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ABTR Core Design Summary

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A U.S. Department of Energy laboratory managed by The University of Chicago

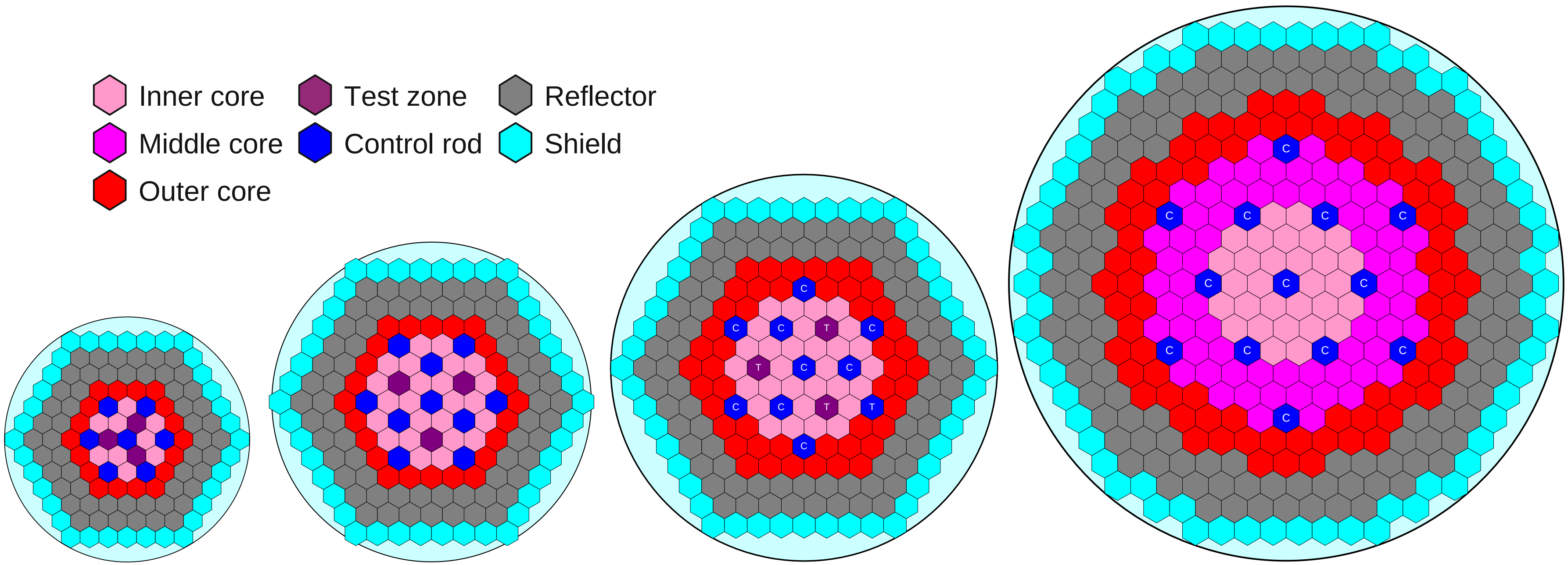
Work sponsored by U.S. Department of Energy Office of Nuclear Energy, Science & Technology

Trade-off Study for ABTR Power Rating

- A trade-off study was performed to determine the appropriate power level of the ABTR
- Focused on determining the minimum power level that provides performance characteristics good enough to demonstrate the ABR design features
  - Low TRU conversion ratio to support the demonstration of the benefits of closure of the nuclear fuel cycle to the repository
  - High neutron flux level to provide a test bed for advanced fuels and material developments
  - Irradiation environment similar to envisioned ABR design
- Wide ranges of power level and assembly design parameters
  - Core configurations for 125, 250, 440, and 840 MWt, based on SMFR, SMFR-2, FFTF and PRISM Mod-B designs
  - Fuel pin diameters from 0.58 cm to 1.05 cm

Configurations for ABTR Power Rating Study

- Core configurations
  - Fixed linear power (~26 kW/m)
    - Slightly lower linear power for 125 MWt core because of limited assembly locations



125 MWt **250 MWt** **400 MWt** **840 MWt**

Trade-off Study for ABTR Power Rating (cont'd)

