SAND2008-4336P

Spent Fuel Sabotage Program: June 2008

David R. Miller, Martin A. Molecke, Michael W. Gregson,
John E. Brockmann, and Michele Steyskal
Sandia National Laboratories

WGSTSC, International Working Group for Sabotage Concerns of Transport and Storage Casks

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under contract DE-AC04-94AL85000.

SNL
Spent Fuel Sabotage Program

- Introductions
- Program description, objectives/needs, data applications
- U.S. and International Partners and Leveraging
- Historical SFR, large-scale testing, results, uncertainties
- Experimental program phases, major results (Phases 1 – 3)
- Existing results, interpretations, and future testing plans
- Phase 4 Spent Fuel testing, planning, needs, and contingencies
- Wrap-up: sponsorship, testing, modeling

Spent Fuel Sabotage Aerosol Research: Introduction

- **TERRORIST SCENARIO:**
  - An intentional sabotage attack an nuclear transport/storage casks by armor-piercing weapons (HEDD) with the intent of radiological aerosol & respirable particle dispersal.

- **HISTORY:**
  - Radiological dispersal initially addressed by NRC in 1970s sabotage studies.
  - Limited explosive-aerosol testing in U.S. (1980s) and Germany (1990s).
  - 9-11 terrorist attacks prompted U.S. and European agencies to increase knowledge about spent fuel and HLW sabotage effects and release.

Spent Fuel Sabotage Aerosol Research: Approach

- **GOAL:** To determine the extent of radiological particle production and release in the event of a proposed terrorist HEDD sabotage attack.
  - At SNL: experimentally quantify source-term data and aerosol particles *produced* from surrogate (CeO_2, DUO_2) and actual Spent Nuclear Fuel single test rodlets.
- **USE of DATA and RESULTS:**
  - To use reliably measured data for follow-on modeling studies of release-aerosol dispersion and transportation consequence assessments.
  - To support consequence determinations made in numerous, earlier Environmental Impact Statements.
  - To provide a defensible technical basis to defend the safety evaluations of proposed transportation systems and security programs.

Spent Fuel Sabotage Aerosol Research: Why

- **IMPORTANCE:**
  To ensure the safe transport of spent nuclear fuels or nuclear wastes to an interim, reprocessing or final disposal facility.
  - To defensibly quantify the extent of radiological release and consequences.
  - To help alleviate the concerns of the general public.
- **RESEARCH SUPPORT:**
  Provided by the DOE, NRC, and … International WGSTSC participants in Europe and Japan.
- **LEVERAGING:**
  Program capabilities (testing, modeling assessments) shared between International WGSTSC participants and national authorities.

Spent Nuclear Fuel / Sabotage Aerosol Data Needs: What

- **Reliably measured source-term data:**
  - **Respirable Fraction (RF)** ***produced*** **(0 - 10 µm AED) and aerosol particle size distributions (< 100 µm)**
  - **Fission Product enhanced sorption (Cs, Ru, Sr, Eu … dopants)**
    - **Integrated Enrichment Factor (IEF) & differential (EF)**
  - **Spent Fuel Ratio (SFR), measurements (single rod test-scale to cask) provide bridge to several large-scale surrogate cask tests, limited 1980s lab measurements, and radiological consequence modeling;**
    - **SFR required for scaling, extrapolation, and modeling studies**

SFR = $\frac{\text{irradiated, Spent Fuel RF}}{\text{unirradiated, surrogate } (DUO_2) \text{ RF}}$ = $\frac{\text{Test Phase 4}}{\text{Test Phase 3}}$

(with ~ identical test conditions)

  - **reduced uncertainties**

Spent Fuel Sabotage/ Aerosol Test Program: How

- **SNL/WGSTSC 4-Phase Testing**
  - **Phase 1: Glass plates & pellets, HEDD** (2001-02, 6 tests)
  - **Phase 2: Surrogate CeO_2 pellets w/ fission product dopants** (2002-04, 24 tests)
  - **Phase 2+: Cesium F.P. Enrichment Factor studies** (2005 at SNL, 6 tests) (2006 at Fraunhofer, 3 tests)

    +: Test 2 in 50 m^3 chamber at SNL, 3/07
  - **Phase 2/Phase 3: Coss-over operational tests** (2004, 3 tests in ECF; 2009 in GIF w/DUO_2 ?)
  - **Phase 3: Six DUO_2 tests @ SNL ECF**

    3 tests performed to determine SFR

  - **Phase 4: eight Spent Fuel rodlet tests @ SNL GIF**

    4 w/ HB Robinson fuel, high burn-up (delayed, ~2009)
    4 w/ Surry fuel, low-med burn-up (delayed, ~2010)
    Required to determine SFR

Phase 3

Sandia National Laboratories

Spent Nuclear Fuel Sabotage Major Testing Objectives & Needs:

1. **Provide reliable, measured source-term data (aerosol generation) for supporting realistic sabotage consequence assessments of radiological, respirable particle atmospheric dispersion**
   - Enhance very limited, 20+ yr-old data and assumptions
   - Reduce uncertainties to enable better risk & consequence analyses
   - Experimental data needed to ensure accurate modeling

2. **Measured data will allow defensible prioritization of security planning, safeguards, and mitigation responses for sabotage attacks on SNF, nuclear materials in use, transport, and storage**
   - Would reduce expenses associated with conservatively designed transport systems…

3. **Provide further validation of NRC vulnerability studies**
   - Supplement vulnerability studies performed by NRC and support DHS in planning for terrorism response activities

Spent Nuclear Fuel Sabotage Major Program Objectives & Needs:

4. Guide and validate technical bases for transport & storage regulations (10 CFR Parts 71, 72, and 73)

5. These tests are the culmination of multi-year, international collaborative efforts: U.S. DOE, NRC, with German, French, British, Japanese WGSTSC partners -- to counter nuclear terrorism

   - test data & modeling sharing w/ Multi-Lateral Agreement

6. Provide support to DOE OCRWM - Yucca Mountain Repository transportation sabotage evaluations

7. Measured results and analyses may enhance public confidence or tolerance of risks associated with SNF and hazardous shipments

8. Needs of new program sponsors can be incorporated

International Working Group for Sabotage Concerns of Transport and Storage Casks

WGSTSC Program Partners and Leveraging:

★ cooperative research and analyses since 1999 ★

- **Sandia National Laboratories** (SNL)

Transport/ Nuclear TESTING	EXPLOSIVE Technologies	Chemistry
NUCLEAR Facilities	AEROSOL Processes	Ceramics

- **DOE** (OCRWM; NA, EM): primary funding
- **DOE SSO/NNSA** (facilities)
- **NRC** (RES; NSIR, SFPO): co-funding support
- **Argonne National Laboratory** (ANL): spent fuel

- **Germany:** (GRS) Gesellschaft für Anlagen- und Reaktorsicherheit, and Fraunhofer (ITEM & HMI)
- **France:** Institut de Radioprotection et de Surete Nucleaire (IRSN)

- **UK:** Office for Civil Nuclear Security (OCNS)
- **Japan:** (JNES, JAEA)

multinational data & modeling sharing, MLA

Reference:

