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New Shielding Analysis Method for General Payload (LLW) Type B Shipping Casks

Need for New Shielding Analysis Method

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NRC expects increased rigor for General Payload (LLW) Cask shielding analyses

- A "general" payload may contain any mixture of isotopes, and has an arbitrary geometry and material composition

Previous Approach

- Analyses based on "Worst Case" payloads (often Co-60 point sources)
- Smearing, or averaging payload materials & sources allowed
- Assurance of Normal Condition of Transport (NCT) compliance based on user loading practices
- Effects of variable material compositions, material densities and source densities not rigorously analyzed
- Payload/Source redistribution (under Hypothetical Accident Conditions) not addressed

Need for New Method - continued

New Requirements

- All potential payloads allowed by cask specs must be demonstrably bounded by analyses
  - Material compositions/densities
  - Source distributions within cask cavity
- Potential source redistribution Under NCT and HAC must be addressed
- Penetrating radiation produced from Beta sources must be addressed

Challenges for New Analysis Method

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- General Analysis (vs. payload-specific approach)
- Finite Set of Analyses that Bounds:
  - All Possible Payload Materials/Densities
  - All Possible Gamma Energies (or isotopes)
  - All Possible Geometric Source Configurations
  - Any Potential Source Redistributions (under HAC)
  - Mixed Payloads Containing:
    - Multiple Source Energies
    - Multiple Source Materials and Densities
    - Multiple Source Concentrations
    - Distributed and Concentrated Sources (together in cask)

New Analysis – Basic Principles

- Point source bounding for any source with a given (γ/sec)
  - Concentrated (higher peak cask exterior dose rates)
  - No self-shielding
  - Point source placed in worst-case location within cavity
- Cavity filled with maximum activity density material (γ/sec-gram) bounding for any distributed source
  - Bounds lower source strength density material
  - Bounds any partially filled cavity
  - Issues of source strength variation within payload, or location of payload within cavity all disappear
- For a given activity density (Ci/g), lower g/cc payloads are bounded when modeled at a higher g/cc

New Analysis – Basic Principles

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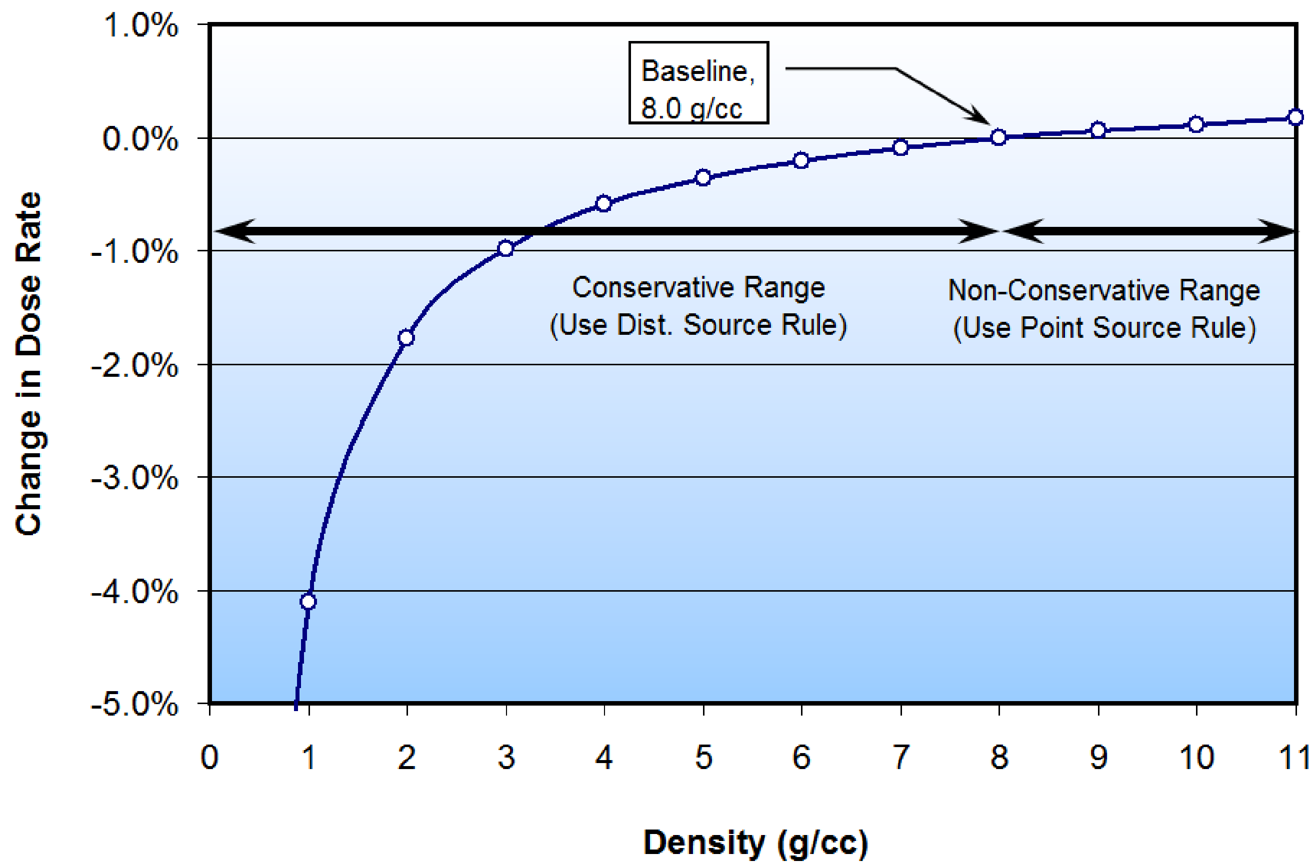
- Demonstration of effect of g/cc changes while holding specific activity (Ci/g) constant



