SAND2019-13054PE



Design and Footprint of Liquid Hydrogen-Supplied Refueling Stations for Urban Sites

Brian Ehrhart

Sandia National Laboratories

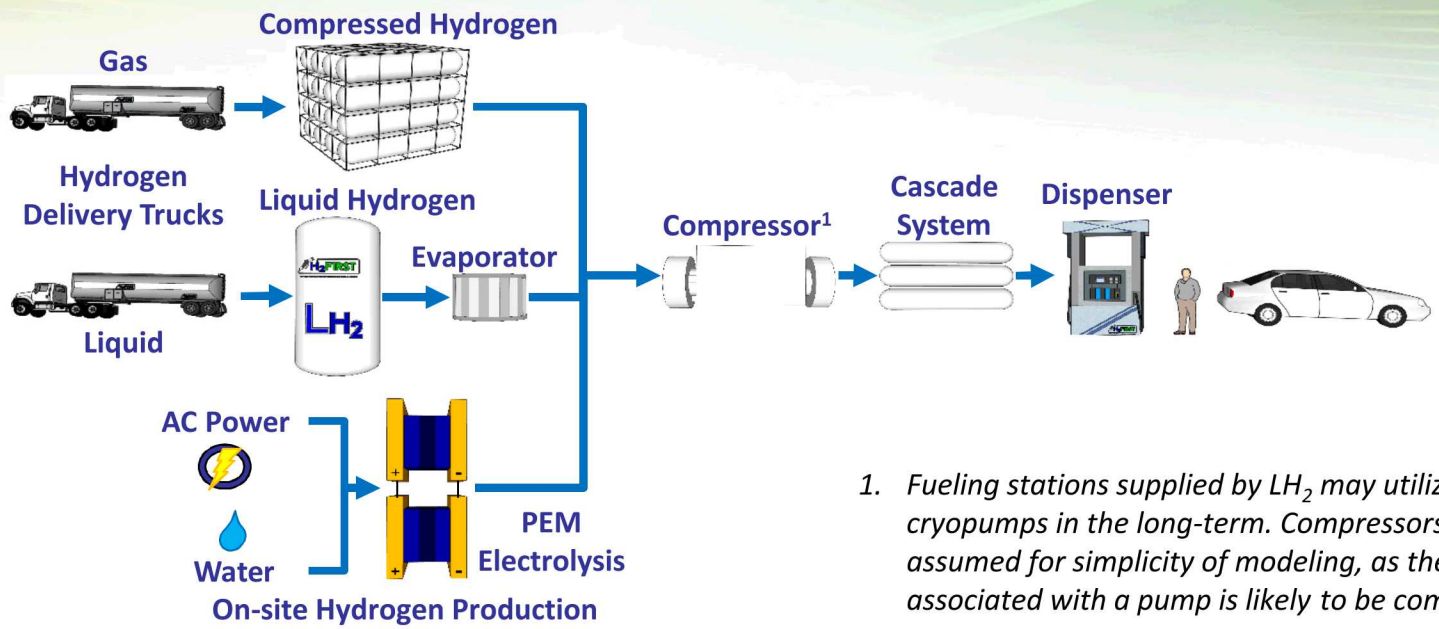
Call with NREL and UMD

October 29, 2019

SAND2019-XXXX

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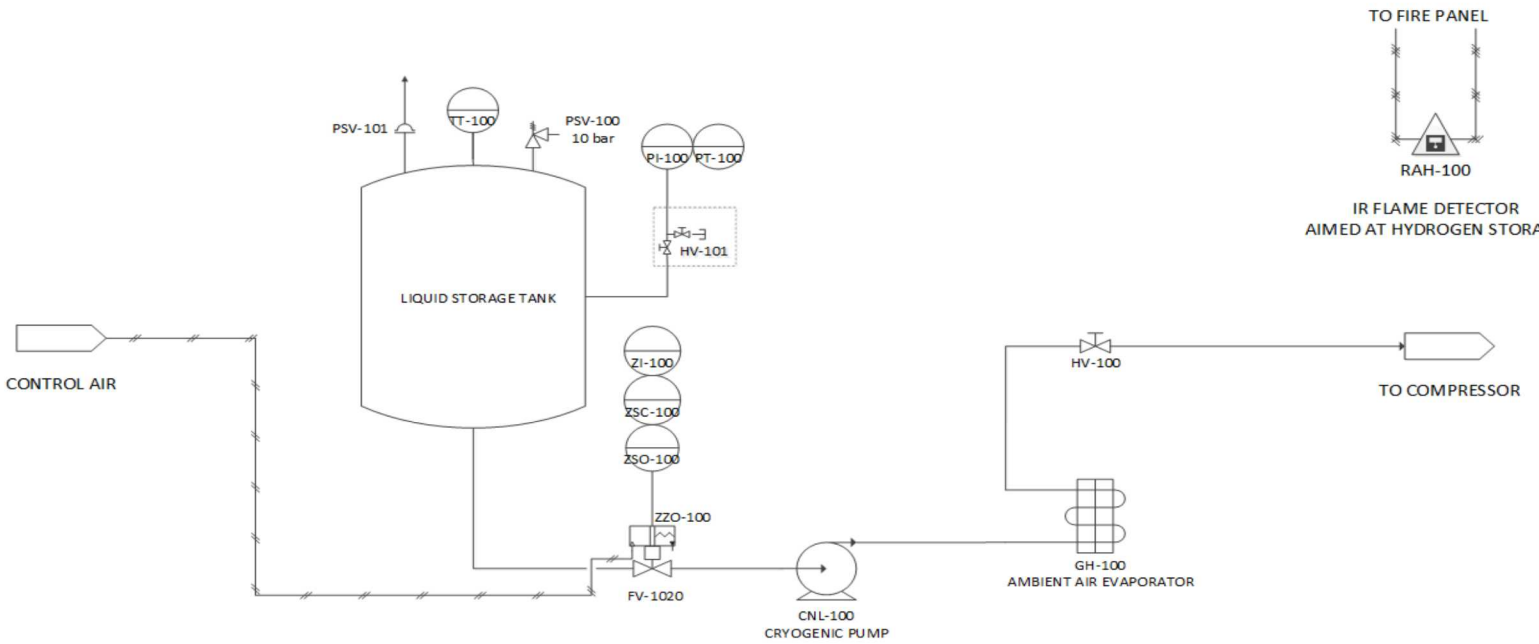
Specified components needed for three methods of hydrogen supply



