

ADVANCED FUEL CYCLE DEVELOPMENT AT CHALK RIVER LABORATORIES

Mark Floyd
HWR Future Conference
2011 October 2-5



PRESENTATION OUTLINE

- **INTRODUCTION**
- **UO₂ FUEL**
- **MOX FUEL**
- **THORIA-BASED FUEL**
- **BURNABLE NEUTRON ABSORBERS**
- **FUEL CLAD TECHNOLOGY**
- **SUMMARY**



INTRODUCTION

CRL VISION & MANDATE

- **Generate, access and share nuclear fuel S&T**
 - work with others to apply and exploit it to produce energy
 - clean, sustainable, economical, safe, secure
- **Develop advanced nuclear fuel technologies for HWRs (and other reactor designs/concepts)**

INTRODUCTION

CRL FUEL DEVELOPMENT

- **Fabrication Technology**
- **Irradiation Testing**
- **Post-Irradiation Examination (PIE)**
- **Materials Characterization & Development**
- **Modeling**

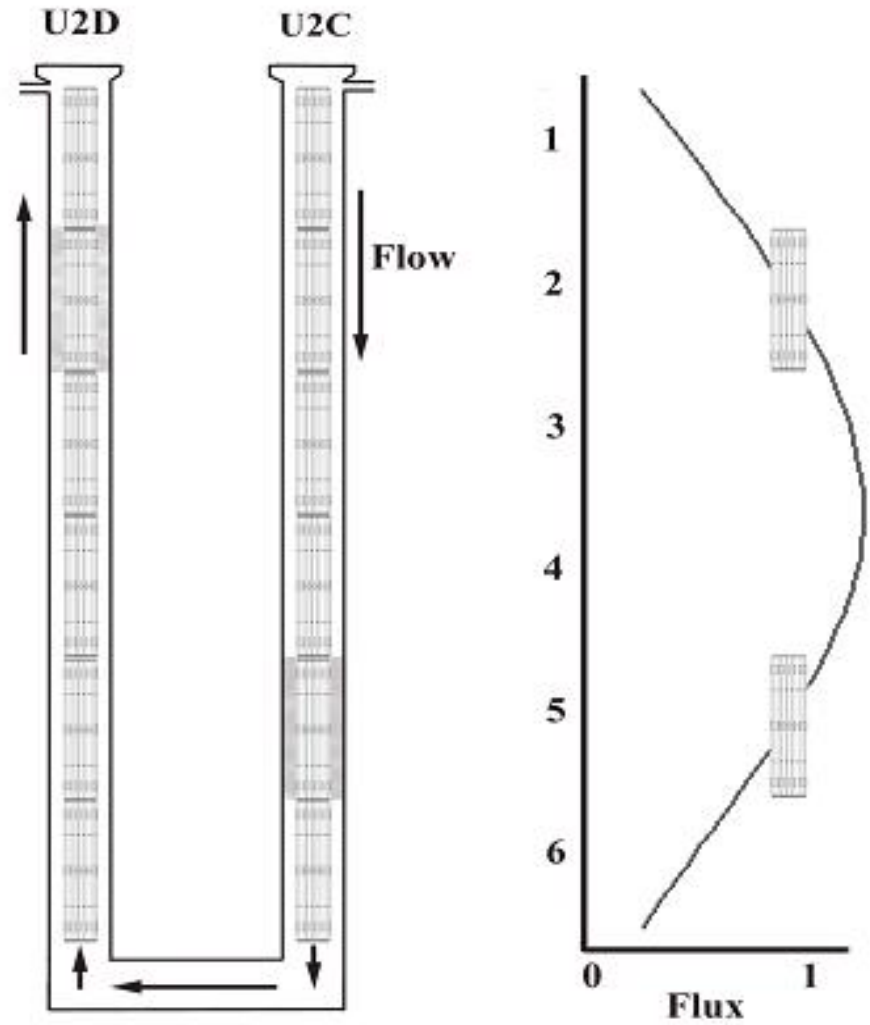


UO₂, thoria, MOX, BNA

FABRICATION TECHNOLOGY



IRRADIATION TESTING



POST-IRRADIATION EXAMINATION



Non-Destructive

- Visual examination
- Dimensioning
- Gamma scanning

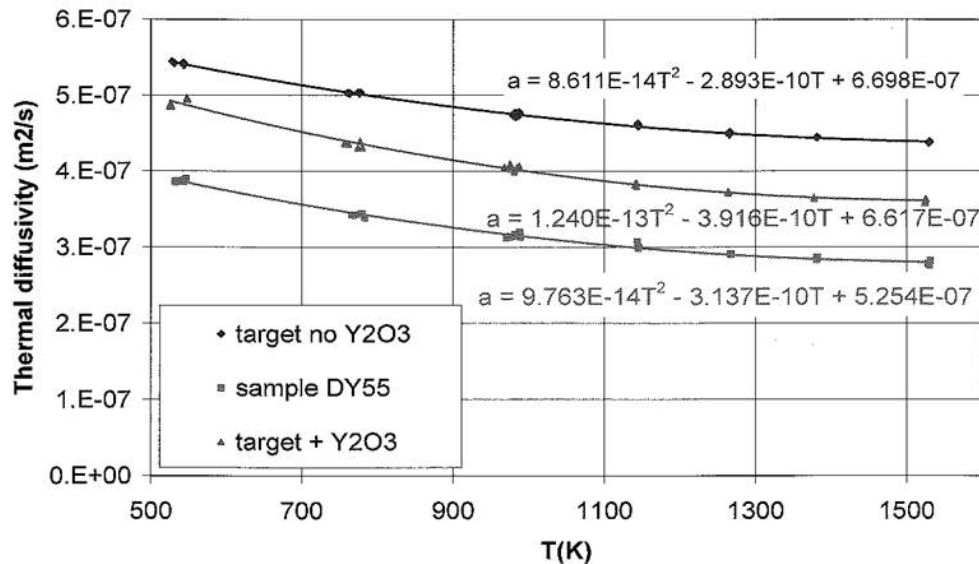
Destructive

- Internal gas analyses
- Sheath H/D analyses
- Sheath metallography
- Pellet ceramography
- Autoradiography
- Burnup measurement

