Alpha Event and Follow up

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Candu Industry Philosophy

- Ratio of beta to alpha the determining factor for protection;
- If ratios high:
  - Precautions for beta will provide adequate protection from alpha
  - Whole Body Counting (WBC) – dosimetry for beta adequate
- If ratios low:
  - Specific monitoring for alpha becomes necessary to verify control and becomes a significant factor for dosimetry
- In operating CANDU plants, ratios were expected in the order of 10,000:1
  - Focus on Alpha was limited to characterization in fuel handling areas in the operating plant
  - Individual knowledge limited

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Alpha Dosimetry in Canada

- Regulatory approved Alpha dosimetry laboratory required:
  - AECL Chalk River is only accredited facility
  - Large-volume, very low threshold alpha bioassay analysis capability (TIMs), but throughput is limited and results not quickly available – was also not commercially available service
  - No Canadian NPPs, including Bruce Power, are currently approved for alpha dosimetry

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Bruce Power Reactors

- Two of Bruce Power's reactors have been under major refurbishment since Q4 2004
- Lay-up of the reactors was in place for many years before this, Unit 1 shutdown in 1995, Unit 2 in 1997
- Significant decontamination efforts had been conducted prior to refurbishment to improve conditions for working
  - H-3 source term had been reduced
  - Beta gamma contamination levels were low
  - Much work was conducted without respiratory protection
- As contamination ages, ratios decrease and the alpha proportion becomes more significant dosimetrically

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Refurbishment Work

- Refurbishment included cutting, magnetite removal and machining of feeders
- Feeder preparation prior to welding conducted in 2009
- ALARA Plan prepared
- Engineered controls to prevent the spread of contamination
- HEPA vacuum system
- Specially designed tools used to contain and collect contamination during work
- PPE controls included the wearing of Plastics Suits

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Refurbishment Work

- U2 feeder work completed successfully in fall 2009
  - No detection of any beta airborne activity
  - Low beta contamination levels
- Unit 1 commenced at the end of November 2009
  - Same controls used in Unit 2 were used in Unit 1
  - Airborne beta activity detected early
  - Additional controls were placed on work
  - Work tented to enclose activity
  - Further monitoring added
  - Detected alpha contamination

Initial Response

- All work was suspended in Unit 1
- Canadian regulator notified of event
- Root cause investigation was initiated
- Initial group of most exposed workers removed from work
- Obtained approval to use AECL dosimetry lab for our employees
- Alpha surveys conducted in U1 and U2
- Extensive cleaning of Unit 1 conducted
- Further work suspended – PHT work in U2
- Purchase of new and deployment of existing alpha monitoring equipment – friskers, air samplers, personnel monitors

