Thermo-Mechanical Study of Bare 48Y UF_6 Containers Exposed to the Regulatory Fire Environment

PATRAM 2010

October 3-9, 2010

London, UK

Carlos López, Charles Morrow, and Douglas J. Ammerman
Sandia National Laboratories

Marc-André Charette
Cameco Corporation

Tim Korbmacher
URENCO Enrichment Company Limited

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

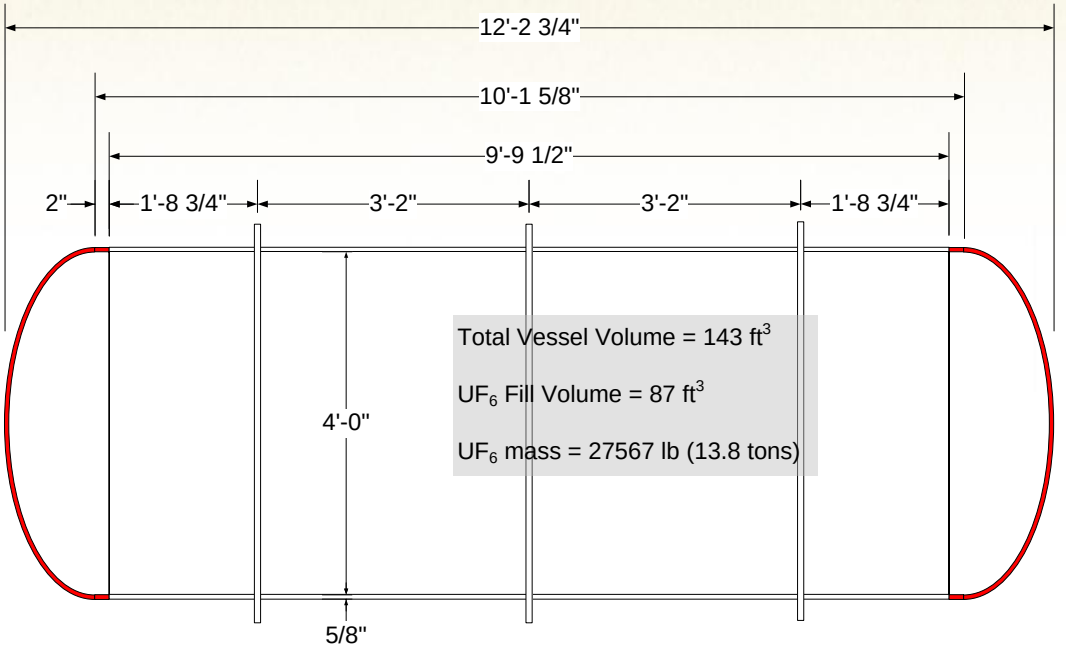
Background

- **Commercial quantities of natural (or depleted) uranium hexafluoride (UF_6) are transported internationally in mild steel cylinders**
- **The most common packaging is the 48Y cylinder (described in ANSI N14.1 and ISO7195 standards)**
- **Transport regulations require the package to survive a 800°C fully engulfing fire environment for 30 minutes**
- **To meet this requirement, thermal protectors are used on 48Y cylinders (excluding North America)**
- **This thermal study will attempt to optimize the thermal protection currently used on 48Y cylinders**
  - **Using coupled multi-physics codes**

