#### PERFORMANCE OF GAS STORAGE & PIPELINE SYSTEM SURFACE INFRASTRUCTURE

In-Plane and out-of-plane cyclic tests on welded steel pipe tee joints

12NCEE - Salt Lake City, June 28, 2022 Seismic Risk Assessment Methodologies and Open-Source Tools for Natural Gas Infrastructure



## INTRODUCTION

- Natural gas needs to run above ground at several locations
- Example: storage facilities
- Past earthquake damage



Source: SoCalGas (2016). Well Inspection at Aliso Canyon Storage Facility.





Adjusted from US DoT (n.d.). Natural gas pipeline systems. U.S. Department of Transportation.

#### SEISMIC FRAGILITY OF THE SURFACE INFRASTRUCTURE

• Identify critical subsystems

GOAL: Build fragility curves of several critical subsystems

- Numerical models of subsystems in OpenSees
- Experimental evaluation:
  - Test on critical components at UCSD
  - Test on a piping subsystem at UNR





## COMPONENT TESTS ON CRITICAL COMPONENTS

Component		Diam, Sch. [D/t]	Direction	Name
	90°	4", Sch.80 [13]	In-plane	4E-90
ELDUW	45°	4", Sch.80 [13]	In-plane	4E-45
TEES		1" Cab 90 [12]	In-plane	4T-IP
		4, 501.00 [15]	Out-of-plane	4T-OP
		9" Sch 40 [27]	In-plane	8T-IP
		o , 3011.40 [27]	Out-of-plane	8T-OP

- Displacement controlled pseudo-static tests following FEMA 461 load protocol
- Values of target displacements found from pretest ABAQUS simulations
- Internal pressure at ~30psi (test continued until a through crack developed)







### **TEST ON TEES: Setup**



- Instrumentation: linear potentiometers, string potentiometers, strain gauges
- Between 15-35 channels of sensors per specimen

- Typical evolution of damage (example for 4T-IP)
  - 1. Visible ovalization/bulging
  - 2. Flaking
  - 3. First shallow network of cracks
  - 4. Through cracks and sudden pressure loss







	Observation				
	First visible ovalization	Flaking	First crack	Peak rotation before full loss of pressure	
4T-IP	<b>4.4</b> °	6.1°	17.1°	24.2°	
4T-OP	<b>8.6</b> °	12.1°	17.1°	24.2°	



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8T-OP	<mark>1.3°</mark>	N/A	<mark>9.8°</mark>	<mark>9.8°</mark>	





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# CONCLUSIONS

- Surface systems of the natural gas infrastructure
  - Generally robust
  - Additional analysis of different subsystem is recommended
- <u>Tees</u>
  - Large ductility
  - Relative brittle failure for some geometries [tee with flat body]

#### Thanks to the OpenSRA team

- Professor Jonathan Bray (PI)
- Powell Laboratory staff
- UMEC

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