CH2MHILL
Plateau Remediation Company

Integral Cross-Sections and Other Useful Information Extracted from Spent Fuel Data

Hans Toffer
(Consultant for CH2M HILL Plateau Remediation Company)
Warren Wittekind, Raymond Puigh, David Erickson
(Fluor Government Group)
Michael Westfall (Consultant)

2010 ANS Winter Meeting
November 7 – 11, 2010

One Team. One Culture.

Contents

- Why Bother With Actinides? (Th-Lr)
- Introduction – Background
- Burn-up Credit (BUC)
- Reactors and Special Tests
- Applications of Actinides
- Am-Cm Test
- Conclusions and Recommendations

U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

Why Bother With Actinides?

- Stepping Stones to Higher Mass Elements
  - Example Cf-252
- Burn-up Code and Cross Sections Need Validation
- Extensive Experiments With Actinides
  - 75+ Data Sets N Reactor and Single Pass Reactors
- Actinides Reactions Separated into Reaction Trees
  - U-Np-Pu
  - Am-Cm
  - Th-U

Introduction – Background

- 1950's-1960's Reliance on Experiments for Design and Operation Support
- Code Development Needs Validation Data
- Types of Data -- Point vs. Core Average
- Past Reactor Irradiations -- Source of Transmutation Data
- Low Enriched Uranium Ranges from Depleted to 2.1% U-235

U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

Chronology of Hanford Reactors

Reactor Designation	Start Operation	Shutdown	Power Level	
			Design	Maximum
B Reactor	9/26/1944	2/12/1968	250MW	2090MW
D	12/17/1944	6/26/1967	250MW	2090MW
F	2/25/1945	6/25/1965	250MW	2090MW
DR	10/3/1950	12/30/1964	250MW	2090MW
H	10/29/1949	4/21/1965	400MW	2090MW
C	10/18/1952	4/25/1969	600MW	2460MW
KW	1/4/1955	2/1/1970	1800MW	4620MW
KE	4/17/1955	1/29/1971	1800MW	4620MW
N	12/31/1963	1/1987	4000MW	4800MW

