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Hydrail: Phase II

Demonstration of Alstom Coradia iLint in Quebec

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Abstract

Transport Canada (TC) engaged the National Research Council of Canada (NRC) to study the deployment of the Alstom Coradia iLint, a hydrogen-powered passenger train, in Quebec during the summer of 2023. This project, marking the first appearance of a passenger hydrogen fuel-cell-powered (or “hydrail”) train in North America, operated under the jurisdiction of the Province of Quebec rather than federal authorities. Conducted in collaboration with Harnois Énergies, Charlevoix Railway, and HTEC (Hydrogen Technology and Energy Corporation), the demonstration aimed to showcase the potential of hydrogen-powered passenger trains in Canada and attract the attention of both the public and the industry.

The study focused on understanding safety practices, the design of hydrogen trains, risk assessments, and the necessary physical testing. The iLint train operated using hydrogen fuel cells and lithium-ion batteries, with specific protocols for startup, shutdown, and refueling. Emergency response training followed standard regulations and incorporated monitoring systems for smoke and fire. Relevant standards, including 49 CFR 238.215 and CSA HGV 2, were referenced by industry, with an emphasis on the importance of considering GTR13 in future evaluations of applicable codes and standards.

The project also explored how key considerations identified by NRC were reflected in the demonstration. Site visits noted that, as a European model, the train was designed to meet a different set of standards than those commonly applied in North America. The demonstration proceeded smoothly and offered valuable insights into the practical deployment of hydrogen-powered rail. Looking ahead, future initiatives could benefit from continued collaboration and proactive information sharing to support effective planning and knowledge transfer.

Executive summary

Transport Canada (TC) commissioned the National Research Council of Canada (NRC) to gather information on the deployment of the Alstom Coradia iLint, a hydrogen-powered passenger train, in Quebec during the summer of 2023. This project marked the North American debut of the hydrogen fuel-cell-powered (or “hydrail”) passenger train, which had previously been operated in Europe. Conducted in collaboration with Harnois Énergies, Charlevoix Railway, HTEC (Hydrogen Technology and Energy Corporation), and the Province of Quebec, the demonstration aimed to provide insights into safety requirements, design criteria, and risk management for hydrogen trains.

The investigation had several objectives: to understand safety requirements and practices, build knowledge on hydrogen train design and safeguards, expose TC and NRC researchers to a deployed hydrogen train, update risk and hazard assessments, and evaluate differences between the use of standards in Europe against those used in Canada. Using the best available information, the study covered various aspects including the trainset, maintenance areas, storage, and physical platforms, focusing on codes, standards, risk classifications, hydrogen sensor configurations, storage architecture, refuelling processes, fire safety mechanisms, crew responsibilities, and risk analysis.

The iLint train used eight Type 4 hydrogen cylinders and 110 kWh of lithium-ion batteries. The hydrogen tanks could be pressurized to 350 bar, but they were typically charged to 220 bar during the demonstration. The fuel cells, roof-mounted along with the hydrogen tanks, charged the batteries, with traction power provided by Type 6 ENA 2554 electric motors. The system included a health monitoring system and thermal management unit.

Operational protocols for startup and shutdown utilized shore power to condition the batteries and fuel cells. Refuelling involved a manual process with safety protocols, including electrical grounding and pressure monitoring. The demonstration project used a hydrogen tube trailer for daily refuelling.

Various standards, including U.S. government 49 CFR 238.215 and CSA/ANSI HGV 2, were referenced by the manufacturer during the project. The report identifies the need to include GTR13 in future considerations. In a previous work, the NRC identified 501 specific risks, with three classified as medium risk: impact damage to a tank element, thermal pressure relief device failure, and hydrogen venting into an enclosed space. Mitigation measures included compliance with 49 CFR 238.215 and CSA HGV2.

Emergency response training was conducted in alignment with standard passenger rail protocols and included monitoring systems for smoke and fire. It was noted that first responder training was coordinated locally by the operator and municipal authorities. Observations from two site visits indicated that the demonstration train, being a European model, was designed to meet a different set of standards than those typically applied in North America. The observations noted the presence of tank pressure and temperature displays in the driver's cab, along with emergency alert systems.

