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Data from Rossi-α and Pulsed Neutron Prompt Neutron Time Decay Measurements at the Oak Ridge Critical Experiments Facility

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Isotope and Fuel Cycle Technology Division

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ABSTRACT

This report briefly describes the prompt neutron decay measurements by the Rossi-α and pulsed neutron methods performed at the Oak Ridge Critical Experiments Facility. It briefly describes the measurement equipment, the type of data, and how to access the actual data from the Laboratory Records Department at Oak Ridge National Laboratory and the International Nuclear Criticality Safety Benchmark Evaluation Program at Idaho National Laboratory. Most of the data was acquired between 1960 and 1975 with weapons-grade enriched uranium metal assemblies. It also includes measurement of these types performed at Los Alamos National Laboratory by Oak Ridge National Laboratory with the JEZEBEL and FLATTOP criticality assemblies and other plutonium metal parts. The purpose of this report is to support future mining of the data for publication of additional information that can be used to verify calculational methods and nuclear cross sections. Present calculational methods can be used to directly calculate the measured data.

1. INRODUCTION

This report briefly describes the prompt neutron decay measurement by the Rossi-α and pulsed neutron methods performed at the Oak Ridge Critical Experiments Facility (ORCEF) between 1960 and 1975. It briefly describes the measurement equipment, type of sources, type of detectors, the type of data, and how to access the actual data from the Laboratory Records Department at Oak Ridge National Laboratory (ORNL) and the International Nuclear Criticality Safety Benchmark Evaluation Program (INCSBEP) at Idaho National Laboratory. It also describes how the logbooks that describe the measurements can be accessed. Most of the data was acquired between 1960 and 1975 with weapons-grade enriched uranium metal assemblies. The data was originally on 240,000 punch cards and was transformed to digital form for easy access. The fissile material configurations are carefully described in the references and by the EURATOM Nuclear Energy Agency (NEA) and the INCSBEP at Idaho National Laboratory nuclear criticality safety benchmarks,. This report also provides a partial list of references for some publications of these measurements. The purpose of this report is to support future mining of the data for publication of additional information that can be used to verify calculational methods and nuclear cross sections. Present calculational methods can be used to directly calculate the measured data.

2. NEUTRON SOURCES

Data were collected using a variety of neutron sources: time tagged californium sources, and a Cockcroft–Walton accelerator that produced repetitive pulses in neutron bursts with a variety of repetition rates.

2.1 ACCELERATOR SOURCE

A 150 kV Cockcroft–Walton accelerator was purchased from Texas Instruments Corp. Deuterium–tritium (D-T) neutrons (14.1 MeV) were produced by accelerating deuterium into a water cooled tritiated target. Pulses in the microsecond to millisecond time range were produced by ion source pulsing. For pulses in the tens of nanoseconds range, the deuterium beam was swept across a narrow slit using radio frequency techniques. Figure 1 is a photograph of this system, and Figure 2 is a photograph with the target of the accelerator close to a uranium–molybdenum metal assembly. To minimize reflection effects, the accelerator is spaced some distance above the uranium metal assembly.

