DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Part 571

[Docket No. NHTSA–2024–0090]

RIN 2127–AM40

Federal Motor Vehicle Safety Standards; Fuel System Integrity of Hydrogen Vehicles; Compressed Hydrogen Storage System Integrity; Incorporation by Reference

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: This final rule establishes two new Federal Motor Vehicle Safety Standards (FMVSS) specifying performance requirements for all motor vehicles that use hydrogen as a fuel source. The final rule is based on Global Technical Regulation (GTR) No. 13, Hydrogen and Fuel Cell Vehicles. FMVSS No. 307, ''Fuel system integrity of hydrogen vehicles,'' specifies requirements for the integrity of the fuel system in hydrogen vehicles during normal vehicle operations and after crashes. FMVSS No. 308, ''Compressed hydrogen storage system integrity,'' specifies requirements for the compressed hydrogen storage system to ensure the safe storage of hydrogen onboard vehicles. These two standards will reduce deaths and injuries from fires due to hydrogen fuel leakages and/or explosion of the hydrogen storage system.

DATES:

Effective date: This final rule is effective July 16, 2025.

IBR date: The incorporation by reference of certain publications listed in the rule is approved by the Director of the Federal Register as of July 16, 2025.

Compliance Dates: The compliance date is September 1, 2028.

Petitions for reconsideration: Petitions for reconsideration of this final rule must be received no later than March 3, 2025.

ADDRESSES: Petitions for reconsideration of this final rule must refer to the docket and notice number set forth above and be submitted to the Administrator, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, West Building, Washington, DC 20590. All petitions received will be posted without change to *http://www.regulations.gov,* including any personal information provided.

Privacy Act: DOT will post any petition for reconsideration, and any other submission, without edit, to *http://www.regulations.gov,* as described in the system of records notice, DOT/ALL–14 FDMS, accessible through *https://www.transportation.gov/individuals/privacy/privacy-act-system-records-notices.* Anyone is able to search the electronic form of all submissions to any of our dockets by the name of the individual submitting the submission (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review DOT's complete Privacy Act Statement in the **Federal Register** published on April 11, 2000 (Volume 65, Number 70; Pages 19477–78).

FOR FURTHER INFORMATION CONTACT: For technical issues, Ian MacIntire, General Engineer, Special Vehicles & Systems Division within the Division of Rulemaking, at (202) 493–0248 or *Ian.MacIntire@dot.gov.* For legal issues, Paul Connet, Attorney-Advisor, NHTSA Office of Chief Counsel, at (202) 366–5547 or *Paul.Connet@dot.gov* or Evita St. Andre, Attorney-Advisor, NHTSA Office of Chief Counsel, at (617) 494–2767 or *Evita.St.Andre@dot.gov.* The mailing address of these officials is: National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC 20590.

SUPPLEMENTARY INFORMATION:

Table of Contents

I. Executive Summary

Vehicle manufacturers have continued to seek out renewable and clean fuel sources as alternatives to gasoline and diesel. Compressed hydrogen has emerged as a promising potential alternative because hydrogen is an abundant element in the atmosphere and does not produce tailpipe greenhouse gas emissions when used as a motor fuel. However, hydrogen must be compressed to high pressures to be an efficient motor fuel and is also highly flammable, similar to other motor fuels. NHTSA has already set regulations ensuring the safe containment of other motor vehicle fuels such as gasoline in FMVSS No. 301, ''Fuel system integrity,'' and compressed natural gas (CNG) in FMVSS No. 304, ''Compressed natural gas fuel container integrity,'' and the fuel integrity systems of those fuels in FMVSS No. 301 and FMVSS No. 303, ''Fuel system integrity of compressed natural gas vehicles,'' respectively. No such standards currently exist in the United States covering vehicles that operate on hydrogen. Accordingly, this document establishes two new FMVSS to address safety concerns relating to the storage and use of hydrogen in motor vehicles, and to align the safety regulations of hydrogen vehicles with those of vehicles that operate using other fuel sources.

NHTSA published the Notice of Proposed Rulemaking (NPRM) on April 17, 2024, seeking comments on the proposed standards.[1] This final rule responds to and addresses the comments to the NPRM, reflecting input from stakeholders on various concerns and recommendations. The rule was developed in concert with efforts to harmonize hydrogen vehicle standards with international partners through the GTR process and harmonizes the FMVSS with GTR No. 13, Hydrogen and Fuel Cell Vehicles.[2]

The two new FMVSS established by this document are: FMVSS No. 307, ''Fuel system integrity of hydrogen vehicles,'' and FMVSS No. 308, ''Compressed hydrogen storage system integrity.'' FMVSS No. 307 regulates the integrity of the fuel system in hydrogen vehicles during normal vehicle operations and after crashes. To this end, it includes performance requirements for the hydrogen fuel system to mitigate hazards associated with hydrogen leakage and discharge from the fuel system, as well as post-crash restrictions on hydrogen leakage, concentration in enclosed spaces, container displacement, and fire. FMVSS No. 308 regulates the compressed hydrogen storage system (CHSS) itself and primarily includes performance requirements that ensure the CHSS is unlikely to leak or burst during use, as well as requirements intended to ensure that hydrogen is safely expelled from the container when it is exposed to a fire. FMVSS No. 308 also specifies performance requirements for different closure devices in the CHSS.

FMVSS No. 308 applies to all motor vehicles that use compressed hydrogen gas as a fuel source to propel the vehicle, regardless of the vehicle's gross

[1] *See* 89 FR 27502 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[2] A copy of GTR No. 13 as updated by the Phase 2 amendments is available at: *https://unece.org/sites/default/files/2023-07/ECE-TRANS-180-Add.13-Amend1e.pdf*

vehicle weight rating (GVWR), except vehicles that are only equipped with cryo-compressed hydrogen storage systems or solid-state hydrogen storage systems to propel the vehicle. Portions of FMVSS No. 307 also apply to all motor vehicles that use compressed hydrogen gas as a fuel source to propel the vehicle, regardless of the vehicle's GVWR. However, while FMVSS No. 307's fuel system integrity requirements during normal vehicle operations apply to both light vehicles (vehicles with a GVWR of 4,536 kg or less) and to heavy vehicles (vehicles with a GVWR greater than 4,536 kg), FMVSS No. 307's post-crash fuel system integrity requirements apply only to compressed hydrogen-fueled light vehicles and to all

II. Background

A. Overview of GTR No. 13

1. The GTR Process

The United States is a contracting party to the the Agreement concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts which can be fitted and/or be used on Wheeled Vehicles (''1998 Agreement''). This agreement entered into force in 2000 and is administered by the United Nations Economic Commission for Europe's (UN ECE's) World Forum for the Harmonization of Vehicle Regulations (WP.29). The purpose of this agreement is to establish Global Technical Regulations (GTRs).

At its 160th session in June 2013, UN ECE WP.29 formally adopted the proposal to establish GTR No. 13. NHTSA chaired the development of GTR No. 13 and voted in favor of establishing GTR No. 13. The Phase 2 updates to GTR No. 13 were adopted at the 190th Session of WP.29 on June 21, 2023.[3]

As a Contracting Party Member to the 1998 Global Agreement that voted in favor of GTR No. 13 and the Phase 2 updates to GTR No. 13, NHTSA is obligated to initiate the process used in the U.S. to adopt Phase 2 GTR No. 13 as an agency regulation. This process was initiated by the NPRM published on April 17, 2024. NHTSA is not obligated to adopt the GTR, in whole or in part, after initiating this process. Additionally, NHTSA may adopt a modified version of the GTR to ensure that it meets relevant requirements. In deciding whether to adopt a GTR as an FMVSS, NHTSA follows the requirements for NHTSA rulemaking, including the Administrative Procedure Act, the National Traffic and Motor Vehicle Safety Act (Vehicle Safety Act), Presidential Executive Orders, and DOT and NHTSA policies, procedures, and regulations. Among other things, FMVSS issued under the Vehicle Safety Act ''shall be practicable, meet the need for motor vehicle safety, and be stated in objective terms.''

2. GTR No. 13 and Phase 2 Updates

GTR No. 13 specifies safety-related performance requirements and test procedures with the purpose of minimizing human harm that may occur as a result of fire, burst, or explosion related to the hydrogen fuel system of vehicles. The regulation consists of system performance requirements for CHSS, CHSS closure devices, and the vehicle fuel delivery system. GTR No. 13 does not specify the type of crash tests for post-crash safety evaluation and instead permits Contracting Parties to use their domestic regulated crash tests.

The Phase 2 updates of GTR No. 13 accomplished several goals, including: broadening of the scope and application of GTR No. 13 to cover heavy/commercial vehicles; harmonizing, clarifying, and expanding the requirements for thermally-activated pressure relief device (TPRD) discharge direction in case of controlled release of hydrogen; strengthening test procedures for containers with pressures below 70 MPa, including comprehensive fire exposure tests; and extending the requirements to 25 years to more accurately capture the expected useful life of vehicles.

B. April 2024 NPRM

The April 2024 NPRM[4] proposed to establish two new FMVSS for hydrogen vehicles that are based on GTR No. 13, Phase 2. The proposed FMVSS No. 307, ''Fuel System Integrity of Hydrogen Vehicles,'' is designed to set performance requirements to ensure the integrity of the hydrogen fuel system during normal vehicle operations and after crashes. These requirements aimed to mitigate safety risks associated with hydrogen fuel leakages, fires, and explosions, ensuring that hydrogen would not pose risks to vehicle occupants or those nearby. The standard addressed the hazards posed by the flammability of hydrogen and its tendency to leak under high pressure, particularly in crash scenarios.

FMVSS No. 307 prescribes a series of performance standards aimed at ensuring the safety of hydrogen vehicle fuel systems during both normal operations and post-crash scenarios. The NPRM proposed five key performance requirements for hydrogen fueling receptacles to prevent leakage, incorrect fueling, and contamination from dirt or water. These included reverse flow prevention, clear labeling, positive locking, protection against contamination, and secure placement to avoid crash-related deformations. An over-pressure protection device requirement was proposed to protect downstream components from excessive pressure. The proposal also included requirements for hydrogen discharge mechanisms, specifying that vent lines must be protected from dirt and water and that hydrogen gas discharge must be directed safely away from critical components like the wheels, doors, and emergency exits.

The NPRM also proposed requirements in FMVSS No. 307 to protect against flammable conditions. These included a visual warning system that would alert the driver if hydrogen concentrations reached dangerous levels (above 3% in enclosed or semi-enclosed spaces), and an automatic shut-off valve closure if hazardous hydrogen concentrations were detected. The proposed standard further specified that hydrogen concentrations in the exhaust system must not exceed set thresholds during normal vehicle operation.

In post-crash scenarios, the proposal set limits on fuel leakage and specified crash tests to ensure that the hydrogen containers remained intact and that any post-crash hydrogen leakage remained within manageable limits. The proposal allowed a hydrogen leak rate not to exceed 118 normal liters per minute for a duration of 60 minutes after impact.

The NPRM also proposed establishing FMVSS No. 308, ''Compressed Hydrogen Storage System Integrity,'' focused on ensuring the safety and durability of the CHSS used in hydrogen vehicles. The proposed standard outlined performance requirements for the CHSS to prevent leaks, bursts, and other failures during normal vehicle use and under extreme conditions, such as exposure to fire. The proposal included tests and performance criteria to evaluate the CHSS's resistance to various stress factors that could occur over the vehicle's lifetime. The CHSS, which includes components such as the hydrogen container, check valve, shut-off valve, and TPRD, was required to meet several durability and safety benchmarks throughout its operational lifespan.

The proposal established specific requirements for hydrogen containers,

[3] *See https://unece.org/sites/default/files/2023-07/ECE-TRANS-180-Add.13-Amend1e.pdf.*

[4] *See* 89 FR 27502 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

which are the primary components of the CHSS. Testing procedures for these containers included hydraulic pressure tests to evaluate burst thresholds, pressure cycling tests to simulate long-term use in service, and tests applying a series of external stress factors such as impact, chemical exposure, high and low temperatures, high pressure hold, and over-pressure along with pressure cycling to assess the container's durability against leak or burst during its lifetime.

The proposed FMVSS No. 308 also included an on-road performance test for the entire CHSS to ensure the CHSS contains hydrogen without leak or burst. This test uses on-road operating conditions including fueling and defueling the container at different ambient conditions with hydrogen gas at low and high temperatures, a static high-pressure hold, and an overpressure, designed to replicate the stress factors the system could encounter during a vehicle's operational life.

Fire exposure testing was another critical aspect in the proposed FMVSS No. 308, evaluating whether the CHSS could prevent dangerous hydrogen release or explosion in a vehicle fire scenario. The proposed fire test includes a localized and engulfing stage, which were developed based on real vehicle fire data. The NPRM also proposed requirements for the CHSS's closure devices (check valves, shut-off valves, and TPRDs). Additionally, the NPRM proposed labeling requirements in FMVSS No. 308 for hydrogen containers.

Together, the two proposed standards, FMVSS No. 307 and FMVSS No. 308, aimed to align U.S. regulations with GTR No. 13 and address the specific safety challenges posed by hydrogen as a vehicle fuel source.

C. How the Final Rule Differs From the NPRM

The final rule largely mirrors the proposed standards, with some minor changes to the requirements and test procedures based on the public comments and feedback received. Details of the reasoning behind each of the changes is provided in relevant sections of the notice.

FMVSS No. 307, established by this final rule, differs from the proposed FMVSS No. 307 in the following ways:

- Revises the definition for enclosed or semi-enclosed spaces to be more specific and avoid ambiguity.
- Removes the requirement for an overpressure protection device.
- Removes the requirement that the fueling receptacle ''shall not be mounted to or within the impact energy-absorbing elements of the vehicle.''
- Removes the requirements for specific TPRD discharge angles.
- Eliminates the option to use an electronic leak detector in section S6.6, leaving leak detection liquid as the only applicable test method.
- Revises the regulatory text in instances where the NPRM stated that the vehicle is set to the ''on'' or ''run'' position (and preventing the vehicle from idling) to instead state that the propulsion system shall be operational.

FMVSS No. 308, established by this final rule, differs from the proposed FMVSS No. 308 in the following ways:

- Excludes cryo-compressed and solid-state hydrogen storage systems from the requirements in FMVSS No. 308.
- Requires manufacturers to provide the median initial burst pressure for a container (BP_O) within fifteen business days instead of five.
- Removes the requirement to include BP_O on the container label.
- Removes the requirement for container burst pressure variability to be within 10 percent of BP_O.
- Changes the requirement that the manufacturer specify the primary constituent of the container to specifying whether the primary constituent of the container is glass fiber composite.
- Increases the timeframe from 5 business days to 15 business days for manufacturers to submit vehicle-specific information for testing purposes.
- Revises the cycling rate for the baseline initial pressure cycle test to be no more than ten cycles per minute.
- Removes the minimum time of three minutes to sustain a visible leak before the baseline initial pressure cycle test can end successfully due to ''leak before burst.''
- Removes the proof pressure test from both the test for performance durability and the test for expected on-road performance.
- Permits the option to conduct the closure tests with an inert gas such as helium instead of hydrogen gas.

For both standards, various editorial and clerical updates were made to improve clarity and consistency throughout the document.

III. Summary of Comments

The NPRM preceding this final rule included requests for comment on several topics. From April 17, 2024, to July 17, 2024, the agency received 31 comments on the NPRM, four of which were requests to extend the NPRM comment period.[5] The comments were generally supportive of the proposed rule, particularly regarding harmonization with international regulations. Many commenters suggested modifications to the proposed requirements, including details of various test procedures. Of the 26 unique comments, the majority (21 comments) were submitted by vehicle and component manufacturers and industry associations. Comments were also submitted by standards testing laboratories (1 comment), and other stakeholders (4 comments).

The vehicle and component manufacturers that provided comments were Ballard Power Systems (''Ballard''), Daimler Truck North America (''DTNA''), Ford Motor Company (''Ford''), Glickenhaus Zero and Scuderia Cameron Glickenhaus LLC (collectively, ''Glickenhaus''), Hexagon Agility, Inc. (''Agility''), Hyundai America Technical Center, Inc. (''HATCI''), Hyundai Motor Group (''Hyundai''), Luxfer Gas Cylinders, New Flyer of America (''NFA''), Nikola Corporation (''Nikola''), Noble Gas Systems (''NGS''), Hyzon Motors Inc. (Hyzon), H2MOF, Inc. (''H2MOF''), Quantum Fuel Systems, LLC (''Quantum''), Verne, Inc. (''Verne''), Westport Fuel Systems Canada, Inc. (''WFS''), and Air Products and Chemicals, Inc. (''Air Products'').

The industry associations that provided comments were the Alliance for Automotive Innovation (''Auto Innovators''), The Vehicle Suppliers Association (''MEMA''), the Transport Project (''TTP''), and the Truck and Engine Manufacturers Association (''EMA''). Some manufacturers stated support for the comments submitted by an industry association.

The testing laboratory that provided comments was TesTneT Canada, Inc. (''TesTneT''). The other stakeholders that provided comments were Faurecia Hydrogen Solutions (''FORVIA''), Consumer Reports, Newhouse Technology, LLC (''Newhouse''), and an anonymous commenter.

IV. Response to Comments on Proposed Requirements

A. Deviation From GTR No. 13

Several commenters submitted repeated comments for many sections of the proposed FMVSS Nos. 307 and 308 asking that the agency follow GTR No.

[5] In response to the comments to extend the comment period, NHTSA extended the comment period for the NPRM by 30 days. The original comment period for the NPRM was scheduled to end on June 17, 2024. The extended comment period ended on July 17, 2024.

13 exactly, often without further explanation or justification. Several commenters also stated that the agency should completely harmonize with various industry standards.

Commenters seem to misunderstand the requirements of the 1998 Agreement and NHTSA's obligation under the Agreement. As noted earlier, under the 1998 Agreement, NHTSA must propose a GTR on which it has voted in the affirmative. NHTSA is committed to harmonizing to the extent practical, but NHTSA is not required to finalize the text of a GTR when it has justification to deviate from that text. The 1998 Agreement, by design, does not include mutual recognition [6] because the 1998 Agreement spans different regulatory regimes (*i.e.,* type approval and self-certification), and it acknowledges the domestic rulemaking and substantive legal requirements in the United States.

The FMVSS are designed to be a unique set of regulations tailored specifically for the United States' regulatory approach to vehicle safety. FMVSS must adhere strictly to principles of objectivity and verifiability, as these are foundational to the self-certification process required in the U.S. automotive market. Some other standards, like industry standards and regulations from other countries, may include some degree of subjectivity or flexibility in their criteria due to their broader focus and the differing regulatory frameworks across countries.

NHTSA aimed to harmonize FMVSS Nos. 307 and 308 with GTR No. 13 and the related industry standards to the maximum extent possible. However, it was not always feasible or appropriate to match the regulations word for word. FMVSS must remain objective, ensuring that every requirement is clear, measurable, and enforceable. FMVSS must also have clear, unambiguous test procedures with minimal discretion given to test facilities. This requirement ensures the integrity of the self-certification system and protects consumers and manufacturers alike. Ignoring these fundamental requirements for FMVSS would undermine the effectiveness of FMVSS and could potentially compromise vehicle safety in the U.S.

[6] Mutual recognition occurs when two or more countries or other institutions recognize one another's decisions or policies, for example in the field of conformity assessment, professional qualifications or in relation to criminal matters.

B. FMVSS No. 308, "Compressed Hydrogen Storage System Integrity"

1. FMVSS No. 308 as a Vehicle-Level Standard

Background

Consistent with GTR No. 13, NHTSA proposed that FMVSS No. 308 be a vehicle-level standard, rather than an equipment standard. Some performance requirements and test procedures for the CHSS in FMVSS No. 308 are specific to the vehicle design and to its gross vehicle weight rating. NHTSA sought comment on whether FMVSS No. 308 should remain a vehicle standard.

Comments Received

Auto Innovators expressed concern about NHTSA's proposal to structure FMVSS No. 308 as a vehicle-level standard, arguing that the development and quality assurance of CHSS require specialized knowledge. Since many vehicle manufacturers source CHSS from independent suppliers, Auto Innovators suggested that compliance responsibility should lie with the CHSS supplier. It further stated that it is unclear how vehicle manufacturers could practically implement testing, given that CHSS design is more applicable to suppliers. It also emphasized the importance of including replacement parts in FMVSS No. 308 to maintain consistency and ensure integrity during repairs.

DTNA supported the proposal to maintain FMVSS No. 308 as a vehicle-level standard. It agreed that the performance requirements should apply only to originally equipped CHSS and stated that further research is needed before addressing replacement CHSS. It also concurred that the CHSS performance should be evaluated based on vehicle design and gross vehicle weight rating.

EMA recommended revising FMVSS No. 308 to apply as an equipment standard that would also include replacement containers. It proposed that both motor vehicles using compressed hydrogen gas and containers designed to store it should be subject to the standard.

Glickenhaus advocated for FMVSS No. 308 to focus on tank-level testing rather than vehicle-level certification, arguing that CHSS components should be certified by the component manufacturer. It pointed out that NHTSA has a precedent in other FMVSS standards for differentiating requirements based on vehicle weight and size, and suggested that FMVSS No. 308 could follow a similar approach. This approach, according to Glickenhaus, would reduce costs by allowing tanks to be certified for use across multiple vehicle platforms without re-certification for each vehicle.

H2MOF proposed that FMVSS No. 308 remain a component standard with applicability for hydrogen storage systems ranging from 10 MPa to 70 MPa.

Nikola stated that FMVSS No. 308 should remain a separate standard but questioned why replacement parts should not be required to meet the standard and suggested using separate markings to indicate which vehicle types a particular component is suitable for.

Newhouse suggested that FMVSS No. 308 should be an equipment standard focusing on the fuel container and directly integral components, such as the valve and TPRD. It recommended that FMVSS No. 307 cover system issues, including the connection of fuel containers with tubing.

FORVIA agreed with not extending FMVSS No. 308 to replacement parts, stating it would provide replacement parts equivalent to the original ones.

Luxfer Gas Cylinders referenced compliance with FMVSS No. 304, where CNG fuel containers were purchased directly from manufacturers, and questioned whether NHTSA intended to purchase hydrogen vehicles to obtain CHSS for testing. It also asked if NHTSA plans to test both containers and TPRDs from container manufacturers or vehicle providers. It stated that FMVSS No. 308 would be more appropriate as a component-level standard since it focuses on performance tests for CHSS rather than the vehicle as a whole.

Agency Response

NHTSA is maintaining FMVSS No. 308 as a vehicle-level standard, as proposed. Several requirements in FMVSS No. 308 are specific to the vehicle design and to the gross vehicle weight rating of the vehicle in which a CHSS is installed.[7] It is not possible to fully evaluate the performance of a CHSS without knowledge of the vehicle in which it is installed.

While CHSSs may be sourced from specialized equipment suppliers, vehicle manufacturers must ensure that the CHSS installed on their vehicles meet all applicable FMVSS requirements to certify that the entire vehicle is compliant. Vehicle manufacturers may consider working

[7] For example, as discussed below, the number of pressure cycles to which the container is subjected during the baseline initial pressure cycle test is dependent on the vehicle GVWR, with a different number of cycles required for light and heavy vehicles.

closely with CHSS suppliers regarding system design to ensure all requirements are met for a particular vehicle.

Following the lead of GTR No. 13, FMVSS No. 308 establishes standards intended to ensure the safety and integrity of the CHSS throughout the lifetime of a vehicle. NHTSA recognizes that some containers and parts may still need to be replaced due to damage incurred through extraordinary events or due to defects, but in general, the agency expects the demand for replacement CHSS parts to be minimal. Given the likely low demand for replacement containers by ordinary consumers, the limited current market penetration of hydrogen vehicles, and the fact that any recalls will be serviced by manufacturers, we expect the market for aftermarket products to be negligible, and that replacement parts will be supplied predominantly through OEMs, therefore obviating the safety need to set an equipment-level standard. However, NHTSA will monitor the deployment of hydrogen vehicles and how consumers are replacing parts of the fuel system and update the standard as necessary.

While NHTSA recognizes that some manufacturers would prefer that FMVSS No. 308 be an equipment standard, thus potentially shifting the burden of certification onto other entities like suppliers, NHTSA remains invested in ensuring that the end product it regulates—the vehicle—is as safe as possible. The safety of the end product is most important to protecting consumers and the public. Because a compliant CHSS is essential to certifying the safety of the end product, NHTSA maintains the vehicle-level standard. Additionally, NHTSA expects that manufacturers will maintain proper record-keeping practices, including detailed hardware bills of materials, to ensure traceability to originating suppliers.

Regarding the procurement of CHSS or subcomponents for compliance testing, NHTSA will have the option of purchasing complete vehicles or the relevant replacement parts from the vehicle or sub-component manufacturer. This flexibility will enable NHTSA to obtain the needed vehicle and components to conduct compliance testing efficiently.

Additionally, final-stage vehicle manufacturers will not necessarily be required to conduct CHSS testing themselves. Vehicle manufacturers must take reasonable care in certifying that their vehicles meet FMVSS No. 308, but they are not required to follow any set testing procedure and may, if they find it reasonable, work with CHSS suppliers to ensure compliance with FMVSS No. 308. This approach allows vehicle manufacturers to use their discretion in determining which party is best suited to conduct specific tests. This arrangement is often formalized through contractual obligations, with CHSS suppliers guaranteeing the functionality of their systems and agreeing to supply replacement parts exclusively through the vehicle manufacturer, ensuring consistency and regulatory compliance.

2. FMVSS No 307 and 308 as Separate Standards

Background

NHTSA sought comment on whether FMVSS Nos. 307 and 308 should be combined into a single standard in the final rule.

Comment Received

Luxfer Gas Cylinders commented that it would be better to keep FMVSS Nos. 307 and 308 separate. EMA also supported maintaining separate standards, recommending that FMVSS No. 308 be applicable to vehicles using hydrogen as a motor fuel, as well as to hydrogen containers designed for on-board storage, similar to FMVSS No. 304 for CNG containers. Glickenhaus agreed that FMVSS Nos. 307 and 308 should remain distinct. H2MOF similarly stated that the two standards should not be combined. Nikola argued that FMVSS No. 308 should remain its own standard, pointing out that component-specific testing is common in FMVSS regulations, citing examples such as FMVSS Nos. 106, 108, and 304. Nikola further suggested that FMVSS No. 307 should cover vehicle-level requirements, while FMVSS No. 308 should address component-specific requirements. Hyundai supported the separation of the standards, stating that it is logical to distinguish between fuel system integrity and hydrogen storage system requirements, drawing a parallel with FMVSS Nos. 303 and 304 for CNG vehicles. FORVIA, while generally neutral, expressed a preference for combining the standards, suggesting that doing so could simplify future amendments and create a more consistent alignment with GTR No. 13.

Agency Response

NHTSA is keeping FMVSS No. 307 and FMVSS No. 308 as separate standards, as proposed. This separation will make future management of the standards more efficient and is consistent with FMVSS No. 303, ''Fuel system integrity of compressed natural gas vehicles,'' and FMVSS No. 304. All commenters on this matter supported requirements in separate standards, as proposed. Regarding H2MOF's comment, NHTSA does not believe that combining FMVSS No. 307 and 308 into a single standard will improve consistency with GTR No. 13. Consistency relates to the specifics of the requirements themselves, and is not based on whether those requirements are in a single standard or in two standards.

3. Change of Design Table

Background

Some international standards include what is known as a ''change of design table.'' This type of table is used in type-approval regulatory systems to specify what qualification testing must be redone for a given change in an approved system's design. GTR No. 13 does not contain a change of design table because GTRs are neutral toward the different national certification systems used and change of design tables are only relevant in type-approval systems.

Comments Received

Quantum Fuel Systems, LLC commented that the proposed standard omits the deviation table, also known as a change of design table, that is included in Economic Commission for Europe Regulation No. 134, (UN ECE R134).[8] Quantum Fuel Systems, LLC stated that the only difference between GTR No. 13 and UN ECE 134 is that UN ECE 134 also includes a deviation table. Quantum Fuel Systems, LLC provided a copy of the change of design table in UN ECE R134. Quantum Fuel Systems, LLC stated it would like the change of design table to be added to the FMVSS Nos. 307 and 308 standards.

Agency Response

NHTSA is not including a change of design table in FMVSS Nos. 307 and 308. Change of design tables are not relevant to FMVSS because FMVSS are self-certification standards. Manufacturers themselves are responsible for determining if any design changes require re-certification of the overall design or system.

[8] *See* Economic Commission for Europe Regulation No. 134, *Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety related performance of hydrogen-fuelled vehicles. https://unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2015/R134e.pdf.*

4. Compressed Hydrogen Storage System

a. Container Definition

Background

GTR No. 13 defines a container as ''the pressure-bearing component on the vehicle that stores the primary volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.'' NHTSA proposed a similar definition with the following modifications:

• Replace ''the vehicle'' with ''a compressed hydrogen storage system'' to clarify that the container is a subcomponent of a CHSS, and therefore a container cannot exist on its own without the other components of the CHSS.

• Remove the word ''primary'' because this word introduces ambiguity regarding secondary or tertiary volumes of stored hydrogen.

• Add the word ''continuous'' to clarify that a container does not have any valves or other obstructions that may separate its different chambers.

Thus, NHTSA proposed that ''container means pressure-bearing component of a compressed hydrogen storage system that stores a continuous volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.'' NHTSA sought comment on the proposed definition for the container.

Comments Received

Commenters provided a range of opinions on NHTSA's proposed definition of ''container'' in FMVSS No. 308. Auto Innovators suggested that NHTSA should harmonize with the definition in GTR No. 13, stating that it is well understood and provides sufficient clarity without necessitating a new definition. Similarly, DTNA raised concerns that removing the word ''primary'' could introduce ambiguity, particularly in relation to whether plumbing and piping systems might be considered part of the container and thus subject to the same testing requirements as the container itself. It requested clarification that such systems are not part of the container.

Glickenhaus and H2MOF expressed support for the proposed definition, with Glickenhaus backing the entire proposal and H2MOF agreeing with the characterization of a container as consisting of a single chamber or multiple interconnected chambers. However, Agility voiced concerns about the practicality of certain performance tests, specifically with live lines, and requested clarification on how multiple-chamber containers would be tested.

Several commenters, including Nikola, WFS, TesTneT, and FORVIA, advocated for retaining the definition from GTR No. 13. WFS suggested that if changes are necessary, only the modification to replace ''the vehicle'' with ''a compressed hydrogen storage system'' should be adopted, while the term ''primary'' should remain to prevent confusion between containers and the CHSS. FORVIA also opposed adding the term ''continuous,'' noting that it could mislead interpretations of interconnected chambers. It suggested that further clarification could be provided through additional notes, especially regarding the definition of ''permanently interconnected.''

HATCI supported NHTSA's proposed definitions for the container, closure devices, shut-off valves, and container attachments, stating agreement with the rationale provided.

Agency Response

NHTSA is maintaining the definition of container as proposed. It is important to indicate in the definition that a container is a component of a CHSS, rather than simply a component of a vehicle. This language makes clear that a container cannot exist outside a CHSS. In other words, there can be no ''independent'' containers that are not part of a CHSS. This clarification is important because the CHSS includes the critical safety functions of shut-off valve, check valve, and TPRD, as discussed below. A container without these functions is unsafe and is not permitted by the standard. All containers must exist as a component of a CHSS, and a vehicle may not have containers that are not part of a CHSS.

It is also important to remove the word ''primary'' from the definition of container. Including the word ''primary'' could introduce ambiguity about secondary or tertiary volumes of stored hydrogen, or secondary or tertiary containers on the vehicle. All containers onboard a vehicle that supply hydrogen to propel the vehicle need to be regulated by the standard, and including the word primary in the definition could imply that only the ''first'' or ''primary'' container is covered by the regulation, while other ''secondary'' containers and their respective CHSS are unregulated. This is not NHTSA's intent, and therefore the word ''primary'' has been removed.

Additionally, it is important to include the word ''continuous'' in the definition. This word is used to determine the specific volume that constitutes a container's single or multiple permanently interconnected chambers. The continuous volume that constitutes the container continues until it is ''interrupted'' or ''broken'' by a shut-off valve. Any continuous volume up to the shut-off valve is considered part of the container. For example, if there are lines [9] between a cylindrical chamber and the shut off valve, then those lines are considered part of the continuous volume that constitutes the container with hydrogen stored at high pressure. A conformable container design consisting of multiple small high-pressure cylinders interconnected by high-pressure piping that are all enclosed in a casing, and that collectively have one set of closure devices (*i.e.* shut-off valve, TPRD, check valve), would be considered as one container by this definition. Such conformable containers are in development for vehicle application in the near future.

Similarly, if two conventional high-pressure containers share a single shut-off valve through piping or lines, such lines present the same safety risks as the container itself, due to the large quantity of stored high-pressure hydrogen that could be uncontrollably released in the event of a failure of those lines to contain the hydrogen. Therefore, those lines would be required to undergo durability testing along with the remainder of the container. However, if the lines are attached to the cylindrical chamber with high pressure hydrogen after the shut-off valve, then they would not be considered part of the continuous volume that constitutes the container. These lines after the shut-off valve do not present the same safety risk of uncontrolled release of high-pressure hydrogen, due to the shut-off valve's ability to close and isolate the stored hydrogen.

Including the word continuous is also important to clarify that a container does not have any valves or other obstructions that may separate its different chambers, in the case of a container with multiple permanently interconnected chambers. There cannot be a shut-off valve or other obstruction between any of the chambers of a container that is composed of multiple permanently interconnected chambers (such as the example provided earlier of a conformable container). Containers composed of multiple chambers forming a continuous volume are tested as a single unit, whereas if there are valves or other obstructions that separate the chambers and ''break'' the continuous volume, the chambers are considered separate containers and are evaluated

[9] In this context, ''lines'' refers to any plumbing, piping, and/or connections where hydrogen fuel may be present.

separately. For example, in the case of three permanently interconnected chambers joined together by piping before a single shut-off valve, all three chambers and the piping together would be considered ''the container.'' Alternatively, if each of the three chambers had its own shut-off valve prior to the piping connections, then each of the three chambers would be a separate container.

Finally, NHTSA does not intend to apply the definition of container to fuel lines outside a CHSS after the shut-off valve, or to low pressure fuel system components downstream of the shut-off valve that may contain residual hydrogen. These lines are covered by other requirements such as the fuel system leakage requirement in FMVSS No. 307, discussed below, which specifies that the fuel system shall not leak, as evaluated by FMVSS No. 307 S6.6, *Test for fuel system leakage.*

b. Container Attachments Definition

Background

NHTSA proposed defining ''container attachments'' as ''non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be removed only with the use of tools for the specific purpose of maintenance and/or inspection.'' GTR No. 13 defined container attachments as ''non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be only temporarily removed for maintenance and/or inspection only with the use of tools.'' NHTSA's definition is similar to that in GTR No. 13 with some exceptions.

GTR No. 13 uses the phrase ''only temporarily removed for maintenance and/or inspection'' in the definition of container attachment. In the NPRM proposed definition, the words ''only temporarily'' and ''for maintenance and/or inspection,'' were removed because anything that can be removed temporarily can also be removed permanently. Additionally, from a regulatory perspective, it is not possible to control and monitor the purpose of removing the container attachments and so the phrase ''for maintenance and/or inspection'' was removed.

Comments Received

Several commenters, including Nikola, Auto Innovators, TesTneT, NGS, and FORVIA, suggested that the definition should remain aligned with GTR No. 13 to maintain consistency. Nikola expressed concern that changes could lead to unintended consequences, while Auto Innovators acknowledged NHTSA's rationale for removing the term ''temporary'' but stated that the amendment was unnecessary and recommended harmonization with GTR No. 13. TesTneT also noted that the proposed change was insignificant, and NGS recommended keeping the GTR No. 13 definition but adding a safety mark to parts critical to the system's function.

EMA proposed adding ''repair'' to the definition and emphasized the need for consistency between FMVSS Nos. 307 and 308. It pointed out a discrepancy in the wording of the definitions between the two standards and suggested it be addressed. FORVIA opposed permitting permanent removal of container attachments, stating that it could pose safety risks, and emphasized the need for allowing only temporary removal for repairs.

In contrast, H2MOF and HATCI supported NHTSA's proposed definition, with H2MOF agreeing directly and HATCI expressing support for the definitions of container attachments as well as other related components.

Agency Response

NHTSA is maintaining the definition of container attachments as proposed. The agency does not anticipate unintended consequences from removing the word ''temporary'' from the definition. By removing the word ''temporary,'' NHTSA is avoiding having to determine whether an attachment was designed to be removed permanently or temporarily. As stated in the NPRM, anything that can be removed temporarily can also be removed permanently, so a distinction between temporary removal and permanent removal is not meaningful.

It is also not necessary to add the word ''repair'' to the definition or keep the phrase ''for maintenance and/or inspection,'' because any attachments that can be removed for maintenance, inspection, or repair can also be removed for other reasons and FMVSS No. 308 cannot enforce the purpose of removing the attachments.

In response to the comment from EMA regarding discrepancy in the definition of container attachment in FMVSS Nos. 307 and 308, NHTSA acknowledges that the omission of ''and/'' from the definition in FMVSS No. 307 was a clerical omission and the definition has been corrected in this final rule.

c. Closure Devices Definition

Background

GTR No. 13 refers to closure devices as ''primary'' closure devices. This language creates ambiguity about potential secondary or tertiary closure devices. As a result, NHTSA proposed to define the term ''closure devices'' as ''the check valve(s), shut-off valve(s) and thermally-activated pressure relief device(s) that control the flow of hydrogen into and/or out of a CHSS'' and does not use the word ''primary.''

Comments Received

Commenters provided mixed feedback on NHTSA's proposal to remove the word ''primary'' from the definition of closure devices. HATCI supported NHTSA's proposed definitions and agreed with the rationale provided. On the other hand, Auto Innovators opposed the removal, stating that ''primary'' is necessary to distinguish between primary, secondary, and tertiary closure devices, which may be outside the regulation's scope. It recommended harmonizing with GTR No. 13, which it argued provides sufficient clarity by defining primary closure devices as those directly attached to the chamber or manifold. Glickenhaus also disagreed with the proposed change, noting that its design approach includes redundant safety measures for critical components. It questioned whether secondary shut-off valves would be considered part of the CHSS if the term ''primary'' was removed.

H2MOF commented that ''primary'' should remain, as additional devices like pressure-activated pressure relief devices may be required in some cases. It also suggested adding a clarification that CHSS test units do not need closure devices, as most tests are performed hydraulically. Nikola agreed that the definition should retain ''primary'' to differentiate between main shut-off valves and secondary valves like manual isolation valves, which are outside the document's scope.

DTNA noted its concern for removal of the word ''primary'' from the definition of ''closure devices.'' It stated that ''volumes of hydrogen that are located between other valves, often along the piping, could be considered part of the CHSS.'' WFS similarly recommended keeping the word ''primary,'' as its removal would create more ambiguity regarding the distinction between the CHSS and the broader fuel system. TesTneT and FORVIA also opposed the change, with FORVIA asserting that the differentiation between primary and secondary closure devices is essential, as GTR No. 13 only covers primary devices. It stated that removing ''primary'' would create uncertainty about whether secondary closures are included.

Agency Response

NHTSA is keeping the proposed definition of closure devices. NHTSA's intention is to subject all TPRDs, check-valves, and shut-off valves that directly control flow of hydrogen into and/or out of the CHSS to the requirements of FMVSS No. 308 S5.1.5. Therefore, there is no need to identify closure devices as ''primary.'' Whether a closure device directly controls the flow into and/or out of the CHSS will be dispositive. Redundant, back-up, or downstream devices are not intended to be subject to the requirements of FMVSS No. 308 S.5.1.5.

There will be no confusion about ''other'' closure devices because the proposed definition specifically identifies only ''the check valve(s), shut-off valve(s) and thermally-activated pressure relief device(s) that control the flow of hydrogen into and/or out of a CHSS,'' and the CHSS is defined as ''a system that stores compressed hydrogen fuel for a hydrogen-fueled vehicle, composed of a container, container attachments (if any), and all closure devices required to isolate the stored hydrogen from the remainder of the fuel system and the environment.'' Any other device types, as well as any devices that do not directly control flow into and/or out of a CHSS, are not closure devices under this definition, or are not part of the CHSS and therefore are not subject to the requirements of FMVSS No. 308 S5.1.5. For example, a valve that is not providing the CHSS with one or all of its required functions of check valve, shut-off valve, and TPRD is not considered a closure device and would not be tested under the standard. Similarly, a valve located ''downstream'' from the CHSS shut-off valve is not considered a closure device since it would not be controlling flow into or out of the CHSS. Likewise, a ''manual isolation valve'' is not a shut-off valve because it is not automatically activated, and so would not be considered a closure device per the final rule.

d. Shut-Off Valve Definition

Background

GTR No. 13 defines a shut-off valve as ''a valve between the container and the vehicle fuel system that must default to the 'closed' position when not connected to a power source.'' NHTSA proposed adding the words ''electrically activated'' to the definition, so that a shut-off valve would be ''an electrically activated valve between the container and the vehicle fuel system that must default to the 'closed' position when not connected to a power source.''

Comments Received

Commenters expressed a strong preference for maintaining alignment with the definition of a shut-off valve as outlined in GTR No. 13. Nikola commented that the existing GTR No. 13 definition should be retained, arguing that other activation methods, such as pneumatic, are possible and that the proposed change to ''electrically activated'' would be overly prescriptive. Auto Innovators recommended harmonizing the definitions of shut-off valves in FMVSS Nos. 307 and 308 with the definition in GTR No. 13, noting that the definitions in these FMVSS standards are currently inconsistent. Similarly, DTNA requested the removal of ''electrically activated'' from the definition, suggesting that the term is not design-neutral and could limit future innovations. DTNA further proposed using the term ''automatically activated'' as a more inclusive option. EMA supported consistency with GTR No. 13 and recommended that NHTSA harmonize the definition of shut-off valves across FMVSS Nos. 307 and 308, offering an alternative definition that would omit ''electrically activated.''

Several commenters, including H2MOF and TesTneT, opposed adding ''electrically activated,'' with H2MOF stating that shut-off valves can also be pneumatically activated. WFS suggested that while leaving the definition as written in GTR No. 13 would suffice, there would be no harm in adding ''electrically activated'' if NHTSA felt it improved clarity. NGS and FORVIA also raised concerns about restricting future innovations, such as pneumatic systems, if the definition were limited to electrically activated valves. Both commenters advocated for retaining the GTR No. 13 wording to avoid stifling potential advancements in valve technology.

Agency Response

NHTSA agrees with the commenters and has removed the words ''electrically activated,'' consistent with the definition in GTR No. 13. This change avoids the possibility of being design restrictive by specifying ''electrically activated.'' NHTSA notes, however, that the definition indicates that the valve must default to the ''closed'' position when not connected to a power source, which directly implies the valve must utilize electrical actuation of some kind.

NHTSA made an editorial modification to the definition of ''shut-off valve'' by replacing the words ''when not connected to a power source'' with ''unpowered.'' This was an editorial change for conciseness. However, NHTSA omitted this update from the definition for shut-off valve in FMVSS No. 307, and only applied it in FMVSS No. 308. In the final rule, both definitions have been revised to reflect this update.

e. CHSS Definition

Background

NHTSA proposed a definition of the CHSS that matches the definition in GTR No. 13, with the exception of the removal of the word ''primary'' before ''closure devices,'' as discussed above.

Comments Received

Luxfer Gas Cylinders commented that the proposed definition of CHSS is appropriate but noted that most of the hydraulic performance tests in FMVSS No. 308 cannot be conducted with the check valve, shut-off valve, and TPRD attached to the container. NFA suggested that NHTSA should consider including Figure-3, the Typical CHSS diagram from the NPRM, in the standard to help clarify the definition.

Agency Response

NHTSA is maintaining the definition of CHSS as proposed. The regulatory text clearly specifies where the CHSS or its subcomponents, such as the container, must meet the various requirements. For example, FMVSS No. 308 S5.1.2 specifies that the test for performance durability is conducted only with the container, and in some cases, container attachments. As Luxfer Gas Cylinders points out, it is not possible to conduct hydraulic tests with the closure devices attached to the container.

NHTSA is not including a figure in the definition because the definition is already clear, and the referenced figure only shows a generic CHSS that may not be representative of all CHSS types that meet the definition.

f. Cryo-Compressed Hydrogen Systems

Background

Cryo-compressed hydrogen (CcH2) storage systems store compressed hydrogen gas at very low temperatures and high pressures. NHTSA proposed that FMVSS No. 307 and 308 would apply to ''each motor vehicle that uses compressed hydrogen gas as a fuel source.''

Comments Received

Verne, Inc. commented that many of the performance requirements in GTR No. 13 and FMVSS Nos. 307 and 308 are relevant for ensuring the safety of some aspects of cryo-compressed hydrogen storage systems. These aspects include crash safety, fire resistance, external vehicle hazards, and performance durability. However, Verne stated that these regulations do not adequately address the specific design, components, and service conditions of CcH2 systems. It further noted that CcH2 technology, which operates at a nominal working pressure (NWP) of 35 MPa and temperatures below −200 °C, is not sufficiently covered by existing global or local regulations, codes, and standards.

Verne requested clarification from NHTSA on whether CcH2 storage systems and hydrogen-powered vehicles using such systems fall under the scope of FMVSS Nos. 307 and 308 as a type of CHSS. Verne also stated that while CcH2 is not explicitly out of scope in GTR No. 13, there is a note in GTR No. 13 Part I Section C.3 that could suggest it should not be included. It emphasized that CcH2 systems meet the definition of CHSS, including key components like a container, TPRD, shut-off valve, and check valve.

Verne listed several ways in which CcH2 systems differ from conventional gaseous CHSS, such as the inclusion of additional devices like multiple pressure relief devices, insulation, and an all-metal vacuum jacket. It also highlighted that due to the pressure dynamics after fueling, the target and maximum fueling pressure should be set lower than 43.75 MPa, suggesting a target of 35 MPa and operational relief at 40 MPa. Furthermore, Verne noted that CcH2 systems are designed to operate at temperatures far below the typical range for gaseous hydrogen systems, with expected operational temperatures between −253 °C and +85 °C.

Verne requested an exemption from FMVSS No. 308 S5.1.3, *Test for expected on-road performance,* for CcH2 systems, stating that test primarily assesses the performance of non-metallic liners in Type 4 containers and non-metallic sealing interfaces. Verne stated that since CcH2 systems rely on metal-to-metal sealing designs to perform at cryogenic temperatures, they do not face the same vulnerabilities as systems using non-metallics. Verne also stated that the temperature conditions in the on-road performance test do not accurately reflect the normal or extreme operational conditions of CcH2 systems. It stated that the current requirements would make the test impossible to execute due to the lower setpoints of the PRDs in CcH2 systems. Finally, Verne stated that the test for on-road performance, as currently written, is costly and provides little safety assurance for CcH2 systems, recommending that it be revised to better suit the technology.

Agency Response

Verne, Inc. has highlighted significant differences between CcH2 and conventional CHSS,[10] including very low operational temperatures, the use of metal-to-metal sealing at cryogenic temperatures, and the presence of PRDs in the storage system. CcH2 systems operate under significantly different conditions than conventional CHSS, including lower temperatures and altered pressure dynamics. These technological distinctions would pose challenges for applying FMVSS No. 308 to CcH2 systems given that the current testing protocols do not adequately address these differences.[11]

GTR No. 13, on which FMSS No. 308 is based, was developed to consider conventional CHSS and does not yet provide sufficient guidance for CcH2 systems. GTR No. 13 acknowledges the potential inclusion of additional storage technologies, such as cryo-compressed systems, in future revisions of the GTR and as the development of these systems progresses. However, it is likely that more research and safety standard development will be required to address the technological distinctions between CcH2 systems and conventional CHSS before GTR No. 13 can be expanded to include these systems.

As such, applying the specific performance requirements of FMVSS No. 308 to vehicles utilizing CcH2 systems is not feasible. Therefore, NHTSA will not apply the requirements of FMVSS No. 308 to vehicles using CcH2 storage systems at this time. However, while CcH2 systems are unique hydrogen storage systems and distinct from conventional CHSSs, most of the vehicle fuel delivery system (piping, pressure regulators, filters, flow control valves, and heat exchangers) and the fuel cell system used to power and propel a vehicle with CcH2 storage systems are similar to those in hydrogen powered vehicles with conventional CHSSs. Additionally, the safety aspects associated with the hydrogen fuel delivery system and the fuel cell system in vehicles with CcH2 storage systems would be similar to that in vehicles with conventional CHSSs. Therefore, NHTSA will still require that vehicles utilizing CcH2, like all vehicles that use hydrogen fuel, meet the vehicle safety requirements outlined in FMVSS No. 307. These include provisions for in-use fuel system integrity and post-crash fuel system integrity, ensuring that vehicles using CcH2 technology maintain overall vehicle safety. Additionally, while NHTSA is exempting CcH2 systems from the requirements of FMVSS No. 308 at this time, NHTSA will continue to monitor developments in cryogenic storage technologies and associated safety standards to inform future regulatory actions.

g. Solid State Hydrogen Systems

Background

Solid-state hydrogen storage systems use advanced materials designed for the storage of hydrogen within solid structures. These materials are composed of porous frameworks onto which hydrogen can adsorb. These frameworks feature expansive internal surface areas that allow the capture and storage of hydrogen molecules within porous networks. These systems can store hydrogen at high densities due to their structural versatility and their ability to reversibly absorb and release hydrogen.

Comments Received

H2MOF commented that its solid-state hydrogen storage systems use adsorbent materials to store hydrogen safely and efficiently. H2MOF stated this method helps reduce costs associated with hydrogen storage, transportation, and use by avoiding the expenses of gas compression and cryogenic liquefaction. H2MOF stated its system involves hydrogen adsorption materials housed within a metallic pressure vessel, which typically operates at 5 MPa, and is enclosed in an insulated outer shell. H2MOF requested that low-pressure solid-state storage solutions operating below 10 MPa be exempted from the requirements of the NPRM, which H2MOF stated are designed for non-metallic high-pressure

[10] By "conventional CHSS," we mean a CHSS that stores hydrogen in gaseous form at high pressures, typically 35 to 70 MPa

[11] There are varied CcH2 system designs under development and there are no standardized testing protocols that address safety issues unique to each of these CcH2 systems. CcH2 storage system manufacturers conduct Failure Modes Effects Analysis (FMEA) to identify potential failure modes, analyze the causes of these failures, and assess their potential effects on the system's safety and functionality, including hydrogen leaks, pressure surges, thermal issues, and component malfunctions. The manufacturers take steps to ensure their CcH2 system designs prevent occurrence of these failures and mitigate the safety effects of any failure mode.

vessels functioning at 35 MPa and 70 MPa.

Agency Response

Similar to the case of CcH2 systems discussed in the previous section, H2MOF has highlighted significant differences between its low-pressure solid-state storage systems and conventional CHSS. These distinctions include the use of adsorbent materials within metallic pressure vessels, lower operational pressures, and the avoidance of high-pressure compression fueling typically seen in traditional CHSS. As with CcH2 systems, these technological differences present challenges for applying the proposed FMVSS No. 308, which was developed for conventional high-pressure gaseous CHSS and does not consider the unique characteristics of solid-state hydrogen storage systems. As with CcH2 systems, NHTSA recognizes the need for more research and standards development to address the specific safety characteristics of solid-state hydrogen storage systems.

Therefore, NHTSA has determined that it is not feasible to apply the performance requirements of FMVSS No. 308 to vehicles using solid-state hydrogen storage systems. However, similar to vehicles with CcH2 storage systems and for the same reasoning, vehicles that use solid-state hydrogen storage technology must still comply with the overall vehicle safety requirements specified in FMVSS No. 307, including in-use fuel system integrity and post-crash fuel system integrity.[12] While NHTSA is exempting solid-state hydrogen storage systems from the requirements of FMVSS No. 308 at this time, NHTSA will continue to monitor advancements in solid-state hydrogen storage technology and consider future regulatory updates as these systems and associated safety standards further develop.

5. General Requirements for the CHSS

a. Maximum CHSS Working Pressure of 70 MPa

Background

Consistent with GTR No. 13, NHTSA proposed requiring that CHSS have a NWP of 70 MPa or less. This is because working pressures above 70 MPa for motor vehicle applications are currently considered impractical and may pose a safety risk given current known technologies. The energy density of hydrogen does not increase significantly when pressurized above 70 MPa, so there is no significant improvement in hydrogen storage efficiency at pressures above 70 MPa. Pressures above 70 MPa, however, may present a greater safety hazard. NHTSA sought comment on this requirement, and specifically asked commenters to identify any technologies that can safely store hydrogen at pressures above 70 MPa.

Comments Received

Nikola stated that CHSS are identified by NWP and maximum filling pressure, with pressures above 70 MPa offering diminishing returns. Nikola also commented that current industry does not have containers that operate above this threshold. Auto Innovators generally agreed with NHTSA's rationale but requested a plan for adapting to future technological developments. It recommended aligning with GTR No. 13, which sets 70 MPa as the highest NWP, and expressed that it would be inappropriate to specify anything higher. Luxfer Gas Cylinders commented that 70 MPa is the appropriate limit due to the absence of filling infrastructure for pressures above this level.

