EIHP II Final Technical Report

WP4 Vehicle

WP4.1 Monitoring of Draft
WP4.2 Global Technical Regulation
WP4.3 Periodic Inspection
WP4.4 Validation of EIHP I Draft

WP4 Summary

Within the frame of EIHP II, working on the drafts ECE regulations did continue and has progressed to the most advanced state possible. Both the LH2 draft and the CGH2 draft have now reached the status of official documents at GRPE (working party on pollution and energy, subsidiary body of WP.29 the world forum for harmonization of vehicle regulations, member of UNECE) and could be forwarded to WP.29 for political voting.

After EIHP I had been finalized, it became obvious that working just on the draft ECE regulations for LH2 and CGH2 would not lead to the desired results.

Therefore, as another major area of work, communication to outside groups/organisations has been established in order to promote the results of EIHP and to ensure that duplicating of work is avoided: A workshop with US authorities was held, a meeting with ISO TC 197 took place, a meeting of ISO and GRPE was initiated/held, a workshop with ELEDRIVE was attended as well as the launch of the European H2 Technology Platform.

GRPE decided in their 44^{th} session in November 2002 to stop working on Global Technical Regulations (GTRs) and to focus on ECE regulations. During the 47^{th} session in January 2004 the Informal Group Hydrogen of GRPE (IGH) has presented a roadmap to GRPE proposing that GTRs should be generated. However, no agreement could be reached on how to deal with the two draft ECE regulations.

In terms of periodic inspection a draft amending the directive 96/96/EC has been created and is now waiting to be forwarded to ACEA/OICA (European/world association of automobile manufacturers) in order to start the approval process.

The validation of the EIHP I drafts has made good progress, although this area is facing some challenges due to the fact that there is not as much experience with hydrogen as with other energy carriers.
Storage systems for liquid and compressed gaseous Hydrogen have been manufactured and their function has been proved. Automobiles using these H2 storage systems have been developed or are currently progressing through the design phase.

WP4.1 Monitoring of Draft
WP4.2 Global Technical Regulation

All efforts have been made improving the LH2 and CGH2 draft. Many iteration steps were taken and so the LH2 draft has progressed from revision 10 to revision 14 plus an addendum. The CGH2 draft has progressed from revision 8 to 12b.

Both drafts are now official documents at GRPE and could be forwarded to WP.29 for voting. Since representatives of the USA and Japan do not support the draft regulations, they are held back at GRPE.

The final results of WP4.1 are documented on the UNECE web sites of WP.29. The LH2 draft is listed under TRANS/WP.29/GRPE/2003/14 and TRANS/WP.29/GRPE/2003/14/Add.1, the CGH2 draft is listed under TRANS/WP.29/GRPE/2004/3. An example (cover page only) is shown below:

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World Forum for Harmonization of Vehicle Regulations (WP.29)

Working Party on Pollution and Energy (GRPE)
(Forty-sixth session, 19-23 May 2003,
agenda item 8.)

PROPOSAL FOR A NEW DRAFT REGULATION

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:
I. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID HYDROGEN
II. VEHICLE WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF LIQUID HYDROGEN

Transmitted by the members of the informal group "hydrogen / fuel cell - vehicles"

USA and Japan would prefer working on GTRs for LH2 and CGH2 vehicles. However, work on GTRs has been stopped at 44^{th} session of GRPE (November 2001) and could start again as early as of June 2004. This would depend on the outcome of the June sessions of GRPE and WP.29.

WP4.3 Periodic Inspection
(Source: report from Opel)

Safe operation of hydrogen fuelled vehicles requires periodic inspection of the hydrogen storage system. Therefore, a procedure for the periodic inspection of hydrogen vehicles has been drafted.

To begin with, the existing directive 96/96/EC (roadworthiness test for motor vehicles) was investigated. National regulations, codes and standards concerning the periodic inspection of hydrogen storage systems (mobile and stationary application) were analysed. Regulations and standards for hydrogen, natural gas and gas and high-pressure applications have been taken into consideration.

