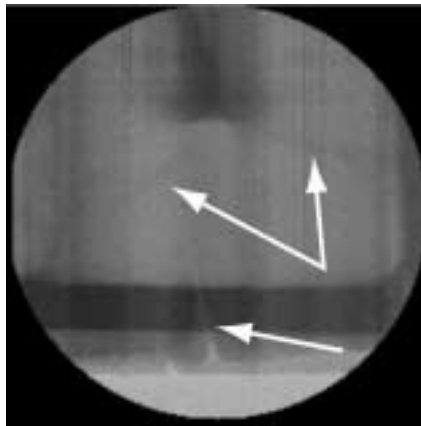
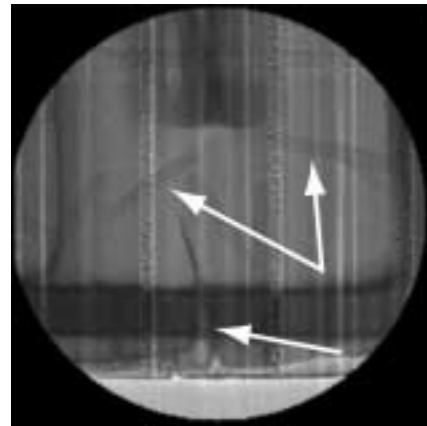

TECHNICAL ACTIVITIES

Neutron Interactions and Dosimetry Group

Ionizing Radiation Division
National Institute of Standards and Technology



Conventional Neutron
Radiograph



Phase-Contrast
Radiograph

December 2000

Cover:

The neutron radiographs on the cover show the phase-contrast enhancement of images of cracks in a turbine blade. The phase-contrast image was made by a novel method without the use of a neutron interferometer. See *Nature*, 408, 9 November 2000, p.158.

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INTRODUCTION

Neutron Interactions and Dosimetry Group

This Group provides measurement services, standards, and fundamental research in support of NIST's mission as it relates to neutron technology and neutron physics. The industrial interests served include scientific instrument calibration, electric power production, radiation protection, national defense, radiation therapy, neutron imaging, and magnetic resonance imaging.

The Group's activities for the year 1999 are presented in the following pages under three project headings:

A. Fundamental Neutron Physics - including development of an ultracold neutron source, applications of neutron interferometry and neutron optical techniques, development of neutron spin filters based on laser polarization of ^3He , measurement of the beta decay lifetime of the neutron, and investigations of other coupling constants and symmetries of the weak interaction. This project involves a large number of collaborators from universities and national laboratories.

B. Standard Neutron Fields and Applications - utilizing both thermal and fast neutron fields for dosimetry in nuclear reactor and defense applications and for personnel dosimetry in radiation protection. These neutron fields include thermal neutron beams, "white" and monochromatic cold neutron beams, a thermal-neutron-induced ^{235}U fission neutron field, and ^{252}Cf fission neutron fields, both moderated and unmoderated. The calibration of these neutron fields is derived from related artifacts, facilities, and capabilities maintained by the project: the national standard neutron source NBS-I, a manganous sulfate bath for neutron source comparisons, a collection of fissionable isotope mass standards (FIMS), a collection of boron and lithium isotopic standards, and spectroscopy facilities for both gamma rays and alpha particles.

C. Neutron Cross Section Standards - including experimental advancement of the accuracy of neutron cross section standards, as well as evaluation, compilation and dissemination of these standards. These data standards are important for nuclear reactor safety and performance calculations, for development of fusion energy, for understanding high-energy neutron dosimetry in radiation protection and radiation therapy, and for basic science studies in astrophysics.

Summary of Main Accomplishments

Accomplishments this year have included (i) demonstration of phase-contrast neutron radiography without an interferometer, (ii) demonstration of thermal-neutron-induced soft failures in SRAM and DRAM chips, (iii) further investigation of the separation of coherent scattering from incoherent scattering using ^3He -based polarization analysis in small angle neutron scattering (SANS), and (iv) completion of the final data-taking runs of the Penning-Trap neutron lifetime experiment.

