Technical Activities 1982
Center for Radiation Research

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Measurement Laboratory
Center for Radiation Research
Washington, DC 20234

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DEPARTMENT OF COMMERCE
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TECHNICAL ACTIVITIES 1982
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Chris E. Kuyatt, Director

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

This report summarizes research projects, measurement method development, testing and data evaluation activities, carried out during Fiscal Year 1982 in the NBS Center for Radiation Research. These activities fall in the areas of radiation measurements, atomic and plasma radiation, nuclear radiation, radiation physics, radiometric physics, and radiation sources and instrumentation.

Key Words: Atomic radiation; nuclear radiation; plasma radiation; radiation instrumentation; radiation measurements; radiation physics; radiation sources; radiometric physics.

INTRODUCTION

This report is a summary of the technical activities of the NBS Center for Radiation Research (CRR) for the period October 1, 1981 to September 30, 1982. The Center is one of five Centers in the National Measurement Laboratory.

The Center for Radiation Research develops and maintains the scientific competences and experimental facilities necessary to provide the nation with a central basis for uniform physical measurements, measurements methodology, and measurement services in the areas of optical radiation, ultraviolet radiation, and ionizing radiation (x rays, gamma rays, electrons, neutrons, and radioactivity); provides government, industry, and the private sector with essential calibrations for field radiation measurements needed in such applied areas as nuclear power, health care, radiation processing, advanced laser development, and radiation protection for public safety; carries out research in order to develop improved radiation standards, new radiation measurement technology, and improved understanding of atomic, molecular, and nuclear radiation processes; collects, compiles, critically evaluates and supplements the existing atomic, molecular, and nuclear data base in order to meet the major demands of the nation for such data; and participates in collaborative efforts with other NBS Centers in the interdisciplinary applications of radiation.

The summary of activities is organized in six parts, one for the Office of Radiation Measurement, and one for each of the five Divisions in the Center: Atomic and Plasma Radiation, Nuclear Radiation, Radiation Physics, Radiometric Physics, and Radiation Sources and Instrumentation. Each Division tells its own story in its own way. In general there is an introduction followed by a series of short reports on current activities, publications during the year, talks given, committee participation, and professional interactions.

A detailed table of contents has been provided to permit the reader to find those activities of greatest interest. To obtain more information about particular work, the reader should address the individual scientists or their division, c/o Center for Radiation Research, Radiation Physics Building, C229, National Bureau of Standards, Washington, D.C. 20234.

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TECHNICAL ACTIVITIES

530, Office of Radiation Measurement

Task No. 11201 (new task no. 15201) - Radiation Standards Dissemination

The function of the Office of Radiation Measurement is to promote the dissemination to federal, state, and local radiation control programs, and to the medical, industrial, and defense communities, of the measurement standards and technology required for reliable measurement of ionizing radiation that may be hazardous. The Office assists the technical organizational components of CRR in monitoring the radiation measurement needs of these national user groups, and in activities undertaken to meet national needs. The latter include methods for improving the consistency of field measurements with the national physical measurement standards. The office maintains liaison with organizations that conduct measurement-intensive programs in the areas of radiation safety, energy, health, and environmental contamination. Examples are the Nuclear Regulatory Commission, Department of Energy, Bureau of Radiological Health, Environmental Protection Agency, Occupational Safety and Health Administration, and the Conference of Radiation Control Program Directors. The Office participates in collaborative programs with most of these organizations to satisfy specific measurement traceability and quality assurance requirements. Another function of the Office is to provide the secretariat and chairman for American National Standards Committee N43, concerned with equipment for non-medical applications of ionizing radiation.

Because of a growing desire for quality assurance by those who make routine radiation measurements, the Office is devoting an increasing fraction of its resources to the development of methods for achieving measurement quality assurance. The following examples of activities conducted during the past year will illustrate the various types of programs that are under development to provide greater assurance that field measurements are consistent with the national standards.

Radon

As in the past few years, various radon-related projects continue to occupy a significant share of the Office's activities. A technical analysis and study of suitable calibration standards and support services for radon measurements was performed. This study comprised an evaluation of user needs and present NBS capabilities, an analysis of technical feasibility, and the development of detailed program plans. The proposed NBS program consists of a broad-based comprehensive effort to upgrade and expand NBS measurement and calibration facilities, to develop several types of transfer standards (a solid-source radon transfer standard, an instrument-based radon transfer standard, and a radon flux density transfer

standard), as well as to provide direct support services to other laboratories. The results of this study were used to prepare several internal and external funding proposals for NBS management for two offices in the Department of Energy, and for the Nuclear Regulatory Commission. The pursuit of adequate funding for this proposed program is continuing.

The Office also performed an analysis of the use and advantages of ionization chambers as radon transfer standards, and as the primary calibration instruments in user laboratories. This was done as part of a study of the feasibility and design of a model intermediate calibration laboratory (ICL) for radon measurements. The analysis considered three different types of ionization chambers in terms of their technical advantages and disadvantages, uses and interactions in an NBS-ICL network, and design and cost considerations. Additional work requires developing and testing laboratory prototype instruments.

The Office continued to provide direct laboratory assistance to staff members of Division 532. This assistance was in the form of volume calibrations of radon sampling bulbs used in an interlaboratory radon measurement comparison; completing the design of the radon chamber's sampling and recirculation systems; plumbing the systems and performing leak tests; testing and calibrating the chamber's ambient temperature and dew point probes; testing the performance characteristics of the mass flow transducers for the chamber; and preparing the radium sources for a prototype regenerative radon-in-water transfer standard.

The Office also continues to coordinate the interactions between NBS and other radon measurement laboratories, such as the DOE Environmental Measurements Laboratory, two EPA laboratories at Montgomery and Las Vegas, the U.S. Bureau of Mines Denver Research Center, and national laboratories including Lawrence Berkeley Lab, Argonne National Lab, and Oak Ridge National Lab.

In cooperation with the Radon Measurement Subcommittee of the Conference of Radiation Control Program Directors (CRCPD), a survey of the state radiation control program directors was conducted to determine the radon measurement needs and present activities in state programs. The survey focused on a wide variety of methods for measurement of radon and related quantities. This includes methods for measurement of radon (^{222}Rn) concentration in air, potential alpha energy concentration, individual radon progeny concentrations, radon exhalation or flux density from surfaces, radon concentration in water, and thoron (^{220}Rn) or thoron progeny concentrations in air. The survey identified the sources of radon and thoron which necessitate measurements in the states; the types of measurements and measurement methods that are performed routinely, or that the states would like to obtain or improve the capability of performing; existing calibration capabilities for these measurement methods; and the perceived needs for improving the quality of the measurements. A report summarizing the findings of the survey was published (NBS GCR 82-394) and distributed. The survey findings have also been prepared for publication in the journal Environment International.

The Radon Measurement Subcommittee is continuing its work on a directory and catalog of commercially available radon and radon progeny measurement instrumentation. This catalog should be completed in the coming year. The subcommittee has also initiated a project to develop a users' handbook of simple radon and radon progeny measurement procedures to assist inexperienced state laboratories that are just beginning to perform radon measurements. The results of both of these ongoing projects will be very useful to the states.

Detection Limits

Over the years, it has become apparent that many persons peforming low-level environmental radioactivity measurements continue to confuse and misapply *a priori* detection limits and *a posteriori* criteria for the presence of activity. To address this, the Office has completed the theoretical development and sample calculations for a series of papers on detection limits and statistical hypothesis testing for the presence of activity. The series considers the purposes of detection limits, and discusses and illustrates their misapplications; presents the well-known approaches to calculating detection limits (assuming particular distributions), and develops a set of distribution-free detection limits based on Chebyshev-Like Inequalities; and presents the classical Neyman-Pearson hypothesis testing approaches for determining whether activity above background is present, and extends this with a novel Bayesian statistical approach.

Regional State Laboratories

The regional calibration laboratories being established in the states of Illinois, Washington, and South Carolina are in various stages of development. In Illinois, the primary emphasis has been on making the x-ray beams operational. The basic measurements necessary to characterize the x-ray beams have been completed but some ancillary measurements will have to be made. Analysis of the original data revealed a problem with either the half-value layers or with the true kilovoltage of the x-ray machine. This will have to be resolved before the laboratory can become fully operational. In the meantime, protocols are being developed for x-ray calibrations, procedures for acquiring and monitoring calibration data are being developed, and details of the calibration report are being determined. These procedures are being tested by calibrating state-owned instruments. Preliminary investigations have begun on methods to characterize the reference fields at radiation levels suitable for calibrating radiation survey instruments and the pressurized ionization chambers used by states to monitor nuclear power plants. For calibrations at higher photon energies a 3-curie cesium-137 source has been obtained, but its implementation awaits completion of the procedures for x-ray calibrations.

Substantial progress was made during the past year in development of the State of Washington laboratory. A 3-curie, cesium-137 irradiator was installed and all equipment necessary for calibrating instruments at

this energy was delivered. The University of Washington will be responsible for routine operation of the facility, and the radiation control office will use it to calibrate its own instruments. An on-site training course in calibration procedures was given at the laboratory in May 1982, and the regional aspect was emphasized when personnel from the Oregon and Idaho radiation control offices attended. During the training session, preliminary measurements on how well the reference field was being determined were made using a duplicate set of instrumentation. Since no major problems were encountered, the final physical arrangement of apparatus is being decided and measurements necessary to characterize the laboratory and develop protocols has begun.

In South Carolina, the building renovations necessary to house the laboratory were completed only recently, almost a year behind schedule. The x-ray machine was installed recently for testing purposes, but electrical and water connections must be modified to meet specifications. Radiation survey measurements are presently being made to determine the need for additional room shielding.

Discussions with representatives of the State of California are continuing, and a candidate facility was visited. It is likely that this facility, which presently has limited capability for calibrating emergency response instruments, will be expanded to increase its range of capability. Preliminary interactions with the Federal Emergency Management Agency have indicated that it will probably provide the necessary funds.

A preliminary draft of a training and procedures manual has been developed to assist state personnel in setting up the laboratories, in developing protocols and calibration reports, and in developing quality control programs. This draft manual was first used in conjunction with the training course given in Seattle, Washington. Due to a wide variation in the backgrounds of personnel to be trained, and the complexity of the material that should be covered for a proper understanding of the fundamentals, the proper balance between introductory and advanced material must be determined before the manual is revised.

Personnel Dosimetry

The Nuclear Regulatory Commission has officially requested that the National Voluntary Laboratory Accreditation Program (NVLAP) procedures be used by NBS to develop an accreditation program for processors of personnel dosimeters. It is anticipated that the NRC will issue regulations which require its licensees to use only those processors who have been accredited under this program. Technical support for the NVLAP program will be provided by several elements of the Center for Radiation Research, including the Office of Radiation Measurement. During the past year, some effort has been devoted to preparation for the upcoming program, including procurement of the services of a proficiency testing laboratory (PTL) that will test the performance of dosimetry processors. The Request

for Proposal (RFP) to be used for procurement of the services of a PTL is nearing completion. It contains preliminary requirements for quality control in the PTL, for initial testing of the PTL by NBS, and for periodic review of PTL performance.

During the past year, the interagency committee formed to provide guidance and coordination for development of a national program for personnel dosimetry performance testing continued to function under the chairmanship of an Office staff member. The group agreed to expand its scope to include the development of similar national programs for testing the performance of radiation survey instruments and bioassay laboratories. To reflect this broadened scope, the name was changed to Interagency Committee on Occupational Radiation Protection Measurements.

Performance Testing Criteria

Because of the increasing demand for performance testing programs, such as that for personnel dosimetry, the Office has begun to evaluate the algorithms and criteria used for evaluating measurement performance. Existing performance algorithms use a relatively simple approach which is often encumbered with many unverified statistical assumptions. Efforts have been made to formulate a more general approach which has a sound axiomatic basis. It is hoped that this approach will lead to the development of improved performance indices which can be used as performance testing criteria.

Measurement Quality Assurance Services

Under an interagency agreement with the Nuclear Regulatory Commission the Center for Radiation Research is conducting a 3-year program generally directed toward quality assurance for radiation measurements made by the NRC. Major tasks include (1) characterization and evaluation of the thermoluminescence dosimetry system used to monitor power reactors; (2) development of radiation fields and evaluation of the performance of selected radiation survey instruments; and (3) development of a measurement quality assurance (MQA) service for laboratories that calibrate survey instruments for NRC inspectors. The Office coordinates this program and has specific responsibility for conducting some of the activities relating to task 3, development of an MQA service. In cooperation with the Dosimetry Group, the basic principles for MQA services have been documented and specific procedures are under development. The initial service will be limited to photon radiation, and will be made available to four laboratories that serve NRC inspectors, plus seven additional laboratories that desire similar MQA services from NBS.

Other Activities

For the 36th year, NBS served during 1982 as the secretariat of American National Standards Committee N43, Equipment for Non-Medical

Radiation Applications. With leadership, coordination, and assistance from the Office, a new standard on panoramic, wet-source-storage irradiators was completed and approved by the Committee. The subcommittee on electron microscopes made substantial progress on developing a draft standard. Several existing standards are being reviewed under the ANSI five-year rule that requires either withdrawal, revision, or confirmation.

The Office provided the NBS delegate to a working group of the International Bureau of Weights and Measures (BIPM) on reporting measurement uncertainties. This group prepared a set of recommendations for use by international standardizing laboratories. The recommendations provide an overall philosopy or general approach for reporting uncertainties, and were ratified by the International Committee on Weights and Measures (CIPM) in October, 1982. A report by the working group on the recommendations is being published and distributed by BIPM.

In cooperation with the Center for Applied Mathematics, the Office is preparing a new chapter on measurement uncertainties for the revised Condon and Odishaw Handbook of Physics.

The directory of commercial services for calibrating ionizing radiation survey instruments, which was prepared in cooperation with the CRCPD, proved to be so popular that a second printing was necessary. Prior to publication of this directory, there was no single source of comprehensive information on where calibrations could be obtained, types of services offered, and radiation sources used.

During the past year, the Office continued its participation in a cooperative agreement with the National Council on Radiation Protection and Measurements for development of a handbook on measuring neutrons generated by medical accelerators.

Under the terms of another cooperative agreement, the CRCPD Committee on Radiation Measurements made further progress on revision of its 1979 publication entitled "Ionizing Radiation Measurement Criteria for Regulatory Purposes". The revised draft includes more specific references to regulations that necessitate measurements, terminology for measurement of ionizing radiation, principles of measurement quality assurance, and generic characteristics of various types of instruments.

INVITED TALKS

530, Office of Radiation Measurement

Collé, R., Panel Discussion on Instrumentation and Measurement Methods, International Meeting on Radon and Radon Progeny Measurements, Montgomery, AL, August 28, 1981.

