ORTEC®

Neutron Coincidence Counting Software

INCC-B32

- **Neutron Coincidence Counting Program from Los Alamos**
- **Calibration, QA, data analysis, and report generation are included in one package**
- **Supports a wide range of shift register hardware, including the Advanced Multiplicity Shift Register, AMSR 150**
- **Includes a wide variety of Active and Passive Neutron Data analysis techniques**
- **Includes Deming Curve Fitting for development of calibration curves, with graphical plotting of results**
- **Measurement results stored in standard format database files**
- **Built-in Quality Assurance testing**

INCC-B32 is the PC version of the Los Alamos general-purpose Neutron Coincidence Counting program (INCC). It runs under Microsoft Windows 2000/XP. INCC is suitable for nondestructive passive and active neutron applications for U and Pu. Passive neutron verification techniques include known alpha, known multiplication, add-a-source, multiplicity, curium ratio, and truncated multiplicity. Active techniques include multiplicity, collar, and active/passive. Active multiplicity presently determines the neutron multiplication of a uranium item, but does not determine the uranium mass.

Items may be verified using multiple methods simultaneously. For example, plutonium items may be verified via the passive calibration curve and the known alpha techniques simultaneously. (Collar verifications may not be combined with other verification techniques.)

Hardware Supported

The following coincidence counting electronics are supported:

ORTEC/ANTECH Advanced Multiplicity Shift Register AMSR 150

Canberra JSR-11, JSR-12, and JSR-14

Los Alamos MSR4 Multiplicity Module

Canberra 2150 Multiplicity Module

Aquila Portable Shift Register (PSR)

Los Alamos Intelligent Shift Register (ISR)

Los Alamos Dual-Gated Shift Register (DGSR).

Calibration

Calibration curves are calculated internally in the program. This is done using calibration standards and the data being fitted by the Deming least squares fitting process. The resulting calibration coefficients are automatically transferred to calibration files and the system is then ready for verification measurements. Calibration curves may be plotted along with the calibration and verification measurement data to produce graphical summaries of calibration and verification results.

Easy-to-Use Output Reports

All measurement results are stored in both database and text files. Reports may be created, reviewed, and printed for any measurement data or results at any time.

Summary reports of verification results may be generated, one measurement per line, in comma-separated variable format for input to a spreadsheet program such as Excel®.

Material mass may be calculated, and the results displayed for verification. Measurement data files may be imported from the Radiation Review program, and results for background and normalization measurement data files may also be processed and displayed. (These files are created from measurements made by the Shift Register Collect or Multi-Instrument Collect running in unattended mode.) The results remain in the database, and can be reviewed or reanalyzed at any time.

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Quality Assurance

Measurement control options are included for quality assurance purposes. They include normalization and precision tests to check the detector efficiency and stability; raw data tests and outlier tests to check for data consistency.

Analysis Details

INCC-B32 provides the following analysis capabilities when used with appropriate neutron-counting hardware:

Rates Only
Rates only measurements produce singles, doubles, and triples rates and errors as the only result. The rates are corrected for dead time, passive background, and normalization.

Background
Passive background measurements automatically replace previous passive singles, doubles, and triples background rates with the new measured rates. An active background measurement automatically replaces the previous active background singles rate.

Initial Source
For americium-lithium (AmLi) initial source measurements, excluding the UNCL, the singles rate and measurement date are stored in the database as the reference values for normalization measurements. For ^{252}Cf initial source measurements the doubles rate and error and the measurement date are stored in the database as the reference values for normalization measurements. These rates are corrected for dead time and background.

Normalization
The normalization measurement determines a normalization constant to correct for a change in the detector efficiency since the initial source measurement.

Precision
Precision measurements test the short term system stability by determining whether the observed scatter in a series of doubles measurements is statistically consistent with the expected scatter. The result is the measured chi-squared value, the upper and lower limits, and a pass/fail message.

Verification Measurements — General
There are five types of passive verifications and four types of active verifications. The passive verifications determine Pu mass while the active verifications (except for active multiplicity) determine ^{235}U mass. All verifications start with the measurement of count rates as described above, followed by one or more verification calculations. Each verification type has its own analysis method; the rates from an item can be analyzed with several analysis methods simultaneously. The Pu isotopic composition is used by all of the passive methods to convert the effective ^{240}Pu mass to Pu mass; it is also used with the ^{241}Am content in the known alpha method to calculate the alpha value and in the known multiplication method to calculate the effective ^{239}Pu mass. The Pu and Am content is decay corrected from the analysis date or dates to the verification date.

Verification Measurements — Passive Calibration Curve
The verification is based on a calibration curve of corrected doubles rate vs. effective ^{240}Pu mass. Four curve types are provided with the general form $D = D(m, a, b, ...)$, where D is the doubles rate, m is the effective ^{240}Pu mass, and a, b, etc. are calibration constants. The effective ^{240}Pu mass is calculated from $D, a, b,$ etc. and the standard deviation of m is calculated using standard error propagation techniques. In addition, an extra error term is included to account for additional sources of error. The Pu mass is calculated from m and the isotopic composition; the error of the Pu mass is calculated with standard error propagation techniques using the errors of m and the Pu isotopes.

Verification Measurements — Known Alpha
The verification is based on a calibration curve of multiplication corrected doubles rate vs. effective ^{240}Pu mass. The multiplication corrected doubles rate Dc is calculated from the singles and doubles rates, the alpha value, rho-zero, and a constant k. The calibration curve has the form $Dc = a + bm$, where a and b are calibration constants. Otherwise, the analysis procedure is the same as for the passive calibration curve procedure.