Glickenhaus raised concerns about unintended consequences from limiting the NWP of CHSS to 70 MPa. It pointed out that limiting pressures could hinder future research, comparing this to past limitations when 35 MPa was the industry standard. Glickenhaus commented that today's 70 MPa containers were made possible by technological advances, and a similar restriction in the past might have hindered progress. It also stated that high temperature conditions could reduce the effectiveness of refueling at a fueling station with 70 MPa containers, leading to slower refills and greater energy consumption due to the thermodynamics relating pressure, volume, temperature, and amount of gas.

H2MOF supported the proposal to limit NWP to 70 MPa and requested that FMVSS Nos. 307 and 308 apply to containers ranging from 10 MPa to 70 MPa NWP. WFS agreed with NHTSA's proposal, noting that it aligns with GTR No. 13 and the practical limit for on-board storage. While hydrogen can be safely stored above 70 MPa at fueling stations, it commented that 70 MPa is the practical upper limit for on-board storage.

TesTneT referenced the GTR No. 13 requirement that all new compressed hydrogen storage systems produced for on-road vehicle service have an NWP of 70 MPa or less. TesTneT also noted that there is no increased risk with higher storage pressures, and stated that greater container wall thickness at higher pressures provides more resistance to damage and fire effects. TesTneT noted that the safety issues at pressures higher than 70 MPa involves the ability to seal connections within valves and regulators. It mentioned that it currently use 95 MPa and 100 MPa containers for storing hydrogen at a fueling station. FORVIA agreed with the proposal and commented that introducing additional pressure levels would not benefit interoperability between vehicles and fueling stations, further supporting the 70 MPa limit.

Agency Response

NHTSA is adopting its proposal to limit the NWP of CHSS to 70 MPa or less. Most commenters agreed with the proposal, noting that NWP above 70 MPa offer diminishing returns and that current fueling infrastructure is not compatible with CHSS with NWP greater than 70 MPa. NHTSA has determined that limiting the NWP of CHSS to 70 MPa or less is critical due to safety concerns at higher pressures.

TesTneT noted that it uses 95 MPa and 100 MPa NWP containers to store hydrogen at a fueling station and that the thicker walls of these containers make them inherently safer against damage and fire. NHTSA notes that TesTneT's example of containers with NWP greater than 70 MPa are stationary storage containers. While containers with thicker walls are more resistant to damage and fire, they are significantly heavier and likely not practical for use in hydrogen vehicles.

The requirements in this final rule do not fully address the safety risks associated with storage pressures above 70 MPa. Higher pressures present a greater risk of severe leaks and/or rupture, and the consequences of such failures at increased pressures are more severe due to the larger quantity of energy that could be released. TPRD releases may also be unsafe due to the quantity of hydrogen that must be released at pressures above 70 MPa. Additionally, the test for performance durability of containers in this final rule may not be sufficient to address stress rupture risk for containers with NWP greater than 70 MPa. NHTSA is concerned that a container with NWP greater than 70 MPa may comply with the performance durability requirements and yet have a significant risk of catastrophic stress rupture. As a result, additional safety considerations are necessary for pressures exceeding 70 MPa, and the safety of such systems is not yet known.

[12] The vehicle fuel delivery system and the fuel cell system in vehicles using solid-state hydrogen storage systems are similar to hydrogen powered vehicles with conventional CHSSs.

Therefore, consistent with GTR No. 13, NHTSA is maintaining the requirement that all CHSS must have an NWP of 70 MPa or less.[13]

Glickenhaus stated that limiting the NWP of CHSS to 70 MPa could have unintended consequences by hindering technological advances in hydrogen storage. While Auto Innovators generally agreed with the proposal to limit NWP of CHSS to 70 MPa, it requested a plan for adopting future technological developments. NHTSA agrees with the commenters that technological advances are likely to continue in this space and the agency will monitor such advancement and continue research work on CHSS and hydrogen fuel system integrity. NHTSA coordinates closely with the U.S. Department of Energy (USDOE) and the Pipeline and Hazardous Materials Safety Administration (PHMSA) on research, technical advancements, and standards development for hydrogen vehicles, and plans to update the standards in the future, as needed. Additionally, for vehicles using CHSS with NWP greater than 70 MPa, NHTSA has provisions for exemptions for alternative fuel vehicles that vehicle manufacturers may use.[14]

Glickenhaus commented that fueling stations with 70 MPa tanks would take longer and more energy to refuel hydrogen powered vehicle tanks in extremely hot weather. NHTSA notes that the NPRM and final rule apply to hydrogen storage systems in vehicles used for vehicle propulsion and not the tanks used in fueling stations. Generally, the tanks in fueling stations are at about 100 MPa (similar to those noted by TesTneT). This final rule does not apply to hydrogen tanks in fueling stations.

Limiting CHSS NWP to 70 MPa does not mean 70 MPa is the maximum pressure that can occur inside a CHSS. Under hot conditions or during fueling, a fully fueled CHSS may experience pressures of 125 percent NWP (87.5 MPa for a 70 MPa CHSS). Limiting CHSS NWP to 70 MPa does not limit the maximum allowable working pressure of the container to 70 MPa, nor does it limit manufacturers' ability to design containers that can withstand severe over-pressurization events as tested in subsequent tests.

Finally, H2MOF requested that low-pressure solid-state storage systems typically operating at pressure below 10 MPa be exempted from the requirements of the NPRM, which H2MOF stated are designed for non-metallic high-pressure vessels functioning at 35 MPa and 70 MPa. NHTSA notes that it is not limiting applicability of the standard to vehicles with CHSS pressures above 10 MPa. Instead, NHTSA is excluding low-pressure sold-state hydrogen storage systems from FMVSS No. 308 requirements, as explained earlier in this notice.

b. Mounting Closure Devices On or Within Each Container

Background

GTR No. 13 provided contracting parties with the discretion to require that the closure devices be mounted directly on or within each hydrogen fuel container. The relevant safety concern is that the high-pressure lines required to connect remotely located closure devices with the container could be susceptible to damage or leak. However, as discussed above, the definition of a container is sufficiently broad that it includes lines that are part of the continuous volume of stored hydrogen (as determined by the location of the shut-off valve or any other obstruction that ''breaks'' or ''interrupts'' the container's continuous volume). Thus, any lines that form part of the container's continuous volume are themselves part of the container and will be included in the container performance testing discussed below. If a container (which includes any lines that are part of the container's continuous volume) can successfully complete the performance testing in FMVSS No. 308, then the risk of failure of the lines has been addressed. As a result, NHTSA tentatively concluded that it is not necessary to specify that closure devices be mounted directly on or within each container. NHTSA sought comment on requiring closure devices to be mounted directly on or within each container.

Comments Received

Commenters generally supported NHTSA's proposal not to require closure devices to be mounted directly on or within each container, with most agreeing that this approach provides necessary flexibility for system design. Auto Innovators noted that discussions within the GTR No. 13 Phase 2 Informal Working Group suggested mounting the closure device directly on a chamber for single-chamber systems or on one of the chambers for multi-chamber systems, but also highlighted the benefits of allowing manufacturers discretion, particularly for non-traditional designs like conformable tanks. H2MOF, HATCI, and WFS also supported leaving the location of closure devices to manufacturer discretion, stating that this flexibility enhances design options. WFS and TesTneT pointed out that allowing remote TPRDs, which have been safely used in the CNG industry, could enhance system safety in fire protection. However, Nikola disagreed with NHTSA's approach, stating that ''CNG is not the same as hydrogen'' and that allowing this could lead to unintended issues. Luxfer Gas Cylinders and NGS agreed with NHTSA's proposal, with NGS emphasizing the importance of not limiting manufacturers' ability to design systems tailored to their specific applications.

Agency Response

NHTSA will not require closure devices to be mounted on or within each container. As discussed above, the definition of ''container'' in the final rule is sufficiently broad to include any lines that may form part of the container's continuous volume of pressurized hydrogen up to the closure device.[15] Therefore, these lines must be included in the applicable performance testing as part of the container itself. If a container, including all portions of the container's continuous volume, can successfully complete the performance testing in FMVSS No. 308, then the risk of failure of the lines has been sufficiently addressed.

c. Requiring Check Valve Functionality as Part of the CHSS

Background

During fueling, hydrogen enters the CHSS after passing through a check valve. The check valve prevents back-flow of hydrogen into the fueling supply line or even out of the fueling receptacle to the atmosphere. NHTSA proposed that the CHSS be required to include the functionality of a check valve. However, NHTSA is aware of CNG vehicles that do not include check valves as part of their CNG storage system. NHTSA sought comment on whether the check valves should be required as part of the CHSS.

[13] Storing hydrogen above 70 MPa is also impractical given current technology. As pressure increases beyond 70 MPa, hydrogen becomes increasingly difficult to compress. This difficulty leads to diminishing returns in terms of hydrogen storage density, where only a small increase in stored hydrogen results from a disproportionately higher input of compression energy. Storing hydrogen at higher pressures also requires containers with thicker walls to manage the increased stress from extreme pressurization. These thicker containers add considerable weight, which is impractical for vehicle use where minimizing weight is critical.

[14] *See* Part 555—Temporary Exemption from Motor Vehicle Safety and Bumper Standards, *https://www.ecfr.gov/current/title-49/part-555.*

[15] In this context, ''lines'' refers to any pluming, piping, and/or connections where hydrogen fuel may be present.

Comments Received

Commenters expressed mixed opinions on whether check valves should be required as part of the CHSS. Some, including Nikola, EMA, HATCI, and FORVIA, supported requiring check valves, citing the higher pressure of hydrogen and the role of check valves in ensuring safety, especially for multi-container systems. FORVIA stated that not including a check valve would leave the fueling line vulnerable to hydrogen leakage.

Others, such as Agility, Glickenhaus, H2MOF, and TesTneT, opposed making check valves a mandatory component of the CHSS. Agility stated that system-level protections are appropriate and requested clarification whether a single check valve near the fuel receptacle is adequate. Glickenhaus argued that a remotely located check valve could offer advantages. H2MOF pointed to the safety record of millions of CNG vehicles without check valves in its storage systems and suggested the requirement would be too design restrictive. TesTneT noted that check valve functionality could be integrated into other components, making a separate check valve unnecessary.

WFS commented that the key issue is not having a dedicated check valve but ensuring ''check valve functionality,'' which could be incorporated into other system components, as outlined in GTR No. 13.

Agency Response

Consistent with GTR No. 13, NHTSA is requiring that the CHSS include a check valve or the function of a check-valve. A check valve means ''a valve that prevents reverse flow.'' Therefore, each CHSS must have hydrogen flow control functionality equivalent to a valve that prevents reverse flow. This requirement is not design restrictive because manufacturers have the option to design systems that provide the required functionality without the need for a traditional check valve. For example, the functions of check valve and shut-off valve may be combined into a single device, or multiple containers may share a single check valve. Additionally, it may be possible for a vehicle to use a single check valve located at the fueling receptacle to provide check valve functionality to multiple CHSS. In such a design, each CHSS onboard the vehicle would derive the function of check valve from the single check valve located at the fueling receptacle.

6. Specification of BP_O on the Container Label

Background

Several of the performance tests in FMVSS No. 308 use a manufacturer-supplied value known as BP_O. A container's BP_O is a design parameter specified by the manufacturer that represents the median burst pressure for a batch of containers. To facilitate compliance testing, NHTSA proposed that manufacturers specify the BP_O associated with each container on the container label.

Comments Received

Several commenters addressed the proposal to include the manufacturer-specified median burst pressure (BP_O) on container labels. Nikola stated that BP_O is not useful to and could confuse end users, suggesting that if BP_O is not available for compliance testing, NHTSA should assume a value of 2.25 times NWP. Luxfer Gas Cylinders argued that requiring BP_O on labels is unnecessary, as the burst pressure is a quality control measure, and the median burst pressure of a batch is irrelevant to manufacturers or end users. Auto Innovators disagreed with the assertion that BP_O varies significantly between batches, stated that BP_O is based on manufacturer testing, and recommended consistency with GTR No. 13. Auto Innovators opposed including BP_O on labels, citing potential confusion for end users and lack of safety benefits, and noted that BP_O can be provided to NHTSA during testing without needing to be on the label. EMA echoed concerns about potential customer confusion and recommended alignment with GTR No. 13, suggesting that BP_O could be provided by the manufacturer upon request.

Glickenhaus supported a labeling requirement for burst pressure but raised concerns that NHTSA's proposed definition of BP_O could restrict manufacturers' ability to maintain higher safety margins. It proposed an alternative definition of BP_O based on the minimum burst pressure from the design and manufacturing process to allow for increased safety margins. H2MOF and HATCI both stated the requirement was impractical and unnecessary, with HATCI stressing that BP_O is primarily a design parameter and market strategy issue, often considered confidential. Agility and TesTneT also opposed the requirement, with Agility calling it impracticable and TesTneT suggesting that compliance testing should focus on meeting minimum standards rather than a manufacturer-specified value.

Other commenters, including NGS and Newhouse, requested aligning with GTR No. 13, with Newhouse noting that BP_O information can be found through part numbers if needed. FORVIA expressed strong opposition to including BP_O on labels, citing concerns over confidentiality and potential misinterpretation by consumers and requested alignment with GTR No. 13. Several commenters, including Auto Innovators and Luxfer Gas Cylinders, reiterated concerns that labeling BP_O would create confusion and add unnecessary burdens without any clear safety benefit, recommending harmonization with GTR No. 13 instead.

Agency Response

After consideration of the comments, NHTSA will not require BP_O to be listed on the container label. NHTSA agrees this requirement could cause confusion for consumers regarding slight differences in BP_O that may exist between vehicles. Such differences will have no impact on safety or performance. NHTSA also acknowledges that listing BP_O on the container label could create confusion about the highest rated pressure for a given vehicle. Since BP_O will typically be a multiple of NWP, but have the same pressure units, it could be dangerous for a user to mistake BP_O for NWP.

Nevertheless, NHTSA still needs to know the value of BP_O to conduct compliance testing on a given vehicle. Instead of requiring BP_O on the container label, NHTSA will obtain BP_O directly from the vehicle manufacturer. The method for obtaining BP_O from the manufacturer will match that for obtaining the primary constituent of the container, discussed below.

Some comments appear to reflect a misunderstanding of the role of BP_O within the proposed regulation. The BP_O is a manufacturer-specified parameter that represents the median burst pressure for a batch of containers. Manufacturers are free to incorporate additional safety factors into their designs if they wish. The use of BP_O in the requirements does not restrict this ability. As discussed in the NPRM, the use of BP_O during the residual strength burst test ensures that containers at the end of their service life would still be safe even if they were to remain in service.[16] Specifically, the burst pressure after testing must be at least 80% of the container's BP_O. This

[16] *See* 89 FR 27518 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

requirement controls the degradation rate of the container over time, preventing a high degradation rate that could lead to dangerous bursts if the container were to remains in use beyond its intended life. This standard is comparable to safety standards for other vehicle components like seatbelt webbing.

Additionally, the concerns raised about the ambiguity of the BP_O definition are misplaced, as the regulation does not provide a prescriptive definition but rather relies on the manufacturer's expertise in determining BP_O. There is no requirement to calculate a mean burst pressure by bursting every tank in a batch. Manufacturers may use standard industry practices based on their design, materials, manufacturing processes, and testing to determine BP_O.

7. Tests for Baseline Metrics

a. Required Number of Containers Tested

Background

GTR No. 13 requires three new containers to be tested during the baseline initial burst test and the baseline pressure cycle test. As NHTSA explained in the proposal, this requirement originates from the type-approval certification process commonly found in other nations and that NHTSA did not believe that three new containers needed to be tested under the U.S. self-certification system where NHTSA buys and tests vehicles and equipment at the point of sale. Therefore, NHTSA proposed basing the results of testing of any container for the baseline initial pressure cycle test. NHTSA sought comment on this decision.

Comments Received

FORVIA and TesTneT agreed with the proposal, stating that only one container needs to be pressure cycled to demonstrate compliance with the cycle life requirements. TesTneT likened this approach to batch testing, where only one container is required to be tested, rather than three.

DTNA expressed concern that testing only one container for baseline metrics might not provide sufficient information on the burst behavior of all containers in vehicles equipped with multiple containers. DTNA acknowledged that NHTSA purchases vehicles and equipment from the public market to monitor FMVSS compliance, but proposed that for vehicles with multiple containers, at least two should be subjected to the baseline initial pressure cycle test.

Luxfer Gas Cylinders commented that testing any one container is reasonable, noting that all cylinders must pass the minimum required cycle tests and that testing three containers does not represent a significant statistical sample.

Nikola disagreed with the proposal, suggesting that NHTSA obtain containers directly from tank manufacturers, similar to how testing is conducted under FMVSS No. 304 compliance.

H2MOF supported NHTSA's proposal to test one container for the baseline initial pressure cycle test and recommended allowing a retest if there is an assignable cause of any non-compliance.

Agency Response

NHTSA is maintaining its decision that it is not required to test three containers for the baseline initial burst test, as specified by GTR No. 13. Under the U.S. self-certification system, NHTSA purchases vehicles and equipment for testing randomly at the point of sale, and the selected container must meet all applicable safety requirements. This approach ensures that manufacturers are incentivized to ensure all vehicles consistently comply with safety standards, knowing that any one of their containers could be tested. Removing the requirement to test three containers, the test burden is potentially reduced without compromising safety, and allowing NHTSA to potentially test more containers with the same operating budget. Manufacturers must still ensure that each vehicle meets the standard.

Additionally, concerns about variability among containers are addressed through the random selection process, which provides an effective representation of real-world conditions. While some commenters raised concerns about vehicles with multiple containers, NHTSA has the flexibility to conduct repeat tests, as well as additional tests on any of the various container types if needed. This allows NHTSA to respond to specific cases where there may be a safety concern without mandating the testing of three containers in every instance, which maintains an efficient means of ensuring safety.

b. Baseline Initial Burst Pressure Test

(1) Need for the Baseline Initial Burst Test

Background

Consistent with GTR No. 13, NHTSA proposed the baseline initial burst pressure test in addition to the test for performance durability, which includes a 1000 hour high-temperature (85 °C) static pressure test designed to evaluate the container's resistance to stress rupture, in combination with other lifetime stress factors. Given that the high-temperature static pressure test evaluates stress rupture risk, and the test for performance durability represents an overall worst-case lifetime of multiple stress factors, NHTSA sought comment on whether the baseline initial burst pressure test even needs to be included in the standard's requirements.

Comments Received

Nikola commented that the baseline initial burst pressure test is necessary to ensure that the container meets its initial strength integrity requirements, which can then be compared to the final burst pressure. Agility expressed concern that the high-temperature static pressure test does not sufficiently evaluate reliability against stress rupture, stating that testing one million cylinders would be required to demonstrate the same reliability. EMA recommended that the baseline initial burst pressure test is unnecessary, proposing the removal of S5.1.1.1 from the standard. H2MOF stated that the residual burst pressure after the performance durability test is a better indicator of design fitness than an initial burst pressure test. Auto Innovators suggested aligning with GTR No. 13, which uses the initial baseline burst pressure for comparison with residual values.

TesTneT clarified that the high-temperature static pressure test, originally called the ''accelerated stress rupture test,'' was developed to assess combined effects on the container but not the individual stress rupture characteristics of fiber strands. TesTneT stated that the baseline initial burst pressure test is necessary for container design and manufacturing control. Newhouse commented that both tests should be conducted, as they assess different factors. FORVIA recommended including the baseline initial burst pressure test for harmonization with GTR No. 13, while also questioning whether NHTSA must perform all tests during field surveillance or if it has discretion in test selection. Auto Innovators reiterated its support for harmonizing with GTR No. 13.

Agency Response

NHTSA is maintaining the proposed baseline initial burst pressure test. Several commenters provided sufficient explanation of why the baseline initial pressure test is different from the test for performance durability. On the other hand, the commenters proposing the removal of the baseline initial burst pressure test did not provide sufficient justification why the baseline initial burst pressure test is not needed. The initial burst pressure test evaluates the container's start-of-life integrity, whereas the test for performance durability examines different aspects of material performance and stresses, such as resistance to physical damage, chemical exposure, and extreme environmental temperatures, and the container's subsequent end-of-life integrity. Therefore, both testing requirements should be included in the standard, as proposed. NHTSA notes, however, that the results of the baseline initial burst pressure test are not referenced in subsequent tests as a comparison or ''baseline.'' Instead, subsequent tests reference the BP_O value discussed above. Regarding field surveillance, NHTSA may conduct any of the tests in the FMVSS as part of field surveillance.

(2) Burst Pressure Within ±10 Percent of BP_O

Background

As proposed, the baseline initial burst pressure test would have verified that the initial burst pressure is within 10 percent of the manufacturer specified BP_O. The requirement that the container tested must have a burst pressure within ±10 percent of BP_O was based on the need to control variability in container production. If a manufacturing process produces containers with highly variable initial burst pressures, there is a possibility of a container with a dangerously low burst pressure. NHTSA sought comment on the safety need for specifying a limit on burst pressure variability in a batch and whether the 10 percent limit is appropriate. Commenters were asked to provide supporting data if they believed another limit was appropriate.

Comments Received

Commenters provided mixed opinions regarding the proposal for a ±10 percent limit on burst pressure variability, with some supporting the limit and others suggesting it is unnecessary or impractical. Nikola commented that the ±10 percent limit is achievable and accepted by manufacturers. Agility stated that limiting maximum burst pressure does not necessarily improve safety and suggested that variability in carbon fiber strength would take up most of the proposed limit, making it impractical. Agility also recommended omitting the requirement, stating that the existing minimum burst requirement already addresses safety concerns. HATCI and Auto Innovators both noted that burst pressure variability could be managed through a manufacturer's quality management system, with Auto Innovators supporting alignment with GTR No. 13 and affirming the appropriateness of the ±10 percent limit. Luxfer Gas Cylinders stated that specifying a limit is unnecessary, as manufacturers already ensure no cylinder bursts below the minimum level, typically by setting burst pressures significantly higher than required. TesTneT also supported the ±10 percent limit, noting that burst testing in accordance with GTR No. 13 had not revealed any issues with the limit.

In contrast, Quantum suggested that the 10 percent requirement is unrealistic due to the influence of factors such as carbon fiber performance, recommending a more lenient limit of 20 percent. NGS and H2MOF commented that managing batch variation should be left to the manufacturer as long as the minimum burst pressure is met. Newhouse questioned the practicality of the ±10 percent limit, noting that variability is inherent in the production process and that meeting the minimum burst pressure is a more meaningful safety measure. MEMA and FORVIA both supported maintaining alignment with GTR No. 13, with FORVIA emphasizing that the 10 percent variability allowance accounts for reasonable manufacturing differences while maintaining safety margins. FORVIA also discouraged adding new batch-related requirements, suggesting that automotive production often relies on other control methods, such as sampling in continuous production.

Agency Response

NHTSA is removing the requirement that the burst pressure of the container be within 10 percent of the BP_O. FMVSS are designed to set minimum safety performance standards for vehicles, rather than control variability in manufacturing processes. This approach ensures that every vehicle meets a baseline level of safety, regardless of specific manufacturing methods or variability in production. The responsibility for managing variability and ensuring consistent quality within manufacturing processes falls to the manufacturers themselves. They must ensure that their production processes consistently produce vehicles that meet or exceed the FMVSS requirements.

When NHTSA tests a vehicle component to ensure it meets the FMVSS, the component is expected to meet or exceed the specified performance criteria every time it is tested, regardless of variability in the manufacturing process. NHTSA's approach to testing typically involves randomly selecting a single test article for evaluation. If this single component fails to meet the standard, it indicates that the entire batch, or potentially the entire production process, may be flawed.

Per the requirements of the Safety Act, manufacturers are required to ensure that every unit produced meets the FMVSS requirements. This requirement compels manufacturers to control the variability within their production processes. If a manufacturer allows too much variability, there is a risk that the vehicle may not meet the standards, which could result in non-compliance. The prospect of non-compliance drives manufacturers to maintain high levels of consistency and quality control, ensuring that every component or vehicle produced is likely to pass NHTSA's testing, no matter which one is chosen for evaluation. This method of testing essentially requires control of variability indirectly, as manufacturers must ensure that all of their products, not just a select few, comply with FMVSS requirements.

(3) BP_{min} of 200% NWP

Background

For the reasons discussed in the NPRM, NHTSA believes that the minimum burst pressure, BP_{min}, of 200 percent NWP, as set forth in GTR No. 13 Phase 2, meets the need for safety.[17] The proposed BP_{min} of 200 percent NWP facilitates hydrogen vehicle development without unnecessary overdesign of components. NHTSA sought comment on the proposed BP_{min} of 200 percent NWP instead of the 225 percent NWP specified in GTR No. 13 Phase 1.

Comments Received

Several commenters supported NHTSA's proposal to set the BP_{min} at 200 percent of NWP as aligned with GTR No. 13 Phase 2. Luxfer Gas Cylinders commented that the 200 percent of NWP for BP_{min} is ''acceptable.'' Auto Innovators expressed support for both the harmonization with GTR No. 13 and the

[17] *See* 89 FR 27511 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.* This section's discussion applies to containers that do not contain glass fiber composite as a primary constituent. Containers with glass fiber composite as a primary constituent are discussed in the following section.

BP_{min} of 200 percent, noting that it reflects the consensus of the Informal Working Group from GTR No. 13 Phase 2. Nikola also agreed with the proposed 200 percent BP_{min}.

Agility commented that while 200 percent NWP may be adequate for high-strength carbon fiber, it may not be sufficient for other materials or thin-walled cylinders. Agility suggested requiring 225 percent for NWP values of 35 MPa or lower, as permitted by GTR No. 13. HATCI expressed support for both the proposed BP_{min} and the harmonization with GTR No. 13.

Glickenhaus disagreed with reducing the burst pressure for carbon fiber containers from 225 percent to 200 percent NWP, stating that the proposed 200 percent is too low and could create safety risks, particularly when considering variability in actual burst pressures. Glickenhaus provided an example involving a theoretical container with an NWP of 100 bar. Based on the example where a container with a baseline initial burst pressure of 200 percent NWP had an end-of-life burst pressure of only 160 percent NWP, it recommended retaining a 225 percent BP_{min}.

H2MOF supported the proposal, stating that a BP_{min} of 200 percent would avoid unnecessary overdesign. TesTneT also supported the 200 percent NWP BP_{min}, stating it is safe as proposed. NGS agreed with the 200 percent BP_{min} for carbon fiber but requested that other fibers be allowed if sufficient data proves their durability.

Newhouse commented that 200 percent NWP should be adequate for carbon fiber reinforced containers, but it suggested establishing a minimum NWP of 350 bar for this standard. For containers with lower NWP, Newhouse recommended retaining a BP_{min} of 225 percent due to concerns about reduced damage tolerance and safety. Newhouse further noted that stress rupture is not adequately addressed by specifying a burst ratio and recommended using stress ratios to ensure safety for different container types, especially Type 2 and Type 3 containers.

FORVIA expressed agreement with the 200 percent BP_{min}, stating that GTR No. 13 Phase 2 has demonstrated that this value is sufficient based on performance data.

Agency Response

NHTSA is maintaining the proposed BP_{min} of 200 percent NWP for containers that do not contain glass-fiber as the primary constituent. The counterexample given by a commenter in which a container with a BP_O of 200 percent NWP underwent the test for performance durability and finished with an end-of-life burst pressure of 160 percent NWP is not valid. The residual pressure test at the end of the test for performance durability requires a four-minute hold period at 180 percent of NWP. Therefore, a container with an end-of-life burst pressure of 160 percent would fail to meet the performance requirements of the standard and thereby be prohibited from entering service. There is no option to meet some but not all the requirements of the test for performance durability.

NHTSA is not currently considering requirements related to strain gauges to further address stress rupture, nor is it considering prohibitions on metal liners as that would likely be design restrictive. Regarding the concerns about the durability of thin-walled containers, the durability of all containers is rigorously evaluated with the test for performance durability. The baseline initial burst pressure test is not intended to address container durability throughout its lifetime.

Regarding allowing the use of other fiber types, NHTSA is not restricting designs to any particular fiber type nor excluding any particular fiber type. Manufacturers are free to design products using any material they choose. The requirements are designed to apply to containers regardless of material type. The only material-specific consideration for containers is for those containers that have glass fiber composite as a primary constituent, as discussed in the next section.

Lastly, burst ratios such as BP_{min} are a well-established safety metrics that ensure containers' structural integrity, even if differences exist between burst ratio and stress ratio for some container types. The proposed requirement for BP_{min} of at least 200 percent NWP along with the 1,000 hour high temperature pressure hold test in the sequential test for performance durability are in accordance with the requirements in GTR No. 13 Phase 2 and likely sufficient to mitigate the risks associated with stress rupture in most containers. Further research would be needed to fully understand the relationship between burst ratios, stress ratios, and risk of stress rupture. For now, this final rule adopts the proposed requirement for an initial baseline burst pressure of at least 200 percent NWP.

(4) Primary Constituent

Background

NHTSA sought comment on how NHTSA could determine if a container has glass fiber as a primary constituent and on appropriate criteria to determine the primary constituent of a container.

In the case of containers constructed of both glass and carbon fibers, NHTSA proposed to apply the requirements according to the primary constituent of the container as specified by the manufacturer. NHTSA proposed that the manufacturer shall specify upon request, in writing, and within five business days, the primary constituent of the container. NHTSA proposed that if the manufacturer fails to specify upon request, in writing, and within five business days, the primary constituent of a container, the burst pressure of the container must not be less than 350 percent of NWP.

Comments Received

Luxfer Gas Cylinders commented that a higher minimum burst pressure is typically required for containers with glass-fiber composites and suggested that NHTSA request information from manufacturers regarding the container's composite overwrap and stress analysis to assess the load share of glass fiber in hybrid designs. Nikola had no objections to the 350 percent NWP requirement and stated that NHTSA could either ask the manufacturer for details or cut a container to determine its composition. Agility expressed concern over the definition of ''primary constituent'' and suggested that other materials might also be inappropriate at 200 percent NWP burst. It recommended that manufacturers be asked to provide the load share of glass fiber, which could then be used to adjust the minimum burst pressure.

HATCI supported confirming the primary constituent with manufacturers but opposed the proposed five-day response time, recommending that NHTSA use its existing information request authority without specifying a timeline in the regulation. Luxfer Gas Cylinders added that the five-day period was too short, suggesting a revision to at least 14 business days due to potential delays in identifying the appropriate contact at the container manufacturer. EMA requested a ten-day response period and recommended that the required burst pressure be based on the material specified by the manufacturer rather than defaulting to 350 percent NWP. Glickenhaus suggested that the primary container composition be included in labeling requirements to ensure transparency throughout the container's lifecycle, eliminating the need for inquiries to manufacturers. It also proposed that container manufacturers be required to register with NHTSA, similar to other safety-critical component manufacturers, and submit relevant data such as burst pressures and NWP ratings.

TesTneT downplayed concerns about glass-fiber-reinforced containers in hydrogen service, noting that such designs are rare and impractical for hydrogen applications. It also pointed out the lack of a test method for determining the primary constituent, suggesting that asking the manufacturer is the only feasible approach. NGS supported the requirement for manufacturers to provide primary constituent details but argued that the response time should be extended to 30 days. Newhouse highlighted the complexity of determining the primary constituent in hybrid designs, noting that analysis is required to assess load-sharing between fibers, and simply specifying a burst ratio does not ensure safety. Newhouse provided an alternative approach which provides specific guidelines for hybrid constructions based on fiber load sharing.

MEMA questioned the implementation and enforcement of the response time requirements, suggesting that the information could be provided as part of the self-certification process without the need for a specified deadline. FORVIA disagreed with changing requirements based on potential delays in mailing and proposed that NHTSA conduct field surveillance testing. If a burst test raises suspicions of glass fiber being a primary constituent, further investigation could be conducted. Auto Innovators expressed support for harmonization with GTR No. 13 and agreed with the 350 percent NWP burst pressure requirement for glass-fiber-reinforced containers. H2MOF also supported the higher burst pressure requirement, citing its success in CNG containers over the past two decades. It suggested that the test agency could verify the container's composition after conducting a burst test.

Agency Response

NHTSA is maintaining the requirement that container with glass fiber composite as a primary constituent shall have a BP_{min} of 350 percent of NWP. However, commenters did not provide a specific method for determining the primary constituent of a container. Since NHTSA has no way of determining the load sharing properties of a container's individual fibers, nor a way to determine whether that load sharing is fundamental to the strength of the container, whether or not glass fiber composite is the container's primary constituent must be determined by and specified by the manufacturer.

NHTSA will not require the primary constituent to be listed on the label. Similar to BP_O, listing the primary constituent on the container label could potentially confuse consumers. Additionally, NHTSA does not need to know the specifics of the container's primary constituent other than whether the primary constituent is glass fiber composite. Therefore, NHTSA will require that the manufacturer specify upon request, and in writing, whether the primary constituent of the container is glass fiber composite or not. Based on the comments, however, the timeline for responding to the request has been increased to 15 business days instead of five business days.[18] NHTSA is removing the option that if the manufacturer fails to respond to the request, then the container minimum burst pressure must not be less than 350 percent of NWP. This option is not appropriate for containers other than those with glass fiber composite as a primary constituent, and therefore, the only option is for the manufacturer to specify whether the container's primary constituent is glass fiber composite. FMVSS No. 308 S5.1.1.1 has been updated to reflect this change. S6.2.2.2(e), which contained a similar five business day response timeline, has also been updated to 15 business days.

Furthermore, NHTSA will not obtain a copy of the stress analysis for the container to determine the load sharing from glass fiber in a mixed fiber overwrap. The stress analysis for the container is outside the scope of the proposed regulation. NHTSA will simply obtain the primary constituent from the manufacturer, and then conduct the tests as specified depending on whether the container includes glass fiber composite as a primary constituent.

(5) Pressurization Rates Above 0.35 MPa/sec

Background

GTR No. 13 states that if the pressurization rate exceeds 0.35 MPa/s at pressures higher than 150 percent NWP, then either the container must be placed in series between the pressure source and the pressure measurement device, or the time at the pressure above a target burst pressure must exceed 5 seconds. The first option of placing the container in series between the pressure source and the pressure sensor ensures that the container will experience the pressure before the sensor, so there is no chance that the pressure sensor could read a pressure level that is not being experienced by the container. However, NHTSA did not propose the second option that the time at the pressure above the target burst pressure exceeds 5 seconds because it is unclear and difficult to enforce. It is not clear what pressure the "target burst pressure" is referring to since during the test, pressure will be increasing continuously.

Comments Received

Nikola stated that it do not want any changes to the procedure outlined in GTR No. 13. Luxfer Gas Cylinders commented that while the procedure is effective for cycle tests, it may not be feasible for burst testing due to the risk of damaging the pressure measurement device when placed after the container. It suggested either placing the container in series between the pressure source and the measurement device or including a five-second hold at the minimum burst pressure to ensure the container experiences the correct pressure. TesTneT agreed with NHTSA's approach of situating the container between the pressure source and the sensor but noted that this setup is not always practical or necessary. It mentioned that it has performed many burst tests with the sensor positioned before the container and have not encountered any issues, as the slow pressurization rate effectively eliminates pressure drop concerns. It also stated that holding the pressure for five seconds at the target burst pressure is clear and enforceable.

Glickenhaus supported NHTSA's decision not to adopt the second option from GTR No. 13, agreeing that the sensor should be placed in series between the pressure source and the container to maintain clear and objective testing. H2MOF recommended including the second method, noting that various industry standards specify a five-second hold at the target burst pressure. Newhouse commented that the five-second hold allows time for the pressure to equalize inside the container, ensuring accurate readings in cases where flow restrictions may be present. FORVIA stated that the "target burst pressure" should be understood as the minimum burst pressure. It suggested keeping the pressurization rate below 0.35 MPa/s at pressures exceeding 150 percent NWP or placing the container in series between the pressure source and the sensor, maintaining the wording of GTR No. 13.

Auto Innovators stated that is not practical for all designs to have

[18] The increase from five days to 15 days is intended to give manufacturers additional time to respond to NHTSA's request.

containers placed in series between pressure source and pressure measurement device. It requested an alternative method be provided. It also stated that the pressure pulsations are small to moderate compared to the absolute pressure level.

Agency Response

Consistent with GTR No. 13, NHTSA proposed that ''If the rate exceeds 0.35 MPa per second at pressures higher than 1.50 times NWP, then the container is placed in series between the pressure source and the pressure measurement device.'' GTR No. 13 also provides the alternative option that ''the time at the pressure above a target burst pressure exceeds five seconds.'' As discussed in the NPRM, NHTSA did not select this latter option because it is unclear.[19] A five-second hold period may be feasible for manufacturers that are ''targeting'' a particular burst pressure. In such a case, manufacturers can simply pressurize the container to the ''target'' pressure and hold for five seconds. NHTSA, however, will need to determine an unknown burst pressure for the container. Since there is no ''target'' burst pressure stated in the test procedure, the pressure inside the container is increased continuously until the container bursts. It is not possible to hold for five seconds at each and every pressure level that occurs during a burst test. The commenters did not provide any explanation regarding how, with continuously increasing pressure, any single specific pressure could be considered to have been held for five seconds. Instead, NHTSA has selected to use only the option to put the container in series between the pressure source and the measurement device. This way the container can be pressurized continuously until it bursts, and the container's burst pressure can be determined without prior knowledge of a target burst pressure.

Additionally, a configuration where the container is placed in series between the pressure source and the pressure measurement device can be achieved regardless of container design and does not necessitate alternative methods for different container designs. For example, a pressurization setup that includes a T-fitting, through which the container connects to both the pressure source and to a line leading to the pressure measurement device, in which the line leading to the pressure measurement device is equal in length to or longer than the connection from the container to the T-fitting, would meet the requirement for the container to be placed in series between the pressure source and the pressure measurement device. This configuration ensures that the container experiences all pressure increases as or before the sensor records them, accurately reflecting the container's pressurization level. Furthermore, the maximum allowable pressurization rate of 1.4 MPa/s for pressures exceeding 150 NWP provides adequate time for the pressure measurement device to capture accurate pressure readings during pressurization without premature or unrepresentative measurements.

c. Number of Cycles for the Baseline Initial Pressure Cycle Test for Containers on Light and Heavy Vehicles

Background

NHTSA proposed 7,500 as the number of cycles in the baseline initial pressure cycle test for which the container does not leak nor burst for light vehicles. To ensure the container leaks before bursting after reaching the maximum service life, the container is pressure cycled beyond the 7,500 cycles (representing maximum service life) until either a container leak occurs without burst or the container does not leak nor burst for up to a maximum of 22,000 hydraulic pressure cycles. In accordance with GTR No. 13 Phase 2, NHTSA proposed that heavy vehicle containers to neither leak nor burst for 11,000 hydraulic pressure cycles, and also to leak without burst (or neither leak nor burst) beyond the 11,000 hydraulic pressure cycles up to a maximum of 22,000 pressure cycles. As discussed in the NPRM, these number of cycles are based on a service life for light and heavy vehicles of 25 years.[20] This service life, number of hydraulic pressure cycles representing the maximum service life for which the container is required to not leak nor burst, and the number of pressure cycles beyond that representing maximum service life of the container for which the container is required to leak without burst or not leak nor burst at all are summarized in Table 1 for light and heavy vehicles.

TABLE 1—SERVICE LIFE AND NUMBER OF CYCLES IN THE BASELINE HYDRAULIC PRESSURE CYCLE TEST FOR LIGHT AND HEAVY VEHICLES

Vehicle type	Service life (years)	Number of cycles representing maximum service life for which the container does not leak nor burst	Numbe of cycles for which the container leaks without burst, or does not leak nor burst
Light	25	7,500	7,501–22,000
Heavy	25	11,000	11,001–22,000

NHTSA sought comment on the proposed number of cycles in Table 1. NHTSA also sought any additional data available related to vehicle life, lifetime miles travelled, and number of lifetime fuel cycles.

Comments Received

Several commenters provided feedback on the proposed number of pressure cycles in Table 1 of the NPRM. Nikola expressed agreement with the approach outlined, while Luxfer Gas Cylinders also stated that the cycle values were appropriate. Auto Innovators supported the approach and suggested that it would be more straightforward to define the number of cycles beyond the maximum service life as double the number of cycles for which the container does not leak nor burst. It stated that specifying 15,000 cycles for light vehicles and 22,000 cycles for heavy vehicles would be sufficient.

H2MOF, however, recommended a significantly lower cycle count, suggesting that 1,500 cycles as recommended by the USDOE would be more appropriate. It calculated that at

[19] *See* 89 FR 27511 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[20] *See* 89 FR 27513 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

300 miles per fill, this would result in 450,000 miles of service. TesTneT commented that while light vehicles may experience fewer fill cycles than heavy vehicles, factors such as partial fill cycles should be considered. It stated that the industry is not particularly concerned with fatigue cracking, as no fuel cylinder in CNG or hydrogen service has experienced this issue. Additionally, it noted that there is little cost or weight savings in reducing the cycle numbers and suggested aligning with GTR No. 13 cycle numbers.

FORVIA commented that the proposed numbers were conservative but reasonable. It indicated that these cycle numbers would cover all vehicle service life expectations and that containers could handle these cycles without issue. Therefore, it supported keeping the table as it is.

Agency Response

NHTSA is maintaining the number of cycles of the baseline initial pressure cycle test as proposed in the NPRM and listed in Table-1 above. NHTSA is not lowering the number of cycles for which the light vehicle container leaks without burst, or does not leak nor burst, to 15,000. Because the potential harm from a potential burst would be catastrophic, the number 22,000 was selected to both exceed extreme on-road vehicle lifetime range and promote global harmonization with GTR No. 13, as requested by commenters, and therefore there is no need to lower this number of cycles. As discussed in the NPRM, 22,000 cycles simulate over 6 million miles of driving, which is well beyond extreme vehicle lifetimes. The use of 22,000 cycles ensures that containers leak before bursting in all extreme cases.[21]

The comment regarding a 1,500-cycle recommendation from USDOE appears to be referring to technical performance targets for CHSS published by USDOE.[22] However, performance targets are not the same as safety standards. Performance targets are goals for how a system performs under optimal conditions, whereas safety standards are designed to protect users by minimizing risks and preventing harm in hazardous or sub-optimal conditions. Therefore, NHTSA is not lowering the number of cycles for the baseline initial pressure cycle test to 1,500.

d. Details of the Baseline Initial Cycle Test for Containers on Light and Heavy Vehicles

(1) Leak Before Burst and Sustaining a Visible Leak for 3 Minutes

Background

A burst may be preceded by an instantaneous moment of leakage, especially if observed in slow motion. Therefore, NHTSA proposed a minimum time of 3 minutes to sustain a visible leak before the test can end successfully due to ''leak before burst.'' NHTSA sought comment on this additional requirement.

Comments Received

Luxfer Gas Cylinders commented that NHTSA's proposed wording regarding the number of hydraulic pressure cycles is unclear. It noted that the phrasing ''neither leak nor burst'' contradicts itself by allowing leakage after 11,000 cycles but also stating neither leakage nor bursting should occur. It suggested the wording should be revised to state: ''The cylinder shall be allowed to leak, but not burst, beyond the 11,000 cycles up to a maximum of 22,000 pressure cycles.'' Luxfer also expressed concerns about the 3-minute sustained leak requirement, stating that most pressure equipment is designed to shut off when detecting pressure loss, making it difficult to hold a leak under pressure for three minutes. It proposed alternative wording to state that containers should fail by leakage but not rupture.

H2MOF raised concerns about the proposed 3-minute hold requirement for a visible leak, stating that if the pressure vessel leaks, the pump may not be able to maintain pressure, potentially causing the test to abort.

Nikola disagreed with NHTSA's proposal, commenting that leak-before-burst is not currently a requirement and that the term implies the container should leak and never burst at the end of its life.

FORVIA also disagreed with the 3-minute sustained leak requirement and recommended keeping the test procedure harmonized with GTR No. 13. It questioned the justification for the 3-minute requirement and noted that the behavior described, where a burst is preceded by leakage, is extremely improbable. It suggested that pressure should be allowed to drop below a certain level instead of imposing a time-based requirement, as this behavior is unknown in its experience.

TesTneT commented that the 3-minute sustained leak requirement changes the test from a leak-before-burst test to a stress rupture test. Based on its 35 years of experience performing leak-before-burst testing, it stated it has never encountered an issue distinguishing between a leak and a burst. TesTneT also referred to NHTSA's mention of observing leaks in slow motion and suggested that it is unnecessary to observe the location of failure during testing. It recommended maintaining the current wording in GTR No. 13 without any changes.

Agency Response

The requirements regarding the number of cycles for which a container shall not leak nor burst, and thereafter shall not burst are clarified in the proposed FMVSS No. 308 S5.1.1.2. The proposed S5.1.1.2 clearly specifies the number of cycles for which a container shall not leak nor burst and thereafter the number of cycles for which the container shall not burst. The number of cycles specified is dependent on the GVWR of the vehicle under test.

Based on the comments, however, NHTSA is removing the statement about sustaining a visible leak for three minutes before the test can end successfully due to ''leak before burst.'' Instead, the final rule simply states that if a leak occurs while conducting the test as specified in S5.1.1.2(a)(2) or S5.1.1.2(b)(2), the test is stopped and not considered a failure. Test labs will not observe the baseline initial pressure cycling test in slow motion and therefore it will be clear to the test lab whether the test has resulted in leakage or in a burst.

NHTSA also made a clerical correction to S6.2.2.2(e) to remove the word ''container,'' such that S6.2.2.2(e) reads ''The manufacturer may specify a hydraulic cycling profile within the specifications of S6.2.2.2(c).''

(2) Effect of the Cycling Profile

Background

NHTSA proposed a maximum hydraulic pressure cycle rate of five to ten cycles/minute for the baseline initial pressure cycle test. This rate was selected to allow for efficient compliance testing. Actual fueling cycles for hydrogen vehicles occur more slowly. Therefore, the container manufacturer may specify a hydraulic pressure cycle profile that will prevent premature failure of the container due to test conditions outside of the container design envelope. NHTSA sought comment on cycling profiles and whether the pressure cycling profile

[21] *See* 89 FR 27512 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[22] *See https://www.energy.gov/eere/fuelcells/doe-technical-targets-onboard-hydrogen-storage-light-duty-vehicles.*

will significantly affect the test result. NHTSA sought comment on more specifics of what manufacturers should be allowed to specify regarding an appropriate pressure cycling profile for testing their system.

Comments Received

Luxfer Gas Cylinders stated that the maximum cycle rate of 10 cycles per minute specified in GTR No. 13 is rarely approached in testing, noting that Luxfer uses 4 cycles per minute for larger containers. Auto Innovators commented that cycle rates and profiles do affect container performance, and manufacturers should be allowed to specify these parameters, as unrealistic testing conditions could lead to failures not representative of actual service. It suggested that NHTSA consider aligning with GTR No. 13 Phase 2, which specifies a maximum of 10 cycles per minute. It also stated that the pressure cycling profile has not been seen to significantly affect test results and that manufacturers generally cycle as quickly as is safe and practical.

H2MOF agreed with NHTSA that the cycling profile can impact test results depending on materials and design margins, emphasizing the importance of the number of cycles and pressure limits. It supported allowing manufacturers to specify pressurization and depressurization rates, as well as hold times.

TesTneT, drawing on over 35 years of experience, disagreed with the idea that cycling profiles affect test results, stating that no evidence supports this concern and criticizing the Powertech report referenced by NHTSA. It also noted that GTR No. 13 allows manufacturers to specify any cycle profile as long as it stays within the 10 cycles per minute limit.

Nikola commented that the defueling or unloading phase of the pressure cycle can impact container life, supporting the idea that manufacturers should be allowed to specify an appropriate profile. HATCI recommended that NHTSA fully harmonize with the GTR No. 13 Phase 2 requirement where the container is cycled less than or equal to 10 cycles per minute.

Agency Response

NHTSA is maintaining the maximum hydraulic pressure cycle rate of 10 cycles/minute for the baseline initial pressure cycle test, consistent with GTR No. 13. However, NHTSA will remove the lower cycling limit of 5 cycles per minute. As a result, the cycling rate may be any rate up to 10 cycles per minute. This change will accommodate larger containers which may take longer to cycle.

While some commenters stated that the cycling profile is inconsequential, others stated the profile can have an effect for some container designs. NHTSA acknowledges that the cycling profile may affect the test result for some containers. As a result, NHTSA will maintain the specification that manufacturers may specify a pressure cycling profile for testing their system. The manufacturer's specifications will need to be within the above cycling rate range and the other conditions specified in FMVSS No. 308 S6.2.2.2(c). At NHTSA's option, NHTSA will cycle the container within 10 percent of the manufacturer's specified cycling profile.

8. Test for Performance Durability

Background

The test for performance durability addresses impact (drop during installation and/or road wear), static high pressure from long-term parking, over-pressurization from fueling and fueling station malfunction and environmental exposures (chemicals and temperature/humidity). These stresses are compounded in a series is because a container may experience all of these stresses during its service life, and the safety need for a hydrogen system remains an issue for the vehicle's entire service life.

Comments Received

Luxfer Gas Cylinders commented that the verification tests for performance durability, on-road performance, and service-terminating performance in fire can be expensive, with costs exceeding $500,000, and potentially reaching $1,000,000 for larger containers. It asked whether NHTSA was aware of the high cost associated with conducting the proposed test program.

Quantum stated that completing the entire hydraulic and pneumatic test sequences with the on-tank-valves (OTV) installed would significantly increase the time required for testing. It explained that the small orifice size of OTVs restricts hydrogen or hydraulic fluid flow, thus extending the duration of each test sequence. Additionally, Quantum noted that other components of the CHSS, such as the TPRD, check valve, and shut-off valve, are tested separately from the container for cycle life. Since these valves are designed for gas use rather than continuous liquid flow, Quantum recommended removing the requirement for the OTV to be installed during testing.

Agency Response

NHTSA is aware of the test burden of the proposed tests. FMVSS establish minimum safety requirements and the FMVSS test procedures establish how the agency would verify compliance. However, manufacturers are not required to conduct the exact test in the FMVSS to certify their vehicles. The Safety Act requires manufacturers to certify that their vehicles meet all applicable FMVSS, and specifies that manufacturers may not certify compliance if, in exercising reasonable care, the manufacturer has reason to know the certificate is false or misleading. Manufacturers may use different types of tests or even simulations to certify their vehicles if they exercise reasonable care in doing so. In other words, manufacturers must ensure that their vehicles will meet the requirements of FMVSS No. 308 when NHTSA tests the vehicles in accordance with the test procedures specified in the standard, but manufacturers may use different test procedures and evaluation methods to do so.

Regarding Quantum's comment regarding testing with OTVs, the NPRM clearly specifies that only the container is subject to the requirements of the test for performance durability. The ''container,'' as defined the regulation, does not include closure devices. On the other hand, the test for expected on-road performance is conducted using hydrogen gas, and with the entire CHSS. The test for expected on-road performance therefore includes closure devices as part of the CHSS.

a. Proof Pressure Test

Background

GTR No. 13 states that a container that has undergone a proof pressure test in manufacture is exempt from this test. However, NHTSA may not know whether a container has undergone the proof pressure test. As a result, NHTSA proposed that all containers will be subjected to the proof pressure test as part of the test for performance durability. In the event that a proof pressure test is conducted during manufacture and as part of the tests for performance durability, the container would experience two proof pressure tests. NHTSA sought comment on conducting the proof pressure test on all containers.

Comments Received

Nikola opposed NHTSA's proposal to add the proof pressure test, stating that all onboard vehicle containers already undergo 100 percent proof pressure tests by manufacturers. Luxfer Gas Cylinders supported the decision to require all containers to undergo the proof pressure test as part of the test for performance durability. Auto Innovators disagreed, arguing that this would add unnecessary burden without additional safety benefits, as proof pressure testing is already required before service. It requested harmonization with GTR No. 13 Phase 2, which exempts containers that have already undergone proof testing during manufacturing.

Air Products suggested reviewing the proposed 30- to 35-second hold time, as it is significantly shorter than the 10-minute hold period specified in other industry standards. DTNA supported NHTSA's proposal for consistency, stating that all containers should undergo the proof pressure test regardless of prior testing during manufacturing. H2MOF opposed duplicating the test, stating that the additional high-stress cycle would negatively impact container performance during durability testing, as containers are already factory proof tested according to industry standards. HATCI also opposed the requirement, recommending the adoption of GTR No. 13 Phase 2, which exempts containers that have undergone proof pressure testing in manufacture.

TesTneT commented that proof pressure testing is conducted on all designs during production, not merely to confirm the container's resistance to over-pressurization, but to ensure consistency in manufacturing through measurements of elastic and permanent expansion. It suggested that if a design is damaged by a proof pressure test, it would become apparent during pressure cycle testing, thus rendering additional proof pressure testing unnecessary.

MEMA disagreed with the assumption that it is unknown whether a container has undergone proof testing during manufacturing, stating that some manufacturers conduct this test as part of the fabrication process, which is required under GTR No. 13. MEMA suggested adding language to FMVSS No. 308 allowing an exemption for containers that have already undergone proof pressure testing.

FORVIA acknowledged concerns about dual testing but suggested that NHTSA incorporate language from GTR No. 13 Phase 2, which allows for exemptions for duplicative proof tests, ensuring that all containers comply with FMVSS requirements. It further argued that if a second test is deemed not to significantly stress the container, the first test should also be considered adequate, as repeated pressurizations are unlikely to make a significant difference.