WGSTSC Meeting History

- **7/1999: 1st mtg, @ SNL**
  - SNL & DOE-NN info exchange
  - common experimental work
- **3/2000: 2nd mtg, @ IPSN, Paris**
  - decision: surrogate vs. spent fuel
- **7/2000: 3rd mtg, @ GRS, Berlin**
  - Joint Test Proposal GRS-SNL, w/IPSN
- **12/2000: 1st Tech. Mtg, @ SNL**
  - rev. Joint Proposal
  - define working package
- **5/2001: 4th mtg, OCNS, London**
- **11/2001: 2nd Tech. Mtg, IRSN @ Cadarache, France**
- **7/2002: 3rd Tech. Mtg, @ SNL**
- **11/2002: 4th Tech. Mtg, @ SNL**
- **5/2003: 5th Tech. Mtg, @ GRS, Köln**
- **11/2003: 6th Tech. Mtg, @ ANL & DC**
- **5/2004: 7th T.mtg, OCNS, Edinburgh**
- **11/2004: 8th Tech. Mtg, @ SNL**
- **5/2005: 9th Tech. Mtg, IRSN, @ Cadarache**
- **11/2005: 10th Tech. Mtg, @ SNL**
- **5/2006: 11th Tech. Mtg, GRS, @ Kandern & Garching, Germany**
- **12/2006: 12th Tech. Mtg, SNL, @ LV**
- **5/2007: 13th Tech. Mtg, IRSN @ Fontenay-Aux-Roses & Saclay**
- **10/2007: informal mtg, PATRAM, Miami**
- **??**

Spent Fuel Sabotage/ Aerosol Testing History: A

- **Small-Scale: DUO_2 & Spent Fuel**
  - **Idaho INEL (SNL/DOE) 1982, Alvarez et al.:**
    - 2 tests w/ HB Robinson SF, single pellets; very small CSC used
    - SFR ~5.6 (sieve … est.) & ~ 0.53 calc.
    - Impactor data which would have provided direct SFR determination was lost
    - Cs EF ~56 or 35 (< 0.2 or <1 μm), Ru EF ~16 or ~10
  - **Battelle BCL (NRC) 1982, Schmidt et al.:**
    - 8 tests w/ HB Robinson SF
    - SFR ~ 3.0; Cs EF ~16 (<1 μm), Ru EF ~5

- **Large-Scale Cask: DUO_2 Surrogate**
  - **SNL 1980-83, Sandoval et al.:**
    - full-scale and ¼-scale cask tests (single assembly) ➡
  - **GRS (Gramat), 1992-94, Pretzsch & Lange:**
    - 1/3-length Castor cask tests
    - Luna (2001) calculated DUO_2 RF = 1.7 - 5.3% (1-wall), RF = 2.8 - 12% (2-wall)
  - **IRSN:** other tests not in the open literature

Spent Fuel Sabotage/ Aerosol Testing History: B

- **Spent Fuel Ratio, data & uncertainties**
  - INEL, BCL calc. values based on assumptions …
  - No statistics available
  - Existing SFR range of 0.5 to 12, (factor ~ 10) with uncertainties, but are only SFR values available to date
  - A value of 3 used in the YMP EIS (Luna, 1999)
  - SFR = 3 was subject of questions in EIS comments
  - Limited fission product EF from INEL, BCL
  - Conservative assumptions & calculations

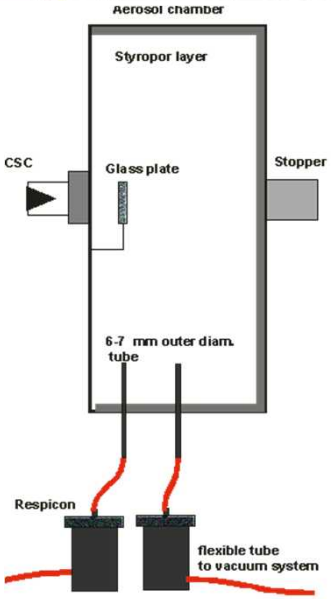
- **WGSTSC: Joint Proposal (2000)**
  - WGSTSC > more explosive-aerosol testing needed …
  - GRS/SNL aerosol testing plan proposed to measure SFR
  - 3 test phases proposed: glass, DUO_2, & Spent Fuel
  - Modified to 4 test phases in 2002

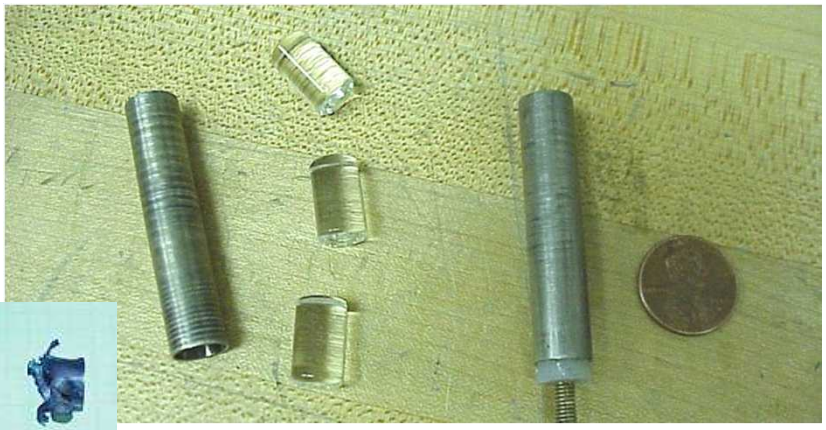
Reference:

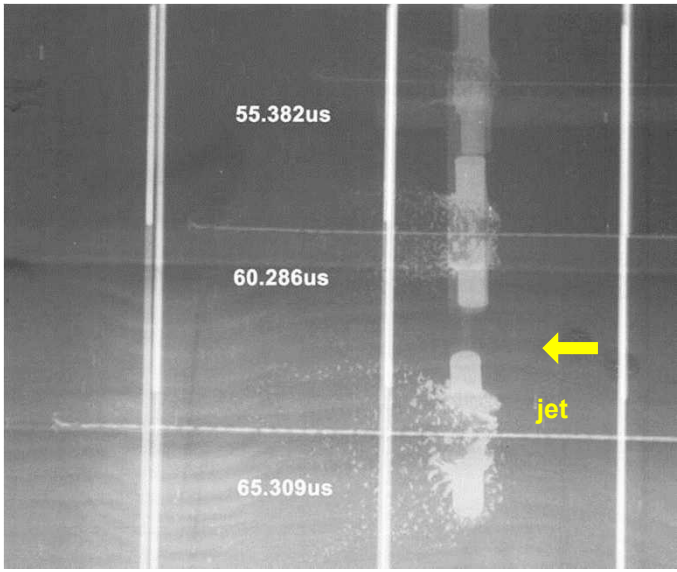
Spent Fuel Sabotage 4-Phase Test Program

Phase 1: Glass, HEDD (2001 - 02)

- HEDD/ CSC evaluation tests
- Validate brittle material fracture law
  - leaded-glass plates (4 tests)
  - glass pellets/Zircaloy tube (2 tests)
- Aerosol testing at SNL (ECF) & in Germany
- Development of test apparatus
- SAND2005-5873







Flash X-Ray of HEDD jet and glass pellets

Sandia National Laboratories

Reference:

Spent Fuel Sabotage 4-Phase Test Program

8/2003 ⬆ ⬇ 2/2004

Phase 2: CeO_2 Pellets (10/2002 - 5/04)

- Chemical, ceramic surrogate for UO2
- 24 explosive- aerosol tests
- Test multiple variables at SNL ECF
- Multiple aerosol particle impactors
- Respirable Fractions, distributions, particle chemical analyses by ICP-MS, and non-aerosol particle sieving
- w/ fission product dopants (Cs, Ru, Sr, Eu) (measured RF & EF, integrated & differential)
- Multiple aerosol particle sampler systems
- Component qualifications & optimizations for Phase 3 and 4 tests

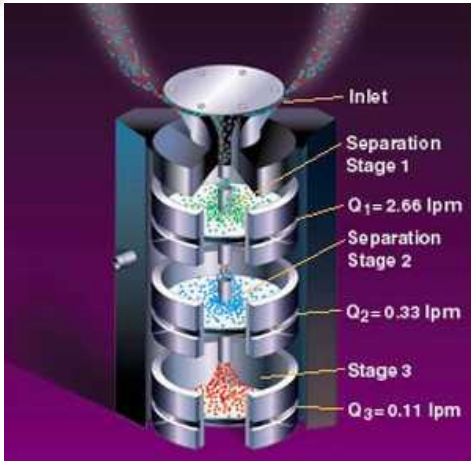
⬅ 24-32 mm of **rodlet "particulated"** pellets captured in tube

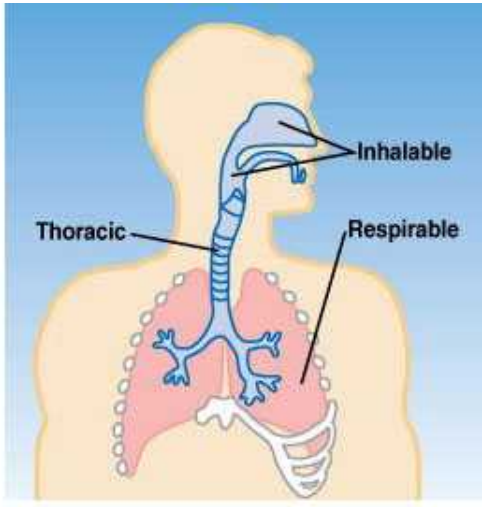
⬅ S.N.L.-German test cooperation **HLW glass rods**

Sandia National Laboratories

Reference:

Respirable & Aerosol Particle Collection - a





RESPICON 3-stage virtual impactor

aerosol particle collection device

(early Phase 2)

Respirable & Aerosol Particles:

★ **Top:** Respirable fraction, 0 ~ 4 μm AED

★ **Middle:** Thoracic fraction, > 4 ~ 10 μm

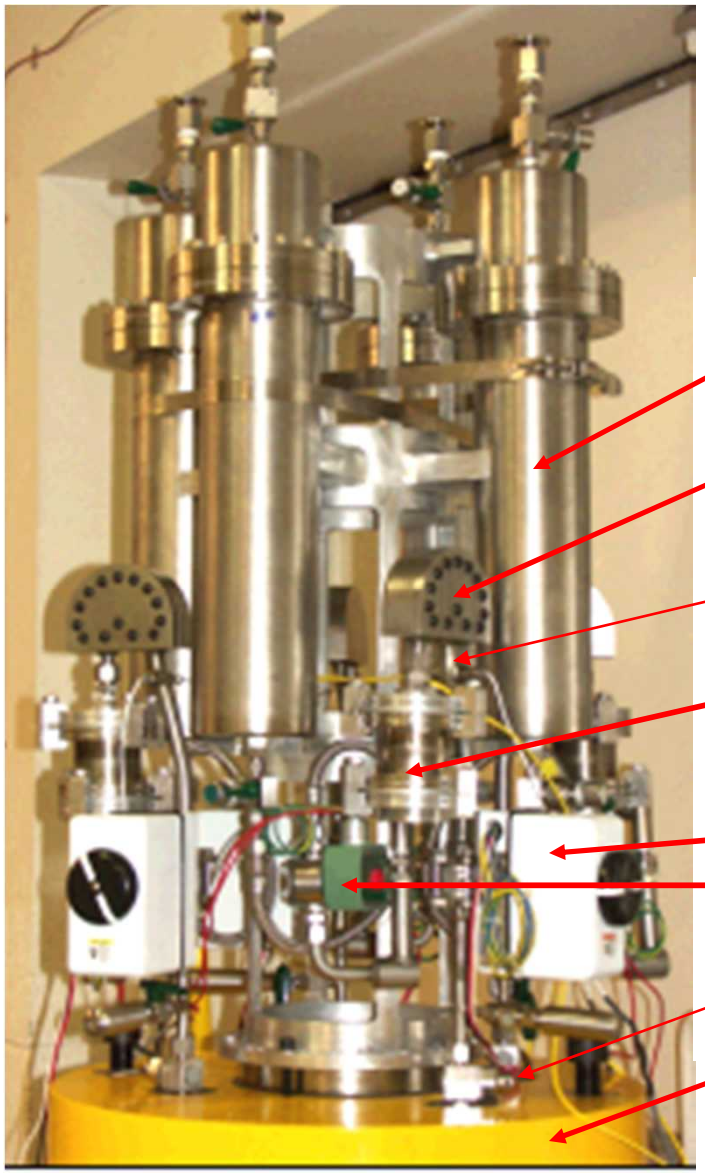
- -

Bottom: Inhalable fraction, >10 ~ 100 μm

(★ *ground shine, fallout …*)

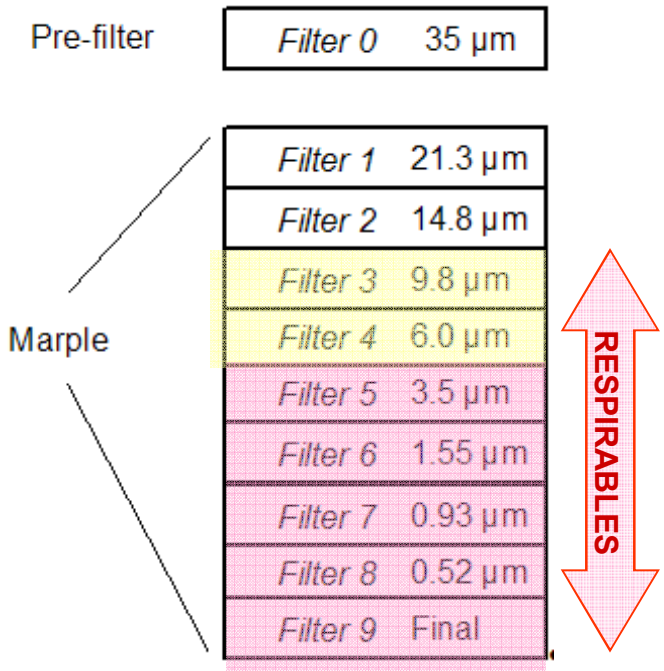
AED = Geometric Diam. x $(\text{density})^{½}$