Collé, R., "Radon Measurements: National Needs and the Role of NBS", American Nuclear Society Winter Meeting, San Francisco, CA, December 1, 1981.

Eisenhower, E. H., "A Quality Assurance Program for Personnel Dosimetry", 14th Annual National Conference on Radiation Control, Portland, ME, May 26, 1982.

Heaton, H. T., II, "Traceability to NBS for State Regional Calibration Laboratories", Department of Nuclear Engineering, University of Washington, Seattle, WA, May 10, 1982.

PUBLICATIONS

530, Office of Radiation Measurement

Collé, R., BOOK REVIEW of Nuclear Chemistry: Theory and Applications by G. R. Choppin and J. Rydberg, International Journal of Applied Radiation and Isotopes 32, 687-688 (1981).

Collé, R., Radon Measurements: National Needs and the Role of NBS, Transactions of the American Nuclear Society 39, 84-86 (1981).

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

530, Office of Radiation Measurement

Ronald Collé

Delegate, Bureau International des Poids et Mesures (BIPM) Working Group on the Statement of Uncertainties.

Resource Person, Conference of Radiation Control Program Directors, Subcommittee on Radon Measurements.

Resource Person, Conference of Radiation Control Program Directors, Task Force on the Clean Air Act.

Member, Ad Hoc Committee on Interlaboratory Calibration of Radon and Radon Daughter Instruments.

Elmer H. Eisenhower

Alternate Representative, ANSI N44, Equipment and Materials for Medical Radiation Applications.

Chairman, ANSI N43, Equipment for Non-Medical Radiation Applications.

Member, ANSI Nuclear Technical Advisory Group for ISO TC85.

Chairman, Interagency Committee on Occupational Radiation Protection Measurements.

Resource Person, Conference of Radiation Control Program Directors, Committee on Radiation Measurements.

H. Thompson Heaton, II

Secretary, ANSI N43, Equipment for Non-Medical Radiation Applications.

Member, ANSI N43-3.4, Subcommittee for Gamma Irradiators.

Member, ANSI N43-8, Subcommittee for Electron Microscopes.

MAJOR CONSULTING AND ADVISORY SERVICES

530, Office of Radiation Measurement

1. R. Collé advised Wisconsin Health Department on calibration procedures for radiochemical yield determinations and reviewed the measurement protocol, data analysis, and results of a radon monitoring program associated with uranium exploration in northern Wisconsin.

2. R. Collé assisted a field test engineer (contractor) at the Three Mile Island nuclear power plant by performing a literature search and providing advice on possible damage to a NaI (Tl) stack monitor from accidental releases.

3. R. Collé assisted Pylon Electronic Instruments Co. by performing extensive calculations of the steady-state and time-dependent activity concentrations from flow-through thoron (^{220}Rn) calibration sources.

4. R. Collé advised the radiation safety office at the University of Maryland Medical Center (Baltimore) on a continuous radon monitoring system for a radium needle storage facility, and on a calibration protocol for the system.

5. R. Collé advised University of California at Davis, Crocker Nuclear Laboratory, on the calculation and propagation of uncertainties in proton energies for measurements of nuclear reaction excitation functions by stacked-foil activation methods.

6. R. Collé advised and assisted staff members in various NBS divisions on the treatment and reporting of measurement uncertainties, and on the interpretation of measurement performance criteria.

7. H. T. Heaton, II, advised the Nuclear Regulatory Commission on a proposed regulatory guide on calibration procedures for radiation survey instruments.

8. H. T. Heaton, II, was consulted by the Department of Defense on a calibration manual for ionizing radiation instruments that will be used at DOD calibration laboratories.

9. H. T. Heaton, II, was consulted by Radcal Corporation on using an ionization chamber in the "rate of charge" method for determining their x-ray field.

TECHNICAL ACTIVITIES

Division 531, Atomic and Plasma Radiation

Task No. 11211 (new task no. 15211) - Atomic Radiation Data and Standards
Task No. 11212 (new task no. 15212) - Atomic Processes in Plasmas

The Atomic and Plasma Radiation Division carries out a broad range of experimental and theoretical research on atomic structure and atomic radiation in plasmas. The division determines a large variety of atomic radiation and collision data, encompassing wavelengths of spectral lines; atomic energy levels; ionization potentials; atomic transition probabilities; plasma line broadening parameters; ionization and excitation cross sections and rate coefficients, and dielectronic rate coefficients. Two data centers located in the division critically evaluate and compile atomic energy levels and transition probabilities. The division is also engaged in research on the interaction of atomic radiation with plasma environments, and it explores such effects for the development of new measurement techniques. Furthermore, well-defined atomic radiation sources are developed as radiometric standards or wavelength standards.

These activities support several important areas of science and technology. A good deal of our work ties into magnetic fusion research, where atomic data are needed for studies of the effects of heavy ion impurities and where atomic radiation processes are utilized as non-interfering plasma probes. Other areas of direct applications are space physics and vacuum ultraviolet laser development, where atomic radiation data are one of the basic inputs. In the former area our vacuum ultraviolet radiometry work is now, for the first time, providing small calibrated source packages to allow radiometric calibrations on board spacecraft, which are used, for example, for accurate monitoring of the solar ultraviolet radiation.

The division consists of three technical groups: Atomic Spectroscopy, Atomic Radiation Data, and the Plasma Radiation Groups. The division has currently 22 professional physicists, among them 18 Ph.D.s, plus 3 postdocs. Also, during the last year the division had guest workers from France, China, Yugoslavia, Poland, and Russia.

The past year was again a very productive one, as will be seen from the following sections, where the principal work of the three technical groups during the last year is briefly described.

I. Atomic Spectroscopy Group

(a) Vacuum UV Spectra of Atomic Ions--We continued our research on spectra of highly ionized atoms needed for high-temperature plasma diagnostics by exciting, identifying and accurately measuring the transitions of the type $2s^m2p^n$-$2s^{m-1}2p^{n+1}$ in boron-like ions of Cl^{12+} through Ti^{17+} (Z = 17-22, except Ar). The spectra were excited in laser-generated plasmas and observed with the NBS 10.7-m grazing-incidence spectrograph. Also of importance for predicting magnetic-dipole forbidden lines in plasmas are our new identifications of $3p^63d^9$-$3p^53d^{10}$ lines in eight ions from Ba^{29+} to Yb^{43+} with spectra we observed earlier at Los Alamos. Our work on the Mg-like ionic spectra from Si^{26+} to Rb^{33+}, also with the Los Alamos observations, was completed. The $4d^9$-$4d^85p$ resonance transitions have been identified in Xe^{9+} and Cs^{10+}.

We are using two major facilities outside NBS in our work on high-ionization spectroscopy. With the Plasma Radiation group, we observed and identified magnetic-dipole transitions within the $3s^23p^k$ ground configurations of highly ionized Kr in the TEXT tokamak at the Fusion Plasma Research Facility in Austin, Texas. Accurate calculations of the wavelengths and intensities of these lines were essential for this work, which is being continued with the goal of similar identifications for ions of iron-group and heavier elements. We also recently observed spectra of highly ionized Nb and Mo with the powerful Nd/glass GDL laser at the National Laser Users Facility at Rochester. These observations yielded isoelectronic extensions of the resonance lines of F-like ions to Nb^{32+} and Mo^{33+}; further research with this laser is planned.

Several of our predictions of magnetic-dipole wavelengths for highly ionized species have recently been used to identify lines in tokamaks, notably by the Princeton Plasma Physics group in their work on the PLT and PDX tokamaks.

(b) Atomic Inner-shell Photoabsorption--We have observed a suprising photoabsorption spectrum of neutral Cs and interpreted it as arising from transitions of the type $5p^66s$-$5p^56snd$ and $5p^66s$-$5p^56sns$. In contrast with expectation and with the known 5p absorption in Xe, the Cs $5p^56snd$ resonances are narrow, whereas the $5p^56sns$ resonances are broad (autoionization). Attempts to understand the results as due to strong $5p^56sns \times 5p^6$ εp interactions are in progress. Our 10.7 m grazing-incidence spectrograph was essential for this experiment, since previous spectroscopy of Cs in other laboratories failed to yield the resonances with sufficient resolution for a correct analysis.

In collaboration with Division 533 and theorists elsewhere (W.R. Johnson, K.T. Cheng) we recently completed an interpretation of the striking changes in the photoabsorption spectra along the isoelectronic sequence Xe to Ba^{2+} in terms of the altering relative magnitudes of the basic interactions involved. We have begun attempts to apply laser-driven ionization techniques to Cs in a source to be used with our 10.7-m grazing-incidence spectrograph in order to provide the experimental data for Cs^{+}, the intermediate ion of this sequence.

(c) Laser Spectroscopy--Our main goal in this new program is to apply state-selective and state-sensitive techniques to extend the structural data for selected complex spectra--especially spectra for which additional data are needed for applications in plasma physics, laser physics, astronomy, etc. Pending assembly of a second dye-laser system and development of scanning techniques to cover a broader range, we have begun an experiment using Doppler-free intermodulated fluorescence spectroscopy to obtain accurate wavelengths for several ^{4}He I transitions of interest. The results will complement measurements of two-photon transitions from 1s2s levels made in other laboratories.

(d) Atomic Energy Levels Data Center--During the past 6 years we completed new critical compilations of the energy levels for all 235 spectra of the iron-group elements K through Ni (Z = 19-28). The data were published separately by element. We are now updating and extending these compilations for a single-volume collection of the data for the entire iron group. New results for many of the spectra are being incorporated and extensive use of isoelectronic and other regularities are being made to increase the reliability of the data. We hope to complete the major part of this work during the next year.

We have submitted for publication new energy-level compilations for all the Si spectra. These include extensive recent experimental and theoretical results (some unpublished) assembled for the first time. The Si data are part of a project covering the Na-Ar group (Z = 11-18) and complete the series for Na-Si (Z = 11-14). We have investigated the derivation of improved ionization energies by combining theoretical and experimental results along a number of isoelectronic sequences in connection with these compilations; the results will probably yield the best available values for many highly ionized species.

We prepared two reports on recent results in atomic spectroscopy of astronomical interest for the International Astronomical Union. We monitor the literature on atomic energy levels, wavelengths, wavefunctions, etc., and the resulting reference files and published bibliographies are made available to a wide clientele.

II. Atomic Radiation Data Group

(a) Theoretical Studies--The work of this theoretical group has concentrated on (1) the production of critically evaluated data on basic atomic processes and (2) the exploration of the basic atomic physics needed for developing new theoretical methods for producing data. The processes studied are electron impact ionization, dielectronic recombination, and radiative transitions. To a large extent these data are important for understanding atomic processes in plasmas, particularly fusion plasmas.

Our research on electron impact ionization has concentrated on the systematics of light ion data and a further assessment of the distorted wave (DW) method for the heavier elements. Distorted wave calculations of ionization cross sections have been done for the L-shell ions of iron, Fe XVII-XXVI, and for the M-shell ions of iron and scandium, Fe IX-XV and Sc IV-X. Also, ionization rate coefficients were calculated, assuming a Maxwellian electron distribution. Simple analytic fits were made to these data, giving the rate coefficient as a function of temperature, and in a form easy to use for plasma modelling purposes. DW calculations were also carried out for the chlorine and krypton isoelectronic sequences. Just as with the argon sequence, the krypton-like ions, in low stages of ionization, show pronounced term-dependent effects in the ^1P channel which improves the agreement with experimental data at low energies, although significant discrepancies remain at higher energies. Exploratory studies have also been started in the direction of modelling the ionization process by an effective transition potential.

The work on dielectronic recombination has developed in two parallel directions. A general computer program is being written to compute the total rate of recombination for an arbitrary atom in an arbitrary stage of ionization. This program is based on the single configuration, LS-coupling and distorted wave approximation. No further approximations are involved. All the basic codes have been written and we are now in the process of assembling them into a single program. We are also in the process of making detailed calculations of the recombination rate of Fe^{+23}, via the doubly excited dielectronic states, in order to assess the importance of both configuration interaction and intermediate coupling. So far, we have the perplexing result that configuration interaction has virtually no effect on the total rate, even though individual LS-channels are affected by as much as 40%.

We continue our collaboration with members of the far UV group investigating the interesting intricacies of f-shell collapse in the region of the periodic table around z = 54-57. A variety of pronounced term dependent effects has been found in both the single- and multi-configuration Hartree-Fock approximation.

The upgraded atomic structure codes are now working, although much remains to be done to improve their performance and to broaden their scope to include a variety of approaches to the correlation problem. Preliminary results have been obtained on the 4s-4p transition probabilities of neutral argon, in which intershell correlation shifts have been included in the intermediate coupling calculations.

Our group hosted a second workshop on atomic physics problems related to magnetic fusion research on November 16-17, 1981. This time the topic was dielectronic recombination rates. Again, the meeting turned out to be very stimulating and productive. By concentrating on an assessment of the current state of dielectronic recombination rate calculations and by identifying promising future directions, the theoretical work in this area was for the first time brought into focus.

(b) Data Center--In the Data Center on Atomic Transition Probabilities, the revision of atomic-transition-probability tables for allowed lines of the elements scandium through nickel, which were published in past issues of J. Phys. Chem. Ref. Data, is nearing completion as the end of 1982 approaches. Work was started on preparing tables of forbidden lines of these elements. Based on the exploratory work done by computer scientists at Vanderbilt University on the possibilities of developing a database of atomic spectroscopic data--with detailed guidance by the Data Center--discussions are underway with Office of Standard Reference Data personnel concerning the design of an actual database and the equipment which should be procured and utilized for such a project. A critical data compilation of atomic transition probabilities on high ions of titanium was undertaken in collaboration with K. Mori of the Institute of Physical and Chemical Research, Tokyo. Also, a critical review and tabulation of Stark widths and shifts for non-hydrogenic spectral lines of ionized atoms was undertaken in collaboration with N. Konjevic of the Institute of Physics, Belgrade, and is nearing completion. An extensive report on recent developments in atomic transition probabilities with a very detailed bibliography for the last two years was prepared for the International Astronomical Union. We have also continued to co-edit, in collaboration with Oak Ridge National Laboratory, the bimonthly newsletter, "Atomic Data for Fusion."

III. Plasma Radiation Group

(a) Collisional Rate Coefficients with the 50 KJ Theta Pinch--The ionization rates of Ti IX, Ne VI and VIII, and O VI ions are determined using a plasma condition characterized by an electron temperature of $\sim$ 55 eV and 2 x $10^{16}/cm^3$ density. Comparison with theoretical predictions based on the commonly used semiempirical formula due to Lotz showed that the theoretical values are a factor of two to three lower

than the experiment. The higher values in the experiment are attributed to the possible contribution of the two-step process of excitation followed by ionization. In order to extend this important comparison over a wider range of temperatures, upgrading of θ-pinch to run at 40 KV with 50 kJ energy is in preparation. At present, the upgrading procedure is tested out by building a small prototype unit.

