Studies of Past Operations at the High Flux Isotope Reactor

David Chandler

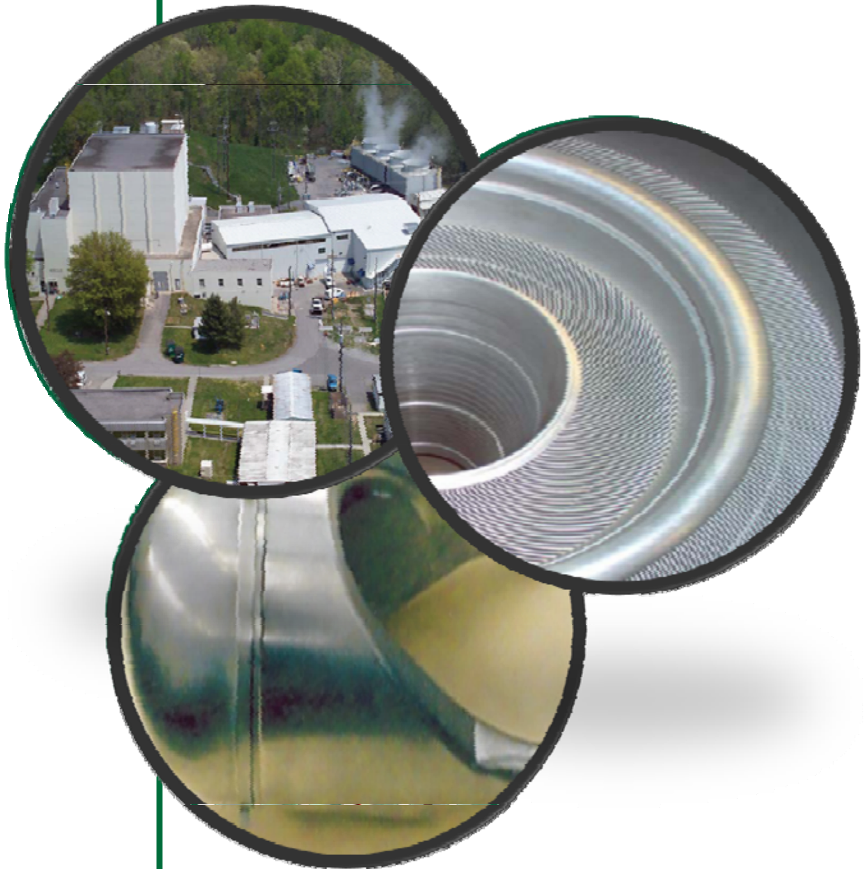
University of Tennessee

Trent Primm

Research Reactors Division/Oak Ridge National Laboratory

Presented by
Trent Primm

Presented at the 2009 Meeting of the
International Group on Research Reactors
Beijing, China
October 28-30, 2009



U.S. DEPARTMENT OF ENERGY

HFIR

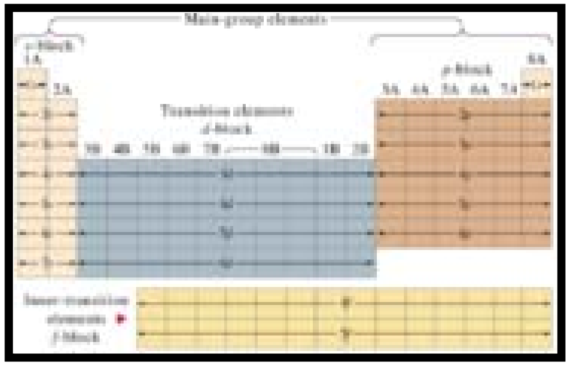
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Two, seemingly simple questions instigated the studies reported here

- HFIR fuel (geometry, materials, ^{235}U content, reflector) are unchanged since reactor full-power startup (1966). Is end-of-life burnup today the same as in 1966?

1966 → ***2009***

- The HFIR core reflector is fabricated from beryllium. Is discharged beryllium transuranic waste?



