New regulatory framework for type approval and certification of hydrogen-powered vehicles and their components in the European Union after repeal of regulation (EC) 79/2009

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ABSTRACT:

Increasingly stringent regulations to reduce pollutant and CO2 emissions from road vehicles have raised enthusiasm for registration and development of hydrogen-powered vehicles in the European Union. With this trend, questions arise how the market entry of hydrogen-powered vehicles is regulated. Until 2022, the current legislative framework in the EU referenced three regulations which could be applied: Reg. (EC) 79/2009, Reg. (EU) 2021/535 and UN Regulation No 134, whereby Reg. (EC) 79/2009 was repealed in July 2022. This led to regulatory gaps, since the scope of these regulations is not completely congruent. This paper discusses the status and possible solutions for this issue. As first step, the European Union issued regulation (EU) 2021/535, which also takes material compatibility of the hydrogen system or liquified hydrogen into account. Another solution might be to implement relevant requirements from Reg. (EC) 79/2009 to other remaining regulations. It is also in the interest of manufacturers to address product liability issues not only by fulfilling type approval requirements, but also qualifying their products according to relevant industry norms and standards. This becomes especially relevant if no regulation for type approval is in place.

KEY WORDS: hydrogen, fuel cell, vehicle, type approval, certification, European Union, norms, regulations, market access

1. INTRODUCTION

Increasingly strict rules for reducing emissions are being set by the EU legislation (for example by the so called “European Green Deal”), which aims to reduce 90% of transport related greenhouse gas (GHG) emissions by 2050 compared to the level of 1990 [1]. Of course, this heavily affects future economic strategies in the automotive sector. Consequently, there is great enthusiasm behind hydrogen-powered vehicles in current debates on decarbonization of the industry, especially when looking at heavy-duty transport (trucks, buses, trains etc.).
Alongside battery-electric vehicles, Fuel Cell Electric Vehicles (FCEV) and H2 Internal Combustion Engine Vehicles (H2-ICEV) are considered key technologies for achieving climate goals. Emitting no or virtually no harmful tank-to-wheel emissions, they are categorized as Zero and Low Emission Vehicles (ZLEV), and their numbers are expected to increase in the next few years [2].
Thus, the question of how to enable a safe and easy market launch in connection with regulatory requirements is arising throughout the industry. Notably, the European Commission’s decision to withdraw the existing (EC) 79/2009 [3] regulation for the type approval of hydrogen powered vehicles has raised concerns.
This paper intends to provide insights into the current regulatory framework for the type approval of hydrogen-powered vehicles, and to show paths to a safe and reliable market access after Reg. (EC) 79/2009 was repealed in July 2022.

2. STATUS OF THE EUROPEAN LEGISLATION UNTIL JULY 2022

In September 2018, the EU established Regulation (EU) 2018/858 for the type approval and market surveillance of motor vehicles of categories M (passenger vehicles) and N (vehicles for carriage of goods) and their trailers of category O, as well as systems, components and separate technical units intended for such vehicles, repealing Directive 2007/46/EC [4]. This regulation lays down the administrative provisions and technical requirements for type approvals in the EU and is amended by the new General Safety Regulation (GSR2) – (EU) 2019/2144 – focusing on the general road safety and the protection of vehicle occupants and vulnerable road users [5].
In the EU, UNECE regulations (as issued by the United Nations Economic Commission for Europe) can be applied as an alternative or in addition to European Regulations and Directives if the EU has incorporated them accordingly. With that said, the current legislative framework in the EU referenced two equally leveled regulations for type approving hydrogen vehicles, vehicle systems, and components, which could be applied: Reg. (EC) 79/2009, UN Regulation No 134 [6] and Reg. (EU) 2021/535 [7].
An overview of the interaction between the regulations concerning the hydrogen storage system (HSS) can be seen in the graphic below.