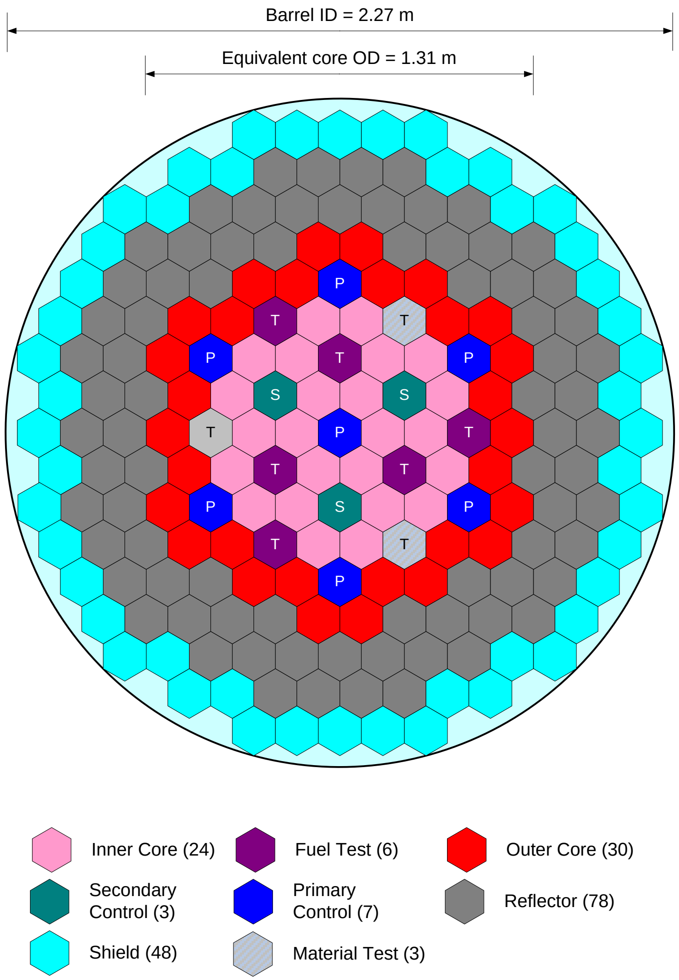
- **REBUS-3 equilibrium cycle analysis**
  - U-TRU-10Zr ternary metal fuel
  - TRU recovered from 10-year cooled, medium burnup (33 GWD/MTHM) spent fuels of light water reactors
  - 12 month cycle with 90% capacity factor
  - 3 batch scattered loading
  - Enrichment splitting (low/medium/high) = 1.0/1.13/1.25
  - No attempt was made to optimize the burnup reactivity swing and discharge burnup
- **Maximum fuel cycle length was estimated later such that the burnup reactivity swing is within the reactivity control capability of primary control system**

250 MWt Reactor Meets the GNEP Requirements

- **Most of performance parameters are monotonically improved with increasing power rating**
  - Except for TRU conversion ratio, core size and TRU loading
- **In particular, the average flux level decreases significantly as the power level decreases**
  - The TRU enrichment for the cases of small power rating and fuel pin size is higher than 30%, which is beyond the current irradiation experience
  - In addition, the peak linear power limit is violated for some of these cases, since the fuel solidus temperature decreases with increasing TRU enrichment
- **The average flux level achievable within the linear power limit appears to be ~1.9×10^{15} and ~2.7×10^{15} n/cm^2s for the 125 and 250 MWt cores, respectively**
  - The corresponding conversion ratios are 0.30 and 0.41 for the 125 and 250 MWt cores, respectively
- **These results suggest that ~250 MWt is a reasonable compromise to allow a low project cost, at the same time providing a reasonable test bed for demonstrating the ABR design features**

Reference Core Configuration

- **Small compact core**
  - Two enrichment zones
    - *Inner core: 24 assemblies*
    - *Outer core: 30 assemblies*
  - Two independent control systems
    - *Primary control: 7*
    - *Secondary control: 3*
  - Six fuel test assemblies
  - Three material test assemblies
- **TRU from LWR spent fuel is used for fuel test assemblies**



Fuel Assembly Design Parameters

		Metal Fuel	Oxide Fuel
Fuel form		U-TRU-10Zr	UO_2-$TRUO_2$
Hexagon pitch, cm		14.598	
Inter-assembly gap, mm		4.0	
Duct outside flat-to-flat, cm		14.198	
Duct wall thickness, mm		3.0	
Pin diameter, mm		8.00	
Pin pitch-to-diameter ratio		1.13	
Cladding thickness, mm		0.52	
No. of fuel pins		217	
Helical pitch of wire-wrap, cm		20.32	
Wire wrap diameter, mm		1.03	
Height (core/plenum), cm		80/120	90/135
Fuel smeared density, %		75.0	88.4
Average linear power, kW/m		22.2	20.8
Pin bundle pressure drop, psi		46.9	56.6
Volume fraction, %	Fuel	33.6	41.6
	Bond	11.2	3.1
	Structure	23.2	23.2
	Coolant	32.1	32.1

Comparison of TRU Inventory and Consumption Rate

		Metal Fuel		Oxide Fuel	
External TRU source		WG-Pu	LWR SNF	WG-Pu	LWR SNF
HM inventory (BOEC/EOEC), kg		4027/3999	4029/4001	3673/3645	3675/3647
TRU inventory (BOEC/EOEC), kg		732/723	975/964	779/770	1046/1035
TRU consumption rate (kg/yr)		25.9	32.0	26.8	34.3
HM mass per assembly, kg		70.1	70.1	64.2	64.2
TRU mass per assembly, kg	**IC**	11.6	15.3	12.3	16.4
	OC	14.5	19.1	15.4	20.5
	test	13.1	17.3	13.9	18.6