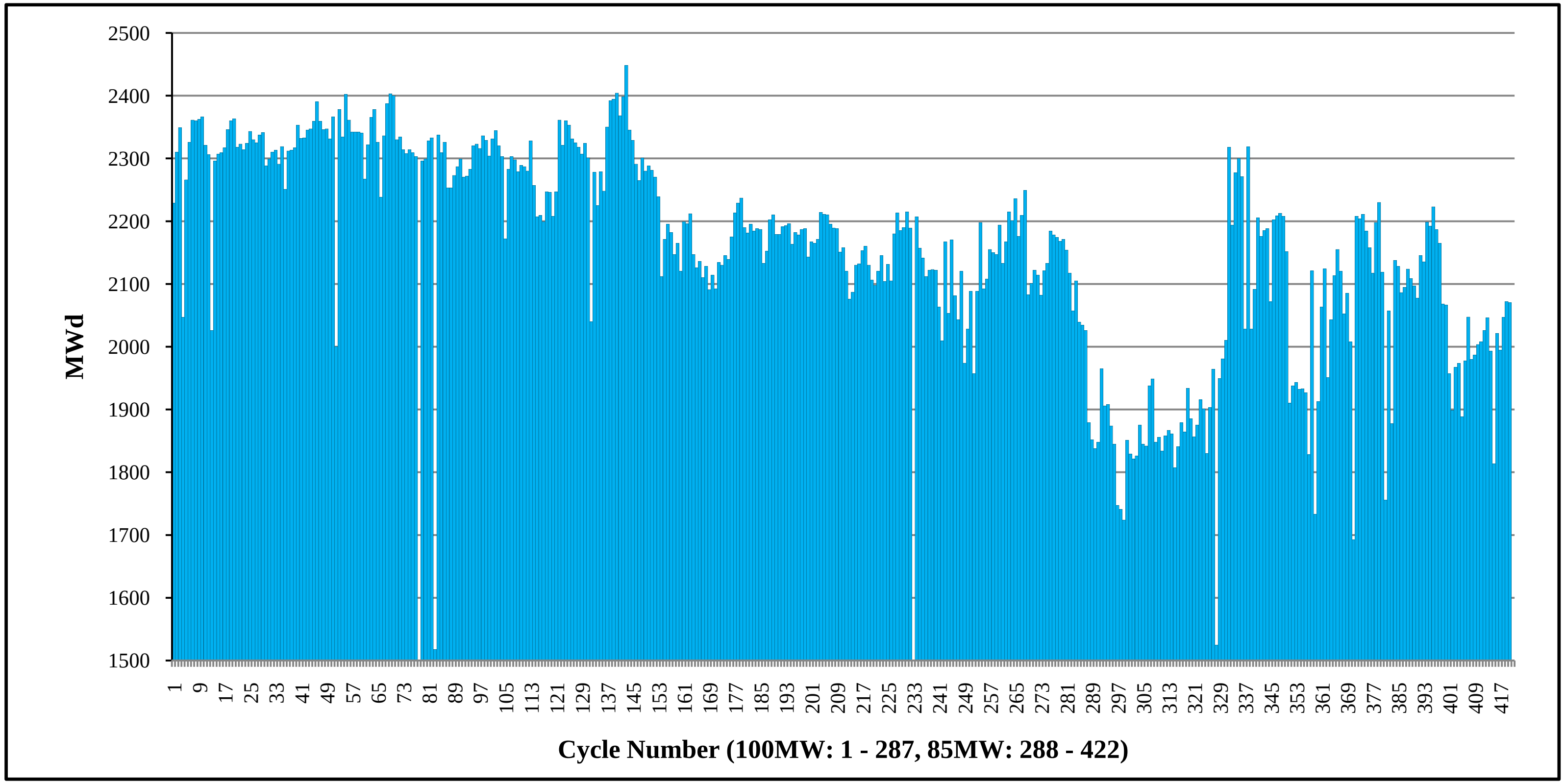
The Reduced Enrichment for Research and Test Reactors (RERTR) Program sponsors studies of conversion of HFIR from HEU to LEU

- Maintaining HFIR flux performance requires LEU-fuelled HFIR to operate at 100 MW (current HEU-fuelled operates at 85 MW)
- Highest recent discharge exposure, 2200 MWD (cycles 389 and 397; 2002 and 2003, respectively), 26 days at 85 MW
- Mission of HFIR is to serve experimenters; must maintain same calendar days per cycle
- 26 days at 100 MWD = 2600 MWD

The principal concern with extending HFIR burnup is the integrity of the fuel clad

- Buildup and spallation of aluminum oxide on the surface of the clad
  - Current methodology (HFIR SAR) does not show strong sensitivity to heat flux over the range considered (85-100 MW)
  - Oxide growth is a function of operating time but spalls at a thickness of 75 microns
- Increase in fission product gas inventory in the fuel relative to current and past irradiation exposure
  - Can address impact by calculation and/or experiment
  - Led authors to investigate all HFIR fuel cycles to find maximum exposure

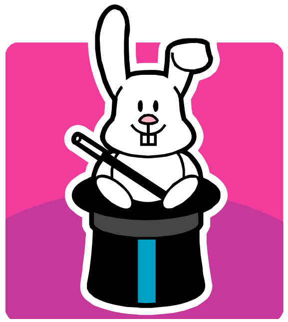
End-of-cycle burnup values were retrieved from summary reports and “end-of-cycle” data packages



Scatter in data due to premature shutdowns due to equipment failure, off-site power loss, etc., changes in experiment loadings in either the central target region or the beryllium reflector, and documentation inconsistencies.

