Discharge Characteristics of the Super-Pressurized Halocarbon Agents

Arash Agan

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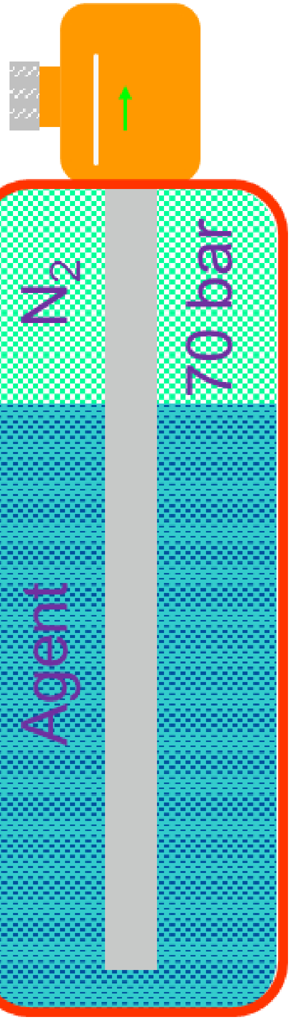
Outline

- Introduction
- Objectives
- Numerical Model
  - Assumptions and limitations
  - Consevation equations
  - Algorithm
  - Computer program
- Results
- Discussions
- Future Work

Introduction

- Using the pressure of Nitrogen
- Types of discharge
  - Super-Pressurization
  - Nitrogen in separate container
- Pushing the limits
  - Increasing container pressure
  - Increasing the fill density inside the container
  - Increasing the pipe to agent volume ratio
- Comply with NFPA standards
  - 95% discharge time
  - Pressure at the nozzles



Objectives

- Create a mathematical model for the container discharge
- Analyze the properties of the container during the discharge
- Find the limits of pressure, fill density, …
- Compare the performance of different materials as agent/inert gas

Numerical Model

- Assumptions
- Conservation Equations
- Algorithm and Computer program

Numerical Model - Assumptions

- Container volume is constant
- Isentropic process (Adiabatic and reversible process)
- Inertial effects are negligible
- Thermodynamic equilibrium inside the container
- Inherent properties of materials only change with temperature

Conservation Equations

- Continuity

$$\left(m_{vapor} + m_{liquid} + m_{Nitrogen}\right)_1 = \left(m_{vapor} + m_{liquid} + m_{Nitrogen}\right)_2 + \dot{m}_{out}\Delta t$$

- Isentropic process

$$\left(m_{liquid} s_{liquid}\right)_1 - \dot{m}_{out}\Delta t \left(s_{liquid}\right)_1 = \left(m_{vapor} s_{vapor} + m_{liquid} s_{liquid} + m_{Nitrogen} s_{Nitrogen}\right)_2$$

- Constant Container Volume

$$\left(m^1_{liquid} v^1_{liquid} + m^1_{vapor} v^1_{vapor}\right)_{T1} = \left(m^2_{liquid} v^2_{liquid} + m^2_{vapor} v^2_{vapor}\right)_{T2}$$

