Hydrogen Energy Association

Hydrogen Refuelling Infrastructure: Standardisation

A Position Paper

May 2024

1 Introduction

Mobility has been identified as one of Hydrogen's key use applications. The transport sector made up 34% of the UK's CO2 emissions in 2022. Furthermore, the UK's total emissions are in the 15% most polluting countries globally so the transition is undeniably significant[1]. Decarbonising the UK's transport sector is vital for net zero, both nationally and internationally.

Whilst CO2 emissions for the UK's transport sector are seeing an overall decline[2], the pace needs to increase significantly. According to the UK Government, transport emissions need to fall by 78% by 2035 compared to 1990 levels[3]. This means that 80% of new cars and 70% of new vans sold in Great Britain will have to be zero emission by 2030, increasing to 100% by 2035. In January 2024, the UK Government enacted this zero-emissions vehicle pathway as law[4]. Notwithstanding this positive development, there is an urgent need for greater Government support to realise the decarbonisation potential of hydrogen across the full range of transport modes.

78%

the amount transport emissions need to fall by 2035 in comparison to 1990 levels

Hydrogen is complementary to battery electric technology in the decarbonisation of transport. It can decarbonise hard-to-electrify transport applications across road, maritime, rail and aviation, particularly where long haul transport applications, faster refuelling times and economic loads are required. IDTechEx recently published its prediction that almost a fifth of zero-emission trucks will run on hydrogen in 2044, demonstrating the large market share that hydrogen is likely to have in heavy duty road transport[5].

As road transport makes up the majority of the UK's transport emissions, the need to decarbonise this segment of the sector is most urgent. Thus, this Position Paper focuses on road transport and, in particular, the area where Hydrogen for transport demand could be highest: heavy duty vehicles. In particular, Hydrogen refuelling infrastructure is a critical enabler of the use of hydrogen for transport and will thus constitute the focus of this paper.

1 United Kingdom: CO2 Country Profile - Our World in Data
2 2022 UK greenhouse gas emissions: provisional figures - statistical release (publishing.service.gov.uk)
3 Transport decarbonisation plan - GOV.UK (www.gov.uk)
4 Pathway for zero emission vehicle transition by 2035 becomes law - GOV.UK (www.gov.uk)
5 Only 4% of zero-emissions vehicles will be powered by hydrogen in 20 years' time: analyst | Hydrogen news and intelligence (hydrogeninsight.com)

Hydrogen Refuelling Infrastructure

Hydrogen refuelling infrastructure is the network of stations and equipment that provides hydrogen fuel for vehicles powered by fuel cells and hydrogen combustion vehicles. One of the key differentiators of hydrogen fuelled versus Battery Electric Vehicles (BEVs) is the time it takes to refuel and / or recharge. Hydrogen refuelling times are similar to that of conventional petrol or diesel vehicles. Whilst BEV charging times are reducing withincreasing innovation, they still remain significantly longer than hydrogen. Hydrogen refuelling will always be able to provide faster refuelling times and, therefore, The faster refuelling times of hydrogen versus electric charging means it is well placed to serve the needs of the transport sector where electrification is not feasible.

With the development of the hydrogen economy in full swing in the UK and internationally, hydrogen refuelling infrastructure, as a critical enabler, has received global policy and investor attention. Over 900 hydrogen refuelling stations (HRS) were installed globally by the end of 2023. Over 50% of these HRS are in Japan, South Korea, and China, with nearly 100 stations installed during 2022-2023, reflecting annual growth of about 35%. Europe accounts for about 230 HRS and the US 80, whereas the UK has less than 10 HRS currently live[6].

900+

hydrogen refuelling stations (HRS) were installed globally by the end of 2023

The difference between the number of HRS in Europe compared to the UK is stark. The European Parliament's vote to commit to constructing a HRS every 100km on all EU trunk routes by 2027 will be a key driver of future growth.

The HEA welcomes funding aimed at deploying fleets and infrastructure at the local / regional level, such as the £11 million of funding to support the Tees Valley hydrogen transport hub's fund, of which £2 million was recently announced for the construction of a publicly accessible HRS in Middlesborough[7]. However, at current rates of deployment, this approach will not deliver the level of hydrogen fuelled transport that we need if the UK is to meet its targets. We call on Government to act quickly and ambitiously to deliver a hydrogen for transport strategy at a national level, providing a clear roadmap to support the rapidly needed rollout of vehicles across various mode and HRS.

The HEA has long been campaigning for a similar approach to its European counterpart on UK HRS through various areas of our work including:

- The HEA's Consultation response on 'Infrastructure for zero emission heavy goods vehicles and coaches';
- 'Quick Wins' Government Strategy paper;
- The Role of Hydrogen Transportation and Storage in delivering the Hydrogen transition;
- Regular Government dialogue at both the Ministerial and policy levels (e.g. Department for Energy Security and Net Zero (DESNZ) and Department for Transport (DfT)).

Without this policy certainty, industry and private investment into HRS will remain delayed and the achievement of our net zero goals will be at risk.

6 Hydrogen Champion Report: Recommendations to government and industry to accelerate the development of the UK hydrogen economy (publishing.service.gov.uk)

7 Exolum to construct a green hydrogen production plant and refuelling station in the Tees Valley – Exolum

2 Standardisation: a key mechanism to facilitate the rapid roll-out of HRS

Standardisation is the process of developing and implementing technical standards based on health and safety protocols and consensus amongst technical experts from a diverse range of stakeholders.

The development of hydrogen standards requires stakeholders across the entire hydrogen value chain, supply chains, governments and regulatory bodies' to work together. Standardisation can help maximise quality, safety, repeatability and interoperability. These features are all key to the fast growth of the Hydrogen sector. The International Energy Agency (IEA), in its latest Global Hydrogen Review, highlighted standardisation, alongside regulation and certification as one of its key needs for the Hydrogen economy to deliver its decarbonisation targets[8].

Given its ability to not only streamline and channel the efficient use of resources for both Industry and Government, but also to keep the industry safe, standardisation has a particularly important role in accelerating the roll-out of hydrogen infrastructure. On another important note, European-wide and international standardisation can maximise the UK's supply chains expertise and export potential.

The leading standardisation bodies relevant to the UK's HRS conversation

Global standardisation activities are delivered by the International Standards Organisation (ISO) and the The International Electrotechnical Commission (IEC). These bodies are made up of around 170 independent National Standardisation Bodies (NSB), including the UK's national standards body, the British Standards Institute (BSI). These are underpinned by the coordinated expertise of the NSB, ISO and IEC, which develop voluntary standards to facilitate international trade between markets. The leading European standards bodies are the European Committee for Standardisation (CEN, French: Comité Européen de Normalisation) and the European Committees for Electrotechnical Standardisation (CENELEC). The latter is made up of the NSB's of the 34 Member countries including EU member states and the UK, amongst others. Since Brexit, the BSI has an agreement with CEN and CENELEC to ensure its full membership and participation in the European standards system. CEN and CENELEC's standards are mandatory and therefore NSB have to withdraw any conflicting national standards. This means that BSI standards are also mandatory for UK industry. To see a full picture of how the technical committees of the CEN and CENELEC relate to ISO, see page 14 of ECH2A's report[9].

NSB sell and distribute the implemented European Standards, with the BSI detailing how UK standards relate to relevant European and international standards on its website. The BSI does have autonomy to develop a UK specific standard if there is a UK specific need, although this is not expected to be the case for the Hydrogen

8 Executive summary – Global Hydrogen Review 2021 – Analysis - IEA
9 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

sector. The BSI standards development process is overseen by a relatively new overarching committee, GSE/5, who is responsible for:

"a) coordinating hydrogen-related information across relevant BSI committees and other sources as a horizontal 'systems' committee;

b) providing guidance on developing standards to address gaps in the hydrogen standards portfolio; c) advising BSI committees on national requirements in support of legislation relating to hydrogen standardization;

d) advising external stakeholders, including Government, of the hydrogen standards landscape; and e) mirroring any European or international standards strategic development."