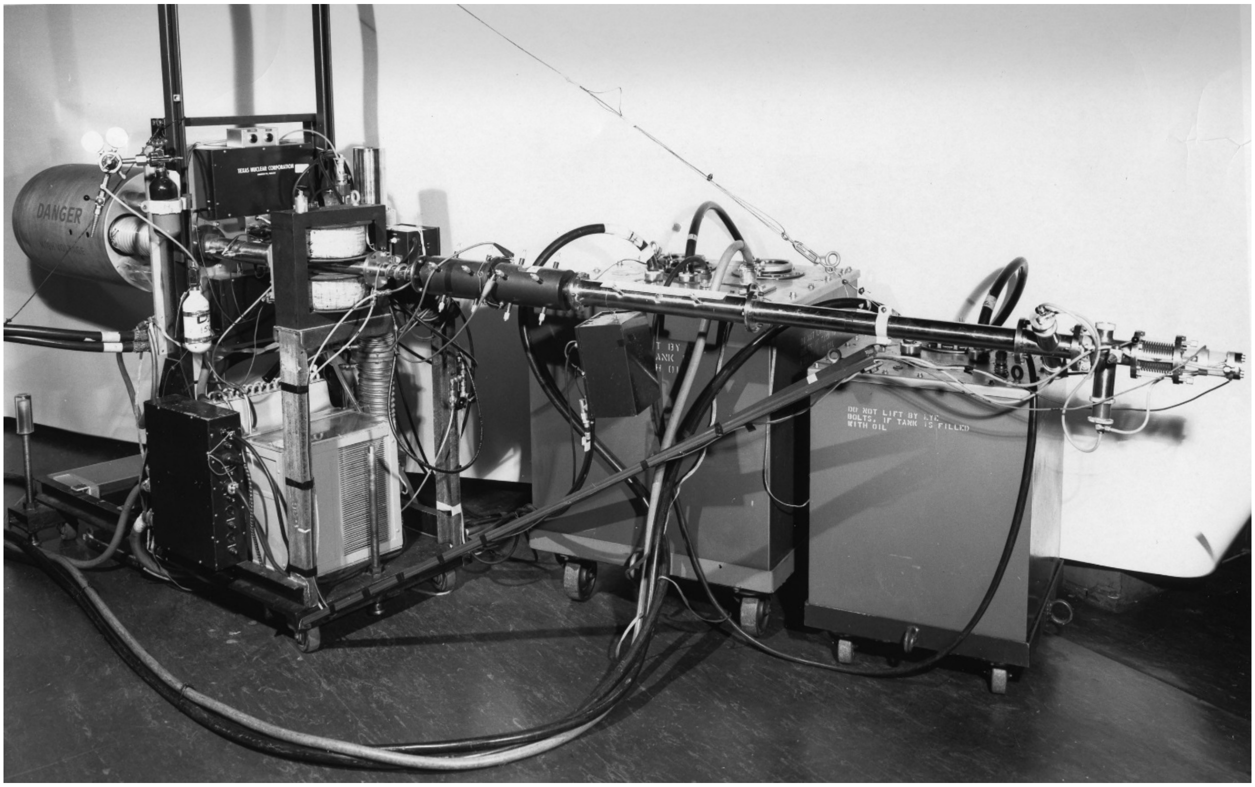

Figure 1. Photograph of the Cockcroft–Walton accelerator.. The target is on the right, and the power supplies are on wheels in the background. This system is approximately 15 ft long.

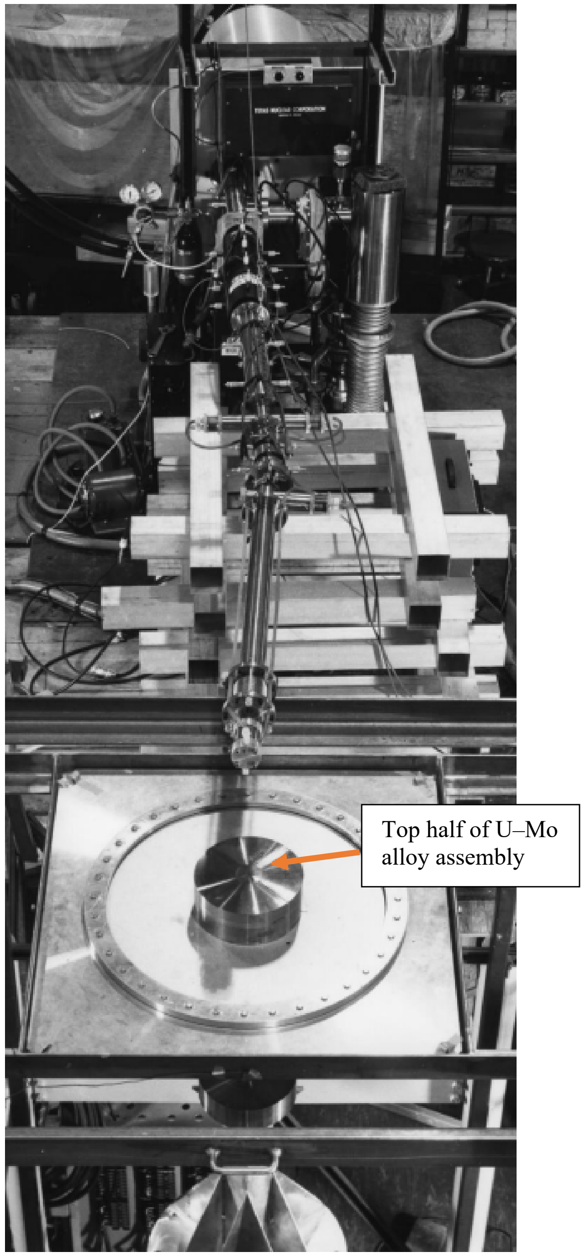

Figure 2. Photograph of the Cockcroft–Walton accelerator with the target near a uranium–molybdenum metal assembly on the upper stationary half of the vertical assembly machine at ORCEF.

