Characterization of Radiation Fields for Dose Reduction During Outages at Darlington Nuclear Station

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Presentation Flow

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Toronto, Canada
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OATM Surveys for All CANDU Stations in Ontario

Background

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 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

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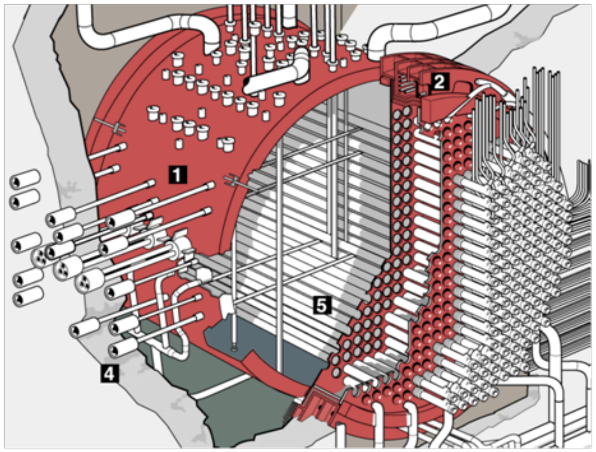
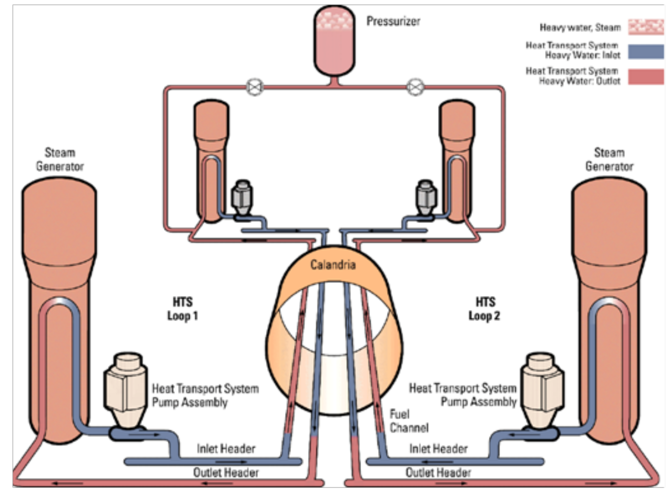
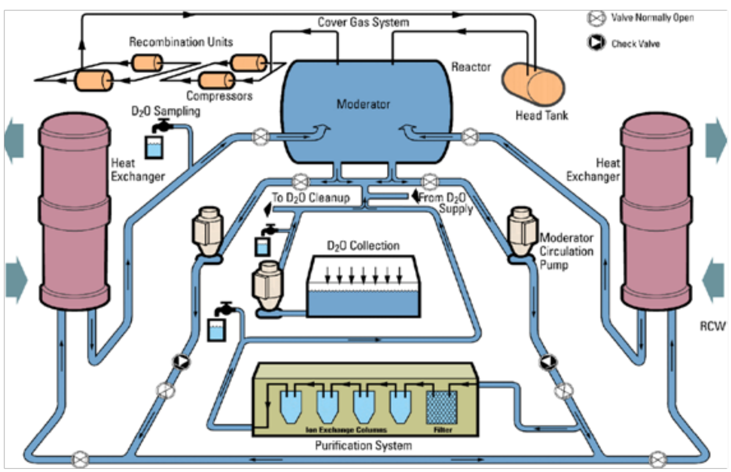
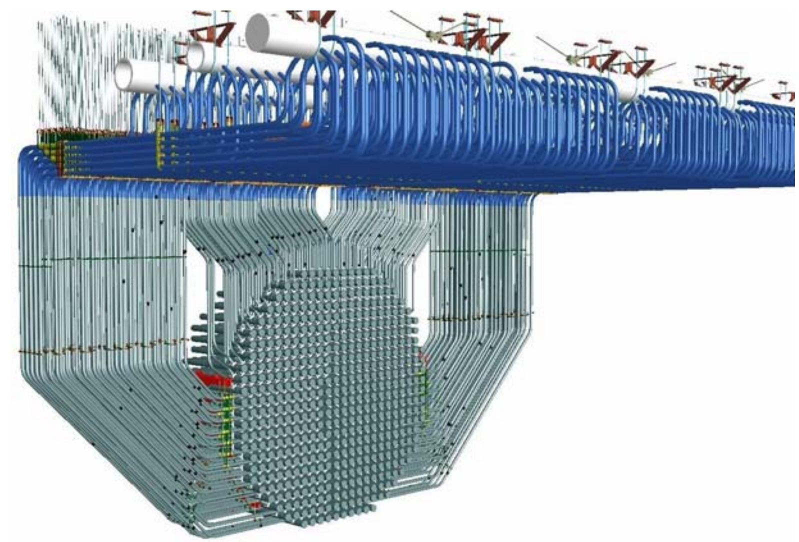


Primary Heat Transport System







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 measured gamma spectrum
- Interpretation method based on radiation field model of reactor component
- Radiation field simulated by MICROSHIED (single-source scene) / MERCURAD (multi-source scene)

Why OATM Surveys are Required

Effective way to meet the ALARA principle:

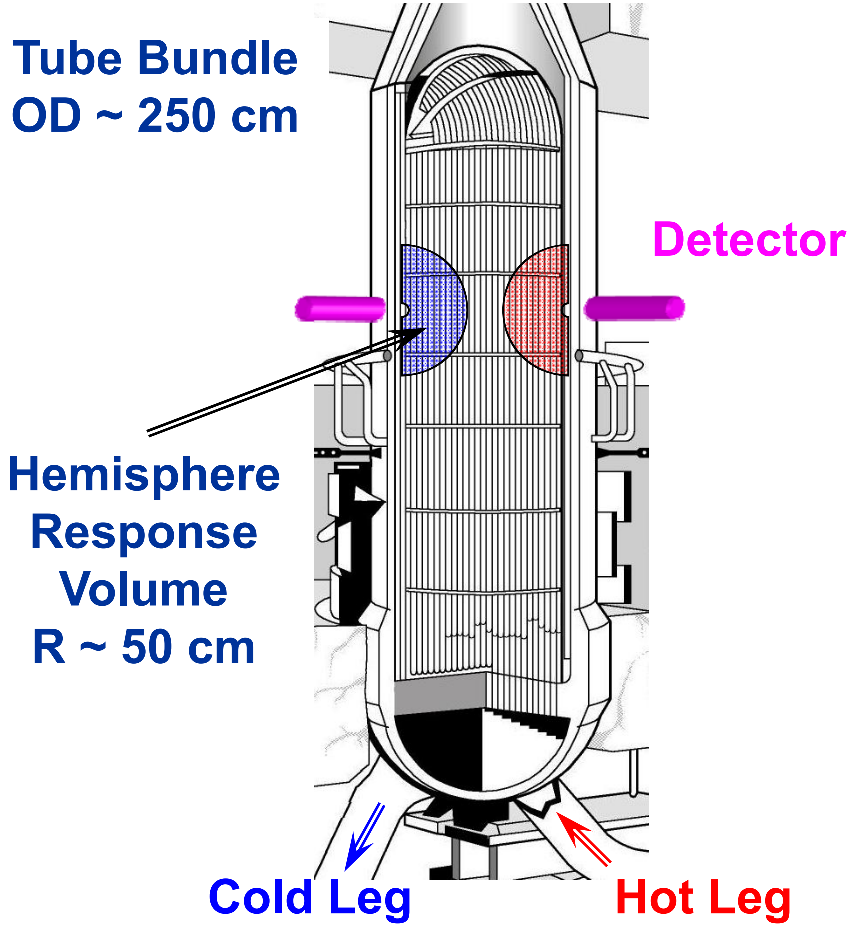
- Short-term strategy – Minimize worker dose from existing radiation sources;
- Long-term Strategy – Develop and put in place radiation source term reduction technologies

