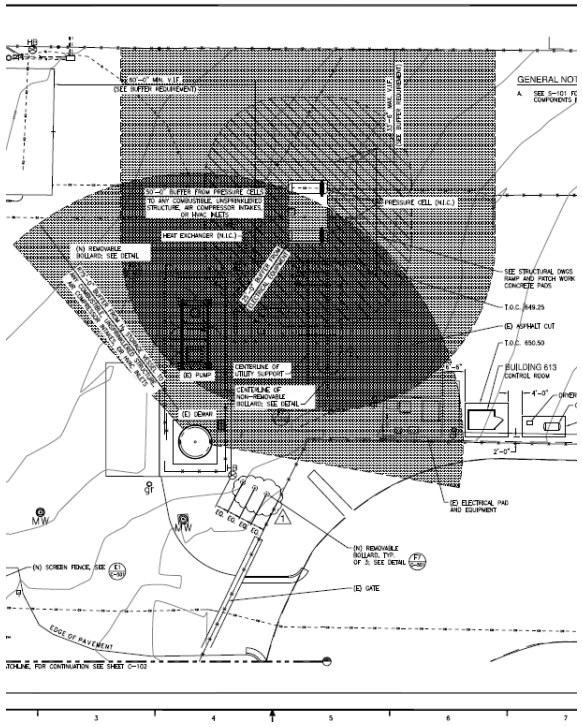
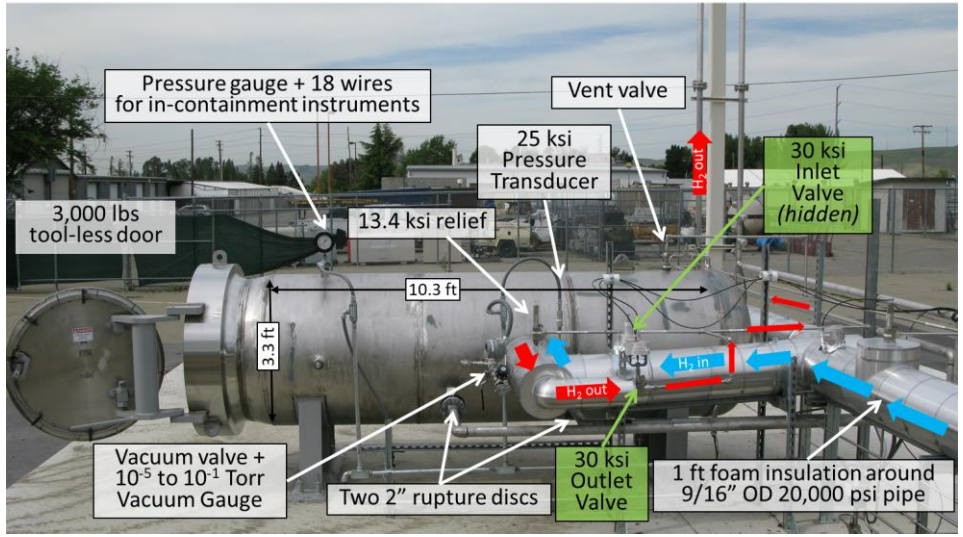
Instrumentation at LLNL's LH_2 facility (California, USA)