MATERIALS CHARACTERIZATION

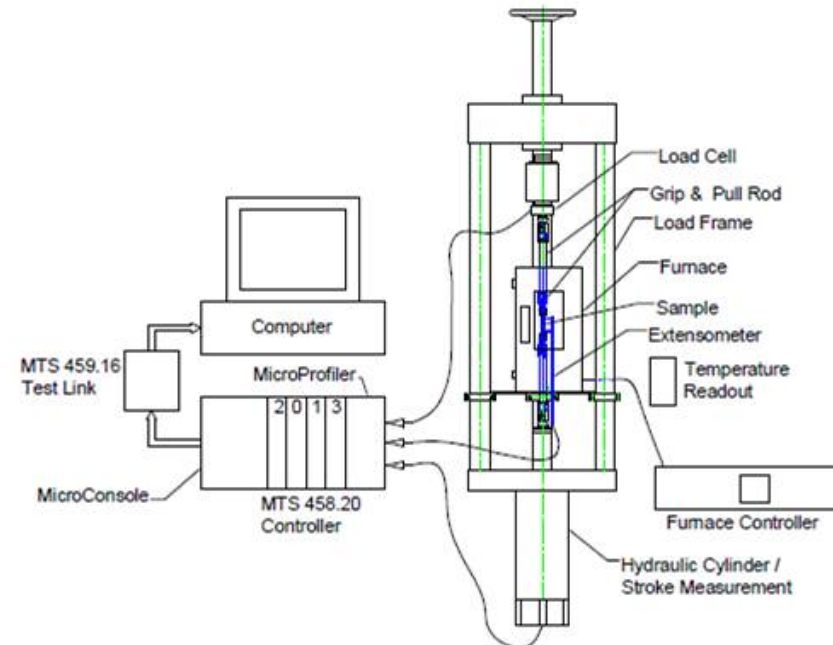
CERAMIC PELLETS

- Mechanical Properties
- Oxidation Behaviour
- Phase Diagrams
- Leaching Behaviour
- Thermal Conductivity



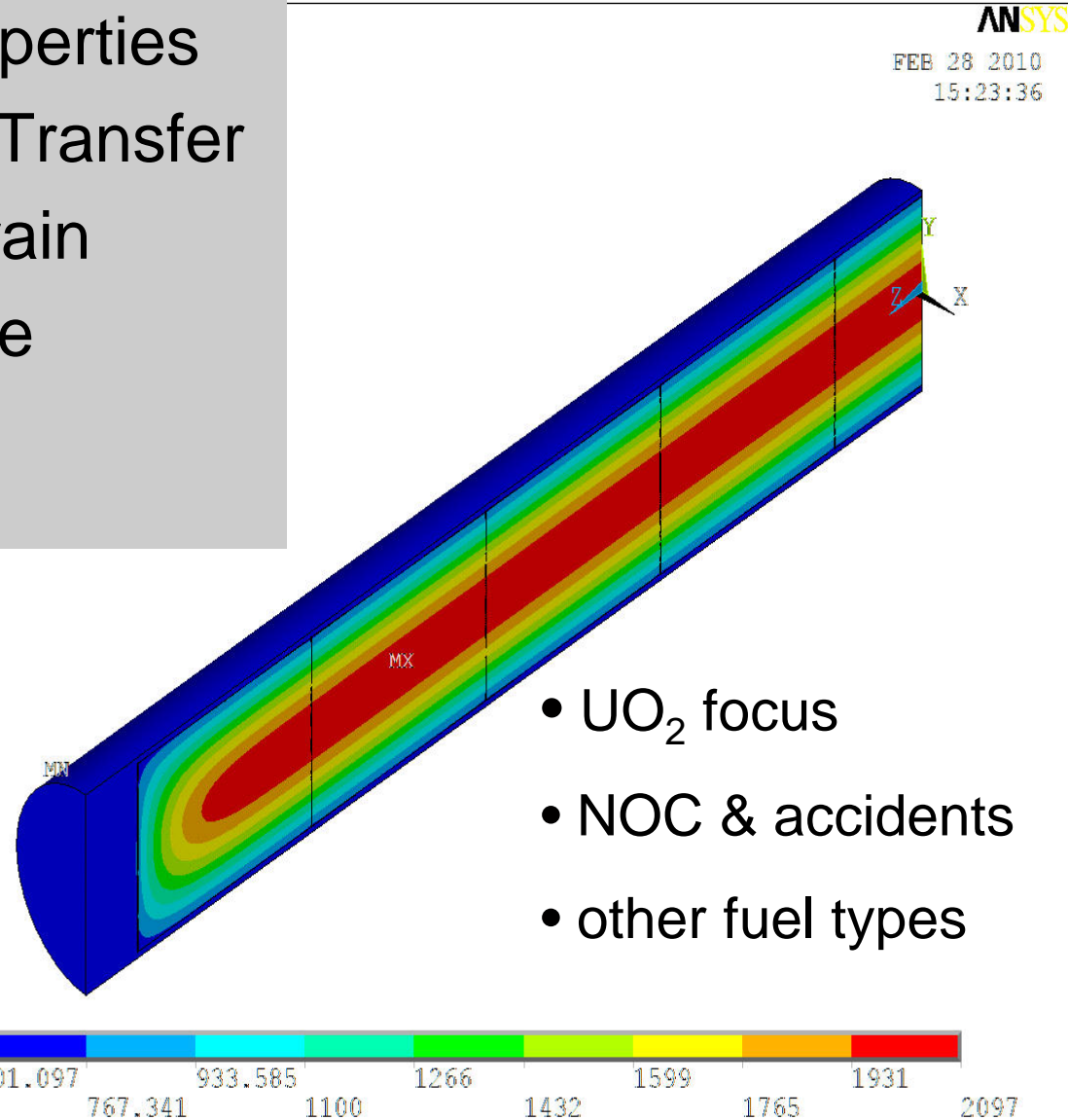
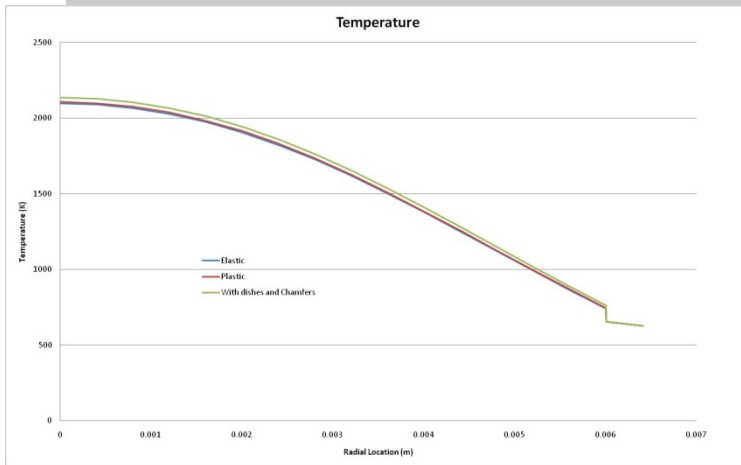
SHEATH ALLOYS

