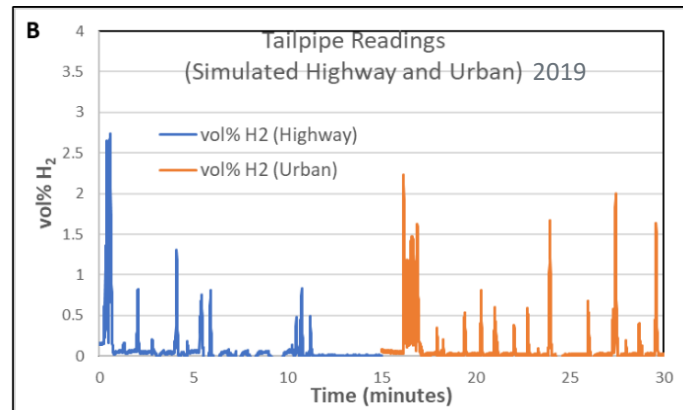
2019

- Prototype Analyzer deployed at ECCC
 - Chassis dynamometer
- Successfully monitored FCEV exhaust
 - Multiple driving simulated driving conditions
 - Water entrainment was an issue
 - Results presented at ICHS 2019



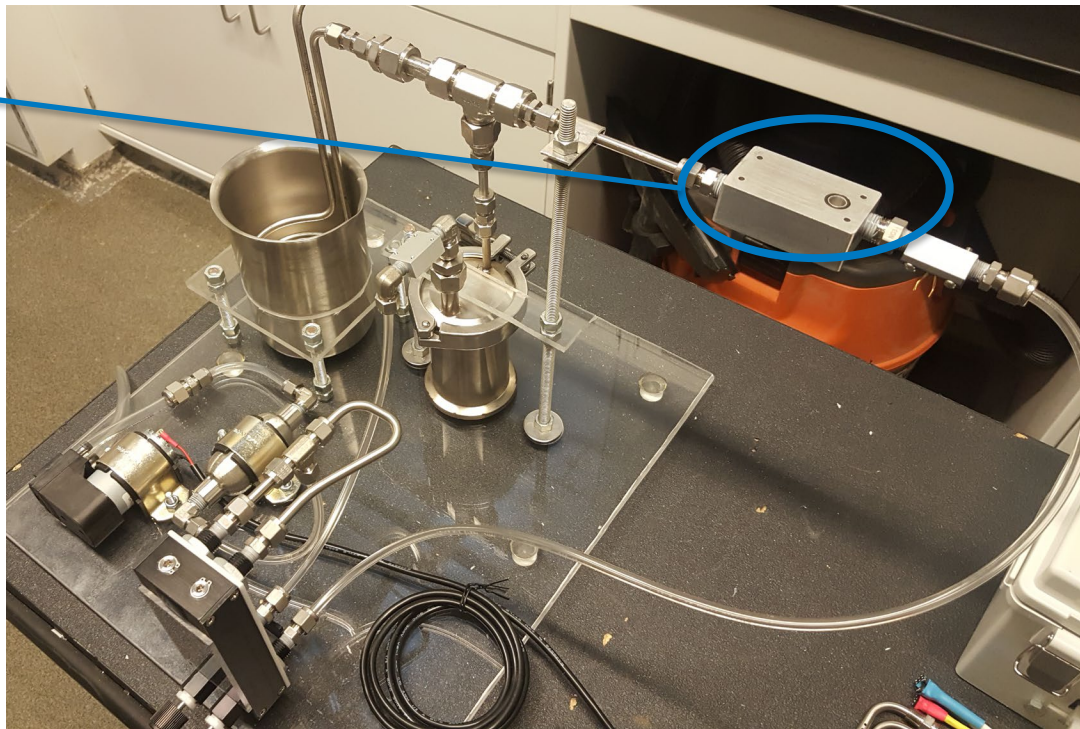
2021

- Modified sample collection system to mitigate water entrainment
 - Demonstrated in laboratory
 - Ongoing deployment at ECCC (Sept 2021)
 - Basis for an NREL record of invention