The BSI GSE/5 is currently working on a UK hydrogen standards gap analysis to identify areas for urgent work. As part of this project, the Committee is looking to recruit new industry representatives for both new and existing technical committees to match the fast-evolving Hydrogen Industry needs.

As mentioned, the GSE/5 coordinates a broad range of technical committees that work on Hydrogen, including PVE/3/8. PVE/3 is responsible for the UK input into ISO/TC 197 and CEN-CLC/JTC 6 for standards related to systems and devices for the production, storage, transport, measurement and use of hydrogen. It excludes cryogenic vessels and aerosols.

Given the standard gaps across the UK and European HRS' standards landscape to date, industry has looked to the Society of Automotive Engineering International (SAE), a US based global association of engineers and technical experts in the aerospace, automotive and commercial vehicle industries, to manufacture and operate against their latest standards, particularly for refuelling protocols. Another influential body that has been crucial to the development of standards for the hydrogen refuelling industry is the Clean Energy Partnership (CEP). CEP is a European industry alliance working to further electrolytic-based hydrogen and fuel cell powered mobility by setting standards across all modes of transport. CEP is made up of technology, petroleum and energy / utility companies, gas producers, and car manufacturers, all collaborating across industries and sectors.

The work that these aforementioned standardisation bodies and their predominantly voluntary technical committees are doing in the hydrogen standards space has set important foundations for future standards. Nevertheless, it is widely recognised that there are too many gaps in Hydrogen standards. Such gaps in standardisation risk undermining the integrity of hydrogen's safety record and its wider reputation. Standardisation for hydrogen mobility has also been earmarked to be in great need of further development by our respective European colleagues, in particular the European Clean Hydrogen Alliance's (ECH2A) roadmap[10]. As the UK still complies with European standards, this reality is true to the UK context as well.

In 2017 the Association for Petroleum and Explosives Administration (APEA), British Compressed Gases Association (BCGA) and the Service station panel of the Energy Institute (EI) jointly published 'Guidance on hydrogen delivery systems for refuelling of motor vehicles, co-located with petrol fuelling stations (Supplement to the Blue Book)'. This publication provided a summary of technical guidance for the design, construction, maintenance and management of hydrogen fuelling stations in relation to their interaction with petrol filling stations when the two facilities are co-located. It is understood that the an update to the Blue Book is under development. Depending on the scope, this is likely to be a useful development for hydrogen refuelling in general.

10 20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

3 Current refuelling protocols and relevant standards

Refuelling protocols are a set of guidelines that dictate how vehicles should be refuelled, and in the context of this paper, at HRS. These protocols are designed to ensure that the refuelling process is safe, efficient and effective. There are different types of refuelling protocols for different types of vehicles, such as light-duty and heavy-duty vehicles. Standardisation of these protocols is critical for a safe, inter-operable and viable global HRS network.

This section maps the refuelling protocol research and standards that exist and links them to communication, mechanical connection, hydrogen quality and general requirement standards. It then details industry's current challenges due to the lack of appropriate standards. Finally, the HEA presents its recommendations to standards bodies, particularly focusing on hydrogen refuelling for heavy duty vehicles.

Standards on interoperability between vehicle and dispenser for Compressed Gaseous Hydrogen (CGH2).

The key refuelling protocol standards are the EN 17127 and BS ISO 19885-1/2, SAE J2601-1/-2/-3 and the recently published (-4/-5) and the CEP technical standards.

BS ISO 19880 – Gaseous hydrogen – Fuelling stations. Design, installation, operation, maintenance and testing of HRS (See Annex A for more information on BS ISO 19880)
BS ISO 19880 is a mandatory BSI standard adopted from ISO. It defines the minimum requirements considered applicable worldwide for the hydrogen and electrical safety of hydrogen refuelling stations, providing guidance on design, installation, operation, maintenance and testing of HRS[11]. BS ISO 19880 covers risk assessment, emergency procedures, fire protection, and personnel training. In Europe, EN ISO 19880-1 and in the UK, BS ISO 19880-1:2020, references SAE J 2601. These standards are mostly used for light duty hydrogen-powered vehicle refuelling[12].

BS EN 17127 – Outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocols (See Annex B for more information on BS EN 17127)
BS EN 17127 is a mandatory standard that defines the minimum requirements to ensure the interoperability of hydrogen refuelling points, including refuelling protocols that dispense gaseous hydrogen to road vehicles, complying with relevant legislation and in line with SAE J2601 and based on the test procedures of the ISO 19880-1[13].

11 ISO 19880-1:2020 - Gaseous hydrogen — Fuelling stations — Part 1: General requirements
12 Refuelling buses and trucks - CEP (cleanenergypartnership.de)
13 ZSW: Acceptance tests of hydrogen refueling stations (zsw-bw.de)

ISO 19885-1/2 – General refuelling protocols and communication interface for hydrogen vehicles (See Annex C for more information on BS EN 17127)

ISO 19885-1 and ISO 19885-2 are the most up to date standards that define the protocols for hydrogen-fuelled vehicles. ISO 19885-1 specifies the design and development process for fuelling protocols, while ISO 19885-2 defines the communication interface between the vehicle and the hydrogen refuelling station. BS ISO 19885 Part 1 is available for public comment and Part 2 is in the proposal stage.

PRHYDE Project – Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU)

The PRHYDE project, funded by Fuel Cells and Hydrogen 2 Joint Undertaking in Europe, is a key research initiative that developed recommendations for a non-proprietary heavy-duty refuelling protocol used for future standardisation activities for trucks and other heavy-duty transport systems applying hydrogen technologies. PRHYDE project results have and continue to shape the standards development processes for high flow hydrogen refuelling protocols that are discussed below.

BS ISO 19885-3 – High flow hydrogen refuelling protocols for heavy duty vehicles (Withdrawn)

BS ISO 19885-3 was a part of the BS ISO 19885 series of standards that defined gaseous hydrogen fuelling protocols for hydrogen-fuelled vehicles. It was titled 'Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles — Part 3: High flow hydrogen fuelling protocols for heavy duty road vehicles'[14]. Unfortunately, BS ISO 19885-3 and ISO 19885-3 have been withdrawn and therefore there will be a delay in updated guidance under BSI and/ or ISO for high flow hydrogen refuelling protocols for heavy duty vehicles[15].

SAE J2601 – SAE's Fuelling protocol standard series for light and heavy duty vehicles, and forklifts

SAE J2601 is a series of fuelling protocol standards to address the needs of light duty and heavy duty vehicles, and forklifts.[16] SAE J2601-1 is a development of J2601, which standardises 'Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles' (see Annex D for further information on SAE J2601-1). Category D of SAE J2601-1 was the previous refuelling protocol standard for heavy duty vehicles at 70MPa pressure class. Category D of the refuelling protocol standard is widely recognised as largely insufficient due to its slow flow rate. Category D is expected to be removed from SAE J2601-1 in its next review.

SAE J2601-2 standardises 'Fuelling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles'. SAE J2601-3 is for 'Fuelling Protocol for Gaseous Hydrogen Powered Industrial Trucks'. In December 2023, SAE released two new updates: the SAE J2601-4 and -5. SAE J2601-4 for 'Ambient Temperature Fixed Orifice Fuelling' and TIR SAE J2601-5 for 'High-Flow Prescriptive Fuelling Protocols for Gaseous Hydrogen Powered Medium and Heavy-Duty Vehicles'. We understand that SAE J2601-3 and SAE J2601-4 may be / may have been incorporated into SAE J2601-5.