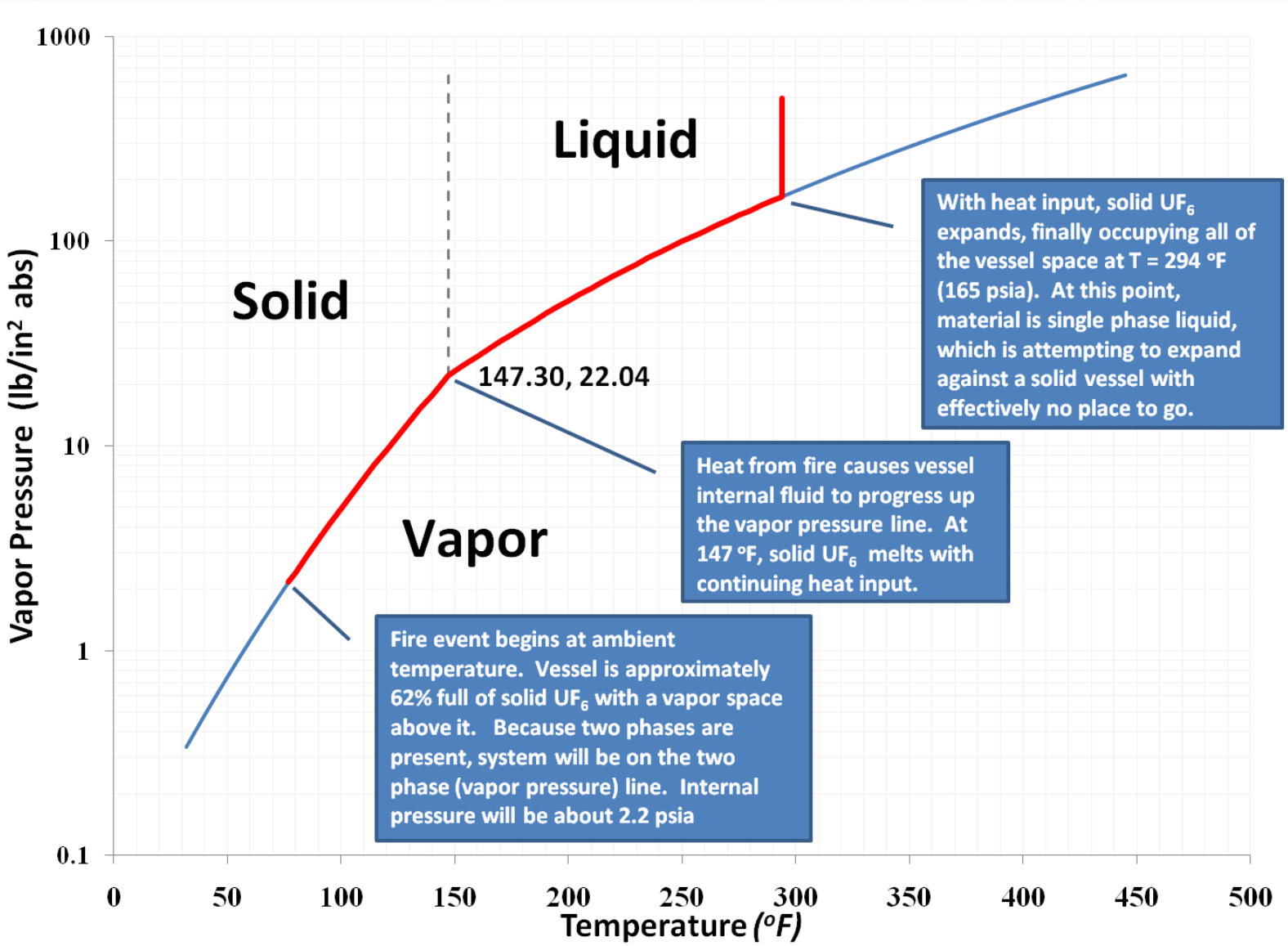
Regulatory Requirements

- **Since the 1996 Edition of the TS-R-1 (or ST-1)**
  - **Three tests relevant to UF_6 package certification**
- **Packages need to withstand:**
  - **Structural test without leakage (hydrostatic pressure test)**
  - **Free drop test without loss of UF_6**
    - **Free drop test was a new requirement in the 1996 Edition of TS-R-1**
    - **Resulted in a new valve protector assembly and new plug design**
  - **Thermal test without rupture of the containment system**
    - **Thermal test was new and demonstration of a bare 48-inch cylinder to withstand the standard IAEA fire test conditions was not available**
      - **A Coordinated Research Programme (1992-1998) resulted in no consensus**
      - **Survival time calculated ranged from ~25 to 35 minutes**