1. *Fueling stations supplied by LH_2 may utilize cryopumps in the long-term. Compressors were assumed for simplicity of modeling, as the footprint associated with a pump is likely to be comparable.*

- Compressor
  - 25 kg/hr flow rate (constant 600 kg/day)
  - Outlet pressure of 94.4 MPa (13,688 psi)
- Chillers
  - 25.2 kW (7.2 tons) of refrigeration needed for each chiller
  - Aluminum cooling block of 1,330 kg (0.49 m^3) needed for each
- Cascade
  - 10 cascade units, each containing 5 (1:1:3) pressure vessels
  - Outlet flow rate 60 kg/hr to each dispenser
- Dispensing
  - 4 fueling positions, 70 MPa, -40°C

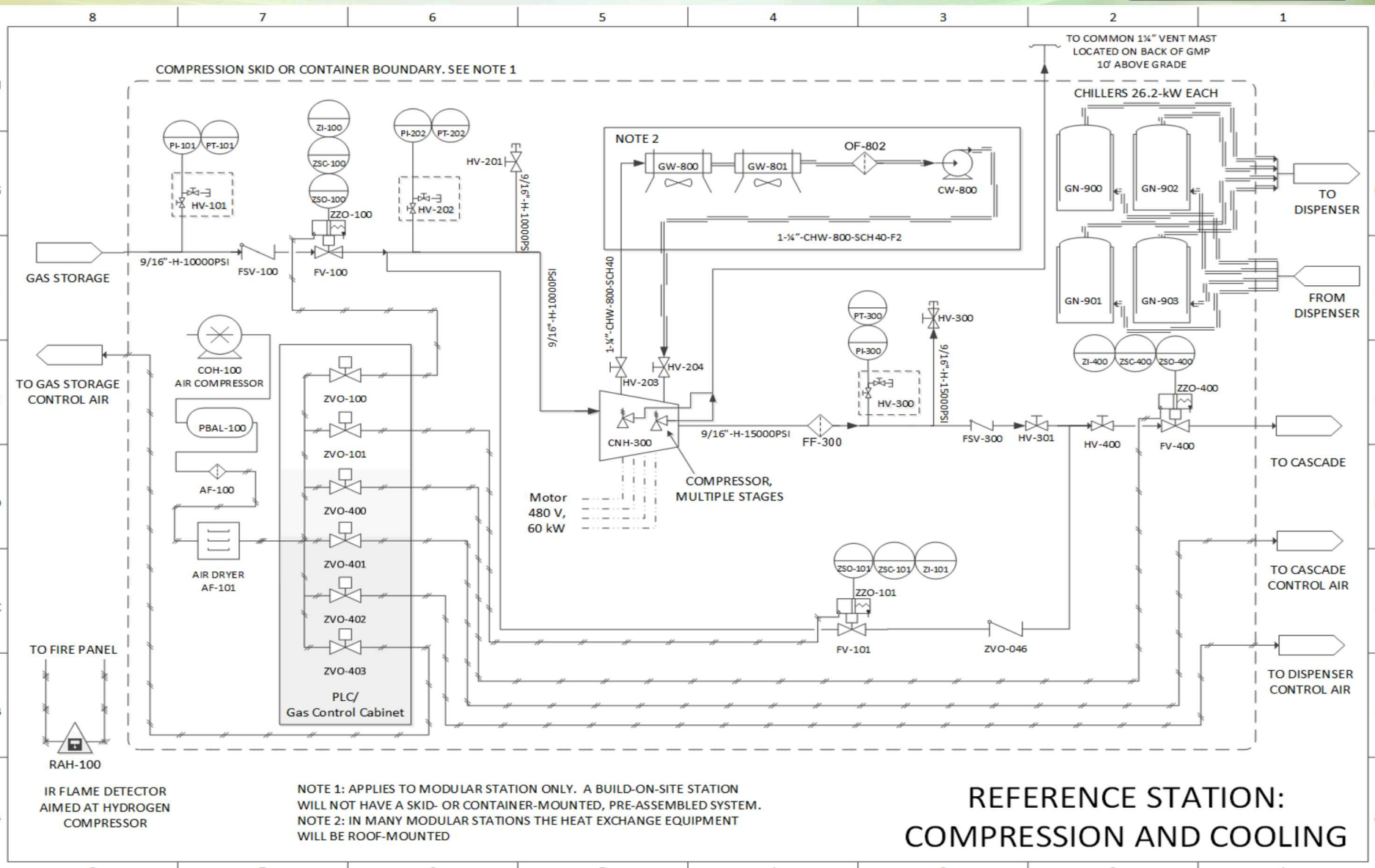
Liquid Storage P&ID



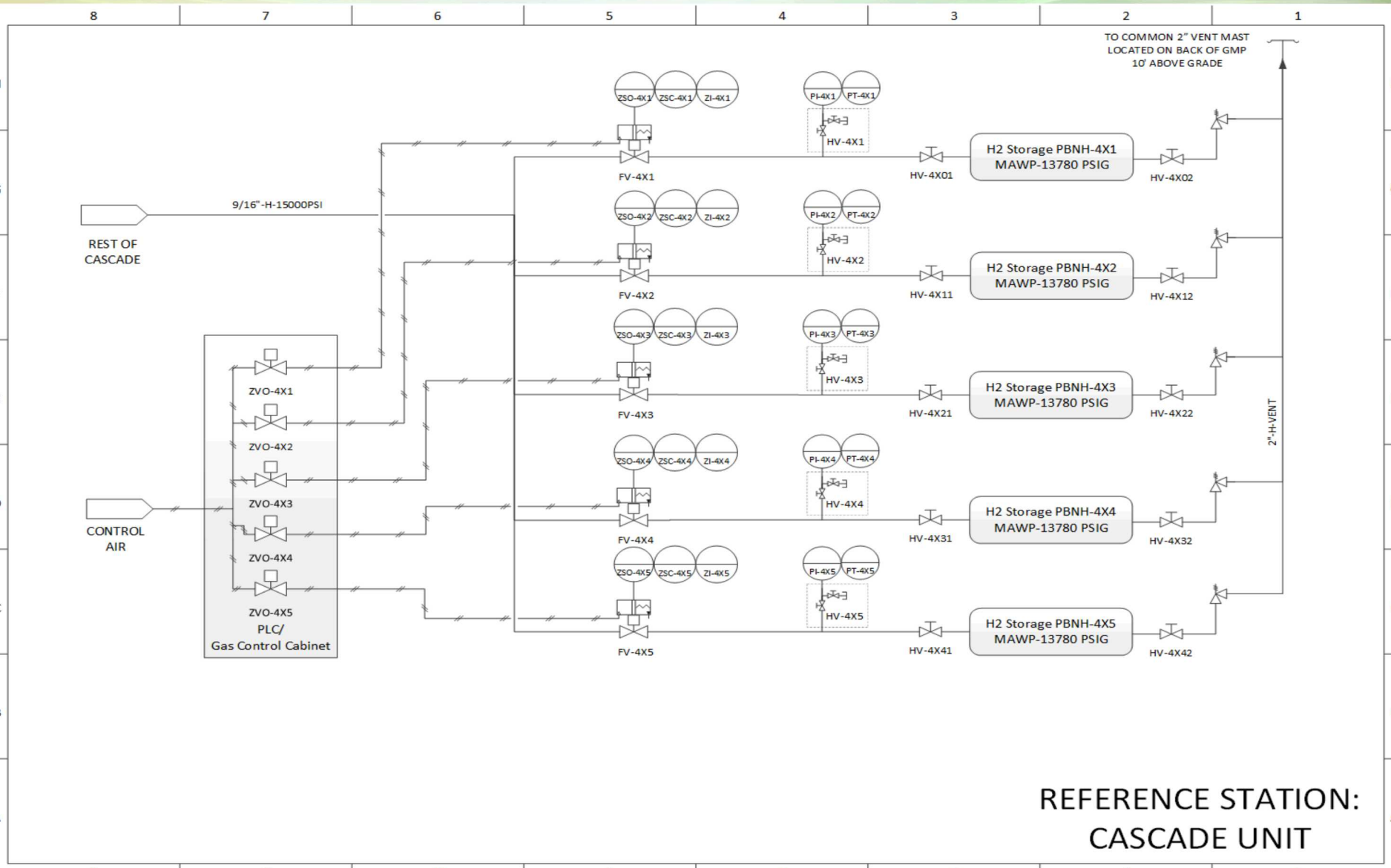
NOTE 1: APPLIES TO MODULAR STATION ONLY. A BUILD-ON-SITE STATION WILL NOT HAVE A SKID- OR CONTAINER-MOUNTED, PRE-ASSEMBLED SYSTEM.