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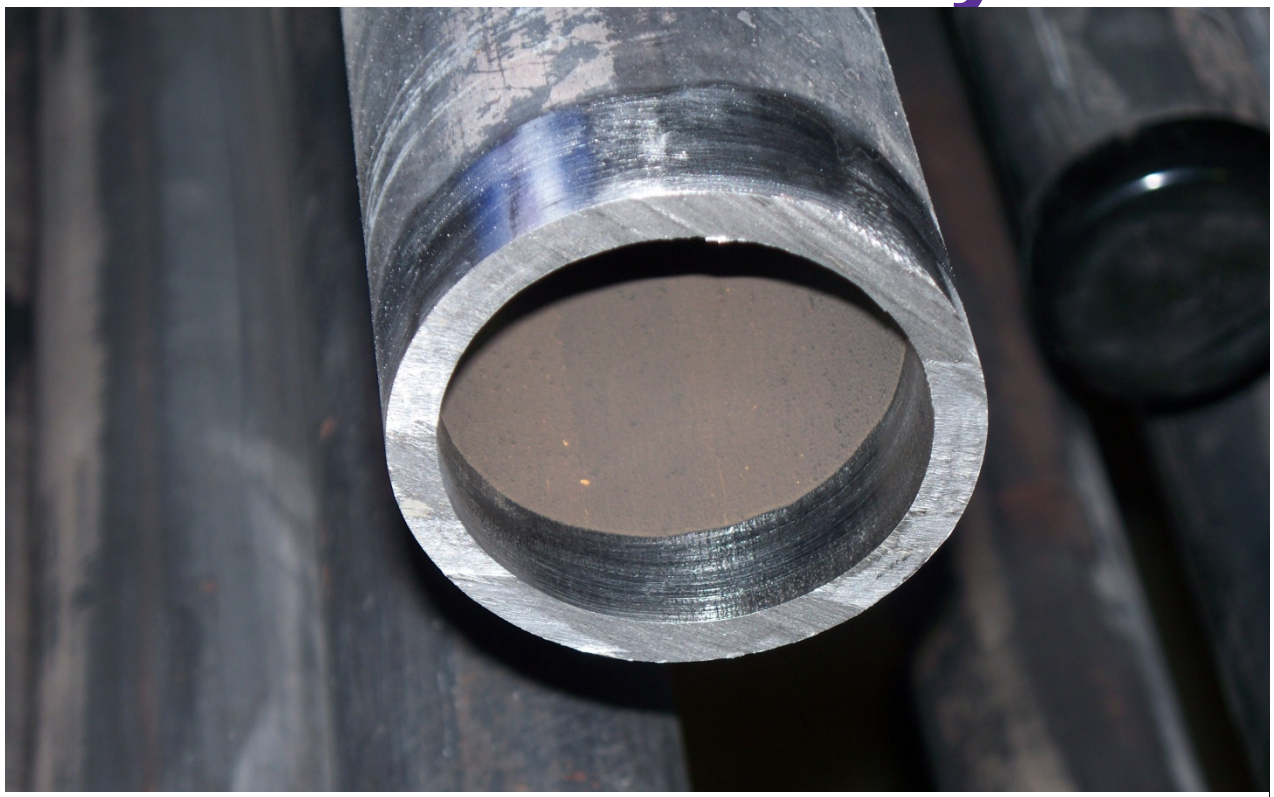
Unit 1 History



In 1979 there was an accident during fuelling the Unit 1 reactor channel P13 that resulted in a crushed fuel bundle. Not all of the fuel was recovered.

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Dose Assessments

- Difficult to assess dose based on limited information
- Prioritized assessment process developed
- Dose estimates based on:
  - Vault access logs that documents all entries for all personnel
  - Air sample results (beta and alpha)
  - Conservative models to determine the hazard levels during work evolution
- All workers in vault assessed for possible exposures:
  - Before building tents for feeder work
  - After tents until the end of feeder work

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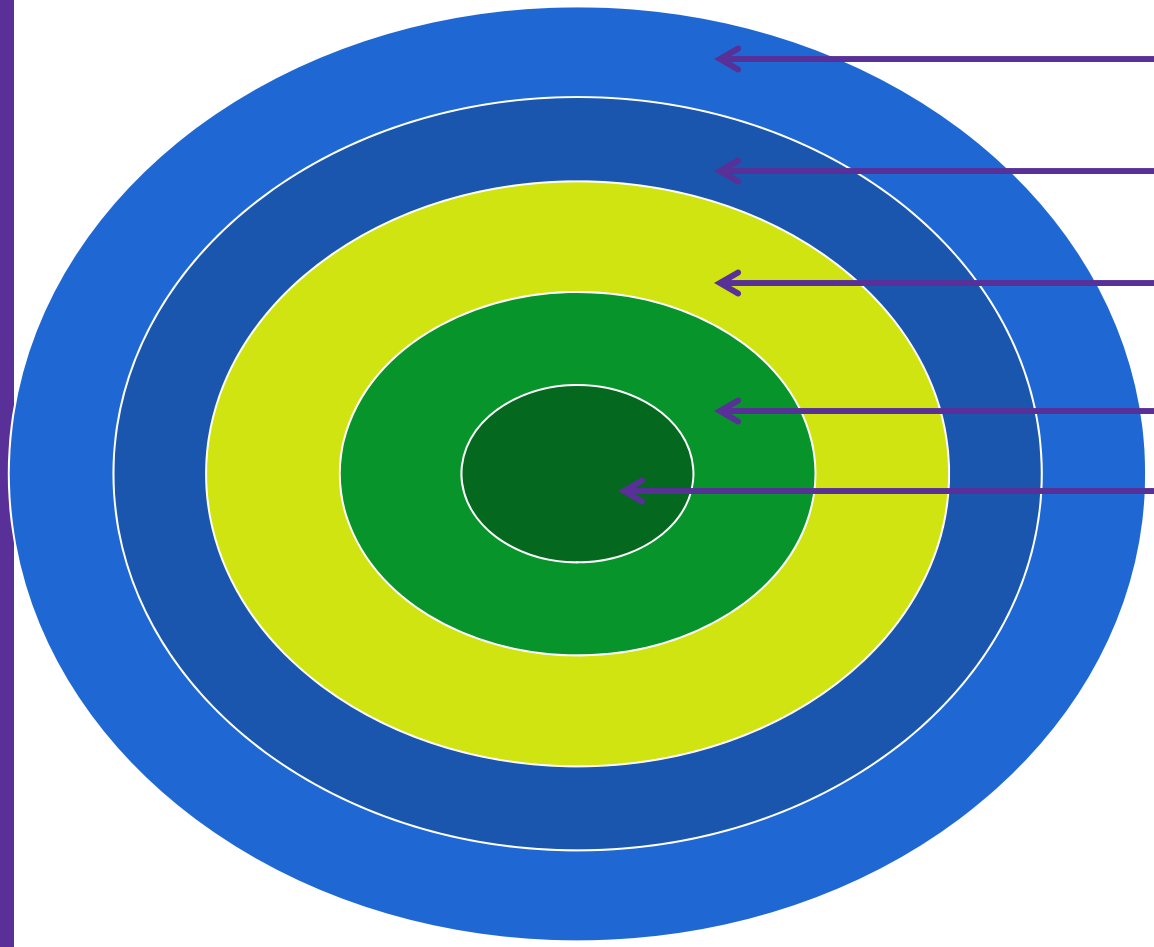
Further Response