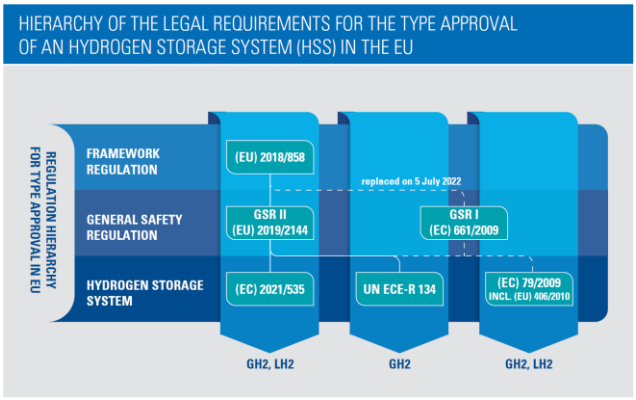

Figure 1: Hierarchy of the legal requirements for the type approval in the EU until July 2022

COMPONENTS CONSIDERED IN REG. (EC) 79/2009, UN REGULATION NO 134 AND REG. (EU) 2021/535

	Reg. (EC) 79/2009	UN Regulation No 134	Reg. (EU) 2021/535
Compressed gaseous hydrogen (CGH2)			
Hydrogen container	x	x	x
PRD	x	x	x
Automatic shut-off valves	x	x	x
Check valves	x	x	x
Pressure relief valves	x		
Heat exchangers	x		
Refueling connections	x	(x)	(x)
Receptacles	x	(x)	(x)
Pressure regulators	x		
Sensors for hydrogen systems	x	(x)	
Flexible fuel lines	x		
Fittings	x		
Hydrogen filters	x		
Removable storage system connectors	x		
Liquid hydrogen (LH2)			
Hydrogen container	x	N.A.	x
PRD	x		x
Automatic shut-off valves	x		x
Check valves	x		x
Boil-off system	x		x
Heat exchangers	x		
Refueling connections or receptacles	x		(x)
Pressure regulators	x		
Sensors	x		
Flexible fuel lines	x		

Figure 2: Components considered in reg. (EC) 79/2009, UN regulation No 134 and reg. (EU) 2012/535

2.1. Regulations (EC) 79/2009 and (EU) 406/2010

Reg. (EC) 79/2009 was a safety-related regulation on hydrogen-powered vehicles of categories M and N (see (EU) 2018/858) and hydrogen systems and components designed for those types of vehicles. Its scope addresses both liquid and compressed gaseous hydrogen. It was published in January 2009, amending Directive (EC) 2007/46 to provide general requirements for type approval of hydrogen components and systems and to list applicable test procedures in the EU member states. In order to provide applicants with more detailed technical requirements and to implement detailed procedures for approval-relevant testing requirements as listed in Reg. (EC) 79/2009, Commission Regulation (EU) 406/2010 [8] was published one year later. Gaseous hydrogen tanks and components could be type-approved according to Reg. (EC) 79/2009 if their nominal working pressure was higher than 3.0 MPa. Type approvals could be achieved for all components within the scope of Reg. (EC) 79/2009 (see Figure 2).

2.2. UN Regulation No. 134

UN Regulation No 134 is a regulation issued by the United Nations Economic Commission for Europe, based on UN GTR 13, a United Nations Global Technical Regulation which is developed under the UN 1998 agreement [9]. UN Regulation No 134 is developed under the UN 1958 agreement [10] and relevant for European type approval.
The contents and testing procedures described in both regulations are closely linked to each other: UN GTR 13 contents are created by an informal working group and subsequently transferred into UN Regulation No 134. UN Regulation No 134 provides rules for approving hydrogen vehicles and their components on a "safety related performance" basis.
Its scope is much smaller than of Reg. (EC) 79/2009, as UN Regulation No 134 only refers to the so-called "Compressed Hydrogen Storage System (CHSS)". As per definition, a typical CHSS consists of the components "tank/storage container", "container shut-off valve", "check valve" and "TPRD". As seen from Figure 2, many components from Reg. (EC) 79/2009 are not in the scope of UN Regulation No 134, showing that the regulations are not completely congruent.
In addition, UN Regulation No 134 is focusing on gaseous hydrogen and there is no comparable UN or UN/ECE regulation in place for "Liquid Hydrogen Storage Systems (LHSS)". For liquid hydrogen, Reg. (EC) 79/2009 was the only applicable regulation for EU type approval for a long time.
UN Regulation No 134 also does not include requirements regarding the electrical safety of the electric powertrain, post-crash fuel system integrity in the event of a collision, and material compatibility.

