

Radiochemical Assay Data for Use in Burnup Credit Analysis

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Overview

- Spent fuel trends
- Assay data availability
- Recent acquisitions
- Fission products
- SFCOMPO
- Potential sources of new data
- Data needs
- Concluding remarks

SNF Trends and Data Needs

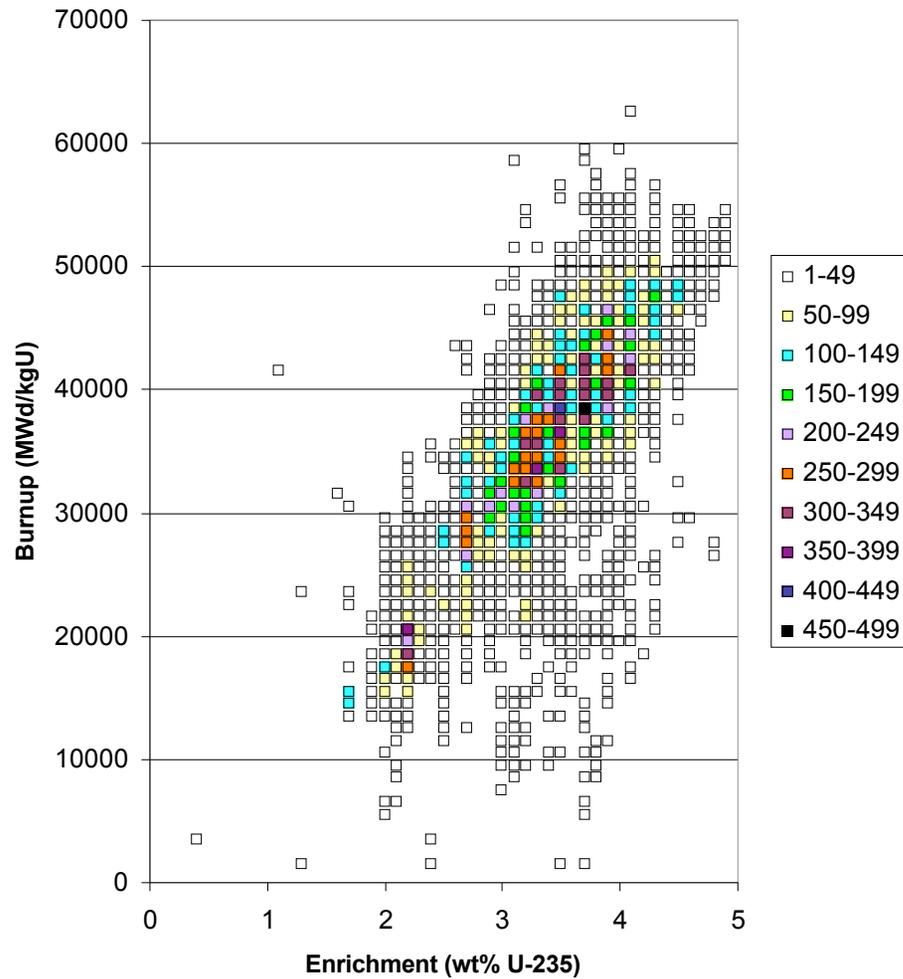
- PWR Isotopic assay data previously analyzed
 - generally limited < 3.5-wt % and 40 GWd/t
 - predominantly actinide measurements
 - limited to older assembly designs
 - few BPR designs
 - no IBA (e.g., Gd_2O_3) designs
 - ORNL benchmarking using 38 spent fuel samples
- Near-term availability of assay data to validate depletion codes beyond 4-wt % and 40 GWd/t is limited
- Present trend is towards higher enrichments (5-wt %) and higher discharge burnups (<70 GWd/t)