Below we consider the current scope of SAE J2601-1 and TIR SAE J2601-5, how developments of TIR SAE J2601-5 for medium and heavy-duty vehicles tackle industry's previously identified challenges and what more is needed so that SAE J2601-1's 2024 review serves key industry's needs and so that TIR SAE J2601-5 is made into a standard. Currently, TIR SAE J2601-5 is a Technical Information Report (TIR), the pre-requisite to a standard. More field data needs to submitted for the standard to be published.

CEP technical standards

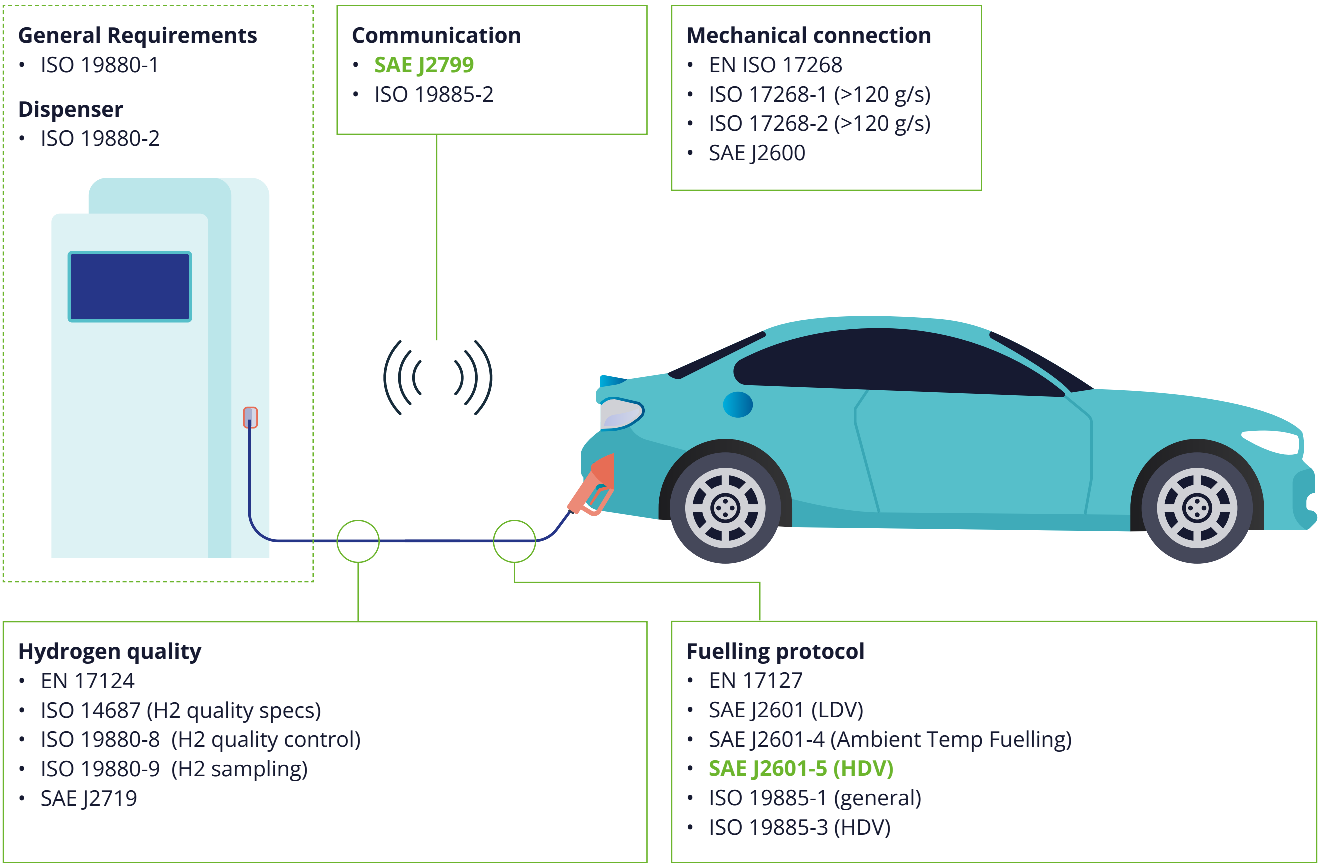
It is also important to mention that, in the UK and Europe, the industry-wide CEP technical standards are also widely used for truck refuelling at nominal working pressure (NWP) 35MPa[17], as well as for HRS fuelling at ambient temperature[18].

14 https://www.iso.org/standard/82558.html
15 ISO/WD 19885-3 - Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles — Part 3: High flow hydrogen fuelling protocols for heavy duty road vehicles
16 nrel.gov/docs/fy20osti/77368.pdf
17 Truck refuelling paths - CEP (cleanenergypartnership.de)
18 Microsoft Word - CEP - Requirements for Refuelling at Ambient Temperatures v1.2.docx (cleanenergypartnership.de)

Other refuelling standards

Communication's key standards are SAE J2799 and ISO 19885-2 and mechanical connections are SAE J2600 and BS EN ISO 17268:2020. ISO 17268-1 is being published by the end of 2024, with changes to the flow capacities up to and including <120g / s and ISO 17268-2 with changes to the flow capacities >120g / s is being published by the end of 2026. BS EN ISO 17268-1 is being drafted and available for public comments in March 2024. There is no current mention of BS EN ISO 17268-2, yet BS ISO 17268-3 for Cryo-compressed hydrogen gas is in its proposal phase. Hydrogen quality's key standards are SAE J2719, EN 17124, ISO 4687 (H2 quality specs), ISO 19880-8 (H2 quality control) and ISO 19880-9 (H2 sampling)[19].

Figure 1: Standards on inter-operability between vehicle and dispenser for compressed gaseous hydrogen[20]



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19 PART 01 – SAE J2601-5 Betankungsprotokoll – Vincent Mattelaer, Toyota Motor Europe (youtube.com)
20 Source: Clean Energy Partnership's public webinar: TIR SAE J2601-5 Refuelling Protocol, delivered by Vincent Matteaer from Toyota Motor Europe

Industry's key standards related challenges

The UK HRS Industry, similarly to the rest of the global market, has struggled with the lack of appropriate standards for:

Faster refuelling rates to increase the commercial appeal of transitioning to Zero-Emission mobility

Fast refuelling is continually demanded by end users and is needed to improve the efficiency and profitability of business case for Zero-Emission vehicles.

Refuelling at ambient temperatures so that the transition to Zero-Emission mobility is affordable

Pre-cooling before refuelling comes at a cost and cost is a key factor determining the viability of the business models for manufacturers, operators, and end users. The HEA advocates for the greater availability of ambient hydrogen refuelling as a standardised market choice for off-takers.

Realistic safety zone regulations so that the transition to Zero-Emission mobility is safe yet practical

Currently, the lack of wide-spread understanding around how hydrogen works mean safe zones are too restrictive and create unnecessary complexity for manufacturers, operators and users of HRS. The HEA recommends that the safety zone requirements for hydrogen be re-assessed.

"Fast refuelling is continually demanded by end users and is needed to improve the efficiency and profitability of business case for Zero-Emission vehicles."

Recommendations for UK standards

The HEA encourages increasing pace to update standards needed for the hydrogen refuelling industry. It is important to note that BS ISO 19885-1 (General) is expected to publish its review later this year and that the SAE J2601-1 (General) will be reviewed in 2024. It is likely that BSI will not publish a mandatory standard for high flow refuelling for heavy duty vehicles before 2025, due to the BSI ISO 19885-3's project being withdrawn.

For heavy duty vehicles, the HEA recommends that the UK hydrogen refuelling industry follows the TIR SAE J2601-5 (the protocol and process limits for hydrogen fuelling of heavy-duty vehicles) until BS ISO updates guidance for refuelling protocols of heavy-duty vehicles is developed. The future BSI ISO 19885-3 standard is expected to use TIR SAE J2601-5 and PRHYDE's results as the basis for its standard.