SFR Test Aerosol Particle Collection - b



4 independent aerosol sampling systems

- **vacuum bottle**
- **Large Particle Separator, LPS * *** (~ 30 – 100 µm)
- pressure, temperature sensors
- **Marple Impactor** (enclosed)
- **valves: primary, secondary, manual**
- **aerosol test chamber**



Marple impactor stages
< 0.5 ~ 20 µm AED

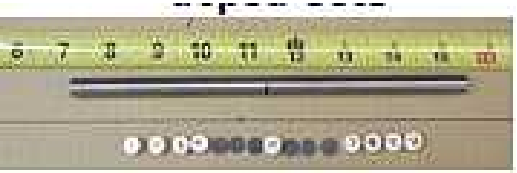
Sandia National Laboratories

Phase 2+ FP Evaluations
Surrogate CeO_2 & HLW Glass

Reference:

- **9 tests: 6 @ SNL (2005), 3 @ Fraunhofer (2006)**
- **"semi-open" Aerosol Test Chamber: with external CSC**
- **Horizontal jet, target rodlet, valved hole, multi-instrumented (T, P)**
  ⬅ uses same 4 independent aerosol sampling systems
- **Evaluate different types of fission product dopant techniques, w/ CeO_2**
  (Enrichment Factor effects)

real time & slow-motion
video (4 views) ➡



dopant disks, 2/10A, B

doped pellets, 2/10C, D / G, H
(mixed-in, thermally diffused)

9 German doped glass, 2/10E, F

test setup at SNL ECF Gun Site, 7-2005

Reference:

Phase 2+ Test 2/CSC

- **Spent Fuel Sabotage and Explosive Dissemination Surrogate Test**
- **single test in 50 m^3 aerosol chamber @ SNL, March 2007**
  - **target: Phase 2/2+ CeO_2 pellets, Zirc-4 tube, with fission product dopant disks**
  - multiple Marple impactor & other particle samplers; thermocouples
  - minimizes pressure variation, low temperatures during sampling relative to other Phase 2 tests
  - significant dilution of explosive-soot effects
  - minimizes sampling inlet and sampling tube particle deposition effects
  - **sponsored by NRC RES**

Sandia National Laboratories

Spent Fuel Sabotage Aerosol Ratio 4-Phase Test Program:

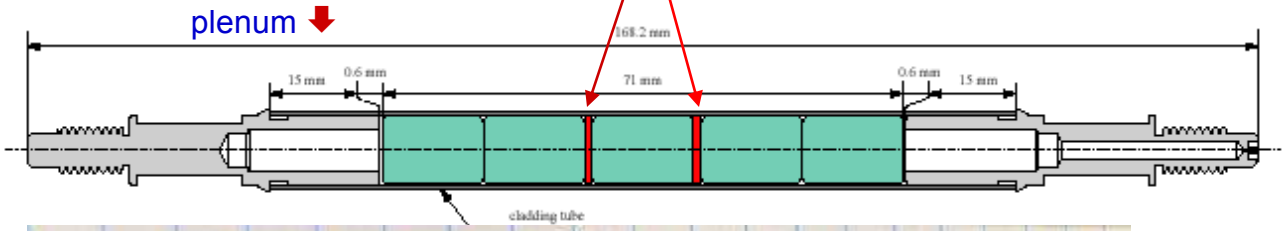
4 independent aerosol sampling systems ⬇

Phase 3: DUO_2 Surrogate

- vertical explosive-aerosol containment test chamber (reusable)
- test rodlets from France, IRSN
- variables: **FP dopants, P= 1- 40 atm** (plenum), **air/N_2**
- **required for SFR determination**

- 3 of 6 tests completed @ SNL ECF
- same test conditions as Phase 4

plenum ⬇



⬅ post-test

Spent Fuel Sabotage Aerosol Ratio 4-Phase Test Program:

Phase 3: DUO_2 test detail

- **Variables: FP dopants, ⬇ ⬇ P= 1- 40 atm** (plenum), **air/N2**
- **Same test conditions as Phase 4**
- **3 tests @ SNL ECF** (3 completed: 10/05, 1/06, 3/06)
- **SNL ECF cleaned-out, 2007; Phase 3 test equipment in storage**

Test # (order)	Rodlet	Pressure	Dopant	Variables	ECF Date
3/2 (A)	DUR-2	1 bar	no	air (in aerosol chamber)	10/14/2005
3/5 (B)	DUR-5	40 (He)	no	air	1/12/2006
3/1 (C)	DUR-1	1	yes	air	3/09/2006
3/3 (D)	DUR-3	1	yes	N_2 (in aerosol chamber)	TBD in GIF
3/4 (E)	DUR-4	40	yes	air	TBD in GIF
3/6 (F)	DUR-6	40	yes	N_2	TBD in GIF

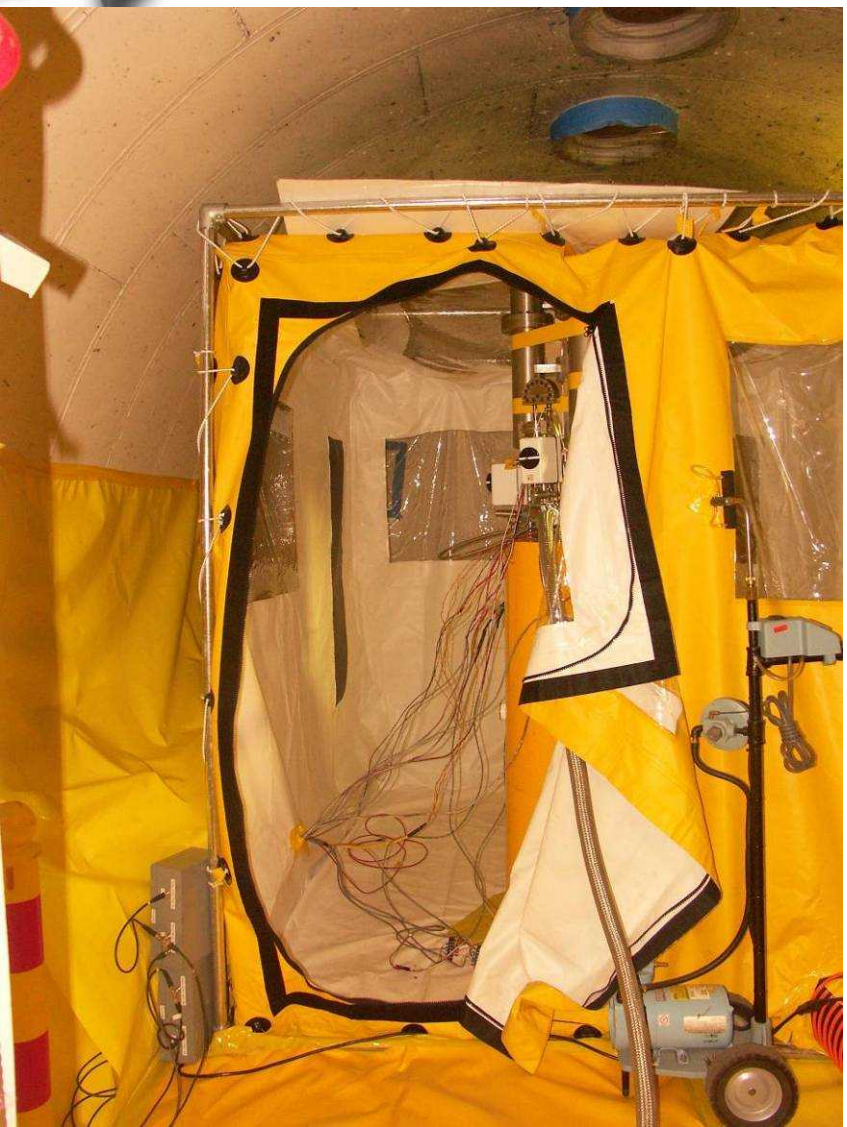
4 independent aerosol sampling systems ⬇

