KINECTRICS

Ideas Into Energy®

Outage Activity Transport Monitoring Surveys at CANDU Stations

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Presentation Flow

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I Introduction

II Outage Activity Transport Monitoring (OATM) Methodology

III Results of OATM Surveys

a) Reactor vault

b) Reactor face

c) Steam generator

d) Moderator heat exchanger

e) Abnormally high radiation fields

IV Further Developments

V Conclusions

Introduction

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Deposition of radionuclides on out-of-core surfaces leads to:

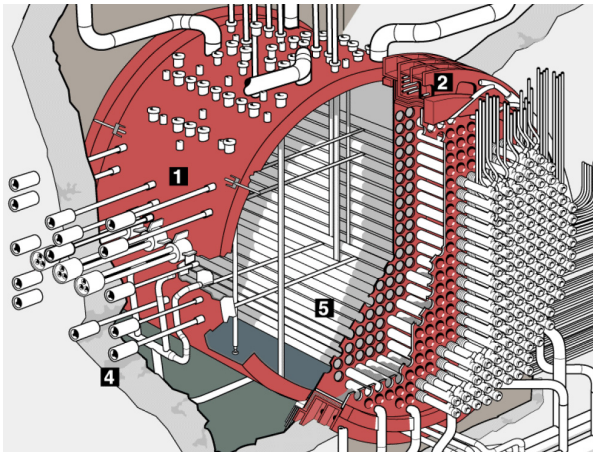
a) growth of station gamma fields, and

b) effect on worker dose

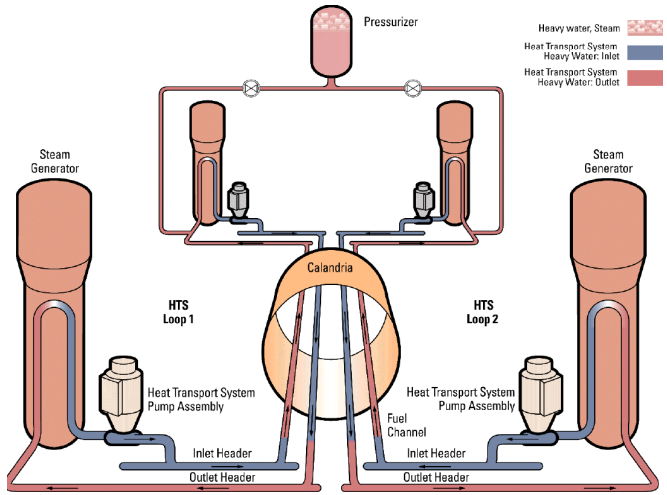
Major contributors to external radiation fields around various station components:

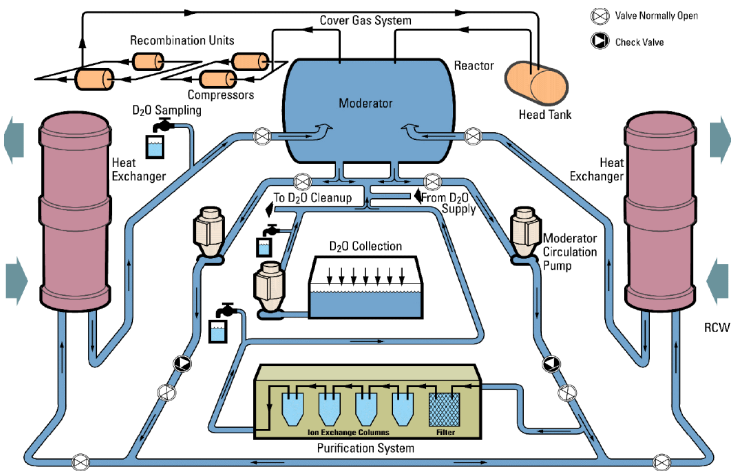
- Activated transition metals: ^{60}Co, ^{58}Co, ^{51}Cr, ^{54}Mn, ^{59}Fe
- Radioantimony group: ^{122}Sb, ^{124}Sb, ^{125}Sb
- Nb/Zr group: ^{94}Nb, ^{95}Nb, ^{95}Zr
- Fission product group: ^{137}Cs, ^{140}Ba/^{140}La, ^{103}Ru, ^{106}Rh

CANDU Station

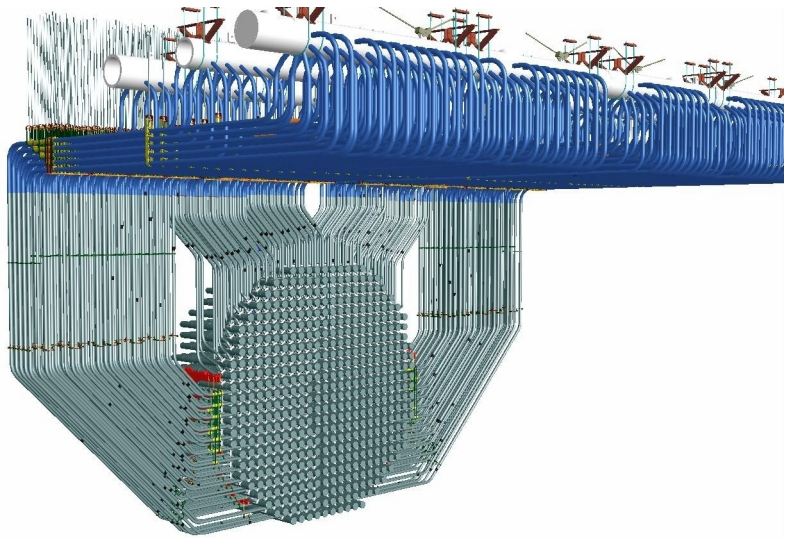


Primary Heat Transport System





Moderator System



Outage Activity Transport Monitoring

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Objective

Identification of radionuclides responsible for observed radiation field and their specific activities

Approach

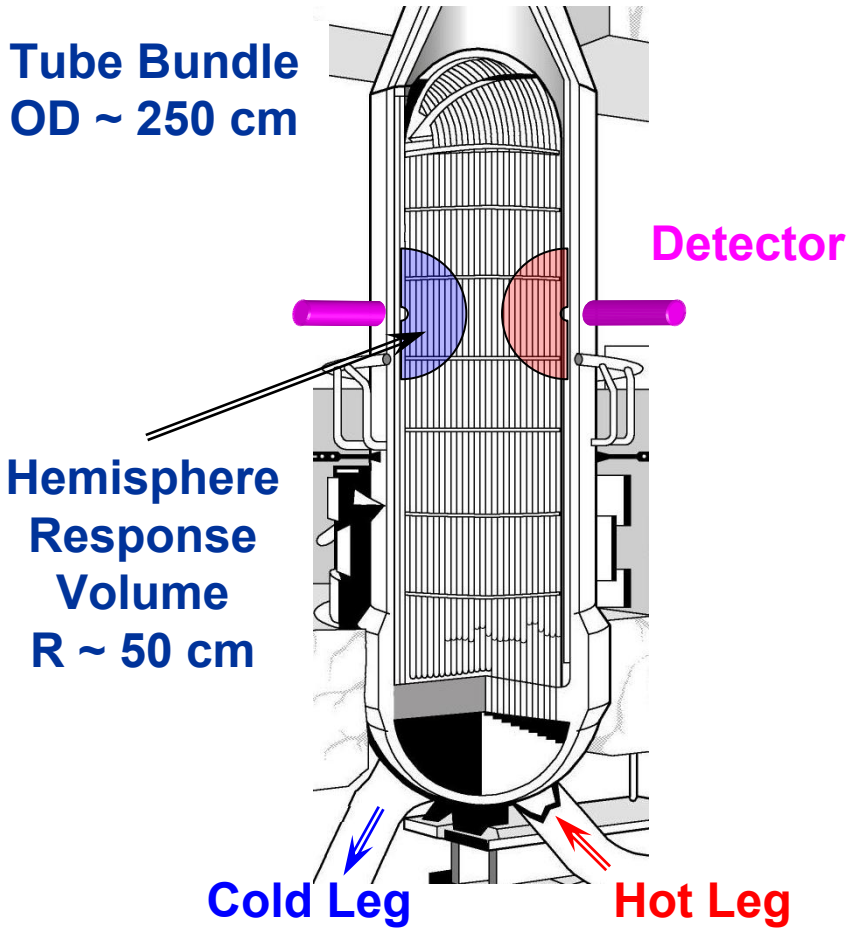
In-situ gamma spectroscopy and dose rate measurements coupled with interpretation method

Approximations

- **Radionuclide identification based on photopeak in the measured gamma spectrum**
- **Reactor component – a homogeneous structure with uniformly distributed radionuclides.**