OATM Surveys can Provide:

- Radiation job optimization with regard to radioprotections and cost;
- Evaluation of effectiveness of the radiation source term reduction technologies

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

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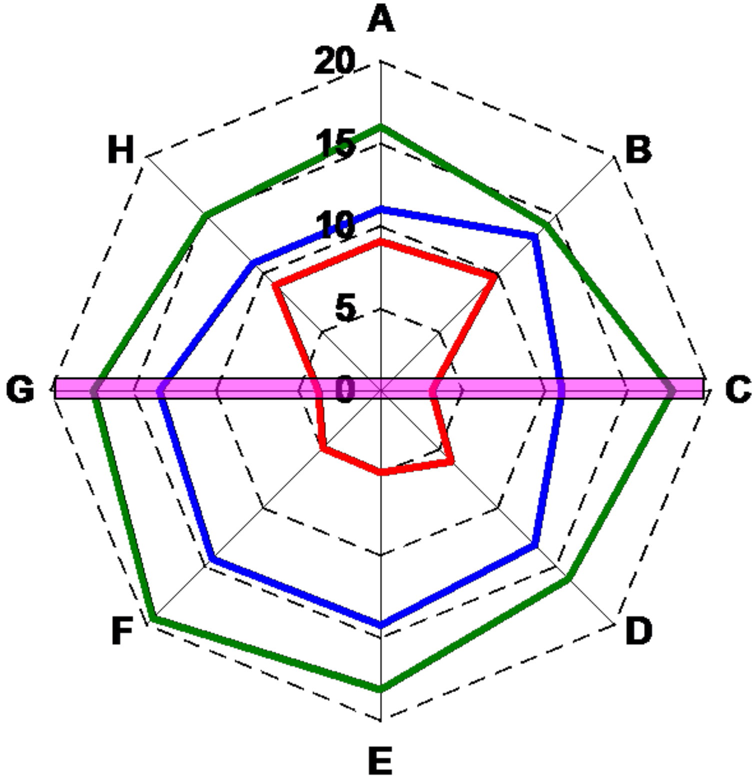
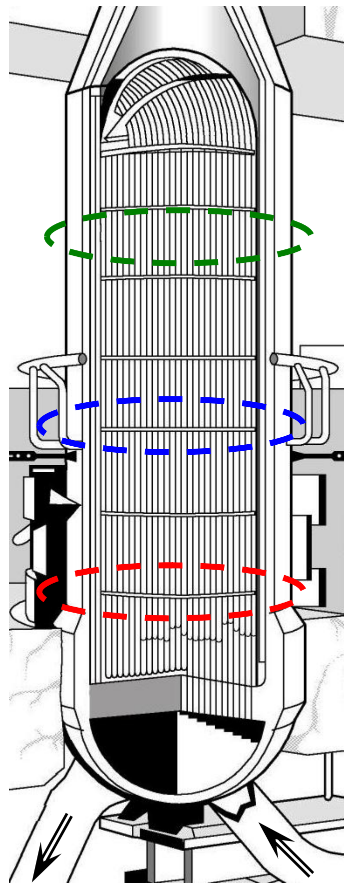


