SAND2021-9459PE

Assessment of Leak Frequencies in Compressed Natural Gas Systems

08854 | Fire, Risk, & Transp. Systems

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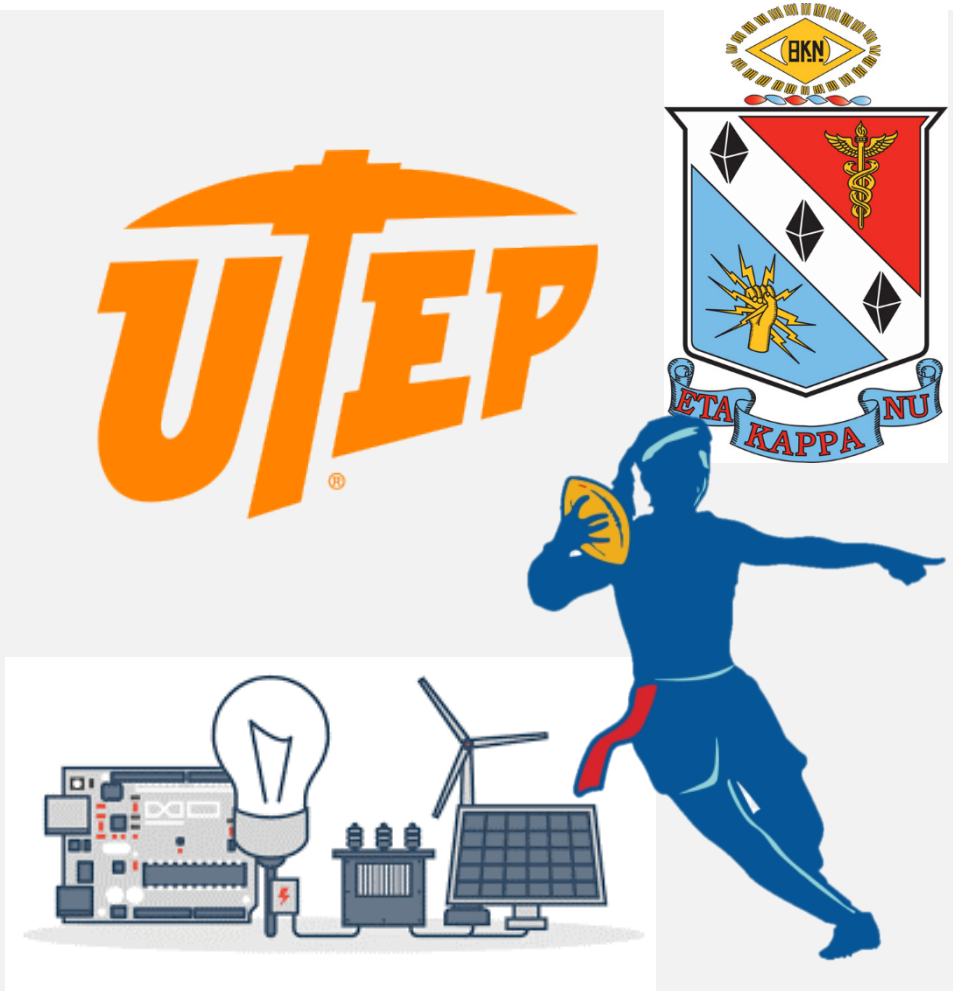
About Me

Future Electrical Engineer

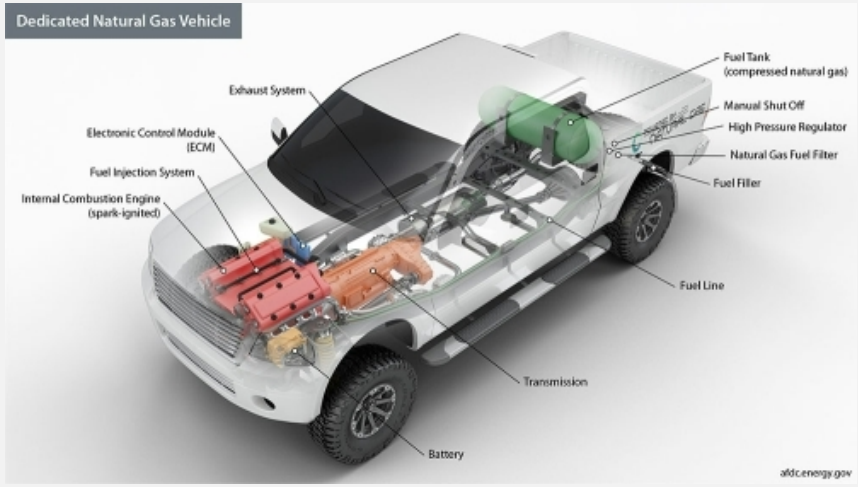
Hobbies: Flag Football

Fun Fact: I have a twin sister!



