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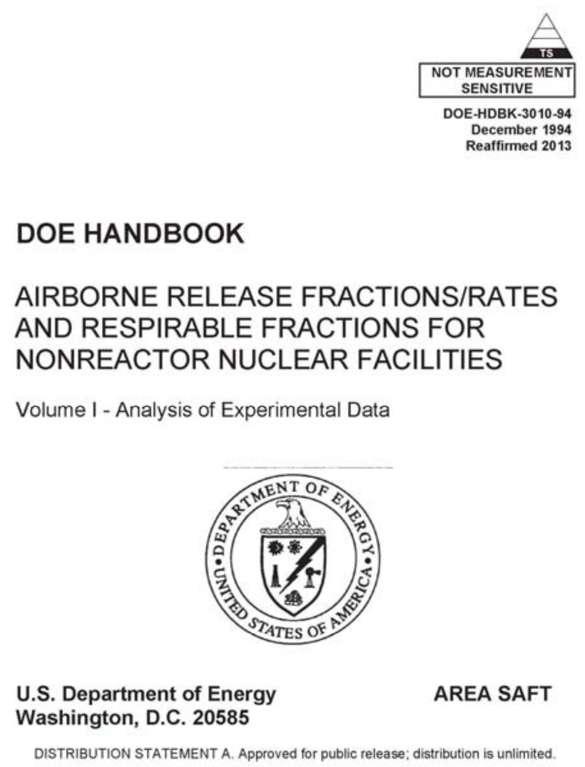
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DOE-HDBK-3010-94
December 1994
Reaffirmed 2013

DOE HANDBOOK

AIRBORNE RELEASE FRACTIONS/RATES AND RESPIRABLE FRACTIONS FOR NONREACTOR NUCLEAR FACILITIES

Volume I - Analysis of Experimental Data

U.S. Department of Energy
Washington, D.C. 20585

AREA SAFT

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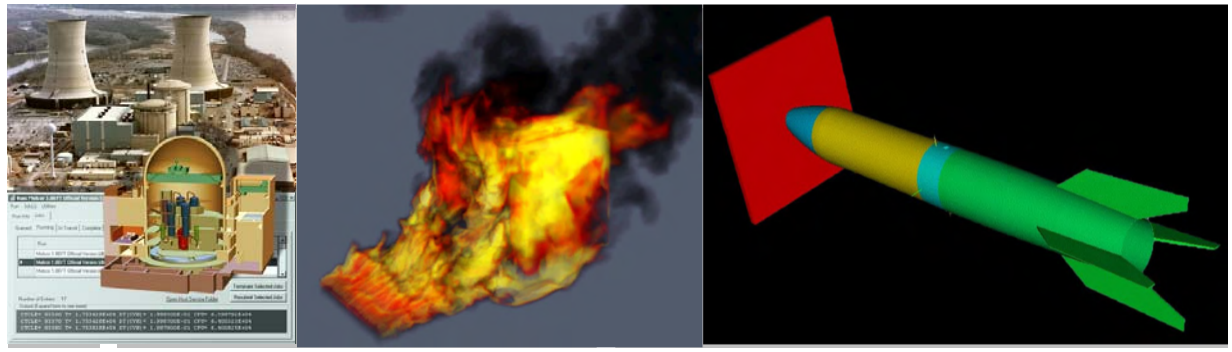

Computational Capability to Substantiate DOE-HDBK-3010 Data

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Why Want to Substantiate Handbook?

- Safety analysts at DOE complex rely heavily on the data provided in this Handbook to determine the source term (ST)
- Five Factor Formula
  - $\mathrm{ST} = \mathrm{MAR} \cdot \mathrm{DR} \cdot \mathrm{ARF} \cdot \mathrm{RF} \cdot \mathrm{LPF}$
    - MAR - material at risk, DR – damage ratio, ARF – airborne release fraction, RF – respirable fraction & LPF – leak path factor
- More often, analysts simply take the bounding values to perform ST calculations to avoid regulatory critique
- Derived data (i.e., ARF & RF) from Handbook:
  - Very limited table-top and bench/laboratory experiments
  - Engineering judgement which may not have adequate bases
  - Actual situation may not be represented

Technical Approach/Benefits

- To leverage the state of art 3-D integrated computer codes developed at Sandia – Sierra Code Suite to substantiate the data in the Handbook:
  - Ensure that table-top and bench experiments in Handbook can be substantiated
  - Provide physical insights into the events that leads to the airborne release
  - Provide data assessment for the realistic accident conditions
- The goal of this approach is to ensure the accuracy and technical defensibility of the airborne release safety analyses
  - Non-conservative data – underestimates ST – safety concern
  - Over-conservative data – overestimates ST – Substantial cost to DOE/NNSA

Sandia Sierra Code Suite

- Sierra code suite includes solid mechanics (i.e., PRESTO), structural dynamics, thermal mechanics, fluid dynamics (i.e., FUEGO) and a number of utilities that can be coupled for simulating multi-physics problems
- This code suite is compliant with DOE Order 414.1D (SAND2008-5517)
- The codes are installed on supercomputing clusters at Sandia, and readily available for use within Sandia
- There is no license fee associated with the usage
- Use and information release are subject to approval

