The Boice Report #45

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From Oak Ridge to Indian Point
Studying Workers at Nuclear Power Plants

Paraphrasing Thomas Edison, epidemiology is 5% inspiration and 95% perspiration. The inspiration for the Million Person Study of Low Dose Health Effects (MPS) came over 30 years ago with recommendations to create a registry of radiation workers among U.S. Nuclear Regulatory Commission (NRC) licensees (see June 2015 Boice Report #37). The 30 years of perspiration are outlined below.

Thirty years in the making. Today, the Radiation Exposure Information and Reporting System (REIRS) database closely approximates a U.S. occupational radiation exposure registry (ORISE 2011). REIRS dates back to 1969 when U.S. Atomic Energy Commission (AEC) licensees were required to report radiation exposure data for individual workers at the end of employment and exposure summaries for sites on an annual basis. At that time, AEC licensees were only required to submit radiation-monitoring records upon an employee's termination of employment. However, in 1986, Gil Beebe and I, both at the National Cancer Institute (NCI), composed a letter sent by NCI Director Vincent DeVita, MD, to NRC Chairman Lando Zech requesting that reporting requirements be changed to support epidemiologic health studies. In 1991 a positive response was received from NRC Chairman Kenneth Carr to NCI Director Samuel Broder. In 1994, as part of the implementation of the 1991 revisions of 10 CFR 20 "Standards for Protection Against Radiation," the NRC began requiring annual radiation exposure records for every monitored worker (NRC Regulatory Guide 8.7). In 1994 I wrote Bill Morris, director of the Division of Regulatory Applications, Office of Nuclear Regulatory Research, urging the voluntary reporting of additional occupational radiation exposure data so that a high-quality radiation worker registry might be created for epidemiologic studies. In 1994 NRC requested that licensed utilities report voluntarily the career doses of current and past employees (NRC Generic Letter 94-04); the utilities responded favorably to this request, and a registry of radiation workers suitable for epidemiologic study was born.

How are REIRS data used for health studies? Annual radiation doses for over 1.1 million unique workers are in REIRS, including external whole-body exposure and, since 1994, internal exposure. Identifying information includes name, social security number, date of birth, sex, licensee code, and dates monitoring began and ended. We selected all 425,713 nuclear power plant workers first monitored before 1985, sampled 10% of the 307,553 workers with cumulative doses less than 10 mSv, and removed 3,688 workers with duplicate, incomplete, or invalid dose records for a study population of 145,227 workers. Workers hired after 1984 were excluded because they received much lower doses than earlier workers and because their younger age would not provide mortality information for many years. 1980 was originally chosen as the cutoff date for inclusion, but after the Three Mile Island accident in 1979, NRC required reactor modifications that increased workers' exposures for several years. The 10% sample of low-dose subjects was based on cost consideration, i.e., it would be expensive to trace over 300,000 low-dose workers when their contribution to a health study could be adequately addressed by studying 30,000.

How valid are the radiation dose data? The key to high-quality epidemiology is equally high-quality dosimetry. NCRP Scientific Committee 6-9 is providing guidance, direction, and advice for the MPS. The committee has met six times in Oak Ridge, most recently in November 2015 (see photo). Most nuclear utility worker exposure is to high-energy gamma radiation from fission products (e.g., ^{137}Cs) or activation products (^{60}Co and ^{58}Co) and there is minimal neutron exposure or ingestion of radioactive material. Measurement uncertainty includes sensitivity, energy response, angular dependence, calibration, processing, and fading. Model uncertainty includes radiation fields, geometry, badge placement, missing doses, and conversion from badge reading to absorbed dose to organ of interest. A comprehensive report should be out this year that addresses these specific

SC 6-9 Meeting at Oak Ridge, November 2015. Front row, left to right: Dick Toohey (MH Chew, Inc.), Larry Dauer (Memorial Sloan Kettering Cancer Center [MSKCC]), John Boice (NCRP/Vanderbilt), Andre Bouville (NCI, retired), Kathy Pryor (Pacific Northwest National Laboratory), and John Till (Risk Assessment Corporation); back row, left to right: Keith Eckerman (Oak Ridge National Laboratory [ORNL]), Cary Zeitlin (Southwest Research Institute), Rich Leggett (ORNL), Harold Beck (DOE, retired), Mike Mumma (International Epidemiology Institute [IEI]), Derek Hagemeyer (Oak Ridge Associated Universities [ORAU]), and Craig Yoder (Landauer).

Nuclear Power Plant Workshop in New York City, December 2015. Left to right: Larry Dauer (MSKCC), John Kelly (former radiation protection manager at Indian Point 3), Dennis Quinn (DAQ, Inc.), John Boice (NCRP/Vanderbilt), Matthew Williamson (MSKCC), Joseph Perrotta (retired–quality assurance manager, Indian Point Energy Center). Not Pictured: Craig Yoder (Landauer), Don Mayer (director, Indian Point Unit 1), Mike Mumma (IEI), Derek Hagemeyer (ORAU).

dosimetric concerns and challenges (and ways to overcome them).

How complete is REIRS? Before the NRC reporting changes in 1994 and the voluntary reporting of worker data back to 1957, I wrote that the REIRS data based on termination notices alone were limited. Since the reporting changes, the REIRS data are judged suitable for health effects studies. Further, data completeness back to 1969 was validated based on a comparison with workers identified from utility company records at the Calvert Cliffs Nuclear Power Plant and on comparisons of workers at two utilities included in a prior study (Howe 2004). Comparisons with data available from Landauer, Inc., also were remarkably consistent. The Landauer, Inc., records accounted for less than 0.8% of the cohort.

Focus group evaluation. Well, not really a focus group (a catchy politically correct phrase), but a daylong meeting with current and former workers at the Indian Point Nuclear Power Plant and other national dosimetry specialists held in December 2015 (see photo). The exchange of information enhanced our understanding of dosimetry and radiation protection practices at nuclear reactors during the early years of the nuclear industry. Insights (for me):

- 80% of exposures occurred during outages for maintenance, modifications, and refueling. Refueling might occur every 18–24 months but maintenance is more frequent.
- Multiple badges were worn by approximately 1% of workers for some repairs, with the highest value reported.
- The conversion from film badge reading, $H_p(10)$, to organ dose is facilitated because most exposure is from high-energy gamma rays, facilitating an adjustment with a scaling factor (conversion coefficient).
- There are few missing doses to impute because of reporting practices and requirements.
- Neutron exposures and intakes of radioactive elements were rare—whole-body counting was done each year, as were annual physicals for radiation workers.
- During one challenging outage, hundreds of welders received up to 20 mSv over a period of one to two days—while unusual, some workers with high cumulative doses may have received exposures at a relatively high dose rate.
- A famous incident of a worker who received 100 mSv in one minute contributed to a change in NRC regulations for access to high radiation areas.

Future. The first manuscript on radiation-related leukemia is under review. Follow-up through 2011 identified 30,993 deaths from all causes, including 320 from leukemia other than chronic lymphocytic leukemia (CLL). For workers with cumulative doses greater than 10 mSv, the mean active bone marrow dose was 61 mSv (maximum 1.0 Sv; 8.4% of workers had doses greater than 100 mSv). Subsequent manuscripts will evaluate over 1,200 cases of leukemia other than CLL, combining data from industrial radiographers, atomic veterans, and U.S. Department of Energy worker cohorts. Results will significantly augment scientific knowledge on the lifetime risk of cancer and leukemia following relatively low-dose exposures received gradually over time.