D. M. Gilliam, December 2000

Technical Activities

A. Fundamental Neutron Physics

- **Tests of the Weak Interaction and the Neutron Lifetime**

(M.S. Dewey, J. Nico, P. Huffman, F. Wietfeldt, J. Adams, A. Thompson, with M. Arif, T. Gentile, F. Bateman, D. Gilliam, D. Jacobson)

The cold neutron guide hall at the NIST Center for Neutron Research (NCNR) provides a unique opportunity for the U.S. to compete for a leading role in research on the physics of fundamental particles. High precision measurements at very low neutron energies complement high energy research at national and international particle accelerator laboratories. Measurement techniques developed for this research improve NIST's ability to provide measurement services and calibrations. The Neutron Interactions and Dosimetry Group pursues a research program of its own, as well as supporting a national user facility for industrial and university researchers.

Two different neutron lifetime experiments, one a Harvard-led ultracold neutron (UCN) experiment, the other a NIST-led cold neutron beam experiment, are currently able to take data on our polychromatic neutron beam at the NCNR.

Complete three-dimensional magnetic trapping of ultracold neutrons was demonstrated by the Harvard/NIST collaboration for the first time, as reported in the journal *Nature* (**403**, 2000). Trapping of neutral and charged particles is an invaluable tool for the study of both composite and

elementary particles. The main advantages of trapping are long interaction times and isolation from perturbing environments. In the present work, inelastic scattering in superfluid ^4He is used to load neutrons into the trap, and the helium also acts as a scintillator for detection of neutron decay. The work described in the *Nature* article verified the theoretical predictions of the loading process and the technique of magnetic trapping of neutrons. During CY00 major upgrades to the apparatus were installed, including a larger trapping magnet and a monochromator to prefilter the incident beam. These improvements should result in a precise measurement of the beta-decay lifetime of the neutron sometime in CY01.

The NIST-led lifetime experiment utilizes a Penning trap for decay protons and a thin ^6Li neutron fluence monitor to measure the lifetime of free neutrons in a 30 K thermal neutron beam. During CY00 final data taking runs of the experiment were completed. A major source of uncertainty in this experiment comes from measurement of the neutron fluence. In the past the neutron monitor calibration factor was calculated from a cold neutron capture cross section, the areal density of the ^6Li deposit through which the neutrons pass, and the measured solid angle of the detector. Now in collaboration with Indiana University, an independent calibration of the neutron fluence monitor is being achieved by use of a totally absorbing cryogenic calorimeter. Several absorbing targets are being intercompared: LiPb, LiMg, and liquid ^3He . The LiMg target results have verified the thin ^6Li monitor results within about 0.4%, as reported in a recent Ph.D. thesis. When

completed in early CY01, this work is expected to reduce the uncertainty in the neutron fluence by at least a factor of two.

Preliminary work has begun on a NIST-led experiment to measure the electron-antineutrino correlation in neutron beta decay using a novel asymmetry technique that does not rely on precise proton spectroscopy. This correlation coefficient was last measured in 1978 and has a 5% uncertainty (by comparison the other better known correlation coefficients are known to slightly better than 1%). This experiment requires an electron spectrometer with a high degree of backscatter suppression to minimize the low-energy tail in the response function. During CY00 a prototype electron spectrometer consisting of a conical array of plastic scintillator detectors coupled to photomultipliers was designed and constructed, and testing was begun on our 4 MeV electron Van de Graaf.

In CY00 the large collaborations responsible for two previous experiments on our polychromatic beam continued major drives to upgrade those experiments in preparation for further running on our beam. Both projects, a search for time-reversal symmetry violating correlations in neutron decay and a search for parity violating spin rotation of neutrons in bulk media, are expecting to be ready for beam time sometime in late CY01. These projects have produced three recent Ph.D. theses and have already made modest improvements on the best preceding results.

The results of the time-reversal asymmetry experiment were recently published in *Phys. Rev. C*.

Throughout the year our group explored promising new ideas for experiments that

probe the weak interactions with scientists from Los Alamos National Laboratory (LANL). The most promising ideas would lead to participation in a LANL-led measurement of the parity-violating gamma-ray asymmetry in the “npd \otimes ” reaction (polarized neutron plus proton goes to deuteron plus gamma-ray) at the spallation neutron source at LANL, and to participation in a LANL-led measurement of the electric dipole moment of the neutron using UCN.

- **Polarized ^3He for Neutron Spin Filters**

(T. Gentile, A. Thompson, D. Rich)

The primary focus of the polarized ^3He program is the development of neutron spin filters and application of these devices to both materials science and fundamental physics. We are developing two optical pumping methods, spin-exchange and metastability-exchange, for producing the polarized ^3He gas. In collaboration with materials scientists, we are conducting experiments at the NCNR to demonstrate the advantages of ^3He spin filters for certain materials science applications. In addition, we are contributing to an experiment in weak interaction physics at the Los Alamos National Laboratory, and are also collaborating with Indiana University in applications at the Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory.