2.3. Regulation (EU) 2021/535

The commission implementing regulation (EU) 2021/535, published in March 2021, lays down rules for the application of GSR2. With regard to hydrogen-powered vehicles, it effectively repeals Reg. (EC) 79/2009 and (EU) 406/2010 as of 6 July 2022. It is based on a safety-related regulation for vehicles of categories M, N and O and hydrogen systems and components designed for those types of vehicles and also provides for uniform procedures allowing European type approval.
In the context of hydrogen-powered vehicles, this regulation mentions the safety performance and material compatibility of LHSS and CHSS in Annex XIV. Since UN Regulation No 134 does not contain any material requirements or requirements for liquified hydrogen for example, the following statements from Reg. (EU) 2021/535 are in place and can be seen as recitals of this regulation:

(12) Global harmonisation of safety requirements with respect to hydrogen-powered vehicles is an important step to promote alternative fuel vehicles. UN Regulation No 134 applies in the Union, however, it does not contain any requirements on material compatibility and hydrogen embrittlement for hydrogen systems and components for hydrogen-powered vehicles. Such requirements are necessary to ensure a high level of safety as regards material selection in hydrogen systems.
(13) Specific provisions for liquefied hydrogen storage systems as well as geometries of the fuelling receptacles are also not yet included in UN Regulation No 134, whereas they need to be carried over from Regulation (EC) No 79/2009 to ensure consistency.
(14) Sufficient time is needed for manufacturers to adjust to the new requirements with regard to the statutory markings and the space for mounting and fixing of the front registration plates.

Therefore, transitional provisions are needed to ensure that those requirements will first apply to new vehicle types. [7]

3. REPEALING OF REGULATION (EC) 79/2009

3.1. Background and timeline

As defined in the legislative act (EU) 2019/2144, both Reg. (EC) 79/2009 and UN Regulation No 134 apply to the type approval of (certain) hydrogen vehicle components. But with (EU) 2019/2144 taking effect, it was decided that in the interest of clarity, rationality and simplification of UN-level test procedures, Reg. (EC) 79/2009, including Commission Regulation (EU) 406/2010, were to be withdrawn on 5th July 2022. After this date, type approvals according to this regulation were no longer possible, leaving the significant gaps in both the compressed gaseous and the liquid hydrogen worlds as described above.

3.2. New legal framework for type approvals

Since 6th July 2022, European type approvals for hydrogen systems and each installed component are solely based on UN Regulation No 134 and parts of Reg. (EU) 2021/535.
However, as described above, problems arise from the narrow scope of these regulations. Components like pressure regulators, sensors and fittings are left with no applicable type approval framework, as they simply are not within the scope of UN Regulation No 134 and Reg. (EU) 2021/535.
A potential solution could be to widen the scope of UN Regulation No 134 or Reg. (EU) 2021/535, including testing requirements for hydrogen components. However, as of late 2022, the second version of UN GTR 13 (“Phase II”) is in its finalization phase and the informal working group has decided against widening the scope. There is also no final agreement on whether a Phase III or an amendment to Phase II will be created, leaving no timeline in sight for when the regulatory gap left by the soon-to-be repealed Reg. (EC) 79/2009 will be filled.
The situation is much simpler for the components of the CHSS. Storage containers, shut-off valves, check valves and TPRDs can still be type approved according to UN Regulation No 134 and Reg. (EU) 2021/535. For all the other components installed in a typical FCEV, an alternative solution should be developed.

