A New Design Concept of Burnable Poison for Longer Cycle PWR

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Outline

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1 Introduction

Motivation

□ Limitations of Conventional Burnable Poison (BP)

- This table shows the advantages and disadvantages of conventional BP*

Limitations	Gadolinia	Erbia	IFBA	WABA
Affect on Fuel Performance	• Displaces fuel • Reduces thermal conductivity	• Displaces fuel • Reduces thermal conductivity (if >2w/o)	• Increases rod internal pressure	• None • Limited to GT without control rod
Residual Reactivity Penalty	• High	• High (if >2w/o) • Moderate	• Negligible	• Low
MTC Control	• Good	• Very Good	• Good	• Good
Reactivity Control	• Strong local	• Dispersed	• Dispersed	• Strong local
Power Peaking	• High	• Low	• Low	• High

* S. Jeffrey R and B. Jeffery A, "Westinghouse PWR Burnable Absorber Evolution and Usage," 2010.

Motivation

□ Previous Studies

- Many studies suggested different solutions In order to overcome the disadvantages of the conventional BP:
  - To use single isotopes (1),
  - To use UO_2-$^{157}Gd_2O_3$ rod covered with a thin layer of $Zr^{167}Er_2$ (2),
  - To use small concentration of Er_2O_3 with all fuel rods (3),
  - To use BigT absorber (4),
  - To use SLOBA absorber (5),
  - To use $AlGdO_3$-UO_2 (6),
  - To use the combination of two different conventional BP in the same FA (7-10).

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(4) H. Yu, M.-S. Yahya, Y. Kim, A Reduced-Boron OPR1000 Core Based on the BigT Burnable Absorber, Nuclear Engineering and Technology (2016).
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(7)] Jeffery A. Brown, Ho Q. Lam, Hybrid IFBA Gad Assembly Designs for Long PWR Cycles, in: 2017 Water Reactor Fuel Performance Meeting, Ramada Plaza Jeju, Jeju Island, Korea, Sep. 10-14, 2017.
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(10) MinJae Lee, Aiman Dandi, Myung Hyun Kim, Soon Ki Kim, Sang Rin Shon, The Combinational Use of Burnable Poison Pins for 24 Months Cycle PWR, in: 2018 Transactions of the American Nuclear Society Summer Meeting, Philadelphia, Pennsylvania, USA, June 17–21, (2018).

Motivation

□ This Study

- An attempt was done to invent a new BP design with good properties.

2 Reference Design Model

Reference Design Model

□ Design Tools

- DeCART2D code was used to perform assembly calculations.

□ Note:

- In this study the concentration is on the performance and characteristics of the new BP design.
- Therefore, core calculation is beyond the scope of the study.

□ Reference Design

- 17×17 WH type.

□ Design Modification

- Only the fuel enrichment was increased > 5w/o (6.96w/o) in order to simulate longer cycle operation.

Reference Fuel Assembly Design Parameters

- This table and Fig.1 show the WH Fuel Assembly Design Parameters.

Design Parameter	WH
Fuel Rod Array	17×17
Number of Fuel Rods	264
Active Fuel Length	365.76
Number of Guide Tube	24
Number of Instrumentation tube	1
Fuel Assembly Length (cm)	406.3
Fuel Assembly Pitch (cm)	21.5040
Fuel Rod Length (cm)	388.1
Cell Pitch (cm)	1.260
Fuel Diameter (cm)	0.8192
Cladding material	ZIRLO
Cladding I.D. (cm)	0.8357
Cladding O.D. (cm)	0.95
Guide Tube material	ZIRLO
Guide Tube I.D. (cm)	1.008
Guide Tube O.D. (cm)	1.224

