C1Po3B-04: Development of the Cool Fuel School: A Comprehensive Hands-On Cryogenic Design and Safety Program

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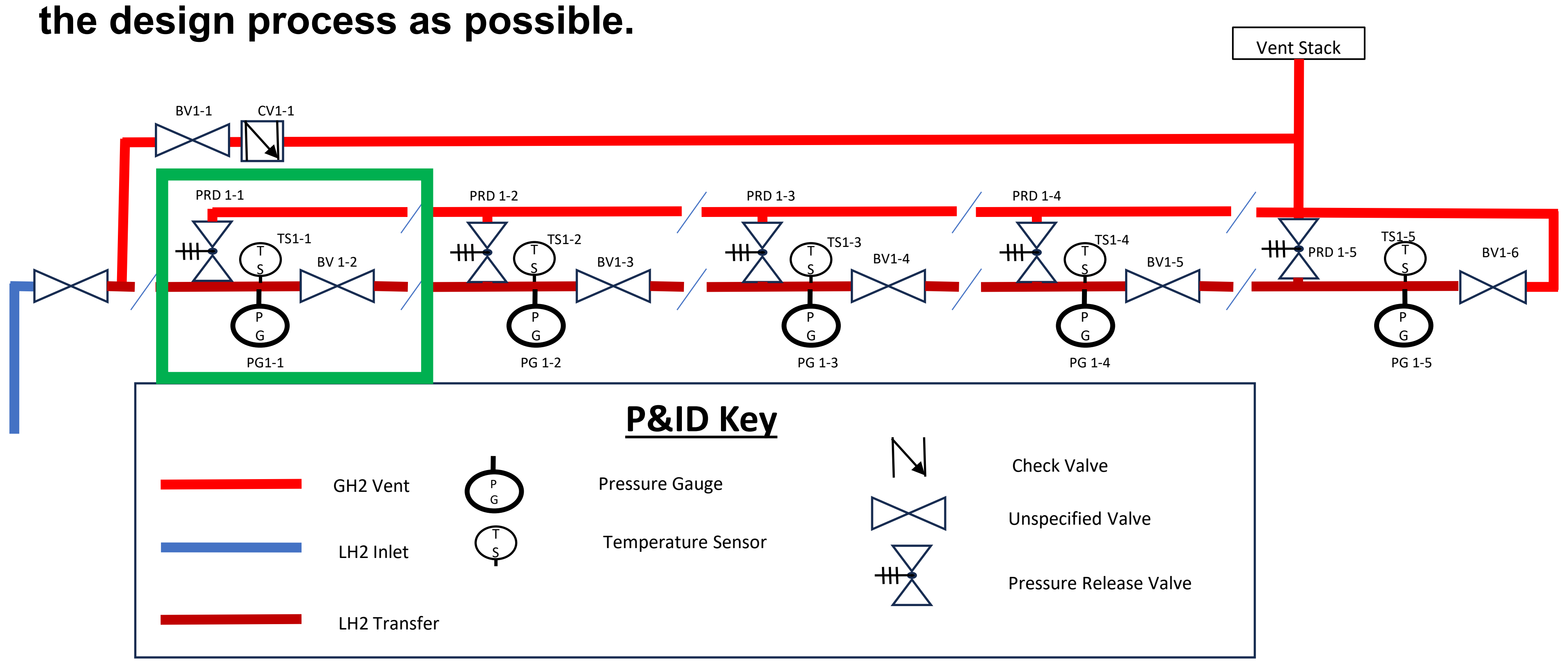
The HYPER-Chain in the process of performing a transfer of liquid Hydrogen from HYPER's Mobile Hydrogen Generation Unit

Developing a comprehensive hands-on cryogenic hydrogen design and safety training program

Investments in the hydrogen economy, including the 7-billion USD Hydrogen Hub initiative, are poised to greatly expand employment in the hydrogen sector. Training and education at all levels will be essential for ensuring hydrogen fuel maintains an excellent safety record amid expanding use. However, few cryogenic hydrogen safety programs are available and little to no data on program effectiveness are available in the open literature.

The HYPER Center has developed the Cool Fuel School – a week-long training program built from HYPER's safety onboarding for new lab members – to train outside engineers on safe design of cryogenic hydrogen systems. The program is centered around constructing the "HYPER-Chain" – a system to receive LH2, use it, and transfer it safely to an exhaust. Each participant is responsible for a link (shown in a green box in the figure below) of the chain, including flow control, pressure relief, and process variable monitoring. Participants are also introduced to HYPER's 10-stage integrated safety design process – by treating inherent safety as a design constraint, safety concerns are identified as early in the design process as possible.