In May 2000, we employed polarized ^3He -based neutron polarization analysis for an experiment on the NCNR NG7 small angle neutron scattering (SANS) instrument. The goal was to separate the magnetic and nuclear scattering obtained from a sample of the colossal magnetoresistive (CMR) material

$\text{La}_{0.85}\text{Sr}_{0.15}\text{MnO}_3$. Materials in this class are of interest for application of polarized ^3He because no other method exists for isolation of the magnetic scattering. Data was acquired using cells polarized by both optical pumping methods. The ferromagnetic transition of the material at 235 K was clearly identified by depolarization of the neutron beam by the sample. However, analysis of the scattering data has proved to be problematic, which may be due to the overwhelming structural scattering in this sample. Hence we are planning experiments on other samples so that the method can be demonstrated clearly in a simple case before tackling such difficult samples again.

Besides production of the polarized ^3He gas required for spin filters, an important issue in the application of spin filters is the interaction with the sample and instrument environments.

Relaxation of the ^3He polarization in different holding field scenarios is being studied with a diode-laser based apparatus for metastability-exchange optical pumping.

The ^3He polarization achievable with the diaphragm compressor apparatus has been improved using a more efficient optical pumping scheme. For the SANS experiment the polarizations obtained from each of the optical pumping methods were both just under 50%, but the spin-exchange cell was the better performer because of the extremely long relaxation time of the spin-exchange cell (130 hours). Hence the focus of attention for the metastable work will shift from improving the polarization to improving the cell relaxation times by using alkali coatings.

We are also investigating spin-exchange optical pumping with spectrally narrowed high

power diode lasers. One of the reasons we typically use high ^3He pressure (3.5 bar) for spin-exchange cells is to increase the pressure-broadened absorption width to better match the broad spectrum of high power diode lasers. Recently spectrally narrowed diode lasers have been developed by other researchers, which might allow reduced pressures for spin-exchange cells. In addition to relaxing the mechanical constraints on spin-exchange cells, lower pressure cells would allow for the possibility of extremely long cell relaxation times because of the reduced dipole-dipole relaxation. We have recently produced a neutron-compatible cell at 1 bar with a relaxation time of at least 400 hours, a world record to our knowledge. Such cells would allow for quite stable polarization even in the absence of continuous optical pumping.

NIST is collaborating with LANL in the application of ^3He polarizers to the proposed npd@ LANSCE experiment. A recent test run at LANSCE (Nov., 2000) utilized a NIST “double” spin-exchange cell (i.e., separate volumes for optical pumping and spin filtering). Indiana University recently employed a metastability-exchange cell prepared and tested at NIST for an experiment to demonstrate ^3He -based neutron polarization analysis in polarized neutron reflectometry.

- **Neutron Interferometry and Optics Facility (NIOF)**

(M. Arif, D. Jacobson, S.A. Werner, P. Huffman, T. Gentile, A. Thompson)

During the past year at the NIOF a number of fundamental and applied physics experiments have been started and/or completed with collaborators from the University of

Melbourne, Australia, the University of Missouri, the University of Indiana, and the University of North Carolina: Phase Contrast Radiography, Neutron-Deuteron Scattering Length in Gaseous Deuterium, Dynamical Diffraction Measurement of the Neutron-Electron Scattering Length, and Visualization of Lithium Ion Migration in Ion Conductors.

The results of an experiment to produce quantitative Phase Contrast Radiographs of small objects were reported in the journal *Nature* (**408**, 2000). This experiment was the result of collaborative efforts between NIOF, the University of Melbourne, and the University of Missouri. This Phase Contrast Radiography technique is novel since it provides a way of extracting phase information in an image without the use of an interferometer. Images taken have shown that this technique makes small and delicate features much more prominent. Eventually this technique will be applied to neutron phase contrast tomography as well.

Major progress has been made in the design and construction of a highly sensitive experimental assembly for the precision measurement of the scattering lengths of gases in a neutron interferometer. This will lead to an upcoming experiment that will measure the scattering length of deuterium gas. This achievement is important since the neutron interferometer represents the only neutron optical device capable of precisely measuring the scattering lengths of gaseous samples. Accurate knowledge of the scattering length is important in many theoretical models of the neutron interaction in few body problems. By using gaseous samples, one can avoid some of the difficulties encountered in interpreting the results of similar scattering length

measurements in solid state systems e.g. Bragg reflection interferences.

