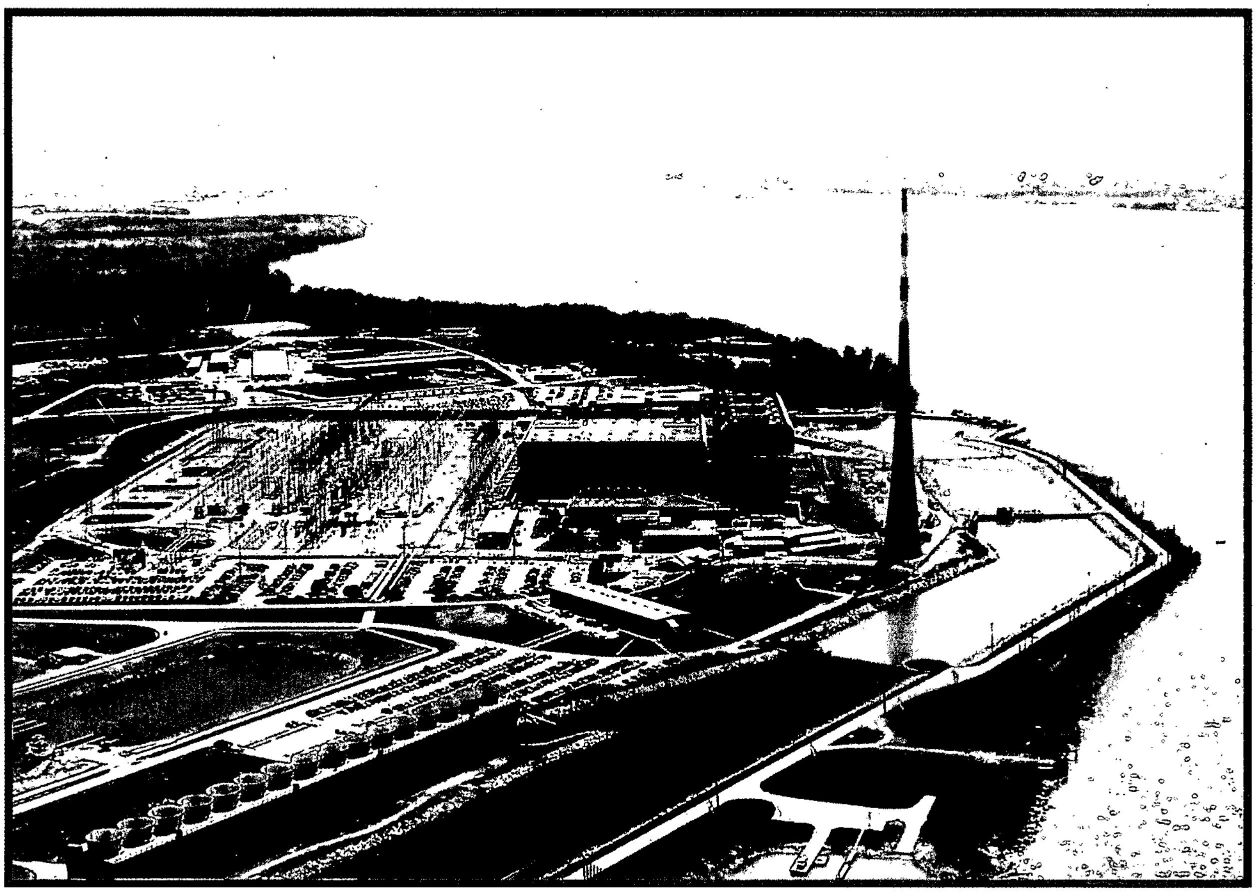
TVA

AREVA

Loading BLEU Fuel in Browns Ferry Unit 1



Introduction

- In 1997, the Tennessee Valley Authority agreed to take from the Department of Energy over 30 metric tons of highly enriched uranium (HEU) to be converted to blended, low enriched uranium (BLEU) for use as fuel.

- AREVA and TVA entered into an agreement for AREVA to provide this BLEU material in ATRIUM™-10* BWR fuel assemblies for Browns Ferry Units 2 and 3.

- AREVA and TVA modified the agreement in 2008, adding Browns Ferry Unit 1 as another unit loading BLEU fuel.

- In April 2005, TVA reached a key milestone by loading its first reload of BLEU fuel into Browns Ferry Unit 2.

- AREVA has manufactured 1238 BLEU ATRIUM-10 assemblies that have been loaded and operated at Browns Ferry Units 2 and 3.