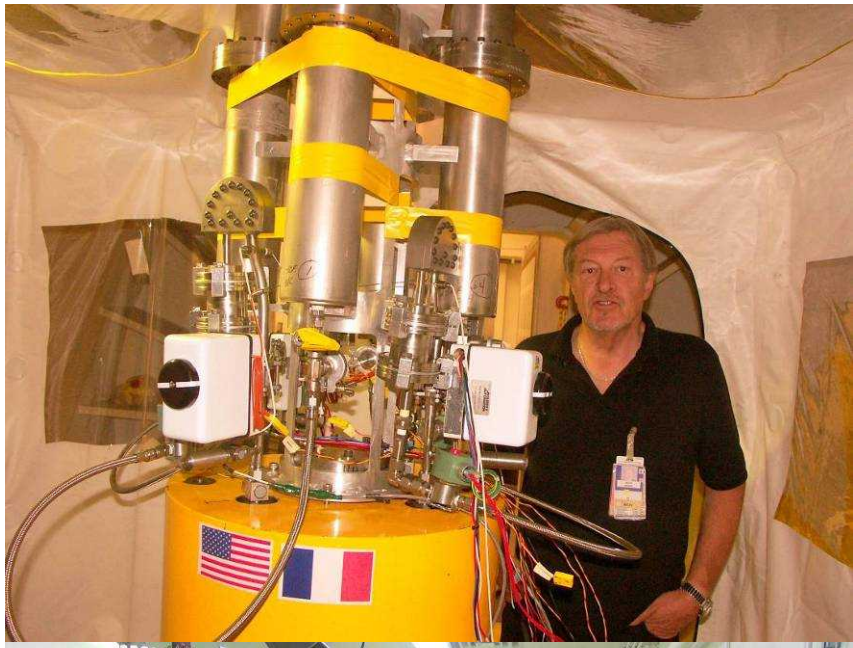
Sandia National Laboratories

Phase 3 DUO_2 Test
at SNL Explosive Components Facility

Reference:

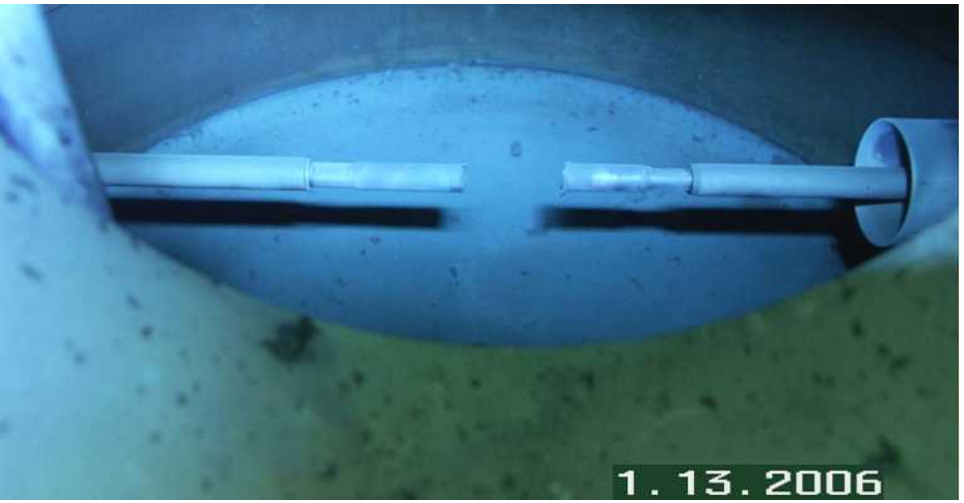
test chamber and secondary enclosure
within large blast chamber





Sandia National Laboratories

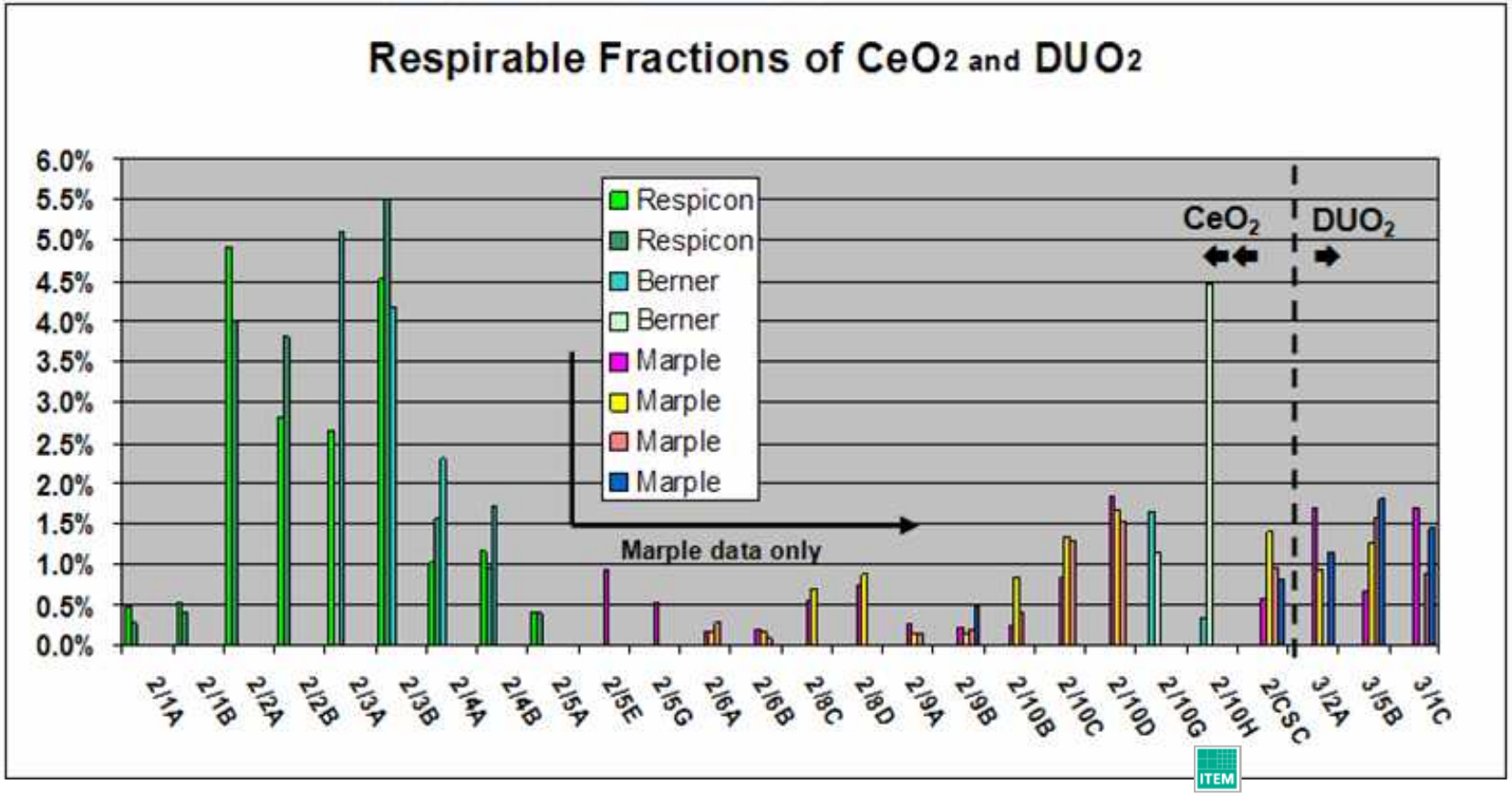
Phase 3 DUO_2 Test
Post-test Disassembly