The results of an ongoing experiment to measure the neutron-electron interaction amplitude via the scattering length b_{ne} have been extremely promising. This very fundamental quantity b_{ne} is critical to the understanding of the charge structure of the neutron and of the deuteron charge structure in atomic physics. After four decades of sustained effort discrepancies between different experimental values and between experiment and theory persist. Using a novel dynamical diffraction effect for a perfect single crystal inside a neutron interferometer, we are attempting to measure b_{ne} directly and accurately. This measurement does not suffer from many of the systematic errors common to most of the previous experiments.

Ongoing experiments supported by the NIST Advanced Technology Program attempt to image lithium ion conduction in batteries and reveal the isotopic lithium concentration in ion conductors. This research effort aims at providing new methods for evaluating the effectiveness of future battery technologies.

Finally, after a highly successful effort to design, construct, and operate a mobile 3-D neutron imaging station, new funding has been secured to aid in the construction of a more permanent neutron tomography facility. The DOE Office of Transportation Technologies Fuel Cell Program is supporting the establishment of a fuel cell test and evaluation facility here at NIST. This station will afford industrial researchers the tools of neutron tomography to aid the future development of advanced fuel cell related technologies.

B. Standard Neutron Fields and Applications

- **Neutron Dosimetry**
(J. Adams, J. Nico, A. Thompson, D. Gilliam)

The number of routine calibrations and irradiations was somewhat lower this year than in the preceding year, but there were some important new developments.

For the first time we provided a neutron survey instrument calibration in an Am-Be neutron field. We still have some development work to do on this capability before we can provide these calibrations with uncertainties as low as those done with ^{252}Cf sources. Nevertheless, the customer was very pleased to get a calibration that relates directly to his own Am-Be transfer source.

Another important development was the initiation of accelerated testing for neutron-induced soft failures in SRAM and DRAM chips. This accelerated testing was done both with thermal neutrons and ^{252}Cf neutrons. In this work, it was shown conclusively that thermal neutrons at normal environmental levels (from cosmic rays) have begun to be a serious problem for some batches of SRAM and DRAM chips which incorporate borosilicate glass films in their manufacture.

The neutron source calibrations this year included one calibration for a secondary standards laboratory and two calibrations for industrial customers. The radiation protection dosimetry calibration customers included one DOE fuel processing facility and four industrial customers. Special tests for two neutron detector manufacturers were

performed with thermal neutron beams at the reactor thermal column.

C. Neutron Cross Section Standards

- **Neutron Cross Section Standards**
(A. Carlson, D. Gilliam)

The NIST Neutron Cross Section Standards Project has played an important role in the improvement of the neutron cross section standards through both evaluation and experimental work. We are leading an effort that will result in a new international evaluation of the neutron cross section standards. This has involved motivating and coordinating new standards measurements, examining the standards database, and pursuing the extension of the standards over a larger energy range. This work is taking place through participation in the U.S. Cross Section Evaluation Working Group and two international committees, the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency Nuclear Science Committee. An IAEA Coordinated Research Project has been formed to provide resources to allow meetings of the contributors to this evaluation process. An objective is to complete the evaluation in time for the major international cross section evaluation projects to use the improved standards in forming new versions of their libraries.

This NIST project has continued to maintain a limited experimental role in the measurements of the standards. This role has led to a new, NIST-LANL-Ohio University collaborative measurement of the $\text{H}(n,n)$ angular distribution at Ohio University at 10 MeV neutron energy. The final results of the data indicate differences with the most recent

U.S. evaluation of this angular distribution. As a result of these differences, measurements are planned at about 15 MeV neutron energy to determine the energy dependence. This work was initiated as a result of concerns about that evaluation expressed by European standards groups. The H(n,n) angular distribution is one of the most important neutron cross section standards. Also, plans are being made for a new measurement, which will lead to improvements in the $^{10}\text{B}(n,\gamma)$ standard at low neutron energies. This work will be done at the new NIST monochromatic neutron beam facility on NG6.