We welcome the developments of TIR SAE J2601-5, catering for the higher flow refuelling needs of heavy-duty vehicles at different pressure classes as well as communication and non-communication scenarios. There is a table-based protocol and an MC Formula-based protocol, which utilises a dynamic pressure ramp rate continuously calculated throughout the fill. Under TIR SAE J2601-5, using an MC Formula-based protocol at a 70MPa pressure class will be able to standardise high flows of 120 g/s and in the future 300 g/s. These developments directly tackle some of industry's challenges mentioned above. For example, an increase in the maximum flow rate of the dispenser supports industry in delivering faster refuelling rates (see Annex E for further information on TIR SAE J2601-5).

The HEA echoes the CEP's recommendation to the European hydrogen refuelling sector to upgrade its stations and/or stations in the pipeline, that currently adhere to J2601-1's Category D.

Next steps for light duty vehicles' standards (BS ISO 19885-1/2)

(See Annex C for further information on BS ISO 19885-1/2 and Annex D on SAE J2601-1)

We recommend consideration of the following:

- Expansion of the fuel delivery temperature category to include ambient cooling temperatures to be considered as part of the reviewed scope of all light duty vehicle refuelling standards.
- Increase in the flow rate for the refuelling of light duty vehicles.

Next steps for TIR SAE J2601-5

(See to Annex E for further information)

The HEA calls on industry to submit its field data to facilitate the standardisation of TIR SAE J26015. As previously mentioned, SAE J2601-5 has only been published as a TIR.

We recommend that a future standard includes the H35 FM60 in the dynamic refuelling protocol type, MC Formula, named MCF-HF-G, for TIR SAE J2601-5; it is not currently.

More clarity on the updating process for the Alternative Fuels Infrastructure Regulations

The HEA asks for the Department for Transport to ensure that the Alternative Fuels Infrastructure Regulations (AFIR) updates technical specifications in the AFIR regulations when standards are updated. This recommendation has occurred due to there being uncertainty as to whether the 2024 update of ISO 17268-2 for High Flow connectors will be compliant with AFIR, as it quotes the 2016 version.

Future evolution of safety requirements

The ATEX directive is an **EU directive that describes the minimum safety requirements for workplaces and equipment used in explosive atmospheres**. The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations (EPS) 2016 (S.I. 2016/1107) is the UK's implementation of the ATEX directive[21]. As briefly mentioned in the challenges that industry has faced, the HEA recommends that the ATEX (EU), EPS (UK) and IECEx (an international system for certification) re-evaluate the requirements for hydrogen to be safe, yet less restrictive. All the above regulations align with the same standards (e.g., IEC-EN 60079)[22].

The HEA has field data to suggests that hydrogen gas at the pump could come under an ATEX level 2, and its equivalents for EPS and IECEx, rather than ATEX level 1.

21 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/942114/ds-0008-21-atex-notice.pdf

22 IEC-EN 60079 is a series of **explosive atmosphere standards** that covers a wide array of considerations for component usage in hazardous areas, as well as defining different hazardous area classifications.

4 Components and instrumentation and their standards needs

HRS require a variety of components and instrumentation to ensure safe and efficient operation[23]. A robust regulatory and standards framework helps to ensure that high-quality components and instrumentation are incorporated into systems where high integrity is crucial.

Currently, there are regulatory and standards gaps prohibiting the efficient roll out of HRS. This section begins by introducing the regulatory landscape of hydrogen system components and instrumentation. It then details the existing standards for the components and instrumentation of hydrogen systems. Finally, the HEA make a series of recommendations to facilitate a full set of standards for instrumentation manufacturing, testing, operating, calibrating and maintaining.

Overview of the current regulatory landscape for HRS components and instrumentation

The United Nations Regulation No 134 applies to the type approval of some of the hydrogen vehicle components. The main European regulation on type-approval requirements for motor vehicles and their trailers, systems, components and separate technical units intended for such vehicles is (EU) 2019/2144. Regulation (EU) 2021/535 provides the norms for the application of Regulation (EU) 2019/2144. In the UK, the Government have implemented EU regulation 2019/2144 (C(2022)5402) to supplement the existing 'General Safety Regulation' 2019/2144, which sets type-approval requirements for road vehicles[24]. With the introduction of EU 2019/2144, (EC) 79 / 2009 has been repealed. (EC) 79 / 2009 was also the main piece of EU regulation for type approval of hydrogen vehicle components. There are now regulatory gaps on hydrogen systems and components as it is only (partly) guided by UN Regulation No 134 and parts of Reg. (EU) 2021/535[25]. (Annex F details the current regulatory gaps for hydrogen systems and its components).

Standards relevant to components and instrumentation

BS ISO 12619 – CGH2 hydrogen/natural gas blends fuel system components

ISO 12619 covers CGH2 and hydrogen / natural gas blend fuel system components. BS ISO 12619-1:2014 provides general requirements and definitions, as well as general design principles

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23 Components are the physical parts of the refuelling station that are responsible for storing, compressing, and dispensing hydrogen fuel. These include storage containers, compressors, pre-cooling devices, dispensers, and fuelling connectors. Whereas, instrumentation refers to the sensors, gauges, and other devices that are used to monitor and control the flow of hydrogen fuel throughout the refuelling process. This includes flow meters, pressure sensors, temperature sensors, and other safety devices.

24 EM on EU regulation 2019/2144 (C(2022)5402) - GOV.UK (www.gov.uk)

25 EU type approval of hydrogen-powered vehicles and their components after repeal of Regulation (EC) 79/2009

and requirements for instructions and markings. We understand that parts of BS ISO 12619 are being updated in 2024 (Annex G describes BS ISO 12619's scope). It was developed with CSA/ANSI HGV 3.1 to provide conformity between standards and specifies requirements for **CGH2 and hydrogen / natural gas blends fuel system components**[26].

HGV 3.1 – CSA/ANSI's standard for fuel system components for compressed hydrogen gas powered vehicles

The Canadian Standards Association group (CSA) and American National Standards Institute (ANSI) published CSA/ANSI HGV 3.1, which is one of the leading standards for fuel system components for compressed hydrogen gas powered vehicles (Annex I details its scope). HGV 3.1 is recognised internationally and is regularly updated. BS ISO has used it as a basis to create its own standards. Thus, various HEA members standardise their components and instrumentation with HGV 3.1.

BS ISO 19887 – Gaseous Hydrogen — Fuel system components for hydrogen fuelled vehicles

ISO 19887 standard specifies the requirements and test methods for fuel system components for hydrogen fuelled vehicles with a maximum working pressure of 110MPa. It is based on CSA/ANSI HGV 3.1 and ISO 12619. ISO 19887 is being revised and is due to be published as an international standard in 2024[27]. It is not expected that fuelling receptacles will be covered in the ISO 19887 update. This is also the case for CSA/ANSI HGV 3.1 (See more in Annex J).

BS ISO 19887 is under development at the time of writing[28]. It will apply to components that have a nominal working pressure of 25MPa, 35MPa, 50MPa, or 70MPa at 15°C and other nominal working pressures where qualification test requirements are met.

BS ISO 19887, alongside CSA/ANSI HGV 3.1, is expected to become the industry norm for testing the conformity of the components missing from the scope of UN Regulation No 134, after the repealing of Reg. (EC) 79 / 2009[29].

Other relevant standards

As can be seen in the Refuelling Protocols section (3.1.8 Other Standards), BS ISO 17268 and SAE J2600 provide specific requirements for hydrogen fuelling nozzles and receptacles. BS ISO 17268 is continually being improved. ISO 17268-1 (<120 g/s) is being published by the end of 2024 and ISO 17268-2 (>120 g/s) is being published by the end of 2026. (See Figure 6 in Annex G for more details on the standards for HRS materials, components and containers).