Five cycles achieved burnup values greater than 2400 MWD

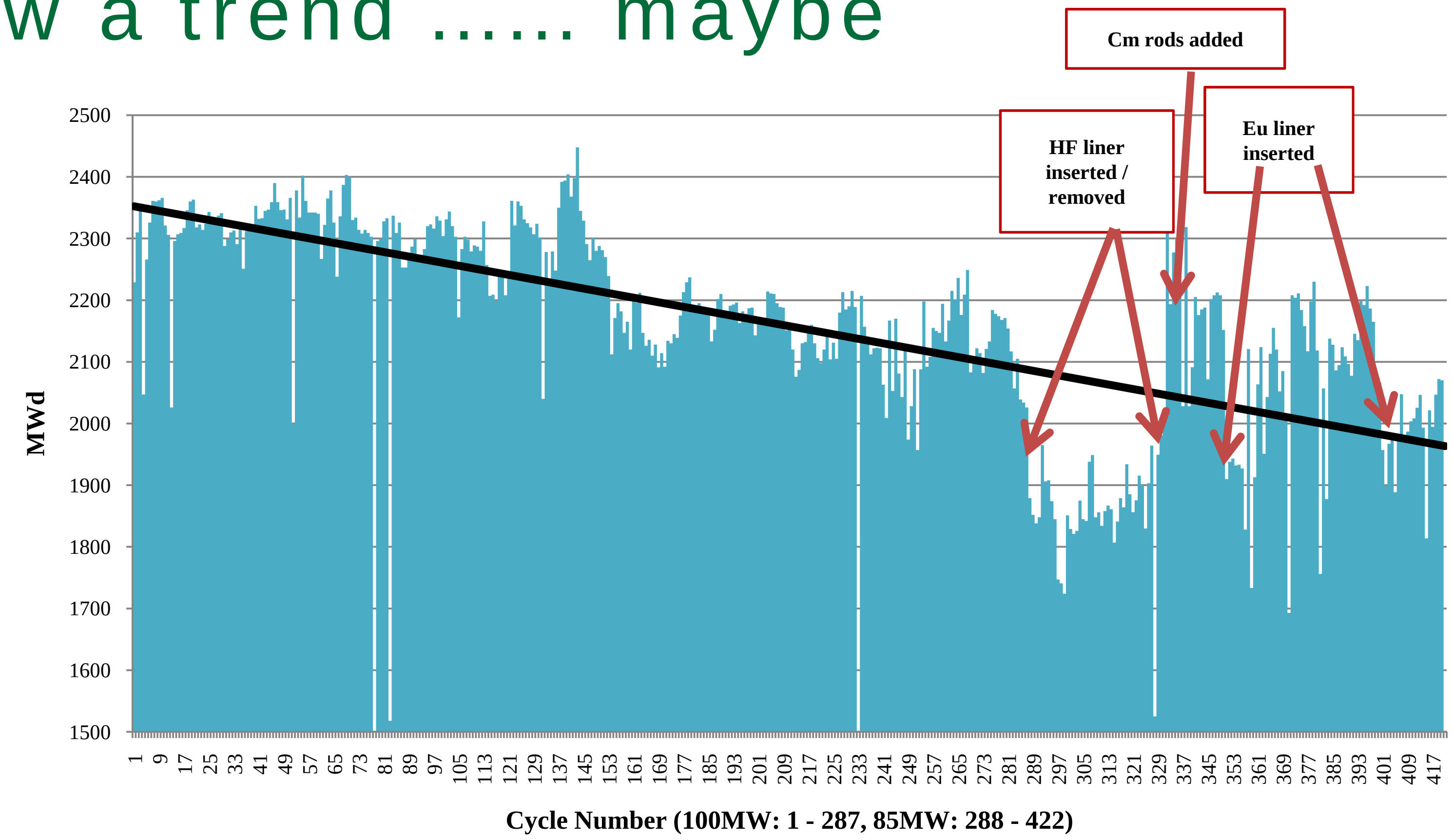
- All prior to decrease in power from 100 MW to 85 MW
- Two of these cycles (cycles 143 – Feb. 1977 and 267 – June 1985) were reported with burnups close to 2450 MWD
  - Documentation inconsistency found; two cores in one cycle – cycle 267; the core from cycle 266 was reloaded once the core initially loaded in cycle 267 was discharged due to expended fuel