DOSIMETRY INSTRUMENT AND SOURCE CALIBRATIONS, 2000

Customer Classification	Type of Service	No. of Customers	No. of Tests Performed	Service Fee Income (\$)
Industrial	H	2	2	5,465
	I	4	5	7,308
Government Agencies	H	1	1	2,309
	I	1	1	1,410
<hr/>				
SUBTOTALS	H	3	3	7,774
	I	5	6	8,718
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GRAND TOTALS	H and I	8	9	16,492

Service Code	Type of Service	SP250 Number
H	Radioactive Neutron Source Calibrations	44010C, 44020C
I	Neutron Survey Instrument Calibrations	44060C

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Smith, D.A., Smith, T.B., Welsh, R.C.,
Wietfeldt, F.E., Wilburn, W.S.,
Yuan, V.W., and Zerger, J.,
“Measurement of the Parity Violating
Asymmetry A_γ in $n + p \rightarrow d + \gamma$,” *Nucl.
Instrum. Meth. A* **440**, 729-735 (2000).

Snow, W.M., Chowdhuri, Z.,
Dewey, M.S., Fei, X., Gilliam, D.M.,
Greene, G.L., Nico, J.S., and
Wietfeldt, F.E. “A Measurement of the
Neutron Lifetime by Counting Trapped
Protons,” *Nucl. Instr. Meth. A* **440**, 528-
534 (2000)

Stanka, M.B., Adams, J.M., and
Eisenhauer, C.M., “Proton Recoil
Measurements of the ^{252}Cf Fission
Neutron Leakage Spectrum from an Iron

Sphere,” Nuclear Sci. and Eng., **134** 68-76 (2000).

INVITED TALKS

Adams, J.M., "The Neutron Source Calibration Program at the National Institute of Standards and Technology," 2000 American Nuclear Society Annual Meeting, San Diego, CA, June 4-8, 2000.

Arif, M., "Neutron Interferometric Measurement of the Neutron-Electron Interaction Length," Atomic and Optical Physics Division Seminar, April 6, 2000.

Arif, M., "NDE of Fuel Cells via Neutron Imaging," presentation at the DOE Program Review Conference, Richland, WA, June 8, 2000.

Carlson, A.D., "Recent NIST Nuclear Data Activities," U.S. Nuclear Data Program Meeting, Lawrence Berkeley National Laboratory, Berkeley, CA, April 26, 2000.

Carlson, A.D., "Status of the International Evaluation of the Neutron Cross Section Standards," Working Party on International Evaluation Cooperation Meeting, Japan Atomic Energy Research Institute, Tokai-Mura, Japan, June 20, 2000.

Carlson, A.D., "The U.S. Nuclear Data Measurement Program," Working Party on International Evaluation Cooperation Meeting, Japan Atomic Energy Research Institute, Tokai-Mura, Japan, June 21, 2000.

Carlson, A.D., "New Data for the International Neutron Standards Project", Cross Section Evaluation Working Group Meeting, Brookhaven National Laboratory, November 8, 2000.

Dewey, M.S., "Measuring the Neutron Lifetime by Counting Trapped Protons" and "A New Experiment to Measure the Beta-Antineutrino Correlation in Neutron Decay," Division of Nuclear Physics meeting, October 1999.

Dewey, M.S., "Fundamental Physics with Cold and Ultracold Neutrons," State University of New York at Stony Brook, December 1999.

Dewey, M.S., "A Measurement of the Neutron Lifetime Using a Penning Trap," American Physical Society spring meeting, May 2000.

Dewey, M.S., "Fundamental Physics with Pulsed Neutron Beams," Spallation Neutron Source Workshop, June 2000.

Dewey, M.S., "New Experiment to Measure the Electron-Antineutrino Correlation in Neutron Beta Decay," Division of Nuclear Physics meeting, October 2000.

Gentile, T.R., "Polarized ^3He : Use it to Polarize Neutrons, Image Lungs, Study Neutron Structure - and it's a Floor Wax, too," University of Maryland at College

Park, College Park, MD, February 14, 2000.

Gentile, T.R., "Polarized ^3He for Neutron Spin Filters and Lung Imaging," California Institute of Technology, Pasadena, CA, March 3, 2000.

Gilliam, D.M., "NIST Neutron Physics and Dosimetry," American Nuclear Society/European Nuclear Society Winter Meeting, Washington, DC, November 15, 2000.

Gilliam, D.M., "Neutron Target Mass Standards at NIST," 16th International Conference on the Application of Accelerators in Research and Industry, CAARI-2000, Denton, TX, November 2, 2000.