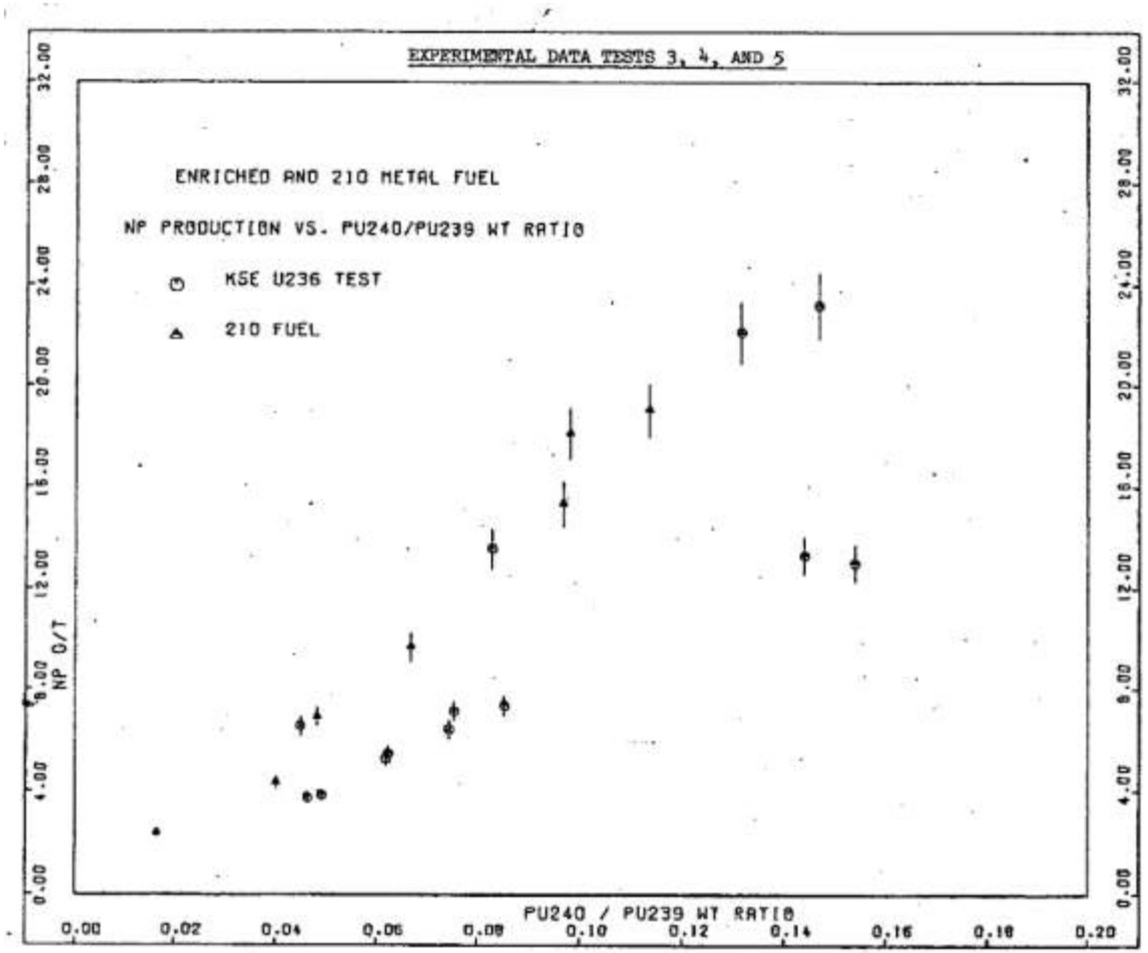
Introduction – Background

- 1950's-1960's Reliance on Experiments for Design and Operation Support
- Code Development Needs Validation Data
- Types of Data -- Point vs. Core Average
- Past Reactor Irradiations -- Source of Transmutation Data
- Low Enriched Uranium Ranges from Depleted to 2.1% U-235

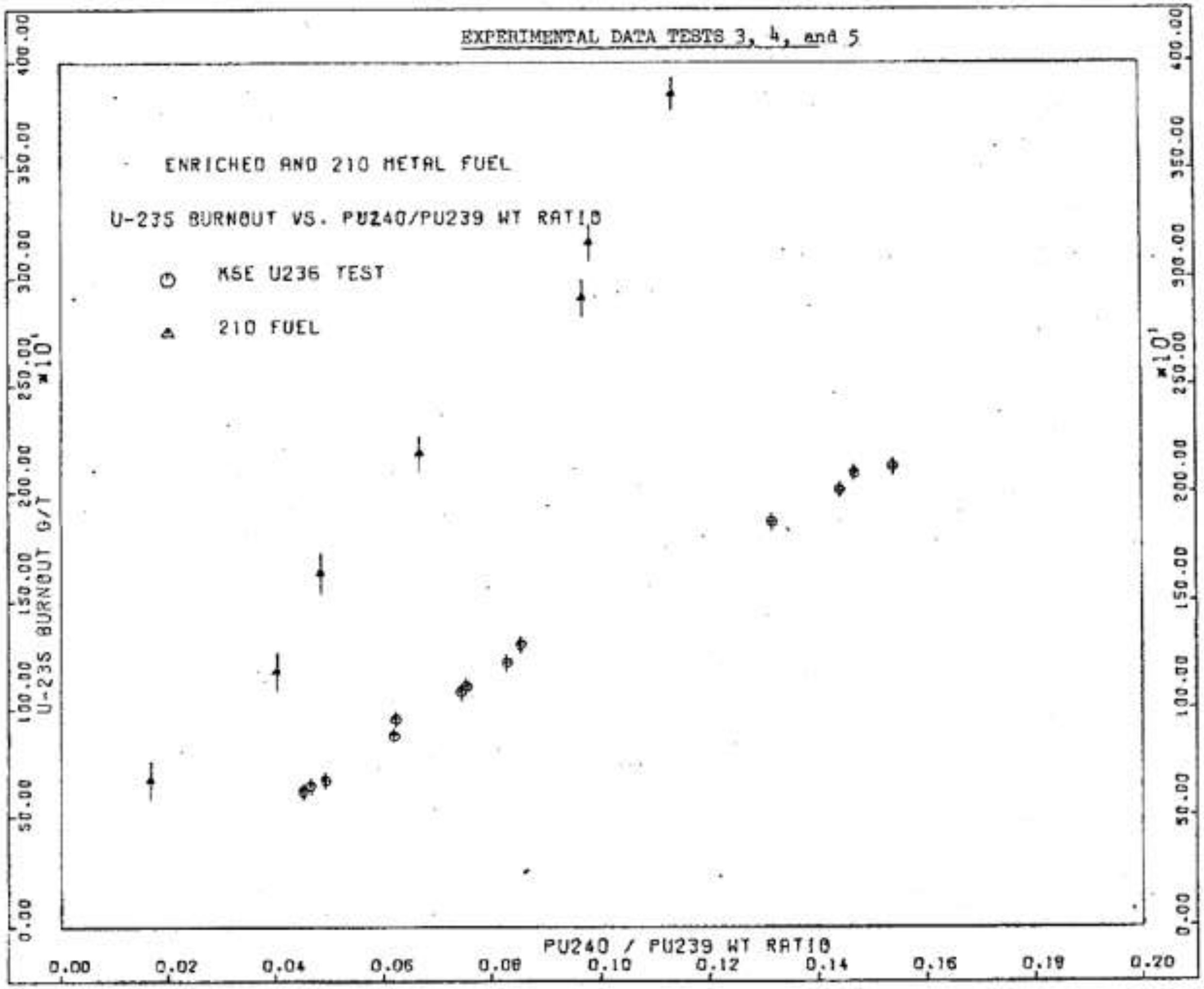
U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