- Mechanical Properties
- Effects of:
 - Microstructure
 - Hydrogen/Deuterium pickup
 - Irradiation Effects



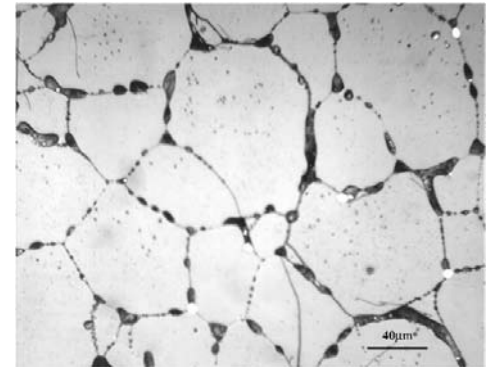
MODELING/CODES

- Pellet & Sheath Properties
- Pellet-Sheath Heat Transfer
- Sheath Stress & Strain
- Fission-Gas Release
- Endcap Effects



UO₂ FUEL

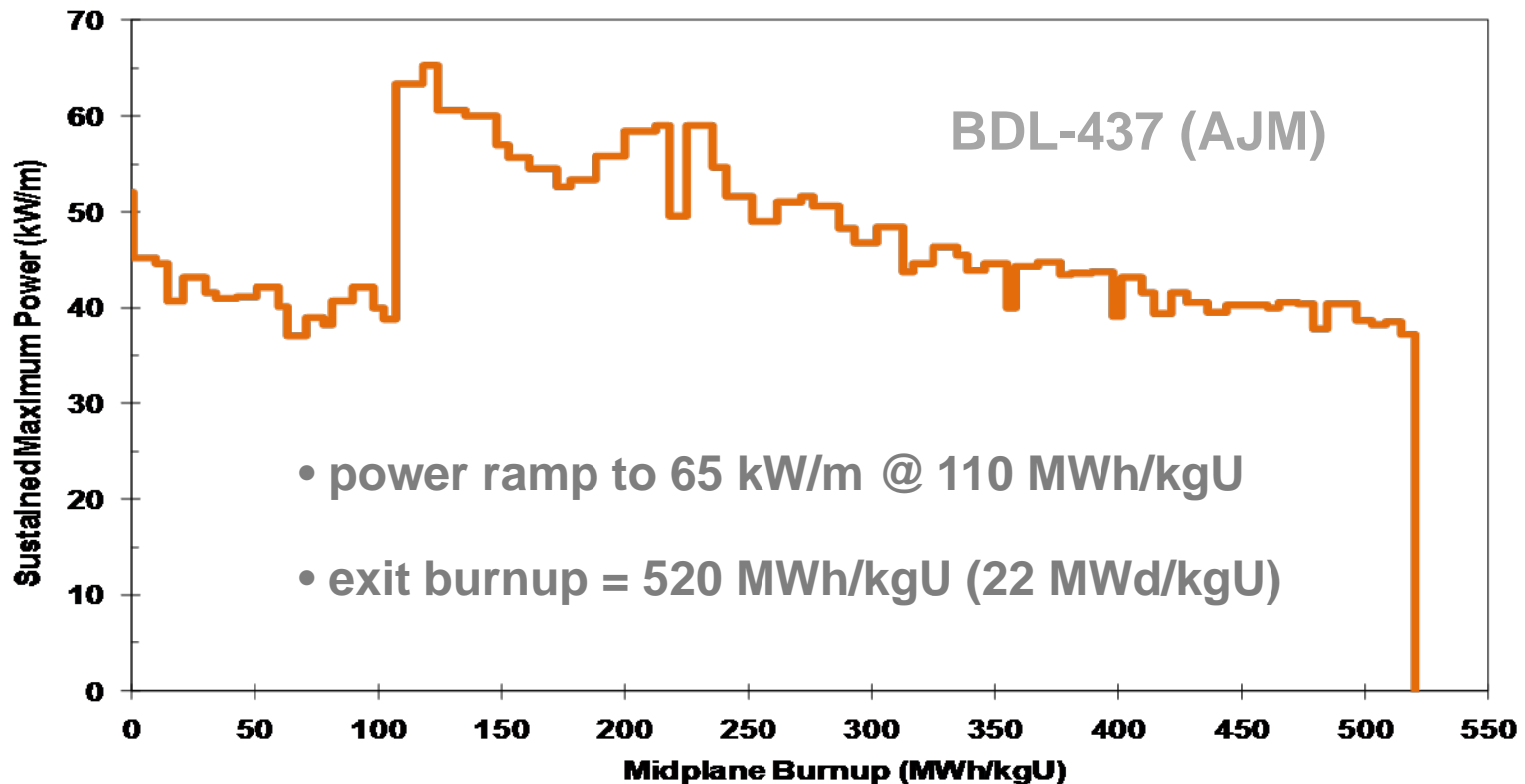
- **2005 CANDU Fuel Conference Paper**
 - **review of advanced CANDU UO₂ technology development during 1995-2005**
 - **43-element CANFLEX bundle**
 - **extended burnup technology**
 - **low-void reactivity fuel (LVRF) technology**



