SAND2018-2595PE

INVESTIGATIONS OF FLOWS & PARTICLE TRANSPORT THROUGH STRESS CORROSION CRACKS IN DRY STORAGE CANISTERS

March 14-15, 2018
CGSC/1155

Meetings & Discussions

Sandia National Laboratories &
Bundesanstalt für Materialforschung und –prüfung (BAM)

PRESENTED BY

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Sandia National Laboratories

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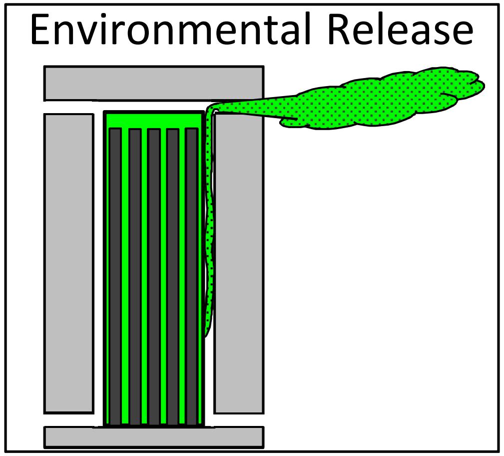
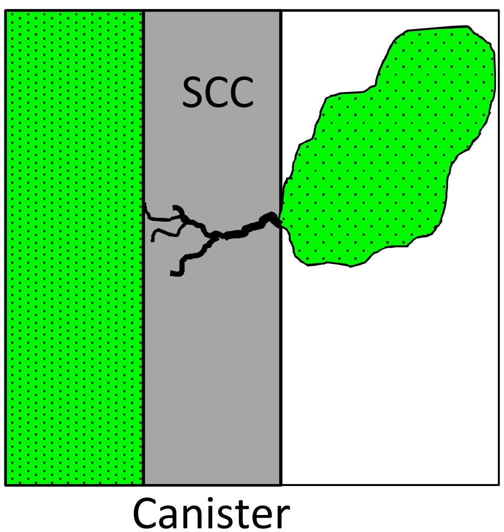
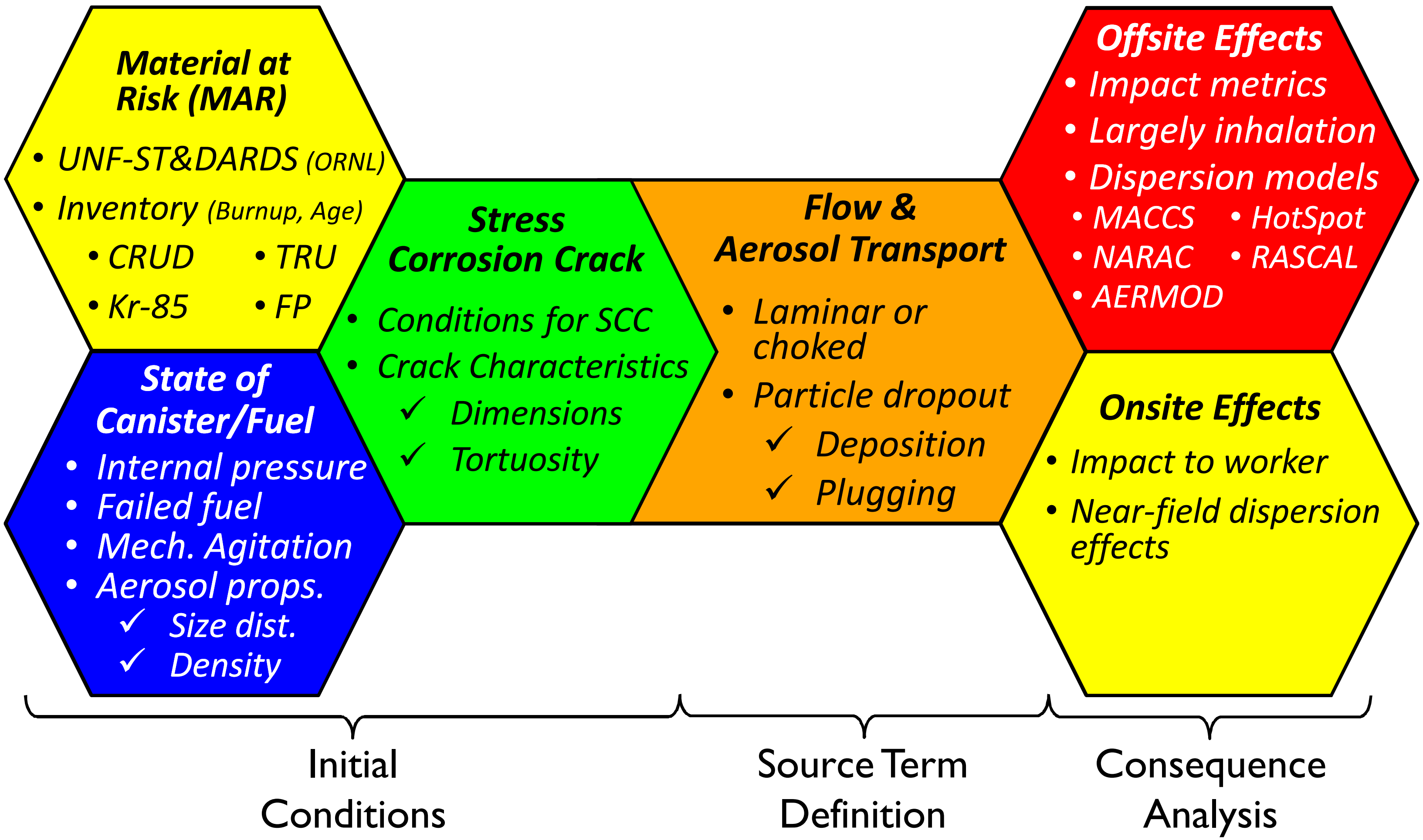
PROBLEM STATEMENT



