

Proceedings of the Mid-Term Assessment Workshop of the European Integrated Hydrogen Project - Phase II [EIHP2]



Proceedings Volume 4 *Breakout Session Vehicle*

held at the European Commission's
CCAB - Centre Albert Borchette
Brussels, 02 October 2002



Moderators: Dieter Stoll/ Laurent Allidiers

- **14:10: “Development of a Regulation for LH2 Vehicles ” (D. Stoll, BMW)**
- **14:35: “Development of a Regulation for CGH2 Vehicles ” (P. Adams, Volvo)**
- **15:00: “Necessary Modifications of Existing ECE Regulations and EC Directives” (R. Bauer, DaimlerChrysler)**
- **15:25: “Development of Procedures for Periodic Vehicle Inspections” (H. Mettlach, Opel)**
- **15:50: “Development of a Standard for Calculation of Safety Valves for Vehicle Applications” (L. Allidiers, Air Liquide)**
- **16:15: General discussion and formulation of conclusions/findings**



Session notes and remarks by Dr. Günther Krainz, Magna-Steyr

Conclusions:

1. Development of LH₂ and CGH₂ Regulations

There is no need for an adjustment of the process

- Continue as planned
- Further comments are expected due to the ongoing process of the development of new onboard storage systems



2. Modification of existing legal requirements

The drafts for fuel consumption and exhaust emission will be verified by MAN and FIAT prior to the discussion in ACEA and OICA (feedback until end of November)

J2572 will be forwarded from Tony Androsky to Pablo Laguna and Dieter Stoll. INTA and BMW will comment it (EPA spent a lot of time in participating)

3. Component tests should be standardised throughout the vehicle manufacturers in order to make the performance compatible (this is out of scope of EHHP but the idea will be picked up from manufacturers)



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Presentation by
Dieter Stoll
BMW Group



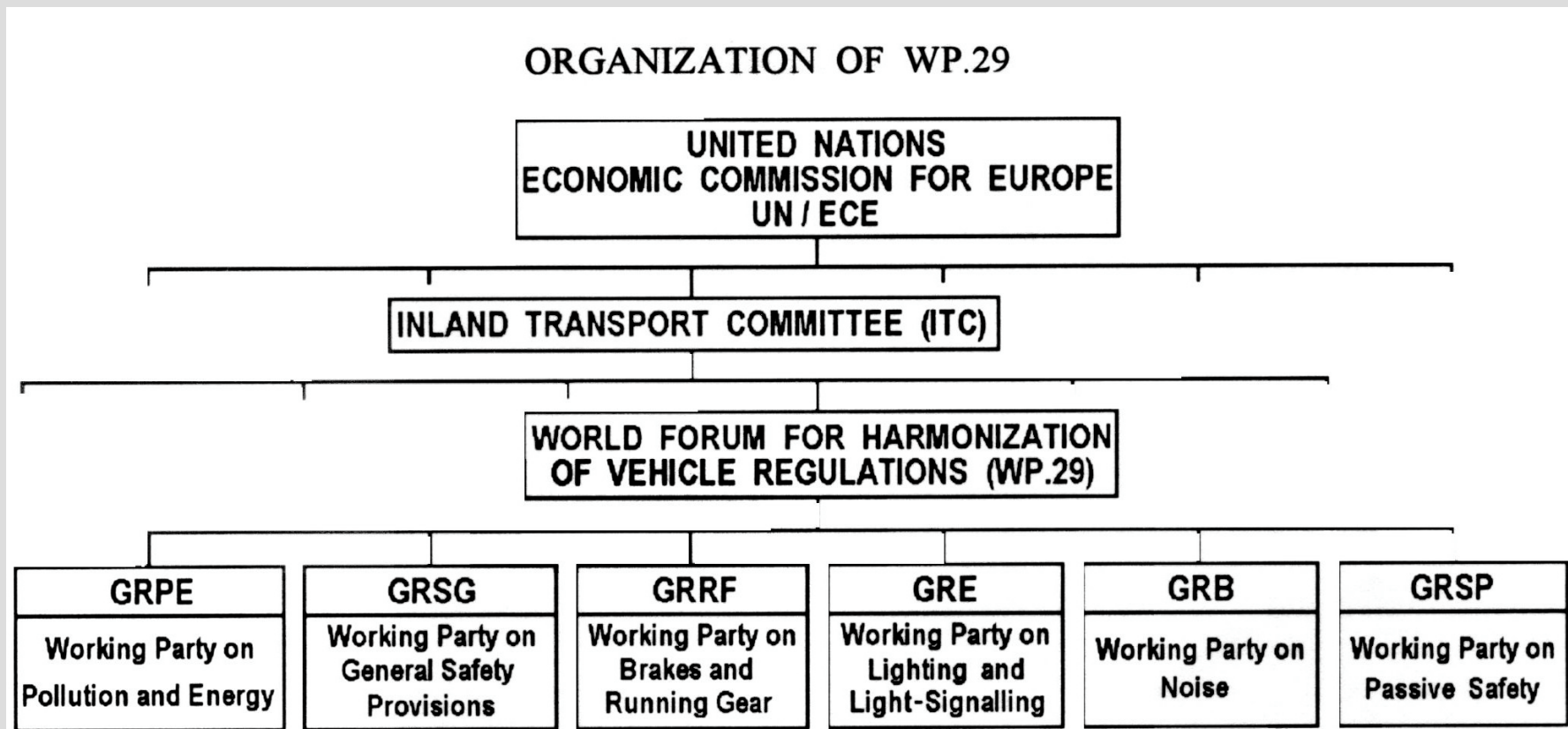
Development of a regulation for LH2 vehicles