Infrequently – General Vault Area (358)

Frequently – General Vault Area (176)

Areas near Feeder Work (13)

Spurious WBC (6)

Directly involved

Prioritize assessment based on work group activity and time spent in vault

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Significant Challenges

- Lack of familiarity with alpha - not an issue in operating plants so individual knowledge limited
- Large number of people to reach out to
- No CNSC approved laboratories in Canada for alpha dosimetry:
  - Large-volume Alpha bioassay analysis available in Canada but limited and results not quickly available
  - Alpha bioassay analysis process is complicated, therefore dose results not quickly available
  - New suppliers required for fecal analysis
- Alpha related work restrictions necessary to ensure sample purity
- Complicated issue to explain and lack of trust
- Several stakeholders

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Interim actions

- Alpha monitoring controls were added to U1 and U2 vault for general access:
  - Personal alpha contamination monitors
  - Routine air sample counting for alpha
- Back to Work
  - Staged return to work process developed (all work was suspended for 2 months)
  - Return to work criteria and plan for work in both vaults were established – additional alpha contamination and airborne monitoring and controls included
  - Comprehensive alpha characterisation of systems and areas
- Protocols/procedures developed
  - Work planning criteria and work controls for alpha
  - Alpha monitoring and air sampling protocols
  - Alpha free release standards and protocols
  - Verification waste streams to consider alpha
  - Incident response for alpha, including dosimetry requirements

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Summary of Improvements Made

- Improvements initially focused on restart, but now extended to all operating units and fuel handling:
  - New standards for alpha control
  - New RPPE
  - New procedures
  - New training
  - New alpha instrumentation
  - Enhanced air sampling program
  - New alpha dosimetry processes
  - Permits revised for alpha controls
  - Engaged external experts

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Communications

- Extensive communications have been conducted
  - Workers
  - Management
  - Industry
  - Joint Health and Safety Committees
  - Joint Committee on Radiation Protection

- Communications continue on improvements and changes in operating units and with dosimetry practices and results

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Contributors

- Rad work planning procedure
- Source Term Procedure
- Performance testing of tool
- Technical Knowledge
- Tent Installation
- Rad Workplace Monitoring

7. EPRI
8. REPS
9. Loose contamination
10. Group think
11. Analysis
12. Bruce Power Oversight

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Bioassay sampling statistics

- 556 people were in the vault during the work period in question
  - Initial estimates indicated up to 193 could require further bioassay testing
- 552 personnel were tested - at least one sample
  - 33 individuals provided multiple samples (average 4 each)
  - 9 individuals remain on ongoing sampling
  - Total of 177 urine and 1086 fecal samples taken in 2009
  - Process of dosimetry has taken 12 months to complete
- Final results confirm initial estimates