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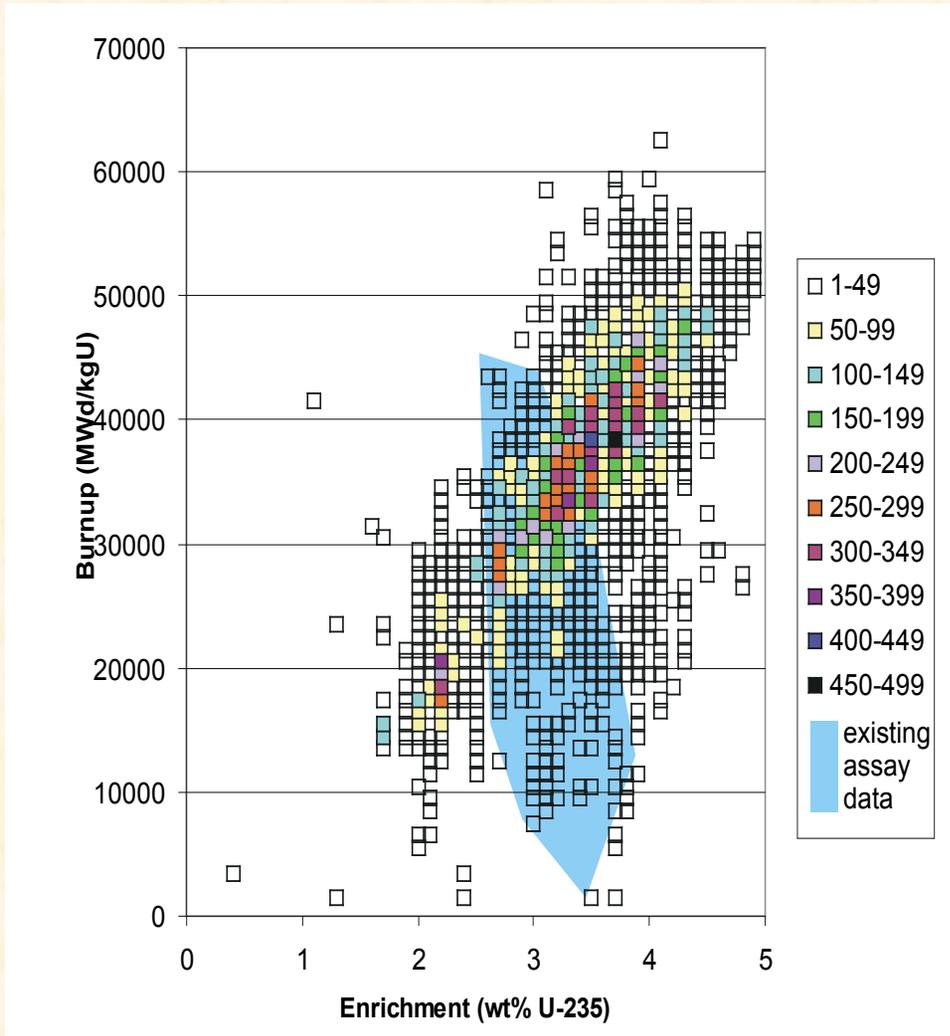
SNF Trends and Data Needs (cont'd)

- BWR assay data more limited
 - 4 reactor types
 - Maximum enrichment 2.9 wt% ^{235}U
 - Maximum burnup 34 GWd/MTU
 - ORNL benchmarking using 26 spent fuel samples
- “Recent Acquisitions”
 - Takahama-3, Kansai Electric Ltd., Japan
 - Extended enrichments and burnups
 - Comprehensive actinide and fission product measurements
 - Russian V. G. Khlopin Radium Institute
 - Independent analysis of Calvert Cliffs Approved Test Material (ATM) samples
 - Includes additional fission product measurements

PWR Discharge Data Through 1998



PWR Discharge Data Through 1998



PWR Experimental Assay Data

Reactor	Lattice type	Enrichment (wt %)	Burnup (GWd/t)	Absorbers	No. of samples
Trino Vercellese	WE 15□15	3.13	11.5 □ 24.5		13
		3.897	12.0		1
Turkey Point	WE 15□15	2.556	30.5 □ 31.5		5
Obrigheim	CE 14□14	3.13	25.9 □ 29.5		6
Robinson-2	WE 15□15	2.561	16.0 □ 31.7	BPRs ^a	4
Yankee Rowe	WE 17□18	3.4	16.0 – 36.0	CRs ^b	8
Calvert Cliffs	CE 14□14	3.038	27.4 – 44.3		3
		2.72	18.7 – 33.2		3
		2.453	31.4 – 46.5		BPRs
Takahama-3	WE 17□17	4.11	14.3 – 47.3	BPRs	10
		2.56 – 4.11	11.5 – 47.3		56

