FBR炉心設計における核拡散抵抗性検討
A Consideration on Proliferation Resistance of a FBR Core Design

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GIF PR&PP核拡散抵抗性6指標

指標　Measures (例:「高さ」)

- 技術的困難性
  Technical Difficulty
- 検知確率
  Detection Probability
- 物質タイプ
  Material Type
- 拡散コスト
  Proliferation Cost
- 拡散時間
  Proliferation Time
- 保障措置コスト
  Safeguards Cost

尺度　Metrics (例:「メートル」)

Rev.5報告書中に例示

尺度	抵抗性
HEU	Very Low
WG-Pu	Low
RG-Pu	Medium
DB-Pu	High
LEU	Very High

FBR径方向ブランケットの検討

- FBRブランケット中には高フィッサイルのPuが生成

  One of the PR&PP concerns of FBR is the plutonium with a relatively higher Pu-239 isotope fraction generated in the UO_2 blanket surrounding the fast reactor core

- 径方向ブランケットに関し、3つの仮想的炉心概念について検討

  Three hypothetical reactor core concepts were defined, focused on radial blankets.

- 各炉心概念について複数の核物質タイプ（MT)で評価

  Three metrics of material attractiveness were estimated for each core concept.

N. Inoue, et. al., Proc. of 51st INMM, Baltimore, 2010

対象とした核物質タイプ尺度

- ペローの物質区分　Plutonium classification in Pellaud's article
  - 「より効率的効果的な保障措置のためには、Puについてもいくつかに分類した方が良い」

    "For the purpose of more effective and efficient safeguards by adopting of several categories of plutonium"
  - 「伝統的に、Pu混合物の核爆発装置への適用性は含まれるPu-240量によって決まる、と言われている」

    Traditionally, the suitability of a plutonium mixture for explosive devices is determined by its Pu-240 content
  - 原子炉級Pu **(>18% Pu-240)**-現在のLWP使用済燃料と同じレベル

    Rector-grade plutonium **(>18% Pu-240)** – the same level of the current LWR spent fuel

B. Pellaud, J. Nuclear Material Management, Vol. XXXI, No.1, Fall (2002)

対象とした核物質タイプ尺度

- ケスラーのクライテリア　Kessler's criterion
  - 「原子炉級PuのPu-238含有量と発熱量は（核拡散抵抗性の）キーパラメータである。」

    "the content of Pu-238 and the heat it generates in reactor-grade Pu is the key (proliferation resistance) parameter"
  - 「核兵器国でも9%以上のPu-238を含む原子炉級Puを用いて高性能HNEDを開発することは実現不可能。9%(Pu-238)という値は非核兵器国にとっては極めて保守的な値。」

    "high-technology HNEDs of NWSs would be unfeasible technically with reactor-grade plutonium containing more than approximately **9% (Pu-238)**" – extremely conservative value for non-NWS

HNED: Hypothetical Nuclear Explosion Device
（仮想的な核爆発装置）
NWS: Nuclear Weapon State(核兵器国）

G. Kessler, et. al., Nuclear Eng. And Design, 238(2008) 3429-3444

対象とした核物質タイプ尺度

- Bathke's の魅力度　attractiveness level (Figure of Merit: FOM)
  - 「魅力度」概念はもともと米国DOEの"graded (domestic) safeguards table"に用いられているもの

    The concept of "attractiveness level" is originally for "graded (domestic) safeguards table" of US-DOE

$$FOM_1 = 1 - \log_{10}\left[\frac{M}{800} + \frac{Mh}{4500} + \frac{M}{50}\left(\frac{D}{500}\right)^{1/\log_{10} 2}\right]$$

$$FOM_2 = 1 - \log_{10}\left[\frac{M}{800} + \frac{Mh}{4500} + \frac{MS}{6.8\times10^{6}} + \frac{M}{50}\left(\frac{D}{500}\right)^{1/\log_{10} 2}\right]$$

    - M: Bare critical mass of the metal in (kg), h: heat content (W/kg), D: dose rate of 0.2·M evaluated at 1m from the surface (rad/h), S: spontaneous-fission neutron production rate (n/s/kg)