Levels above the T/S

— 1.1 m

— 4.5 m

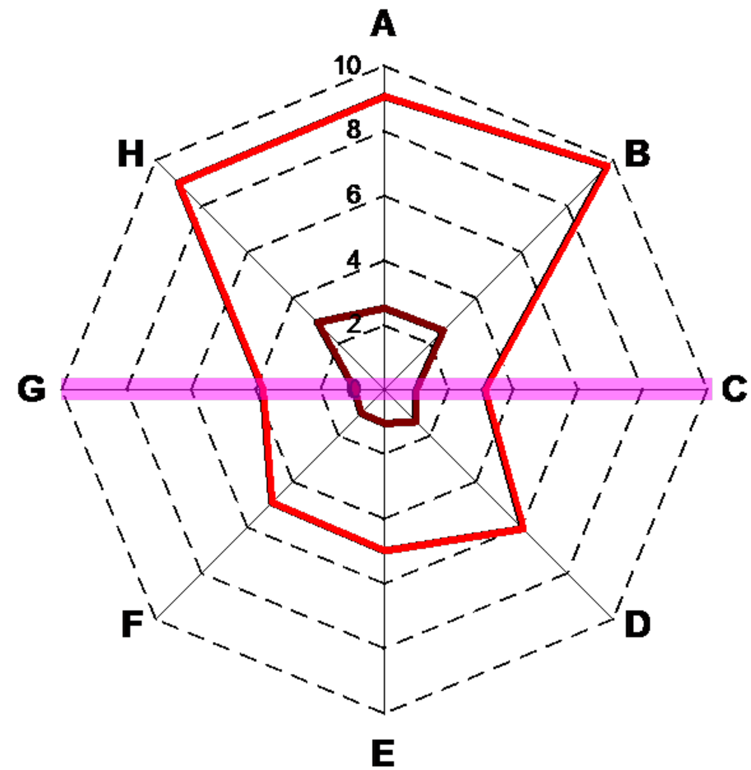
— 6.5 m



Cold Leg

Hot Leg

All contact readings in mrem/h



Divider Plate

SG State

— Empty

— Full

Steam Generator – Radionuclides

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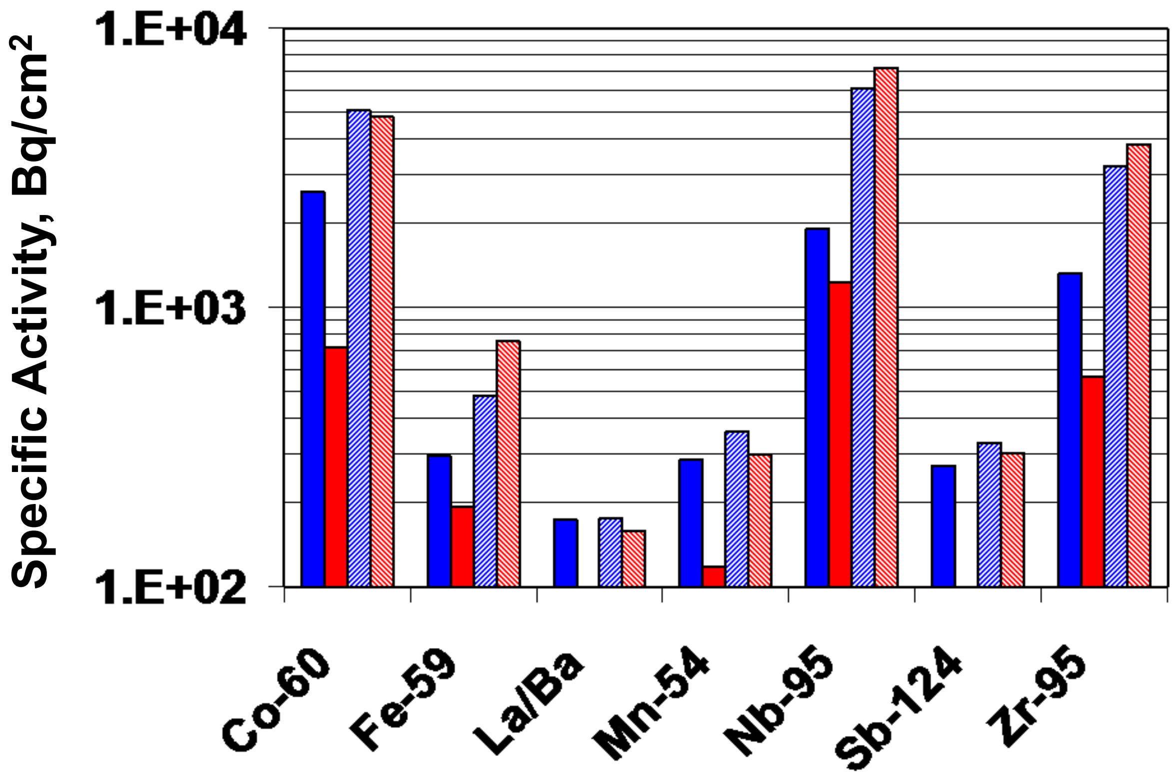