4. NEW REGULATORY FRAMEWORK

4.1. Transitional provisions

Type approvals granted before the repealing of Reg. (EC) 79/2009 will not be invalidated and extensions shall still be granted, unless the relevant requirements have been modified, or new requirements have been added.
As written above, the transitional provisions for the CHSS are clearly defined in Reg. (EU) 2019/2144. This is shown in Annex 2, subject A17/ A18 – (Hydrogen Safety and material qualification), with the withdrawal of Reg. (EC) 79/2009 on 5th July 2022 [5].
With regards to liquid hydrogen, the new implementation regulation (EU) 2021/535 lays down the rules for applying (EU) 2019/2144 to general construction characteristics and vehicle safety. In this context, Reg. (EU) 2021/535 also mentions the application of EU component type approvals with regards to liquid hydrogen components. References on this can be found in chapter IV, article 9. Annex XIV of Reg. (EU) 2021/535 is detailing the safety performance and material compatibility of the LHSS and the CHSS, with Part 2 describing the technical specifications for type approval. The regulation takes into account liquid hydrogen tanks, PRDs, automatic shut-off valves and the boil-off system, making the scope similar to what UN Regulation No 134 provides for gaseous hydrogen. Thus, a basis for the European type approvals of LHSS is created through this regulation. On the other hand, CHSS components require double marking from UN Regulation No 134 and Reg. (EU) 2021/535 in the future.
Knowing the above-mentioned recitals of Reg. (EU) 2021/535 and to ensure a high level of safety of the hydrogen system, there are arguments for the further application of some parts of Reg. (EC) 79/2009 by including specific requirements into a new regulation.
Since regulations should correspond to the state of the art as far as possible, it would make sense, from our point of view, to use a combination of the requirements of Reg. (EC) 79/2009 and Reg. (EU) 2021/535 or UN Regulation No 134 in the future, e.g. in form of a new implementation regulation for Reg. (EU) 2021/535. Even if the type approval shows a gap with the repealing of Reg. (EC) 79/2009, the state of the art, in particular with regard to product liability, should not be disregarded, whereby the Reg. (EC) 79/2009 and other applicable standards keep their right of application.

4.2. Differences between type approval and state of the art

For a safe and uncomplicated market entry, a whole-vehicle type approval process is not only formally required in the EU, but it also provides multiple benefits to vehicle, system, and component manufacturers. Among others, it provides manufacturers with the legal permission to access the market of the EU and to avoid costly penalties for non-compliance or costly recalls. Typically, the type approval process in the EU unites three stakeholders: the manufacturer, the authority of the approving country, and a technical service. The following graphic highlights how these stakeholders function together.

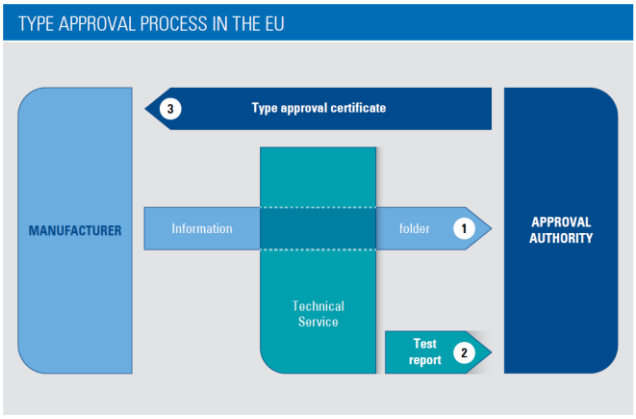

Figure 3: Type approval process in the EU

The test report as issued by the technical service is based on regulatory requirements and the respective test program. If the approval type fully complies with those requirements, the approval authority issues a type approval certificate.
As type approval for certain components of the FCEV hydrogen system is no longer be possible after Reg. (EC) 79/2009 was repealed (leaving no applicable regulation in place), the legal framework considers “norms and standards” as the next relevant level of obligation regarding product liability duties of the manufacturer. If no relevant regulation is in place, a relevant norm should be identified and followed instead, and components must be tested for conformity with it.