Recommendations on components and instrumentation standards

Next steps for ISO 19887:2024 / BS ISO 19887:2024

The HEA recommends that the minimum material requirements for hydrogen are re-assessed. The ECH2A standardisation working group identified the same pre-normative research activities as the HEA in our research and outreach for this Position Paper. These areas include safety aspects (e.g. material compatibility, leakage) or issues linked to different energy carriers.

Next steps for CSA/ANSI HGV 3.1

CSA/ANSI HGV 3.1 specifies leak valve limitations of no more than 2.7x10-3 bar·ml/s, i.e. 10 Ncm3/h. The HEA recommends that the level of this limitation is reconsidered.

The HEA's overarching recommendations for standards on instrumentation:

The HEA recommends that BSI ensures that there is a complete series of product specification standards covering component certifications and

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26 ISO 12619-1:2014 - Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components — Part 1: General requirements and definitions
27 ISO/DIS 19887 - Gaseous Hydrogen — Fuel system components for hydrogen fuelled vehicles
28 British Standards Institution - Project (bsigroup.com)
29 https://www.tuvsud.com/en/-/media/global/pdf-files/whitepaper-report-e-books/tuvsud-eu-type-approval-of-hydrogen-powered-vehicles.pdf

testing. This will help the industry and market to function more efficiently and effectively.

The HEA stresses the need for product selection and System Design Guidelines covering recommended components and jointing methods for different pressure classes (1000, 700, 500 and 350 bar). It is recommended that the BSI work with industry to produce these guidelines. The guidelines should cover, not only the material composition of the pressure transmitters and recommended fitting connections, but also instructions to designers relating to the factors for procuring components from a mix of suppliers, as well as for installers on how to assemble the fittings correctly.

In the absence of a standardised leak testing procedure and minimum test procedure, an acceptable pass criteria is also needed in these guidelines.

The HEA recommends that guidelines are developed to operate, calibrate and maintain instruments and sensors for use with compressed (gaseous) hydrogen. The operating instructions would need to include the calibration and testing method, calibration intervals, leaking test procedures, pressure checks, maintenance instructions, maintenance intervals and applicable certification.

5 The need for HRS training standards

As the hydrogen market is rapidly developing, we have to invest quickly and systematically through the skills value chain to ensure that the UK has the national workforce capability.

Whilst there is momentum to respond proactively to this challenge, greater provision, standardisation and coordination is needed to deliver the right skills at the right time to the rapidly growing hydrogen sector. Hence, this section firstly highlights the latest advancements on developing the hydrogen skills workforce, notably led by the Hydrogen Skills Alliance, the development of a Hydrogen skills Strategy and National Occupational Standards for Hydrogen. The HEA then presents its recommendations on training needs for hydrogen refueling infrastructure based on the current challenges that industry are facing.

"... greater provision, standardisation and coordination is needed to deliver the right skills at the right time to the rapidly growing hydrogen sector."

Work in progress

2023 saw an encouraging upswing in work to progress the hydrogen skills agenda. In particular, the Hydrogen Skills Alliance (HSA), established in March 2023, is working to coordinate and standardise the hydrogen skills that the UK greatly needs. The HSA is convened by Cogent Skills, **the sector skills body for the science and technology industries**, and the National Composites Centre, and is made up of the HEA, other UK national and regional trade associations, R&D institutions, training providers and universities. Currently the alliance is working together on six workstreams: Stakeholder and Government Engagement, Landscape Mapping, Workforce Foresighting, Workforce Demand Forecasting and Strategy.

Green Jobs Action Plan

The highlights of the HSA activity so far is its work to develop a Hydrogen Skills Workforce Assessment, which is feeding into the Green Jobs Action Plan, a national plan being led by the Green Jobs Taskforce which is co-chaired by the Minister of State for Energy Security and Net Zero. This assessment will shape the Skills Strategy that will be developed by the Hydrogen Delivery Council this year.

Hydrogen workforce foresighting

The HSA has delivered the first workforce foresighting project for hydrogen, funded by Innovate UK, as part of the Workforce Foresighting Hub programme. Workforce foresighting aligns the skills development of the future workforce, with the needs and opportunities of emerging technologies. The National Composites Centre (member of the HSA) and Manufacturing Technology Centre's (MTC) workforce foresighting experts have collected data on how the current skills provision matches the future needs for Hydrogen Cryogenic and Pressurised Storage Tanks in bulk storage for commercial use. This data will be publicly available.

Skills framework

The HEA endorses the HSA's long-term mission to create an open-source Hydrogen Skills Framework covering the entire value chain. A skills framework maps out existing and emerging job roles and career pathways for developing sectors. The HEA welcomes the small contribution of Government funding that has been received to begin developing a hydrogen skills framework for Production.

National occupational standards

It is also important to mention that Cogent Skills has been commissioned by Scottish Qualification Authority to develop National Occupational Standards (NOS) across hydrogen usage, hydrogen fuel cell manufacture, hydrogen storage and CCUS for England, Scotland, Wales and Northern Ireland. NOS are valuable benchmarks that define the skills, knowledge, and competencies required for individuals to perform effectively in their job roles within a particular sector. NOS provide value to industry and its employees in a number of ways:

1. They set clear standards of competence for recruitment and job descriptions
2. They build and underpin qualifications and training programmes
3. They facilitate the monitoring of performance and appraisal
4. They set out clear career development pathways
5. They support workforce planning and the identification of skill gaps.

The current work follows on from a 2022 project to develop NOS for hydrogen production, storage and transportation. In 2024, NOS will be published prioritising the most pressing needs across hydrogen usage, hydrogen fuel cell manufacture, hydrogen storage and CCUS.

Industry's key training challenges in the roll-out of hydrogen refuelling infrastructure and recommendations for their resolution

The HEA has identified three key training / skills challenges across UK HRS. These are discussed below.

No skills framework for hydrogen systems

The lack of formal qualifications and a skills framework to design, build and install hydrogen systems is causing various challenges for industry, including, but not limited to:

- Putting at risk the acceleration and growth of the hydrogen industry
- Wasting industry's resources, as currently each individual company is creating training independently from one another which is a duplication of efforts and inefficient; and
- Preventing interoperability.

Recommendations for the Hydrogen Skills Alliance and its training providers

- The HEA recommends that NOS development for Hydrogen Refuelling Infrastructure is prioritised
- The HEA recommends that the next focus area for the HSA's Workforce Foresighting project is Hydrogen Refuelling Infrastructure system designing, building and installation
- The HEA recommends that a Hydrogen Refuelling Infrastructure System training framework is prioritised in the HSA's Hydrogen Skills framework pipeline.

Recommendations for Government and its Departments

- The HEA calls on the Department for Energy Security and Net Zero and Department for Education to build capacity of the Hydrogen Skills Alliance to develop a complete Hydrogen Skills framework.

Technical Recommendations

A Hydrogen Refuelling System skills framework needs to include the following elements:

- A requirement that engineers and technicians working on hydrogen projects have suitable engineering qualifications and a specification on which engineers and technicians can carry out which responsibilities - for instance:
  - Systems can be designed by Incorporated Engineers yet the sign-off has to be done by Chartered Engineers - both with appropriate training and qualifications.
  - Building and installing the systems can be carried out by Engineering Technicians with appropriate training / qualifications.

As part of this recommendation, the HEA highlights the importance for training providers to work with the Engineering Council.

- The HEA recommends that the training framework considers how non-UK qualifications are certified against the standards developed for designing, building and installing hydrogen systems in the UK.

