METROLOGY for HYDROGEN VEHICLES

REPORT:

A1.1.2: Public report on operating conditions and uncertainty sources of a Hydrogen Refuelling Station(HRS)

This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

www.metrohyve.eu

This report was written as part of activity A1.1.2 from the EMPIR Metrology for Hydrogen Vehicles (MetroHyVe) project. The three-year European project commenced on 1st June 2017 and focused on providing solutions to four measurement challenges faced by the hydrogen industry (flow metering, quality assurance, quality control and sampling). For more details about this project please visit www.metrohyve.eu.

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Table of contents

Introduction

In the framework of the work package 1 ("Flow metering"), the task 1.1 aims to identify and assess the uncertainty sources for hydrogen metering. The purpose of activity A1.1.1 is to collect information on the various types of HRS and provide an estimate of the related uncertainty in flow metering based on the different manufacturer's designs. Establishing a firm basis on how hydrogen refuelling stations operate is essential in proceeding in this task.

As a first step, a survey has been conducted involving the participation from HRS operators from which a set of operating ranges in pressure, temperature, piping, flow disturbances and flow rates for various designs of hydrogen fuelling stations, as well as working principles, have been determined.

One important variable is the location of the flow meter within the station. For example, it can be positioned before or after a heat exchanger, which leads to other type of constraints on the measuring capabilities of the flow meter and the dynamic range in environmental conditions it is subjected to.

Another variable is the type of fuelling procedures, i.e. Tank-to-Tank Filling (hydrogen stored under high pressure and forced into the vehicle) or Direct Compression Filling (hydrogen stored at low pressure and then compressed directly in the vehicle).

Feedback from the questionnaire

The questionnaire has been created by all WP members and is available on the MetroHyVe website. In this report, although the focus is flow metering (Wp1), questions about chemistry, for example, were asked in the questionnaire for the benefit of other work packages.

HRS description (700 bar)

The OIML R139 describes a Hydrogen Refuelling Station as a measuring system which should include at least:

a) meter;
b) pressure and/or flow control device;
c) emergency power supply;
d) transfer point;
e) gas piping;
f) zero-setting device.

The measuring system may also be provided with the following other ancillary and additional devices:

g) calculator;
h) associated measuring instruments;
i) pressure gauge;
j) digital indicating device;
k) self-service arrangement;
l) pre-setting device;
m) memory device;
n) price indicating device;
o) printing device;
p) heat exchanging device
q) other ancillary and additional devices.

The “devices” listed above can be designated as a “typical” configuration of a measuring system that is represented in the Figure 1 below:

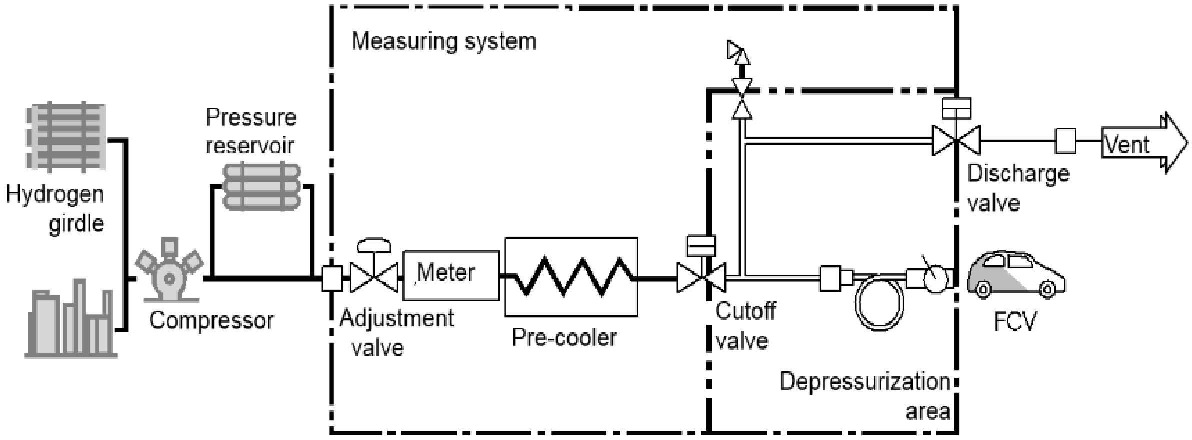

Figure 1: HRS representation

Figure 2 shows a picture of a refuelling station in use.