Agency Response

Based on the comments received, NHTSA is removing the proof pressure test. Commenters emphasized that 100 percent of all containers already undergo a proof pressure test during manufacturing, as part of standard production practices, and that requiring an additional proof pressure test would be redundant and burdensome without offering any additional safety benefits. Several commenters also raised concerns that subjecting a container to multiple proof pressure tests could introduce unnecessary stress and possibly affect the container's performance in subsequent tests.

After considering these comments, NHTSA agrees that a second proof pressure test would not provide additional safety benefits and could possibly impose undue stress on the container. As a result, the proof pressure test has been removed from the test for performance durability and the test for expected on-road performance, discussed below.

b. Drop Test

(1) Damage That Prevents Further Testing

Background

It is possible that the container could experience damage from the drop test that prevents continuing with the remainder of the tests for performance durability. This damage would prevent NHTSA from completing the evaluation of a container. To address this possibility, NHTSA proposed that if any damage to the container following the drop test prevents further testing of the container, the container is considered to have failed the tests for performance durability and no further testing is conducted.

Comments Received

HATCI commented that the inability to conduct subsequent tests after damage from the drop test should not automatically result in a failed test for performance durability. It suggested that additional containers should be used for further testing in such cases. As an example, it noted that deformation of an aluminum nozzle opening or valve connection after a drop test could prevent further testing, but this deformation does not necessarily indicate a lack of durability.

MEMA agreed with the single drop event specified in FMVSS No. 308 S5.1.2.2 but raised concerns about the potential for confusion regarding the damage criteria. It suggested that NHTSA clarify the wording to specify ''irrecoverable damage'' or ''damage that cannot be readily repaired'' to account for conditions where minor repairs, such as fixing damaged threads on a shut-off valve, could allow testing to continue.

Agency Response

NHTSA is maintaining the test requirements as proposed. Damage that prevents the continuation of testing under S6.2.3.4 must be considered a failure of the test for performance durability because the required test sequence cannot be completed in its entirety. NHTSA will not repair containers that are damaged during the drop test.

(2) Including Container Attachments for the Drop Test

Background

The drop test is a test in which container attachments may improve performance by protecting the container when it impacts the ground. Consistent with GTR No. 13, the drop test is conducted on the container with any associated container attachments. NHTSA sought comment on including container attachments for the drop test.

Comments Received

EMA stated that its members lack experience with dropping containers with attachments and are unsure of what qualifies as a ''container attachment'' for heavy vehicles, which often use multiple hydrogen containers. EMA commented that including attachments could make it difficult to ensure consistent impact locations during the test and recommended aligning FMVSS No. 308 with UN ECE R134, dropping the container without attachments unless the manufacturer opts to include impact-mitigating attachments. It suggested requiring the manufacturer to specify whether container attachments should be included for the test.

H2MOF supported conducting the drop test with container attachments, as it reflects real-life scenarios. Auto Innovators opposed including attachments unless they are permanently fixed to the container, arguing that removable attachments should be excluded to maintain flexibility and focus on container robustness. It noted that this approach aligns with GTR No. 13's intent to demonstrate container durability before installation.

Nikola commented that attachments should be included only if they are present during shipping; if added during vehicle assembly, they should be excluded. Luxfer Gas Cylinders opposed dropping containers with attachments, stating that the attachments are more likely to break than the container itself, and including them would complicate the test by introducing additional variables. It also noted that conducting the test with valves and PRDs attached would be impractical. TesTneT commented that if attachments are part of the container when it leaves production, they should remain for the drop test, as the test addresses potential handling damage before installation. FORVIA supported including container attachments in the drop test, referencing that their inclusion was a key factor in the development of GTR No. 13.

Agency Response

''Container attachments'' means non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be removed only with the use of tools for the specific purpose of maintenance or inspection. Container attachments do not refer to the structures that physically attach the container(s) to the vehicle. NHTSA will not rely on the manufacturer to specify container attachment configurations as this adds unnecessary complexity. NHTSA will simply purchase vehicles or replacement containers at the point of sale and conduct the drop test with any included, pre-installed container attachment that meet the definition for container attachments. Given that manufacturers are required to ensure that the vehicle is compliant at the time it is delivered to a dealer or distributor, manufacturers should take reasonable care to ensure they are not damaging or installing damaged containers into vehicles. If a container is sold at the point of sale without pre-installed container attachments, it will be tested as such.

(3) Center of Gravity

Background

In the case of a non-cylindrical or asymmetric container, the horizontal and vertical axes may not be clear. The proposed rule provided that in such cases, to conduct the drop test, the container will be oriented using its center of gravity and the center of any of its shut-off valve interface locations. The two points will be aligned horizontally (*i.e.,* perpendicular to gravity), vertically (*i.e.,* parallel to gravity) or at a 45° angle relative to vertical. The center of gravity of an asymmetric container may not be easily identifiable, so NHTSA sought comment on the appropriateness of using the center of gravity as a reference point for this compliance test and how to properly determine the center of gravity for a highly asymmetric container.

Comments Received

Auto Innovators supported NHTSA's proposal to align with GTR No. 13, stating that for asymmetric containers, orientation is typically determined when mounted in a vehicle. It added that technical information on the center of gravity could be provided to NHTSA if needed, noting that identifying the center of gravity, even for asymmetric shapes, is not particularly difficult. It advocated for maintaining the same specifications as GTR No. 13 Phase 2, which it found to be adequate.

DTNA agreed that using the center of gravity as a reference for the drop test was appropriate, as it ensures reproducibility in test results. It emphasized that determining the center of gravity accurately is critical for valid test outcomes. DTNA recommended that manufacturers provide this data to NHTSA prior to testing, allowing the agency to verify the information and request clarification if necessary. It highlighted that the accuracy of this reference point is essential, especially given the NPRM's proposal that failure of the drop test would result in failing the entire performance durability testing process.

H2MOF proposed that the center of gravity for a highly asymmetric container be determined using the container's geometric CAD file. Nikola suggested maintaining the current center of gravity definition as outlined in GTR No. 13.

TesTneT supported using the center of gravity as a reference, noting that it is a physical characteristic shared by all container designs, including asymmetric ones. It added that orientation for such containers could be determined when installed on a vehicle, and the center of gravity could be established in consultation with the manufacturer.

FORVIA stated that keeping the test procedure harmonized with GTR No. 13 was appropriate. It noted that identifying the center of gravity experimentally is not overly difficult, and it believed that fully asymmetric containers are unlikely to be prevalent in the market. Instead, it anticipated new rectangular designs with centers of gravity near their geometric centers, providing a good basis for testing.

Agency Response

The center of gravity is not defined in GTR No. 13, nor is a method provided for determine the center of gravity for an asymmetric container. NHTSA will not have access to CAD files for the container. Therefore, in the case of an asymmetric container, NHTSA will obtain the center of gravity from the manufacturer, similar to how it obtains the primary constituent and BP_O. The manufacturer shall specify, in writing, and within 15 business days, the center of gravity of the container. In the drop test, t container will be oriented using its center of gravity and the center of any of its shut-off valve interface locations. These two points will be aligned horizontally (*i.e.,* perpendicular to gravity), vertically (*i.e.,* parallel to gravity) or at a 45° angle relative to vertical, as specified.

c. Surface Damage Test

Background

NHTSA proposed the surface damage test based on GTR No. 13 Phase 2. The surface damage test applies cuts and impacts to the surface of the container. The surface damage test consists of two linear cuts and five pendulum impacts.

Comments Received

MEMA commented on the surface damage test proposed by NHTSA, stating that there were differences between the proposed requirements and those in GTR No. 13. It stated that in Section 6.2.3.3(a), for non-metallic containers, NHTSA's proposal includes two longitudinal saw cuts, which is consistent with GTR No. 13. However, it stated that NHTSA proposed different lengths and depths for the cuts without explaining why the differences are necessary or how they might improve test results.

MEMA further stated that NHTSA's proposal specifies the first cut as being 0.75 millimeters to 1.25 millimeters deep and 200 millimeters to 205 millimeters long, while the second cut, only required for containers affixed to the vehicle by compressing its composite surface (*i.e.,* clamped), would be 1.25 millimeters to 1.75 millimeters deep and 25 millimeters to 28 millimeters long. MEMA stated that GTR No. 13 requires two cuts regardless of how the container is affixed, with the first cut being at least 1.25 millimeters deep and 25 millimeters long toward the valve end, and the second cut being at least 0.75 millimeters deep and 200 millimeters long toward the opposite end.

MEMA stated that its members believe that the GTR No. 13 requirements provide a better minimum threshold and requested that NHTSA harmonize FMVSS No. 308 with GTR No. 13 on this matter. It also expressed concern that additional surface damage test requirements, as part of the already lengthy pressure cycling test, would increase the complexity, duration, and cost of the process without delivering more representative or improved results. MEMA proposed that FMVSS No. 308 S6.2.3.3. be revised to align with GTR No. 13.

Agency Response

The commenter appears to be referencing the original version of GTR No. 13. GTR No. 13 has undergone a comprehensive Phase 2 revision that was adopted at the 190th Session of WP.29 on June 21, 2023.[23] Phase 2 accomplished several goals, including strengthening test procedures for containers with pressures below 70 MPa. The U.S. voted in favor of adopting Phase 2 and the changes made to GTR No. 13 by Phase 2 are reflected in NHTSA's proposal for FMVSS Nos. 307 and 308 and in this final rule. GTR No. 13 Phase 2 states in section 6.2.3.3(a): ''Surface flaw generation: A saw cut at least 0.75 mm deep and 200 mm long is made on the surface specified above. If the container is to be affixed to the vehicle by compressing its composite surface, then a second cut at least 1.25 mm deep and 25 mm long is applied at the end of the container which is opposite to the location of the first cut.'' Regarding the difference in lengths of the proposed FMVSS No. 308 S6.2.3.3(a), these differences are simply due to tolerances added to FMVSS No. 308, as discussed below.

(1) Including Container Attachments

Background

The surface damage test is a test in which container attachments may improve performance by shielding the container from the impacts. For containers with container attachments, GTR No. 13 specifies that if the container surface is accessible, then the test is conducted on the container surface. Determining whether the container surface is accessible is subjective because ''accessible'' is not defined in the GTR and could have many potential meanings. Therefore, NHTSA did not propose a specification involving the accessibility of the container surface. Instead, NHTSA proposed that if the container attachments can be removed using a process specified by the manufacturer, they will be removed and not included for the surface damage test nor for the remaining portions of the test for performance durability. Container attachments that cannot be removed are included for the test. NHTSA sought comment on including container attachments for the surface damage test.

Comments Received

HATCI expressed agreement with NHTSA's proposal to remove container attachments, when possible, and to exclude them from the surface damage test. Auto Innovators recommended harmonizing with GTR No. 13, supporting the removal of attachments if specified by the manufacturer, and including non-removable attachments, as doing so ensures the test is conducted on the container's pressure-bearing chamber. H2MOF agreed that non-removable container attachments should be included in the test.

Luxfer Gas Cylinders commented that containers can be used in various vehicle systems with different attachments, making it impractical to test each type of attachment. It supported testing containers without attachments if they can be removed, adding that the drop test and the four-minute hold at 180 percent NWP are the primary design drivers, and it is unnecessary to include attachments in any tests. TesTneT stated that pendulum impacts do not affect the integrity of composite containers and were originally intended to test protective coatings. It recommended including attachments in the test if these attachments are designed to protect the container surface from road conditions. FORVIA requested keeping non-removable attachments in the surface damage test, noting that these attachments were introduced in GTR No. 13 due to the surface damage test.

Agency Response

NHTSA is maintaining the surface damage test as proposed. If the container attachments can be removed using a process specified by the manufacturer, they will be removed and not included for the surface damage test nor for the remaining portions of the test for performance durability. Testing the container without its container attachments is representative of a situation in which installation personnel remove the container attachments and fail to re-install them before the container enters service. Additionally, since the goal of a surface damage test is to test the surface, it makes sense to remove the container attachments that are capable of being removed. While NHTSA has chosen to keep container attachments on for other tests (*e.g.* the drop test, if the container attachment is pre-installed and meets the definition of container attachment), the surface damage test is different enough to warrant a deviation from that practice. Container attachments that cannot be removed are included for the test.

If different vehicles require different configurations of container attachments, each configuration would be subject the requirements separately. If some of the configurations have removable container attachments, those container attachments would be removed. If some configurations have non-removable container attachments, those container attachments would remain in place during the surface damage test.

(2) Exempting All-Metal Containers

Background

GTR No. 13 exempts all-metal containers from the linear cuts. NHTSA's proposal included this exemption, but NHTSA sought comment on whether another objective and practicable procedure exists for evaluating surface abrasions that could apply to all containers, such as, for example, the application of a defined cutting force to the container surface.

Comments Received

TesTneT commented that its experience with CNG cylinders has shown that steel cylinders are resistant to abrasion damage of the magnitude proposed for composite containers. It noted that developing a performance test to simulate defect dimensions as outlined in GTR No. 13 would be complicated, involving variables such as the shape, angle, and force of impact. Since surface abrasions do not cause failure in thinner-walled CNG cylinders, it suggested such abrasions would not pose a problem for hydrogen containers. Nikola and H2MOF both agreed with the exemption for all-metal containers from the linear cuts.

Auto Innovators supported the proposed exemption for metal containers and stated that requiring a test for a defined cutting force would add unnecessary regulatory burden. It emphasized that container manufacturers should provide sufficient technical information for compliance purposes. Verne, Inc. recommended extending the exemption to all-metal container attachments as well, noting that metal is resistant to scratches and cuts, and flaw cut depths may exceed the wall thickness of metal attachments.

Luxfer Gas Cylinders raised the concern that containers could experience cuts during service, such as from poorly fitted brackets. It suggested that metal containers with walls thin enough to be penetrated by cuts would be unsuitable for high-pressure vehicle

[23] A copy of GTR No. 13 as updated by the Phase 2 amendments is available at *https://unece.org/transport/documents/2023/07/standards/un-global-technical-regulation-no-13-amendment-1.*

fuel systems and recommended a more clearly defined test instead of a blanket exemption. FORVIA requested that the test procedure remain harmonized with GTR No. 13, noting that GTR No. 13 sets minimum requirements. It asked for clear justification if flaws in metallic containers are considered a concern and suggested discussing this issue in GTR No. 13 phase 3.

Agency Response

NHTSA is maintaining the exemption from the linear cuts for all-metal containers. The commenters did not provide sufficient information regarding how to conduct an alternative test with a defined cutting force applied to the metal container surface. Moreover, as stated by the commenters, metal containers are resistant to abrasions so this form of surface damage is not expected to be a significant safety concern. NHTSA is not extending the exemption to all-metal container attachments, however. Doing so would add complexity to the testing process where some container attachments would be treated differently from others. Furthermore, container attachments may be in place to protect the containers from abrasions and other surface damage, so the container attachments themselves should be able to tolerate surface damage.

The global community also considered this issue in developing GTR 13 and found that an exemption for-all metal containers was appropriate based on challenges with an adequate test procedure. Accordingly, both harmonization and practical challenges favor exempting all-metal containers from the linear cuts at this time. However, NHTSA has robust enforcement authority to address defects that pose an unreasonable risk to safety, including in all-metal containers. NHTSA will continue to monitor the state of the industry and will revise the standard in a future rulemaking as necessary.

(3) Applying Impacts on the Opposite Side vs. a Different Chamber

Background

In accordance with GTR No. 13, NHTSA specified the pendulum impacts ''on the side opposite from the saw cuts.'' For containers with multiple permanently interconnected chambers, GTR No. 13 specifies applying the pendulum impacts to a different chamber to that where the saw cuts were made. However, the agency did not propose this distinction for pendulum impact location for containers with multiple permanently interconnected chambers because NHTSA was concerned that it may be less stringent than when impacts are to the same chamber where the cuts were applied. NHTSA sought comment on whether applying the impacts to the opposite side of the same chamber that received the saw cuts may be more stringent than applying the impacts to a separate chamber, and whether including the specification as written in GTR No. 13 would reduce stringency for containers with multiple permanently interconnected chambers relative to containers with a single chamber.

Comments Received

H2MOF supported the approach in GTR No. 13, stating that the likelihood of both saw cuts and pendulum impacts affecting the same chamber is extremely low. HATCI supported NHTSA's proposal to harmonize with the GTR No. 13 surface damage test but recommended also adopting the GTR No. 13 requirement to apply the pendulum impact to a different chamber when multiple chambers are present. While acknowledging NHTSA's concerns, HATCI recommended harmonization with GTR No. 13 Phase 2 specifications.

Auto Innovators supported adopting the GTR No. 13 requirements and commented that applying impacts to the same chamber does not make the test more stringent than performing the impacts on separate chambers. TesTneT stated that pendulum impacts are designed to puncture protective coatings or resin gel coats but do not affect the structural integrity of the composite reinforcement. It argued that there is no reason to deviate from GTR No. 13 since stringency is not an issue.

MEMA members also supported the procedure outlined in GTR No. 13 and did not see the need for modifications. MEMA encouraged NHTSA to fully align with GTR No. 13 for the pendulum impact portion of the surface damage test. FORVIA echoed the recommendation to align with GTR No. 13 Phase 2, stating that different specifications based on chamber type could introduce confusion in testing. It added that there is no evidence suggesting changes in the surface cut and pendulum impact locations would impact safety and recommended following the industry standard until further research is conducted. FORVIA also commented that combining surface flaws with pendulum impacts and chemical exposure in testing is unnecessary since such damage combinations are highly improbable during service life.

Agency Response

Based on the comments received, in the case of a container with multiple permanently interconnected chambers, NHTSA will specify the impacts on the surface of a different chamber. NHTSA is convinced that applying the impacts to a different chamber is equivalently stringent to applying the impacts on the opposite side of a single chamber. NHTSA agrees that the pendulum impacts were not intended to be compounded in close proximity with the surface cuts as would occur if both types of damage were applied to a single small chamber of a multi-chamber container. FMVSS No. 308 S6.2.3.3(b) has been updated to reflect this change.

d. Chemical Exposure and Ambient Pressure Cycling Test

Background

The chemical exposure test is a test in which container attachments may improve performance by shielding the container from the chemical exposures. The proposed rule provided that container attachments will be included in the chemical exposure test unless they were removed prior to the surface damage test. NHTSA sought comment on including container attachments for the chemical exposure test.

Comments Received

Auto Innovators supported harmonizing these requirements with GTR No. 13, commenting that if attachments can be removed, they should be removed before testing, but if they cannot be removed, they should be included in the test. Auto Innovators added that if chemicals can reach the surface of removable attachments, then the surface should also be exposed to chemicals. EMA recommended modifying FMVSS No. 308, S6.2.3.4 to state that each of the five areas preconditioned by pendulum impact should be exposed to a different solution. H2MOF agreed that container attachments may be present during the chemical exposure test, as they are present during regular service. TesTneT commented that any attachments included in a vehicle installation should also be included in the chemical exposure test, as these attachments might protect the container surface from road conditions. FORVIA stated that non-removable container attachments should be allowed in the chemical exposure test, noting that the test contributed to the introduction of container attachments in GTR No. 13.

Agency Response

NHTSA is maintaining the inclusion of container attachments in the chemical exposure test unless they were removed prior to the surface damage test, as discussed above. NHTSA is not including 'EMA's proposed edit specifying that a different solution is applied to each preconditioned area. There is no need to specify that a different solution is applied to each area. This language is consistent with GTR No. 13, which specifies that each of the five areas ''is exposed to one of five solutions.''

e. High Temperature Static Pressure Test

Background

Consistent with GTR No. 13, the high temperature static pressure test involves holding the container for 1000 hours at 85 °C and 125 percent NWP.

Comments Received

Auto Innovators stated that it supports NHTSA's proposal to harmonize these requirements with GTR No. 13.

Agency Response

NHTSA is maintaining the high temperature static pressure test as proposed.

f. Extreme Temperature Pressure Cycling Test

Background

Consistent with GTR No. 13, the extreme temperature pressure cycling test involves pressure cycling at extreme temperatures and simulates operation (fueling and defueling) in extreme temperature conditions. The test for performance durability uses the same number of cycles as required by the baseline initial cycle test before leakage. This is a total of 7,500 cycles for light vehicles or 11,000 cycles for heavy vehicles. The extreme temperature pressure cycling test consists of 40 percent of these total cycles, of which half (20 percent of the total) are conducted at −40 °C and the other half are conducted at 85 °C.

Comments Received

Quantum Fuel Systems, LLC commented on an ambiguity in GTR No. 13 related to the number of cycles required for the extreme cold and hot tests. It stated that clarification is needed to determine whether the total number of cycles for the extreme temperature pressure cycling test should be 22,000 or 11,000. Quantum also proposed edits to Table 6 of GTR No. 13 to address this ambiguity. Auto Innovators expressed support for NHTSA's proposal to harmonize these requirements with GTR No. 13.

Agency Response

NHTSA is maintaining the extreme temperature pressure cycling test as proposed. The proposed requirement clearly specifies that ''the container is pressure cycled in accordance with S6.2.3.6 for 40 percent of the number of cycles specified in S5.1.1.2(a)(1) or S5.1.1.2(b)(1) as applicable.'' FMVSS No. 308 S5.1.1.2(a)(1) and S5.1.1.2(b)(1) clearly list 7,500 and 11,000 cycles, respectively. The number of cycles used for the extreme temperature pressure cycling test is not based on 22,000 cycles.

g. Residual Pressure Test

Background

Consistent with GTR No. 13, the residual pressure test requires pressurizing the container to 180 percent NWP and holding this pressure for 4 minutes.

Comments Received

Auto Innovators expressed support for NHTSA's proposal to harmonize the residual pressure test requirements with GTR No. 13. Agility commented that the residual pressure test requirement should remain at 180 percent NWP, regardless of BP_O. It added that manufacturers would still have incentives to limit performance degradation due to its effects on cost and repeatability.

Agency Response

NHTSA is maintaining the residual pressure test as proposed. The requirement of 180 percent NWP with a four-minute hold period is independent of BP_O. The residual pressure test does not address degradation rate. Degradation rate is addressed by the residual strength burst test, discussed in the next section.

h. Residual Strength Burst Test

Background

Consistent with GTR No. 13, the residual strength burst test involves subjecting the end-of-life container to a burst test identical to the baseline initial burst pressure test. The burst pressure at the end of the durability test is required to be at least 80 percent of the BP_O specified on the container label. This requirement effectively controls the burst pressure degradation rate throughout an extreme service life.

Comments Received

Auto Innovators expressed support for NHTSA's proposal to harmonize these requirements with GTR No. 13. Luxfer Gas Cylinders commented on the likelihood of a rapid rate of degradation in end-of-life burst pressure, stating that there is a ''vanishingly small likelihood that this would occur.'' It noted that no manufacturer would produce containers with a BP_O double the specified minimum requirement and questioned what mechanism would cause such degradation, suggesting that only severe damage could lead to it, in which case the container would be removed from service.

Agency Response

NHTSA is maintaining the residual strength burst test as proposed. As the commenter states, it is unlikely that a container would have such high degradation as to fail to maintain at least 80 percent of BP_O at its end-of-life burst pressure. However, the residual strength burst test is straightforward to pass for containers that do not experience severe burst strength degradation in service. Therefore, including this requirement does not significantly challenge container design or create an unnecessary burden on manufacturers. Instead, it simply prevents the possibility of a poor-performing container from posing a serious risk to safety due to severe burst strength degradation while in service.

9. Test for Expected On-Road Performance

Background

Consistent with GTR No. 13, NHTSA proposed the test for expected on-road performance. The proposed test is closely consistent with the industry standard SAE J2579_201806, ''Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles.'' [24]

Comments Received

Luxfer Gas Cylinders commented that the proposed test is time-consuming and expensive to conduct. It stated that for large 800 liter containers, there is only one test lab that can conduct the test. It stated that the cost of testing exceeds $500,000. It questioned if NHTSA proposing to evaluate containers using the proposed test procedures.

Agency Response

NHTSA is aware of the burden of the proposed test. FMVSS establish minimum safety requirements and the FMVSS test procedures establish how the agency would verify compliance. However, manufacturers are not

[24] SAE J2579_201806. Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles. *https://www.sae.org/standards/content/j2579_201806/.*

required to conduct the exact test in the FMVSS to certify their vehicles. The Safety Act requires manufacturers to certify that their vehicles meet all applicable FMVSS, and specifies that manufacturers may not certify compliance if, in exercising reasonable care, the manufacturer has reason to know the certificate is false or misleading. A manufacturer may use different types of tests or even simulations to certify its vehicles if the manufacturer exercises reasonable care in doing so. In other words, manufacturers must ensure that their vehicles will meet the requirements of FMVSS No. 308 when NHTSA tests the vehicles in accordance with the test procedures specified in the standard, but manufacturers may use different test procedures and evaluation methods to do so. Additionally, as hydrogen vehicles become more common, the number of test labs performing this test will likely increase, and the costs associated with testing will likely come down as a result.

a. Proof Pressure Test

Background

Consistent with GTR No. 13, NHTSA proposed a hydrogen-gas proof pressure test at the start of the test for expected on-road performance.

Comments Received

Auto Innovators expressed support for NHTSA's proposal to harmonize the proof pressure test with GTR No. 13. Agility questioned the purpose of performing the proof test with hydrogen instead of using a hydraulic testing method, commenting that the proposed approach seems unnecessarily high-risk and costly.

Agency Response

For the reasons discussed above for the test for performance durability, NHTSA is removing proof pressure testing from FMVSS No. 308. Since 100 percent of all containers already undergo the proof pressure test during manufacture, including this test would be redundant and unnecessary.

b. Ambient and Extreme Temperature Gas Pressure Cycling Test

Background

NHTSA proposed an ambient and extreme temperature gas pressure cycling test that is closely consistent with GTR No. 13.

Comments Received

Auto Innovators expressed support for NHTSA's proposal to harmonize the ambient and extreme temperature gas pressure cycling test with GTR No. 13, stating that tests should be conducted with temperature and pressure control devices in place, or that equivalent measures should be used to strictly adhere to the parameters. HATCI requested that NHTSA either harmonize with GTR No. 13 Phase 2 requirements or ensure strict adherence to proposed pressure and temperature ranges during testing. HATCI noted that container pressure should not exceed 100 percent state of charge (SOC) and that the minimum pressure should be 2 MPa. Based on internal testing, HATCI commented that temperatures outside the specified operational range could lead to o-ring failures, resulting in leakage. It added that during low-temperature pneumatic tests, internal temperatures can drop below −40 °C, sometimes reaching −45 °C, which does not reflect real environmental conditions and is not considered in container design. HATCI also recommended that NHTSA test CHSS within the manufacturer's design limits or within a temperature range of −40 °C to 85 °C, with manufacturers responsible for providing design temperature data upon NHTSA's request.

Agency Response

NHTSA is maintaining the ambient and extreme temperature gas pressure cycling test as proposed. The ambient and extreme temperature gas pressure cycling test does not subject the container to external temperature conditions below −30 °C. Additionally, the ambient and extreme temperature gas pressure cycling test does not consider the internal temperature of the container; only the ambient temperature surrounding the container is controlled, along with the fuel delivery temperature and the initial system equilibration temperature. Neither GTR No. 13 nor by the commenters provide a method for monitoring the internal temperature of the container during cycling. Instead, the container must be able to withstand the internal temperatures that result from the pressure cycling series as specified. As discussed in the NPRM, the pressurization rates specified in Table 5 to S6.2.4.1(c) of FMVSS No. 308 are based on real-world refueling rates, and the temperatures specified during the test are also based on real-world conditions, so this test for expected on-road performance is representative of conditions that can occur in-service.[25]

[25] *See* 89 FR 27520 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

The other differences noted by HATCI are related to test tolerances, which are discussed below.

c. Extreme Temperature Static Gas Pressure Leak/Permeation Test

Background

NHTSA proposed the extreme temperature static gas pressure leak/permeation test consistent with GTR No. 13, except for the removal of the localize leak requirement in the proposed standard. The localized leak limit was removed because it is not objectively enforceable due to the subjective estimation of bubble sizes. NHTSA sought comment on not including the localize leak requirement during the extreme temperature static gas pressure leak/permeation test and specifically requested that if commenters believed it should be included, that they explain (1) how they believe it could be made more objective and (2) how specifically it would add to the standard's ability to meet the safety need.

Comments Received

Commenters provided diverse feedback on the proposed removal of the localized leak requirement from the extreme temperature static gas pressure leak/permeation test.

Nikola suggested that while the bubble requirement could be removed, the single-point leak rate should not be eliminated, and a mass spectrometer could be used by testing facilities instead. It also noted that numerous hydrogen performance test facilities that can evaluate localized leaks.

Luxfer Gas Cylinders stated that permeation rate measurements are well-established, typically involving the CHSS in an airtight container with surrounding gas content measured accurately. Luxfer supported the decision to remove the localized leak requirement.

Auto Innovators agreed with the decision not to include the localized leak test. Similarly, DTNA commented that the localized leak test was unnecessary because the full system permeation test evaluates the overall system. However, if a localized leak test were necessary, DTNA suggested replacing the bubble test with a concentration-based hydrogen leak limit of 0.5 percent, derived from standards applied to CNG and propane vehicles.

TesTneT described its method of using a gas chromatograph or mass spectrometer in an enclosed, temperature-controlled chamber for accurate permeation measurement. It also use a mass spectrometer to quantify leakage after locating potential leak sites with a soapy solution. TesTneT raised concerns about hydrogen permeation risks in enclosed spaces, pointing out that hydrogen can leak out over time, making it difficult to accumulate in dangerous amounts.

Newhouse commented that NHTSA's proposed permeation rate of 46 mL/L/h at 55 °C is unreasonably low and noted several issues, such as considering worst-case scenarios and ventilation assumptions. Newhouse suggested allowing a higher limit of 100 percent of the lower flammability limit (LFL), or 4 percent hydrogen in air, and questioned the use of 55 °C as a peak temperature, stating that a lower average would be more representative. Newhouse also recommended increasing the allowable permeation rate to 184 mL/L/h at 55 °C and noted that the probability of failure remains low, even with more conventional ventilation rates in garage spaces.

FORVIA acknowledged that different methods can accurately measure leakage and permeation and suggested that guidance on measurement could be provided outside the FMVSS text. It was open to considering localized leak requirements but noted that the submersion method, though simple, may require more accurate measurements near the limits. It indicated that omitting this test for field surveillance would be acceptable, as production containers typically exhibit far less leakage. H2MOF proposed exempting all-metal containers from the static gas leak/permeation test and suggested that procedures from industry standards be used for guidance.

Agency Response

NHTSA is maintaining the extreme temperature static gas pressure leak/permeation test as proposed, without the localized leak limit. The commenters did not provide any explanation for the safety need of the localized leak limit. Commenters did not provide any evidence that omitting the localized leakage requirement is less stringent when there is also an overall permeation limit applied to the CHSS as a whole.

Furthermore, commenters did not provide sufficient explanation of how, if included, the localized leakage limit could be made more objective. Some commenters suggested using analytical chemistry equipment such as mass spectrometers. However, these types of instruments are highly complex, and additional research would be needed by NHTSA before they could be used to objectively quantify a leak. Even if the agency determined that mass spectrometers were viable for detecting localized leaks, the agency would still need to consider the safety need being addressed by the requirement.

NHTSA is not changing the overall permeation rate of 46 mL/L/h based on the comments. This permeation limit is found in GTR No. 13 and is widely accepted by the industry as an appropriate permeation limit. Well-developed rationale for this limit is provided in GTR No. 13 and in the NPRM.[26] In particular, the conservative 25 percent LFL limit accounts for concentration non-homogeneities that may be present, and the choice of 55 °C is a worst-case temperature condition, not one that is expected to occur commonly. Permeation is higher at higher temperatures, so NHTSA considered this worst-case condition when evaluating the permeation limit. This permeation limit is also applied in the industry standard SAE J2579_201806. The commenters did not establish sufficient rationale for NHTSA to deviate from the established 46 mL/L/h.

NHTSA is not exempting CHSS with all-metal containers from the extreme temperature static gas pressure leak/permeation test. All-metal containers must demonstrate the same level of performance and safety as other containers. NHTSA is not replacing the proposed test with either of the standards recommended by H2MOF. The commenter did not establish any justification for why doing so would improve safety, nor did it provide any detailed information regarding the alternative standards.

d. Residual Pressure Test & Residual Strength Burst Test

Background

The residual pressure test and residual strength burst test are conducted in the same manner and for the same reasons discussed above for the test for performance durability.

Comments Received

Auto Innovators stated support for NHTSA's proposal to harmonize these requirements with GTR No. 13.

Agency Response

NHTSA is maintaining the residual pressure test and residual strength burst test as proposed.

[26] *See* 89 FR 27522 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

10. Test for Service Terminating Performance in Fire

Background

NHTSA proposed a fire test based closely on the GTR No. 13 Phase 2 fire test. The updates to the fire test by the IWG of GTR No. 13 Phase 2 focused on improving the repeatability and reproducibility across test laboratories. Two significant improvements to the fire test are (1) the use of a pre-test checkout procedure and (2) basic burner specifications. The pre-test checkout requires conducting a preliminary fire exposure on a standardized steel container to verify that specified fire temperatures can be achieved for the localized and engulfing fire segments of the test prior to conducting the fire test on a CHSS. During this pre-test checkout, the fuel flow is adjusted to achieve fire temperatures within the specified limits as measured on the surface of the pre-test steel container. The use of a pre-test steel container instead of an actual CHSS improves the accuracy and repeatability of the test because it avoids possible container material degradation that could affect the temperature measurements.

Comments Received

Luxfer Gas Cylinders commented that the recent changes introduced in GTR No. 13 regarding the fire test are ''excessive'' and do not enhance test performance. Luxfer stated that the pre-test using a steel container is only relevant when the steel container matches the size of the composite container being tested. For larger containers, such as those used in heavy vehicles, Luxfer stated that the pre-test becomes unnecessary. Luxfer and H2MOF both suggested that NHTSA consider adopting the Bonfire test from NGV 2 2019, ''Compressed natural gas vehicle fuel containers.''[27] Additionally, Luxfer expressed concerns about the increased costs of the new GTR No. 13 fire test. It questioned whether NHTSA intends to apply this test to containers that have been withdrawn from service.

Agility commented that the fire source and pre-test procedures in GTR No. 13 do not accurately represent vehicle fire scenarios, particularly for heavy applications. It highlighted that the fire source width is set at 500 mm regardless of the container's diameter and that the temperature requirements focus solely on the area beneath and directly on the container surface. Agility further pointed out the lack of

[27] *See https://webstore.ansi.org/standards/csa/csaansingv2019.*

requirements for measuring temperatures around the container, which is where remotely mounted PRDs are typically located.

Agency Response

NHTSA acknowledges the comments regarding the proposed fire test based on GTR No. 13 Phase 2 but does not find them persuasive enough to warrant any significant changes to the proposed test procedures. Specifically, the concern that the pre-test checkout using a steel cylinder is only relevant if it matches the size of the composite container is not valid. The pre-test checkout procedure is designed to ensure the consistency of fire temperature measurements, which can be achieved regardless of the difference in size between the pre-test container and the actual CHSS. The objective of the pre-test checkout is to verify the fire conditions produce the specified temperatures, which improves the accuracy and repeatability of the test across different laboratories.

Regarding the commenters' suggestions to adopt the fire test in NGV 2 2019, NHTSA is aware of ANSI NGV 2 2019, but the GTR No. 13 fire test remains more representative of real-world conditions. The proposed fire test procedure based on GTR No. 13 includes both localized and engulfing fire stages, which are designed based on actual vehicle fire data, as discussed in the NPRM.[28] The proposed fire test procedure is the most realistic fire test available that is representative of a range of possible real-world vehicle fires. The NGV 2 fire test does not provide the same level of comprehensiveness as the standard. The NGV 2 fire test does not include any pre-test procedures to improve repeatability and reproducibility, nor does it include a localized fire exposure. The fire test procedure, on the other hand, provides a rigorous, repeatable test that accounts for both localized and engulfing fire conditions, addressing various fire exposure scenarios. Due to the large volumes of hydrogen stored on hydrogen fueled vehicles, NHTSA maintains that the proposed fire test procedure is needed to ensure vehicles are designed with a high level of performance in fire conditions. NHTSA further notes that the pre-test checkout includes temperature specifications for the bottom, sides, and top of the pre-test container.

Regarding the concern about increased costs, vehicle manufacturers are already designing their vehicles to meet or exceed the requirements of the proposed fire test based on GTR No. 13, so NHTSA does not expect significant increased costs from implementing the proposed fire test. Regarding applying the requirements to containers that have been withdrawn from service, NHTSA purchases new vehicles at the point of sale for compliance testing. NHTSA does not conduct compliance testing on used vehicles or equipment.

a. Burner Specification

Background

To further improve test reproducibility, a burner configuration is defined with localized and engulfing fire zones. These specifications allow the fire test to be performed without a burner development program. NHTSA explained in the NPRM that it believes that the use of a standardized burner configuration is a practical way of conducting fire testing and should reduce variability in test results through commonality in hardware.[29] Flexibility is provided to adjust the length of the engulfing fire zone to match the CHSS length, up to a maximum of 1.65 m. The width of the burner, however, is fixed at 500 mm for all fire tests, regardless of the width or diameter of the CHSS container to be tested, so that each CHSS is evaluated with the same fire condition regardless of size. The length of the localized fire zone is also fixed to 250 mm for all fire tests. NHTSA sought comment on a specification for the burner rail tubing shape and size, which can affect the spacing between the nozzle tips.

Comments Received

MEMA expressed concerns that the burner specifications in FMVSS No. 308 S6.2.5.3 are more rigid than those in GTR No. 13, which specifies a larger burner assembly, allowing for the testing of larger hydrogen storage containers. MEMA suggested that the proposed limitations could create challenges for testing and qualifying hydrogen pressure vessels for the U.S. market, requesting that NHTSA to align more closely with GTR No. 13. MEMA also recommended revising the language in FMVSS No. 308 S6.2.5.2(c)(2) regarding nozzle orientation to avoid potential confusion and align with GTR No. 13, which targets the lowest elevation of the CHSS.

Auto Innovators recommended harmonizing with GTR No. 13, stating that industry standards already establish 1.65 meters as the length of the engulfing fire zone. Auto Innovators recommended maintaining the basic burner design from GTR No. 13. TesTneT commented that rails measuring 50 mm square, spaced at 100 mm, provide optimal nozzle tip spacing. It stated that the square rail is crucial for proper burner tip installation, and any deviation in rail size could reduce burner temperatures.

FORVIA emphasized the importance of maintaining equivalence with GTR No. 13, urging NHTSA to keep the burner configuration consistent with phase 2 of GTR No. 13. It cautioned that any changes to the burner specification could lead to ''serious dis-harmonization'' and result in the need for double testing for products sold across different regions.

Agency Response

In both GTR No. 13 and the proposed FMVSS No. 308, the burner width is between 450 millimeters and 550 millimeters in width. The additional length mentioned by TesTneT of 100 mm is intended to be a tolerance. Tolerances are discussed below. However, to ensure the maximum possible burner size consistent with GTR No. 13, FMVSS No. 308 S6.2.5.2(b) has been updated to allow the engulfing burner to extend up to a maximum of 1.75 meters.

NHTSA has determined there is no need to specify square burner rails. While this shape may be the most convenient shape for the burner rails, and test labs may prefer square rails, it may be possible to construct a burner using non-square rails. If such a burner were to meet all burner specifications and satisfy the prescribed temperature requirements, it would be considered an acceptable burner. Sufficient burner specifications, as well as the pre-test checkout procedure ensure the repeatability and reproducibility of the burner.

GTR No. 13 specifies that ''[t]he pre-test cylinder used for the pre-test checkout shall be mounted at a height of 100 ± 5 mm above the burner and located over the burner such that nozzles from the two centrally-located manifolds are pointing toward the bottom centre'' of the pre-test container. NHTSA similarly proposed mounting the pre-test container ''such that the nozzles from the two center rails are pointing toward the bottom center of the pre-test container.'' NHTSA is

[28] *See* 89 FR 27523 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[29] *See* 89 FR 27527 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

maintaining this language in the final rule. This specification is sufficiently objective to ensure repeatability and reproducibility of the test. Furthermore, a specification regarding ''elevation'' may be ambiguous, and has not been included. For the CHSS fire test, the CHSS will be positioned for the localized fire test by orienting the CHSS such that the distance from the center of the localized fire exposure to the TPRD(s) and TPRD sense point(s) is at or near maximum. NHTSA is maintaining this orientation in the final rule.

b. Additional Pre-Test Procedurs for Irregularly Shaped Containers

Background

GTR No. 13 specifies additional pre-test checkout procedures intended for irregularly shaped CHSS which are expected to impede air flow through the burner. These procedures involve constructing a pre-test plate having similar dimensions to the CHSS to be tested. A second pre-test check out is conducted using the pre-test plate and using the burner monitor thermocouples. If the burner monitor thermocouple temperatures do not satisfy the specified minimum temperatures, then the pre-test plate is raised by 50 mm, and a third pre-test checkout is conducted. GTR No. 13 specifies that this process is repeated until burner monitor thermocouple temperatures satisfy the required minimum temperatures. NHTSA considered this additional pre-test process and determined that it is unnecessary. The goal of the pre-test checkout is a repeatable and reproducible fire exposure among different testing facilities. NHTSA has determined there is no need for design-specific modification to the fire test procedure. Furthermore, the additional pre-test procedures add considerable complexity to the test procedure, and as a result could undermine the repeatability and reproducibility of the fire test. Therefore, NHTSA did not propose these additional pre-test procedures. NHTSA sought comment on this decision.

Comments Received

Auto Innovators generally agreed with NHTSA's decision to streamline pre-test procedures but suggested that clarification is needed to ensure that a repeat test is only required if the pre-test does not meet the specified requirements. It emphasized that incorrect pre-test temperatures could result in over or under testing of the CHSS, potentially leading to a false pass or failure.

FORVIA disagreed with NHTSA's decision, advocating for the retention of the existing pre-test procedures for irregularly shaped CHSS as specified in GTR No. 13. It stated that consistency across global markets is crucial to minimize discrepancies and ensure manufacturers follow uniform guidelines. FORVIA acknowledged that the additional pre-test procedures might add time but noted that they would likely reduce the need for retesting and avoid introducing variables that could compromise repeatability. It emphasized that GTR No. 13 procedures had been validated through significant work, including round robin testing, and stated that deviating from these standards could undermine the enforceability of failed tests.

HATCI also stated that the additional pre-test procedures for irregularly shaped CHSS are necessary, stating that a lack of uniform temperature distribution could negatively affect TRPD activation. It stressed the importance of ensuring proper testing for all CHSS designs and suggested that the repeatability and reproducibility of the test could be reassessed as more irregular containers are introduced. TesTneT, on the other hand, agreed with NHTSA's decision, stating that additional pre-test procedures are unnecessary.

Agency Response

NHTSA is not including additional pretest procedures for irregularly shaped containers. NHTSA conducted fire testing of large, irregularly shaped CHSS according to the proposed test procedure. The test was highly successful, with the CHSS TPRD activating within one minute of the ignition of the localize burner. The results of this testing are summarized in the test report ''GTR No. 13 Fire and Closures Tests.'' [30] These results indicate that additional design-specific procedures are not required and irregularly shaped CHSS can successfully complete the test for service terminating performance in fire. The use of the pre-test container is simply to verify the burner and is not intended to precisely match the size of the CHSS.

c. Pre-Test Container Length Compared to CHSS

Background

NHTSA conducted CHSS fire testing to verify the feasibility of the test for service termination performance in fire as proposed. In some cases during testing, temperatures measured at the burner monitor thermocouples did not satisfy the required minimum value for the burner monitor temperature during the engulfing fire stage (T_{minENG}).[31] NHTSA's testing indicated that the airflow during the pre-test may be different from that of the CHSS if the pre-test container length is substantially different from that of the CHSS to be tested. The difference in air flow between the two tests could cause differences in fire input to the CHSS compared to the pre-test container. Therefore, NHTSA recommended that for CHSS of length between 600 mm and 1650 mm, the difference in the length of the pre-test container and the CHSS be no more than 200 mm. NHTSA sought comment on whether this recommendation should be a specification for the pre-test container.

Comments Received

Several commenters disagreed with NHTSA's recommendation to specify a length difference between the pre-test container and the CHSS being tested. Nikola stated disagreement with the proposal, explaining that the pre-test is conducted according to GTR No. 13 and that additional specifications on length differences are unnecessary. TesTneT also commented that the pre-test container should align with GTR No. 13 and argued that since the burner system is uniform, there is no need to correlate the pre-test container's length with that of the CHSS. TesTneT added that observations regarding the influence of CHSS length on pre-test results were incorrect. Auto Innovators similarly disagreed, stating that the pre-test container's role is to verify the burner and is not directly related to the CHSS size.

FORVIA expressed opposition as well, recommending that NHTSA keep the test procedure equivalent to GTR No. 13. It emphasized that adding length specifications would increase both time and costs for pre-testing, while the existing GTR No. 13 requirements are sufficient to ensure reproducible conditions. FORVIA noted that the GTR No. 13 fire test procedure had been validated through extensive testing and

[30] See the report titled ''GTR No. 13 Fire and Closures Tests'' which can be found at: *https://downloads.regulations.gov/NHTSA-2024-0006-0002/attachment_4.pdf.* This report will also be submitted to the National Transportation Library. *https://rosap.ntl.bts.gov/.*

[31] T_{minENG} is calculated by subtracting 50 °C from the minimum of the 60-second rolling average of the average burner monitor temperature in the engulfing fire zone of the pre-test checkout.

provided significant improvements over previous testing methods for CNG and hydrogen containers.

Agency Response

NHTSA is not including any requirements regarding the difference in length for the pre-test container and the CHSS. The recommendation that for CHSS of length between 600 mm and 1650 mm, the difference in the length of the pre-test container and the CHSS be no more than 200 mm, will remain a recommendation for future test labs. Following this recommendation will not be required as part of the testing, and not adhering to the recommendation will not invalidate test results.

d. Pretest Checkout Frequency

Background

The pre-test checkout is performed at least once before the commissioning of a new test site. Additionally, if the burner and test setup is modified to accommodate a test of different CHSS configurations than originally defined or serviced, then repeat of the pre-test checkout is needed prior to performing CHSS fire tests. NHTSA sought comment on the frequency of conducting this pre-test checkout for ensuring repeatability of the fire test on CHSS.

Comments Received

Several commenters responded to NHTSA's inquiry about the frequency of the pre-test checkout for CHSS fire testing, with most agreeing that additional requirements were unnecessary if no modifications were made to the burner or test setup.

Auto Innovators agreed that a repeat of the pre-test checkout is necessary if the burner or test setup is modified but recommended that the pre-test be performed at the manufacturer's discretion if no modifications have occurred. HATCI similarly commented that the pre-test checkout should be performed at the manufacturer's discretion. Nikola stated that the frequency of the pre-test should be determined by the testing agency, in accordance with ISO 17025, ''General requirements for the competence of testing and calibration laboratories,'' accreditation requirements.

TesTneT referred to GTR No. 13, noting that the pre-test only needs to be conducted once to verify the burner setup, unless modifications are made. It emphasized that multiple pre-tests are unnecessary if the test stand remains unchanged between tests. FORVIA disagreed with adding additional requirements, requesting harmonization with GTR No. 13 and stating that the pre-test checkout before commissioning and following modifications is sufficient. It suggested that any additional pre-test checkouts should be at the discretion of the test site operator, but recommended not adding further requirements to FMVSS.

Agency Response

NHTSA reiterates that the pre-test checkout will be performed at least once before the commissioning of a new test site and when the burner or test setup is modified to accommodate different CHSS configurations. NHTSA believes this approach ensures the consistency and reliability of testing procedures. No changes are being made to the proposed requirements based on the comments.

e. Thermocouple Positioning

Background

NHTSA proposed positioning the three burner monitor thermocouples 25 mm below the pre-test container. Since these thermocouples are intended to monitor the burner, an alternative would be to position these thermocouples relative to the burner itself. NHTSA sought comment on whether it is preferable to position the burner monitor thermocouples relative to the pre-test container or relative to the burner.

Comments Received

Commenters generally supported harmonizing the positioning of the burner monitor thermocouples with GTR No. 13 and opposed NHTSA's proposal to position the thermocouples relative to the burner.

HATCI commented that environmental factors, such as wind and temperature, could influence test results, recommending alignment with GTR No. 13, where thermocouples are positioned relative to the pre-test container. Auto Innovators also recommended positioning the thermocouples relative to the pre-test container to ensure that temperatures measured on the container are representative, and for aiding harmonization with GTR No. 13. It further referenced discussions during GTR No. 13 Phase 2, highlighting concerns about potential thermocouple failure due to material expansion from the test article and noted that GTR No. 13 offers solutions, including backup thermocouples.

Nikola stated that the purpose of the test is to measure the heat flux to the container and emphasized the importance of adhering to GTR No. 13, as the industry standard is to measure heat from the container being tested. TesTneT added that the thermocouples are positioned relative to both the pre-test container and the burner, placed 25 mm below the container and 75 mm above the burner tips, and stated there is no preferable alternative position. DTNA stated that the distance of the CHSS to the burner is the key factor that drives the characterization of the test. DTNA stated that it supports the effort in the NPRM to establish repeatable and objective test scenarios. FORVIA disagreed with introducing alternative measurements and stressed the importance of maintaining equivalency with GTR No. 13 to avoid unnecessary confusion. It suggested that any clearer requirements should be introduced in GTR No. 13 Phase 3.

Agency Response

NHTSA will maintain the burner monitor thermocouples 25 mm below the pre-test container, as specified in GTR No. 13. NHTSA acknowledges TesTneT's 'point that, due to the prescribed height of the pre-test container above the burner, specifying a point's distance below the pre-test container also specifies that point's distance above the burner.

f. Temperature Variation Greater Than 50 °C and the Associated Calculations

Background

The minimum value for the burner monitor temperature during the localized fire stage (T_{minLOC}) is calculated by subtracting 50 °C from the minimum of the 60-second rolling average of the burner monitor temperature in the localized fire zone of the pre-test checkout. The minimum value for the burner monitor temperature during the engulfing fire stage (T_{minENG}) is calculated by subtracting 50 °C from the minimum of the 60-second rolling average of the average burner monitor temperature in the engulfing fire zone of the pre-test checkout.

NHTSA sought comment on the possibility of allowing for a wider variation than 50 °C below the pre-test temperatures. Furthermore, as currently specified, the minimum temperatures T_{minLOC} and T_{minENG} would be time-dependent variables because they are based on a time-dependent rolling average. Having T_{minLOC} and T_{minENG} being time-dependent is complex and would make the testing difficult to monitor. NHTSA sought comment on a simpler calculation for T_{minLOC} and T_{minENG} that will result in constant values for T_{minLOC} and T_{minENG}. NHTSA proposed that T_{minLOC} be calculated by subtracting 50 °C from the minimum value of the 60-second rolling average of the burner monitor temperature in the localized fire zone of the pre-test checkout. Similarly, NHTSA proposed that T_{minENG} be calculated by subtracting 50 °C from minimum value of the 60-second rolling average of the average of the three burner monitor temperatures during the engulfing fire stage of the pre-test checkout. NHTSA sought comment on whether these revised calculations for T_{minLOC} and T_{minENG} should be required.

Comments Received

Most commenters opposed NHTSA's proposal to allow a wider temperature variation or change the calculation method for T_{minLOC} and T_{minENG}, instead requesting harmonization with GTR No. 13.

HATCI and Auto Innovators both recommended maintaining the 50 °C variation requirement from GTR No. 13, stating that wider temperature variations could affect test results and impact CHSS design. Auto Innovators also requested that NHTSA align with GTR No. 13 in terms of calculations for T_{minLOC} and T_{minENG}, particularly with respect to their time-dependent nature.

TesTneT commented that the requirements in GTR No. 13 are clear. It stated that there is no need to modify the calculations or allow for wider temperature variations. It further stated that the revised calculations proposed by NHTSA are unnecessary, referencing section 6.2.5.4.5.4 of GTR No. 13, which establishes the minimum values for T_{minLOC} and T_{minENG}.

FORVIA also disagreed with the proposed changes, urging NHTSA to maintain the test procedure equivalent to GTR No. 13 for simplicity. It suggested discussing any potential simplifications during the development of GTR No. 13 Phase 3 rather than changing the existing method.

Agency Response

NHTSA will maintain calculations for T_{minLOC} and T_{minENG} that are aligned with those specified in GTR No. 13, and as proposed in FMVSS No. 308 S6.2.5.3(h). NHTSA will not adopt wider temperature variations or simplified calculations for T_{minLOC} and T_{minENG} relative to GTR No. 13. The calculation method in the final rule specifies a 50 °C variation from the 60-second rolling average of the burner monitor thermocouple(s) during the respective stage of the pre-test checkout. NHTSA notes that this method results in time-dependency of T_{minLOC} and T_{minENG}. Test labs should plot T_{minLOC} and T_{minENG} over time to observe the time-dependency of these variables.

g. Vehicle-Specific Shielding

Background

The test for service terminating performance in fire evaluates the CHSS. It is possible that vehicle manufacturers may add additional fire protection features as part of overall vehicle design, and GTR No. 13 includes the option of conducting CHSS fire testing with vehicle shields, panels, wraps, structural elements, and other features as specified by the manufacturer. However, adding vehicle-level protection features is not practical for testing. Furthermore, NHTSA explained in the NPRM that it believes that it is important for safety that the CHSS itself can withstand fire and safely vent in the event its shielding is compromised.[32] For example, if a crash damages the shielding, and the shielding was an integral part of the CHSS's ability to withstand fire, then the CHSS should be able to vent properly before it explodes. As a result, vehicle-level protection measures are not evaluated by the test for service terminating performance in fire. However, if a CHSS includes container attachments, these attachments are included in the fire test. NHTSA sought comment on excluding vehicle-specific shielding and on including container attachments as part of the fire test, particularly in the case of container attachments which can be removed using a process specified by the manufacturer.

