

June 21, 2010

MEMORANDUM TO: Undine Shoop, Chief  
Health Physics and Human Performance Branch  
Division of Inspection and Regional Support  
Office of Nuclear Reactor Regulation

FROM: Steven Garry, Sr. Health Physicist */RA/*  
Health Physics and Human Performance Branch  
Division of Inspection and Regional Support  
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF JUNE 10, 2010, CATEGORY 2 PUBLIC MEETING WITH  
THE NUCLEAR ENERGY INSTITUTE (NEI) and THE ELECTRIC  
POWER RESEARCH INSTITUTE (EPRI) TO DISCUSS CARBON 14  
SOURCE TERM

On June 10, 2010, a public meeting was held between the U.S. Nuclear Regulatory Commission (NRC), and representatives of the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI) and nuclear power industry at the U.S. Nuclear Regulatory Commission Headquarters, Room O-16B4, 11555 Rockville Pike, Rockville, MD 20852. The purpose of the meeting was to provide NEI, EPRI and the nuclear power industry representatives an opportunity to discuss their evaluation of the power reactor carbon-14 radioactive release source term.

The meeting generally followed the agenda. Enclosure 1 contains the meeting minutes, and Enclosure 2 contains the attendee list.

Enclosures:  
As stated

CONTACT: Steven Garry, NRR/DIRS  
301-415-2766

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|--------|---------------|------------------|
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| DATE   | 06/21/10      | 06/17 /10        |

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## Meeting Minutes

A meeting between NRC, NEI, and nuclear power representatives was held on June 10, 2010 to provide a forum for discussion of the power reactor carbon-14 (C-14) source term. The meeting generally followed the agenda proposed in a May 14, 2010, Public Meeting Notice (Agencywide Documents Access and Management System (ADAMS) Accession No. ML101340180.)

### I. ADMINISTRATIVE

The meeting started with welcome to the participants, and a round of self-introductions, and a brief opening statement by Undine Shoop, Chief of the Health Physics and Human Performance Branch, Office of Nuclear Reactor Regulation (NRR).

### II. DISCUSSION

Ralph Andersen from NEI thanked the NRC for hosting the meeting, and requested a series of three future meetings as the research progressed further. Mr. Andersen stated that his purpose in requesting the meeting was to update the NRC on the results of their preliminary research into C-14 effluent discharges. A follow-up meeting was requested for the September or October time frame, with a specific date to be proposed later.

EPRI distributed a PowerPoint presentation titled "Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents" for discussion during the meeting (ADAMS No. ML101650129). EPRI stated that the objectives of the study were four fold:

- to review international research and development data related to carbon-14 generation and release,
- to review carbon-14 generation and release mechanisms,
- to provide a methodology for accurately estimating C-14 source term, and
- to benchmark nuclear power plant types (boiling water reactors and pressurized water reactors).

Karen Kim from EPRI discussed that the C-14 production is dependent upon the neutron flux, concentrations of target nuclide and the neutron cross sections for reactions yielding C-14 (refer to the presentation):

- The neutron flux in a PWR and BWR is described as a function of neutron energy, with the flux peaking in the thermal region, and at the upper region above 1 MeV,
- the neutron absorption cross sections for the oxygen-17, nitrogen-14, and carbon-13 reactions are also peaking in the thermal region and in the region above 1 MeV,
- the natural abundance of target nuclide for oxygen-17 (O-17) is 0.038%, N-14 is 99.632%, and C-13 is 1.07%. The nitrogen is most prevalent in PWRs as a result of the

ENCLOSURE 1

nitrogen component of the additives hydrazine and zinc acetate. The primary production of C-14 is from O-17, with production from N-14 approximately 10% of the total C-14 produced. The activation of C-13 is insignificant in comparison to the total C-14 produced from O-17 and N-14.

NRC stated that the neutron flux data would need to be reviewed by reactor physicists. In EPRI's calculations, the effective cross sections were subdivided into 3 neutron energy groupings: thermal neutrons, intermediate neutrons, and fast neutrons. This method results in the PWR source term being estimated as 0.354  $\mu\text{Ci}/\text{MWh}_{\text{TH}}$  for the O-17 reaction and 0.09 Ci/yr – ppm nitrogen for the N-14 reaction. A large 3549  $\text{MWh}_{\text{TH}}$  PWR would produce approximately 11.18 Ci/y of C-14. Operational practices affecting nitrogen concentrations would need to be considered, such as hydrazine addition at startup, and other startup practices to reduce oxygen such as reactor coolant system vacuum enhanced startup.

For the BWR source term, the method results in an estimated 0.575  $\mu\text{Ci}/\text{MWh}_{\text{TH}}$  for the O-17 reaction and 0.26 Ci/yr-ppm nitrogen (a negligible amount for the N-14 reaction). A large, 3579  $\text{MW}_{\text{TH}}$  BWR would produce approximately 18 Ci/yr C-14.

EPRI discussed the chemical forms of carbon-14 production as carbon dioxide, carbon monoxide, formic acid, formaldehyde, methanol, and methane. The C-14 releases occur as either gaseous releases (90 – 98%), liquid releases (<1%), and solids (2-10%). For the gaseous and liquid effluent releases, approximately 99% are in the gaseous form and <1% is in the liquid form.

For a PWR, the gaseous releases are 5 – 30% in the chemical form of  $\text{CO}_2$ , and 70-95% in an organic chemical form such as methane, ethane, propane, or butane. For a BWR, the gaseous releases are 95%  $\text{CO}_2$ .