UO₂ FUEL

- **SEU fuel cycle development (CANDU)**

- **PIE of extended burnup bundle 'AJM' (NRU)**



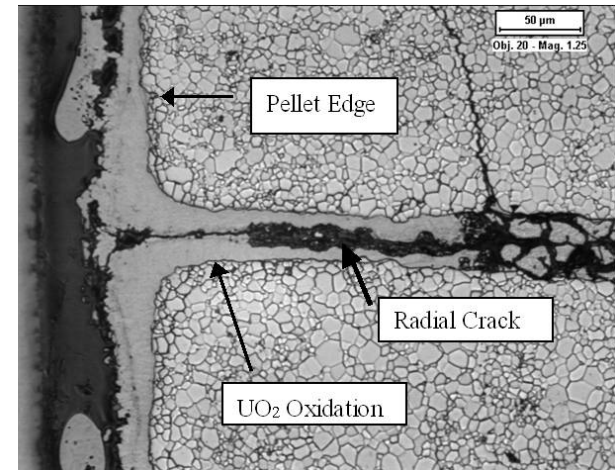
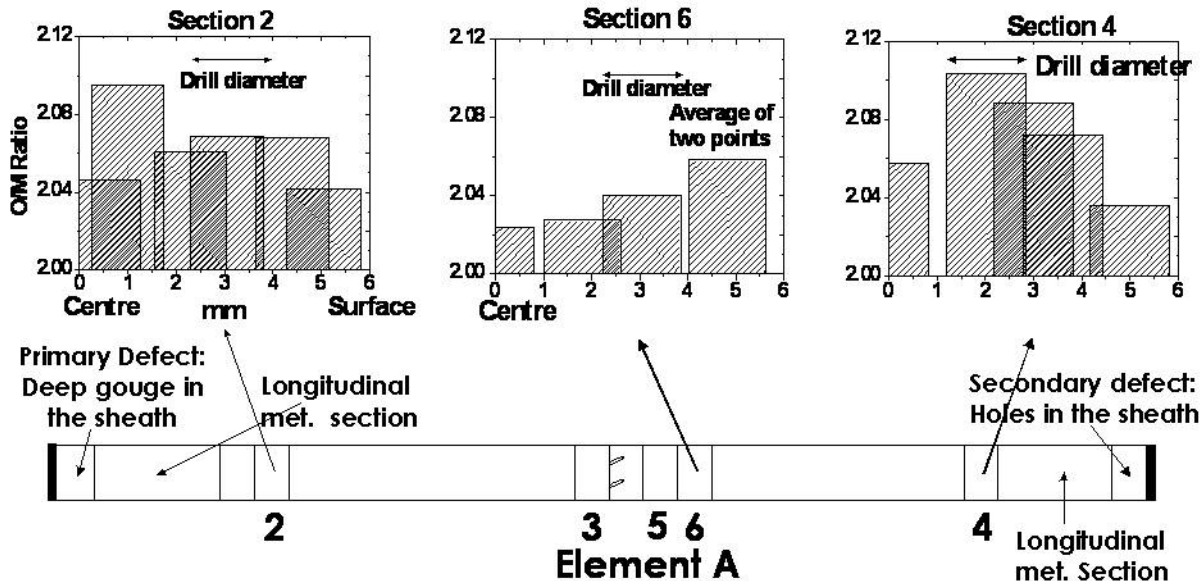
UO_2 FUEL

- **SEU fuel design development (CANDU)**
 - **DME-225 power tamp test (pellet geometry)**
 - bundle fabrication complete
 - irradiation testing in 2012



UO₂ FUEL

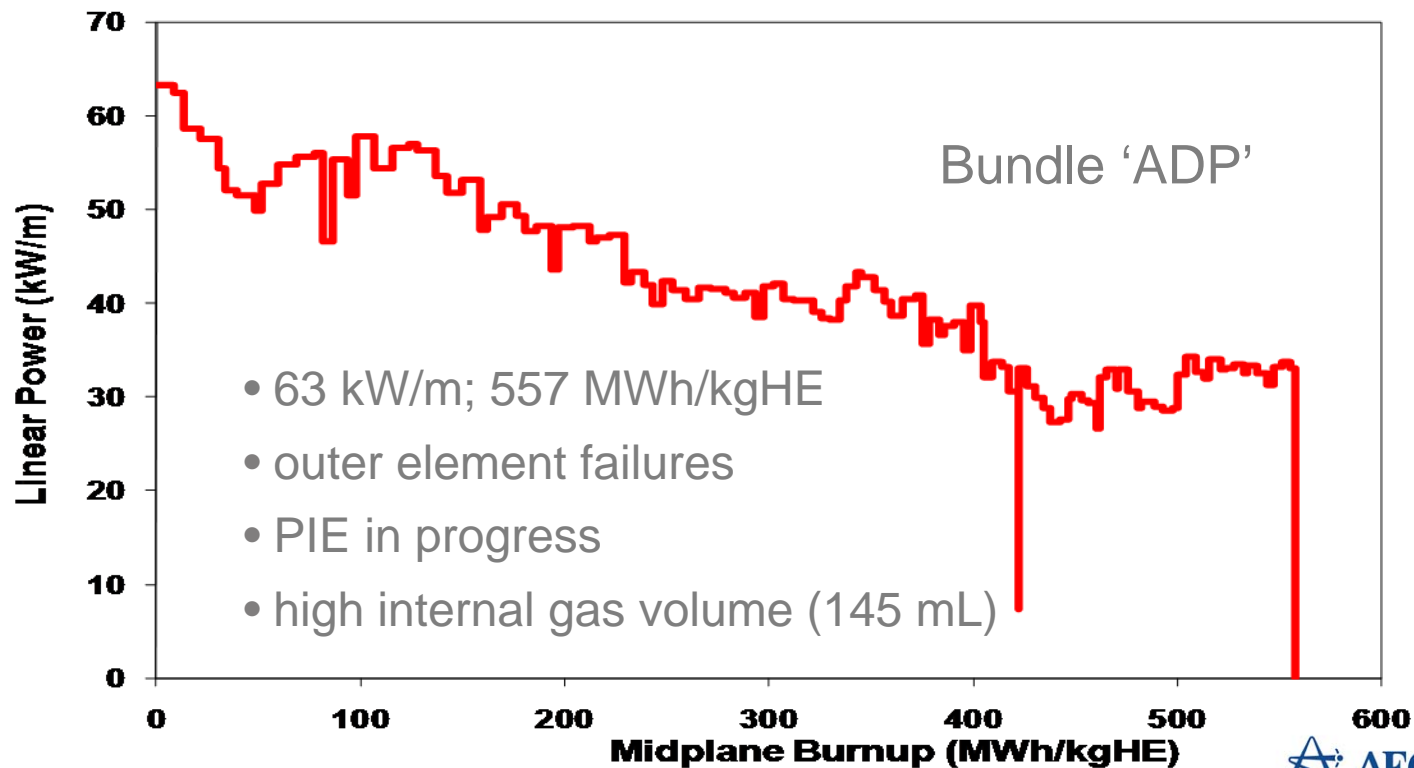
- Effect of coolant ingress in defected fuel
 - pellet oxidation measurements & models (RMC)
 - coulometric titration technique (O/M)