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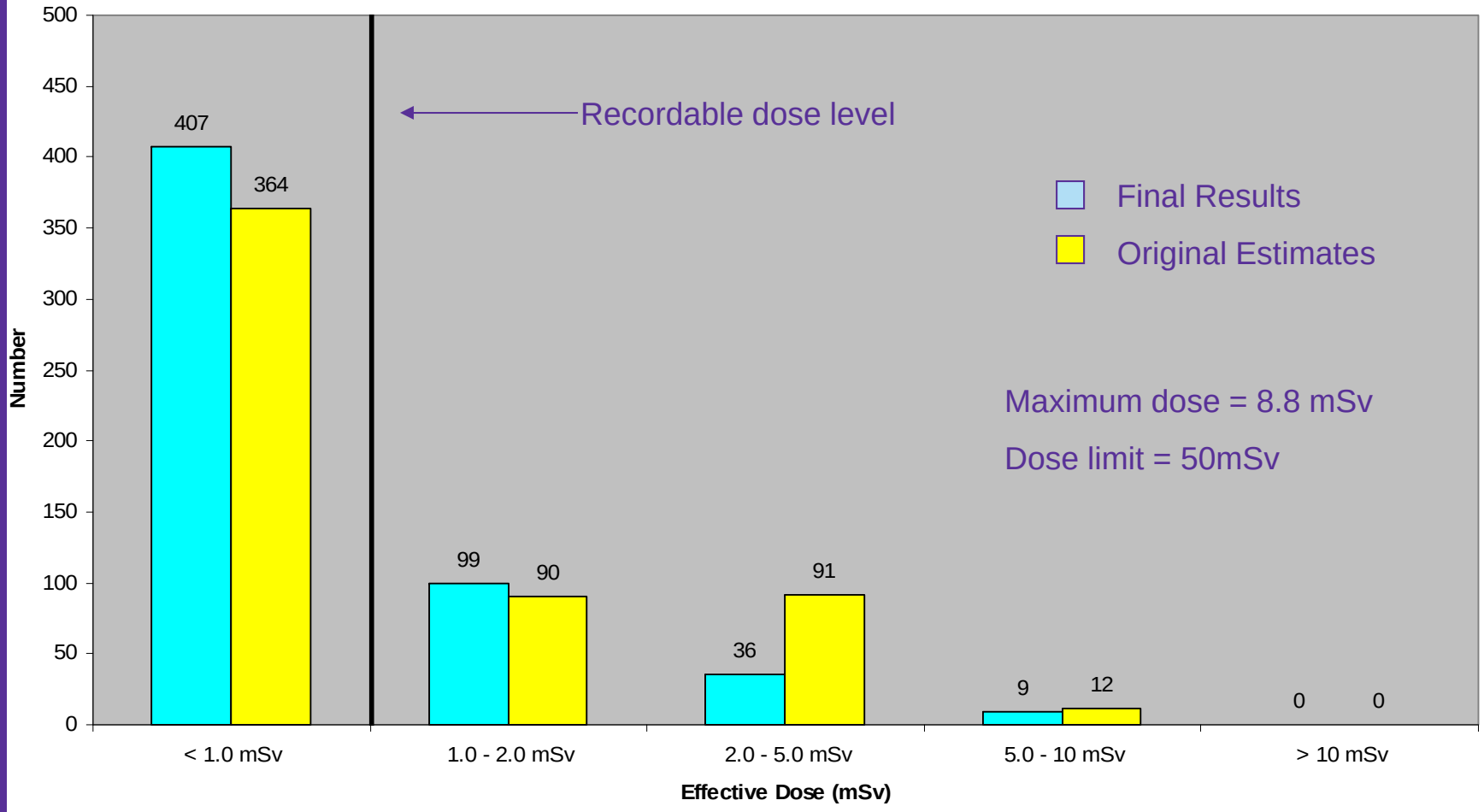
Alpha Contamination Event Dose Histogram
(Updated to 29 November, 2010)