  - Cycle 143 operated for 24 days and 11.65 hours at a power of 100 MW

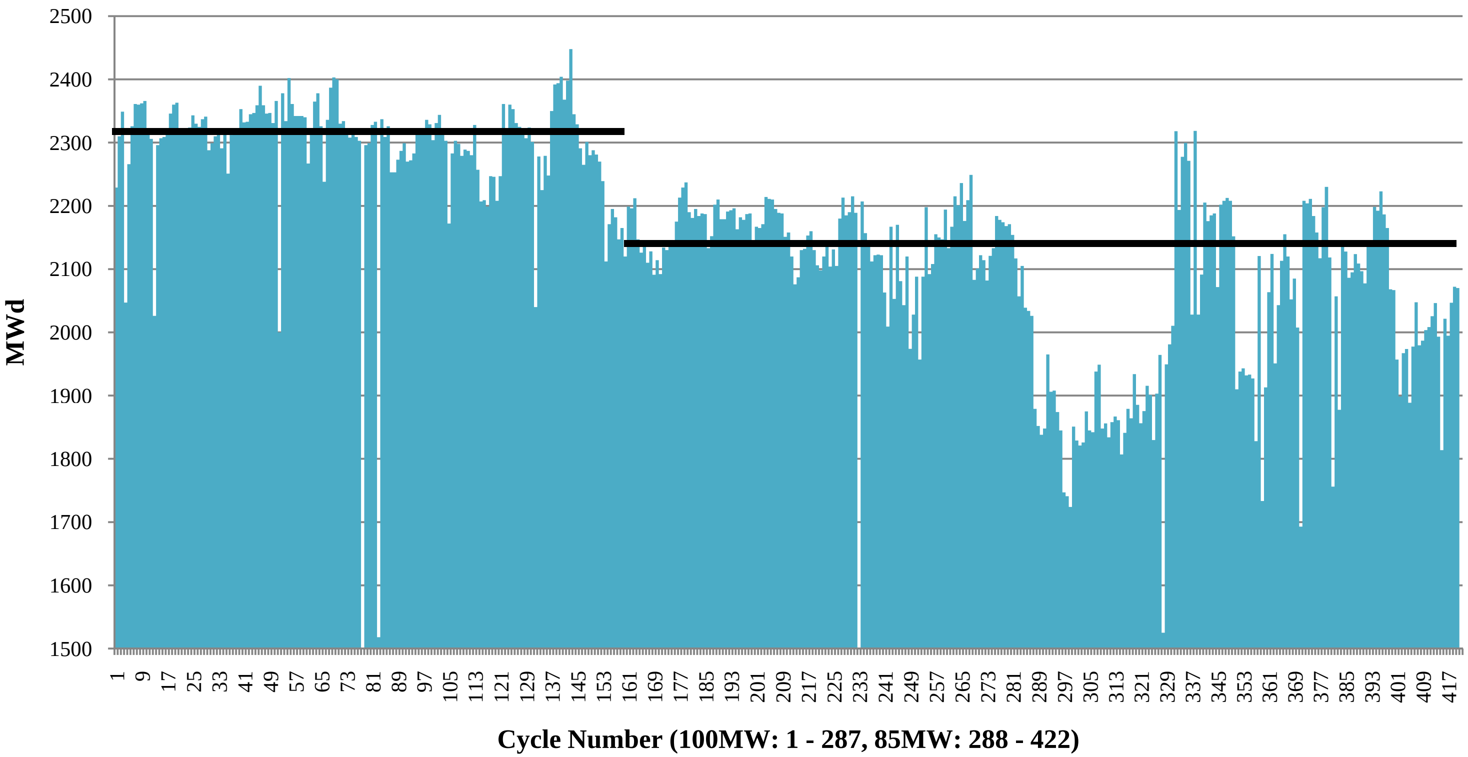
but still less than 2600 MWD

Though the goal was to search for the highest EOC exposure; data seem to show a trend …… maybe



- Some exposure changes explainable
  - Hf or Eu liners on expt. positions to modify spectra (Office of Science allows expts that degrade cycle length <= 10%)
  - Cm-bearing rods substituted for Al “place-holder” rods

Removing the perturbations that are understood, a breakpoint appears around cycle 150 (summer 1977)