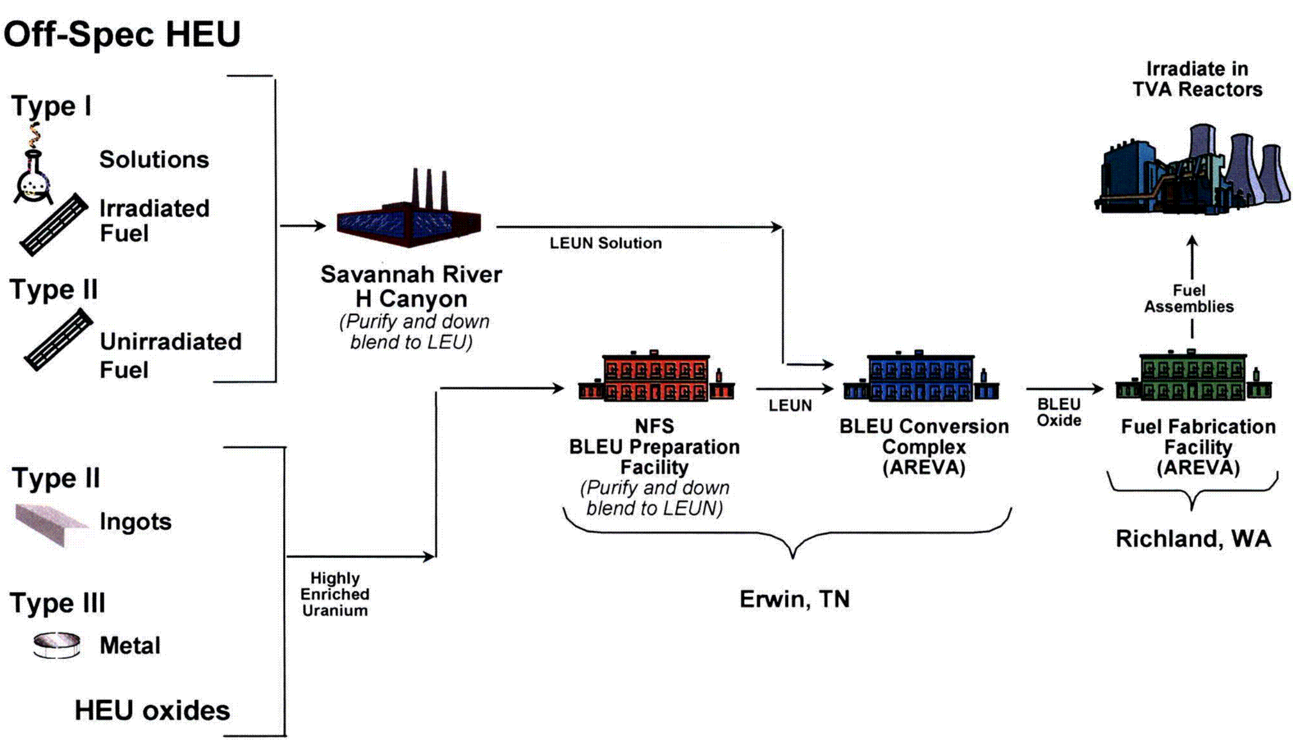
- The Unit 1 transition will benefit from the experience already gained transitioning at Units 2 and 3.

- A dominant characteristic of BLEU is a high U^{234} and U^{236} content compared to commercial grade uranium (CGU).

* ATRIUM is a trademark of AREVA NP

What is BLEU Fuel?

- Material Process
  - HEU is downblended to low-enriched aqueous uranyl nitrate, then converted to uranium oxide powder.
  - AREVA processes this into UO_2 pellets and loads them into BWR fuel assemblies.



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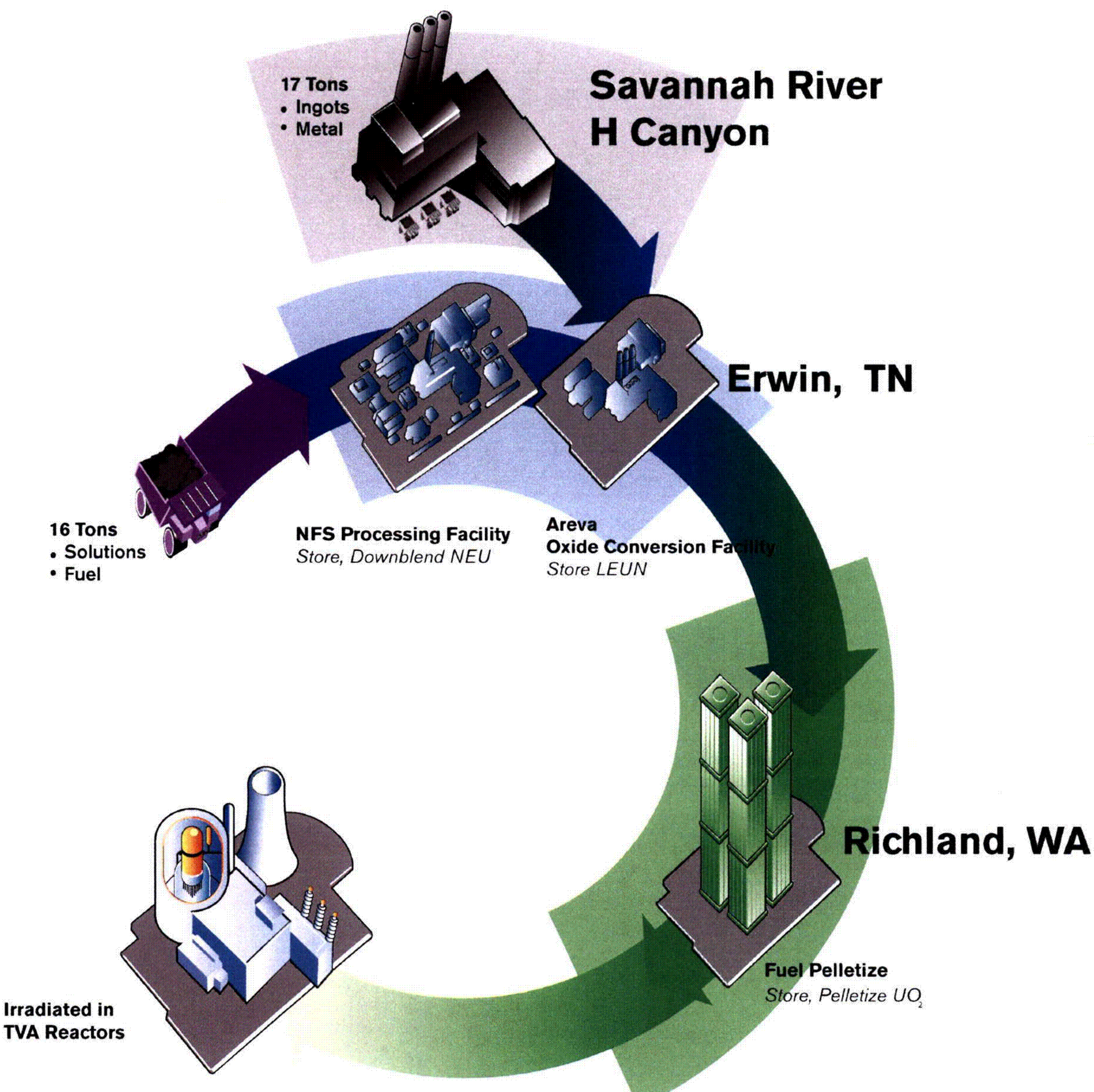


