Source Term Assessment

2014 ISOE ALARA Symposium

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Bruce Site History

- Bruce A - 4 pack commissioned in late 1970s
  - Unit 2 shutdown in 1995
  - Units 1,3,4 shutdown in 1997
  - Bruce Power born in 2001
    - Restarted units 3 & 4 in 2003-4
    - Refurbished units 1 & 2 online in 2012
- Bruce B – 4 pack commissioned in mid 1980s
  - Approaching end-of-life
- Currently largest operating site

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Morning Commute To Work at The Bruce

Objectives of the Presentation

- Sources and their origins in CANDU
- Most recent trends at Bruce
  - Cobalt -60
  - Reactor Face
  - Collective Exposures
- Shutdown Chemistry Challenges
- Unique Challenges with 8 Reactors

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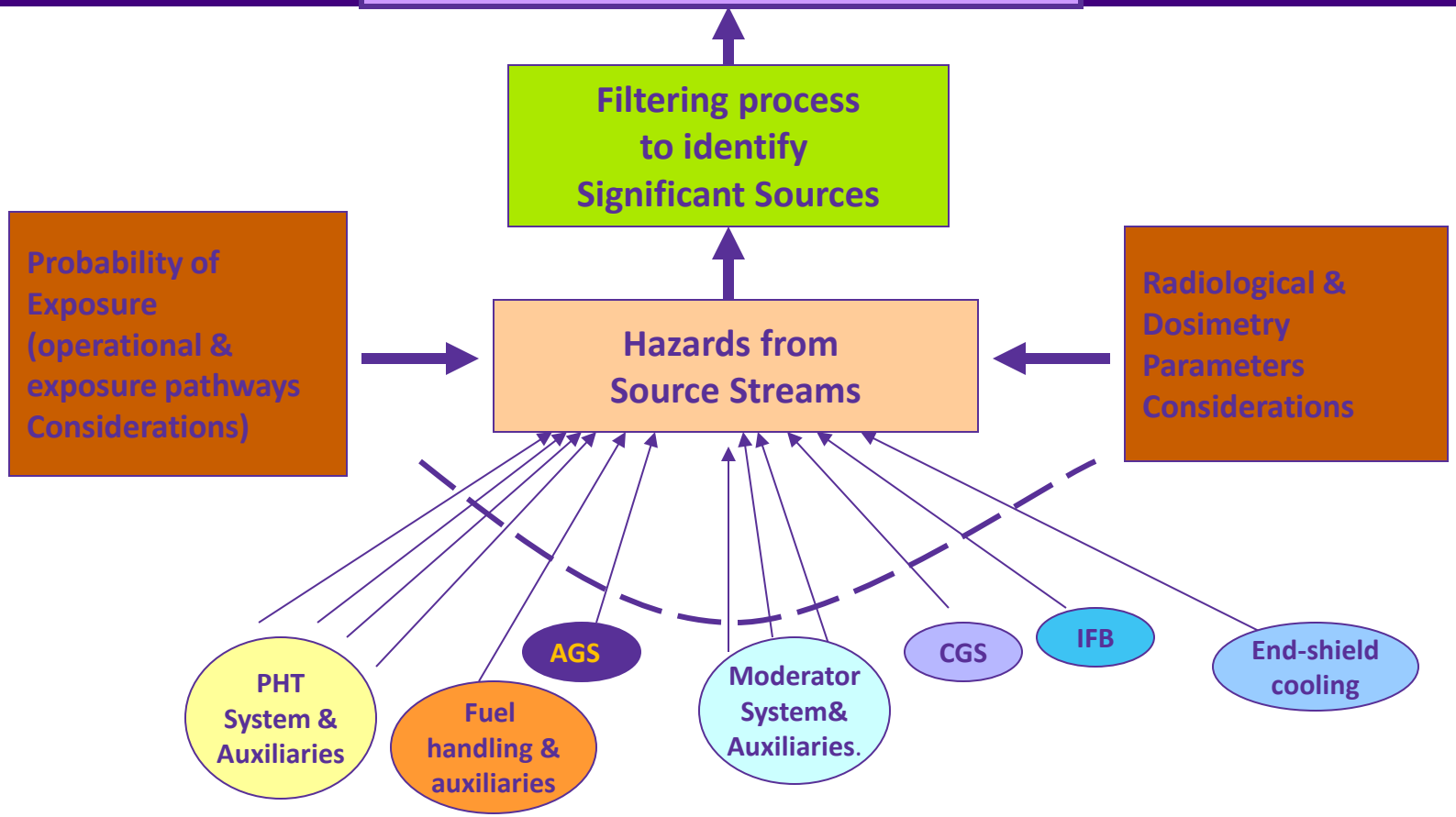
Radiation Source Term for Radionuclides of Significance For Internal Dose at Candu Nuclear Facilities