contamination during aerosol apparatus removal and within glovebox:
at or below detectable levels

Sandia National Laboratories

Measured Respirable Fractions



- CeO_2 RF = 0.65% ± 0.23% ave., Marple Impactors (99% confidence interval)
- CeO_2 RF = 1.36% ± 0.50% ave., all data, old & Marple (99% confidence interval)
- DUO_2 RF = 1.32% ± 0.32% (99% confidence interval)

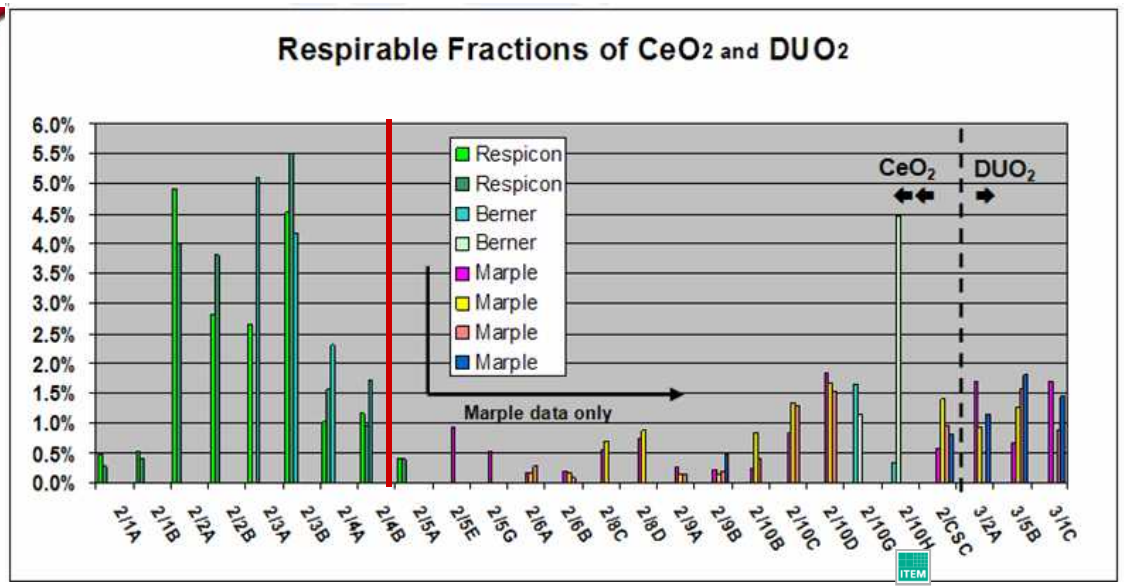
(Luna, 2001, calc. RF=1.7-5.3% (1-wall), RF=2.8-12% (2-wall), for GRS/Gramat)

Ce and DU RFs comparable, but RF for DU may be higher based on Marple data

★ 5 % RF conservatively estimated for UO_2 spent fuel, YMP EIS (Luna, 1999)
(as measured ➡ *reduced consequences*)

Sandia National Laboratories

Respirable Fractions, Data Reliability



- Except for test series 2/2 - 2/4 (sq. box), meas. RF results have been relatively consistent across multi-test variables. DUO_2 RF values reproducible ...
- CeO_2 RF = 0.65% ± 0.23% ave., Marple Impactors (99% confidence interval)
- DUO_2 RF = 1.32% ± 0.32% (99% confidence interval)

- Test 2/CSC indicated that observed particle deposition has minimal effect on RFs
- Three Phase 3 tests show good precision, repeatability
- Each Phase 3 & Phase 4 test has 4 replicate aerosol measurement systems … providing good statistics, much lower uncertainties than historical results

- All results to date (RF, f.p. EF, size distributions) documented in SAND2007-8070, SAND2006-5674, other reports & presentations

Sandia National Laboratories

Spent Fuel Sabotage Aerosol Ratio 4-Phase Test Program:

Phase 4: Spent Fuel Rodlets

- **Explosive - aerosol testing, w/ actual SNF**
- **Needed for SFR determination (measure RF, EF)**
- **U.S. PWR spent fuel rodlet segments, characterization and fabrication (+ NA $$$) at Argonne National Laboratory ***
  w/ high & low-mid burn-up:

  4 - H.B. Robinson, 72 GWd/MTU ✓
  4 - Surry, 38 GWd/MTU
  (DOE-owned SNF for research)

- ***8* tests planned @ SNL GIF**
  (with quadruplicate respirable/aerosol results)
- **Spent Fuel test preparations at SNL:**
  - **SNL GIF feasibility study, 8/2002**
  - **GIF DSA approval process started in 2003 (+ NRC $$)**
  - **2 of 8 test chambers fabricated & qualified, 2005**
  - **DOE SSO approved GIF DSA + SER, 2007)**

Sandia National Laboratories

Phase 4 test chamber
(one-time use only)

Spent Fuel Sabotage Aerosol Ratio 4-Phase Test Program:

Phase 4: Spent Fuel test detail

- now^ 1 Atm internal P (rev. in 2006); air or N_2 in test chamber
- ~ same rodlet design as Phase 3 (incl. orig. irradiated Zircaloy tube)
- post-test wt. & γ @ SNL + post-test particle ICP/MS @ ANL

Test #	Pressure ^	Variables	GIF Date
4/1	~ 1 bar (rod plenum)	**H.B. Robinson**, high-burnup, ~72 GWd/MTU	2009 TBD
4/2	~ 1 (He)	**Air** (in aerosol chamber)	2009 TBD
4/3	~ 1	N_2	2009 TBD
4/4	~ 1	N_2	2010 TBD
4/5	~ 1 bar	**Surry**, low-med burnup, ~38 GWd/MTU	2010 TBD
4/6	~ 1 (He)	**Air**	2010 TBD
4/7	~ 1	N_2	2010 TBD
4/8	~ 1	N_2	2010 TBD

- post-test SNF test chambers to off-site interim storage, shipped in GE 2000 cask, then disposal in YM

➡ CONTINGENCIES …

Sandia National Laboratories

Phase 4 Spent Fuel Sabotage Testing Importance and Technical Bases:

1. Phase 4 tests are the culmination of on-going cooperative planning and sabotage testing efforts, with review by transportation, nuclear, aerosol, and explosive experts in the U.S. & international community.

