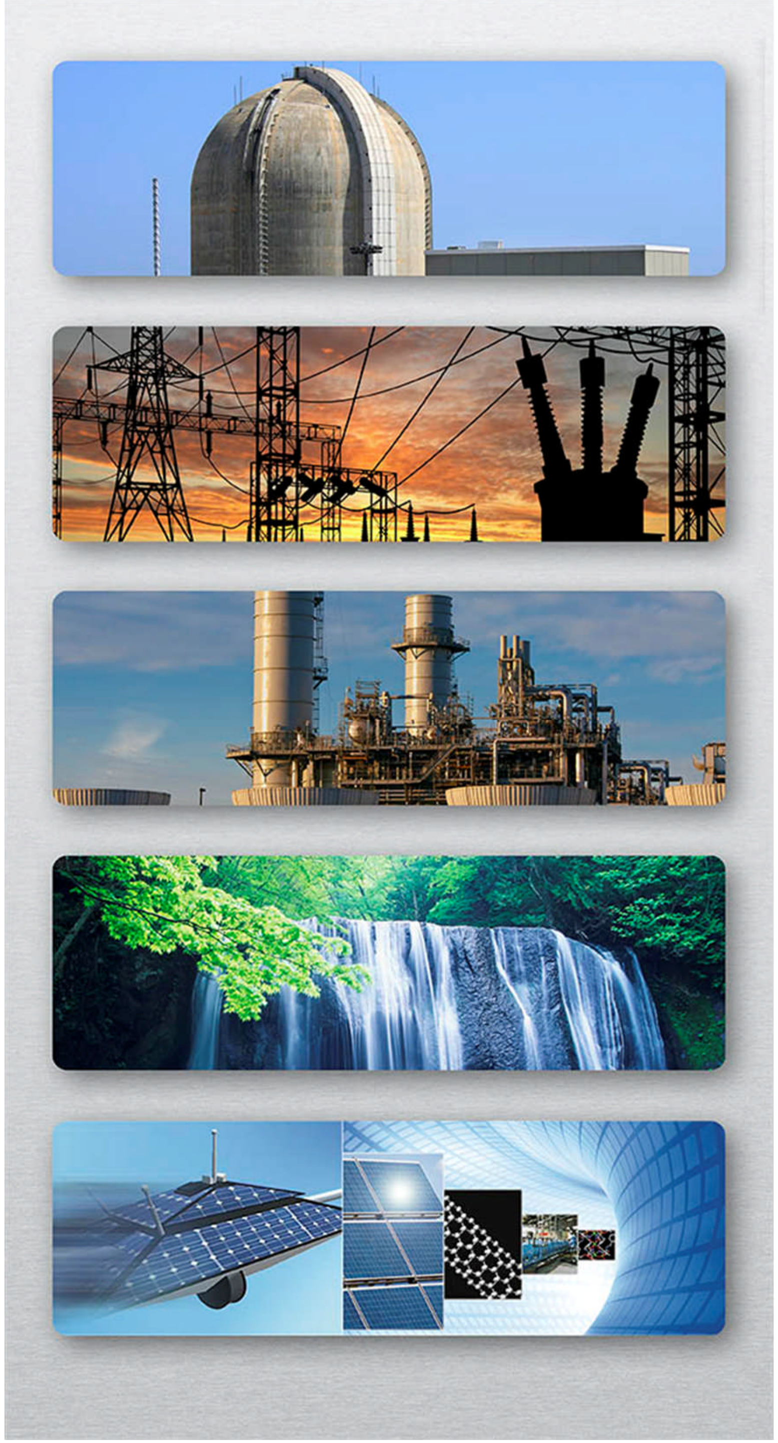

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EPRI Research and Development on Carbon-14 in Gaseous Effluents

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2011 RETS-REMP Workshop
June 29-30, 2011 Oak Brook, IL

Objectives of EPRI Research

- Provide technical guidance and support for:
  - Estimation of carbon-14 generation and release from nuclear power plants.
  - Estimation of carbon-14 dose to the public from nuclear power plants.
- Up to date data, science, and research
- Develop methods for estimation where gaps exist
- Provide best practices and technical guidance

2010-2013 EPRI C-14 Research

- ***C-14 Generation & Release:***
  - Estimation of Methodology for C-14 generation and release (2010)
  - Impact of operations and gaseous release practices on C-14 release, forms, and dose calculations. (2011)
  - Guidance & Best Practices for C-14 Sampling. (2012)
  - Validation of EPRI C-14 Estimation Methodology. (2012-2013)

- ***C-14 Dose Calculation:***
  - Best practices for C-14 dose calculations. (2011)
  - Research background (non-plant related) carbon-14 concentrations in the environment (2012)
  - Investigate dose pathways of inorganic and organic carbon-14 to humans (2012-2013)
  - Technical guidance for site-specific dose pathway analyses (2013)

Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents 1021106, 12/2010

- **Results:**
  - Developed EPRI methodology that is **more accurate and more conservative** than GALE Code.
  - Provide guidance for **site-specific calculation** of C-14 generation with coolant mass and two or three neutron energy groups.
  - Developed **default value** based on research for reliable scaling factor based on reactor MWth.
  - Developed estimates for **inorganic vs. organic** C-14 released through gaseous effluent pathways.
  - Presented to **U.S. NRC** in January 2011 for review and feedback.