(b) Tokamak Spectroscopy--The first experimental results on magnetic dipole transition of highly ionized Kr have been obtained utilizing the TEXT tokamak at the Fusion Plasma Research Facility in Austin, Texas. Our NBS group has been the first users group on this facility. Wavelengths, predicted by a semiempirical method, have been observed for Kr XVIII through Kr XXII using instrumentation installed on TEXT by our NBS group. These new observations will allow Doppler ion temperature measurements on magnetically confined fusion plasmas in the range 500 to 1500 eV, and will be immediately applied to the TEXT tokamak.

(c) Strongly Coupled Plasma--This year we began a program to generate a novel form of matter known as a "strongly coupled plasma" (SCP). In normal plasmas the interaction energy between the charged particles is far out weighed by the random motional energy. Just the opposite case pertains in a SCP. The particle interaction dominates the randomizing processes, collective effects are extremely important, the system behaves more like a charged liquid than a gas, and phase transitions to even a solid-like phase are predicted. Our technique for generating a SCP is to photoionize a gas of cryogenic hydrogen atoms with a laser to create a cold (5 degrees Kelvin) plasma of protons and electrons. Such a plasma is strongly coupled even at relatively low densities. The experiments are presently performed at MIT in collaboration with Professor Kleppner's group there, where the cryogenic hydrogen atom source was recently developed. Recently we have observed comparatively large ionization signals, as well as the detailed line shape for the resonant photoionization process. An unexpected result of potentially great practical application has been the observation of efficient harmonic generation of coherent Lα radiation (vacuum ultraviolet) in the hydrogen beam.

(d) Stark Effect on Autoionization Resonances--One of the few remaining problems in the atomic physics of electric fields is the effect of such fields on autoionization (AI) resonances. Such resonance levels actually comprise a considerable portion of the levels relevant to plasma and astrophysical problems. Last year we reported the first measurements of the monotonic broadening of AI resonances in an electric field. Recently we have been developing a theoretical model to explain why bound-bound mixing appears to be the dominant broadening mechanism, and in which cases continuum-continuum mixing may be important. The

model is near completion, and we hope to have numerical results within the next year. We have also observed the broadening of a very narrow AI resonance in Gd at extremely low fields on the order of 1 volt/cm. This surprising result appears to be related to the dense spectrum of opposite parity levels characteristic of complex atoms.

(e) Collisional Redistribution of Radiation--Polarized light from a dye laser, tuned to the first Balmer line of hydrogen (H_α), was used to probe the collisional redistribution of radiation in a plasma. Radiation incident in the wing of the line was redistributed to the core by radiative broadening of the lower level of H_α and by collisions. The intensity and polarization of the fluorescence were measured as a function of laser detuning from the line center. The line profile was found to be symmetric and Lorentzian outside the Doppler core, reflecting the dominant effects of radiative and resonance collision broadening. The polarization in the absence of collisions was calculated, and compared to the measured polarization. This led to the conclusion that, on the average, elastic upper level collisions were about 65% efficient in depolarizing the atom.

Collisional redistribution has also been observed in a helium line ($2\ ^1S$-$3\ ^1P$; λ = 502 nm). Preliminary results are currently being analyzed. These represent the first radiation redistribution measurements in a plasma, and the first made from an excited state. They should provide fundamental results required to address the principal unsolved problems in stellar radiative transfer.

(f) Stark Broadening, Shifts and Asymmetries of Hydrogenic Ion Lines--We are continuing our work on the widths and shifts of Stark broadened He II hydrogenic ion lines emitted from a pulsed plasma source. A new pulsed arc source with reduced boundary effects has been designed and built. This new source allows for more accurate line profile measurements and should provide improved electron density measurements which are obtained using a laser interferometer. The source was mounted on the large 10 meter normal incidence spectrometer for studies in the visible and VUV spectral regions. We have also assembled a new multichannel spectral detector replacing our aging OMA (Optical Multichannel Analyzer) device. The detector was integrated to a minicomputer for on-line data acquisition and analysis. We are currently measuring the shift of the He II H_α VUV line at 1640 Å, which can be compared with widely varying theoretical estimates for the shift of hydrogenic ion lines. Improvements in the measurements using advanced wavelength calibration techniques are underway. Our new source provides a versatile tool for measurements on many other species, and we have also begun measurements on Ar II.

(g) Rayleigh Scattering--We continue the investigation of the effect of laser temporal pulse shape on Rayleigh scattering, which is used as an absolute calibration of Thomson scattering to determine electron densities in plasma diagnostics. Using pulse shaping techniques, we have demonstrated that the Rayleigh scattering cross section is independent of pulse rise times as well as pulse durations.

We are applying for the first time the near-resonant-Rayleigh-scattering technique as an ion density measurement to plasma diagnostics. A barium vapor heat pipe, driven by a pump dye laser tuned at the Ba I resonance transition, provides a low-temperature and homogeneous plasma. The resultant Ba II population will be measured through a near-resonant-Rayleigh-scattering method by a probe dye laser, tuned in the neighborhood of a Ba II resonance transition.

(h) Vacuum Ultraviolet Radiometry with Plasmas--Our work on early models of portable low-powered (15 W) rf-excited dimer lamps has shown that these lamps make good standards of irradiance but are deficient as standards of radiance. Further work by us has shown that changes in the lamp design can also produce a satisfactory radiance standard, and we are currently evaluating several newly designed lamps to determine their suitability for use on the FOS (faint-object spectrograph) space shuttle experiment.

We have also been investigating two new types of radiometric sources. The first is an irradiance source of highly pure Lyman-α radiation which does not utilize a monochromator. The second is a radiance source in which an electrostatic discharge is set up in a narrow gap between two metal plates.

A deuterium lamp selected and calibrated by us was flown on the SUSIM (solar ultraviolet spectral irradiance monitor) space shuttle experiment as the first in-flight calibration source. As a part of this project our calibrations of several similar deuterium lamps were compared with calibrations of the same lamps carried out at NPL (England). This international comparison was made to ensure highest reliability of the irradiance scales.

Finally, we performed several calibrations of argon mini-arcs for agencies active in the field of space research. The projects involved were the HRST (high resolution space telescope) and the FOS. In connection with these calibrations, measurements were made to quantitatively determine radiation damage to the arc windows from long exposures.

(i) Quantitative Spectroscopy of D.C. Arcs--The computerization of the data acquisition and analysis system has been completed and refined

to the point that this laboratory now possesses state-of-the-art efficiency, versatility and precision in the study of visible, near-infrared and near-ultraviolet radiation. An on-line microcomputer is used to acquire and analyze high resolution spectral line profiles observed in the radiation emitted from a variety of study gasses injected into a wall-stabilized arc source which operates near local thermodynamic equilibrium. The analysis includes corrections for dark current, spectral sensitivity, self-absorption, continuum radiation, blended spectral lines and spectral line-wing truncations. In the first utilization of this apparatus 13 lines of the Ar I 4s-4p transition array were studied. These measurements yielded relative lifetimes for five 4p levels, Stark widths and shifts for all 13 lines, level widths for five 4p levels and four 4s levels, and transition probabilities for all 13 lines. The values obtained in all cases rank among the most precise measurements presently available. Plans for the immediate future include a further study of Ar I lines to include the transitions from the 5p levels and similar systematic studies of carbon, oxygen and nitrogen.

SPONSORED CONFERENCES

Division 531, Atomic and Plasma Radiation

NBS Workshop on Dielectronic Recombination Rates, NBS, Gaithersburg, Maryland, W. L. Wiese and L. J. Roszman, November 16-17, 1981.

INVITED TALKS

Division 531, Atomic and Plasma Radiation

Clark, Charles W., "Diamagnetism in Excited States of Hydrogen," Proceedings of Centre National de la Recherche Scientific, Aussois, France, June 6-12, 1982.

Jones, Douglas W., "Precision Computer Automated Transition Probability Measurements," Naval Postgraduate School, Physics Department, Monterey, California, March 26, 1982.

Martin, W. C., "Atomic Spectra - Some Recent Data of Astrophysical Interest," Joint Meeting of Commissions 14, 29, 36; 18th General Assembly of the International Astronomical Union, Patras, Greece, August 23, 1982.

Reader, Joseph, "Spectroscopy of Highly Ionized Atoms with Laser-Produced Plasmas," Chemistry Department Colloquium, Howard University, Washington, D.C., October 8, 1982.

Wiese, W. L., "Cascading Problems in Beam Foil Spectroscopy,", Physics Department, Kyoto University, Kyoto, Japan, October 16, 1981.

Wiese, W. L., "The Transition Probabilities of Argon--A Continuing Problem," Department of Engineering Science, Kyoto University, Kyoto, Japan, October 16, 1981.

Wiese, W. L., "Spectroscopy of Highly Ionized Atoms," Fall meeting of the Japanese Physical Society, Niigata, Japan, October 4, 1981.

Wiese, W. L., "Radiation Data and VUV Radiometric Calibrations for Heavy Ion Lines," Japanese Atomic Energy Research Institute, Tokai, Japan, October 6, 1981.

Wiese, W. L., "The Transition Probabilities of Ar I and II--A Continuing Puzzle," Atomic Spectroscopy Symposium, Tokyo, Japan, October 13, 1981.

Wiese, W. L., "Experimental and Theoretical Studies of Collision Rates and Cross Sections at NBS," Physics Colloquium at University of Nagoya, Japan, October 15, 1981.

Wiese, W. L., "Cascading Problems in Beam Foil Spectroscopy," Nuclear Physics Colloquium, Institute for Physical and Chemical Research, Saitama, Japan, October 20, 1981.

Division 531, Invited Talks (cont'd.)

Wiese, W. L., "Current Topics in Atomic and Plasma Radiation Research at NBS," Atomic Physics Seminar, Institute for Physical and Chemical Research, Saitama, Japan, October 22, 1982.

Wiese, W. L., "Progress on Atomic Oscillator Strengths," 18th General Assembly of International Union (IAU), Patras, Greece, August 23, 1982.

Wiese, W. L., "Atomic Transition Probabilities and Lifetime Studies for Argon," XIth international Symposium on the Physics of Ionized Gases, Dubrovnik, Yugoslavia, August 25, 1982.

Younger, S. M., "Ionization and Recombination in High Temperature Plasmas," Physics Department, Howard University, Washington, D.C., January 22, 1982.

Younger, S. M., "Ionization and Recombination in High Temperature Plasmas," Lawrence Livermore Laboratory, Livermore, California, December 8, 1981.

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Lucatorto, T. B., McIlrath, T. J., Sugar, J. and Younger, S. M., Radical Redistribution of the 4d Oscillator Strength Observed in the Photoabsorption of Ba, Ba^{+}, and Ba^{++} Sequence, Phys. Rev. Lett. 47, 1124-1128 (1981).

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Musiol, K., Jones, Douglas W., and Wiese, W. L., Lifetime Ratios for Ar I 4p Levels, J. Quant. Spectrosc. Radiat. Transfer (in press, 1982).

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Reader, J., $3p^63d^9$-$3p^53d^{10}$ Transitions in Cobalt-like Ions from Ba^{29+} to Yb^{43+}, J. Opt. Soc. Am. (accepted for publication, 1982).

Roszman, L. J., Dielectronic Recombination in Collision of Electrons with Multicharged Ions, Proceedings VII ICPEAC, Physics of Electronic and Atomic Collisions (1982).

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TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 531, Atomic and Plasma Radiation Division

Victor Kaufman

Member, 1982 William F. Meggers Award Committee, Optical Society of America.

Georgia A. Martin

Member, National Academy of Sciences-National Research Council Committee on Line Spectra of the Elements--Atomic Spectroscopy.

Chairperson (effective June 1983), National Academy of Sciences--National Research Council Committee on Line Spectra of the Elements--Atomic Spectroscopy.

William C. Martin

Chairman, Working Group on Structure of Atomic Spectra, Commission 14 of International Astronomical Union.

Member, National Academy of Sciences-National Research Council Committee on Line Spectra of the Elements--Atomic Spectroscopy.

Member, IAEA Network of Atomic Data Centers for Fusion.

Wolfgang L. Wiese

Member, Program Committee for the series of International Conferences on Spectral Line Shapes.

Member of Organizing Committee, International Astronomical Union, Commission 14.

Chairman, International Astronomical Union, Commission 14, Working Group on Atomic Transition Probabilities.

Member, IAEA Network of Atomic Data Centers for Fusion.

Member, Steering Committee of the TEXT users organization (TEXT = Texas Experimental Tokamak, a national plasma research facility).

Member, Program Committee for the 13 Symposium on Ionized Gases.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 531, Atomic and Plasma Radiation

1. Numerous evaluation tests and calibrations of four rf dimer lamps are being performed this year as part of contract work for Martin Marietta Aerospace. This work involves close consultation with Martin Marietta personnel concerning the results of each test and plans for successive tests and calibrations.

2. The Data Centers on Atomic Energy Levels and Transitions Probabilities routinely fill requests for atomic data or literature information submitted by scientists in a wide range of research areas. The requests average about 15 per week. On occasion, special reports are prepared for particular user groups. Thus, W. C. Martin and W. L. Wiese have written updates on atomic data of interest for the astrophysical community for the 1982 IAU Transactions, and have given review reports at the 1982 General Assembly of the International Astronomical Union.

3. W. L. Wiese serves on the steering committee for the TEXT users organization (TUO). TEXT stands for Texas Experimental Tokamak and is a national plasma users facility. The TUO steering committee considers the special needs of off-site user groups and has then provided advice and perspective on the users program to the TEXT managers and the Office of Fusion Energy at DOE.

JOURNAL EDITORSHIPS

Division 531, Atomic and Plasma Radiation

W. C. Martin, Editorial Board, Journal of Physical and Chemical Reference Data.

W. L. Wiese, Associate Editor, Journal of Quantitative Spectroscopy and Radiative Transfer.

W. L. Wiese, Co-Editor of newsletter, "Atomic Data for Fusion," published by the Oak Ridge National Laboratory.

TRIPS SPONSORED BY OTHERS

Division 531, Atomic and Plasma Radiation

J. M. Bridges traveled to Boulder, Colorado for consultation with Ball Brothers concerning calibration work. Entire trip paid by Ball Brothers. (August 2-4, 1982)

J. M. Bridges consulted with scientists at the National Physical Laboratory in London, England and participated in calibrations. Trip sponsored by Naval Research Laboratory. (July 10-17, 1982)

Charles W. Clark presented an invited talk at Centre National de la Recherche Scientific in Aussois, France, entitled "Atomic and Molecular Physics Near Ionization Thresholds in High Fields." The entire trip was paid by CNRS. (June 6-12, 1982)

Charles W. Clark presented an invited talk at the University of Chicago, entitled "Negative Ion Resonances in Electron Scattering by Noble Gases." (September 27-29, 1982) Trip was paid by University of Chicago.

