HYDROGEN FUEL PRECOOLER

Objectives

- Design a heat exchanger system that can accept variable temperatures and flow rates of hydrogen gas, and output the gas at three standardized temperatures.
- Design PID control to ensure fuel reaches the desired standard.
- Design Parameters:
  - Inlet Temperature range: 50 to -20 ℃
  - Outlet Temperatures: -20, -30, and -40 ℃
  - H_2 Gas pressures: 10 MPa to 87.5 MPa
  - Pressure Ramp Rate: 1 MPa/min to 19.9 MPa/min

  (From SAE J2601 standards: T20, T30, T40)
- Requirements/Conditions:
  - Closed-Loop System
  - Fueling Heavy Duty Vehicles
  - Limit pressure drop
  - Outdoor operation
  - Long term use

Industry Overview

- Benefits:
  - Light, storable, energy dense, and versatile
  - Can be transported by pipeline or ship
  - Environmentally friendly (when produced by nuclear or renewable energy)
  - Helps to decarbonize energy and transportation industries
  - Growing demand and support, globally
- Challenges:
  - Integration into established industries (transportation, building, power generation)
  - Currently produced using fossil fuels, which contributes to CO_2 emissions

Oregon State University

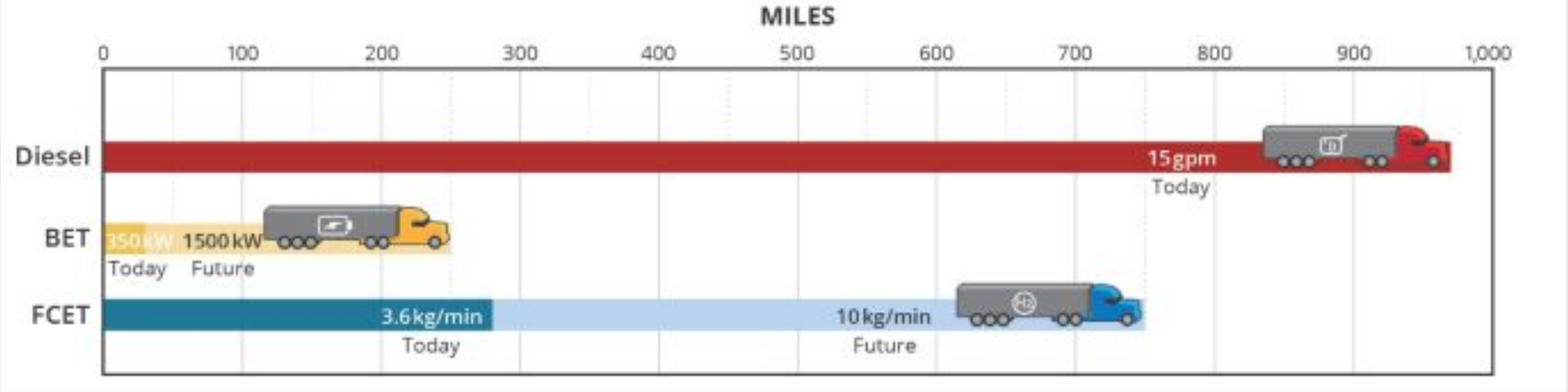
Exploring the future of fueling with renewable Hydrogen Fuel, working on proposing a fueling solution for Heavy Duty vehicles including larger trucks which make up ~72% of all US freight transportation in the US

Background

Hydrogen gas is a low emission fuel with a high energy content that could act as a replacement for conventional fuel sources. With current technology, hydrogen fuel can push a vehicle more than 6 times the distance per pound of fuel used (27 miles H_2 vs 4 miles gas). However delivery must be done at high pressures and low temperatures to store enough fuel within the vehicle for extended range use.