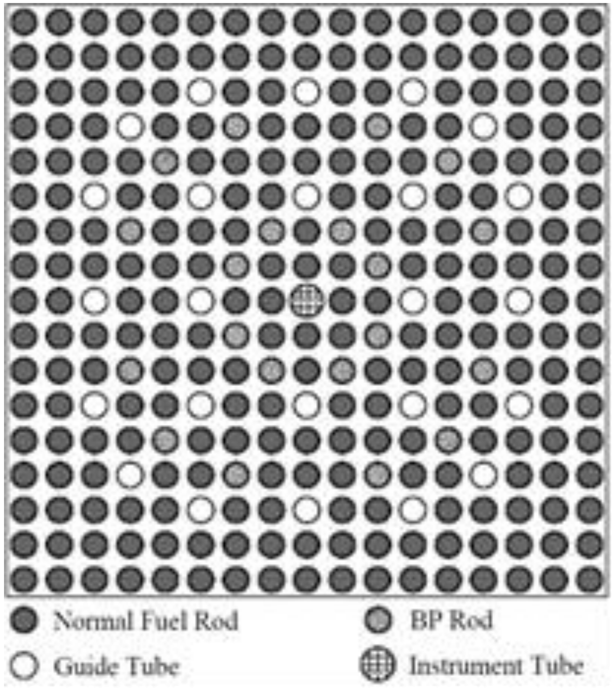


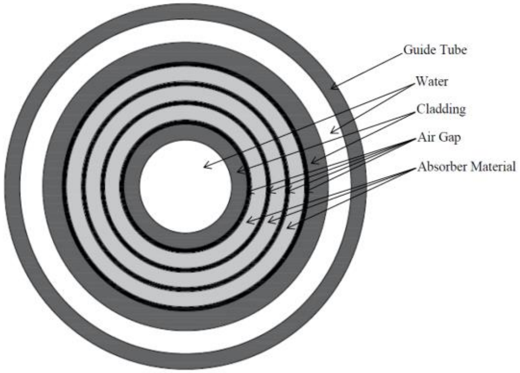
Fig. 1. WH fuel assembly type

3 New Design Concept of BP

The Story Behind The Design

- Each BP has its own advantages and disadvantages.
- Previous studies suggested to combine two or three different BP types to optimize their performance.
- In this study different absorber materials combined together in the same discrete BP pin.
- The easiest method is to make different tubes inside each other.

- Matryoshka Doll Burnable Poison (MDBP) came to exists.



Matryoshka Doll Burnable Poison (MDBP)

□ **Note:**

- MDBP can consist more than two tubes.
- Any absorber material with any concentration can be used.

- In this study MDBP consists of two tubes (Al_2O_3-B_4C & ZIRLO+40%Er_2O_3) inside each other and covered with clad as shown in Fig.3.
- MDBP is installed in GT.

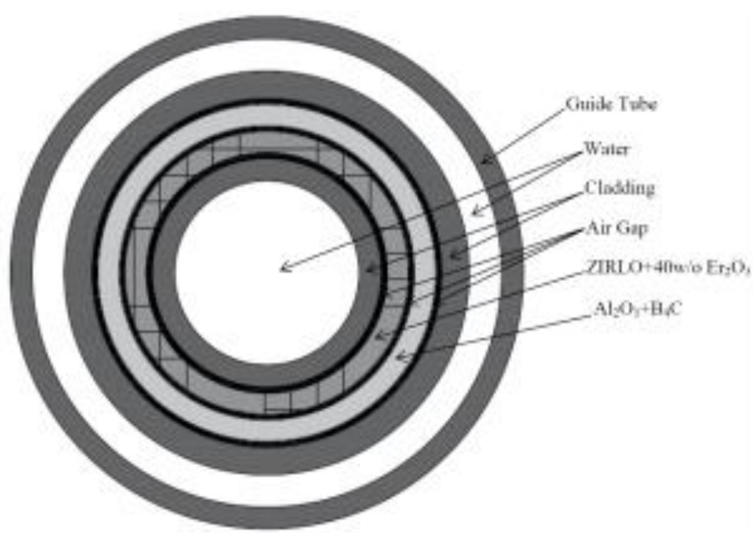


Fig. 3. Conceptual MDBP design

MDBP Advantages

□ Manufacturing Advantages

- Easy to manufacture,
- A radiological regulated facility is not required to manufacture it,
- At refueling time MDBP can be removed from the fuel assembly,

□ Performance Advantages

- Flexible to optimize,
- The neutron flux can reach the absorber material from inside and outside,
- Strong effect to hold-down the initial excess reactivity. (Less # is required than WABA)
- More negative MTC value due to Er.