Content:

- **Economic Commission for Europe (ECE)**
- **Consideration and Establishment of Regulations**
- **Application for an ECE Regulation**
- **The way of the draft regulation for LH2 vehicles until today**
- **Next steps**





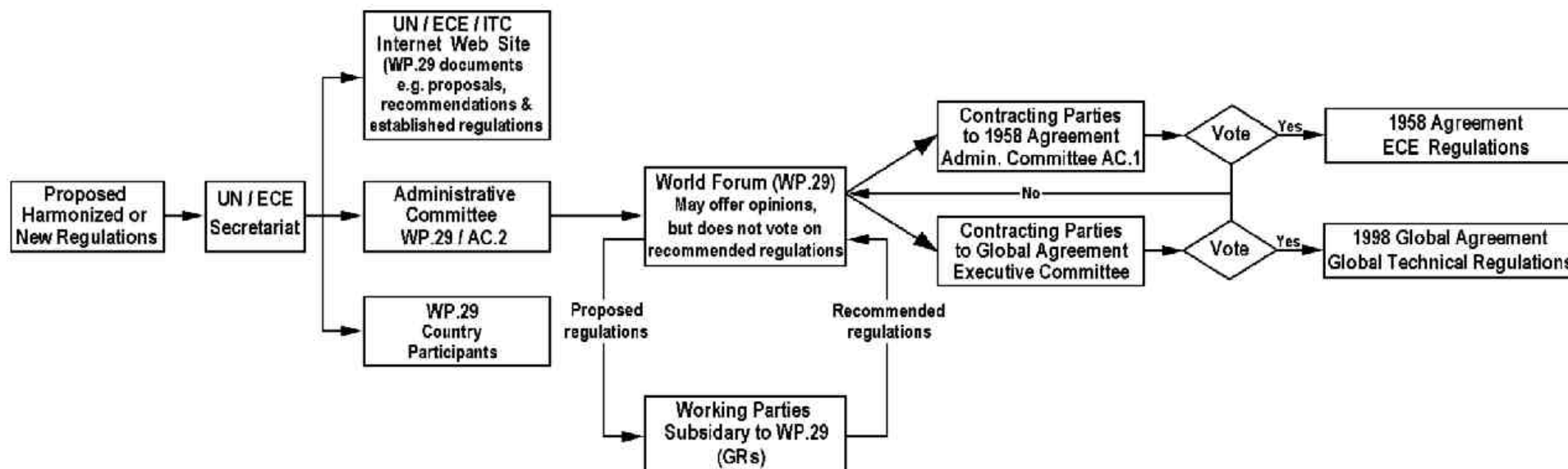
WP 29 currently administers 3 agreements:

- **The 1958 Agreement**
- **The 1998 Global Agreement**
- **The 1997 Agreement on Periodical Technical Inspections**



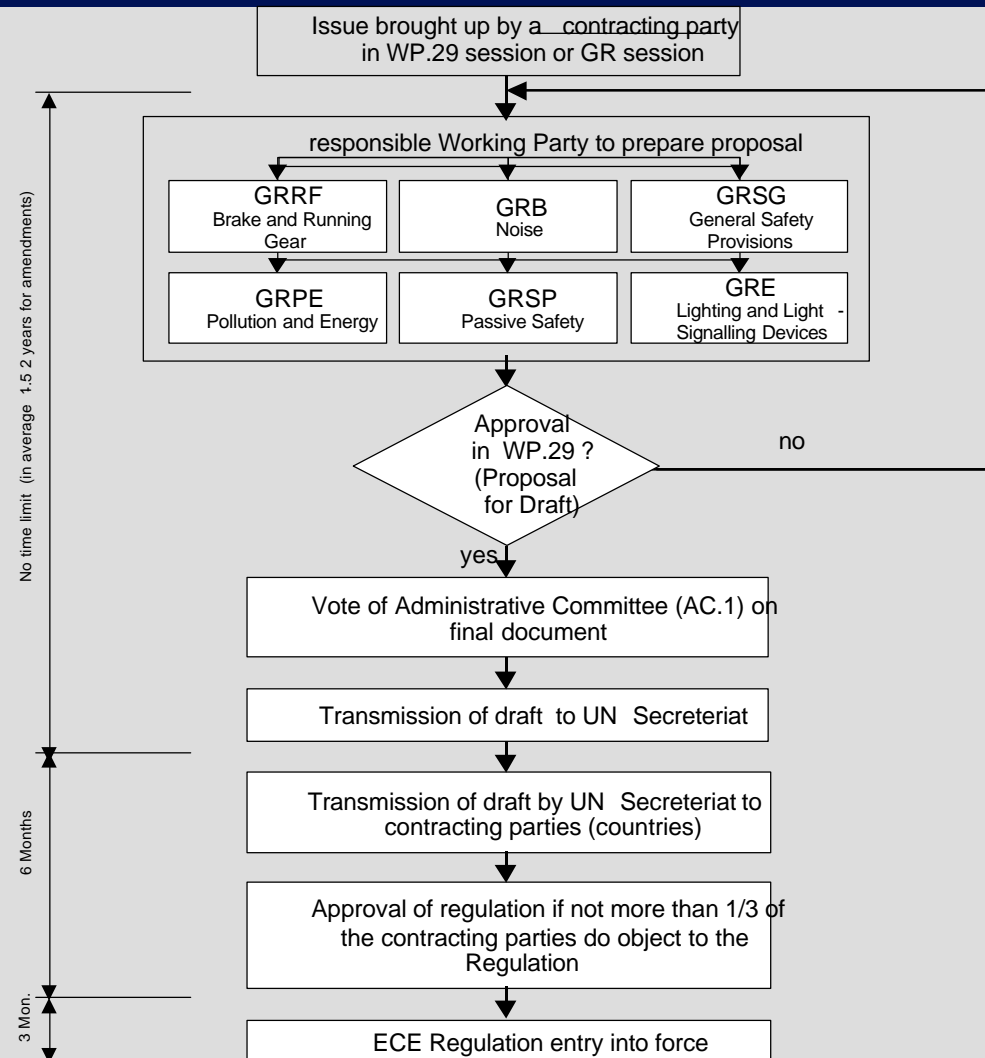
Considerations and Establishment of Regulations