What is BLEU Fuel?

◆ Material Characteristics

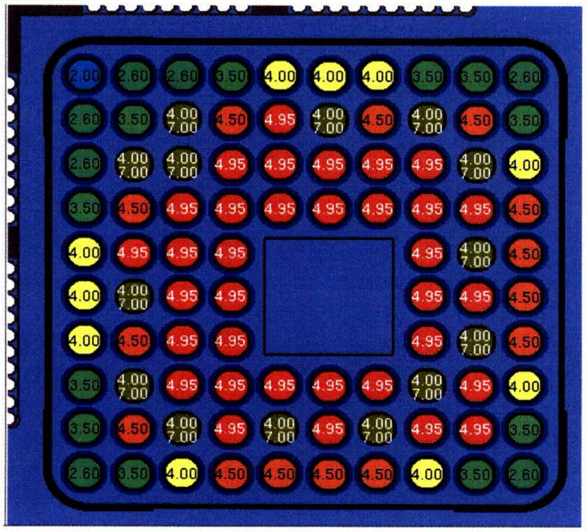
- BLEU material meets the CGU specification with the exception of the isotopes U^{232}, U^{234}, and U^{236}.

Characteristics of Blended, Low-Enriched Uranium (BLEU)

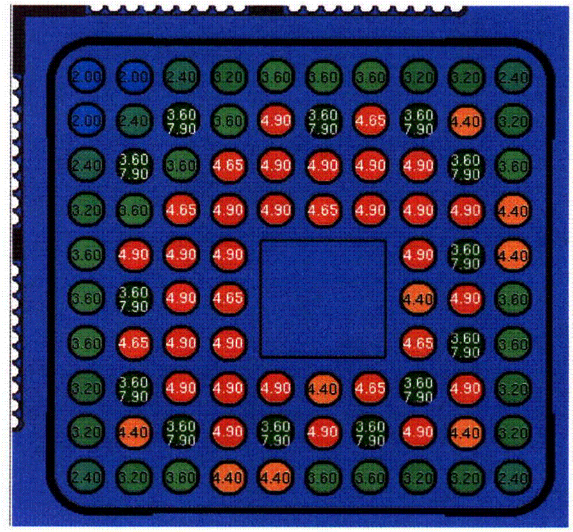
Parameter	Commercial Grade Uranium (CGU)	Blended, Low-Enriched Uranium (BLEU)	Comment
Chemically	---	Same as CGU	Within fuel fabrication process isotopes are inseparable from BLEU feed.
U^{235} Enrichment Limit, wt%U^{235}	4.95	4.95	Effective Fuel Fabrication plant limit.
U^{234} wt% (in 4.95 wt% U^{235} BLEU)	0.05 (ASTM limit)	0.07	~1.4 times the ASTM limit
U^{236} wt% (in 4.95 wt% U^{235} BLEU)	0.025 (ASTM limit)	1.5	~60 times the ASTM limit

- The impact of the U^{234}, and U^{236} isotopes is to decrease reactivity due primarily to the absorption of neutrons by the U^{236}.
- In CGU at fuel burnups beyond 25 GWd/MTU there is a buildup of U^{236} concentrations of about one-third of those expected in BLEU.