48Y UF_6 Transport Container and Thermal Protection

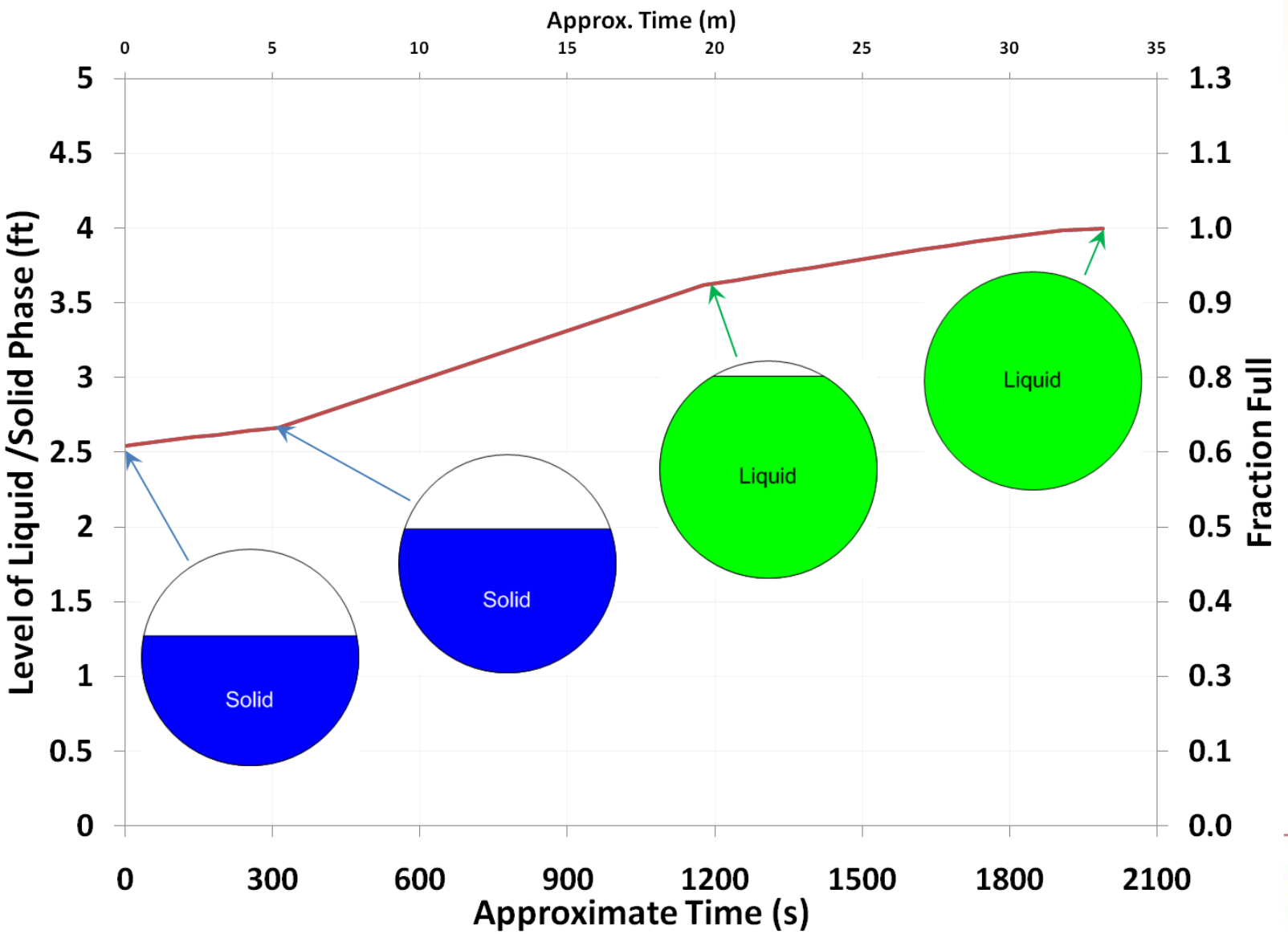


Simple 48Y Fire Model: Event Progression