REFERENCE STATION: LIQUID STORAGE

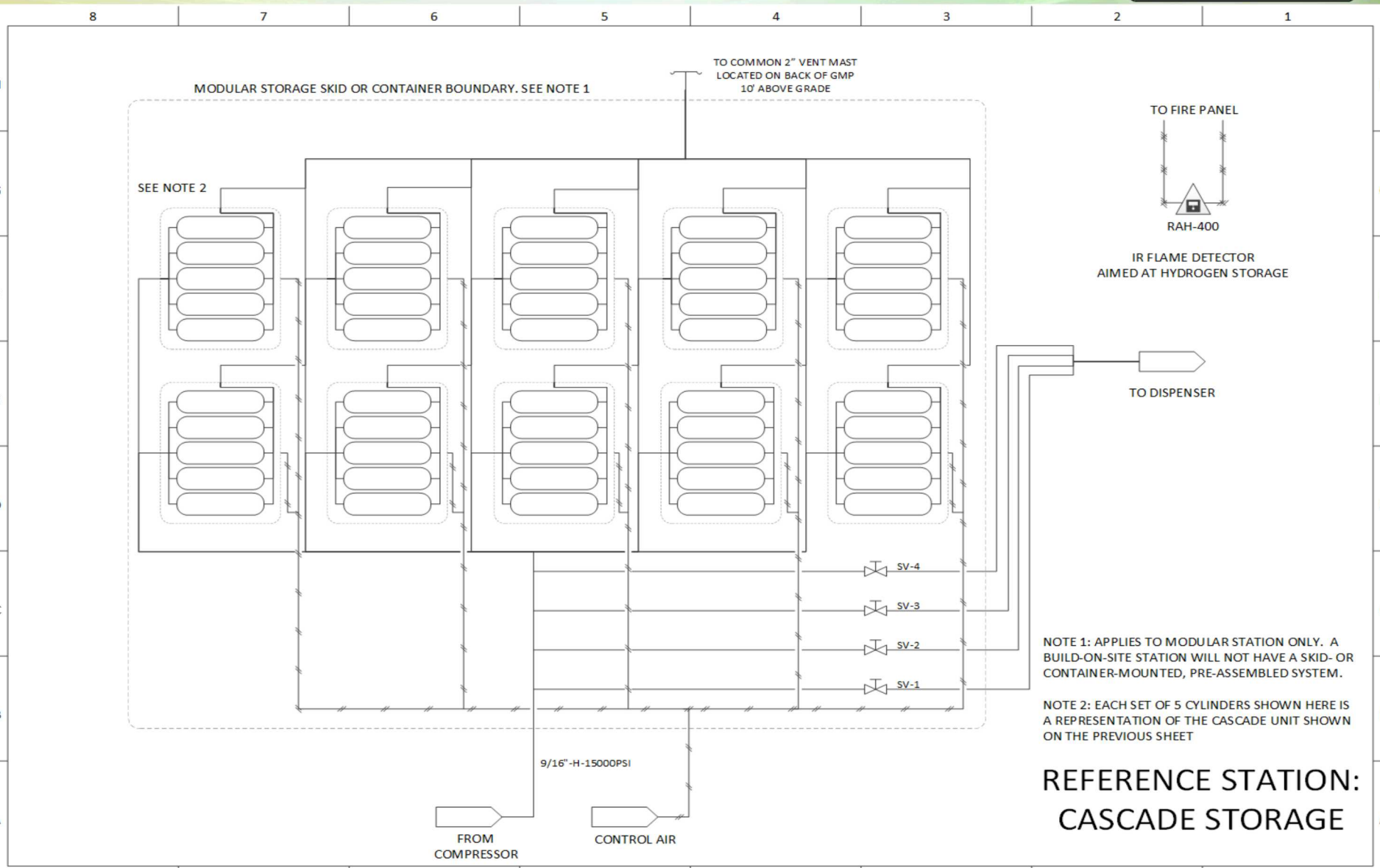
Compressor and Other Equipment P&ID



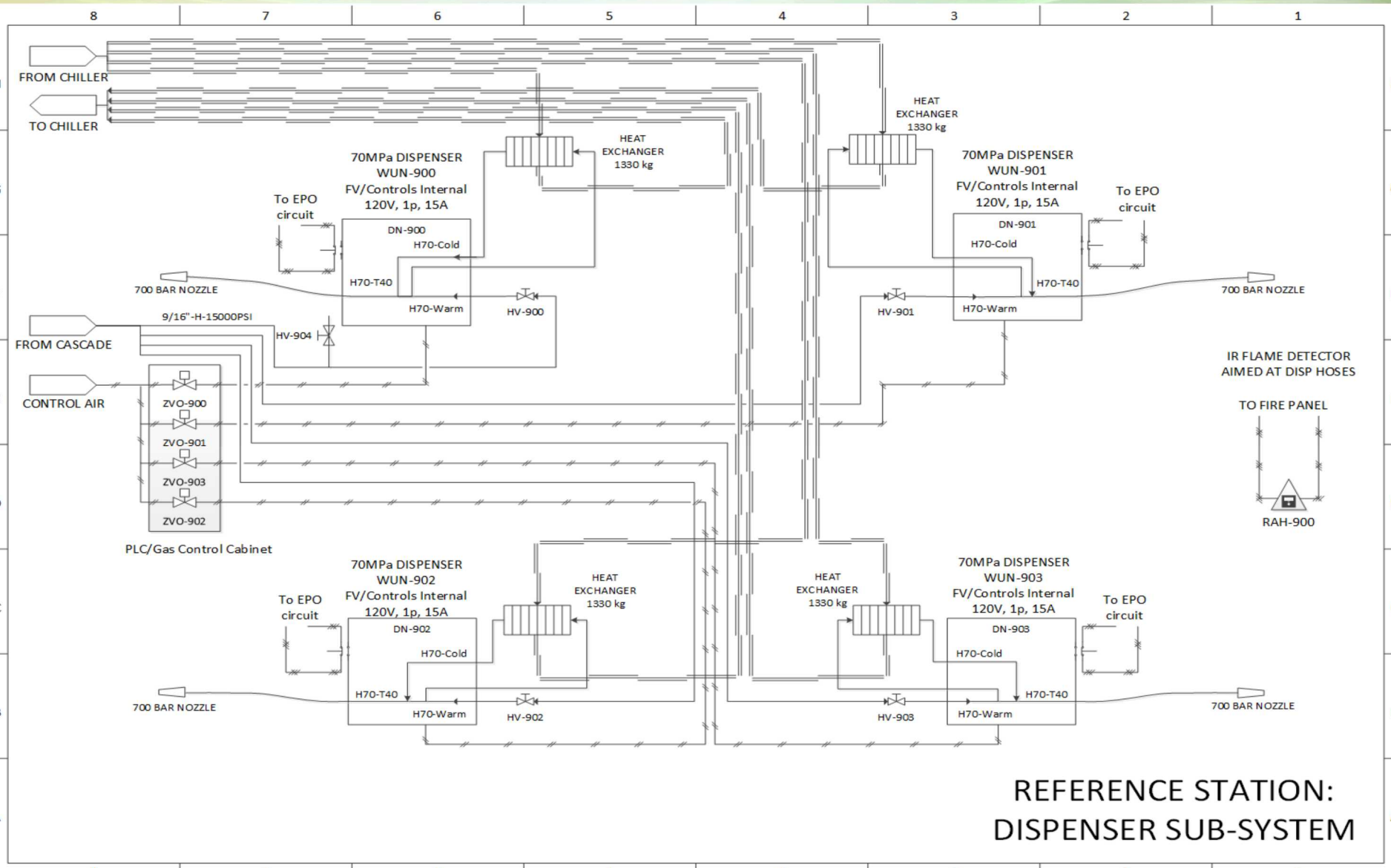
Cascade P&ID - Detail



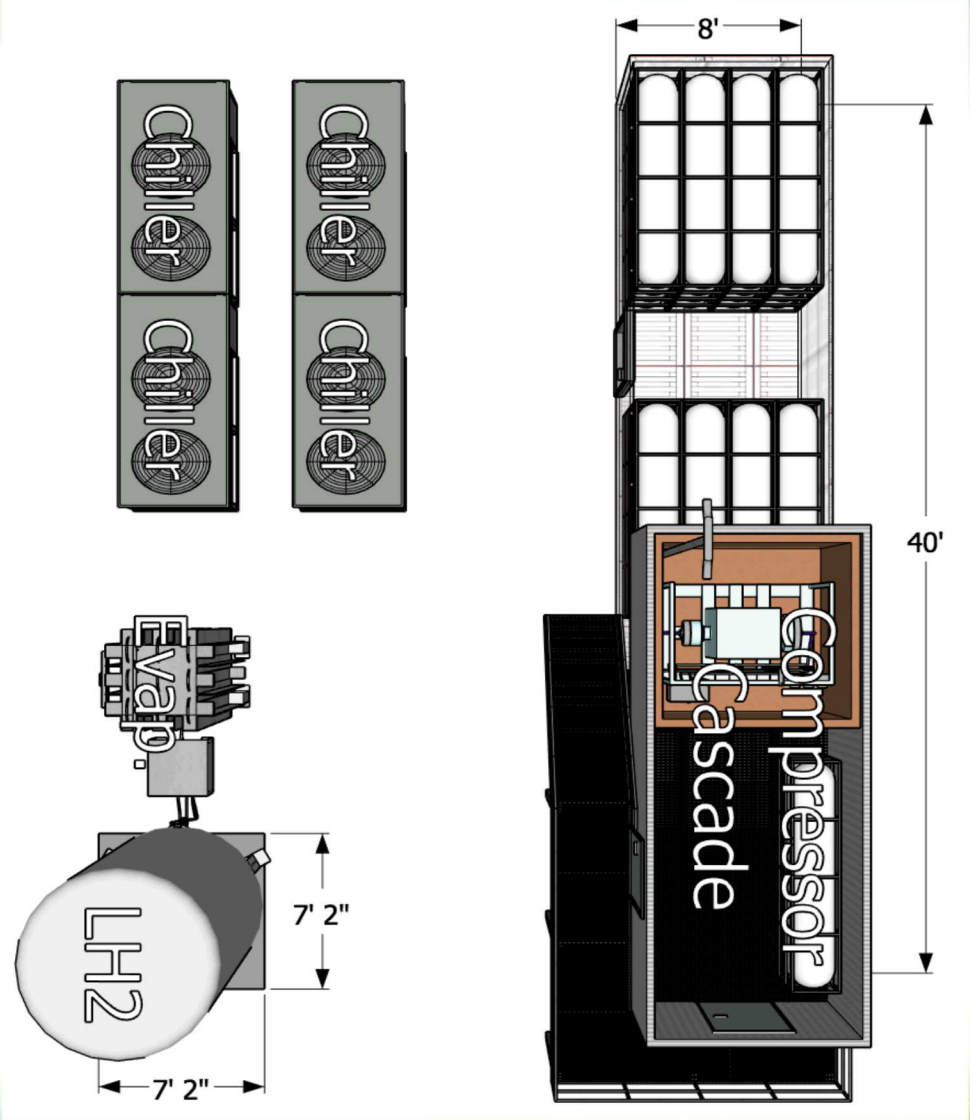
Cascade P&ID - Overview



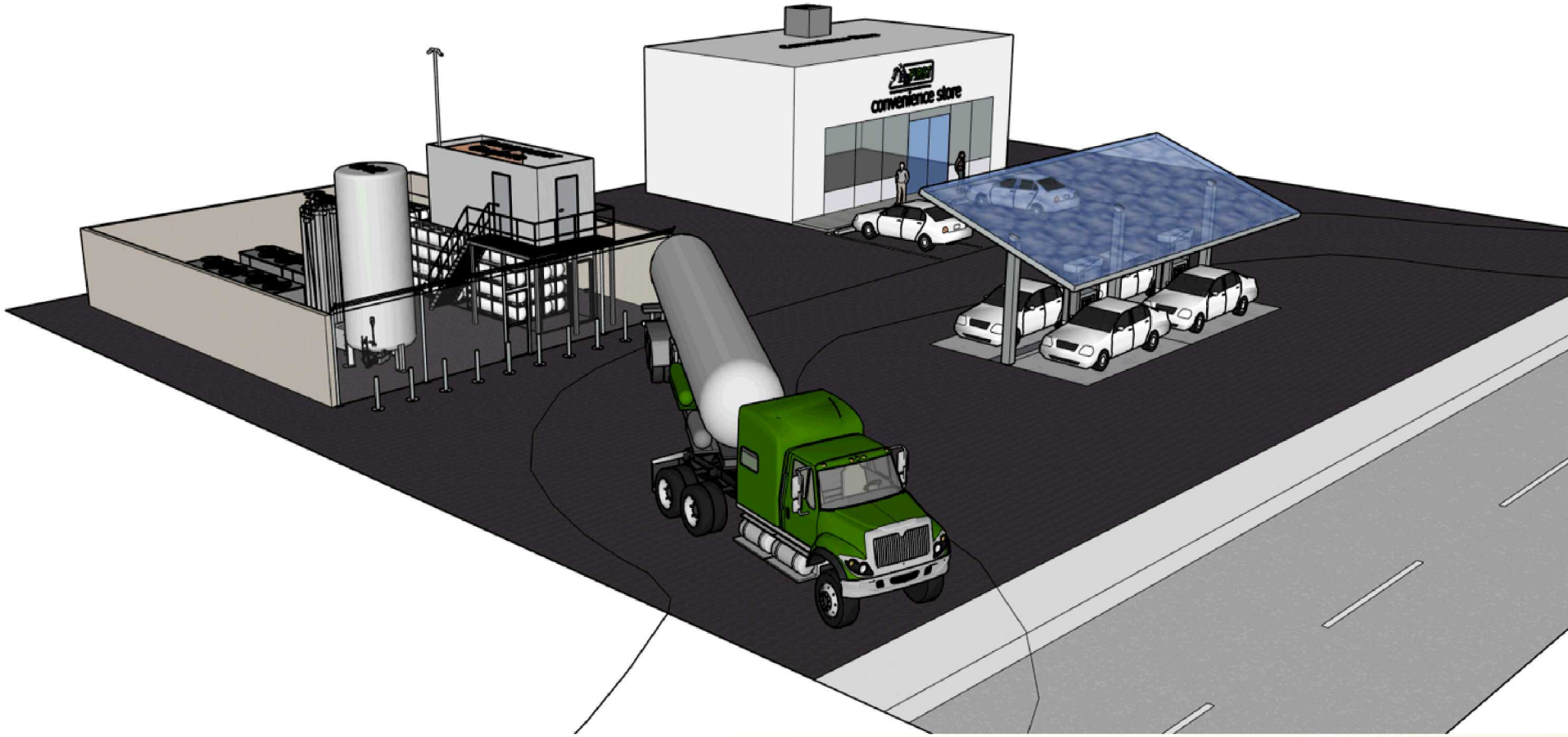
Dispenser P&ID