Huffman, P.R., "Prospects for an Improved Neutron Lifetime Measurement Using Magnetically Trapped Ultracold Neutrons," College III seminar, Institute Laue Langevin, Grenoble, France, September 29, 2000.

Huffman, P.R., "Magnetic Trapping of Ultracold Neutrons," Special Physics Seminar, Lancaster University, Bailrigg, Lancaster, United Kingdom, August 22, 2000.

Huffman, P.R., "Magnetic Trapping of Ultracold Neutrons," NIST Center for Neutron Research Seminar, Gaithersburg, MD 20899, August 2, 2000.

Huffman, P.R., "Magnetic Trapping of Ultracold Neutrons," April Meeting of the American Physical Society, Long Beach, CA, 90831, May 1, 2000.

Huffman, P.R., "Magnetic Trapping of Neutrons," Nuclear Physics Seminar, University of Maryland, College Park, MD 20742, April 3, 2000.

Huffman, P.R., "Magnetic Trapping of Neutrons," Physics Seminar, Hahn-Meitner-Institut, Berlin, Germany, March 24, 2000.

Huffman, P.R., "Magnetic Trapping of Neutrons," Physics Department Colloquium, The Catholic University of America, Washington, DC 20064, February 23, 2000.

Huffman, P.R., "Magnetic Trapping of Neutrons," Nuclear Physics Seminar, University of Wisconsin, Madison, WI 53706, February 8, 2000.

Nico, J.S., "Measuring the Neutron Lifetime," University of Washington, Nuclear Physics Laboratory Seminar, Seattle, WA, April, 2000.

Thompson, A.K., "Issues and Procedures for Neutron Dosimeter Calibrations at NIST," presented at 2000 Harshaw TLD User Symposium, September 19, 2000.

Wietfeldt, F.E., "The Decay of the Neutron," Indiana University, Nuclear Physics Seminar, March 24, 2000.

Wietfeldt, F.E., "The Decay of the Neutron," University of North Carolina – Wilmington, Physics Department Colloquium, March 9, 2000.

Wietfeldt, F.E., "The Decay of the Neutron," University of Wisconsin – Madison Nuclear Physics Seminar, February 24, 2000.

**TECHNICAL AND PROFESSIONAL COMMITTEE
PARTICIPATION AND LEADERSHIP**

James M. Adams

Member, American Society for Testing and Materials, Committee E10 on Nuclear Technology and Applications

Secretary, American Society for Testing and Materials, Subcommittee E10.05 on Nuclear Radiation Metrology

Chairman, American Society for Testing and Materials, Task Group E10.05.05 on Activation Reactions

Secretary, American Society for Testing and Materials Symposium Committee and Program Committee for the Eleventh International Symposium on Reactor Dosimetry

Member, American Nuclear Society Committee ANS-19.10 on Fast Neutron Fluence to Pressurized Water Reactors

Member, Council on Ionizing Radiation Measurements and Standards, Subcommittee on Industrial Applications and Materials Effects

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Chairman, NIST Research Advisory Committee (RAC)

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Member, Cross Section Evaluation Working Group (CSEWG), National Nuclear Data Center

Member, Evaluation Committee of CSEWG

Coordinator, Subgroup on Evaluation of the Nuclear Data Standards of The Working

Party on International Evaluation Cooperation (WPEC) of the Nuclear Energy Agency Nuclear Science Committee
Chairman, WPEC Subgroup on the Cross Section Standards

Member, Measurements Committee of CSEWG

Member, Coordinating Committee of the U.S. DOE Nuclear Data Program

Member, International Technical Program Committee for the International Conference on Nuclear Data for Science and Technology to be held in Japan, Oct. 2001

David M. Gilliam

Member, ASTM Subcommittee E0.05, Nuclear Radiation Metrology

Chair, ASTM Task Group E10.05.10, Neutron Metrology

Member, Program Advisory Committee, North Carolina State University Reactor Facility

NIST Representative, CCRI, Section III-Measures Neutroniques

Chair, Technical Review Committee, UCN Beta Asymmetry Experiment, Los Alamos National Laboratory

Member, Symposium Committee, ASTM-EURATOM Symposium Committee on Reactor Dosimetry

Recording Secretary, International Nuclear
Target Development Society

Robert B. Schwartz

Member, Report Committee for report
“Determination of Operational Dose-
Equivalent Quantities for Neutrons,”
International Commission on Radiation Units
and Measurements (ICRU)

Alan K. Thompson

Member, ANSI N13-38, Standards for
Neutron Personnel Protection Meters

Member, ISO Technical Committee 85,
Subcommittee 2, Working Group 2
(Reference Radiations)

SPONSORED WORKSHOPS

A.K. Thompson was co-chair of the scientific committee to organize “Dosimetry for Radiation Hardness Testing: Sources, Detectors and Computational Methods,” a workshop held as part of CIRMS 2000. The workshop took place at NIST in Gaithersburg, MD on October 30, 2000.