Comments Received

Agility commented that there is insufficient justification to deviate from GTR No. 13 in this area, stating that damaged vehicle shielding could compromise PRDs as well. It stated that vehicle-level protection is appropriate for addressing localized fire risks and stated that vehicle-specific shielding should not be excluded as it is part of the container's fire protection. TesTneT stated concerns that a crash could also compromise a CHSS's ability to vent properly in a fire, suggesting that the test's length, duration, and intensity are somewhat arbitrary. It stated that surviving the test without attachments does not necessarily guarantee survival in a real-world vehicle fire, which could vary significantly.

MEMA commented that NHTSA already acknowledges the importance of protective attachments in other tests, such as surface damage and chemical corrosion tests. MEMA requested that NHTSA allow vehicle-specific shields where applicable.

FORVIA strongly opposed excluding vehicle-specific shielding and container attachments from CHSS fire testing. It stated that including shields in the test provides a more accurate representation of real-world vehicle fire scenarios. FORVIA stated that if shields are excluded, manufacturers may resort to more complex and costly protection methods, reducing the practicality of these systems. It requested that shields remain part of fire testing to fully assess all safety features. FORVIA requested that shields be specified by manufacturers, and also stated that it is important to include container attachments in the fire test. Nikola stated support for the provisions in GTR No. 13 and stated that allowing container attachments in the test is appropriate and both options should be permitted.

Agency Response

NHTSA has considered the comments submitted regarding the inclusion of vehicle-specific shielding and container attachments in the test for service terminating performance in fire. While several commenters advocated for allowing vehicle-specific shielding to be part of the fire test, NHTSA maintains its position to exclude vehicle-specific shielding from the CHSS fire test.

It is important that the CHSS itself can withstand fire exposure and properly vent in the event of a failure, regardless of any additional vehicle-level protection. This approach is based on the possibility that vehicle shielding or other protective elements could be compromised in real-world scenarios, such as during a crash. If the vehicle shielding is damaged or removed, the CHSS must still be able to perform its critical safety function without relying on external protection. Including vehicle-specific shielding in the test would not adequately evaluate the inherent fire resistance and safety performance of the CHSS.

In addition, vehicle-specific shielding introduces unnecessary complexity into the testing process which could affect repeatability and reproducibility of the results. Testing that focuses on the CHSS itself provides a consistent, uniform assessment that is critical to safety.

Some commenters expressed concerns that the exclusion of vehicle-level protection measures may not fully represent real-world fire scenarios. NHTSA recognizes these concerns but emphasizes that the primary goal of the fire test is to ensure the resilience of the CHSS as an independent system. In the

[32] *See* 89 FR 27524 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

event of a crash or severe incident that compromises the vehicle's shielding, it is essential that the CHSS be capable of withstanding fire exposure and safely venting without the added protection of vehicle-level components.

Furthermore, the proposed fire test procedure, based on GTR No. 13, is specifically designed to replicate realistic fire scenarios that vehicles may encounter. As detailed in the NPRM, the test includes both localized and engulfing fire stages, which reflect actual vehicle fire data.[33] This data-driven approach ensures that the test conditions are neither arbitrary nor excessive, but instead provide a realistic assessment of the CHSS's performance during a fire.

Regarding container attachments, NHTSA clarifies that if the CHSS includes container attachments, they may be part of the fire test. Container attachments, as defined, are considered part of the CHSS itself.

h. Worst-Case Orientation

Background

GTR No. 13 specifies that the CHSS is rotated relative to the localized burner to minimize the ability for TPRDs to sense the fire and respond. GTR No. 13 specifies establishing a worst-case based on the specific CHSS design. However, NHTSA is concerned that establishing a worst-case based on a specific design is subjective. NHTSA instead proposed that the CHSS be positioned for the localized fire by orienting the CHSS relative to the localized burner such that the distance from the center of the localized fire exposure to the TPRD(s) and TPRD sense point(s) is at or near maximum. This positioning provides a challenging condition where the TPRD(s) may not sense the localized fire. NHTSA sought comment on the proposed orientation of the CHSS relative to the localized burner.

Comments Received

TesTneT referenced section 6.2.5.5.2 of GTR No. 13, stating that it already provides clear instructions on how to identify a worst-case condition. It commented that while NHTSA proposed some challenging orientations, these may not necessarily represent the worst-case scenario, and there is no need to deviate from the guidance in GTR No. 13. On the other hand, Nikola agreed with NHTSA's proposed orientation of the CHSS relative to the burner.

Auto Innovators agreed with NHTSA on the need to address the subjectivity in defining a ''worst-case'' orientation but stated that this issue is already addressed in GTR No. 13, which offers clear instructions for identifying such conditions. It stated that while NHTSA's proposal may represent a challenging condition, it may not always be considered the worst-case scenario.

Agency Response

NHTSA is maintaining the CHSS positioning specifications as proposed. NHTSA believes that its test procedure aligns well with the requirements of GTR No. 13 and will provide the level of safety intended by GTR No. 13's ''worst-case'' orientation. Further, NHTSA believes that the final standard will simplify determining the orientation for compliance testing.

NHTSA disagrees with the commenters that GTR No. 13 provides clear instruction on how a worst-case condition is identified. GTR No. 13 paragraph 6.2.5.5.2 states ''the CHSS test article shall be rotated relative to the localized burner to minimize the ability to [*sic*] TPRDs to sense the fire and respond. Shields, panels, wraps, structural elements and other features added to the container shall be considered when establishing the worst-case orientation relative to the localized fire as parts and features intended to protect sections of the container but can (inadvertently) leave other potions or joints/seams vulnerable to attack and/or hinder the ability of TPRDs to respond. For CHSS where the manufacturer has opted to include vehicle-specific features (as defined in paragraph 6.2.5.1.), the CHSS test article is oriented relative to the localized burner to provide the worst-case fire exposure identified for the specific vehicle.'' This specification requires the subjective judgement of the test lab and is therefore not objectively enforceable.

i. Jet Flame Measurement

Background

Jet flames occurring anywhere other than a TPRD outlet, such as the container walls or joints, cannot exceed 0.5 meters in length. NHTSA sought comment on how to accurately measure jet flames.

Comments Received

Nikola stated that because most jet fires exceed 0.5 meters, the presence of jet fire would result in a flame exceeding the length limit and be a clear test failure. However, it suggested that, if needed, the test facility can measure the jet flame length using video capture. Auto Innovators recommended using camera systems or similar imaging devices, such as infrared, to identify the length of jet flames. TesTneT commented that fire tests at its facility are monitored using several video cameras, and the flame length can be measured by comparing it to the known diameter of the container as seen in the videos. FORVIA also stated that jet flames are visible in practice, and the length can be measured by placing an object with a known length near the TPRD outlet and comparing the jet flame length to this object in video or pictures taken during the test.

Agency Response

NHTSA will maintain the jet flame requirement as proposed. Jet flames occurring anywhere other than a TPRD outlet, such as the container walls or joints, may not exceed 0.5 meters in length. This 0.5 meter limit aligns with GTR 13, as requested by many commenters, and seeks to minimize the safety risk because this is both the threshold at which a jet flame is clearly distinguishable from other flames present during testing and the point where the risk of spread to the surroundings increases significantly.

NHTSA appreciates the comments regarding the measurement of jet flames using video capture, reference objects of known length, and thermal imaging technologies to accurately measure jet flame length during testing. NHTSA agrees that these methods offer practical ways to assess flame length in a manner that is consistent with real-time observations during testing.

At this time, however, NHTSA will not prescribe a specific measurement methodology in the regulatory text. Instead, the method of measurement will be left to the discretion of the testing facility. Test laboratories are encouraged to use suitable techniques for ensuring compliance with the 0.5-meter jet flame requirement.

j. Heat Release Rate (HRR/A)

Background

In addition to temperature requirements, GTR No. 13 also specifies required heat release rates per unit area (HRR/A) during the localized and engulfing fire stages. NHTSA considered the specification for HRR/A and determined that it could result in over-specification of the test parameters, potentially making it very difficult to conduct the test. In addition, NHTSA believes that the detailed temperature specifications for the pre-test container during the pre-test checkout are

[33] *See* 89 FR 27523 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

sufficient to ensure repeatability and reproducibility of the test. Therefore, NHTSA did not propose specifications for HRR/A. NHTSA sought comment on that decision.

Comments Received

Auto Innovators disagreed with NHTSA's decision, recommending that HRR/A specifications be maintained to ensure test repeatability and reproducibility. It pointed out that the HRR/A specifications in GTR No. 13 were introduced to address inconsistencies observed in round-robin testing between labs. It argued that without HRR/A specifications, the amount of heat energy delivered during testing could vary, potentially leading to inconsistent test results. HATCI also disagreed, stating that the absence of HRR/A specifications could cause variability in the energy delivered during testing, affecting the outcome. It recommended that NHTSA adopt the HRR/A specifications in GTR No. 13 to avoid this issue.

Nikola supported maintaining the GTR No. 13 specification for HRR/A, noting that the test has already been validated and used by several test labs globally. TesTneT also disagreed with NHTSA's decision, stating that HRR/A is important to the fire test because temperature measurements alone cannot always be relied upon. It explained that during testing, events like hydrogen venting or coatings dripping onto thermocouples can disturb temperature readings, and HRR/A provides a way to ensure that fire conditions remain consistent despite such disturbances. In contrast, H2MOF agreed with NHTSA's approach not to specify HRR/A.

Agency Response

NHTSA is not including specifications for HRR/A. Such a specification could result in over-specification of the test parameters, potentially making it very difficult to conduct the test. In addition, NHTSA believes that the detailed temperature specifications for the pre-test container during the pre-test checkout are sufficient to ensure repeatability and reproducibility of the test.

Failure to satisfy a temperature specification will result in an invalid test. Simply adding an additional specification related to HRR/A will not resolve a failure to meet the temperature specifications. If the specified temperatures are not met, the test will be invalid regardless of whether an HRR/A specification is present and satisfied.

k. Wind Speed and Shielding

Background

When testing is conducted outdoors, wind shielding is required to prevent wind from interfering with the flame temperatures. To ensure that wind shields do not obstruct the drafting of air to burner, which could cause variations in test results, the wind shields need to be at least 0.5 m away from the CHSS being tested. Additionally, for consistency, the wind shielding used for the pre-test checkout must be the same as that for the CHSS fire test. NHTSA sought comment on whether specifications for wind shielding should be provided in the regulatory text of the standard, and if so, what the specifications should be. As an additional approach to addressing wind interference with flame temperatures, NHTSA sought comment on limiting wind speed during testing to an average wind velocity during testing to 2.24 meters/second, as in FMVSS No. 304.[34]

Comments Received

DTNA supported including wind shielding specifications in the regulatory text, stating that wind is critical to the spread of fire and that clear wind velocity limits would ensure reproducibility of test results. Glickenhaus agreed with NHTSA's proposal to limit wind speed to 2.24 meters per second, while HATCI recommended adding language to ensure wind does not affect flame direction or temperatures. HATCI also sought clarity on where wind speed measurements should be taken, recommending they occur between the wind shield and the test specimen, with the wind speed at the measuring point being near 0 meters per second.

In contrast, Nikola commented that maintaining the correct temperature profile is sufficient and aligned with GTR No. 13, making wind speed specifications irrelevant. TesTneT argued that specifying wind speed is unnecessary, as the requirement to meet temperature specifications already accounts for wind interference. It added that wind gusts could momentarily exceed the limit, potentially invalidating the test, even if temperature conditions were maintained. TesTneT also noted that its use of a large diameter pipe for testing eliminates wind effects without needing a wind speed specification.

MEMA stated a wind speed limit would be impractical, and that the fire itself could create an updraft, complicating efforts to limit wind speed. MEMA expressed concern that this requirement would cause deviations between GTR No. 13 and FMVSS No. 308, and requested that NHTSA eliminate the wind speed limit, instead recommending that wind speed only be measured and recorded, consistent with GTR No. 13. FORVIA also opposed the wind speed limit, stating it introduces unnecessary complexities and technical challenges, such as determining where and how to measure wind speed. It noted that wind can be unpredictable and suggested that industry practices, which involve conducting tests under calm conditions and recording wind speed, are sufficient to address this issue. FORVIA stated that the pre-test checkout already addresses draft effects from both external wind and the fire itself, making wind speed limits unnecessary.

Agency Response

NHTSA is not including additional specification for wind or wind speed. FMVSS No. 308 requires that wind shielding be used for outdoor fire test sites. It also requires that the separation between the pre-test container and the walls of the wind shields be at least 0.5 meters. This standard requires test facilities to provide sufficient protection against wind to prevent an impact on test results.

NHTSA is not including a requirement that air temperature, wind speed, and/or wind direction be measured and recorded if testing conducted outdoors. If these parameters are not used to conduct the test or determine the test result, then there is no reason to require them to be recorded. Manufacturers and test labs may wish to retain this information for their own purposes, but collecting this information is not a specific requirement of the test for service terminating performance in fire. As some commenters noted, the burner monitor temperature specifications already account for wind interference. If the temperature requirements are met during testing, this result indicates that wind is not interfering with the test to such a degree that would significantly affect the results.

11. Tests for Performance Durability of Closure Devices

Background

The tests for performance durability of closure devices in GTR No. 13 are closely consistent with the industry standards CSA/ANSI HPRD 1–2021, ''Thermally activated pressure relief

[34] FMVSS No. 304, ''Compressed natural gas fuel container integrity,'' *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.304.*

devices for compressed hydrogen vehicle fuel containers,'' [35] and CSA/ANSI HGV 3.1–2022, ''Fuel System Components for Compressed Hydrogen Gas Powered Vehicles.'' [36] The GTR No. 13 tests for performance durability of closure devices carry a significant test burden. To evaluate a single TPRD design, 13 TPRD units are required for a total of 29 individual tests (some units undergo multiple tests in a sequence). Similarly, to evaluate a single shut-off valve or check valve, 8 units are required for a total of 17 individual tests. While NHTSA proposed these requirements to be consistent with GTR No. 13, NHTSA sought comment on whether testing of this extent is necessary to meet the need for safety, or whether it is still possible to meet the need for safety with a less burdensome test approach or with a subset of the test for performance durability of closure devices. NHTSA requested that if commenters believe another approach or subset of tests is appropriate and meets the need for safety, that they provide specific detail on (1) the alternate approach or subset of tests and (2) how it meets the need for safety adequately.

Furthermore, FMVSS represent minimum performance requirements for safety. FMVSS does not address issues such as component reliability or best practices. These considerations are left to industry standards. NHTSA sought comment on whether a reduced subset of the tests for performance durability of closure devices could ensure safety with a lower overall test burden. In such a subset, only those tests directly linked to critical safety risks would be included.

Comments Received

Auto Innovators expressed support for maintaining consistency with GTR No. 13 for the tests for performance and durability of closure devices. Luxfer Gas Cylinders commented that obtaining 13 TPRDs for testing would not be difficult and stated that the associated costs and time were not burdensome when compared to container testing. Nikola also supported adherence to GTR No. 13.

WFS commented that the tests in GTR No. 13, Phase 2, are already aligned with industry standards such as CSA/ANSI HPRD 1 and CSA/ANSI HGV 3.1, and that these GTR No. 13 tests were chosen by the IWG of GTR No. 13 Phase 2 as the minimum required to ensure safety. WFS also suggested that FMVSS could potentially include a provision allowing closure devices compliant with relevant industry standards to be considered compliant with FMVSS requirements, except for occasional spot checks by NHTSA. FORVIA commented that while the proposed testing numbers are necessary for initial component validation and type certification due to their safety relevance, these numbers may not be needed for field surveillance testing. FORVIA suggested limiting the sample number to one per test and allowing NHTSA to focus selectively on specific tests at its discretion.

Agency Response

Based on the comments, NHTSA is maintaining the proposed test requirements. The commenters indicated the tests are not overly burdensome and the number of tests has already been minimized to cover essential safety aspects. NHTSA received no alternative proposals or specific data showing how a reduced subset of the tests would adequately meet safety needs. Since commenters did not provide any evidence for removing tests, NHTSA will maintain the original testing scope as proposed to ensure safety and maintain consistency with GTR No. 13. Additionally, there is no option to certify compliance with any FMVSS requirement by simply stating compliance with a set of industry standards. Manufacturers must certify direct compliance with the applicable FMVSS.

a. Hydrogen Impurities and Testing With Inert Gas

Background

NHTSA proposes that testing be conducted at an ambient temperature of 5°C to 35°C, unless otherwise specified. In addition, GTR No. 13 specifies that all tests be performed using either:

- Hydrogen gas compliant with SAE J2719_202003, ''Hydrogen Fuel Quality for Fuel Cell Vehicles,'' or
- Hydrogen gas with a hydrogen purity of at least 99.97 percent, less than or equal to 5 parts per million of water, and less or equal to 1 part per million particulate, or
- A non-reactive gas instead of hydrogen.

The standard J2719_202003 specifies maximum concentrations of individual contaminants such as methane and oxygen. Limiting these individual contaminants is critical for fuel cell operation; however, these contaminants are unlikely to affect the results of the tests for performance durability of closure devices.

As a result, FMVSS No. 308 will only require hydrogen with a purity of at least 99.97 percent, less than or equal to 5 parts per million of water, and less than or equal to 1 part per million particulate. NHTSA sought comment on any other impurities that could affect the results of the tests for performance durability of closure devices.

Using a non-reactive gas for testing would have the benefit of reducing the test lab safety risk related to handling pressurized hydrogen. However, it is not clear if replacing hydrogen with a non-reactive gas reduces stringency and therefore may not adequately address the safety need. As a result, this option has not been proposed in FMVSS No. 308. NHTSA sought comment on whether testing with a non-reactive gas instead of hydrogen reduces test stringency.

Comments Received

Auto Innovators stated the levels of impurities are important and that other impurities are addressed and limited in SAE J2719. Nikola agreed that no other impurities would impact the closure device tests. WFS stated that hydrogen with a purity of 99.97 percent and the specified water and particulate limits would be adequate, as additional impurity limits in SAE J2719 are relevant only to fuel cell performance.

On the subject of testing with inert gas, comments were mixed. Agility noted that test stringency could vary depending on the specific test, citing a bonfire test as an example where replacing hydrogen could be less stringent. Conversely, Agility commented that using inert gases would not affect the stringency of TPRD flow rate measurements. Auto Innovators suggested that testing with hydrogen, helium, or a non-reactive gas mixture containing detectable helium, in line with GTR No. 13, would be acceptable as long as the test conditions, such as pressure levels and cycle numbers, remained unchanged. HATCI expressed similar support, stating that using a non-reactive gas under consistent conditions should not reduce stringency.

Nikola commented that helium is an appropriate replacement for hydrogen in tests, as it does not compromise test stringency and facilitates testing procedures. WFS recommended aligning FMVSS with GTR No. 13, which lists acceptable gases such as hydrogen, helium, and non-reactive gas mixtures containing detectable helium or hydrogen. WFS noted that nitrogen would be suitable for tests involving pressure stress, while helium would be appropriate for leak tests. WFS stated

[35] *See https://webstore.ansi.org/standards/csa/csaansihprd2021.*

[36] *See https://webstore.ansi.org/standards/csa/csaansihgv2015r2019.*

that these test gas options are consistent with various industry standards.

FORVIA expressed concerns about potential material compatibility issues with impurities not specified in the proposed requirements. It recommended consulting manufacturers if there are questions about compatibility. Additionally, FORVIA commented that while hydrogen tests can help assess resistance to hydrogen embrittlement and fatigue, the use of alternative gases like dry nitrogen should be suitable.

Agency Response

NHTSA agrees with commenters that using an inert gas will not reduce the stringency of the tests for performance stability of closure devices. Therefore, in the final rule, NHTSA has added the option of using inert gas for conducting the tests for performance durability of closure devices. NHTSA notes there is no bonfire testing included in the tests for performance durability of the closure devices, nor any similar tests where the flammability of hydrogen would play a significant role in the outcome of the test.

NHTSA does not expect that impurities below 0.03 percent will have any meaningful impact on the test results. Therefore, NHTSA is maintaining the specification for hydrogen at 99.97 percent purity, less than or equal to 5 parts per million of water, and less than or equal to 1 part per million particulate. As noted in the NPRM, while fuel cells are highly susceptible to impurities, the test for performance durability of closure devices does not involve operating or testing fuel cells, and therefore, strictly controlling the specifics of the impurities below 0.03 percent is of little importance.

b. TPRD

Background

GTR No. 13 does not consider the possibility of the TPRD activating during the pressure cycling test, temperature cycling test, salt corrosion test, vehicle environment test, stress corrosion cracking test, drop and vibration test, or leak test. The temperatures applied during these tests are not characteristic of fire and therefore should not cause the TPRD to activate. TPRD activation in the absence of temperatures characteristic of a fire indicates that the TPRD is not functioning as intended and presents a safety risk due to the hazards associated with TPRD discharge. As a result, NHTSA proposed that if the TPRD activates at any point during the pressure cycling test, temperature cycling test, salt corrosion test, vehicle environment test, stress corrosion cracking test, drop and vibration test, or leak test, that TPRD will be considered to have failed the test. NHTSA sought comment on this requirement.

Comments Received

Auto Innovators stated that it agrees with the agency proposal to integrate the TPRD failure assessment as when evaluating other aspects of performance. Nikola stated that this requirement aligns with GTR No. 13, which mandates that the TPRD meet the criteria of each subsequent test. Therefore, Nikola stated, if a TPRD fails, the entire test is considered failed. Agility and Luxfer Gas Cylinders both stated that unintended activation could pose a safety risk, indicating support for the proposal.

WFS, however, recommended leaving the test requirements as they are currently written in GTR No. 13, noting that pressure cycling is a unique test that involves pressure fluctuations which could directly cause TPRD failure. WFS stated that in other tests like corrosion, it is difficult to detect TPRD activation until a subsequent leak test, which serves as the main criterion to confirm failure. FORVIA disagreed with the proposal, arguing that the concept of ''activation'' is not a clear requirement and may be difficult to measure. FORVIA suggested that all tests, except for the stress corrosion cracking test, already use a leak test as the appropriate pass/fail criterion. For the stress corrosion cracking test, FORVIA noted that a separate pass/fail criterion is necessary, as exposure to ammonia solution does not necessarily cause TPRD activation or leakage.

Agency Response

NHTSA is maintaining the requirement that the TPRD not activate during the pressure cycling test, temperature cycling test, salt corrosion test, vehicle environment test, stress corrosion cracking test, drop and vibration test, or leak test. The TPRD should not activate outside of fire-related conditions. Activation during tests that do not simulate fire indicates malfunction and poses a safety risk. While some commenters suggest relying solely on the leak test, this approach does not fully address the hazards of unintended TPRD discharge. Unintended activation is a critical failure mode that warrants a direct requirement. Thus, the requirement to treat TPRD activation as a test failure is necessary to ensure safety.

A separate test to detect TPRD activation is not necessary. A TPRD activation event will be evident to the test lab during the existing tests. TPRD activation is a significant event that will be clear through visual observation or other monitoring methods already in place during the tests.

(1) Pressure Cycling Test

Background

The NPRM proposed that one TPRD unit undergo 15,000 internal pressure cycles with hydrogen gas. While the proposed 15,000 pressure cycles for the TPRD is consistent with GTR No. 13, NHTSA noted that this number of cycles is higher than the maximum 11,000 pressure cycles applied to containers. NHTSA sought comment on the need for 15,000 pressure cycles for TPRDs.

Comments Received

Commenters generally supported NHTSA's proposal to require 15,000 pressure cycles for TPRDs, aligning with GTR No. 13. Auto Innovators recommended that NHTSA maintain consistency with GTR No. 13 and stated that the 15,000-cycle requirement is harmonized with other industry standards. Agility also supported the proposal, stating that 15,000 cycles are consistent with industry standards.

Nikola commented that GTR No. 13 and the industry have agreed on this higher standard for TPRDs as a safety measure. WFS noted that during the development of GTR No. 13 Phase 2, Task Force 3 (TF3) recognized the need for a higher cycle count for primary closure components compared to containers. WFS stated that TF3 decided to harmonize TPRD cycle requirements with industry standards, establishing 15,000 cycles to provide a slightly higher safety margin. WFS pointed out that TF3 applied the same approach to check valve pressure cycle requirements.

FORVIA expressed support for the proposed 15,000 pressure cycles, noting that the recently updated UN ECE R134 also mandates 15,000 cycles, aligning with GTR No. 13 Phase 2 and the NHTSA proposal. FORVIA suggested maintaining this standard as a safety margin and considering any revisions during Phase 3 of GTR No. 13.

Agency Response

Consistent with GTR No. 13, and based on the comments received, NHTSA is maintaining 15,000 pressure cycles for TPRDs. NHTSA emphasizes that maintaining the 15,000 pressure cycle requirement for TPRDs is consistent with both GTR No. 13 and other relevant standards such as HPRD–

1.[37] As noted by multiple commenters, TPRDs are critical safety components, and subjecting them to a slightly higher cycle count compared to containers provides an added safety margin, which is appropriate given their role in preventing catastrophic failures.

(2) Accelerated Life Test

Background

NHTSA proposed the accelerated life test consistent with GTR No. 13. This test verifies that a TPRD will activate at its intended activation temperature, but also will not activate prematurely due to a long-duration exposure to elevated temperature that is below its activation temperature.

Comments Received

Auto Innovators recommended NHTSA remain consistent with the requirements of GTR No. 13.

Agency Response

NHTSA is maintaining the accelerated life test as proposed.

(3)Temperature Cycling Test

Background

NHTSA proposed the temperature cycling test consistent with GTR No. 13. This test verifies that a TPRD can withstand extreme temperatures while in service.

Comments Received

Auto Innovators recommended NHTSA remain consistent with the requirements of GTR No. 13.

Agency Response

NHTSA is maintaining the temperature cycling test as proposed.

(4) Salt Corrosion Resistance Test

Background

NHTSA sought comment on the clarity and objectivity of the salt corrosion resistance test procedure. NHTSA asked that if commenters had suggestions on how to change the salt corrosion resistance test procedure, that they explain how their suggested changes improve the clarity and objectivity, and how they continue to meet the need for safety represented by this test.

Comments Received

Auto Innovators and Nikola both recommended maintaining alignment with GTR No. 13. WFS also advised against changes, stating that the procedure aligns with existing industry standards in North America. WFS acknowledged that the 100-day test duration is more extensive compared to previous tests, such as a 144-hour salt spray test, but noted that this longer test reflects best practices adopted by U.S. automakers and integrated into industry standards for primary closure devices.

FORVIA cautioned against adding additional criteria such as staining or pitting resistance, stating that these are cosmetic issues that are almost inevitable in aggressive salt corrosion conditions. It stated that GTR No. 13 specifies criteria like cracking, softening, and swelling, and that a requirement that TPRDs must not show signs of physical degradation would adequately addresses concerns about pitting and corrosion levels that could impact the device's function. FORVIA stated that the salt corrosion resistance test is a sufficient minimum baseline.

Agency Response

Based on the comments received, NHTSA is maintaining the salt corrosion test as proposed. In GTR No. 13 and in the proposed standard, after the salt corrosion exposure, the TPRD units are subjected to the leak test, benchtop activation test, and flow rate test. Neither GTR No. 13 nor the standard container requirements related to cracking, softening, swelling, or physical degradation. NHTSA is not including such requirements in the standard for the salt corrosion test. Subjecting the TPRD to the leak test, benchtop activation test, and flow rate test is sufficient to evaluate the performance of the TPRD after the salt corrosion test exposure.

(5) Vehicle Environment Test

Background

The vehicle environment test exposes the TPRD to the following fluids for 24 hours each: 19 percent sulfuric acid, 10 percent ethanol, and 50 percent methanol. GTR No. 13 does not specify the method of exposure to these chemical solutions. NHTSA sought comment on the exposure method. GTR No. 13 further specifies that ''cosmetic changes such as pitting or staining are not considered failures.'' NHTSA sought comment on including this specification and noted that pitting can be an aggressive form of corrosion which can ultimately lead to component failure due to cracking at the pitting site.

Comments Received

Auto Innovators and HATCI both recommended that NHTSA align with GTR No. 13's criteria, which state that cosmetic changes are not considered failures. HATCI pointed out that the TPRD undergoes further performance evaluations, such as leak and flow rate tests, after the vehicle environment test. It stated that these subsequent tests would detect any significant degradation in performance caused by corrosion, ensuring safety.

Luxfer Gas Cylinders commented that the 24-hour exposure is not aggressive enough to cause pitting and suggested removing references to cosmetic changes. Nikola added that pitting and cracking issues are associated with the use of brass, which is not commonly used for TPRDs, and stated that manufacturers already adhere to these requirements since they are harmonized with industry standards. WFS suggested that while the language in GTR No. 13 is sufficient, NHTSA could consider specifying an exposure method, as outlined in HPRD 1. WFS explained that this standard provides two methods—periodic spraying or full immersion—and recommended adopting this language if more detail is needed. However, WFS agreed that the current approach, which leaves the exposure method to the test lab, is also acceptable.

FORVIA stated that the existing language provides sufficient guidance for conducting the test. FORVIA reiterated that cosmetic changes, like minor pitting, should not result in failure unless they indicate more significant corrosion issues. FORVIA also suggested discussing any potential test modifications in the future during GTR No. 13 Phase 3 development.

Agency Response

Consistent with GTR No. 13, NHTSA will include the statement that ''cosmetic changes such as pitting or staining are not considered failures'' in S5.1.5.1(e). Cosmetic changes such as pitting or staining that do not affect the performance of the component do not present a safety concern and are therefore not considered failures. NHTSA notes that, after the vehicle environment test, TPRDs must undergo the leak test, benchtop activation test, and flow rate test, as discussed below. These subsequent tests are sufficient to ensure the vehicle environment test has not degraded the performance of the TPRD.

NHTSA agrees that either of the exposure methods described by WFS would be valid. There could also be other valid exposure methods. Therefore, NHTSA will not specify exposure by either immersion or by misting, and instead the test facility may determine an appropriate exposure method for the component.

[37] *See, https://webstore.ansi.org/standards/csa/csaansihprd2021.*

(6) Stress Corrosion Cracking Test

Background

The stress corrosion cracking test exposes the TPRD for ten days to a moist ammonia air mixture maintained in a glass chamber. Under GTR No. 13, the moist ammonia-air mixture is achieved using an ammonia-water mixture with specific gravity of 0.94. Specific gravity is affected by temperature and, therefore, is an inconvenient metric for concentration specification because concentrations will need to be adjusted for different temperatures. NHTSA sought comment on a more direct metric for ammonia concentration specification, such as 20 weight percent ammonium hydroxide in water.

In GTR No. 13, the only requirement to pass the stress corrosion cracking test is that the components must not exhibit cracking or delaminating due to this test. NHTSA sought comment on this performance requirement and on whether there are alternative requirements for this test beyond basic visual inspection, such as subjecting the TPRD to the leak test.

Comments Received

Luxfer Gas Cylinders commented that using a more direct metric for ammonia concentration, such as 20 weight percent ammonium hydroxide in water, ''would be an improvement.'' It stated that this test is usually seen as a material test rather than a component test. Luxfer also stated that industry cylinder standards require stress corrosion testing specific to the material, which involves sectioning and microscopic visual inspection. It suggested that FMVSS No. 308 adopt the stress corrosion cracking test specified in ISO 11119, ''Gas cylinders—Refillable composite gas cylinders and tubes—Design, construction and testing—Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners,'' or ISO 11515, ''Gas cylinders—Refillable composite reinforced tubes of water capacity between 450 L and 3000 L—Design, construction and testing.'' Luxfer stated that a leak test is not an effective method to detect stress corrosion.

Auto Innovators stated that material requirements for hydrogen applications are well established in industry standards. It recommended NHTSA refer to GTR No. 13 Phase 2, which outlines material evaluation and stress corrosion cracking tests for aluminum alloys. It stated that if these standards cannot be adopted as performance requirements, alternative measures should be considered.

HATCI recommended harmonizing with GTR No. 13 Phase 2, in which the stress corrosion cracking test is confirmed through visual inspection. They cautioned that adding a leak test could lead to failures due to affected o-rings rather than actual TPRD issues. HATCI also noted that under GTR No. 13, the test only applies to TPRDs containing copper alloys and requested clarity on whether NHTSA intends to follow this approach.

WFS suggested no changes to the test procedure in GTR No. 13, emphasizing that it is already harmonized with other standards such as HPRD 1:21 and ISO 19882, ''Gaseous hydrogen—Thermally-activated pressure relief devices for compressed hydrogen vehicle fuel containers.'' They commented that third-party laboratories are capable of adjusting the moist ammonia concentration and that visual examination is the appropriate pass criteria.

Regarding the proposed concentration metric of 20 weight percent ammonium hydroxide, FORVIA disagreed with adding additional measurement criteria, noting that these tests are performed in temperature-controlled laboratories with established procedures. They recommended making any new measurement criteria optional and compatible with the specific gravity method. FORVIA also stated that a leak test may not be appropriate and supported visual inspection as sufficient for identifying cracking or delamination, advocating for consistency with GTR No. 13.

Agency Response

Regarding the performance requirement for the stress corrosion cracking test, NHTSA has decided to retain the visual inspection criterion as the only pass/fail measure. Visual inspection for cracking or delamination is the appropriate criteria for determining the results of the test. NHTSA considered the possibility of additional testing beyond visual inspection, such as leak tests, but concurs with the commenters that a leak test may not be the best test to evaluate for stress corrosion. Therefore, introducing a leak test would not effectively indicate whether stress corrosion cracking has occurred, and NHTSA has decided against requiring this additional test.

NHTSA is not adopting the stress corrosion cracking test in ISO 11119 or ISO 11515. NHTSA is implementing a stress corrosion cracking test aligned with GTR No. 13, as proposed in the NPRM.[38] This test is sufficient to address the risk of stress corrosion cracking in TPRDs used in hydrogen vehicles. NHTSA is also not including the humid gas stress corrosion cracking testing for aluminum alloys from Part I of GTR No. 13. This test is not a requirement in GTR No. 13 and was not proposed in the NPRM. Therefore, this test is outside the scope of this final rule.

Lastly, NHTSA has decided to specify an ammonia concentration between 19 weight percent and 21 weight percent ammonium hydroxide solution in water as the standard concentration for this test. This decision is based on successful testing conducted by NHTSA, which used 16.7 wt% ammonium hydroxide in water to evaluate closure devices.[39] NHTSA believes specifying between 19 weight percent and 21 weight percent ammonium hydroxide in water provides a more practical metric for ammonia concentration specification than specific gravity, while still mirroring the effect of an ammonia-water mixtures with a specific gravity of 0.94. This specification using weight percent also addresses the ambiguity regarding the variability of specific gravity due to temperature fluctuations. This concentration of between 19 and 21 weight percent falls with the range of commercially available pre-mixed ammonium hydroxide solutions.

(7) Drop and Vibration Test

Background

NHTSA proposed the drop and vibration test consistent with GTR No. 13. TPRDs are first dropped in any one of six different orientations. The units are vibrated for 30 minutes along each of the three orthogonal axes. The units are vibrated at a resonant frequency which is determined by using an acceleration of 1.5 g and sweeping through a sinusoidal frequency range of 10 to 500 Hz with a sweep time of 10 minutes. According to GTR No. 13, the resonance frequency is identified by a ''pronounced'' increase in vibration amplitude. However, if the resonance frequency is not found, the test is conducted at 40 Hz. NHTSA was concerned that specifying a pronounced

[38] *See* 89 FR 27531 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[39] See the report titled ''GTR No. 13 Fire and Closures Tests'' which can be found at: *https://downloads.regulations.gov/NHTSA-2024-0006-0002/attachment_4.pdf.* This report will also be submitted to the National Transportation Library. *https://rosap.ntl.bts.gov/.*

increase in vibration amplitude could be partially subjective. NHTSA sought comment on more objective criteria for establishing resonance, such as a frequency where the amplitude of the response of the test article is at least twice the input energy as measured by response accelerometers. Furthermore, the acceleration level was not defined in GTR No. 13 for the resonant dwells. NHTSA sought comment on an appropriate acceleration level for the resonant dwells.

Comments Received

Nikola stated that GTR No. 13 already has a defined resonance frequency and that the current test procedure is sufficient. WFS recommended maintaining the drop and vibration test as harmonized with GTR No. 13, noting that it is also consistent with HPRD 1:21 and ISO 19882. WFS explained that the phrase ''pronounced increase'' was added to GTR No. 13 for clarity and stated that a test laboratory with vibration testing capabilities should be able to detect resonance, as most shaker table software can automatically identify it. WFS stated there was no need for additional criteria to establish resonance. Regarding the acceleration level for resonant dwells or the 40 Hz default, WFS indicated that it should remain at 1.5 g, which is the same level as used in the sine sweep portion of the test.

FORVIA also supported keeping the test procedure harmonized with GTR No. 13, stating that while the measurement method is left open in the regulation, the definition of a pronounced increase is sufficiently precise. FORVIA commented that the test setup must be sensitive enough to identify the highest resonance, which is typically not an issue in practice. FORVIA expressed confusion over the justification for NHTSA's proposal to define resonance as a frequency where the amplitude response is at least twice the input energy, preferring to adhere to the existing GTR No. 13 criteria.

Agency Response

NHTSA is maintaining the proposed requirement consistent with GTR No. 13. If a resonant frequency cannot be identified, the test is conducted at 40 Hz, which is sufficiently objective. As the commenters note, test facilities will be able to detect and identify the resonant frequency, and therefore NHTSA will allow test facilities to determine the appropriate resonant frequency, or otherwise they may use 40 Hz.

(8) Leak Test

Background

NHTSA proposed the leak test consistent with GTR No. 13. The leak test evaluates the TPRD's ability to contain hydrogen at each of the following temperatures and pressures:

- Ambient temperature: 5°C to 35°C, test at 2 MPa and 125 percent NWP
- High temperature: 85°C, test at 2 MPa and 125 percent NWP
- Low temperature: −40°C, test at 2 MPa and 100 percent NWP

NHTSA sought comment on the need to perform the leak test at 2 MPa in addition to the higher pressures.

The leak evaluation involves observing the pressurized unit for hydrogen bubbles while the unit is immersed in the temperature-controlled fluid. If hydrogen bubbles are observed, the leak rate is measured by any method available to the test lab. The total leak rate must be less than 10 NmL/h, which represents an extremely low leak rate. NHTSA sought comment on the leak rate requirement of 10 NmL/hour, noting that this leak rate is much lower than the minimum hydrogen flow rate of 3.6 NmL/min necessary for initiating a flame.[40] NHTSA sought comment on objective methods for measuring the leak rate.

Comments Received

Agility commented that performing the leak test at higher pressures is sufficient and that testing at 2 MPa is unnecessary, as leak rates typically decrease with lower pressures. Nikola stated the opposite, suggesting that a container is more likely to leak at low pressure and low temperatures due to decreased rigidity. HATCI agreed with Agility, indicating that testing at the higher pressure is adequate and additional testing at 2 MPa does not add to safety assurance. However, Auto Innovators supported harmonizing with GTR No. 13, stating it is important to evaluate seal performance under both low- and high-pressure conditions as well as low temperatures.

DTNA recommended revising the proposed leak rate of 10 NmL/h, stating that it is significantly lower than the minimum hydrogen flow rate necessary to initiate a flame and suggesting a limit of 3.6 NmL/min instead. It stated that this higher limit would reduce the risk of flame initiation and account for testing variability. Agility, on the other hand, supported the 10 NmL/h leak rate, stating that it is consistent with HPRD 1 and GTR No. 13, and suggested using pressure measurements over time with trace gases as one method to determine leakage. Nikola acknowledged that although 10 NmL/h is a low rate, the impact could be amplified when considering multiple devices. It suggested using bubble tests to confirm the presence of leaks and employing mass spectrometers or gasometers to quantify the rate if bubbles are detected.

FORVIA stated disagreement that 10NmL/min is a high leak rate, given the potential for multiple leakage points. It noted that this rate would be detectable through submersion and bubble tests but recommended maintaining consistency with GTR No. 13 for both TPRDs and valves. FORVIA supported the inclusion of the low-pressure leak test, stating that poor gasket designs can leak at low pressure but may become leak-tight at higher pressures.

WFS also advocated for consistency with GTR No. 13, stating that the test accounts for both empty and full container conditions. It noted that while the high-pressure condition is typically the most severe, low pressure can be a challenging scenario in some cases. WFS supported the 10 NmL/h requirement as it aligns with HPRD 1:21 and ISO 19882 and suggested leaving the choice of measurement methods to the testing laboratories, which have various available techniques for detecting leakage at these levels.

MEMA agreed with omitting visual evaluations of bubble formation, as proposed by NHTSA, acknowledging the agency's aim to avoid subjective assessments. MEMA also supported the proposed maximum leak rate of 10 NmL/h.

Agency Response

NHTSA is maintaining the leak test as proposed. The commenters established reasons for conducting the leak test at low pressure in addition to high pressure, including gaskets leaking at low pressure levels and decreasing container rigidity at low pressures and temperatures. Regarding the leakage limit of 10 NmL/h, NHTSA notes that there may be more than one TPRD on a vehicle. Therefore, the leakage from any single TPRD must be very low and the proposed leakage rate of 10 NmL/h is a reasonable limit. Based on the comments, NHTSA will leave the leakage rate quantification method to the discretion of the test lab. As stated by the commenters, possible methods for quantification include capturing bubbles or measurement with sensitive hydrogen or helium leak detectors.

[40] SAE Technical report 2008–01–0726. Flame Quenching Limits of Hydrogen Leaks. The paper finds that the lowest possible flammable flow is about 0.005 mg/s (3.6 NmL/min).

(9) Benchtop Activation Test

Background

Three new TRPD units are tested to establish a baseline activation time, which is the average of the activation time of the three new TPRDs. TPRD units used in the pressure cycling test, accelerated life test, temperature cycling test, salt corrosion resistance test, vehicle environment test, and drop and vibration test are also tested in the benchtop activation test and these TPRDs must activate within 2 minutes of the average activation time established from the tests with the new units.

GTR No. 13 does not provide any information on how to proceed when a TPRD does not activate at all during the benchtop activation test. A TPRD that does not activate when inserted into the oven or chimney is not functioning as intended and therefore presents a safety risk. As a result, NHTSA proposed that if a TPRD does not activate within 120 minutes from the time of insertion into the oven or chimney, the TPRD is considered to have failed the test. The time limit of 120 minutes is selected based on the maximum possible duration of the CHSS fire test. NHTSA sought comment on this requirement.

Comments Received

Agility supported the proposed 120-minute time limit for TPRD activation, describing the rationale as reasonable. Auto Innovators also agreed with NHTSA's proposal regarding the failure assessment for TPRDs that do not activate within the specified period. However, Nikola expressed concern, stating that 120 minutes is too long and dangerous, and that the activation window should be limited to 2 minutes beyond the baseline established by the new units.

FORVIA agreed that a TPRD must function as intended and activate within a specified time and temperature range. It stated that a failure to activate within 120 minutes should be recognizable using sound engineering judgment. FORVIA suggested that the lack of an explicit time limit in GTR No. 13 might be intentional and recommended clear articulation of any additional failure criteria if introduced. It argued that such a long activation time is unnecessary, as a TPRD taking this long to activate under 600 °C conditions would not pass the performance-based fire test.

WFS disagreed with the 120-minute time limit, recommending that the benchtop activation test remain consistent with GTR No. 13. It noted that this test is harmonized with HPRD 1:21 and ISO 19882 and differs from the CHSS fire test. WFS argued that 120 minutes is excessively long for a chimney test, where activation usually occurs within 5 minutes, and suggested a 10-minute limit as more appropriate. It also stated that qualified test labs can determine suitable cut-off times and safely vent gas in case of TPRD failure.

Agency Response

Applying engineering judgment to determine whether a sample has passed or failed the benchtop activation test is likely to be subjective. In addition, a test lab determining an appropriate ''cut-off time'' during the benchtop activation test may also be subjective. Therefore, NHTSA is maintaining the maximum time limit of 120 minutes from insertion into the oven or chimney for the TPRD to activate. Any TPRD that does not activate within 120 minutes from insertion into the oven or chimney during the benchtop activation test, including any of the TPRDs used to establish the baseline activation time, will be considered to have failed the test.

The time limit of 120 minutes is not intended to set the activation performance timeframe. Instead, it is simply the maximum amount of time the test lab must wait without an activation before declaring the TPRD to have failed the test. This standard does not create a dangerous situation because TPRDs will likely activate much faster than 120 minutes, and the CHSS fire test evaluates the performance of the overall system in a fire scenario. The CHSS fire test also has a time limit of 120 minutes for complete CHSS venting to below 1 MPa.

(10) Flow Rate Test

Background

The flow rate test evaluates the TPRD for flow capacity of a TPRD. Flow rate through the TPRD is measured with the inlet pressurized to 2 MPa and the outlet unpressurized. The lowest measured flow rate must be no less than 90 percent of a baseline flow rate established as the measured flow rate of a new TPRD. The number of significant figures used in the measurement of flow rate can impact the test result. For example, a test flow rate of 1.7 flow units compared against a baseline flow rate of 2.0 flow units does not meet the requirement. However, in this case, if flow rate were measured using only one significant figure, the two flow rates would be identical (2 flow units). As a result, NHTSA proposed requiring that the flow rate be measured in units of kilograms per minute with a precision of at least 2 significant digits. NHTSA sought comment on this proposed requirement.

Comments Received

Auto Innovators and HATCI expressed support for NHTSA's proposal regarding the use of flow rate measurement in units of kilograms per minute with a precision of at least two significant digits. Nikola also agreed with the proposal to use two significant digits. However, Agility opposed using mass flow rate units, emphasizing that the properties of different gases must be considered in such an approach. It stated that the use of percentage difference as specified in GTR No. 13 is clear and not open to interpretation.

WFS recommended no changes to the existing procedure in GTR No. 13, noting that the test is harmonized with HPRD 1:21 and ISO 19882. It argued that specifying units as kilograms per minute is unnecessary since most flow tests for hydrogen components are conducted in grams per second. It explained that the key aspect of the test is the comparison of one TPRD flow rate to another, making the specific units less critical. WFS also cautioned that requiring two significant digits might suggest a level of precision not achievable with current equipment, due to minor flow fluctuations during testing. It added that a flow rate measured in grams per second with one significant digit can be more precise than a rate in kilograms per hour with two significant digits. FORVIA provided a neutral stance but noted that GTR No. 13, HPRD 1, and ISO 19882 also use ±2 percent.

Agency Response

NHTSA is maintaining the specification for units of kilograms per minute with at least two significant digits. NHTSA conducted testing in which these units were used successfully by the test lab to evaluate TPRD flowrates.[41] The test lab used a Coriolis meter to directly measure the mass flow rate through each TPRD in units of kg/min. NHTSA also notes that units are interchangeable, so other test labs may use units such as g/s and simply convert the results to kg/min using the appropriate conversion factors, while preserving the significant digits in the measurement.

[41] See the report titled ''GTR No. 13 Fire and Closures Tests'' which can be found at: *https://downloads.regulations.gov/NHTSA-2024-0006-0002/attachment_4.pdf.* This report will also be submitted to the National Transportation Library. *https://rosap.ntl.bts.gov/.*

(11) Atmospheric Exposure Test

Background

GTR No. 13 includes an atmospheric exposure test to ensure that non-metallic components that are exposed to the atmosphere and provide a fuel-containing seal have sufficient resistance to oxygen. This test requires that the component not crack nor show visible evidence of deterioration upon exposure to pressurized oxygen for 96 hours at 70 °C. However, NHTSA is concerned that this test is not objectively enforceable because the requirement involves a subjective determination of evidence of deterioration. Furthermore, the test would require NHTSA to determine which components are non-metallic, exposed to the atmosphere, and provide a fuel-containing seal. As a result, this test was not included in the proposed FMVSS No. 308. NHTSA sought comment on not including the atmospheric exposure test.

Comments Received

Agility stated that the atmospheric exposure test is appropriate for non-metallic materials, but noted that most hydrogen components are metallic and would not require such a test. It added that this test could be relevant for electrical components with plastic connectors. Auto Innovators and HATCI supported NHTSA's proposal to exclude the atmospheric exposure test, agreeing with the agency's reasoning. Glickenhaus also agreed with the decision, stating that the requirement for ''no visible deterioration'' is not objectively measurable and should be omitted.

WFS commented that the atmospheric exposure test is used in various industry standards and noted that in third-party laboratories, determining cracks in rubber materials during testing has been clear for those incompatible with oxygen exposure. WFS indicated that even if the test is removed from FMVSS No. 308, manufacturers may still conduct the test in line with the requirements of industry standards. FORVIA stated that while it believes the test is feasible and visual inspection could serve as a pass/fail criterion, it expressed no objections if NHTSA decides to remove the test.

Agency Response

NHTSA is not including the atmospheric exposure test in FMVSS No. 308. The test criteria are not objectively enforceable, and the commenters did not provide any alternative criteria for conducting the test with improved objectivity. The commenters also did not provide any specific methodology for NHTSA to determine which components are non-metallic and provide a fuel-containing seal within the closure device of interest.

c. Check Valves and Shut-Off Valves

(1) Hydrostatic Strength Test

Background

The hydrostatic strength test is conducted to ensure the valves can withstand extreme pressure of up to 250 percent NWP. Additionally, the test also ensures that the burst pressure of the valves exposed to various environmental conditions during prior testing is not degraded beyond 80 percent of a new unexposed valve's burst pressure.

In the event of a significant leak, it may become impossible for the test laboratory to increase pressure on the valve. This condition occurs when any increase in applied pressure is offset by leakage flow, thereby negating the pressure increase. If it occurs, it is not possible to complete testing. To address this issue, NHTSA proposed that valves shall not leak during the hydrostatic strength test, and that a leak would constitute a test failure. NHTSA sought comment on the requirement that valves not leak during the hydrostatic strength test.

Comments Received

Auto Innovators agreed with NHTSA's proposal to require that valves not leak during this test. WFS also supported NHTSA's proposal, commenting that leakage during a hydrostatic strength test would signify a rupture of the pressure-containing boundary and thus constitute a failure. It pointed out that this detail is implied in HGV 3.1–2022 and further clarified in ISO 19887, ''Gaseous Hydrogen—Fuel system components for hydrogen-fuelled vehicles,'' which states: ''The components shall be examined to verify that leakage or rupture has not occurred.'' WFS added that adopting this language could help with clarity and harmonization if NHTSA deems it necessary.

In contrast, FORVIA disagreed with the proposal, stating that leak tightness above 125 percent NWP is not required and that such a requirement would not correspond to actual service conditions. It suggested that in the event of a leak during hydrostatic testing, there should be no test result, and the test should be repeated. FORVIA also commented that the leak test should sufficiently address this potential failure mode.

Agency Response

While NHTSA proposed the requirement that the valve not leak during the hydrostatic strength test, this requirement is not intended to test specifically for leakage above 125 percent NWP. Unlike the leak test, the valve will not be submerged in a fluid and observed for bubbles from leakage during the hydrostatic strength test. Instead, this requirement is intended to avoid a situation where a test lab cannot complete testing due to significant leakage from the valve that prevents continued pressurization to the required pressures. Even if such a test were considered ''no result'' and repeated, the same leak could occur with subsequent test samples. Therefore, there needs to be a requirement that the valve not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c) during the hydrostatic strength test. Accordingly, NHTSA is revising this part of the requirement to state the valve ''shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c).''

Regarding adding the language proposed by WFS, NHTSA is revising the language as stated above. This is the most clear and concise way to state the requirement.

(2) Leak Test

Background

NHTSA proposed the leak test consistent with GTR No. 13, and similar to the leak test discussed above for TPRDs. NHTSA sought comment on objective methods for measuring the leak rate.

Comments Received

Nikola stated that the specified leak rate of 10 NmL/h, while applicable to a single point, could accumulate quickly when considering multiple leak points throughout the CHSS. WFS commented that the leak test is harmonized with industry standards and can be measured using various methods, including bubble capture or sensitive hydrogen or helium leak detectors capable of measuring levels lower than visible bubbles. It stated there is no need for NHTSA to specify a particular measurement method, as it can be determined by the testing facility based on available equipment.

FORVIA disagreed with the proposed leak rate of 10 NmL/h, stating that it is relatively high, especially if multiple leakage points in the vehicle are at this level. It suggested that the leak rate can be identified using submersion and bubble tests, but noted that more accurate testing methods, such as global accumulation tests, are available.

Agency Response

NHTSA is maintaining the leak test as proposed. NHTSA notes that there may be more than one closure device on a vehicle. Therefore, the leakage from any single closure device must be very low and the proposed leakage rate of 10 NmL/h is a reasonable limit. Based on the comments, NHTSA will leave the leakage rate quantification method to the test lab. As stated by the commenters, possible methods for quantification include capturing bubbles or measurement with sensitive hydrogen or helium leak detectors.