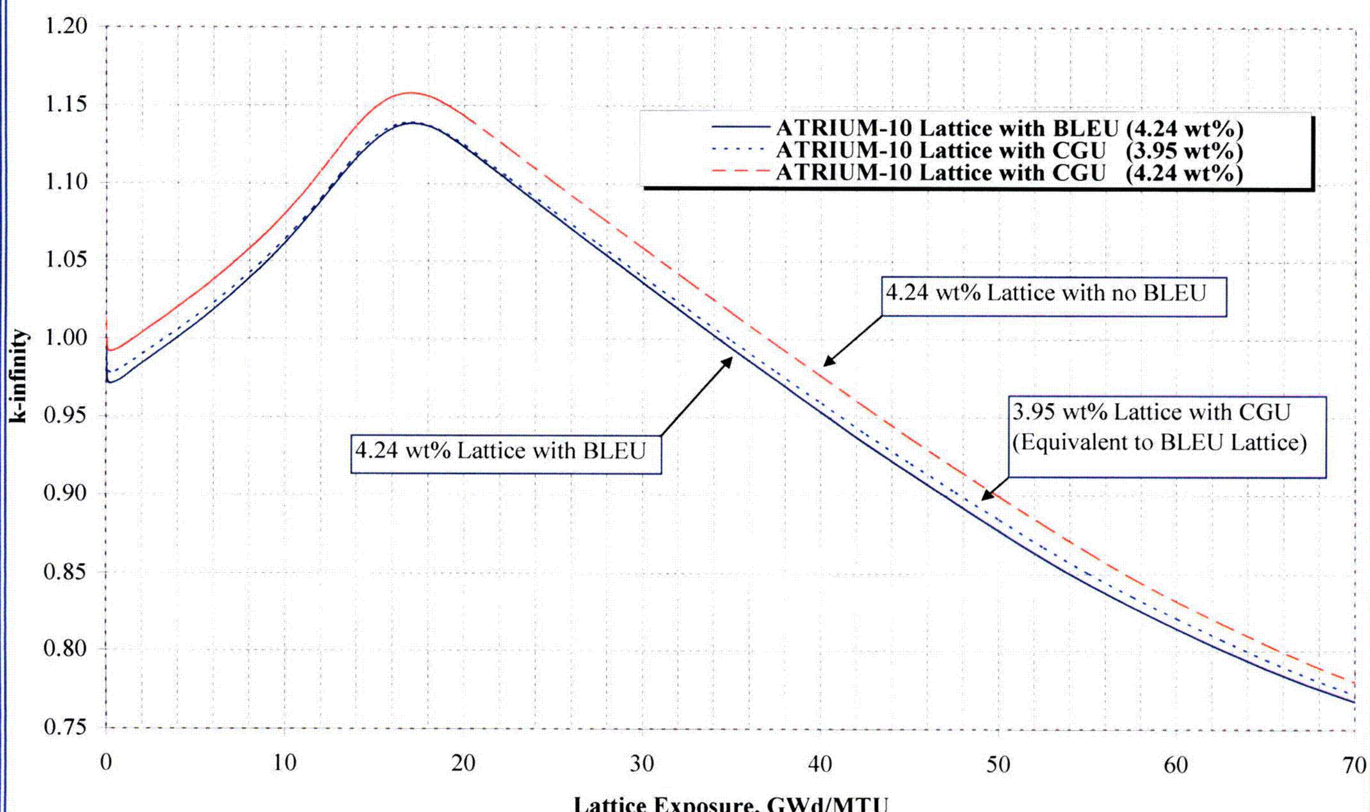
Reactivity Impact of BLEU



BLEU Lattice
4.24 wt% U^{235} Average Enrichment



Equivalent CGU Lattice
3.95 wt% U^{235} Average Enrichment



CGU and BLEU ATRIUM-10 Fuel

Hot Operating, Uncontrolled, 40% Voids,

k-infinity versus Exposure

BLEU Reactivity Characteristics

- AREVA analytical methods employ the NRC-approved CASMO-4/MICROBURN-B2 3-D core simulator and lattice code.
- Parallel Unit 2 Cycle 14 calculations were performed – one utilizing CGU material and one with BLEU material.
- When explicitly accounting for the higher U^{234}/U^{236} content, a comparison of key core reactivity characteristics shows that core response will not be significantly different between BLEU and CGU cores.

Kinetic Parameters Comparison

Calculated Core Average Parameter	Browns Ferry 2 Cycle 14	
	ATRIUM-10 with CGU	ATRIUM-10 with BLEU
EOC Doppler Reactivity Coefficient, Δk/k/°F	-1.3×10^{-5}	-1.4×10^{-5}
EOC Delayed Neutron Fraction, βeff	0.0053	0.0052
EOC Control Rod SCRAM Worth, Δk/k	-0.22	-0.22
EOC Void Reactivity Coefficient, Δk/k/%VF	-0.11	-0.10

BLEU in Operation

Browns Ferry Units 2/3 Transitioned to AREVA ATRIUM-10 BWR Fuel Design

Key Core Design Parameters

Parameter	Value	Comments
Reactor-Browns Ferry 2/3	BWR/4, D-Lattice, 764 Assemblies 3458 MWt, 51 kW/l	Planned 120% uprates to 3952 MWt, 58.5 kW/l
Fuel type/co-resident fuel	ATRIUM-10 BLEU GE-13/-14	
Loading Strategy	Scatter load	
Cycle Length, months	24	