- **FOM<1であればその物質は核爆発装置に使用するには非魅力的**

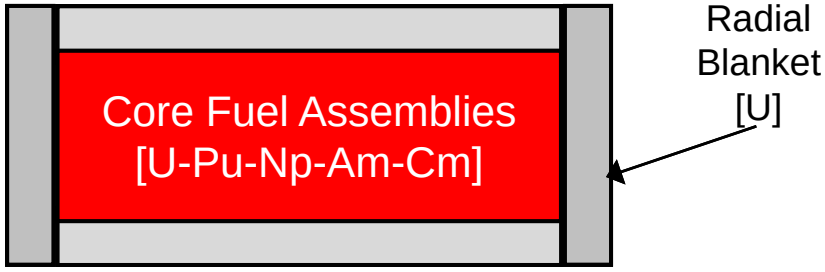
When **FOM<1**, the material is unattractive for use in nuclear devices

C.G. Bathke, et. al., Proc. of Global 2009, Paris, France, September 6-44, 2009

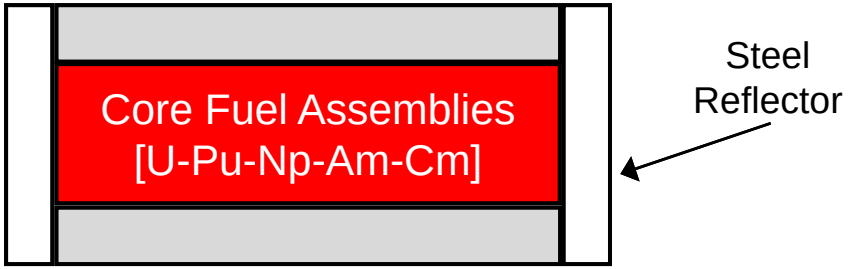
仮想的な炉心概念

For Transition Period: Breeding Ratio = 1.1

Case-0: Reference Core

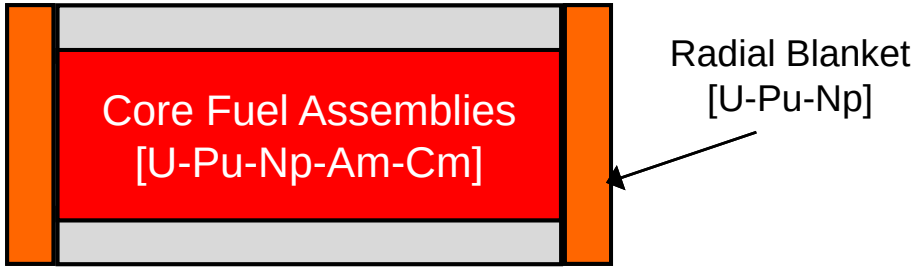


Case-1: Radial Blanket-Free Core



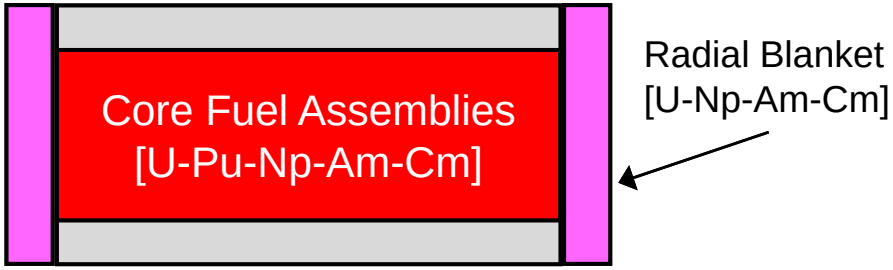
Case-2: MOX Blanket

- Blanket doped with low-fissile Pu



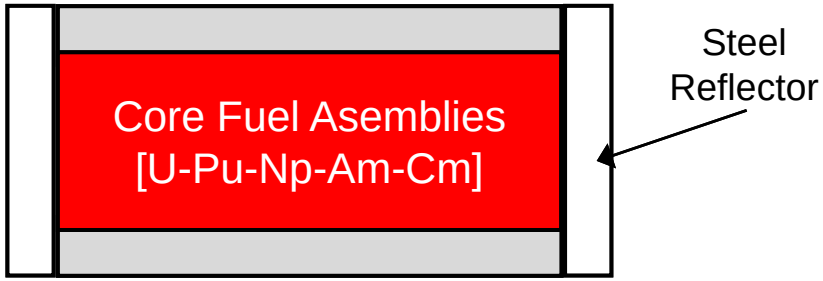
Case-3:Blanket with Minor Actinide (MA)