Revised FCEV Exhaust Gas Analyzer

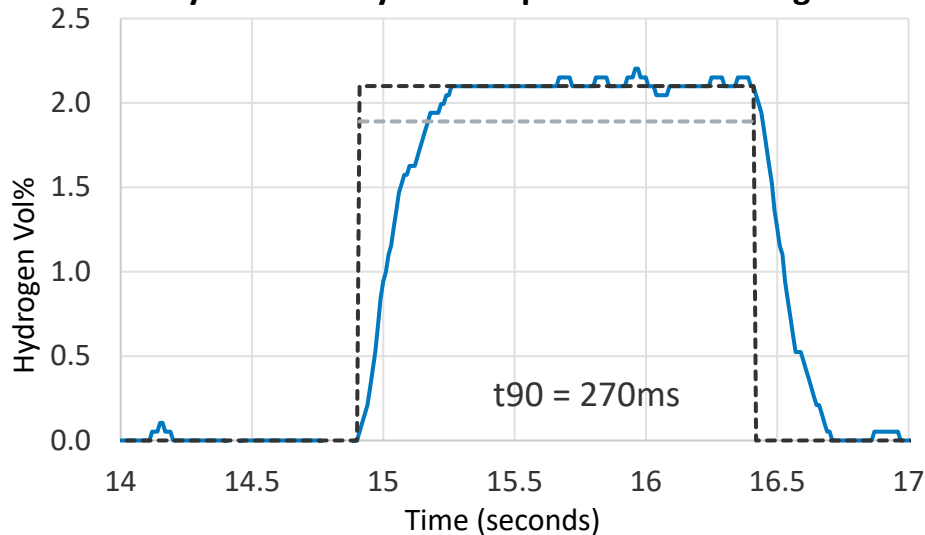
- FCEV exhaust gas analyzer consists of:
 - Hydrogen sensing element.
 - Sample collection system.
- NREL has developed a test apparatus that simulates FCEV exhaust conditions. (e.g., simulated tail pipe)
- Laboratory demonstrations of the analyzer including the sample collection system were performed using the simulated FCEV tail pipe.
- Sample collection system is designed to be compatible with the laboratory fixture and the ECCC exhaust gas collection system.



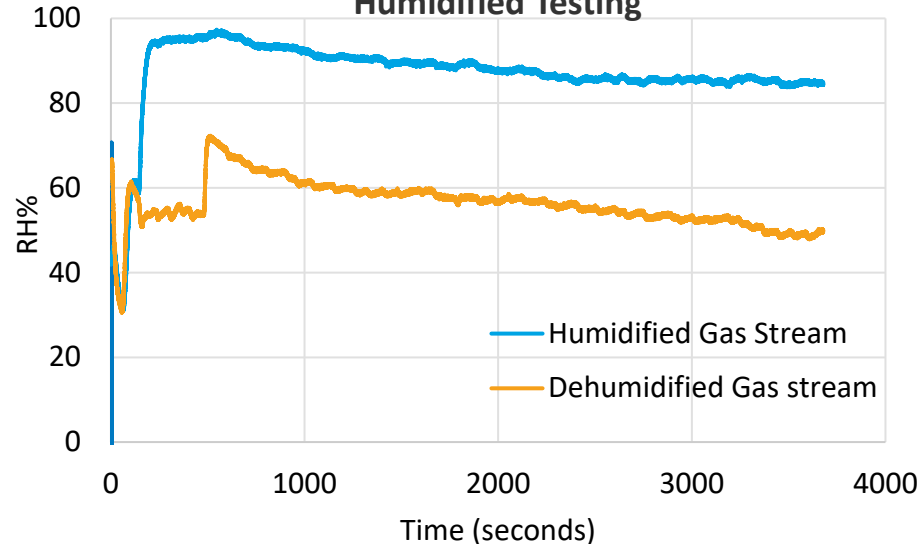
Gas Collection sample system for FCEV exhaust gas analyzer was designed to mitigate water entrainment.