Figure 2: Real HRS in use

List of hydrogen refuelling station operators:

The list of all the hydrogen refuelling station operators involved in the survey are listed in the Table 1 below:

Company name	Country
McPhy	France
Empa	Switzerland
H2Energy	Switzerland
NEL Hydrogen	Denmark
H2 Logic	Sweden
BOC	United Kingdom
Air Liquide	France

Table 1: List of participants to the HRS survey

The Table 2 below lists all the questions from the survey for task A1.1.1 and A1.2.2.

1-General questions	How is the hydrogen produced? How is the hydrogen stored? What is the fuelling procedure (e.g. tank-to-tank filling (hydrogen stored under high pressure and forced into the vehicle) or direct compression filling (hydrogen stored at low pressure and then compressed directly in the vehicle)? What pressure of hydrogen is supplied to the vehicle? Is the station in operation and already refuelling vehicles? If so, how many per day?
2-Flow meter questions	What is the location of the flow meter? How far is it from the filling nozzle? What make/model is the flow meter that you use? What type of flow meter is used? Does the meter measure based on mass? What range of flow rates are encountered? What size is the flowmeter and pipework? What pipework is upstream/downstream of the flow meter? How much straight length of pipe is there before/after the flow meter? Are there any bends? Which temperature and pressure sensors are closest to the flow meter and where are they located?
3-Heat Exchanger questions	Do you have a heat exchanger? Where is the heat exchanger located? What is the heat exchanger's duty? What temperature is the fluid pre-cooled to?
4-Compressor questions	What type of compressor do you use? Where is the compressor located?
5-Temperature and pressure measurement questions	What temperature ranges do you encounter overall? What pressure ranges do you encounter overall? What is your ambient temperature range? How many pressure and temperature sensors are being used in the dispenser? Where are they located? What make/model are the temperature/ pressure sensors? What is the fluid temperature before the flow meter? Is there large variation across the system? Where/how is this measured? (may already be answered with above questions)
6-Additional system questions	Do you measure the depressurization of the hose (valve)? Where is the pressure valve located? What is the achievable pressure stability (during the fuelling)? Is there a calibration of the dead volume by a notified body? Do you know the size of this dead volume? Is there a pressure pulse before starting the refuelling to get information regarding the hydrogen level in the tank? How many buffers are being used in your HRS? Where is the transfer point in your HRS?
7-Sampling questions	Which laboratory do you use to perform hydrogen purity testing (please state 'none' if not performed yet) Do (or would) you perform your own sampling for obtaining hydrogen for purity testing? What sampling device is used for sampling? When sampling hydrogen what range of pressure can you provide?
8-Calibration / uncertainty questions	How often are temperature/pressure sensors and the flow meter calibrated? What ranges are they calibrated across? What is your understanding of the system's overall accuracy/ uncertainty? Do you have any accuracy/uncertainty information about the individual components (e.g. flow meter, temperature/pressure sensors)?
9-Other questions	How do you charge customers for their hydrogen? How long does it take to fill a vehicle from empty? Can you provide a basic flow diagram of the fuelling station (ideally showing compressor/heat exchanger/flow meter/ temperature/pressure measurement locations etc.)? Would you be willing to provide answers to questions we may have later on in the project?

Table 2: Questions of the task 1.1.2 in the questionnaire

This questionnaire was sent to many HRS end users or manufacturers. So far, the consortium has received replies from BOC, H2logic, NEL hydrogen, H2energy, Empa, Mc Phy and Air liquide. They represent major players within Hydrogen fuelling.

1-General questions:

How is the hydrogen produced?