W. L. Wiese, sponsored by The Institute of Physical and Chemical Research in Tokyo, visited the Thermonuclear Fusion Laboratory in Tokyo and attended a Symposium on Atomic Spectroscopy. He also visited Kyoto, Niigata, Tokai, and Nagoya and gave invited talks. (September 23-October 23, 1981)

W. L. Wiese, sponsored by Yugoslavian grants, attended XI International Symposium on the Physics of Ionized Gases in Dubrovnik and gave invited talks on "Atomic Transition Probabilities and Lifetime Studies of Argon" and "Stark Broadening Regularities of 4s-4p Ar I Lines". Also did collaborative work at Institute for Applied Physics in Beograde. (August 23-September 10, 1982)

S. M. Younger traveled to Livermore, California to present an invited talk at Lawrence Livermore Laboratory, Livermore, California. Entire trip was paid for by LLL. (December 8, 1982)

CALIBRATION SERVICES PERFORMED

Division 531, Atomic and Plasma Radiation

Type of Service	Customer	SP 250	No. of Tests	Income
Mini Arc Sources and Calibrations	Ball Aerospace	7.5 S	4	23.00 k$
Mini Arc Calibrations	Ball Aerospace	7.5 X	1	1.43
Mini Arc Calibrations	Midwest Research (SERI)	7.5 S	1	1.38
Dimer Lamp	Ball Aerospace	7.5 S	1	2.00
Dimer Lamp	Ball Aerospace	7.5 S	1	1.10
Dimer Lamp	Ball Aerospace	7.5 S	1	1.50

TECHNICAL ACTIVITIES

Division 532, Nuclear Radiation

Task No. 11221 (new task no. 15221) - Neutron Radiation Safety
Task No. 11222 (new task no. 15222) - Nuclear Structure and Standards
Task No. 11223 (new task no. 15223) - Nuclear Radiation Research
Task No. 11225 (new task no. 15225) - Neutron Field Standards
Task No. 11226 (new task no. 15226) - Radioactivity Standards
Task No. 11227 (new task no. 15227) - Neutron Measurements and Research
Task No. 14302 (new task no. 15602) - Physical/Technological Property SRM Research
Task No. 14402 (new task no. 15645) - Computerization of Standard Reference Bases
Task No. 14420 (new task no. 15650) - Physical Data for Energy Applications

The Nuclear Radiation Division encompasses a broad range of activities including both fundamental and applied research. It includes five groups designated as Nuclear Theory, Nuclear Research, Neutron Measurements and Research, Neutron Field Standards, and Radioactivity. Of these the first two are mostly basic nuclear research, and the last three are mostly applied research. In addition, a project on Dosimetry Standards for Neutron Radiation Therapy is attached to the Division Office. Photonuclear data collection, as part of the Photon and Charged Particle Data Center, is located in the Nuclear Research Group.

Activities of the Division support important national areas of concern: medicine (e.g. radioactivity standards for nuclear medicine), fission and fusion nuclear power (neutron cross sections, fission rate measurements in power reactors, environmental radioactivity standards, nuclear materials safeguards), environment (environmental radioactivity in natural matrices), occupational safety (neutron personnel monitoring), and science (nuclear structure and dynamics through electromagnetic interactions, and molecular physics with eV neutrons).

We continue to attract many guest workers. Some of our scientific colleagues who have come to NBS for extended stays are: Hall Crannell and William Stapor, Catholic University of America; Elisa Wolynec, University of São Paulo, Brazil; Li Linpei, National Institute of Metrology, Peking, China; Mauro Dias, Instituto de Pesquises Energéticas e Nucleares, São Paulo, Brazil; Hans-Georg Menzel, University of Saarlandes, Hamburg, West Germany; Bernd Siebert, Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany; Augustin Grau Malonda, Junta de Energia Nuclear, Madrid, Spain; Johann Rafelski, University of Frankfurt, West Germany; and Sunaryo Wiryosumarto, National Atomic Energy Agency, Republic of Indonesia.

Members of Nuclear Radiation Division staff on extended stays elsewhere include Leonard Maximon and Michael Danos, Centre d'Etudes Nucléaires de Saclay, France; Michael Danos, University of Frankfurt, West Germany; J. Joseph Coyne, Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany; Evans Hayward, University of São Paulo, Brazil, and Max-Planck Institut für Chemie, Mainz, West Germany; and Sydney Meshkov, California Institute of Technology, University of California, Irvine, and University of California, Los Angeles.

Dosimetry Standards for Neutron Radiation Therapy. This program, supported by the National Institutes of Health, has been continued to improve the accuracy and consistency of absorbed dose measurements for neutron therapy through provision of national dosimetry standards and improved theoretical information on neutron interactions with tissue and tissue-equivalent materials. A longer term goal is to develop a calibration facility at NBS where neutron dosimeters can be calibrated and their energy dependence studied.

As an initial step in establishing the neutron dosimetry standards program, measurements of the neutron and gamma-ray kerma rates of a ^{252}Cf source were made using tissue-equivalent ionization chambers, magnesium-argon ionization chambers, Geiger-Müller dosimeters and a tissue-equivalent proportional counter. After resolving a problem due to a radiation field component with low penetration, the measured neutron tissue kerma rates agreed within 3% with the value calculated from the accurately measured neutron emission rate of the source. A report describing this study has been prepared for publication. The experience gained from these measurements showed that the proportional counter can provide valuable information for mixed-field dosimetry and a graphite-walled proportional counter and auxiliary electronic instrumentation has been acquired for future use. To facilitate precise monitoring of neutron beams, a voltage-to-frequency module and a frequency divider module have been constructed. Construction of a tissue-equivalent radiation calorimeter is being negotiated with Battelle-Pacific Northwest Laboratory and the necessary auxiliary equipment for the calorimetry system is being acquired.

Work was completed on the construction of a new charged particle beam line into the shielded room of the CRR's 3 MeV Van de Graaff accelerator for use in producing moderately intense fields of monoenergetic neutrons. This work included installation and testing of all beam line components (magnets, vacuum pump, valves, power supplies) and the design, construction, and installation of a radiation safety system.

Three tritium targets and one deuterium target were obtained from the Oak Ridge National Laboratory specially fabricated on copper target blanks for water cooling. A maximum deuteron beam current of 62 μA at 0.5 MeV was

accelerated onto one of the tritium targets to produce 15 MeV neutrons. Simultaneous measurements made in this neutron field with a tissue-equivalent ionization chamber and a ^{235}U fission counter yielded neutron kerma rates which agreed within a few percent, well within the experimental uncertainties.

A report titled "The NBS Program in Dosimetry Standards for Neutron Radiation Therapy" was given at the Advisory Group Meeting on Advances in the Dosimetry for Fast Neutrons and Heavy Charged Particles for Therapy Applications conducted by the International Atomic Energy Agency.

I. Nuclear Theory Group

This group works on high energy theory, nuclear theory, Coulomb interactions, neutron standards theory, and theoretical neutron dosimetry, relating particularly to the experimental nuclear research and neutron standards research programs in the Division.

Elementary Particle Theory. Quantum Chromodynamics (QCD), our present theory of the strong interactions, describes hadrons as being composed of colored quarks and antiquarks. The strong force between quarks and between quarks and antiquarks is mediated by the exchange of massless colored gluons, just as the electrical force between electrons and between electrons and positrons is mediated by the exchange of massless photons. Convincing manifestations of the existence of the gluon have been displayed in recent e^+e^- annihilation experiments at 27 and 31.6 GeV. QCD implies that glueballs (gluonia) should exist. These are mesons which are composed entirely of gluons; they contain no quarks and have no color.

A current activity of the NBS Elementary Particle Program is the study of gluonium, i.e., to set criteria for its existence, and to try to understand how to distinguish gluonic states from the usual quark states experimentally. Understanding the formation, structure, and decay of gluonic systems requires a full knowledge of the spectroscopy of "quarkful" mesons, i.e., those described in the usual way as quarks and antiquarks moving with a relative orbital angular momentum L. Fortunately, the latter is a major component of high energy activity of NBS as manifested by work on charmonium and other "onium" spectroscopy.

Following studies carried out over the past two years in collaboration with P. Fishbane of the University of Virginia and C. Carlson and F. Gross of the College of William and Mary, a critical evaluation of our knowledge of glueball masses, widths and possible production and decay mechanisms was carried out. In a comprehensive report presented at an International

Conference in Florence, Italy, it was concluded that the $\iota(1440)$ and $\theta(1640)$ states, possible glueball candidates, should not be regarded as glueballs, but are most likely something else, probably quark-antiquark radial excitations. Recent work demonstrating this in a simple mixing model has been carried out with P. Fishbane and G. Karl (University of Guelph, Canada) and is being prepared for rapid publication. In addition, it appears that the various glueball excitations are more massive than previously believed.

Nuclear Theory. In the past, nuclear forces have been treated in terms of meson exchanges between point nucleons, although it was realized that these nucleons were not point particles but in fact occupied a large part of the volume of nuclei. Now the origin of nuclear forces must be rethought in terms of the underlying quark structure. The model available for this treatment is the bag model. However, two-nucleon interactions in this model have six quarks in the bag, and if an exchanged meson is included then there are seven quarks and an antiquark. There are many-body correlations among the quarks. A program to investigate these forces has been started, but due to the unique confining properties of the quark-quark forces the correlation problem is not easily solved.

The current hadron bag model treats the confinement problem in a purely *ad hoc*, unphysical, manner, *i.e.*, by imposing a scalar boundary condition on the quark wave function. However, no scalar fields exist in the QCD Lagrangian, which could serve to take up the momentum transfer implied by the boundary condition. In order to eliminate this drawback, and to put the description of the hadrons on a more physical basis a reformulation of the quark bag model for the nucleon in terms of the methods of NBS Monograph 147 has been initiated. The first steps, in progress at this time, consist of rewriting the QCD Hamiltonian in the Schrödinger picture, and of computing the specific QCD matrix elements not contained in 147.

A vexing problem of nuclear physics is the apparent isospin impurity of the α-particle, which manifests itself in the ratio $\sigma(\gamma,p)/\sigma(\gamma,n)$ which does not equal unity. This experimental fact has lead to speculation that the nuclear force itself may not be isospin invariant. A program has been started to test whether the Coulomb interaction itself, contrary to previous calculations, can explain the observed cross section ratio.

Photonuclear Theory. A very important source of the high energy photons used in photonuclear research is the bremsstrahlung radiation produced when accelerated electrons collide with a suitable target. Recently there has been a strong trend toward the utilization of "monochromatic" photon beams rather than bremsstrahlung photon beams. The experimental technique which now promises great success in achieving good

comprises between the conflicting requirements of small energy resolution, high flux, low counting rates associated with unwanted photons and a well defined, and easily and continuously adjustable photon energy is the bremsstrahlung monochromator or photon "tagging" technique. The tagged photon technique detects the electron after bremsstrahlung to determine the emitted photon energy. This detected electron is put in time coincidence with a nuclear decay product following the photon induced reaction. The photon tagging technique has become increasingly popular as electron beams of duty cycle approaching 100%, such as the racetrack microtron currently under construction at the National Bureau of Standards, become available. Following a first report (NBSIR 81-2262), prepared for the explicit use of the experimenters who are designing and using tagged photon systems as a means of doing experiments with monoenergetic photons, we have prepared a second report on polarized tagged photons (NBSIR 82-2454). This report has already been used by expermental groups both in the U.S. and abroad, for the design of bremsstrahlung monochromators.

Theoretical work on the photodisintegration of few body systems continues in collaboration with physicists from George Washington University. Two reports detailing the mathematics needed to incorporate the Coulomb interaction in reaction amplitudes have been prepared, GWU/DP/TR-82/1 and GWU/DP/TR-82/2. This work has already been used by experimenters at M.I.T. in their analysis of experiments on the photodisintegration of ^{3}He.

Theoretical Neutron Dosimetry. A theoretical program on Neutron Interactions with Biological Tissue is carried out with joint support from NBS and the Office of Health and Environmental Research, Department of Energy. The objective of this program is to obtain information about neutron interactions with tissue through secondary charged particles using theoretical calculations whose input includes neutron cross section data; range, stopping power, and straggling information; and geometrical properties. This information is basic to radiological physics, radiation biology, radiation protection of workers, and standards for neutron dose measurement.

There is increased interest in studying very small cavity sizes (of the order of nanometers). For these cavity sizes our analytical calculations will not be valid because of the importance of delta rays and straggling, or track structure in general. For this reason, and because it will be needed to improve calculations at high neutron energy, we are developing a Monte Carlo code to calculate energy depositon spectra for fast neutrons. The first version has been designed so as to duplicate the results of the analytic code. This code is now operating successfully and gives identical results to the analytic code within the Monte-Carlo statistics. Preliminary studies have been completed on how to include straggling and delta-ray effects. As a first step we will use the "Landau" straggling, which is valid for small thicknesses of material--certainly the case for nanometer cavities.

The analytic code used for neutron energy deposition studies has been extended in two ways: (1) use of bin-averaged cross sections so that arbitrary neutron spectra may be calculated, useful even for "monoenergetic" neutron sources since they are seldom completely monoenergetic, and also for distributed-energy neutron sources such as cyclotrons with either protons or deuterons on beryllium as the neutron-producing reaction; and (2) calculation of ionization yield spectra for small sites which are more directly comparable to the experimentally-measured spectra obtained with walled and wall-less tissue-equivalent proportional counters.

Kerma factors have been calculated for 44 compounds and mixtures encompassing a large number of materials of interest to radiation biology, radiation therapy, neutron protection, dosimetry, and radiation chemistry. This material is in press.

Neutron Personnel Monitoring. Under contracts with the DoE and NRC we have continued studies of calibration of neutron monitoring instruments used in neutron fields of interest to these two agencies. For DoE we published an NBS report on "Procedures for Calibrating Neutron Personnel Dosimeters." This report gives detailed recipes for correcting calibration measurements for effects of air scatter, room scatter, and scatter in source encapsulation. We have made both calculations and measurements of the photon component from ^{252}Cf spontaneous fission neutron sources for NRC. Also we are reviewing measurements made in maintenance areas of nuclear power plants in order to recommend optimum procedures for evaluating the radiation dose received by workers in those plants.

We have devised a synthesis of two simple expressions for (1) reflection of neutrons from a plane surface and (2) reflection of neutrons from a source at the center of a cubical room. Predictions of the combined expression agree very well with Monte Carlo calculations of neutron reflection for sources at a general position in rooms of arbitrary shape.