2.2 TIME TAGGED CALIFORNIUM NEUTRON SOURCES

In 1968, californium-252 was deposited on one plate of a parallel plate ionization chamber. Ionization of the chamber gas by the fission products produces an electrical pulse that can be used to time the emission of neutrons. The fission product pulses can easily be discriminated from the ionization pulses produced by α emission, which is about 30 times more numerous than fission product pulses. Figure 3 is a sketch of the initial singly contained aluminum ionization chamber. In 1983, a doubly contained stainless steel ionization chamber was constructed, and a sketch of one of these is given in Figure 4. This sketch is for a Monte Carlo simulation given in INCSBEP benchmark SUB-HEU-SOL-THERM-001.The doubly contained chamber was used for all measurement after 1983. In 2001, the doubly contained ionization chambers were redesigned to be hemispherical to minimize the largest α pulses by limiting the possible length of paths of the alpha pulses. After initial use in the laboratory, it failed and was never used for measurements with fissile material. It has since been redesigned but the latest design has not been built. These californium ionization chambers served as a randomly pulsed neutron source and replaced the use of the Cockcroft–Walton accelerator, which was very cumbersome to use as is obvious from Figure 2.

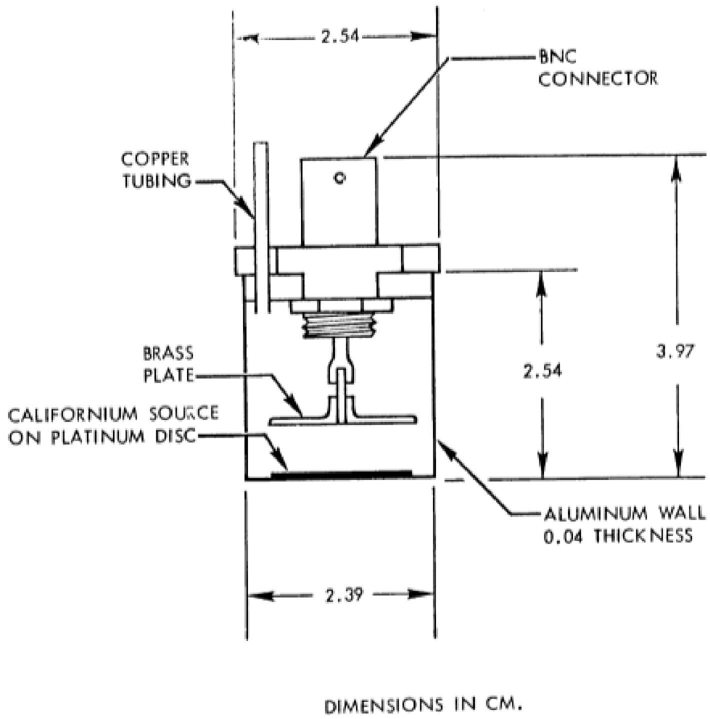

Figure 3. Sketch of the initial aluminum ionization chamber. The californium deposit was a 1 cm diameter disc in the center of the platinum foil.