5



Establishment of an ECE Regulation

6



- 6.10.1998 Revision 0 was established
- 25.2.2000 Revision 10 was released

Further development

- Specification for a LH2 Onboard Storage System is in process
- EIHP requirements are integrated in the specifications
- Specifications are forwarded to external partner as well as to internal engineering departments
- Requirements are therefore verified by the engineers of the series development departments
- Numerous comments are already received



Revision 11 was established on 29.8.2001

Agreement with German TÜV to use requirements of revision 11 for single approval



Outside the EIHP partnership the drafts were reviewed in 2001 by different companies/bodies:

- TÜV Süddeutschland
- MPA (Staatliche Materialprüfungsanstalt der Universität Stuttgart)
- ET, Gesellschaft für innovative Energie und Wasserstofftechnologie



- 42nd Session of ECE-GRPE, 29.5.2001 – 1.6.2001
EIHP approach was presented
an ECE GRPE ad hoc working group „Hydrogen vehicles – onboard storage systems“
was formed
Participants: Canada, France, Germany (chairmanship), Italy, Netherlands,
Russian Federation, United Kingdom, USA,
NGO's: CLEPA, ENGVA, ISO, JASIC (Japan), OICA
- 124th session of ECE WP.29, 26.6.2001 – 29.6.2001
Approach was confirmed
- 1st meeting of ECE-GRPE ad hoc working group, 29.11.2001
- 43rd Session of ECE-GRPE, 15.1.2002 – 18.1.2002
the development of a GTR was proposed
- 2nd meeting of ECE-GRPE ad hoc working group, 19.2.2002
Discussion of LH2 technique
Discussion of the draft for LH2 storage
Definition of further proceeding



- 1st Global cooperation meeting, Sacramento, 20.3.2002
- 3rd meeting of ECE-GRPE ad hoc working group, 4.6.2002 – 5.6.2002
 - Discussion of the draft for LH2 storage
 - Elaboration of a time frame
- 2nd Global cooperation meeting, Montreal, 12.6.2002
- 1st ISO/GRPE meeting, Munich, 29.07.2002
 - Discussion of technical requirements
- 2nd ISO/GRPE meeting, Montreal, 26.09.2002 – 27.9.2002
 - Discussion of technical requirements



- **Elaboration of Revision 12 of draft regulation**
- **4th meeting of ECE-GRPE ad hoc working group, 14.11.2002 – 15.11.2002**
Discussion of the draft for LH2 storage
- **Informal document to GRPE**
- **Official document to GRPE**



12



Proposal for a new draft regulation

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

- I. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID HYDROGEN
- II. VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF LIQUID HYDROGEN

Available under <http://www.eihp.org/unece/index.html>



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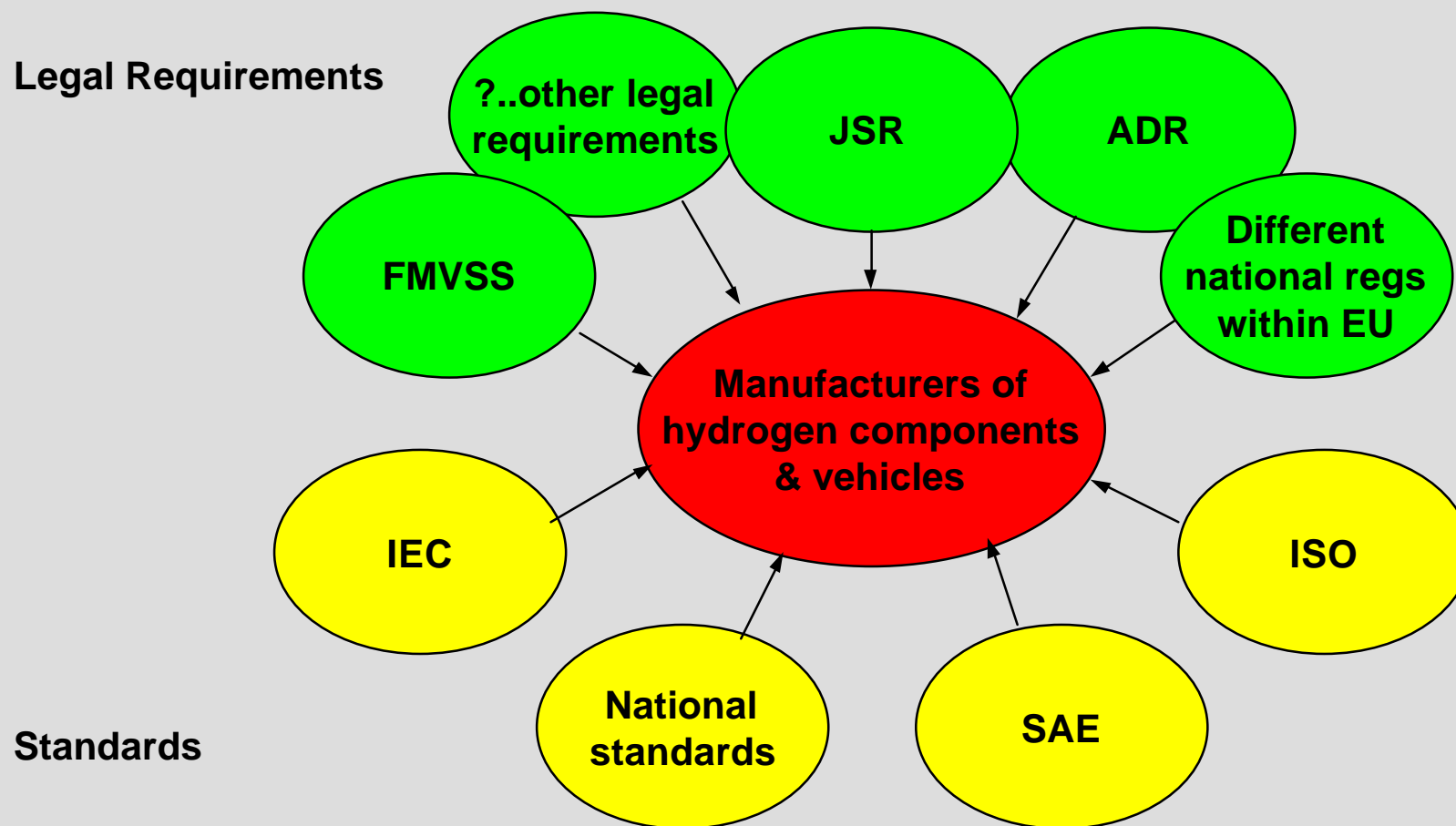
Presentation by

