LOGISTICS

# Impact of Higher Burnups on the Transportation Package Design: Radiation Shielding Perspective

**Presented by Dr. Jayant Bondre**
**for Prakash Narayanan**

# Agenda

- Introduction
- Effect of High Burnup Fuel on Transportation Package Design
- Shielding Design Optimization for High Burnup Fuel
- Conclusions

# Introduction

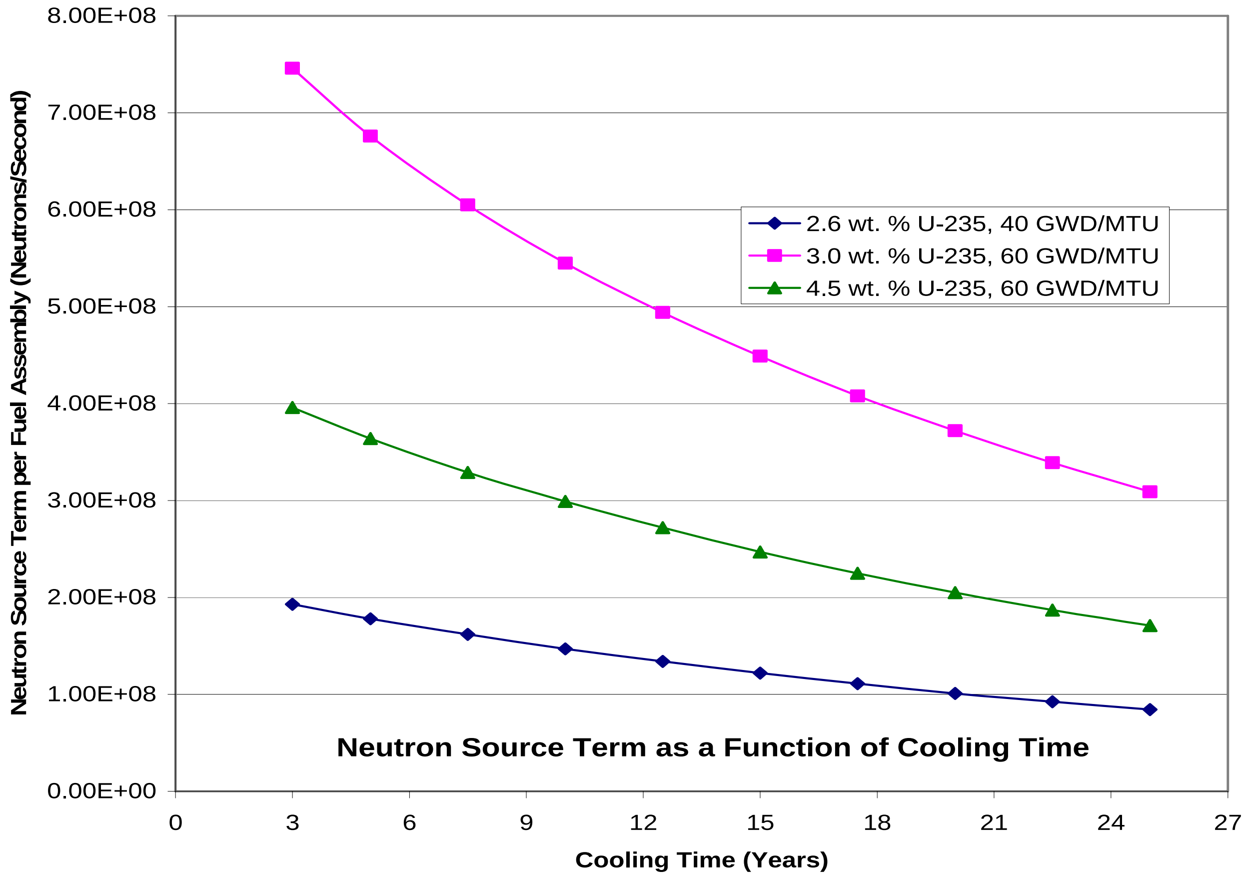
- **Due to improvements in fuel design and in-core fuel management, the discharge burnups of fuel assemblies have been steadily increasing**
- **High burnup typically refers to fuel assemblies with discharge burnup greater than 45 GWD/MTU**
- **Currently discharge burnups are typically in the 55 to 60 GWD/MTU range but some of them can be as high as 70 GWD/MTU**