Browns Ferry Unit 1 to Transition to AREVA

ATRIUM-10 BWR Fuel Design

Key Core Design Parameters

Parameter	Value	Comments
Reactor-Browns Ferry Unit 1	BWR/4, D-Lattice, 764 Assemblies 3952 MWt, 58.5 kW/l	Same as planned uprates at Units 2 and 3
Fuel type/co-resident fuel	ATRIUM-10 BLEU GE-13/-14	Same as Units 2/3 experience
Loading Strategy	Scatter load	Same as Units 2/3 experience
Cycle Length, months	24	Same as Units 2/3 experience

BLEU in Operation

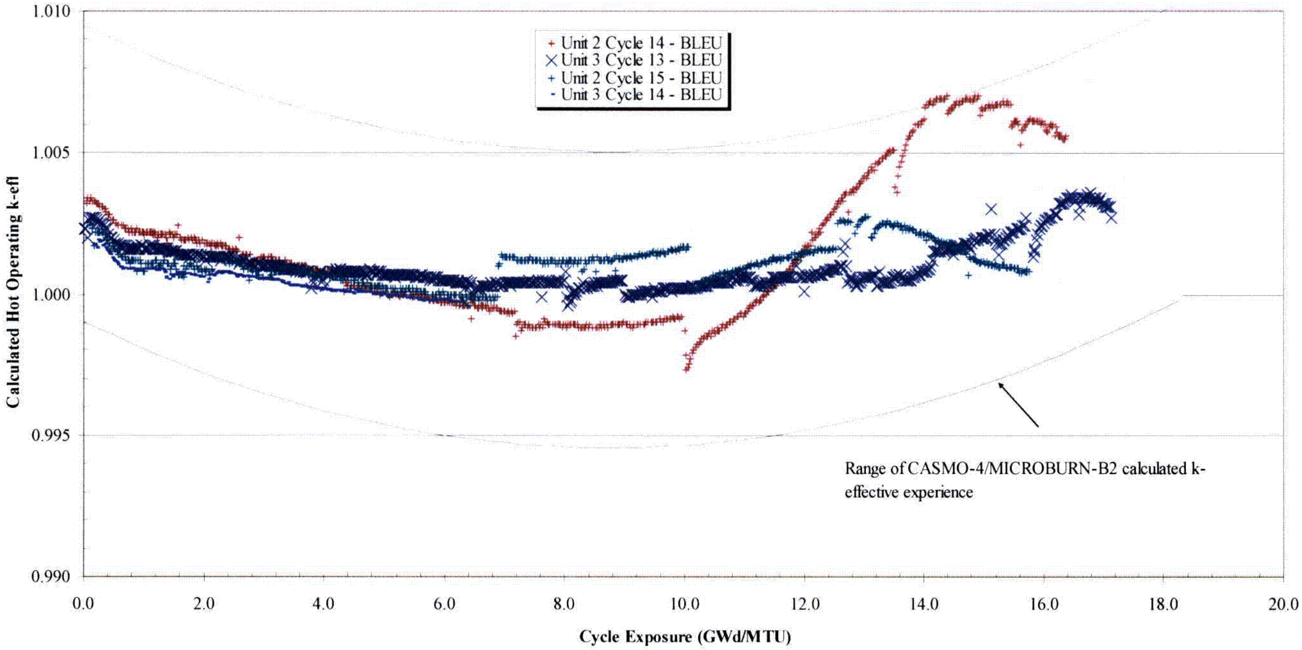
BLEU Operating Experience - Cycles Completed

Parameter	Unit 3 Cycle 12	Unit 2 Cycle 14	Unit 3 Cycle 13
Cycle Length, EFPD (GWd)	699 (2,417)	669 (2,312)	694 (2,400)
Reload Fuel Type	ATRIUM-10	ATRIUM-10	ATRIUM-10
Fuel Material Type	CGU	BLEU	BLEU
Batch Average Enrichment, % U-235	3.82	3.92	4.17
Reload Batch Size	300 (39%)	280 (37%)	296 (39%)
Predicted BOC Cold Shutdown Margin, %Δk/k	1.3	1.5	1.4
Measured BOC Cold Shutdown Margin, %Δk/k	1.4	1.6	1.6

BLEU Operating Experience - Currently Operating

Parameter	Unit 2 Cycle 15	Unit 3 Cycle 14
Cycle Length, EFPD (GWd)	779 (2,693)	652 (2,254)
Reload Fuel Type	ATRIUM-10	ATRIUM-10
Fuel Material Type	BLEU	BLEU
Batch Average Enrichment, % U-235	4.13	4.22
Reload Batch Size	374 (49%)	288 (38%)
Predicted BOC Cold Shutdown Margin, %Δk/k	1.2	1.3
Measured BOC Cold Shutdown Margin, %Δk/k	1.3	1.2