Some uncertainties regarding the characteristics of the demonstration train arose due to limited access to primary technical documentation. Given the temporary nature of the project, certain operational differences were anticipated compared to a permanent deployment. The importance of international coordination on regulatory standards was also noted. Overall, the demonstration project concluded successfully and offered valuable insights into the practical application of hydrogen-powered passenger rail in a Canadian context. While access to some documentation remained limited, the experience highlighted opportunities to strengthen future initiatives through early engagement, clearer roles, and improved access to supporting materials.

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1 Introduction

1.1 Background

As part of a larger project researching various aspects of hydrogen train (hydrail) deployment, Transport Canada (TC) asked the National Research Council of Canada (NRC) to gather information related to the deployment of a hydrail passenger train in Quebec during the summer of 2023. This report presents the results of those inquiries.

Figure 1: Map of the Train de Charlevoix line

Alstom, a French rolling stock manufacturer and services provider, carried out a demonstration of their Coradia iLint in Quebec between June and September 2023. While previously operated in Europe, this marked the debut of this hydrogen-powered train in North America, and was conducted in collaboration with Harnois Énergies, Charlevoix Railway, HTEC (Hydrogen Technology and Energy Corporation), and the Province of Quebec. The commercial Coradia iLint can travel up to 1,000 kilometers on a full hydrogen tank, enabling operation on non-electrified railway lines without expensive infrastructure changes. It reaches speeds of up to 140 km/h, ideal for regional and suburban services, and accommodates up to 153 seated and 150 standing passengers [1].

By the end of the demonstration period, it had carried over 10,000 passengers across 117 journeys between Chute-Montmorency and Baie-Saint-Paul. Operation through to Malbaie was not possible due to incompatibility with existing track geometry. Likewise, the existing track only permitted speeds below 50 km/h, much lower than the demonstration train’s design speed of 160 km/h.

The Charlevoix Train Company, part of the Charlevoix Network, set a summer season record by doubling its passenger numbers due to the initiative called "The Hydrogen Experience." This involved replacing one of their diesel trains with the Coradia iLint. Built by Alstom in Germany, the train was brought from Europe with the help of $3 million in financial support from the Quebec government's Technoclimat program, contributing to the total project budget of $8 million [1].

As the demonstration vehicle had been designed for conformity with the European regulatory and standards environment, it was believed to represent an opportunity to learn from an implemented approach to managing risks posed by these types of vehicles. Consequently, TC requested that the NRC liaise with Alstom to gather information about this project, with specific attention to risk assessment and mitigation strategies.

1.2 Objectives

The purpose of these investigations was as follows:

1. To give TC and the NRC an understanding of the safety requirements and practices in place for the train at the centre of this demonstration project.
2. To build knowledge regarding hydrogen passenger train design criteria and currently employed safeguards.
3. To give researchers exposure to a deployed hydrogen passenger train.
4. To update the risks and hazards assessment, prepared in Phase I of this research [2], with information learned from a real-world deployment.
5. To help define any physical testing that may be required to prepare for deployment of hydrogen or battery-electric locomotives in Canada.

Objective 4 has been primarily addressed in a separate report as part of the Phase II work [3]; however, risks and hazards identified through the NRC’s discussions of this demonstration project are also summarized here.

1.3 Scope

These investigations are intended to cover the trainset, maintenance areas, trainset storage and physical platforms. This includes both physical designs and operational procedures. For example:

- codes or standards implemented
- configuration of hydrogen sensors in passenger compartments
- architecture, capacity of any type of hydrogen storage containers
- refuelling flow rate, process, and controls
- fire safety mechanisms
- differences in responsibilities of trainset crew compared to diesel trainset
- risk analysis for this operation
- setup of pressure relief valves

This report covers information collected through two site visits and the responses to written questions submitted to Alstom, with the exception of Sections 5 and 0, which reference other NRC work on this project. The site visits were guided walkthroughs of the train operation by project staff.