OATM Methodology

Example for a Steam Generator – Darlington NGS



Modeling

- ✓ Representative structure
- ✓ Sensitivity analysis
- ✓ Measurement conditions

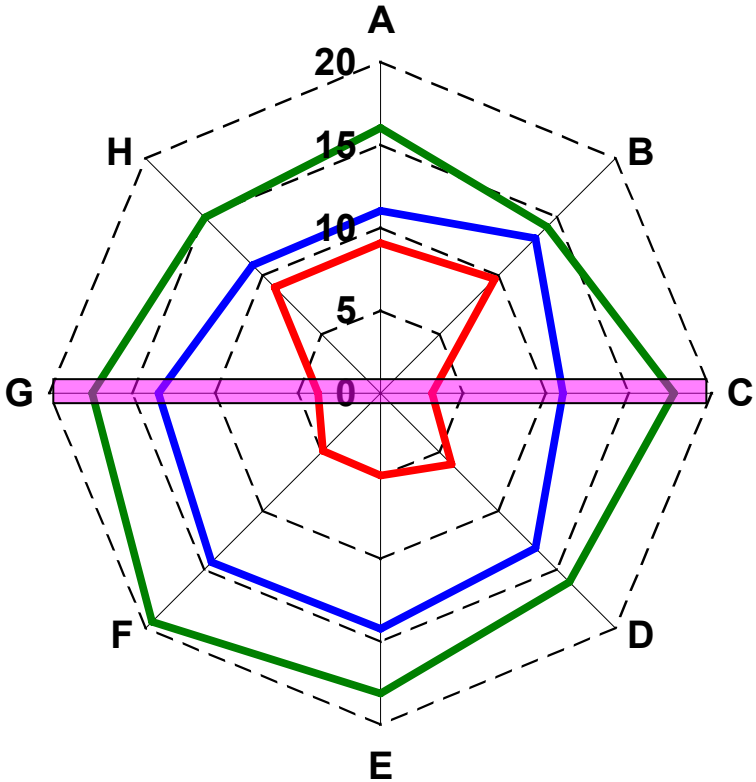
Measurements

- ✓ Dose rate distribution
- ✓ Spectroscopy data

Analysis

- ✓ Specific activities
- ✓ Dose rate
- ✓ Measured/Calculated

Steam Generator – Dose Rate Distributions

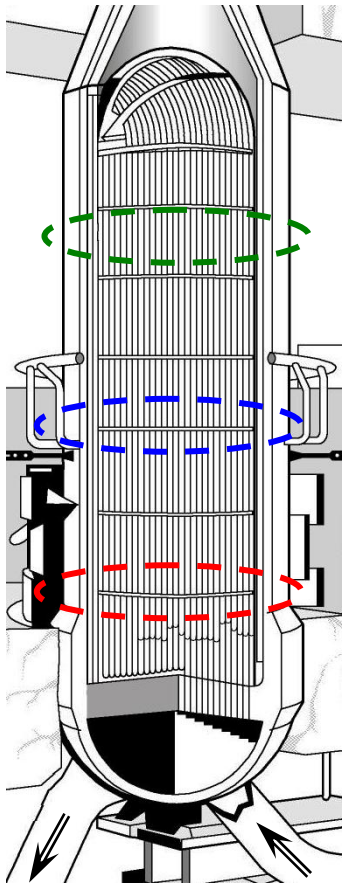


Levels above the T/S

— 1.1 m

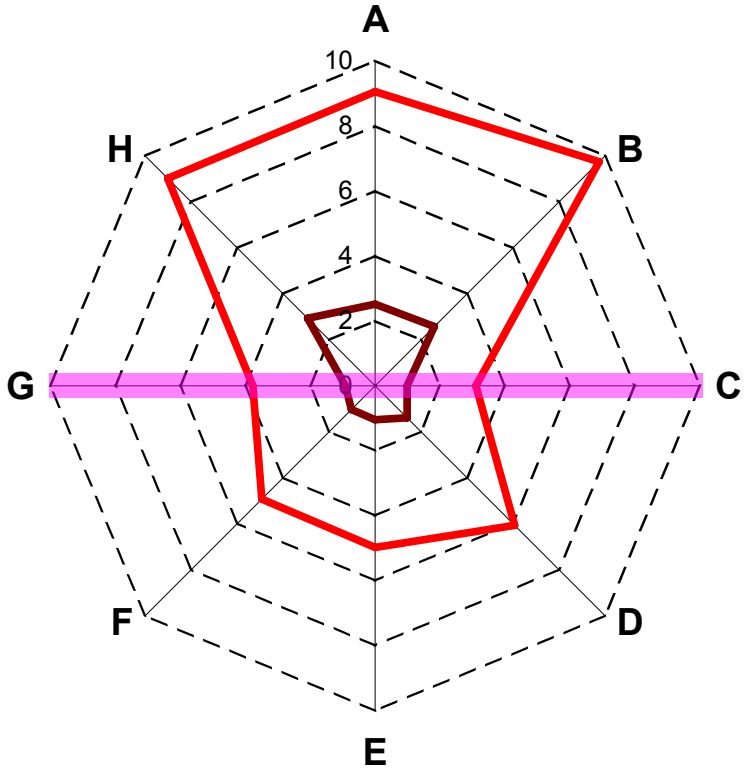
— 4.5 m

— 6.5 m



Cold Leg Hot Leg

All contact readings in mrem/h



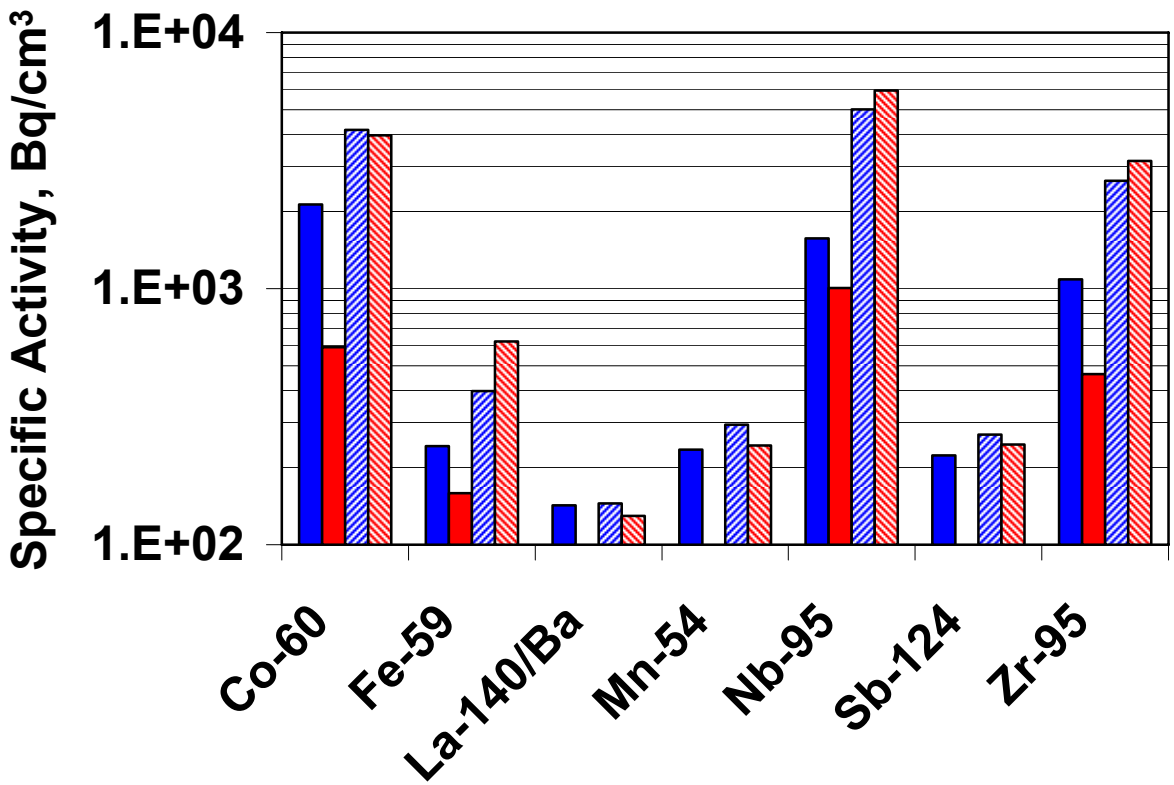
Divider Plate