- Nitrogen Pressure

$$P_2 = \frac{RT_2}{\left(m_{Nitrogen} v_{Nitrogen}\right)_2}$$

Algorithm and Computer Program

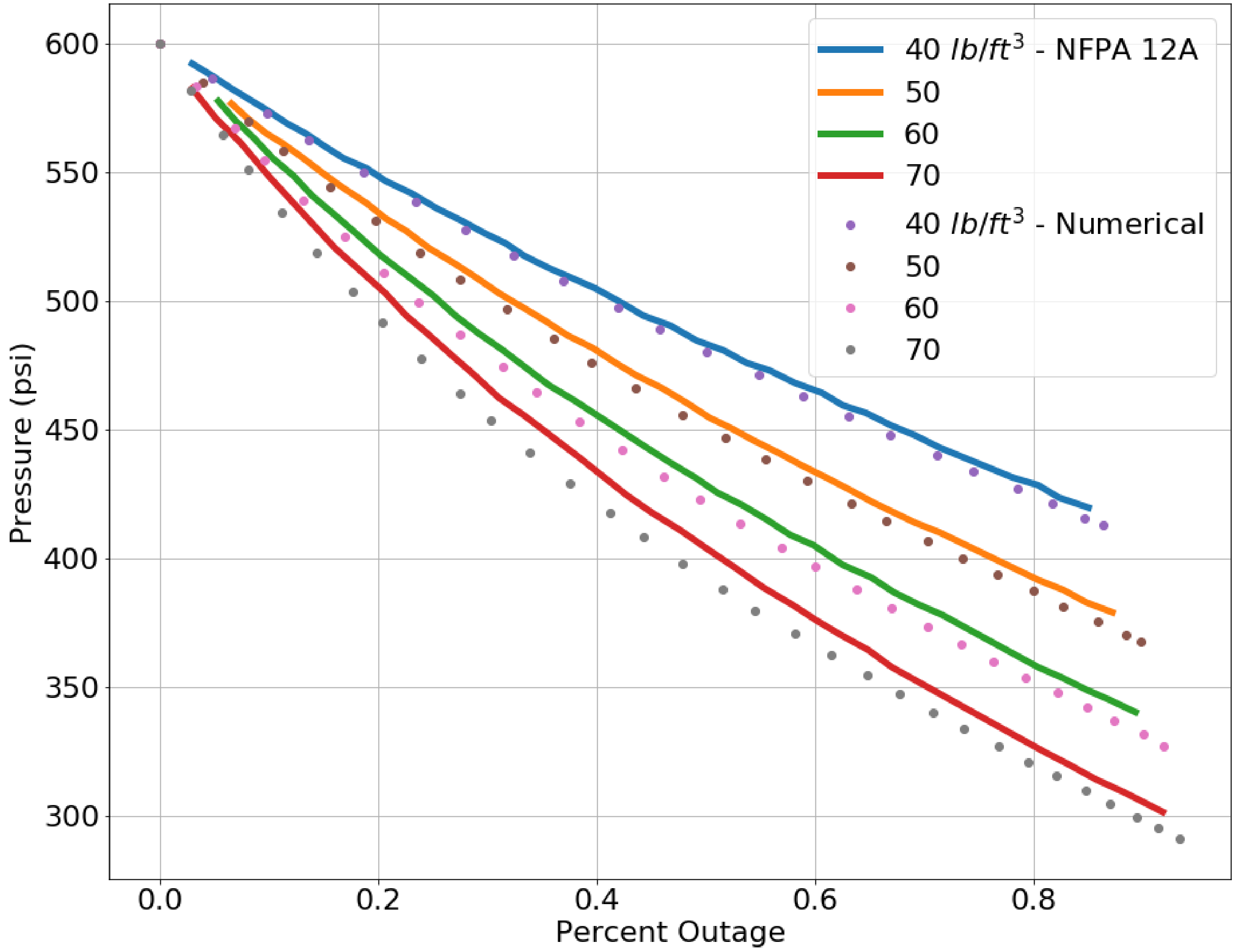
- Algorithm
  - Initial condition of the container
  - Guess value for the discharge of liquid agent
  - Calculate the properties of the tank using properties of the agent at the lower temperature
  - Compare the calculated properties to the Nitrogen’s properties
  - Adjust the guess value until the solution converges for the next available properties at lower temperature
  - Set the initial condition to the calculated condition and start over

- Computer program
  - Object oriented
  - Material properties saved as a separate file
  - Extendable to any Agent/Inert gas
  - Interfaces for different unit systems
  - Verbose/Concise result reporting

Results

- Comparison to NFPA 12A (Halon 1301)
- Comparison to experimental data (FK-5-1-12)
- Comparing Halon 1301 to FK-5-1-12