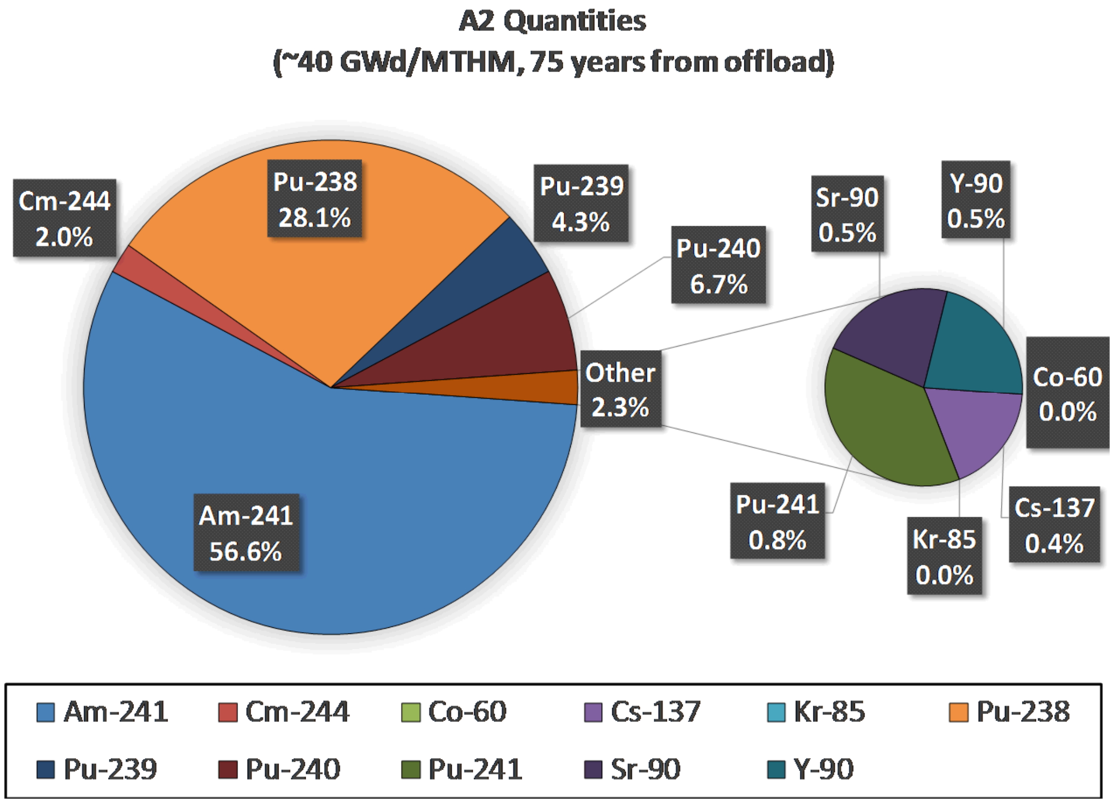


- What is the potential impact of a through-wall stress corrosion crack (SCC)?
  - Relatively low availability of mobile radionuclides under normal storage and transportation
- Significant amount of literature on aerosol transport through idealized leak paths
- Further information needed on following topics
  - Available source term inside canister
  - Characteristics of SCC
  - Flow and particle transport through prototypic SCCs
  - Combined analysis
    - ✓ From Material at Risk → SCC → Gas & Aerosol Transport → Consequence Analysis