(Required MA to be provided from LWR)



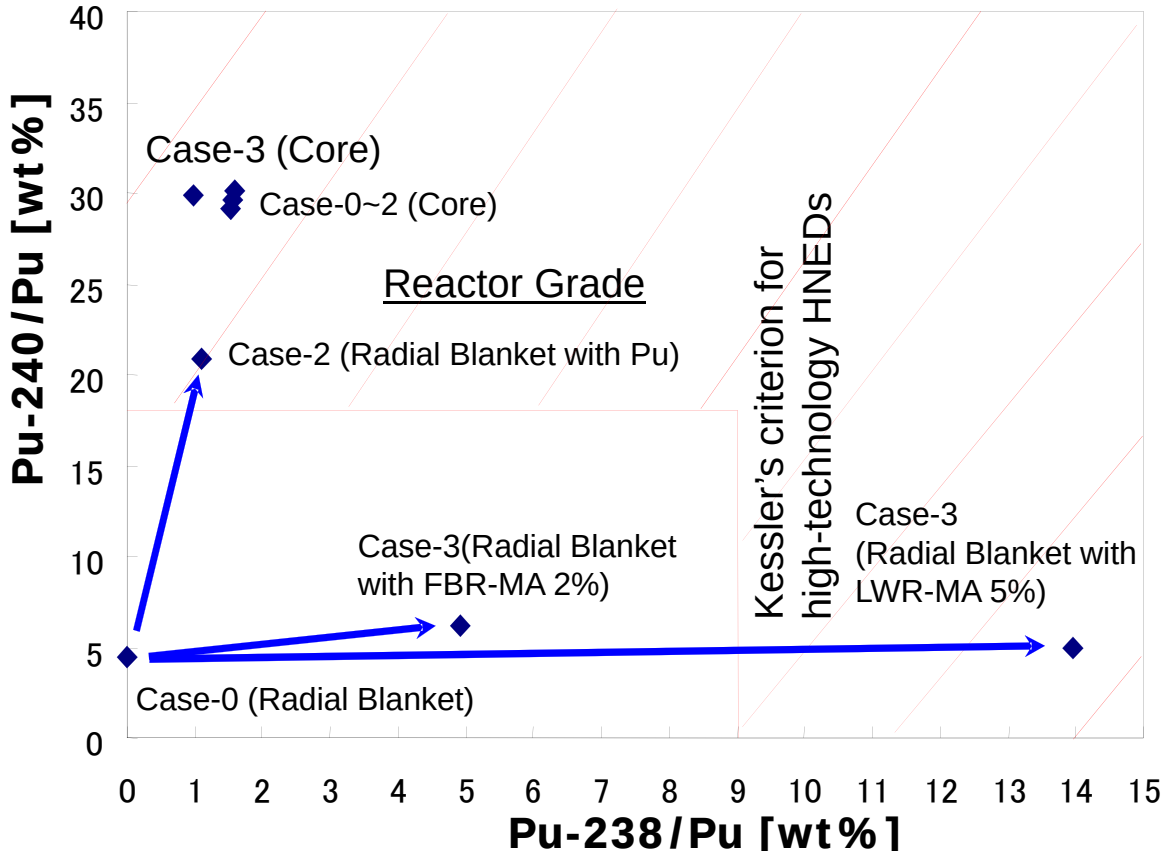
For Equilibrium Period: Breeding Ratio = 1.03