Laboratory Demonstration

Analyzer accuracy and Response time Testing



Humidified Testing

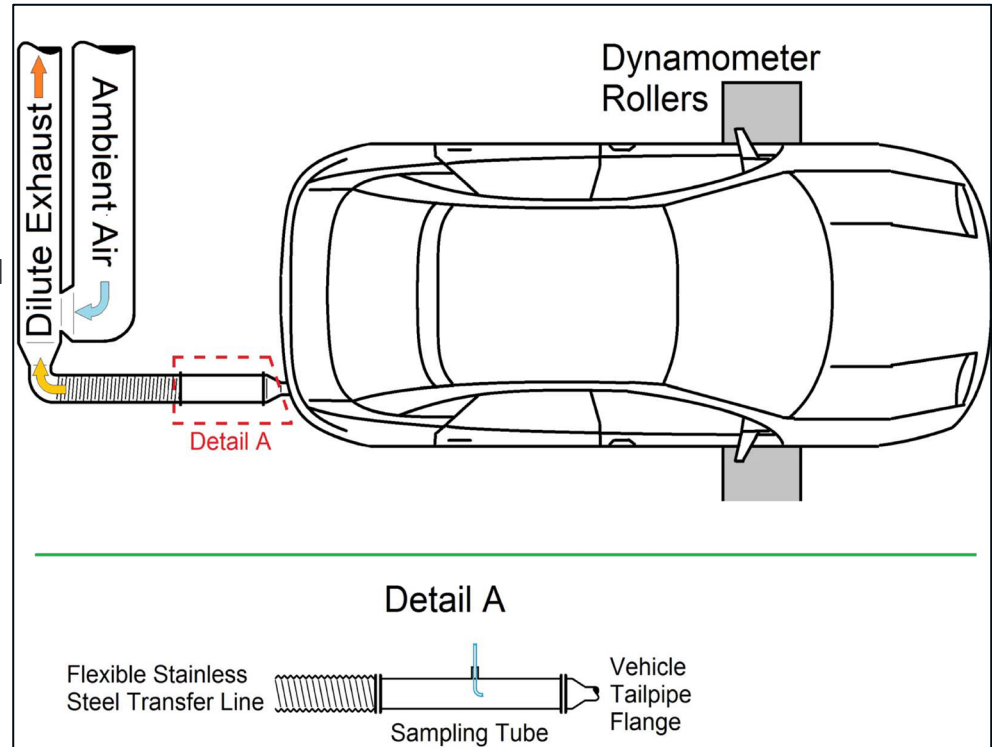


- Hydrogen exposures demonstrate compliance to GTR response time requirements and accuracy.
- Incoming exhaust test gas (60°C-70°C, saturated humidity with water droplets) is dehumidified (40%-60%, 25°C) for analysis.

GTR response time requirements are met without interference from water entrainment

Deployment at ECCC

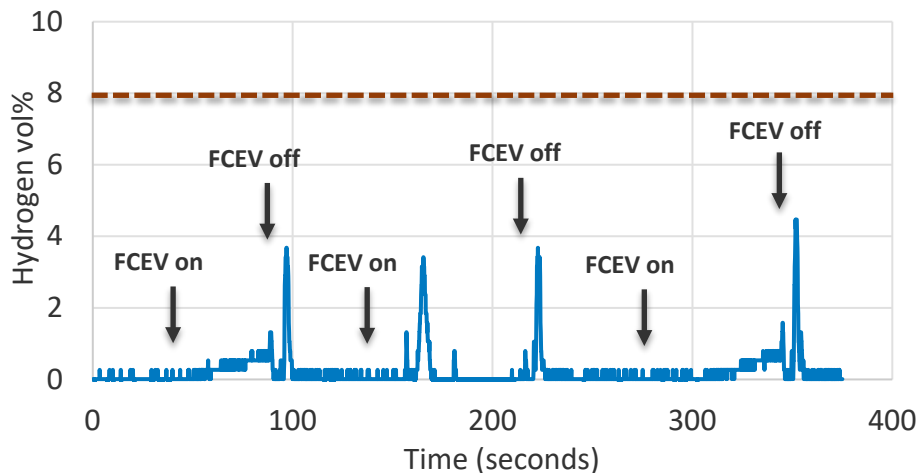
- Successful laboratory demonstration warranted deployment at ECCC.
- Vehicle operated on chassis dynamometer
 - Allow testing under simulated driving conditions (urban, highway, static)
 - Standard test procedures have been developed for ICE vehicles
- The Transfer Line connects to the tail-pipe. Test samples are drawn from the transfer line. In this project, the gas stream is vented outdoors
- Gas Sampling Tube (Detail A) transports test gas to Analyzer
 - Design utilized by ECCC for other applications
 - Adapted to include moisture mitigation strategies.