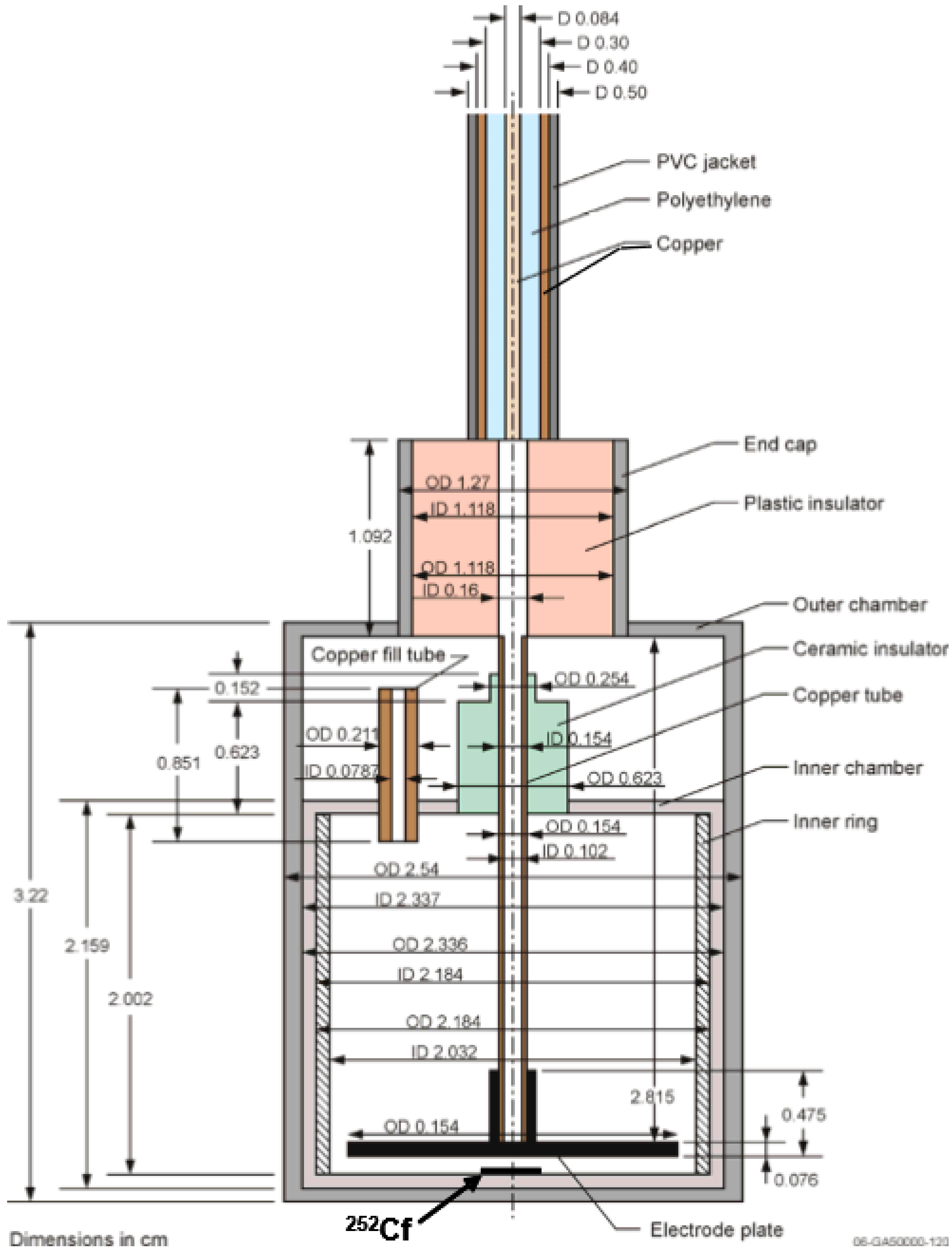

Figure 4. Sketch of the double contained stainless steel ionization chambers. Image courtesy of the ICSBEP benchmark SUB-HEU-SOL-THERM-001.

Other special chambers were built to insert in the fissile metal assemblies including the Oak Ridge Sphere, JEZEBEL, and FLATTOP. The latter two assemblies were Los Alamos National Laboratory (LANL) critical assemblies in the critical facility, and these chambers are described in the references.

3. ACQUISITION OF DATA

The time decay data was acquired with three types of data acquisition systems:

1. A Technical Measurements Corporation time analyzer was used for longer time decays for nonmetallic fissile systems. This system was used for pulsed neutron measurements with a Cockcroft–Walton 150 kV D-T accelerator. This is a Type II analyzer, and one trigger pulse measures subsequent counts as a function of time. A 32 channel Type II analyzer was also available with channel widths as low as 10 ns. This analyzer was a rack of 32 scalers that could be triggered on sequentially for preselected time intervals larger than 10 nanoseconds.