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CURRICULUM VITAE

ADAMS, JAMES M., b Brookline, MA, December 5, 1957; PHYSICS, Nuclear Engineering, BA, Holy Cross 79; MS, Penn State University 90; Ph.D., Penn State University, 1995; NIST, 96-present, Commissioned Officer, USN, 1979-1984; Senior Engineer, Westinghouse Electric Corp., 1985-1988; Research Fellow, University of Michigan and Guest Researcher, NIST, 1995-1996; American Physical Society, American Nuclear Society, American Society for Testing & Materials. Res: Neutron dosimetry, neutron physics, hyperfine interactions.

ARIF, MUHAMMAD, b Madaripur, Bangladesh, January 24, 1954; PHYSICS, BS, Dacca Univ., Bangladesh, 76; MS, Ohio Univ., 80; Ph.D., Univ. of Missouri-Columbia, 86; Univ. of Missouri; Postdoctoral Fellow, 86-88; Physicist, NIST, 88-present. Res: Neutron and X-ray scattering, single crystal diffraction studies, x-ray and neutron interferometry.

CARLSON, ALLAN D., b Fargo, North Dakota, June 19, 1939; PHYSICS, BA, Concordia College, 61; MS, Univ. of Wisconsin, 63; Ph.D., Univ. of Wisconsin, 66; Research Associate, Argonne Nat'l. Laboratory, 61-62; Research Assistant, Univ. of Wisconsin, 61-66; Staff Associate, General Dynamics, 66-67; Staff Member, Gulf General Atomic, 67-70; Staff Scientist, Gulf Energy & Environmental Systems, 70-72; Nuclear Physicist, NIST, 72-present. APS, Standards Subcommittee of the Cross Section Evaluation Work Group (Chairman). Res: Experimental nuclear physics, neutron standards reference data.

DEWEY, MAYNARD S., b Ann Arbor, MI, August 22, 1956; PHYSICS, BS, State University of New York at Stony Brook, 78;

Ph.D., Princeton University, 84; Research Associate, Princeton University, 86; NIST, 86-present. Mem: American Physical Society. Res: Neutron lifetime measurement, neutron fluence measurement, ultra-high resolution gamma-ray measurements.

EISENHAUER, CHARLES M., b New York, NY, February 6, 1930; MATHEMATICS, BS, Queens College (now CUNY), 51; Graduate studies in PHYSICS, Columbia University; Guest Scientist, Brookhaven National Laboratory, 55-57; NBS/NIST, 58-94; Contract Researcher, NIST 94-present. Fellow, American Nuclear Society; Consultant, President's Commission on Three Mile Island, 78-79; Member, CIRRPC, 84-94; Member, NCRP, 91-95. Res: Cold neutrons, lattice dynamics, gamma-ray, electron, and neutron transport, scattering calculations for materials dosimetry, calibration of neutron personnel instruments.

GENTILE, THOMAS R., b Syosset, NY, July 27, 1957; PHYSICS, BS, State University of New York at Stony Brook, 79; Ph.D., Massachusetts Institute of Technology, 90; Research Fellow, California Institute of Technology, 90-92; NIST, 93-present. Member: American Physical Society. Res: Neutron polarization based on polarized ^3He , neutron tomography.