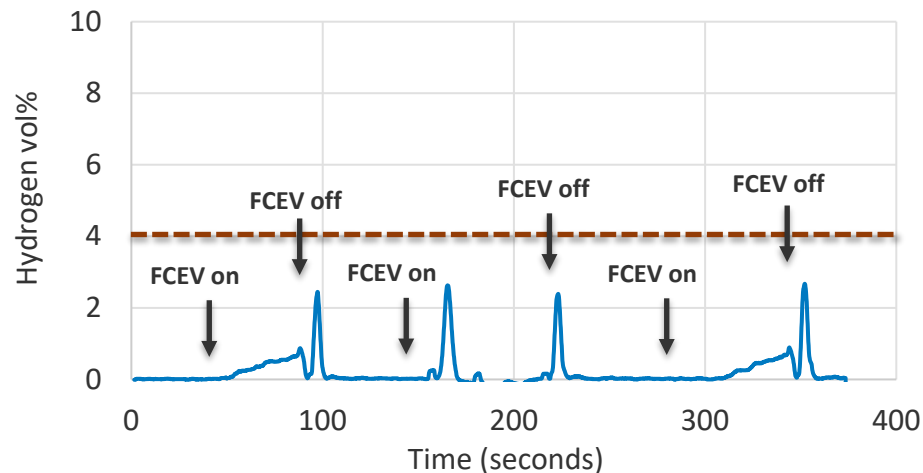
NREL's analyzer was shipped to ECCC to test with a FCEV.

Test Results from ECCC – GTR Protocol (3 runs)

GTR Protocol



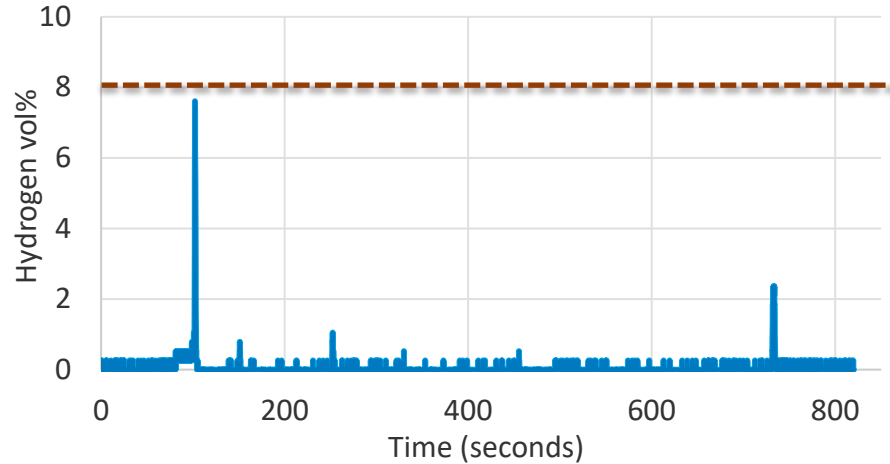
GTR Protocol 3-second moving average



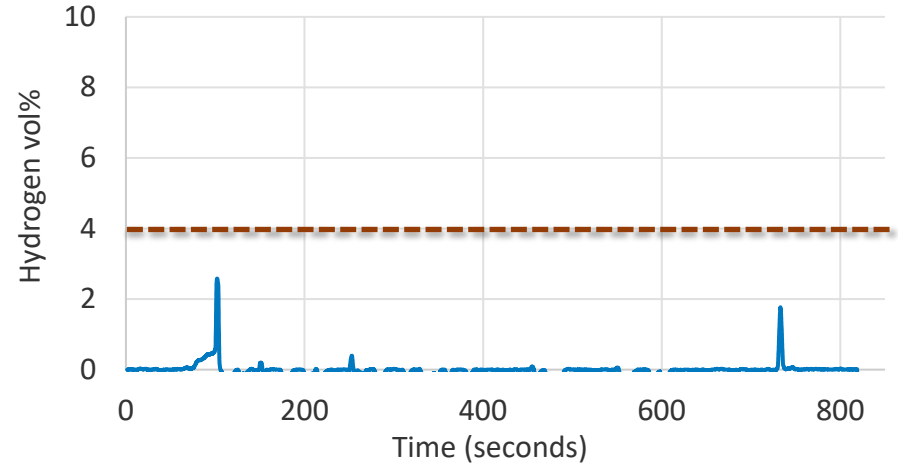
- Hydrogen transients observed with the FCEV per GTR-13 requirements.
 - Data logged 10 pt/sec