ORGANIZATION OF ANALYSES

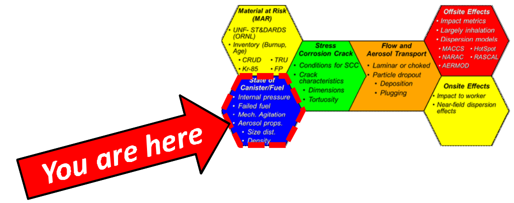


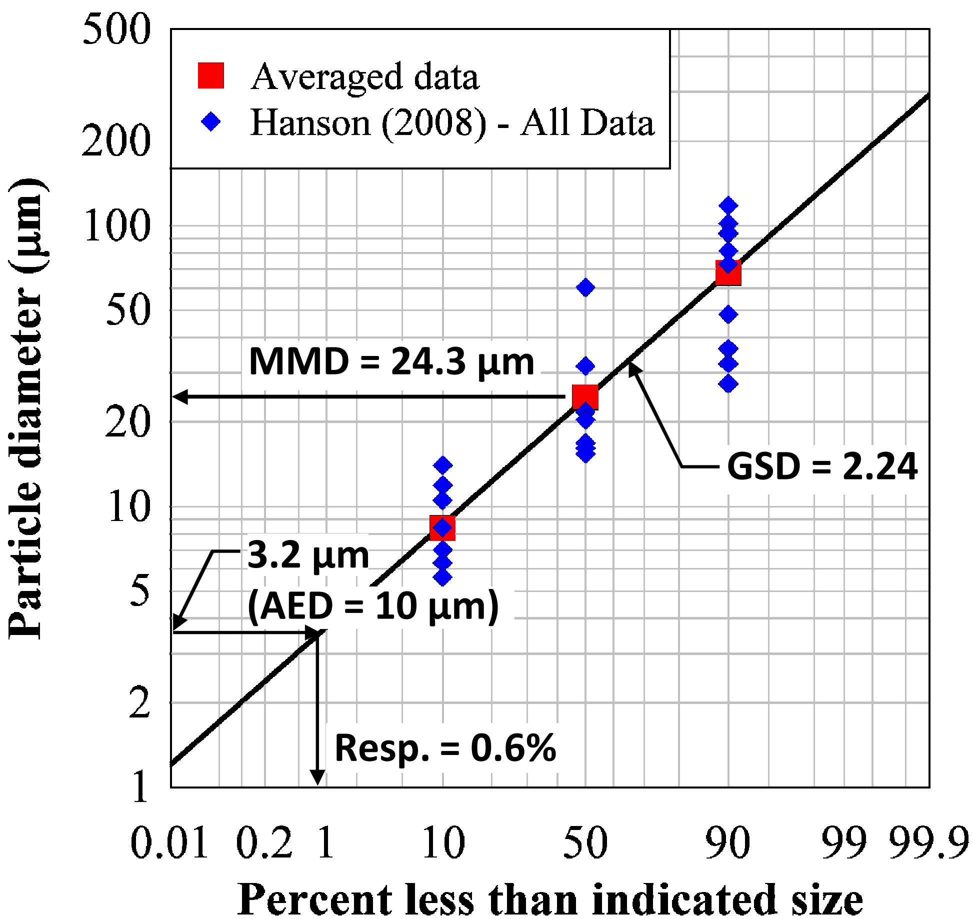
RADIOISOTOPES OF INTEREST



Nuclide	Activity (Bq)	A2 Quantities
Am-241	1.75E+15	1.75E+06
Ce-144	7.76E-11	3.88E-22
Cm-244	1.22E+14	6.10E+04
Co-60	7.61E+10	1.90E-01
Cs-134	2.06E+06	2.95E-06
Cs-137	7.55E+15	1.26E+04
Eu-154	8.22E+12	1.37E+01
Kr-85	3.76E+13	3.76E+00
Pu-238	8.67E+14	8.67E+05
Pu-239	1.33E+14	1.33E+05
Pu-240	2.05E+14	2.05E+05
Pu-241	1.57E+15	2.62E+04
Ru-106	1.45E-04	7.25E-16
Sr-90	4.67E+15	1.56E+04
Y-90	4.67E+15	1.56E+04