Dr. Guillaume Petitpas, Air Liquide





PRESLHY

Prenormative Research for Safe Use of Liquid Hydrogen

Research and Innovation Action Supported by the FCH JU 2.0

2nd Project Meeting / October 16-18, 2018

Air Liquide CRPS, Loges-En-Josas

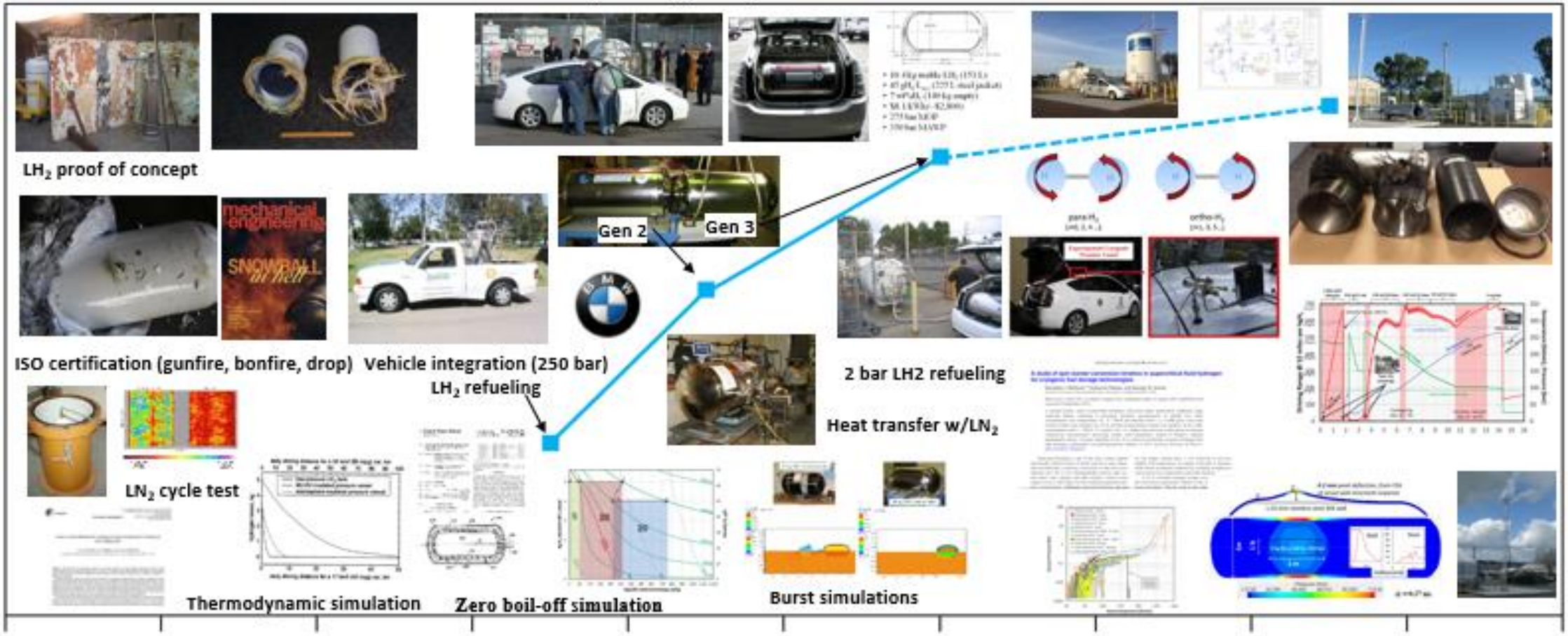
LLNL has pioneered CcH_2 using a comprehensive approach to improve system density, dormancy, cost, & safety with rapid fueling

1997-2003
Dormancy simulation
Subscale vessel testing

2003-2010
Onboard type III vessel
350 bar, 10 kg LH_2

2010-2013
Para-ortho H_2, LH_2 pump
Subscale heat transfer

2013-2017
Full-scale cycling facility, non-Al liner



60
50
40
30
20
10
0

H_2 storage density, gH_2/L_{system}

1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017

LLNL has designed and built a unique LH_2 testing facility in North-America

- 250 ft. X 125 ft. = 32 000 sqft. controlled access area, located South-East of LLNL campus

- 3,3000 gallon LH_2 storage
- 875 bar , 100+ kg/hr LH_2 pump (Linde)