SG State

— Empty

— Full

Steam Generator – Radionuclides



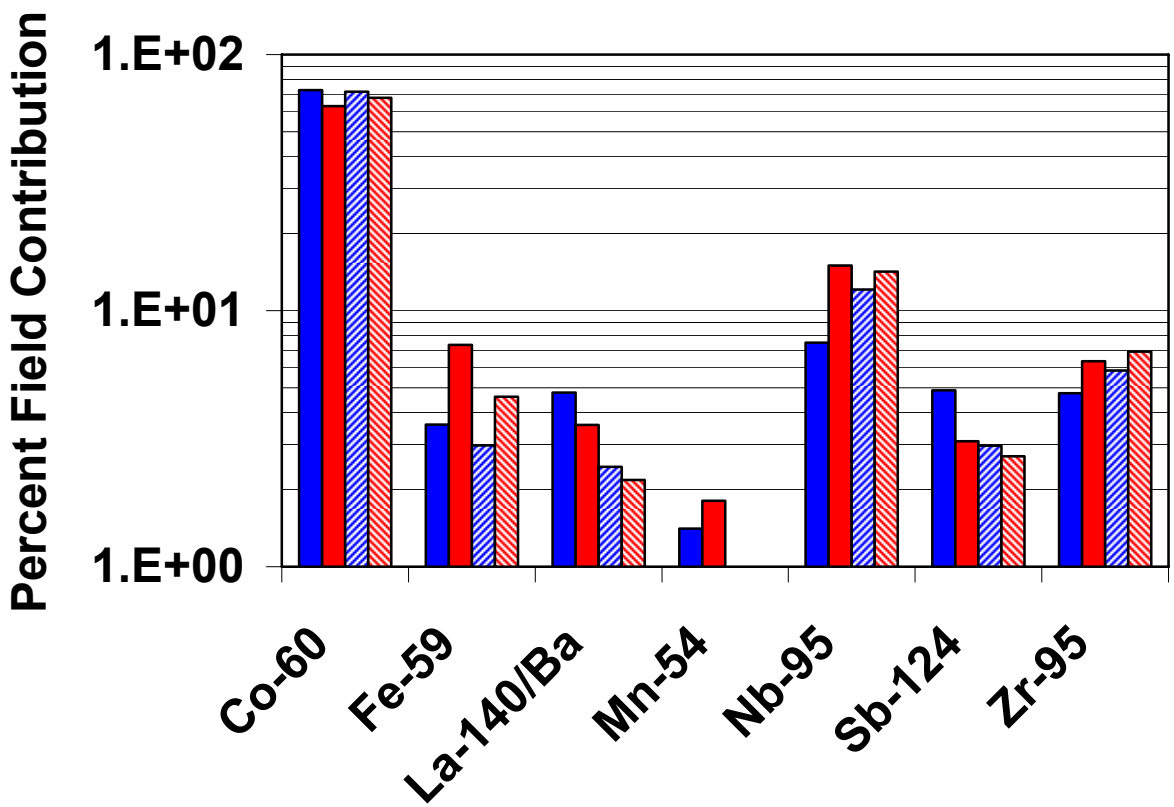
Darlington / Unit 1

SG # 4

SG state – Full

Elev.	Cold Leg	Hot Leg
117		
122		

Steam Generator – Dose Contributors



Darlington / Unit 1

SG # 4

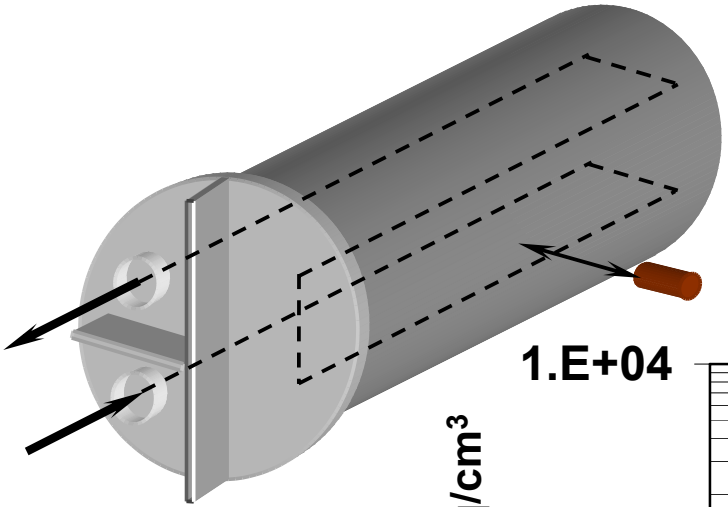
SG state – Full

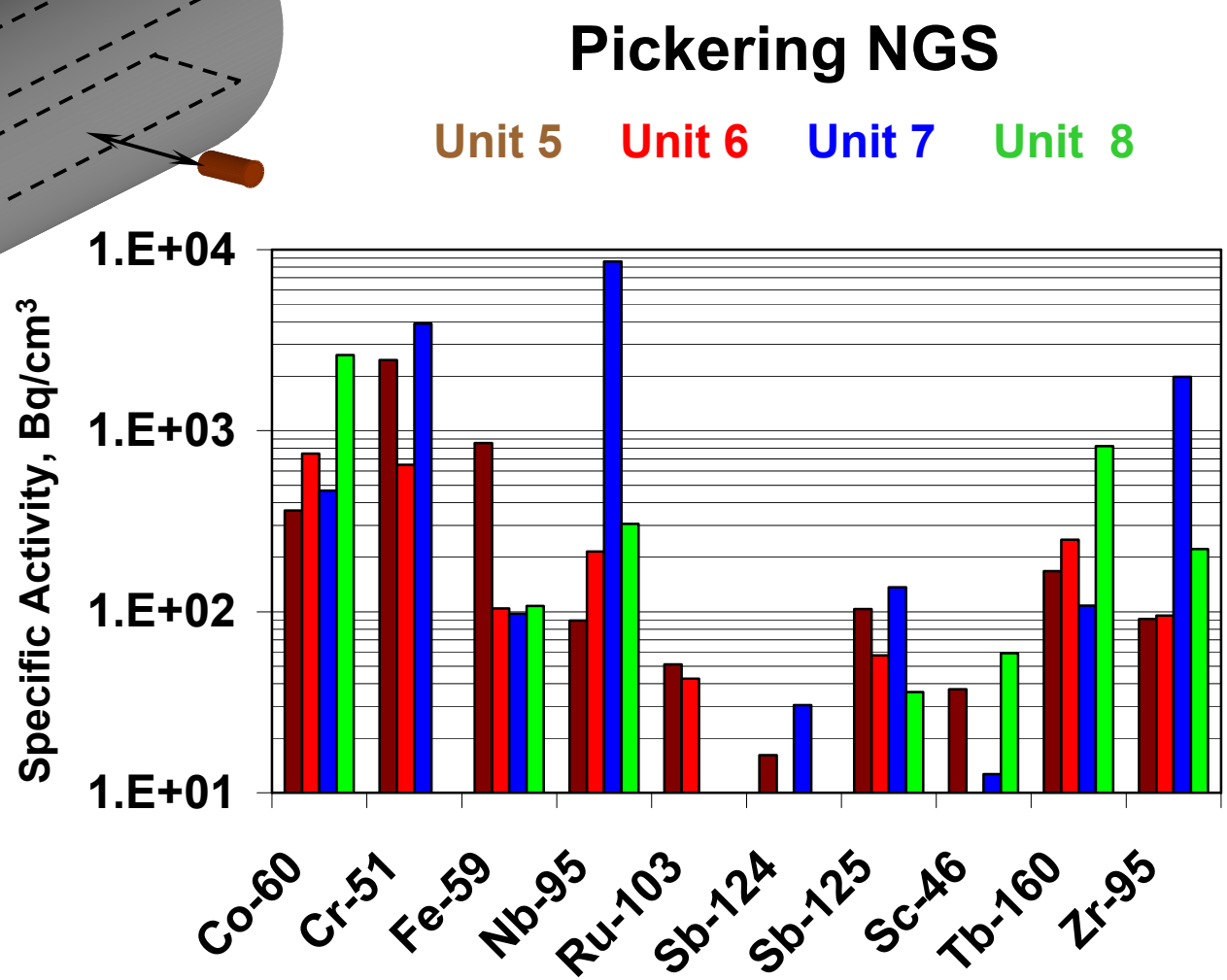
Elev.	Cold Leg	Hot Leg
117		
122		

OATM Methodology – Summary

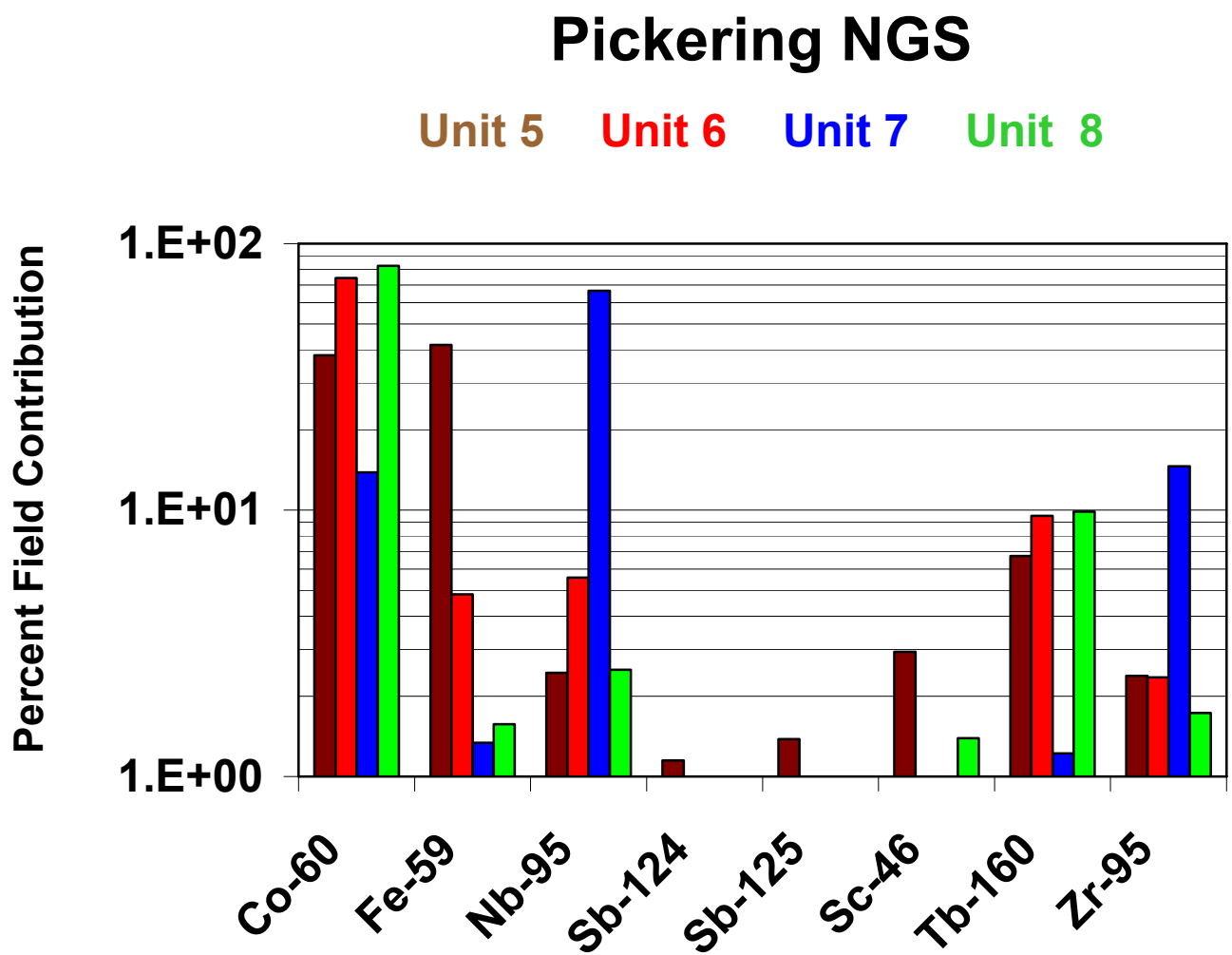
Parameter	OATM Methodology	
	Previous	Proposed
Dose Contribution	Yes	Yes
Specific Activity	No	Yes
Dose Rate Distribution	No	Yes
Self-Check Ability	No	Yes