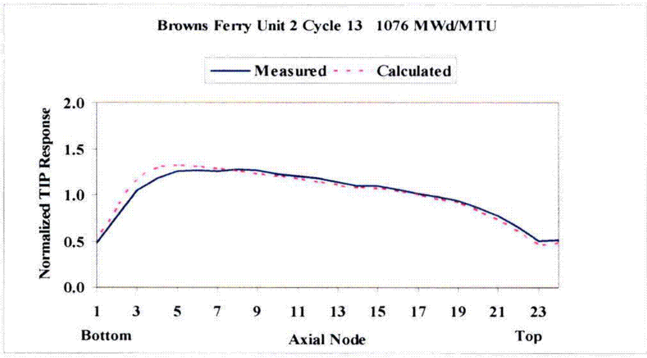
Calculated Core Reactivity

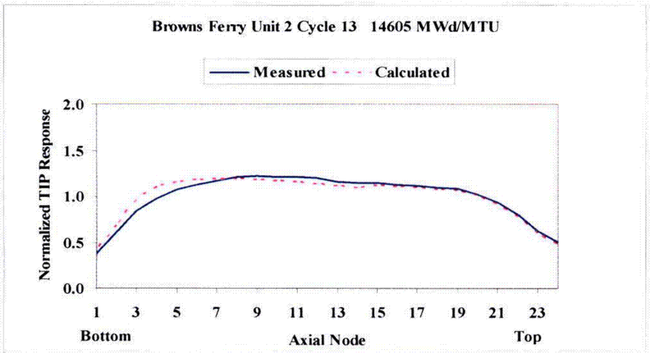


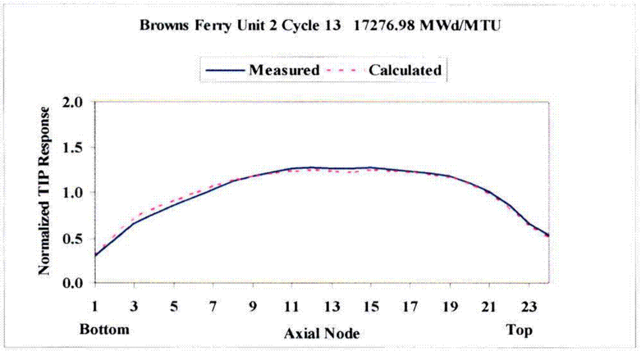
Comparison of Calculated Browns Ferry 2/3 BLEU k-effectives with Other CASMO-4/MICROBURN-B2 Experience

Browns Ferry Unit 2 Average TIP Comparison

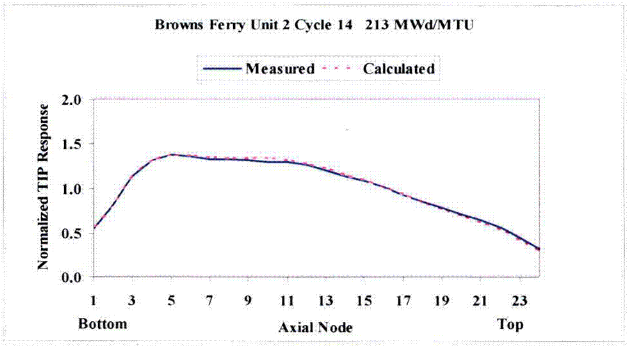
Pre-BLEU (Cycle 13)

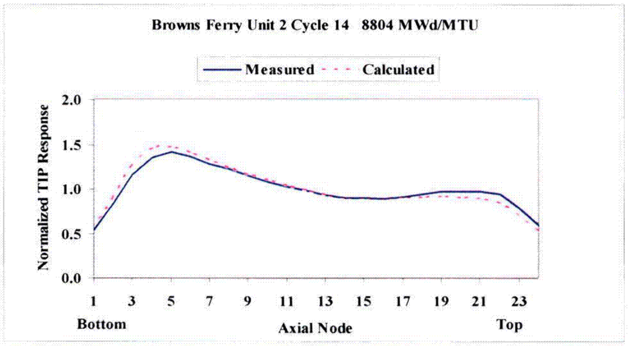


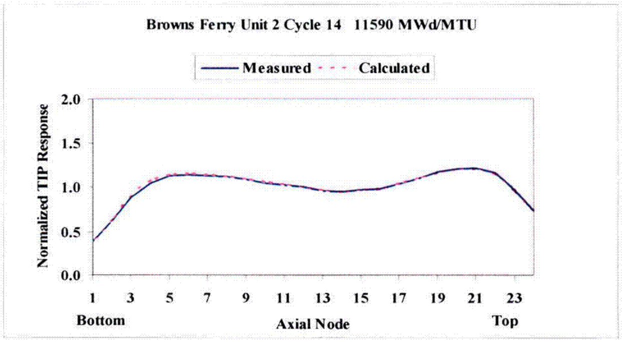




BLEU (Cycle 14)