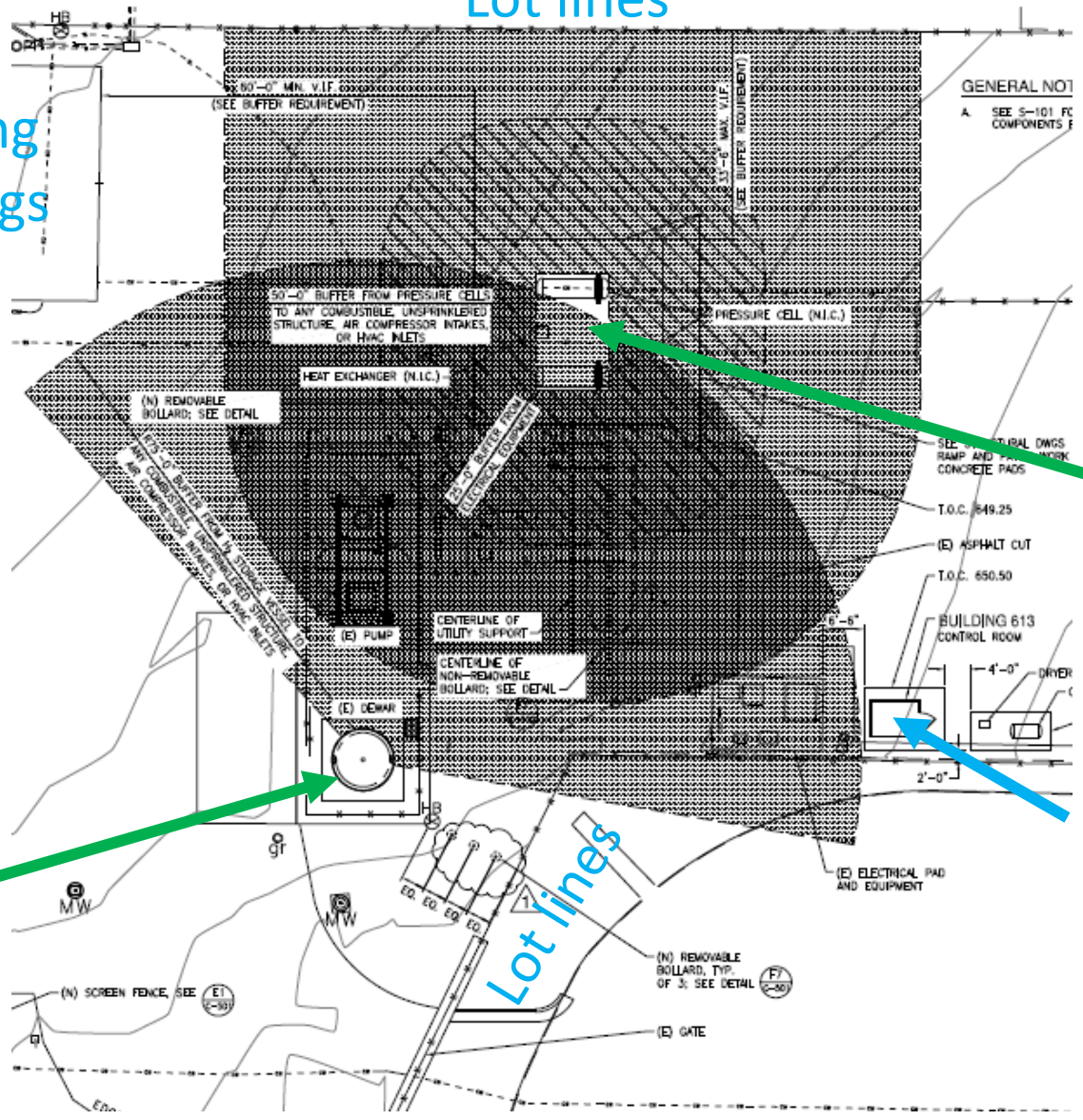
- 30 ft. X 30 ft. concrete test pad, class 1 Div. 1 group B
- 30 ft. , 2 in. OD vent stacks (2)
- 3,3 m^3 containment vessel
- 40 kW_e electric heater
- 2000 bar air-operated valves
- 1400 bar foam insulated piping