For analysing purposes an assembly of the hydrogen related components of the onboard hydrogen storage system was created according to the LH2 draft proposal (revision 12). This assembly contains the necessary components as well as the optional components of an onboard storage system for liquid hydrogen.
Based on this assembly and the experience gathered from the operation of vehicles fuelled with hydrogen, inspection critical components were identified and a proposal for a procedure for the periodic inspection of hydrogen related components was compiled that could be used both for regular vehicle inspection at the workshop and for roadworthiness inspection. The proposals were discussed and improved together with the EIHP project partners (e.g. DaimlerChrysler with their experience from operating busses and passenger cars fuelled with CGH2).

Main difficulty was the lack of field data concerning reliability of hydrogen storage systems. Although there are prototype vehicles and even small fleets of vehicles and busses with on board hydrogen storage systems on the road for some years, there are no large fleets or private customer cars on the road yet. In particular high storage pressure up to 70MPa is an area where practically no experience is available.

The draft can now be forwarded to the relevant organisations e.g. ACEA or OICA in order to start the process of amending directive 96/96/EC

WP4.4 Validation of EIHP I Draft

1 Storage System
(Source: Report from Messer)

1.1 Summary

The first “European Liquid Hydrogen Vehicle Storage Tank” has been constructed by Messer according to the EIHP draft version 10...12. For the approval procedure with two TÜV organisations 103 new items had to be clarified. The approval successfully could be obtained.
As the liquid hydrogen system was planned to be installed into a new BMW 7 series vehicle, additional specifications from BMW could be fulfilled to a great extent.
The whole tank system was tested at the Messer liquid hydrogen test stand. It shows excellent data e.g. referring to the overall insulation quality, the autonomy time and the supply flow of more than 20 kg/h.
While working on the tank system the EIHP draft has further been developed together with BMW towards version 14 forwarded to GRPE by BMW.

1.2 Details and main results

During the design process of the liquid hydrogen vehicle storage system the original EIHP1 draft “SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID HYDROGEN” could be further discussed and developed with the partners and the TÜV as far as version 10. During the design phase of the tank system the draft has been further developed towards version 12.

Figure 1 shows the first “European Liquid Hydrogen Vehicle Storage Tank” manufactured by Messer with its main performance data.

First „European“ Liquid Hydrogen Vehicle Storage Tank *

- New design and insulation concept
- 12 kg LH2 storage capacity
- > 20 kg/h hydrogen supply
- > 3 days authonomy without evaporation
- < 3%/d evaporation rate
- Demonstration planned in a new BMW-7 vehicle

*) Design and approval according to the new European draft standard (EIHP Rev.10 …12)

Fig. 1: Messer LH2 vehicle storage system

The approval of the prototype took place in several steps and needed more time than expected. A total of 103 new technical issues had to be clarified with the two participating TUV organisations. In the end an approval was successfully obtained.

Regarding the installation of the prototype tank system into a new BMW 7 series vehicle, additional specifications from BMW had to be fulfilled. An overview of the mandatory requirements given by BMW and how they have been met by the Messer LH2 system is listed in figure 2.

Features of the Messer LH_2 Storage System EIHP – WP 4.4

compared to BMW „P1"-Specifications (Mandatory)

1 EIHP, Draft for Regulation	☺	13 instruction manual	under work
2 tank evacuatable	☺	14 no liquid fuel run out	☺
3 refuelling no longer than 5 minutes	☺	15 gas tight housing vented to the fuel filler cap	☺
4 - possible at 5°	☺	16 2 separate vent lines pressure relief	☺
5 - stop automatically	☺	17 Accurate cleaning	☺ no doc.
6 hold time (P1) > 3 days	☺	18 refuelling connection on the right side	☺
7 supply temp. -40 °C to +80 °C	☺	19 basic shape cylindrical	☺
8 mass flow rate 0 to 20 kg per hour	☺	20 service intervals = vehicles service intervals	s. EIHP
9 min. to max. flow within 1 second	☺	21 electrical signals shall be accessible	☺
10 total leakage < 5 g/H_2 per day	☺	22 empty tank without power supply	☺
11 no electromagnetic interferences	☺ ?	23 Safety Relief Valves: design temp. 30 K .. 363 K	☺
12 electrical grounding	☺	24 Boil-off Valves: design temp. 218 K .. 363 K	☺

Fig. 2: Fulfillment of BMW specifications by the Messer LH2 storage system

The entire tank system was tested at the Messer liquid hydrogen test stand according to a specific test program.