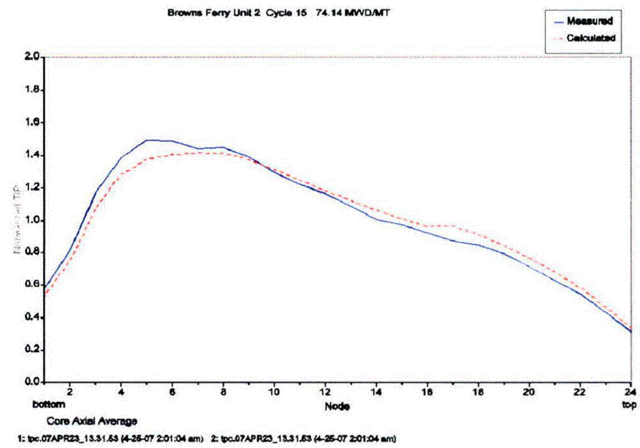


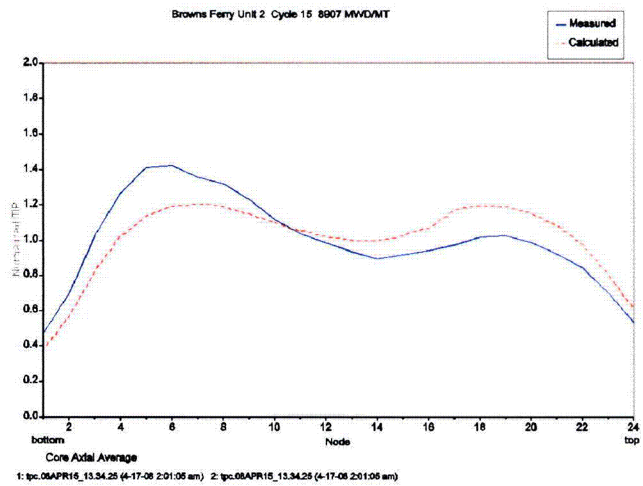


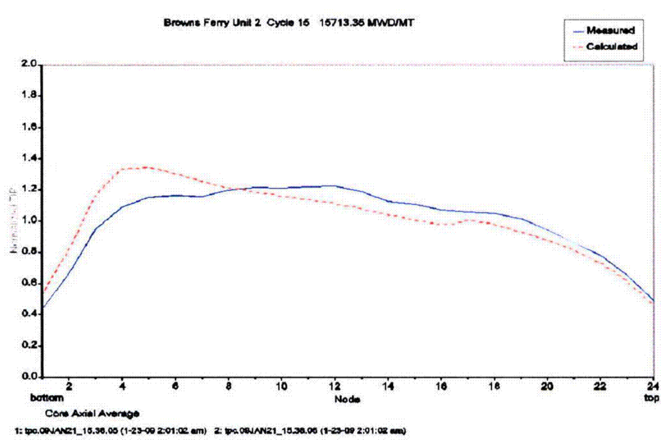


Browns Ferry Unit 2 Average TIP Comparison

BLEU (Cycle 15)

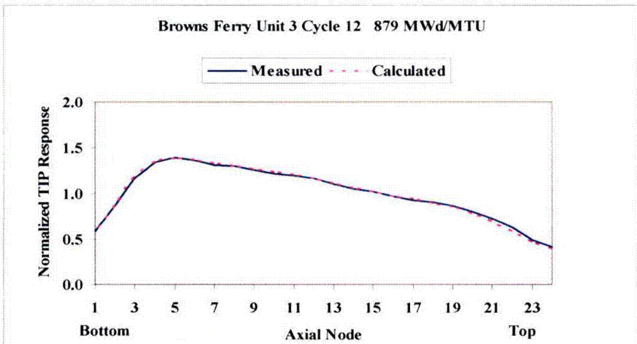


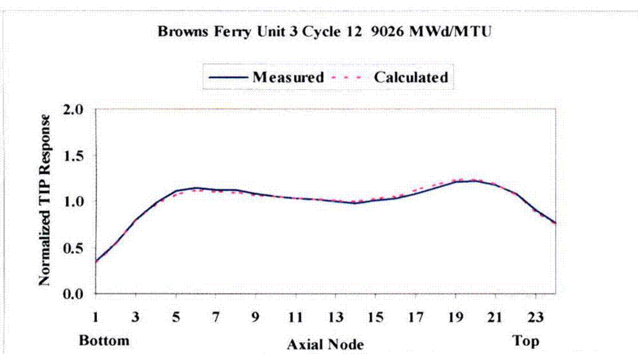


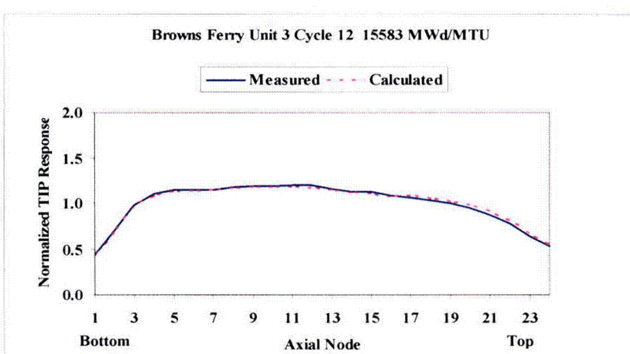


Browns Ferry Unit 3 Average TIP Comparison

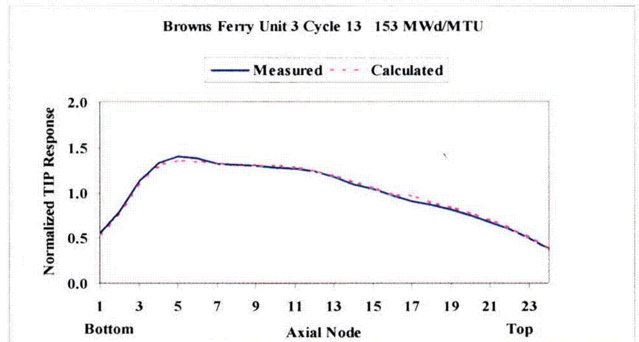
Pre-BLEU (Cycle 12)