Scope

Address common accident scenarios encountered across the complex, namely fire

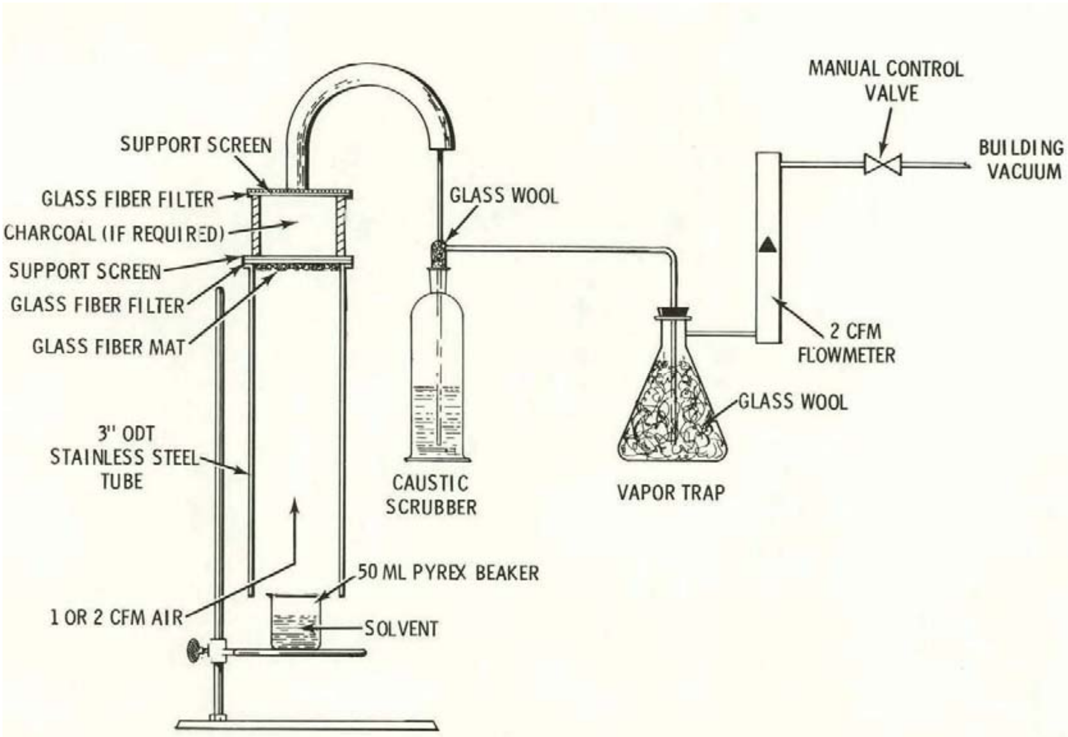
- Analyze contaminated liquid pool fires using FUEGO (Section 3.3 of Handbook)
  - Validate mechanistic FUEGO capability – lab-scaled experimental data in Handbook

Provide exploratory simulations (i.e., PRESTO and FUEGO) to address solid/powder

Simulation of Liquid Fire using FUEGO

- Chapter 3 of Handbook discusses release related to liquid
- From other work, we have demonstrated that Sierra code suite (PRESTO/FUEGO) can be used to simulate an explosion accident involving combustible liquids
  - Similarly, we believe we could simulate liquid nuclear excursion using the combination of PRESTO/FUEGO
  - Liquid explosion – chemical energy and by-product
  - Nuclear excursion – fission energy and fission product
- We currently simulate liquid fire experiments described in the Handbook (Section 3.3)
  - Beaker fire (BNWL-B-274)
  - Gasoline pool fire (BNWL-1732)

Beaker Fire (BNWL-B274)



- Apparatus – 50 ml beaker
- Liquid – kerosene with 30% TBP (25 ml)
- Pre-heated liquid to boiling point then ignited
- Beaker assumed to be 56 mm x 42 mm diameter

FUEGO Simulation:

- Boiling assumed uniformly
- Receded level is not modeled
- Use Kataoka and Ishii boiling model to predict mass flux
- Use Borkowski et al. for initial drop size distribution
- Simulation Results
  - Much of mass released at the beginning of the fire (initial pulse)
  - Wall deposition is significant
  - ARF computed are in agreement with the experiment