# Management of High Burnup Fuel

- **Management of high burnup fuel is accomplished considering the following options:**
  - **Wet storage in spent fuel pool**
  - **Use intermediate dry storage in a dual purpose system at site**
  - **Transport this fuel to an interim storage facility**
  - **Transport this fuel to a reprocessing facility or to a disposal site**

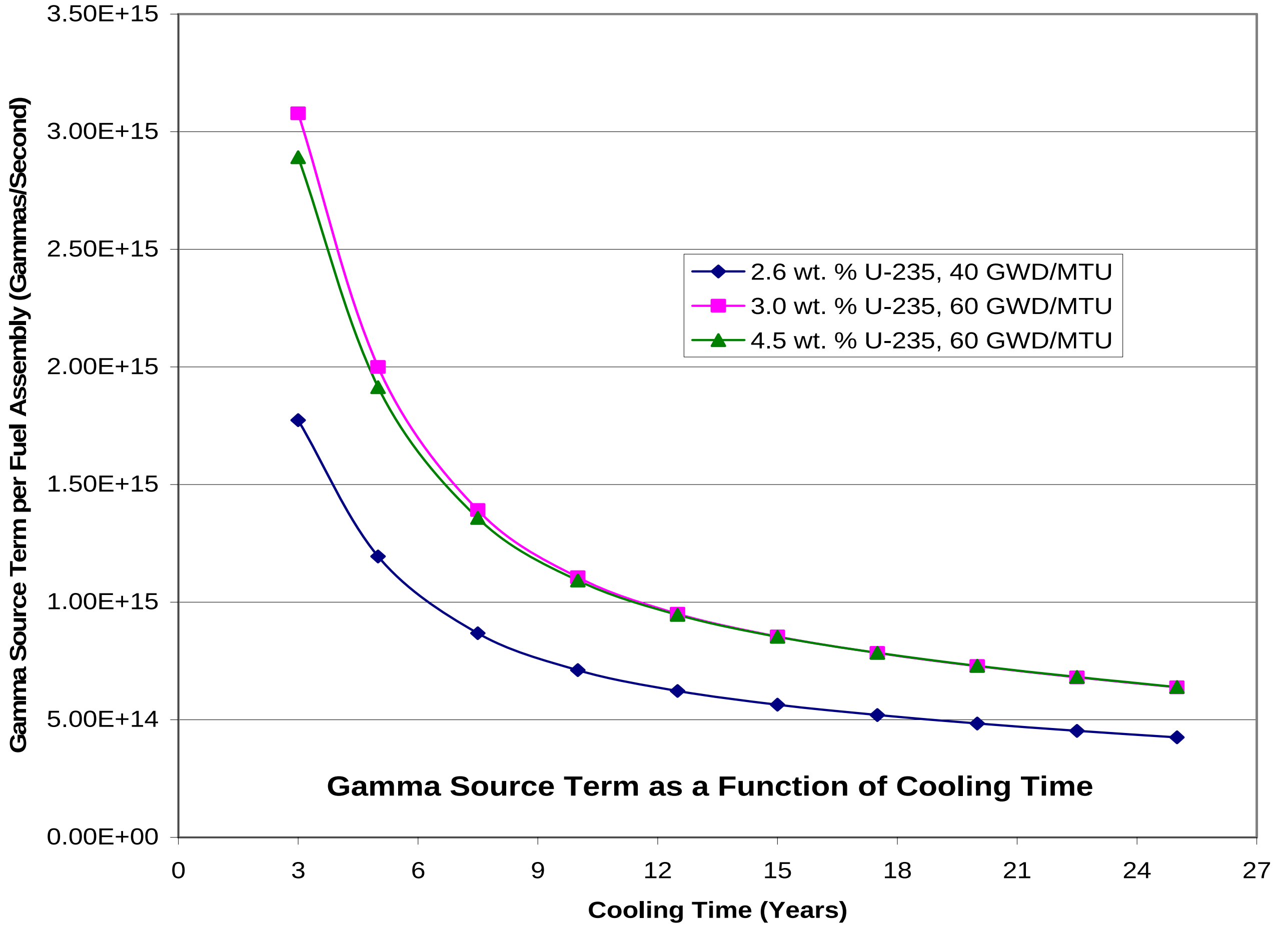
# Transportation Package Design for High Burnup Fuel: Neutron Source Terms