MOX FUEL

BDL-419: fifteen (U, Pu)O₂ bundles

- 13 bundles: irradiation completed (< 850 MWh/kgHE)
- 2 bundles: irradiation in progress (> 1000 MWh/kgHE)



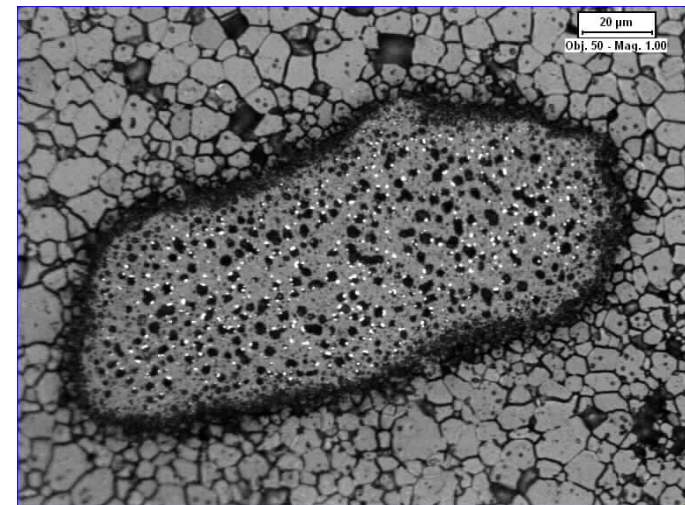
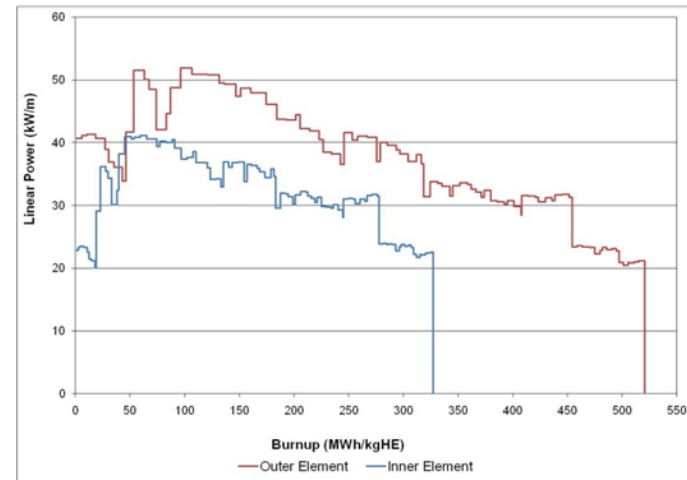
MOX FUEL