Hydrogen is produced by electrolysis, either onsite or delivered. If the hydrogen is produced on-site (57% of responding people), it is done by electrolysis (sometimes powered by solar panel).

How is the hydrogen stored?

All the participants have reported buffer storage but the pressure can vary significantly from low pressure 200 bar, medium pressure 500 bar and high pressure 800-1200 bar.

What is the fuelling procedure (e.g. tank-to-tank filling or direct compression filling)?

There is only one way to fuel a car reported by the responding people. They all perform a tank-to-tank fuelling.

What pressure of hydrogen is supplied to the vehicle?

Mostly 700 bar, some stations offer also 350 bar. The pressure of hydrogen depends of the nature of the vehicle. If it is a car then the pressure will certainly be 700 bar whereas if it is a utility vehicle (i.e. bus and truck) it is most probably 350 bar. Many manufacturers offer the capability to supply both pressure targets.

Is the station in operation and already refuelling vehicles? If so, approx. how many per day?

All the HRS end users have reported operating refuelling stations. The oldest has been inaugurated in 2011, upgraded in 2014 to be the first commercial-scale solar powered hydrogen refuelling station.

The number of cars refuelled per day differs significantly from 7 cars per day down to 15 cars per month.

2-Flow meter questions:

What is the location of the flow meter? How far is it from the filling nozzle?

The flow meter is generally mounted in the dispenser but it could be in the station at the compressor vicinity. The distance from the flow meter to the filling nozzle car can then vary from 3m to more than 20m depending on the flow meter position (dispenser or station). The flow meter can also either be in a warm zone (before heat exchanger) or in a cold zone (after heat exchanger).

What make/model is the flow meter that you use?

All participants use Coriolis flow meter to measure the hydrogen mass flow in the refuelling station. It is the only technology reported so far. There are several Coriolis manufacturers used by the responding people: Emerson (350 bar), Heinrichs (TM-SH 14), Endress+Hauser (350 bar), Rheonik (RM08 for 350 bar, RHM04 for 700 bar), Siemens (350 bar), Tricor (TCM 0450-HC-SPMS-PZZS-EX). There are limited suppliers of Coriolis flow meters working up to 700 bar.

What range of flow rates are encountered?

The mass flow range is directly linked to the SAE- J2601 fuelling protocol. Depending on pressure, temperature conditions and aiming to reduce the temperature increases of the buffer vehicle tanks, the mass flow range is in the range 5 g/s to 60 g/s.

Flow meter size and pipework?

The inner pipe diameter has been reported to be in between 2.4mm and 9.5mm, depending on pressure. 700 bar stations have smaller pipework diameter than 350 bar stations.

What pipework is upstream/downstream of the flow meter? How much straight length of pipe is there before/after the flow meter? Are there any bends?

Depending on the design, there is a large variation of answers from the panel. Indeed, the flow meter location plays an important role here since the space is limited in the dispenser whereas it is more convenient if the flow meter is mounted close to the hydrogen supply.

Some manufacturers reported that bends can be positioned before and after the flow meter but it should be expressed as a function of internal Coriolis diameter inlet (as generally recommended by Coriolis manufacturers). This information was not available and has not been reported in the questionnaire.

Which temperature and pressure sensors are closest to the flow meter and where are they located?

There are often pressure and temperature sensors at the vicinity of the compressor or in the dispenser. There is not specific information pointed out by the responding people of the specific location regarding the sensors themselves but the next section is devoted to the pressure and temperatures measurements.

3-Temperature and pressure measurements questions:

What temperature ranges do you encounter overall?

Depending on the design (i.e. the Coriolis flow meter location), the fluid temperature can vary significantly. If the flow meter is in the cold area (after heat exchanger), the temperature can start from ambient temperature and decreases rapidly to -33°C accordingly to the SAE J2601 protocol during refuelling (after 30 seconds).

If the flow meter is located in the warm zone, the fluid temperature is directly linked to the ambient temperature. It is almost constant within a fuelling but can vary between winter to summer (-20°C to 40°C approximatively).