GILLIAM, DAVID M., b Galveston, TX, May 18, 1942; NUCLEAR ENGINEERING, PHYSICS; BA, Rice Univ. 64; MS, Rice Univ., 66; Ph.D., U. Michigan, 73; NBS/NIST, Neutron Interactions and Dosimetry Group, 73-present; National Measurement Laboratory Analyst, 85; Associate Division Chief, 86-87; Group Leader, 94-present; APS, ANS, ASTM E10.05, ANSI E 13.3, Comité Consultatif

pour des Rayonnements Ionisants, Section III, Mesures neutroniques. Res: Absolute neutron reaction rate measurements.
GRUNDL, JAMES A., b, Milwaukee, WI, March 15, 1929; PHYSICS, BS, Marquette Univ., 51; MS, Univ. of Wisconsin, 52; Ph.D., Univ. of New Mexico, 63; Staff Member, Nuclear Propulsion and Weapons Divisions at Los Alamos National Laboratory, 52-70; Group Leader, Neutron Interactions and Dosimetry Group, Ionizing Radiation Division, NIST, 70-94, Contract Researcher, 94-present. Consultant: National Atomic Museum. Mem: ANS, ASTM. Res: Neutron measurement standardization, reactor physics, materials neutron dosimetry, public perception of nuclear energy radiation effects.

HUFFMAN, PAUL R., b Winston-Salem, NC, June 6, 1968; PHYSICS, BS, North Carolina State University, 1990; MS, Duke University, 1992; Ph.D., Duke University, 1995; Postdoctoral Fellow, Harvard University, 1995-1998; Physicist, NIST, 98-present. Mem: American Physical Society. Res: low-energy neutron weak interactions, fundamental symmetries, neutron optics.

JACOBSON, DAVID L., b Kansas City, KS, May 21, 1968; PHYSICS, BA, Westminster College, 90; Ph.D., University of Missouri-Columbia, 96; Postdoctoral Fellow, University of Missouri-Columbia, 96; NIST, 96-present. Res: Neutron optics and neutron interferometry.

NICO, JEFFREY S., b Lansing, MI, September 12, 1961; PHYSICS, BS, Michigan State Univ., 1983; MS, U. of Michigan, 1990; Ph.D., U. of Michigan, 1991; Postdoctoral Fellow, U. of Michigan, 1991 and Los Alamos National Laboratory, 1991-1994; Physicist, NIST, 94-present. Res: Absolute neutron reaction rate measurements, weak interactions, neutron dosimetry.

RICH, DENNIS R., b Berwyn, IL, February 11, 1971; PHYSICS, BS, University of Illinois-Urbana, 1993; MS, Indiana

University, 1994; Ph.D., Indiana University, 1999; Postdoctoral Fellow, Indiana University/NIST, 99-present. Member: American Physical Society. Res: ^3He polarization, neutron polarization, low energy weak interactions.

SCHRACK, ROALD A., b Ft. Meade, FL, August 26, 1926; PHYSICS, BS, Univ. of Calif. at Los Angeles, 49; MS, Univ. of Calif. at Los Angeles, 50; Ph.D., Univ. of Maryland, 61; Physicist, NIST, 49-present; APS, Institute of Electronic and Electrical Engineers. Res: Neutron cross section measurement, computer analysis, electronic instrumentation.

SCHWARTZ, ROBERT B., b Brooklyn, NY September 2, 1929; NUCLEAR PHYSICS, BS, Union College 51; Ph.D., Yale University, 55; Assistant Physicist, Brookhaven Nat'l Lab., 59-60; Research Physicist, Naval Research Lab., 60-62; Physicist, NBS, 62-74; Guest Scientist, AERE, Harwell, 74-75; Physicist, NIST, 75-present. Mem: Amer. Physical Soc., Health Physics Soc. Chairman, Reference Neutron Radiations Subgroup, ISO TC 85/SC 2/WG 2. Res: Personnel dosimetry, neutron instrument design, testing and calibration.

THOMPSON, ALAN K., b Austin, TX, April 9, 1964; PHYSICS, BA, Rice U., 86; Ph.D., Mass. Inst. Tech., 91; Research Associate, Harvard U., 91-93; Physicist, NIST, 93-present, Member: American Physical Society. Res: ^3He polarization, neutron polarization, tests of fundamental symmetries, structure of the neutron weak interactions, neutron dosimetry.

WIETFELDT, FRED E., b Brooklyn, NY, January 21, 1963; PHYSICS, BS, Massachusetts Institute of Technology, 84; Ph.D., University of California at Berkeley, 94; U.S. Naval Officer, nuclear engineering, 84-89; Lawrence Berkeley Laboratory, Research Assistant 91-94, Postdoctoral Fellow 94; NRC Postdoctoral Associate, NIST, 95-96, NIST, 97-present. Res: Fundamental interactions and symmetries in nuclear physics, nuclear astrophysics.