- **For same burnups, the neutron source terms increases with lower initial U-235 enrichment**
- **No rapid reduction over the storage period since the half-life is of the order of 20 years**



# Transportation Package Design for High Burnup Fuel: Gamma Source Terms

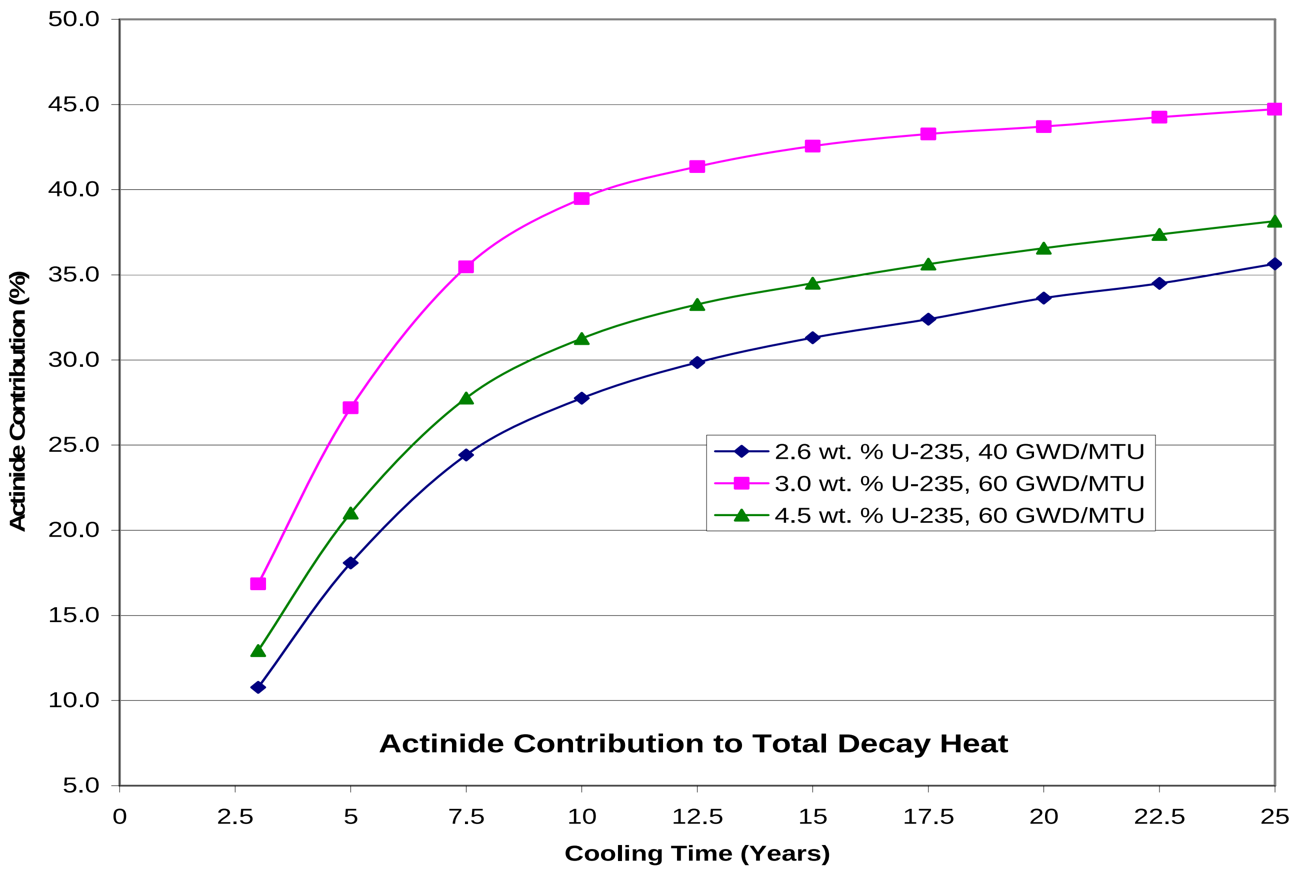
- **Gamma is not a strong function of initial U-235 enrichment, but burnups only**
- **However it undergoes a rapid reduction over the initial storage period**