2 Propulsion system

Energy storage for the iLint demonstration train consisted of eight Type 4 hydrogen cylinders, with a maximum capacity of 66.5 kg of hydrogen, along with 110 kWh of battery capacity. The batteries are lithium ion—a mix of lithium-titanate-oxide (LTO) modules and lithium-nickel-manganese-cobalt-oxide (NMC) modules, with the chemistry mix varying in commercial designs based on the customer's required duty cycle. Standard system voltage was stated to be 750 V direct current, with the system capable of outputting 220 kW at peak load. The hydrogen tanks could be pressurized to a maximum of 350 bar at 15°C, but anecdotally they were typically charged to 220 bar during the demonstration period. Supply pressure to the fuel cell was stated to vary between 8.6 and 9.6 bar. According to the Université du Québec à Trois-Rivières (UQTR) [1], an average hydrogen consumption of 26.8 kg/100 km occurred during this demonstration.

Figure 2: Flow of energy from the hydrogen to the major components

The hydrogen tanks fed Cummins-manufactured fuel cells, which were used to charge the batteries. Unfortunately, the specifications for the fuel cells are not known at this time. During the initial site visit, it was observed that the batteries were charged via station power while hydrogen re-fuelling was completed. The demonstration trainset was a European model not originally intended for North American operation, and as such, it may have been designed for a different duty cycle than what was experienced during the demonstration project, which could have influenced the fuel cell's ability to fully charge the batteries under normal operating conditions. Alternatively, the operational approach may have been shaped by efforts to manage hydrogen consumption. Shore power was provided using a diesel generator; the use of this approach may have been considered a practical or cost-effective option, particularly given the short-term demonstration nature of the operation.

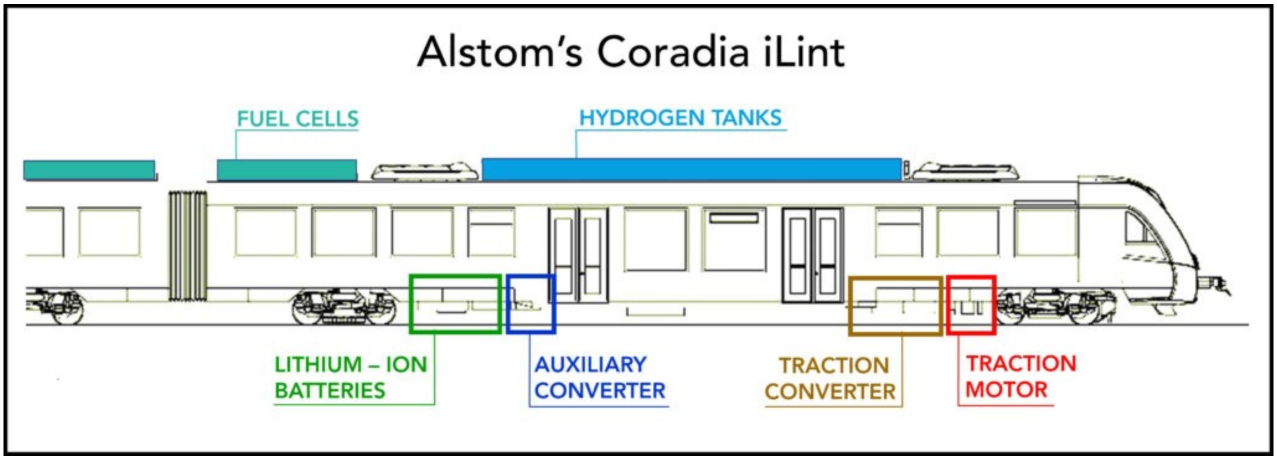

Figure 3: Coradia iLint general arrangement of major components [4]

Both the hydrogen tanks and the fuel cells were roof-mounted, which is believed to simplify the venting and ventilation arrangement in case of hydrogen releases or leaks, and allows provision for separation from the passenger compartment. Given hydrogen's buoyancy, placing the fuel cells and storage systems on top is a logical approach to mitigate risks in the event of a leak. This arrangement also positions the fuel cells and hydrogen tanks as far away as possible from the lithium batteries, converters, and traction motors. It would have been helpful to know the separation distances between the fuel cell ventilation system's air exhaust and the passenger doors. The air exhaust for the fuel cell ventilation system is likely positioned at the center of the roof to maximize this separation. However, the environmental control system (ECS) seemed to be located between the hydrogen storage and the fuel cell power plant on the roof.