4 Calculation Results

Study Cases Design Parameters

- This table shows the Design Parameters of MDBP and conventional BP

Design Parameter	MDBP	WABA	IFBA	Gadolinia	Erbia
# of BP pins in FA	24	24	96	24	96
Absorber Material	1) Nat.B 2) Er	Nat. B	Nat. B	Gd	Er
Concentration	1) 10.96w/o 2) 40w/o	10.96w/o	19.15w/o	8.0w/o	2.0w/o
Fuel enrichment	-	-	-	2.5w/o	6.96w/o

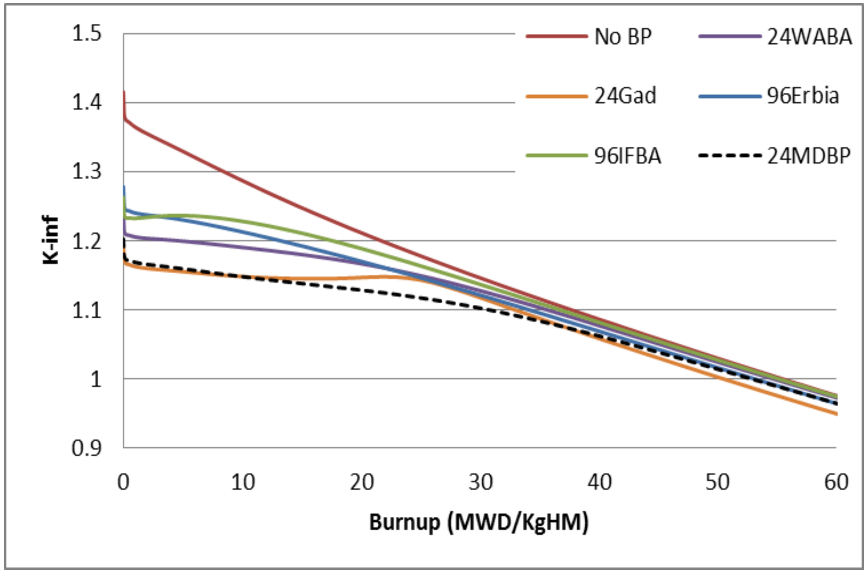
*Normal fuel enrichment = 6.96w/o

- MDBP is compared with the conventional BPs in terms of k-infinite, Peaking Factor and MTC.

k-infinite

□ At BOL

- MDBP and Gad have the highest ability to hold-down the initial excess reactivity by 12,500pcm.
  - ➢ Due to the larger amount of BP in MDBP.



□ At MOL

- Only MDBP can hold-down the excess reactivity effectively.
  - ➢ Due to the slow depletion of Er in MDBP.

□ At EOL

- MDBP and Erbia have almost the same residual reactivity penalty about 1,162pcm.
  - ➢ Due to the undestroyed Er daughter isotopes in MDBP.
- It is much lower than Gad (2,800pcm).