- Single person, remote operation
- Fully instrumented: boil-off, vacuum, pressure, temperature, power

NFPA 2 setback distances were used to design overall layout

Lot lines

Unsprinklered building with operable openings

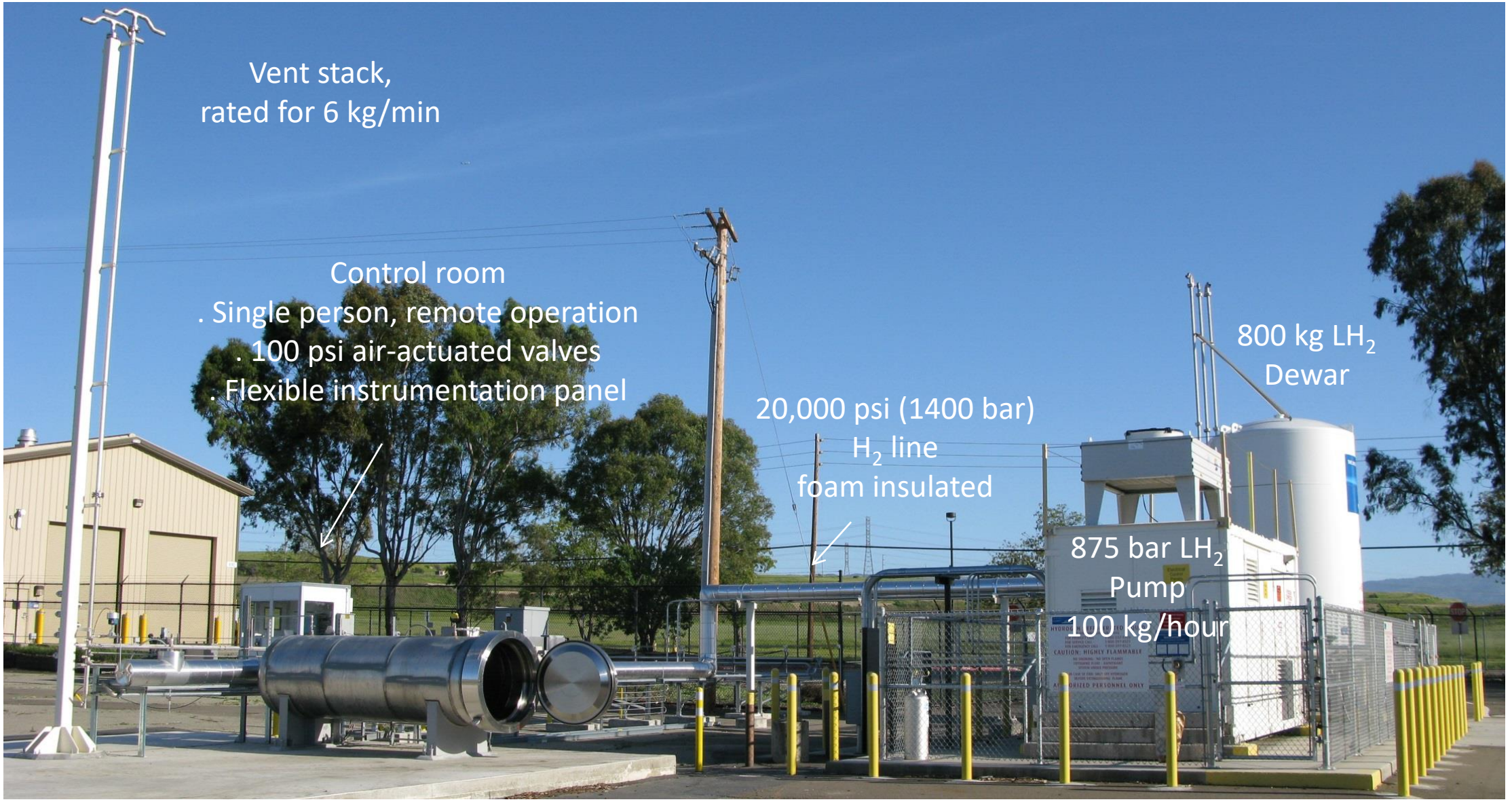


Pressurized H_2
50 ft. to unsprinklered buildings
and air intake
25 ft. to electrical
25 ft. to lot lines