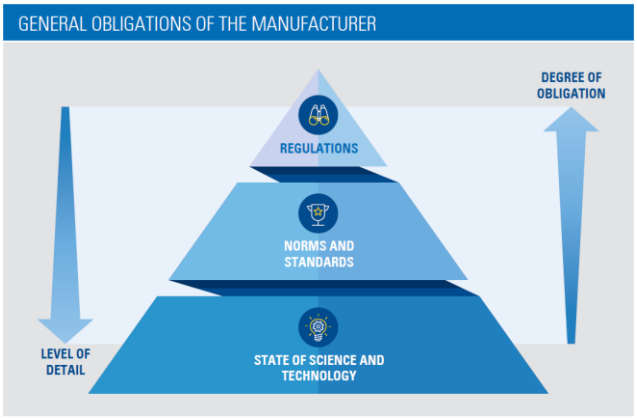

Figure 4: General obligations of the manufacturer

As part of the product liability and product safety, the manufacturer is obliged to carry out a hazard and risk assessment. Such an assessment typically defines additional safety goals (as for example defined in relevant norms and standards), which exceed the minimum requirements as defined in the regulation relevant for type approval.
Some of the most relevant norms and standards sometimes can even be formally referenced in a regulation and thus made legally binding on a similar level as the regulation itself (the international norm for hydrogen refueling connections ISO 17268 [11], for example, is referenced in the "Alternative Fuels Infrastructure Directive (AFID)" [12] and most likely also in the coming version of a "Alternative Fuels Infrastructure Regulation (AFIR)" [12].
In addition to type approval and certification, most OEMs have specific testing requirements that components must successfully pass, based on typical use conditions of the vehicle, OEM's special requirements and the state of science and technology.

THREE-STEP APPROACH FOR SAFE MARKET ENTRY

Underlying code	Result
Regulation	Type approval
Norm, standard	Certification
Others (manufacturer requirements, individual method)	TÜV SÜD test report

Figure 5: Three-step approach for safe market entry

4.3. Applicable norms related to compressed gaseous hydrogen

When searching for norms and standards related to compressed gaseous hydrogen components, several entries can be found which might be difficult to distinguish at first glance. But they mostly descend from the same basis: ANSI CSA HGV 2 [13] and HGV 3.1 [14].
The first version of HGV 3.1 was issued in 2009 by the American National Standards Institute and the Canadian Standards Association. With the first few hydrogen-powered vehicles ready to enter the market, the need for a normative or regulatory framework was not only detected in the EU (leading to the creation of Reg. (EC) 79/2009), but also in North America. Led by a CSA technical committee, the performance-based norm HGV 3.1:2009, was created. Updated versions followed in 2013, 2015, 2019 (re-affirmation of the 2015 version only) and 2022. Conformity with HGV 3.1 allows component manufacturers to expand beyond the European market access into North America. HGV 3.1 served as a baseline when the ISO 12619 norms were created [16]. This series provides testing requirements for the fuel system components of road vehicles using hydrogen or hydrogen / natural gas blends. The latest version of ISO 12619 was published in 2017.
In this context, the ISO/Technical Committee 197 initiated a new work item called ISO 19887 [15], based on HGV 3.1 and ISO 12619, scheduled to be published as an international standard in 2024.
ISO 19887 will focus on the fuel system components of gaseous hydrogen powered vehicles. In parallel, work on a revised version of ISO 12619 is ongoing, aiming to focus on hydrogen / natural gas blends.
Alongside HGV 3.1, ISO 19887 is likely to evolve into the relevant norm for testing for conformity of the components missing in the scope of UN Regulation No 134 after the repealing of Reg. (EC) 79/2009.
Fueling receptacles are not in the scope of HGV 3.1 and will, most likely, not be in the scope of ISO 19887 either, as two other existing norms, ISO 17268 and SAE J2600 [18], provide specific requirements for hydrogen fueling nozzles and receptacles. ISO 17268 is almost permanently being improved.
HGV 2 is HGV 3.1's equivalent for on-board hydrogen containers (with HGV 3.1 being applicable for hydrogen components like valves). Like almost all CSA standards, it is accurately serviced and updated (the latest version came out in 2021). Testing for conformity with HGV 2 is recommended, especially for the North American market.
Another option for gaseous hydrogen on-board containers is ISO 19881 [19], which was published in 2018. Testing for conformity with this norm grants the benefits of the worldwide acceptance of a certification according to an ISO standard.
Other noteworthy norms include the ISO 19880 series [20], the HGV 4 series [21], EN 12245 [22] and ISO 11119 [23], although they all focus on stationary or transportable applications and might therefore not properly address the requirements for components or containers used in a vehicle fuel system.
The hydrogen compatibility of metallic and non-metallic materials is addressed in CSA ANSI CHMC-1 [24] and ISO 11114-4 (metals) [25], as well as in CSA ANSI CHMC-2 [26] and ISO 11114-2 (non-metals) [27]. In addition, TÜV SÜD has published an own standard addressing the hydrogen compatibility of metallic materials (PPP 52387) [28].