It would have been helpful to know the separation distances between the ECS and the hydrogen storage and fuel cell power plant and how that proximity was handled. It would also have been helpful to understand where the air intake and outlet of the ECS were located with respect to the hydrogen systems. While the requirements for these parameters are not well defined by standard, a better understanding of how they were implemented in this instance could have led to an understanding of how engineering judgement was applied and standardization gaps that may need to be addressed through future work.

The hydrogen tanks are each equipped with a manual isolation valve, and were not linked between cars, so each car was fuelled separately. To meet the requirements of 49 CFR 238.215, the system was designed not only to prevent intrusion into the passenger compartment in the event of a rollover, but also to remain structurally intact following such an event. During the initial site visit by the NRC, it was noted that a major modification from non-hydrogen-fueled variants of the train involved reinforcement of the roof supports. This adjustment was necessary to accommodate the additional weight of the hydrogen components mounted on the roof, which also affected the train's center of gravity.

Traction power was provided by Type 6 ENA 2554 motors, with a maximum rated speed of 140 km/h. For the duration of the demonstration project, speeds were limited to 50 km/h due to existing track limitations.

The hydrogen cylinders used in the Coradia iLint were provided by HTEC, and the fuel cells used were manufactured by Accelera Cummins. The battery provider was not identified. The maximum permissible system temperature was stated to be 85°C, accompanied by corresponding pressure increases. This is consistent with the CSA/ANSI HGV 2:21 (Compressed hydrogen gas vehicle fuel containers) standard, which allows container and gas temperature variations from −40°C to 85°C.

A health monitoring system connected to the Battery Management System (BMS) collected diagnostic data, which was downloadable for off-site analysis, but a full accounting of all data collected was not provided. It is believed that this data would have included the readings from tank-mounted pressure and temperature sensors, which are displayed in the driver's cab, as well as a pressure sensor at the output of the pressure regulator, and thermal sensors on the fuel cell, batteries, and traction motors. It may also have included signals from the cabin management system, which include smoke detectors monitoring the driver's cab, passenger compartments, and toilets, as well as linear heat detectors (LHD) on the power converter housing, hydrogen tanks, traction batteries, fuel cells, and auxiliary system converter and heaters. No hydrogen sensors were located within the passenger cabin.

Thermal management of the fuel cell and batteries appears to be handled by a shared thermal conditioning unit, which includes an electric heating element, active cooling system, fans, pumps, and oil storage to maintain optimal operating temperatures. The system is also understood to monitor for out-of-range conditions that may require shutdown and isolation, although specific details regarding the monitoring and intervention capabilities were not available.

3 Startup/Shutdown/parking processes and protocols

Startup was typically completed under shore power, allowing conditioning of the batteries and fuel cells as well as heating, ventilation, and air conditioning (HVAC) initiation to be completed without depletion of the batteries or consumption of hydrogen. The duration of this would vary depending on outside temperature, but Alstom stated an approximate power consumption of 18 kW per train for this activity. Startup without external power was stated to be possible, but was not observed during the site visits.

Details regarding the startup sequence for the fuel cell system were not available for review. In some cases, components compliant with requirements for use in designated hazardous areas are activated first, followed by the ventilation system. If the ventilation system does not engage as expected, the startup process is halted. This behaviour would be consistent with existing fuel cell standards, such as CSA/ANSI FC 1:21/CSA C22.2 NO. 62282-3-100:21 (the North American adaption of IEC 62282-3-100:2019) and ANSI/CSA AMERICA FC 3-2004. The motors in the ventilation system are typically brushless, and the fan materials are selected to prevent static buildup and the risk of static discharge. Similarly, the fans, their connections, and the wiring methods comply with other requirements for classified areas (e.g., motors designed to remain in a safe condition in flammable environments during locked rotor situations). After a few air exchanges through the ventilation system, the remaining components are usually powered, and hydrogen and air are introduced to the fuel cells. The purging is done because, sometimes, areas inside the system may be declassified (allowing the use of components for ordinary locations) based on ventilation, which is why the ventilation system needs to be activated first. Additionally, this displaces any residual hydrogen from the previous operational cycle before the system is restarted.