Ensuring best industry practice transporting and depositing hydrogen at point of use

Transporting hydrogen on the road and depositing it at point of use is an area of the market that is in transition. Previously a small number of large players have moved and used hydrogen, whereas now there are many more companies implicated with transporting and depositing hydrogen. Thus, standardised guidance and protocols for moving and depositing hydrogen is needed so that best industry practice is maintained, for instance, how to operate trailers efficiently and safely in accordance with Regulation via the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR).

Recommendation to the Hydrogen Skills Alliance and its training providers

- The HEA recommends that workforce foresighting of the safe operating of Multi-Element Gas Containers (MEGC), when transporting hydrogen, is prioritised.

Recommendations to Government and its Departments

The HEA recommends that the following initiatives are considered and supported by Government and its non-ministerial qualification departments and forums to ensure their delivery:

- Increase the rate of NOS development to cover transporting hydrogen in any MEGC and depositing hydrogen at any filling station.
- The development of a licence to operate a scheme that considers audited equipment.
  - The development of a hydrogen equivalent of the Petroleum Driver Passport[30] and Safe Loading Pass Scheme[31]. The current Downstream Fuel Distribution Forum (DFDF) or a new Hydrogen forum of a similar format could design a Hydrogen Driver Passport Scheme and a Safe Loading Pass Scheme.
  - Government should also consider developing a national database for training like PDP for both petrol tanker drivers and for Multi-Element Gas Containers (MEGC) units. MEGC units should be referenced against Pressure Regulations[32].

Lack of widespread knowledge of how hydrogen and its refuelling process works

There continues to be a hydrogen knowledge gap across a range of key stakeholders relevant to the roll-out of HRS. The absence of sufficient knowledge of how hydrogen and its refuelling process works is hampering progress. As roll-out progresses, hydrogen awareness across the wider public sector will become relevant.

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30 Home | Petroleum Driver Passport (pdpassport.com)
31 Safe Loading Pass Scheme
32 Transportable pressure equipment (TPE) should have the 'Rho' marking to show its compliance with the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG 2009) - GB-appointed bodies are appointed by the Vehicle Certification Agency on behalf of the Department for Transport to undertake inspection activity in accordance with RID / ADR

Recommendations to Government and its departments

- The HEA does not envisage trained attendants being essential given that a refuelling process cannot begin without the whole system being hermetically connected and pressure tested. However, widespread knowledge transfer is needed from HRS developers to various stakeholders e.g. Vehicle OEMs, fleet operators and local fire officers to ensure that it is safe and simple to transport and deposit hydrogen. The Government need to support in convening and facilitating knowledge transfer amongst these key stakeholders. Widespread knowledge of how hydrogen and its refuelling process works will facilitate the development of appropriate risk assessments, fast roll-out and HRS that are easy to use.

Recommendations to engage the Health and Safety Executive in development of training provisions

- The HEA calls for the HSA to work with the Health and Safety Executive to ensure the skills framework articulates safety requirements
- The HEA asks for there to be a recognised training standard, such as the process safety training standard, that providers can use to ensure that there is consistent approach to training people.

6 Closing remarks

This Hydrogen Refuelling Infrastructure Position Paper aims to raise awareness of the role that standardisation can play in accelerating the roll out of HRS, describe the complex standards space for relevant stakeholders and provide clear actionable recommendations for the UK Government, BSI and the UK hydrogen sector to accelerate progress. This plan also highlights the power of standardisation to maximise the hydrogen business opportunity for the UK's supply chains.

The HEA calls on UK Government to leverage its position to propel forward the development of hydrogen standards. Providing a clear roadmap to support the rapidly needed rollout of vehicles across various modes and HRS as part of a broader hydrogen for transport strategy is a key action that the HEA continues to ask the UK Government to pursue. The HEA also recommends that the BSI update its approach to developing standards, adopting a more holistic approach to meeting the needs of hydrogen mobility. We recommend that HRS standards are developed systematically rather than part by part. For example, developing a standard for the whole HRS and its components rather than a separate standard for each individual component of HRS. Due to the sheer scale of action and deployment needed to meet the demands for hydrogen, an update to the standards development process is important.

Annex A – The scope of BS ISO 19880

The BS ISO 19880 defines the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles (e.g. fuel cell electric vehicles).

The standard is not applicable to the dispensing of cryogenic hydrogen, or hydrogen to metal hydride applications.

Since the standard is intended to provide minimum requirements for fuelling stations, manufacturers can take additional safety precautions as determined by a risk management methodology to address potential safety risks of specific designs and applications.

While this document is targeted for the fuelling of light duty hydrogen road vehicles, requirements and guidance for fuelling medium and heavy duty road vehicles (e.g. buses, trucks) are also covered.

Many of the generic requirements within this document are applicable to fuelling stations for other hydrogen applications, including but not limited to the following:

- fuelling stations for motorcycles, fork-lift trucks, trams, trains, fluvial and marine applications;
- fuelling stations with indoor dispensing;
- residential applications to fuel land vehicles;
- mobile fuelling stations; and
- non-public demonstration fuelling stations.

However, further specific requirements that can be necessary for the safe operation of such fuelling stations are not addressed in this document.

Currently various parts of BS ISO 19880 are under development:

- Part 2: Dispensers and dispensing systems;
- Part 4: Compressors
- Part 5: Dispensers hoses and hose assemblies
- Part 6: Fittings
- Part 7: Rubber O-rings
- Part 8: Fuel quality control
- Part 9: Sampling for fuel quality analysis

More details on the BS ISO 19880 standard can be found here

Annex B – The scope of BS EN 17127

BS EN 17127 on outdoor hydrogen refuelling point**s** is useful for:

- Electric vehicles manufacturers
- Quality control laboratories
- Fuel pump or stations

According the legal requirements given in the Alternative Fuels Infrastructure Directive (AFID) and **BS EN 17127** specify only the required specifications for ensuring the interoperability of refuelling points to be provided. European standards and common requirements with respect to "interoperability" mean the capacity of an infrastructure to supply energy (in **BS EN 17127** hydrogen) that is compatible with all vehicle technologies and allows seamless EU-wide mobility and a clear definition of fuel pressure and temperature levels and connector designs.

BS EN 17127 provides requirements to ensure the interoperability of hydrogen refuelling points, including refuelling protocols that dispense gaseous hydrogen to road vehicles.

BS EN 17127 provides a synthesis of information regarding the hydrogen fuelling infrastructure to power fuel cell vehicles. The compilation includes research on hydrogen infrastructure deployment, fuel pathways, and planning based on developments in the prominent fuel cell vehicle growth markets around the world.

More details on the BS EN 17127 standard can be found here.

Annex C – The scope of ISO 19885-1/2/3

This standard is intended to identify and describe requirements for the design and development of hydrogen dispenser fuelling protocols and address issues with current protocols with regard to their acceptance and thoroughness of verification as well as the safe implementation in dispenser systems.

This standard is intended to coordinate with the ISO 19880 family of documents with regard to road vehicles and, at the same time, address a more general need with the regard to fuelling a far broader range of vehicles. Creation of this standard to address technical details of the fuelling process will allow ISO 19880-1 to be streamlined and focus on basic requirements of the fuelling station.

This standard is expected to be the first part in a series of documents dealing with fuelling protocols for a broad range of vehicle applications. ISO 19885-2, when completed, will define communication requirements between the vehicle and dispensing system, and ISO 19885-3, when completed, will address the fuelling of heavy-duty vehicles.

More details on the ISO 198851/2/3— standard can be found here.