Peaking Factor

□ At BOL

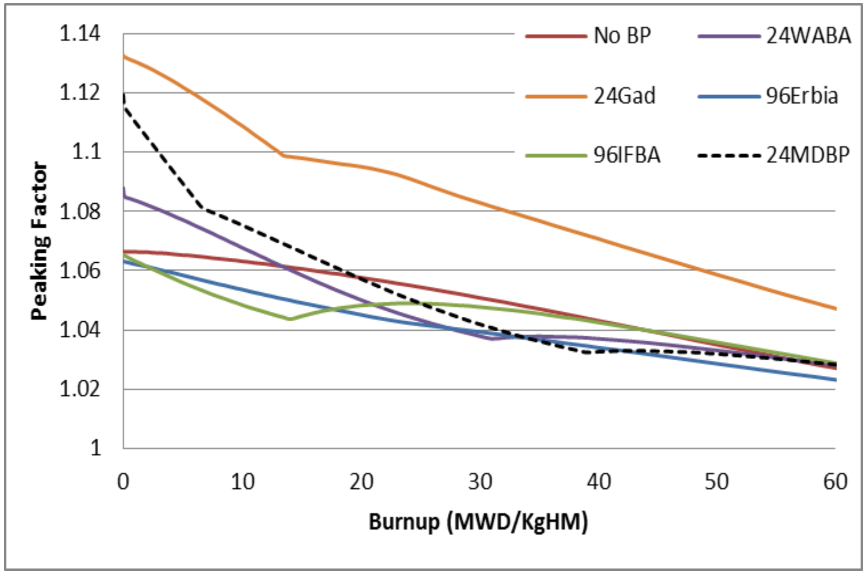
- Even though MDBP and Gad have the same strength to hold-down the initial excess reactivity, MDBP has lower peaking factor.
  - ➢ Due to smaller absorption cross-section of B and Er in MDBP.

□ At MOL & EOL

- Differences of all cases become small except Gad case has peaking factor much higher.

□ Note:

- The peaking factor value no need to be very low, but should be within the design limitations.

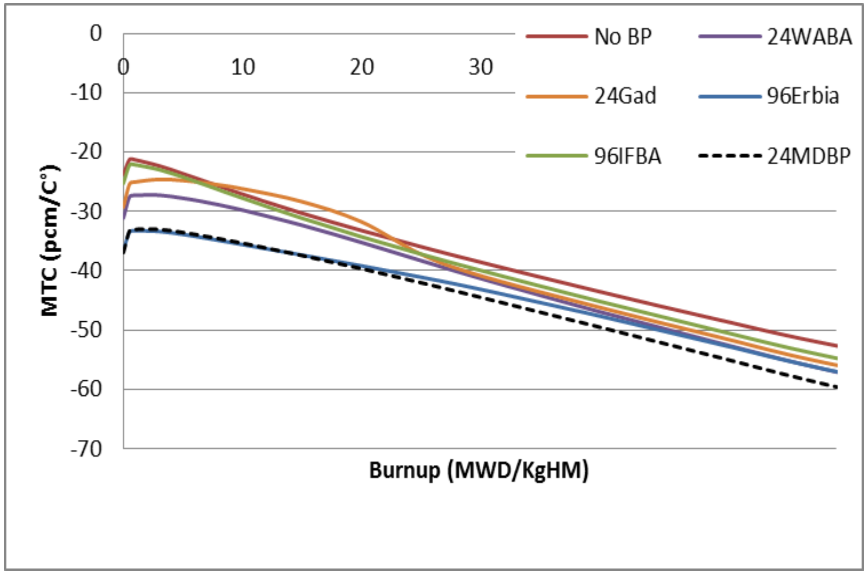


MTC

- MDBP and Erbia have the most negative MTC about -31.07 pcm/C°.
  - Due to the resonant behavior effect of Er in MDBP.
- This means MDBP and Erbia have the highest chance of MTC to be negative at HZP.

□ Note:

- The MTC value no need to be very low, but should be within the design limitations.



5 Conclusions

Conclusions and Future Work

□ Conclusions

- Matryoshka Doll Burnable Poison (MDBP) is firstly introduced in this study.
- MDBP reduces the initial excess reactivity by about 43%.
- MDBP last longer than any other design by about 30%.
- MDBP can be removed from the fuel assembly during the refueling time.
- MDBP guarantees the MTC value as negative as Erbia case.
- Even though any BP designs provide power peaking factor within the design limitation are acceptable, MDBP case has lower power peaking factor than Gad case.

□ Future Work

- More investigation is needed.

Thanks for your attention!