BDL-446: one (U, Pu)O₂ bundle

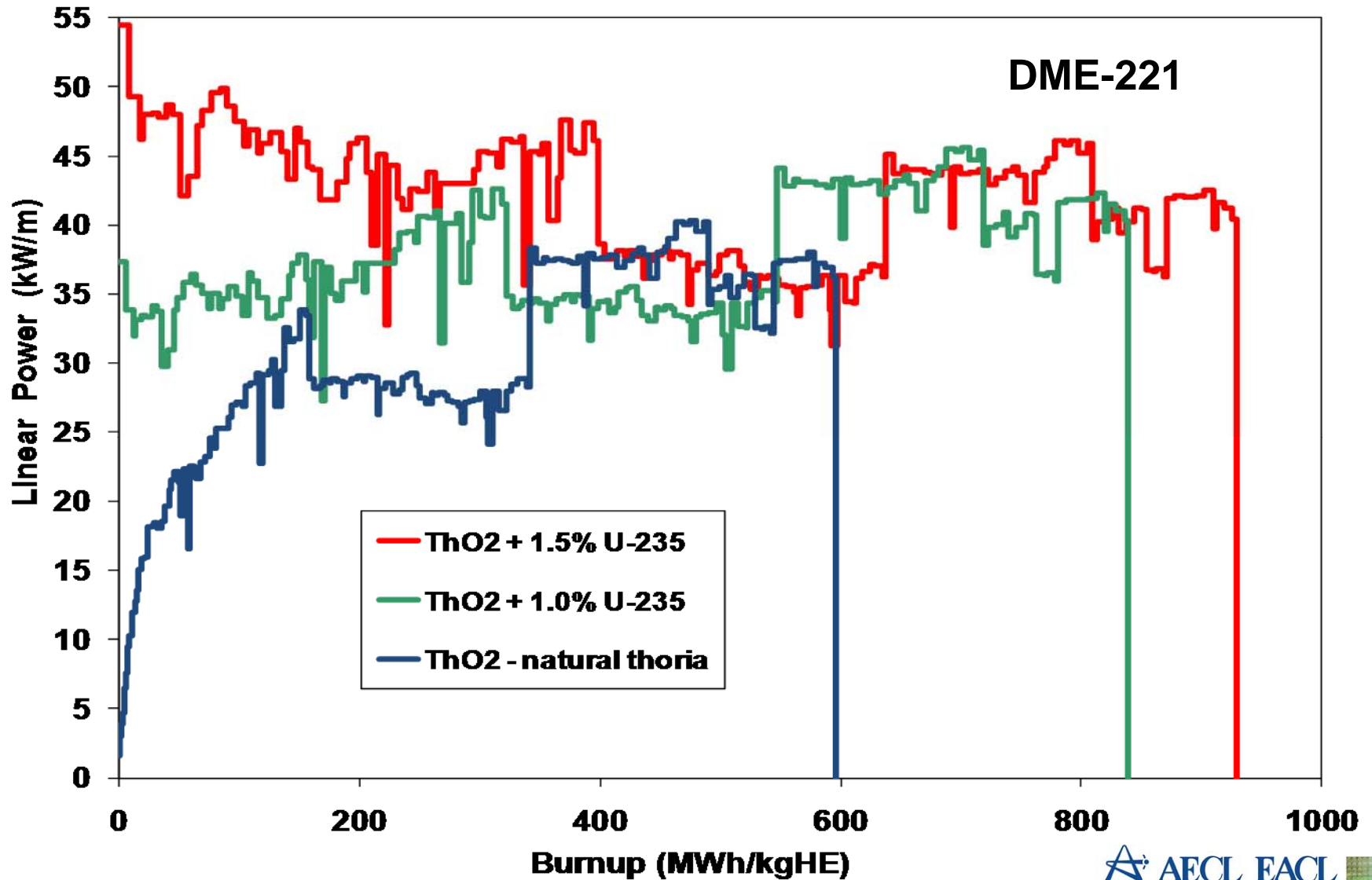
- varied pellet Pu homogeneity

1. Pure Pu particles (6% FGR)
2. Pu-rich particles (2-3% FGR)
3. Pu in solid solution (2-3% FGR)

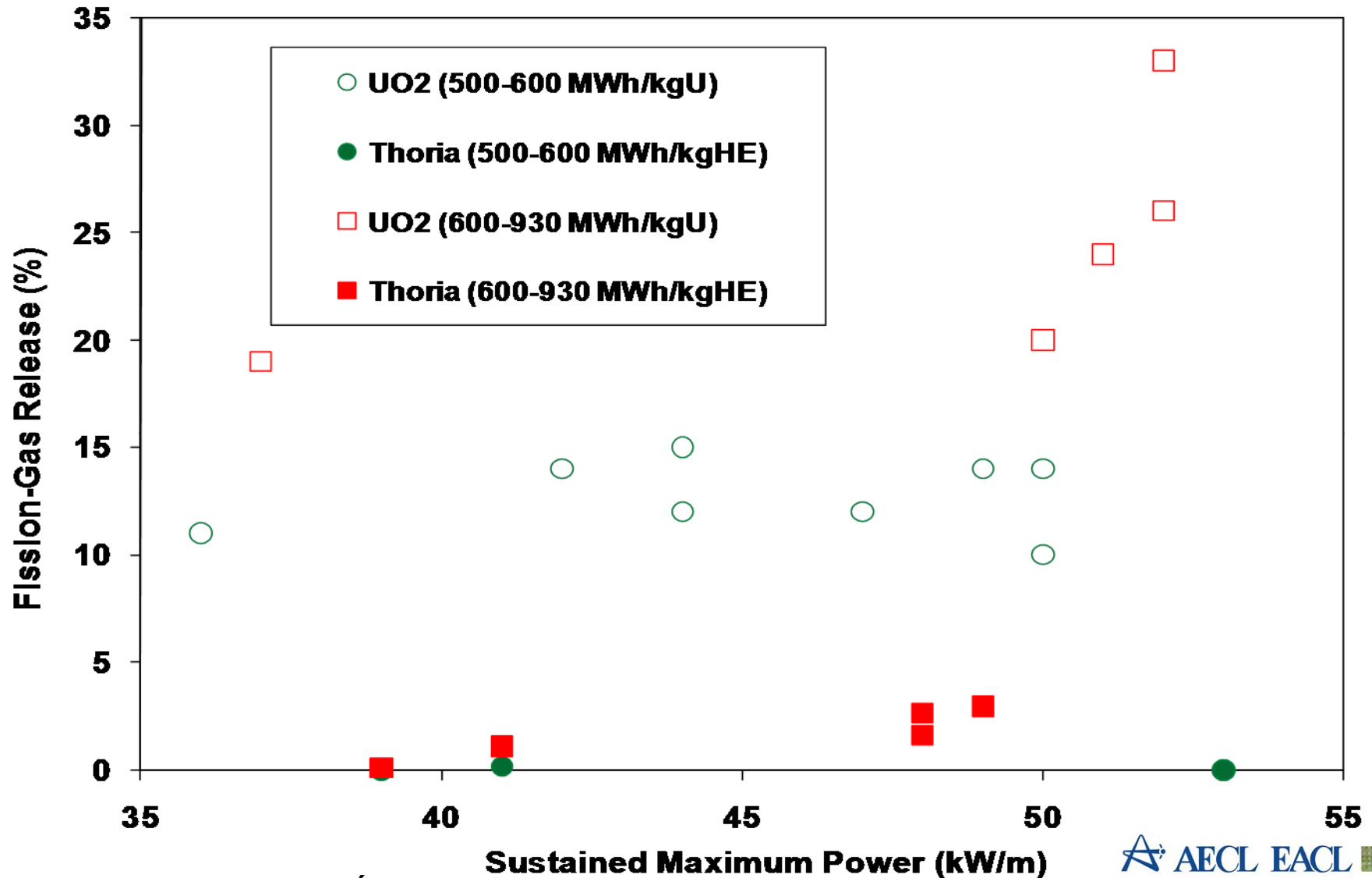
- effect of fabrication technology