2. An ORTEC time to pulse height converter (TPHC) output was input to a pulse height analyzer. This is a Type III analyzer, and it only accepts one count from the detector for one trigger from the source and then takes a short time to reset and repeat the process. The TPHC was used for two detector Rossi-α measurements and pulsed neutron measurements for fissile metallic systems. The normal way to use the TPHC is to use the accelerator or californium source signal to start the TPHC and the detector signal to stop the TPHC. Since the detector signal is usually lower than the accelerator rate, many of the starts have no stop signal. To increase the useful start rates and to reduce dead time effects in pulse neutron measurements, the detector pulse usually started the TPHC, and the accelerator pulse stopped it. In this use, the accelerator pulse had to be delayed the total time interval of the measurement, and the direction of the time decay was reversed. In this case, the TPHC was triggered only when there was a meaningful detector pulse.

3. A 19 time channel dual-input LANL shift register was designed and built. This system accepts multiple sequential triggers and multiple sequential detector events. This system could be use with one or two inputs. It measured the time distribution of counts in one detector with respect to a previous count in the same detector (singles mode––single detector Rossi-α) or another detector (doubles mode—two-detector Rossi-α or pulsed neutron measurement with the pulse associated with the source into channel 1 and the detector pulse into channel 2). This system also measured the singles, doubles, triples, quadruples, and quintuples that occurred in the time interval of the measurement (19 channels multiplied by the time width of each channel). These multiplicities are recorded in the East cell logbooks. It was used for fissile metallic systems at ORNL and LANL. At LANL, both highly enriched uranium (HEU) metal and plutonium metal measurements were performed.

In the 1990s, a Nuclear Material Identification System (NMIS) processor was developed and was a multichannel 1 GHz shift register that is a Type I analyzer that accepts all triggers and detector pulses consistent with the few nanosecond (10^{-9} seconds) dead time determined by the width of the narrowest detector pulses. The widths of the time intervals vary from 1 ns up. Longer time decay measurements can be performed by using sequential 512 ns blocks of data. The original five channel NMIS processor has been modified to ten channels that recognize the detector pulse widths and has been used to multiplex multiple detector pulses of different time widths. This processor accepted up to 60 detector inputs (about 6 per detection channel) by sorting the times of arrival of the pulses according to pulse width.

3.1 DATA FILES

Other than NMIS data, the data files consist of an initial title card that contains a description of the configuration, date of the measurement, channel width, and logbook page where the measurement was recorded, followed by cards with the time decay data. All measurements at ORNL were completed in the East cell of ORCEF. The date of the measurements can signify which East cell logbook the measurement was recorded because all entries in East cell logbooks were sequential. The NMIS data are not yet in this database. The structure of a representative title card for a non-NMIS file is described below.

3-15-72 G 19 D 9213 SPHERE DC CF59E200 HE3 .1E-6 P-144

This title card first gives the date **3-15-72** first. The date can be associated with a logbook since there were no logbooks with multiple entries on the same date.

G denotes run G on the above date.

19 denotes the number of time channels for the LANL shift register.

D denotes double or two detector measurement where the time distribution of count in the detector in channel 2 is measured with respect to a previous count in detector 1 in channel 1. If an **S** appears here, it is a single detector Rossi-α measurement, and the time distribution of counts in a detector is measured with respect to a previous count in the same detector.

9213 is the building number for ORCEF.

Sphere denotes the uranium metal sphere, so the assembly is 9213 SPHERE.

DC denotes a measurement at delayed criticality.

CF59 indicates that time tagged californium source number 59 was used and will always be the input to channel 1.

HE3 indicates the type of detector signals in channel 2.

0.1E-6 indicates the time channel width of 0.1µs.

P-144 indicates the page number in the logbook. Logbooks for the East cell can be determined from the date because all East cell logbook entries were sequential.

The californium signal is input to channel 1 of the LANL shift register, and the HE3 detector signal is input to channel 2. The time distribution of count in the detector is measured with respect to a previous count in the time tagged Cf source.

Logbooks in the East cell of ORCEF are sequential by date. Look at the list of logbooks at INCSBEP and find one for the date 3-15-72, and look on page 144 for more information on the measurement.