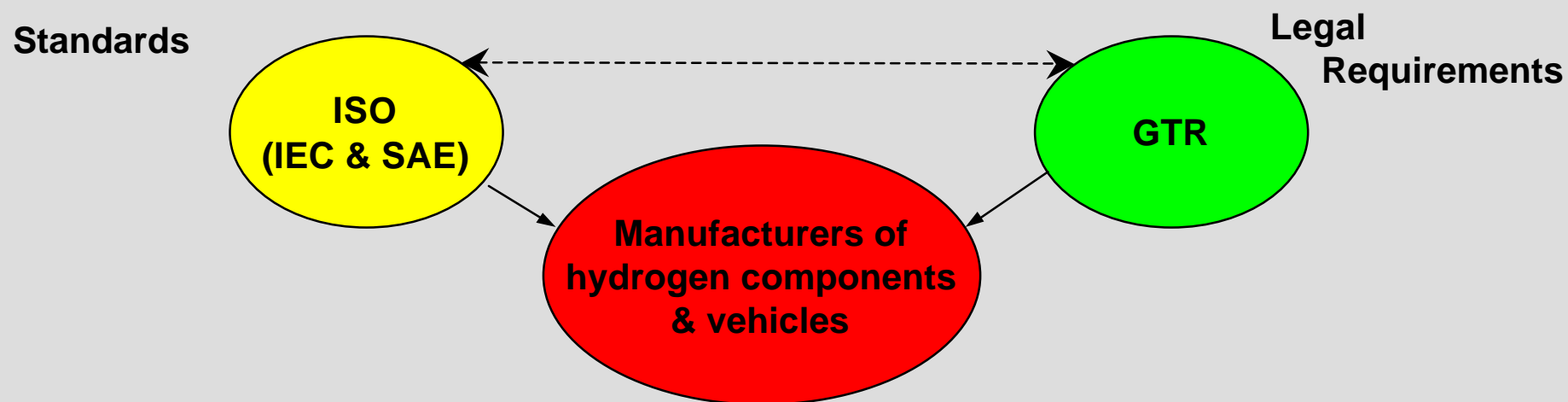
Paul Adams
Volvo Technology Corp.