Moderator Heat Exchanger – Radionuclides

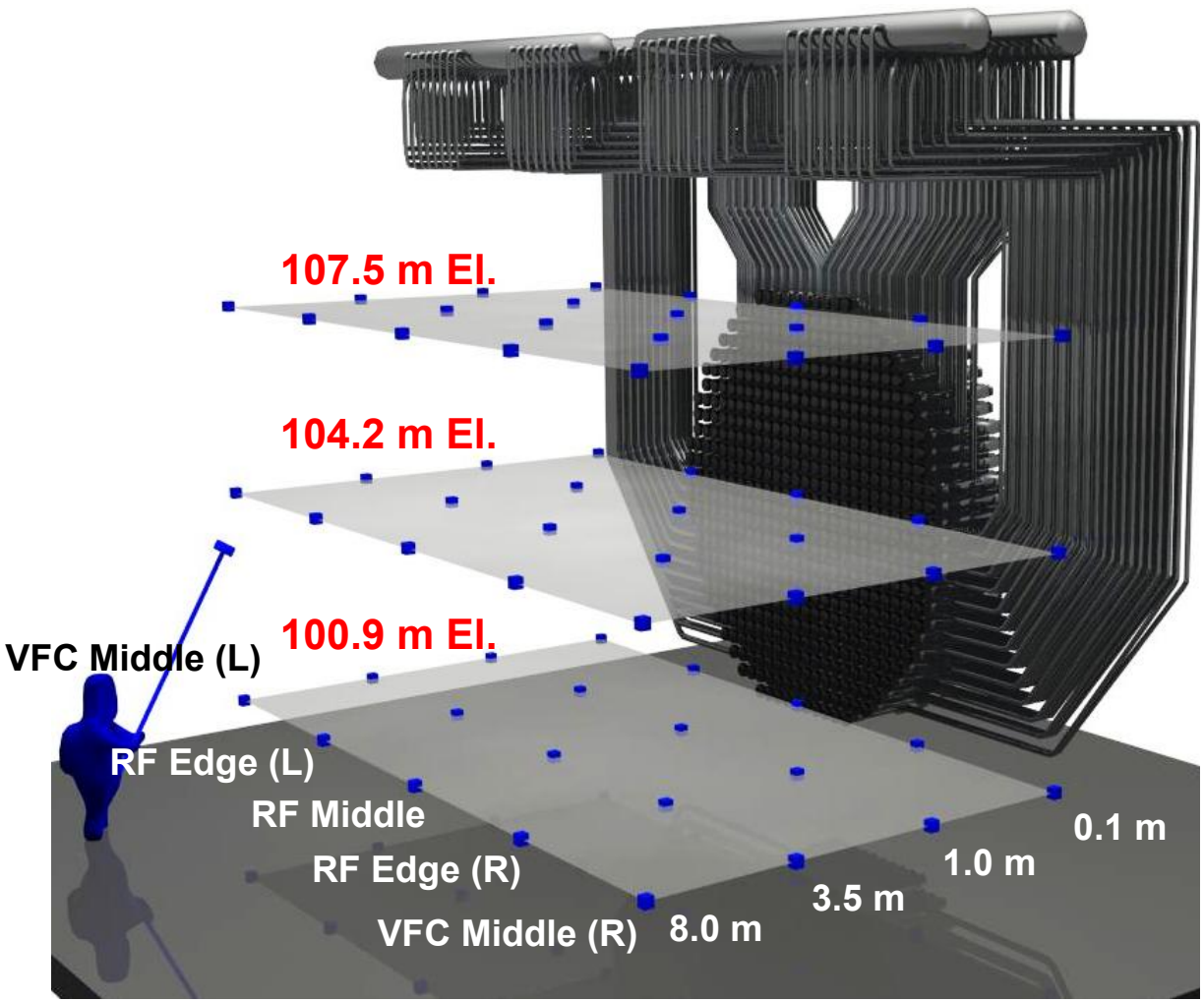




Moderator Heat Exchanger – Dose

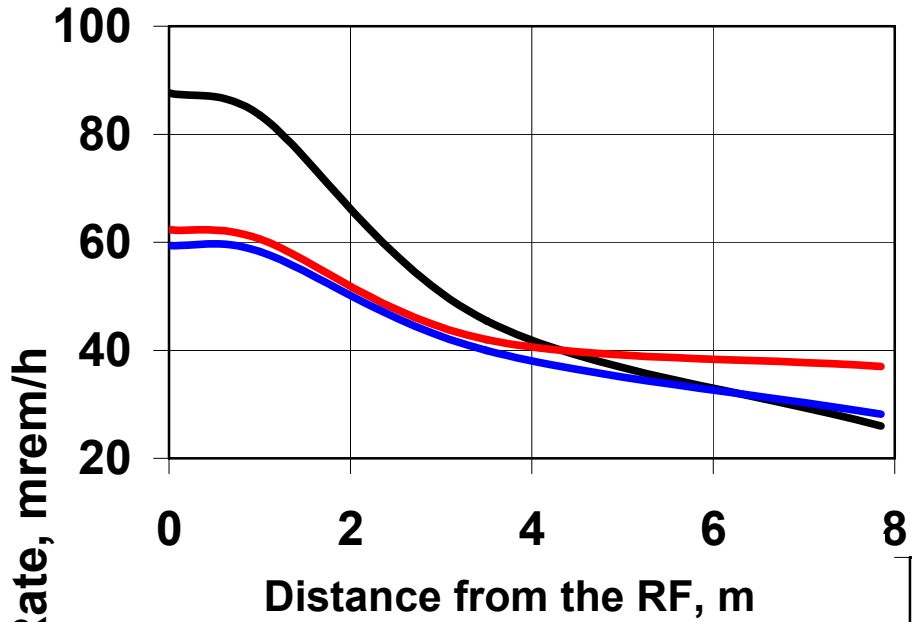


Surveys in the Reactor Vault



VFC – Vertical Feeder Cabinet; RF – Reactor Face

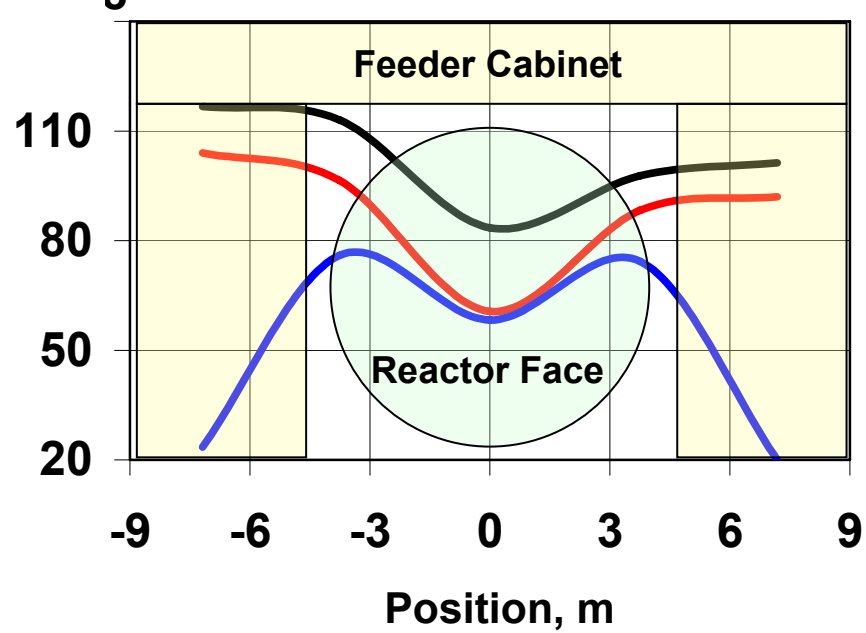
Reactor Vault – Dose Rate Distributions



Darlington NGS Unit 1

West Reactor Face