^a Assembly contained burnable poison rods

^b Reactor operated with control rods

^c **Takahama-3 data are new**

Takahama-3 Data

- Actinide and fission product isotopic assay measurements performed in Japan for Takahama-3 PWR (Kansai Electric Ltd.)
- Westinghouse 17x17 fuel assembly
- Initial fuel enrichment, 4.11 wt% ^{235}U
- Assembly included 14 BPRs, 2.6 wt% UO_2 + 6 wt% Gadolinia (Gd_2O_3)
- Assay data for fuel rods (10 samples) and 1 poison rod
- Takahama-3 data significantly extends enrichment and burnup range (samples up to 48 GWd/MTU)

Takahama-3 Nuclides

- Actinides

- U-234, U-235, U-236, U-238, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-242m, Am-243, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247

Fission Products

Nd-143, Nd-144, Nd-145, Nd-146, Nd-148, Nd-150, Cs-137, Cs-134, Eu-154, Ce-144, Sb-125, Ru-106, Sm-147, Sm-148, Sm-149, Sm-150, Sm-151, Sm-152, Sm-154

Burnup credit nuclides

Russian Khlopin Data

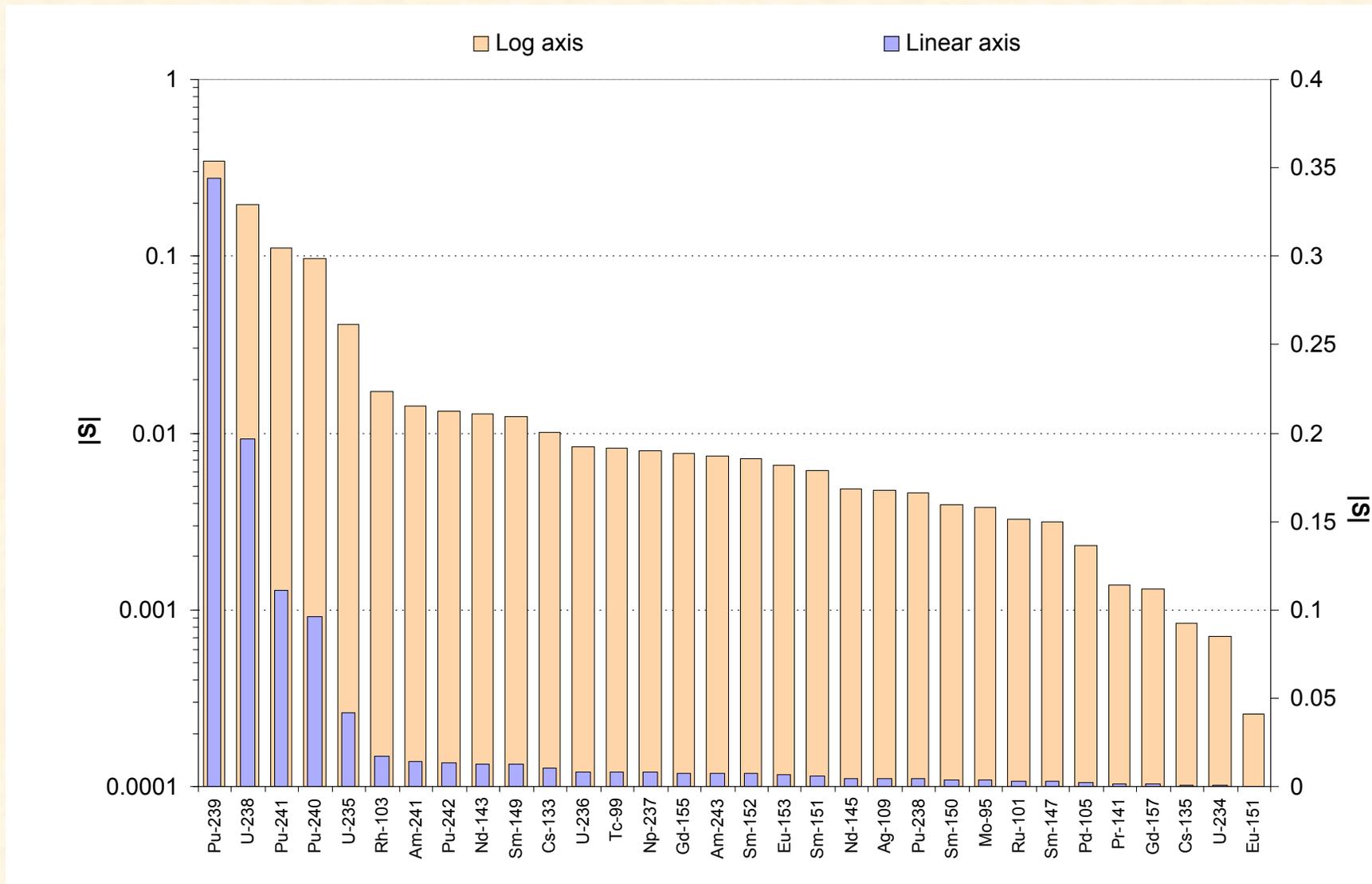
- Independent chemical analysis of 4 Calvert Cliffs samples (ATM-104 and ATM-106 programs)
- V. G. Khlopin Radium Institute, St. Petersburg
- Includes rare earth measurements (Nd, Sm, Eu, Gd)
- *Plus* measurement for Rh-103 for AMT-106 sample NBD107-GG
- Represents the *only* publicly available Rh-103 measurement
- Also provides ^{147}Sm , ^{151}Sm , ^{151}Eu , and ^{155}Gd measurements (previous measurements combined parent and daughter)
- Results published in PNNL-13677 (Sept 2001)