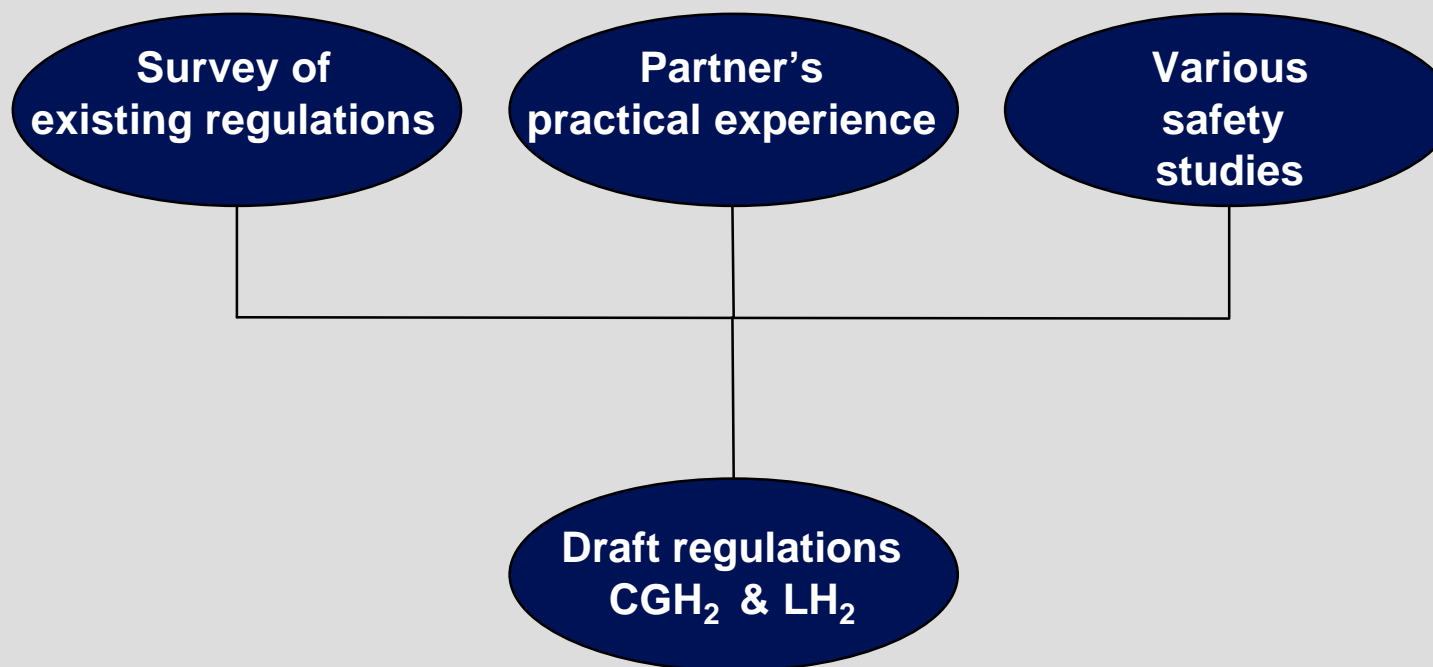
DEVELOPMENT OF A REGULATION FOR COMPRESSED GASEOUS HYDROGEN VEHICLES

- Development of the EIHP proposals for draft CGH₂ vehicle regulations
- Key features of the proposed regulations
- Validation of the EIHP proposals
- Current status









- **ECE framework**
- **Hydrogen components & installation within vehicles**
- **Separate regulations for LH₂ & CGH₂**
- **Exclude propulsion systems**
- **Primary objectives:**
 - **Avoid defining solutions**
 - **Avoid restricting new technology**
- **External validation exercises**



Initial draft based on:

- **ECE CNG proposals (now R110)**
- **EIHP LH₂ proposals**
- **ISO WD 15869 ***
- **Various studies**
- **CNG experience of the Partners**

* - ISO WD 15869 High pressure containers for the on-board storage of hydrogen gas or hydrogen gas blends as a fuel for automotive vehicles
March 1999



Principal Sections Of The Proposed Regulations

7

Part	Section		
I	1	Scope	General
	2	Definitions, Service Conditions, etc.	
	3 & 5	Administrative	Components
	4	Markings	
II	6	Specifications for components	
	7-11	Administrative	Vehicle Installation
	12-13	Administrative	
	14	Requirements for vehicle installation	
Annexes	15-19	Administrative	Detailed Test Requirements
	1-6	Component details, approval marks & forms	
	7	Requirements & approval test procedures for containers	
	8-9	Requirements & approval test procedures for components other than containers	
	10	Electronic control system	



- **Components**
- **Vehicles (Categories M & N)**
- **Specifically excludes hybrid cryogenic/ high pressure systems**
- **Specifically excludes the propulsion system or APU**



- Key words or phrases defined to avoid ambiguity
- Highlighted in the text to indicate that the terms are specifically defined for the purposes of the regulation
- **Hydrogen System**, key definition defining the boundary of the systems covered by the regulation:
 - An assembly of *Hydrogen Components* and connecting parts fitted on motor vehicles using hydrogen, excluding the *Hydrogen Conversion System(s)*. The boundary between the *Hydrogen System* and the *Hydrogen Conversion System(s)* is defined as the point(s) at which the *Working Pressure* is higher than the:
 - i) Maximum operating *Pressure* of fuel cell system(s),
 - ii) The inlet *Pressure* of the gas mixer (carburettor or injector(s)) for internal combustion engines or other combustion devices.
- **Multifunctional Component**
 - Specific Components* combined or fitted together and which may include *Hydrogen Components*.
- Container Type 5 included to provide a basis for the approval of unforeseen technologies



- **Service life**
 - Specified by vehicle manufacturer
 - Maximum of 20 years
- **Operating temperature range (only 1 climate zone)**
 - 40°C to +85°C (ICE compartment +120°C)
- **Filling & pressure cycles**
 - Old concept - 1000 cycles per year of service:
1000 x 20 years x 400 km range = 8 million km !!!!
 - New concept bases number of filling cycles on lifetime vehicle mileage, with the number of pressure cycles derived by applying a safety factor for prolonged use, etc.



- **General requirements**
- **Provisions for various types of component generally refer to Annexes 7 & 8 for requirements and test procedures**
- **Requirements provided for:**
 - **Welded fittings**
 - **Rigid fuel lines**
 - **Electrical components**



- **General requirements, e.g. complete system leakage**
- **Container installation, e.g. accelerations applied**
- **Container accessories, e.g. automatic shut off valves**
- **Requirements for other critical installations,
e.g. refilling system, gas tight housing, electrical**
- **Re-qualification (periodic, collisions, fire)**