2. Governmental and regulatory agencies in the U.S. and Europe have provided multi-year support for this program. All share the same sabotage-related concerns and needs for defensible, corroborating data.

3. Phase 4 tests are required to determine reliable Spent Fuel Ratio value, to permit scaling/extrapolations to large-scale cask systems.

4. Phase 4 test results are necessary to confirm and extend earlier surrogate material test results (RF, EF).

Phase 4 Spent Fuel Sabotage Testing Importance and Technical Bases:

5. Phase 4 will provide replicate, actual measured aerosol source-term data (RF, EF, SFR) to replace conservative, estimated values used for radiological dispersion calculations.

6. This test program will result in more realistic, defensible modeling of radiological dispersion and consequence assessments.

7. These data will allow U.S. government agencies to focus security planning plus resources on other areas posing greater risks. Therefore, significant cost savings could be realized.

Reference:

GIF Cell 3

Sandia National Laboratories

SNL WGSTSC
Number of Tests & Delays

(current status)

Tests:	2002	2003	2004	2005	2006	2007	2008 ?	2009 ?	2010 ?
Phase 1	6								
Phase 2	5	8	11						
Phase 2+				6 SNL	3 ITEM	1 2/CSC, 50 m^3			
Phase 2/3			3					2 ?	
Phase 3			delay GIF DSA	1 ECF	2 ECF	suspend $$	suspend $	??? ECF $$$	
Phase 4				delay GIF DSA	delay GIF DSA $$$	postpone $$ GIF DSA ✓	postpone $?	3 ? $$$	5 ? $$$
Total:	11	8	14	7	2+3	1	0	4-6 ???	5-6 ?

DOE RW funding re-allocations …

Sandia National Laboratories

Spent Fuel Sabotage
Phase 4 Test Contingencies

- **Future option to re-start Phase 4 spent fuel testing remains open and is dependent on:**

1. ANL rodlet fabrication: stopped, w/ storage @ ANL
   option to complete at ANL - ORNL … ; shipment to SNL
2. Idaho post-test spent fuel chambers interim storage approval …
   (➡ DOE RW / EM)
3. GE-2000 cask CoC approval work/ NRC license …
4. SNL GIF engineering preparations
5. ★★ New Sponsors - SNL further program funding ★★
6. Continued DOE, NRC, WGSTSC cooperation (testing & modeling)
7. MLA, Multi-Lateral Agreement … (DOE/DOS ➡ WGSTSC)

Spent Fuel Sabotage
Phase 4 Test Contingencies – 1

1. **ANL spent fuel rodlet fabrication, shipment to SNL**
   - ANL AGHCF has been closed for "programmatic" work since July 2005, by ANL management – not available for: SNL-WGSTSC rodlet fabrication, NRC programs, …
   - probable resolution: coop. w/ ORNL to complete fabrication
   - rodlet plenum-area pressurization issues resolved, WGSTSC '06 (1 atm)
   - fabrication status:
     - characterization work complete HBR ✓ Surry isotopic X
     - sectioning of 8 3-inch-long (7.6 cm) test samples complete ✓
     - rodlet end-piece design, to-be-revised w/ext. weld (ANL/SNL)
     - welding end fixtures to the test samples -- not complete; ORNL
   - fabrication completion not yet scheduled; *delayed – funding*
   - shipment to SNL in GE-100 cask in 2009?
     - requires ANL Transportation Plan preparation
     - requires inputs and receipt approval from DOE SSO and SNL Transportation Department, WGA, …
     - requires approved *post-test disposition path* … ⬇ (per SNL & DOE SSO)

Spent Fuel Sabotage
Phase 4 Test Contingencies – 2,3 & 4

2. **Idaho post-test spent fuel test chambers storage approval**
   - SNL cannot accept ANL spent fuel without disposal pathway
   - Test chamber, overpacked, fits within Std. DOE SNF Canister ✓
   - SNL to ship to INL CPP-749 in GE-2000 cask (DOE-owned & leased), (INL interim … storage), to YM in ~2035 (final disposal)
   - DOE RW and EM negotiations still in progress …
   - DOE to provide shipment, storage funding in future
   - *Critical path issue !*

3. **GE-2000 cask CoC approval work/ NRC license … (high BU)**
   - SNL sub-contract w/ GE Vallecitos (~ 3-months of work)
   - funding: ➡ postponed in FY '06, delayed till FY '09 ?

4. **SNL GIF engineering, test preparations**
   - Can initiate design and fabrication of GIF support equipment, secondary containment, controls, started in FY '08 ✓, set-up in FY '09 (presuming funding support)
   - Perform 2-3 operational DUO_2 tests in GIF, FY '09
   - Can order 6 Phase 4 test chambers, for FY '09 delivery ($$)

Spent Fuel Sabotage
Phase 4 Test Contingencies – 5

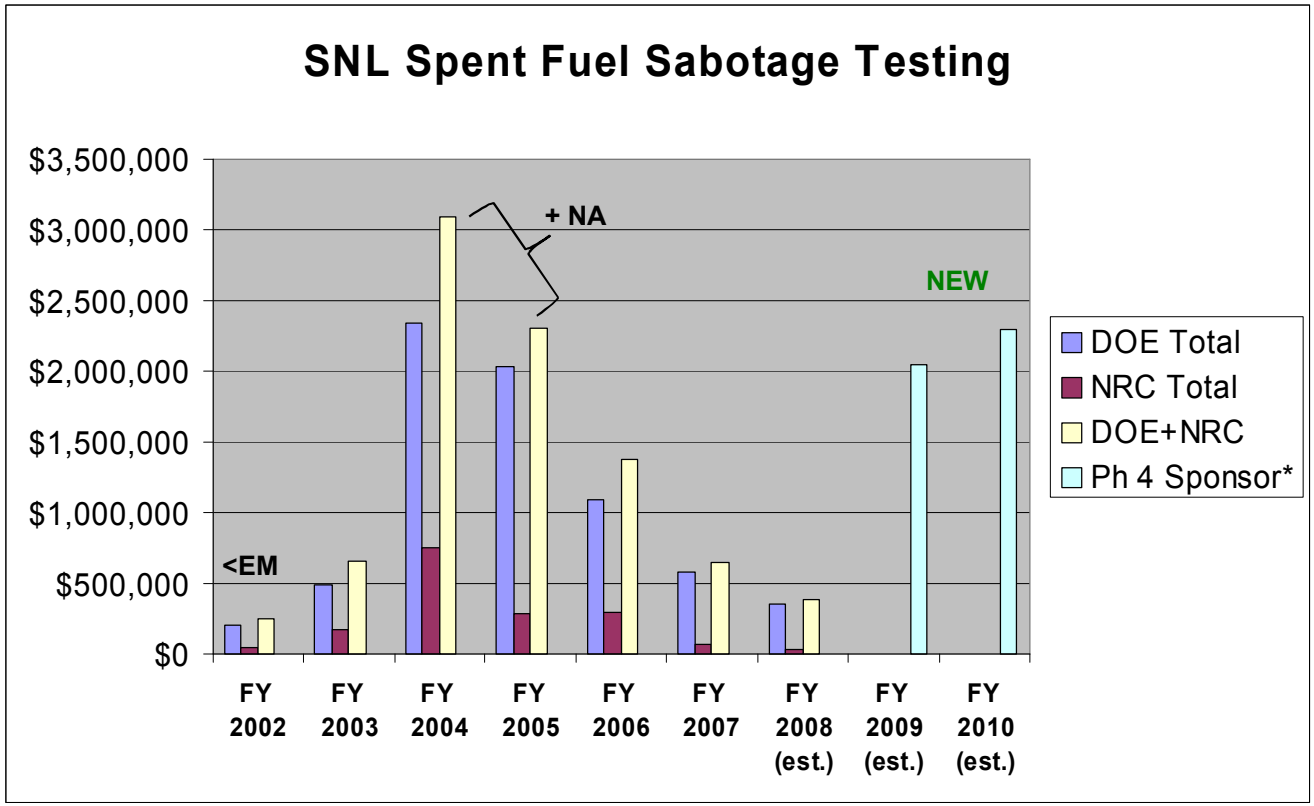
5. Program funding support to SNL, Phase 4 Testing