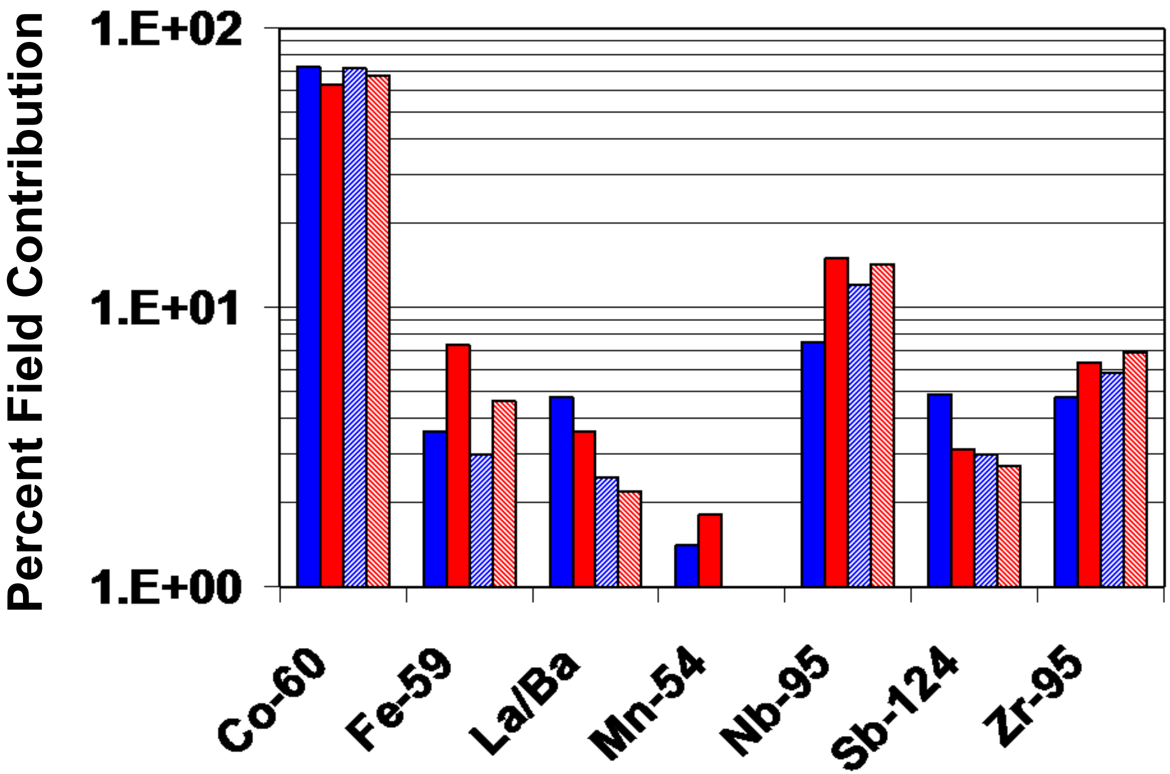
Darlington / Unit 1

SG # 4

SG state – Full

Elev.	Cold Leg	Hot Leg
117		
122		

Steam Generator – Dose Contributors



Darlington / Unit 1

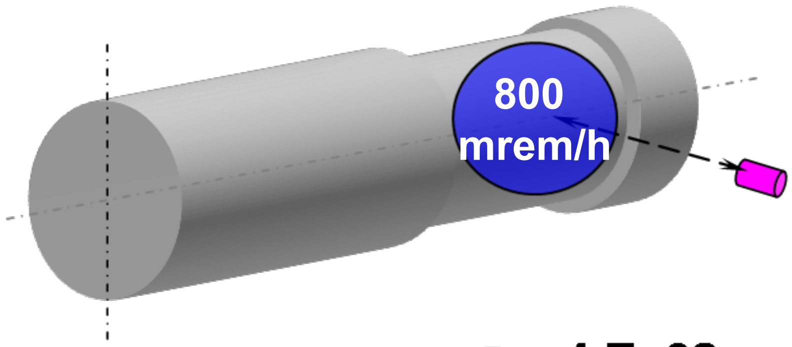
SG # 4

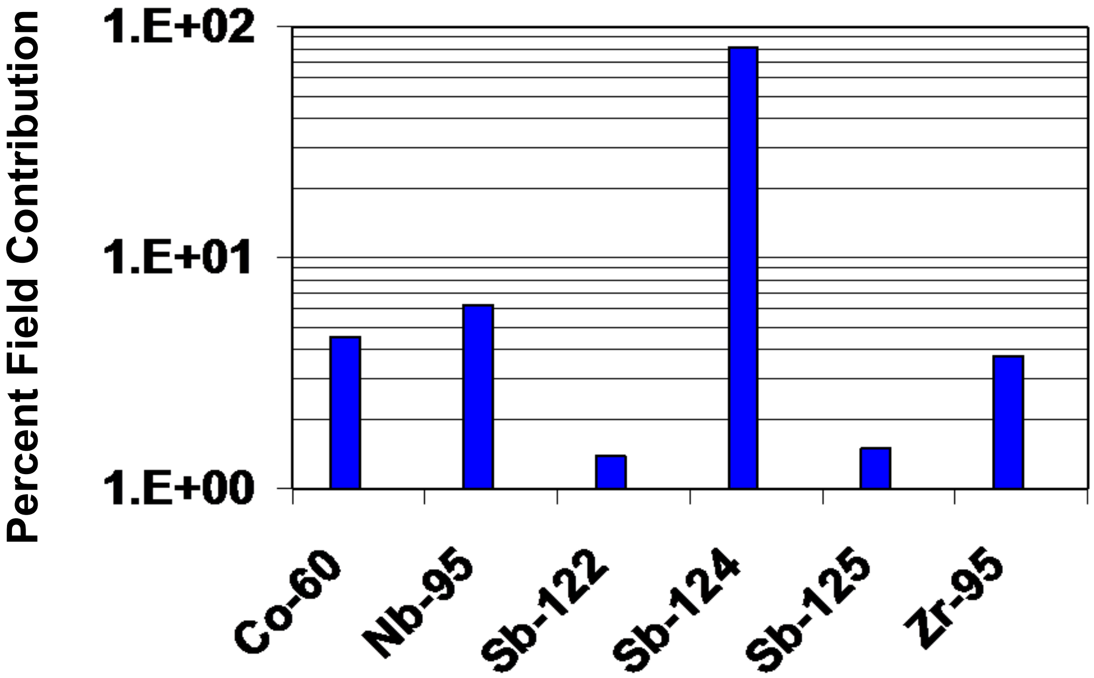
SG state – Full

Elev.	Cold Leg	Hot Leg
117		
122		

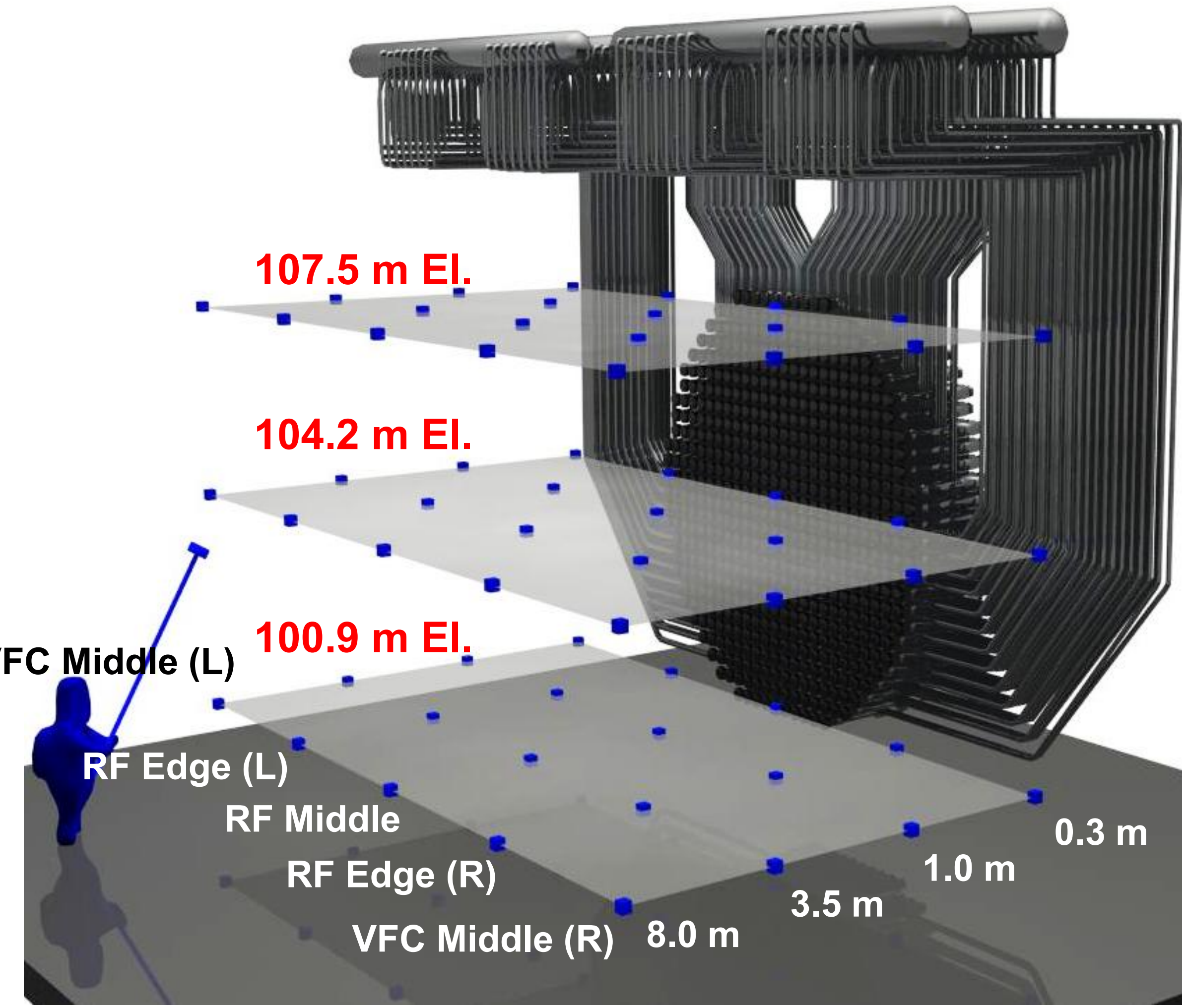
Bleed Cooler Radiation Field

Darlington NGS
Unit 1



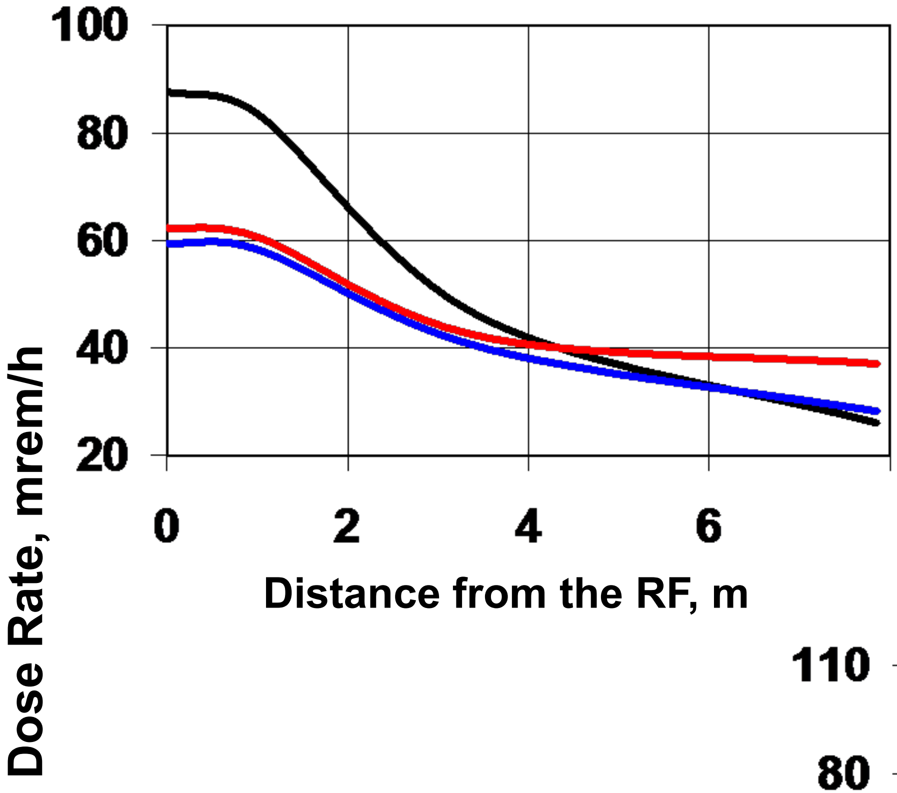