Np Production vs Pu-240/Pu-239 Wt Ratio



U-235 Burnout vs Pu-240/Pu-239 Wt Ratio



Typical Radiochemical Data

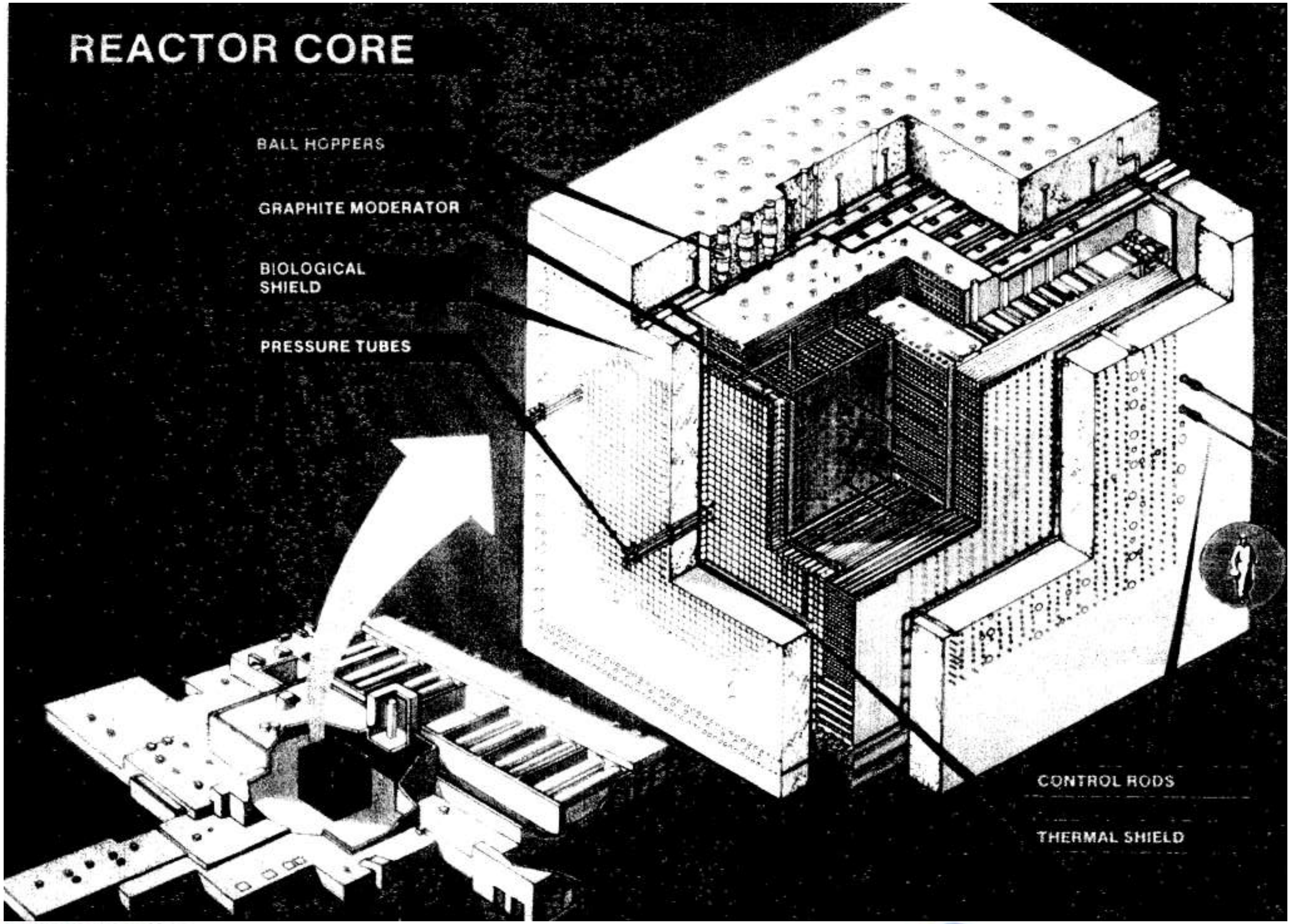
NUCLEAR FUEL BURNUP ANALYSIS RESULTS
[ND-148 IDMS METHOD]