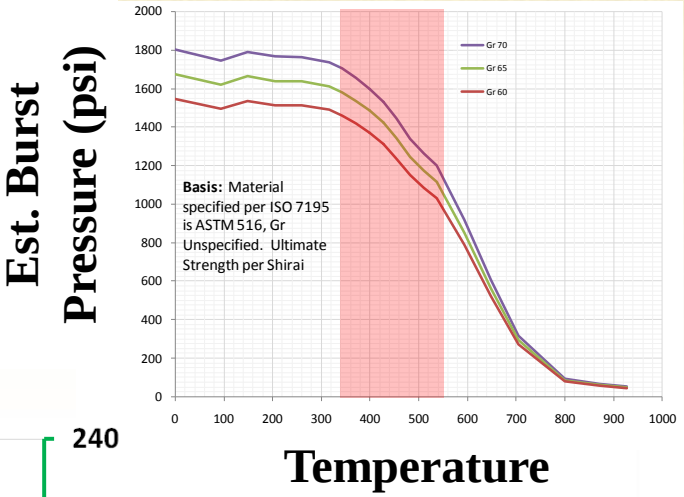
Sandia National Laboratories

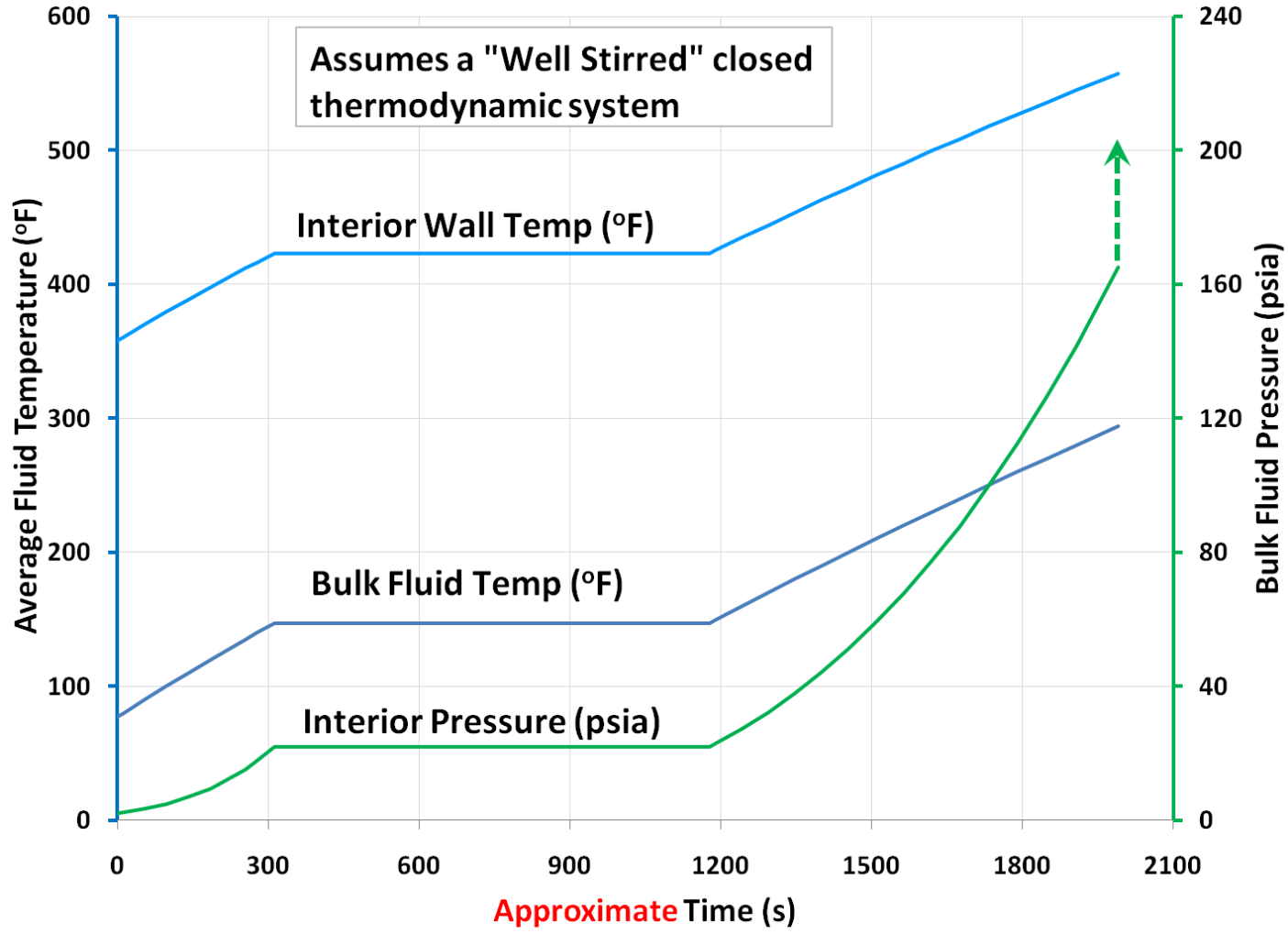
Simple 48Y Fire Model: Liquid Level Progression