Major Source Streams in CANDU Reactors

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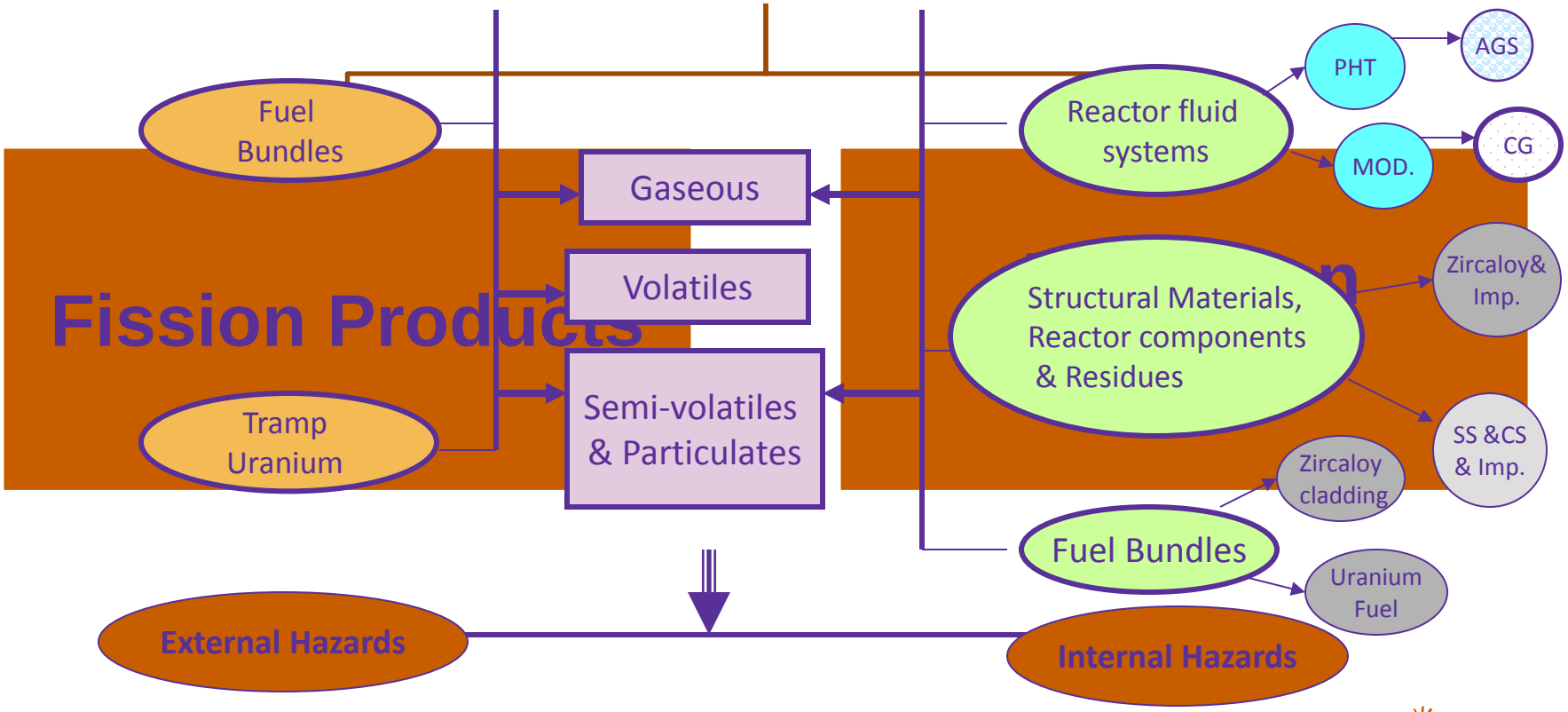
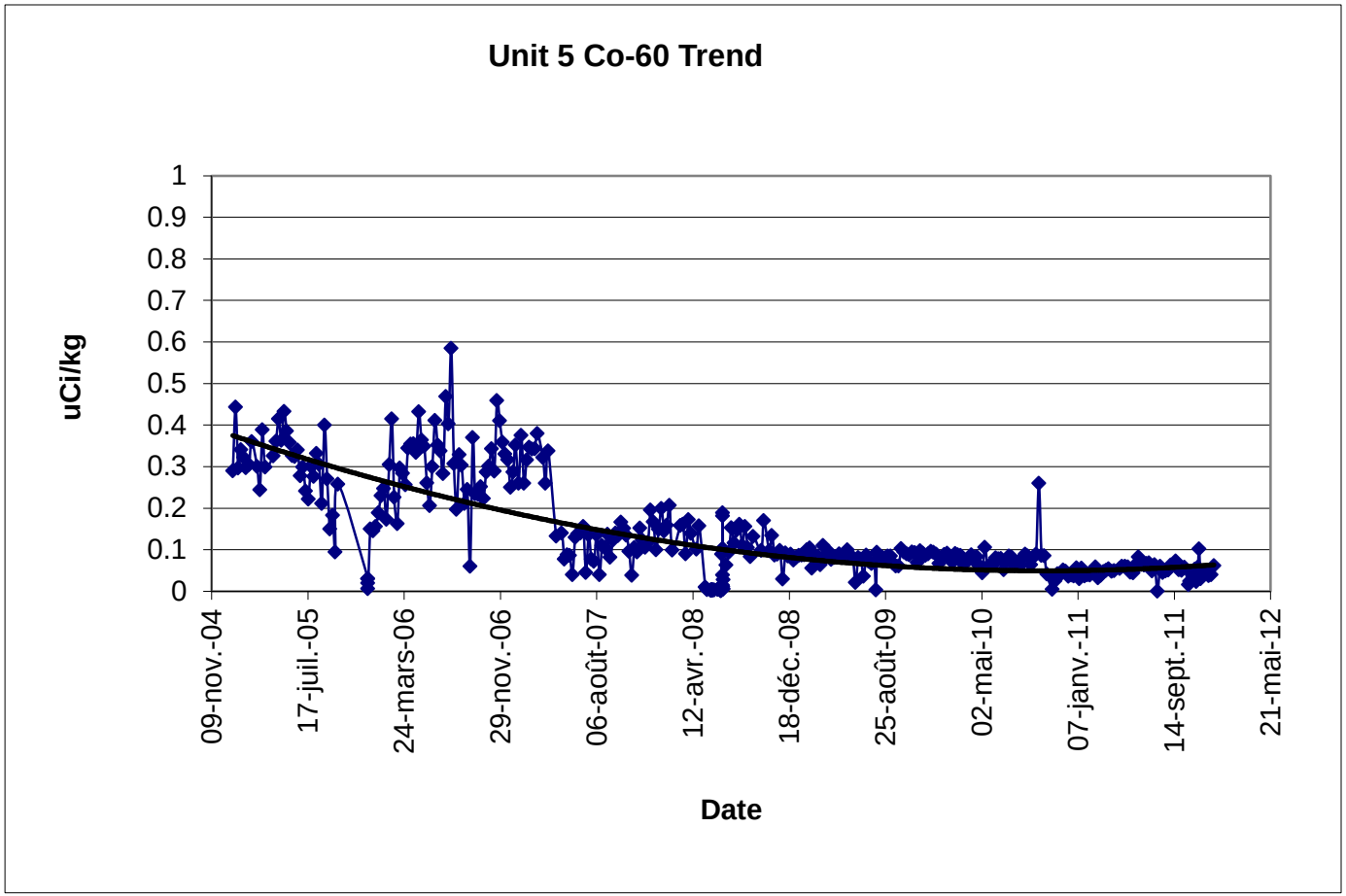
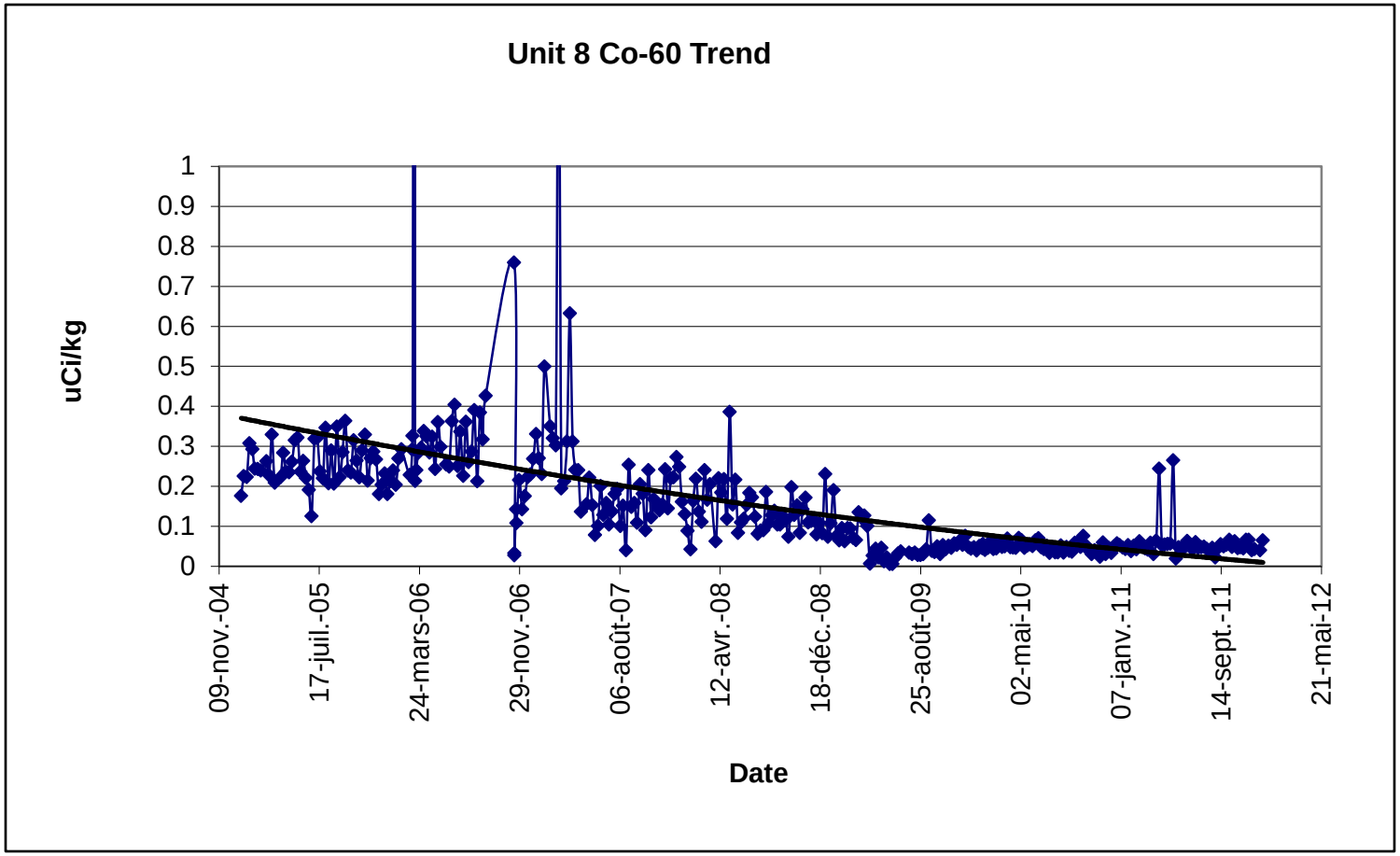
Streams of Radiation Sources Generated In CANDU Reactors