What pressure ranges do you encounter overall?

The pressure evolves depending on the location in the HRS. Typical reported values are 200-240 bar (bundle supply): 430-1000 bar (fuelling storage): Station module (350 & 700) bar or up to 900 bar. In some specific location, the pressure can be increased up to 1200 bar.

What is your ambient temperature range?

The ambient temperature (lower / highest reported values) is in the range of -20°C to 40°C but every supplier has set specific values for their equipment.

How many pressure and temperature sensors are being used in the dispenser? Where are they located?

The panel of replies is broad since some manufacturers have stated that one pressure and one temperature sensor are being used in the dispenser whereas other has reported 6 pressure sensors and 2 temperature sensors (entrance to control pressure source - upstream/downstream compressor - upstream/downstream HP source (buffer) - upstream distribution).

What make/model are the temperature/ pressure sensors?

Pressure sensor: ABB 261GS, Keller PA-33XEi; Siemens / Idac; ABB & Keller.

Thermocouple: Thermo-Est; TC direct; Sensy.

What is the fluid temperature before the flow meter? Is there large variation across the system? Where/how is this measured?

As already explained, it is directly linked to the design. If the flow meter is located in the cold region, the variation of temperature should remain low (as reported by several manufacturers) except at the beginning of the fuelling (without seasonal concerns). The same holds for the hot region as well, there should not be a large temperature variation in the flow meter during refuelling. Ambient conditions can vary depending on seasons.

4-Additionnal system questions:

What is the achievable pressure stability (during the fuelling)?

The pressure should follow the SAE-J2601 fuelling protocol to avoid a temperature increasing above 85°C of the receiving tank. There are several tables giving the pressure ramp and the target pressure as a function of initial tank pressure, ambient temperature, the fluid temperature and total amount of mass needed. The Table 3 is an example of pressure ramp for a 2-4 kg refuelling at -40°C and 700 bar and non-communication fuelling:

H70-T40 2-4kg non-comm		APRR [MPa/min]	Target Pressure, P_{target} [MPa]											
			Initial Tank Pressure, P_0 [MPa]											
			0,5	2	5	10	15	20	30	40	50	60	70	> 70
Ambient Temperature, T_{amb} [°C]	> 50	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling
	50	3,2	no fueling	77,2	76,8	76,4	76,1	75,7	75,2	74,8	74,3	73,7	72,7	no fueling
	45	5,8	75,3	76,5	76,2	75,8	75,8	75,5	75,1	74,9	74,3	73,7	72,7	no fueling
	40	8,6	72,2	74,9	76,0	75,7	75,7	75,5	75,1	74,9	74,3	73,6	72,6	no fueling
	35	9,7	71,3	74,2	75,8	75,4	75,5	75,4	74,9	74,7	74,1	73,5	72,6	no fueling
	30	12,5	69,1	73,2	75,1	74,6	74,8	74,6	73,9	73,7	72,9	72,2	71,3	no fueling
	25	15,7	66,4	71,2	74,5	73,9	74,2	73,8	72,9	72,6	71,6	70,9	no fueling	no fueling
	20	19,3	66,2	70,9	74,0	73,1	73,4	73,0	71,8	71,5	70,3	69,5	no fueling	no fueling
	10	27,0	66,1	70,9	73,1	71,7	72,0	71,2	70,4	69,2	68,0	66,7	no fueling	no fueling
	0	28,5	73,8	73,3	72,3	70,4	70,5	69,4	68,1	66,6	65,3	63,9	no fueling	no fueling
	-10	28,5	73,1	72,6	71,6	71,2	69,7	68,2	66,2	63,9	62,5	61,2	no fueling	no fueling
	-20	28,5	72,4	71,9	70,9	70,6	69,1	67,6	65,4	62,2	59,7	no fueling	no fueling	no fueling
	-30	28,5	71,4	71,0	70,1	69,8	68,4	67,0	64,8	61,7	58,6	no fueling	no fueling	no fueling
	-40	28,5	70,9	70,5	69,6	69,4	68,0	66,5	64,4	61,4	58,4	no fueling	no fueling	no fueling
	< -40	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling

Table 3: SAE-J2601 fuelling protocol for H70-T40 2-4kg refuelling and non-communication fuelling

Do you measure the depressurization of the hose (valve)?