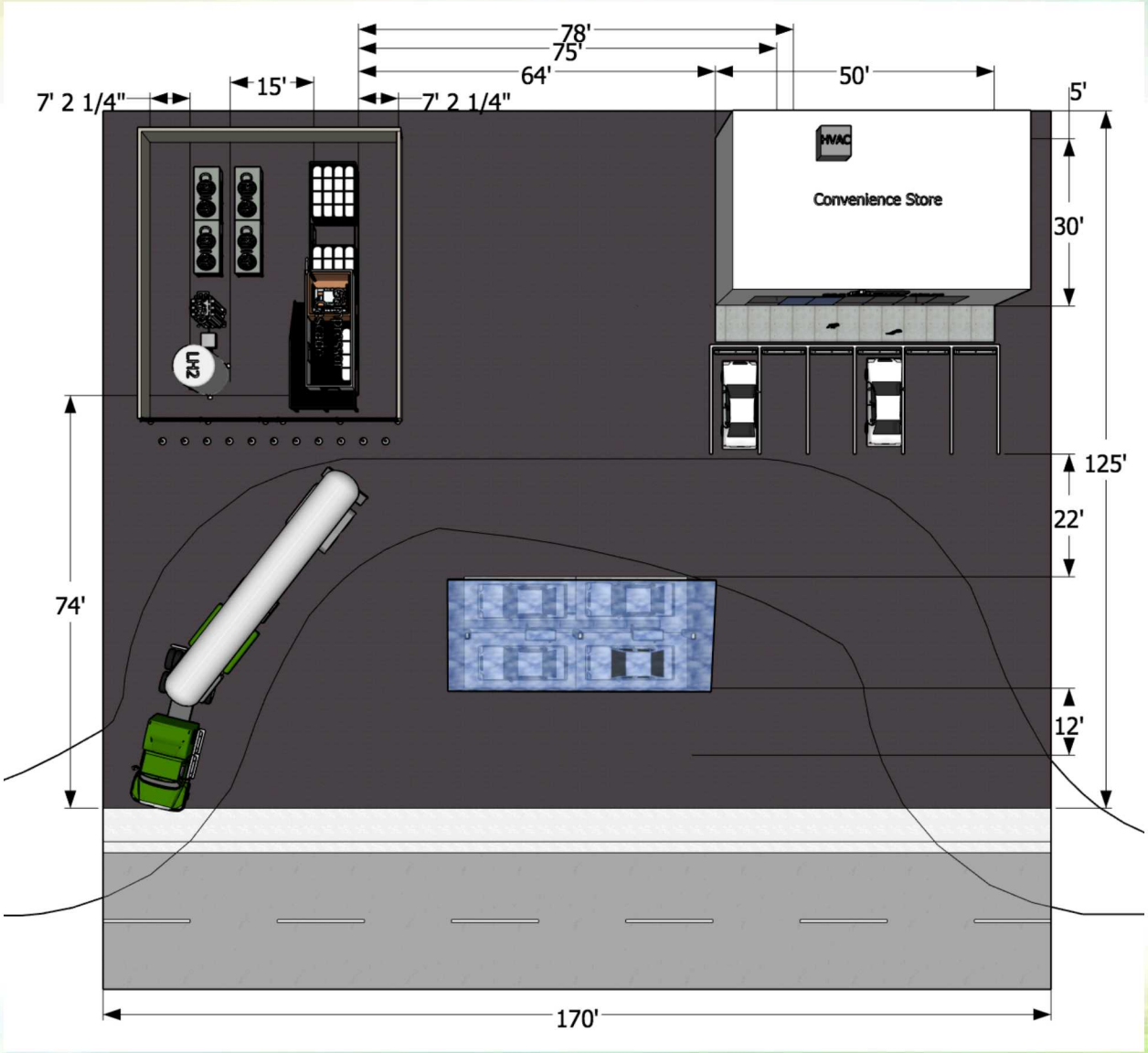
Hydrogen System Layout



LH2 Base Case View



Base Case Liquid: Large footprint due to delivery truck and non-reducible 75 ft. air intakes setback



- Bulk liquid storage
  - 800 kg, 11,299 L (2,985 gal)
- Lot size: 170 x 125 ft
- Total Area: 21,250 ft^2