- **Annex 7 restructured to:**
 - Remove design related requirements & restrictions
 - Improve logic
 - Take into account comments received
 - Take into account recent practical experience of EIHP2 Partners with the similar ECE R110 (CNG)
- **All pressures now based on Working Pressure in agreement with ISO**
- **Introduction of self-testing concept for less critical components (Pt.I: 3.3 & 3.4)**
- **Introduction of option for container bundles (Pt.I: 6.2.3)**
- **Improve logic in Pt.I: 6 & Pt.II: 14**
- **Removal of:**
 - Duplicated requirements
 - Unnecessary cross references
 - Unnecessary informative statements
- **Numerous editorial improvements**



- **Similar revision to the work undertaken for Annex 7, i.e. EIHP2 will restructure Annexes 8 & 9 to:**
 - **Combine Annexes 8 & 9 into a single annex**
 - **Remove design related requirements and restrictions**
 - **Improve logic**
 - **Take into account comments received**
 - **Take into account recent practical experience of EIHP2 partners with earlier revisions and the similar ECE R110 (CNG)**



- **“Public” workshop (March 1999)**
- **Comments from:**
 - National authorities**
 - Industry**
 - External experts**
- Rev. 6 - Spring 2000**
- Rev. 7 - Generally available since April 2000**
- Rev. 8 - Generally available since November 2001**
- Rev. 9 - Generally available since May 2002**



- **GRPE established an Ad-hoc Working Group**
- **The EIHP2 proposals are now being developed to achieve global consensus by the GRPE Ad-hoc Working Group:**
 - **CGH₂ Regulations Revision 9 (Dated 06.05.02)**
- **ISO take part in the GRPE Ad-hoc Working Group**
- **Early November – Rev.10 available**
- **14 & 15 November: GRPE Ad-hoc working group meeting**
- **Formal presentation of proposals to GRPE in 2003?**
- **For more details: www.eihp.org**



Mid-Term Assessment Workshop

Brussels
02 October 2002

Presentation by
Rainer Bauer



Necessary Modifications of existing ECE - Regulations and EC - Directives



- **Identification of the relevant Regulations and Directives**
- **Development of draft proposals**
- **Distribution within the WP - members**
- **Incorporation of the comments received**
- **Submission of proposals within the responsible committees**



70/156/EEC

70/220/EEC & ECE R 83

70/221/EEC & ECE R 34/58

78/316/EEC

78/317/EEC

80/1268/EEC & ECE R 101

80/1269/EEC & ECE R 85

88/77/EEC & ECE R 49

96/27/EC & ECE R 95

96/79/EC & ECE R 94

99/94/EC

ECE R 100

Type Approval Directive

Emissions of vehicles

Fuel Tanks / Rear Protective Device

Identification of Controls

Defrost / Demist

Fuel Consumption

Engine Power

Emissions of Pollutants by Engines

Side Impact

Frontal Impact

CO2 Labeling

Electric Vehicles



70/220/EEC & ECE R 83

70/221/EEC & ECE R 34/58

78/316/EEC

80/1268/EEC & ECE R 101

96/27/EC & ECE R 95

96/79/EC & ECE R 94

99/94/EC

Emissions of vehicles

Fuel Tanks / Rear Protective Device

Identification of Controls

Fuel Consumption

Side Impact

Frontal Impact

CO2 Labeling



70/220/EEC & ECE R 83

Emissions of vehicles

- only NOX to be considered as a pollutant
- Tests to be performed only Type I, III and V
- special reduced requirements for bifuelled vehicles with a reduced tank capacity (e.g. OBD requirements)

70/221/EEC & ECE R 34/58

Fuel Tanks / Rear Protective Device

- no change needed

78/316/EEC

Identification of Controls

- a new symbol for a tell-tale to be defined



Example

Proposed amendments to Directive 70/221/EEC (Fuel Tanks / Rear Underrun Protection)

- Fuel Tanks

This regulation applies only to vehicles with fuel tanks for liquid fuels, where liquid means liquid under ambient conditions. The relevant requirements for vehicles with hydrogen as a fuel are covered in the draft regulations for LH2 and CGH2.

No change needed.

- Rear Underrun Protection

The provisions for the rear underrun protection are independent of the fuel used to propel the vehicle.

No change needed.

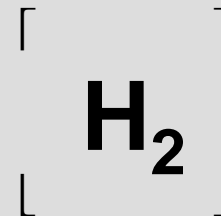


Example

Proposed amendments to Directive 78/316/EEC (Identification of Controls)

Figure 24
Defect within the Hydrogen Supply
Color of tell-tale light : red

Annex II
A new Symbol to be defined



Annex V
Insert a new row 24 in the summary table of 9.10.2.3



80/1268/EEC & ECE R 101

Fuel Consumption

- the scope is restricted to consumption if H₂ is used as fuel
- introduction of measurement of H₂ consumption
- bifuelled vehicles with a reduced tank capacity will be considered as H₂ vehicles

96/27/EC & ECE R 95

Side Impact

- requirements for LPG,CNG,CGH₂ and LH₂ added
- determination of tightness resp. maximum pressure drop
- determination of additional conditions for the test procedure

96/79/EC & ECE R 94

Frontal Impact

- requirements for LPG,CNG,CGH₂ and LH₂ added
- determination of tightness resp. maximum pressure drop
- determination of additional conditions for the test procedure

99/94/EC

CO₂ Labeling

- to add to the preamble the importance of promotion of alternatively fuelled vehicles
- to add to Article 2 the boundary conditions for bifuelled vehicles under which consumption and CO₂ emissions of only the alternative fuel should be indicated



- **Preparation of proposals for amending the remaining regulations**
- **Introduction to the responsible national WGs and MOTs**
- **Discussion within ACEA, OICA**
- **Introduction into the GRs in Geneva**
- **Introduction into MVWG in Brussels**