Civil Defense. We have written computer codes to evaluate shielding afforded by structures against neutrons and gamma rays from nuclear weapons. The codes are consistent with the input data format used by FEMA to evaluate protection in structures from fallout radiation. The shielding curves used by the codes are based on data generated by L. V. Spencer and by SAI, under contract to NBS. The codes calculate the protection against both neutrons and gamma rays at the center of a building and include effects of internal reflection of neutrons and the shielding effects of nearby buildings.

II. Nuclear Research Group

The study of the interactions of high energy photons and electrons with nuclei is leading to new understandings of how nucleons behave inside complex nuclei, i.e. in what form they exist and how they interact with each other. Activities of the Nuclear Research Group cover experimental and theoretical investigations of many different electromagnetically induced nuclear reactions. This includes high energy electron and photon scattering from nuclei, electrodisintegration experiments in which nuclear reaction products are studied, and electroactivation studies in which integrated reaction cross sections are studied via induced radioactivities.

The photon scattering work was terminated in August 1981 to make room for construction of the NBS microtron. Before this time, however, work was completed on the scattering of high energy photons from ^{16}O at several angles. These data along with similar data on ^{12}C have been analyzed to yield the E2 strength in these nuclei. A paper is in preparation on this work.

The electron scattering program has encompassed several different activities. A precision measurement of the ^{4}He radius has been made by comparing it to that of ^{12}C. This work will constitute the PhD thesis of W. Stapor of Catholic University. A similar measurement of the proton radius is now being planned and will form the basis of the thesis of M. McCord. Maruyama has continued in his study of stretched configurations in collaboration with the group at the University of Massachusetts; the measurements are made at the Bates Laboratory. Lightbody and Maruyama are also engaged in a collaboration at Bates to investigate the convection and magnetization current contribution to the transverse cross section of the first excited state of ^{52}Cr.

O'Connell organized a collaboration with a group of physicists from Lund, MIT, American Unviersity, and NBS to investigate the apparent failure of the Coulomb sum rule. At the Bates Laboratory, we measured the spectra of electrons scattered through 20° by six targets at four electron energies. During the course of the measurements we found an intrumental background produced by the electrons striking the interface between the spectrometer and the scattering chamber and established a procedure for subtracting it off. Within the uncertainties in the experiment our results are consistent with the sum rule and it is now believed that the discrepancy found in previous experiments stemmed partly from the instrumental problem.

The electrodisintegration experiments performed in collaboration with E. Wolynec of São Paulo have continued. The work on the isochromat of the electric dipole virtual photon spectrum for zirconium has been completed and a paper sent to the Physical Review. We now plan to study the (e,α) and (e,p) cross sections for Zr. In addition, we will complete the measurement and interpretation of the $^{63}Cr(e,n)$ cross section.

At the present time the Nuclear Research Group is engaged in writing a proposal to request funds to support the physics that can be done with the 200 MeV CW microtron now under construction. This proposal describes the coincidence experiments that we want to perform and the required instrumentation. They are of the type (e,e'x) or (γ,x) using tagged photons.

The proposal also describes a plan to use the 200 MeV machine as an injector for a much larger 1 GeV microtron. This will involve an enlargement of the laboratory which will become a national user facility. Most of the physics planned for the 1 GeV facility involves studies of the few-nucleon problem. Huge magnetic spectrometers will be required.

III. Neutron Measurements and Research Group

This group is concerned with measurements of neutron interactions which depend strongly on the neutron's energy. The interactions include both nuclear and molecular effects and require neutron spectroscopic capability from 0.005 eV to 50 MeV--over ten decades of energy. The largest program is devoted to a continuing international effort to push the accuracy of reference neutron cross sections into the $\pm$1% (1 SD) range. Other programs are concerned with the development and exploration of analytical techniques based on the unique features of the neutron's interaction with matter. Both the standards and analytical studies require a significant component of fundamental neutron research. The NBS facilities used are the 100 MeV linac, 3 MV positive-ion Van de Graaff, and nuclear reactor.

The standards measurements during the past year concentrated on the neutron induced fission cross section of ^{235}U. Progress in fusion research and concerns about tactical neutron warheads are driving current interest in this standard. Three of the group's previously reported measurements on this standard using different techniques and neutron energies were published in Nuclear Science and Engineering. The first paper covering the experiment at 14 MeV using the associated-particle technique reported an accuracy of 1.5% (1 SD). An evaluation of all measurements at 14 MeV shows that the cross section at 14 MeV, with an accuracy of better than 1%, is as well known as at thermal energy. The second paper covering experiments in the 0.2-1.2 MeV region using the black neutron detector reported an accuracy of 2.3% (1 SD). The cross sections were approximately 2% lower than the ENDF/B-V evaluation. Also published was the measurement of the ^{235}U mass contained in the large fission chamber which is used in several of the cross section measurements. The shape measurements in the 6-800 keV region using the hydrogen-gas counter flux monitor which were reported in 1976 were reevaluated and also published.

A significant accomplishment was the development of a new neutron detector for flux measurements in the 1-15 MeV region. The detector consists of two thin plates of plastic scintillator optically separated and independently coupled to phototubes. The response of the detector approximates the proton recoil spectrum from n-p scattering and can be calculated from the well known hydrogen cross section. The efficiency of the detector was measured at 2.5 MeV and 14 MeV using the associated particle technique and was extended into the intermediate energy regions by means of Monte-Carlo based calculations.

Our measurement efforts concentrated on the low MeV neutron region where serious discrepancies still exist. Analysis continues of measurements in the 0.3 to 3 MeV region that were made using the black neutron detector at the linac facility. A similar measurement is in progress in the 1-6 MeV region using the thin scintillator flux monitor described above. An experiment at 2.6 MeV using the associated particle technique with the $D(d,n)^3He$ reaction at the Van de Graaff is underway but will require an improved TiD target for completion. Upon completion of this work, the NBS will have completed 9 measurement efforts on ^{235}U in the 5 eV to 20 MeV range. It appears that the long existing objective of 1% for the cross section may also be within reach throughout much of this energy region when the NBS data is combined with other data in the final evaluation.

New studies of the few percent deviations of the $^6Li(n,\alpha)$ to $^{10}B(n,\alpha)$ cross section ratios from the ENDF/B-V evaluation observed previously in the eV energy region continued. Transmission measurements at the NBS reactor thermal column were done for 2 ^6Li glass scintillators so that accurate self-shielding corrections could be applied to the ratio measurements. These scintillators were used in a collaborative ratio measurement at Oak Ridge National Laboratory which confirmed the anomalous behavior in the eV region which might result from molecular effects.

Theoretical studies of electronic excitation in atoms and molecules by neutron-nucleus scattering have been completed. The work was carried out in collaboration with Dr. S. W. Lovesey of the Rutherford Appleton Laboratory. Two mechanisms were considered for producing electronic excitations, center-of-mass recoil and the coupling between electrons and nuclei arising from non-adiabatic terms neglected in the Born-Oppenheimer approximation. A significant cross section for electronic excitations is predicted in this study. The effect of this previously neglected energy-loss mechanism on moderation problems is currently being addressed. The Monte-Carlo technique is being used to study the differences in moderated neutron spectra with and without the possibility of electron excitations. These studies are just beginning.

Experimental studies of inelastic neutron scattering in the 1-15 eV range are continuing. A careful measurement of the inelastic scattering spectrum from H_2O at 30° reveals that molecular binding effects persist in this energy range. These results are confirmed by a recent Los Alamos National Laboratory measurement using a slightly different technique where inelastic scattering from the hydrogen in H_2O is seen at 90°. Efforts are now underway to fit the present data using the theoretical model of Nelkin. Preliminary results indicate that this model which incorporates rotational and vibration excitations can quantitatively describe the data. It should be noted that this model has been extensively used in the reactor physics codes but in a lower energy range.

We considered the effect of the thermal neutron absorption cross section of sulfur on the value of $\bar{\nu}$ for ^{252}Cf obtained in the Mn bath measurements. A 10% increase in this cross section (3 times experimental error) is required to remove the discrepancy between bath and scintillator measurements of $\bar{\nu}$. Measurements are in progress at the University of New Mexico of the effective sulfur absorption cross section in the bath medium. A different value in the medium would indicate that molecular or moderation effects on the neutron absorption could be important and should be further studied at NBS.

We have also studied the discrepancy between the ^4He production from ^{10}B measured with integral measurements and that calculated from ENDF/B-V cross sections. This ^{10}B problem has received considerable attention in the international community. New evaluation codes are being used which can utilize both differential and integral measurements and covariance information. We are involved in this process and if required will investigate possible moderation effects which could affect the flux in the integral measurements. The most direct approach to the ^{10}B measurement discrepancy with calculations is to perform ^4He production measurements in existing NBS standard neutron fields. The first of such measurements in the thick shell ISNF began in FY-82 and will continue in FY-83.

Studies of neutron-induced fission cross section systematics for a wide range of nuclei are yielding encouraging results in the MeV energy region. The present work involves the prediction of the fission cross sections of the short-lived nuclides based on the properties of the nearby long-lived nuclides. The status of the fast fission cross section ratios is also being maintained for a subcommittee of the Cross Section Evaluation Working Group.

We were quite pleased to see the technical accomplishments of our group acknowledged by a national organization. Dr. Roald Schrack was granted the IR-100 Award by Industrial Research magazine for one of the hundred most important technological advances of the year. This advance was the development of the micro-channel plate position sensitive neutron

detector. This device has a time resolution of approximately one microsecond and a spatial resolution of about one-half millimeter. Using this detector and the technique of resonance neutron radiography, images have been produced of the distribution of an isotope in a complex matrix. Measurements of the special nuclear material content of waste materials are in progress at the linac facility using this technique.

We continue to maintain strong international relationships through the BIPM, the IAEA, and the European Nuclear Energy Agency Nuclear Data Committee and participate in planning internationally coordinated measurement programs. We have established a 14 MeV standard neutron facility at the Van de Graaff which was used in an international intercomparison of neutron source strength. The facility is being extended to 2.6 MeV neutron energy and a 6-7 MeV standard γ-ray field using the $^{19}F(p,\alpha\gamma)$ reaction is being developed.

The transfer of NBS neutron measurement results to the outside community has been a significant part of our program during the past year. The DoE Cross Section Evaluation Working Group (CSEWG) continues to be an effective means of implementing our data improvements quickly into industrial and government programs. Dr. Allan Carlson continues as chairman of the standards subcommittee of CSEWG. The NM&R group continues an active program of communication of new neutron measurement methods and related technology to the U.S. national laboratories. The new analytical methods for spent fuel analysis, fuel reprocessing material accounting, and breeding ratio measurement have been discussed closely with staff members at BNL and Argonne National Laboratories. The group has provided consulting services to LLNL and LANL on new neutron measurement methods and on the development of new methods for materials science studies using neutrons.

The continued availability of suitable accelerator sources of neutrons for NBS is a matter of growing concern. The NBS Center for Radiation Research has commissioned a further study of possible alternatives for improved accelerator neutron sources at the NBS. This study, which is also extending the areas of study to include high-LET radiation in order to broaden the support base within the NBS for an improved accelerator, will be presented for consideration by the NBS management.

IV. Neutron Field Standards Group

The objectives of this group are to provide neutron dosimetry standardization and neutron source and detector calibrations for energy generation technology and radiation exposure monitoring. Activities are divided between response to calibration and measurement service requests and the application of existing standard neutron fields and related capabilities to neutron reaction-rate measurement standardization. Strong

interactions with outside organizations, both in the federal and private sector, continue to be the main programmatic characteristics of this group's activities.

Concern for neutron field measurements is on the increase as was noted last year. More neutron field calibration and related measurements were undertaken this year than last in order to improve the level of standardization for personnel neutron dosimetry, for materials performance under stress of radiation, and for advanced power reactor development. Fission chamber experiments in a variety of circumstances continue to dominate our activities: measurements in neutron flux intensities which differ by 7 orders of magnitude, for example, or in neutron fields under 10 meters of water vs. open air experiments where inverse-r^2 field gradients are closely approximated.

Neutron personnel dosimetry activities involving hundreds of dosimeter and dosimetry instrumentation calibrations were carried out during the year at NBS with five different standard neutron fields. Clients ranged from nuclear utilities and dosimetry vendors to DoE laboratories participating in dosimetry improvement programs. Dosimetry for materials performance focused on preparing and evaluating the documentation describing reactor pressure vessel (RPV) mock-up measurements at ORNL. Experimental characterization of the neutron field in the RPV mock-up rests largely upon neutron reaction rate measurements that were referenced to fission neutron standard fields at NBS. The industry problem behind this effort, steel embrittlement under stress of radiation in a reactor vessel, continues to be an important component of our program. The new impetus, arising from the recognition of thermal shock potential in certain pressure vessels as a result of post-TMI changes in emergency reactor-shutdown procedures continues to exercise the industry, the NRC, and even the media. A paper presented at the Ninth Water Reactor Safety Information Meeting examined the effectiveness of making supplementary, on-demand dosimetry measurements in the so-called RPV cavity of older power reactors where the thermal shock question is of most consequence.

A triumph of sorts occurred when the Subcommittee on Standards explicitly recognized the fission-spectrum-averaged cross section of U-235 in the Cf-252 fission spectrum as a basic normalization measurement for the U-235 fission cross section. Remeasurement of this normalization quantity is continuing and this year included fissionable deposit mass intercomparisons at the thermal column. In addition, a re-evaluation of earlier measurements was completed and the results forwarded to CSEWG:

$$\overline{\sigma}_f(\text{U-235}, \chi_{cf}) = 1216 \pm 19 \text{ mb}$$

There was little change from the previously published value but the error in the rms sense was reduced by a factor of two. This improvement came

from (1) revision of mass scale for NBS fissionable deposits (error reduced to ± 0.75%); (2) new detailed Monte-Carlo scattering calculations for the fission chamber and the fissionable deposit backings carried out at Los Alamos; and (3) reduction of the error assigned to the source strength of NBS-I, the National Standard Neutron Source (error reduced to ± 0.9%).

A new and quite different kind of activity was initiated this year. A thermal-neutron-autoradiography facility for diagnostic irradiations of art works was undertaken in cooperation with the Reactor Division and the Smithsonian Institution. Substantial modifications at the thermal column, fabricated and installed by our group, were designed to achieve a high intensity flux of thermal neutrons over a large area. The design also made possible rapid recovery of irradiated paintings so that short-lived activities could be included in the post-irradiation diagnostic procedures. Preliminary and successful irradiations of prototype paintings were completed.