Row / Elevation

A / 107.5
M / 104.2
Y / 100.9

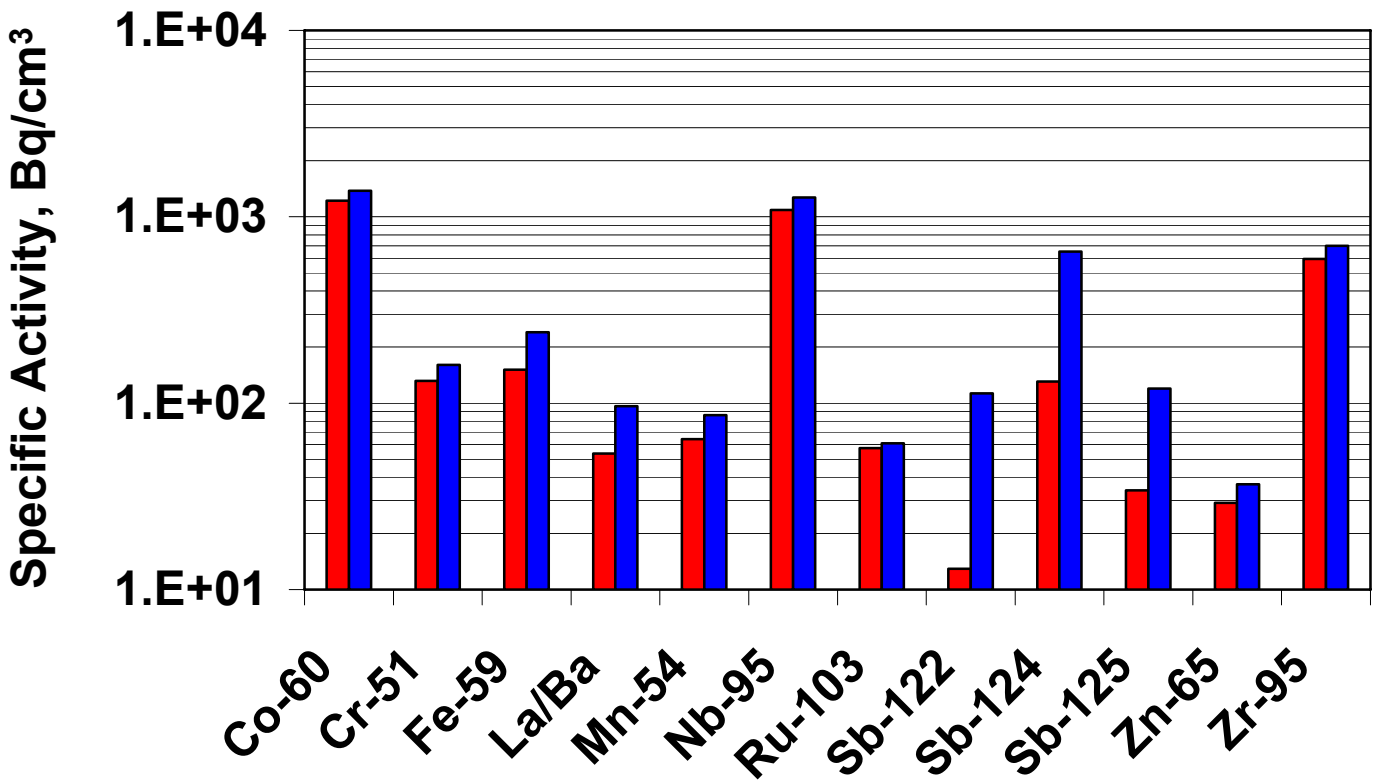


Reactor Vault – Radionuclides

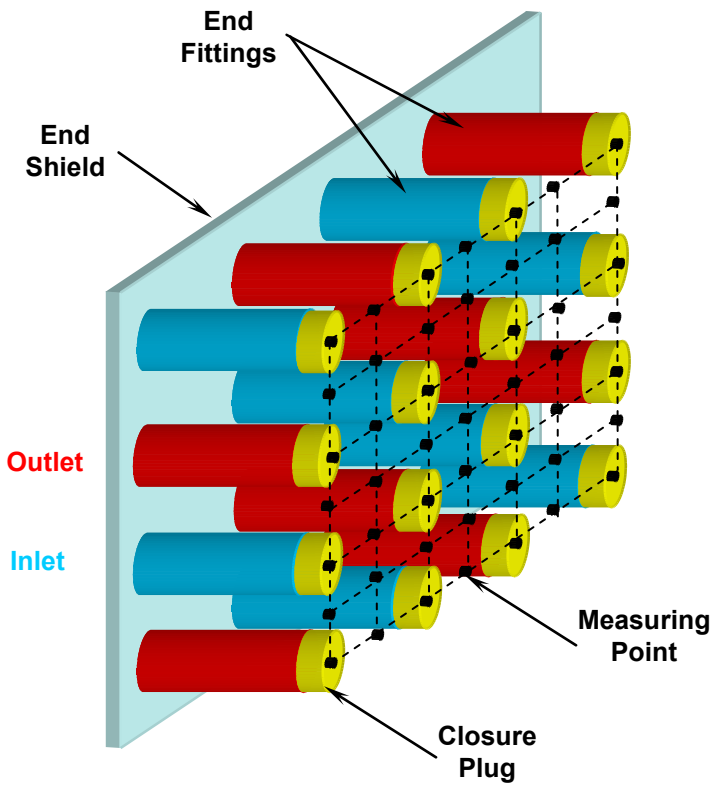
Darlington NGS Unit 1

Reactor Face

East **West**



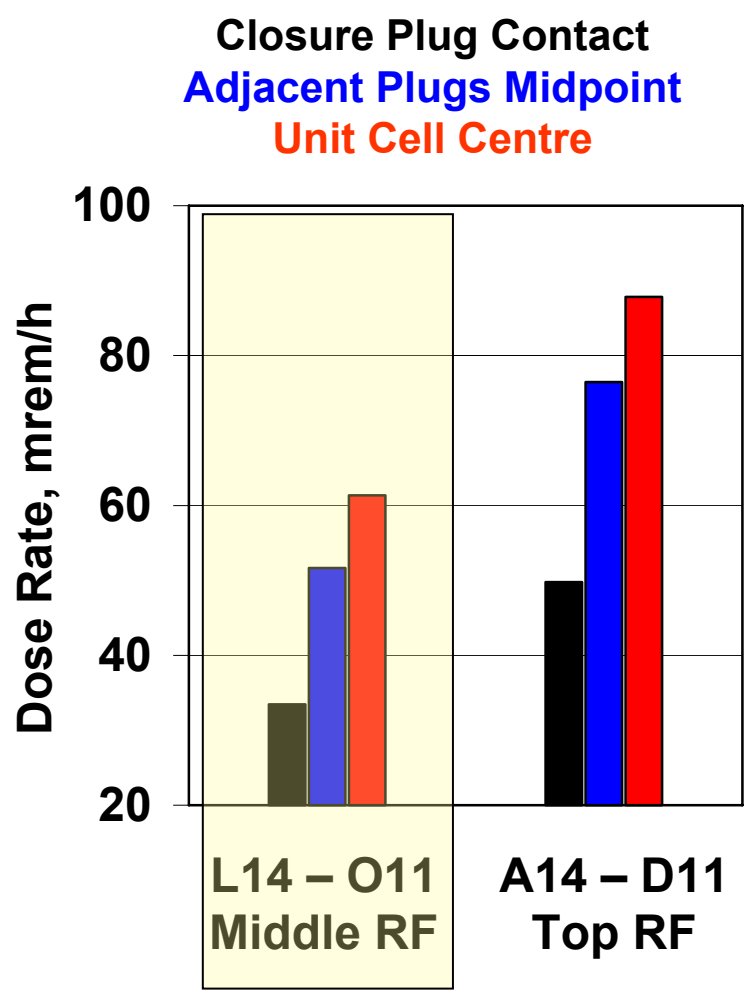
4 x 4 End Fitting Cell Survey



A14 – D11

Cell is bounded by rows A & D and columns 14 & 11

Darlington Unit 1 -- West Reactor Face