Beaker Fire FUEGO Simulation

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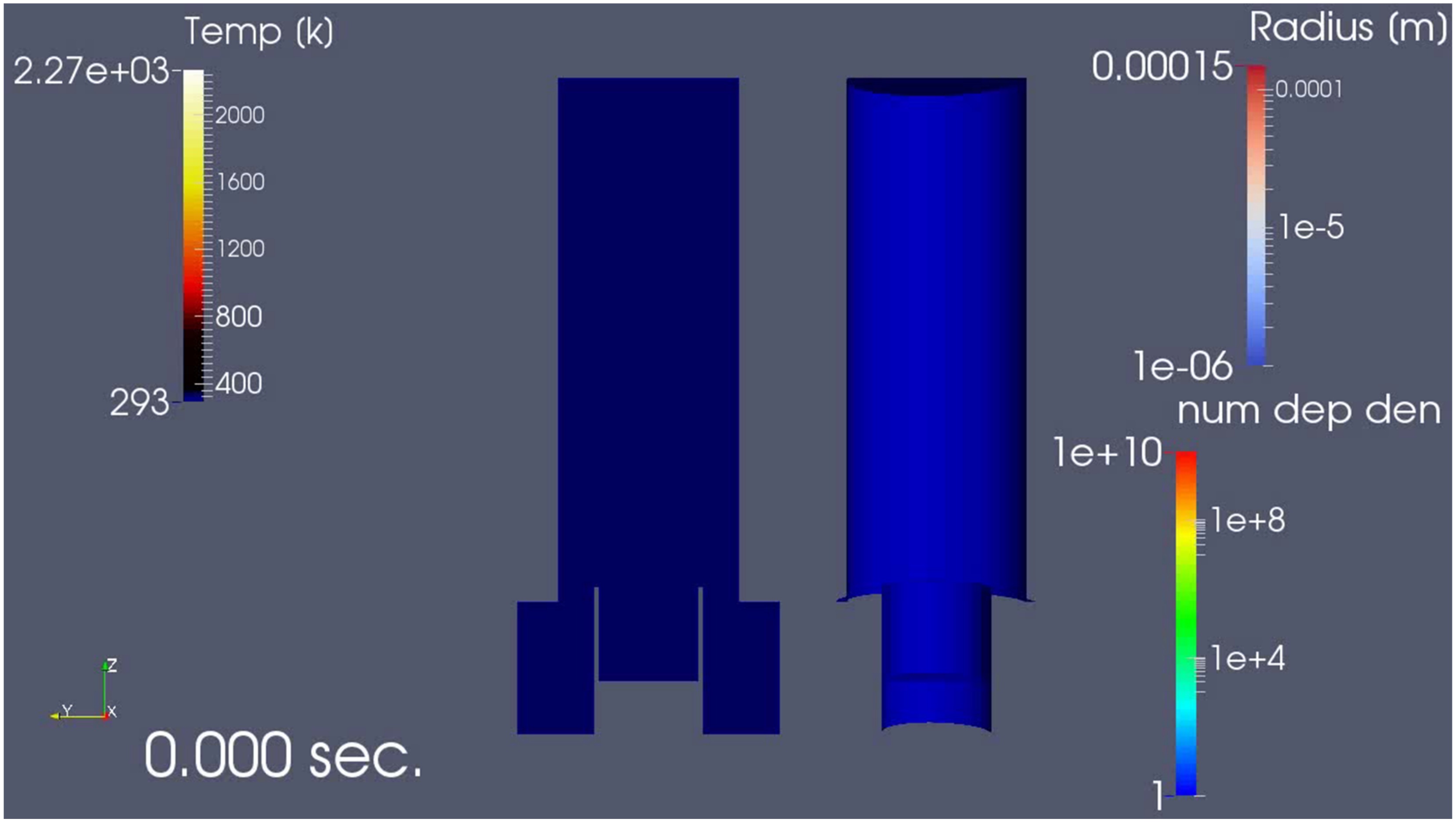
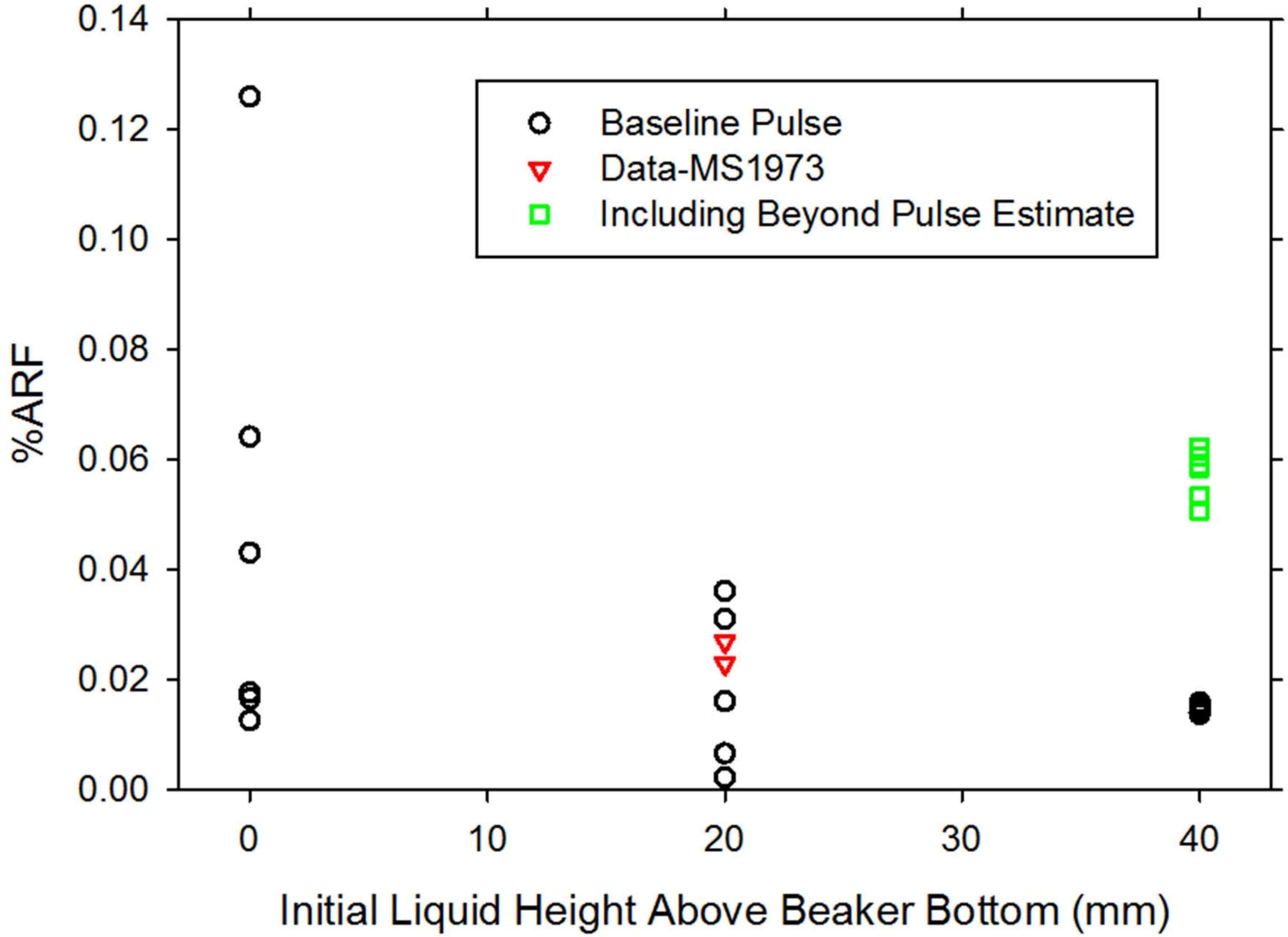
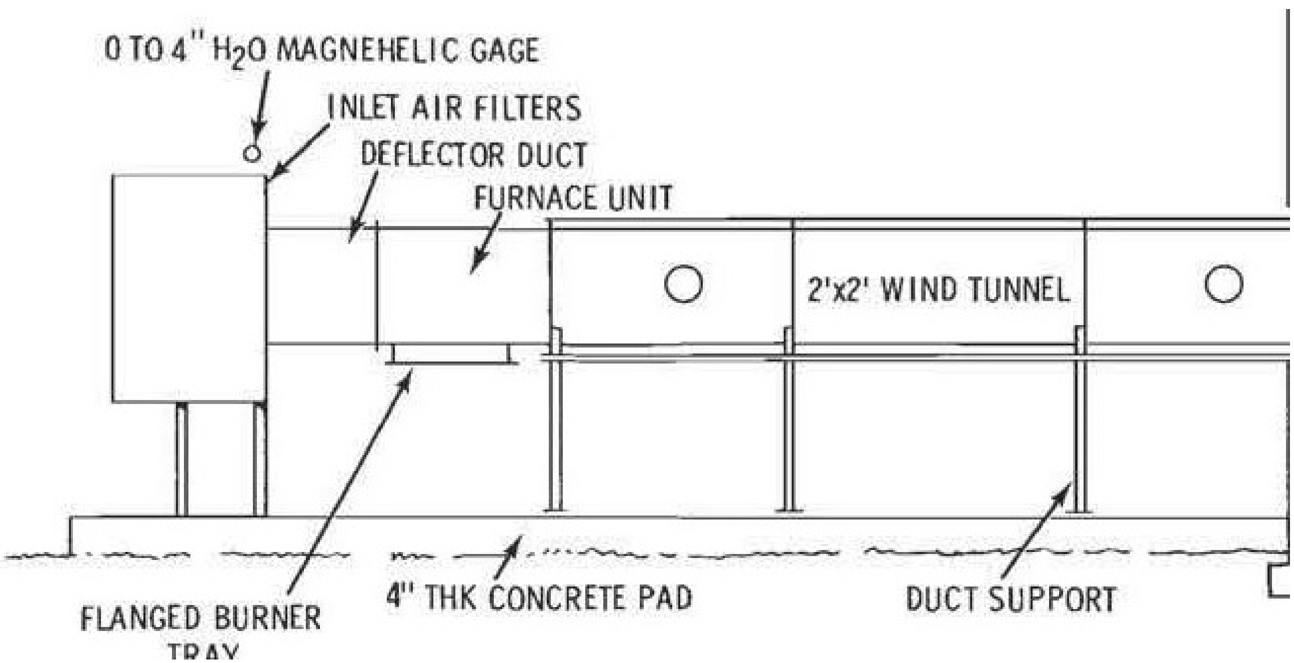