In summary, EPRI concluded that the C-14 production calculational methodology has been developed, and EPRI is collecting operational data from power plants with which to perform C-14 estimations and compare with available carbon-14 data. A draft methodology is expected in the fall, 2010. An NRC staff member from the Office of New Reactors indicated that for BWRs, some current estimates are underestimating the C-14 source term as compared to measurements.

NRC discussed the results with the NEI and EPRI staff. NRC asked about the potential activation of O-16 to O-17, creating a potential for an increased O-17 target concentration. EPRI noted that they will evaluate this possibility.

NRC asked whether EPRI is studying the dispersion and bioaccumulation of C-14 in the environment. EPRI noted that at this time, their study has been limited to estimating the source term. EPRI is reviewing literature on the direct measurement of C-14, and noted that Canada, Sweden, and South Korea have been performing C-14 measurements. A member of the public suggested the possibility of C-14 measurements in primary coolant using liquid scintillation counting to verify the calculated estimates of C-14 in effluents.

NRC noted that additional information on dispersion and bioaccumulation may be obtained from the International Atomic Energy Agency (IAEA) Technical Reports Series No. 364, "Handbook of parameter values for the prediction of radionuclide transfer in temperate environments." NRC

staff also suggested useful information may be found in the IAEA Technical Reports Series No. 421, entitled "Management of Waste Containing Tritium and Carbon-14."

NRC staff mentioned that Mr. Bruce Napier from the Pacific Northwest National Laboratory has worked on the development and implementation of models concerned with the environmental transport of radiological and chemical contaminants. This modeling has been included in the computer code named GENII, "Generalized Environmental Radiation Dosimetry Software System - Hanford Dosimetry System (Generation II)" developed for the Environmental Protection Agency (EPA) at Pacific Northwest National Laboratory (PNNL).

NRC asked whether environmental sampling near nuclear plants could distinguish the additional component to natural C-14 from the nuclear power plant C-14. NEI/EPRI responded that the natural component would most likely over-ride the nuclear power plant C-14, as noted in Regulatory Guide 4.1.

The NRR staff then introduced the staff from the NRC Office of Research (RES), who discussed national and international activities associated with the biokinetic and dosimetric modeling of C-14. RES staff provided background information on SECY 08-0197 and its associated Staff Requirements Memorandum. This activity supports the development of a future policy paper that would delineate options and impacts on moving the NRC's radiation protection standards toward greater alignment with the recommendations outlined in ICRP-103.

RES staff introduced (by telephone) Dr. Keith Eckerman and Mr. Ryan Manger from Oak Ridge National Laboratory (ORNL). Dr. Eckerman summarized ORNL's ongoing work to update biokinetic and radiation dosimetry models in support of ICRP Committee 2 as it implements the radiation protection recommendations of ICRP-103. Currently, ORNL is developing new dose coefficients (so-called dose factors) for radionuclides in two phases (occupational exposures, followed by environmental exposures). Technical information on C-14 is being collected and analyzed now and this research may be published in the open literature next year. Following publication, the results will be submitted to ICRP Committee 2 for consideration in the 2012-2013 timeframe. An important technical consideration for estimating the radiological dose from an environmental release of C-14 is the chemical form because the chemical form influences the C-14 behavior in the human body.

NEI questioned whether the most recent ICRP Publication 72 organ dose coefficients could be used in lieu of ICRP-2 based dose coefficients in the calculation of C-14 dose for purposes of demonstrating compliance with Technical Specifications related to ALARA controls. Steve Garry took an action item to obtain a resolution to the question.

Under general discussion of other radiation protection topics, NEI questioned when the Ground Water Contamination Task Force Report would be issued. NRC staff noted that the report is expected to be public in June, 2010.

### III. PUBLIC PARTICIPATION

This was a Category 2 public meeting, with two members of the public attending the meeting in person or by teleconference. Opportunities were provided for comment after each segment of the meeting. One suggestion was made on the measurement of C-14 in reactor coolant using liquid scintillation counting, and another suggestion was made to recognize that measurements

will result in some data being outliers. Outliers should be evaluated to determine whether the data is representative of an anomaly, or whether the data indicating that the model is not applicable under the assumed conditions. Controlling parameters must be identified to bound assumptions.

Public Meeting Feedback 659 Forms were available and 2 completed forms were received. Participants over the teleconference were also provided opportunity to comment using the public meeting feedback form. Meeting was adjourned.

**June 10, 2010 NRC, NEI, EPRI, Nuclear Industry and Public  
Attendance List**

| Name                       | Company  |
|----------------------------|--|
| Undine Shoop               | NRC  |
| Steven Garry               | NRC  |
| Richard Conatser           | NRC  |
| Tony Huffert               | NRC  |
| Casper Sun                 | NRC  |
| William Ott                | NRC  |
| Steve Schaffer             | NRC  |
| George Kuzo                | NRC  |
| Jenee Partor               | NRC  |
| Ralph Andersen             | NEI  |
| Karen Kim                  | EPRI   |
| Sean Bushart               | EPRI   |
| Greg Barley                | Progress Energy                                      |
| Kathy Yhip                 | Southern California Edison                           |
| G.F. Palino                | NWT Corporation                                      |
| Dale Holden                | Duke Energy  |
| Ken Sejkora (telephone)    | Pilgrim Station                                      |
| Stu Bland                  | Chesapeake Nuclear (member of public)                |
| Mike Millinor              | Progress Energy                                      |
| Doug Wahl (telephone)      | Exelon Limerick                                      |
| Keith Eckerman (telephone) | ORNL   |
| Ryan Manger (telephone)    | ORNL   |
| Suzanne McElligott         | McGraw-Hill Platts (news service) (member of public) |