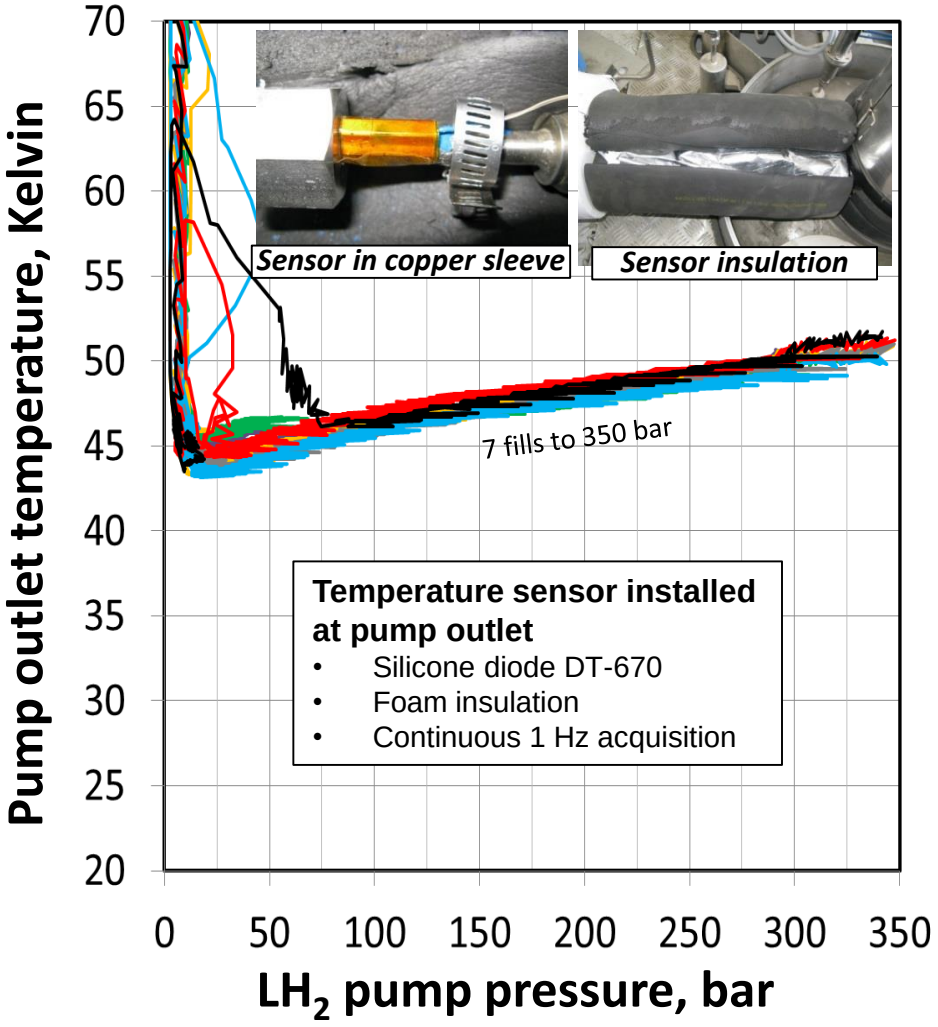
Control Room
Unsprinklered building, with AC