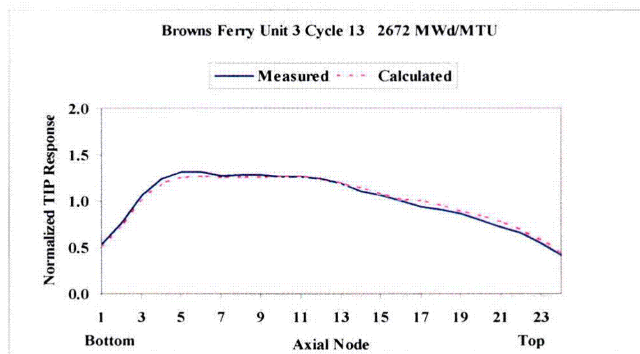


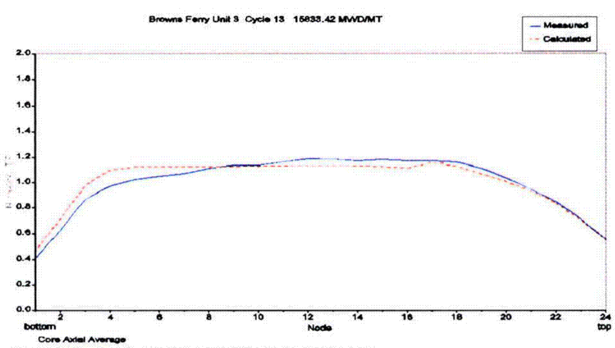




BLEU (Cycle 13)

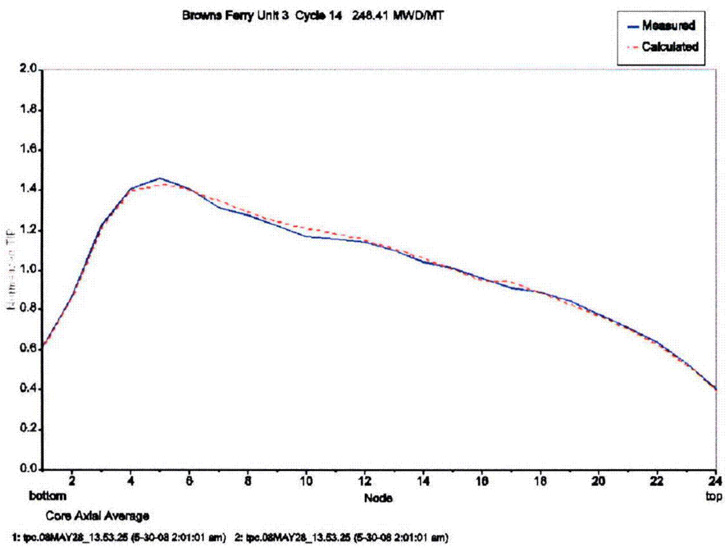


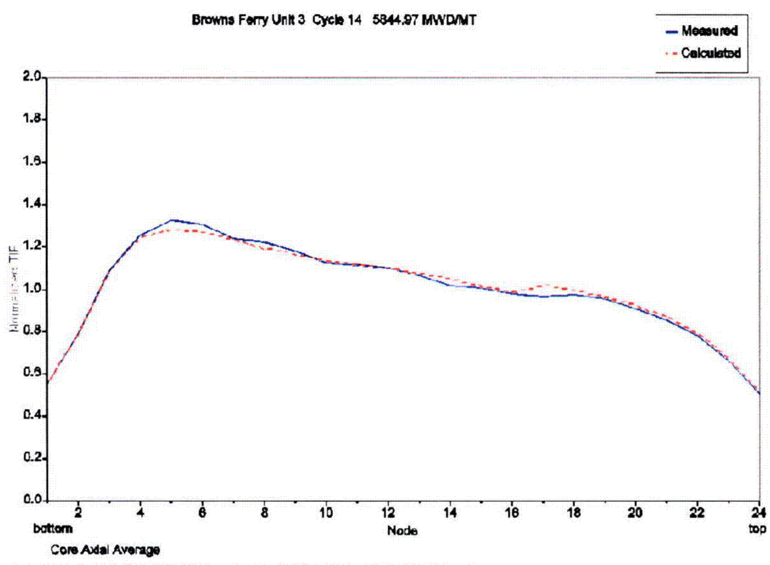




Browns Ferry Unit 3 Average TIP Comparison

BLEU (Cycle 14)





Conclusion

- BLEU fuel has been successfully loaded and operated in TVA's Browns Ferry Units 2 and 3.
  - Each unit has completed one complete cycle of operation with BLEU fuel and is currently in the second cycle.
- The transition at Unit 1 will be similar to what has already been successfully done at Units 2 and 3.
- AREVA CASMO-4/MICROBURN-B2 neutronic modeling methodology very accurately models fuel behavior of BLEU fuel
  - No significant differences are seen between BLEU and non-BLEU core designs.
  - Initial reactor measured data are very good and consistent with prior cycle results.