Results – Comparison to NFPA 12A results



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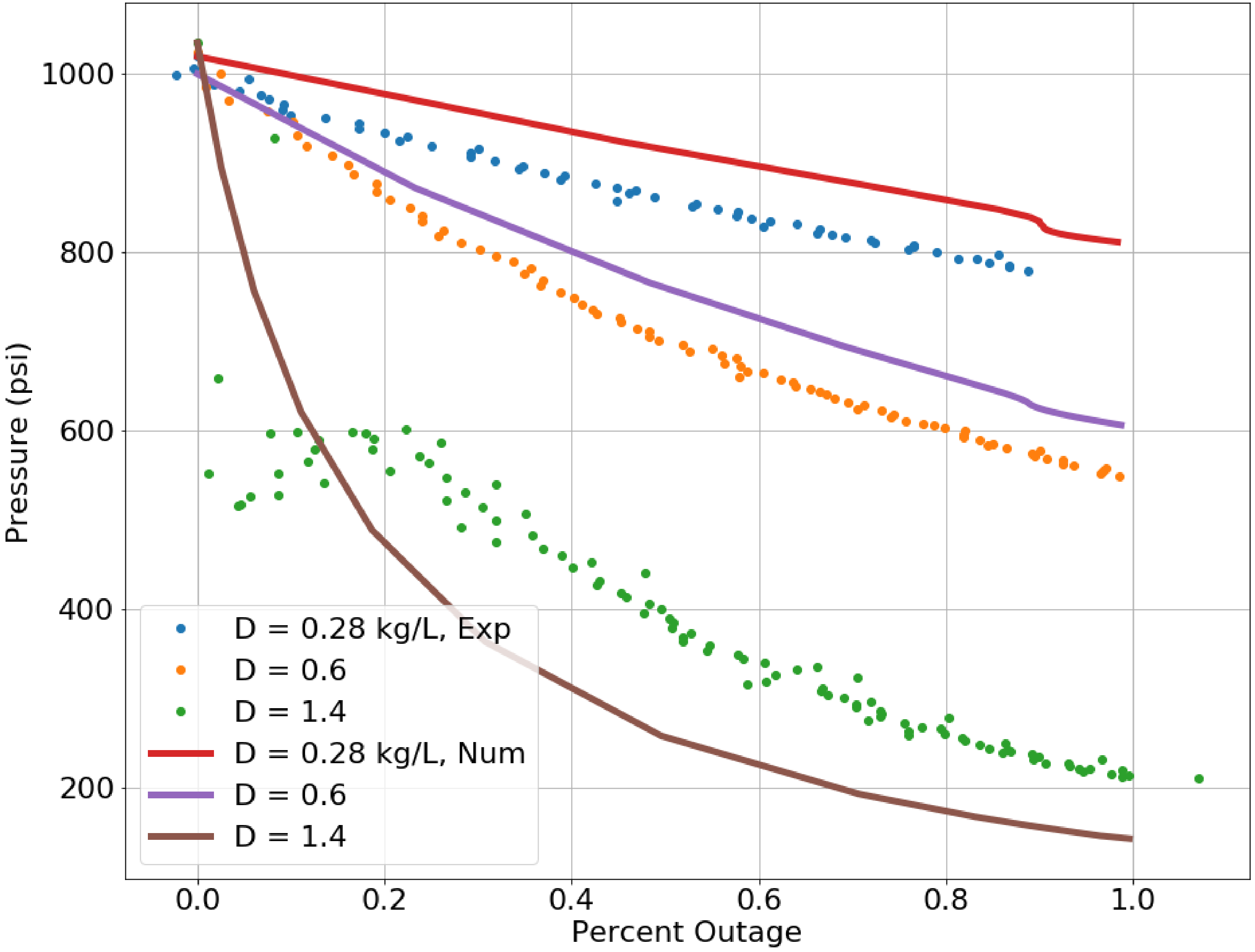
Results – Comparison to experimental results