Identified challenges in interpretation and implementation of NFPA 2 leading to code updates

Gaseous setback distances

- Large system can have "bulk storage" before and after compressor

- Complexity of system makes selection of single pressure and diameter challenging
  - Single system could take worst-case: maximum pressure from one area and maximum ID from other area
  - Could also calculate setback distances for each system section and select largest
    - In Appendix I, but nowhere else

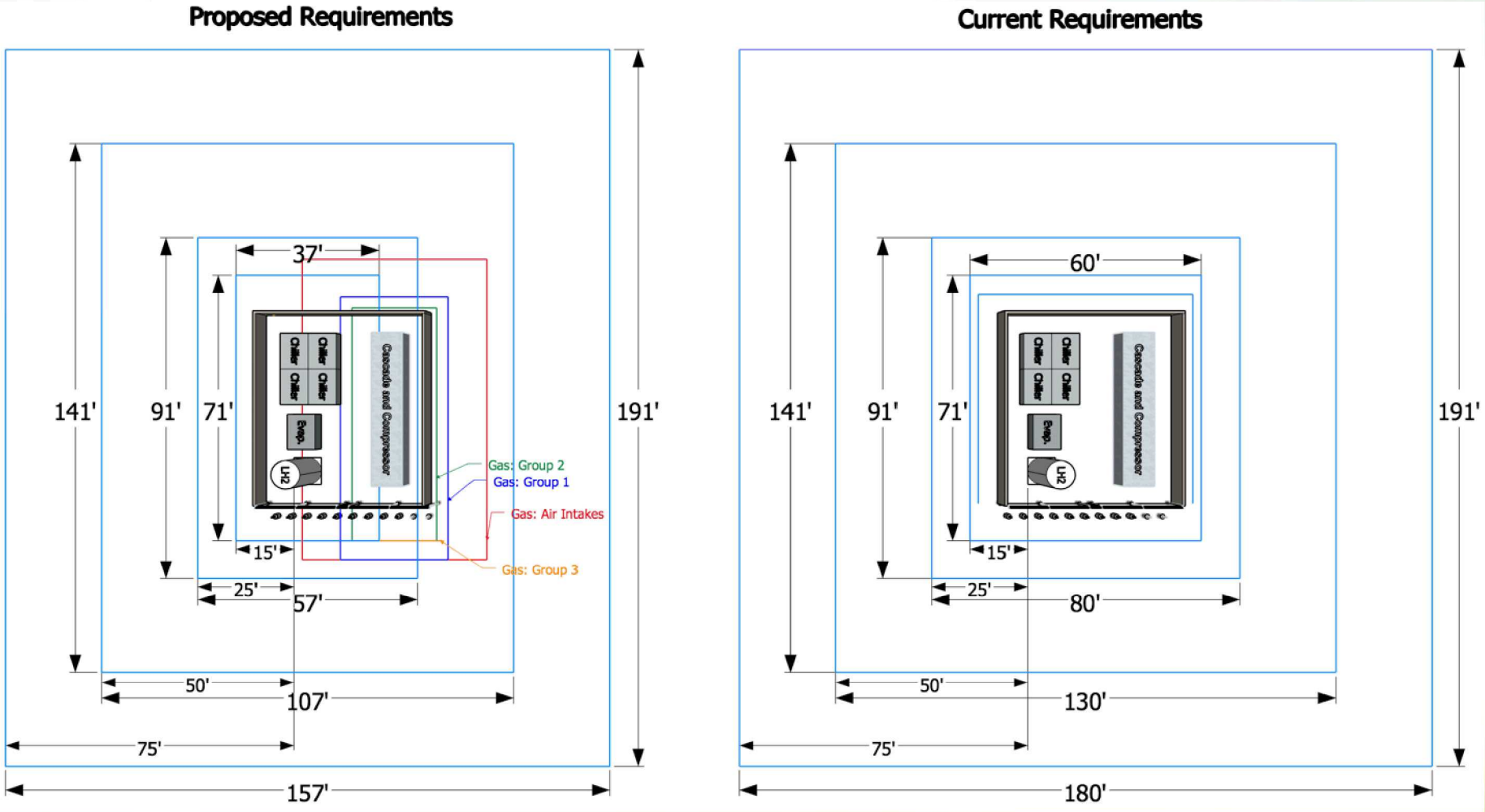
Calculations for larger system may lead to unintended setback distances