Surveys in the Reactor Vault



VFC – Vertical Feeder Cabinet; RF – Reactor Face

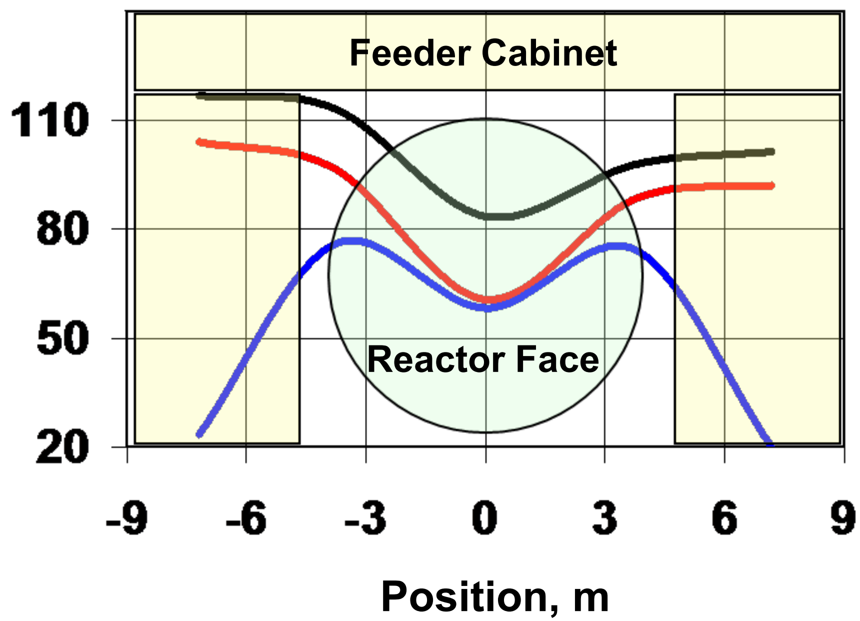
Reactor Vault – Dose Rate Distributions



D811 Outage

Row / Elevation

A / 107.5
M / 104.2
Y / 100.9

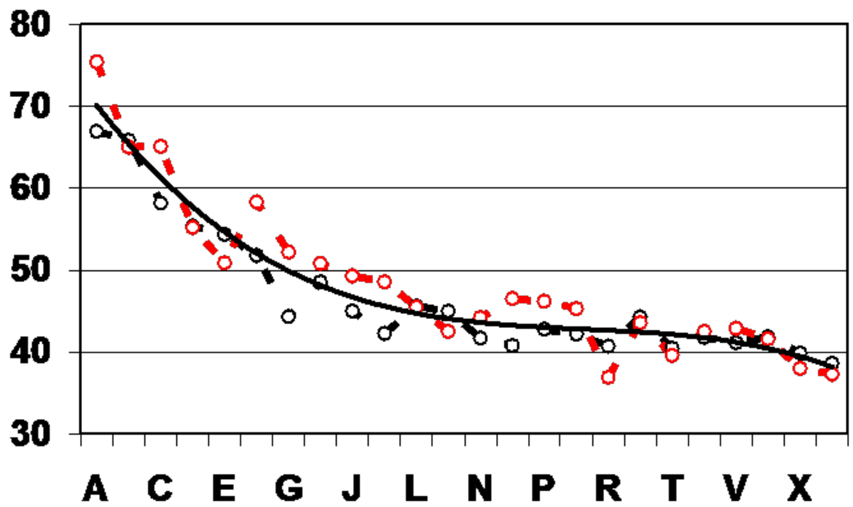


Radiation Field across the Reactor Face

D811 Outage

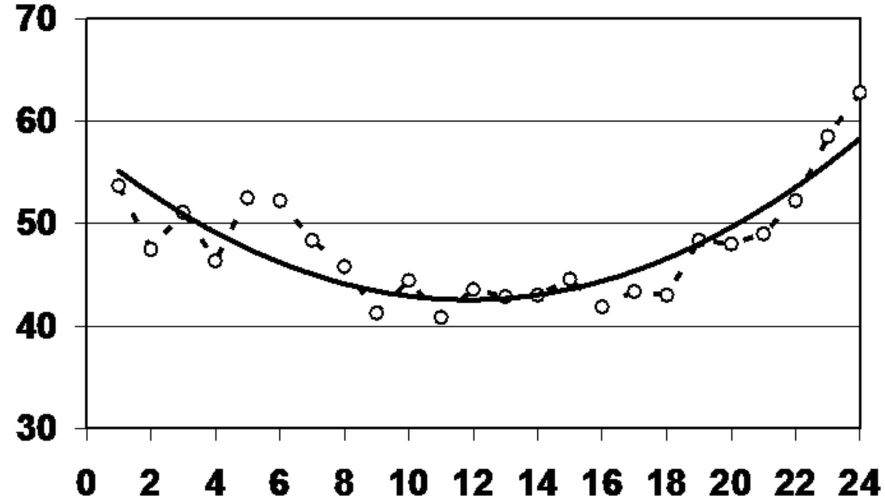
East Face
West Face

Dose Rate, mrem/h



Variation across Rows (Top to Bottom)

Variation across Columns (Left to Right)