(3) Extreme Temperature Pressure Cycling Test

Background

The extreme temperature pressure cycling test simulates extreme temperature conditions that may lead to gas release failures when combined with pressure cycling. The total number of operational cycles is 15,000 for the check valve, consistent with the 15,000 cycles used for the TPRD above. The total number of operational cycles is 50,000 for the shut-off valve. The higher 50,000 cycles for the shut-off valve reflects the multiple pressure pulses the shut-off valve experiences as it opens and closes repeatedly during service. In contrast, the check valve only experiences a pressure pulse during fueling. NHTSA sought comment on the number of pressure cycles for check valves and shut-off valves.

Pressure cycling is conducted at different environmental temperatures and pressures:

- Ambient: Between 5.0°C and 35.0°C, 100 percent NWP
- High: 85°C, 125 percent NWP
- Low: −40 °C, 80 percent NWP

After cycling, each valve is subjected to 24 hours of "chatter flow" to simulate the chatter condition described above. Chatter flow means the application of a flow rate of gas through the valve that results in chatter as described above. NHTSA was concerned, however, that the application of chatter flow could be partially subjective. NHTSA sought comment on the following aspects of the chatter flow test:

- Appropriate methodology or a procedure for inducing chatter flow.
- Appropriate instrumentation and criteria to measure and quantify chatter flow such as a decibel meter and minimum sound pressure level.
- How to proceed in cases where no chatter occurs.
- The specific safety risks that are addressed by the chatter flow test.
- The possibility of not including the chatter flow test.

In the case of shut-off valves, GTR No. 13 specifies that the chatter flow test is required only in the case of a shut-off valve which functions as a check valve during fueling and that the flow rate used to induce chatter should be within the normal operating conditions of the valve. However, NHTSA has no way of determining whether a shut-off valve is functioning as a check valve during fueling or the normal operating conditions of the valve. As a result, NHTSA proposed that the chatter flow test will apply to all shut-off valves and will not specify flow rate limitations for the chatter flow test. NHTSA sought comment on this decision.

Comments Received

Auto Innovators recommended aligning the number of pressure cycles with GTR No. 13. FORVIA expressed support for the proposed minimum values, confirming that 15,000 cycles for check valves and 50,000 cycles for shut-off valves are consistent with GTR No. 13. Similarly, Nikola commented that safety devices should adhere to higher standards, in alignment with GTR No. 13. Agility suggested using 50,000 cycles for both check valves and shut-off valves.

Regarding the chatter flow test, HATCI requested that NHTSA exclude this requirement if a CHSS component prevents chatter within the shut-off valve, suggesting that manufacturers could provide documentation to demonstrate this. WFS stated that the test is harmonized with industry standards and stated it is sufficiently defined. It commented that GTR No. 13 already describes an appropriate methodology for inducing chatter flow by specifying a gas flow rate through the valve at the level that causes the most chatter. WFS stated that additional instrumentation, such as decibel meters, is unnecessary since chatter is detectable by ear. WFS also stated that if no chatter occurs during the flow test, GTR No. 13 specifies that the 24-hour chatter test is not necessary. Regarding the specific safety risks that are addressed by the chatter flow test, WFS stated that chatter could lead to premature wear and failure of the valve's check functionality. WFS recommended keeping the procedure as written in GTR No. 13, noting that if a shut-off valve lacks check valve functionality, the test should not be required since chatter only occurs during unidirectional flow through a check valve.

Agency Response

NHTSA is maintaining the number of pressure cycles as proposed. For the reasons discussed in the NPRM, and confirmed by the commenters, 15,000 pressure cycles for check-valves and 50,000 pressure cycles for shut-off valves are the industry standard for minimum safety of these components.[42]

NHTSA is maintaining the chatter flow test as proposed. NHTSA will leave it to test labs to determine the flowrate that cases the most valve flutter. As the commenters note, this determination could be accomplished by listening for audible sound changes. In the case of valves that do not experience chatter, or vehicles with components that prevent chatter, the chatter flow test should not adversely impact the test results because these valves will not experience chatter. Therefore, a specific exemption is not required for shut-off valves that do not experience chatter or for vehicles that have components to prevent chatter flow.

As stated above, NHTSA has no way of determining whether a shut-off valve is functioning as a check valve during fueling or the normal operating conditions of the valve; therefore NHTSA is maintaining the test as proposed. This determination is not expected to adversely impact test results because, as stated by the commenters, chatter only occurs during unidirectional flow through a check valve. Therefore, if a shut-off valve is not functioning as a check valve, it will not experience unidirectional flow nor chatter.

(4) Salt Corrosion Resistance Test

Background

NHTSA proposed a salt corrosion resistance test for check valves and shut-off valves equivalent to the salt corrosion resistance test for TPRDs discussed above.

Comments Received

Auto Innovators recommended that NHTSA maintain consistency with GTR No. 13. Nikola agreed with the proposal, noting that it is harmonized with industry standards.

Agency Response

Based on the comments received, NHTSA is maintaining the salt corrosion test as proposed.

[42] *See* 89 FR 27530, 27533 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

(5) Vehicle Environment Test

Background

NHTSA proposed a vehicle environment test for check valves and shut-off valves equivalent to the vehicle environment test for TPRDs discussed above.

Comments Received

Auto Innovators recommended that NHTSA remain consistent with GTR No. 13. Nikola stated that the tests from GTR No. 13 are aligned with industry standards and would be conducted by manufacturers regardless.

Agency Response

Based on the comments received, NHTSA is maintaining the vehicle environment test as proposed.

(6) Atmospheric Exposure Test

Background

For the reasons discussed above to the TPRD atmospheric exposure test, NHTSA did not propose the atmospheric test for check valves and shut-off valves.

Comments Received

Auto Innovators and HATCI both expressed support for NHTSA's proposal to not include the atmospheric exposure test for check valves and shut-off valves. WFS suggested leaving the requirement in the FMVSS, consistent with its feedback on the atmospheric exposure test for TPRDs. However, it noted that if NHTSA chooses to remove the test, manufacturers will still perform it in accordance with HGV 3.1. FORVIA commented that the test is feasible, and a visible inspection could serve as a pass/fail criterion, but indicated that it would find it acceptable if NHTSA decided to eliminate this test.

Agency Response

NHTSA is not including the atmospheric exposure test for check valves and shut-off valves for the same reasons discussed above for TPRDs.

(7) Electrical Tests

Background

The electrical tests apply to the shut-off valve only. The electrical tests evaluate the shut-off valve for:

- Leakage, unintentional valve opening, fire, and/or melting after exposure to an abnormal voltage.
- Failure of the electrical insulation between the power conductor and casing when the valve is exposed to a high voltage.

The exposure to abnormal voltage is conducted by applying twice the valve's rated voltage or 60 V, whichever is less to the valve for at least one minute. After the test, the valve is subject to the leak test and leak requirements. The test for electrical insulation is conducted by applying 1000 V between the power conductor and the component casing for at least two seconds. The isolation resistance between the valve and the casing must be 240 kΩ or more.

Some valves may have requirements specified by their manufacturers for peak and hold pulse width modulation duty cycle. NHTSA sought comment on whether and how to adjust the proposed test procedure to account for a manufacturer's specified peak and hold pulse width modulation (PWM) duty cycle requirements.

Comments Received

Commenters provided various perspectives on potential adjustments to the proposed test procedure to account for a manufacturer's specified peak and hold PWM duty cycle requirements. Auto Innovators stated that more information is needed to understand NHTSA's intent, emphasizing that ''operation of the valve has no bearing on insulation resistance'' and that the insulation resistance should be verified between a single conductor and the component casing, regardless of the modulation type. HATCI similarly stated that the PWM or peak specification is not relevant to the electrical tests, arguing that these tests are meant to check compliance under abnormal conditions, such as atypical voltages. Agility suggested that any inclusion of PWM requirements would go beyond the requirements of GTR No. 13 and would require further investigation, adding that it did not recommend including such requirements. WFS commented that the test should be consistent with GTR No. 13 and noted that peak and hold modulation is only applicable when testing to open a valve and keep it open, which is not the purpose of this insulation resistance test. WFS stated that the coil is not actually energized during this test, as it is similar to a Hipot test where one lead is attached to the coil and the other to the body to confirm insulation.

FORVIA stated that NHTSA appears to be proposing new test procedures for valves, specifically related to PWM duty cycle requirements, and acknowledged concerns about additional certification tests to address specific manufacturer-set operational requirements. It stated that these operational conditions would already be thoroughly evaluated during the manufacturer's Design Validation (DV) and Production Validation (PV) phases, where the valve's performance is tested against specified requirements. FORVIA concluded that the existing DV and PV processes adequately address concerns about PWM duty cycles and stated that additional test scenarios are unnecessary. It also recommended maintaining equivalence with GTR No. 13 and noted that the test is independent of peak/hold or modulation of the voltage, as it validates the component's ''electrical robustness.''

Agency Response

NHTSA is maintaining the electrical tests as proposed. As supported by the commenters, NHTSA has determined that procedures to account for pulse width modulation specifications are not necessary. The electrical tests expose the valve to abnormal voltages and evaluate its insulation resistance. The results of these tests will not be affected by PWM variations during testing.

(8) Vibration Test

Background

The vibration test evaluates a valve's resistance to vibration. The valve is pressurized to 100 percent NWP and exposed to vibration for 30 minutes along each of the three orthogonal axes (vertical, lateral, and longitudinal). After vibration, the valve shall comply with the leak test and the hydrostatic strength test to verify it retains its basic ability to contain hydrogen and resist burst due to over-pressurization. GTR No. 13 also contains a requirement that ''each sample shall not show visible exterior damage that indicates that the performance of the part is compromised.'' Showing signs of damage is a subjective measure and lacks the objectivity needed per the Motor Vehicle Safety Act. Therefore, this language was removed.

Comments Received

Auto Innovators expressed agreement with NHTSA's assessment, stating that the lack of an objective measure for evaluating vibrations justified the removal of the language. Nikola also indicated its agreement with this decision.

Agency Response

NHTSA is maintaining the vibration test as proposed, which does not include the requirement regarding visible exterior damage indicating that the performance of the part is compromised.

(9) Stress Corrosion Cracking Test

Background

NHTSA proposed conducting the stress corrosion cracking test in the same manner and for the same reasons discussed above for TPRDs.

Comments Received

Auto Innovators agreed with NHTSA's proposal.

Agency Response

NHTSA will maintain an equivalent stress corrosion cracking test for check-valves and shut-off valves as the stress corrosion cracking test for TPRDs, discussed above.

12. Labeling Requirements

Background

NHTSA proposed that the container label(s) include the following information:

- Manufacturer, serial number, and date of manufacture.
- The statement ''Compressed Hydrogen Only.''
- The container's NWP in MPa and pounds per square inch (psi).
- Date when the system should be removed from service.
- BP_O in MPa and psi.

Comments Received

Nikola recommended adding a DOT/FMVSS compliance statement to the label. MEMA agreed with NHTSA's proposal to list information such as the manufacturer's name and contact details, serial number, NWP, fuel type, and the container's service removal date. However, MEMA objected to including an inspection schedule on the label. It also pointed out that such a requirement is not part of GTR No. 13 and requested NHTSA reconsider its inclusion. Glickenhaus noted a lack of sufficient information to specify a performance standard for label attachment that would prevent localized degradation or stress.

Agency Response

As discussed above, NHTSA will not require BP_O to be listed on the container label. NHTSA is maintaining the other labeling requirements as proposed. These labeling and inspection requirements are consistent with the established labeling requirements for CNG fuel containers in FMVSS No. 304.[43] Having this information on the container label will help operators properly maintain their vehicles through regular safety inspections.

Additionally, since FMVSS No. 308 is a vehicle-level standard, the DOT/FMVSS compliance statement should be located on the vehicle itself, not directly on the container. Lastly, while concerns were raised about label attachment durability, label attachment methods are expected to be developed based on best practices, and this issue does not affect the requirement to specify information on the container label.

C. FMVSS No. 307, ''Fuel System Integrity of Hydrogen Vehicles''

Background

FMVSS No. 307 sets requirements for the vehicle fuel system to mitigate hazards associated with hydrogen leakage and discharge from the fuel system, as well as requirements to ensure hydrogen leakage, hydrogen concentration in enclosed spaces of the vehicle, and hydrogen container displacement are within safe limits post-crash. The fuel system integrity requirements for normal vehicle operations would apply to all hydrogen-fueled vehicles, while the post-crash fuel system integrity requirements only apply to light vehicles and compressed hydrogen-fueled school buses regardless of GVWR. NHTSA sought comment on the application of FMVSS No. 307 to all vehicles, including heavy vehicles (vehicles with a GVWR greater than 4,536 kg (10,000 pounds). As proposed, portions of FMVSS No. 307 would apply to all hydrogen vehicles regardless of GVWR. However, not all vehicles would be subject to crash testing under FMVSS No. 307. As described below, passenger cars, multipurpose passenger vehicles, trucks and buses with a GVWR of less than or equal to 4,536 kg would be subject to barrier crash testing, as would school buses with a GVWR greater than 4,536 kg. Heavy vehicles other than school buses with a GVWR greater than 4,536 kg would not be subject to crash testing under the proposed standard.

Comments Received

Agility commented that FMVSS No. 307 should not apply to all vehicles, citing significant differences between light and heavy vehicles that warrant separate consideration. It stated that while some requirements could be the same, fuel system-specific configurations and integration into the vehicle body should be addressed separately, given the differences in vehicle accelerations and impacts based on GVWR. Luxfer Gas Cylinders supported the application of FMVSS No. 307 to all vehicles. Auto Innovators stated that while the safety and integrity of hydrogen vehicles are priorities regardless of size, it does not support the inclusion of heavy vehicles under FMVSS No. 307 at this time. Auto Innovators cited the design implications for heavy vehicles, which have not been previously subject to such requirements, and called for further research to justify this inclusion. It recommended that if NHTSA considers including heavy vehicles, a comprehensive regulatory impact analysis should be conducted, and a new rulemaking proposal issued as either a separate rulemaking notice or a supplemental notice of proposed rulemaking. Auto Innovators also stated the need for additional research to determine if alternative test procedures are required to evaluate heavy vehicle performance and understand the potential impact on vehicle design. Nikola stated ''leave it to the OEM to decide.''

Agency Response

NHTSA is maintaining the application of FMVSS No. 307 as proposed, consistent with GTR No. 13, which applies to both light and heavy vehicles.[44] While Auto Innovators cited need for more research to support application of FMVSS No. 307 to heavy vehicles, Hyundai Motor Group noted that heavy commercial vehicles and buses will be important types of hydrogen powered vehicles. Indeed, NHTSA and industry expect heavy vehicles to comprise a significant portion of the hydrogen fleet. In 2023, about 33 percent of hydrogen-powered vehicles were commercial vehicles and this percentage is expected to grow in the coming years.[45] Because hydrogen fuel poses risks regardless of a vehicle's GVWR, safety need compels that the requirements for normal vehicle operation apply to heavy vehicles just as they apply to light vehicles so long as the standard is able to be practicable and objective. The performance tests under normal vehicle operations adopted in the final rule are aligned with GTR No. 13 and have already been implemented for hydrogen powered vehicles (regardless of GVWR) in other

[43] FMVSS No. 304, ''Compressed natural gas fuel container integrity.'' *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.304.*

[44] The scope of GTR No. 13 states that ''[t]his regulation applies to all hydrogen-fueled vehicles of Categories 1 and 2 with a maximum design speed exceeding 25 km/h.'' ''Category 1 vehicle'' means a power-driven vehicle with four or more wheels designed and constructed primarily for the carriage of (a) person(s). ''Category 2 vehicle'' means a power-driven vehicle with four or more wheels designed and constructed primarily for the carriage of goods. *See* TRANS–WP29–1045e, Annex 2, *https://unece.org/DAM/trans/doc/2005/wp29/TRANS-WP29-1045e.pdf.*

[45] *See* Global Market Insights: Hydrogen Vehicle Market size, *https://www.gminsights.com/industry-analysis/hydrogen-vehicle-market#:~:text=Hydrogen%20Vehicle%20Market%20size%20was,expenses%20associated%20with%20hydrogen%20vehicles.*

countries.[46] These tests are simple and can be performed similarly for light and heavy vehicles. Therefore, the same minimum safety requirements must be applied to all vehicles that use compressed hydrogen as a fuel source. Specifically, heavy vehicles must meet the same requirements as light vehicles for fueling receptacles, hydrogen discharge systems, protection against flammable conditions, fuel system leakage, and tell-tale warnings provided to the driver. This approach also harmonizes with commenters' requests for harmonization with GTR No 13.[47]

Furthermore, NHTSA will not leave it to vehicle manufacturers to decide whether to apply FMVSS No. 307 to their vehicles. Allowing manufacturers to decide whether to apply FMVSS No. 307 to their vehicles would not be consistent with the application of other FMVSS.

As discussed below, NHTSA agrees more research would be beneficial before the crash test requirements of FMVSS No. 307 are applied to all heavy vehicles. Hyundai suggested post-crash requirements similar to that proposed for heavy school buses. EMA suggested use of component level tests, while Nikola stated it is developing its own crash test requirements based on the FMVSS No. 214 side impact moving barrier crash test. This final rule only requires heavy vehicles to comply with the fuel system integrity requirements under normal vehicle operations. As discussed below, NHTSA is considering conducting research on post-crash requirements for heavy vehicles and will consider the commenters' suggestions on this matter.

1. Enclosed or Semi-Enclosed Spaces Definition

Background

GTR No. 13 defines ''enclosed or semi-enclosed spaces' as ''the special volumes within the vehicle (or the vehicle outline across openings) that are external to the hydrogen system (storage system, fuel cell system, internal combustion engine (ICE) and fuel flow management system) and its housings (if any) where hydrogen may accumulate (and thereby pose a hazard).'' NHTSA proposed a similar definition of ''enclosed or semi-enclosed spaces means the volumes external to the hydrogen fuel system such as the passenger compartment, luggage compartment, and space under the hood.'' NHTSA also proposed defining that ''hydrogen fuel system means the fueling receptacle, CHSS, fuel cell system or internal combustion engine, fuel lines, and exhaust systems.''

Comments Received

EMA raised concerns about the proposed definition of ''enclosed or semi-enclosed spaces,'' calling it ambiguous and a departure from NHTSA's intent to harmonize with GTR No. 13. It commented that NHTSA's use of ''such as'' implies a non-exhaustive list, potentially encompassing unintended areas outside the vehicle's hydrogen system. It cited various references in the NPRM where NHTSA repeatedly linked ''enclosed or semi-enclosed spaces'' to volumes that allow hydrogen accumulation. EMA highlighted specific alleged problems with the proposed definition's broadness, such as in the fueling receptacle requirements of S5.1.1, arguing the term's literal interpretation would limit receptacle mounting to components within the hydrogen system, leading to potentially unsafe situations. Similarly, in section S5.1.3.1(c) on pressure relief systems, EMA argued that directing hydrogen discharge solely towards the hydrogen system is unsafe. It noted that the proposed term appears nine times outside the definition in FMVSS No. 307, with several instances relating to hydrogen detection. EMA suggested revising the definition to align with GTR No. 13 or adding a specification that such spaces are where hydrogen can accumulate and pose a hazard.

FORVIA also expressed the need for clearer criteria, recommending NHTSA define ''semi-enclosed spaces'' by specifying volumes and enclosed sides to avoid testing ambiguities. Meanwhile, Auto Innovators opposed the inclusion of ''space under the hood'' in the definition, stating it diverged from GTR No. 13.

Agency Response

NHTSA agrees with the commenters that the proposed definition of ''enclosed or semi-enclosed spaces'' is vague and ambiguous. To avoid ambiguity, NHTSA has revised the definition of enclosed or semi-enclosed spaces to mean ''the passenger compartment, luggage compartment, and space under the hood.'' This definition no longer contains the words ''such as,'' so it no longer implies the inclusion of ambiguous additional volumes beyond those listed in the definition.

The ''space under the hood'' is included in the definition of enclosed or semi-enclosed spaces because there is a risk of hydrogen accumulation under the hood just as there is a risk of hydrogen accumulation in the passenger compartment and/or in the luggage compartment. If hydrogen were to accumulate heavily in the space under the hood, it could result in a fire if an ignition source were present. By including the ''space under the hood'' in the definition of enclosed or semi-enclosed spaces, the requirements of FMVSS No. 307 S5.1.3(b) apply, thereby preventing accumulation of hydrogen to unsafe levels under the hood.

Furthermore, NHTSA believes that including ''space under the hood'' in the enclosed and semi-enclose spaces is consistent with GTR No. 13. GTR No. 13 defines enclosed or semi-enclosed spaces as ''the special volumes within the vehicle (or the vehicle outline across openings) that are external to the hydrogen system (storage system, fuel cell system, internal combustion engine (ICE) and fuel flow management system) and its housings (if any) where hydrogen may accumulate (and thereby pose a hazard).'' Space under the hood can be considered a special volume within the vehicle, external to the hydrogen system and its housings, where hydrogen may accumulate.

2. Fuel System Integrity During Normal Vehicle Operations

a. Fueling Receptacles

Background

The first proposed requirement for the fueling receptacle was to prevent reverse flow to the atmosphere. The second proposed requirement was for a label with the statement, ''Compressed Hydrogen Only'' as well as the statement ''Service pressure ______ MPa (_____ psig).'' The label must also contain the statement, ''See instructions on fuel container(s) for inspection and service life.'' The third proposed requirement was for positive locking that prevents the disconnection of the fueling hose during fueling. The fourth proposed requirement was for protection against ingress of dirt and water to protect the fueling receptacle from contamination that could lead to degradation of the fuel system over time. The fifth proposed requirement was to prevent the receptacle from being mounted in a location that would be highly susceptible to crash deformations in order to prevent degradation in the

[46] *See* ECE R.134, ''Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen fuelled vehicles,'' *https://unece.org/transport/documents/2024/10/standards/addendum-133-regulation-no-134-revision-1.*

[47] Hyundai and Nikola are already producing vehicles that comply with GTR No. 13 fuel system integrity requirements. As of October 2024, Nikola has sold 235 fuel cell electric Class 8 heavy-duty trucks in the United States. About 70 Hyundai Class 8 XCIENT fuel cell trucks have already been sold in the United States.

event of a crash. NHTSA also proposed that the receptacle be prevented from being mounted in the enclosed or semi-enclosed spaces of the vehicle because these areas can accumulate hydrogen.

NHTSA proposed that the assessment for all five receptacle requirements would be by visual inspection. NHTSA sought comment on the proposed requirements for the fueling receptacle and on the objectivity of assessment by visual inspection.

Comments Received

Luxfer Gas Cylinders questioned how NHTSA intends to conduct visual inspections of the fueling receptacle and inquired about the number of receptacles that would be tested annually. It also questioned how positive locking would be assessed for the variety of vehicle designs in service. Luxfer further commented on the requirement that the fueling receptacle should not be mounted in impact energy-absorbing areas, stating that since receptacles are typically mounted on a vehicle's outer surface for accessibility, any such surface is inherently vulnerable in a crash, making this requirement appear unnecessary.

Auto Innovators noted that there is no reference test provided for the requirement to prevent reverse flow to the atmosphere and recommended using the GTR No. 13 leak test for check valves and shut-off valves. It also requested clarification on the label location. Air Products recommended adding a disconnect switch to fueling receptacles for medium and heavy vehicles to prevent starting or drive-away, as used in light vehicles. It stated that GTR No. 13 Phase 2 standardizes references to fueling receptacle profiles to ensure vehicles are fueled only with appropriate pressure classes and prevent cross-fueling with other compressed gas dispensing stations. Air products cited standards ISO 17268, ''Gaseous hydrogen land vehicle refuelling connection devices,'' and SAE J2600, ''Compressed Hydrogen Surface Vehicle Fueling Connection Devices,'' in this context.

HATCI expressed concerns about the lack of space for the proposed labeling requirements and recommended omitting additional lines of text compared to GTR No. 13. It supported the requirement to prevent ingress of water and oil, agreeing that this could affect the closure device tests. Nikola and Agility both stated that visual inspection is an acceptable means of assessment. FORVIA disagreed with the proposed requirements and requested that NHTSA align them exactly with GTR No. 13.

Agency Response

Regarding the requirement for the fueling receptacle to not be mounted in locations ''highly susceptible to crash deformations,'' the proposed requirements do not use the term ''highly susceptible.'' Instead, NHTSA proposed that ''[t]he fueling receptacle shall not be mounted to or within the impact energy-absorbing elements of the vehicle.'' However, in response to concerns raised, NHTSA has reconsidered the necessity of this requirement.

The commenters correctly note that it is generally expected for the fueling receptacle to be mounted on the exterior of the vehicle to facilitate fuel filling, which inherently exposes it to potential damage in the event of a crash. NHTSA agrees that this reality limits the effectiveness and practicality of restricting the mounting location based on energy-absorbing elements of the vehicle. Given that any surface-mounted device, by its nature, could be subject to damage in a collision, maintaining the proposed restriction would not significantly enhance vehicle safety and could introduce unnecessary design constraints.

Therefore, after careful review, NHTSA has decided to remove the requirement that fueling receptacles shall not be mounted in the energy-absorbing elements of the vehicle. This decision aligns with the practical considerations raised by commenters and reflects the understanding that modern vehicle design incorporates various safety mechanisms, such as reinforced mounting systems and advanced materials, that can adequately protect external components like fueling receptacles from damage without the need for this specific regulation. NHTSA believes that removing this requirement will not compromise safety objectives while allowing for greater flexibility in vehicle design.

NHTSA is maintaining the other fueling receptacle requirements as proposed. NHTSA will conduct visual inspection by observation of the fueling receptacle, its location within the vehicle, and through basic operation of the vehicle such as attaching a fueling nozzle to the receptacle to test for positive locking. NHTSA has discretion regarding how many vehicles it inspects per year.

NHTSA notes that the referenced GTR No. 13 leak test outlines the check valve and shut-off valve leak test. While a fueling receptacle may contain a check valve, the test procedure is not written to accommodate fueling receptacles. In addition, testing of CHSS check valves is already covered under FMVSS No. 308 S5.1.5.2, and it would be redundant to apply the same test to the receptacle. As a result, NHTSA is maintaining visual inspection as the evaluation method for the requirements of FMVSS No 307 S5.1.1.

NHTSA is not requiring a disconnect switch to prevent vehicle starting and drive away on light duty vehicles. However, vehicle manufacturers are free to include this technology in their designs.

NHTSA is also not including requirements for the fueling receptacle profile or setting requirements for different ''Pressure Classes.'' Such specification would be design restrictive.

There is no exact location specified for the location of the fueling receptacle label. The presence of this label will be verified by visual inspection. Manufacturers may consider this inspection method when determining where to locate the label. The additional statement ''See instructions on fuel container(s) for inspection and service life'' is consistent with FMVSS No. 303.[48] This statement is important for the purpose of helping operators properly maintain their vehicles through regular safety inspections.

Lastly, NHTSA notes that the fueling receptacle design is not standardized by GTR No. 13. The preamble to GTR No. 13 simply references industry standards where examples of fueling receptacles can be found. This language in GTR No. 13does not constitute a requirement or a standardization of the fueling receptacle. NHTSA believes fueling receptacle designs may still be evolving. Therefore, while there may be safety benefits to standardizing fueling receptable designs, to do so at this time would be premature.

b. Over-Pressure Protection for Low-Pressure Systems

Background

NHTSA proposed GTR No. 13's requirement of over-pressure protection for low-pressure systems. Accordingly, the agency proposed requiring countermeasures to prevent failure of downstream components in the event a pressure regulator fails to properly reduce the fuel pressure from the much higher pressure in the CHSS. The activation pressure of the overpressure protection device shall be lower than or equal to the maximum allowable working pressure for the appropriate

[48] FMVSS No. 303, ''Fuel system integrity of compressed natural gas vehicles,'' *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.303.*

section of the hydrogen system as determined by the manufacturer. NHTSA sought comment on the requirement for an overpressure protection device in the fuel system and how to test the performance of such a device.

Comments Received

Auto Innovators recommended that NHTSA align with GTR No. 13 and avoid requiring an additional test. It stated that the main areas of GTR No. 13 cover CHSS, high-pressure closures, PRD, fuel lines, electrical safety, and performance and other subsystem requirements in the vehicle. It commented that the proposed overpressure protection falls under the ''Hydrogen Delivery'' system of a hydrogen fuel cell vehicle, which it stated should be outside the scope of this regulation. Auto Innovators noted that while low-pressure systems are not covered by GTR No. 13, it clearly defines overpressure protection for these systems as ensuring that ''the hydrogen system downstream of a pressure regulator shall be protected against overpressure due to the possible failure of the pressure regulator,'' which each manufacturer will verify. Thus, it stated that there is no need to add this requirement to FMVSS No. 307.

HATCI supported NHTSA's proposal to harmonize with GTR No. 13 and agreed that an overpressure protection device should be included in the system. However, it stated that evaluating every overpressure protection device in a system would need to end with regulator failure and compromise the whole system. It suggested that if such evaluation is necessary, the device's operation could be verified at the component level by applying a reverse pressure. Agility found the requirement acceptable and proposed testing the component on a bench by measuring its activation pressure. It also noted the possibility of testing it on the vehicle by deliberately exposing a PRD to its activation pressure, though it cautioned that this exposure could pose risks to vehicle safety.

Nikola commented that no additional test is needed since this component falls outside the scope of the regulation. FORVIA agreed with keeping alignment to GTR No. 13 Phase 2 and recommended using visual inspection as the test procedure. It argued that conducting an actual test on the vehicle would be difficult due to vehicle-dependent factors.

Agency Response

Based on the comments received, NHTSA is removing the requirement for an overpressure protection device in the fuel system. There is no test available to evaluate the performance of the over-pressure protection device, and therefore the proposed requirement that ''the activation pressure of the over-pressure protection device be lower than or equal to the maximum allowable working pressure for the respective downstream section of the hydrogen system'' is unenforceable. Simply requiring a device to be present with no test to evaluate its performance does not improve safety, and therefore, the requirement for an over-pressure protection device has been removed.

c. Hydrogen Discharge Systems

(1) TPRD Discharge Direction

Background

Consistent with GTR No. 13, NHTSA proposed that the TPRD vent line be protected from ingress of dirt or water to prevent contamination that could degrade or compromise the TPRD. NHTSA proposed several requirements related to the TPRD vent discharge direction, requiring that the TPRD discharge must not be directed towards nor impinge upon:

1. Any enclosed or semi-enclosed spaces where hydrogen could unintentionally accumulate, such as the trunk, passenger compartment, or engine compartment.
2. The vehicle wheel housing.
3. Hydrogen containers.
4. Rechargeable electrical energy storage system (REESS).
5. Any emergency exit(s) or service door(s).

In addition to these requirements, NHTSA proposed an additional requirement to protect potential occupants attempting to exit the vehicle or first responders approaching the vehicle. This requirement stated that hydrogen vented through the TPRD(s) be directed upwards within 20° of vertical relative to the level surface or downwards within 45° of vertical relative to the level surface. NHTSA sought comment on this additional requirement for TPRD discharge direction, and on the proposed discharge angles.

Comments Received

Air Products commented that venting downward could be acceptable for light vehicles but recommended any downward TPRD vent flow should be diffused to minimize a jet fire scenario. It also proposed specific considerations for heavy vehicles, suggesting that venting should be oriented away from cargo and vertically positioned outside the CHSS enclosure and vehicle. It stated the importance of designing vent stacks to withstand back pressure, thrust forces, and vehicle accidents.

Air Products also stated that venting high-pressure hydrogen in confined areas increases the likelihood of deflagration or detonation. It described the possibility of flame impingement at the TPRD outlet potentially leading to a cascading effect and larger hydrogen releases. It proposed modifications to include ''enclosed or semi-enclosed spaces including portions of the CHSS'' as a location the discharge shall not impinge upon.

Agility stated that the proposed requirement for a discharge angle within 20 degrees of vertical does not align with existing standards. It suggested using the wording from GTR No. 13 and commented that while venting within 45 degrees of vertical from the top could be acceptable, venting from the bottom at any angle other than vertical could lead to horizontal gas/flame plumes, posing risks to passengers and first responders. Agility also noted that these requirements could become irrelevant in vehicle rollovers.

Nikola and FORVIA both expressed concerns over the prescriptiveness of specifying venting angles. Nikola stated that discussions among experts concluded that manufacturers should be given the responsibility to determine safe venting designs. It cited GTR No. 13, which only specifies prohibited venting directions rather than mandating specific angles. FORVIA similarly stated that the topic is highly vehicle-specific and should be addressed on a case-by-case basis. FORVIA noted that the phrase ''not be directed towards'' could be interpreted subjectively, leading to compliance challenges. FORVIA agreed with the requirements other than the venting direction angles, but recommended aligning the wording exactly with GTR No. 13.

Luxfer Gas Cylinders viewed the proposed requirements as an improvement but indicated uncertainty about manufacturers' ability to comply. Auto Innovators did not support the proposed requirements in S5.1.3.1(b), citing extensive discussions within GTR No. 13 Phase 2, which highlighted structural differences among vehicles, especially heavy vehicles, that complicate establishing a ''one-size-fits-all'' requirement. It stated that prescribing discharge directions could limit design flexibility without improving safety. It also recommended deleting the proposed S5.1.3.1(c)(5) and

(6), because these requirements are inconsistent with GTR No. 13 and because the intent is not clear.

Agency Response

NHTSA acknowledges commenters' stated concerns that setting specific discharge angles was extensively discussed during GTR No. 13 Phase 2, and that the Informal Working Group ultimately chose not to include such specific requirements due to the complexities involved, especially given that vehicles—especially larger vehicles—have heterogenous designs and that a specific approach that works for some vehicles may not work for other vehicles. NHTSA also acknowledges that in certain situations, such as vehicle rollovers, angle requirements could become less relevant. After reviewing the comments and considering the real-world scenarios presented, NHTSA has decided to remove the proposed discharge angle requirements until more information is available to determine whether a generalized discharge angle is reasonable and beneficial. NHTSA will, however, retain the other TPRD discharge direction requirements as proposed. NHTSA notes that the requirements specify that ''[t]he hydrogen gas discharge from TPRD(s) of the CHSS shall not impinge upon'' as opposed to ''shall not be directed towards.''

NHTSA is not adding any additional requirements based on cargo locations within the vehicle or vent stack design at this time. Similar to the above discussion, cargo-specific TPRD directional venting requirements may be overly prescriptive, and until more data is available, it could potentially be unworkable given the variety of vehicle designs and cargo configurations or be a suboptimal safety solution. Furthermore, requirements for vent stack design, such as ensuring mechanical support for thrust forces, are design considerations that NHTSA does not intend to regulate and are outside the scope of the proposed standards.

Additionally, there is no need to specify additional portions of the CHSS to avoid venting onto, because the requirements list the container, which is the main component of the CHSS. Not directing TPRD discharge towards the container will effectively avoid the CHSS as well, so an additional specification regarding the CHSS would be redundant.

Lastly, NHTSA is retaining the specifications regarding ''emergency exit(s) as identified in FMVSS No. 217'' and ''service door(s).'' As stated in the NPRM, the purpose of these requirements is to prevent safety hazards due to hydrogen discharge from the TPRD that could inhibit the ability of passengers to safely exit the vehicle.[49]

(2) Possible Test To Evaluate TPRD Discharge Direction

Background

NHTSA proposed that the discharge direction from TPRDs and other pressure relief devices be evaluated through visual inspection. NHTSA sought comment on whether there is a more appropriate test.

Comments Received

Nikola recommended relying on a visual inspection for evaluating TPRD discharge direction. In contrast, HATCI suggested that NHTSA adopt a detailed emission measurement method, which would use the end of the valve angle relative to horizontal, instead of solely depending on visual inspection.

Agency Response

NHTSA will maintain visual inspection as the evaluation for TPRD discharge direction. It will be clear from the orientation of the TPRD and/or the TPRD vent lines where the TPRD discharge is being directed. While the suggestion to use valve angle measurements to verify compliance is plausible, the commenters did not provide a specific procedure for conducting an objective valve angle measurement. If a more comprehensive and detailed testing procedure is identified in the future, the agency may consider incorporating it in the future.

d. Vehicle Exhaust Systems

Background

NHTSA proposed the vehicle exhaust requirements outlined in GTR No. 13. NHTSA proposed that the test procedure be conducted after the vehicle has been set to the ''on'' or ''run'' position for at least five minutes prior to testing. A hydrogen measuring device is placed in the center line of the exhaust within 100 mm from the external discharge point. The fuel system would undergo a shutdown, start-up, and idle operation to stimulate normal operating conditions. The measurement device used should have a response time of less than 0.3 seconds to ensure an accurate three second moving average calculation. Response times higher than 0.3 seconds could result in inaccurate data collection because the sensor may not have time to register the true concentration levels before recording each data point.

The time period of three seconds for the rolling average ensures that the space around the vehicle remains non-hazardous in the case of an idling vehicle in a closed garage. This time period is conservatively determined by assuming that a standard size vehicle purges the equivalent of a 250 kW (340 HP) fuel cell system.[50] The time is then calculated for a nominal space occupied by a standard passenger vehicle (4.6 meters × 2.6 meters × 2.6 meters) to build up to 25 percent of the LFL, or one percent by volume in air. The time limit for this rolling-average situation is determined to be three seconds.[51]

Comments Received

Luxfer Gas Cylinders questioned how NHTSA intends to ensure compliance with these requirements. Auto Innovators expressed support for harmonizing the exhaust requirements with GTR No. 13 but suggested revising the terminology from ''on'' or ''run'' position to align with the GTR standard, which specifies that ''the propulsion system of the test vehicle is started, warmed up to its normal operating temperature, and left operating for the test duration.'' Nikola stated agreement with adopting the requirements in GTR No. 13.

Agency Response

NHTSA will ensure compliance with the requirements of FMVSS No. 307 S5.1.2.2, *Vehicle exhaust system,* by testing vehicles in accordance with FMVSS No. 307 S6.5, *Test for the vehicle exhaust system.* Additionally, for the reasons discussed below in section IV.C.2.f., Protection against flammable conditions, NHTSA has revised the requirement that ''the vehicle shall be set to the 'on' or 'run' position for at least 5 minutes prior to testing, and left operating for the test duration.'' The new requirement will specify that ''the vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test.'' This change ensures the safe operation of fuel cell vehicles during testing while still meeting the intended objectives of the proposed test protocol.

[49] *See* 89 FR 27536 (Apr. 17, 2024), *available at https://www.federalregister.gov/documents/2024/04/17/2024-07116/federal-motor-vehicle-safety-standards-fuel-system-integrity-of-hydrogen-vehicles-compressed.*

[50] In comparison, the power system output of a Toyota Mirai is 182 HP.

[51] SAE 2578_201408. Recommended Practice for General Fuel Cell Vehicle Safety. Appendix C3. *https://www.sae.org/standards/content/j2578_201408/.*

e. Fuel System Leakage

Background

GTR No. 13 includes fuel system leakage requirements specifying no leakage from the fuel lines. A flammable or explosive condition can arise if hydrogen leaks from the fuel lines and accumulates. However, the safety risk of a leak applies to the entire fuel system, not only to the fuel lines. As a result, NHTSA proposed that the fuel system leakage requirement for no leakage apply to the entire hydrogen fuel system downstream of the shut-off valve, which includes the fuel lines and the fuel cell system. NHTSA further proposed to define fuel lines to include all piping, tubing, joints, and any components such as flow controllers, valves, heat exchangers, and pressure regulators. From a safety standpoint, there is no difference between a leak coming from fuel line piping, and a leak coming from a valve, pressure regulator, or the fuel cell system itself. Consistent with GTR No. 13, NHTSA proposed a strict no leakage standard. NHTSA sought comment on whether there is a safe level of hydrogen that may leak, and if so, what would be an objective leakage limit and how to accurately quantify hydrogen leakage from the fuel system.

NHTSA proposed to test this requirement using either a gas leak detector or leak detecting liquid (bubble test). NHTSA sought comment if one of these tests is preferrable. NHTSA also proposed that the test be conducted with the fuel system at NWP after having been in the ''on'' or ''run'' position for at least five minutes. NHTSA sought comment on whether alternative conditions would better simulate realistic scenarios when downstream lines are more likely to leak.

Comments Received

Luxfer Gas Cylinders commented that either a gas leak detector or a bubble test is acceptable, noting the long-standing effectiveness of the bubble test and expressing support for the proposed five-minute warm-up period. Ballard Power Systems stated that achieving a strict no leakage standard is likely impractical due to the extensive use of elastomeric seals and non-metallic materials in fuel cell vehicles. It stated that fuel cell stacks typically have a leakage rate around 200 mL/min hydrogen at the beginning of life, and that standards such as HGV 3.1 permit a maximum leak rate of 10 Ncc/h. It recommended establishing a leakage requirement that ensures flammable releases are negligible, suggesting that gas mixtures with hydrogen concentrations below the lower flammability limit do not pose combustion risks. Ballard proposed mitigation techniques like enclosing components prone to leaks and using ventilation and hydrogen detection to manage non-flammable releases.

Auto Innovators disagreed with a strict no leakage requirement, stating that leakage can be detected at very low levels well below hazardous thresholds using sensitive equipment. It advocated for aligning the allowable leakage rate with the single-point leakage definition in GTR No. 13. It also supported NHTSA's proposal for the five-minute warm-up but suggested adopting GTR No. 13's terminology and test conditions. Air Products recommended conducting the leak check at 1.25 times NWP to align with industry standards.

HATCI supported harmonizing with GTR No. 13 and advised adopting criteria that focus on leak detection at accessible fuel line sections, especially at joints, as specified in GTR No. 13 section 6.1.5. HATCI also proposed adopting a 3 percent hydrogen concentration limit as a flammability condition and suggested clarifying regulatory text regarding the vehicle's ''on'' or ''run'' position during testing. Agility noted that complete leak-free connections are impossible and referenced SAE J1267, which states that ''absolute leak tightness is an absolute impossibility.'' It recommended specifying maximum allowable leak rates consistent with existing standards, emphasizing that both bubble solutions and electronic leak detection are feasible methods.

Nikola proposed adopting GTR No. 13's leak rate requirement of 0.005 mg/s and supported the bubble test as a reliable method to check for joint leaks, suggesting that more advanced instrumentation be required only if a bubble test indicates leakage. Hyzon expressed concerns about the subjectivity of bubble testing and recommended that NHTSA use additional accurate testing methods, including detection devices that meet industry standards. NFA commented that a safe level of hydrogen leak should reference standards like SAE technical paper 2008–01–0726, ''Flame Quenching Limits of Hydrogen Leaks,'' and SAE J2579, which limit leak rates to prevent hazardous concentrations. It questioned why FMVSS No. 308 would apply a different standard to the CHSS compared with the standard that applies to the rest of the fuel system. NFA emphasized the practicality of bubble tests for detecting localized leaks and noted that metallic ferrule style tube fittings can be validated to be bubble-tight.

FORVIA suggested revising the wording of the proposal to specify ''no detectable leakage'' based on a test method or minimum measurement sensitivity. DTNA argued that a zero percent leak rate is not feasible due to hydrogen's chemical properties and current measurement technology limitations. It proposed a leak rate below 3.6 NmL/min, which it stated is the lowest flow necessary for flame initiation.

Agency Response

NHTSA has determined that a demonstratable ''no leakage'' standard as evaluated by a bubble test is consistent with GTR No. 13, which specifies that ''the hydrogen fueling line downstream of the main shut-off valve(s) shall not leak.'' GTR No. 13 does not provide any leakage limit in either section 5.2.1.5 or 6.1.5. Thus, NHTSA's application of a demonstratable no-leakage requirement as evaluated by a bubble test aligns with GTR No. 13.

NHTSA acknowledges the concerns regarding the practicality of achieving a true no-leakage standard, noting that very low levels of hydrogen leakage may occur due to the tiny size of hydrogen molecules and the materials and sealing technologies used in hydrogen fuel systems. However, NHTSA emphasizes that any detectable hydrogen leakage poses potential safety risks. Even minimal levels of hydrogen leakage present the possibility of gas accumulation in enclosed spaces, which could create hazardous conditions. Multiple individual points of leakage could produce an additive effect where the cumulative leakage rate becomes significant.

In response to suggestions that NHTSA define specific test methods for leak detection, the proposed regulation already includes objective test procedures for verifying compliance with the no-leakage requirement in FMVSS No. 307 S6.6. As such, suggestions to include additional specificity in test methods are redundant, as the regulation already addresses this concern. Furthermore, NHTSA is not including in S6.6 the statement ''primarily at joints'' that is found in GTR No. 13. This language is unnecessary, as NHTSA will be able to evaluate joints as well as other portions of the fuel system for leakage regardless of whether this language is included or not. Additionally, it is not possible to define a fuel system leakage limit based on a concentration of hydrogen in the surrounding air, as some commenters suggested. Doing so would require several assumptions to be made regarding factors such as the volume of air in which the hydrogen may accumulate, the location of leakage points relative to the air volume, number of leakage points, and the possibility of air-exchange rates.

To address concerns about the high sensitivity of leak detection equipment, NHTSA has decided to remove the option of using an electronic leak detector and will instead require the use of the bubble test method exclusively. As some commenters noted, the bubble test has been effectively used for decades and provides a practical, reliable means of visually detecting leaks. This method, which is less sensitive than advanced electronic leak detectors, is based on simple visual observation as to the expansion and/or propagation of bubbles and is not dependent on the subjective opinions of individuals. It addresses the need for an objective evaluation of leakage while acknowledging the concerns about detecting insignificant background levels of hydrogen that do not present a direct hazard. The bubble test will allow for a practical assessment of compliance with the no-leakage requirement without the possibility of test equipment detecting harmless levels of hydrogen. If no leakage is detectable using the bubble test specified in S6.6, then the vehicle will be deemed to have acceptable performance. To further clarify this standard, FMVSS No. 307 S5.1.4 has been revised to read: ''When tested in accordance with S6.6, the hydrogen fuel system downstream of the shut-off valve(s) shall not exhibit observable leakage.'' Adding the words ''exhibit observable leakage'' clarifies that leaks which do not result in observable bubble expansion during the S6.6 test procedure are not considered failures.

Additionally, for the reasons discussed below in section IV.C.2.f., *Protection against flammable conditions,* NHTSA has revised the requirement that ''the vehicle shall be set to the 'on' or 'run' position for at least 5 minutes prior to testing, and left operating for the test duration.'' If the vehicle is not a fuel cell vehicle, it shall be warmed up and kept idling. If the test vehicle has a system to stop idling automatically, measures shall be taken to prevent the engine from stopping.'' The new requirement will specify that ''the vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test.'' This change ensures the safe operation of fuel cell vehicles during testing while still meeting the intended objectives of the proposed test protocol.

f. Protection Against Flammable Conditions

Background

NHTSA proposed requiring a visual warning within 10 seconds in the event that the hydrogen concentration in an enclosed or semi-enclosed space exceeds 3.0 percent (75 percent of the LFL). Additionally, consistent with GTR No. 13, NHTSA proposed requiring the shut-off valve to close within 10 seconds if at any point the concentration in an enclosed or semi-enclosed space exceeds 4.0 percent (the LFL).

GTR No. 13 provides two options for evaluating this requirement. The first option is to use a remote-controlled release of hydrogen to simulate a leak, along with laboratory-installed hydrogen concentration detectors in the enclosed or semi-enclosed spaces. The laboratory-installed hydrogen concentration detectors are used to verify that the required warning and shut-off valve closure occur at the appropriate hydrogen concentrations in the enclosed or semi-enclosed spaces. GTR No. 13 allows for the remote-controlled release of hydrogen to be drawn from the vehicle's own CHSS. Therefore, by using this option, it is possible for a vehicle to meet the requirements without a built-in hydrogen concentration detector. This objective is accomplished by the vehicle monitoring hydrogen outflow from its CHSS. The vehicle can then trigger the required warning and shut-off valve closure if significant hydrogen outflow from the CHSS is detected that is not accounted for by fuel cell hydrogen consumption.

The second option for evaluating the requirement is to use an induction hose and a cover to apply hydrogen test gas directly to the vehicle's built-in hydrogen concentration detector(s) within the enclosed or semi-enclosed spaces. Test gas with a hydrogen concentration of 3.0 to 4.0 percent is used to verify the warning, and test gas with a hydrogen concentration of 4.0 to 6.0 percent is used to verify the closure of the shut-off valve. The warning and shut-off valve closure must occur within 10 seconds of applying the respective test gas to the detector. The warning is verified by visual inspection, and the shut-off valve closure can be verified by monitoring the electric power to the shut-off valve or by the sound of the shut-off valve activation.

This second option indirectly requires the presence of at least one hydrogen concentration detector in the enclosed or semi-enclosed spaces that can detect the hydrogen test gas and trigger the warning and shut-off valve closure at appropriate hydrogen concentration levels. NHTSA proposed this second option as the only test method in FMVSS No. 307, which would thereby require each vehicle to have at least one built-in hydrogen concentration detector. NHTSA sought comment on requiring built-in hydrogen concentration detectors and on the reliability of the required warning and shut-off valve closure for vehicles that do not have built-in hydrogen concentration detectors.

In addition to the above requirement regarding a warning and shut-off valve closure, GTR No. 13 includes a requirement that any failure downstream of the main hydrogen shut off valve shall not result in any level of hydrogen concentration in the passenger compartment. This requirement is evaluated by applying a remote-controlled release of hydrogen simulating a leak in the fuel system, along with laboratory-installed hydrogen concertation detectors in the passenger compartment. After remote release of hydrogen, GTR No. 13 requires that the hydrogen concentration in the passenger compartment not exceed 1.0 percent. The number, location, and flow capacity of the release points for the remote-controlled release of hydrogen are determined by the vehicle manufacturer.

NHTSA instead proposed that the remote-controlled release of hydrogen shall not result in a hydrogen concentration exceeding 3.0 percent in the enclosed or semi-enclosed spaces of the vehicle (including the passenger compartment). NHTSA sought comment on this requirement and on specific test procedures for initiating a remote-controlled release of hydrogen in a vehicle.

To evaluate this requirement, NHTSA proposed that a hydrogen concentration detector be installed in any enclosed or semi-enclosed space where hydrogen may accumulate from the simulated hydrogen release. After the remote-controlled release of hydrogen, the hydrogen concentration would be measured continuously using the laboratory-installed hydrogen concertation detector. The test would be completed five minutes after initiating the simulated leak or when the hydrogen concentration does not change for three minutes, whichever is longer. Five minutes was selected as the minimum time for monitoring the hydrogen concentration because five minutes is generally considered a sufficient time frame for vehicle occupants to evacuate in the event of an emergency.

Comments Received

Agility commented that using built-in hydrogen detectors is feasible and analogous to requirements for liquified natural gas (LNG) vehicle systems. It emphasized the need for electronic detection due to hydrogen's odorless nature, comparing it to the established reliability of natural gas sensors. Agility also stated that any remote release of hydrogen should not be built into every vehicle directly, citing potential safety risks and increased costs. Instead, it recommended using separate testing equipment operated by qualified personnel.

Luxfer Gas Cylinders expressed concern that requiring detectors and warnings for all enclosed and semi-enclosed spaces might be excessively difficult due to the number of such spaces in both light and heavy vehicles. Air Products suggested incorporating passive or mechanical ventilation into the CHSS to help dissipate leaks before they accumulate to hazardous levels, in addition to other safety measures.

Glickenhaus raised safety concerns regarding the idling of fuel cell electric vehicles during tests, commenting that forcing fuel cell vehicles to idle could be dangerous or even impossible depending on the fuel cell's minimum output and battery capacity. Glickenhaus stated that while hydrogen internal combustion vehicles might idle safely, fuel cell vehicles could face significant risks of overcharging or electrical failure.

HATCI sought clarity on specific test requirements. It questioned the definition of the air component in the mixed hydrogen gases for testing and expressed concerns over the difficulty of obtaining the specified mixtures based on geographical availability. Additionally, HATCI supported the flexibility in defining release points downstream of the shut-off valve, as proposed by NHTSA, allowing manufacturers to determine these parameters.

Nikola recommended not adding an additional 10-second requirement for visual warnings beyond what is specified in GTR No. 13. It also preferred allowing OEMs to decide how to meet safety requirements rather than requiring built-in hydrogen detectors. It requested that NHTSA maintain the lower leakage concentration limit of one percent inside the passenger compartment to align with GTR No. 13. FORVIA disagreed with deviations from GTR No. 13, requesting that NHTSA keep the requirements fully aligned and avoid requiring hydrogen detectors in enclosed spaces, suggesting that ventilation might suffice as a safety measure.

Agency Response

After careful consideration of the comments received, NHTSA has decided to maintain the proposed requirements, with the exception of revisions related to the idling requirements, discussed below, and the revision to the definition of enclosed and semi-enclosed spaces, discussed above.

Regarding the use of built-in hydrogen detectors, some commenters supported their use, drawing parallels to systems required in LNG vehicles due to the lack of odorant in the fuel, which makes electronic detection necessary. NHTSA has determined that built-in hydrogen detectors are critical for safety. Hydrogen's odorless and highly flammable properties necessitate on-board hydrogen detection capability to mitigate risks. The proposed test method verifies that hydrogen detectors can activate a warning and shut-off valve closure within the prescribed time frame and concentration thresholds, thereby ensuring that vehicles can detect and respond to hydrogen leaks promptly. There will not be an excessive number of spaces that will require hydrogen detectors because, as discussed above, the definition of "enclosed and semi-enclosed spaces" has been revised to be very specific, including only the passenger compartment, luggage compartment, and space under the hood.