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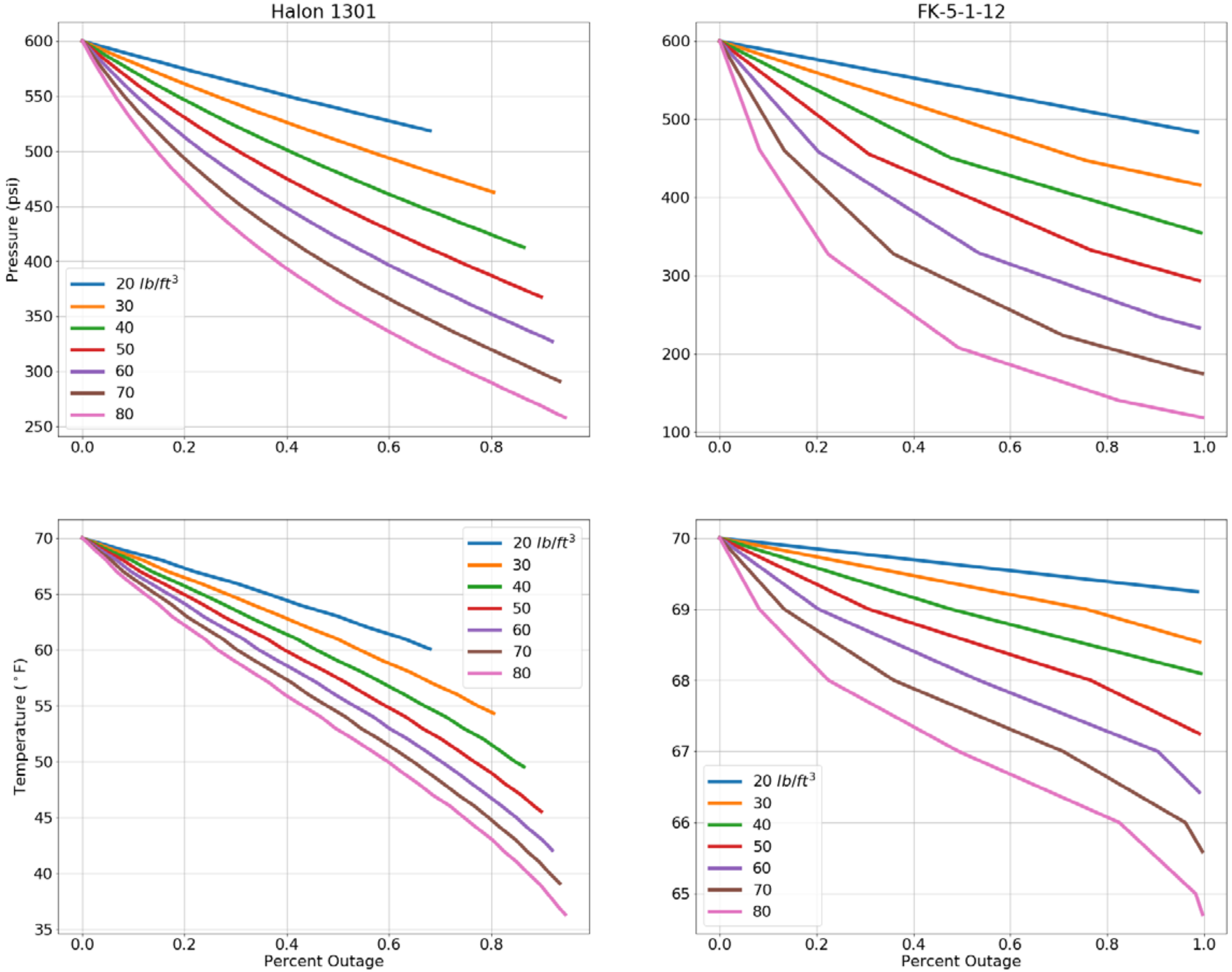
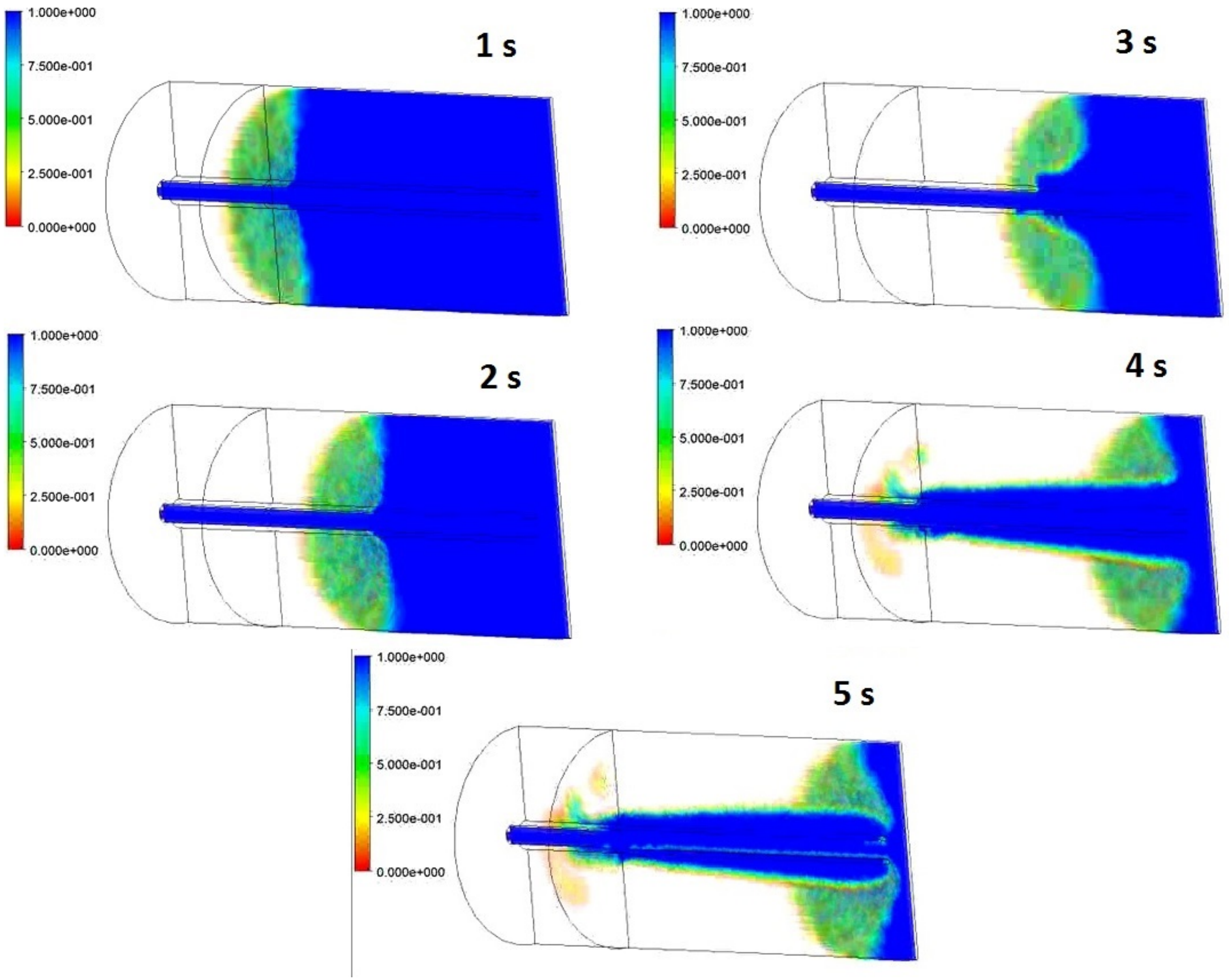
Results – Comparing Halon 1301 to FK-5-1-12 discharges



Discussion – Inertia effects

- 10s discharge time (NFPA 2001)
- Higher mass of agent results in higher mass flow rate



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Discussion – Hydraulic Calculations

- Container properties as a starting point for hydraulic calculations
- Highly transient process
- Two phase flow process
- Turbulence and heat transfer
- Definition of design pressure in NFPA 12A and 2001
- Restrictions on the design pressure
- Flow characteristics at tees

Future Work

- Optimization of the container geometry
- Effect of substituting Nitrogen with other gases
- Looking at the container discharge of other halocarbon clean agents
- Transient hydraulic calculations

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Thank you!

Questions?