Density (g/cc)	Delta (%)
0.5	-10.3%
1	-4.1%
2	-1.8%
3	-1.0%
4	-0.6%
5	-0.4%
6	-0.2%
7	-0.1%
8	0.0%
9	0.1%
10	0.1%
11	0.2%

New Analysis Approach – Primary Features

Point Source Analyses

- Used to establish limits on payload source strength (γ/sec)
- Payload materials (self-shielding) conservatively neglected
- Point source placed at worst location in cavity
- Analysis performed for several gamma energies

New Analysis Approach – Primary Features

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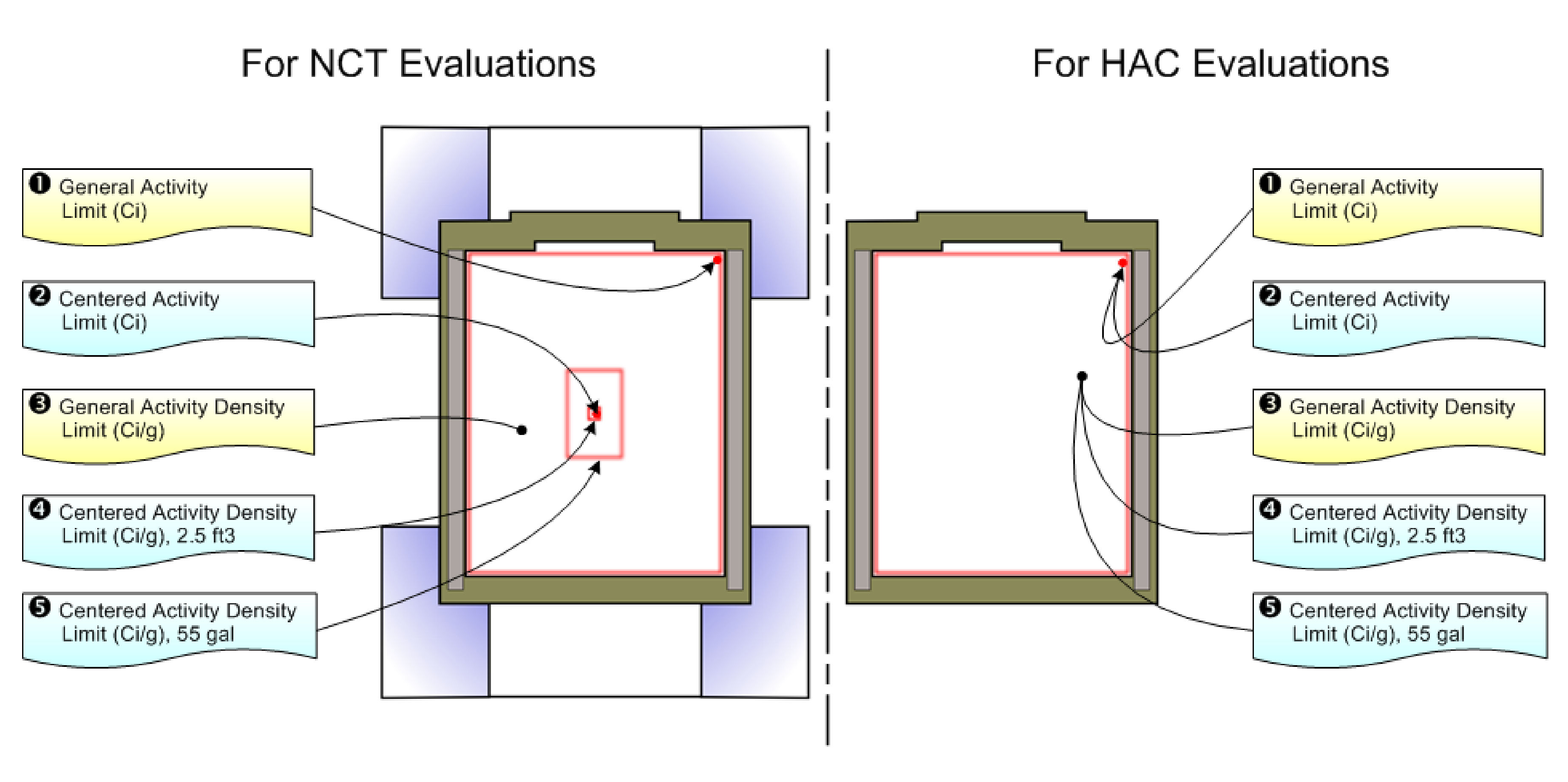
Distributed Source Analyses