4.4. Applicable norms related to liquid hydrogen

In the liquid hydrogen world, there are few applicable standards. In fact, on an ISO level, there are only ISO 13984:1999 [29] and ISO 13985:2006 [30]. The latter takes LH2 for refillable fuel tanks into account. It includes the design requirements for LHSS in land vehicles and the corresponding test procedures to ensure the adequately protection from loss of life and property resulting from fires and explosions.
ISO 13984:1999 deals with fueling system interfaces for land vehicles that use LH2. It specifies the characteristics of refueling and dispensing systems of all types of land vehicles. As a result, it does not directly cover the LHSS, but deals with the interface between refueling stations and vehicle tanks, to reduce the risk of fires and explosions. It applies to the design and installation of LH2 fueling and dispensing systems.
In China, there is the GB/T 30719-2014 [31] standard, which is synchronized with the contents of ISO 13984:1999.
Recent RCS activities aim to revise the existing ISO standards and adjust them to the state-of-the-art LH2 vehicle technology.

4.5. Applicable norms for specific purposes related to hydrogen vehicles

For both LH2 and CGH2, the applicable regulations include several additional references to norms and standards for special

or specific purposes, such as EN 1251-2 [32] for defining design requirements for the LHSS, or ISO 11114 for defining hydrogen materials compatibility requirements. Although Reg. (EC) 79/2009 was repealed, these standards will of course remain valid and must still be used for demonstrating the requirements of a safe hydrogen system regarding compliance with Reg. (EU) 2021/535.
Below list shows some of the mentioned norms for hydrogen vehicle fuels system components and containers. The list is not comprehensive but includes the most relevant and most used norms.

RELEVANT NORMS FOR HYDROGEN VEHICLE FUEL SYSTEM COMPONENTS AND CONTAINERS

	Materials	Components	Containers
Gaseous hydrogen	CHMC-1	HGV 3.1	HGV 2
	CHMC-2	ISO 12619	ISO 19881
	ISO 11114	ISO 19887	
	TÜV SÜD standard	ISO 17268	
		SAE J2600	
Liquid hydrogen	EN 1252	ISO 13984	ISO 13985

Figure 6: Relevant norms for hydrogen vehicle fuel system components and containers

5. CONCLUSIONS AND OUTLOOK

For allowing a safe market entry for gaseous and liquid hydrogen vehicles, their components should be assessed and tested using the best method available. Regulations provide a legally binding way to type approvals, but after the withdrawal of Reg. (EC) 79/2009 in July 2022, an applicable regulation is no longer existent for some components. A preliminary solution to this issue was the introduction of Reg. (EU) 2019/2144 to replace Reg. (EC) 79/2009 (by referencing to UN Regulation No 134) and to include certain testing requirements into the implementation Reg. (EU) 2021/535. For the LHSS, European type approval is possible via Reg. (EU) 2021/535, while for the components of a CHSS (i.e. high pressure container and primary closure devices), a double marking according to regulations Reg. (EU) 2021/535 and UN Regulation No 134 is required.
However, from our point of view, a more sophisticated solution is needed to ensure consistency. In our opinion, it would make sense to combine requirements from Reg. (EC) 79/2009, Reg. (EU) 2021/535 and UN Regulation No 134 for the type approval procedure.
If there is no regulation in place for certain components of the hydrogen system (and therefore type approval is not possible), relevant norms and standards regarding a manufacturer's product liability and product safety obligations would need to be identified and followed instead. As it is in the natural interest of manufacturers to evaluate the safety and performance of their products in the best possible way, testing for conformity with such norms would be the result.
We recommend manufacturers to get in direct consultation with a notified body, to receive support for identifying the optimal solution for their specific products and for ensuring a safe and uncomplicated market entry at an early stage.

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