Radiation Field in the Reactor Vault

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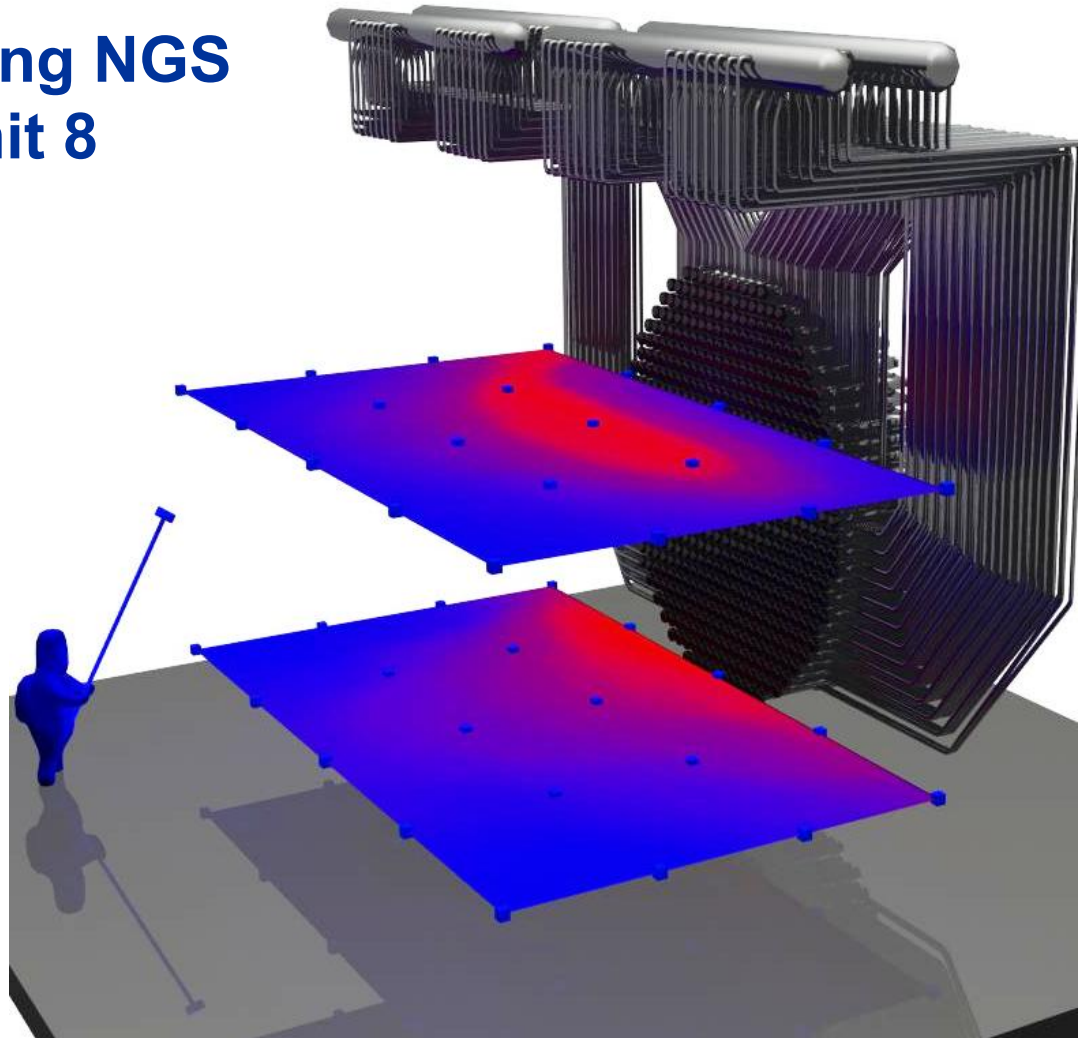
Pickering NGS
Unit 8



Radiation Field across the Reactor Face

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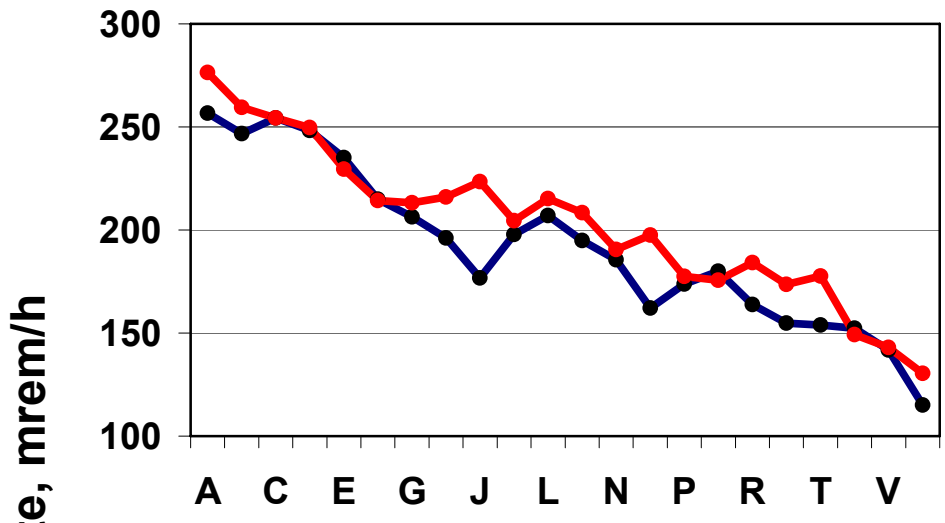
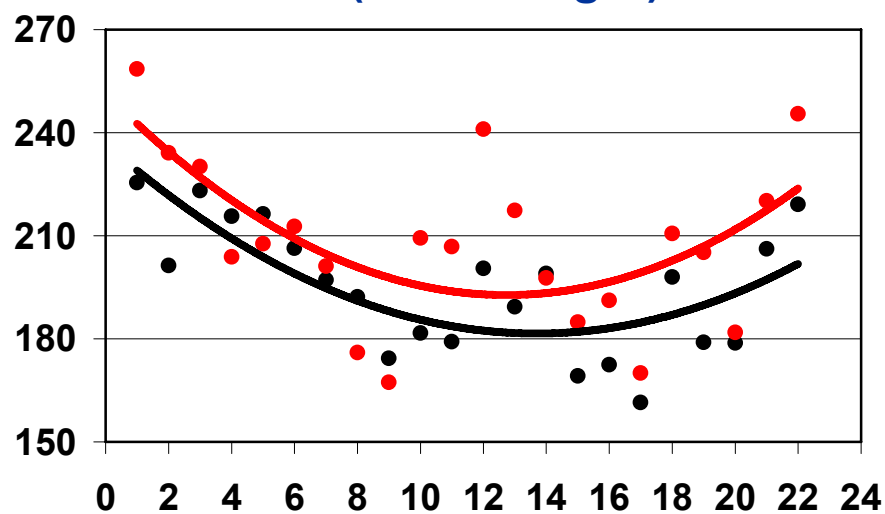
Pickering NGS Unit 8