SPENT FUEL RELEASE DATA

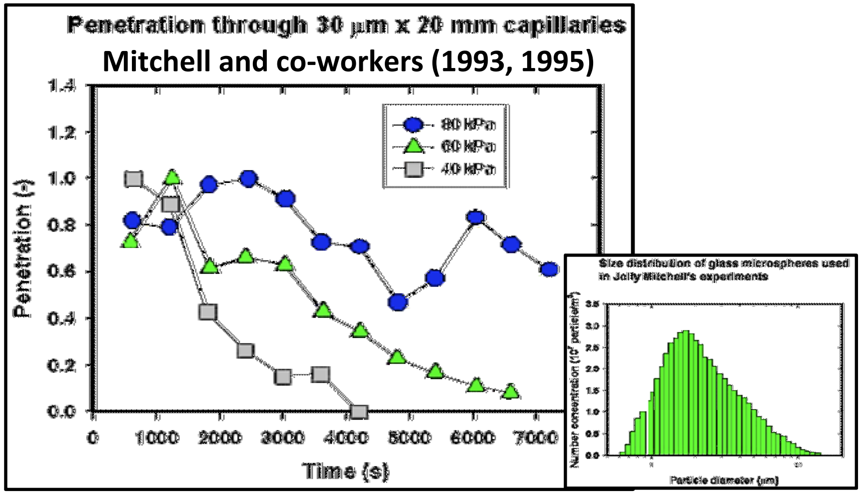


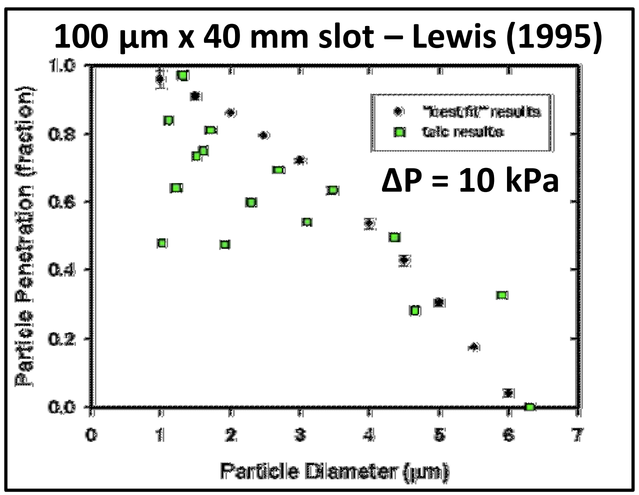


Hanson, B.D., et al., "Fuel-In-Air FY07 Summary Report," Pacific Northwest National Laboratory, PNNL-17275, September 2008

- Hanson (2008) quantified releases from SNF rods
  - Forced air through segmented fuel
- Average of all data
  - CMD = 3.46 µm, GSD = 2.24
  - Release fraction = 1.9E-5
    - ✓ 4.8E-6 cited in NUREG-2125
    - ✓ Assumes 100% respirable
- Derived quantities of interest
  - MMD = 24.3 µm
    - ✓ Resp. fraction = 6E-3 {for particles < 3.2 µm (or 10 µm AED)}
    - ✓ Resp. release fraction = 1.1E-7