Fission cross-section measurements in the thick-shell ISNF were performed for the following isotopes: U-233, Pu-240, Pu-241, and Th-232. Combined with earlier measurements of U-235, U-238, Pu-239, and Np-237, there now exists for ISNF a consistent set of integral fission cross-section data for essentially all of the fissionable isotopes important for reactor technology. A representative result,

$$\sigma_f(\text{Pu-240, ISNF}) = 824 \text{ mb} \pm 2.8\%,$$

agrees well with the value predicted by ENDF/B-V (the U.S. nuclear data file for reactor technology):

$$\frac{\text{Calculated}}{\text{Observed}} = 1.00 \pm 3.0\%.$$

A characteristic of this result which identifies it as coming from a standard neutron field is the inclusion of a component error in the 3.0% total uncertainty for the propagated effect of ISNF spectrum uncertainties. Each physical and nuclear parameter of ISNF has been subject to a spectrum variational analysis which is subsequently propagated to a set of spectrum-associated errors for each species of reaction rate measurements performed in ISNF. Thus, calculated to observed ratios like the one above for Pu-240, is an unambiguous check of the corresponding energy-dependent reaction rate cross section.

An archive deposit of U-233, a recent addition to the NBS set of fissionable isotope mass standards, was employed for the ISNF measurements just described as well as for earlier Cf fission spectrum cross section

measurements. The complex alpha spectrum of U-233 and its daughters, and the fact that the deposit is a fluoride compound rather than the usual oxide, creates special problems in the mass assay. In order to carry out the thermal-fission component of the assay, fission fragment self-absorption in fluoride vs. oxide deposits was investigated this year in a series of thermal beam measurements.

The testing of neutron personnel dosimetry instrumentation which continued at a high level made notable and proper institutional use of the filtered beams, the thermal column, and the D_2O-moderated fission spectrum irradiation facility. Systematic performance tests have now been performed on essentially all types of passive neutron dosimeters used in the United States. Calibration of active neutron dosimetry instrumentation (remmeters and BF_3 counters) served the needs of a variety of agencies, laboratories, and commercial vendors, and most significantly, to meet the vital calibration requirements of a suddenly increased number of power reactor operators. The latter service often enough was called upon to accommodate difficult and costly deadlines imposed upon us by the reactor operators.

Neutron fluence standards prepared with the cavity fission source were sent to ORNL for calibration of a new dosimetry counting system. Activation reactions included were In(n,n'), Al(n,α), Ni-58(n,p), and Fe-54(n,p). The facility at ORNL will be employed for neutron dosimetry measurements in existing and planned irradiations there designed to test embrittlement rates in reactor pressure vessel steels. For this work and other enhanced activities at the cavity fission source, a specialized fission chamber of small diameter purchased in France was installed at the entrance penetration of the reactor thermal column cavity. It is now possible to perform time-history flux monitoring of ^{235}U fission spectrum irradiations. Other notable improvements in the Cavity Fission Source were: (1) experimental examination of flux gradients over the region of detector placement; and (2) receipt of preliminary results of source detector scattering calculations. The latter are part of extensive Monte Carlo calculations being carried out at Los Alamos under joint cooperation and contract.

The cavity fission source, after its varied applications to neutron dosimetry calibration, was employed for the first time in a cross-section measurement. The U-235 fission-spectrum-average cross section for the activation dosimetry reaction Ni-58(n,p) was determined in a set of cavity fission source irradiations. The absolute flux for the experiment was established by the method neutron flux transfer from the Cf-252 fission source using the In (n,n') reaction. The preliminary result of this measurement:

$$\sigma(Ni,\chi_{25}) = 101 \pm 3 \text{ mb}$$

caused some spirited discussion when reported at the Fourth ASTM-EURATOM Symposium on Reactor Dosimetry in March of this year. The accepted experimental value of this important cross section is some 8% higher than the one above. There is added provocation in the fact that the preliminary NBS experimental value agrees with the calculated spectrum-averaged cross section whereas the accepted measured value does not and, in fact, has been used to challenge the shape of the U-235 fission spectrum.

Miscellaneous measurement and related activities make poor material for accomplishment reporting, but unfortunately they constitute a substantial part of the NSF Group effort. A sampling of these activities in FY-82 are as follows: (1) performance test irradiation of proton-recoil emulsion detectors with thermal neutrons; (2) post-irradiation checks of Co-Al and Co-Zr dosimeter wires for validating cobalt concentrations; (3) quality control tests of navy shipboard area monitors; (4) refurbishing and check out of fission chambers for CEN/SCK (Belgium), and the University of Arkansas; (5) performance investigation of position-sensitive, proportional counter to be used for linac-resonance radiography development; and (6) initial neutron flux measurement at the new 14 MeV Van de Graaff source.

Specific reference is made here to last year's narrative of technical activities (Annual Report 1981; Div. 532). Most of the information provided there is applicable to this year's activities. Fourteen publications and reports were part of the group's activities this year; the total for FY-81 and FY-82 is twenty-six--see Publications Section.

Meetings and committee work continue to occupy a prominent place in our program. We provide a secretary for the ASTM Subcommittee on Radiation Metrology which presently is heavily engaged in the parallel development of nineteen standards for reactor pressure vessel irradiation surveillance and steel embrittlement prediction. Participation at symposia and program reviews in radiation personnel dosimetry continued and the effort to draft a new IAEA Manual on Neutron Dosimetry Calibrations moved forward. The Fourth ASTM/EURATOM Symposium on Reactor Dosimetry was held at NBS this year. We tried our best, and by individual generosity of effort, probably did cope with playing host, under legislated limitations, to an international group of government and private sector experts accustomed to European levels of conference facilities (e.g. simultaneous translation) and hospitality (e.g. a noteworthy banquet). Attendance was rich and varied with program managers from government agencies and industry organizations mixing it up with the working troops. Formal program review meetings (a total of four, one held at NBS) for the NRC-sponsored LWR-Pressure Vessel Dosimetry Irradiation Surveillance Program and the DoE-sponsored Personnel Dosimetry Upgrading Program require active participation spread out among five staff members.

Division 532, Technical Activities (cont'd)

V. Radioactivity Group

A. Standard Reference Materials and Calibration Services

Most visible of the group activities are the distribution of selected radionuclides as Standard Reference Materials (SRM's) and the calibration of submitted radionuclides for which SRM's are not suitable. Traceability exercises which can be associated with either program test the abilities of other laboratories to obtain results in satisfactory agreement with NBS values. Booklets describing both programs are kept current and distributed to potential users.

Table 1 summarizes SRM distributions, calibrations and some traceability activities for the year ending August 1, 1982. Included are the significant Atomic Industrial Forum program, which links a major fraction of U.S. radiopharmaceutical manufacturers with NBS calibrations, and traceability exercises with regulatory agency laboratories.

Table 1

Standards and Calibration Services	No. of Units	K$
Standard Reference Materials	1375	260.3
Atomic Industrial Forum, traceability tests of radiopharmaceutical manufacturers	85	(27.5)
NRC (11) and EPA (6) Traceability Programs	17	--
Reports of Test (NBS 94)	40	30.4
Scheduled Calibrations (OMS)	58	34.9

A few new SRM's should be noted. Three natural matrix radioactivity standards were calibrated and issued as SRM's - Peruvian Soil, Human Liver, and Human Lung. Many laboratories cooperated in the calibrations, which utilized a variety of low-level measurement procedures. A new mixed-radionuclide gas standard was developed and distributed for supplying efficiency calibration points at several energies for germanium gamma-ray spectrometers used in monitoring reactor off gases.

The tests included direct traceability checks on several batches of multi-gamma-ray standards similar to those developed and formerly supplied by NBS, but now available from commercial suppliers.

The result of a careful measurement of the activity of a ^{238}Pu solution for the Idaho National Engineering Laboratory was used by them in determining the gamma-ray-probability per decay for that radionuclide.

B. Basic Activity and Nuclear Data Measurements

Most of the basic calibrations for gamma-ray-emitting radionuclides are retained on stable ionization chambers or germanium-spectrometry systems. This permits routine service calibrations or SRM production with minimum repetitious use of the more complex direct calibration techniques. These techniques can be used instead to produce calibrations for new radionuclides of growing significance. Spectrometry systems which are used to check the purity and accuracy of all x- and gamma-ray-emitting radionuclides are also used to measure accurately probabilities per decay for some radiations, in order to relate emission rate and activity measurements. Half lives are measured in order to prolong the accurate application of SRM's, and new techniques for measurement are pursued in order to improve or expand our measuring abilities. Recent examples of these follow.

Half lives measured in the group for 50 radionuclides were published in 1982, together with gamma-ray probabilities per decay for 7 radionuclides.

The half life of ^{121m}Sn was found to be about 35 years, in disagreement with tabulated values of 55 years.

The 109-minute half-life radionuclide fluorine-18 was calibrated by three different techniques: calibrated $4\pi\ \gamma$ ionization chamber, Ge(Li) gamma-ray spectrometry, and $4\pi\ \beta$ liquid-scintillation counting. Results by the three techniques agreed to within 1.5 percent.

The long-lived radionuclide technetium-99 was standardized by the method of J. A. B. Gibson using standard solutions of hydrogen-3, carbon-14, and cobalt-60. Results using the three radionuclides agreed to within 0.32 percent. Combined with accurate mass measurements, this calibration led to a new half life of $(2.109 \pm 0.036) \times 10^5$ years.

The very long extending dead times possible in an anticoincidence 4π e-γ system constructed in the group were applied to a preliminary direct measurement of the contribution of an 18-ms state in the activity calibration of selenium-75.

A collaboration with members of the neutron field standards group led to improved values for spectrum-averaged cross sections for $^{54}Fe(n,p)$, $^{58}Ni(n,p)$, and $^{115}In(n,n')$.

Preparations are being made for cooperative studies with D. E. Murnick of Bell to check the half life of 2 x 10^5-y krypton-81m by combining activity measurements with atom counting.

C. Other Agency Programs

In addition to the traceability programs mentioned above, several other calibration techniques or special sources have been developed for other agencies. Examples of these in the past year follow.

Calibrated ^{3}H, ^{90}Sr, ^{137}Cs, ^{235}U, ^{238}Pu, ^{241}Am, and natural uranium solutions were furnished to Pacific Northwest Laboratories (PNL) and Humanoid Systems as part of the NBS contribution to a joint NRC/DoE-sponsored program aimed at testing the quality of bioassays of occupationally exposed individuals. PNL has a formal program to evaluate technically a draft ANSI standard N13.30, which describes criteria for the performance of radiobioassay laboratories.

A radon-in-water standard is under development as a portion of an EPA contract. At present, a source which exhales radon at a constant rate under water has been shown to be stable for at least 4 months. Work is progressing toward delivering the radon-containing water to whatever receptacle is desired by prospective users of the standard.

The response of several survey instruments immersed in a ^{133}Xe atmosphere of known activity concentration was measured for NRC.

Group members cooperated with the Analytical Chemistry Division in the design of an instrument to assay radioisotopes of xenon for the Air Force Technical Applications Center. A device, based on the conclusions of the study document, is being constructed for test. Low-level hydrogen-3 in water samples were also prepared for the Air Force to use in their internal quality control program.

D. International Activities

Just as accurate U.S. radioactivity measurements are anchored on NBS standards, our results must be checked on an international basis. Techniques and calibrations are exchanged and compared with the corresponding laboratories in other nations, and with international organizations. These sometime involve working visits or formal intercomparisons. Some of our international activities in the past year are given below.

A compilation of data from recent measurements made in ICRM member laboratories was published as NBS Special Publication 626 in January 1982. The data are useful for the calibration of germanium-spectrometry-system efficiencies.

Cesium-137 was measured as part of a BIPM-sponsored intercomparison by the method of 4π β-γ coincidence efficiency tracing using cesium-134 for the tracer radionuclide.

Carbon-14, hydrogen-3, and technetium-99 were sent to Poland (IBJ), but conditions are not favorable for a continuation of these intercomparisons.

Carbon-14 intercomparisons are underway with the USSR (VNIIFTRI) and United Kingdom (NPL). The NBS calibration for hydrogen-3 was compared with that of the CBNM (Central Bureau Nuclear Measurements), Geel, Belgium.

The Low-level and Alpha-spectrometry Groups of the ICRM are jointly organizing a seminar at Harwell, U.K. to discuss the present state of metrology and quality control in the respective fields and organize possible new future work.

Advice was given to new standardizing laboratories being established in Korea and Taiwan.

Sunaryo, a Guest Worker from the laboratory responsible for radioactivity standardization and monitoring in Indonesia, was supported by the IAEA for a 6-month period at NBS. During this time, he studied our techniques, assisted in the preparation of Standard Reference Materials, and made activity measurements on selenium-75.

Dr. Augustin Grau Malonda from the Junta de Energia Nuclear in Madrid, Spain visited NBS as a Guest Worker and collaborated on measurements of fluorine-18. Plans were also drawn up for a long-term collaboration in radioactivity calibration techniques involving liquid-scintillation counting.

B. M. Coursey visited the National Office of Measures in Budapest, Hungary as part of the continuing scientific exchange program with Hungary.

SPONSORED CONFERENCES

Division 532, Nuclear Radiation

International Program Review Meeting on Reactor Pressure Vessel Irradiation Surveillance, NBS, Gaithersburg, Maryland, E. D. McGarry, October 27-31, 1981.

Ninth Annual Water Reactor Safety Information Meeting, NBS, Gaithersburg, Maryland, sponsored by Nuclear Regulatory Commission, J. A. Grundl, liaison, October 1981.

Fourth ASTM-Euratom Symposium on Reactor Dosimetry, NBS, Gaithersburg, Maryland, J. A. Grundl, C. M. Eisenhauer, E. D. McGarry, March 22-26, 1982.

Workshop on Electromagnetic Nuclear Reactions Below 1 GeV, Lewes Center for Physics, Delaware, J. S. O'Connell, coordinator, June 13-19, 1982.

INVITED TALKS

Division 532, Nuclear Radiation

Calhoun, J. M., "Radiopharmacy," College of Pharmacy, Howard University, April 22, 1982.

Caswell, R. S., "Neutron Interactions with Biological Tissue," Department of Energy 15th Annual Radiological Physics Contractors Meeting on The Biological Effects of Ionizing Radiation: Radiological Physics, Gettysburg, Pennsylvania, May 4-6, 1982.

Coursey, B. M., "Liquid Scintillation Counting Techniques in Radioimmunoassay," Department of Radiopharmaceutical Chemistry, George Washington University, Washington, D.C., October 14, 1981.

Coursey, B. M., "Radioactivity Calibrations and Standard Reference Materials at the National Bureau of Standards," Országos Mérésügyi Hivatal, Budapest, Hungary, April 30, 1982.

Eisenhauer, C. M., "Gamma-Ray Component of ^{252}Cf Spontaneous Fission Neutron Source," Ninth DoE Workshop on Personnel Neutron Dosimetry, June 24-25, 1982.