The depressurization of the hose is generally not taken into account in the process of the Hydrogen Refuelling Station. This amount of hydrogen is vented to the atmosphere even if it has been counted by the flow meter. This information will definitively impact the uncertainty budget if the depressurization in not properly managed (measured or estimated).

Where is the pressure valve located?

The control pressure valve can either be in the dispenser or near the compressor and high pressure buffer (sometimes more than 15 meters far from the nozzle exit).

Is there a pressure pulse before starting the refuelling to get information regarding the hydrogen level in the tank?

Yes, there is a pulse to ensure that the sealing is correctly done and gain information regarding the tank (in terms of pressure).

How many buffers are being used in your HRS?

Depending on the design or the owner, the HRS mainly use one single bank (high pressure buffer but multiple banks at different pressure can also be used).

Where is the transfer point in your HRS?

The transfer point has been designated to be at the nozzle exit of the hose.

5-Calibration / uncertainty questions:

How often are temperature/pressure sensors and the flow meter calibrated? What ranges are they calibrated across?

The responses from the responding people are very different since there is no calibration at all for certain HRS, according to operation manual or once a year.

What is your understanding of the system's overall accuracy/ uncertainty?

There is no clear indication of overall accuracy / uncertainty even if people believe that the quantity of mass displayed generally agrees with expected mass. One HRS operators has reported an estimate between 2% and 5% of accuracy.

Do you have any accuracy/uncertainty information about the individual components (e.g. flow meter, temperature/pressure sensors)?

It seems that the operators generally don't have relevant information regarding individual components. One entry is about the mass flow meter reading accuracy being 1% (above 12 g/s) and 5% to 6% at lower flow rate (2 g/s).

6-Other questions:

How do you charge customers for their hydrogen?

People often need a refuelling card and can either be charge monthly or directly paid (around 1€/100g of hydrogen) at the refuelling station.

How long does it take to fill a vehicle from empty?

It has been reported an average time of 2.5 minutes to fill completely the tank with the highest average pressure ramp rate (APRR) and up to 15 minutes with the lower APRR (50°C T ambient). This duration is directly linked to the SAE-J2601 fuelling protocol.

Uncertainty sources and measurement error evaluation

In this section, an extensive list of uncertainty sources and measurement errors will be given and sorted out by their influence on the calculation of the hydrogen mass displayed by the dispenser. From the questionnaire, it appears that several potential uncertainty sources can be listed. Table 4 presents each component that will be discussed and explained in detail. The colour code indicates how large an impact the source can have on the uncertainty budget (red: significant, yellow: medium, green: low).

Main Uncertainty Sources	Estimated Significance of Uncertainty	Confidence in Uncertainty	Comments
Mass flow rate from Coriolis meter			1
Pressure measurements (in particular those closest to flow meter/dead volume/fuel transfer point) Pressure measurements may be used for pressure corrections to the flow meter and for calculating the density of hydrogen in the dead volume to allow the mass to be determined.			2
Temperature measurements (in particular those closest to flow meter/dead volume/fuel transfer point) Temperature measurements may be used for temperature corrections to the flow meter and for calculating the density of hydrogen in the dead volume to allow the mass to be determined.			3
Depressurisation of fuel hose & dead volume connecting volume between flow meter and fuel nozzle (generally in hose)			4
Position of flow meter (this will affect the dead volume)			5
Hydrogen density equation			6
System repeatability			7
System reproducibility			8
Minimum Measurable Quantity			9

Table 4 : List of potential uncertainty sources and their impact on the uncertainty budget.