Shutdown follows a similar process, but in reverse. Shore power was recommended to keep the thermal conditioning units operational, both to enable faster start-up times and to protect the system from potentially damaging environmental temperatures, while also ensuring that the on-board hydrogen leak and flame detectors remain active. It was observed that the fuel cell power plant continued to make fan noise for a few minutes after the train stopped at the terminal. This could have been due to the cooling system or ventilation system remaining on after the train had stopped. It is possible that the ventilation system completes several air exchanges (post-purge) to ensure any residual hydrogen is well diluted before shutdown. Additionally, the system was very loud, indicating a very high air flow rate. It would have been helpful to understand the ventilation rate in relation to fuel cell stack leaks and potential leaks caused by component faults. Information regarding hydrogen safety protocols—such as ventilation dilution, hydrogen sensing systems, activation procedures, and related measures—was not readily available for review. A procedure existed for purging the fuelling hydrogen system for long-term storage and isolating the high-pressure hydrogen supply, but the details of that procedure were not available.

Parking indoors was recommended for weather protection; however, such a facility would require continuous ventilation to prevent hydrogen accumulation. Alstom also recommended a hydrogen gas detection alarm linked to an active ventilation system. For the demonstration project, a partially covered outdoor area was used, so these steps were not implemented or considered necessary because hydrogen can dissipate into the open air. Spark-proofing the storage area was stated to be a requirement, but the details of how that was implemented on the demonstration project were not available for review.

4 Refuelling stations

Refuelling was accomplished through free flow caused by a storage pressure differential between the on-board hydrogen tanks and the refueling station. The UQTR notes that Harnois Énergies produced hydrogen for the demonstration via water electrolysis at their Quebec City refuelling station. The hydrogen was shipped by truck to Baie Saint Paul for the Train de Charlevoix. Harnois Énergies used HTEC's PC-45 storage units, each with five tanks with 315-litre capacity holding 9 kg of hydrogen at 450 bar. Each trailer had 4 units, allowing for transport of 180 kg at the same pressure. The refuelling was carried out by the train technician and onboard agent from Alstom, along with the truck driver from Harnois Énergies and the Train de Charlevoix driver. [1]

Prior to refuelling, the refuelling equipment was electrically bonded to the train chassis through grounding cables connected to the rail. The hose from the refuelling station was then attached to the train's inlet, pressurized, and the valve leading to the storage tank was closed. An HTEC transfer module connected the train and truck tanks to ensure all equipment and personnel maintain the same electrical potential. This module monitored pressure and included a safety system [1]. Seal adequacy was manually assured by monitoring the pressure decay within the hose over a fixed period of time. Once the hose connection was completed, valves on both ends of the hose were opened and hydrogen was allowed to flow due to a positive pressure differential between the refueling station storage pressure and the maximum pressure of the onboard tanks.

Pressure in the train and storage tanks was monitored from the refueling station with pressure gauges while fuelling. Tank temperature and pressure were monitored manually in the train control room as well. For disconnection, a 10-psi pressure was maintained within the nozzle to prevent air ingress. A 15-minute refuelling time was targeted, with the tanks being filled 2 at a time. As each car held 10 tanks, manual valves between the tanks were operated during the refueling process until the desired volume of hydrogen was loaded or the tanks were full. There was no hydrogen connection between cars, so each car was fuelled separately.

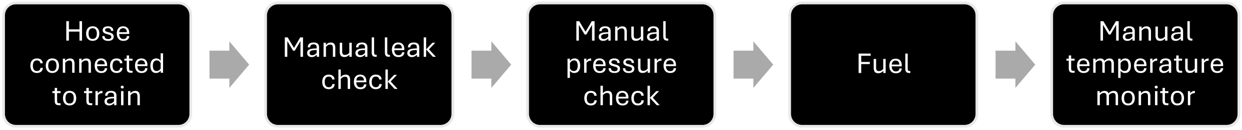

Figure 4: Refuelling process (repeated for each pair on onboard tanks)

As detailed in Section 5, an automotive standard for the refuelling protocol, which attempts to optimize refuelling time based on current conditions, was stated to be used but did not appear to be employed during the site visit, where the manual process described above was used. This likely resulted in a slower fueling process than might have been possible. However, given the limited nature of the deployment, the potential time savings may not have justified the additional effort required to implement the protocol. Protocols require all staff involved in the refuelling process remove all electronics while refuelling, and not undertake any refuelling during thunderstorms or for 15 minutes afterwards. All brakes must be applied, no external power may be connected, no occupants are permitted in the vehicle, and the refuelling area must be secured against unauthorized entry. NRC staff observed during the site visit that the hydrogen fuelling station appeared to be equipped with an infrared flame detector.