PREVIOUS AEROSOL TRANSPORT STUDIES

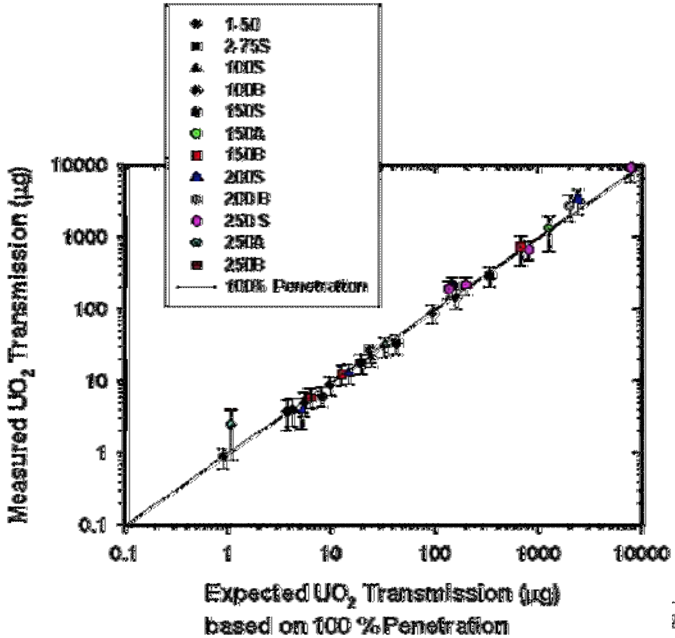


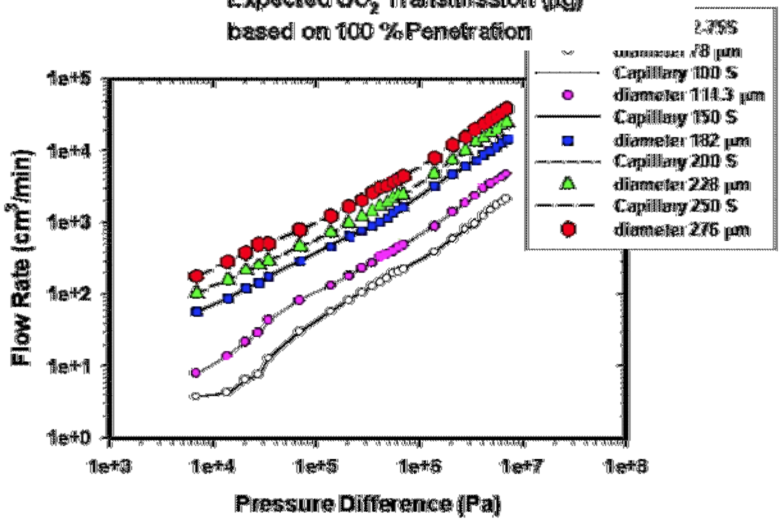


- Review of Aerosol Transport in Leak Paths by Powers (2009)
  - Primarily focused on leaks from containment structures
  - "abundant data (are) available on the deposition of aerosol in idealizations of leak pathways. Data are available for capillaries, orifices, slots and ***cracks in concrete***."
  - Relatively high transmission for moderate pressures
  - Large surface roughness and tortuosity not well characterized

Powers, D.A., "Aerosol Penetration of Leak Pathways –
An Examination of the Available Data and Models," SAND2009-1701, (2009)

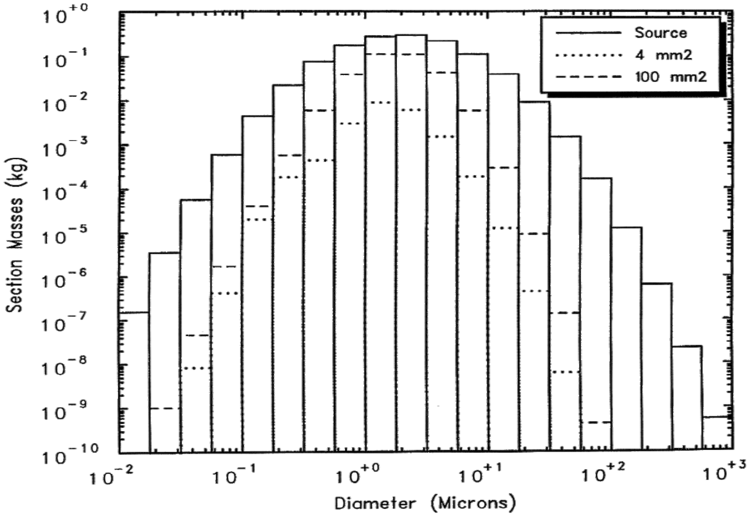
PREVIOUS AEROSOL TRANSPORT STUDIES (CONT.)

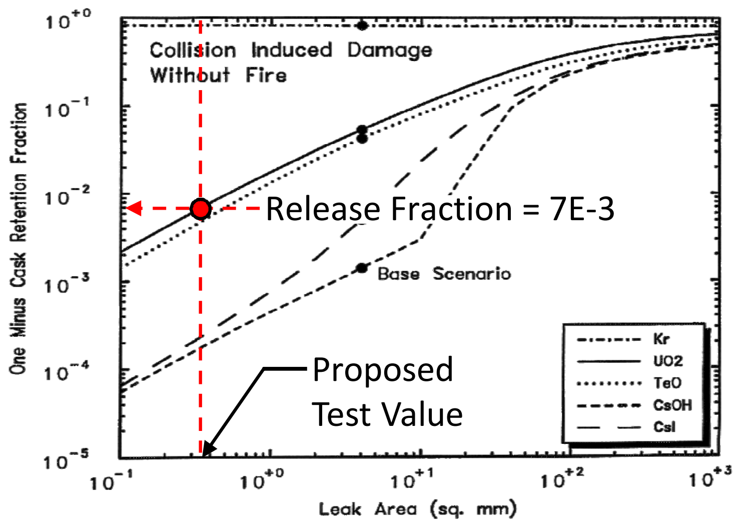




- Continued Review of Aerosol Transport in Leak Paths by Powers (2009)
  - DUO_2 studies
    - ✓ Sutter et al., *"Depleted Uranium Dioxide Powder Flow Through Very Small Openings,"* NUREG/CR-1099, PNL-3177, (1980)
    - ✓ Nearly perfect transport through capillaries and orifices
    - ✓ Includes pressure differentials in range of interest

PREVIOUS AEROSOL TRANSPORT STUDIES (CONT.)