Isotopic Mass Flow Rates of Metal Fuel Core

	WG-Pu				LWR SNF			
	Inventory, kg		Mass flow , kg/year		Inventory, kg		Mass flow , kg/year	
	BOEC	**EOEC**	**Charge**	**Discharge**	**BOEC**	**EOEC**	**Charge**	**Discharge**
U-234	**0.0**	**0.0**	**0.00**	**0.01**	**0.3**	**0.3**	**0.0**	**0.1**
U-235	**5.2**	**5.0**	**1.52**	**0.84**	**4.9**	**4.7**	**1.4**	**0.8**
U-236	**0.3**	**0.4**	**0.00**	**0.14**	**0.3**	**0.4**	**0.0**	**0.1**
U-238	**3289.6**	**3270.2**	**768.35**	**710.29**	**3048.7**	**3031.2**	**712.1**	**659.8**
NP237	**3.6**	**3.6**	**0.89**	**0.88**	**39.8**	**38.6**	**10.6**	**7.1**
PU236	**0.0**	**0.0**	**0.00**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**
PU238	**1.6**	**1.7**	**0.28**	**0.56**	**20.1**	**21.1**	**3.1**	**5.8**
PU239	**628.6**	**617.0**	**156.83**	**121.80**	**493.5**	**486.7**	**120.0**	**99.7**
PU240	**80.2**	**83.1**	**13.74**	**22.29**	**242.4**	**241.4**	**55.1**	**52.2**
PU241	**8.9**	**9.0**	**2.09**	**2.26**	**65.4**	**63.0**	**18.2**	**11.3**
PU242	**4.0**	**4.0**	**0.96**	**1.03**	**49.5**	**49.4**	**11.0**	**10.9**
AM241	**3.8**	**3.8**	**1.00**	**0.90**	**48.5**	**47.7**	**11.9**	**9.4**
AM242	**0.1**	**0.1**	**0.00**	**0.05**	**1.3**	**1.5**	**0.0**	**0.5**
AM243	**0.7**	**0.8**	**0.18**	**0.20**	**9.9**	**10.0**	**2.1**	**2.3**
CM242	**0.1**	**0.1**	**0.00**	**0.04**	**1.5**	**1.7**	**0.0**	**0.4**
CM243	**0.0**	**0.0**	**0.00**	**0.00**	**0.1**	**0.1**	**0.0**	**0.0**
CM244	**0.2**	**0.2**	**0.03**	**0.06**	**2.5**	**2.6**	**0.4**	**0.7**
CM245	**0.0**	**0.0**	**0.00**	**0.01**	**0.2**	**0.2**	**0.0**	**0.1**
CM246	**0.0**	**0.0**	**0.00**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**
total HM	**4027.2**	**3999.0**	**945.9**	**861.3**	**4028.8**	**4000.6**	**945.9**	**861.3**
total TRU	**732.0**	**723.4**	**176.0**	**150.1**	**974.7**	**964.0**	**232.4**	**200.4**

Kinetics Parameters and Reactivity Coefficients

	Unit	WG-Pu metal fuel		WG-Pu oxide fuel	
		BOEC	EOEC	BOEC	EOEC
Effective delayed neutron fraction		0.0033	0.0033	0.0032	0.0032
Prompt neutron lifetime	μs	0.33	0.33	0.42	0.42
Radial expansion coefficient	cent/°C	-0.59	-0.60	-0.55	-0.56
Axial expansion coefficient	cent/°C	-0.06	-0.05	-0.06	-0.06
Fuel density coefficient	cent/°C	-0.75	-0.76	-0.51	-0.58
Structure density coefficient	cent/°C	0.03	0.03	0.03	0.04
Sodium void worth	$	1.75	1.85	1.32	1.40
Sodium density coefficient	cent/°C	0.03	0.03	0.01	0.01
Doppler coefficient	cent/°C	-0.10	-0.10	-0.20	-0.20
Sodium voided Doppler coefficient	cent/°C	-0.07	-0.07	-0.16	-0.16

Summary of ABTR Core Design

- **A reference ABTR design was developed using weapons-grade plutonium-based ternary metal fuel**
  - Medium TRU conversion ratio: 0.65
  - Reactivity swing of ~3.7$ over 4-month cycle
  - Average discharge burnup is 98 MWd/kg
  - Core average flux level is ~2.4E15 n/cm^{2}s and test assembly flux level is ~2.9E15 n/cm^{2}s
- **An alternative MOX core design was developed**
  - Core height was increased to 90 cm from 80 cm
  - ~15% higher TRU enrichment is required
  - ~9% smaller HM inventory, ~10% higher burnup reactivity swing, ~9% higher discharge burnup, and ~8% lower flux level
  - Slight design modification is required to satisfy the linear power limit