- Used to determine limits on activity density, in γ/sec per gram of material
- Analysis conservatively based on cask cavity filled with maximum activity density material
- Payload modeled as minimum attenuation material at maximum density (e.g., 8.0 g/cc)
  - Zirconium is minimum attenuation material at most energies
  - Analysis bounding for all other materials and all lower densities
- Analysis performed at several gamma energies

Shielding Analysis – Analyzed Configurations

- NCT and HAC Configuration Modeled for Point and Distributed-Case Analyses



Method of Determining Source Limits

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- Per-source-particle dose rates are determined over each regulatory surface (i.e., a 1.0 γ/sec source modeled)
  - NCT: 2-meter side plane, package side, bottom and top
  - HAC: 1-meter side, top and bottom plane
- Determine the maximum per-source-particle dose rate that applies for each regulatory limit (2-m NCT, Package NCT, 1-m HAC)
- Divide dose rate limits by max per-source-particle dose rates to yield limiting source strengths, in γ/sec (which would produce peak dose rates right at limits)
- Select lowest limiting source strength as allowable value
- For distributed cases, divide allowable source strength by modeled payload mass to determine allowable source strength density (mass = bounding density x cavity vol.)

Final Product of Shielding Analyses

- Limits on Source Strength (γ/sec) and Source Density (γ/sec-gram) for Various Gamma Energies and/or Isotopes

	Source Limits	
Gamma Energy (MeV)	Source Strength (γ/sec)	Source Density (γ/sec-gram)
3.50	7.903E+09	3.502E+05
2.75	1.045E+10	5.471E+05
2.25	1.477E+10	8.879E+05
1.83	2.426E+10	1.701E+06
1.50	4.776E+10	3.988E+06
1.17	1.641E+11	1.092E+07
0.90	8.629E+11	3.447E+07
0.70	1.815E+12	1.164E+08
0.50	6.237E+12	7.702E+08
Co-60	1.073E+11	7.997E+06
Cs-137	2.305E+12	1.556E+08

Application of Analysis Results

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- Determine gamma energy for payload
- Determine total payload source strength (γ/sec)
- Determine maximum source strength density (γ/sec-gram) that occurs within payload
  - Maximum that occurs anywhere, within any material, or for any component within payload
  - Smearing or averaging is not allowed
- Compare source strength and source strength density to their respective limits (from analysis), based on gamma energy
- If <u>either</u> the source strength or source strength density limit is met, the <u>payload is acceptable</u> for shipment

Treatment of Non-Gamma Sources

Beta Sources

- Converted into equivalent gamma source, based on:
  - Beta source strength
  - Beta source energy distribution
  - Source and waste liner material composition
- Then treated like any other gamma source using process described earlier

Neutron Sources

- Significant neutron sources not qualified for shipment in most general payload (LLW) casks, e.g., the 8-120B.
- To qualify neutron sources, they should be analyzed separately, using traditional methods.
  - They would be added to gamma sources using sum of fractions

Treatment of Multiple Sources/Energies

- Entire process repeated for….
  - Each gamma energy level
  - Each payload source component
- Determine fraction of limit for each energy/component
  - May use γ/sec or γ/sec-gram limit, whichever gives lower fraction
- Sum fractions for all gamma energies and/or payload components
- Sum-of-fractions may not exceed 1.0
- Payload splitting (into source components) generally used for mix of distributed and concentrated sources
  - Distributed sources qualified under γ/sec-gram limit
  - Concentrated sources qualified under γ/sec limit

Payload Splitting Example

- Distributed Source
  - Cs-137 resin beads
  - Fills cask cavity
- Concentrated Source
  - Co-60 (metal)
  - Anywhere in cavity
- γ/sec fraction for Co-60 source added to γ/sec-gram fraction for resin bead source

	Source 1	Source 2
Isotope	Cs-137	Co-60
Source Strength (γ/sec)	3.0×10^{14}	5.0×10^{10}
Mass (grams)	3.7×10^{6}	10.0
Source Str. Density (γ/sec-gram)	8.1×10^{7}	5.0×10^{9}
Allowable Source Strength (γ/sec)	2.305×10^{12}	1.073×10^{11}
Allowable Source Str. Density (γ/sec-gram)	1.556×10^{8}	7.997×10^{6}
Payload/Allowable Source Strength Fraction	130	0.466
Payload/Allowable Source Str. Density Fraction	0.521	625
Selected Fraction	0.521	0.466
Sum of Fractions	0.987	

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Thank You