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ORNL

FOREIGN TRIP REPORT

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DATE: January 29, 2014

SUBJECT: Report of Foreign Travel to Aix-En-Provence and Paris, France – Luiz C. Leal, Reactor and Nuclear Systems Division

TO: Jerry N. McKamy, Director, Office of Environment, Safety, and Health, National Nuclear Security Administration / NA-00-10/GTN, 1000 Independence Ave., SW, Washington, DC 20585-1290

FROM: Luiz C. Leal

PURPOSE: The primary purpose of the travel is to perform nuclear cross-section evaluation work in accordance with the U.S. Nuclear Criticality Safety Program (NCSP) Five Year Plan tasks for developing nuclear data evaluations for ^{235}U and ^{56}Fe. Specifically, the tasks include cross-section evaluation work and benchmark testing of the ORNL evaluations. Furthermore, the travel provided the opportunity for Leal to work with staff from the Commissariat a l'Energie Atomique (CEA) / Cadarache and the "Institut de Radioprotection et de Sûreté (IRSN)" (i.e., the French Institute for Radiological Protection and Nuclear Safety) to test and improve the new ^{235}U and ^{56}Fe evaluations using proprietary integral benchmark experiments from CEA and IRSN, respectively. All of these work tasks have been performed in accordance with the NCSP Five Year Plan.

SITES VISITED: CEA/Cadarache and IRSN

ABSTRACT: During the first three weeks of travel, Leal worked with CEA/Cadarache staff to update the ^{235}U resonance evaluation and test the evaluation using proprietary CEA benchmark experiments. Based on the benchmark testing effort, Leal has been able to improve the ^{235}U resonance evaluation in the intermediate energy range, and the collaborative work effort has resulted in an improved ^{235}U resonance evaluation for nuclear criticality safety applications. Following the visit to CEA, Leal spent the remaining part of the travel working with IRSN staff to update and test the new ^{56}Fe resonance evaluation using proprietary IRSN benchmark experiment data. The collaborative work effort with IRSN has resulted in an improved ^{56}Fe resonance evaluation for nuclear criticality safety applications. Additional work will be needed in FY14 to finalize the ^{235}U and ^{56}Fe evaluations; however, the collaborative work efforts with CEA and IRSN have accelerated the cross-section evaluation and testing effort thereby supporting the NCSP Five Year Plan tasks for these key nuclear data evaluations.

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REPORT OF FOREIGN TRAVEL

Luiz C. Leal
Aix-En-Provence and Paris, France
September 13–November 30, 2013

PURPOSE OF TRAVEL

The primary purpose of the travel is to perform nuclear cross-section evaluation work in accordance with the U.S. Nuclear Criticality Safety Program (NCSP) Five Year Plan tasks for developing nuclear data evaluations for ^{235}U and ^{56}Fe. Specifically, the tasks included cross-section evaluation work and benchmark testing of the ORNL evaluations. Furthermore, the travel provided the opportunity for Leal to work with staff from the Commissariat a l'Energie Atomique (CEA) / Cadarache and the "Institut de Radioprotection et de Sûreté (IRSN)" (i.e., the French Institute for Radiological Protection and Nuclear Safety) to test and improve the new ^{235}U and ^{56}Fe evaluations using proprietary integral benchmark experiments from CEA and IRSN, respectively. All of these work tasks have been performed in accordance with the NCSP Five Year Plan.

Report

CEA/Cadarache

The first part of the trip consisted of working for three weeks with CEA/Cadarache researchers to test and evaluate the performance of the ^{235}U resonance parameters to address criticality safety issues for benchmark systems in the intermediate energy region.

As part of the NCSP nuclear data work effort, Leal has performed a neutron resonance analysis for ^{235}U using the ORNL-developed SAMMY R-matrix analysis software, and he has produced a new ^{235}U evaluation based on new differential ^{235}U data measured at the Rensselaer Polytechnic Institute (RPI). The new RPI data are fission and capture cross-section data in the energy region from 100 eV to 4 keV. The resolved resonance energy range for ^{235}U is from thermal to 2.25 keV. The new RPI measurements confirm a problem with the latest ^{235}U capture cross-section evaluation at energies above 100 eV. The existing Evaluated Nuclear Data File Version VII.1 (ENDF/B-VII.1) ^{235}U evaluation provides higher capture cross-section values relative to the new measured data from RPI. In addition, independent cross-section measurements have been completed at Los Alamos National Laboratory (LANL) for ^{235}U. The LANL measurements were performed at the Los Alamos Neutron Science Center (LANSCE) using the Detector for Advanced Neutron Capture Experiments (DANCE). Although the LANL measured data have less energy resolution relative to the RPI data, their average calculated cross sections confirm the issue with the ENDF/B-VII.1 ^{235}U resonance evaluation. Leal has performed a SAMMY resolved resonance analysis and re-evaluation of the ^{235}U ENDF/B-VII.1 evaluation using the new data from RPI and LANL. As a result, a new set of ^{235}U resonance parameters covering the energy region from thermal to 2.25 keV has been produced. Leal's visit to CEA/Cadarache was important because the visit provided an opportunity to test the new ^{235}U resonance evaluation using proprietary CEA/Cadarache integral benchmark data for ^{235}U that are not available in the open literature. Specifically, the integral benchmark experiments have been performed at the CEA experimental facilities EOLE, MASURCA, MINERVE. These CEA experiments were performed to investigate various nuclear criticality safety and reactor physics issues with fissionable systems involving ^{235}U at thermal and intermediate neutron energies.