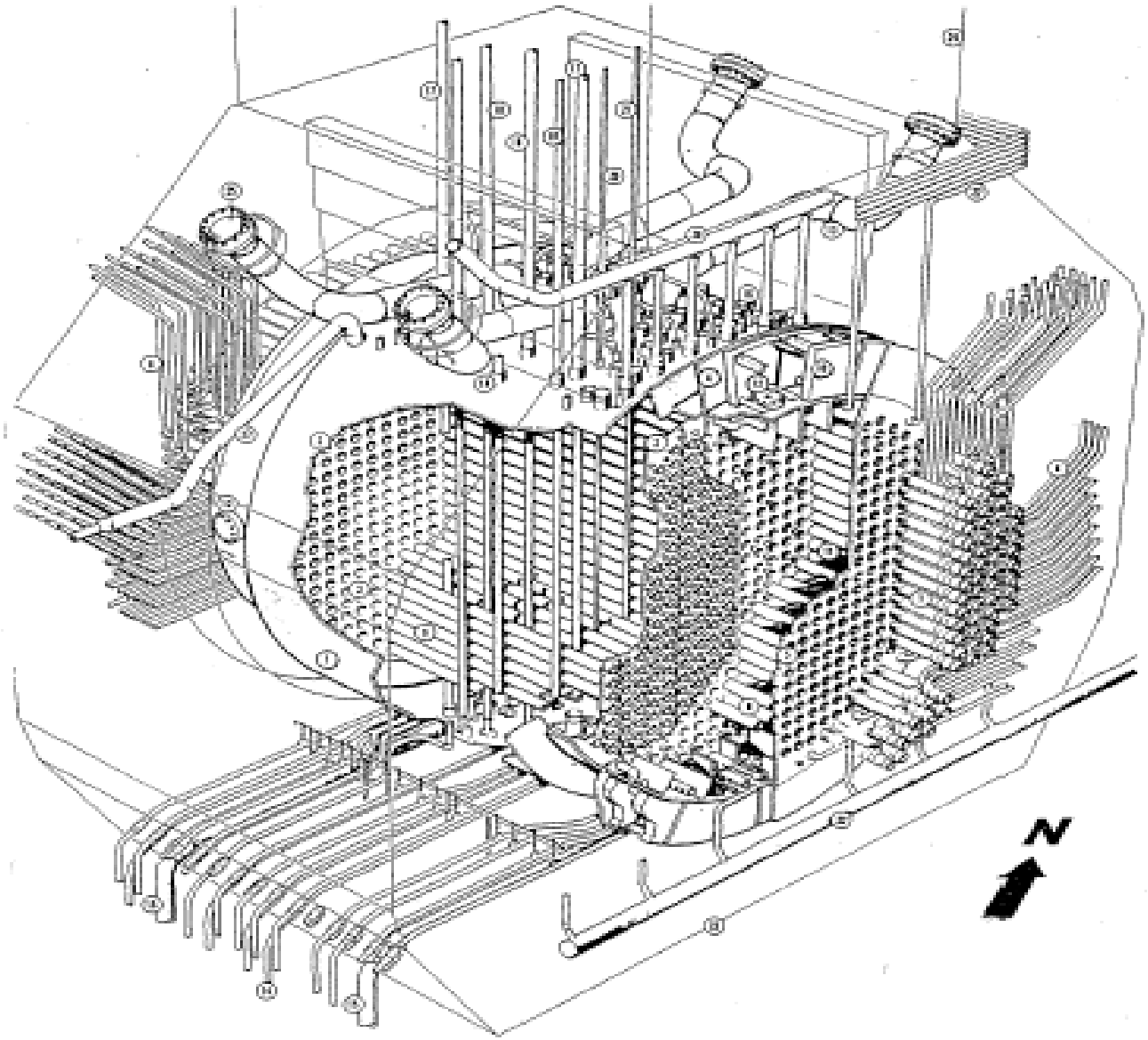


Cobalt Trend U5



Cobalt Trend U8





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