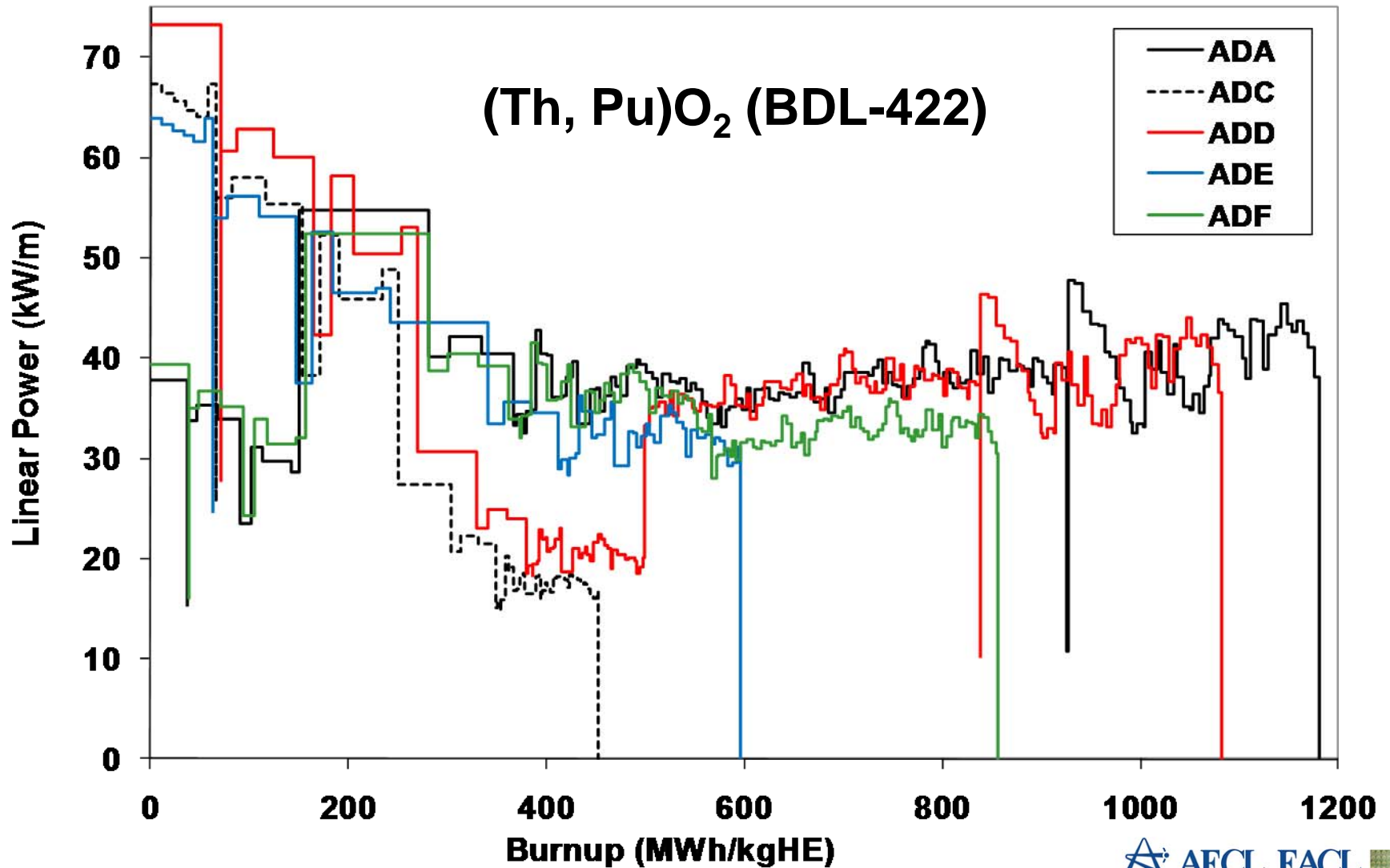
THORIA FUEL



THORIA FUEL



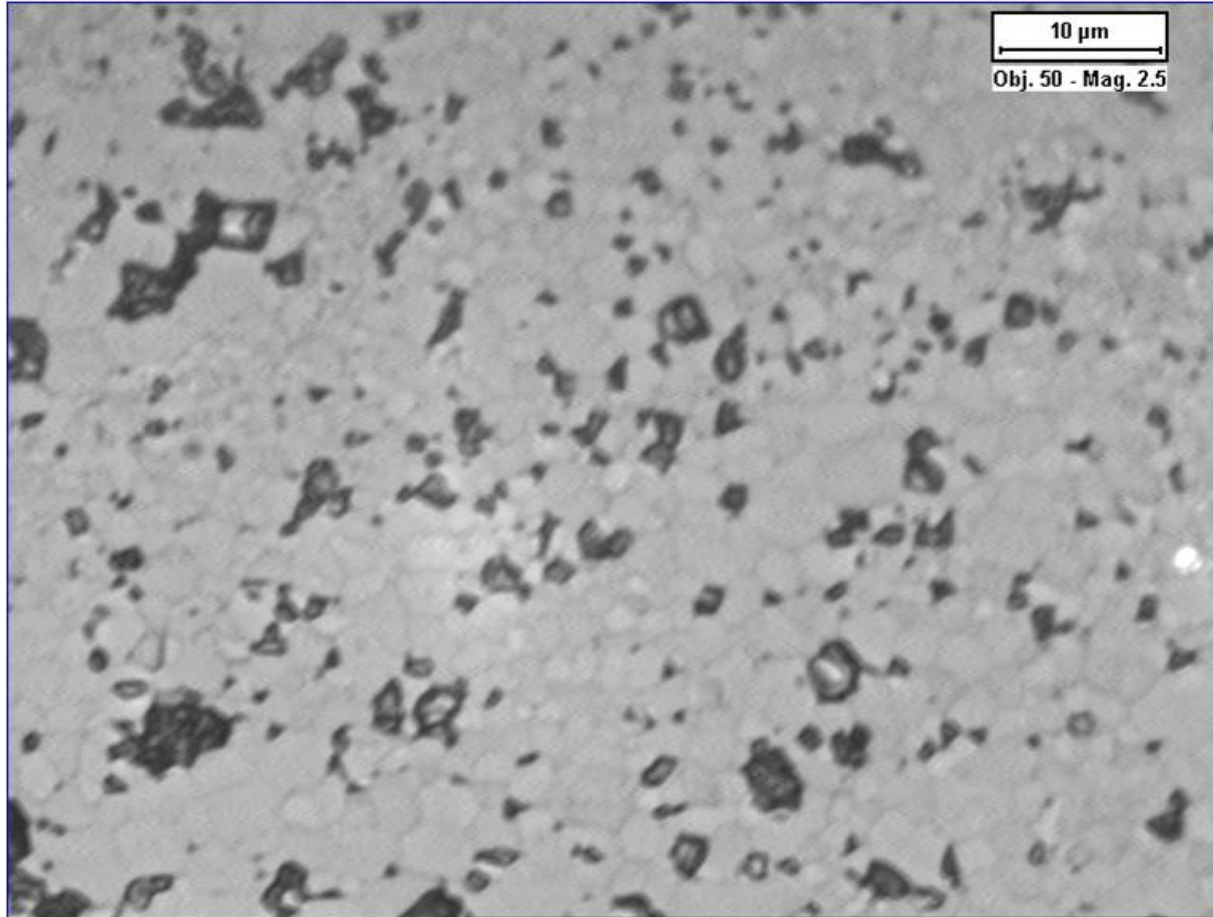
THORIA FUEL



(Th, Pu)O₂ FUEL

Fuel Bundle (BDL-422)	Max. Power (kW/m)	Burnup (MWh/kgHE)	Fission-Gas Release (%)
ADC	67	451	5
ADE	64	597	1
ADF	52	856	3
ADA	54	1181	30
ADD	73	1082	23