Summary of %ARF Plot for Beaker Fire



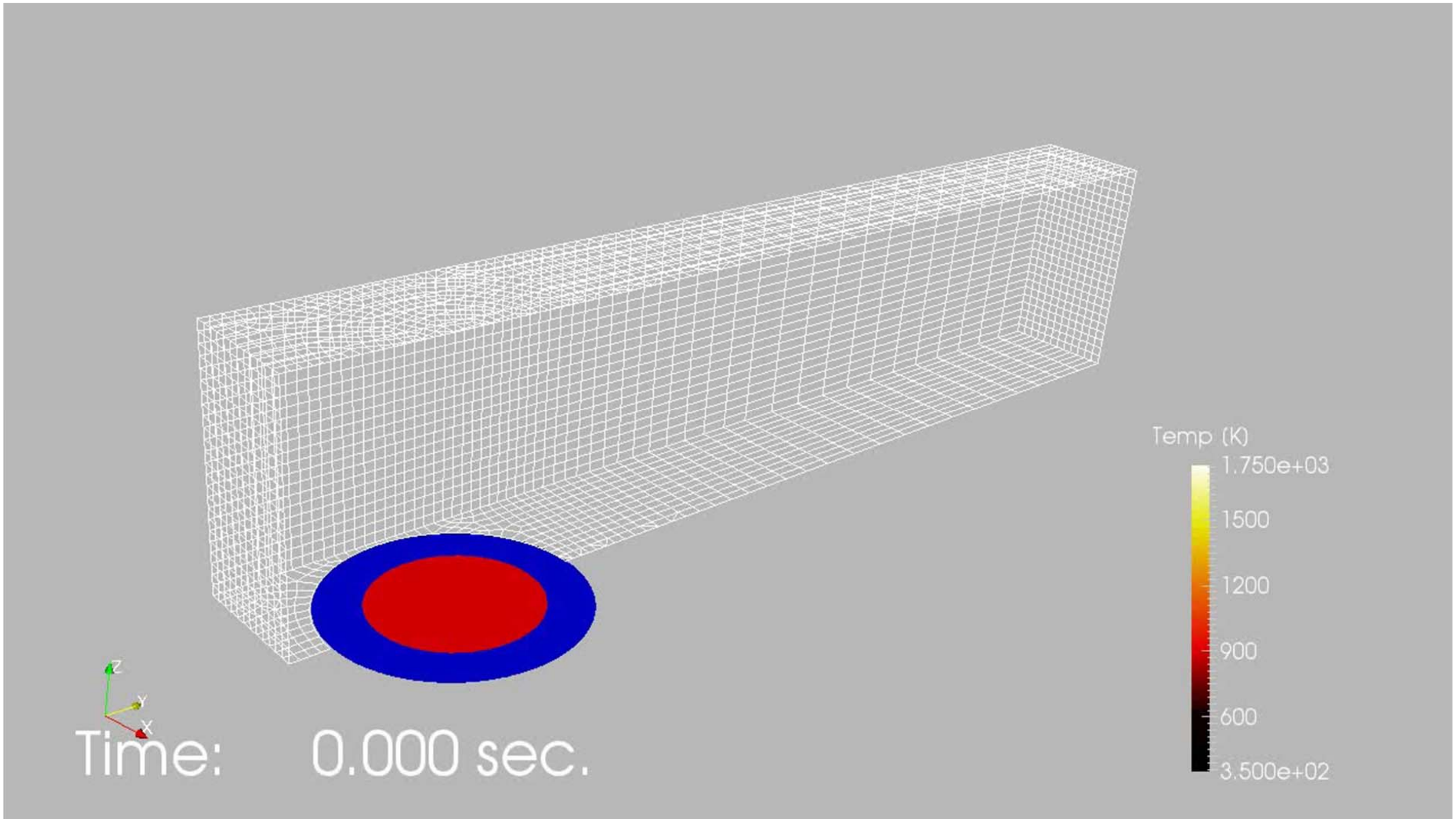
Gasoline Pool Fire (BNWL-1732)

- 1 gallon gasoline onto pan surface
- UO_2 powder, 50 g poured before gasoline
- Pan size 15-inch diameter tray used



- FUEGO Simulation
  - Reproducing the test environment as closely as possible
- Simulation Results
  - Base case -20 s run
- Sensitivity Study is in progress – particle generation
  - Gasoline vaporization
  - Boiling surface rupture
  - Residue re-suspension