Mid-Term Assessment Workshop

Brussels
02 October 2002

Presentation by
Adam Opel AG



Partners: BMW, CEA, Ford, INTA, LAL, RA
Opel (sub task coordinator)

Goal of the work package:

- For a safe operation of hydrogen fuelled vehicles, it is necessary to ensure the proper function of safety relevant components of the on board hydrogen storage system during the whole vehicle life
- A procedure for the periodic inspection will contribute to the safe operation of hydrogen fuelled vehicles
- A draft for amending directive 96/96/EC will complement the work concerning the “EC-Whole Vehicle Type Approval”



- Existing regulations and proposals for the periodic inspection of an on board hydrogen storage system shall be investigated.
- An analysis (e.g. FMEA) of an on board hydrogen storage system shall be carried out in order to identify inspection critical components and the need for regular inspection for both LH₂ and CGH₂ systems.
- Based on these results and the knowledge gained from operation of hydrogen fuelled vehicles, a procedure for the inspection of the hydrogen storage system during the normal vehicle periodic roadworthiness inspection shall be created.
- Finally, a draft for amending directive 96/96/EC (roadworthiness test for motor vehicles) shall be created.



Council Directive
96/96/EC relates to
the roadworthiness
tests for motor
vehicles and their
trailers

COUNTRY :EEC.

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ORIGINAL :O.J.L 48 of February 17, 1997

COUNCIL DIRECTIVE 96/96/EC

of December 20, 1996

on the approximation of the laws of the Member States relating to roadworthiness tests for motor vehicles and their trailers

As amended by Directive 1999/53/EC, 2001/7/EC and 2001/11/EC

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 75 thereof,

Having regard to the proposal from the Commission ⁽¹⁾,

Having regard to the opinion of the Economic and Social Committee ⁽²⁾,

Acting in accordance with the procedure laid down in Article 189c of the Treaty ⁽³⁾,

- (1) Whereas Council Directive 77/143/EEC of December 20, 1976 on the approximation of the laws of the Member States relating to roadworthiness test for motor vehicles and their trailers ⁽⁴⁾ has been substantially amended on a number of occasions; whereas, now that it is to be further amended, the Directive should, for reasons of clarity, be consolidated into a single text;
- (2) Whereas, within the framework of the common transport policy, certain road traffic within the Community should operate under the most favourable circumstances as regards both safety and competitive conditions applying to carriers in the Member States;
- (3) Whereas the growth of road traffic and the resultant increase in danger and nuisance present all Member States with safety problems of a similar nature and seriousness;



- In directive 96/96/EC the roadworthiness test for motor vehicles and their trailers is described.
- The main focus of 96/96/EC is today on the braking system, the exhaust emissions and the speed limitation devices for trucks & busses
- Hydrogen as fuel is not considered yet. The fuel storage system has only to undergo an optical inspection
- 96/96/EC allows for an increase of the items to be tested
However, the testing should be relatively simple, quick and inexpensive
- 96/96/EC gives the chance to withdraw vehicles from public roads in case of severe safety defects



- A list with the rules and regulations, the relevant fuel, the kind of inspection required and the period was compiled and distributed



- Following rules and regulations have been investigated:

Rules:

ISO 15869 (CGH₂)
VdTÜV 757 (CNG & CGH₂)
TRB 801 (CNG, CGH₂ & LH₂)
ISO 13985-2 (LH₂)
ISO 13984 (LH₂)
SAE J2600 (CGH₂)

Regulations:

ECE R110 (CNG)
96/96/EC
FMVSS 304 (CNG)
DruckbehV (CNG, CGH₂ & LH₂)
EIHP draft (CGH₂)
EIHP draft (LH₂)



- A list with the rules and regulations, the relevant fuel, the kind of inspection required and the period was compiled and distributed
- Based on an generic mechanization for an onboard LH₂ storage system the storage system was analyzed
- Safety relevant components have been identified and possible failure modes have been indicated
- A draft proposal for the inspection of critical components of an on board LH₂ storage system was created



- A trade off has to be found in order take every measure necessary to ensure the save operation of the vehicles using the new fuel hydrogen and on the other hand not to burden the new fuel and the new technology with unnecessary and unaffordable tests and inspections
- It turned out to be difficult to perform a Failure Mode Effect Analysis (FMEA) without having a real on board hydrogen storage system
- The period of the different inspections / tests depends heavily on the reliability of the components
- In order to have a good understanding of the failure modes and the reliability of the components of an on board hydrogen storage systems, a lot of experience with the operation of hydrogen fuelled vehicles is needed
- The basis for the on board H₂ storage system, the CGH₂ draft and the LH₂ draft are still under development



- The draft proposal for the inspection of an on board LH₂ storage system and the analysis of the generic LH₂ storage system will be further discussed within EIHP2
- As next step, a generic mechanization for an on board CGH₂ storage systems will be created and has to be reviewed
- A proposal for the inspection of the CGH₂ storage systems has to be compiled
- Finally, a proposal for amending directive 96/96/EC will be created from the proposals for inspection of LH₂ and CGH₂ on board storage systems



European Integrated Hydrogen Project - Phase II

1

Mid-Term Assessment Workshop

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Presentation by
Laurent ALLIDIERES
Air Liquide
Division Techniques Avancées