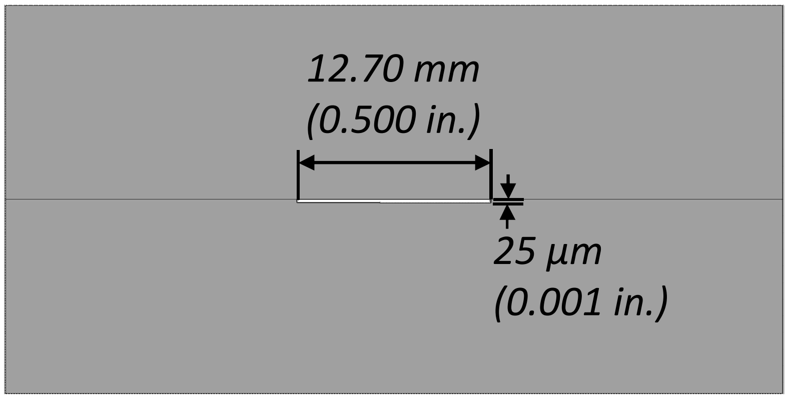


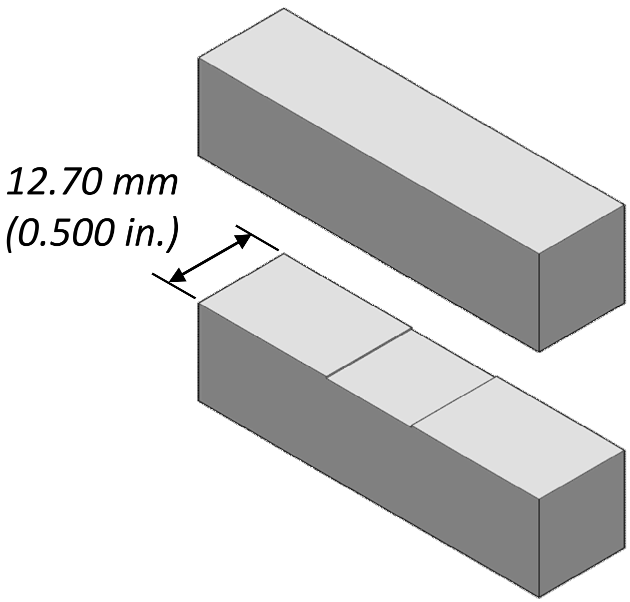


- Transient considerations
  - Blowdown time calculated based on leak area
  - Aerosols depleted in canister during blowdown
  - Assumed canister pressure in range of interest
    - ✓ P_{high} = 507 kPa
  - Depletion fraction = 0.993

Sprung, J.L., et al., "Reexamination of Spent Fuel Shipment Risk Estimates," NUREG/CR-6672, (2000)