Mass Flow rate from Coriolis meter

From literature [1], errors greater than 10 % have been reported for Coriolis meters in transient gas flows. There is no information about how the accuracy will vary at the extreme temperatures and pressures the meter can operate at. From the Coriolis mass flow meter (CFM) manuals, accuracy (including zero stability) has a maximum of ~1.5 % (based on the reference conditions).

Excluding zero stability, the uncertainty varies from (0.1 - 0.6) % depending on flow rate and calibration. There is no information about how reliable this information is for varying flow conditions. There is no information about pressure corrections in the CFM manual, but there is a temperature compensation option in the flow meter.

Potential uncertainty sources:

- The rapid variation in temperatures/pressure can affect stress and torsion on the meter and might modify the meter accuracy / performance.
  - The CFM manual (tested) states that the temperature variation shall be no more than 1°C per second.
  - During the pulse initial phase, literature suggests large errors can be expected. Is the pulse measurable for the CFM?
- The zero adjustment has to be done once before type approval or periodic verification but how reliable is it if conditions evolve significantly?

Pressure measurements

Pressure measurements at the flow meter will be required if the pressure is required for pressure corrections. The location of the sensor may vary between HRS designs. It can affect how the pressure correction can be applied.

Potential uncertainty sources:

- A pressure measurement will be required for 'dead volume' gas density calculations and correction. Literature suggests that drift of the pressure sensors can be a significant issue.

Temperature measurements

Temperature measurements at the flow meter will be required if the temperature is required for temperature corrections. The sensor must be able to respond to rapid variations and must be mounted close to the meter.

Potential uncertainty source:

- A temperature measurement will be required for 'dead volume' gas density calculations.

Additional comment:

A potential reliability issue of the temperature sensors was highlighted during a visit to a HRS by one of the respondent.

Dead volume:

Dead volume is the volume between the flow meter and the point of transfer into the vehicle (fuel nozzle at the end of the hose mainly). The mass dispensed into a vehicle is the mass measured by the flow meter minus the mass in the dead volume (generally refuelling hose) at the end of a fill (assuming there was no gas mass in the dead volume to begin with). If hydrogen was present in the dead volume at the start of the fill, the mass dispensed into a vehicle is the mass measured by the flow meter minus the difference in mass in the dead volume at the end of the fill and start of the fill. The design of the system shall ensure that the measured quantity is delivered.

Figure 3 shows what is usually vented in a HRS.

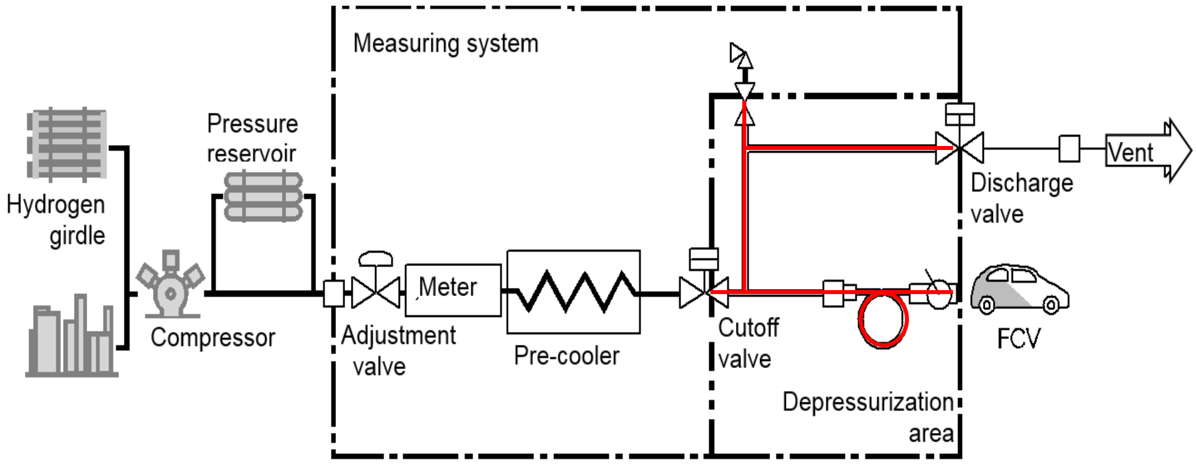

Figure 3 : Depressurization in a HRS

The size of the dead volume is therefore required.