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Fission Product Data

- Extremely limited database
 - Calvert Cliffs ATM-104 (3 samples)
 - New Khlopin ATM-106 (1 sample) Rh-103 measurement
 - New Takahama-3 (10 samples) limited to Nd and Sm isotopes
- Currently no data for ^{95}Mo , ^{101}Ru , ^{109}Ag
- Single ^{103}Rh measurement

Nuclide Sensitivities (60 GWd/t)



Fission Product Data (cont.)

Number of measurements (in order of decreasing importance in high burnup fuel)

Rh-103	1	<i>(Khlopin)</i>
Nd-143	13	
Sm-149	8	
Cs-133	3	
Tc-99	9	
Gd-155	3	
Sm-152	8	
Eu-153	3	
Sm-151	8	
Nd-145	13	
Ag-109	0	
Sm-150	8	
Mo-95	0	
Ru-101	0	
Sm-147	8	

SFCOMPO

- Spent Fuel Composition Database
- Compendium of isotopic data and reactor specifications needed to perform isotopic calculations for 7 PWR and 7 BWR reactors
- Maintained by Japan Atomic Energy Research Institute (JAERI)
- Report JAERI-Data/Code 2001-020 (2001)
- WWW version 2

–<http://typhoon.tokai.jaeri.go.jp/sfcompo/index.html>

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SFCOMPO

- Database contains old (previously published) and new benchmarks

PWR

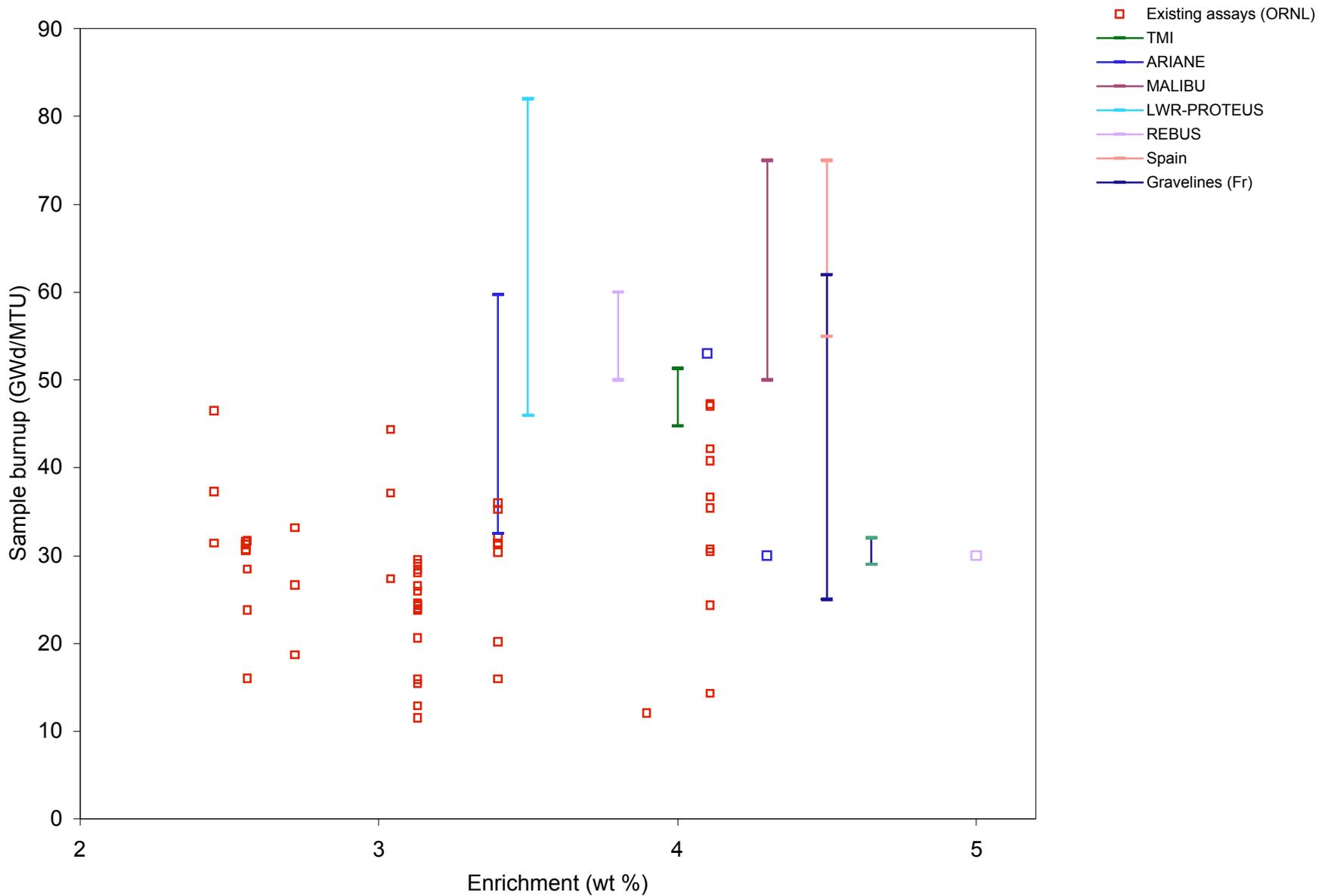
- Trino Versellese, Obrighiem, Mihama-3, Genkai-1, H. B. Robinson-2, Calvert Cliffs-1, Takahama-3