At the end of the week-long course, participants use the components they built and the procedures they wrote to safely perform a liquid hydrogen transfer. This makes the Cool Fuel School the only program open to the public to allow an engineer hands-on experience with liquid Hydrogen.

The first open session of the Cool Fuel School will be held on-site at the HYPER Center in Pullman Washington, in December of 2025. Participants in this first session will complete pre- and post- assessments to evaluate the effectiveness of the program, which will then be used for continuous improvement of the program in future offerings.

Lesson 1: The "3 Bs" of Cryogenic Safety

Participants use liquid nitrogen to demonstrate the 3 key risks of cryogenic fluids, referred to as the "3 Bs": Burns, both hot and cold, Bursts from pressure buildup, and Breaths, oxygen displacement hazards. These risks will inform all safety planning for the remainder of the course.

Lesson 2: Safety Plans and the Design Process

Participants receive design requirements for the "HYPER-Chain" – a system to receive liquid Hydrogen from a source, transfer it through a valve manifold, and out to a safe exhaust. Participants learn the HAZOP and FMEA process to outline a Safety Plan – a document outlining how these design criteria will be safely met.

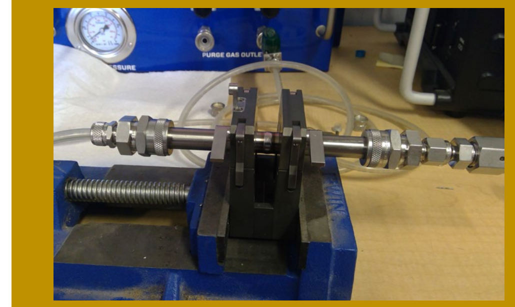
Lesson 3: Valving & Pressure Relief

Participants are introduced to CGA codes for safe use of pressurized gas, and learn how to select control valves and pressure relief valves to ensure safe operation of their link of the HYPER-Chain

Lesson 4: Instrumentation & Control

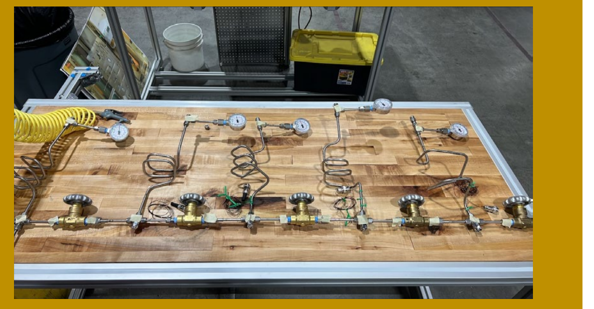
Participants learn how to select instruments to operate in vacuum, cryogenic temperatures, and flammable gas environments, then use that knowledge to pick monitoring instruments for their link of the HYPER-Chain.

Lesson 5: Fittings & Seals



Participants learn to use standards like NPT, VCR, and Swage, as well as Indium crush gaskets and orbital TIG welding to make airtight seals for cryogenic environments. These techniques are then used to assemble each link of the HYPER-Chain.

Lesson 6: Plumbing & CTE Matching



Participants learn how thermal contraction affects cryogenic systems, and how to select components for resilience to these effects. Those components are then installed on each link of the HYPER-Chain.

Lesson 7: Insulation & Vacuum

Participants learn how to use vacuum systems and thermal insulation around cryogenic systems. After learning about different types of vacuum insulation available, participants will select an appropriate type to use on their link of HYPER-Chain, then learn how to install it onto their system.

Lesson 8: Leak-Checking & Purge

Participants learn how to leak-check an assembled system using sound, bubble-checks, and mass spectrometers, then use vacuum purging or purge gasses to clear out any contaminants. After this lesson, each link of HYPER-Chain will be certified for cryogenic hydrogen service.

Lesson 9: Procedures and Procedural HAZOP

Participants draft procedures for operating the HYPER-Chain, then return to the HAZOP Process to assess each step of the procedure for inherent safety and resilience to operator error.

Lesson 10: Transferring LH2

Participants review the site safety requirements of NFPA-2 to verify that HYPER's Outdoor Research Facility is suitable for testing the HYPER-Chain with LH2, then use the procedures they wrote to receive LH2 into their link of HYPER-Chain and transfer it safely out to exhaust.

Acknowledgements: This program was developed in collaboration with Airbus

[1] ***Leachman, J. W., Matveev, K. I., & Wilhelmsen, Ø. (2025). Cool Fuel: The Science and Engineering of Cryogenic Hydrogen.***