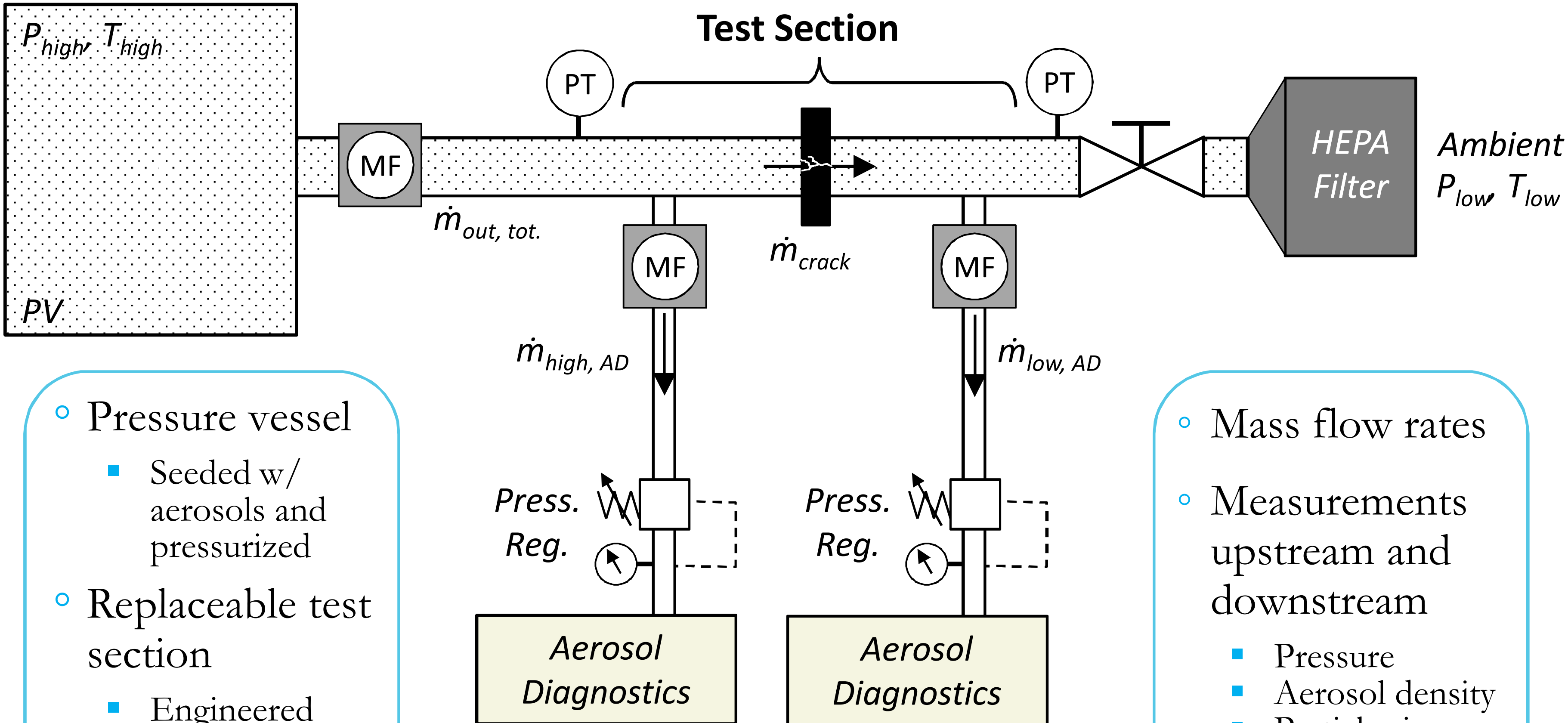
CONVERGENT EXPERIMENTAL ACTIVITIES





- Improve understanding of transmission through SCC's
  - Parallel activities
    - ✓ Understand SCC formation & characteristics
    - ✓ ***Develop testing capability to measure flow and aerosol transport***
- Initial testing with engineered orifices as crack surrogates
  - Measurement comparisons against analytic models and empirical data
  - Verification and refinement of techniques and instrumentation
- Replaceable test section
  - Ultimately conduct experiments with representative SCCs

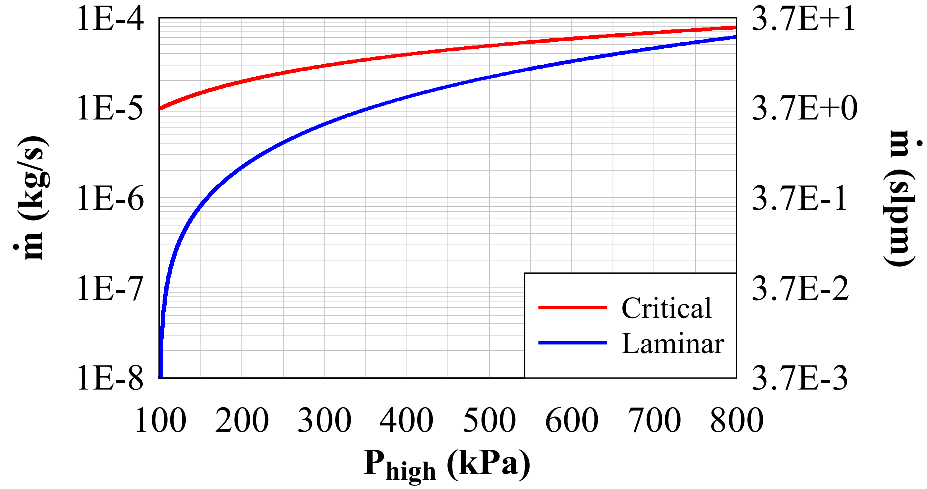
FLOW AND AEROSOL TRANSPORT (TEST APPARATUS)

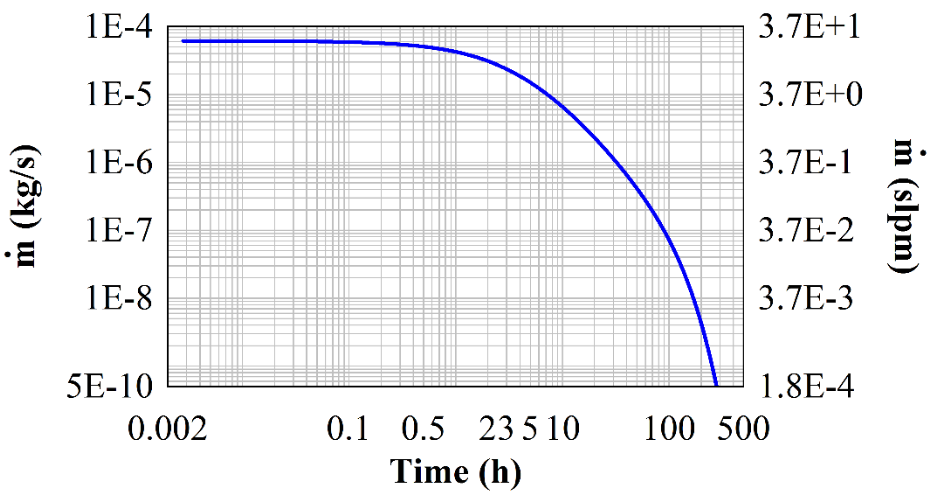


- Pressure vessel
  - Seeded w/ aerosols and pressurized
- Replaceable test section
  - Engineered orifices
  - Representative SCC's