- FY ’99-’02: DOE EM & NRC SFPO
- FY ’03-’05: RW + NA + NRC NSIR & RES;
  spent fuel characterization, fabrication activities at ANL,
  fabrication of Phase 3 and 2 Phase 4 test chambers
- FY ’06: Phase 3 testing on hold since 4/06;
  RW funding decrease (funding/yr chart ➡)
- SNL modeling program un-funded since FY ‘05
- FY ’07: 1 test, 2/CSC, w. NRC RES; RW funding
- FY ’07: not adequate for German/WGSTSC large-scale testing
- FY ‘07: NRC RES support ended
- FY ’07-’08: $$ not adequate to begin Phase 4 tests
- Program delays jeopardize WGSTSC support, Phase 4 testing

Reference:

Sandia National Laboratories Spent Fuel Sabotage Testing
Funding History and Future

- Since testing inception, FY 2002 - 08: $8.7M ($7.1M DOE / $1.6M NRC)
- Phase 4 testing estimate, ~ $4.3 million
- Phase 4 testing conduct planned in FY 2009-2010
- Estimate does not include modeling programs



Sandia National Laboratories

Spent Fuel Sabotage
Phase 4 Test Completion

- **OPTIMISM?: perform 8 Phase 4 spent fuel tests in GIF, 2009-10 …**
  - With adequate SNL funding from new program sponsors
  - Perform aerosol particle analyses, SNL & ANL, 2009-10
  - Clean-up GIF, put post-test chambers in GIF temp. storage, 2010
  - Complete test data analyses and interpretations, 2010 …

- **WGSTSC Program progressions:**
  - From small-scale, simplified rodlet testing focus (now)
  - Potentially to large, cask-scale surrogate WGSTSC testing
    (➡ GRS, '08 …; IRSN ?; aerosol blow-down & release …)
  - Phase 4 and existing surrogate data used in continuing modeling follow-on analyses (2008 ➡➡) for radiological dispersion, consequence assessments, safeguards …

Challenges and DOE Proposed Solutions

- Phase 4 spent fuel test performance at SNL is currently on-hold due to limited DOE-RW funding. Limited Phase 4 preparations continue.
- International WGSTSC program participants have provided supporting testing, equipment, analyses, & modeling, *but NO direct funding*. GRS and IRSN support continues.
- Adequate SNF sabotage test program funding is needed for successful program re-start and completion!
- DOE-RW is seeking new funding sponsors to support this program.
- DOE-RW will resolve technical and administrative issues to permit tests to proceed, and to store post-test spent fuel chambers.
- DOE-RW is proposing a multi-agency partnership using an Integrated Project Team to oversee all aspects of the project.
- Successful program completion will provide benefits to all U.S. and international program participants.
- Data & modeling sharing is covered under Multi-Lateral Agreement (MLA *in draft*)

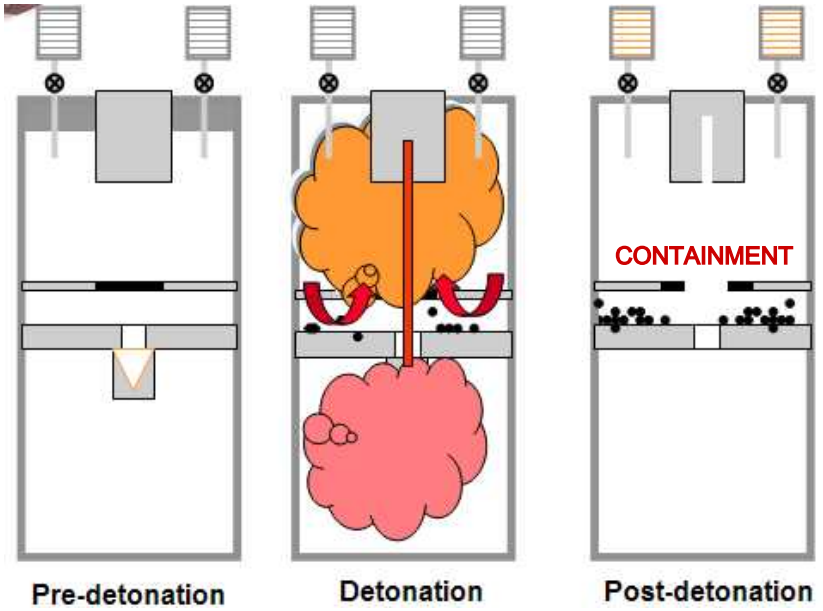
Spent Fuel Sabotage Testing
Continuing Evaluations

- Measured source-term data and SFR value to be used for:
- Parametric modeling evaluations for other hazard scenarios
- Parallel modeling efforts (SNL, DOE, NRC, WGSTSC, others)
  - near-field aerosol dispersion & hazard consequence assessments
  - atmospheric dispersion
  - computational fluid dynamics; transport cask relevant
  - Regulatory agencies evaluations
- Planned large-scale, surrogate testing by WGSTSC, & contributions:
  - effects of cask hole size produced, internal P & T on blow-out releases (GRS/Fraunhofer testing, 2008 …)
  - determine aerosols produced, internal distribution, & amounts blown out
  - rod bundle fragmentation vs. deformation studies

Reference:

SNL-WGSTSC Spent Fuel Sabotage: Program Overview

- **SCENARIO:** plausible sabotage attack on nuclear transport casks by HEDD ...
- **GOALS-Experimental:** Quantify source-term data and analyses on aerosol particles *produced* from surrogate (CeO_2, DUO_2) fuel and actual Spent Fuel single rodlets
- **APPLICATIONS:** data & technology transfer for follow-on modeling studies of radiological release-aerosol dispersion hazards and transportation consequence assessments; security implications
- **SUPPORT:** by and to DOE, NRC, & International WGSTSC, + assessments
- **LEVERAGE:** program capabilities and benefits over all International WGSTSC participants, national authorities, and additional program sponsors
- **REVIEW:** existing results, interpretations, and future testing plans



Sandia National Laboratories