For Heavy Duty vehicles, high pressure hydrogen fuel needs to be delivered within a target of 5 minutes, and must meet a 70 MPa pressure threshold

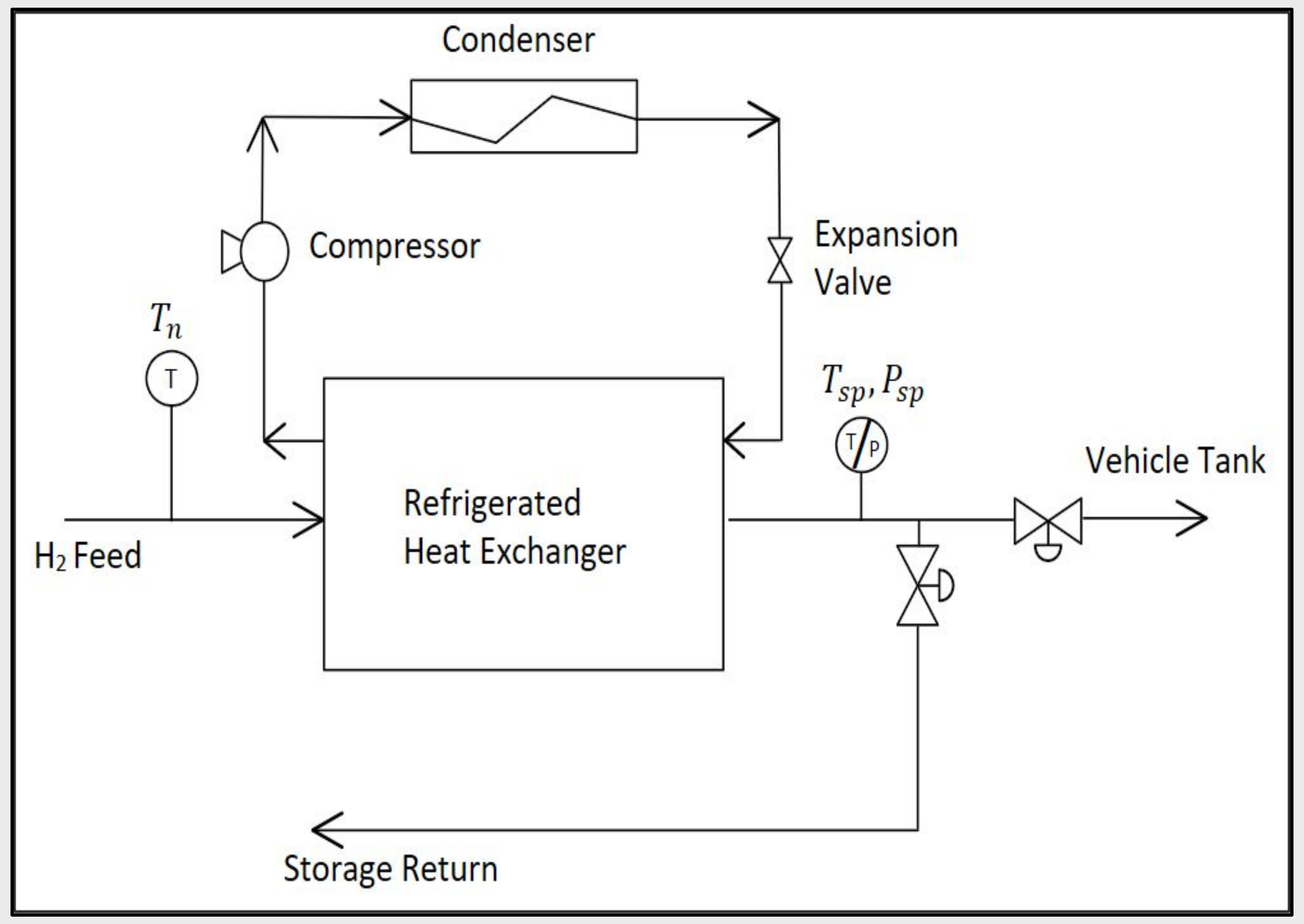
(Generated using DreamStudio by StabilityAI)