West Face —
East Face —

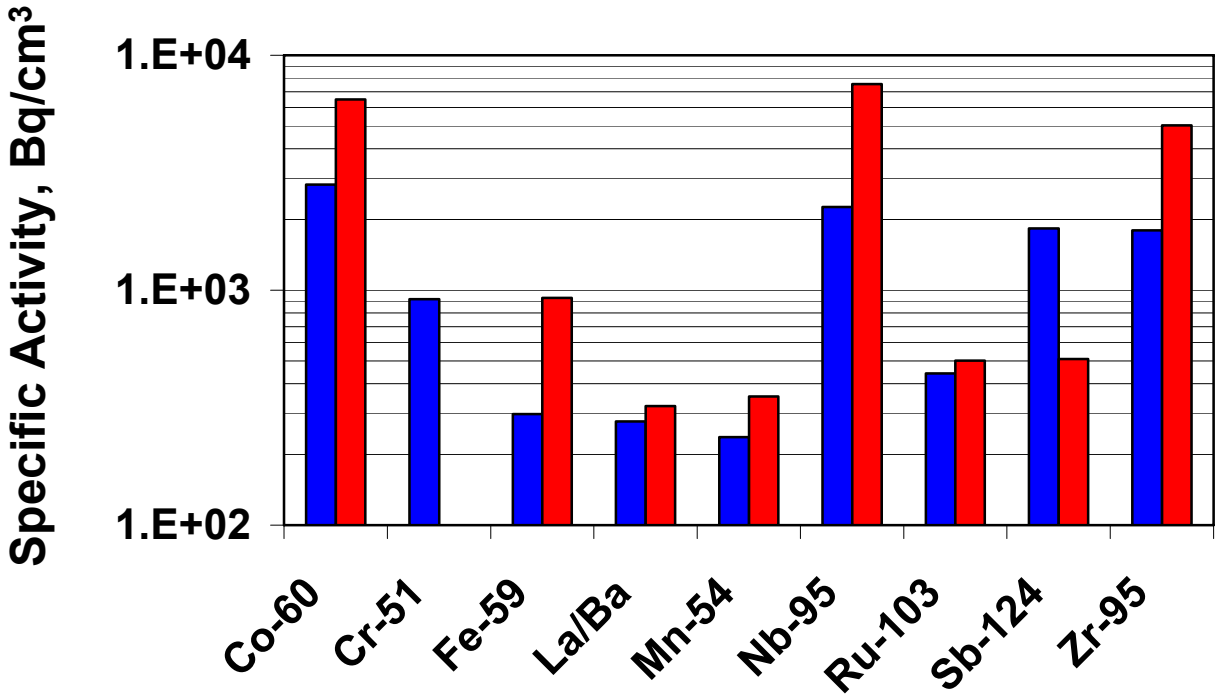


Variation across Rows (Top to Bottom)

Variation across Columns (Left to Right)



Reactor Face – Radionuclides



Pickering NGS

Unit 5

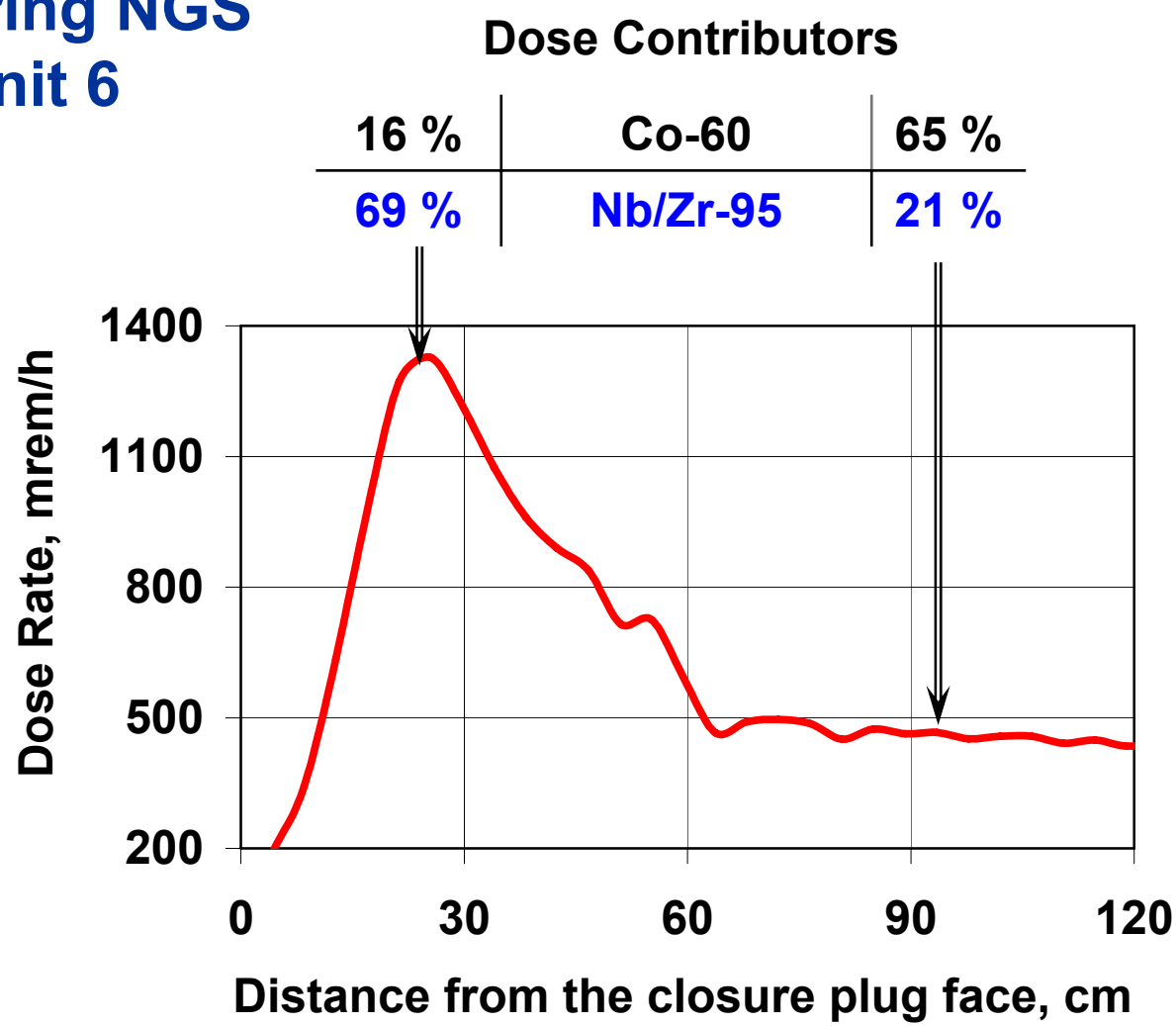
&

Unit 8

Location – 6 m from RF		Unit 5	Unit 8
Dose Rate mrem/h	Calculated	46	89
	Measured	55	100
Ratio C/M		0.8	0.9

Inlet End Fitting Survey

Pickering NGS Unit 6



Bleed Cooler Radiation Field

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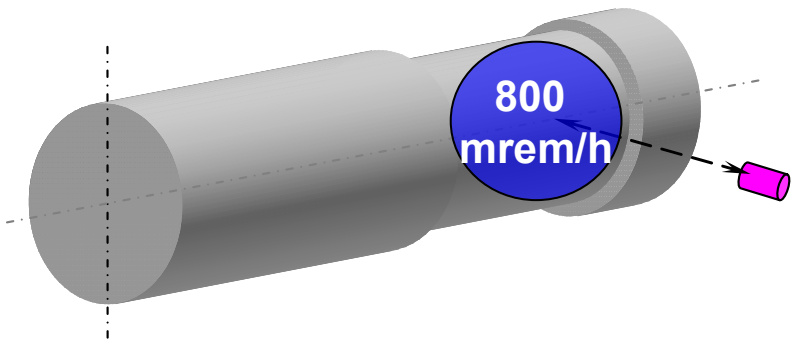
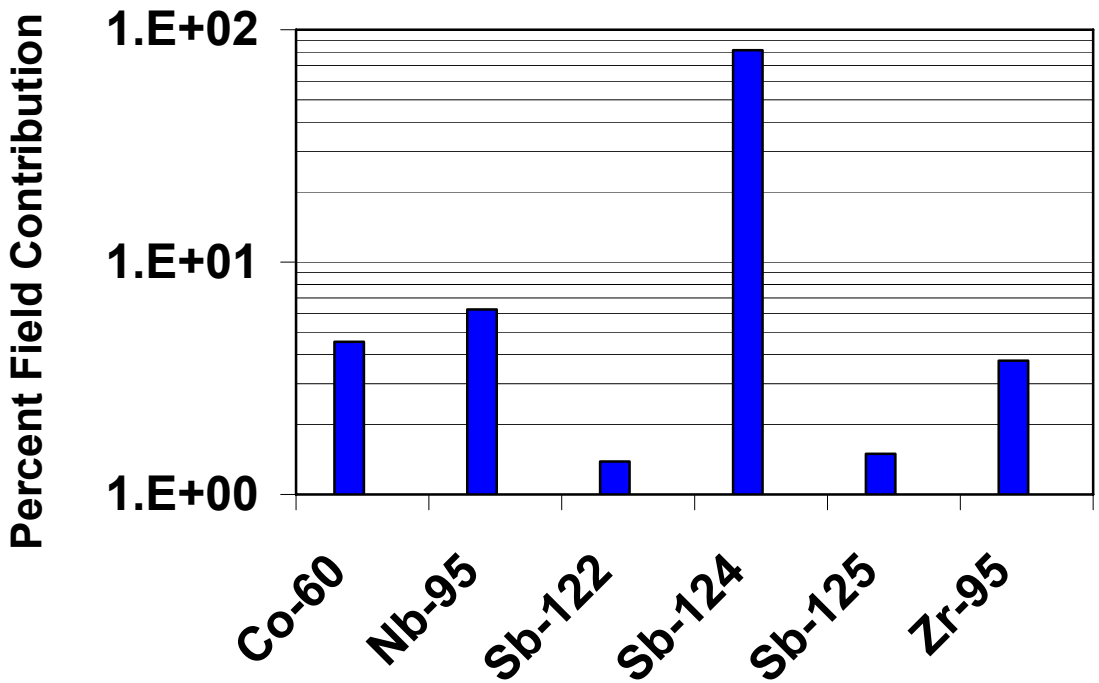
Darlington NGS Unit 1





