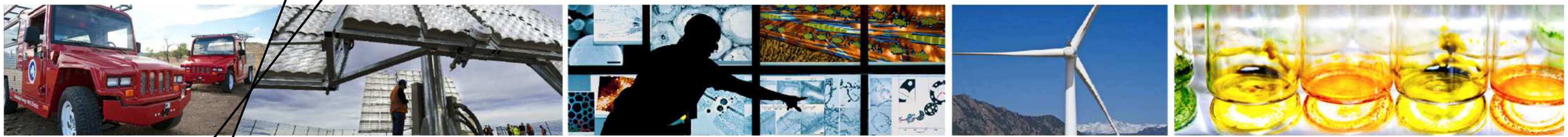
Hydrogen Systems Component Safety



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Purpose and Background

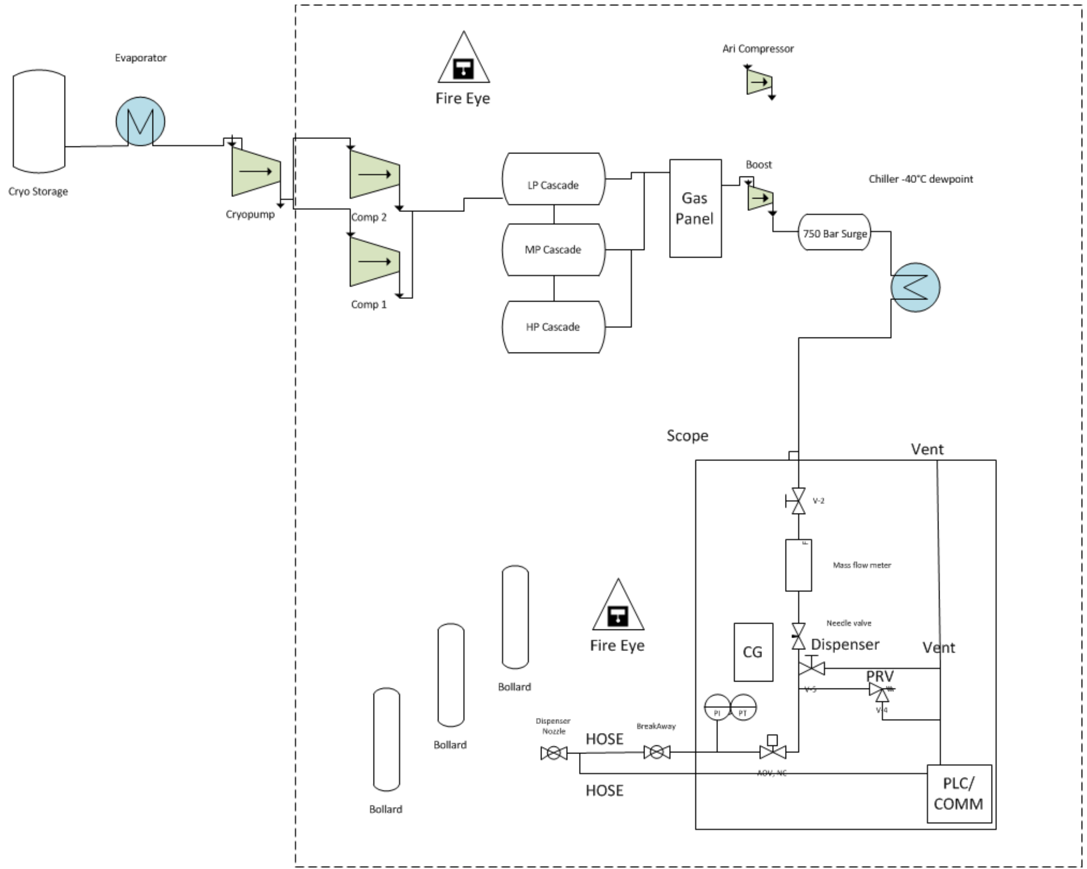
- NREL gathers data on hydrogen fueling station operations through the Technology Validation project
- NREL also gathers data on hydrogen fueling operations by running a hydrogen fueling station to support an on-site fleet of Hydrogen Fuel Cell Vehicles (FCHEVs)
- Data indicate safety and performance issues with hydrogen fueling operations
- The analysis described in this paper and presentation were conducted to assess the hydrogen fueling issues
- The outcome is a prioritized list of safety/performance issues for hydrogen fueling operations

Methodology

Process Hazard Analysis (PHA) of a representative (10,000 psi) hydrogen fueling system conducted to determine which components present the greatest risk

Group conducting analysis composed of experienced hydrogen fueling station design and operation engineers

NREL employed PHAWorks®5, a spreadsheet software package designed to perform risk analyses



PHAWorks®5

Worksheet Summary

Company:
Facility:

1 Node 1 Dispensing Nozzle
- Flow
- Temperature

2 Node 2 Dispensing Hose
- Flow

3 Node 3 Dispenser Cabinet
- Flow

4 Node 4 Cascade tanks to Dispenser
- Flow
- Pressure

5 Node 5 Compressors to Cascade tanks
- Pressure

6 Node 6 Cryogenic Storage to Compressors
- Temperature

7 7 Air System
- Flow

8 8.Control electronics
- Level

Risk Matrix

Event Probability Classification Table

Probability (Probability that the potential consequence occurs)		
Level	**Annual Probability**	**Potential Consequences**
A	Frequent > 1.0	Likely to occur many times during the life cycle of the system (test/activity/operation)
B	Reasonably Probable 1.0 to 0.1	Likely to occur several times during the life cycle of the system
C	Occasional 0.01 to 0.1	Likely to occur sometime during the life cycle of the system
D	Remote 0.0001 to 0.01	Not likely to occur in the life cycle of the system, but possible
E	Extremely Remote 0.000001 to 0.0001	Probability of occurrence cannot be distinguished from zero
F	Impossible < 0.000001	Physically impossible to occur

Consequence		
Category	Description (Est. $ Lost)	Potential Consequences
I	Catastrophic (equipment loss > $1,000,000)	May cause death or system loss.
II	Critical ($100,000 to $1,000,000)	May cause severe injury or occupational illness, or minor system damage.
III	Marginal ($10,000 to $100,000)	May cause minor injury or occupational illness, or minor system damage.
IV	Negligible (< $10,000)	Will not result in injury, occupational illness, or system damage.

Risk Matrix

Hazard/Consequence Classification Table

NREL Risk Assessment Matrix

			Probability					
	Category	Descriptive Word	A Frequent	B Reasonably Probable	C Occasional	D Remote	E Extremely Remote	F Impossible
Consequences	I	Catastrophic						Hose rupture
	II	Critical					Nozzle Leak	
	III	Marginal					Compressor failure	
	IV	Negligible						

High Risk	Moderate Risk	Low Risk	Routine Risk

PHAWorks®5

Company:
Facility:

Session: (1) 3/14/2013
Node: (1) Node 1 Dispensing Nozzle
Drawings:
Parameter: Flow

Revision:

Intention:

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	REF#	RECOMMENDATIONS	BY
Flow	Leak	Degraded o-rings in nozzle	Hydrogen leak/	Maintenance Proper material selection and design Fire eyes EPO/human detection Pressure sensors in dispenser Class I Div 11 at dispenser	3	D	L R			
			Noise	Maintenance Proper material selection and design Fire eyes EPO/human detection Pressure sensors in dispenser Class I Div 11 at dispenser	3	D	L R			
			Fire	Maintenance Proper material selection and design	1	E	L R			

Analysis Methodology

- The risk that each consequence presented was evaluated at each node and a severity and probability was assigned
- Data from NREL's Technology Validation program was used, along with onsite NREL data, to determine both severity and frequency
- Each node presented multiple undesirable consequences
- Using the NREL matrix system, the combination or product of severity and probability produces a qualitative risk assignment for each consequence
- This analysis produced the table shown on the next slide

Risk at Nodes

Node	High Risk	Medium Risk	Low Risk	Routine Risk	Total
Node 1 Dispensing Nozzle	0	0	5	1	6
Node 2 Dispensing Hose	0	2	3	0	5
Node 3 Dispenser cabinet	0	0	0	0	0
Node 4 Cascade Tanks to Dispenser	0	0	2	5	7
Node 5 Compressors to Cascade Tanks	0	0	7	9	16
Node 6 Cryogenic Storage to Compressors	0	0	0	1	1
Node 7 Air Flow System	0	0	0	5	5
Node 8 Control Electronics	0	0	2	4	6
Total	0	2	19	25	46

Analysis Methodology

- With the consequences evaluated for each system node the next step in the process of developing a picture of relative risk that nodes/components present is ranking
- Using the weighting system of:
- HR=4
- MR=3
- LR=2
- RR=1
- The total risk at each node can be calculated.
- For example the aggregate risk/total at node 1 Nozzle = 2LR * 5 + 1RR * 1= 11

Total Risk at Node

Node	Node Description	HR	MR	LR	RR	Node Total Risk
5	Compressor to Cascade Tank	0	0	7	9	23
2	Hose	0	2	3	0	12
1	Nozzle	0	0	5	1	11
4	Cascade Tanks to Dispenser	0	0	2	5	9
8	Control Electronics	0	0	2	4	8
7	Air System	0	0	0	5	5
6	Cryo Storage to Compressor	0	0	0	1	1

HR - High Risk
MR - Medium Risk
LR - Low Risk
RR - Routine Risk

Conclusions

- Compressor highest total risk node
- Hose was only node with any consequences that achieved a medium risk assignment
- Nozzle was third highest aggregate risk node
- So-
- Safety analysis work on hoses and compressors has started at NREL
- DOE has developed a comprehensive plan to address component and systems safety for hydrogen fueling and infrastructure

Conclusion

- This work was funded by the US Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Office of Fuel Cell Technologies
- Questions
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