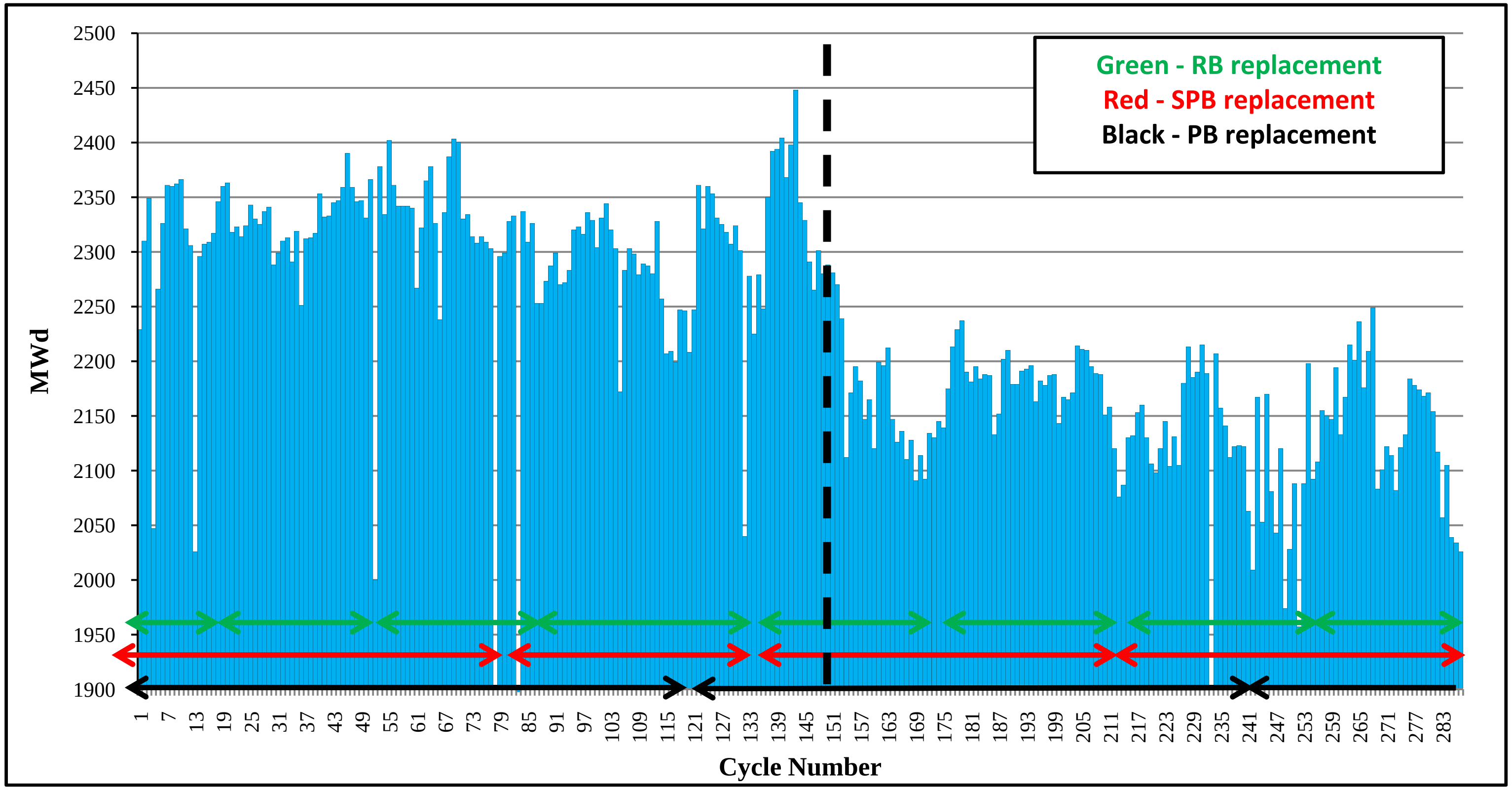


- Mean value of 2303 MWD before cycle 150
- Mean value is 2141 MWD for cycles after 150 (excluding poison filter cycles)
- Difference in end-of-cycle burnup corresponds to approximately 1.9 days of operation at 85 MW, 7.6% of a current, nominal operating cycle time of 25 days

There are factors that could account for a permanent, “step change” in reactivity and therefore cycle length