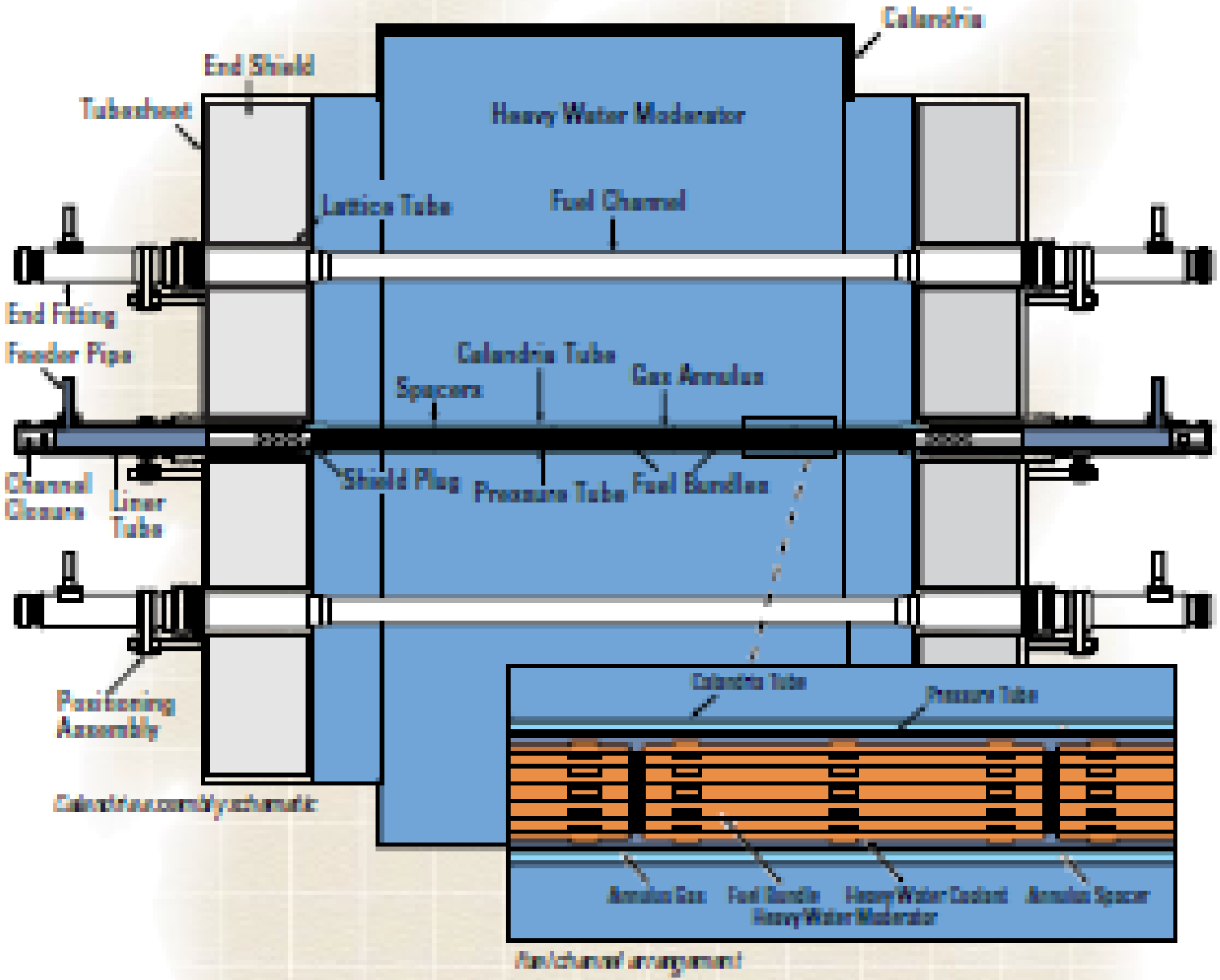
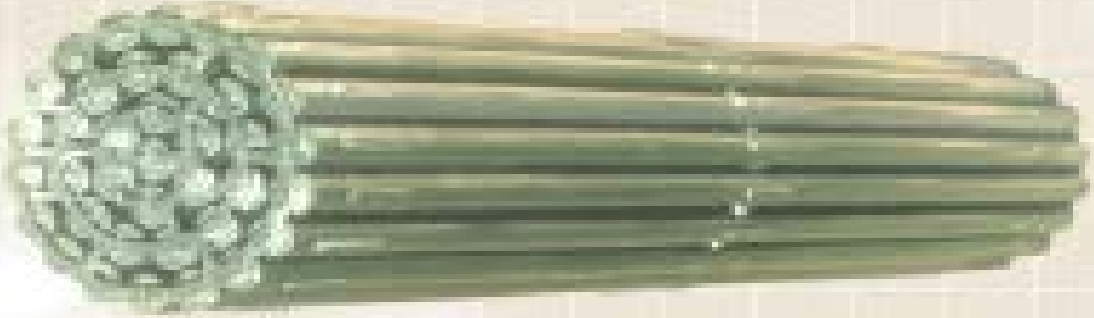
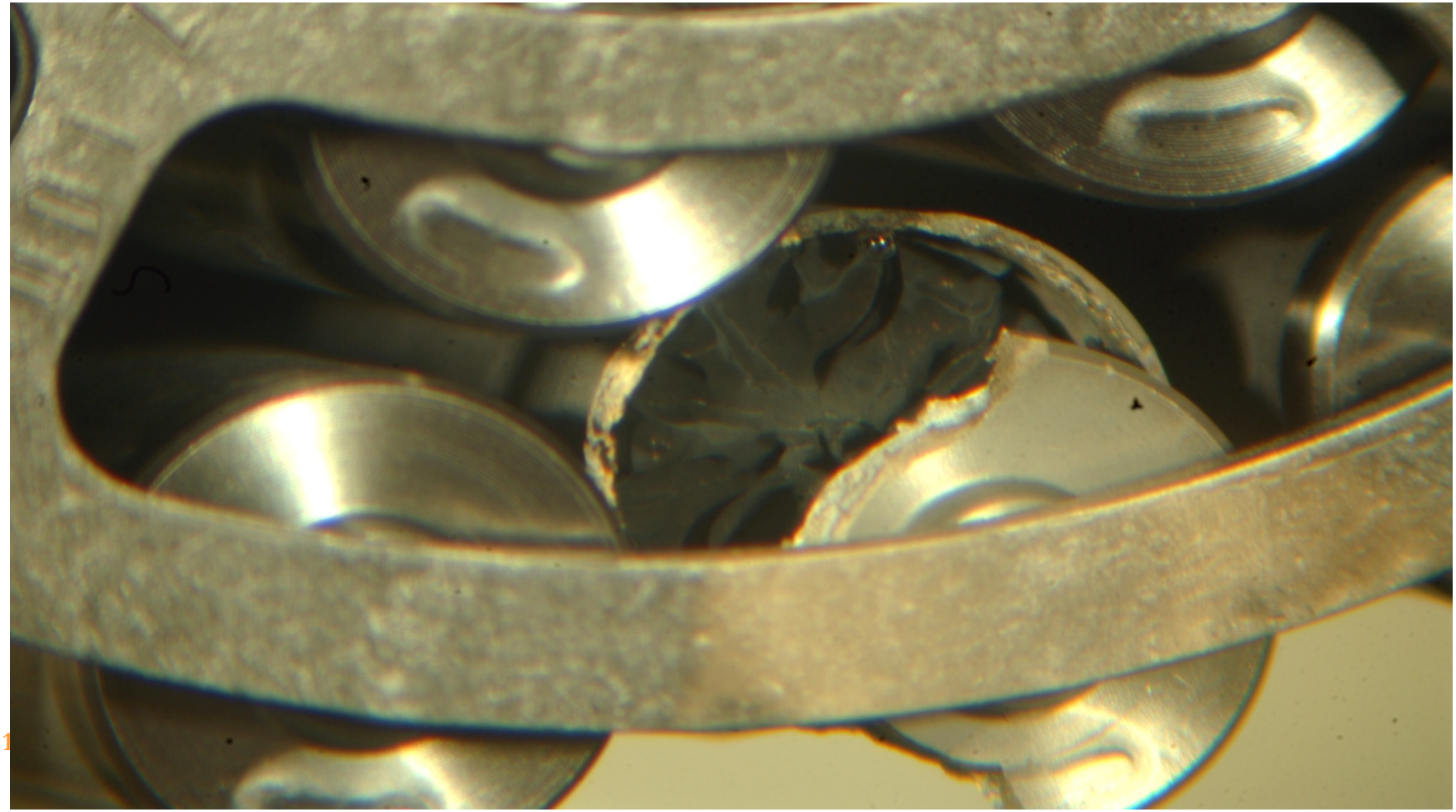