Compressed Natural Gas (CNG)

- Advantages of natural gas as transportation fuel:
  - Domestic availability
  - Widespread distribution infrastructure
  - Reduced gas emissions



Source: https://afdc.energy.gov/vehicles/how-do-natural-gas-cars-work

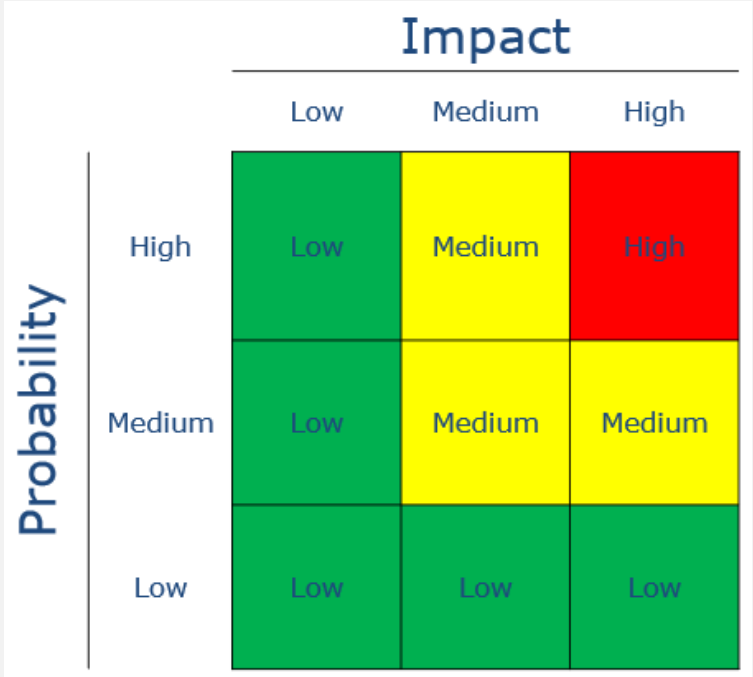
- Compressed Natural Gas (CNG) is made by compressing natural gas down to less than 1% of its original volume

Risk Assessment 101

Risk assessment is the systematic overall process of Hazard Identification, Risk Analysis and Risk Control.

Why is it important?

- ✓ Creates Awareness
- ✓ Prevents Catastrophes
- ✓ Prioritizes Hazards
- ✓ Identifies who may be at risk
- ✓ Meets legal requirements
- ✓ Determines if current measures are adequate



Source: https://www.stakeholdermap.com/risk/risk-assessment-matrix-simple-3x3.html

Past Work at Sandia

- Hydrogen
  - Hydrogen Risk Assessment Models (HyRAM) software is a free and open source toolkit for simplified estimations of risk for gaseous hydrogen systems

- Liquified Natural Gas (LNG)
  - "Using Bayesian Methodology to Estimate Liquefied Natural Gas Leak Frequencies" *(April 2021)*

Methodology: Literature review

The first step on the project was the literature review in CNG:

- **Components:** Pipe, tank, heat exchanger, valves, hoses, loading arms, compressor, flanges & gaskets, and joints
- **Order-to-magnitude fractional leak areas (LA):** 0.0001, 0.001, 0.01, 0.1 and 1.0
- Qualitative leak areas: " very small leak", "medium leakage", "rupture", etc.

Examples of Assumptions in Pipe's data

Table 5. Failure frequencies of pipeline estimated with EGIG and BG Transco data

Failure causes	Failure frequency of different hole size (1/year km)		
	Small	Medium	Great
External interference	1.7×10^{-5}	2.2×10^{-5}	2.1×10^{-5}
Construction defects	7.6×10^{-5}	2.8×10^{-5}	0.7×10^{-5}
Corrosion	7.9×10^{-5}	2.4×10^{-6}	8.1×10^{-7}
Ground movement	1.0×10^{-6}	1.1×10^{-6}	1.4×10^{-6}
Others/unknown	4.0×10^{-5}	1.4×10^{-5}	5.4×10^{-7}
Total failure rate	2.1×10^{-4}	6.8×10^{-5}	3.10×10^{-5}

Pipeline: 1000 mm diameter, 50 bar operating pressure, 130 cm the depth of cover and located in a town area. $\varphi_{small,EI} = 0.001e^{-4.18-2.18562} \times 0.54 \times 1 \times 18.77 \times 1.03 = 1.7 \times 10^{-5}$;

$\varphi_{medium,EI} = 0.001e^{-4.12-2.02841} \times 0.54 \times 1 \times 18.77 \times 1.03 = 2.2 \times 10^{-5}$;

$\varphi_{great,EI} = 0.001e^{-4.05-2.13441} \times 0.54 \times 1 \times 18.77 \times 1.03 = 2.1 \times 10^{-5}$.