LAB. NO. : / SAMPLE I. D. :		8045 / UNC-8A0	8046 / UNC-8BI	8047 / UNC-8B0
U [GRAMS/G]	{1}	1. 067E-01	3. 846E-02	1. 574E-01
U [GRAMS/G]	{1}	1. 067E-01	3. 846E-02	1. 574E-01
U [ATOMS/G]	{1}	2. 700E+20	9. 729E+19	3. 983E+20
U-234 WT %		0. 009 { 1}	0. 008 { 1}	0. 009 { 1}
U-235 WT %		1. 083 { 6}	0. 855 { 6}	1. 096 { 6}
U-236 WT %		0. 062 { 1}	0. 064 { 1}	0. 060 { 1}
U-238 WT %		98. 845 { 10}	99. 072 { 10}	98. 833 { 10}
PU [GRAMS/G]	{1}	1. 297E-04	3. 759E-05	1. 820E-04
PU [ATOMS/G]	{1}	3. 266E+17	9. 468E+16	4. 584E+17
PU-238 WT %		0. 035 { 4}	0. 038 { 4}	0. 036 { 4}
PU-239 WT %		91. 834 { 80}	93. 640 { 80}	92. 179 { 80}
PU-240 WT %		7. 147 { 50}	5. 633 { 50}	6. 875 { 50}
PU-241 WT %		0. 951 { 7}	0. 671 { 7}	0. 880 { 7}
PU-242 WT %		0. 033 { 1}	0. 018 { 1}	0. 030 { 1}
FP-TOT [GRAMS/G]	{1}	1. 854E-04	4. 185E-05	2. 551E-04
ND-148 [ATOMS/G]	{1}	7. 993E+15	1. 809E+15	1. 100E+16
ND-143/148	{2}	3. 23664	3. 09571	3. 25310
ND-144/148		2. 60321	2. 47299	2. 60679
ND-145/148		2. 19879	2. 14060	2. 20459
ND-146/148		1. 74709	1. 71613	1. 74900
ND-150/148		0. 42267	0. 43825	0. 42365
ND-148 E. F. Y.	{3}	1. 686	1. 691	1. 686
PU-239 [FF]	{3}	0. 09310	0. 09783	0. 08886
PU-240 [FF]		0. 00000	0. 00000	0. 00000
PU-241 [FF]		0. 00104	0. 00076	0. 00091
U-235 [FF]		0. 85944	0. 84177	0. 86381
U-238 [FF]		0. 04643	0. 05964	0. 04641
BURNUP CALCULATIONS:	{4}	UNC-N BASED	UNC-N BASED	UNC-N BASED
MWD/FISSION	{3}	3. 765E-22	3. 767E-22	3. 764E-22
AVG. AT. WT. FISSIONED		235. 563	235. 620	235. 545
BU ATOM % [ND-148]		1. 750E-01	1. 097E-01	1. 633E-01
BU MWD/MTM [ND-148]		1. 668E+03	1. 045E+03	1. 555E+03

U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

N Reactor Schematic



U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

Burn-up Credit (BUC)

- Benchmarks for BUC Calculation Scarce
- Burn-up Credit in Criticality Safety Analysis Requires Validation
- Past Reactor Data - Rich and Untapped
- Hanford Data Would Mesh with Power Plant Info at 2.1% U-235

U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company

Reactors and Special Tests

- Nine Reactors (1944-1987) Graphite Moderated, Water Cooled, Cylindrical Fuel in Horizontal Process Tubes, Mission to Produce Isotopes, K Reactors Largest, N Reactor-Dual Purpose Super Cell, and Full Core Tests
- Isotope Creation: Pu-239, U-233
- Special Materials: Np, Pu-238, Am, Cm

Application of Actinides

- Power density in N Reactor Inner and Outer Fuel Tube, Use of Effective Cross-Sections Used to Improve Fuel Design
- Calibration Fuel Elements for the Fuel Segregation Program

Application of Actinides – Continued

- Generation of New Production Tables
  - The code, PTABLE2, solves the simultaneous boundary value differential equations for the U-Np-Pu tree.
  - Results from the end of an irradiation cycle are interacted with analytic chemical results until a match is achieved. The original effective one-group cross-section values adjusted for the chemical results represent extracted cross-sections needed to generate new isotope production tables.
  - Plans to modify PTABLE2 for other fuel cycles.

Am-Cm Test

- Definitive test to confirm production rates of higher mass actinides and decay of Cm-242 to clean Pu-238
- 6 Targets – 2 each containing 10g/ft, 20g/ft, 40g/ft, Am241
- Irradiation time of 250 days. Actual discharged 10 days beyond goal
- Water and air cooled 40 years
- Now stored in Experimental Breeder Reactor II cask storage facility waiting
- Valuable transmutation info for long term storage

Conclusions and Recommendations

- Recovery of actinide cross-sections from production reactor operations and special tests is a novel and promising alternative to costly and time consuming new measurements

- Burn-up Credit could benefit from the Hanford data for validation

- Am-Cm Test should be analyzed to obtain improved build-up and decay parameters

U.S. DEPARTMENT OF ENERGY

CH2MHILL Plateau Remediation Company