Reactor Vault – Radionuclides

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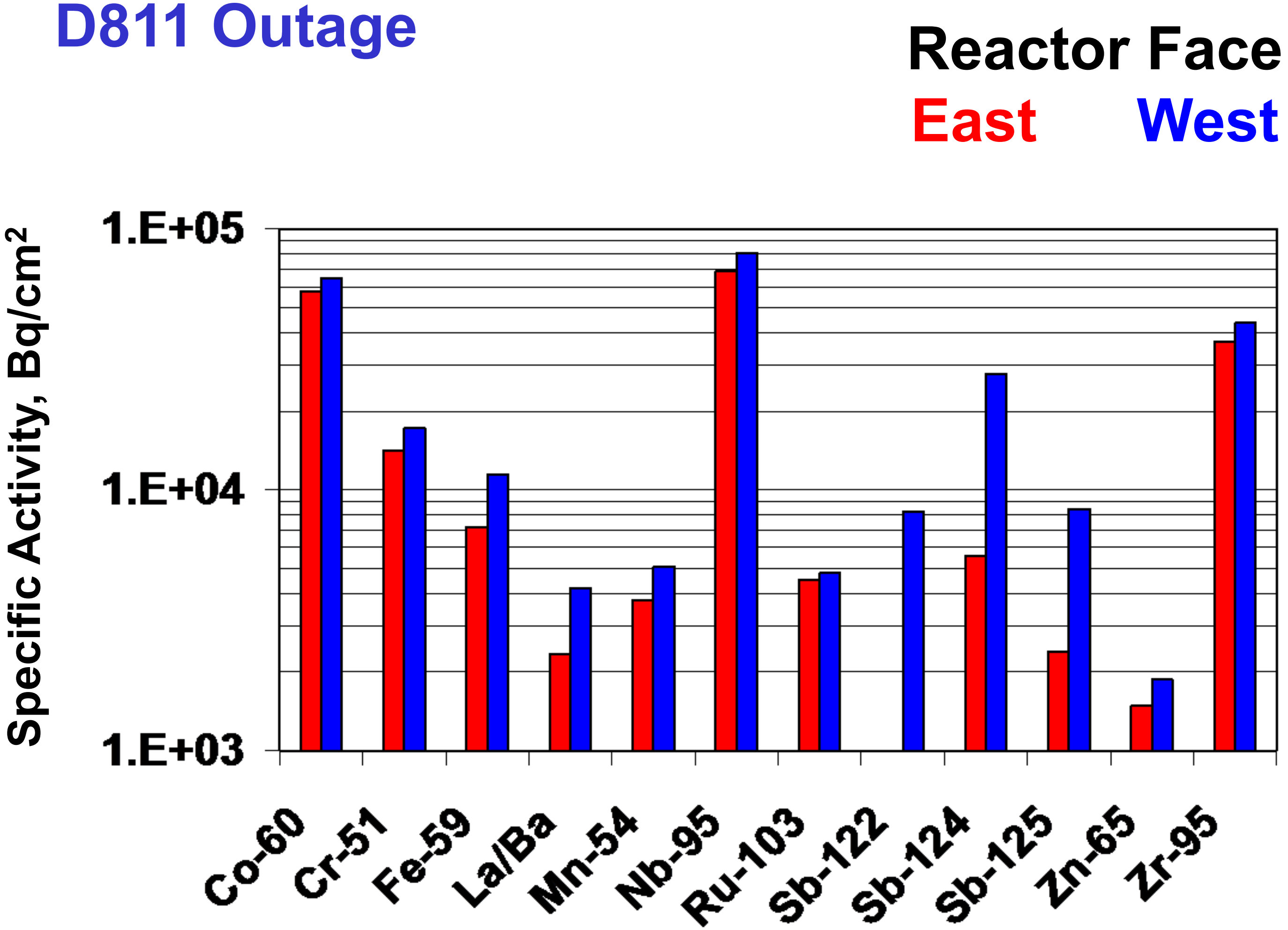
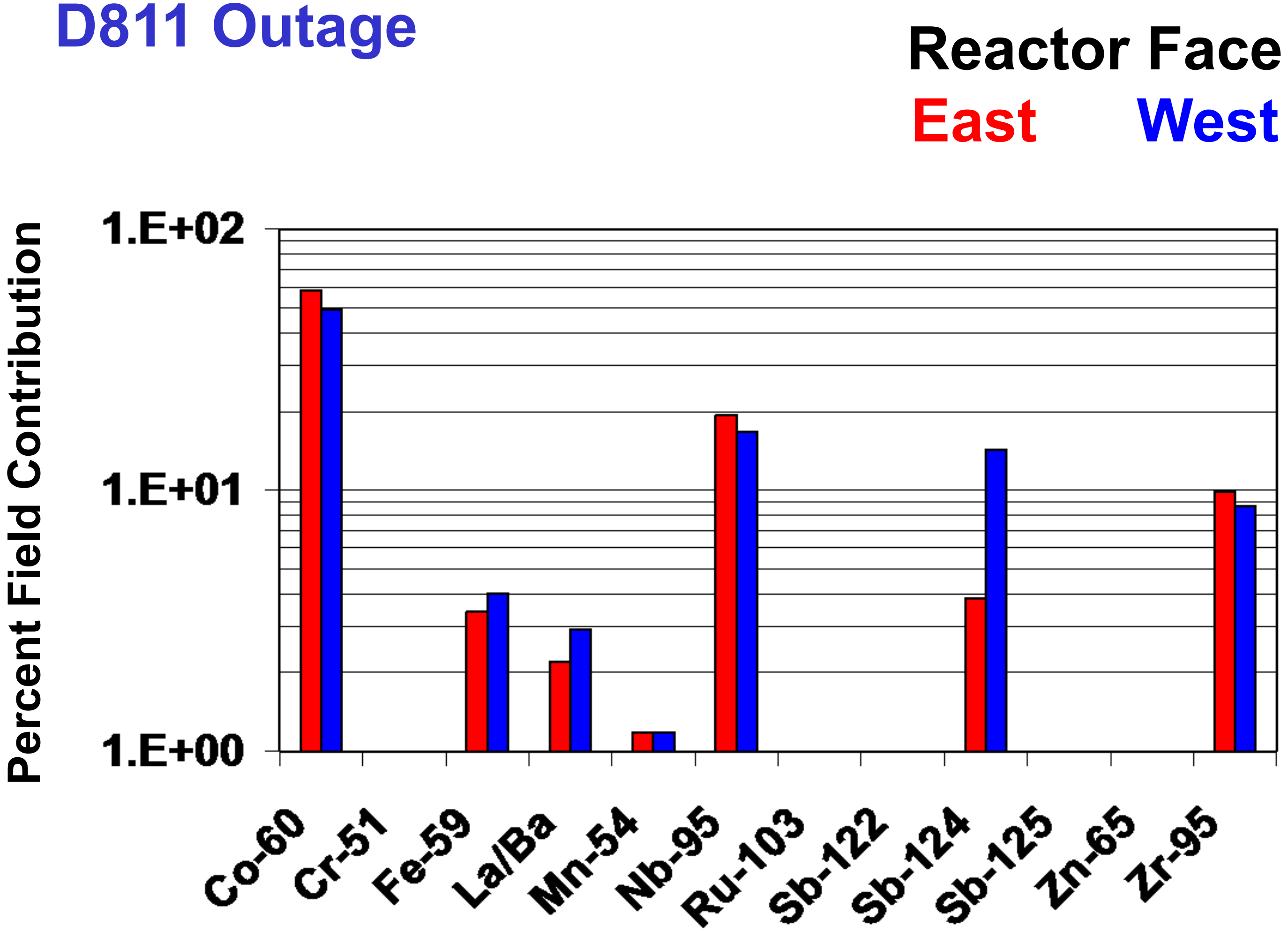
D811 Outage