3.2 TYPICAL DATA

Typical data for a time correlation measurement between a detector and a californium source for HEU metal subcritical cylinders are given in Figure 5 with the source in the center of flat surface and detector adjacent to the radial surface in 1/4 in. thick lead shield. The lead shield was to reduce the detection of low energy gamma rays from uranium. The data shown in Figure 6 were acquired with a Type III analyzer, and the trigger was a time tagged Cf source and the time distribution of count with respect to californium fission is recorded. The signal from the detector was delayed slightly so that the buildup of the distribution could also be measured. Note, sometime after the peak elapses before exponential decay occurs. The data of Figure 7 are for a two detector Rossi-α for a unreflected and unmoderated HEU metal cylinder. The signal from the second detector has been delayed so that both halves of the time correlation function were measured. The results of fitting the backgrounded subtracted data to obtain the prompt neutron decay constant form each half of the time correlation function are given in the figure and agree as they should.

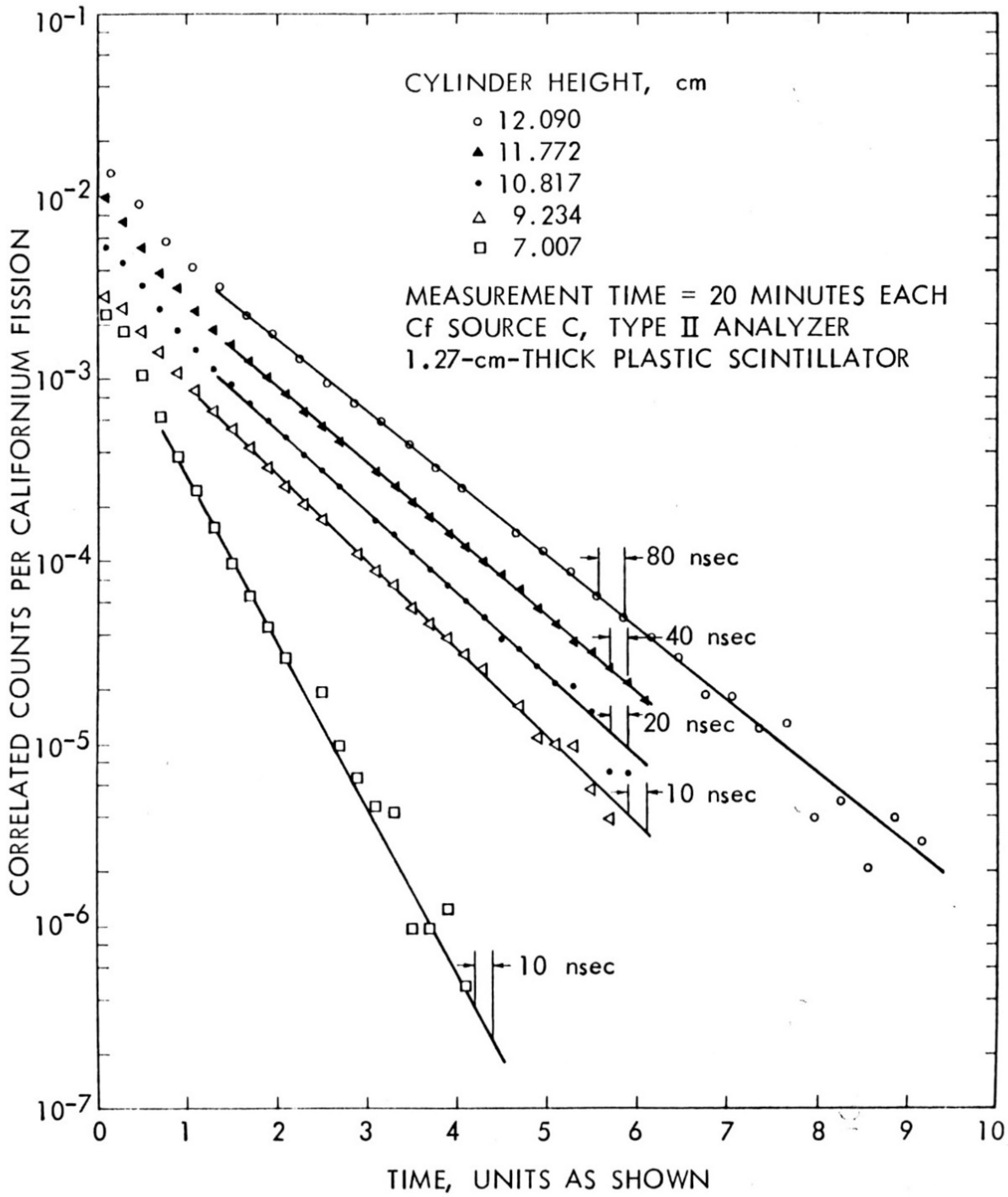

Figure 5. Time distribution of counts after californium source fission for 17.77 cm diameter HEU metal cylinders as a function of thickness for a Type II analyzer. The time channel varied from 10 to 80 ns depending on the height of the cylinders.