Gasoline Pool Fire (Simulation)



Exploratory Simulations (other than liquid)

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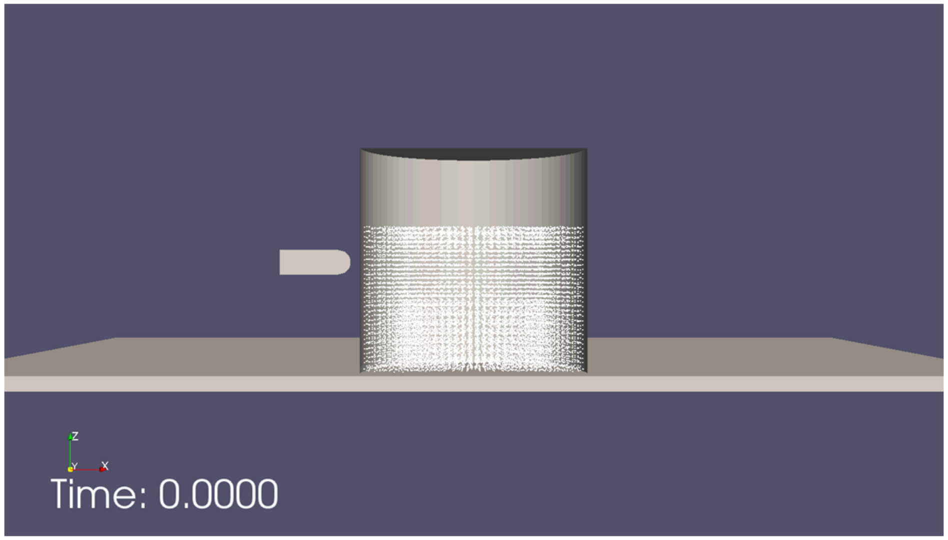
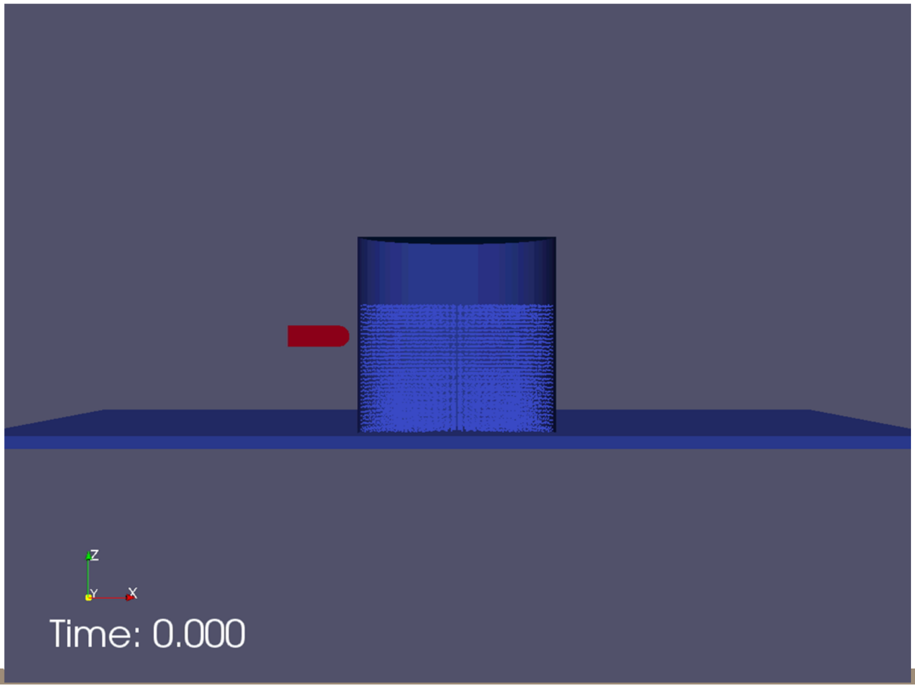
- We currently focus on the powder release
- We selected two powder scenarios to simulate using PRESTO and FUEGO
  - An object hitting a can filling with powder
    - Use Sierra SM code, PRESTO
    - Particle (SPH) model available
    - A coarse model is simulated. A refined model is in progress
  - A pressurized release of powder from a chamber into a containment volume
    - Experiment of PNL-4566 described in Section 4.4 of Handbook
    - A model is simulated (at 100,000 particles, at 250 psig, at 50 psig) using FUEGO
    - Preliminary MELCOR 2.1 models have been developed