Common with all Cases :Without Blanket



N. Inoue, et. al., Proc. of 51st INMM, Baltimore, 2010

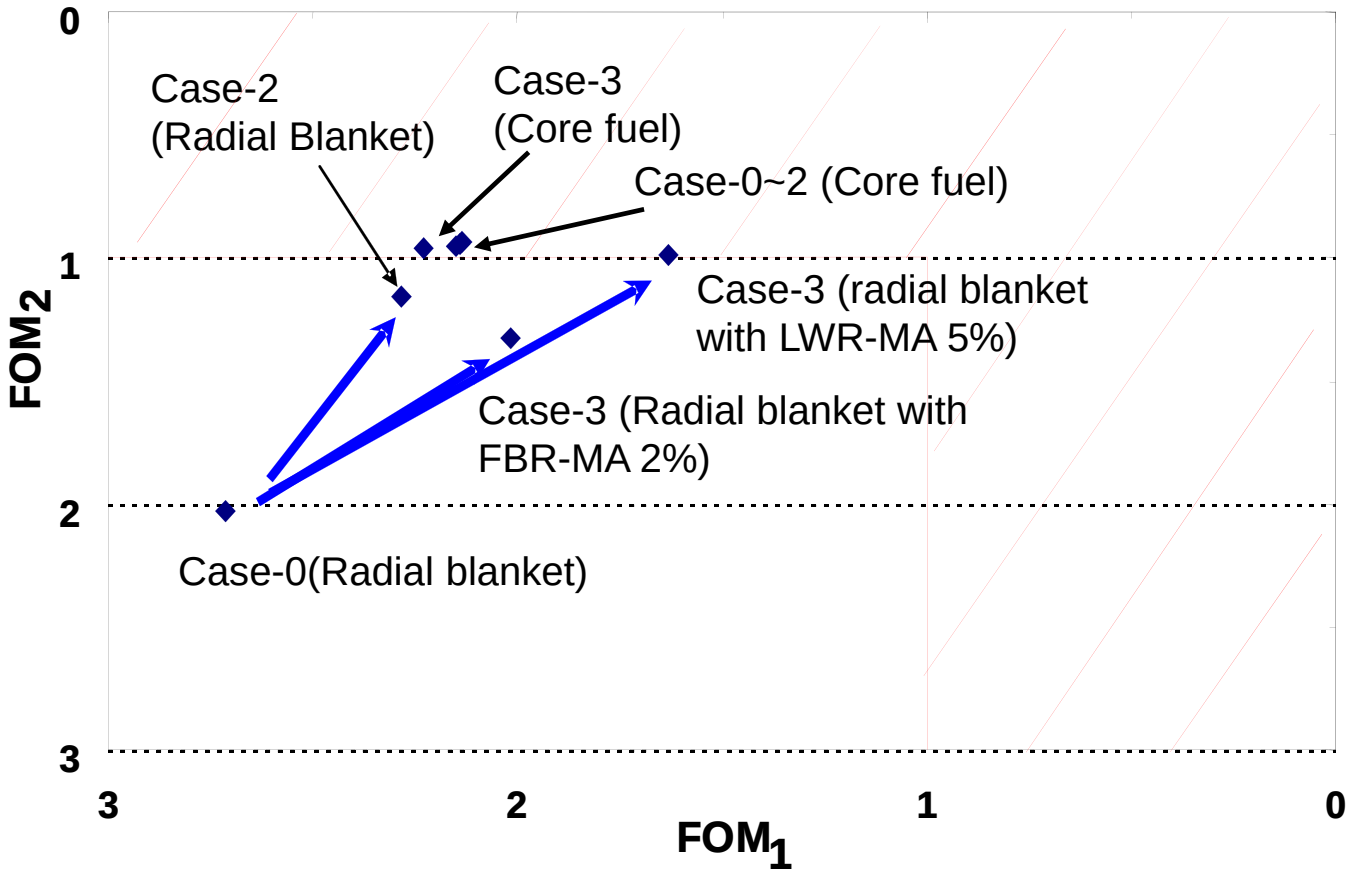
Evaluation of Hypothetical Core Concepts – Pellaud & Kessler (1/2)



- All the core concepts decrease the attractiveness
- Radial blanket of Case-2 is classified RG-Pu (Pellaud's)
- Radial Blanket of Case-3 could meet Kessler's Criteria with high content of MA

N. Inoue, et. al., Proc. of 51st INMM, Baltimore, 2010

Evaluation of Hypothetical Core Concepts - Bathke's FOM (2/2)



- All the core concepts considerably decrease the attractiveness
- Some cases could barely meet FOM2
- FOM1 cannot be met in any case

N. Inoue, et. al., Proc. of 51st INMM, Baltimore, 2010

得られた知見

- いずれの尺度も魅力度の低減が表現できている

  Each metric can express the decrease of attractiveness.

- BathkeのFOM1<1はSFR炉心では満足しない

  Bathke's FOM1<1 cannot be met by the sodium fast reactor case.

- 重要なのはこれら尺度を「どう使うか？」ということ。

  How to use those metrics is a challenge.