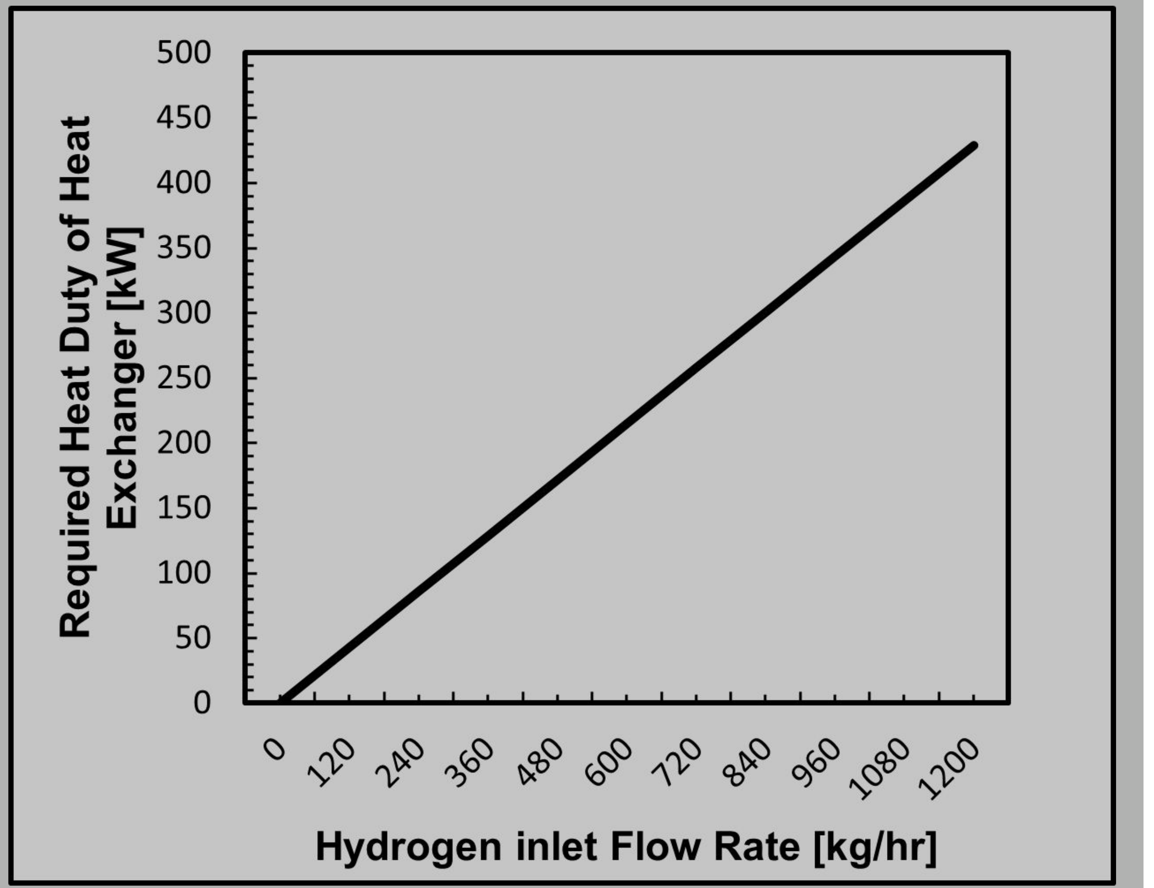
(California Hydrogen Business Council 2020 Fact Sheet)

Design process

- To complete our design, we opted to use the highest possible demand on the heat exchanger, cooling hydrogen from 50 to -40 ℃ at our expected max flow rate of 20 kg/min.
- Our team opted to use a conventional refrigeration setup as opposed to a more exotic version and we chose to use a different refrigerant than the onsite R410a.
- We opted for a smaller sized heat exchanger with high heat exchange area to reduce the overall footprint of the fueling station
- Since the pressure of the hydrogen coming in is variable a PID temperature controller is needed to account for fluctuating inlet flow rate



Energy use analysis



This figure shows the the heat duty of the heat exchanger as hydrogen inlet flow increases at the worst case scenario of an inlet flow of 50 ℃ with the maximum flow of 1200 kg/hr being the maximum we would expect for this process.

Future

- Research more into compressor efficiency and aggregating into a single stage unit rather than multiple stage compression.
- Research further into alternative methods of cooling (i.e. vortex tubes) as a possible route to reducing coolant.
- Research into alternative types of refrigeration coolants that are more efficient and less toxic than the refrigerants currently in use
- Research into different methods of heat exchanging to reduce overall size of process and footprint of the fueling station

Acknowledgements

We would like to thank our sponsor, Jacob Thorson at National Energy Research Laboratory, and our teaching team Dr. Nicholas AuYeung, Dr. Patrick Geoghegan, and our LA Owen Case.