With respect to concerns about remote-controlled hydrogen release for testing purposes, some commenters stated that incorporating this feature into every vehicle could introduce safety risks or unnecessary costs. This is not a correct interpretation of the proposal. FMVSS No. 307 S6.4.2(b) states that "[p]rior to the test, the vehicle is prepared to simulate remotely controllable hydrogen releases from the fuel system or from an external fuel supply." This language indicates the use of separate, specialized test equipment that is only applied to the test vehicle(s) rather than integrating the capability into all vehicles.

Regarding the hydrogen concentration limit in the passenger compartment, some commenters advocated for maintaining the 1.0 percent limit specified in GTR No. 13, citing it as more conservative. However, NHTSA proposed a 3.0 percent limit in the enclosed and semi-enclosed spaces (not just the passenger compartment). The 3.0 percent limit aligns with the lower flammability limit (LFL) of hydrogen, and providing a more balanced requirement across all the enclosed and semi-enclosed spaces and ensures that hydrogen concentrations remain below hazardous levels. NHTSA has therefore chosen to maintain this requirement as proposed. Note that the definition for enclosed and semi-enclosed spaces has been revised to eliminate ambiguity, as discussed above in section IV.C.1.

Regarding the comment that the components of the air in the mixed gas were not defined in S6.4.1(b), this concern is unfounded. The proposed regulatory text specifies the required hydrogen concentrations in the test gas mixtures: "The first test gas has any hydrogen concentration between 3.0 and 4.0 percent by volume in air to verify function of the warning, and the second test gas has any hydrogen concentration between 4.0 and 6.0 percent by volume in air to verify function of the shut-down." NHTSA can clarify that "air" refers to the natural atmospheric air composition, which is globally consistent across the surface of the Earth. Atmospheric air is primarily composed of approximately 78% nitrogen, 21% oxygen, and trace amounts of other gases such as argon and carbon dioxide. This standard atmospheric composition is well understood and used in numerous industrial and scientific applications. Therefore, the air component in the hydrogen-air mixture is inherently defined and does not require additional specification or definition within the regulatory text.

Regarding the time of 10 seconds to activate the warning or the shut-off valve closure, GTR No 13 does not contain a time limit for activation. The test can continue indefinitely if the warning has not come on or the shut-off valve has not closed. NHTSA cannot have a test that may continue indefinitely; therefore, the agency is maintain the proposed 10-second time limit to activate the warning and close the shut-off valve after the respective mixtures of hydrogen gas are applied.

Lastly, concerns were raised about the idling requirements for fuel cell vehicles during testing. One commenter emphasized that forcing fuel cell vehicles to idle for extended periods could pose significant safety risks, including the potential for battery overcharging or fuel cell malfunction. NHTSA recognizes these concerns and has revised the regulatory language. The new requirement will specify that "the vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test.'' This change ensures the safe operation of fuel cell vehicles during testing while still meeting the intended objectives of the proposed test protocol.

(1) Wind Control During Testing

Background

The proposed test procedures in this section would be conducted without the influence of any wind. NHTSA sought comment on providing more specific wind protection requirements and sought comment on limiting the maximum wind velocity during testing to 2.24 meters/second, as in FMVSS No. 304.[52]

Comments Received

Nikola commented that including wind influence in testing would not be feasible unless tests were conducted indoors, which would introduce additional complexities. It supported using the same wind velocity requirement as FMVSS No. 304. Auto Innovators agreed with NHTSA on the need to establish more specific wind protection requirements.

Agency Response

After careful consideration, NHTSA has determined that it will not impose specific limits on wind velocity or require wind shielding measures as part of the testing protocol. While some commenters suggested adopting a wind velocity limit similar to that in FMVSS No. 304, NHTSA has decided against incorporating explicit wind control specifications. Establishing objective wind control requirements, such as specifications for shielding or velocity limits, present logistical challenges. Furthermore, requiring all tests to be conducted indoors to completely eliminate wind effects could introduce additional safety and operational difficulties, further complicating the testing process. These challenges make prescriptive wind control requirements impractical across different test environments.

Therefore, while NHTSA is maintaining the requirement that ''the test shall be conducted without influence of wind,'' the agency will allow individual test facilities the discretion to manage wind conditions according to their capabilities and procedures. This approach offers necessary flexibility, enabling laboratories to conduct tests under conditions suited to their operational constraints, while still ensuring the accuracy and reliability of test results.

g. Warning for Elevated Hydrogen Concentration

Background

NHTSA proposed requiring a telltale warning when hydrogen concentration exceeds 3.0 percent in the enclosed or semi-enclosed spaces of the vehicle. NHTSA also proposed the visual warning be red in color and remain illuminated while the vehicle is in operation with hydrogen concentration levels exceeding 3.0 percent in enclosed or semi-enclosed spaces of the vehicle. The visual warning must be in clear view of the driver. For a vehicle with an Automated Driving System (ADS) and without manually operated driving controls, the visual warning must be in clear view of all the front seat occupants. NHTSA sought comment on whether the warning should be in clear view of all occupants, including occupants in rear seating positions, in vehicles equipped with an ADS. NHTSA also sought comment on whether an auditory warning should be required when hydrogen concentration exceeds 3.0 percent in the enclosed or semi-enclosed spaces of the vehicle.

NHTSA also proposed that a telltale be activated if the hydrogen warning system malfunctions, such as in the case of a circuit disconnection, short circuit, sensor fault, or other system failure. NHTSA proposed that when the telltale activates for these circumstances, it illuminate as yellow to distinguish a malfunction of the warning system from that of excess hydrogen concentration.

Comments Received

Nikola expressed agreement with the proposal. Auto Innovators highlighted the need to align with the requirements in FMVSS No. 101, ''Controls and displays,'' for vehicles equipped with ADS and recommended maintaining current placement requirements for visual warnings. It noted that defining ''clear view'' lacks objectivity and stated that auditory warnings should not be required in ADS-equipped vehicles until further research is conducted. It stated that ''near-term flexibility'' may be needed to prevent consumer confusion. Auto Innovators supported the proposed activation criteria and color scheme, noting consistency with GTR No. 13.

DTNA suggested adding an audible warning to supplement the visual warning, particularly for heavy vehicles and school buses with complex seating arrangements where occupants might not have clear visibility of the visual indicator. It stated that an audible warning would be essential for crew cabs, trucks with sleeper berths, and school buses, where a visual warning alone would not suffice to communicate risk effectively. Similarly, Glickenhaus supported the addition of an auditory warning and favored the placement of visual warnings in clear view of all seating positions in ADS-equipped vehicles.

HATCI supported harmonization with GTR No. 13 and recommended determining visual warning requirements based on a vehicle's automation level. It stated that visual warnings should be in the driver's view for vehicles at SAE Levels 0 to 3 but more broadly visible for vehicles at SAE Levels 4 or 5. However, HATCI advised against requiring auditory warnings, citing concerns about potential confusion due to the numerous existing auditory alerts.

NFA supported the inclusion of a visual telltale in red for high hydrogen concentration levels, in line with FMVSS No. 307, and agreed with the requirement for a yellow malfunction warning. NFA also provided context for its current hydrogen detection system, which includes warnings at 20 percent and 50 percent of the LFL, indicating that its system already meets the proposed standard. Regarding ADS-equipped vehicles, NFA agreed with NHTSA's proposal as written, noting that transit buses are likely to retain an attendant or driver in the front seating position due to the additional duties they perform. NFA recommended that NHTSA consider how to address the requirements in scenarios where no front seat passengers are present.

Agency Response

After careful consideration, NHTSA is maintaining the proposal as originally outlined. With respect to the inclusion of an auditory warning, NHTSA agrees that further research is necessary to assess the most appropriate auditory alerting mechanisms for hydrogen-fueled vehicles. While some commenters advocated for the inclusion of an auditory warning, NHTSA has determined that additional research is needed to evaluate the use of auditory alerts. For example, the possibility of voice alerts may need to be considered. Voice alerts may offer a clearer communication of the hazard without contributing to confusion. Additionally, NHTSA is cognizant that the proliferation of crash avoidance and driving automation systems has resulted in an increased number of telltales and auditory alerts, many of which are

[52] FMVSS No. 304, ''Compressed natural gas fuel container integrity.'' *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.304.*

voluntarily added by manufacturers. As such, NHTSA will not require auditory warnings at this time. The absence of a requirement for an auditory warning does not preclude manufacturers from voluntarily including such warnings based on their vehicle-specific configurations.

Regarding visual warning placement, NHTSA will not adopt specific requirements based on SAE automation levels at this time. The scope of this final rule is not contingent on a particular vehicle type. NHTSA's focus remains on ensuring that the visual warning is in clear view of the driver or, for ADS-equipped vehicles without manual controls, in view of the front-seat occupants. This approach provides manufacturers with flexibility while maintaining safety for occupants in these advanced vehicles. This approach is also consistent with past updates to the crashworthiness FMVSS to account for ADS-equipped vehicles.[53] The suggestion to include rear-seat occupants in ADS-equipped vehicles is not being implemented at this time, as NHTSA believes that further consideration is needed to determine the most effective and appropriate hydrogen warning systems for rear-seat occupants.

Finally, regarding the distinction between malfunction and hydrogen concentration warnings, NHTSA will retain the proposed color scheme, with yellow indicating a system malfunction and red indicating an elevated hydrogen concentration. This color differentiation is essential to ensure that drivers and occupants can quickly distinguish between a system malfunction and an immediate hydrogen-related hazard.

3. Post-Crash Fuel System Integrity

Background

Consistent with GTR No. 13, NHTSA proposed that the post-crash requirements for vehicles that use hydrogen fuel for propulsion power only apply to passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR less than or equal to 4,536 kg (10,000 pounds) and to all school buses. NHTSA did not propose that the post-crash requirements apply to all heavy vehicles with a GVWR greater than 4,536 kg (10,000 pounds). NHTSA sought comment on whether heavy vehicles should be subject to these proposed post-crash requirements and, if so, what crash tests should NHTSA conduct on heavier vehicles.

NHTSA proposed to use the crash tests equivalent to those applied to conventionally fueled vehicles in accordance with FMVSS No. 301. For light vehicles with a GVWR under 4,536 kg, these crash tests include an 80 kilometers per hour (km/h) (~50 miles per hour (mph)) impact of a rigid barrier into the rear of the vehicle, a 48 km/h (~30 mph) frontal crash test into a rigid barrier, and a 53 km/h (~33 mph) impact of a moving deformable barrier into the side of the vehicle. For school buses with a GVWR greater than or equal to 4,536 kg, the crash test is a moving contoured barrier impact at 48 km/h. NHTSA sought comment on whether there are alternative crash tests that should be used for the forthcoming proposed regulations.

NHTSA proposed that there be no fire during the test, and that vehicles meet three additional post-crash requirements described by GTR No. 13. The first proposed requirement is the volumetric flow of hydrogen gas leakage from the CHSS must not exceed an average of 118 normal liters per minute (NL/min) from the time of vehicle impact through a time interval Δt of at least 60-minutes after impact. The volumetric leak rate of hydrogen post-crash is determined as a function of the pressure in the container before and after the crash test. The interval Δt is at least 60 minutes after impact and the pressure drop measurement should be at least 5 percent of the pressure sensor's full range. Helium may be used in place of hydrogen during crash-testing with an allowable leakage limit for helium of 88.5 NL/min.

The second requirement is a hydrogen concentration limit set to four percent by volume (for helium, this corresponds to a concentration of three percent by volume) in enclosed or semi-enclosed spaces. This requirement is satisfied if the CHSS shut-off valve(s) are confirmed to be closed within five seconds of the crash and there is no hydrogen leakage from the CHSS.

For the purpose of measuring the hydrogen concentration, GTR No. 13 specifies that data from the sensors shall be collected at least every five seconds and continue for a period of 60 minutes. GTR No. 13 also discusses filtering of the data to provide smoothing of the data, but is unclear about the exact data filtration method to be used. NHTSA proposed using a three-data-point rolling average for filtering the data steam. Since a data point will be collected at least every five seconds, this rolling average will be, at most, a 15-second rolling average. NHTSA sought comment on this proposed data filtration method.

The third proposed requirement is that the container(s) remain attached to the vehicle by at least one component anchorage, bracket, or any structure that transfers loads from the device to the vehicle structure. This requirement is evaluated by visual inspection of the container attachment points. NHTSA will evaluate the presence of vehicle fire by visual inspection for the duration of the test, which includes the time needed to determine fuel leakage from the CHSS.

In addition to these requirements, NHTSA sought comment on the safety need for a heavy vehicle sled test. NHTSA sought input and comment with supporting data on implementing a possible alternative heavy vehicle impact test for the CHSS. NHTSA sought comment on the possibility of including a moving contoured barrier impact test on heavy vehicles (other than school buses) in accordance with S6.5 of FMVSS No. 301.

Comments Received

Auto Innovators supported NHTSA's decision to limit the scope of FMVSS No. 307 to light vehicles with a GVWR under 10,000 pounds and school buses. It requested that NHTSA conduct a regulatory impact analysis before including heavy vehicles. Auto Innovators noted that heavy vehicles have varied designs and are produced in low volumes, making full-scale crash testing complex and potentially cost-prohibitive. It recommended that if NHTSA considers including heavy vehicles, it should issue a new rulemaking proposal through either a separate rulemaking notice or supplemental notice of proposed rulemaking. Regarding the proposed crash tests, Auto Innovators agreed with using existing crash tests for vehicles under 10,000 pounds GVWR, stating that existing crash tests are representative of commonly occurring crashes in the field and should be suitable for assessing the post-crash fuel system integrity of hydrogen vehicles. Auto Innovators opposed adding alternative crash tests for hydrogen vehicles without supporting data. Auto Innovators also stated that it agrees with NHTSA's proposed data filtration method.

Hyundai concurred with NHTSA's initial decision to apply the post-crash requirements for heavy vehicles only to school buses but highlighted the potential significance of heavy commercial vehicles for hydrogen applications. It stated that post-crash fuel system integrity should be a

[53] *See* 87 FR 18560 (Mar. 30, 2022), *available at https://www.federalregister.gov/documents/2022/03/30/2022-05426/occupant-protection-for-vehicles-with-automated-driving-systems.*

consideration for these vehicles. It stated that the moving deformable barrier test for heavy school buses could be adapted to include other heavy vehicles. However, if the adaptation would delay the rulemaking, Hyundai suggested that NHTSA consider a follow-on rulemaking to address heavy vehicle standards once those procedures have been developed.

Agility agreed with NHTSA's decision to keep the post-crash requirements separate for heavy vehicles, stating that these vehicles differ significantly from light vehicles and require careful consideration and research before establishing specific crash testing requirements. It suggested benchmarking existing standards for light vehicles as a starting point and adapting similar procedures with appropriate performance criteria for heavy vehicle applications. Agility proposed focusing on fuel system-specific tests, such as a sled test, to account for the complexity of heavy vehicle configurations, stating that such tests could yield consistent results independent of the vehicle's body type or chassis. It also noted that current practices under FMVSS Nos. 303 and 304 have been adequate for heavy CNG vehicles and that a sled test could serve as a viable alternative to full vehicle crash tests, potentially simplifying the process. Agility also supported the use of a 15-second rolling average for data filtration.

DTNA supported NHTSA's decision to exclude heavy vehicles, other than school buses, from the proposed post-crash requirements, citing the lack of existing comparable crash tests and the high costs of conducting full-scale tests for heavy vehicle configurations. DTNA recommended a partial vehicle impact test using a moving deformable barrier (MDB), which allows for evaluating crash protection components like shields and panels without the need for full-vehicle tests. It suggested that vehicle simulations could also be used to assess these components. DTNA supported retaining the moving contoured barrier test for school buses over 10,000 pounds GVWR, as it aligns with current FMVSS No. 301 standards. It proposed a simulation similar to the Federal Motor Carrier Safety Administration's 30-foot drop test requirements outlined in 49 CFR 393.67(e)(1) but advised against conducting a 30-foot drop test solely on the container, stating that this test would not reflect real-world conditions since hydrogen containers often have additional protective components.

EMA supported component-level testing for heavy vehicles, noting that full-scale crash tests would be impractical due to the custom designs and low production volumes of these vehicles. It stated that international standards such as GTR No. 20, ''Electric Vehicle Safety,'' and UN ECE R100, ''Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train,'' rely on mechanical shock tests at the component level. EMA agreed with the inclusion of crash tests for hydrogen-fueled school buses, as these tests align with FMVSS No. 301 and provide consistent safety standards with liquid-fueled buses. EMA stated that heavy school buses have relatively few model offering and vehicle configurations.

Nikola supported applying side impact tests when the CHSS falls within the MDB impact zone defined by FMVSS No. 214, ''Side impact protection,'' and suggested allowing manufacturers to determine the specific impact zones based on vehicle design. Nikola completed frontal, side, and rear impact tests for its own designs and proposed that each manufacturer should be responsible for identifying the relevant strike zones on its vehicles. Nikola also stated that the proposed post-crash CHSS retention and leakage requirements seemed reasonable, but it did not see a need for a sled test.

Hyzon agreed with NHTSA's decision not to introduce new post-crash requirements for hydrogen-powered heavy vehicles (HPHV) in FMVSS No. 307, aligning the standard with GTR No. 13 Phase 2. It stated that NHTSA has not set crash test requirements for any other heavy vehicles, and there is no justification for unique post-crash requirements specifically for HPHVs. Hyzon suggested that further research be conducted before considering additional standards. Hyzon suggested waiting for more data from GTR No. 13 Phase 3 before deciding on any new crash tests.

Glickenhaus expressed safety concerns about crash testing vehicles with hydrogen onboard, stating that the proposed regulations do not reference procedures and processes to make that crash test safe. It pointed out that while NHTSA typically includes safety protocols in its standards, such as substituting Stoddard solvent for gasoline during FMVSS No. 301 testing, the proposed regulations under FMVSS Nos. 307 and 308 would allow crashes with hydrogen or helium. It requested that if manufacturers are expected to choose between testing with hydrogen or helium, this expectation should be explicitly stated in the regulation. Glickenhaus stated that two testing laboratories have expressed reluctance to perform crash tests with hydrogen due to safety concerns, preferring helium or other inert gases. It argued that if these experienced labs are not comfortable testing with hydrogen, it is unlikely that manufacturers could safely conduct these tests on their own. Additionally, Glickenhaus recommended using thermal imaging cameras for fire detection, as hydrogen fires are clear and colorless, making them difficult to identify through visual inspection alone.

NFA commented on the need for mechanical shock testing for heavy vehicles but noted a lack of comprehensive data to conclusively assess the relevance of a sled test. It stated that both NFA and its CHSS manufacturers adhere to the mechanical shock requirements in NGV 6.1, ''Compressed natural gas (CNG) fuel storage and delivery systems for road vehicles,'' which requires 8g inertia loading in all three primary axes without failure, and referenced UN ECE R134, which specifies lower inertia loading requirements of 6.6g longitudinally and 5g transversely. NFA commented that harmonizing regulations across North America and Europe would provide consistency. It recommended continuing testing at the CHSS component level, including the mounting system, to ensure tests reflect real-world installations and establish a baseline performance standard applicable to all vehicle types, regardless of available crash data. It also suggested that NHTSA allow calculation or simulation methods, like Finite Element Analysis, to demonstrate compliance to reduce prototyping and testing costs for OEMs. NFA noted the infrequency of crashes involving its vehicles and the limited full-vehicle testing required by current regulations, adding that it currently position CHSS in less vulnerable areas, such as roof-mounted or protected luggage compartments. However, it stated that if sufficient data becomes available to support a performance requirement, testing should be standardized at the CHSS component or assembly level instead of full-vehicle testing.

HATCI stated that it supports the Agency's harmonization with GTR No. 13 for post-crash fuel system integrity.

Agency Response

After consideration of the comments received, NHTSA has decided to maintain the scope of the post-crash requirements as initially proposed for vehicles that use hydrogen fuel for propulsion power, limiting the applicability to passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR of less than or equal to 4,536 kg (10,000 pounds), as well as all school buses. NHTSA will not extend the post-crash requirements to include all heavy vehicles with a GVWR greater than 4,536 kg at this time.

NHTSA agrees with the commenters that limiting the post-crash requirements to light vehicles with a GVWR of 10,000 pounds or less and to all school buses regardless of GVWR is appropriate at this time, as it helps minimize the testing burden and addresses the practical limitations of conducting full-scale vehicle tests on heavier vehicles. NHTSA agrees that more research is needed before considering the inclusion of heavy vehicles other than school buses in the post-crash requirements, given the complexity of these vehicles and the absence of existing crash tests for heavy vehicles. NHTSA is considering future research to address the comments that component-level testing, rather than full vehicle crash testing, may be appropriate for heavy vehicle fuel systems at this time and that benchmarking against existing light vehicle crash testing procedures is a reasonable starting point for future heavy vehicle applications.

Furthermore, NHTSA is not implementing a moving contoured barrier impact test for heavy vehicles at this time due to the complexity associated with developing an objective test applicable to various heavy vehicle designs. Further research is needed to determine appropriate testing methods for tests involving heavy vehicles, and current data is insufficient to justify the inclusion of such tests.

Regarding the use of helium as an alternative to hydrogen for crash testing, NHTSA proposed this option in the regulatory text to provide flexibility for manufacturers. NHTSA will maintain the proposal that the test gas for compliance testing may be either hydrogen or helium, with the choice of test gas being at the manufacturer's option. Hydrogen and helium gas have similar leak characteristics, so it is expected that a vehicle that meets the performance requirements when tested with one gas will also meet the performance requirements when tested with the other.

NHTSA is not currently specifying the use of thermal imaging cameras as a means to detect post-crash fire. However, test labs are encouraged to use available technology such as thermal cameras or other heat detection equipment when evaluating for the presence of post-crash fire.

D. Tolerances

Background

The concept of test parameter tolerances refers to the allowable variations in the conditions or parameters under which a test is conducted, without impacting the validity or reliability of the test results. In regulatory testing, it is often impractical or impossible to maintain exact, fixed values for all parameters throughout the testing process. Therefore, tolerances are established to allow for slight deviations that are considered acceptable within a specified range. These tolerances ensure that even though the exact conditions may not be strictly identical in each test, the outcomes will remain consistent and comparable, as long as they fall within the defined tolerance limits. NHTSA proposed test parameter tolerances that are generally consistent with the suggested tolerances specified in the GTR No. 13. By adopting these established tolerances, NHTSA ensures that test conditions remain controlled and reliable while allowing for practical flexibility in testing environments.

Comments Received

TesTneT stated that in its 35 years of experience with hydraulic pressure cycle testing, it has not faced issues meeting a low-pressure tolerance of 1 MPa. Nikola stated that the proposed low-pressure range for container pressure cycling was "adequate." However, Luxfer Gas Cylinders commented that the proposed lower limits of 1 MPa to 2 MPa for pressure cycling tests are "too low and too tight." Luxfer stated that few containers would likely reach 1 or 2 MPa during actual service, making the test conditions unrealistic. It also noted challenges in maintaining these limits due to industrial testing equipment constraints and recommended revising the range to align with NGV 2, where cycling occurs between no greater than 10 percent of the service pressure and 125 percent of the service pressure.

Auto Innovators expressed concern over NHTSA's application of GTR No. 13 tolerances. It noted that GTR No. 13 specifies target values and allowable tolerances ($\pm\alpha$), but the NPRM proposed a range between ($X-\alpha$) and ($X+\alpha$) without defining a target. Auto Innovators argued that this proposal could compel manufacturers to set equipment at either extreme of the range, potentially testing at various points in between, which it argued deviates from the test's purpose. Auto Innovators cited the low-pressure cycling test, where NHTSA proposed a range of "between 1 MPa and 2 MPa." It stated that this approach could lead to impractical testing conditions and recommended NHTSA align with GTR No. 13. It also provided a table listing parameters in GTR No. 13 that use minimum (≥) and maximum (≤) values.

H2MOF proposed setting the lower bound of the pressure cycle at no more than 10 percent of the upper cycle, with an absolute maximum of 3 MPa, in line with the standard ISO 11515. H2MOF stated that the upper bound in ISO 11515 is defined as the maximum developed pressure at 65 °C, or approximately 117 percent of NWP. HATCI generally supported harmonizing with GTR No. 13. FORVIA stated that indicators for conditions like 85 degrees Celsius should use "greater than or equal to" and for −40 degrees Celsius, "less than or equal to." It also requested maintaining the low-pressure range of 1 MPa to 2 MPa to ensure a margin above ambient pressure.

Agency Response

The use of open-ended tolerances, such as "greater than or equal to" (≥) and "less than or equal to" (≤) symbols, does not provide the necessary clarity for conducting robust and consistent tests. The use of "≥" or "≤" without specific upper or lower limits could result in impractical testing conditions, potentially leading to tests at unreasonably high or low values that are irrelevant to real-world performance or safety objectives. Without a defined range, the test could extend to extreme values of temperature or pressure, for example, making the test results unrealistic and inconsistent. A specific range with both upper and lower bounds is essential to ensure the tests reflect conditions relevant to vehicle safety, while also providing a controlled and repeatable environment for assessment.

Furthermore, tolerance ranges allow for slight variation in test parameters during testing while maintaining the validity of the results. Testing at any point within the proposed range will not affect the overall outcome, nor will fluctuations within the range impact the results. This concept allows for flexibility within the defined range that does not materially affect the test results because the allowed variation is small enough to be considered insignificant in relation to the overall test objectives.

NHTSA maintains that the test parameter tolerances proposed in the NPRM are generally consistent with GTR No. 13. When GTR No. 13 provides an open-ended range, such as "≤ 2 MPa," the GTR No. 13 suggested tolerance is not listed with "±" because it is not intended to be applied to both sides of range endpoint. Instead, the tolerance is only intended to be applied to the open end of the range. Hence NHTSA's proposal of between 1 MPa and 2 MPa, based on the GTR No. 13 suggested tolerance of 1 MPa.

GTR No. 13 paragraph 245 provides another example, citing GTR No. 13 paragraph 6.2.3.5., where the static hold pressure is specified as ≥125 per cent NWP. In this case, there is a minimum value of the range, but no maximum. GTR No. 13 paragraph 245 states that in this case, ''the tolerance of 5 percent NWP in the table could be applied, which results in a maximum of 130 percent NWP.''

Hence, for the low-pressure range during hydraulic cycling, NHTSA proposed a tolerance of between 1 MPa and 2 MPa, based on the GTR No. 13 suggested tolerance of 1 MPa. Regarding Luxfer Gas Cylinders' comment that the proposed lower limits of 1 MPa to 2 MPa for pressure cycling tests are ''too low and too tight,'' NHTSA notes that the test tolerances proposed in the NPRM are supported by TestNet's comment that in its 35 years of experience with hydraulic pressure cycle testing, it has not faced issues meeting a low-pressure of 1 MPa.

The argument that tolerances would force manufacturers or test labs to test at extreme ends of the range, such as the lowest or highest allowable point and at all points within the range, is inaccurate. NHTSA believes all of the proposed test procedures are robust enough to accommodate minor fluctuations in parameters without affecting the outcome of the test or repeatability of the results. The entire range is designed to ensure consistent and valid test results, regardless of where within the range the test is performed, or whether there are fluctuations within the range during testing. The parameters, as proposed, provide the necessary testing flexibility without sacrificing the repeatability and reproducibility of the testing procedure. Moreover, the use of a specified range prevents the need for excessive precision, which could make testing more difficult and unnecessarily increase the burden on test laboratories.

E. General Comments

Background

NHTSA received several general comments about the proposed standard, reflecting broad perspectives on the overall proposal. These comments did not address specific technical or procedural issues but instead addressed general aspects of the proposed standards.

Comments Received

An anonymous commenter stated that the establishment of new standards for hydrogen fuel systems was an ''excellent next step'' given the increasing prevalence of hydrogen-powered vehicles. It stated that it was important to consider the risks associated with pressurized hydrogen containers, which differ from non-pressurized gasoline or diesel containers, and noted that hydrogen is highly flammable, particularly in a compressed state. The commenter suggested that implementing a safety standard could reduce risks of death and injury related to the integrity of these containers.

Consumer Reports supported the proposed creation of FMVSS Nos. 307 and 308, stating that while hydrogen fuel cell vehicle sales have been limited, manufacturers are making advancements in this technology. It described the standards as necessary for both fuel system integrity and the compressed hydrogen storage system.

Auto Innovators echoed this support but also recommended that NHTSA revise its proposal to better align with GTR No. 13. It highlighted potential challenges due to differences in certification testing, especially when tests are conducted in series, which could lead to increased costs. Ford similarly supported the proposed standards and highlighted its experience in hydrogen technology research. Ford endorsed Auto Innovators' call for close alignment with GTR No. 13 and stated that GTR No. 13 guides its North American product development. Hyundai expressed support for the proposed adoption of FMVSS Nos. 307 and 308 and agreed with NHTSA's statement that the standards address an emerging safety need. Hyundai acknowledged the rationale behind deviations from GTR No. 13 but suggested exploring additional ways to harmonize with the global regulation, and referred to Auto Innovators' comments for specific recommendations.

Glickenhaus commented that the Department of Transportation (DOT) already has extensive regulations prescribing testing and certification requirements for compressed hydrogen storage containers used for transporting hydrogen on public roads under the Hazardous Materials Regulations (HMR) in 49 CFR Subchapter C. It specifically referenced 49 CFR 172, which lists hazardous materials that include compressed hydrogen and hydrogen fuel cell vehicles, and stated that DOT's requirements for cryogenic and compressed hydrogen storage containers, including their manufacturing, testing, and certification, are outlined in 49 CFR part 173. Glickenhaus stated that it does not appear that any of these requirements are referenced or incorporated into the container requirements for FMVSS No. 308. It suggested that if the pressure vessel or components making up a CHSS have already undergone DOT hazardous material transportation certification, it could potentially reduce additional testing requirements specific to using those containers for fuel storage in hydrogen fuel cell vehicles. Glickenhaus expressed concern that the lack of harmony between DOT's HMR standards for compressed hydrogen containers and FMVSS No. 308's requirements could result in a scenario where a container certified for transporting hydrogen over roads, ships, and airways in the United States might not be legal for use in vehicles on those same roads. Alternatively, it stated, if a container were certified under FMVSS No. 308 but not under DOT's hazardous materials transport standards, any towing company might inadvertently violate hazardous material transportation regulations by transporting a hydrogen fuel cell vehicle and its stored hydrogen. It stated that it does not want this responsibility to fall to towing companies. They stated that they do not want NHTSA to create a regulation that would make it a violation of other DOT requirements to tow or transport a hydrogen fuel cell vehicle.

TTP commented that the proposal is not consistent with existing FMVSS Nos. 303 and 304, and that the intent is unclear regarding establishing standards specifically for fuel systems or for the vehicle as a whole. They expressed uncertainty about how the proposed standards, if required by new FMVSS, would be enforced and noted that testing and verification by NHTSA would be costly and impractical. TTP questioned if the intent was to approach enforcement differently from the current methodology under FMVSS Nos. 303 and 304. They recommended that NHTSA harmonize with existing methodologies and allow industry standards to control certification and compliance wherever possible to maintain consistency. TTP also stated there are significant differences between the production processes for light and heavy vehicle applications and that enforcement of the proposals would not be practical for both. They stated that light vehicle OEMs build a complete vehicle, which simplifies homologation due to consistent configurations, whereas the heavy market involves a mix of suppliers and intermediate manufacturers, making enforcement of vehicle-specific requirements impractical. TTP further commented that the proposal does not align with existing industry standards for container requirements, such as HGV 2, ''Compressed Hydrogen Gas Vehicle Fuel Containers,'' and NGV 2, and stated that some proposed requirements may compromise safety or prevent the use of containers with good safety records. They stated the proposal is not consistent with industry standards for component-level fuel system requirements specified in HPRD 1 and HGV 3.1, and they requested harmonization with these standards. Additionally, TTP requested clarification on whether the intent of the proposed FMVSS Nos. 307 and 308 would differ from FMVSS Nos. 303 and 304.

Agency Response

Some commenters raised concerns regarding potential misalignment between FMVSS No. 308 and the DOT hazardous materials regulations for compressed hydrogen storage systems. The regulation of the transportation of hydrogen over roads as cargo within tanker trucks in the United States is governed by the PHMSA through 49 CFR Subchapter C- Hazardous Materials Regulations (HMR).[54] PHMSA standards focus on the safe transportation of hazardous materials like hydrogen across all modes of transport, including trucks, and prioritizes minimizing risks during transport and handling of hydrogen, including potential leaks or spills. On the other hand, FMVSS Nos. 307 and 308 focus on the fuel system integrity of motor vehicles that use compressed hydrogen as a fuel source to propel the vehicle with the purpose of reducing deaths and injuries occurring from fires that result from hydrogen fuel leakage during vehicle operation and after motor vehicle crashes and from explosions resulting from the bursting of pressurized hydrogen containers.

FMVSS No. 308 addresses vehicle-specific safety needs with a focus on vehicle occupant safety that go beyond the PHMSA regulations for the transportation of hazardous materials. While PHMSA regulations govern hydrogen storage containers during transportation and are designed to mitigate safety risks during transport and handling of hydrogen, FMVSS No. 308 is specifically designed to ensure safety in the context of real-world driving, fueling, and crash conditions. Hydrogen storage systems in vehicles used for vehicle propulsion must meet performance standards that address risks unique to vehicle operation, including repeated fueling in different fueling conditions, dynamic driving environments, and potential accidents. Therefore, while DOT regulations and FMVSS No. 308 serve related functions, the standards are distinct and necessary for their respective purposes.

Several commenters also questioned the practicality and intent of the proposed FMVSS Nos. 307 and 308, particularly in relation to existing standards like FMVSS Nos. 303 and 304, which apply to CNG systems. NHTSA believes that hydrogen vehicles present distinct safety challenges that require specific regulatory measures. The unique properties of compressed hydrogen, such as its higher storage pressures and greater flammability, necessitate separate performance requirements to mitigate the associated risks. Hydrogen fuel systems have characteristics that differ significantly from CNG systems, and as a result, the proposed standards reflect the distinct differences presented by hydrogen. While FMVSS Nos. 303 and 304 remain effective for CNG, they are not sufficient to address the safety risks unique to hydrogen fueled vehicles.

Some commenters expressed concerns about the potential lack of harmonization between FMVSS Nos. 307 and 308 and GTR No. 13. As discussed above, NHTSA acknowledges these concerns but emphasizes that the proposed standards have been tailored specifically to address the safety needs of hydrogen vehicles in the context of the FMVSS. While GTR No. 13 is the primary basis for the proposed FMVSS Nos. 307 and 308, exact alignment with GTR No. 13 is not possible in FMVSS, for the reasons discussed above in section IV.A.

Similarly, some commenters suggested that existing industry standards for component-level fuel system requirements should be used as the primary basis for FMVSS Nos. 307 and 308. NHTSA acknowledges the value of the standards HGV 2, HGV 3.1, and HPRD 1, and notes that they were considered during the development of GTR No. 13. However, FMVSS are intended to establish minimum vehicle-level safety performance standards, and it is not necessary nor practical to adopt the entirety of industry standards into the FMVSS. While industry standards play an important role in ensuring the safety of individual components, FMVSS Nos. 307 and 308 set baseline requirements for hydrogen fuel systems to ensure that they function safely as part of the overall vehicle system. NHTSA's focus was in aligning the proposed FMVSS Nos. 307 and 308 with GTR No. 23 to enable global harmonization of regulations for hydrogen powered vehicles.

FMVSS establish minimum safety requirements and the FMVSS test procedures provide notice to establish how the agency would verify compliance. However, this does not mean that manufacturers must conduct the exact test in the FMVSS to certify their vehicles. The Motor Vehicle Safety Act[55] requires manufacturers to certify that their vehicles meet all applicable FMVSS, and specifies that manufacturers may not certify compliance if, in exercising reasonable care, the manufacturer has reason to know the certificate is false or misleading. A manufacturer may use component-level tests to certify its vehicles if it exercises reasonable care in doing so. Manufacturers must ensure that their vehicles will meet the requirements of FMVSS Nos. 307 and 308 when NHTSA tests the vehicles in accordance with the test procedures specified in the standards, but manufacturers may use different test procedures to do so.

In response to concerns about the enforceability of the proposed standards, particularly for heavy vehicles with complex production processes, NHTSA believes that the proposed FMVSS Nos. 307 and 308 standards are practical and enforceable across vehicle types. Although the heavy vehicle market involves a diverse supply chain with multiple intermediate manufacturers, the performance-based nature of these standards allows for flexibility in design. The regulations do not prescribe specific design solutions but instead set performance criteria, which manufacturers can meet using various engineering approaches. This adaptability ensures that both light and heavy vehicles can comply with the safety requirements without imposing impractical regulatory burdens. NHTSA is confident that these standards will not result in undue complexity or unnecessary cost in terms of enforcement.

[54] *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C.*

[55] 49 U.S.C. Ch. 301: Motor Vehicle Safety, *https://uscode.house.gov/view.xhtml?req=granuleid%3AUSC-prelim-title49-chapter301&edition=prelim.*

F. Lead Time

Background

In the NPRM, NHTSA proposed two key dates regarding the implementation of FMVSS Nos. 307 and 308. First, the effective date was proposed as 180 days after the publication of the final rule in the **Federal Register**. This is the date when the final rule would officially go into effect. Second, NHTSA proposed a compliance date for manufacturers to fully adhere to the new requirements. The compliance date was initially stated as September 1, two years after the publication of the final rule. However, in the ''Lead Time'' section, a different compliance date was proposed as September 1 in the year following the rule's publication. This was a clerical error, as both compliance dates should have stated ''the first September 1 that is two years after the publication of the final rule.''

Comments Received

Nikola stated they agree with the rule taking effect the following September. EMA commented that heavy vehicle manufacturers would need at least five years from the final rule's publication to comply, stating that GTR No. 13 Phase 2 had only been recently approved and the revision broadened its scope to include heavy vehicles. EMA cited the need for manufacturers to evaluate the new requirements, conduct validation testing, and potentially redesign components. Similarly, Auto Innovators raised concerns about the proposed compliance period, suggesting that an additional five years beyond the one-year compliance date would be necessary. They noted a lack of harmonization with GTR No. 13, which they stated would require significant design, hardware, and software adjustments for manufacturers.

Several commenters, including Auto Innovators, HATCI, and Glickenhaus, also pointed out conflicting compliance dates within the NPRM. Auto Innovators and HATCI pointed out inconsistencies between the DATES section, which stated the compliance date as two years after publication, and the Lead Time section, which stated it as one year. Both organizations requested additional lead time due to a lack of harmonization with GTR No. 13 and the substantial vehicle design changes they stated will be required. HATCI requested a compliance date of five years from the first September 1 after the final rule's publication, and cited potential impacts on pre-production vehicles due to a lack of harmonization which will prevent manufacturers from utilizing existing hardware and software.

Glickenhaus requested a three-year extension for low volume manufacturers to avoid disruption to current pilot projects. Hyundai also recommended a five-year compliance period after the September 1 following the rule's publication, stating that this is justified by the significant number of changes from GTR No. 13 in FMVSS Nos. 307 and 308, the inclusion of substantive new requirements, and the time required for design changes, validation and certification. Hyundai also noted that these proposed requirements are generally consistent with current industry practices, so there is no immediate safety necessity warranting a shorter lead time.

Agency Response

NHTSA acknowledges the comments regarding the proposed lead time and the concerns raised about the inconsistency between the compliance dates mentioned in the NPRM. NHTSA acknowledges that the ''Lead Time'' section was not updated correctly to reflect the intended proposed compliance timeline. To clarify this issue, first, NHTSA confirms that the effective date remains as proposed: 180 days after the publication of the final rule in the **Federal Register**.

Second, in response to commenters' requests for additional lead time for the compliance date, particularly from heavy vehicle manufacturers and others citing the need for additional time, NHTSA has revised the compliance date in the final rule. The final rule will adopt a compliance date that will be September 1, 2028, more than 3 years after the publication of the final rule. This extension provides additional time for manufacturers to ensure compliance without causing significant disruption.

However, NHTSA emphasizes that the requirements proposed under FMVSS Nos. 307 and 308 are closely aligned with GTR No. 13 and current industry practices. Many manufacturers have already implemented safety systems and testing procedures that meet the requirements of the final rule, and thus an extended lead time beyond the three-year period is not necessary. NHTSA is not aware of any peculiarities of the U.S. market that would necessitate lead times double or triple the lead times in other markets.[56]

V. Other Changes to the Regulatory Text

A clerical correction was made to the S3 *Application* section of FMVSS No. 308 to add the words ''to propel the vehicle.'' These words were included in S3 *Application* of FMVSS No. 307, but were inadvertently omitted from FMVSS No. 308 S3. This edit is editorial in nature to improve the clarity of the section, and does not intend to change the application of the standard.

A clerical correction was made to S6.2.2.2(e), deleting the word ''container'' from ''container manufacture may specify.'' The inclusion of the word ''container'' before manufacturer was erroneous since the standard is being applied as a vehicle-level standard, as discussed above. The section will now simply state that the ''manufacturer may specify.''

A clerical correction was made to the definition of ''hydrogen fuel system'' to replace the word ''mean'' with ''means'' for grammatical accuracy.

S5.2.2 was updated to include the words ''The vehicle shall meet at least'' to clarify that the vehicle must meet at least one of the requirements listed in S5.2.2 (a) though (c).

S6.1 was updated to include the words ''individual test'' before vehicle to clarify that the statement is referring to a specific individual test vehicle, not a line or model of vehicle.

S6.4.2(c) was updated to replace the word ''volumes'' with ''spaces.'' The section is referring to enclosed or semi-enclosed spaces, which are defined in the standard, whereas enclosed or semi-enclosed volumes are not defined.

NHTSA replaced all instances of the word ''manufacturer'' with ''vehicle manufacturer'' to clarify that the vehicle manufacturer is responsible for all aspects of the two standards.

VI. Rulemaking Analyses and Notices

Executive Order 12866, Executive Order 13563, and DOT Regulatory Policies and Procedures

We have considered the potential impact of this final rule under Executive Order 12866, Executive Order 13563, and DOT Order 2100.6A. This final rule is nonsignificant under E.O. 12866 and was not reviewed by the Office of Management and Budget. It is also not considered ''of special note to the Department'' under DOT Order

[56] NHTSA knows from its involvement in UN ECE that the lead times in other markets are sometimes substantially shorter than those often requested by manufacturers in the United States. As an example, Europe's General Safety Regulation was adopted in late 2019 and required that manufacturers equip vehicles with certain vehicle safety features by July 2022. See *https://www.tuvsud.com/en-us/resource-centre/stories/revision-of-the-eu-general-safety-regulation.* This period of less than 3 years is less than the timelines often requested by American industry, who often seek much longer lead times.

2100.6A, Rulemaking and Guidance Procedures.

Today, there are only two publicly available vehicle models that may be affected by the final rule, which collectively equal less than 5,000 vehicles sold per model year. Most manufacturers and vehicle lines currently in production would be unaffected by this rule. Of those vehicles that would be covered by today's standards, we expect the compliance cost to be minimal. As discussed earlier, the few manufacturers that already offer hydrogen vehicles in the marketplace already take safety precautions to attempt to emulate the safety of conventional and battery electric vehicles, and adhere to the industry guidelines that informed the creation of GTR No. 13. Because the final rule is intended to coalesce industry practice and future designs through harmonized regulations, we do not expect that the rule would pose a significant cost to current manufacturers, or for manufacturers that may be planning to enter the market.

Given NHTSA is establishing these standards during the early development of hydrogen vehicles, there is no baseline to compare today's rule against. While we anticipate the regulations will promote safer hydrogen vehicles, we cannot quantify this benefit with any degree of certainty, especially given that we cannot forecast what the industry would look like in the absence of our proposed standard. Furthermore, most of the safety benefits that will accrue to this rule will only be realized when hydrogen vehicles become more prevalent. The net present value of these future costs and benefits is minimal.

Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.,* as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of proposed rulemaking or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.,* small businesses, small organizations, and small governmental jurisdictions). The Small Business Administration's regulations at 13 CFR part 121 define a small business, in part, as a business entity "which operates primarily within the United States." (13 CFR 121.105(a)(1)). No regulatory flexibility analysis is required if the head of an agency certifies the proposed or final rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a proposed or final rule will not have a significant economic impact on a substantial number of small entities.

I certify that these standards will not have a significant impact on a substantial number of small entities. This action creates FMVSS Nos. 307 and 308 to establish minimum safety requirements for the CHSS and fuel system integrity of hydrogen vehicles. FMVSS Nos. 307 and 308 are vehicle standards. We anticipate any burdens of the standard will fall onto manufacturers of hydrogen vehicles. NHTSA is unaware of any small entities that currently manufacture or are planning to manufacture hydrogen vehicles. Furthermore, NHTSA is adopting standards similar to those already in place across industry. Thus, we anticipate the impacts of this final rule on all manufacturers to be minimal regardless of manufacturer size.

Executive Order 13132

NHTSA has examined this final rule pursuant to Executive Order 13132 (64 FR 43255, August 10, 1999) and concluded that no additional consultation with States, local governments or their representatives is mandated beyond the rulemaking process. The Agency has concluded that this action would not have "federalism implications" because it would not have "substantial direct effects on States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government," as specified in section 1 of the Executive order. This final rule would apply to motor vehicle manufacturers. Further, no State has adopted requirements regulating the CHSS or fuel integrity of hydrogen powered vehicles. Thus, Executive Order 13132 is not implicated and consultation with State and local officials is not required.

NHTSA rules can preempt in two ways. First, the National Traffic and Motor Vehicle Safety Act contains an express preemption provision: When a motor vehicle safety standard is in effect under this chapter, a State or a political subdivision of a State may prescribe or continue in effect a standard applicable to the same aspect of performance of a motor vehicle or motor vehicle equipment only if the standard is identical to the standard prescribed under this chapter. 49 U.S.C. 30103(b)(1). It is this statutory command by Congress that preempts any non-identical State legislative and administrative law addressing the same aspect of performance.

The express preemption provision described above is subject to a savings clause under which compliance with a motor vehicle safety standard prescribed under this chapter does not exempt a person from liability at common law. 49 U.S.C. 30103(e). Pursuant to this provision, State common law tort causes of action against motor vehicle manufacturers that might otherwise be preempted by the express preemption provision are generally preserved.

NHTSA rules can also preempt State law if complying with the FMVSS would render the motor vehicle manufacturers liable under State tort law. Pursuant to Executive Order 13132 and 12988, NHTSA has considered whether this rule could or should preempt State common law causes of action. The agency's ability to announce its conclusion regarding the preemptive effect of one of its rules reduces the likelihood that preemption will be an issue in any subsequent tort litigation. To this end, the agency has examined the nature (*i.e.,* the language and structure of the regulatory text) and objectives of this rule and finds that this rule, like many NHTSA rules, would prescribe only a minimum safety standard. As such, NHTSA does not intend this NPRM to preempt State tort law that would effectively impose a higher standard on motor vehicle manufacturers rule. Establishment of a higher standard by means of State tort law will not conflict with the minimum standard adopted here. Without any conflict, there could not be any implied preemption of a State common law tort cause of action.

Executive Order 12988 (Civil Justice Reform)

When promulgating a regulation, Executive Order 12988 specifically requires that the agency must make every reasonable effort to ensure that the regulation, as appropriate: (1) Specifies in clear language the preemptive effect; (2) specifies in clear language the effect on existing Federal law or regulation, including all provisions repealed, circumscribed, displaced, impaired, or modified; (3) provides a clear legal standard for affected conduct rather than a general standard, while promoting simplification and burden reduction; (4) specifies in clear language the retroactive effect; (5) specifies whether administrative proceedings are to be required before parties may file suit in court; (6) explicitly or implicitly defines key terms; and (7) addresses other important issues affecting clarity and general draftsmanship of regulations.

Pursuant to this Order, NHTSA notes as follows. The preemptive effect of this final rule is discussed above in connection with E.O. 13132. NHTSA notes further that there is no requirement that individuals submit a petition for reconsideration or pursue other administrative proceeding before they may file suit in court.

Executive Order 13609 (Promoting International Regulatory Cooperation)

Executive Order 13609, ''Promoting International Regulatory Cooperation,'' promotes international regulatory cooperation to meet shared challenges involving health, safety, labor, security, environmental, and other issues and to reduce, eliminate, or prevent unnecessary differences in regulatory requirements.

The final rule adopts the technical requirements of GTR No.13, a technical standard for hydrogen vehicles adopted by the United Nations Economic Commission for Europe (UN ECE) World Forum for Harmonization of Vehicle Regulations (WP.29). As a Contracting Party that voted in favor of GTR No. 13, NHTSA was obligated to initiate rulemaking to incorporate safety requirements and options specified in GTR, which the agency satisfied when it published its notice of proposed rulemaking NHTSA is not required to finalize the text of the GTR.

While the final rule does contain some differences from GTR No. 13 to reflect U.S. law, they are consistent with the regulatory process envisioned and encouraged from the outset of GTR No. 13. NHTSA will continue to participate with the international community on GTR No. 13 and evaluate further amendments on their merits as they are adopted by WP.29.

NHTSA has analyzed this final rule under the policies and agency responsibilities of Executive Order 13609 and has determined this rule would have no effect on international regulatory cooperation.

National Environmental Policy Act

NHTSA has analyzed this rule for the purposes of the National Environmental Policy Act (42 U.S.C. 4321 et. seq.), as amended. In accordance with 49 C.F.R § 1.81, 42 U.S.C. 4336, and DOT NEPA Order 5610.1C, NHTSA has determined that this rule is categorically excluded pursuant to 23 CFR 771.118(c)(4) (planning and administrative activities, such as promulgation of rules, that do not involve or lead directly to construction).

This rulemaking establishes two new FMVSS, FMVSS No. 307, ''Fuel system integrity of hydrogen vehicles,'' which specifies requirements for the integrity of the fuel system in hydrogen vehicles during normal vehicle operations and after crashes, and FMVSS No. 308, ''Compressed hydrogen storage system integrity,'' which specifies requirements for the compressed hydrogen storage system to ensure the safe storage of hydrogen onboard vehicles. This rulemaking is not anticipated to result in any environmental impacts, and there are no extraordinary circumstances present in connection with this rulemaking.

NHTSA expects the changes to new and existing vehicles to be minimal, and mitigating the hazards associated with fires that result from hydrogen fuel leakage during vehicle operation and after motor vehicle crashes and from explosions resulting from the burst of pressurized hydrogen containers would result in a public health and safety benefit. For these reasons, the agency has determined that implementation of this action will not have any adverse impact on the quality of the human environment.

Paperwork Reduction Act

Under the procedures established by the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501, et. seq.), Federal agencies must obtain approval from the OMB for each collection of information they conduct, sponsor, or require through regulations. A person is not required to respond to a collection of information by a Federal agency unless the collection displays a valid OMB control number. The Information Collection Request (ICR) for a revision of a previously approved collection described below will be forwarded to OMB for review and comment. In compliance with these requirements, NHTSA asks for public comments on the following proposed collection of information for which the agency is seeking approval from OMB. In this final rule, we are finalizing a revision and reinstatement to a previously approved OMB collection, OMB Clearance No. 2127–0512, Consolidated Labeling Requirements for Motor Vehicles (except the VIN).[57]

Title: Consolidated Labeling Requirements for Motor Vehicles (except the VIN).

OMB Control Number: OMB Control No. 2127–0512.

Type of Request: Revision of a previously approved collection.

Type of Review Requested: Regular.

Requested Expiration Date of Approval: 3 years from the date of approval.

Summary of the Collection of Information: FMVSS No. 307 specifies requirements for the integrity of motor vehicle fuel systems using compressed hydrogen as a fuel source. Each hydrogen vehicle must have a permanent label which lists the fuel type, service pressure, and a statement directing vehicle users/operators to instructions for inspection and service life of the fuel container. FMVSS No. 308 specifies requirements for the integrity of compressed hydrogen storage systems (CHSS). Each hydrogen container must have a permanent label containing manufacturer contact information, the container serial number, manufacturing date, date of removal from service, and applicable BP_O burst pressure. If the proposed requirements are made final, we will submit a request for OMB clearance of the proposed collection of information and seek clearance prior to the effective date of the final rule.

Description of the likely respondents: Vehicle manufacturers.

Estimated Number of Respondents: 10.

Estimated Total Annual Burden Hours: $8,616.

It is estimated that vehicle manufacturers will provide labels on 10 different hydrogen vehicle models. Since manufacturers have provided CNG vehicles with similar required labels for many years, it is estimated that manufacturers will have a generalized label template which only requires minor adjustments for hydrogen and population with the required information. There is an annual 1.0 hour burden for manufacturers to have a Mechanical Drafter put the correct information into a label template to create a model specific label. The annual burden for this label creation is 10 hours (10 hydrogen vehicle model labels * 1 hour per model label) and $478 (10 hydrogen vehicle model labels * 1 hour per model label * $33.62 labor rate per hour ÷ 70.3% of labor rate as total wage compensation). Manufacturers will also bear a cost burden of $1,884 (2,850 hydrogen vehicles * $0.73 per label) for the required labels to be attached to the hydrogen vehicles. The combined total annual burden to vehicle manufacturers from the requirements to have the specified label text on hydrogen vehicles is 10 hours and $2,362. These hour and cost burdens represent a new

[57] In compliance with the requirements of the PRA, NHTSA is separately publishing a notice to request comment on NHTSA's reinstatement with modification of the previously approved information collection request.

addition to this information collection request.