Grundl, J. A., "NRC-EPRI Studies of Pressure-Vessel-Cavity Neutron Fields," Ninth Annual Water Reactor Safety Information Meeting, NBS, October 1981.

Hayward, E. V., "Elastic Photon Scattering by ^{12}C and ^{16}O," Lehigh University, Bethlehem, Pennsylvania, December 3, 1981.

Hayward, E. V., "Photon Scattering by ^{12}C," Department of Physics, Université de Montréal, P. Q., Canada, May 31, 1982.

Lightbody, J. W., Jr., "Tests of the Coulomb Sum Rule in Electron Scattering," Department of Physics, Triangle Universities, Nuclear Laboratory, Duke University, Durham, North Carolina, January 21, 1982.

Mann, W. B., "Availability and Use of NBS Radioactivity Standards," University of Alaska, Anchorage, Alaska, November 25, 1981.

Mann, W. B., "An International Reference Material for Radiocarbon Dating," Eleventh International Radiocarbon Conference, Seattle, Washington, June 20-26, 1982.

Maruyama, X. K., "Stretched Configuration States in Medium Weight Nuclei," Department of Physics and Chemistry, Naval Postgraduate School, Monterey, California, January 8, 1982.

Division 532, Invited Talks (cont'd)

McGarry, E. D., "NBS ISNF and Cavity Fission U^{235} Standard Neutron Fields," 4th ASTM-EURATOM Symposium on Reactor Dosimetry, March 1982.

Meshkov, S., "Glueballs and Oddballs," Theoretical Physics Seminar, Univ. of California-Irvine, Irvine, California, December 3, 1981.

Meshkov, S., "Glueballs and Oddballs," Theoretical Physics Seminar, California Institute of Technology, Pasadena, California, April 1, 1982.

Meshkov, S., "Glueballs and Oddballs," Theoretical Physics Seminar, UCLA, Los Angeles, California, April 14, 1982.

Meshkov, S., "Glueballs and Oddballs," Part II, Theoretical Physics Seminar, California Institute of Technology, Pasadena, California, April 16, 1982.

Meshkov, S., "Glueballs, a New Form of Matter," Colloquium, University of California-Irvine, Irvine, California, May 7, 1982.

Meshkov, S., "Glueballs and Oddballs," Elementary Particle Seminar, University of Wisconsin, Madison, Wisconsin, May 10, 1982.

Meshkov, S., "Glueballs and Oddballs," Elementary Particle Seminar, University of Minnesota, Minneapolis, Minnesota, May 11, 1982.

Meshkov, S., "Glueballs and Oddballs," Elementary Particle Seminar, Fermilab, Batavia, Illinois, May 14, 1982.

Meshkov, S., "Glueballs and Oddballs," Sixth Workshop on Current Problems in High Energy Particle Theory, Florence, Italy, June 3, 1982.

Meshkov, S., "Glueballs and Oddballs," Colloquium, Johns Hopkins University, Baltimore, Maryland, September 23, 1982.

O'Connell, J. S., "Unsolved Puzzles in Electronuclear Interactions," Dept. of Physics, Pennsylvania State University, University Park, Pennsylvania, October 21, 1981.

Schrack, R. A., "Resonance Neutron Radiography," Argonne National Laboratory, Argonne, Illinois, May 20-21, 1982.

Schroder, I. G., "Neutron Irradiation Facility for Radiographic Study of Art Works," Ninth International Congress of the International Institute for Conservation of Historic Art Works, Washington, DC, September 1982.

Schwartz, R. B., "Procedures for Calibrating Neutron Personnel Dosimeters," Twenty-seventh Annual Meeting of the Health Physics Society, Las Vegas, Nevada, June 1982.

PUBLICATIONS

Division 532, Nuclear Radiation

Ayres, Robert L., Radioactivity Standardization of ^{99m}Tc and ^{99}Mo, Proceedings of the 27th Annual Meeting of the American Nuclear Society, June 9, 1981, Miami Beach, Florida (in press).

Behrens, J. W., Browne, J. C., and Walden, J. C., Measurement of the Neutron-Induced Fission Cross Section of Neptunium-237 Relative to Uranium-235 from 20 keV to 30 MeV, Nucl. Sci. Eng. 80, 393 (1982).

Behrens, J. W., Browne, J. C., and Ables, E., Measurement of the Neutron-Induced Fission Cross Section of Thorium-232 Relative to Uranium-235 from 0.7 to 30 MeV, Nucl. Sci. Eng. 81, 512 (1982).

Behrens, J. W., Fast Fission Cross Sections of Pu-233, U-237, Np-239, Pu-243, and Am-242, Bull. Am. Phys. Soc. 27, 459 (1982).

Behrens, J. W., Inferred Fission Cross Sections for Short-Lived Actinides in the MeV Range, Conf. The Neutron and Its Applications, September 13-17, 1982, Cambridge, England (to be published in proceedings).

Behrens, J. W., Inferred $^{238}Pu(n,f)$ Cross Section in the MeV Range, ANS Annual Meeting, November 1982, Washington, DC.

Behrens, J. W., Fast Fission Ratio of Th-232 Relative to U-235, Section B, Part XIII; Fast Fission Ratio of U-233 Relative to U-235, Section B, Part XIV; Fast Fission Ratio of U-238 Relative to U-235, Section B, Part XVI; Fast Fission Ratio of Pu-239 Relative to U-235, Section B, Part XVII, Fast Fission Ratio of Pu-241 Relative to U-235, Section B, Part XVIII, Brookhaven National Laboratory Report BNL-NCS-51123 (1982).

Bowman, C. D. and Johnson, R. G., Measurements of Inelastic Neutron Scattering in the eV Range, Seminar/Workshop "Thermal Reactor Benchmark Calculations, Techniques, Results, and Applications," May 17-18, 1982, Brookhaven National Laboratory (to be published in proceedings).

Bowman, C. D., Schrack, R. A., Behrens, J. W., and Johnson, R. G., Neutron Resonance Transmission Analysis of Reactor Spent Fuel Assemblies, World Conference on Neutron Radiography, Dec. 7-10, 1981, San Diego, CA (to be published in proceedings).

Bowman, C. D. and Johnson, R. G., Neutron-Induced Atomic Excitation and Neutron Moderation, Nuclear Data for Science and Technology--Int. Conf., September 6-10, 1982, Antwerp, Belgium (to be published in proceedings).

Division 532, Publications (cont'd)

Brandon, W. E., Cogburn, C. O., Culp, R. R., Sallee, W. W., and Williams, J. G. (University of Arkansas); Eisenhauer, C. M., Grundl, J. A., McGarry, E. D., and Schwartz, R. B. (NBS), Intercomparison of the D_2O-Moderated ^{252}CF Sources at the NBS and at the SEFOR Calibration Center, Proc. 4th ASTM-EURATOM Symposium on Reactor Dosimetry, Vol. II, 649 (1982).

Broadhurst, M. G., Bur, A. J., and Schwartz, R. B., The Effect of Neutron Irradiation on Electric Conductivity in Cellulose Acetate, Rad. Prot. Dos. 3, No. 1 (1982).

Burt, P. E., Fagg, L. W., Crannell, H., Sober, D. I., Stapor, W., O'Brien, J. T., Maruyama, X. K., Lightbody, J. W., and Lindgren, R. A., Electron Scattering Study of the 10.32 MeV Transition in ^{40}Ca, Phys. Rev. C 25, No. 5 (May 1982).

Carlson, A. D. and Behrens, J. W., Absolute Measurement of the $^{235}U(n,f)$ Cross Section from 0.3 to 3 MeV Using the NBS Electron Linac, Proc. Conf. Nuclear Data for Science and Technology, Sept. 6-10, 1982, Antwerp, Belgium (to be published in proceedings).

Carlson, A. D., Standard Cross Section Data, Progress in Nuclear Energy (in press).

Carlson, A. D., Editor, ENDF/B-V Cross Section Measurement Standards, BNL Report (in press).

Carlson, C. E., Coyne, J. J., Fishbane, P. M., Gross, F., and Meshkov, S., Hadronic Decays of Low-Lying Glueballs, Nucl Phys. (in press).

Caswell, R. S., Coyne, J. J., and Goodman, L. J., Comparison of Experimental and Theoretical Ionization Yield Spectra for Neutrons, 4th Symp. on Neutron Dosimetry, GSF, Munich-Neuherberg, Germany, June 1-5, 1981; Commission of the European Communities Report EUR 7448 1, 201-212 (1981).

Caswell, R. S., Radiation Protection and the International Commission on Radiation Units and Measurements (ICRU), Rad. Prot. Dos. 1, No. 4, 241 (1982).

Caswell, R. S., and Coyne, J. J., Kerma Values, Neutron, Encyclopaedia of Physics and Its Applications, Pergamon Press (in press).

Caswell, R. S., Coyne, J. J., and Randolph, M. L., Kerma Factors of Elements and Compounds for Neutron Energies Below 30 MeV, Int. J. Appl. Rad. Isotopes (in press).

Colle, R., Rubin, R. J., Knab, L. I., and Hutchinson, J. M. R., Radon Transport Through and Exhalation from Building Materials: A Review and Assessment, NBS Technical Note 1139 (September 1981).

Coursey, B. M., Hoppes, D. D., and Schima, F. J., Determination of the Photon Emission Rates of the NBS Long-Lived Mixed-Radionuclide Standard, Nuclear Instruments and Methods-Special Issue for the Fifth Symposium on X- and Gamma-ray Sources and Applications, Ann Arbor, Mich. 193, 1-8 (1982).

Coursey, B. M., Calhoun, J. M., Inn, K. G. W., and Lucas, L. L., Liquid-Scintillation-Counting Techniques for Inorganic Radiochemicals, Trans. Am. Nucl. Soc. 39, 25 (1981).

Coyne, J. J., McDonald, J. C., Menzel, H.-G., and Schuhmacher, H., Detailed Intercomparison of Calculated and Measured Ionization Yield Spectra for 20 MeV Neutrons and the Implication for High Energy Dosimetry, Proceedings of the 4th Symposium on Neutron Dosimetry, June 1-5, 1981, GSF, Munich-Neuherberg, Germany; Commission of the European Communities Report EUR 7448 1, 213-223 (1981).

Danos, M., The Bohm-Aharonov Effect: The Quantum Mechanics of the Electrical Transformer, Am. J. Phys. 50, 64-66 (1982).

Dias, M. S. and Renner, C., Si(Li) Efficience Curve for X-Ray Parallel Beam, Nucl. Instr. and Meth. 193, 91 (1982).

Dias, M. S., Johnson, R. G., and Wasson, O. A., An Absolute Neutron Flux Detector for the 1-20 MeV Energy Range, Nuclear Data for Science and Technology Conference, September 6-10, 1982, Antwerp, Belgium (to be published in proceedings).

Dias, M. S., Johnson, R. G., and Wasson, O. A., Absolute Neutron Flux Detector of 1-15 MeV Neutrons for a Measurement of ^{235}U Fission Cross Section, 1982 Fall Meeting of the APS, October 14-16, 1982, Amherst, MA, (to be published in Bull. Am. Phys. Soc.).

Dodge, W. R., Leicht, R. G., Hayward, E., and Wolynec, E., Electrodisintegration of ^{56}Fe, ^{59}Co, and ^{64}Zn, Phys. Rev. C24, 1952 (1981).

Dodge, W. R., Hayward, E., and Wolynec, E., An Experimental Test of Virtual Photon Theory, Phys. Rev. C (in press).

Eisenhauer, C. and Schwartz, R., Difficulties in Calculating Spectrum-Averaged Values of Neutron Dose Equivalent, Health Phys. 41, No. 5, 774-777 (November 1981).

Eisenhauer, C., Schwartz, R., and Johnson, T., Measurement of Neutrons Reflected from the Surfaces of a Calibration Room, Health Phys. 42, 489-495 (April 1982).

Division 532, Publications (cont'd)

Fishbane, P. M., Horn, D., Karl, G., and Meshkov, S., Flavor Symmetry and Glueballs, Phys. Rev. (in press).

Fuller, E. G. and Gerstenberg, H., Photonuclear Data Index, 1973 through 1981, NBSIR 82-2543 (1982).

Gilliam, D. M., Fuller, J. L., Grundl, J. A., and Daughtry, J. W., Absolute Fission Rates in the FFTF, Trans. Am. Nucl. Soc. 39, 901 (November 1981).

Goodman, L. J., Coyne, J. J., and Caswell, R. S., The NBS Program in Dosimetry Standards for Neutron Radiation Therapy, Proc. IAEA Advisory Group on Advances in Dosimetry for Fast Neutrons and Heavy Charged Particles for Therapy Applications, June 14-18, 1982, Vienna, Austria (in press).

Grundl, J. A., Eisenhauer, C. M., and McGarry, E. D., Neutron Flux Measurements in the Pressure Vessel Cavity of an Operating U.S. Power Reactor, LWR Pressure Vessel Irradiation Surveillance Dosimetry Progress Report, HEDL-TME 8218, NUREG/CR-2805 1 (January 1982).

Grundl, J. Eisenhauer, C., Lamaze, G., McGarry, E. D., Cogburn, C., Tsoulfanidis, N., Kellogg, L., and McElroy, W., NRC-EPRI Studies of Pressure-Vessel-Cavity Neutron Fields, NRC Ninth Water Reactor Safety Information Meeting (Oct. 1981) (to be published in proceedings).

Hoppes, D. D. and Schima, F. J., eds., Nuclear Data for the Efficiency Calibration of Germanium Spectrometer Systems, NBS Special Publication 626 (1982).

Hoppes, D. D., Hutchinson, J. M. R., Schima, F. J., and Unterweger, M. P., Nuclear Data for X- or Gamma-Ray Spectrometer Efficiency Calibrations, NBS Special Publication 626 (1982).

Hutchinson, J. M. R. and Mullen, P. A., Calibration of K-x-Ray Emission Rates in the Decay of Vanadium-49 (in press).

Hutchinson, J. M. R. and Mullen, P. A., "Pin-Well"-NaI(Tl) Counting of 59.5-keV Gamma Rays in the Decay of Americium-241 (in press).

Hutchinson, J. M. R., Noyce, J. R., and Kolb, W., Radiochemical Isolation of Radium-228 and its Calibration by Liquid-Scintillation Counting and Gamma-Ray Spectrometry, Int. J. Anal. Radiochem. (in press).

Johnson, R. G. and Bowman, C. D., Inelastic-Scattering Measurements of 1.5-15 ev Neutrons, Phys. Rev. Lett. 49, No. 11, 797-800 (September 13, 1982).

Johnson, R. G., Behrens, J. W., and Bowman, C. D., Source Imaging Using Neutron Pinhole Cameras Based on Position-Sensitive Proportional Counters, Nucl. Technol. 55, 724 (December 1981).