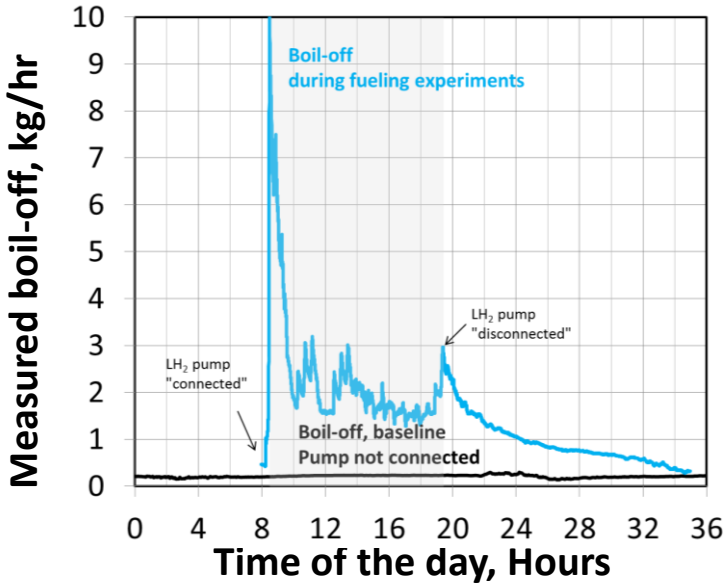
3,300 gallon LH_2 tank
75 ft. to air intake and wall openings
25 ft. to unsprinklered buildings and lot lines

LLNL has designed and built a unique LH_2 testing facility in North-America

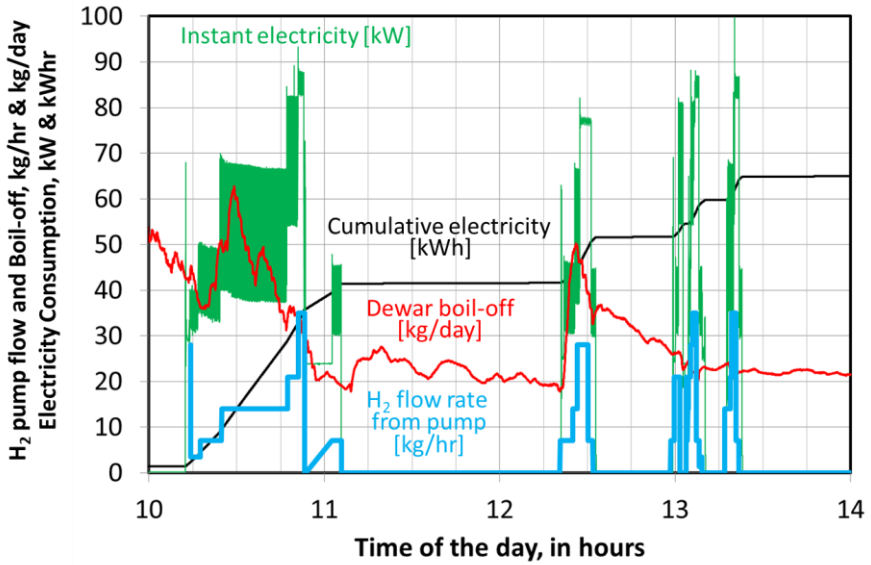


The LH_2 source was instrumented to measure boil-off, outlet pump temperature and power consumption