PRESTO Preliminary Powder Impact Simulation

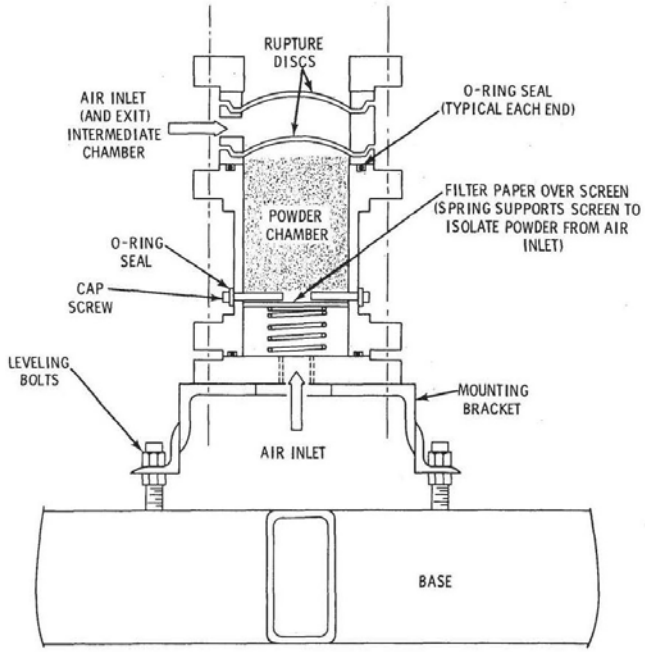
Low velocity case

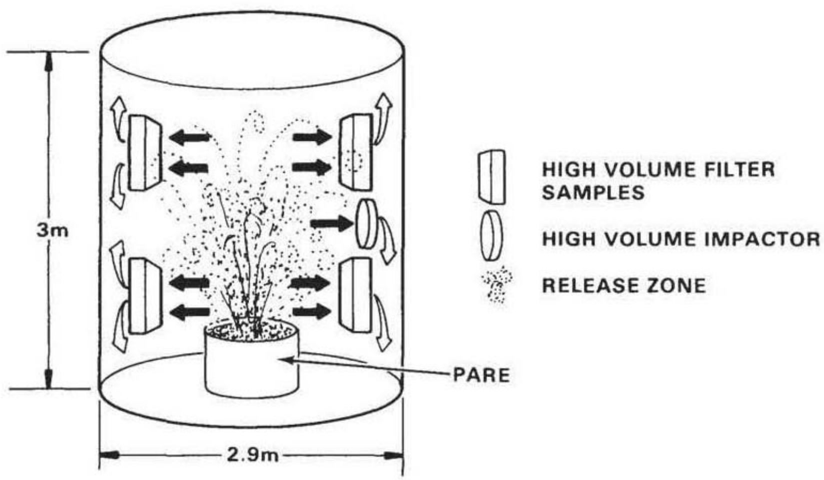


Higher velocity case



Pressurized Powder Release (PNL-4566)





This experiment consists of two chambers

- PARE – 800 cc
- PART– 2.9 m dia x 3 m high

Powder Characteristics

- 100 g of TiO_2
- 1.7 µm

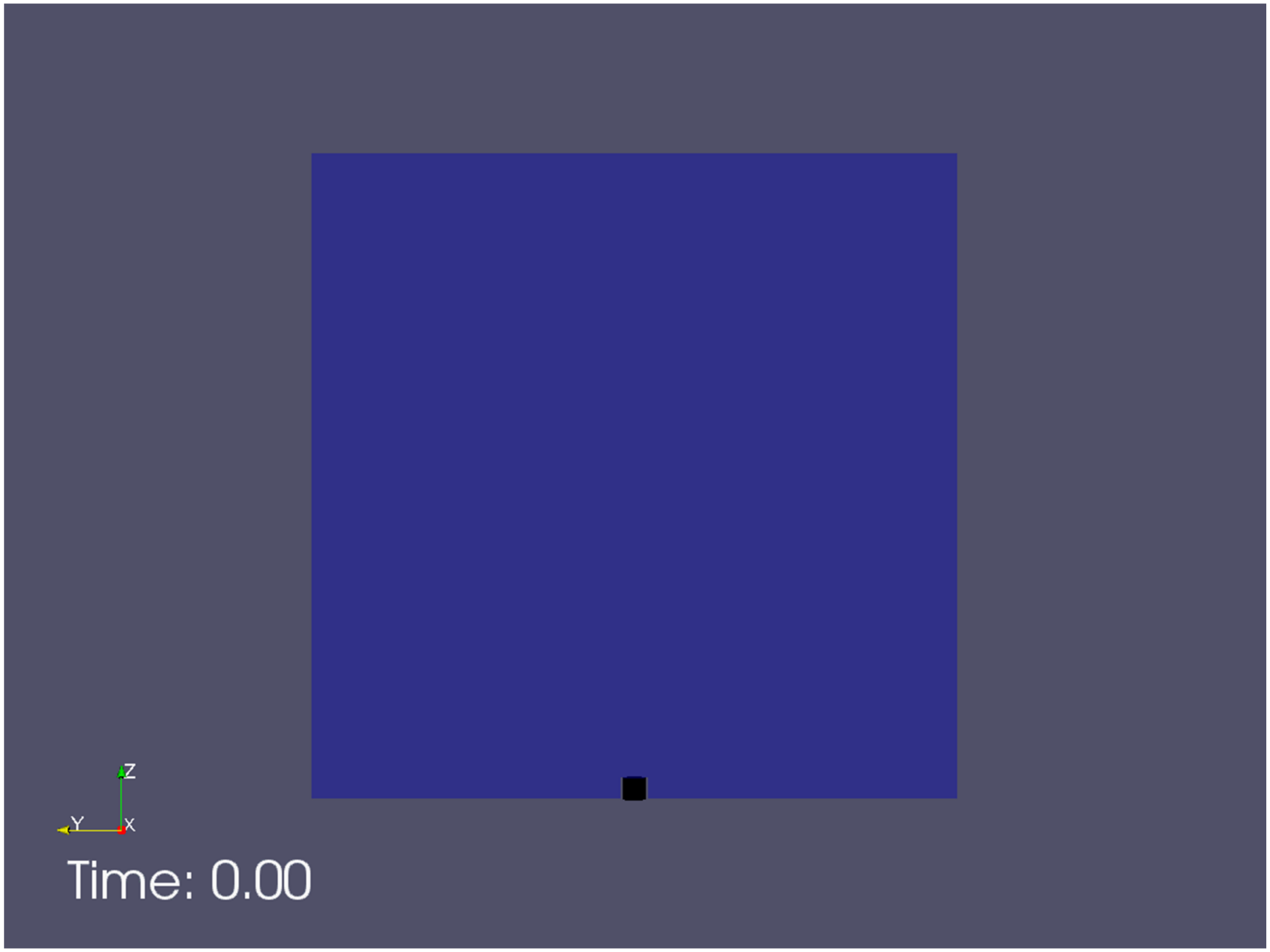
PARE initial Pressure – in psig

Preliminary simulations:

- FUEGO (50)
- MELCOR (50, 250 – 1& 2 control volume cases). It shows that 2-volume case yields a better result