Sandia National Laboratories

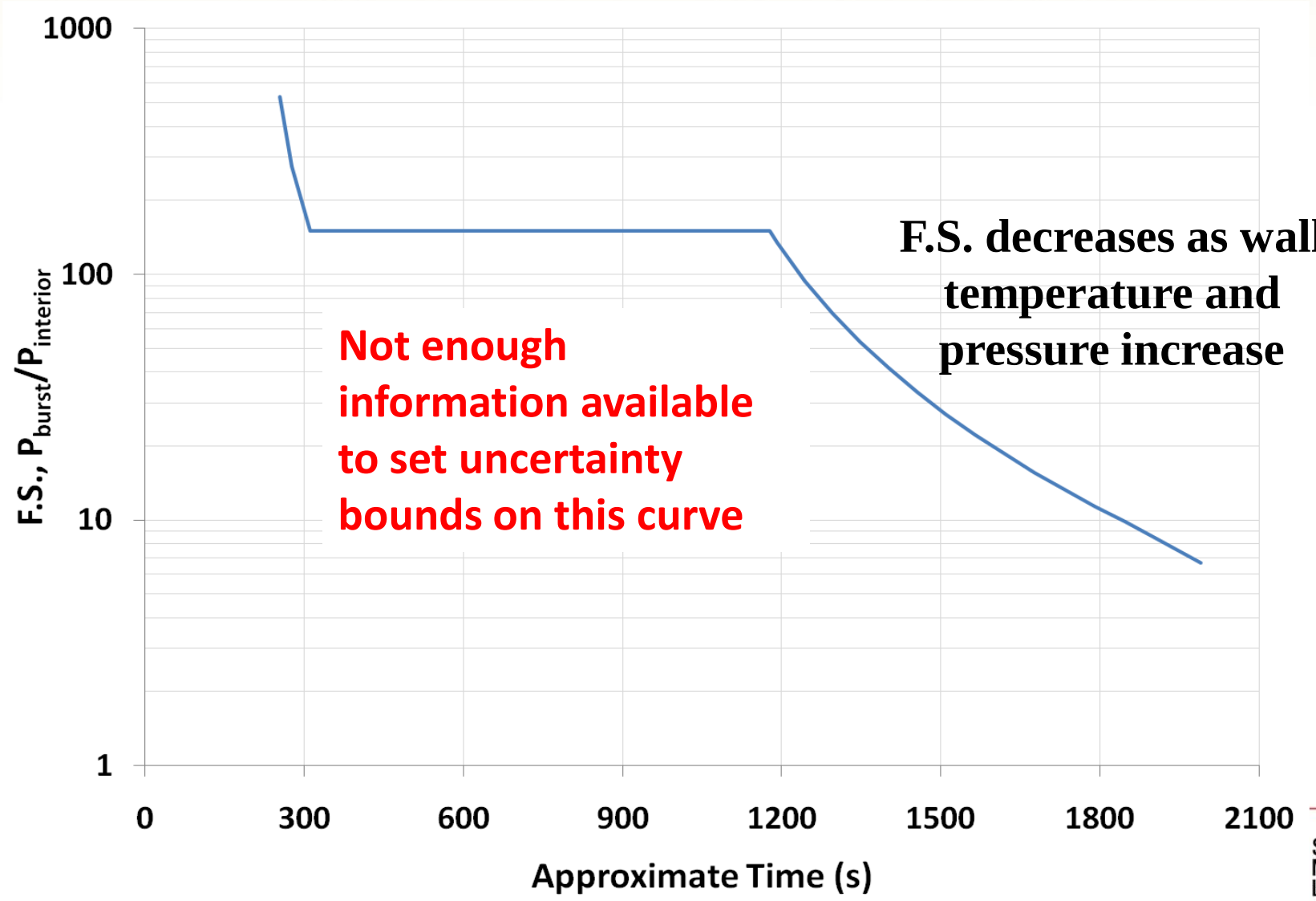
Simple 48Y Fire Model: UF_6 Thermodynamics