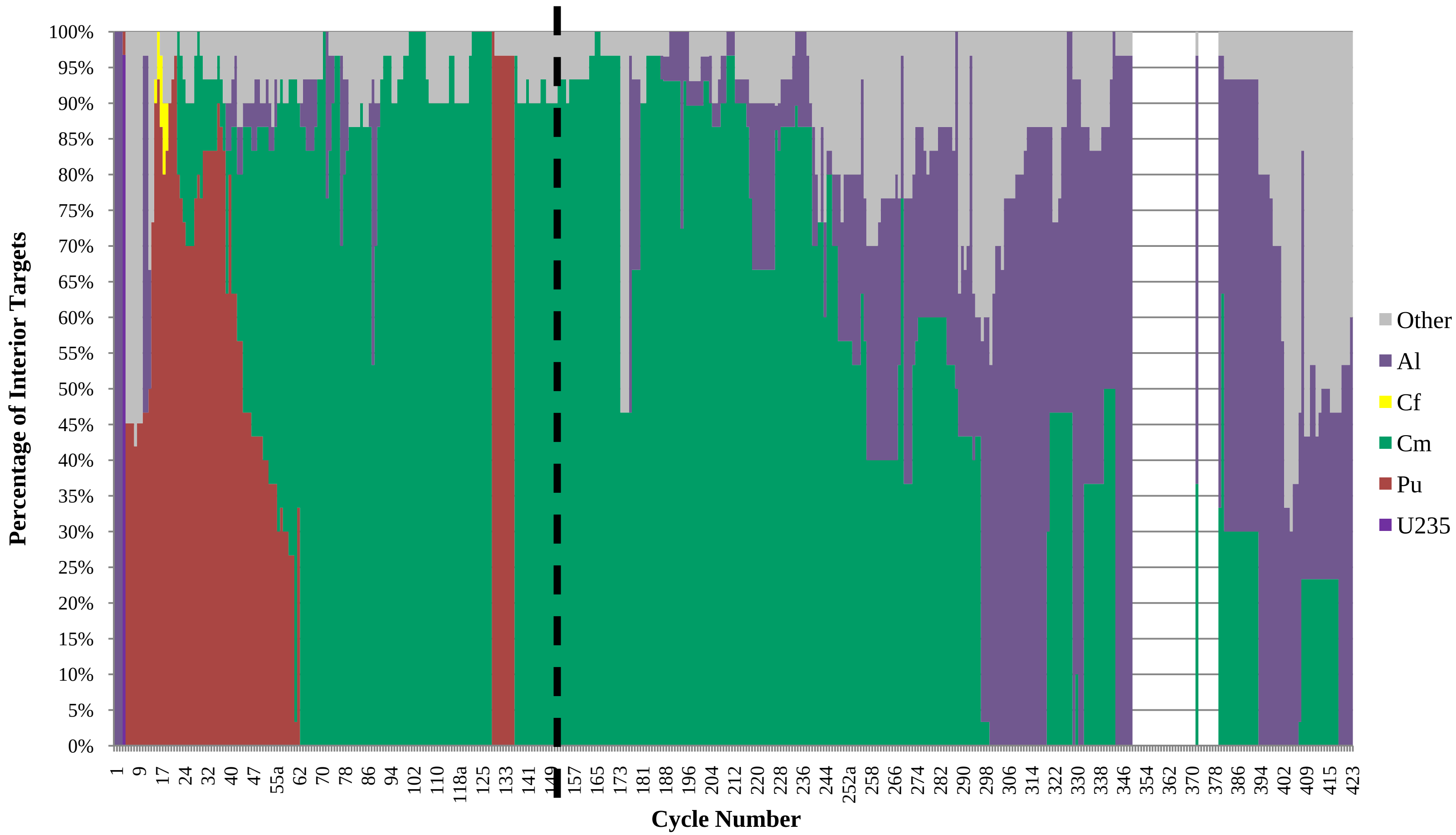
- a change in coolant water chemistry,
  - HFIR coolant water demineralizer system was changed in 1990.
  - There were no changes to the coolant water process during the time span under consideration; eliminate this option.
- replacement of the initial beryllium reflector with subsequent reflectors of poorer quality,
- or a permanent change in the configuration of the central target region.

The HFIR reflector has three pieces; replacement intervals do not coincide with step change



Reflector component	Typical lifetimes		
	Exposure (MWD)	**Reactor operating time at 85 MW (years)**	**Calendar time assuming 8 cycles per year (years)**
Removable Beryllium	83,700	2.7	4.9
Semi-permanent	167,400	5.4	9.8
Permanent	279,000	9.0	16.5

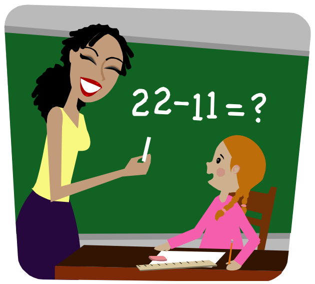
There were no significant changes to the inventory of the central target for many cycles before and after cycle 150



There appears to be a slight reduction, 8%, in the end-of-cycle exposure for HFIR fuel; the reduction occurring after 15 years of operation.

- Reason for this apparent change has not been identified but various potential causes have been excluded.
- Requirement: In the design of a new, LEU fuel cycle, NNSA has stipulated that it will maintain reactor performance but not improve.
- Requirement: The U. S. Office of Science has stipulated that a conversion of the reactor to LEU fuel shall not degrade the performance of the reactor.

FROM *MATH OPEN REFERENCE* WEB PAGE, "A LINE HAS ZERO WIDTH", but where is our line? We have two.



- Not to worry. At start of LEU conversion studies, NNSA defined reactor performance to be 26 days of operation at current flux levels.