Annex D – The scope of SAE J2601-1 fuelling protocols for Light Duty Gaseous Hydrogen Surface Vehicles

SAE J2601-1 establishes the protocol and process limits for hydrogen fuelling of light duty vehicles. These process limits (including fuel temperature, the maximum fuel flow rate, and rate of pressure increase and end pressure) are affected by factors such as ambient temperature, fuel delivery temperature and initial pressure in the vehicle's compressed hydrogen storage system. SAE J2601-2014 establishes standard fuelling protocols based on a look-up table approach with performance targets. The current standard is table-based and provides concise performance targets for both communications and non-communications fuelling.

An important factor in the performance of hydrogen fuelling is the station's dispensing equipment cooling capability and the resultant fuel delivery temperature "T" rating. SAE J2601-1 has a reference fuelling target of 3 minutes with 95-100% State of Charge (SOC) (with communications) with a T40 rated dispenser. However, with lower fuel delivery temperature dispenser ratings (T30 or T20) and / or at high ambient temperatures, fuelling times may be longer.

SAE J2601-1 includes standard fuelling tables for communications and non-communications fuelling, as well as a non-standard, development fuelling protocol. For fuelling with communications, this standard is to be used in conjunction with SAE J2799 - Hydrogen Surface Vehicle to Station Communications Hardware and Software. SAE J2601-1:2014 also includes, a non-standard development fuelling protocol is called MC Formula Protocol. It calculates a dynamic pressure ramp rate using adaptive feedforward control based on the measurement of pressure and temperature at the dispenser in order to minimize the fuelling time[33].

SAE J2601-1 includes protocols for various NWP's, 35 and 70MPa and three fuel delivery temperatures (-40°C, -30°C, -20°C) and compressed hydrogen storage system sizes from 49.7 to 248.6L. Future versions of J2601 may incorporate warmer fuel delivery temperatures (-10°C and ambient) and smaller compressed hydrogen storage system for motorcycles[34].

Figure 2 illustrates the scope of SAE J2601-1 – specifically, its refuelling protocol rules for light to heavy duty vehicles. The current heavy duty vehicles protocol has been Category D.

Pressure Class Designation	H70			
Compressed Hydrogen Storage System (CHSS) Capacity Range (Litres)	49.7 - 99.4	99.4 - 174.0	174.0-248.6	>248.6
CHSS Capacity Range (kg)	2 to 4	4 to 7	7 to 10	>10
CHSS Capacity Category	A	B	C	D
Maximum Flow Rate (g/s)	<60	<60	<60	<60
Fuel Delivery Temperature Category	T20, T30, T40	T20, T30, T40	T20, T30, T40	T20D, T30D, T40D

Figure 2: The scope of SAE J2601-1 Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles[35]

33 PowerPoint Presentation (cleanenergypartnership.de)
34 J2601_202005: Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles - SAE International
35 Source: Clean Energy Partnership's public webinar – TIR SAE J2601-5 Refuelling Protocol delivered by Vincent Matteaer from Toyota Motor Europe

Annex E – The scope of TIR SAE J2601-5 – High-flow prescriptive fuelling protocols for Gaseous Hydrogen Powered Medium and Heavy-Duty Vehicles

Figure 3 illustrates the scope of SAE J2601-5.

Pressure Class Designation	H35	H70		
Protocol Name	MCF-HF-G	Category D HF	MCF-HF-G	
Protocol type	MC Formula	Table Based	MC Formula	
CHSS Capacity Range (Litre)	248.6 to 7500	248 to 5000		
CHSS Capacity Range (kg)	5.97 to 180	10 to 201		
Single Tank Size (Litres)	50 to 1000	50 to 800		
Maximum Flow Rate Class g / s COMM	FM120	FM90	FM90	FM300
Maximum Flow Rate Class g / s NON-COMM	FM120	FM60	FM60	FM300
Coupling Type[36] (*A **coupling type** for a **receptacle** is a mechanism that allows the receptacle to be connected to a power source)	H35HF	H70 (4mm)	H70 (4mm)	H70HF
Fuel Delivery Temperature Category	Ta, T0, T10, T20, T30, T40	T20D, T30D, T40D	T0, T10, T20, T30, T40	
	Ta: 0°C to 20°C	0		
	T0: -10°C to 0°C	0	T0: -10°C to 0°C	
	T10: -17.5°C to -10°C	0	T10: -17.5°C to -10°C	
	T20: -26°C to -17.5°C	T20D: -40°C to -17.5°C	T20: -26°C to -17.5°C	
	T30: -33°C to -26°C	T30D: -40°C to -26°C	T30: -33°C to -26°C	
	T40: -40°C to -33°C	T40D: -40°C to -33°C	T40: -40°C to -33°C	

Figure 3: The scope of SAE J2601-5[37].

36 A coupling type for a receptacle is a mechanism that allows the receptacle to be connected to a power source)
37 Clean Energy Partnership's public webinar: SAE J2601-5 Refuelling Protocol delivered by Vincent Matteaer from Toyota Motor Europe

TIR SAE J2601-5 establishes prescriptive general-purpose high-flow fuelling protocols and process limits for hydrogen fuelling of vehicles. These process limits (including the fuel delivery temperature, the maximum fuel flow rate, the rate of pressure increase, and the ending pressure) are affected by factors such as ambient temperature, fuel delivery temperature, and initial pressure in the vehicle's compressed hydrogen storage system. TIR SAE J2601-5 includes two sets of fuelling protocols: 1) high-flow versions of the Category D protocol described in SAE J2601; and 2) an MC Formula-based fuelling protocol which as mention in the table above utilizes a dynamic pressure ramp rate continuously calculated throughout the fill. The naming convention of the MC Formula-based fuelling protocol is MCF-HF-G (MC Formula - High Flow – General). The protocols allow for fuelling with communications or without communications and provide end-of-fill pressure targets. For fuelling with communications, the fuelling protocols are to be used in conjunction with SAE J2799, Hydrogen Surface Vehicle to Station Communications Hardware and Software.

An important factor in the performance of hydrogen fuelling is the station's dispensing equipment cooling capability and the resultant fuel delivery temperature. The fuelling protocols utilizes fuel delivery temperatures in the range of -40°C to -10°C. There are four fuel delivery temperature categories denoted by a "T" rating - T40, T30, T20, and T10, where T40 is the coldest. Future revisions may expand the fuel delivery temperature range to warmer temperatures. Fuelling times are a function of the fuel delivery temperature and CHSS volume. With a T40 rated dispenser and under reference conditions (ambient temperature of 20°C and initial pressure of 10 MPa, the MCF-HF-G protocol can achieve fuelling times of 5 to 7.5 minutes and a % State of Charge (SOC) of 95 to 100% (with communications). With higher fuel delivery temperature dispenser ratings (T30, T20, or T10) and/or at high ambient temperatures, fuelling times will be longer.

SAE TIR J2601-5 provides prescriptive general-purpose fuelling protocols which are appropriate for use in both private and publicly accessible fuelling stations. TIR SAE J2601-5 is independent from SAE J2601-2 'Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles'.

As see be seen in Figure 3 above, the main developments to the standardisation of refuelling protocols for heavy duty vehicles through SAE J2601-5 is an increase in the maximum flow rate, increase of the CHSS Capacity Range, single tank size and expansion of fuel delivery temperature category including ambient cooling, Ta for a 35MPa pressure class tank (H35) if the MC-Formula protocol is used.

SAE J2601-5's interaction with mechanical connection and communication standards

Mechanical connection

As mentioned previously, the two new ISO standards for the mechanical connection are being published in 2024 and 2026: ISO 17268-1 (<120 g/s) for H70_F90 (2024) ISO 17268-2 (>120 g/s) for H70_F300 (2026). ISO 17268-1 (<120 g/s) will have a 4mm to allow for 90g/s flow rate whereas receptacle dimension for ISO 17268-2 (>120 g/s) for H70_F300 has not been decided yet[38].