Task 4.5 : development of design
rules or safety requirements



E I H P 2 Mid-Term Assessment Meeting



- **WP2 : Refuelling station**
 - ✓ Task 2.1 : Overview of existing regulation
 - ✓ Task 2.2 : Development of a refuelling station layout
 - ✓ Task 2.3 : List of refuelling station main components
- **WP3 : Refuelling interface**
 - ✓ Task 3.1 : Identification of optimum on board pressure
 - ✓ Task 3.2 : remaining CGH2 activities
 - ✓ Task 3.3 : development of LH2 refuelling procedures
- **WP4 : Vehicle**
 - ✓ Task 4.1 : Monitoring of draft
 - ✓ Task 4.3 : Periodic inspection
 - ✓ Task 4.4 : Validation of EIHP1 draft
 - ✓ Task 4.5 : development of design rules or safety requirements

- Definition of a procedure for the calculation and the design of safety valves for vehicle application
- Deliverable : Standard for calculation of safety valves for vehicle application

- Focussed on safety devices
- CEA is not willing to participate in WG4.5 (on added value)
- Trade off between regulations BS/CGA/API/prEN
- No need to develop specific regulation
- Design scenario is described in :
 - ✓ EIHP daft for regulation revision 11 §6.4.1.4
 - ✓ prEN13648-3 : Cryogenic vessels : pressure safety devices - part 3 flow rate to evacuate - capacity and design
- Diphasic and liquid flow detailed in API520
- One question raised : What happens in case of Rollover...
 - ✓ Show Case : EIHP validation tank (WP4.4)

Basis :

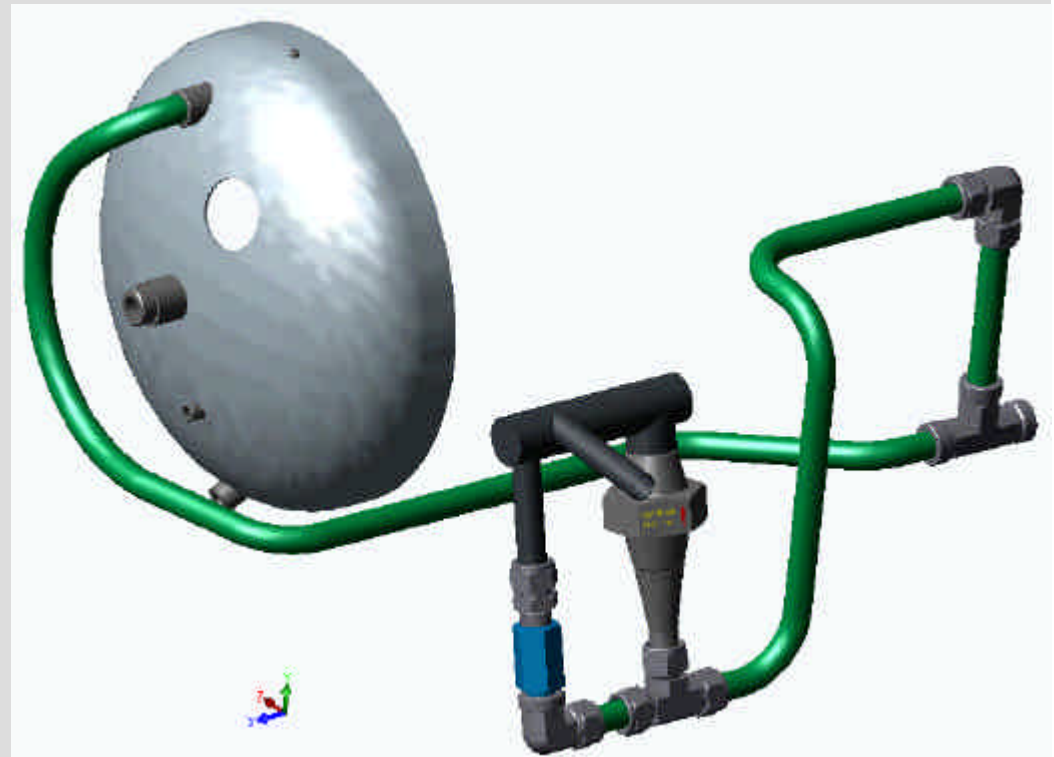
- ✓ Safety equipment as per prEN13648-3 (gaseous release) or CGA 1.2

Scenarii

- ✓ Vehicle rollover and...
- ✓ LH2 flash in suction pipe by natural convection
- ✓ Back pressure in vent line
 - Loss of vacuum without fire
 - Loss of vacuum with fire

Results

- ✓ .../...



Safety discharge line on LH2 tank for mobile application

Results

6

Scenario		A	B
Safety device to be considered		Safety valve	Safety valve + Burst Disk
Liquid flow to evacuate	Kg/h	235	3007
Vapor fraction at safety device inlet (approx)	%	1	<<1 (not including fire heat release)
Back pressure	mbar	20	
Results		Safety valve meets requirements. Installed safety valve Cv > required safety valve Cv	Safety devices allows 1500 kg/h LH2 (approx) discharge flow. Safety devices are not compliant with requirements

- Scenario B does not take fire heat input on suction and discharge piping
- Regulation involves *4 ratio between calculated flow and design flow
- Calculations will be refined and recommendation will be issued
- Other recommendations can be made on safety device design
 - ✓ Safety valve must close after it has released the pressure
 - ✓ Must be compatible with **liquid** Hydrogen
 - ✓ Must be serviceable...
 - ✓ Must be CE marked...
- Deliverable : M9 Y2 (01/2003)
- Safety valves and burst disks are (of course) not the only safety devices in LH2 tanks for mobile application
 - ✓ Vacuum plugs on outer shell
 - ✓ Analyser (?)
 - ✓ Shutoff valves
 - ✓ Hydrogen compatible materials
 - ✓ ...