Verification Measurements — Known M
The verification is based on a calibration curve of multiplication vs. effective ^{239}Pu. The equations relating the singles and doubles rates to the effective ^{240}Pu mass, multiplication (M), and alpha are the same as for the known alpha technique. Alpha and the effective ^{240}Pu mass are the unknowns; M is determined from the calibration curve. The only function for the calibration curve presently in the software is $M = 1 + am + bm^2$, where m is the effective ^{239}Pu mass, and a and b are calibration constants. There is presently no error calculation for the effective ^{240}Pu mass; the only error assigned to the effective ^{240}Pu mass is the additional error term.

Verification Measurements — Passive Multiplicity
For conventional multiplicity analysis the verification is based on the monoenergetic, point-model equations that relate the singles, doubles, and triples rates to the effective ^{240}Pu mass, multiplication, and alpha. For multiplicity analysis with unknown efficiency, the same equations are used, but the neutron multiplication is set to unity and the equations are solved for effective ^{240}Pu mass, efficiency, and alpha.

For multiplicity analysis with the dual-energy model, the energy-dependent, point-model equations are used to determine the effective ^{240}Pu mass, multiplication, and alpha. The errors of the verification results from conventional multiplicity analysis are also used for the errors in dual-energy multiplicity analysis.

There is an empirical correction factor that is applied to the effective ^{240}Pu verification mass to account for a normalization required for items with high neutron multiplication. The correction factor *f* has the form $f = a + b(M–1) + c(M–1)^2$, where *M* is the neutron multiplication and *a, b* and *c* are calibration constants. The correction factor is usually set to 1.

Verification Measurements — Add-A-Source
The add-a-source correction factor f has the form $f = 1 + a + b\delta + c\delta^2 + d\delta^3$, where *a, b, c,* and *d* are calibration constants and $\delta = D_{ref} / D_{meas}–1$, where D_{ref} is the reference doubles rate decayed to the measurement date and D_{meas} is the doubles rate from the verification item with the Cf add-a-source less the doubles rate from the verification item alone. These doubles rates involving the add-a-source are averages over up to five positions of the source. The measured doubles rate from the item is multiplied by *f* and the Pu verification mass is then determined as described above under “Verification Measurement — Passive Calibration Curve.”

Verification Measurements — Curium Ratio
Curium ratio analysis is an indirect method of determining the mass of plutonium and uranium from an observed curium neutron measurement. The curium ratio method was developed for the analysis of waste streams in spent fuel-reprocessing facilities. In these waste streams, ^{244}Curium (^{244}Cm) is the dominant neutron producing species.

This method requires a chemical analysis of the waste stream, after extraction of the plutonium and uranium has been completed, to determine the concentrations of ^{244}Cm, plutonium, and uranium. Ratios of grams curium per gram plutonium and grams curium per gram uranium can then be formed. These ratios are used as input parameters for the curium ratio analysis. It has been shown that these ratios remain constant throughout the waste treatment process (concentration, vitrification).

The actual neutron measurement is an observation of ^{244}Cm spontaneous fission neutrons. Using a typical passive calibration curve analysis, the mass of curium can be determined. The values of the Cm/Pu and Cm/U ratios are then applied to determine the mass of Pu and U from the observed Cm mass. The ratios are decay corrected from the chemical analysis date to the measurement date within the INCC program. Errors in these ratios are propagated and included in the error ascribed to the determined masses. The ^{235}U mass is also calculated by INCC, but this mass is obtained from the ratio of the operator-declared masses for ^{235}U and U.

Verification Measurements —Truncated Multiplicity
The truncated multiplicity method is used for the measurement of very small Pu items when the cosmic ray background interferes with the measurement. Truncated multiplicity analysis uses only the first three multiplicity values (the zeros, ones, and twos) in the multiplicity distributions and thus ignores the higher multiplicities that are produced primarily by cosmic rays; this improves the precision of the assay mass.

Verification Measurements — Active Calibration Curve
This is the same as verification by passive calibration curve, except that the calibration mass is ^{235}U rather than ^{240}Pu and the doubles rate is corrected for the decay of the AmLi sources.

Verification Measurements — Collar
The verification is based on algorithms for thermal-mode and fast-mode active measurements of LWR fuel.

Verification Measurements — Active Multiplicity
In its present state of development, the active multiplicity technique does not verify the ^{235}U mass of an item; it is only able to determine the neutron multiplication of the item. The multiplication is determined from the triples and doubles rates using the active multiplicity equations; the doubles and triples rates in the active multiplicity equations are the same as those in the passive multiplicity equations except that the spontaneous fission moments are replaced by the thermal neutron induced fission moments of ^{235}U, the induced fission moments are replaced by the 2-MeV induced fission moments of ^{235}U, and the spontaneous fission rate is replaced by the rate of ^{235}U fissions induced by AmLi neutrons. The calculation requires the first, second, and third factorial moments of the thermal neutron induced fission of ^{235}U and of the 2-MeV induced fission of ^{235}U.

Verification Measurements — Active/Passive
Active/passive verification is used for active verification (except UNCL verification) when the item has a significant passive neutron yield. The item is measured with and without the americium-lithium (AmLi) interrogation sources. The net doubles rate is used for the verification exactly as for verification by active calibration curve.

Holdup Measurements
The holdup measurement option performs multiple measurements of a glove box at different positions, and then averages the count rate data from each position into a single value for use in calculating the ^{240}Pu effective mass in a glove box. The multiple measurements are obtained from scanning the glove box with neutron slab detectors. The INCC software controls the data collection so that all the measurements for a single glove box are stored in one data file.

System Requirements

Any IBM compatible computer which will operate Windows 2000/XP.

One serial port unless using add-a-source, then two serial ports.

Ordering Information

Model	Description
INCC-B32	INCC Software and User Documentation
INCC-G32	INCC Documentation

Specifications subject to change
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