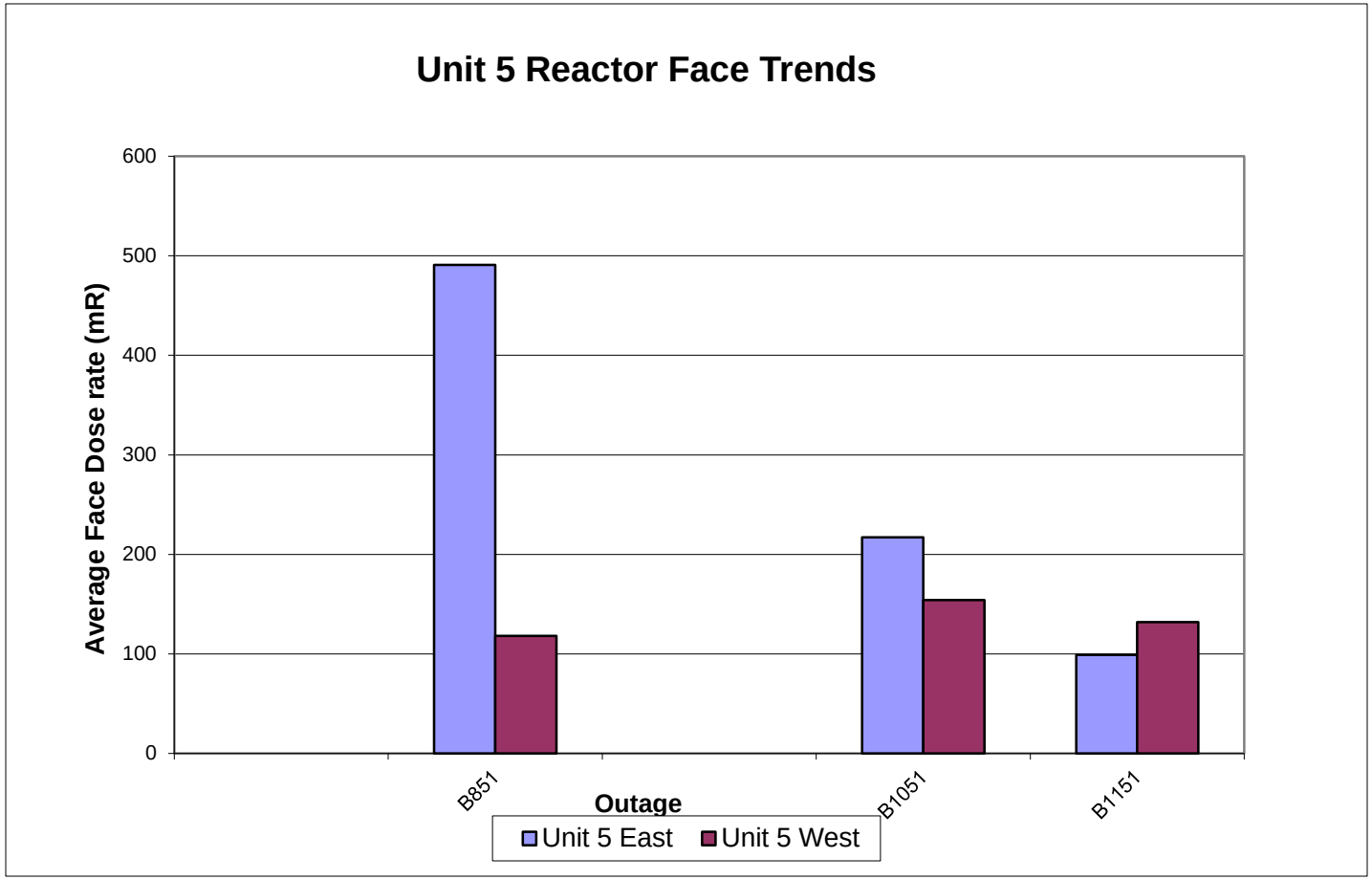
Calandria assembly schematic

Fuel channel arrangement

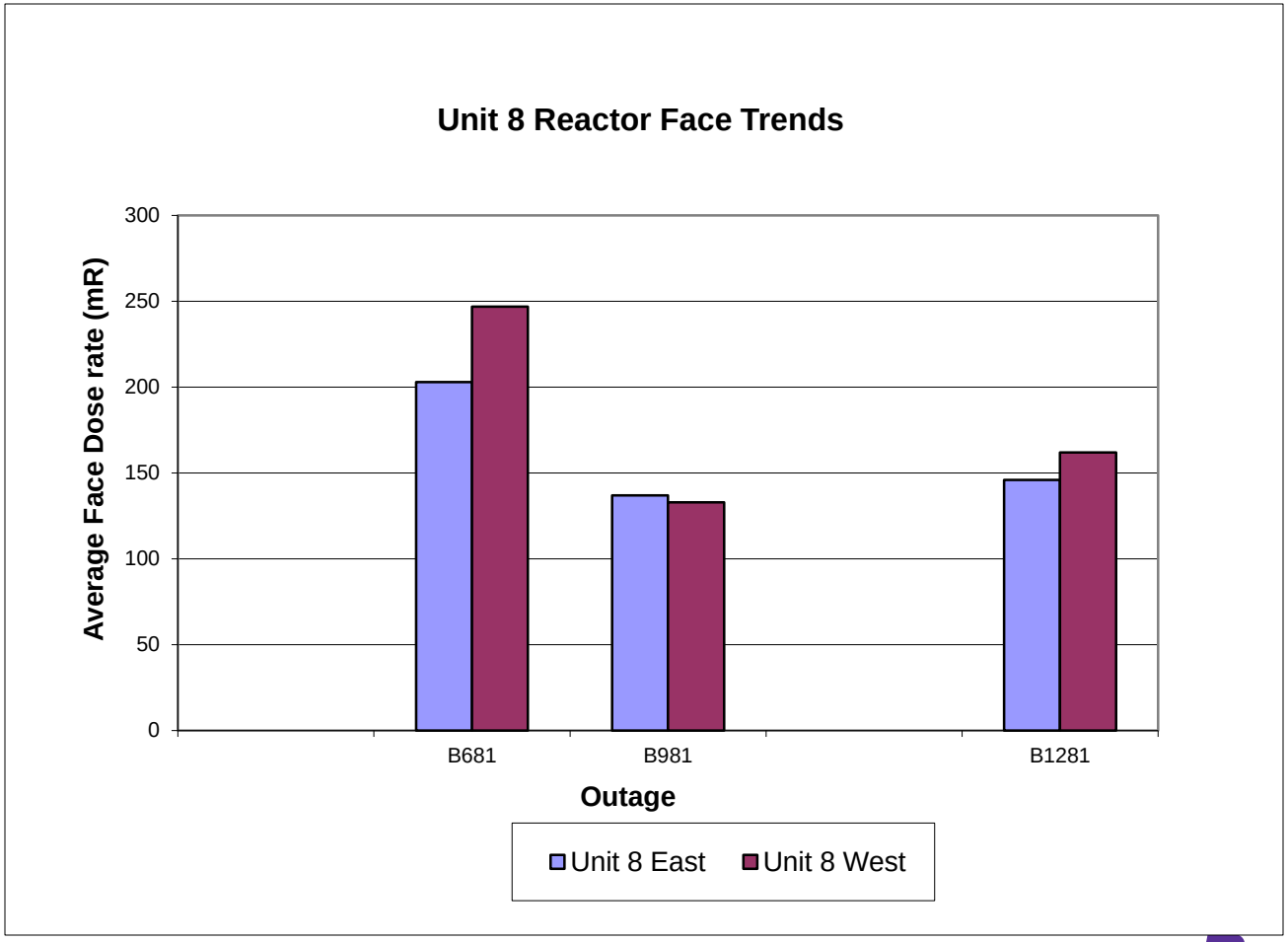

Rod Bundle



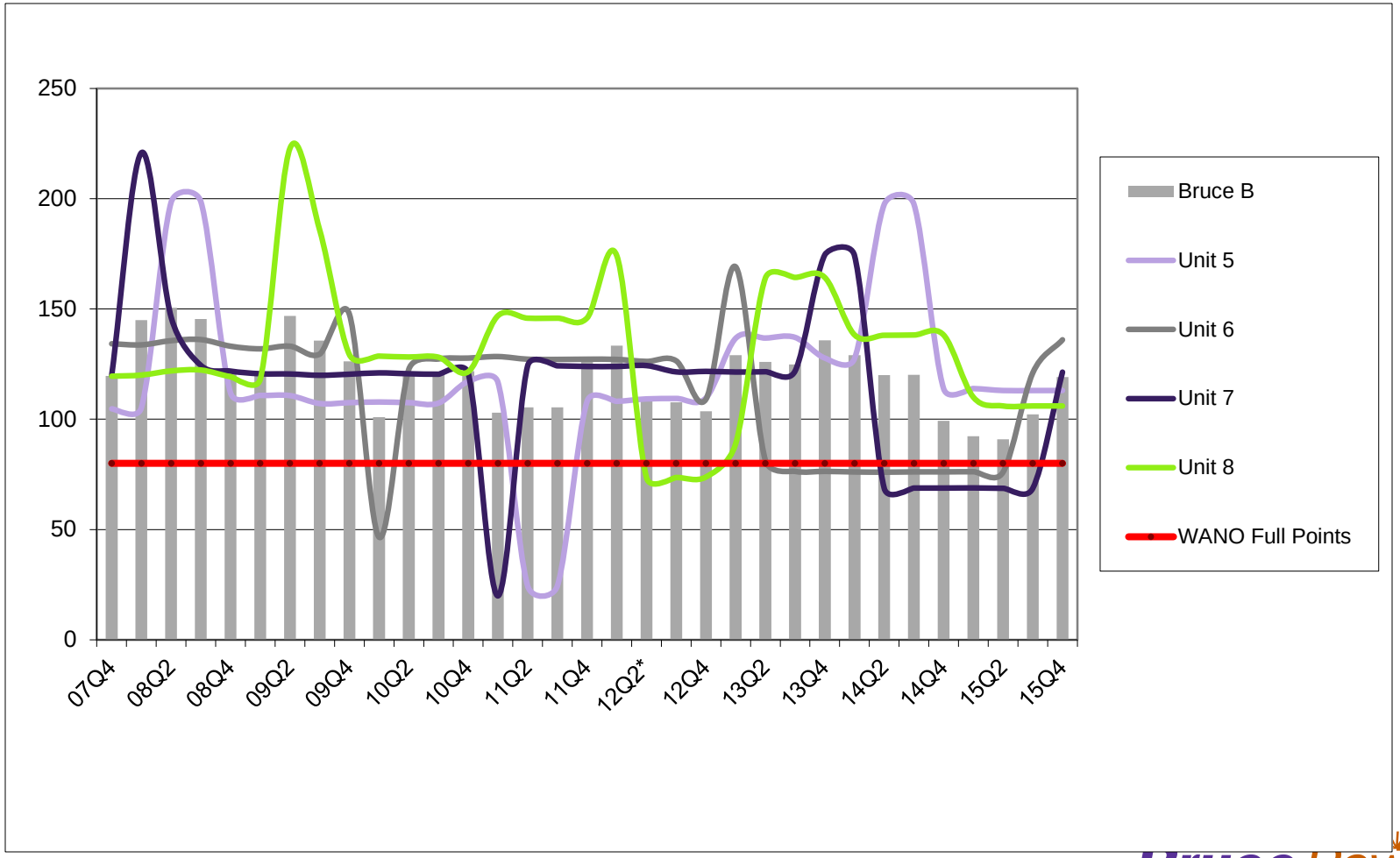
Reactor Face U5



Reactor Face U8