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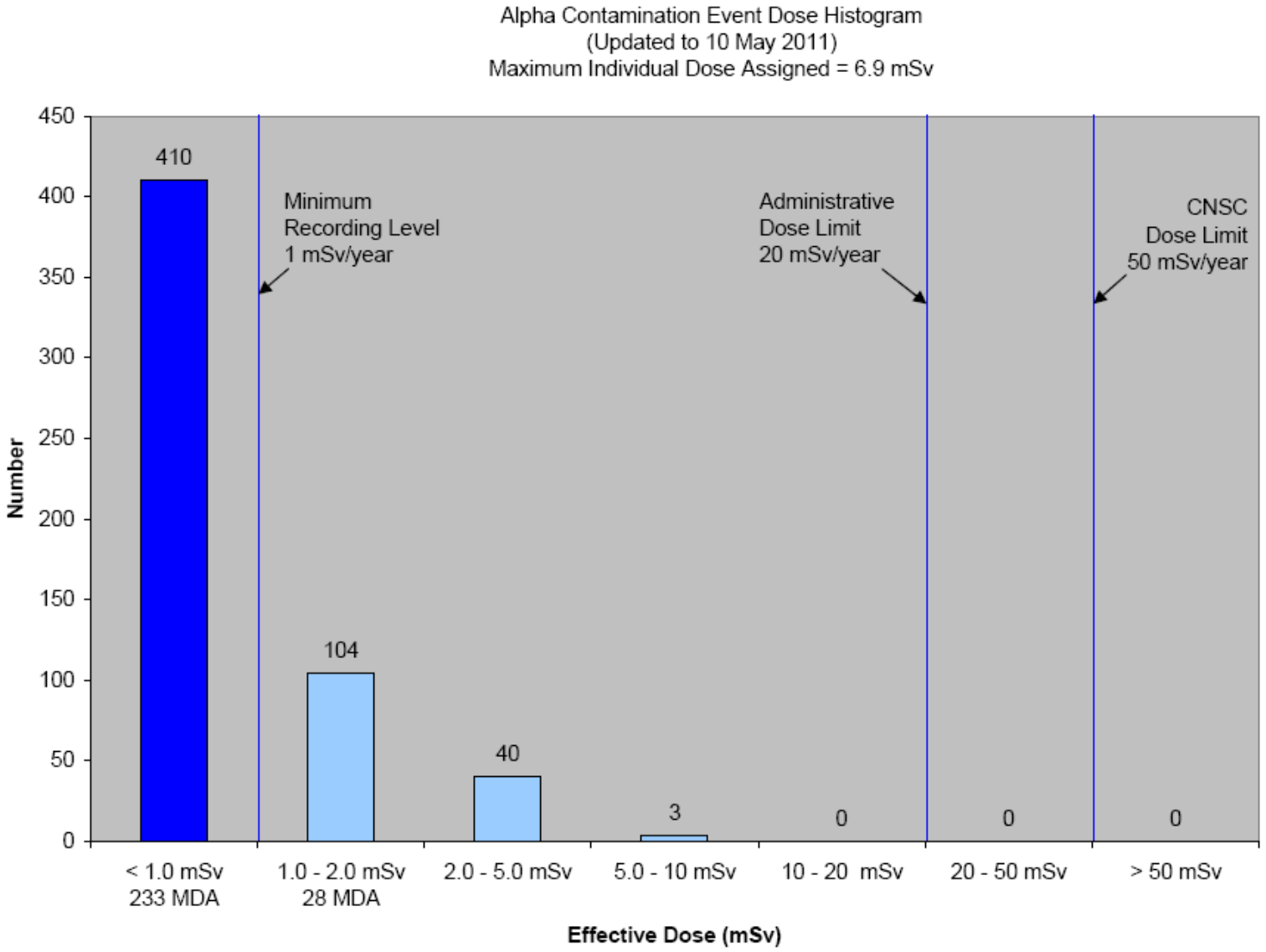
Alpha Contamination Event Dose Histogram
(Updated to 10 May 2011)
Maximum Individual Dose Assigned = 6.9 mSv
Number
450
400
350
300
250
200
150
100
50
0
410
104
40
3
0
0
0
Minimum
Recording Level
1 mSv/year
Administrative
Dose Limit
20 mSv/year
CNSC
Dose Limit
50 mSv/year
< 1.0 mSv
233 MDA
1.0 - 2.0 mSv
28 MDA
2.0 - 5.0 mSv
5.0 - 10 mSv
10 - 20 mSv
20 - 50 mSv
> 50 mSv
Effective Dose (mSv)

