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HI-STAR 180 - Criticality Safety

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A Presentation to the SFST

by

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Criticality Safety

- Neutron Absorbing Basket Material
- Two Basket Designs
- MOX Assemblies
- High Bunup Fuel / Moderator Exclusion
- Results Summary - Maximum k_{eff}
- Burnup Credit / Misloading / Burnup Verification

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Neutron Absorbing Basket Material

	Metamic Classic	**Metamic-HT**
B4C Content	31 wt%	10 wt%
Thickness	0.1 Inch	0.6 Inch
B-10 Loading	0.03 g/cm2	0.06 g/cm2
Configuration	Four panels, one on each side of basket cell	All around assembly

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Neutron Absorbing Basket Material

- Higher B-10 loading in Metamic-HT
- Assemblies completely enclosed
- Overall increased neutron absorption

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Two Basket Designs

- Main reason for having two basket designs is to provide loading capacity options for different assembly characteristics (burnup, cooling time, heat load)
- Both baskets contain flux traps between some but not all assemblies
- F-32
  - Larger and more flux traps
  - All assemblies fresh, 5 wt% UO2
- F-37
  - Smaller and fewer flux traps
  - Some assemblies fresh, 5 wt% UO2
  - Some assemblies burned

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MOX Assemblies

- Bounded by 5 wt% fresh UO2 fuel
- No burnup credit for MOX
- No major concern in criticality evaluations (in comparison to shielding and thermal analyses)

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High Burnup Fuel / Moderator Exclusion

- Design Basis
  - No moderator intrusion under accident condition
  - Cask internally dry
  - Any potential re-configuration of high burnup fuel is inconsequential
- Defense-in-depth
  - Calculations are performed with internally flooded cask, and possible fuel reconfiguration scenarios
  - Effect of those scenarios on the maximum k_{eff} is negligible

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Results Summary – Maximum k_{eff} values

- F-32
  - Flooded – 0.9429
  - Internally dry - < 0.5
- F-37
  - Flooded – 0.9487
  - Internally dry - < 0.5

Burnup credit

- F-37 basket requires moderate amount of actinide-only burnup credit for UO_2 assemblies
- Maximum burnup requirement 35 GWd/mtU (upper burnup limit of 66 GWd/mtU)
- All assemblies assumed to have initial enrichment of 5 wt%, and 3 years cooling time
- Requirements are identical for all burned assemblies in each loading pattern
- Not all burned assemblies
  - 17 to 29 assemblies burned, depending on loading pattern
  - 8 to 20 can be fresh, depending on configuration, assumed 5 wt% enrichment

Burnup Credit – Burnup Verification

- Concerns
  - Misloading (the incorrect assembly is loaded)
  - Incorrect burnup record (correct assembly is loaded, but it has an actual burnup different from the burnup record)
- Misloading has the potential of larger impact on maximum k_{eff}
- Studies performed for single and multiple assembly misloads.

Misloading Studies

- Reference Case (no misloads): max k_{eff} = 0.9441
- All studies performed keeping all other conservative assumptions (bounding dimensions, flooded clad-to-pellet-gap, 90% of minimum B-10, etc.)
- Single assembly misload
  - Misloaded assembly assumed fresh, 5 wt% enrichment
  - Effect depends on location of misloaded assembly in the loading pattern
  - Best case: Misloaded assembly on basket periphery, surrounded by flux traps: max k_{eff} = 0.9445
  - Worst case: Misloaded assembly facing two other fresh assemblies: max k_{eff} = 0.9573

Misloading Studies

- Multiple (all) assemblies misloaded
  - 17 misloaded assemblies, all once burned (12 GWd/mtU), together with 20 correctly loaded fresh assemblies: max k_{eff} = 0.9875
  - All 37 assemblies fresh: max k_{eff} = 1.0070

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Burnup Verification

- Reliance on Burnup Credit is comparatively low
  - Highly effective neutron absorbers
  - Some fluxtraps
  - Low burnup requirement, compared to maximum burnup
- Credible misloading conditions
  - Will leave margin to critical condition
  - Single assembly misload most likely below 0.95
  - Basket fully loaded with fresh assemblies not considered credible
- Consequently
  - Burnup measurement not considered necessary
  - Visual inspection are to be performed to ensure no fresh assemblies are loaded where burned assemblies are required (This will ensure that even the non-credible condition can not occur).
  - Direct use of plant records to show burnup requirements are met is considered sufficient.
  - However, confirmation of plant operating conditions is required, to ensure plant is operated in a typical manner.