Sandia National Laboratories

Simple 48Y Fire Model: Factor of Safety



Sandia National Laboratories

Where Does this "Simple Model" Leave Us?

- **The vessel will probably survive a 30 minute fire**
  - **Small margin for error**
  - **Assumptions & uncertainties need examination**
  - **Thermal physics depend on many intangibles**
  - **Simplified model confidence - uncertain**

- **Comprehensive modeling will help advance current knowledge and better define the margin of safety**

Scope of the Thermal Study

- **Study will advance previous findings**
- **Coupled multi-physics modeling will be used to evaluate this complex thermo-mechanical problem**
- **Objective of the study:**
  - **Optimize thermal protection required for a 48Y cylinder**
    - **Using the existing BTP and CTP**
  - **Predict the thermo-mechanical response of the package**
    - **Using the optimized thermal protection**
    - **Include the survival time at the regulatory test conditions**

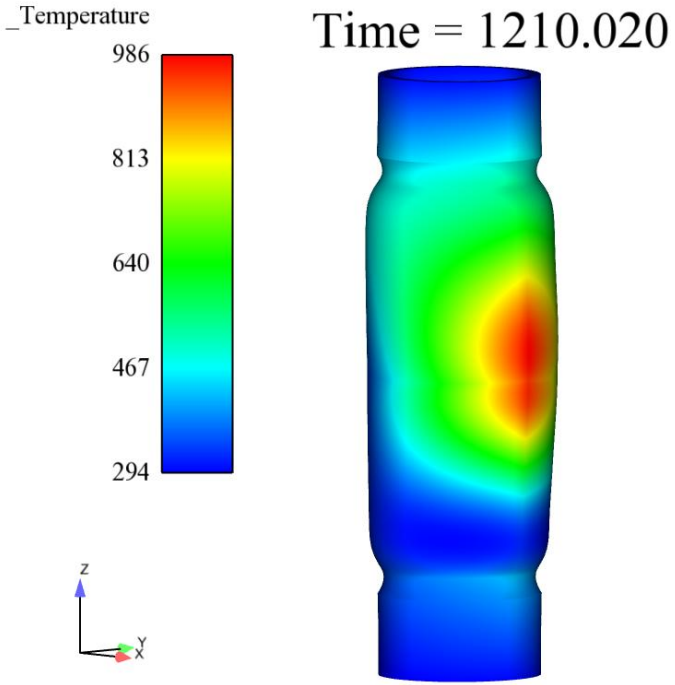
Optimization Through Modeling

- **Coupled models using Sandia codes will be created**
  - **Fire modeling, heat transfer, structural response**
  - **Modeling will be performed on large supercomputers**
- **Initial simulations will assume uniform 800°C heating**
  - **Realistic fire modeling will be added**
- **Estimates of failure times based on relevant existing data**
- **UF_6 will be modeled based on currently available data**
- **Several geometries will be evaluated**
  - **Analysis of container without thermal protectors will be used as reference and for comparison with previous studies**
  - **Different configurations of the thermal protectors**