C-14 Generation Calculation Site-Specific Variables & Inputs

- **Core "Average" Neutron Flux**
  - BOC, Mid-cycle, EOC
  - Two or Three energy groups
- Use **"Effective Cross-Sections"** in the three neutron energy groups
- **"Effective Mass" of coolant** in active core
  - Suggest use mass from "bottom" of active core to "top" of active core
  - BWR → must consider moderator and bypass regions
- **Concentration of Nitrogen** in the coolant (for PWR; BWR negligible.)
- **Calculate BOC, mid-cycle and EOC C-14 source term**
  - Average the three values

Simplistic PWR Transport Model

PWR ^{14}C Generation Default Value:

10 Ci/GW_e-yr (Westinghouse)

11.5 Ci/GW_e-yr (CE)

90% to 98% → **Gaseous Release**

Chemical Form:
5-30% Inorganic CO_2
Remainder, Organic
(without recombiner)

With a recombiner, all of the ^{14}C gaseous release is assumed to be inorganic (CO_2)

< 1% → **Liquid Release**

< 0.1 Ci/yr

2% to 10% → **Solid Release**

Filters and IX Resins

0.2 to 1 Ci/yr

Use 10CFR61 documentation for estimate.

Fraction organic, ^{14}C 30-90%

Example:

1000 MWe (W) PWR

(w/o recombiner)

10 Ci/yr generated

9.8 Ci/yr released

2.94 Ci/yr inorganic

VS

7.3 Ci/yr Total C-14 per GALE Code

Simplistic BWR Transport Model

BWR ^{14}C Generation Default Value:

15 Ci/GW_e-yr

95% to 99% → **Gaseous Release**

Building Vent: ~3%
Off-gas Vent: ~97%

Chemical Form:
~95% Inorganic CO_2
Remainder organic, primarily CH_4

< 0.5% → **Liquid Release**

< 0.1 Ci/yr

<1% to 5% → **Solid Release**

IX Resins
HWC < NWC

0.2 to 1 Ci/yr

Summary of 10CFR61 Documentation needed for estimate.

Condensate resins 2 to 4 times greater than RWCU resins.*

Example:

1000 MWe BWR

15 Ci/yr generated

14.85 Ci/yr released

14.1 Ci/yr inorganic

VS

9.5 Ci/yr per GALE Code

*The RWCU ion exchange resins are expected to contain ^{14}C as carbonate/bicarbonate in the inorganic form and formate in the organic form. The condensate resin is expected to be primarily in the carbonate/ bicarbonate form.

Indian Point 3
3188 MWth, 1051 MWe PWR

Estimation Method	
PWR GALE Code	7.3 Ci/yr
Kunz Sampling Study, Total Gaseous C-14 Released	9.6 Ci/yr
EPRI Study, Total Gaseous C-14 Released	10.5 Ci/yr
Kunz Sampling Study, Inorganic Gaseous C-14 Released (26%)	2.50 Ciyr
EPRI Study, Inorganic Gaseous C-14 Released (30%)	3.15 Ci/yr

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Chemistry and Fuel Considerations

- **Impact of Chemistry on ^{14}C considered negligible:**
  - **For BWRs: HWC or HWC+NMCA chemistry**
    - The form of ^{14}C transported from the vessel via the steam is expected to remain in primarily a highly oxidized state.
    - The chemical form exiting the core and remaining in the reactor coolant may be in a more reduced state and more ^{14}C may be collected on the RWCU resins with a corresponding decrease in steam transport.
    - However, the chemical forms exiting the off-gas treatment system are not expected to change due to the oxidizing environment in the recombiner.
  - **For PWRs: Hydrazine**
    - Hydrazine addition leads to ammonia in coolant. The ammonia can be a source of ^{14}N and contribute to ^{14}C source.
  - For both **BWRs and PWRs, zinc addition** is not anticipated to have impacts on ^{14}C generation.

- **Impact of fuel failures on ^{14}C considered negligible.**

Impact of NPP Operations on C-14 Release (2011)

- Detailed review of available data from PWRs and BWRs on the chemical form of C-14 released.
- Evaluate effect of operational mode at time of measurement and system design on chemical form of release
  - PWR and BWR gaseous waste treatment designs and their impact on the chemical form of release.
  - Waste gas system operations and waste gas routing during startup, normal operation, and shutdown
  - Review of Canadian PHWR experiences with C-14 collection on ion exchange resins.
- Assess possible impact of conversion of methane to carbon dioxide in waste gas system and local environment
- Assess possible impact of low molecular weight hydrocarbon on carbon dioxide on charcoal filters on C-14 release

Question?

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