CRE Trends Bruce B



Shutdown Chemistry

- Carbon Steel Feeders
  - Very large relative surface area
  - Susceptible to FAC
    - Extra inspections and early replacements
- pH cannot be manipulated
  - Stays 10 to 10.5 even during shutdown
- Zinc injection not feasible for CANDUs
- Optimize what we can and shield the rest

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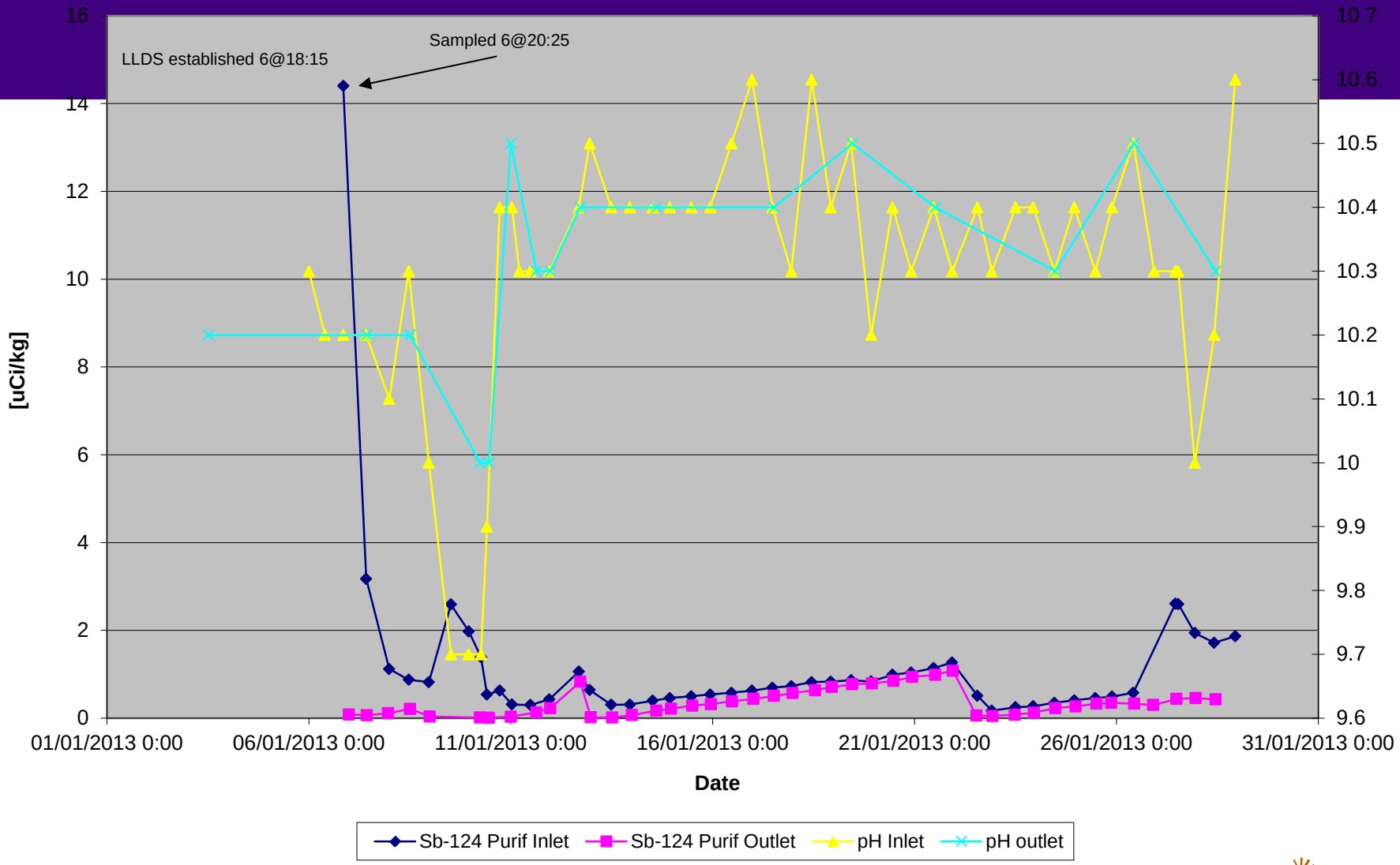
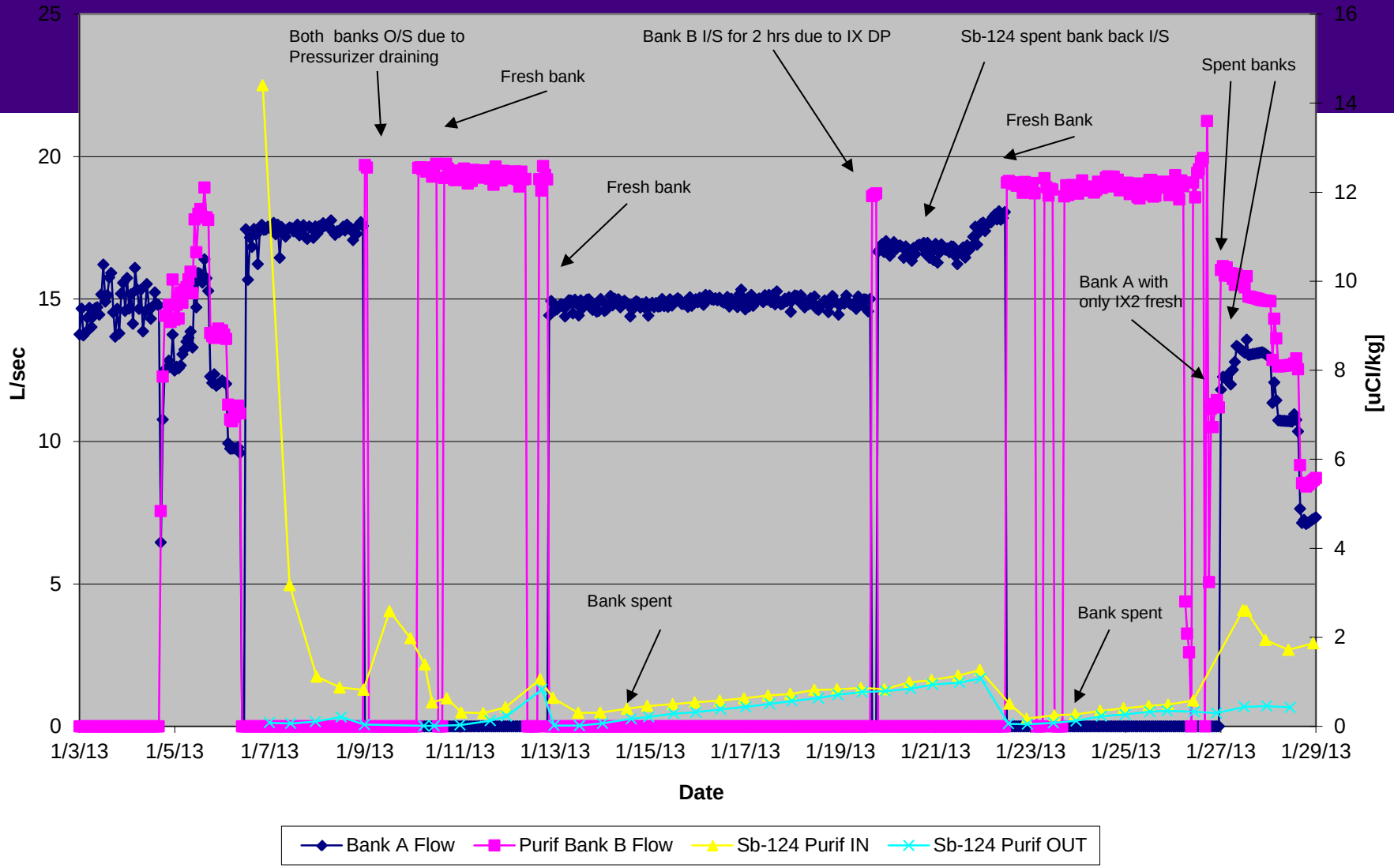
B1351 Outage - PHT Sb-124