Abnormally High Cs-137 Levels

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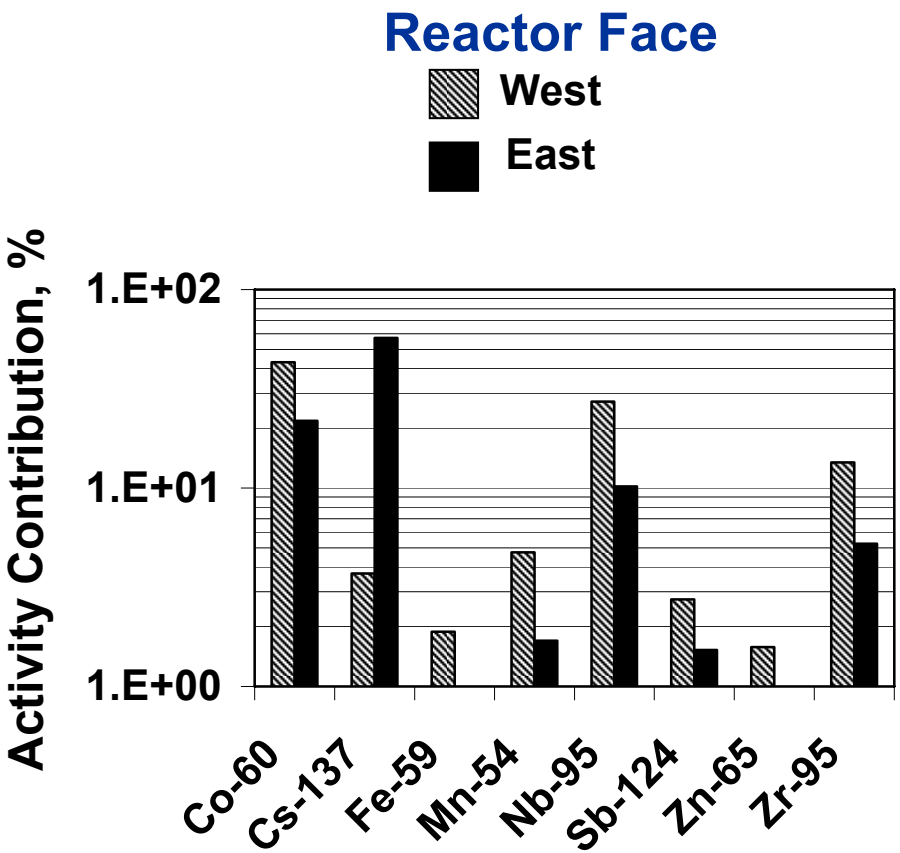
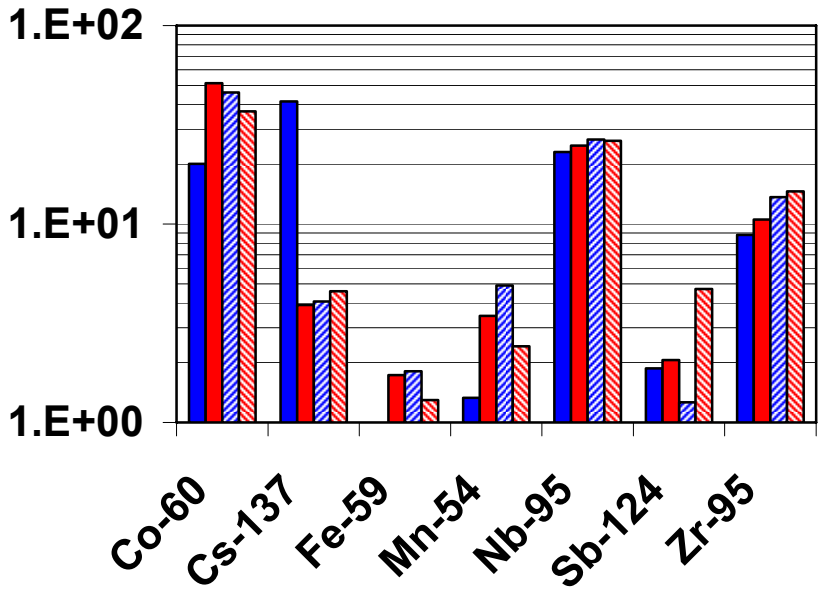
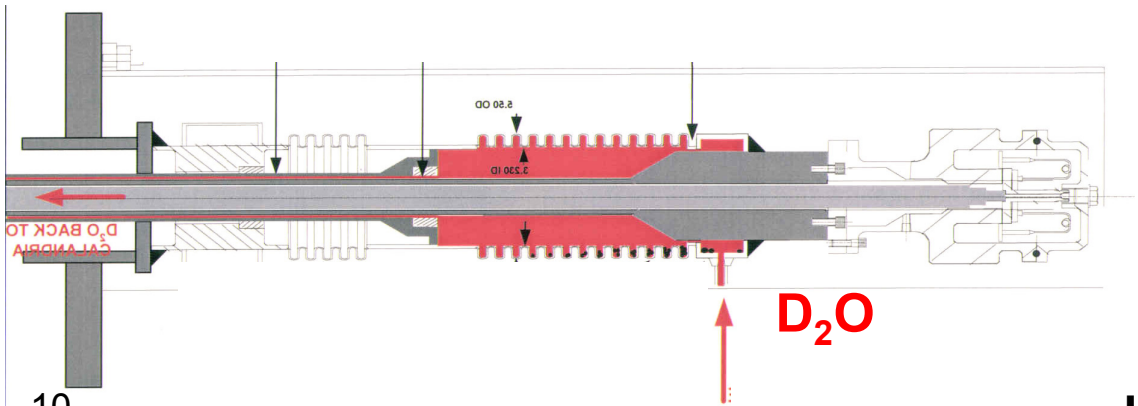
Pickering NGS Unit 1

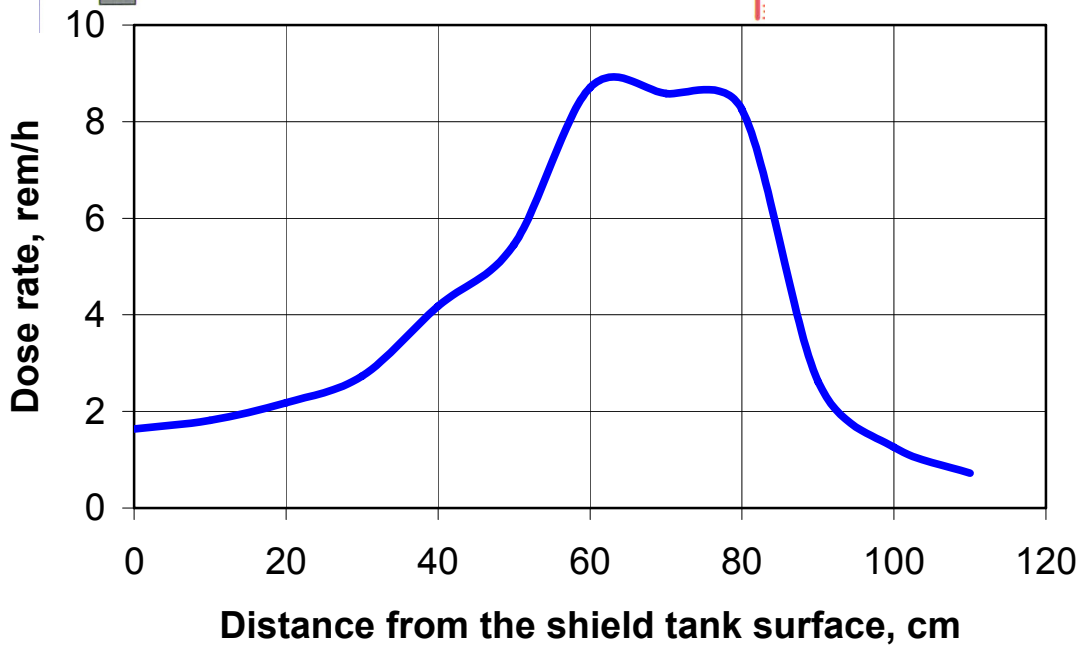


Bank	SG	Cold Leg	Hot Leg
East	8		
West	6		



Horizontal Flux Detector





Darlington NGS

Units 1 & 2

SDS2 Bunker

Initial Condition

HFD dose rate
~ 50 rem/h (contact)

Gamma Scan Survey

- **Co-60**
- **Activity profile**

Result

Optimized shielding

Conclusions

- ✓ OATM surveys provide comprehensive interpretation of observed radiation fields
- ✓ Make consistent comparisons between survey data for various components, reactor units & stations
- ✓ Use radionuclide information to estimate effectiveness of source term reduction technologies
- ✓ Radionuclide profiles yield basic information to optimize shielding, and provide procedures & reduction of worker radiation dose.