- 物質タイプ(MT)は6指標の1つにすぎないということを核拡散抵抗性を検討する時には念頭に置くべき。

  Material type is just one of six PR measures that should be considered in a proliferation resistance plan.

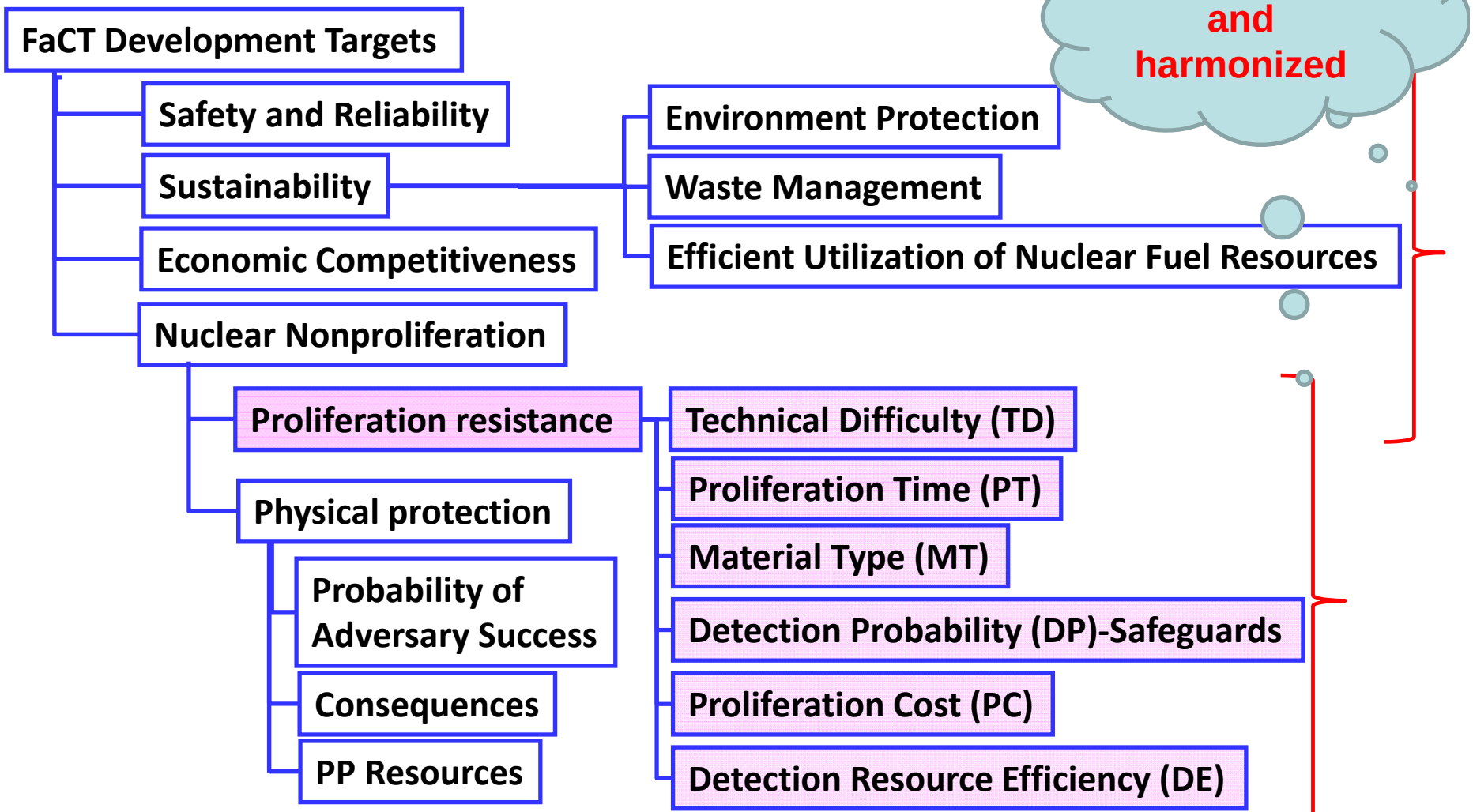
- 他のPR指標や開発目標とどうバランスを取るのかを今後追及すべき

  How to balance material attractiveness with other PR measures, and with other development targets, should be pursued as a further study.

- PR評価手法がその答えを提供できることを期待

  PR evaluation methodology is expected to provide some answers.

FaCT開発目標とPR＆PP指標



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