It is estimated that vehicle manufacturers will provide labels on 10 different hydrogen container models. Since manufacturers have provided CNG containers with similar labels for many years, it is estimated that manufacturers will have a generalized label template which requires only minor adjustments for hydrogen and then population with their current contact information, the container serial number, manufacturing date, and date of removal from service. There is an annual 1.0 hour burden for manufacturers to have a Mechanical Drafter put the correct information into a label template to create a model specific label. The annual burden for this label creation is 10 hours (10 hydrogen container model labels * 1.0 hours per model label) and $478 (10 hydrogen container models labels * 1.0 hours per model label * $33.62 labor rate per hour ÷ 70.3% of labor rate as total wage compensation). Manufacturers will also bear a cost burden of $5,776 (7,910 hydrogen containers * $0.730 per label) for the required labels to be attached to the hydrogen containers. The combined total annual burden to vehicle manufacturers from the requirements to have the specified label text on hydrogen containers is 10 hours and $6,254. These hour and cost burdens represent a new addition to this information collection request.

National Technology Transfer and Advancement Act

Under the National Technology Transfer and Advancement Act of 1995 (NTTAA) (Pub. L. 104) Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) requires NHTSA to evaluate and use existing voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law (*e.g.,* the statutory provisions regarding NHTSA's vehicle safety authority) or otherwise impractical. Voluntary consensus standards are technical standards developed or adopted by voluntary consensus standards bodies. Technical standards are defined by the NTTAA as ''performance-based or design-specific technical specification and related management systems practices.'' They pertain to ''products and processes, such as size, strength, or technical performance of a product, process or material.''

Examples of organizations generally regarded as voluntary consensus standards bodies include ASTM International, the Society of Automotive Engineers (SAE), and the American National Standards Institute (ANSI). If NHTSA does not use available and potentially applicable voluntary consensus standards, we are required by the Act to provide Congress, through OMB, an explanation of the reasons for not using such standards.

Today's final rule establishes standards that are consistent with voluntary standards cited above such as SAEJ2579_201806, HPRD–1 2021, and HGV 3.1 2022.

This final rule adopting key aspects of GTR No. 13 is consistent with the goals of the NTTAA. This final rule adopts much of a global consensus standard. However this final rule includes some minor deviations from GTR No. 13. As discussed above, FMVSS must maintain objectivity, clarity, and practicability, ensuring that every requirement is measurable and enforceable, with unambiguous test procedures. These adjustments ensure FMVSS remain clear, objective, and enforceable. For example, NHTSA is removing subjective requirements such as the TPRD atmospheric exposure test and the and localized leak requirement from the ambient and extreme gas permeation test. NHTSA is also requiring the testing of only one component for some tests instead of multiple components (as specified in GTR No. 13 for assessing variability in response), and eliminating duplicative requirements like the proof pressure tests. NHTSA has also removed unnecessary requirements for burst pressure variability, and removed a requirement for an overpressure protection device that had no corresponding performance test. NHTSA also selected a more balanced requirement for the hydrogen concentration limit in the enclosed and semi-enclosed spaces, rather than applying the GTR's zero limit to only the passenger compartment.

The GTR was developed by a global regulatory body and is designed to increase global harmonization of differing vehicle standards. The GTR leverages the expertise of governments in developing safety requirements for hydrogen fueled vehicles. NHTSA's consideration of GTR No. 13 accords with the principles of NTTAA as NHTSA's consideration of an established, proven regulation has reduced the need for NHTSA to expend significant agency resources on the same safety need addressed by GTR No. 13.

Incorporation by Reference

Under regulations issued by the Office of the Federal Register (1 CFR 51.5(a)), an agency, as part of a proposed rule that includes material incorporated by reference, must summarize material that is proposed to be incorporated by reference and discuss the ways the material is reasonably available to interested parties or how the agency worked to make materials available to interested parties. At the final rule stage, regulations require that the agency seek formal approval, summarize the material that it incorporates by reference in the preamble of the final rule, discuss the ways that the materials are reasonably available to interested parties, and provide other specific information to the Office of the Federal Register.

NHTSA is incorporating by reference two documents into the Code of Federal Regulations. First, NHTSA is incorporating by reference ASTM D1193–06 (Reapproved 2018), *Standard Specification for Reagent Water.* ASTM D1193–06 is an industry standard that defines the requirements for the purity of water used in laboratories, ensuring that experiments and tests are not compromised by water impurities. NHTSA will use a water supply conforming to Type IV requirements of ASTM D1193–06 in testing the compliance of closure devices with the salt corrosion resistance test in 571.308 S6.2.6.1.4.

NHTSA is also incorporating by reference ISO 6270–2:2017, *Paints and Varnishes—Determination of Resistance to Humidity—Part 2: Condensation (In-Cabinet Exposure with Heated Water Reservoir).* ISO 6270–2:2017 specifies methods for assessing the resistance of materials to humidity by focusing on how materials behave when exposed to high humidity. ISO 6270–2:2017 provides detailed procedures and materials for conducting tests where humidity is the primary variable. NHTSA will use the apparatus described within ISO 6270–2:2017 in testing the compliance of closure devices with the salt corrosion resistance test in 571.308 S6.2.6.1.4.

All standards incorporated by reference in this rule are available for review at NHTSA's headquarters in Washington, DC, and for purchase from the organizations promulgating the standards. The ASTM standard is also available for review at ASTM's online reading room.[58]

Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA), Public Law 104–4, requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects

[58] *https://www.astm.org/READINGLIBRARY/.*

of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for the year 2022 results in $177 million (111.416/75.324 = 1.48). This rule will not result in a cost of $177 million or more to State, local, or tribal governments, in the aggregate, or the private sector. Thus, this rule is not subject to the requirements of sections 202 of the UMRA.

Executive Order 13045 (Protection of Children From Environmental Health and Safety Risks)

Executive Order 13045, ''Protection of Children from Environmental Health and Safety Risks,'' (62 FR 19885, April 23, 1997) applies to any proposed or final rule that: (1) Is determined to be ''economically significant,'' as defined in E.O. 12866, and (2) concerns an environmental health or safety risk that NHTSA has reason to believe may have a disproportionate effect on children. If a rule meets both criteria, the agency must evaluate the environmental health or safety effects of the rule on children and explain why the rule is preferable to other potentially effective and reasonably feasible alternatives considered by the agency.

This rulemaking is not subject to the Executive Order because it is not economically significant as defined in E.O. 12866.

Executive Order 13211

Executive Order 13211 (66 FR 28355, May 18, 2001) applies to any rulemaking that: (1) is determined to be economically significant as defined under E.O. 12866, and is likely to have a significantly adverse effect on the supply of, distribution of, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action. This rulemaking is not subject to E.O. 13211 as this rule is not economically significant and should not have an adverse effect on the supply of, distribution of, or use of energy for the same reasons explained in our discussion of Executive Orders 12866 and 13563.

Plain Language

Executive Order 12866 requires each agency to write all rules in plain language. Application of the principles of plain language includes consideration of the following questions:

• Have we organized the material to suit the public's needs?
• Are the requirements in the rule clearly stated?
• Does the rule contain technical language or jargon that isn't clear?
• Would a different format (grouping and order of sections, use of headings, paragraphing) make the rule easier to understand?
• Would more (but shorter) sections be better?
• Could we improve clarity by adding tables, lists, or diagrams?
• What else could we do to make the rule easier to understand?

If you have any responses to these questions, please include them in your comments on this proposal.

Regulation Identifier Number (RIN)

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. You may use the RIN contained in the heading at the beginning of this document to find this action in the Unified Agenda.

List of Subjects in 49 CFR Part 571

Imports, Incorporation by reference, Motor vehicle safety, Reporting and recordkeeping requirements, Tires.

In consideration of the foregoing, NHTSA amends 49 CFR part 571 as set forth below.

PART 571—FEDERAL MOTOR VEHICLE SAFETY STANDARDS

■ 1. The authority citation for part 571 continues to read as follows:

Authority: 49 U.S.C. 322, 30111, 30115, 30117 and 30166; delegation of authority at 49 CFR 1.95.

■ 2. Amend § 571.5 by:
■ a. Redesignating paragraphs (d)(20) through (33) as paragraphs (d)(21) through (34), respectively;
■ b. Adding new paragraph (d)(20);
■ d. Redesignating paragraphs (i)(1) through (4) as paragraphs (i)(2) through (5), respectively; and
■ e. Adding new paragraph (i)(1).

The additions read as follows:

§ 571.5 Matter incorporated by reference.

* * * * *

(d) * * *

(20) ASTM D1193–06 (Reapproved 2018), *Standard Specification for Reagent Water,* approved March 15, 2018, into § 571.308.

* * * * *

(i) * * *

(1) ISO 6270–2:2017(E), *Paints and Varnishes—Determination of Resistance to Humidity—Part 2: Condensation (In-Cabinet Exposure with Heated Water Reservoir),* Second edition, November 2017, into § 571.308.

* * * * *

■ 3. Section 571.307 is added to read as follows:

§ 571.307 Standard No. 307; Fuel system integrity of hydrogen vehicles

S1. *Scope.* This standard specifies requirements for the integrity of motor vehicle hydrogen fuel systems.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries occurring from fires that result from hydrogen fuel leakage during vehicle operation and after motor vehicle crashes.

S3. *Application.* This standard applies to each motor vehicle manufactured on or after September 1, 2028, that uses compressed hydrogen gas as a fuel source to propel the vehicle.

S4. *Definitions.*

Check valve means a valve that prevents reverse flow.

Closure devices mean the check valve(s), shut-off valve(s), and thermally-activated pressure relief device(s) that control the flow of hydrogen into and/or out of a CHSS.

Container means a pressure-bearing component of a compressed hydrogen storage system that stores a continuous volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.

Container attachments mean non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be removed only with the use of tools for the specific purpose of maintenance and/or inspection.

Compressed hydrogen storage system (CHSS) means a system that stores compressed hydrogen fuel for a hydrogen-fueled vehicle, composed of a container, container attachments (if any), and all closure devices required to isolate the stored hydrogen from the remainder of the fuel system and the environment.

Enclosed or semi-enclosed spaces means the passenger compartment, luggage compartment, and space under the hood.

Fuel cell system means a system containing the fuel cell stack(s), air processing system, fuel flow control system, exhaust system, thermal management system, and water management system.

Fueling receptacle means the equipment to which a fueling station nozzle attaches to the vehicle and through which fuel is transferred to the vehicle.

Fuel lines means all piping, tubing, joints, and any components such as flow controllers, valves, heat exchangers, and pressure regulators.

Hydrogen concentration means the percentage of the hydrogen molecules within the mixture of hydrogen and air (equivalent to the partial volume of hydrogen gas).

Hydrogen fuel system means the fueling receptacle, CHSS, fuel cell system or internal combustion engine, fuel lines, and exhaust systems.

Luggage compartment means the space in the vehicle for luggage, cargo, and/or goods accommodation, bounded by a roof, hood, floor, side walls being separated from the passenger compartment by the front bulkhead or the rear bulkhead.

Maximum allowable working pressure (MAWP) means the highest gauge pressure to which a component or system is permitted to operate under normal operating conditions.

Nominal working pressure (NWP) means the settled pressure of compressed gas in a container or CHSS fully fueled to 100 percent state of charge and at a uniform temperature of 15 °C.

Normal milliliter means a quantity of gas that occupies one milliliter of volume when its temperature is 0 °C and its pressure is 1 atmosphere.

Passenger compartment means the space for occupant accommodation that is bounded by the roof, floor, side walls, doors, outside glazing, front bulkhead, and rear bulkhead or rear gate.

Pressure relief device (PRD) means a device that, when activated under specified performance conditions, is used to release hydrogen from a pressurized system and thereby prevent failure of the system.

Rechargeable electrical energy storage system (REESS) means the rechargeable energy storage system that provides electric energy for electrical propulsion.

Service door means a door that allows for the entry and exit of vehicle occupants under normal operating conditions.

Shut-off valve means a valve between the container and the remainder of the hydrogen fuel system that must default to the ''closed'' position when unpowered.

State of charge (SOC) means the density ratio of hydrogen in the CHSS between the actual CHSS condition and that at NWP with the CHSS equilibrated to 15 °C, as expressed as a percentage using equation 1 to this section, where ρ is the density of hydrogen (g/L) at pressure (P) in MegaPascals (MPa) and temperature (T) in Celsius (°C) as listed in table 1 to S4 or linearly interpolated therein:

Equation 1 to § 571.307 S4

$$SOC(\%) = \frac{\rho(P,T)}{\rho(NWP, 15°C)} x100$$

TABLE 1 TO § 571.307 S4

Temperature (°C)	Pressure (MPa)												
	1	10	20	30	35	40	50	60	65	70	75	80	87.5
−40	1.0	9.7	18.1	25.4	28.6	31.7	37.2	42.1	44.3	46.4	48.4	50.3	53.0
−30	1.0	9.4	17.5	24.5	27.7	30.6	36.0	40.8	43.0	45.1	47.1	49.0	51.7
−20	1.0	9.0	16.8	23.7	26.8	29.7	35.0	39.7	41.9	43.9	45.9	47.8	50.4
−10	0.9	8.7	16.2	22.9	25.9	28.7	33.9	38.6	40.7	42.8	44.7	46.6	49.2
0	0.9	8.4	15.7	22.2	25.1	27.9	33.0	37.6	39.7	41.7	43.6	45.5	48.1
10	0.9	8.1	15.2	21.5	24.4	27.1	32.1	36.6	38.7	40.7	42.6	44.4	47.0
15	0.8	7.9	14.9	21.2	24.0	26.7	31.7	36.1	38.2	40.2	42.1	43.9	46.5
20	0.8	7.8	14.7	20.8	23.7	26.3	31.2	35.7	37.7	39.7	41.6	43.4	46.0
30	0.8	7.6	14.3	20.3	23.0	25.6	30.4	34.8	36.8	38.8	40.6	42.4	45.0
40	0.8	7.3	13.9	19.7	22.4	24.9	29.7	34.0	36.0	37.9	39.7	41.5	44.0
50	0.7	7.1	13.5	19.2	21.8	24.3	28.9	33.2	35.2	37.1	38.9	40.6	43.1
60	0.7	6.9	13.1	18.7	21.2	23.7	28.3	32.4	34.4	36.3	38.1	39.8	42.3
70	0.7	6.7	12.7	18.2	20.7	23.1	27.6	31.7	33.6	35.5	37.3	39.0	41.4
80	0.7	6.5	12.4	17.7	20.2	22.6	27.0	31.0	32.9	34.7	36.5	38.2	40.6
85	0.7	6.4	12.2	17.5	20.0	22.3	26.7	30.7	32.6	34.4	36.1	37.8	40.2

Thermally-activated pressure relief device (TPRD) means a non-reclosing PRD that is activated by temperature to open and release hydrogen gas.

S5. *Hydrogen fuel system.*

S5.1. *Fuel system integrity during normal vehicle operations.*

S5.1.1. *Fueling receptacle requirements.* (a) A compressed hydrogen fueling receptacle shall prevent reverse flow to the atmosphere.

(b) A label shall be affixed close to the fueling receptacle showing the following information:

(1) The statement, ''Compressed hydrogen gas only.''

(2) The statement, ''Service pressure ______MPa (_____psig).''

(3) The statement, ''See instructions on fuel container(s) for inspection and service life.''

(c) The fueling receptacle shall ensure positive locking of the fueling nozzle.

(d) The fueling receptacle shall be protected from the ingress of dirt and water.

(e) The fueling receptacle shall not be installed in enclosed or semi-enclosed spaces.

S5.1.2. *Hydrogen discharge systems.*

S5.1.2.1. *Pressure relief systems.* (a) If present, the outlet of the vent line for hydrogen gas discharge from the TPRD(s) of the CHSS shall be protected from ingress of dirt and water.

(b) The hydrogen gas discharge from TPRD(s) of the CHSS shall not impinge upon:

(1) Enclosed or semi-enclosed spaces;

(2) Any vehicle wheel housing;

(3) Container(s);

(4) REESS(s);

(5) Any emergency exit(s) as identified in § 571.217 (FMVSS No. 217); nor

(6) Any service door(s).

S5.1.2.2. *Vehicle exhaust system.* When tested in accordance with S6.5 of this standard, the hydrogen concentration at the vehicle exhaust system's point of discharge shall not:

(a) Exceed an average of 4.0 percent by volume during any moving three-second time interval; nor

(b) Exceed 8.0 percent by volume at any time.

S5.1.3. *Protection against flammable conditions.* (a) When tested in accordance with S6.4.1 of this standard, a warning in accordance with S5.1.6 shall be provided within 10 seconds of the application of the first test gas.

When tested in accordance with S6.4.1, the main shut-off valve shall close within 10 seconds of the application of the second test gas.

(b) When tested in accordance with S6.4.2 of this standard, the hydrogen concentration in the enclosed or semi-enclosed spaces shall be less than 3.0 percent.

S5.1.4. *Fuel system leakage.* When tested in accordance with S6.6 of this standard, the hydrogen fuel system downstream of the shut-off valve(s) shall not exhibit observable leakage.

S5.1.5 *Tell-tale warning.* A warning shall be given to the driver, or to all front seat occupants for vehicles without a driver's designated seating position, by a visual signal or display text with the following properties:

(a) Visible to the driver while seated in the driver's designated seating position or visible to all front seat occupants of vehicles without a driver's designated seating position;

(b) Yellow in color if the warning system malfunctions;

(c) Red in color if hydrogen concentration in enclosed or semi-enclosed spaces exceeds 3.0 percent by volume;

(d) When illuminated, shall be visible to the driver (or to all front seat occupants in vehicles without a driver's designated seating position) under both daylight and nighttime driving conditions; and

(e) Remains illuminated when hydrogen concentration in any of the vehicle's enclosed or semi-enclosed spaces exceeds 3.0 percent by volume or when the warning system malfunctions, and the ignition locking system is in the ''On'' (''Run'') position or the propulsion system is activated.

S5.2. *Post-crash fuel system integrity.* Each vehicle with a gross vehicle weight rating (GVWR) of 4,536 kg or less to which this standard applies must meet the requirements in S5.2.1 through S5.2.4 when tested according to S6 under the conditions of S7. Each school bus with a GVWR greater than 4,536 kg to which this standard applies must meet the requirements in S5.2.1 through S5.2.4 when tested according to S6 under the conditions of S7 of this standard.

S5.2.1. *Fuel leakage limit.* If hydrogen gas is used for testing, the volumetric flow of hydrogen gas leakage shall not exceed an average of 118 normal liters per minute for the time interval, Δt, as determined in accordance with S6.2.1 of this standard. If helium is used for testing, the volumetric flow of helium leakage shall not exceed an average of 88.5 normal litres per minute for the time interval, Δt, as determined in accordance with S6.2.2 of this standard.

S5.2.2. *Concentration limit in enclosed spaces.* The vehicle shall meet at least one of the requirements in S5.2.2(a), (b), or (c).

(a) Hydrogen gas leakage shall not result in a hydrogen concentration in the air greater than 4.0 percent by volume in enclosed or semi-enclosed spaces for 60 minutes after impact when tested in accordance with S6.3 of this standard.

(b) Helium gas leakage shall not result in a helium concentration in the air greater than 3.0 percent by volume in enclosed or semi-enclosed spaces for 60 minutes after impact when tested in accordance with S6.3 of this standard.

(c) The shut-off valve of the CHSS shall close within 5 seconds of the crash.

S5.2.3. *Container displacement.* The container(s) shall remain attached to the vehicle by at least one component anchorage, bracket, or any structure that transfers loads from the container to the vehicle structure.

S5.2.4. *Fire.* There shall be no fire in or around the vehicle for the duration of the test.

S6. *Test Requirements.*

S6.1. *Vehicle Crash Tests.* A test vehicle with a GVWR less than or equal to 4,536 kg, under the conditions of S7 of this standard, is subject to any one single barrier crash test of S6.1.1, S6.1.2, and S6.1.3. A school bus with a GVWR greater than 4,536 kg, under the conditions of S7, is subject to the contoured barrier crash test of S6.1.4. A particular vehicle need not meet further test requirements after having been subjected and evaluated to a single barrier crash test.

S6.1.1. *Frontal barrier crash.* The test vehicle, with test dummies in accordance with S6.1 of 571.301 of this chapter, traveling longitudinally forward at any speed up to and including 48.0 km/h, impacts a fixed collision barrier that is perpendicular to the line of travel of the vehicle, or at an angle up to 30 degrees in either direction from the perpendicular to the line of travel of the vehicle.

S6.1.2. *Rear moving barrier impact.* The test vehicle, with test dummies in accordance with S6.1 of § 571.301, is impacted from the rear by a barrier that conforms to S7.3(b) of § 571.301 and that is moving at any speed up to and including 80.0 km/h.

S6.1.3. *Side moving deformable barrier impact.* The test vehicle, with the appropriate 49 CFR part 572 test dummies specified in § 571.214 (FMVSS No. 214) at positions required for testing by S7.1.1, S7.2.1, or S7.2.2 of Standard 214, is impacted laterally on either side by a moving deformable barrier moving at any speed between 52.0 km/h and 54.0 km/h.

S6.1.4. *Moving contoured barrier crash.* The test vehicle is impacted at any point and at any angle by the moving contoured barrier assembly, specified in S7.5 and S7.6 in § 571.301, traveling longitudinally forward at any speed up to and including 48.0 km/h.

S6.2. *Post-crash CHSS leak test.*

S6.2.1. *Post-crash leak test for CHSS filled with compressed hydrogen.* (a) The hydrogen gas pressure, P_0 (MPa), and temperature, T_0 (°C), shall be measured immediately before the impact. The hydrogen gas pressure P_f (MPa) and temperature, T_f (°C) shall also be measured immediately after a time interval Δt (in minutes) after impact. The time interval, Δt, starting from the time of impact, shall be the greater of S6.2.1(a)(1) or (2):

(1) 60 minutes; or

(2) The time interval calculated with equation 2 to this section, where $R_s = P_s/NWP$, P_s is the pressure range of the pressure sensor (MPa), NWP is the Nominal Working Pressure (MPa), and V_{CHSS} is the volume of the CHSS (L):

Equation 2 to § 571.307 S6.2.1(a)(2)

$$\Delta t = V_{CHSS} \times NWP/1000 \times ((-0.027 \times NWP + 4) \times R_s - 0.21) - 1.7 \times R_s$$

(b) The initial mass of hydrogen M_0 (g) in the CHSS shall be calculated from equations 3 through 5 to this section:

Equation 3 to § 571.307 S6.2.1(b)

$$P_0' = P_0 \times 288/(273 + T_0)$$

Equation 4 to § 571.307 S6.2.1(b)

$$\rho_0' = -0.0027 \times (P_0')^2 + 0.75 \times P_0' + 1.07$$

Equation 5 to § 571.307 S6.2.1(b)

$$M_0 = \rho_0' \times V_{CHSS}$$

(c) The final mass of hydrogen in the CHSS, M_f (in grams), at the end of the time interval, Δt, shall be calculated from equations 6 through 8 to this section, where P_f is the measured final pressure (MPa) at the end of the time interval, and T_f (°C) is the measured final temperature:

Equation 6 to § 571.307 S6.2.1(c)

$$P_f' = P_f \times 288/(273 + T_f)$$

Equation 7 to § 571.307 S6.2.1(c)

$$\rho_f' = -0.0027 \times (P_f')^2 + 0.75 \times P_f' + 1.07$$

Equation 8 to § 571.307 S6.2.1(c)

$$M_f = \rho_f' \times V_{CHSS}$$

(d) The average hydrogen flow rate over the time interval shall be calculated from equation 9 to this section, where V_{H2} is the average volumetric flow rate (normal millilitres per min) over the time interval:

Equation 9 to § 571.307 S6.2.1(d)

$$V_{H2} = (M_f - M_0)/\Delta t \times 22.41/2.016 \times (P_{target}/P_0)$$

S6.2.2 *Post-crash leak test for CHSS filled with compressed helium.*

(a) The helium pressure, P_0 (MPa), and temperature, T_0 (°C), shall be measured immediately before the impact and again immediately after a time interval starting from the time of impact. The time interval, Δt (min), shall be the greater of the values in S6.2.2(a)(1) or (2):

(1) 60 minutes; or

(2) The time interval calculated with equation 10 to this section, where $R_s = P_s/NWP$, P_s is the pressure range of the pressure sensor (MPa), NWP is the Nominal Working Pressure (MPa), and V_{CHSS} is the volume of the CHSS (L):

Equation 10 to § 571.307 S6.2.2(a)(2)

$$\Delta t = V_{CHSS} \times NWP/1000 \times (-0.028 \times NWP + 5.5) \times R_s - 0.3) - 2.6 \times R_s$$

(b) The initial mass of helium M_0 (g) in the CHSS shall be calculated from equations 11 through 13 to this section:

Equation 11 to § 571.307 S6.2.2(b)

$$P_0' = P_0 \times 288/(273 + T_0)$$

Equation 12 to § 571.307 S6.2.2(b)

$$\rho_0' = -0.0043 \times (P_0')^2 + 1.53 \times P_0' + 1.49$$

Equation 13 to § 571.307 S6.2.2(b)

$$M_0 = \rho_0' \times V_{CHSS}$$

(c) The final mass of helium M_f (g) in the CHSS at the end of the time interval, Δt (min), shall be calculated from equations 14 through 16 to this section, where P_f is the measured final pressure (MPa) at the end of the time interval, and T_f (°C) is the measured final temperature:

Equation 14 to § 571.307 S6.2.2(c)

$$P_f' = P_f \times 288/(273 + T_f)$$

Equation 15 to § 571.307 S6.2.2(c)

$$\rho_f' = -0.0043 \times (P_f')^2 + 1.53 \times P_f' + 1.49$$

Equation 16 to § 571.307 S6.2.2(c)

$$M_f = \rho_f' \times V_{CHSS}$$

(d) The average helium flow rate over the time interval shall be calculated from equation 17 to this section, where V_{He} is the average volumetric flow rate (normal millilitres per min) of helium over the time interval:

Equation 17 to § 571.307 S6.2.2(d)

$$V_{He} = (M_f - M_0)/\Delta t \times 22.41/4.003 \times (P_{target}/P_0)$$

S6.3. *Post-crash concentration test for enclosed spaces.* (a) Sensors shall measure either the accumulation of hydrogen or helium gas, as appropriate, or the reduction in oxygen.

(b) Sensors shall have an accuracy of at least 5 percent at 4.0 percent hydrogen or 3.0 percent helium by volume in air, and a full-scale measurement capability of at least 25 percent above these criteria. The sensor shall be capable of a 90 percent response to a full-scale change in concentration within 10 seconds.

(c) Prior to the crash impact, the sensors shall be located in the passenger and luggage compartments of the vehicle as follows:

(1) At any interior point at any distance between 240 mm and 260 mm of the headliner above the driver's seat or near the top center of the passenger compartment.

(2) At any interior point at any distance between 240 mm and 260 mm of the floor in front of the rear (or rear most) seat in the passenger compartment.

(3) At any interior point at any distance between 90 mm and 110 mm below the top of luggage compartment(s).

(d) The sensors shall be securely mounted on the vehicle structure or seats and protected from debris, air bag exhaust gas and projectiles.

(e) The vehicle shall be located either indoors or in an area outdoors protected from direct and indirect wind.

(f) Post-crash data collection in enclosed spaces shall commence from the time of impact. Data from the sensors shall be collected at least every 5 seconds and continue for a period of 60 minutes after the impact.

(g) The data shall be compiled into a three-data-point rolling average prior to evaluating the applicable concentration limit in accordance with S5.2.2(a) or (b) of this standard.

S6.4. *Test procedure for protection against flammable conditions.*

S6.4.1. *Test for hydrogen gas leakage detectors.* (a) The vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test.

(b) Two mixtures of air and hydrogen gas shall be used in the test: The first test gas has any hydrogen concentration between 3.0 and 4.0 percent by volume in air to verify function of the warning, and the second test gas has any hydrogen concentration between 4.0 and 6.0 percent by volume in air to verify function of the shut-down.

(c) The test shall be conducted without influence of wind.

(d) A vehicle hydrogen leakage detector located in the enclosed or semi-enclosed spaces is enclosed with a cover and a test gas induction hose is attached to the hydrogen gas leakage detector.

(e) The hydrogen gas leakage detector is exposed to continuous flow of the first test gas specified in S.6.4.1(b) until the warning turns on.

(f) Then the hydrogen gas leakage detector is exposed to continuous flow of the second test gas specified in S.6.4.1(b) until the main shut-off valve closes to isolate the CHSS. The test is completed when the shut-off valve closes.

S6.4.2. *Test for integrity of enclosed spaces and detection systems.* (a) The test shall be conducted without influence of wind.

(b) Prior to the test, the vehicle is prepared to simulate remotely controllable hydrogen releases from the fuel system or from an external fuel supply. The number, location, and flow capacity of the release points downstream of the shut-off valve are defined by the vehicle manufacturer.

(c) A hydrogen concentration detector shall be installed in any enclosed or semi-enclosed spaces where hydrogen may accumulate from the simulated hydrogen release.

(d) Vehicle doors, windows and other covers are closed.

(e) The vehicle propulsion system shall be operated for at least five minutes and shall continue to operate throughout the remainder of the test.

(f) A leak shall be simulated using the remote controllable function.

(g) The hydrogen concentration is measured continuously until the end of the test.

(h) The test is completed 5 minutes after initiating the simulated leak or when the hydrogen concentration does not change for 3 minutes, whichever is longer.

S6.5. *Test for the vehicle exhaust system.* (a) The vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test, except for times when the propulsion system becomes deactivated by the steps taken during S6.5(c).

(b) The measuring section of the measuring device shall be placed along the centerline of the exhaust gas flow within 100 mm of where the exhaust is released to the atmosphere.

(c) The exhaust hydrogen concentration shall be continuously measured during the following steps:

(1) The fuel cell system shall be shut down.

(2) The fuel cell system shall be immediately restarted.

(3) After one minute, the vehicle shall be set to the ''off'' position and measurement continues until the until the vehicle shutdown is complete.

(d) The measurement device shall have a resolution time of less than 300 milliseconds;

(e) The measurement device shall have a measurement response time ($t_0 - t_{90}$) of less than 2 seconds, where t_0 is the moment of hydrogen concentration switching, and t_{90} is the time when 90 percent of the final indication is reached and shall have a resolution time of less than 300 milliseconds (sampling rate of greater than 3.33 Hz).

S6.6. *Test for fuel system leakage.* The vehicle CHSS shall be filled with hydrogen to any pressure between 90 percent NWP and 100 percent NWP for the duration of the test for fuel system leakage.

(a) The vehicle propulsion system shall be operated for at least five minutes prior to testing and shall continue to operate throughout the test.

(b) Hydrogen leakage shall be evaluated at accessible sections of the hydrogen fuel system downstream of the shut-off valve(s) using a leak detecting liquid. Hydrogen gas leak detection shall be performed immediately after applying the liquid.

S7. *Test conditions.* The requirements of S5.2 shall be met under the following conditions. Where a range of conditions is specified, the vehicle must be capable of meeting the requirements at all points within the range.

(a) Prior to conducting the crash test, instrumentation is installed in the CHSS to perform the required pressure and temperature measurements if the vehicle does not already have instrumentation with the required accuracy.

(b) The CHSS is then purged, if necessary, following vehicle manufacturer directions before filling the CHSS with compressed hydrogen or helium gas, as specified by the vehicle manufacturer.

(c) The target fill pressure P_{target} shall be calculated from equation 18 to this section, where NWP is in MPa, T_o is the ambient temperature in °C to which the CHSS is expected to settle, and P_{target} is the target fill pressure in MPa after the temperature settles:

Equation 18 to § 571.307 S7

$$P_{target} = NWP \times (273 + T_o)/288$$

(d) The container(s) shall be filled to any pressure between 95.0 percent and 100.0 percent of the calculated target fill pressure.

(e) After fueling, the vehicle shall be maintained at rest for any duration between 2.0 and 3.0 hours before conducting a crash test in accordance with S6.1 of this standard.

(f) The CHSS shut-off valve(s) and any other shut-off valves located in the fuel system downstream hydrogen gas piping shall be in normal driving condition immediately prior to the impact.

(g) The parking brake is disengaged and the transmission is in neutral prior to the crash test.

(h) Tires are inflated to manufacturer's specifications.

(i) The vehicle, including test devices and instrumentation, is loaded as follows:

(1) A passenger car, with its fuel system filled as specified in S7(d), is loaded to its unloaded vehicle weight plus its rated cargo and luggage capacity weight, secured in the luggage area, plus the necessary test dummies as specified in S6, restrained only by means that are installed in the vehicle for protection at its seating position(s).

(2) A multipurpose passenger vehicle, truck, or bus with a GVWR of 10,000 pounds or less, whose fuel system is filled as specified in S7(d), is loaded to its unloaded vehicle weight, plus the necessary test dummies as specified in S6 of this standard, plus 136.1 kg, or its rated cargo and luggage capacity weight, whichever is less, secured to the vehicle and distributed so that the weight on each axle as measured at the tire-ground interface is in proportion to its gross axle weight rating (GAWR). Each dummy shall be restrained only by means that are installed in the vehicle for protection at its seating position(s).

(3) A school bus with a GVWR greater than 10,000 pounds, whose fuel system is filled as specified in S7(d), is loaded to its unloaded vehicle weight, plus 54.4 kg of unsecured weight at each designated seating position.

■ 4. Section 571.308 is added to read as follows:

§ 571.308 Standard No. 308; Compressed hydrogen storage system integrity

S1. *Scope.* This standard specifies requirements for compressed hydrogen storage systems used in motor vehicles.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries occurring from fires that result from hydrogen fuel leakage during vehicle operation and to reduce deaths and injuries occurring from explosions resulting from the burst of pressurized hydrogen containers.

S3. *Application.* This standard applies to each motor vehicle manufactured on or after September 1, 2028, that is equipped with compressed hydrogen gas as a fuel source to propel the vehicle. The standard does not apply to vehicles that are only equipped with cryo-compressed hydrogen storage systems and/or solid-state hydrogen storage system to propel the vehicle.

S4. *Definitions.*

BP_O means the vehicle manufacturer-supplied median burst pressure for a batch of new containers.

Burst means to break apart or to break open.

Burst pressure means the highest pressure achieved for a container tested in accordance with S6.2.2.1 of this standard.

Check valve means a valve that prevents reverse flow.

Closure devices mean the check valve(s), shut-off valve(s), and thermally-activated pressure relief device(s) that control the flow of hydrogen into and/or out of a CHSS.

Container means a pressure-bearing component of a compressed hydrogen storage system that stores a continuous volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.

Container attachments mean non-pressure bearing parts attached to the container that provide additional support and/or protection to the container and that may be removed only with the use of tools for the specific purpose of maintenance and/or inspection.

Compressed hydrogen storage system (CHSS) means a system that stores compressed hydrogen fuel for a hydrogen-fueled vehicle, composed of a container, container attachments (if any), and all closure devices required to isolate the stored hydrogen from the remainder of the fuel system and the environment.

Cryo-compressed hydrogen storage system means a system that stores hydrogen by compressing it to high pressure while simultaneously cooling it to very low temperatures, allowing for a higher density of hydrogen storage compared to standard compressed hydrogen systems.

Hydrogen fuel system means the fueling receptacle, CHSS, fuel cell system or internal combustion engine, fuel lines, and exhaust systems.

Nominal working pressure (NWP) means the settled pressure of compressed gas in a container or CHSS fully fueled to 100 percent state of charge and at a uniform temperature of 15 °C.

Normal milliliter means a quantity of gas that occupies one milliliter of volume when its temperature is 0 °C and its pressure is 1 atmosphere.

Pressure relief device (PRD) means a device that, when activated under specified performance conditions, is used to release hydrogen from a pressurized system and thereby prevent failure of the system.

Service life (of a container) means the time frame during which service (usage) is authorized by the vehicle manufacturer.

Shut-off valve means a valve between the container and the remainder of the hydrogen fuel system that must default to the ''closed'' position when unpowered.

Solid-state hydrogen storage system means a system that stores hydrogen at ambient temperatures and low pressures within solid materials that can either physically absorb the hydrogen gas or chemically combine with it.

State of charge (SOC) means the density ratio of hydrogen in the CHSS between the actual CHSS condition and that at NWP with the CHSS equilibrated to 15 °C, as expressed as a percentage using the equation 1 to this section, where ρ is the density of hydrogen (g/L) at pressure (P) in MegaPascals (MPa) and temperature (T) in Celsius (°C) as listed below in Table 1 or linearly interpolated therein:

Equation 1 to § 571.308 S4

$$SOC(\%) = \frac{\rho(P,T)}{\rho(NWP, 15°C)} x100$$

TABLE 1 TO § 571.308 S4

Temperature (°C)	Pressure (MPa)												
	1	10	20	30	35	40	50	60	65	70	75	80	87.5
−40	1.0	9.7	18.1	25.4	28.6	31.7	37.2	42.1	44.3	46.4	48.4	50.3	53.0
−30	1.0	9.4	17.5	24.5	27.7	30.6	36.0	40.8	43.0	45.1	47.1	49.0	51.7
−20	1.0	9.0	16.8	23.7	26.8	29.7	35.0	39.7	41.9	43.9	45.9	47.8	50.4
−10	0.9	8.7	16.2	22.9	25.9	28.7	33.9	38.6	40.7	42.8	44.7	46.6	49.2
0	0.9	8.4	15.7	22.2	25.1	27.9	33.0	37.6	39.7	41.7	43.6	45.5	48.1
10	0.9	8.1	15.2	21.5	24.4	27.1	32.1	36.6	38.7	40.7	42.6	44.4	47.0
15	0.8	7.9	14.9	21.2	24.0	26.7	31.7	36.1	38.2	40.2	42.1	43.9	46.5
20	0.8	7.8	14.7	20.8	23.7	26.3	31.2	35.7	37.7	39.7	41.6	43.4	46.0
30	0.8	7.6	14.3	20.3	23.0	25.6	30.4	34.8	36.8	38.8	40.6	42.4	45.0
40	0.8	7.3	13.9	19.7	22.4	24.9	29.7	34.0	36.0	37.9	39.7	41.5	44.0
50	0.7	7.1	13.5	19.2	21.8	24.3	28.9	33.2	35.2	37.1	38.9	40.6	43.1
60	0.7	6.9	13.1	18.7	21.2	23.7	28.3	32.4	34.4	36.3	38.1	39.8	42.3
70	0.7	6.7	12.7	18.2	20.7	23.1	27.6	31.7	33.6	35.5	37.3	39.0	41.4
80	0.7	6.5	12.4	17.7	20.2	22.6	27.0	31.0	32.9	34.7	36.5	38.2	40.6
85	0.7	6.4	12.2	17.5	20.0	22.3	26.7	30.7	32.6	34.4	36.1	37.8	40.2

Thermally-activated pressure relief device (TPRD) means a non-reclosing PRD that is activated by temperature to open and release hydrogen gas.

TPRD sense point means instrumentation that detects elevated temperature for the purpose of activating a TPRD.

S5. *Requirements.*

S5.1. *Requirements for the CHSS.* Each vehicle CHSS shall include the following functions: shut-off valve, check valve, and TPRD. Each vehicle CHSS shall have a NWP of 70 MPa or less. Each vehicle container, closure device, and CHSS shall meet the applicable performance test requirements listed in table 2 to this section.

TABLE 2 TO § 571.308 S5.1

Requirement section	Test article
S5.1.1. *Tests for baseline metrics*	Container.
S5.1.2. *Test for performance durability*	Container.
S5.1.3. *Test for expected on-road performance*	CHSS.
S5.1.4. *Test for service terminating performance in fire*	CHSS.
S5.1.5. *Tests for performance durability of closure devices*	Closure devices.

S5.1.1. *Tests for baseline metrics.*

S5.1.1.1. *Baseline initial burst pressure.* The vehicle manufacturer shall immediately and irrevocably specify upon request, in writing and within 15 business days: whether the primary constituent of the container is glass fiber composite. When a new container with its container attachments (if any) is tested in accordance with S6.2.2.1 of this standard, both of the following requirements shall be met:

(a) The burst pressure of the container shall not be less than 2 times NWP.

(b) The burst pressure of the container having glass-fiber composite as a primary constituent shall not be less than 3.5 times NWP.

S5.1.1.2. *Baseline initial pressure cycle test.* When a new container with its container attachments (if any) is hydraulically pressure cycled in accordance with S6.2.2.2 of this standard to any pressure between 125.0 percent NWP and 130.0 percent NWP,

(a) Containers for vehicles with a GVWR of 10,000 pounds or less

(1) Shall not leak nor burst for at least 7,500 cycles, and

(2) Thereafter shall not burst for an additional 14,500 cycles. If a leak occurs while conducting the test as specified in S5.1.1.2(a)(2), the test is stopped and not considered a failure.

(b) Containers for vehicles with a GVWR of over 10,000 pounds

(1) Shall not leak nor burst for at least 11,000 cycles, and

(2) Thereafter shall not burst for an additional 11,000 cycles. If a leak occurs while conducting the test as specified in S5.1.1.2(b)(2), the test is stopped and not considered a failure.

S5.1.2. *Test for performance durability.* A new container shall not leak nor burst when subjected to the sequence of tests in S5.1.2.1 through S5.1.2.6. Immediately following S5.1.2.6, and without depressurizing the container, the container is subjected to a burst test in accordance with S6.2.2.1(c) and (d) of this standard. The burst pressure of the container at the end of the sequence of tests in this section shall not be less than 0.8 times the BP_O value specified by the vehicle manufacturer. The sequence of tests and the burst pressure test are illustrated in figure 1 to S5.1.2. The vehicle manufacturer shall immediately and irrevocably specify upon request, in writing and within 15 business days: the BP_O of the container.

S5.1.2.1. *Drop test.* The container with its container attachments (if any) is dropped once in accordance with S6.2.3.2 of this standard in any one of the four orientations specified in that section. Any container with damage from the drop test that prevents further testing of the container in accordance with S6.2.3.4 of this standard shall be considered to have failed to meet the test for performance durability requirements. In the case of an asymmetric container, the vehicle manufacturer shall immediately and irrevocably specify upon request, in writing, and within 15 business days: the center of gravity of the container.

S5.1.2.2. *Surface damage test.* The container, except if an all-metal container, is subjected to the surface damage test in accordance with the S6.2.3.3 of this standard. Container attachments designed to be removed shall be removed and container attachments that are not designed to be removed shall remain in place. Container attachments that are removed shall not be reinstalled for the remainder of S5.1.2; container attachments that are not removed shall remain in place for the remainder of S5.1.2.

S5.1.2.3. *Chemical exposure and ambient-temperature pressure cycling test.* The container is exposed to chemicals in accordance with S6.2.3.4 and then hydraulically pressure cycled in accordance with S6.2.3.4 of this standard for 60 percent of the number of cycles as specified in S5.1.1.2(a)(1) or (b)(1) as applicable. For all but the last 10 of these cycles, the cycling pressure shall be any pressure between 125.0 percent NWP and 130.0 percent NWP. For the last 10 cycles, the pressure shall be any pressure between 150.0 percent NWP and 155.0 percent NWP.

S5.1.2.4. *High temperature static pressure test.* The container is pressurized to any pressure between (or equal to) 125 percent NWP and 130 percent NWP and held at that pressure no less than 1,000 and no more than 1,050 hours in accordance with S6.2.3.5 of this standard and with the temperature surrounding the container at any temperature between 85.0 °C and 90.0 °C.

S5.1.2.5. *Extreme temperature pressure cycling test.* The container is pressure cycled in accordance with S6.2.3.6 for 40 percent of the number of cycles specified in S5.1.1.2(a)(1) or (b)(1) as applicable. The pressure for the first half of these cycles equals any pressure between 80.0 percent NWP and 85.0 percent NWP with the temperature surrounding the container equal to any temperature between −45.0 °C and −40.0 °C. The pressure for the next half of these cycles equals any pressure between 125.0 percent NWP and 130.0 percent NWP and the temperature surrounding the container equal to any temperature between 85.0 °C and 90.0 °C and the relative humidity surrounding the container not less than 80 percent.

S5.1.2.6. *Residual pressure test.* The container is hydraulically pressurized in accordance with S6.2.3.1 of this standard to a pressure between 180.0 percent NWP and 185.0 percent NWP and held for any duration between 240 to 245 seconds.

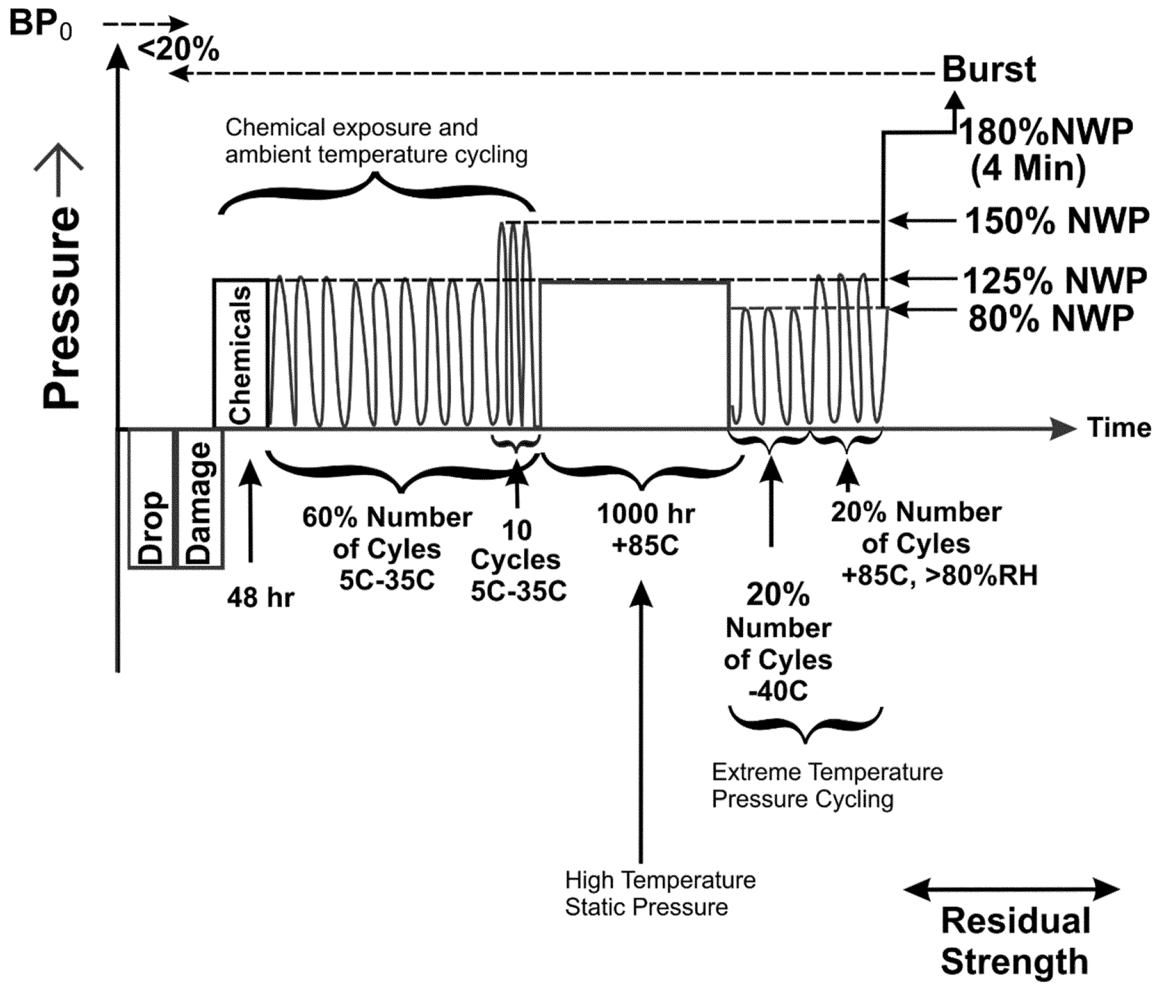

Figure 1 to § 571.308 S5.1.2. Performance Durability Test; (for Illustration Purposes Only)

S5.1.3. *Test for expected on-road performance.* When subjected to the sequence of tests in S5.1.3.1, the CHSS shall meet the permeation and leak requirements specified in S5.1.3.2 and shall not burst. Thereafter, the container of the CHSS shall not burst when subjected to a residual pressure test in accordance with S5.1.3.3. Immediately following the test specified in S5.1.3.3, and without depressurizing the container, the container of the CHSS is subjected to a burst test in accordance with S6.2.2.1(c) and (d) of this standard. The burst pressure of the container at the end of the sequence of tests in this section shall not be less than 0.8 times the BP_O specified by the vehicle manufacturer under S5.1.2.

S5.1.3.1. *Ambient and extreme temperature gas pressure cycling test.* The CHSS is pressure cycled using hydrogen gas for 500 cycles under any temperature and pressure condition for the number of cycles as specified in table 3 to S5.1.3.1, and in accordance with the S6.2.4.1 of this standard test procedure. A static gas pressure leak/permeation test performed in accordance with S5.1.3.2 is conducted after the first 250 pressure cycles and after the remaining 250 pressure cycles.

TABLE 3 TO § 571.308 S5.1.3.1

Number of cycles	*Ambient conditions*	*Initial system equilibration*	*Fuel delivery temperature*	*Cycle initial and final pressure*	*Cycle peak pressure*
5	−30.0 °C to −25.0 °C	−30.0 °C to −25.0 °C	15.0 °C to 25.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
5	−30.0 °C to −25.0 °C	−30.0 °C to −25.0 °C	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
15	−30.0 °C to −25.0 °C	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
5	50.0 °C to 55.0 °C, 80% to 100% relative humidity.	50 °C to 55 °C, 80% to 100% relative humidity.	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
20	50.0 °C to 55.0 °C, 80% to 100% relative humidity.	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
200	5.0 °C to 35.0 °C	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.

TABLE 3 TO § 571.308 S5.1.3.1—Continued

Number of cycles	*Ambient conditions*	*Initial system equilibration*	*Fuel delivery temperature*	*Cycle initial and final pressure*	*Cycle peak pressure*
Extreme temperature static gas pressure leak/permeation test S5.1.3.2.	55.0 °C to 60.0 °C	55.0 °C to 60.0 °C	not appliable	not appliable	100.0% SOC to 105.0% SOC.
25	50.0 °C to 55.0 °C, 80% to 100% relative humidity.	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
25	−30.0 °C to −25.0 °C	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
200	5.0 °C to 35.0 °C	not appliable	−40.0 °C to −33.0 °C	1.0 MPa to 2.0 MPa	100.0% SOC to 105.0% SOC.
Extreme temperature static gas pressure leak/permeation test S5.1.3.2.	55.0 °C to 60.0 °C	55.0 °C to 60.0 °C	not appliable	not appliable	100.0% SOC to 105.0% SOC.

S5.1.3.2. *Extreme temperature static gas pressure leak/permeation test.* When tested in accordance with S6.2.4.2 of this standard after each group of 250 pneumatic pressure cycles in S5.1.3.1, the CHSS shall not discharge hydrogen more than 46 millilitres per hour (mL/h) for each litre of CHSS water capacity.

S5.1.3.3. *Residual pressure test.* The container of the CHSS is hydraulically pressurized in accordance with S6.2.3.1 to any pressure between 1.800 times NWP and 1.850 times NWP and held at that pressure for any duration between 240 to 245 seconds.

S5.1.4. *Test for service terminating performance in fire.* When the CHSS is exposed to the two-stage localized or engulfing fire test in accordance with S6.2.5 of this standard, the container shall not burst. The pressure inside the CHSS shall fall to 1 MPa or less within the test time limit specified in S6.2.5.3(o) of this standard. Any leakage or venting, other than that through TPRD outlet(s), shall not result in jet flames greater than 0.5 m in length. If venting occurs though the TPRD, the venting shall be continuous.

S5.1.5. *Tests for performance durability of closure devices.* All tests are performed at ambient temperature of 5 °C to 35 °C unless otherwise specified.

S5.1.5.1. *TPRD requirements.* The TPRD shall not activate at any point during the test procedures specified in S6.2.6.1.1, S6.2.6.1.3, S6.2.6.1.4, S6.2.6.1.5, S6.2.6.1.6, S6.2.6.1.7, and S6.2.6.1.8 of this standard.

(a) A TPRD subjected to pressure cycling in accordance with S6.2.6.1.1 of this standard shall be sequentially tested in accordance with S6.2.6.1.8, S6.2.6.1.9, and S6.2.6.1.10 of this standard;

(1) When tested in accordance with S6.2.6.1.8, the TPRD shall not exhibit leakage greater than 10 normal milliliters per minute (NmL/hour).