For the filling of the tank a special adapter had to be designed and manufactured (figure 3), as neither BMW nor Linde were able to provide the original Linde adapter for the relatively short duration of the test period.

Fig. 3: Filling adapter for 2-flow interface

The evaporation rate at surrounding temperature and pressure is one of the essential quality data of a LH2 storage system.
Therefore, after a certain cool-down phase the evaporation rate of the LH2 system was measured. After the second filling process an evaporation rate of 2.8 %/day could be reached, such proving an extremely high quality of the insulation system.

A further essential quality requirement is a high system autonomy, which means a long idling time without any product loss. This is verified by looking at the pressure increase (figure 4) during "parking" when no product is withdrawn from the tank. For the Messer tank the autonomy was more than 3 days which also is an excellent value. Measured data were very close to calculated data and no irregularities could be observed during pressure increase.

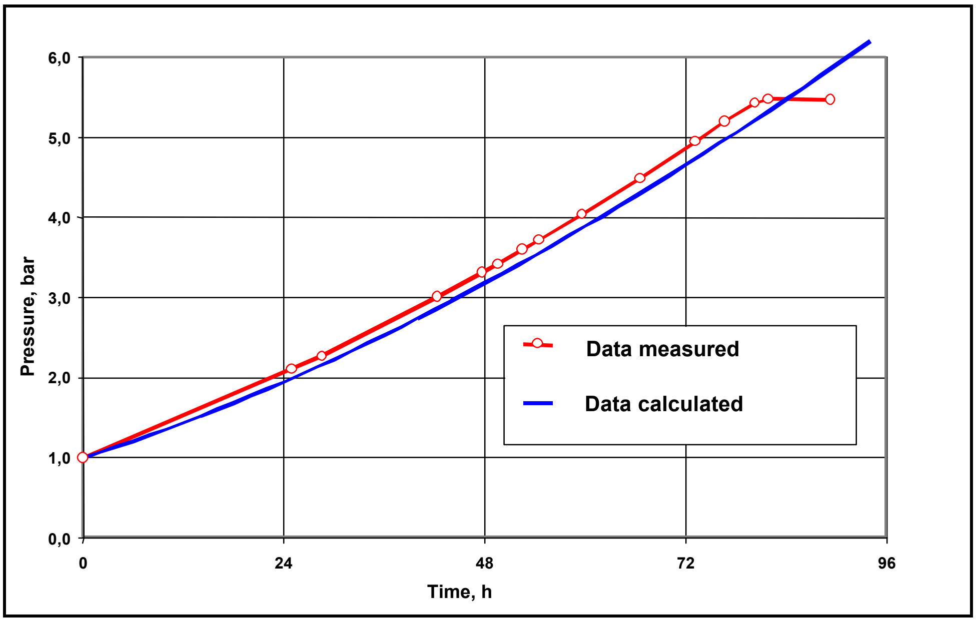


Fig. 4: Pressure increase graph (system autonomy)

For the manufacturer of an internal combustion engine the fuel supply flow is of high importance particularly at fast acceleration. This requirement was specially stressed for the EIHP tank system and could be very well met by the Messer pressurization system. It is characteristic for the Messer solution that even at demanding supply flow changes the tank pressure is hardly influenced.

A supply flow out of the liquid phase of more than 20 kg/h could be realized without problems and even from the gas phase a satisfying flow could be reached.

After delivery of the LH2 vehicle storage system to BMW additional tests have been performed at the test stand of ET. The ET test results confirmed the high performance of the Messer LH2 system and ET stated that the Messer Griesheim tank was the best tank ever tested.

2 BMW 7 series fuelled with LH2

The BMW Group has been working on the field of automotive hydrogen technology for almost three decades. A lot of positive results were achieved thus proving that hydrogen can substitute petrol/diesel as fuel for automobiles.