LOGISTICS

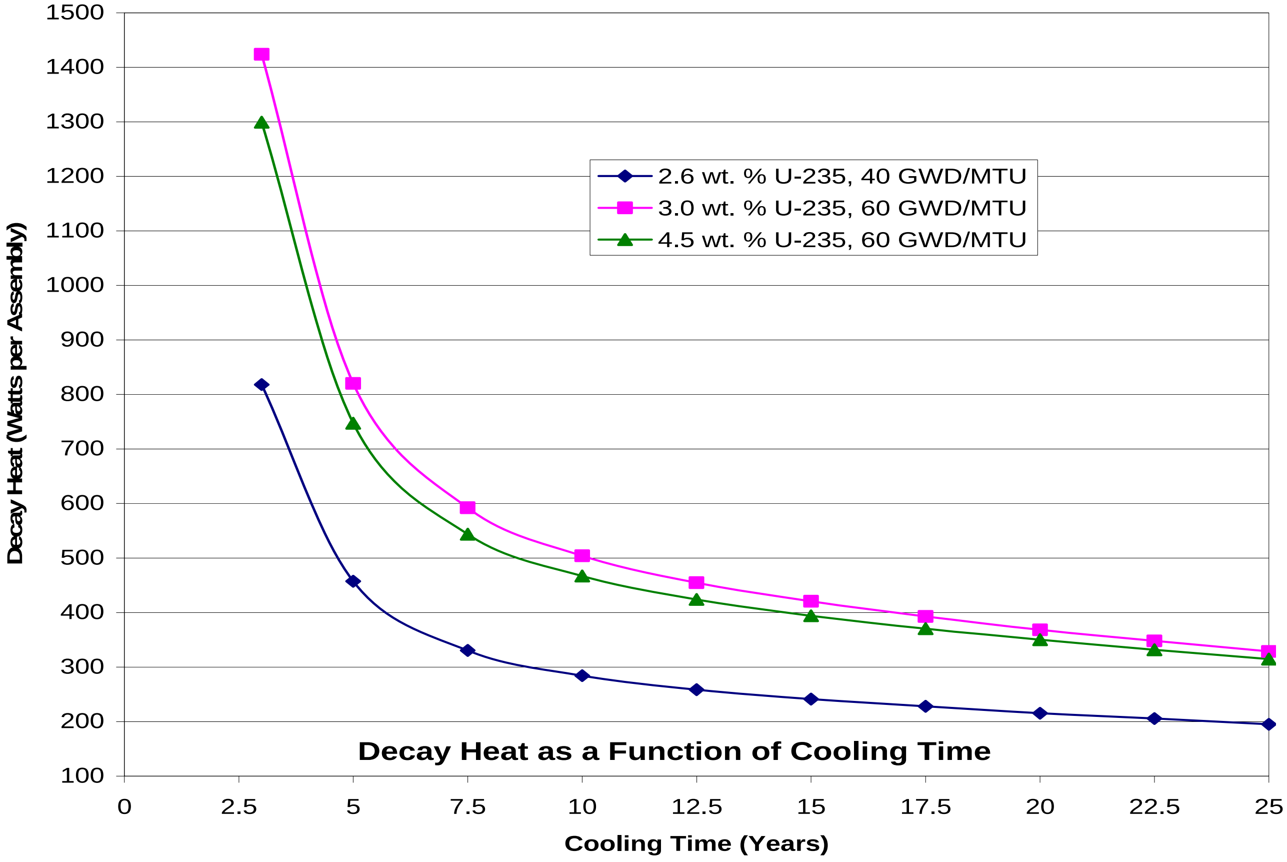
# Transportation Package Design for High Burnup Fuel: Actinide Contribution to Total Decay Heat