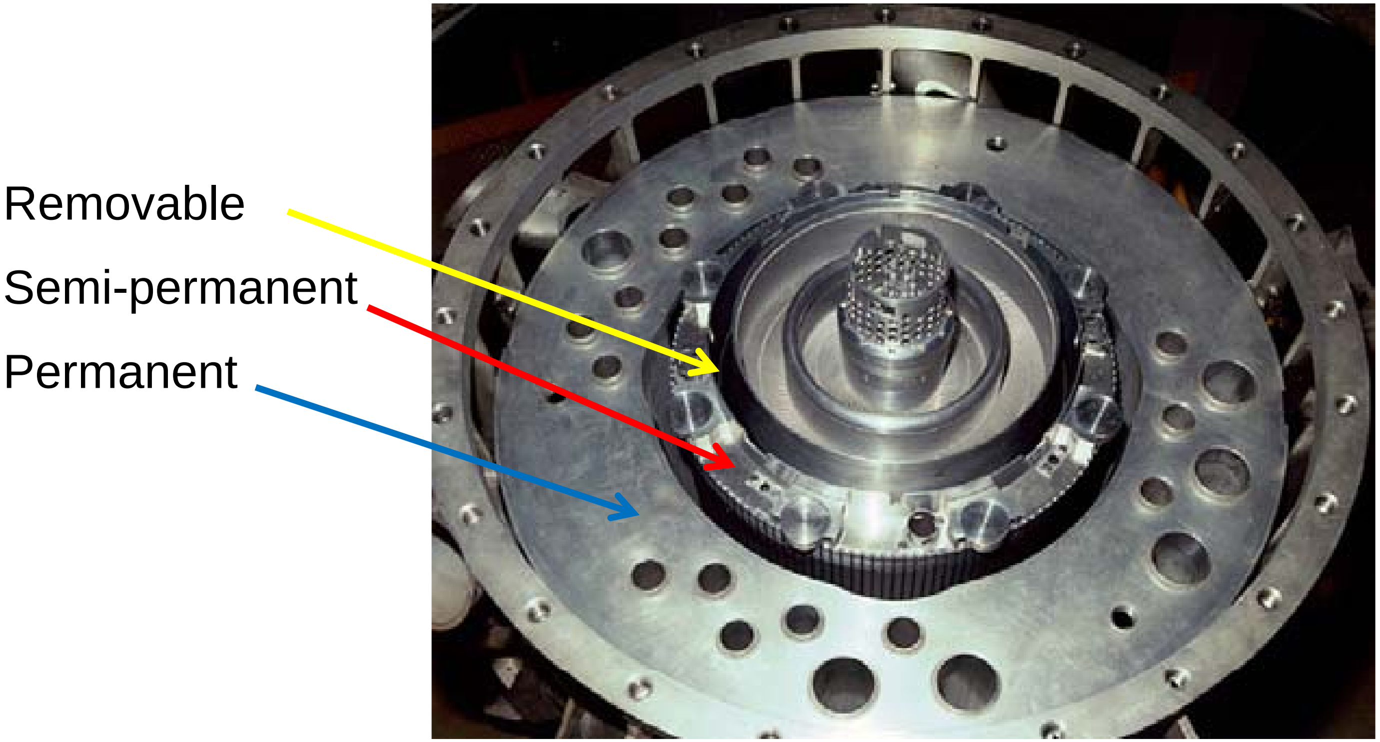
Second topic: HFIR has declared spent Be reflectors “waste with no path to disposal” (WWNPTD) under DOE Order 435.1

- **Order 435.1 requires that we get DOE approval for generating waste with WWNPTD.**
- **HFIR has DOE approval for generating the waste.**
- **HFIR must take steps to identify a path to disposal.**
- **Waste catagory of the reflectors are TRU waste affects the path to disposal.**
- **TRU waste has a defined path, although it is legislatively limited to defense-related TRU waste (WIPP).**
- **Other sites can accept non-TRU waste.**

- **Some prior studies performed at INL (2000 timeframe) and at ORNL (Bill Hill).**

HFIR Be reflectors #2 and #3, when fresh, included trace amounts of U

- #2 is located in a waste storage area on the Oak Ridge Reservation; disposition of #2 is the responsibility of Bechtel Jacobs Company.
- # 3 is located in the HFIR fuel storage pool.