FUEGO Pressurized Release Simulations

50 psig with 100,000 particles



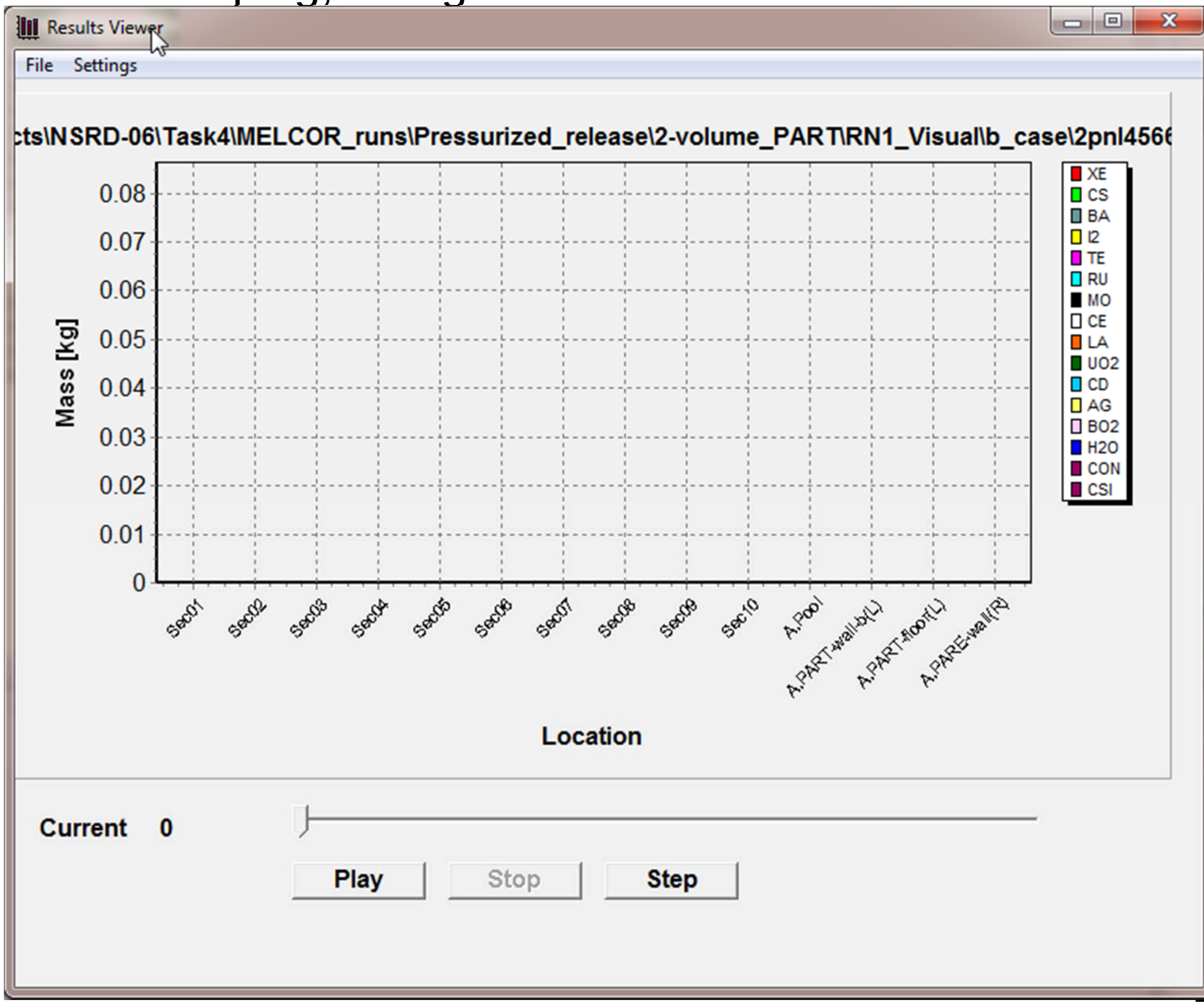
MELCOR 2.1 Preliminary Simulations

Two-Volume Case – 250 psig, 100 g TiO2

PART-bottom Half

PNL-4566 Data –ARF =21.3%

MELCOR – ARF=50%



MELCOR 2.1 Preliminary Simulations

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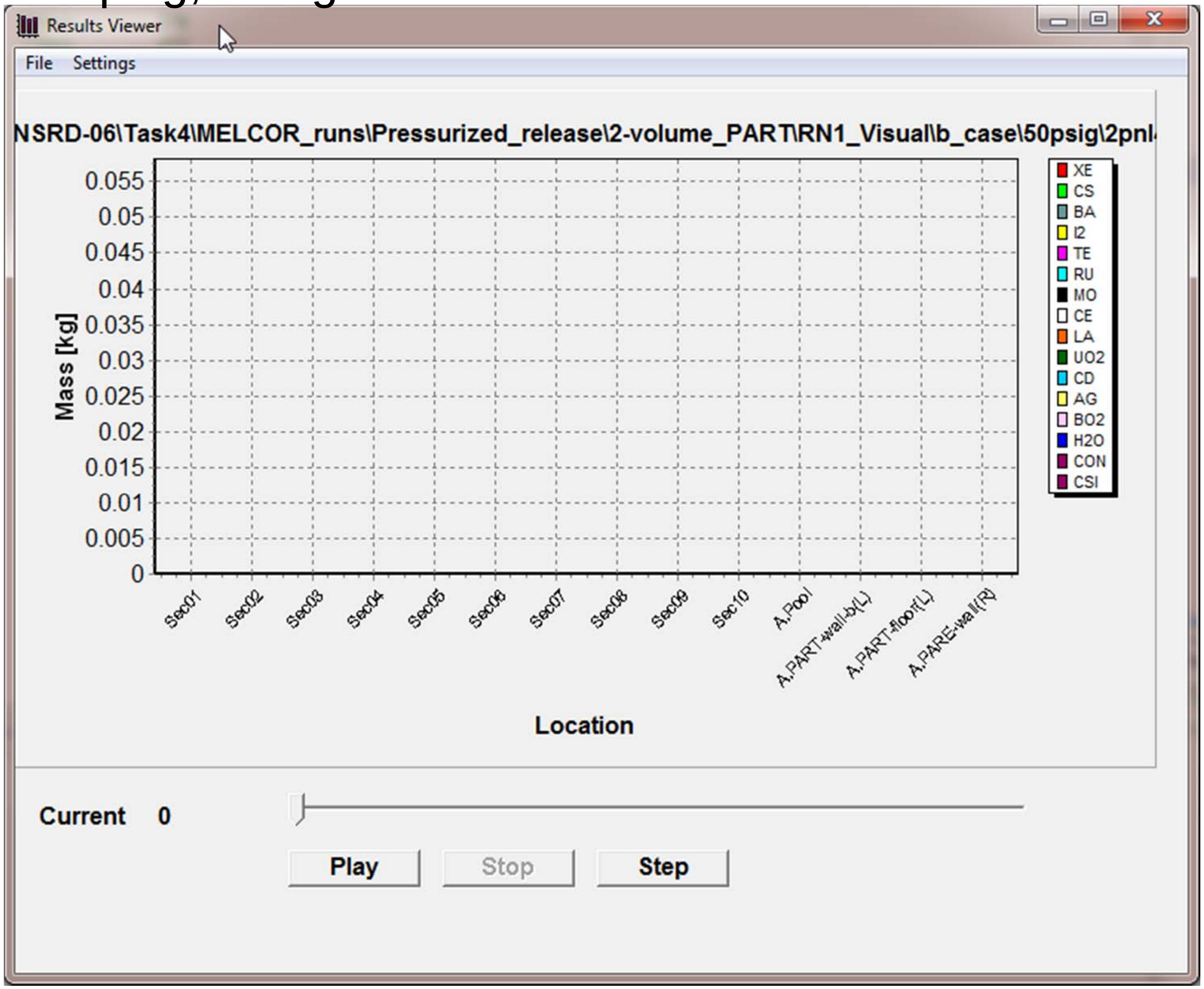
Two-Volume Case – 50psig, 100 g TiO2