Figure 5: Refuelling and maintenance station

During the demonstration project, fuelling was completed daily for data-gathering purposes; Alstom indicated that weekly refuelling would be possible under normal circumstances. For the demonstration project, fuelling was conducted straight from a hydrogen tube trailer parked trackside.

UQTR noted that during the initial filling, the station lines and the trailer were purged with nitrogen to prevent air and hydrogen mixing, followed by multiple hydrogen purges to 3000 PSI to comply with SAE J2719 standards. Nitrogen activates the pneumatic valves during operations. The key safety measures during hydrogen train refuelling include:

- securing the area and restricting public access,
- conducting operations outdoors without potential gas retention zones for leaks,

- limiting system access to authorized personnel only,
- recommending personal protective equipment (PPE) for operators,
- prohibiting electronic devices within 5 meters,
- ensuring a fire extinguisher is nearby, and
- providing a manual emergency stop to isolate hydrogen reservoirs if needed.

Refuelling the Coradia iLint involved accessing the storage system from the vehicle's center at the inter-circulation area, using special couplings with anti-return valves. Protective flaps on reservoirs must be opened during refuelling and need to be monitored; a locked flap stops the train until unlocked. The Gas Transfer Module user manual (H079-MAN-002) was used to determine the necessary PPE for refuelling [1].

5 Codes and standards

A number of standards were referenced in relation to the project; however, in the absence of supporting documentation, it was not always clear which standards had been applied to the demonstration and which were intended for future North American applications. The UQTR notes that the Bureau de normalisation du Québec (BNQ) issued the CAN/BNQ 1784-000/2022 standard, which addresses the requirements for the installation of hydrogen production, distribution, and storage equipment. The most recent revision of this standard is designed to align specific requirements with the American NFPA2, "Hydrogen Technologies Code," thereby ensuring consistent practices between Canada and the United States for the safe application of hydrogen technologies [1]. All codes, standards, and regulations referenced were cross referenced to the Codes and Standards report from Phase I of this project [5]. The results of this cross-referencing are presented in Table 1.

Table 1: Cross-referenced codes & standards

Code, Standard, or Regulation	Mentioned in NRC Codes & Standards report [5]
49 CFR 238.233(a)	General application – not hydrogen specific
IEC EN 61373	General application – not hydrogen specific
EC No. 79	Repealed – no longer applicable
CSA/ANSI HGV 2	Yes
ISO 1988X	Yes
GTR13	No. Should be added going forward.
49 CFR 238.215	General application – not hydrogen specific
ASME B31.12	Yes
ASME B31.3	Yes – incorporated by reference in B31.12
NFPA130	General application – not hydrogen specific
49 CFR 238.103	General application – not hydrogen specific
EN 45545	General application – not hydrogen specific
49 CFR 239	Out-of-scope for Phase I
2014/68/EU	Yes – existing North American equivalents
SAE J2799	Yes

AAR M-1004	Yes
EN 17127	Out-of-scope for Phase I
IEC 62619	Yes
IEC 62928	Yes
NFPA2	Yes
SAE J2574	Yes – incorporated by reference
SAE J2578	Yes

As can be seen from the table, the majority of standards were included in [5]. For the remainder, all but one were out of scope for that report, being either of general application (i.e., not specific to hydrail) or not applying specifically to locomotives. An example is EN 17127—*Outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocols.* While undoubtedly relevant for hydrail deployment, it applies to support infrastructure rather than the locomotive itself, and was therefore not within scope for the Codes and Standards report from Phase I of this project [5].

Not discussed in [5] was GTR13: *Global technical regulation on hydrogen and fuel cell vehicles* in the Phase I report. While primarily a road vehicle regulation, portions of it may be adaptable to hydrail, and it should therefore be included for consideration in related work going forward.