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Future Activities

- Extent of condition work expanded to identify any historical doses
  - Workers in restart from previous work
  - Workers in fuel handling
  - Workers from other facilities
- 1008 individuals will be sampled
  - To date 700 samples complete
- Work is ongoing to assess doses to all personnel
  - Approximately ten percent of those sampled indicated potential intakes
  - Challenge is sensitivity of fecal historically, lack of lower threshold urinalysis capability and volume of personnel
  - Working with industry to create new bioassay laboratory
  - Ongoing, routine dosimetry practices to be defined

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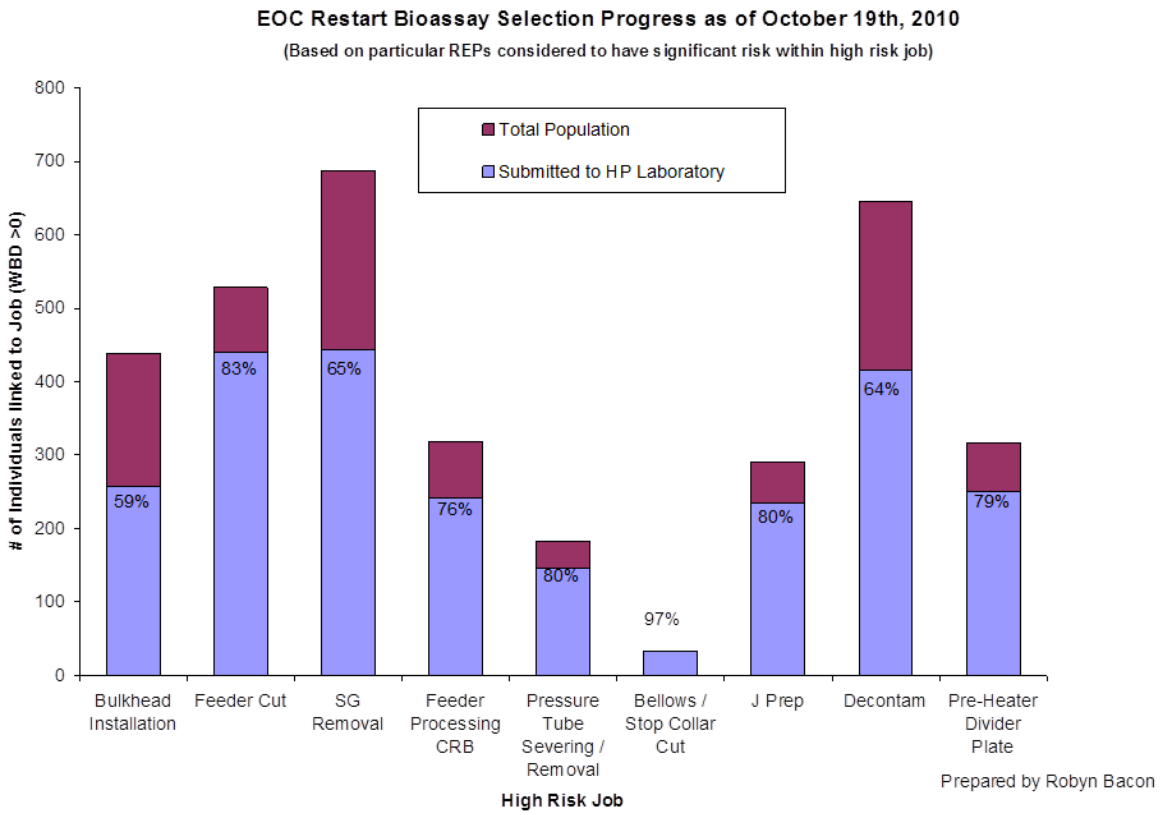
Range of Restart Activities



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Summary

- Significant radiological event with large number of workers exposed to alpha and large consequences for company
- Ongoing work to assess historical impact of alpha and continue to identify any other issues
- Major contributors were lack of understanding of characterization implications and reliance on old assumptions
- Extremely vital to have accurate technical basis, believe instruments when indicating an abnormal condition and challenge assumptions

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