PART-bottom Half

PNL-4566 data – ARF=8.2%

MELCOR – ARF=36%

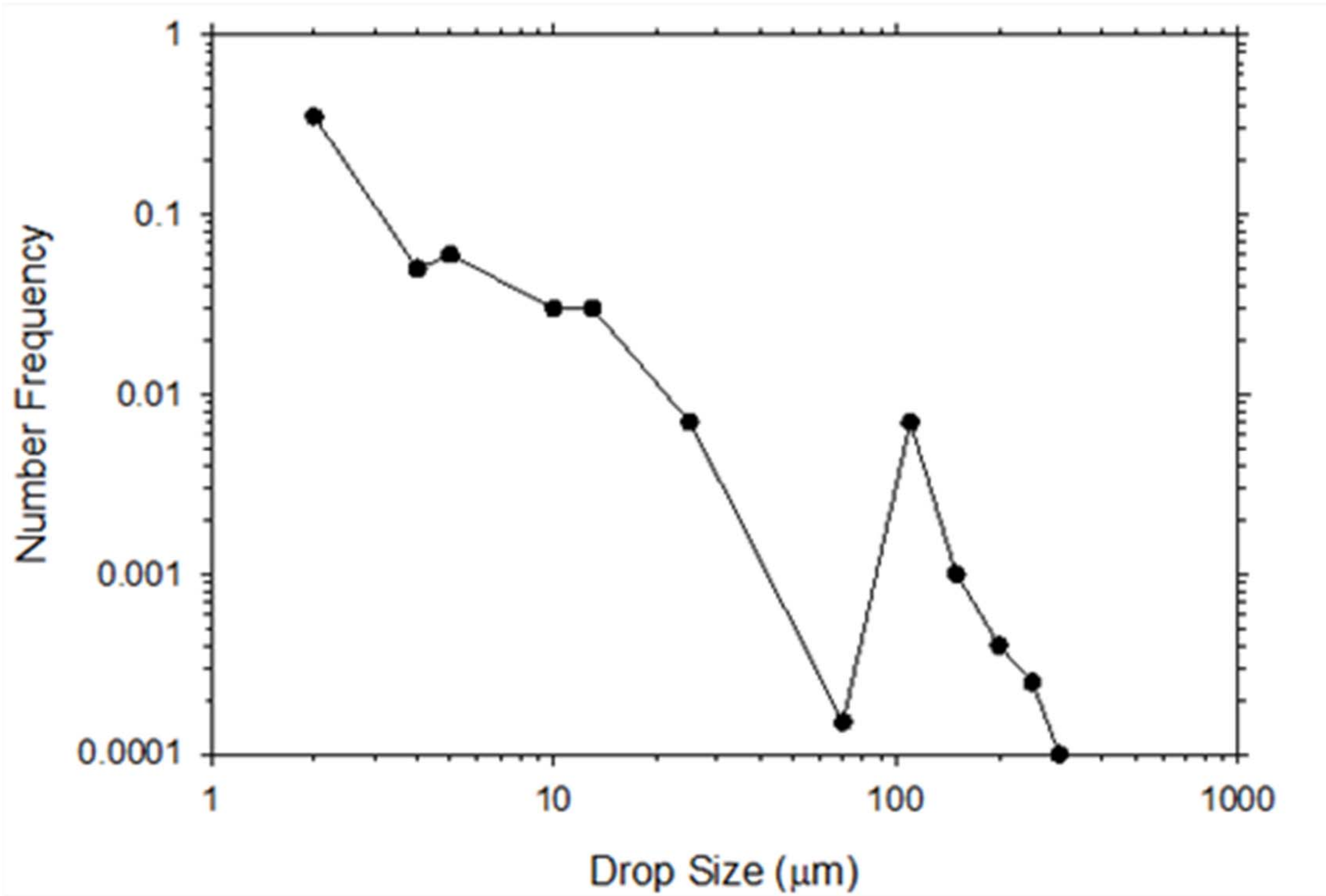


Summary and Concluding Remarks

- This work describes the first steps in an effort to substantiate airborne contamination data in the DOE Handbook using Sandia's Sierra Code Suite
  - Provide physical insights involving liquid fire to ARF and RF
  - Demonstrate the computing tools at Sandia that can be used to investigate the powder release, in additional to the liquid release
  - These simulations also have identified code improvement needs in order to fully use in substantiating the data in the Handbook
- In the coming year, we will expand the capability to study solid release data, in addition to refine the liquid fire and powder release data
- Our ultimate goal is to ensure that the data in the Handbook are accurate, so that the safety basis analysts can apply recommended parameters with confidence

BACK UPs

Droplet Size Distribution Used



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