BWR

- Gundremmingen, Cooper, Monticello, Fukushima-Daiichi, Fukushima-Daini-2, Tsuruga-1, JPDR,

Sources of Potential New PWR Assay Data

Reactor (Program)	Lattice type	Enrichment (wt % ²³⁵ U)	Burnup (GWd/t)	BPRs	IBAs	F.P	U + Pu
TMI-1 (DOE)	W 15 □ 15	4.0, 4.65	30 – 51.3	Y	Y	18/14	9
(REBUS)	17 □ 17	3.8, 5.0	30 – 60	N/A	N/A	23/14	6
Gosgen (ARIANE)	15 □ 15	3.4, 4.1, 4.3	30 – 59.7	N	N	31/16	9
Gosgen (MALIBU)	15 □ 15	4.3	50–75	N	N	31/16	9
LWR-PROTEUS	N/A	3.5, 4.1	36 – 82	N/A	N/A	29/15	9
(Spain PIE)	17x17	4.5	55–75	N/A	N/A	N/A	N/A
Bugey-3 (Fr PIE)	17 □ 17	2.1, 3.1	19 – 38	N	N	14/13	9
Fessemheim (Fr PIE)	17 □ 17	2.6, 3.1	27 – 60	Y	N	14/13	9
Gravelines 2 + 3 (Fr PIE)	17 □ 17	4.5	25 – 62	Y	N	14/13	9
Tihange-1 (Fr PIE)	15 □ 15	3.1	10 – 40	N	N	14/13	9



Isotopic Assay Data Needs

- Actinide isotopic assay data > 3.5 wt% and 40 GWd/t
- Fission product assay data for all regimes
- Modern assembly designs – BPR and IBA designs
- Actinides (reduce isotopic uncertainties)
 - Improved predictions of Pu-239, U-235, Am-241
- Fission products
 - Improved measurements for Sm-149, Gd-155
 - Assays for ~8 isotopes with no data – Rh-103, Ag-109, Mo-95, Ru-101, etc.

Concluding remarks

- Radiochemical assays valuable in validating spent fuel depletion calculations.
- Not all radiochemical assay data are created equal
 - Very few programs performed with burnup credit in mind
 - Useful data must include accurate measurements AND well-qualified operational data (assembly design, operating history, C/R insertion data (if any), boron letdown, etc.)
- Other techniques may be necessary to supplement assay data
 - Integral validation
 - Sensitivity/uncertainty methods

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