Emergency guidelines related to system shutdowns and setback distances from public areas such as schools, playgrounds, and other community spaces were reported to be informed by practices used for hydrogen-fueled buses. While these references provide useful context, further clarification regarding the specific sources or versions of the requirements would support a clearer understanding of their applicability to the demonstration project.

6 Risks and hazards assessment

Concurrently with the iLint demonstration project, the NRC was developing a report on risk assessments for hydrail and battery locomotives [3]. This report classifies the risks into six categories, ranked here by frequency of identification:

- combustible mixture (hydrogen in air)
- high voltage (>50V)
- thermal runaway (of battery)
- over-temperature (insufficient cooling)
- enclosed space (decrease of oxygen in air)
- environmental exposure (e.g., ice on railroad tracks, coolant spill)

The NRC risk assessment [3] identified 501 specific instances of risk, with all but three classified as “low risk”. The remaining instances were classified as “medium risk” and related to:

- impact damage to a tank element,
- thermal pressure relief device failure during a localized fire, and
- hydrogen gas venting from the fuel supply system through the vent into an enclosed space.

Alstom stated that their method of addressing the risk of impact damage to a tank element was the provision of a rollover protection structure as per 49 CFR 238.215 to prevent any damage to the hydrogen tank or associated piping. The NRC risk assessment [3] cited compliance with the recently released CSA standard (TS-601) as a mitigating measure for this risk; when the final version of this standard is released, it may be possible to compare it to Alstom’s approach.

The thermal pressure relief devices and their arrangement were not visible during the site visits, but Alstom referenced CSA HGV2 in their correspondence on this subject. Compliance with this standard is listed as a mitigating factor in [3].

The demonstration project was conducted in a manner that ensured the train never entered an enclosed space. The maintenance area was in open air, and the route was selected for its absence of tunnels. There was therefore no need to address the risk of hydrogen gas venting into an enclosed space.

This demonstration highlighted a major challenge for hydrogen train deployments in Canada. Even if a comprehensive risk assessment is done, there are many mitigation options. Each project identifies mitigation measures from scratch, in the absence of North American or Canadian best practices, standards, or requirements.

7 Emergency preparedness and response

As discussed in Section 0, the cabin management system monitors smoke gas detectors in the passenger compartments, driver’s cab, and toilets. LHDs monitor for fire on the power converter housing, hydrogen tank, traction battery, fuel cell, and auxiliary system converter and heaters. A setback distance of nine meters from the hydrogen fuelling station was also employed.

Emergency response training and information were reported to have been delivered in accordance with standard passenger train regulations, involving crew members, maintenance personnel, and first responders. Certain aspects of emergency response planning were noted to be specific to the operator or to equipment beyond the scope of the demonstration trainset. It was also indicated that the first responder training was conducted in accordance with 49 CFR 239.

UQTR mentions that hydrogen safety training was provided by the Institut de recherche sur l'hydrogène (IRH) to key personnel in the project, including hydrogen delivery truck drivers, train conductors, onboard technicians, and operations managers. Among the staff trained by the IRH, all first-line project participants in Charlevoix operations were included.

Hydrogen delivery truck drivers are responsible for safely transporting hydrogen, adhering to schedules, and implementing safety procedures. They received training in dangerous goods transport and health and safety measures. Hydrogen refuelling technicians refill hydrogen reservoirs and ensure compliance with safety standards. They are trained in safety protocols and use personal protective equipment. Train conductors ensure train safety and operation, following strict protocols and undergoing specific training for the Coradia iLint. Hydrogen training enhanced their understanding of the ecosystem. Onboard technicians maintain train systems, conduct inspections, and handle repairs. They received specialized training on explosive atmospheres, brakes, and battery systems. The chief or head of onboard operations manages passenger experience and coordinates with conductors and technicians, ensuring safety and operational efficiency. Firefighters and first responders play a critical role in hydrogen-related emergencies, having received hydrogen safety briefings and training in emergency interventions. Their expertise in managing explosive gases is crucial for effective response [1].