In order to test the accuracy of the ^{235}U resonance evaluation at energies above 100 keV, benchmark experiments (MOX fuel-like experiments) that include the build-up of ^{236}U were used because these benchmark experiments are sensitive to the ^{235}U capture cross-section data in the energy region of interest. In addition, the CEA/Cadarache codes such as TRIPOLI and APOLLO were used in the calculations. The results demonstrate that the new ORNL resonance evaluation is preforming reasonably well. Sensitivity analyses using CEA/Cadarache radiation transport codes indicate two issues with the ^{235}U evaluation:

a) There is a need to investigate the ^{235}U cross section in the unresolved resonance region (i.e., energies above 2.25 keV).
b) There is a large discrepancy with the ^{235}U capture cross-section data in the energy region from 30 keV to 1 MeV.

During the visit at CEA, Leal did not have time to investigate these additional issues in the unresolved resonance region; however, the benchmark testing with the CEA data helped to clarify additional evaluation work that is needed in the unresolved resonance region.

Another issue that was investigated during the CEA visit is the impact of the (n,γf) process on the ^{235}U cross-section evaluation. The R-matrix analysis does not predict this type of reaction. Therefore, it was postulated that the problem with previous ^{235}U capture cross-section measurements could have been affected by the (n,γf) reaction. Several theoretical calculations were carried out to determine the magnitude of the (n,γf) cross section and its potential impact on benchmark calculations. The conclusion was that since the ^{235}U (n,γ) cross section is much larger than (n,γf), the impact in the benchmark calculations is negligible. Also, issues with the previous capture cross-section measured data cannot be explained on the basis of the (n,γf) process.

IRSN

Following the visit to CEA/Cadarache, Leal traveled to the French Institute for Radiological Protection and Nuclear Safety (IRSN) to perform work on the ^{56}Fe resolved resonance evaluation in accordance with the NCSP Five Year Plan nuclear data work tasks. A new approach has been used at ORNL to extend the ^{56}Fe resolved resonance range from 850 keV in the present evaluation to as high as the experimental energy resolution of the data permits. High-resolution transmission data for ^{56}Fe have been measured at RPI. The measurements were performed on a 250-m flight-path with a neutron burst of 1.5 ns providing excellent data resolution. These data were used to extend the present ENDF/B-VII.1 ^{56}Fe resolved resonance evaluation up to 2 MeV. The energy range above 850 keV includes an inelastic channel. Therefore, the representation of the inelastic cross sections with resonance parameters must be addressed. New inelastic cross-section measurements have been performed using the Geel Electron Linear Accelerator (GELINA) at the Institute for Reference Materials and Measurements (IRMM) in Belgium. The IRMM data were also used in the SAMMY resonance evaluation effort for ^{56}Fe. In addition, ORNL has championed a new approach for generating angular-dependent cross-section data produced from the resonance parameters with the objective of improving the calculation of neutron leakage in criticality safety benchmarks for systems with small dimensions. IRSN has proprietary integral benchmark experiment data in the thermal energy region that were used to test and improve the ^{56}Fe resonance evaluation. In addition to the critical benchmark data, fixed-source benchmark experiments consisting of iron spheres with dimensions ranging from 20 cm to 70 cm radius were also used in the evaluation testing effort. The results of the benchmark testing indicate that, in addition to ^{56}Fe, contributions to natural iron from ^{54}Fe need to be accounted for in the re-evaluation effort. Based on the work at IRSN, a revision to the ^{54}Fe cross-section will be needed to support criticality safety analyses. Furthermore, the benchmark calculations at IRSN indicate that the new ORNL ^{56}Fe evaluation currently does not significantly improve

benchmark results relative to the existing ENDF/B-VII.1 ^{56}Fe evaluation. Based on sensitivity calculations, there is a need to extend the ^{56}Fe resonance evaluation above 2 MeV, and ORNL has initiated an effort to extend the ^{56}Fe resonance evaluation from 2 MeV to 4 MeV.

Overall, Leal's foreign travel to CEA/Cadarache and IRSN has been crucial to completing nuclear data evaluation work tasks as defined in the NCSP Five Year Plan. Furthermore, the travel has accelerated the cross-section evaluation and testing effort for ^{235}U and ^{56}Fe thereby enabling ORNL to perform work toward completing the NCSP Five Year Plan tasks for these key evaluations.

Itinerary

9/13/13 - 9/14/13	Travel from Knoxville, TN, USA to Aix-En-Provence, France
9/16/13 - 9/27/13	Work at CEA/Cadarache
9/28/13 – 9/28/13	Travel from Aix-En-Provence to Paris, France
9/30/13 - 11/29/13	Work at IRSN
11/30/13	Travel from Paris, France to Knoxville, TN, USA

DISTRIBUTION

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