Purification Banks In Service vs Sb-124



Face shielding will save 25 Rem on a typical 50 day outage

8 Unit Challenges

- Source Term varies greatly from BA to BB
  - Source varies from unit-unit
    - Operational histories vary greatly
  - Challenges the technical basis for RP Program
- Aging reactors require an increasing scope of maintenance and inspections
- Increased sensitivity to CRE and need for aggressive ALARA measures
  - BA initiatives can be amortized over 30 years
  - BB initiatives can be amortized over 5 years

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- F.P inventory (ORIGEN-S Calc)- Filtered: decay time <1d and non internal hazards (N.G)
- Hypothetical intake (100 kBq) (based on inventory profile/ per unit mass)
- Significance ranking in the group (based on % of total dose Vs. decay time (Y) after shutdown)

	Shutdown Status		Laid-Up Status		
Rank	S.D (% of total)	0.5 y (% of total)	1 y (% of total)	5y (%of total)	10y(% of total)
1	Ce-144 (35.88)	Ce-144 (48.33)	Ce-144 (46.79)	Sr-90 (63.71)	Sr-90 (83.35)
2	Ru-106 (21.55)	Ru-106 (32.21)	Ru-106 (34.58)	Ru-106 (12.84)	Cs-137 (11.36)
3	Zr-95 (8.41)	Sr-90 (8.32)	Sr-90 (12.41)	Cs-137 (8.62)	Y-90 (1.84)
4	Y-91 (8.12)	Zr-95 (2.45)	Cs-137 (1.67)	Ce-144 (7.58)	Pm-147 (1.19)
5	Ce-141 (6.25)	Y-91 (1.97)	Pm-147 (1.53)	Pm-147 (3.02)	Eu-154 (1.06)
6	Sr-89 (5.52)	Nb-95 (1.49)	Cs-134 (1.08)	Cs-134 (1.60)	Ru-106 (0.63)
7	Ru-103 (4.84)	Pm-147 (1.16)	Zr-95 (0.51)	Y-90 (1.41)	Cs-134 (0.44)
8	Sr-90 (4.01)	Cs-137 (1.12)	Nb-95 (0.34)	Eu-154 (1.22)	Ce-144 (0.13)
9	Nb-95 (2.63)	Cs-134 (0.85)	Y-90 (0.27)	Total: 209 mrem	Total: 229 mrem
10	Pm-147 (0.60)	Ru-103 (0.40)	Eu-154 (0.27)		
11	Cs-137 (0.54)	Ce-141 (0.27)	Sr-89 (0.12)		
12	Cs-134 (0.48)	Y-90 (0.18)	Total: 203 mrem		
13	Te-129m (0.47)	Eu-154 (0.18)			
14	Pm-148 (0.32)	Total: 167 mrem			
	Total: 60 mrem				

Questions