8 Site Visits

The NRC conducted two site visits to the iLint train demonstration during the summer of 2023. Photos from those visits are included in this report.

On-site staff did not receive detailed information regarding the internal configuration of the fuel cell system, which may have reflected confidentiality considerations.

To on-site staff, the fuel cell power plant functioned largely as a closed system, with limited visibility into its internal components or operations. On-site staff mentioned that all 8 tanks were manifolded together with one solenoid valve downstream from the manifold. After the solenoid valve, a pressure regulator reduces the pressure to the fuel cell power plant. Downstream from the pressure regulator there is a secondary solenoid valve. This aligns with North American practices, which recommend providing two solenoid valves in series for redundancy in hydrogen storage systems with larger capacities.

Tank pressure and temperature were observed to be displayed in the driver's cab. Activation of one of the on-board smoke detectors or LHD was stated to result in a visual and audio alert at the driver's station, with the location of the activated sensor indicated on a display, with an accompanying audio alert sounding throughout the train. An operator manual and training were said to be provided for the train operator and cabin crew, with fuelling and maintenance being carried out by Alstom for the duration of the demonstration project, thereby removing the need to train operator staff in these activities.

Figure 6: iLint operator station

Siting of storage, fuelling, and maintenance areas were considered in setting up this demonstration project, with minimum distanced observed from other structures, vegetation, and people. The temporary nature of the demonstration project allowed for some implementation decisions that would likely be impractical for more permanent operations – for example, the open-air nature of the fuelling and maintenance facilities mitigated concerns regarding hydrogen accumulation, but would have raised challenges to winter operation.

9 Conclusion & Recommendations

The Charlevoix Railway demonstration project with the Alstom Coradia iLint hydrail train wrapped up as scheduled in September 2023 without incident. The two site visits provided an opportunity to observe a hydrail train in operation, although the temporary and geographically limited nature of the demonstration project did allow the operation to differ in significant ways from what could be expected from a permanent operation.

These two site visits, in combination with follow-up discussions with Alstom, yielded numerous insights into the design and operation of the train, including the propulsion system, operating and maintenance procedures, and insights into some challenges with bringing EU-designed trainsets to Canada where standards and regulatory requirements for hydrogen and battery systems are nascent.

Acronyms and abbreviations

BMS	Battery management system
BNQ	Bureau de normalisation du Québec
HTEC	Hydrogen Technology and Energy Corporation
HVAC	Heating, ventilation, and air conditioning
Hydrail	Hydrogen-powered train
IRH	Institut de recherche sur l'hydrogène
LHD	Linear heat detectors
LTO	Lithium-titanate-oxide
NMC	Lithium-nickel-manganese-cobalt-oxide
NRC	National Research Council of Canada
PPE	personal protective equipment
TC	Transport Canada

References

[1] M. Baudy, R. Gervais-Lavoie, M. Mohammadmirzaeibafghi, A. Hourri, Y. Bareha and M. Marchand-Lamarche, "Guide d’intégration, de gestion et d’opération d’un train à hydrogène en Amérique du Nord," Institut de Recherche sur l’Hydrogène, Université du Québec à Trois-Rivières, Trois-Rivières, 2024.

[2] M. Hernandez, I. Jimenez, C. Rabbitt and E. Toma, "Risk assessment of hydrogen and battery power in locomotives - Part 2 - Risks and hazards assessment," National Research Council of Canada, Ottawa, 2022.

[3] S. Girard, M. Hernandez and I. Jimenez, "Hydrail and Battery Locomotive Risk Assessment - Companion Report," National Research Council of Canada, 2024.

[4] D. Shirres, "RailEngineer," 16 12 2020. [Online]. Available: https://www.railengineer.co.uk/hydrogen-trains-coming-soon/. [Accessed 18 07 2024].

[5] M. Hernandez, C. Rabbitt, I. Jimenez and E. Toma, "Risk assessment of hydrogen and battery power in locomotives - Part 3 - Codes and standards," National Research Council of Canada, Ottawa, 2022.

[6] A. P. T. Association, "Battery-Electric and Hydrogen Passenger Rail Equipment Safety," [Online]. Available: https://www.apta.com/wp-content/uploads/APTA-PR-PS-WP-007-24.pdf.