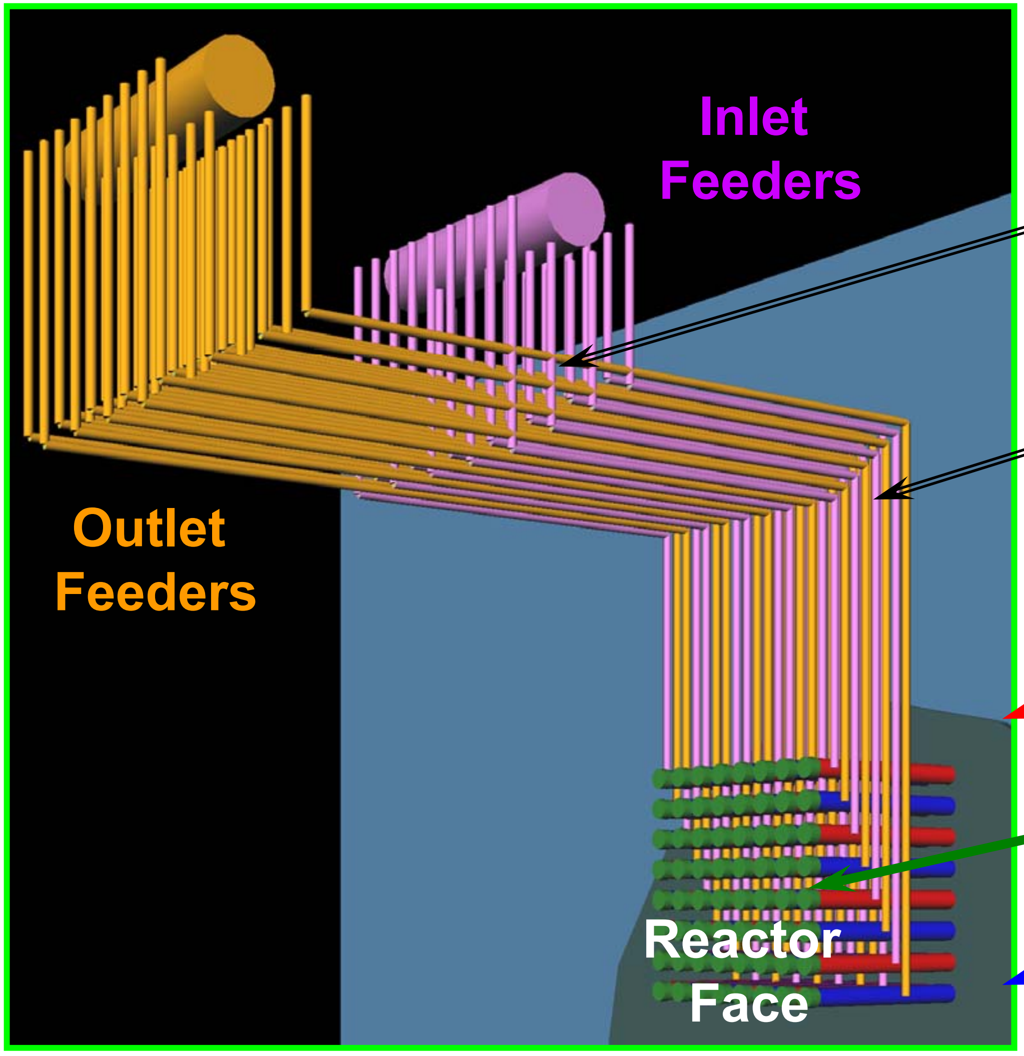


Reactor Vault – Dose Contributors

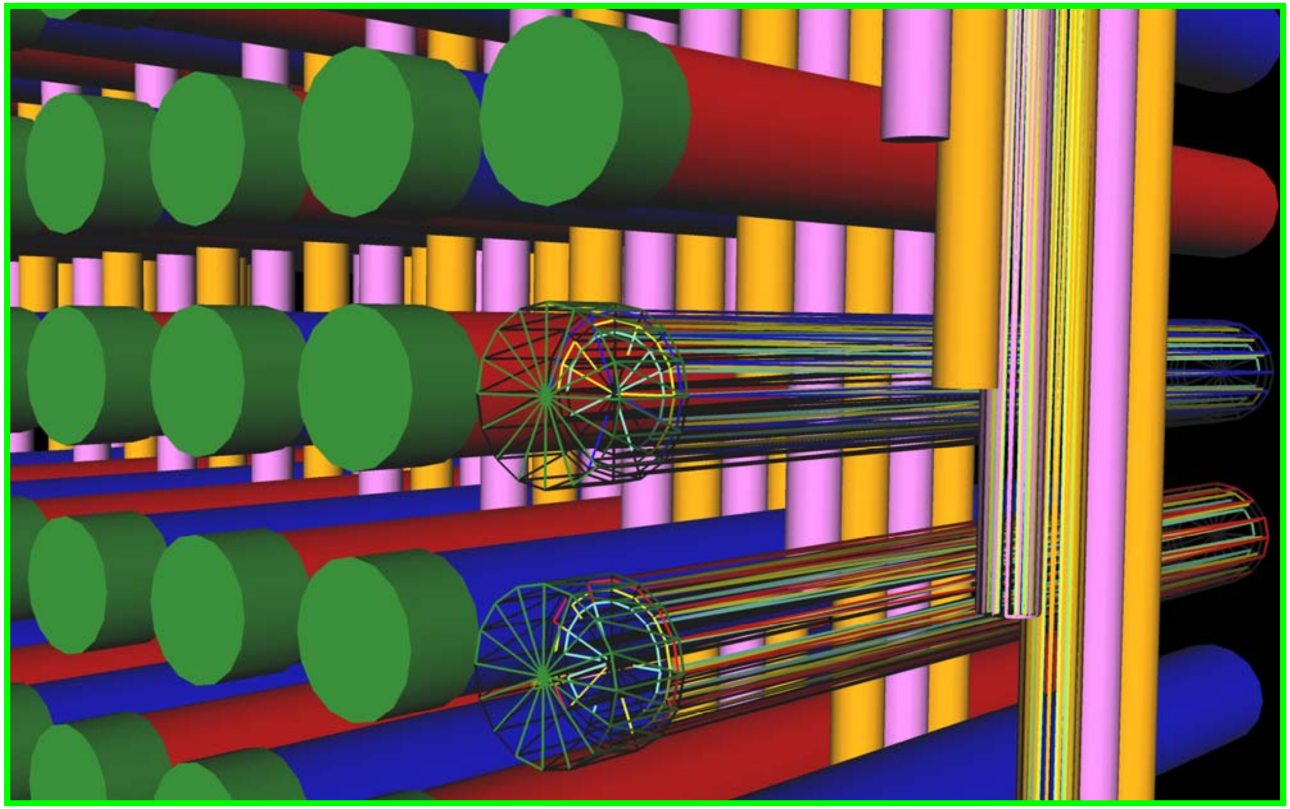
D811 Outage



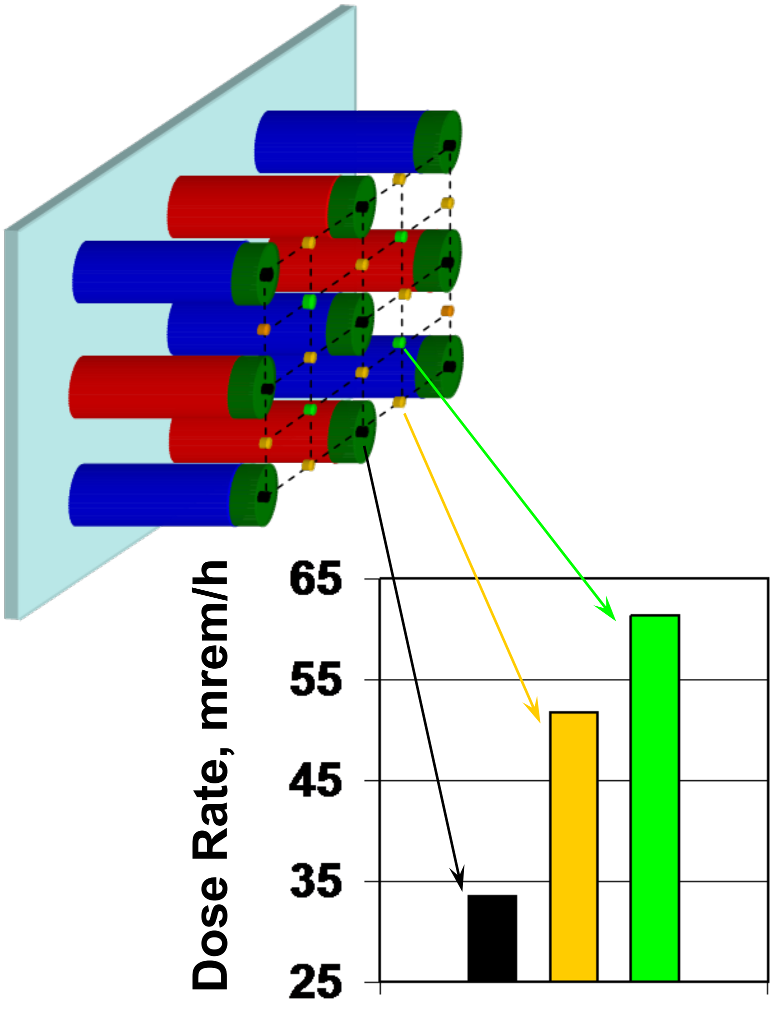
3-D Model of Reactor Face Top



3-D Model of End Fitting Cell

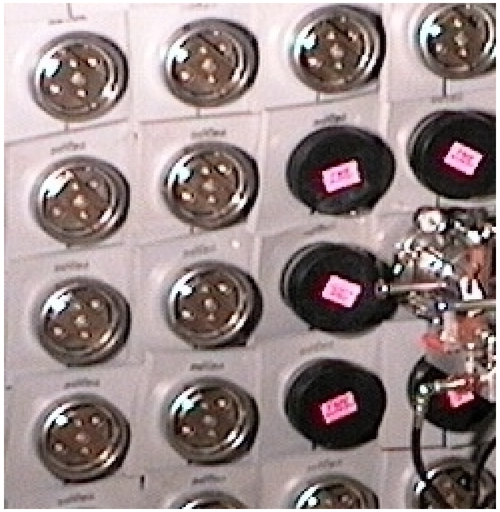


Cell Surveys and Shielding Blocks



Shielding Block:

30cm x 30cm;
Hole ~ Ø 18cm;
Weight ~ 12kg

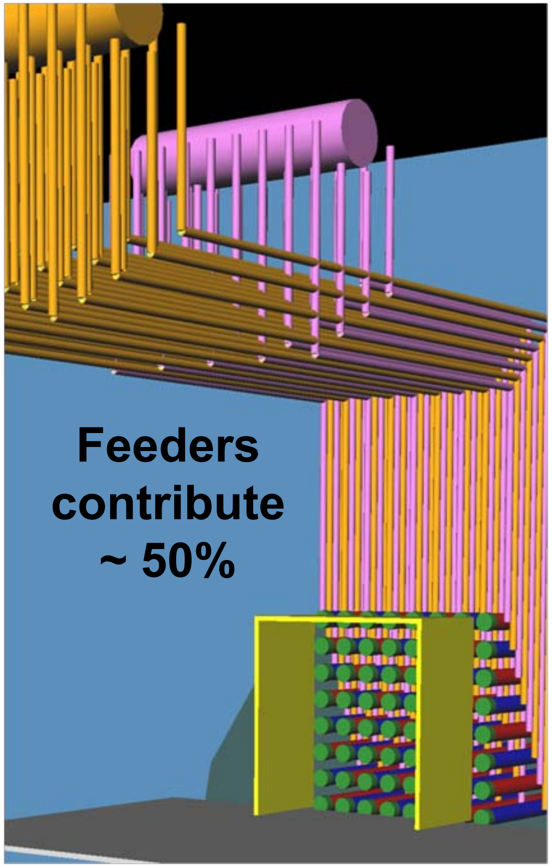


Easy Install:

Block ~ 15 sec

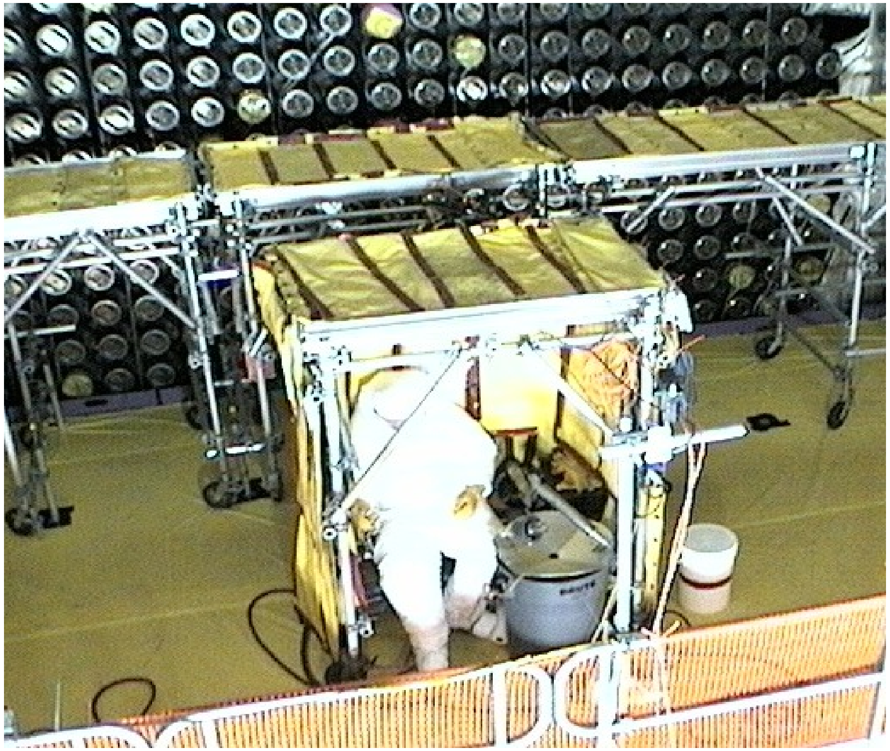
Shielding Factor ~ 4

Overhead Shielding on Reactor Face



Overhead Shielding Concept

Prototype Shielding Structure



Conclusions

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- OATM surveys provide:
  - comprehensive interpretation of observed radiation fields;
  - data for 3-D radiation field model of the reactor component;
  - consistent comparisons between survey data for various components, reactor units & stations;
  - radionuclide information to estimate effectiveness of source term reduction technologies.

Conclusions (cont'd)

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- ✓ 3-D Model of reactor face radiation field was developed to optimize the shielding structures
- ✓ Shielding structures, EF shield block and cabinet, have been successfully used in recent outages and led to significant dose savings
- ✓ Engineering design of large-scale overhead shielding is in progress for future outages.