(2) When tested in accordance with S6.2.6.1.9 of this standard, the TPRD shall activate within no more than 2 minutes of the average activation time of three new TPRDs tested in accordance with S6.2.6.1.9;

(3) When tested in accordance with S6.2.6.1.10 of this standard, the TPRD shall have a flow rate of at least 90 percent of the highest baseline flow rate established in accordance with S6.2.6.1.10;

(b)(1) A TPRD shall activate in less than ten hours when tested at the vehicle manufacturer's specified activation temperature in accordance with S6.2.6.1.2 of this standard;

(2) When tested at the accelerated life temperature in accordance with S6.2.6.1.2 of this standard, a TPRD shall not activate in less than 500 hours and shall not exhibit leakage greater than 10 NmL/hour when tested in accordance with S6.2.6.1.8 of this standard;

(c) A TPRD subjected to temperature cycling testing in accordance with S6.2.6.1.3 of this standard shall be sequentially tested in accordance with S6.2.6.1.8(a)(3), S6.2.6.1.9, and S6.2.6.1.10 of this standard;

(1) When tested in accordance with S6.2.6.1.8(a)(3) of this standard, the TPRD shall not exhibit leakage greater than 10 NmL/hour;

(2) When tested in accordance with S6.2.6.1.9 of this standard, the TPRD shall activate within no more than 2 minutes of the average activation time of three new TPRDs tested in accordance with S6.2.6.1.9;

(3) When tested in accordance with S6.2.6.1.10 of this standard, the TPRD shall have a flow rate of at least 90 percent of the highest baseline flow rate established in accordance with S6.2.6.1.10;

(d) A TPRD subjected to salt corrosion resistance testing in accordance with S6.2.6.1.4 of this standard shall be sequentially tested in accordance with S6.2.6.1.8, S6.2.6.1.9, and S6.2.6.1.10 of this standard;

(1) When tested in accordance with S6.2.6.1.8 of this standard, the TPRD shall not exhibit leakage greater than 10 NmL/hour;

(2) When tested in accordance with S6.2.6.1.9 of this standard, the TPRD shall activate within no more than 2 minutes of the average activation time of three new TPRDs tested in accordance with S6.2.6.1.9;

(3) When tested in accordance with S6.2.6.1.10 of this standard, the TPRD shall have a flow rate of at least 90 percent of the highest baseline flow rate established in accordance with S6.2.6.1.10;

(e) A TPRD subjected to vehicle environment testing in accordance with S6.2.6.1.5 of this standard shall not show signs of cracking, softening, or swelling, and thereafter shall be sequentially tested in accordance with S6.2.6.1.8, S6.2.6.1.9, and S6.2.6.1.10 of this standard. Cosmetic changes such as pitting or staining are not considered failures.

(1) When tested in accordance with S6.2.6.1.8 of this standard, the TPRD shall not exhibit leakage greater than 10 NmL/hour.

(2) When tested in accordance with S6.2.6.1.9 of this standard, the TPRD shall activate within no more than 2 minutes of the average activation time of three new TPRDs tested in accordance with S6.2.6.1.9,

(3) When tested in accordance with S6.2.6.1.10 of this standard, the TPRD shall have a flow rate of at least 90 percent of the highest baseline flow rate established in accordance with S6.2.6.1.10;

(f) A TPRD subjected to stress corrosion cracking testing in accordance with S6.2.6.1.6 of this standard shall not exhibit visible cracking or delaminating;

(g) A TPRD shall be subjected to drop and vibration testing in accordance with

S6.2.6.1.7 of this standard. If the TPRD progresses beyond S6.2.6.1.7(c) to complete testing under S6.2.6.1.7(d), it shall then be sequentially tested in accordance with S6.2.6.1.8, S6.2.6.1.9, and S6.2.6.1.10 of this standard.

(1) When tested in accordance with S6.2.6.1.8 of this standard, the TPRD shall not exhibit leakage greater than 10 NmL/hour.

(2) When tested in accordance with S6.2.6.1.9 of this standard, the TPRD shall activate within no more than 2 minutes of the average activation time of three new TPRDs tested in accordance with S6.2.6.1.9,

(3) When tested in accordance with S6.2.6.1.10 of this standard, the TPRD shall have a flow rate of at least 90 percent of the highest baseline flow rate established in accordance with S6.2.6.1.10;

(h) One new TPRD subjected to leak testing in accordance with S6.2.6.1.8 of this standard shall not exhibit leakage greater than 10 NmL/hour;

(i) Three new TPRDs are subjected to a bench top activation test in accordance with S6.2.6.1.9 of this standard. The maximum difference in the activation time between any two of the three TPRDs shall be 2 minutes or less.

S5.1.5.2. *Check valve and shut-off valve requirements.* This section applies to both check valves and shut-off valves.

(a) A valve subjected to hydrostatic strength testing in accordance with S6.2.6.2.1 of this standard shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c) nor burst at less than 250 percent NWP;

(b) A valve subjected to leak testing in accordance with S6.2.6.2.2 of this standard shall not exhibit leakage greater than 10 NmL/hour;

(c)(1) A check valve shall meet the requirements when tested sequentially as follows:

(i) The check valve shall reseat and prevent reverse flow after each cycle when subjected to 13,500 pressure cycles in accordance with S6.2.6.2.3 of this standard to any pressure between 100.0 and 105.0 percent NWP and at any temperature between 5.0 °C and 35.0 °C;

(ii) The same check valve shall reseat and prevent reverse flow after each cycle when subjected to 750 pressure cycles in accordance with S6.2.6.2.3 of this standard to any pressure between 125.0 and 130.0 percent NWP and at any temperature between 85.0 °C and 90.0 °C;

(iii) The same check valve shall reseat and prevent reverse flow after each cycle when subjected to 750 pressure cycles in accordance with S6.2.6.2.3 of this standard to any pressure between 80.0 and 85.0 percent NWP and at any temperature between −45.0 °C and −40.0 °C;

(iv) The same check valve shall be subjected to chatter flow testing in accordance with S6.2.6.2.4 of this standard;

(v) When tested in accordance with S6.2.6.2.2 of this standard, the same check valve shall not exhibit leakage greater than 10 NmL/hour;

(vi) When tested in accordance with S6.2.6.2.1 of this standard, the same check valve shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c), nor burst at less than 250 percent NWP, nor burst at less than 80 percent of the burst pressure of the new unit tested in accordance with S5.1.5.2(a) unless the burst pressure of the valve exceeds 400 percent NWP.

(2) A shut-off valve shall meet the requirements when tested sequentially as follows:

(i) The shut-off valve shall be subjected to 45,000 pressure cycles in accordance with S6.2.6.2.3 to any pressure between 100.0 and 105.0 percent NWP and at any temperature between 5.0 °C and 35.0 °C;

(ii) The same shut-off valve shall be subjected to 2,500 pressure cycles in accordance with S6.2.6.2.3 of this standard to any pressure between 125.0 and 130.0 percent NWP and at any temperature between 85.0 °C and 90.0 °C;

(iii) The same shut-off valve shall be subjected to 2,500 pressure cycles in accordance with S6.2.6.2.3 of this standard to any pressure between 80.0 and 85.0 percent NWP and at any temperature between −45.0 °C and −40.0 °C;

(iv) The same shut-off valve shall be subjected to chatter flow testing in accordance with S6.2.6.2.4 of this standard;

(v) When tested in accordance with S6.2.6.2.2 of this standard, the same shut-off valve shall not exhibit leakage greater than 10 NmL/hour;

(vi) When tested in accordance with S6.2.6.2.1 of this standard, the same shut-off valve shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c), nor burst at less than 250 percent NWP, nor burst at less than 80 percent of the burst pressure of the new unit tested in accordance with S5.1.5.2(a) unless the burst pressure of the valve exceeds 400 percent NWP.

(d) A valve subjected to salt corrosion resistance testing in accordance with S6.2.6.1.4 of this standard shall be tested sequentially in accordance with S6.2.6.2.2 followed by S6.2.6.2.1 of this standard.

(1) When tested in accordance with S6.2.6.2.2 of this standard, the valve shall not exhibit leakage greater than 10 NmL/hour;

(2) When tested in accordance with S6.2.6.2.1 of this standard, the valve shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c), nor burst at less than 250 percent NWP, nor burst at less than 80 percent of the burst pressure of the new unit tested in accordance with S5.1.5.2(a) unless the burst pressure of the valve exceeds 400 percent NWP.

(e) A valve subjected to vehicle environment testing in accordance with S6.2.6.1.5 of this standard shall not show signs of cracking, softening, or swelling and shall be tested sequentially in accordance with S6.2.6.2.2 followed by S6.2.6.2.1 of this standard. Cosmetic changes such as pitting or staining are not considered failures.

(1) When tested in accordance with S6.2.6.2.2 of this standard, the valve shall not exhibit leakage greater than 10 NmL/hour;

(2) When tested in accordance with S6.2.6.2.1 of this standard, the valve shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c), nor burst at less than 250 percent NWP, nor burst at less than 80 percent of the burst pressure of the new unit tested in accordance with S5.1.5.2(a) unless the burst pressure of the valve exceeds 400 percent NWP;

(f) A shut-off valve shall have a minimum resistance of 240 kΩ between the power conductor and the valve casing, and shall not exhibit open valve, smoke, fire, melting, or leakage greater than 10 NmL/hour when subjected to electrical testing in accordance with S6.2.6.2.5 followed by leak testing in accordance with S6.2.6.2.2 of this standard;

(g) A valve subjected to vibration testing in accordance with S6.2.6.2.6 of this standard shall be tested sequentially in accordance with S6.2.6.2.2 followed by S6.2.6.2.1 of this standard.

(1) When tested in accordance with S6.2.6.2.2 of this standard, the valve shall not exhibit leakage greater than 10 NmL/hour;

(2) When tested in accordance with S6.2.6.2.1 of this standard, the valve shall not leak to an extent that prevents continued pressurization in accordance with S6.2.6.2.1(c), nor burst at less than 250 percent NWP, nor burst at less than 80 percent of the burst pressure of the new unit tested in accordance with

S5.1.5.2(a) unless the burst pressure of the valve exceeds 400 percent NWP.

(h) A valve shall not exhibit visible cracking or delaminating when subjected to stress corrosion cracking testing in accordance with S6.2.6.1.6 of this standard.

S5.1.6. *Labeling.* Each vehicle container shall be permanently labeled with the information specified in paragraphs S5.1.6(a) through (g). Any label affixed to the container in compliance with this section shall remain in place and be legible for the vehicle manufacturer's recommended service life of the container. The information shall be in English and in letters and numbers that are at least 6.35 millimeters (¼ inch) high.

(a) The statement: ''If there is a question about the proper use, installation, or maintenance of this compressed hydrogen storage system, contact ______,'' inserting the vehicle manufacturer's name, address, and telephone number. The name provided shall be consistent with the vehicle manufacturer's filing in accordance with 49 CFR part 566.

(b) The container serial number.

(c) The statement: ''Manufactured in ______,'' inserting the month and year of manufacture of the container.

(d) The statement ''Nominal Working Pressure ______MPa (_____psig),'' Inserting the nominal working pressure which shall be no greater than 70 MPa.

(e) The statement ''Compressed Hydrogen Gas Only.''

(f) The statement: ''Do Not Use After ______,'' inserting the month and year that mark the end of the vehicle manufacturer's recommended service life for the container.

(g) The statement: ''This container should be visually inspected for damage and deterioration after a motor vehicle accident or fire, and either: (i) at least every 12 months when installed on a vehicle with a GVWR greater than 4,536 kg, or (ii) at least every 36 months or 36,000 miles, whichever comes first, when installed on a vehicle with a GVWR less than or equal to 4,536 kg.''

S6. *Test procedures.*

S6.1. [Reserved]

S6.2. *Test procedures for compressed hydrogen storage.*

S6.2.1. Unless otherwise specified, data sampling for pressure cycling under S6.2 shall be at least 1 Hz.

S6.2.2. *Test procedures for baseline performance metrics.*

S6.2.2.1. *Burst test.* (a) The container is filled with a hydraulic fluid.

(b) The container, the surrounding environment, and the hydraulic fluid are at any temperature between 5.0 °C and 35.0 °C.

(c) The rate of pressurization shall be less than or equal to 1.4 MPa per second for pressures higher than 1.50 times NWP. If the rate exceeds 0.35 MPa per second at pressures higher than 1.50 times NWP, then the container is placed in series between the pressure source and the pressure measurement device.

(d) The container is hydraulically pressurized until burst and the burst pressure of the container is recorded.

S6.2.2.2. *Pressure cycling test.* (a) The container is filled with a hydraulic fluid.

(b) The container surface, or the surface of the container attachments if present, the environment surrounding the container, and the hydraulic fluid are at any temperature between 5.0 °C and 35.0 °C at the start of testing and maintained at the specified temperature for the duration of the testing.

(c) The container is pressure cycled at any pressure between 1.0 MPa and 2.0 MPa up to the pressure specified in the respective section of S5. The cycling rate shall be any rate up to 10 cycles per minute.

(d) The temperature of the hydraulic fluid entering the container is maintained and monitored at any temperature between 5.0 °C and 35.0 °C.

(e) The vehicle manufacturer may specify a hydraulic pressure cycle profile within the specifications of S6.2.2.2(c). Vehicle manufacturers shall submit this profile to NHTSA immediately and irrevocably, upon request, in writing, and within 15 business days; otherwise, NHTSA shall determine the profile. At NHTSA's option, NHTSA shall cycle the container within 10 percent of the vehicle manufacturer's specified cycling profile.

S6.2.3. *Performance durability test.*

S6.2.3.1. *Residual pressure test.* The container is pressurized smoothly and continually with hydraulic fluid or hydrogen gas as specified until the pressure level is reached and held for the specified time.

S6.2.3.2. *Drop impact test.* The container is drop tested without internal pressurization or attached valves. The surface onto which the container is dropped shall be a smooth, horizontal, uniform, dry, concrete pad or other flooring type with equivalent hardness. No attempt shall be made to prevent the container from bouncing or falling over during a drop test, except for the vertical drop test, during which the test article shall be prevented from falling over. The container shall be dropped in any one of the following four orientations described below and illustrated in figure 2 to S6.2.3.2.

(a) From a position within 5° of horizontal with the lowest point of the container at any height between 1.800 meters and 1.820 meters above the surface onto which it is dropped. In the case of a non-axisymmetric container, the largest projection area of the container shall be oriented downward and aligned horizontally;

(b) From a position within 5° of vertical with the center of any shut-off valve interface location upward and with any potential energy of between 488 Joules and 538 Joules. If a drop energy of between 488 Joules and 538 Joules would result in the height of the lower end being more than 1.820 meters above the surface onto which it is dropped, the container shall be dropped from any height with the lower end between 1.800 meters and 1.820 meters above the surface onto which it is dropped. If a drop energy of between 488 Joules and 538 Joules would result in the height of the lower end being less than 0.100 meters above the surface onto which it is dropped, the container shall be dropped from any height with the lower end between 0.100 meters and 0.120 meters above the surface onto which it is dropped. In the case of a non-axisymmetric container, the center of any shut-off valve interface location and the container's center of gravity shall be aligned vertically, with the center of that shut-off valve interface location upward;

(c) From a position within 5° of vertical with the center of any shut-off valve interface location downward with any potential energy of between 488 Joules and 538 Joules. If a potential energy of between 488 Joules and 538 Joules would result in the height of the lower end being more than 1.820 meters above the surface onto which it is dropped, the container shall be dropped from any height with the lower end between 1.800 meters and 1.820 meters above the surface onto which it is dropped. If a drop energy of between 488 Joules and 538 Joules would result in the height of the lower end being less than 0.100 meters above the surface onto which it is dropped, the container shall be dropped from any height with the lower end between 0.100 meters and 0.120 meters above the surface onto which it is dropped. In the case of a non-axisymmetric container, the center of any shut-off valve interface location and the container's center of gravity shall be aligned vertically, with the center of that shut-off valve interface location downward;

(d) From any angle between 40° and 50° from the vertical orientation with the center of any shut-off valve interface location downward, and with the container center of gravity between 1.800 meters and 1.820 meters above the surface onto which it is dropped. However, if the lowest point of the container is closer to the ground than 0.60 meters, the drop angle shall be changed so that the lowest point of the container is between 0.60 meters and 0.62 meters above the ground and the center of gravity is between 1.800 meters and 1.820 meters above the surface onto which it is dropped. In the case of a non-axisymmetric container, the line passing through the center of any shut-off valve interface location and the container's center of gravity shall be at any angle between 40° and 50° from the vertical orientation. If this specification results in more than one possible container orientation, the drop shall be conducted from the orientation that results in the lowest positioning of the center of the shut-off valve interface location.

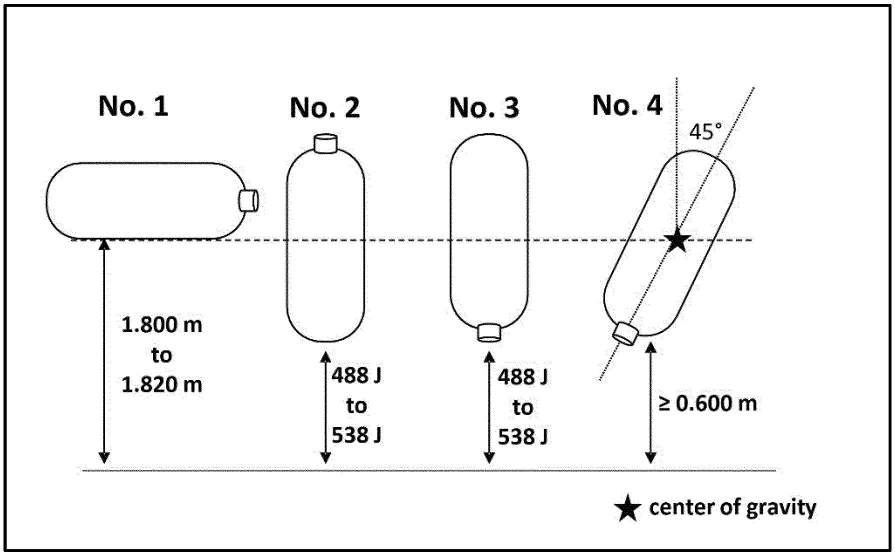

Figure 2 to § 571.308 S6.2.3.2. The Four Drop Orientations; (for Illustration Purposes Only)

S6.2.3.3. *Surface damage test.* The surface damage test consists of surface cut generation and pendulum impacts as described below.

(a) Surface cut generation: Two longitudinal saw cuts are made at any location on the same side of the outer surface of the unpressurized container, as shown in Figure 3, or on the container attachments if present. The first cut is 0.75 millimeters to 1.25 millimeters deep and 200 millimeters to 205 millimeters long; the second cut, which is only required for containers affixed to the vehicle by compressing its composite surface, is 1.25 millimeters to 1.75 millimeters deep and 25 millimeters to 28 millimeters long.

(b) Pendulum impacts: Mark the outer surface of the container, or the container attachments if present, with five separate, non-overlapping circles each having any linear diameter between 100.0 millimeters and 105.0 millimeters, as shown in Figure 3. The marks shall be located on the side opposite from the saw cuts, or located on a different chamber in the case of a container with more than one chamber. Within 30 minutes following preconditioning for any duration from 12 hours to 24 hours in an environmental chamber at any temperature between −45.0 °C and −40.0 °C, impact the center of each of the five areas with a pendulum having a pyramid with equilateral faces and square base, and the tip and edges being rounded to a radius of between 2.0 millimeters and 4.0 millimeters. The center of impact of the pendulum shall coincide with the center of gravity of the pyramid. The energy of the pendulum at the moment of impact with each of the five marked areas on the container is any energy between 30.0 Joules and 35.0 Joules. The container is secured in place during pendulum impacts and is not pressurized above 1 MPa.

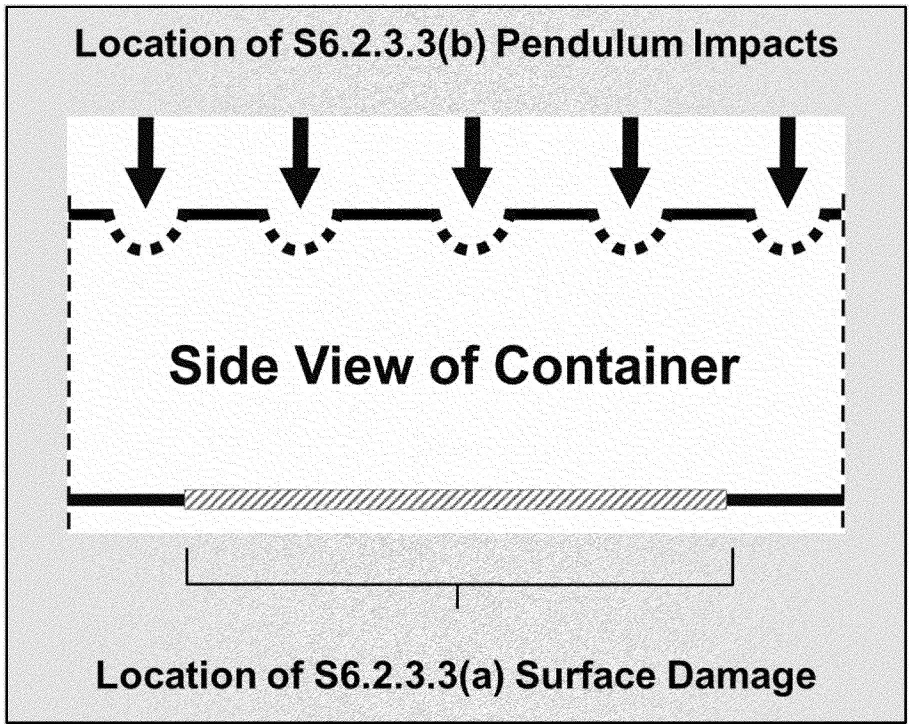

Figure 3 to § 571.308 S6.2.3.3. Locations of Surface Damage for S6.2.3.3(a) and Pendulum Impacts for S6.2.3.3(b); (for Illustration Purposes Only)

S6.2.3.4. *Chemical exposure and ambient temperature pressure cycling test.* (a) Each of the 5 areas preconditioned by pendulum impact in S6.2.3.3(b) is exposed to any one of five solutions:

(1) 19 to 21 percent by volume sulfuric acid in water;

(2) 25 to 27 percent by weight sodium hydroxide in water;

(3) 5 to 7 percent by volume methanol in gasoline;

(4) 28 to 30 percent by weight ammonium nitrate in water; and

(5) 50 to 52 percent by volume methyl alcohol in water.

(b) The container is oriented with the fluid exposure areas on top. A pad of glass wool approximately 0.5 centimeters thick and 100 millimeters in diameter is placed on each of the five preconditioned areas. A sufficient amount of the test fluid is applied to the glass wool to ensure that the pad is wetted across its surface and through its thickness for the duration of the test. A plastic covering shall be applied over the glass wool to prevent evaporation.

(c) The exposure of the container with the glass wool is maintained for at least 48 hours and no more than 60 hours with the container hydraulically pressurized to any pressure between 125.0 percent NWP and 130.0 percent NWP. During exposure, the temperature surrounding the container is maintained at any temperature between 5.0 °C and 35.0 °C.

(d) Hydraulic pressure cycling is performed in accordance with S6.2.2.2 at any pressure within the specified ranges according to S5.1.2.3 for the specified number of cycles. The glass wool pads are removed and the container surface is rinsed with water after the cycles are complete.

S6.2.3.5. *Static pressure test.* The container is hydraulically pressurized to the specified pressure in a temperature-controlled chamber. The temperature of the chamber and the container surface, or the surface of the container attachments if present, are held at the specified temperature for the specified duration.

S6.2.3.6. *Extreme temperature pressure cycling test.* (a) The container is filled with hydraulic fluid for each test;

(b) At the start of each test, the container surface, or the surface of the container attachments if present, the hydraulic fluid, and the environment surrounding the container are at any temperature and relative humidity (if applicable) within the ranges specified in S5.1.2.5 of this standard and maintained for the duration of the testing.

(c) The container is pressure cycled from any pressure between 1.0 MPa and 2.0 MPa up to the specified pressure at a rate not exceeding 10 cycles per minute for the specified number of cycles;

(d) The temperature of the hydraulic fluid entering the container shall be measured as close as possible to the container inlet.

S6.2.4. *Test procedures for expected on-road performance.*

S6.2.4.1. *Ambient and extreme temperature gas pressure cycling test.* (a) In accordance with table 3 to S5.1.3.1 of this standard, the specified ambient conditions of temperature and relative humidity, if applicable, are maintained within the test environment throughout each pressure cycle. When required in accordance with table 3 to S5.1.3.1, the CHSS temperature shall be in the specified initial system equilibration temperature range between pressure cycles.

(b) The CHSS is pressure cycled from any pressure between 1.0 MPa and 2.0 MPa up to any pressure within the specified peak pressure range in accordance with table 3 to this section. The temperature of the hydrogen fuel dispensed to the container is controlled to within the specified temperature range within 30 seconds of fueling initiation. The specified number of pressure cycles are conducted.

(c) The ramp rate for pressurization shall be greater than or equal to the ramp rate given in table 4 to S6.2.4.1(c) according to the CHSS volume, the ambient conditions, and the fuel delivery temperature. If the required ambient temperature is not available in table 4 to this section, the closest ramp rate value or a linearly interpolated value shall be used. The pressure ramp rate shall be decreased if the gas temperature in the container exceeds 85 °C.

TABLE 4 TO § 571.308 S6.2.4.1(c)

CHSS volume (L)	CHSS pressurization rate (MPa/min)			
	50.0 °C to 55.0 °C ambient conditions −33.0 °C to −40.0 °C fuel delivery temperature	5.0 °C to 35.0 °C ambient conditions −33.0 °C to −40.0 °C fuel delivery temperature	−30.0 °C to −25.0 °C ambient conditions −33.0 °C to −40.0 °C fuel delivery temperature	−30.0 °C to −25.0 °C ambient conditions 15.0 °C to 25.0 °C fuel delivery temperature
50	7.6	19.9	28.5	13.1
100	7.6	19.9	28.5	7.7
174	7.6	19.9	19.9	5.2
250	7.6	19.9	19.9	4.1
300	7.6	16.5	16.5	3.6
400	7.6	12.4	12.4	2.9
500	7.6	9.9	9.9	2.3
600	7.6	8.3	8.3	2.1
700	7.1	7.1	7.1	1.9
1,000	5.0	5.0	5.0	1.4
1,500	3.3	3.3	3.3	1.0
2,000	2.5	2.5	2.5	0.7
2,500	2.0	2.0	2.0	0.5

(d) The de-fueling rate shall be any rate greater than or equal to the intended vehicle's maximum fuel-demand rate. Out of the 500 pressure cycles, any 50 pressure cycles are performed using a de-fueling rate greater than or equal to the maintenance de-fueling rate.

S6.2.4.2. *Gas permeation test.* (a) A CHSS is filled with hydrogen gas to any SOC between 100.0 percent and 105.0 percent and placed in a sealed container. The CHSS is held for any duration between 12 hours and 24 hours at any temperature between 55.0 °C and 60.0 °C prior to the start of the test.

(b) The permeation from the CHSS shall be determined hourly throughout the test.

(c) The test shall continue for 500 hours or until the permeation rate reaches a steady state. Steady state is achieved when at least 3 consecutive leak rates separated by any duration between 12 hours and 48 hours are within 10 percent of the previous rate.

S6.2.5. *Test procedures for service terminating performance in fire.* The fire test consists of two stages: a localized fire stage followed by an engulfing fire stage. The burner configuration for the fire test is specified in S6.2.5.1. The overall test configuration of the fire test is verified using a pre-test checkout in accordance with S6.2.5.2 prior to the fire test of the CHSS. The fire test of the CHSS is conducted in accordance with S6.2.5.3.

S6.2.5.1. *Burner configuration.* (a) The fuel for the burner shall be liquefied petroleum gas (LPG).

(b) The width of the burner shall be between 450 millimeters and 550 millimeters.

(c) The length of the burner used for the localized fire stage shall be between 200 millimeters and 300 millimeters.

(d) The length of the burner used for the engulfing fire stage shall be in accordance with S6.2.5.3(m).

(e) The burner nozzle configuration and installation shall be in accordance with table 5 to S6.2.5.1. The nozzles shall be installed uniformly on six rails.

TABLE 5 TO § 571.308 S6.2.5.1

Item	Description
Nozzle type	Liquefied petroleum gas fuel nozzle with air pre-mix.
LPG orifice in nozzle	0.9 to 1.1 millimeter inner diameter.
Air ports in nozzle	Four (4) holes, 5.8 to 7.0 millimeter inner diameter.
Fuel/Air mixing tube in nozzle	9 to 11 millimeter inner diameter.
Number of rails	6.
Center-to-center spacing of rails	100 to 110 millimeter.
Center-to-center nozzle spacing along the rails	45 to 55 millimeter.

S6.2.5.2. *Pre-test checkout.* (a) The pre-test checkout procedure in this section shall be performed to verify the fire test configuration for the CHSS tested in accordance with S6.2.5.3.

(b) A pre-test container is a 12-inch Schedule 40 Nominal Pipe Size steel pipe with end caps. The cylindrical length of the pre-test container shall be equal to or longer than the overall length of the CHSS to be tested in S6.2.5.3, but no shorter than 0.80 m and no longer than 1.75 m.

(c) The pre-test container shall be mounted over the burner:

(1) At any height between 95 millimeters and 105 millimeters above the burner;

(2) Such that the nozzles from the two center rails are pointing toward the bottom center of the pre-test container; and

(3) Such that the container's position relative to the localized and engulfing zones of the burner is consistent with the positioning of the CHSS over the burner in S6.2.5.3.

(d) For outdoor test sites, wind shielding shall be used. The separation between the pre-test container and the walls of the wind shields shall be at least 0.5 meters.

(e) Temperatures during the pre-test check-out shall be measured at least once per second using 3.2 millimeter diameter or less K-type sheath thermocouples.

(f) The thermocouples shall be located in sets to measure temperatures along the cylindrical section of the pre-test container. These thermocouples are secured by straps or other mechanical attachments within 5 millimeters from the pre-test container surface. One set of thermocouples consists of:

(1) One thermocouple located at the bottom surface exposed to the burner flame,

(2) One thermocouple located mid-height along the left side of the cylindrical surface,

(3) One thermocouple located mid-height along the right side of the cylindrical surface, and

(4) One thermocouple located at the top surface opposite to the burner flame.

(g) One set of thermocouples shall be centrally located at the localized fire zone of the CHSS to be tested as determined in S6.2.5.3. Two additional sets of thermocouples shall be spread out over the remaining length of the engulfing fire zone of the CHSS to be tested that is not part of the localized fire zone of the CHSS to be tested.

(h) Burner monitor thermocouples shall be located between 20 millimeters and 30 millimeters below the bottom surface of the pre-test container in the same three horizontal locations described in S6.2.5.2(g). These thermocouples shall be mechanically supported to prevent movement.

(i) With the localized burner ignited, the LPG flow rate to the burner shall be set such that the 60-second rolling averages of individual temperature readings in the localized fire zone shall be in accordance with the localized stage row in the table below.

(j) With the entire burner ignited, the LPG flow rate to the burner shall be set such that the 60-second rolling averages of individual temperature readings shall be in accordance with the engulfing stage row in table 6 to S6.2.5.2.

TABLE 6 TO § 571.308 S6.2.5.2

Fire stage	Temperature range on bottom of pre-test container	Temperature range on sides of pre-test container	Temperature range on top of pre-test container
Localized	450 °C to 700 °C	less than 750 °C.	less than 300 °C.
Engulfing	Average temperatures of the pre-test container surface measured at the three bottom locations shall be greater than 600 °C.	Not applicable.	Average temperatures of the pre-test container surface measured at the three top locations shall be at least 100 °C, and when greater than 750 °C, shall also be less than the average temperatures of the pre-test container surface measured at the three bottom locations.

S6.2.5.3. *CHSS fire test.* (a) The CHSS to be fire tested shall include TPRD vent lines.

(b) The CHSS to be fire tested shall be mounted at any height between 95 millimeters and 105 millimeters above the burner.

(c) CHSS shall be positioned for the localized fire test by orienting the CHSS such that the distance from the center of the localized fire exposure to the TPRD(s) and TPRD sense point(s) is at or near maximum.

(d) When the container is longer than the localized burner, the localized burner shall not extend beyond either end of the container in the CHSS.

(e) The CHSS shall be filled with compressed hydrogen gas to any SOC between 100.0 percent and 105.0 percent.

(f) For outdoor test sites, the same wind shielding shall be used as was used for S6.2.5.2. The separation between the CHSS and the walls of the wind shields shall be at least 0.5 meters.

(g) Burner monitor temperatures shall be measured below the bottom surface of the CHSS in the same positions as specified in S6.2.5.2(h).

(h) The allowable limits for the burner monitor temperatures during the CHSS fire test shall be established based on the results of the pre-test checkout as follows:

(1) The minimum value for the burner monitor temperature during the localized fire stage ($Tmin_{LOC}$) shall be calculated by subtracting 50 °C from the 60-second rolling average of the burner monitor temperature in the localized fire zone of the pre-test checkout. If the resultant $Tmin_{LOC}$ exceeds 600 °C, $Tmin_{LOC}$ shall be 600 °C.

(2) The minimum value for the burner monitor temperature during the engulfing fire stage ($Tmin_{ENG}$) shall be calculated by subtracting 50 °C from the 60-second rolling average of the average of the three burner monitor temperatures during the engulfing fire stage of the pre-test checkout. If the resultant $Tmin_{ENG}$ exceeds 800 °C, $Tmin_{ENG}$ shall be 800 °C.

(i) The localized fire stage is initiated by starting the fuel flow to the localized burner and igniting the burner.

(j) The 10-second rolling average of the burner monitor temperature in the localized fire zone shall be at least 300 °C within 1 minute of ignition and for the next 2 minutes.

(k) Within 3 minutes of the igniting the burner, using the same LPG flow rate as S6.2.5.2(i), the 60-second rolling average of the localized zone burner monitor temperature shall be greater than $Tmin_{LOC}$ as determined in S6.2.5.3(h)(1).

(l) After 10 minutes from igniting the burner, the engulfing fire stage is initiated.

(m) The engulfing fire zone includes the localized fire zone and extends in one direction towards the nearest TPRD or TPRD sense point along the complete length of the container up to a maximum burner length of 1.65 m.

(n) Within 2 minutes of the initiation of the engulfing fire stage, using the same LPG flow rate as S6.2.5.2(j), the 60-second rolling average of the engulfing burner monitor temperature shall be equal or greater than $Tmin_{ENG}$ as determined in S6.2.5.3(h)(2).

(o) The fire testing continues until the pressure inside the CHSS is less than or equal to 1.0 MPa or until:

(1) A total test time of 60 minutes for CHSS on vehicles with a GVWR of 10,000 pounds or less or;

(2) A total test time of 120 minutes for CHSS on vehicles with a GVWR over 10,000 pounds.

S6.2.6. *Test procedures for performance durability of closure devices.*

S6.2.6.1. *TPRD performance tests.* Unless otherwise specified, testing is performed with either hydrogen gas with a purity of at least 99.97 percent, less than or equal to 5 parts per million of water, and less or equal to 1 part per million particulate, or with an inert gas. All tests are performed at any temperature between 5.0 °C and 35.0 °C unless otherwise specified.

S6.2.6.1.1. *Pressure cycling test.* A TPRD undergoes 15,000 internal pressure cycles at a rate not exceeding 10 cycles per minute. The table below summarizes the pressure cycles. Any condition within the ranges specified in table 7 to this section may be selected for testing.

(a) The first 10 pressure cycles shall be from any low pressure of between 1.0 MPa and 2.0 MPa to any high pressure between 150.0 percent NWP and 155.0 percent NWP. These cycles are conducted at any sample temperature between 85.0 °C to 90.0 °C.

(b) The next 2,240 pressure cycles shall be from any low pressure between 1.0 MPa and 2.0 MPa to any high pressure of between 125.0 percent NWP and 130.0 percent NWP. These cycles are conducted at any sample temperature between 85.0 °C to 90.0 °C.

(c) The next 10,000 pressure cycles shall be from any low pressure of between 1.0 MPa and 2.0 MPa to any high pressure between 125.0 percent NWP and 130.0 percent NWP. These cycles are conducted at a sample temperature between 5.0 °C to 35.0 °C.

(d) The final 2,750 pressure cycles shall be from any low pressure between 1.0 MPa and 2.0 MPa to any high pressure between 80.0 percent NWP and 85.0 percent NWP. These cycles are conducted at any sample temperature between −45.0 °C to −40.0 °C.

TABLE 7 TO § 571.308 S6.2.6.1.1

Number of cycles	Low pressure	High pressure	Sample temperature for cycles
First 10	1.0 MPa to 2.0 MPa	150.0% NWP to 155.0% NWP	85.0 °C to 90.0 °C.
Next 2,240	1.0 MPa to 2.0 MPa	125.0% NWP to 130.0% NWP	85.0 °C to 90.0 °C.
Next 10,000	1.0 MPa to 2.0 MPa	125.0% NWP to 130.0% NWP	5.0 °C to 35.0 °C.
Final 2,750	1.0 MPa to 2.0 MPa	80.0% NWP to 85.0% NWP	−45.0 °C to −40.0 °C.

S6.2.6.1.2. *Accelerated life test.* (a) Two TPRDs undergo testing; one at the vehicle manufacturer's specified activation temperature, and one at an accelerated life temperature, T_L, given in °C using equation 2 to this section, where β = 273.15 °C, T_{ME} is 85 °C, and T_f is the vehicle manufacturer's specified activation temperature in °C.:

Equation 2 to § 571.308 S6.2.6.1.2

$$T_L = \left(\frac{0.502}{\beta + T_f} + \frac{0.498}{\beta + T_{ME}}\right)^{-1} - \beta$$

(b) The TPRDs are placed in an oven or liquid bath maintained within 5.0 °C of the specified temperature per S6.2.6.1.2(a). The TPRD inlets are pressurized with hydrogen to any pressure between 125.0 percent NWP and 130.0 percent NWP and time until activation is measured.

S6.2.6.1.3. *Temperature cycling test.* (a) An unpressurized TPRD is placed in a cold liquid bath maintained at any temperature between −45.0 °C and −40.0 °C. The TPRD shall remain in the cold bath for any duration not less than 2 hours and not more than 24 hours. The TPRD is removed from the cold bath and transferred, within five minutes of removal, to a hot liquid bath maintained at any temperature between 85.0 °C and 90.0 °C. The TPRD shall remain in the hot bath for any duration not less than 2 hours and not more than 24 hours. The TPRD is removed from the hot bath and, within five minutes of removal, transferred back into the cold bath maintained at any temperature between −45.0 °C and −40.0 °C.

(b) Step (a) is repeated until 15 thermal cycles have been achieved.

(c) The TPRD remains in the cold liquid bath for any duration not less than 2 and not more than 24 additional hours, then the internal pressure of the TPRD is cycled with hydrogen gas from any pressure between 1.0 MPa and 2.0 MPa to any pressure between 80.0 percent NWP and 85.0 percent NWP for 100 cycles. During cycling, the TPRD remains in the cold bath and the cold bath is maintained at any temperature between −45.0 °C and −40.0 °C.

S6.2.6.1.4. *Salt corrosion resistance test.* (a) Each closure device is exposed to a combination of cyclic conditions of salt solution, temperatures, and humidity. One test cycle is equal to any duration not less than 22 and not more than 26 hours, and is in accordance with table 8 to S6.2.6.1.4.

TABLE 8 TO § 571.308 S6.2.6.1.4

Accelerated cyclic corrosion conditions (1 cycle = 22 hours to 26 hours)			
Cycle condition	Temperature	Relative humidity	Cycle duration
Ambient stage	22.0 °C to 28.0 °C	35 percent to 55 percent	470 minutes to 490 minutes
Transition 55 min to 60 min			
Humid stage	47.0 °C to 51.0 °C	95 percent to 100 percent	410 minutes to 430 minutes
Transition 170 minutes to 190 minutes			
Dry stage	55.0 °C to 65.0 °C	less than 30 percent	290 minutes to 310 minutes

(b) The apparatus used for this test shall consist of a fog/environmental chamber as defined in ISO 6270–2:2017(E) (incorporated by reference, see § 571.5), with a suitable water supply conforming to Type IV requirements in ASTM D1193–06 (Reapproved 2018) (incorporated by reference, see § 571.5). The chamber shall include a supply of compressed air and one or more nozzles for fog generation. The nozzle or nozzles used for the generation of the fog shall be directed or baffled to minimize any direct impingement on the closure devices.

(c) During ''wet-bottom'' generated humidity cycles, water droplets shall be visible on the samples.

(d) Steam generated humidity may be used provided the source of water used in generating the steam is free of corrosion inhibitors and visible water droplets are formed on the samples to achieve proper wetness.

(e) The drying stage shall occur in the following environmental conditions: any temperature not less than 60 °C and not greater than 65 °C and relative humidity no more than 30 percent with air circulation.

(f) The impingement force from the salt solution application shall not remove corrosion and/or damage the coatings of the closure devices.

(g) The complex salt solution in percent by mass shall be as specified in S6.2.6.1.4(g)(1) through (5):

(1) Sodium Chloride: not less than 0.08 and not more than 0.10 percent.

(2) Calcium Chloride: not less than 0.095 and not more than 0.105 percent.

(3) Sodium Bicarbonate: not less than 0.07 and not more than 0.08 percent.

(4) Sodium Chloride must be reagent grade or food grade. Calcium Chloride must be reagent grade. Sodium Bicarbonate must be reagent grade. For the purposes of S6.2.6.1.4, water must meet ASTM D1193–06 (Reapproved 2018) Type IV requirements (incorporated by reference, see § 571.5).

(5) Either calcium chloride or sodium bicarbonate material must be dissolved separately in water and added to the solution of the other materials.

(h) The closure devices shall be installed in accordance with the vehicle manufacturer's recommended procedure and exposed to the 100 daily corrosion cycles, with each corrosion cycle in accordance with table 8 to S6.2.6.1.4.

(i) For each salt mist application, the solution shall be sprayed as an atomized mist, using the spray apparatus to mist the components until all areas are thoroughly wet and dripping. Suitable application techniques include using a plastic bottle, or a siphon spray powered by oil-free regulated air to spray the test samples. The quantity of spray applied should be sufficient to visibly rinse away salt accumulation left from previous sprays. Four salt mist applications shall be applied during the ambient stage. The first salt mist application occurs at the beginning of the ambient stage. Each subsequent salt mist application should be applied not less than 90 and not more than 95 minutes after the previous application.

(j) The time from ambient to the wet condition shall be any duration not less than 60 and not more than 65 minutes and the transition time between wet and dry conditions shall be any duration not less than 180 and not more than 190 minutes.

S6.2.6.1.5. *Vehicle environment test.* (a) The inlet and outlet connections of the closure device are connected or capped in accordance with the vehicle manufacturer's installation instructions. All external surfaces of the closure device are exposed to each of the following fluids for any duration between 24 hours and 26 hours. The temperature during exposure shall be any temperature between 5.0 °C and 35.0 °C. A separate test is performed with each of the fluids sequentially on a single closure device.

(1) Sulfuric acid: not less than 19 and not more than 21 percent by volume in water;

(2) Ethanol/gasoline: not less than 10 and not more than 12 percent by volume ethanol and not less than 88 and not more than 90 percent by volume gasoline; and

(3) Windshield washer fluid: not less than 50 and not more than 52 percent by volume methanol in water.

(b) The fluids are replenished as needed to ensure complete exposure for the duration of the test.

(c) After exposure to each fluid, the closure device is wiped off and rinsed with water.

S6.2.6.1.6. *Stress corrosion cracking test.* (a) All components exposed to the atmosphere shall be degreased. For check valves and shut-off valves, the closure device shall be disassembled, all components degreased, and then reassembled.

(b) The closure device is continuously exposed to a moist ammonia air mixture maintained in a glass chamber having a glass cover. The exposure lasts any duration not less than 240 hours and not more than 242 hours. The aqueous ammonia shall have a composition of between 19 weight percent and 21 weight percent ammonium hydroxide in water. Aqueous ammonia shall be located at the bottom of the glass chamber below the sample at any volume not less than 20 mL and not more than 22 mL of aqueous ammonia per liter of chamber volume. The bottom of the sample is positioned any distance not less than 30 and not more than 40 millimeters above the aqueous ammonia and supported in an inert tray.

(c) The moist ammonia-air mixture is maintained at atmospheric pressure and any temperature not less than 35 °C and not more than 40 °C.

S6.2.6.1.7. *Drop and vibration test.* (a) The TPRD is aligned vertically to any one of the six orientations covering the opposing directions of three orthogonal axes: vertical, lateral and longitudinal.

(b) A TPRD is dropped in free fall from any height between 2.00 meters and 2.02 meters onto a smooth concrete surface. The TPRD is allowed to bounce on the concrete surface after the initial impact.

(c) Any sample with damage from the drop that results in the TPRD not being able to be tested in accordance with S6.2.6.1.7(d) shall not proceed to S6.2.6.1.7(d) and shall not be considered a failure of this test.

(d) Each TPRD dropped in S6.2.6.1.7(a) that did not have damage that results in the TPRD not being able to be tested is mounted in a test fixture in accordance with vehicle manufacturer's installation instructions and vibrated for any duration between 30.0 minutes and 35.0 minutes along each of the three orthogonal axes (vertical, lateral and longitudinal) at the most severe resonant frequency for each axis.

(1) The most severe resonant frequency for each axis is determined using any acceleration between 1.50 g and 1.60 g and sweeping through a sinusoidal frequency range from 10 Hz to 500 Hz with any sweep time between 10.0 minutes and 20.0 minutes. The most severe resonant frequency is identified by a pronounced increase in vibration amplitude.

(2) If the resonance frequency is not found, the test shall be conducted at any frequency between 35 Hz and 45 Hz.

S6.2.6.1.8. *Leak test.* Unless otherwise specified, the TPRD shall be thermally conditioned to the ambient temperature condition, then checked for leakage, then conditioned to the high temperature condition, then checked for leakage, then conditioned to low temperature, then checked for leakage.

(a) The TPRD shall be thermally conditioned at test temperatures in each of the test conditions and held for any duration between 1.0 hour and 24.0 hours. The TPRD is pressurized with hydrogen at the inlet. The required test conditions are:

(1) Ambient temperature: condition the TPRD at any temperature between 5.0 °C and 35.0 °C; test in accordance with S6.2.6.1.8(b) at any pressure between 1.5 MPa and 2.5 MPa and then

at any pressure between 125.0 percent NWP and 130.0 percent NWP.

(2) High temperature: condition the TPRD at any temperature between 85.0 °C and 90.0 °C; test in accordance with S6.2.6.1.8(b) at any pressure between 1.5 MPa and 2.5 MPa and then at any pressure between 125.0 percent NWP and 130.0 percent NWP.

(3) Low temperature: condition the TPRD at any temperature between −45.0 °C and −40.0 °C; test in accordance with S6.2.6.1.8(b) at any pressure between 1.5 MPa and 2.5 MPa and then at any pressure between 100.0 percent NWP and 105.0 percent NWP.

(b) Following conditioning at each of the specified test temperature ranges, the TPRD is observed for leakage while immersed in a temperature-controlled liquid at the same specified temperature range for any duration between 1.0 minutes and 2.0 minutes at each of the pressure ranges listed above. If no bubbles are observed for the specified time period, it is not considered a failure. If bubbles are detected, the leak rate is measured.

S6.2.6.1.9. *Bench top activation test.* (a) The test apparatus consists of either a forced air oven or chimney with air flow. The TPRD is not exposed directly to flame. The TPRD is mounted in the test apparatus according to the vehicle manufacturer's installation instructions.

(b) The temperature of the oven or chimney is at any temperature between 600.0 °C and 605.0 °C for any duration between 2 minutes and 62 minutes prior to inserting the TPRD.

(c) Prior to inserting the TPRD, pressurize the TPRD to any pressure between 1.5 MPa and 2.5 MPa.

(d) The pressurized TPRD is inserted into the oven or chimney, the temperature within the oven or chimney is maintained at any temperature between 600.0 °C and 605.0 °C, and the time for the TPRD to activate is recorded. If the TPRD does not activate within 120 minutes from the time of insertion into the oven or chimney, the TPRD shall be considered to have failed the test.

S6.2.6.1.10. *Flow rate test.* (a) At least one new TPRD is tested to establish a baseline flow rate.

(b) After activation in accordance with S6.2.6.1.9, and without cleaning, removal of parts, or reconditioning, the TPRD is subjected to flow testing using hydrogen, air or an inert gas;

(c) Flow rate testing is conducted with any inlet pressure between 1.5 MPa and 2.5 MPa. The outlet is at atmospheric pressure.

(d) Flow rate is measured in units of kilograms per minute with a precision of at least 2 significant digits.

S6.2.6.2. *Check valve and shut-off valve performance tests.* Unless otherwise specified, testing shall be performed with either hydrogen gas with a purity of at least 99.97 percent, less than or equal to 5 parts per million of water, and less than or equal to 1 part per million particulate, or with an inert gas. All tests are performed at any temperature between 5.0 °C and 35.0 °C unless otherwise specified.

S6.2.6.2.1. *Hydrostatic strength test.* (a) The outlet opening is plugged and valve seats or internal blocks are made to assume the open position.

(b) Any hydrostatic pressure between 250.0 percent NWP and 255.0 percent NWP is applied using water to the valve inlet for any duration between 180.0 seconds and 185.0 seconds. The unit is examined to ensure that burst has not occurred.

(c) The hydrostatic pressure is then increased at a rate of less than or equal to 1.4 MPa/sec until component failure. The hydrostatic pressure at failure is recorded.

S6.2.6.2.2. *Leak test.* Each unit shall be thermally conditioned to the ambient temperature condition, then checked for leakage, then conditioned to the high temperature condition, then checked for leakage, then conditioned to low temperature, then checked for leakage.

(a) Each unit shall be pressurized to any pressure between 2.0 MPa and 3.0 MPa and held for any duration between 1.0 hours and 24.0 hours in the specified temperature range before testing. The outlet opening is plugged. The test conditions are:

(1) Ambient temperature: condition the unit at any temperature between 5.0 °C and 35.0 °C; test at any pressure between 1.5 MPa and 2.5 MPa and at any pressure between 125.0 percent NWP and 130.0 percent NWP.

(2) High temperature: condition the unit at any temperature between 85.0 °C and 90.0 °C; test at any pressure between 1.5 MPa and 2.5 MPa and at any pressure between 125.0 percent NWP and 130.0 percent NWP.

(3) Low temperature: condition the unit at any temperature between −45.0 °C and −40.0 °C; test at any pressure between 1.5 MPa and 2.5 MPa and at any pressure between 100.0 percent NWP and 105.0 percent NWP.

(b) While within the specified temperature and pressure range, the unit is observed for leakage while immersed in a temperature-controlled liquid held within the same specified temperature range as the test condition for any duration between 1.0 minutes and 2.0 minutes at each of the test pressures. If no bubbles are observed for the specified time period, the sample passes the leak test. If bubbles are detected, the leak rate is measured.

S6.2.6.2.3. *Extreme temperature pressure cycling test.* (a) The valve unit is connected to a test fixture.

(b) For a check valve, the pressure is applied in six incremental pulses to the check valve inlet with the outlet closed. The pressure is then vented from the check valve inlet. The pressure is lowered on the check valve outlet side to any pressure between 55.0 percent NWP and 60.0 percent NWP prior to the next cycle.

(c) For a shut-off valve, the specified pressure is applied through the inlet port. The shut-off valve is then energized to open the valve and the pressure is reduced to any pressure less than 50 percent of the specified pressure range. The shut-off valve shall then be de-energized to close the valve prior to the next cycle.

S6.2.6.2.4. *Chatter flow test.* The valve is subjected to between 24.0 hours and 26.0 hours of chatter flow at a flow rate that causes the most valve flutter.

S6.2.6.2.5. *Electrical Tests.* This section applies to shut-off valves only.

(a) The solenoid valve is connected to a variable DC voltage source, and the solenoid valve is operated as follows:

(1) Held for any duration between 60.0 and 65.0 minutes at any voltage between 0.50 V and 1.5 times the rated voltage.

(2) The voltage is increased to any voltage between 0.5 V to two times the rated voltage, or between 60.0 V and 60.5 V, whichever is less, and held for any duration between 60.0 seconds and 70.0 seconds.

(b) Any voltage between 1,000.0 V DC and 1,010.0 V DC is applied between the power conductor and the component casing for any duration between 2.0 seconds to 4.0 seconds.

S6.2.6.2.6. *Vibration test.* (a) The valve is pressurized with hydrogen to any pressure between 100.0 percent NWP and 105.0 percent NWP, sealed at both ends, and vibrated for any duration between 30.0 and 35.0 minutes along each of the three orthogonal axes (vertical, lateral and longitudinal) at the most severe resonant frequencies.

(b) The most severe resonant frequencies are determined using any acceleration between 1.50 g and 1.60 g and sweeping through a sinusoidal frequency range from 10 Hz to 500 Hz with any sweep time between 10.0 minutes and 20.0 minutes. The resonance frequency is identified by a pronounced increase in vibration amplitude.

(c) If the resonance frequency is not found, the test shall be conducted at any frequency between 35 Hz and 45 Hz.

Issued in Washington, DC, under authority delegated in 49 CFR 1.95 and 501.

Adam Raviv,

Chief Counsel.

[FR Doc. 2024–31367 Filed 1–16–25; 8:45 am]

BILLING CODE 4910–59–P