Test Results from ECCC – New York City Cycle (NYCC)

NYCC



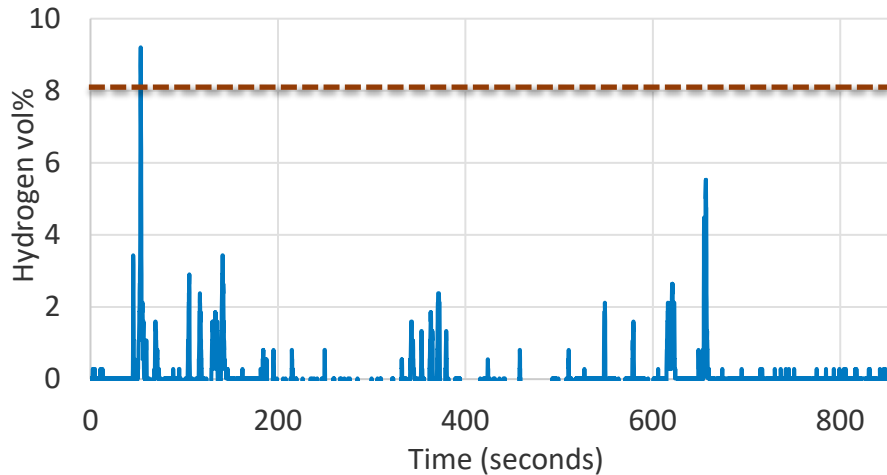
NYCC 3-second moving average



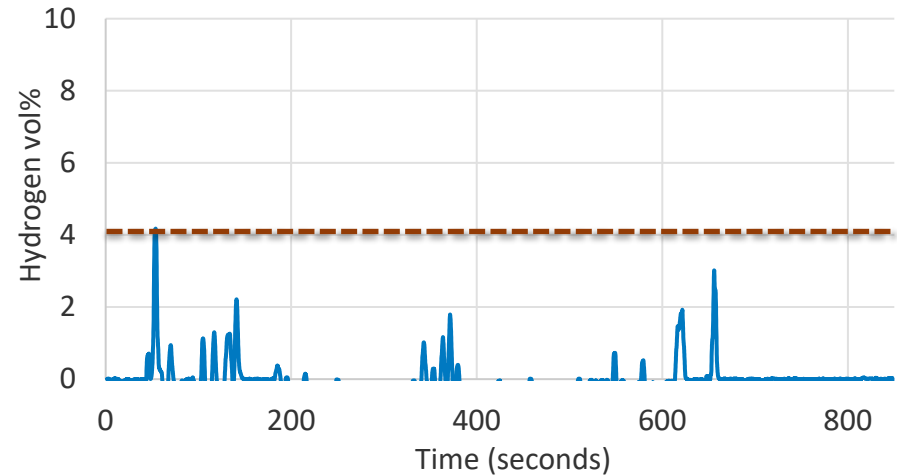
- Hydrogen transients observed with the FCEV driven to mimic city traffic patterns.
- Note: This test is not required for GTR-13 standards.

Test Results from ECCC – US06

US06



US06 3-second moving average



- Hydrogen transients observed with the FCEV driven to mimic highway driving.
 - A large spike in the beginning of the test shows hydrogen concentrations over 8 vol% and the 3-second moving average peaks at just over 4 vol%
- Note: This test is not required for GTR-13 standards.

Summary

- The performance of the prototype FCEV exhaust gas analyzer was demonstrated in the laboratory.
- The metrological specifications of the Analyzer meets the GTR response time and range requirements for FCEV exhaust verification.
- The Analyzer was successfully deployed on a commercial FCEV operating under simulated driving conditions using a chassis dynamometer.
 - Operation of the analyzer was conducted by ECCC personal without onsite NREL support.
- The test vehicle complied to the GTR-13 FCEV exhaust requirements.
 - The GTR-13 currently does not prescribe testing the vehicle under load conditions; such testing should be considered.
- Water mitigation strategies in the sample collection system were improved.
 - Small amounts of water occasionally passed through the dehumidified stream during testing.
 - No consequence on sensor response.
- NREL, ECCC, TCa will maintain on-going collaborating for FCEV safety testing (GTR).

Acknowledgements

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QUESTIONS?

Previous Configuration