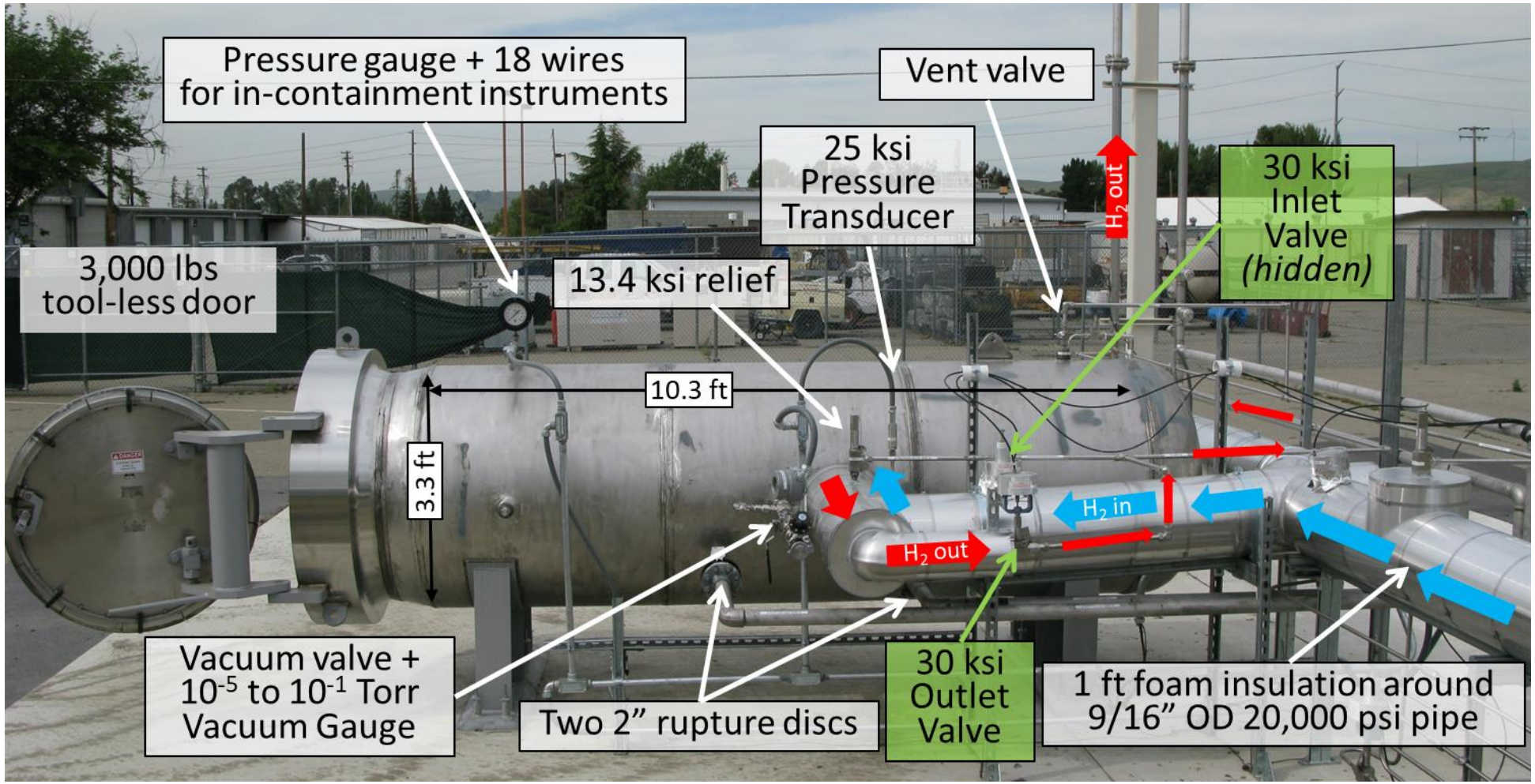




Power Analyzer
- 20 kHz sampling rate
- Memory limited (24 hours)



A steel containment vessel (ASME, 65 bar) was installed to cycle test in pressure and temperature non-rated prototype H_2 vessels



11,000 lb 3 m^3 inert stainless steel containment can withstand 2.4 kg H_2 @ 360 K, 875 bar and 7.4 kg H_2 @ 160 K, 700 bar