- **Actinides + fission products = total decay heat**
- **Actinides contribution same as Neutrons (enrichment and burnups)**
- **FP contribution same as gamma (burnup)**



# Transportation Package Design for High Burnup Fuel: Total Decay Heat

- **Total decay heat undergoes rapid decay initially during the storage period**



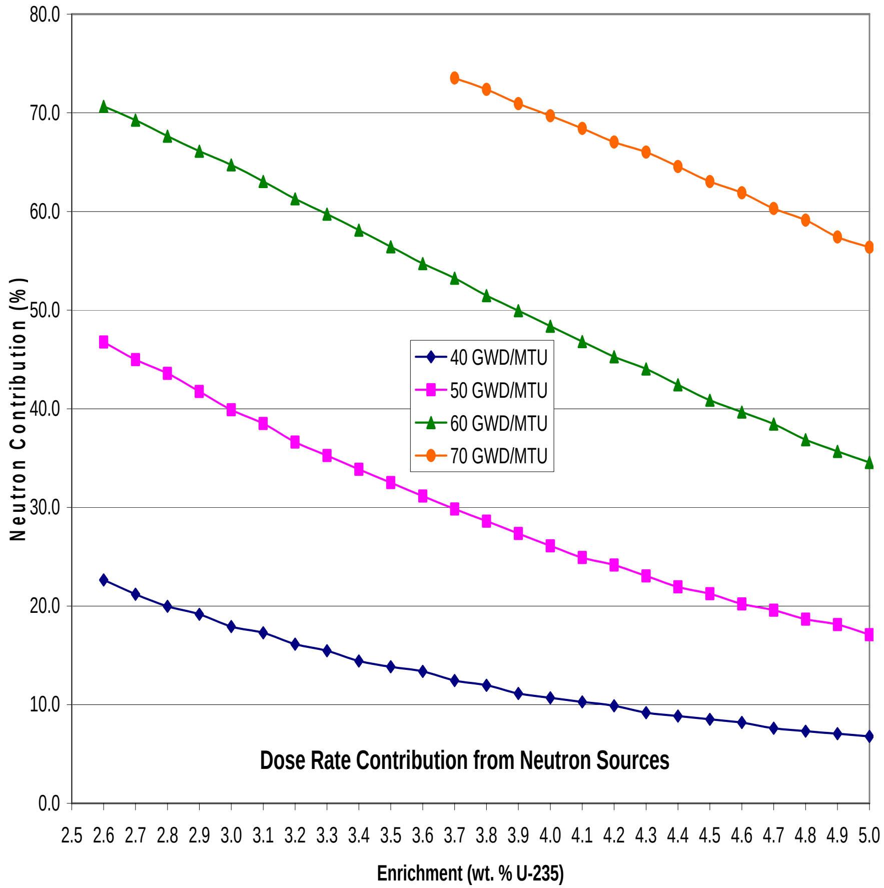
# Effect on Package Designs due to Neutron and Gamma Dose Rates