As a rough approximation, for a 8mm inner diameter (typical 9/16" medium pressure tubing ID) hose that is 5m long, the maximum mass of hydrogen in the dead volume should be approximately 10g (assuming a gas density of ~40 kg/m^3 at 700 bar and 20 °C). The depressurization takes also into account the piping length from the hose to the flow meter.

It has been reported by end users that the vented quantity is generally between 10g and 50g. Since storage masses for cars generally vary from 1 kg (being the minimum quantity) to 5 kg. Fill masses are therefore likely within this range, the dead volume mass can correspond up to 1% of the tank's mass capacity.

As mentioned, pressure and temperature measurements close to the dead volume are required to calculate the density, and therefore the mass of hydrogen in the dead volume. Uncertainty in this could therefore be a significant contributor to the overall uncertainty.

Potential uncertainty source:

- the vented quantity of hydrogen due to depressurization can be large compare to the mass delivered. If the HRS does not make any correction for it, the uncertainty associated with depressurization can be high.

Additional comment:

It is recommended to evaluate the depressurized quantity by at least one method listed in the Table 5:

Method A	Evaluate the maximum value of the depressurized quantity as a specific value for each dispenser from the maximum hydrogen pressure and minimum temperature at the operating condition, and the volume of the depressurization area.	
Method B	Evaluate the depressurized quantity after each filling process completed	
	B1	from the hydrogen temperature / pressure and the volume of the depressurization area.
	B2	using a flowmeter mounted at the discharge valve.

Table 5: methods to take depressurization loses into account

Position of the meter

Flow meter position is important as the further away it is from the point of transfer into the vehicle, the larger the mass of hydrogen that is measured by the flow meter that is not actually dispensed into the vehicle (dead volume).

A study [9] showed that vibrations from a compressor 9m away could give false readings of a Coriolis flow meter by changing the totalizer value from 0.28 kg to 0.34 kg in 40 minutes.

The meter location can have a large influence if it is mounted before or after the heat exchanger. Depending of the position, the flow meter can have a relatively stable temperature during the fuelling in the warm area (before the heat exchanger) or experience a rapid temperature variation at the beginning of the fuelling when hydrogen at ambient temperature is replaced by cooled hydrogen after it went through the heat exchanger. In both case, pressure variations are always present.

Potential uncertainty source:

- Meter location have direct effect the depressurization loss quantity
- Possible pressure / temperature variation due to location
- Vibration can harm the flow meter accuracy if the compressor is located close to the CFM.

Hydrogen density equation

Hydrogen density equation is likely to be very reliable, with the main uncertainties in gas density coming from the temperature and pressure measurements required.

Potential uncertainty source:

- Temperature uncertainty (as expressed earlier)

System repeatability

From literature, accuracy tests on hydrogen refuelling stations suggest poor repeatability with errors varying significantly between fills. Tests by GE on a CFM showed errors to vary by up to 4% between fills. Poor repeatability was thought to be due to temperature gradient issues.

Tests on dispensers in the US similarly showed a large range of % errors between the dispensed mass indicated by the dispenser and the reference. Recent work in the US (NREL [9]) found that for a range of tests (using the meter that showed best performance), 82% of fills fell within 2% accuracy. For high flow rate fills, however, this quantity fell to just 64%.

Minimum Measured Quantity (MMQ)

The current version of OIML R139 (2014) states that the MMQ shall be specified by the manufacturer of the measuring system. It shall have the format 1 x 10^n, 2 x 10^n or 5 x 10^n kg, where n is a positive or negative whole number or zero and it shall satisfy the conditions of use of the measuring system.

The MMQ for the HRS (mass flow lower than 4kg/min) is currently set at 0.5kg.