Liquid setback distances

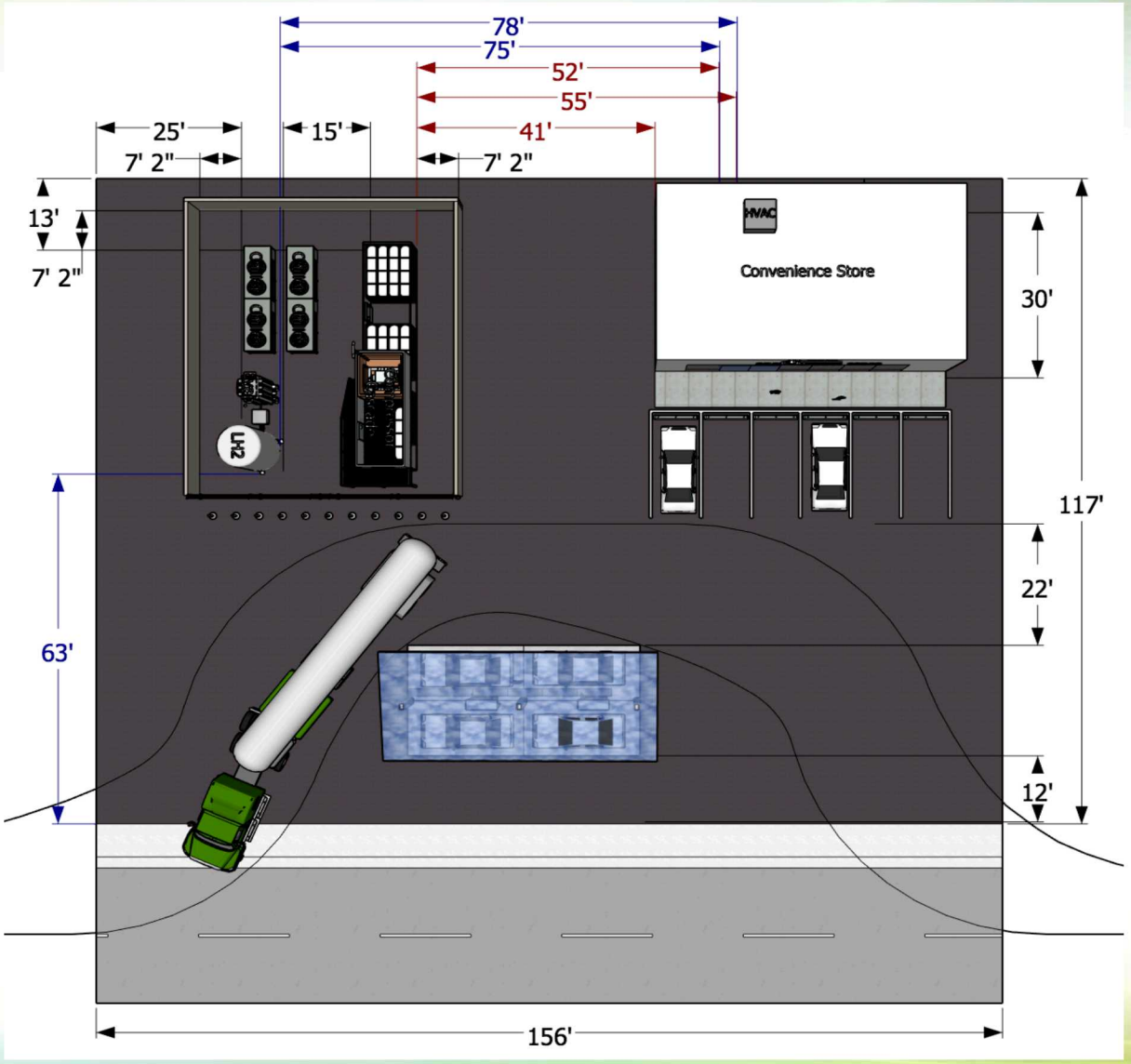
- Hybrid system (liquid-to-gas) analyzed as all-liquid system
  - ***Recently changed in 2020 Ed. of NFPA 55/2***
- Setback distances are different for most exposures, only a few able to be reduced

Group	Exposure	Reducible	Distance
1	1 Lot lines	Yes	15 m (50 ft)
	2 Air intakes		23 m (75 ft)
	3 Operable openings in buildings		23 m (75 ft)
	4 Ignition sources		15 m (50 ft)
2	5 Places of public assembly		23 m (75 ft)
	6 Parked cars		1.7 m (25 ft)
3	7(a)(1) Sprinklered non-combustible building	Yes	1.5 m (5 ft)
	7(a)(2)(i) Unsprinklered, without fire-rated wall	Yes	15 m (50 ft)
	7(a)(2)(ii) Unsprinklered, with fire-rated wall	Yes	1.5 m (5 ft)
	7(b)(1) Sprinklered combustible building	Yes	15 m (50 ft)
	7(b)(2) Unsprinklered combustible building	Yes	23 m (75 ft)
	8 Flammable gas systems (other than H2)	Yes	23 m (75 ft)
	9 Between stationary LH2 containers		1.5 m (5 ft)
	10 All classes of flammable and combustible liquids	Yes	23 m (75 ft)
	11 Hazardous material storage including LO2	Yes	23 m (75 ft)
	12 Heavy timber, coal	Yes	23 m (75 ft)
	13 Wall openings		15 m (50 ft)
	14 Inlet to underground sewers		1.5 m (5 ft)
	15a Utilities overhead: public transit electric wire		15 m (50 ft)
	15b Utilities overhead: other overhead electric wire		7.5 m(25 ft)
	15c Utilities overhead: hazardous material piping		4.6 m (15 ft)
	16 Flammable gas metering and regulating stations		4.6 m (15 ft)