- Mass flow rates
- Measurements upstream and downstream
  - Pressure
  - Aerosol density
  - Particle size distribution

ESTIMATED FLOW RATE





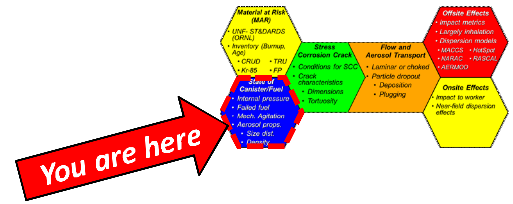
- Flow through 25.4 μm × 12.7 mm slot
  - Flow length 12.7 mm
  - Laminar flow over pressure range of interest
- Mass flow rates span several orders of magnitude
  - Added complication to experimental setup
- Effects of plugging not estimated

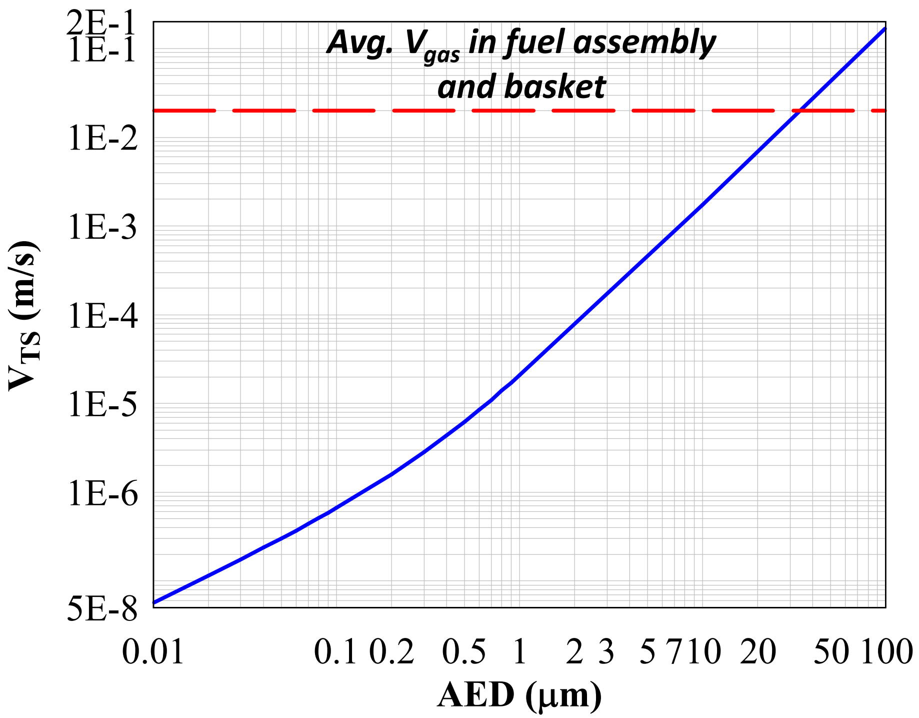
SUMMARY

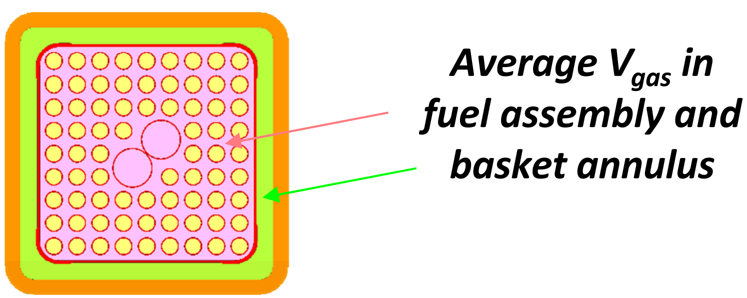
- Inputs and outputs of methods outlined to estimate the impact of a through-wall SCC in a dry storage canister
- Parallel research paths identified to improve understanding of transmission
  - SCC conditions of formation and characterization
    - ✓ Develop representative SCCs under laboratory conditions for future testing
  - Flow and aerosol transport test apparatus
    - ✓ Develop an apparatus capable of measuring flow rates and aerosol characteristics
    - ✓ Interchangeable test section
      - Initial testing with engineered orifices (simplified geometries)
      - Replace with more prototypic SCCs as available

Backup Slides

Canister: Aerosol Settling







- Settling velocity less than average helium velocity for AED < ~30 µm
  - Convective cask design
    - ✓ Assumes 400 kPa and 600 K
    - ✓ Gas velocity increased in downcomer by ~3×
  - Deposition mechanisms will continuously deplete aerosols
    - ✓ Inertial impaction and interception
    - ✓ Gravitational settling
    - ✓ Diffusion
    - ✓ Thermophoresis