The chemical industry shows that the usage of hydrogen is safe. However, one must take into account that up to now hydrogen has been handled by experts.

With respect to public usage of hydrogen for transport purposes, technical concepts and standards have now been developed to enable safe and easy handling of cars. Abuse and extreme situations like collisions have been investigated in order to guarantee at least the same high level of safety as is reached by today’s cars fuelled with petrol or diesel.

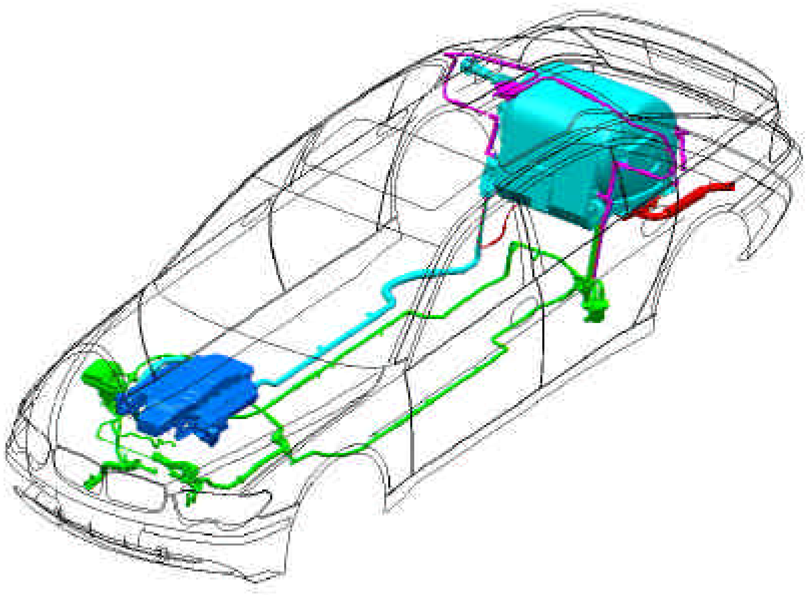
Independently of the vehicle concept (liquid vs. gaseous storage of hydrogen, fuel cell vs. internal combustion engine), there is much communality in safety technology, e.g.:

- Means of hydrogen detection
- Leakages and how to avoid them
- Suitable measures to avoid critical hydrogen/air mixture in- and outside the vehicle
- Crash standards and performance requirements for hydrogen components.

The draft ECE regulation for onboard storage of liquid hydrogen has served as a basis for the development of the LH2 system for the new BMW 7series.

BMW 7 series with internal combustion engine using LH2

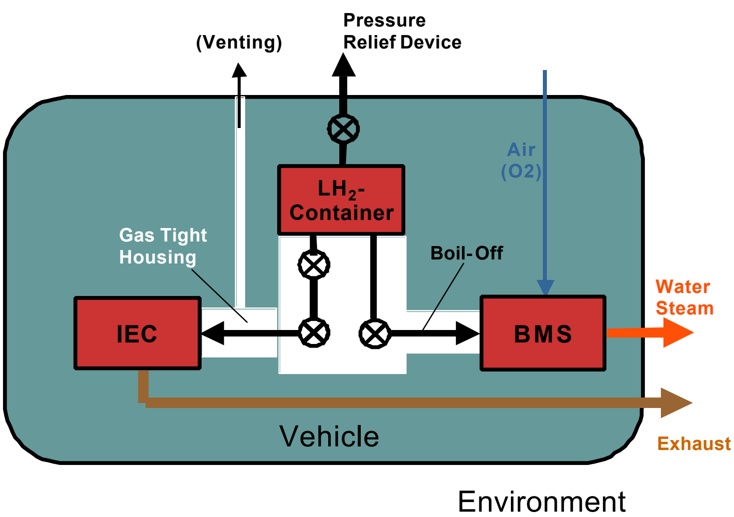
A super insulated container for liquid hydrogen has been developed according to the draft ECE regulation and has been commissioned for and implemented into the present BMW 7 series:



BMW 7 series: LH2 storage and fuel supply system

Initial tests confirm that the safety principles applied to the draft ECE regulation are effective:

- Barrier concept (inside the car the H2-tubes have double walls as long as connections are not welded)
- Closing and safety valves are redundant, i.e. replace each other when necessary
- High mechanical safety for all components exposed to pressure



BMW 7 series: Hydrogen system with gas tight housing concept

BMW use a so-called boil-off-management system (BMS). If the pressure of the gaseous hydrogen phase in the fuel tank reaches a threshold value, the „boil off-valve“ opens and gaseous hydrogen is transferred to a catalytic converter. Hydrogen and oxygen from the air are then transformed into water steam and released into the environment. This catalytic reaction takes place without the need of additional energy or external control devices. First tests of the system have been successfully passed.

Currently, all hydrogen specific components are strictly required to meet the specifications laid down in the draft regulation and have to withstand hardest testing procedures.

In the near future detailed measurements of the hydrogen consumption and the overall emissions of the car are planned.

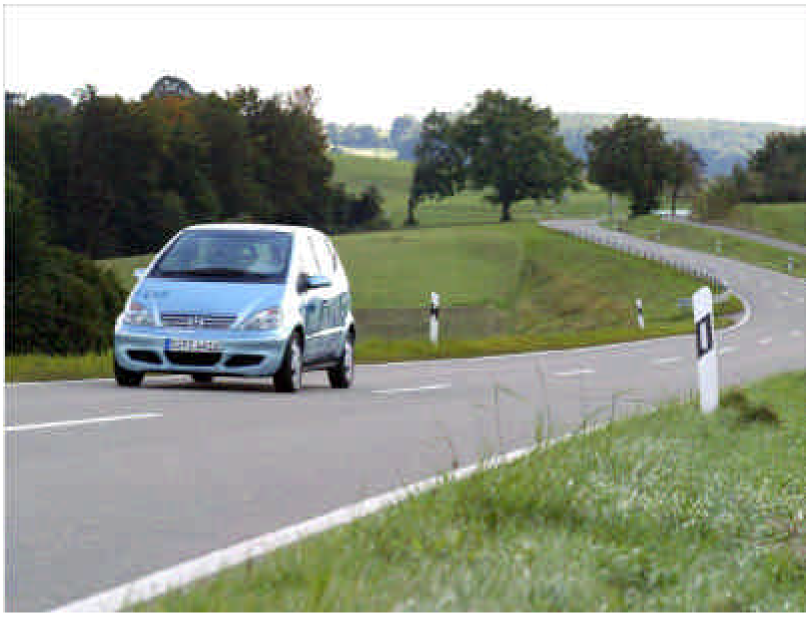
3 DaimlerChrysler A-Class powered by F-Cell and gaseous Hydrogen
(Source: Report from DaimlerChrysler)

The validation of the CGH2 draft took place by applying the approval procedures for components and vehicles according to the requirements of the CGH2 draft. A Technical Service did support these activities and a state of the art fuel cell vehicle with compressed hydrogen onboard storage system was used.

The objectives were to prove the feasibility of the requirements of the draft CGH2 regulation and to identify necessary changes.

The validation of the CGH2 draft done by DaimlerChrysler dealt with part II of the CGH2 draft that details the installation of a hydrogen onboard storage system into a vehicle. The validation of the specific components has been done by the suppliers. Since there are no type approved hydrogen components on disposal, the validation was conducted assuming that type approved hydrogen components would be available.

The project was run using a two steps approach. Each chapter of part II of the CGH2 draft was looked at and DaimlerChrysler experts made a proposal on a technical solution. The proposed solution was then discussed and agreed upon with the technical service (TUV Rheinland) and implemented in a F-Cell vehicle:



If this process resulted in a contradiction to the draft regulation, it was mentioned under comments with a proposal for amending. These comments for amending were sent to the EIHP WP 4.4 leader for distributing and transferring to the ad hoc working group of GRPE.

The vehicle type approval for the F-Cell vehicle is based on the vehicle description, the description of the hydrogen storage system, the safety concept, the component approval, the confirmation of the vehicle manufacturer that the vehicle complies with the relevant regulations (based on testing, results of crash tests, simulations and calculations) and the visual inspection and engineering evaluation by TUV Rheinland.