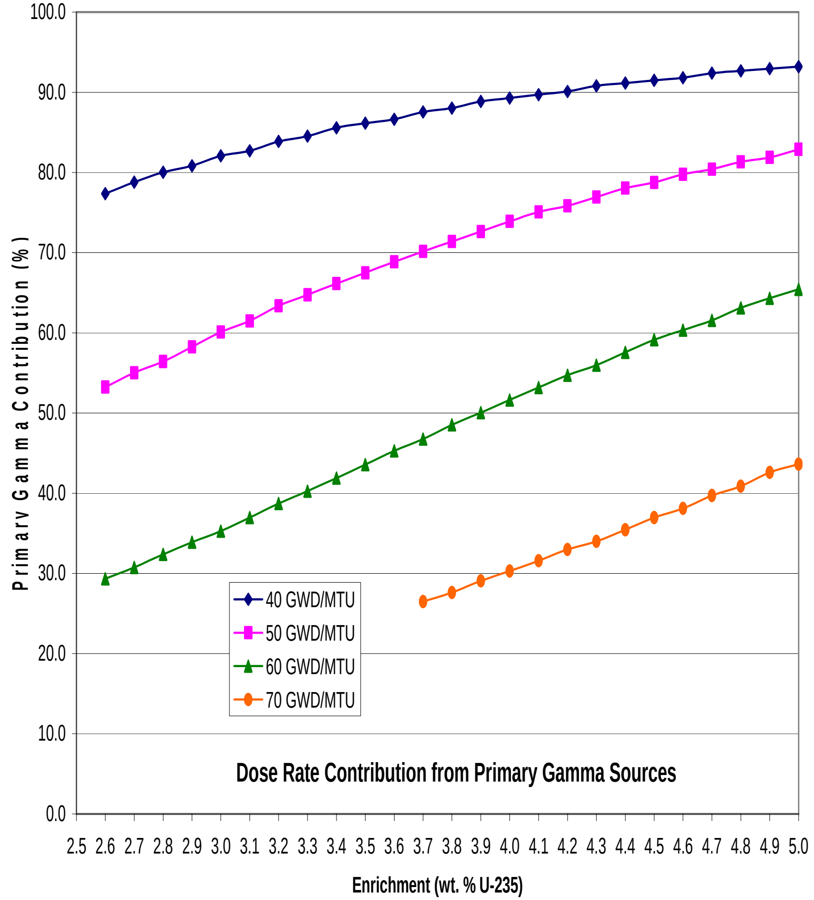
- **The transportation packages that were initially designed for low burnup fuel assemblies (Burnps <45 GWD/MTU) typically did not require a significant amount of neutron shielding**
- **The significant shielding requirements were for gamma source terms as they controlled the total dose rate from the package**
- **For the high burnup fuel assemblies, the relative contribution of the neutron dose rate to the total dose rate from the package is significantly higher due to significant increase in the neutron source terms, resulting in a need for more neutron shielding material for the transportation package**

# Fuel Qualification and Limiting Dose Rates

- **Fuel qualification evaluations are performed to determine acceptable combinations of burnup, enrichment and cooling time (BECT) to ensure that the used fuel assemblies are eligible for transport**
- **In order to qualify the fuel assemblies for transport under the requirements of 10CFR71 for normal conditions of transport, *the dose rate at 2 meters shall be less than 2 mrem/hr* from the transport package**
- **Additional dose rate limits under 10CFR71 typically do not control the package design**
- **A typical example is illustrated in the next few slides**

**The gamma dose rates are dominant (greater than 75% of the total) at lower burnups while the neutron dose rates are dominant at higher burnups, particularly at high burnup, low enrichment combinations**



# Shielding Design Optimization for High Burnup

- **The Transportation Package design for fuel with higher burnups is truly an optimization problem that balances shielding material design, fuel qualification and total package weight (material mass limit)**
- **The shielding material design is dependent on the material mass limits associated with the transportation package and its used fuel payload**
- **Depending on the available material mass limits, the mass of neutron and gamma shielding can be adjusted to obtain the optimum material design**
- **The use of more advanced neutron shielding materials that offer more effective gamma shielding improves the overall shielding effectiveness**

# Conclusions

- **The principal design considerations from a shielding standpoint for the transportation of high burnup used fuel assemblies is in the form of higher neutron source terms**
- **Due to the relatively slower reduction in these source terms as a function of cooling time, it is necessary to optimize the shielding material thicknesses to enhance the neutron shielding capabilities**
- **Depending on the decay heat removal capabilities of the cask system, fuel qualification can also include zone loading to improve the effectiveness of the gamma shielding within the fuel basket**