Source:
https://www.sciencedirect.com/science/article/pii/S0304389405001688

- Conservative assumptions made with qualitative description of leak sizes:
  - "Great" was assumed to be the biggest leak area we have (LA = 1.0)
  - "Medium" and "small" were assigned the leak areas that followed (LA = 0.1 and LA = 0.01)
- Another example was with the word "rupture". It was assumed to be a LA = 1.0

Methodology: Bayesian Model

Bayes' rule is defined by:

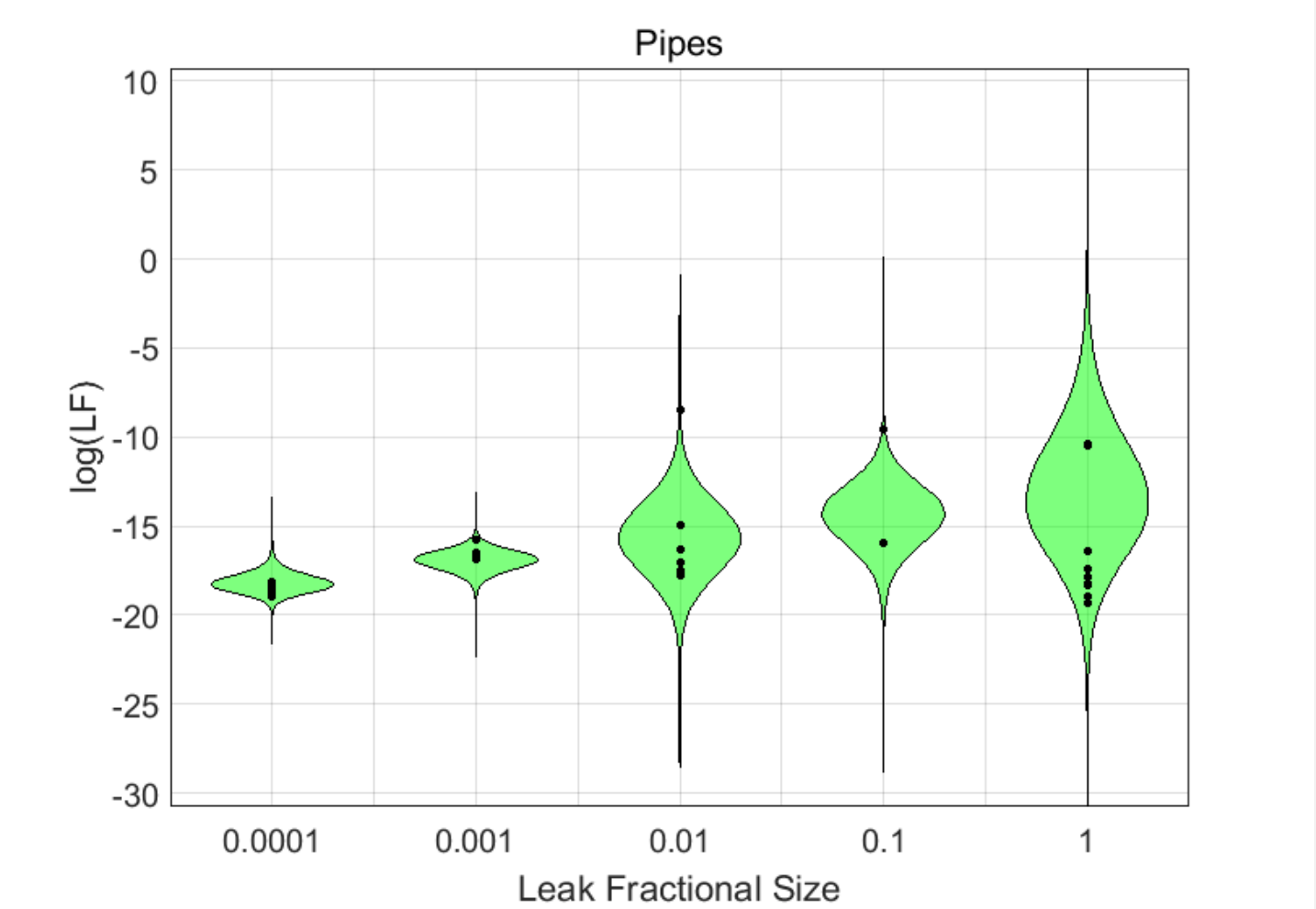
$$\text{posterior} = \frac{likelihood * prior}{scaling\ constant}$$

Posterior being the final leak frequency distribution

Prior is current leak frequency distribution and *likelihood* is data

Results of the Analysis

Violin plot of leak frequency (LF) distributions and data for pipes



Next Steps and Future Work

- Continue the data research on the other components
- Update the Pipe's data set whenever new data is available
- Perform the analysis on the other data sets
- Merge all the analysis into one script

Thank you.

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