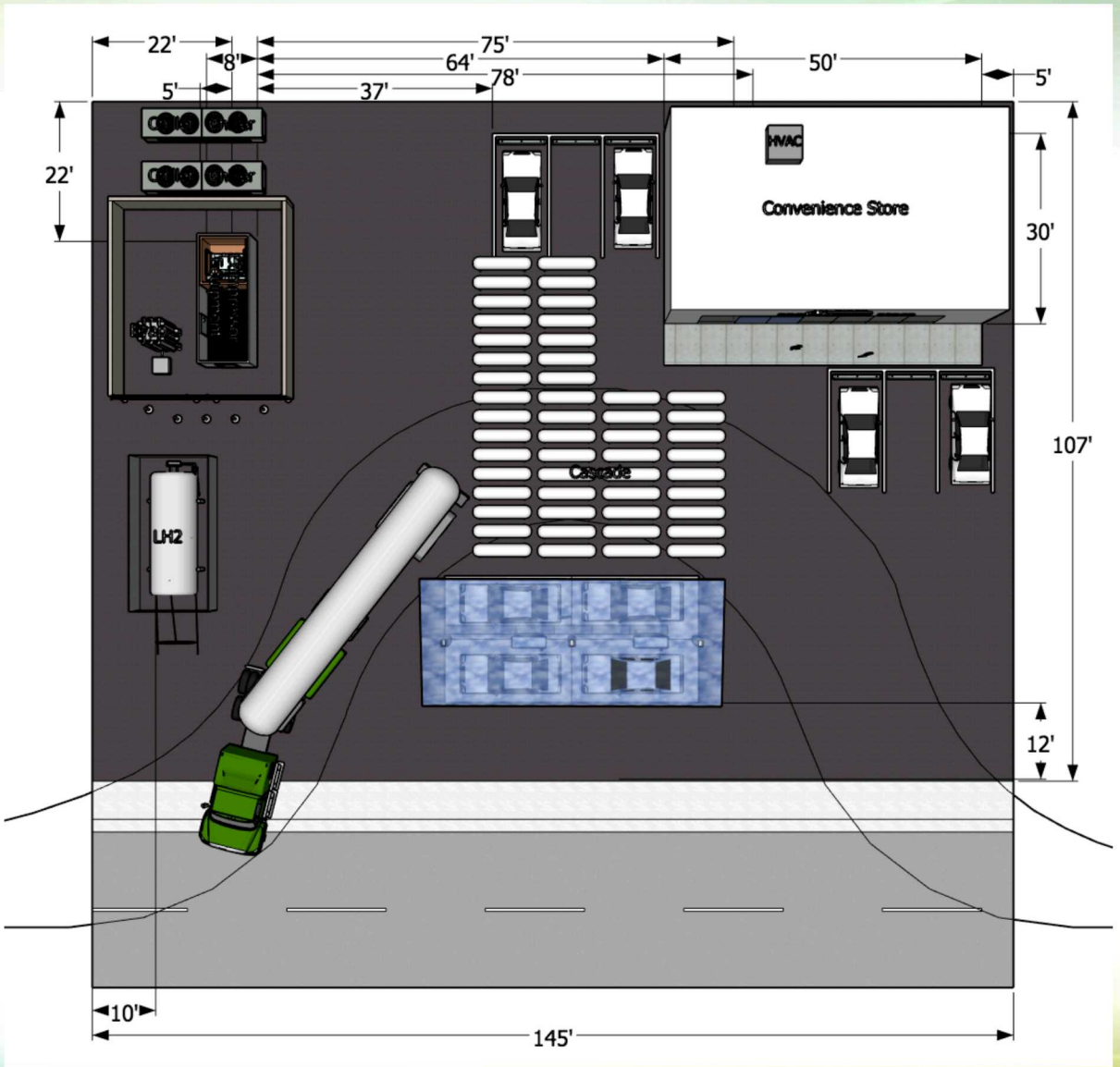
NFPA 2020 Requirements



New NFPA 2020 Liquid Station Layout



Underground Direct Bury



Summary of lot sizes for all cases

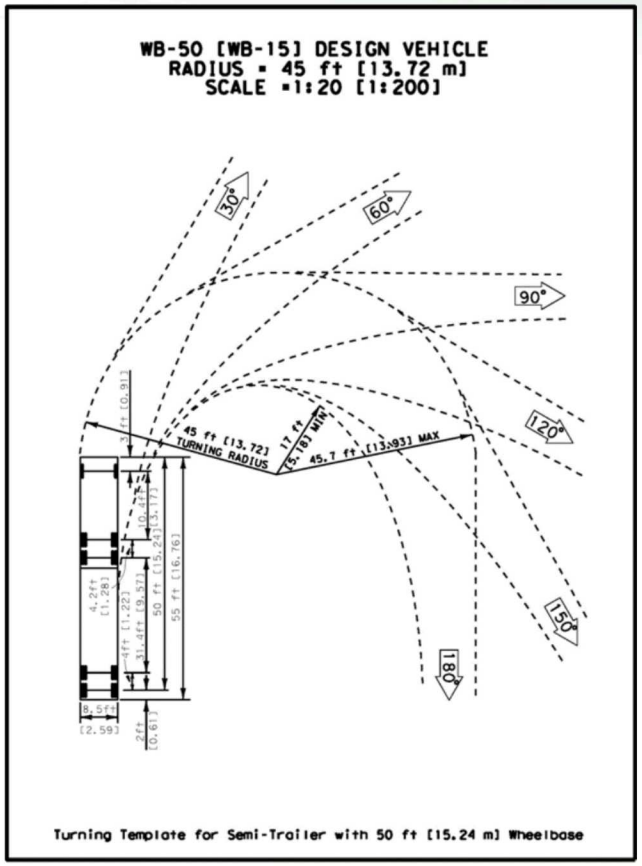
	Design	Total Lot Area (ft^2)	Reduction from Base Case
Delivered Gas	Base Case Gas	17,640	--
	New NFPA Separation Distances	17,640	0.00%
	New Delivery Single Truck	14,391	18.42%
	New Delivery Double Truck	15,875	10.01%
	Gasoline Co-Location	21,980	-24.60% (Increase)
	Underground Direct-Bury	16,060	8.96%
	Underground Vault	13,720	**22.22%**
	Rooftop Storage	15,400	12.70%
Delivered Liquid	Base Case Liquid	21,250	0.00%
	New NFPA Separation Distances	18,252	14.11%
	New Liquid Delivery	19,080	10.21%
	Gasoline Co-Location	**25,330**	-19.20% (Increase)
	Underground Direct-Bury	15,515	**26.99%**
	Rooftop Storage	19,840	6.63 %
On-Site Electrolysis	Base Case	14,756	0.00%
	New NFPA Separation Distances	**11,934**	19.12%
	Gasoline Co-Location	21,980	-48.96% (Increase)
	Underground Direct-Bury	13,340	9.60%
	Underground Vault	16,240	-10.06% (Increase)
	Rooftop Storage	11,466	22.30%

TECHNICAL BACK-UP SLIDES

Non-hydrogen station components have large impact on footprint

Assumptions and considerations:

- Delivery truck path
  - Trucks must be capable of turning without reversing
  - Corner lot not considered (entry and exit only on single lot side)
- Convenience store
  - 50 x 30 ft
- Parking/Traffic Flow
  - Convenience store parking
  - Fueling positions
  - UT Parking Lot Design Manual
- Kept consistent between designs
- System was idealized for comparison
  - Other location-specific factors will also have large impact on footprint



Texas DOT Road Design Manual