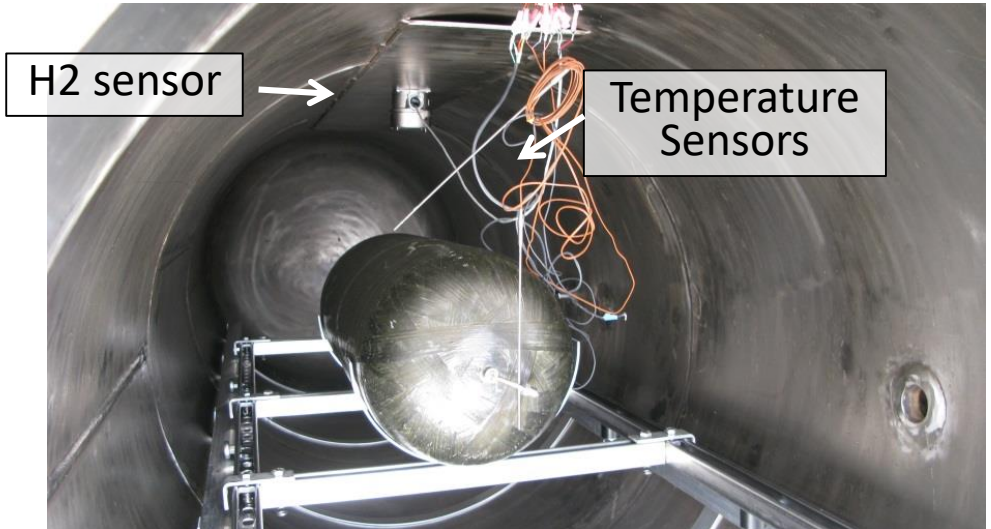
A steel containment vessel (ASME, 65 bar) was installed to cycle test in pressure and temperature non-rated prototype H_2 vessels

"Cold-shocking" (bare fittings)

1 ft foam insulation

Prototype vessel + rail

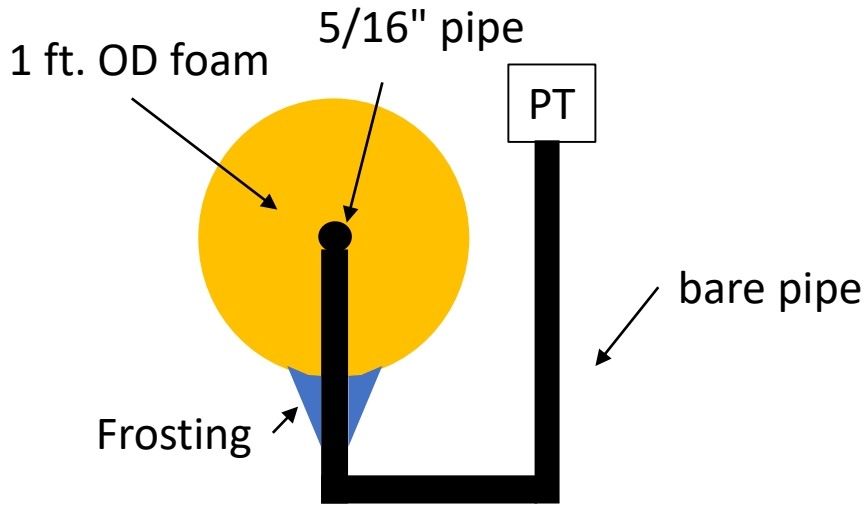
Prototype vessel inside containment



Lessons learned: instrumentation for cryogenic pressurized H_2 testing at LLNL

Temperature: Silicon diodes exhibit good performances but VERY fragile. Pt-100 and Pt-111 sensors seem to have better resistance to mechanical stresses (good repeatability demonstrated over 15+ months with >1000 cryogenic cycles)

Pressure: used Class 1 Div 1 Group B 25,000 psi transducers from Tel-Tru. No temperatures ratings given. U-shape bare piping design seems OK (some frosting near the T jonction just outside the insulation)



Insulation: 1 ft OD foam OK. Make sure piping is « cold-shocked » 3 to 5 times (leak test at room temperature) prior to installing foam. Check valves may be a weak point…
Vaccuum jacketing ideal, but qualification at high pressure is a challenge. Solution: use VERY high rating on pipes since rating decreases upon welding. Remaining challenges: theram losses at couplings and elbows…