Transuranic waste does not include all transuranic isotopes

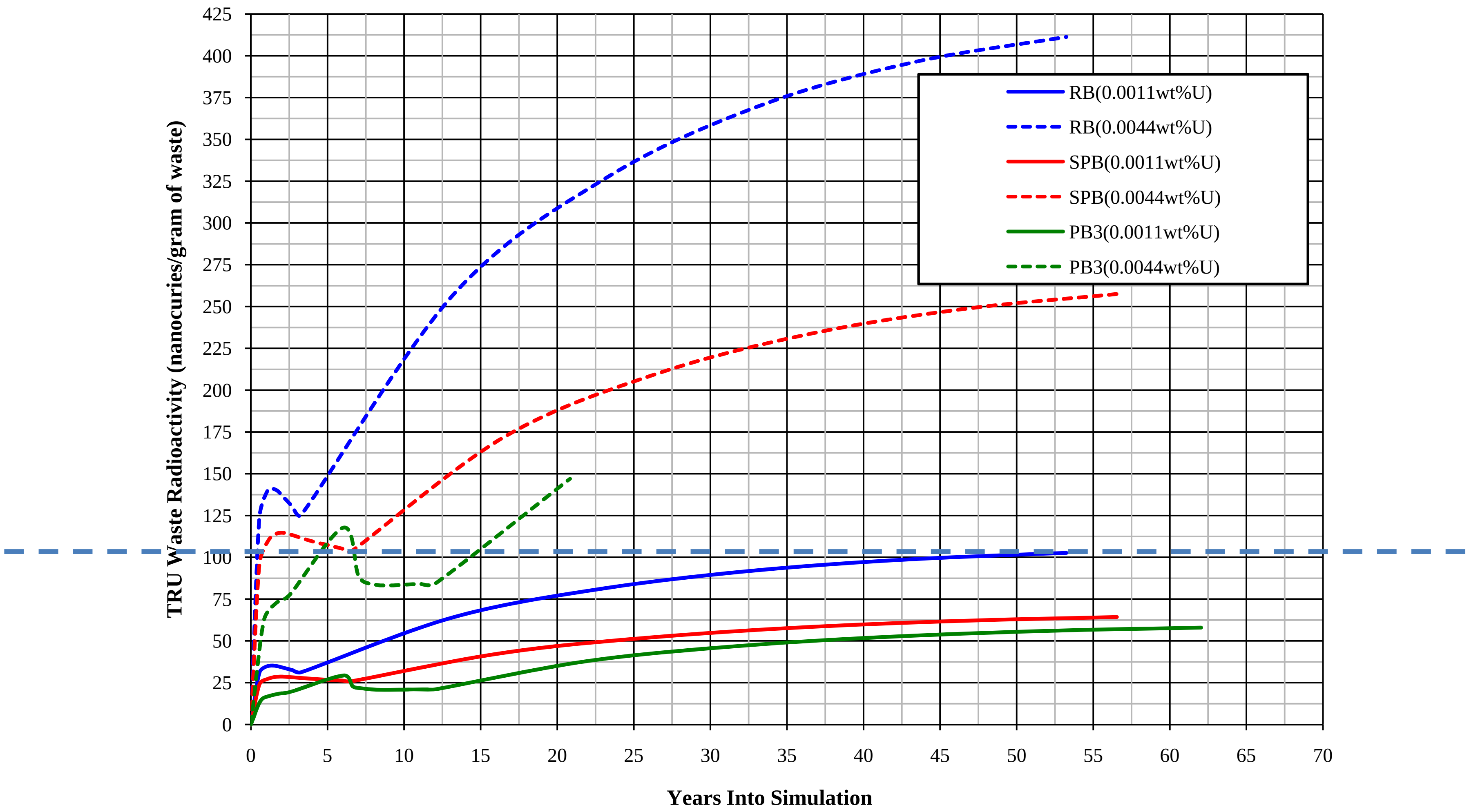
- Defined as radioactive waste containing more than 100 nanoCuries (3700 Becquerels) per gram of waste
- Alpha-emitting transuranic nuclides (nuclides with a Z greater than 92) and with half-lives greater than 20 years
- According to the Nevada Test Site Waste Acceptance Criteria,
  - ^{237}Np,
  - ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{244}Pu,
  - ^{241}Am, ^{242m}Am, ^{243}Am,
  - ^{243}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{248}Cm, ^{250}Cm,
  - ^{247}Bk,
  - ^{249}Cf, and ^{251}Cf

The irradiation cycles for both reflectors were modeled with the SCALE code system

SCALE
Standardized Computer Analyses for Licensing Evaluation

- Found that due to excluding certain transuranic isotopes and HFIR outages, material may become TRU waste, then not TRU waste, then again TRU waste.
- The HFIR beryllium specification calls for the uranium content of the beryllium to be less than or equal to 0.0011 wt. %.
- The uranium content of the permanent beryllium number 3 was measured to be 0.0044 wt. %.

With high U content, reflector #3 pieces are TRU waste; IF #2 was fabricated to HFIR specification (had <0.0011 wt. % U), it is not TRU waste



Waste characterization studies yield considerations for future HFIR Be reflectors

- **Placement of order for next permanent Be reflector expected around 2017**
- **Current permanent Be reflector expected to be discharged in 2020**
- **Is it justifiable to attempt to recover a sample of reflector #2 to assess disposition path or should it be declared TRU waste along with #3?**
- **Does path for disposal of TRU waste impose sufficient additional costs so that for upcoming #5 reflector, special processing is justified to remove uranium?**
- **Or is having U impurity an advantage because a path to disposal is identified?**