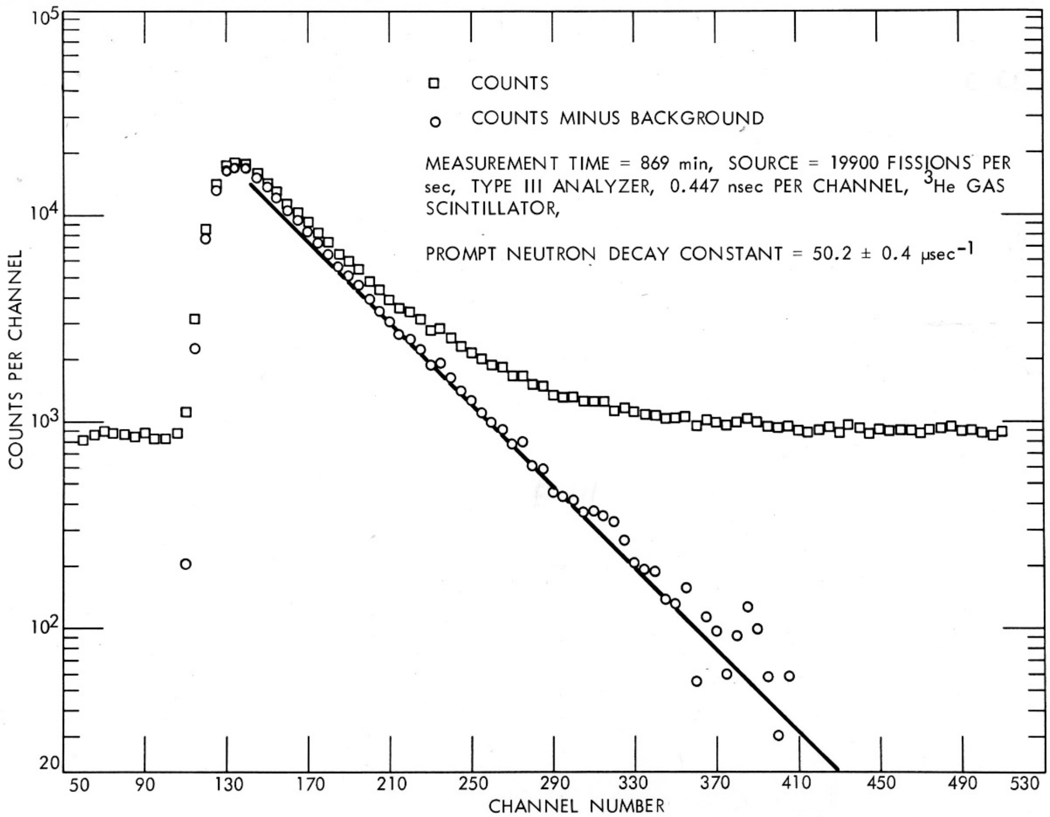

Figure 6. Time distribution of counts in a detector near a uranium metal system after californium fission acquired with a Type III analyzer.