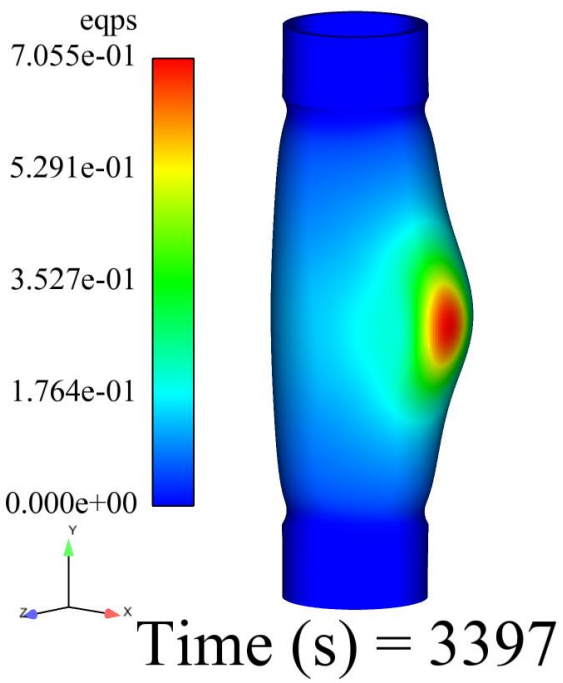
Sandia National Laboratories

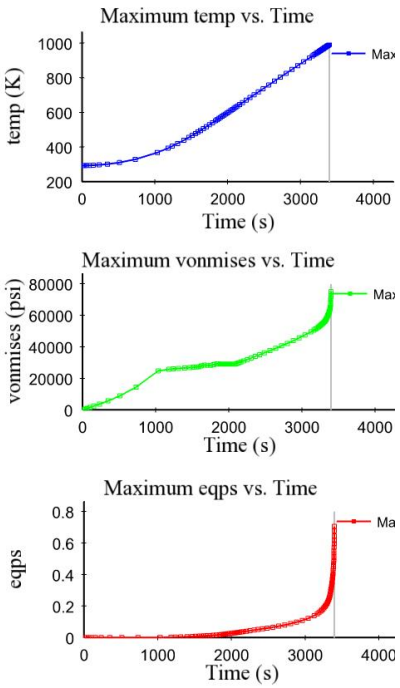
Coupled Thermo-Mechanical Analysis Failure Analysis (Example)