Total uncertainty

A part of the task 1.2 is to assess the total uncertainty and judge whether it is realistic to reach the target of 1%. The target of 1% is chosen to meet the requirements of the OIML R139, however, this is being revised now and the majority of tests so far show that it is not realistic when working with hydrogen.

Task 1.2 is on a very early stage and the assessment will therefore be mostly indicative and based on some overall assumptions. A more thorough assessment will be done after the actual field testing.

As discussed in the separate evaluation of the uncertainty sources there are a few major contributors. Especially the uncertainty of the mass flow meter seems to have a large impact and an unpredictable variation. Uncertainty from depressurisation and dead volume can possibly be estimated and thereby adjusted for.

Studies conducted in the US show that the errors for a HRS typically lie between ±5% (accuracy class 5). In the current revision of OIML R139, it is suggested to include both accuracy class 2 and 4 for hydrogen. Accuracy class 4 seems realistic in the current situation and accuracy class 2 is aimed for in the future.

With the risk of mixing uncertainty and error, the conclusion is that with the knowledge available about the equipment and the tests already conducted worldwide it is not realistic to reach the target of the existing OIML R139 but it is realistic with the expected changes in the revision.

OIML R139 recommendation

This section quotes statements directly taken from the OIML R139 document. This provides an overview of the requirements (in terms of uncertainty) to comply with the OIMLR139 requirements.

OIMLR139(2014)

Overall Maximum Permissible Error

The OIML R139 (2014) "Compressed gaseous fuel measuring systems for vehicles. Part 1: metrological and technical requirements" aims to determine the maximum permissible error for the flow meter.

1-1)"the maximum permissible errors on mass indications, positive or negative at type evaluation, initial verification and subsequent verification, are equal to:

- *for the meter:*

***1 % of the measured quantity**;*

- *for the complete measuring system:*

***1.5 % of the measured quantity**.*

Note: National Authorities may decide whether subsequent verifications should be conducted and whether a different maximum permissible error should be applied for subsequent verification."

The maximum permissible errors apply for all gases to be metered, all possible ambient conditions of temperatures and pressures, and all flow rates for which the system or the meter is intended to be used.

A measuring system or a meter shall be capable of fulfilling all requirements without adjustment or modification during the relevant evaluation procedure.

*1-2)The maximum permissible error on mass indications, positive or negative, during in-service inspection under rated operating conditions**, is equal to 2** % of the measured quantity for the complete measuring system.*

Note 1: "In service" refers to any period of time between verifications (refer to OIML D 16, 2.25).

Note 2: National authorities may decide whether in-service inspections should be conducted and whether a different maximum permissible error should be applied during in-service inspection.

Minimum Measured Quantity

The maximum permissible error applicable to the minimum measured quantity is twice the corresponding value as stated in 5.2.1, where the minimum specified mass deviation (E_{min}) is presented by the following formula:

$E_{min} = 2 \times MMQ \times R_{MPE}$[g;kg] where: R_{MPE} = the maximum permissible error ratio according to 1-1 or 1-2 (as expressed in percentages in the referred sub clauses);

MMQ = the specified minimum measured quantity according to 1-2.

OIML R139(revision – expected 2019)

The OIML R139 is currently being revised by the OIML project group TC8/SC7. The project aims at optimizing the implementation of hydrogen measurements in the OIML R139. Project group P-members have been invited to vote and comment on the second committee draft (CD) until 16 February 2018. Specific sections to hydrogen have been added and the MPE for hydrogen has been increased and is likely to be (as presented in the Figure 4 below):

Table 1 - MPE values

Accuracy class		MPE for the meter [in % ***of the measured quantity value***]	MPE for the complete measuring system [in % ***of the measured quantity value***]	
			at type evaluation, initial or subsequent verification	in-service inspection under rated operating conditions
General applicable	1,5	1	1,5	2
For hydrogen only	2	1,5	2	3
	4	2	4	5

Figure 4:Proposed MPE in the OIML R139 revision (second committee draft)

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