U.S. DEPARTMENT OF ENERGY'S RADIOLOGICAL CALIBRATION INTERCOMPARISON PROGRAM

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The United States Department of Energy's (DOE) Radiological Calibration Intercomparison Program is funded by the DOE Office of Nuclear Safety and carried out at the Pacific Northwest Laboratory (PNL) by Battelle. The program operates in the following manner: An invitation is sent annually to DOE personnel responsible for managing or performing radiological calibrations. Prospective participants return a form requesting either the instrument set or the secondary standard beta source set. The requested set is scheduled for use based on availability. Prior to sending the instrument set, the instruments are calibrated using a ^{137}Cs source. The beta sources are calibrated annually. When the results of the irradiations are returned to PNL, they are compared to PNL calibration values, summarized, and reported to the participant. At year end, results are summarized in an annual report to DOE. Participation in the program is voluntary, and the results are confidential and included in the annual report with the permission of each participant.

The instrument set contains three ionization chambers and a Geiger-Mueller counter (GM) as the detectors, a dosimetry-grade electrometer, a scaler/ratemeter, a battery-pack high-voltage power source, and the cabling necessary to perform the measurements. A 30-cc thin-walled air-equivalent plastic ionization chamber is used for measurements in photon fields. The response of the chamber for measuring air kerma is nearly independent of the energy of incident photons for energies between 20 keV and a few MeV. A build-up cap is provided to extend the useful energy range above 200 keV.

An 80-cc tissue equivalent (A-150) plastic ionization chamber (TE chamber) is used in conjunction with the GM counter for measurements of neutron kerma rate in mixed neutron and gamma fields. For convenience, the chamber is usually operated with ambient air as the fill gas instead of tissue equivalent counting gas.

The GM counter consists of a 0.48-cm-diameter tube with an active volume of 0.12 cc. The fill gas is neon, quenched with a halogen quenching agent. The detector is enclosed in an energy-flattening shield to eliminate the normal low-energy photon response characteristic.

The extrapolation ionization chamber is a 2-cm-diameter parallel plate ionization chamber with a continuously variable volume between 0.1 and 1.4 cc. The entrance window has a density thickness of 6.9 mg/cm^2. The collecting electrode and guard ring are constructed of A-150 tissue equivalent plastic and the chamber is open to ambient air.

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The electrometer is a multifunction meter capable of measuring integral charge between 10^{-8} to 10^{-14} coulombs. The scaler/ratemeter used with the GM counter has a built-in high-voltage power supply and a seven-digit display. The electrometer and scaler/ratemeter both operate on 110 VAC or internally contained battery supplies.

The secondary standard beta source set contains three beta-emitting sources, including 74-mg ^{90}Sr, 18.5-MBq ^{204}Tl, and 518-MBq ^{147}Pm. For irradiations, a source is removed from the storage jig using the source handling tool and secured in the irradiation jig. The shutter on the jig is controlled using a microprocessor-based controller/timer. Also included in the set are beam-flattening filters, reference distance rods, the jig stand, and a set of operating procedures.

The calculations used to determine the reference quantities (absorbed dose rate, tissue kerma rate, or air kerma rate) are described below. For photon irradiations, the average integrated current is multiplied by the air density correction (Ctp), the electrometer calibration factor (Ce), and the chamber calibration factor (Cg). The calibration factor converts collected current to air kerma rate.

The calculations of dose rate from the extrapolation chamber measurements follow the method in the ISO Beta Standard. The average slope of current versus plate separation is multiplied by the air-to-tissue stopping power ratio, the W value of air, and divided by the electrode area and air density to yield a value of absorbed dose rate at 7 mg/cm^2. The air density corrections pertaining to the chamber interior and the electrometer calibration factor are applied to individual collected currents prior to the least-squares fit of data, giving the desired slope mentioned above.

The neutron tissue kerma rate is determined by first determining an equivalent "air kerma rate" using the TE ion chamber and the GM counter and the procedures enumerated for photon irradiations above (substituting counts from the GM for corrected charge). The neutron air kerma rate is the difference of the quantities determined by the TE ion chamber, which measures total kerma rate, and the GM counter, which is used to determine photon kerma rate. The neutron air kerma rate is converted to neutron dose rate in tissue following the method of AAPM Report 7 and ICRU 30. The conversion factor contains the ratios of wall-to-gas stopping powers for neutrons and the calibration source, the ratio of W values of neutrons and the calibration source, the ratio of A-150-to-tissue kerma factors for neutrons and the calibration source, the attenuation and scatter factor, and the air-to-tissue kerma factor conversion.

The absorbed dose rates from the secondary standard beta sources are calculated following the method of Bohm. The dose rate at a specific date of calibration is corrected for radioactive decay and air absorption. The dose rate from the ^{147}Pm source is further corrected for humidity effects.

The results of measurements are divided by reference results determined at PNL to yield ratios of intercomparison. During fiscal year 1986, seventeen measurements were performed on a variety of isotopic photon sources (^{137}Cs, ^{60}Co, and ^{226}Ra). Seven of those measurements utilized the photon transfer chamber. The average of ratios between field measurements and PNL reference values was 1.23 ± 0.26 for the seven measurements. During fiscal year 1987, twenty measurements were performed on ^{137}Cs and ^{60}Co sources using the photon transfer chamber; the average of the ratios was 1.01 ± 0.04.

During fiscal year 1986, one measurement was performed on a ^{239}PuBe neutron source. The ratio of the measurement to reference was 4.55. Six measurements were performed on PuBe sources; the average of the ratios was 1.8 ± 0.9. Problems with measurements of neutron sources stem from low kerma rates and irradiation geometries (e.g., increased neutron scatter in neutron wells).

No measurements have been performed on x-ray or beta sources belonging to individual participants using the intercomparison instrument set.

During fiscal year 1986, results were reported from two irradiations by participants using the intercomparison secondary standard beta set. The average of ratios for the ^{90}Sr source was 1.02 ± 0.05. Only one set of measurements yielded useful ratios for the ^{204}Tl and ^{147}Pm sources and those ratios were 1.11 and 0.63, respectively. During fiscal year 1987, three measurements were performed using the beta set. The ratios from the set of available data were 0.98 for ^{90}Sr, 1.00 for ^{204}Tl, and 1.09 for ^{147}Pm.

In conclusion, the accuracy and precision of intercomparison results has improved since fiscal year 1986. The most important benefit of the program continues to be the dissemination of radiological calibration information through the operation of the intercomparison program and the biannual radiological calibration workshop.