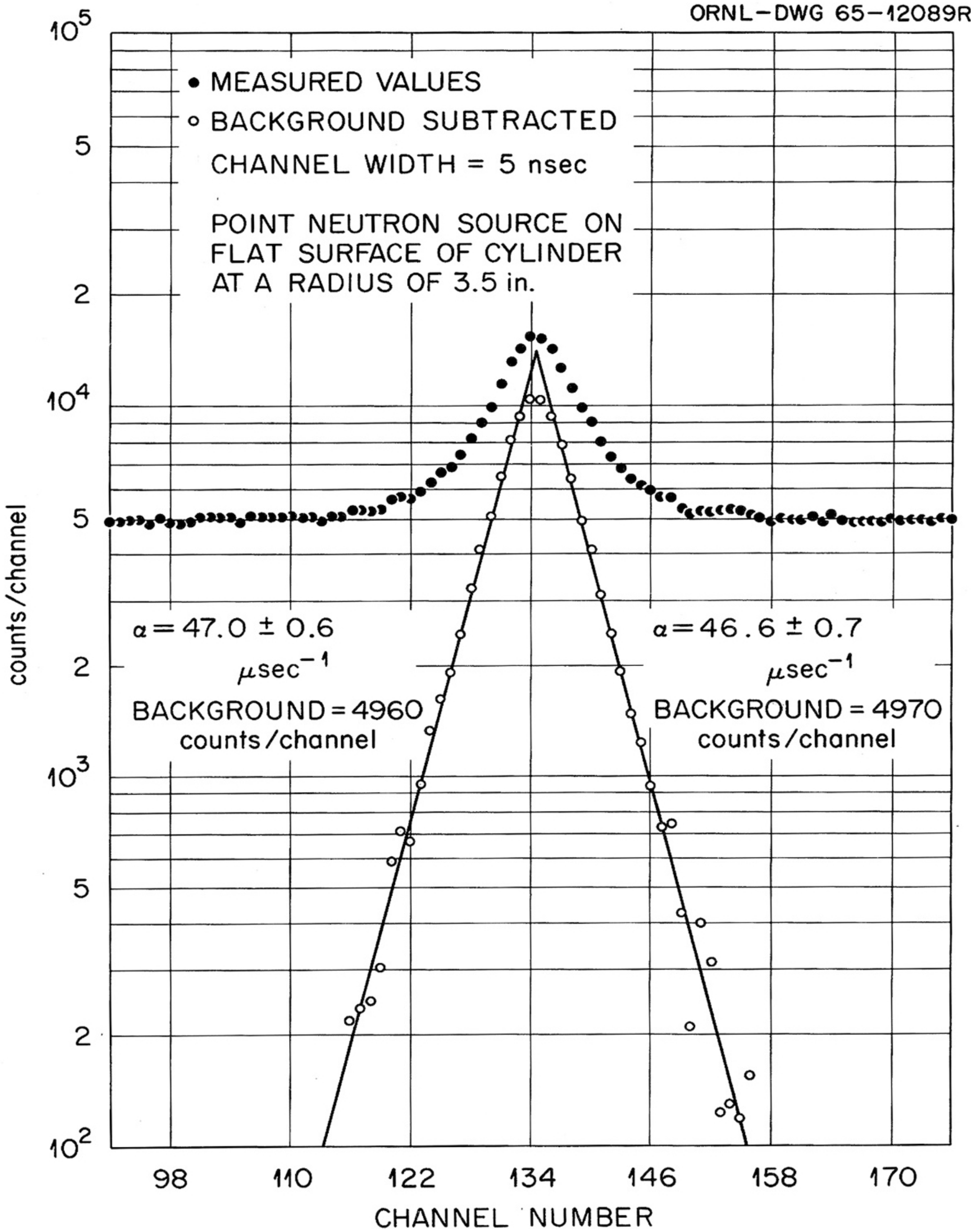

Figure 7. Time distribution of counts from a two-detector Rossi-α measurement for an 11 in. diameter, 2.125 in. thick HEU metal cylinder. Note that the signal in the second detector has been delayed so both halves of the correlation function can be measured.

3.3 ACCESSING THE DATA

The logbooks can be accessed by contacting John Bess at Idaho National Laboratory at 208-526-4375, 208-206-1286, or john.bess@inl.gov.

Access to the data can be obtained by contacting Missy Baird at the ORNL Laboratory Records Department at 865-574-6753 or bairdmh@ornl.gov. Access to the data can also be obtained from John

Bess of INL. In the future the data could also be obtained from the US Department of Energy Office of Scientific and Technical Information (OSTI).

4. CONCLUSIONS

This report briefly describes the prompt neutron decay measurement by the Rossi-α and pulsed neutron measurements performed at ORCEF. It briefly describes the measurement equipment, the type of data, and how to access the actual data from the Laboratory Records Department at ORNL and the INCSBEP at the Idaho National Laboratory. Most of the data was acquired between 1960 and 1975 with weapons-grade HEU metal assemblies. It also includes measurement of these types performed at LANL by ORNL. These data can be calculated directly by present calculational methods and thus can be used to verify calculation methods and cross sections.

5. REFERENCES

This partial list of references includes representative publications in which some of the pulsed neutron and Rossi-α measurements are described. References are divided into three categories: journal articles, technical reports, and presentations at scientific meetings. Not all references are included.

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