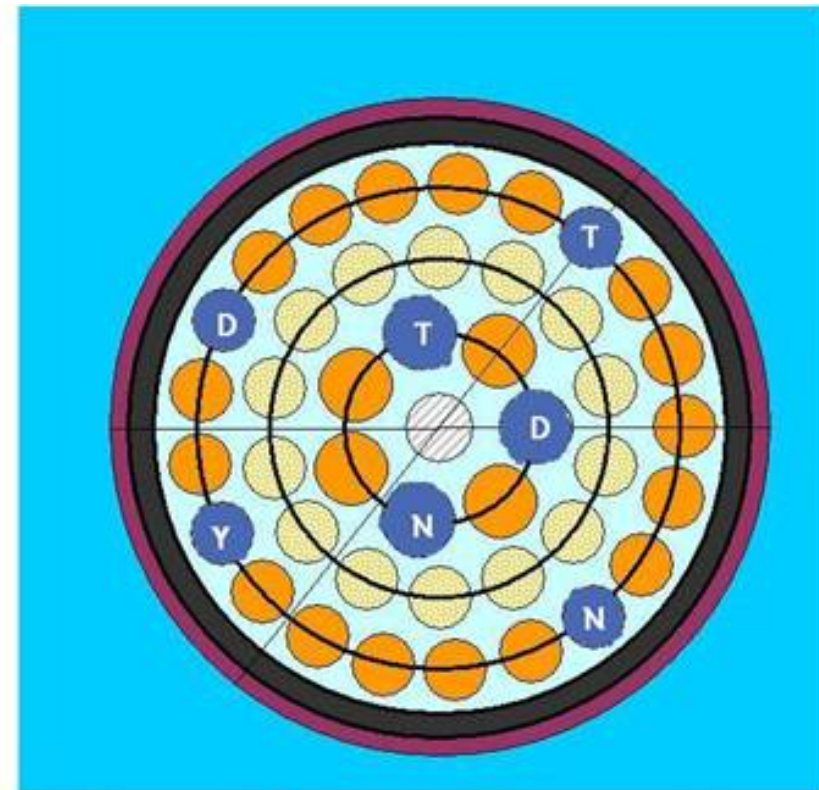
$(Th, Pu)O_2$ FUEL



small initial grain size (3-4 μm) = high FGR at high burnup

BURNABLE NEUTRON ABSORBERS

- Non-fissile pellet material (ZrO_2)
- Rare-earth additives: Y, Dy (BNA), Gd (BNA)
- DME-224 irradiation test
 - 47 day irradiation
 - non-destructive PIE @ 21 days
 - 1000 days planned
 - PIE @ 133, 277 & 565 days

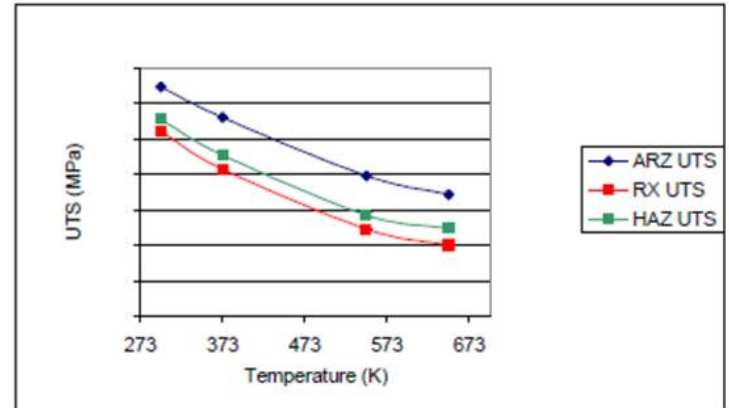


DME-224 BNA IRRADIATION TEST

Element Type	Bundle Location	Dy ₂ O ₃ (vol. %)	Gd ₂ O ₃ (vol. %)	Y ₂ O ₃ (vol. %)	Sheath Strain (%)
T	outer	12	12	15	-0.02
T	inner	12	12	15	-0.16
N	outer	12	12	0	+0.11
N	inner	12	12	0	-0.12
D	outer	55	0	0	-0.01
D	inner	55	0	0	-0.13
Y	outer	0	0	38	-0.04

FUEL CLAD TECHNOLOGY

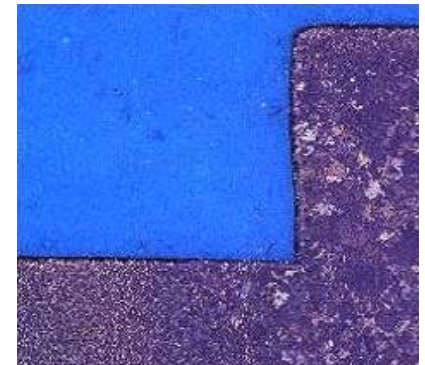
- **Zr-2, Zr-4, Zr-Nb, advanced cladding materials**
- **Mechanical properties**



- effects of microstructure, H/D pickup, irradiation effects

- **Advanced joining techniques**

- improved microstructural properties
- improved fabrication worker safety



- **Collaboration with university & industry partners**

SUMMARY

- **CRL initiatives in advanced fuel technologies**
 - can be deployed in HWRs (or other reactor designs)
- **Significant UO₂, MOX, thoria & BNA initiatives**
- **Fabrication, irradiation, PIE, materials, modelling**
- **Enabled by CRL facilities and collaborations**



UNRESTRICTED / ILLIMITÉ