Communication

Another key element for a HRS to be valid under J2601-5 is that Hydrogen Surface Vehicle to Station Communications Hardware and Software must be upgraded to version 2 of SAE J2799 - Hydrogen Surface Vehicle to Station Communications Hardware and Software. However, J2601-5 still standardises the hydrogen powered heavy duty vehicle just having SAE J2799 version 1 as long as the HRS is programmed for both SAE J2799 version 1 and 2. To understand more on how the SAE J2799 communication standard and J2601-5 relate to one another, please head to Part 4 of CEP's on 'Refuelling protocol as an important milestone for the further expansion of hydrogen refuelling stations'[39].

38 PART 01 – SAE J2601-5 Betankungsprotokoll – Vincent Mattelaer, Toyota Motor Europe - YouTube
39 PART 04 – SAE J2601-5 Betankungsprotokoll – Vincent Mattelaer, Toyota Motor Europe (youtube.com)

Annex F – Regulatory gap analysis

Figure 4 maps the regulatory gaps for Hydrogen fuel systems and their components. X indicates that it is covered.

Figure 4 Regulatory gaps for Hydrogen fuel systems and their components[40]

Components considered in Reg. (EC) 79/2009, UN Regulation No. 134 and Reg (EU) 2021/535			
	Reg. (EC) 29/2009	UN Regulation No. 134	Reg. (EU) 2021/535
	Compressed gaseous hydrogen (CGH2)		
Hydrogen container	x	x	x
PRD	x	x	x
Automatic shut-off valves	x	x	x
Check valves	x	x	x
Pressure relief valves	x		
Heat exchangers	x		
Refuelling connections	x	(x)	(x)
Receptacles	x	(x)	(x)
Pressure regulators	x		
Sensors for hydrogen systems	x	(x)	
Flexible fuel lines	x		
Fittings	x		
Hydrogen filters	x		
Removable storage system connectors	x		
	Liquid hydrogen (LH2)		
Hydrogen container	x	N.A.	x
PRD	x		x
Automatic shut-off valves	x		x
Check valves	x		x
Boil-off system	x		x
Heat exchangers	x		
Refuelling connections or receptacles	x		(x)
Pressure regulators	x		
Sensors	x		
Flexible fuel lines	x		

40 Source: TÜV SÜD whitepaper - EU type approval of hydrogen-powered vehicles and their components after repeal of Regulation (EC) 79/2009

Annex G – Standards for materials, components, and containers

Figure 5 details the relevant norms for Hydrogen vehicle fuel system components and containers.

Relevant norms for Hydrogen vehicle fuel system components and containers			
	Materials standards	Components standards	Containers standards
Gaseous Hydrogen	CHMC-1	HGV 3.1	HGV 2
	CHMC-1	ISO 12619	ISO 19881
	ISO 11114	ISO 19887	
	TÜV SÜD standard	ISO 17268	
		SAE J2600	
Liquid Hydrogen	EN 1252	ISO 13984	ISO 13985

Figure 5 Relevant norms for Hydrogen vehicle fuel system components and containers[41]

41 Source: TÜV SÜD whitepaper - EU type approval of hydrogen-powered vehicles and their components after repeal of Regulation (EC) 79/2009

Annex H – Further details on BS ISO 12619

BS ISO 12619 consists of the following parts, under the general title 'Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components':

- Part 1: General requirements and definitions
- Part 2: Performance and general test methods
- Part 3: Pressure regulator
- Part 4: Check Valve
- Part 5: Manual Cylinder valve
- Part 6: Automatic valve
- Part 7: Gas injector
- Part 8: Pressure indicator
- Part 9: Pressure Relief Valve
- Part 10: Pressure Relief Device
- Part 11: Excess flow valve
- Part 12: Gas tight housing and ventilation hoses
- Part 13: Rigid fuel line in stainless steel
- Part 14: Flexible fuel line
- Part 15: Filter
- Part 16: Fittings

This part of BS ISO 12619 is applicable to vehicles using CGH2 in accordance with ISO 14687-1 or ISO 14687-2 and hydrogen / natural gas blends using natural gas in accordance with ISO 15403-1 and ISO/TR 15403-2. It is not applicable to the following:

- liquefied hydrogen (LH2) fuel system components;
- fuel containers;
- stationary gas engines;
- container mounting hardware;
- electronic fuel management;
- refuelling receptacles.

More details on the ISO 12619 standard can be found here.

Annex I – Details of the scope of CSA/ANSI HGV 3.1: 2022

This Standard establishes requirements for newly produced compressed hydrogen gas fuel system components, as listed below, that are intended for use on hydrogen gas powered vehicles:

- check valves
- manual valves
- manual container valves
- automatic valves and automatic container valves
- hydrogen injectors
- pressure sensors, temperature sensors, and pressure gauges
- pressure regulators
- pressure relief valves (PRV)
- pressure relief devices (PRD)
- excess flow valves
- gastight housing and ventilation passages
- stainless steel rigid fuel lines
- flexible fuel lines, hoses, and assemblies
- filter assemblies
- fittings
- non-metallic, low-pressure rigid fuel lines
- discharge line closures

Other components not specifically covered here can be examined to meet the criteria of CSA/ANSI HGV 3.1 and tested according to the appropriate functional needs.

In the 2022 publication, the major changes to this update include the following:

- adding requirements for flexible fuel lines, hoses, and hose assemblies for use as part of a vehicle's onboard fuel storage system or fuel delivery system; and
- harmonizing test procedures and values within the industry.

More details on the CSA/ANSI HGV 3.1:2022 standard can be found here.

Annex J – Further details on BS ISO 19887

The scope of BS ISO 19887 for newly produced CGH2 fuel system components is summarised by the list below. This applies to hydrogen gas powered land vehicles:

- general requirements including general construction and assembly, failure modes and effects analysis (FMEA), electrical equipment and wiring, component literature and marking
- general test methods including general test requirements, hydrostatic strength, leakage, excess torque resistance, bending moment, continuous operation, corrosion resistance, ultraviolet resistance of external surfaces, automotive fluid exposure, atmospheric exposure, abnormal electrical voltages, non-metallic material hydrogen compatibility, vibration resistance, stress corrosion cracking resistance, insulation resistance and pre-cooled hydrogen exposure.
- quality assurance
- production inspection and acceptance testing
- check valves
- manual valves
- manual container valves
- automatic valves and automatic container valves
- hydrogen injectors
- pressure sensors, temperature sensors, and pressure gauges
- pressure regulators
- pressure relief valves (PRV)
- pressure relief devices (PRD)
- excess flow valves
- gastight housing and leakage capture passages
- rigid fuel lines
- flexible fuel lines, hoses, and assemblies
- filter assemblies
- fittings
- non-metallic, low-pressure rigid fuel
- discharge line closures

Other components not specifically identified here can be examined to meet the criteria of ISO 19887 and tested according to the appropriate functional needs.

BS ISO 19887 applies to components that have a nominal working pressure, as specified by the manufacturer, of 25MPa ("H25"), 35MPa ("H35"), 50MPa ("H50"), or 70MPa ("H70"), at 15°C.

Other nominal working pressure for hydrogen gas besides those defined are allowed if the required qualification test requirements of this document are met.

BS ISO 19887 also applies to components downstream of the first stage of pressure reduction with a maximum operating pressure designated by the manufacturer in MPa or kPa.

There are a number of exclusions:

- hydrogen gas fuel system components incorporated during the manufacture of motor vehicles originally manufactured in compliance with the international regulations on hydrogen and fuel cell vehicles such as UN GTR No. 13, UN Regulation No. 134, UN Regulation No. 146, or IEC 62282-4-101;
- fuel containers;
- stationary power generation applications;
- container mounting hardware;
- electronic fuel management;
- refuelling receptacles; or
- components intended for liquid hydrogen

More details on the BS ISO 19887 standard are available here

Hydrogen Energy Association