Uneven Heating



Structural Response



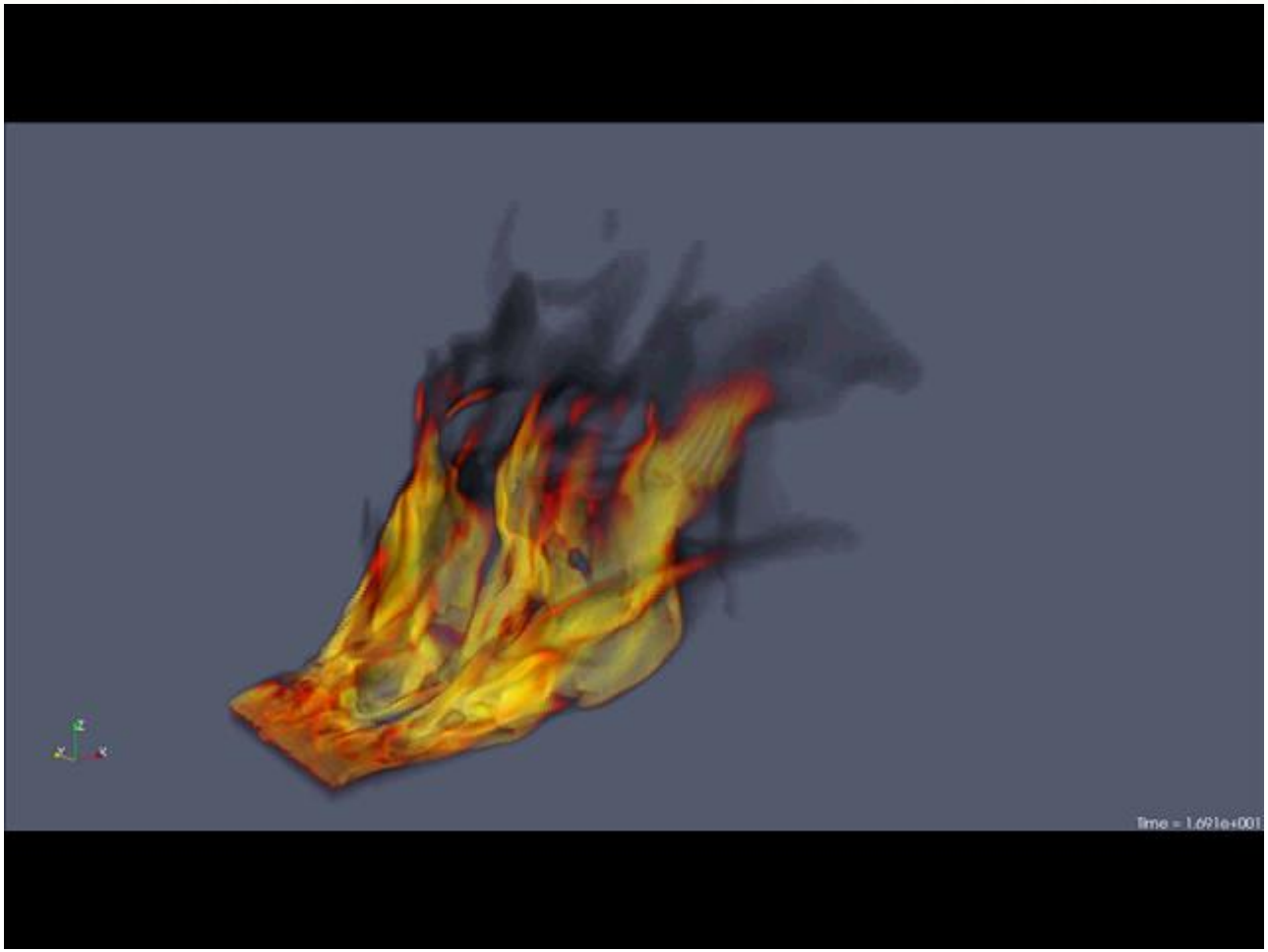


Sandia National Laboratories

Additional Consideration: Evaluation under Realistic Fire Environment

- **Uneven fire-like heating reflects a realistic thermo-mechanical response of a cylinder in an accident scenario**
  - **May make cylinder regions more likely to fail (localized peaks)**
  - **May slow the UF_6 phase change resulting in less cylinder pressurization (time and spatial variable heat input)**
- **Sandia state-of-the-art CFD fire codes are coupled with heat transfer & mechanical codes**
  - **CFD fire code can realistically model the fire environment**
  - **Coupled heat transfer code can accurately track components' heating**
  - **Mechanical code can track deformations and cylinder rupture**
- **Possible to model the UF_6 inside the cylinder**
  - **Coupling codes to obtain unique and advanced results**
- **Modeling performed on massive parallel supercomputers**

Realistic Fire Simulation (Example)



Sandia National Laboratories

Summary

- **Why conduct this study?**
  - **Computer modeling improvements since previous studies**
  - **Codes advances, coupling, & computing power will help quantify safety margin**
- **It is expected that a comprehensive re-evaluation today will advance the current of knowledge**
- **Optimize use of current thermal protectors**