Lamaze, G. P., McGarry, E. D., and Schima, F. J., Integral Reaction Rate Measurements in ^{252}Cf and ^{235}U Fission Spectra, International Conference on Nuclear Data for Science and Technology, September 6-10, 1982, Antwerp, Belgium (to be published in proceedings).

Lightbody, J. W., Jr., Spectrometer Requirements for (e,e'2N) Studies, Proceedings of the Workshop on High-Resolution, Large-Acceptance Spectrometers, Sept. 8-11, 1981, Argonne, IL; ANL/PHY-81-2, Section IV, J-1-10 (1982).

Lightbody, J. W., Jr., Stapor, W. J., Crannell, H., Maruyama, X. K., and O'Brien, J. T., A Flowing Gas Target System for Precision Electron Scattering Measurements, Nucl. Instr. Meth. (in press).

Lightbody, J. W., Jr., Bellicard, J. B., Cavdeon, J. M., Frois, B., Huet, M., Leconte, Ph., Nakada, A., Xuan Ho, Phan, Platchkow, S. K., Turck, S., de Jager, C. W., Lapikás, J. J., and de Witt Hubert, P. K. A., Elastic and Inelastic Electron Scattering from $^{50,52,54}Cr$, Phys. Rev. C. (in press).

Lindgren, R. A., Plum, M. A., Gerace, W. J., Hicks, R. S., Parker, B., Peterson, G. A., Singhal, R., Williamson, C. F., Maruyama, X. K., and Petrovich, F., Isospin Splitting of Isovector High Spin "Stretched" Particle-Hole Excitations in Non-Selfconjugate Nuclei, Phys. Rev. Lett. 47, No. 18 (November 2, 1981).

Lippincott, E. P., Schmittroth, F. A., Oberg, D. L., McElroy, W. N., Gold, R., Fabry, A., Minsart, G., McGarry, E. D., Kam, F., Stallman, F., Analysis of Experimental Data and Calculations in an LWR Pressure Vessel Mockup, Trans. Am. Nucl. Soc. 39 (Dec. 1981).

Lovesey, S. W., Bowman, C. D., and Johnson, R. G., Electron Excitation in Atoms and Molecules by Neutron-Nucleus Scattering, Z. Phys. B-Condensed Matter 47, 137 (1982).

Lovesey, S. W., Bowman, C. D., and Johnson, R. G., Non-Adiabatic Transitions in Molecules by Neutron Scattering, EPS Conf. on Condensed Matter, March 22-25, 1982, Manchester, U.K. (to be published in proceedings).

Lucas, L. L. and Noyce, J. R., The Half-Life of Plutonium-240, Int. J. Appl. Radiat. Isotopes (in press).

Mann, W. B., Unterweger, M. P., and Coursey, B. M., Comments on the NBS Triated-Water Standards and Their Use, Int. J. Appl. Radiat. Isot. 33, 383-386 (1982).

Division 532, Publications (cont'd)

Mann, W. B., An International Reference Material for Radiocarbon Dating, Radiocarbon (June 1982) (abstract only).

Maximon, L. C., Ganz, E., de Miniac, A., and Aniel, T., Polarized Tagged Photons, An Analysis of the Differential Cross Section for Polarized Bremsstrahlung in the Range of Interest for a Tagged Photon System, NBSIR 82-2454 (January 1982).

Maximon, L. C., Eskandarian, A., Lehman, D. R., and Gibson, B. F., Momentum-Space Solution of the Bound Three-Body Problem with Two Charged Particles, Bull. Am. Phys. Soc. II 26, 566 (1981).

Maximon, L. C., Integral Representations for the Regular and Irregular S-wave Coulomb Wave Functions, $W_{-i\eta,\frac{1}{2}}(-2iqr)$, $M_{-i\eta,\frac{1}{2}}(-2iqr)$, $W_{\kappa,\frac{1}{2}}(2\beta r)$, $M_{\kappa,\frac{1}{2}}(2\beta r)$. George Washington University, Department of Physics, Technical Report GWU/DP/TR-82/1 (1982).

Maximon, L. C., A Method for Making Coulomb Effect Corrections to Reaction Amplitudes, George Washington University, Department of Physics, Technical Report GWU/DP/TR-82-2 (1982).

McDonald, J. C. and Goodman, L. J., Measurements of the Thermal Defect for A-150 Plastic, Phys. Med. Biol. 27, No. 2, 229-233 (1982).

McGarry, E. D., Requirements for Reference Reactor Pressure Vessel Dosimetry to Benchmark Neutron Fields, Proc. IAEA Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Reactor Safety Aspects (October 1981).

McGarry, E. D., Lamaze, G. P., Eisenhauer, C. M., Gilliam, D. M., and Schima, F. J., NBS ISNF and Cavity Fission U-235 Standard Neutron Fields, Proc. Fourth ASTM-EURATOM Symposium on Reactor Dosimetry, Washington, DC (March 1982).

Meshkov, S., Glueballs and Oddballs, The 6th Johns Hopkins Workshop on Current Problems in High Energy Particle Theory, June 2-4, 1982, Firenze, Italy, 185-209 (1982).

O'Connell, J. S., Electromagnetic Nuclear Reactions: I. Introduction, Operators, and Sum Rules, NBSIR 82-2547 (September 1982).

O'Connell, J. S., Measuring Nucleon Charge and Magnetization Inside the Nucleus, Comments on Nuclear and Particle Physics XI, No. 1, 1-7 (1982).

Division 532, Publications (cont'd)

O'Connell, J. S., Photonuclear Reactions Above the Pion Threshold, Proceedings of International School of Intermediate Energy Nuclear Physics, July 16-26, 1982, Verona, Italy, 189-215 (1982).

Schrack, R. A., Behrens, J. W., Carlson, A. D., Bowman, C. D., and Johnson, R. G., Quantitative NDE in the Nuclear Industry, Recent Developments in Resonance Neutron Radiography Fifth Int. Conf., May 10-13, 1982, San Diego, CA (to be published in proceedings).

Schrack, R. A., Behrens, J. W., Johnson, R. G., and Bowman, C. D., Resonance Neutron Radiography, World Conf. on Neutron Radiography, Dec. 7-10, 1981, San Diego, CA (to be published in proceedings).

Schwartz, R. B., Endres, G. W. R., and Cummings, F. W., Neutron Dosimeter Performance and Associated Calibrations at Nuclear Power Plants, NUREG/CR-2233 (July 1982).

Schwartz, R. B. and Eisenhauer, C. M., Procedures for Calibrating Neutron Personnel Dosimeters, NBS Special Pub. 633 (May 1982).

Siebert, B. R. L., Coyne, J. J., and Caswell, R. S., Calculation of Quality Factors for Fast Neutrons in Materials Composed of H, C, N and O, Eighth Symposium on Microdosimetry, September 27-October 1, 1982, Jülich, Federal Republic of Germany (to be published in proceedings).

Wasson, O. A. and Meier, M. M., Measurement of the ^{235}U Mass in a Large Volume Multiplated Fission Ionization Chamber, Nucl. Instr. Methods 190, 571 (1981).

Wasson, O. A., Carlson, A. D., and Duvall, K. C., Measurement of the ^{235}U Neutron Induced Fission Cross Section at 14.1 MeV, Nucl. Sci. Eng. 80, 282, (1982).

Wasson, O. A., Meier, M. M., and Duvall, K. C., Absolute Measurement of the ^{235}U Fission Cross Section from 0.2 to 1.2 MeV, Nucl. Sci. Eng. 81, 196 (1982).

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 532, Nuclear Radiation

Robert L. Ayres

Member, International Committee for Radionuclide Metrology (ICRM) Life Sciences Working Group.

Member, Board of Directors, Technical Group for Biology and Medicine, American Nuclear Society.

Consultant, U.S. Pharmacopeia, Advisory Panel on Radiopharmaceuticals.

James W. Behrens

Member, DoE Cross Section Evaluation Working Group (CSEWG), Data Status and Requests Committee.

Member, Isotopes and Radiation Division, American Nuclear Society, Transuranium Task Force.

Charles D. Bowman (resigned May 1982)

Member, DoE Nuclear Data Committee.

Technical Advisor, DoE Cross Section Evaluation Working Group (CSEWG) Standards Committee.

Allan D. Carlson

Chairman, DoE Cross Section Evaluation Working Group (CSEWG), Standards Committee.

Member, DoE CSEWG, Data Status and Requests Subcommittee.

Member, DoE CSEWG, Evaluations Committee.

Randall S. Caswell

Delegate, Comité Consultatif pour les Etalons de Mesure des Rayonnements Ionisants (CCEMRI), Conférence Générale des Poids et Mesures, Paris, France.

Chairman, Section on Neutron Measurements (Section III), CCEMRI, Conférence Générale des Poids et Mesures, Paris, France.

Division 532, Technical and Professional Committee Participation and Leadership (cont'd)

Randall S. Caswell (cont'd)

Member, National Council on Radiation Protection and Measurements (NCRP).

Member, NCRP Board of Directors (until April 1982).

Chairman, NCRP Ad Hoc Committee on SI Units.

Chairman, NCRP Ad Hoc Committee on Publications.

Member and Secretary, International Commission on Radiation Units and Measurements (ICRU).

Sponsor, ICRU Report Committee on Stopping Power.

Sponsor, ICRU Report Committee on Dosimetry at High Doses.

Member, Radiation Research Accelerator Facility (RARAF) Scientific Advisory Committee, Columbia University.

Bert M. Coursey

Member, International Committee for Radionuclide Metrology (ICRM) Life Sciences Working Group.

Member, ANSI Subcommittee N42.2 on Procedural Standards for Calibration of Detectors for Radioactive Materials.

Delegate, Bureau International des Poids et Mesures (BIPM), Consultative Committee for Standards of Ionizing Radiations Task Group on the Feasibility of Liquid Scintillation Counting for the Standardization of Radionuclides which Decay by Emitting Low-Energy Radiations.

Member, Executive Committee, Biology and Medicine Technical Group, American Nuclear Society.

J. Joseph Coyne

Chairman, National Nuclear Data Center (NNDC), Panel on Reference Nuclear Data.

Member, International Commission on Radiation Units and Measurements (ICRU) Committee on Microdosimetry.

Division 532, Technical and Professional Committee Participation and Leadership (cont'd)

Michael Danos

Member, Program Review Committee for the Saclay Electron Linac, Saclay, France.

Charles M. Eisenhauer

Member, National Council on Radiation Protection and Measurements (NCRP) Task Group on Atomic Bomb Survivor Dosimetry; SC-40 Biological Aspects of Radiation Protection Criteria.

Member, Subcommittee on Radiation Research Strategy Implementation, Interagency Radiation Research Committee.

Member, ASTM Subcommittee E10.05 on Nuclear Radiation Metrology.

Member, NAS-NRC Advisory Committee on the Radiation Effects Research Foundation; also subcommittee: Panel on the Reassessment of A-Bomb Dosimetry.

Everett G. Fuller

Member, National Council on Radiation Protection and Measurements (NCRP), Scientific Committee 60, Neutrons from Medical Accelerators.

Leon J. Goodman

Consultant, American Association of Physicists in Medicine, Task Group 18: Fast Neutron Beam Dosimetry Physics.

Member, International Commission on Radiation Units and Measurements, Committee on Clinical Dosimetry for Neutrons.

James A. Grundl

Member, Organizing Committee for Fifth ASTM-EURATOM Symposium on Reactor Dosimetry, NBS, March 1985.

Co-chairman, Steering Committee for Developing ASTM Standards for Reactor Pressure Vessel Irradiation Surveillance.

Member, ASTM Subcommittee E10.05 on Nuclear Radiation Metrology.

Evans V. Hayward

Member, Maryland Governor's Science Advisory Council.

Division 532, Technical and Professional Committee Participation and Leadership (cont'd)

Evans V. Hayward (cont'd)

Member, Argonne Universities Association Special Committee for the Medium Energy Electron Accelerator Facility.

Member, Board of Directors of the Southeastern Universities Research Association.

Member, The Nominating Committee of The American Physical Society.

Dale D. Hoppes

Member, International Committee for Radionuclide Metrology (ICRM) Work Group on Alpha-, Beta-, and Gamma-Ray Spectrometry Group.

Member, Atomic Industrial Forum (AIF)-NBS Standards Program Committee, Standards Steering Committee.

Member, International Committee of Weights and Measures (BIPM), Consultative Committee on Standards for Measuring Ionizing Radiations, Subcommittee Section II: Radionuclide Measurements.

Member, Calibration Advisory Group, NBS.

J. M. Robin Hutchinson

Chairman, International Committee for Radionuclide Metrology (ICRM) Subcommittee on Low-Level Techniques.

Member, American National Standards Institute (ANSI) Committee on Nuclear Instruments and Detectors.

Secretary, ANSI Subcommittee N42.2 on Procedural Standards for Calibration of Detectors for Radioactivity Measurements.

Kenneth G. W. Inn

Member, American Society for Testing and Materials (ASTM) Committee C26.05 Environmental Methods Task Group on Nuclear Fuel Cycle.

Member, Methods of Radiochemical Analysis in Water and Water Deposits, Committee D19.04.

George Lamaze

Secretary, American Society for Testing and Materials (ASTM), Subcommittee E10.05, Nuclear Radiation Metrology.

Division 532, Technical and Professional Committee Participation and Leadership (cont'd)

J. W. Lightbody, Jr.

Chairman, 1982 Gordon Research Conference on Photonuclear Reactions.

Member, Scientific Advisory Committee to Southeastern Universities Research Association, Program Advisory Committee for the MIT Bates accelerator.

Wilfrid B. Mann

Member, Executive Board, International Committee for Radionuclide Metrology.

Consultant, International Commission on Radiation Units and Measurements (ICRU).

Member, DoE Half-Life Evaluation Committee for Pu Isotopes Physical Constants.

Member, American National Standards Institute (ANSI) Institute of Nuclear Materials Management (INMM) Committee on Methods of Nuclear Material Control.

Member, ANSI-INMM Subcommittee N15.8 on Calibration Techniques for Nuclear Material Control.

Member, ANSI-INMM Work Group INMM 8.04 on Calibration Techniques for Calorimetric Assay of Plutonium-Bearing Solids.

Chairman, National Council on Radiation Protection and Measurements (NCRP) Committee 18A on Standards and Measurement of Radioactivity for Radiological Use.

Emmert D. McGarry

Member, Organizing Committee for the Fifth ASTM-EURATOM Symposium on Reactor Dosimetry, NBS, March 1985.

Member, Steering Committee for Developing ASTM Standards for Reactor Pressure Vessel Irradiation Surveillance.

Member, American Society for Testing and Materials (ASTM) Committee on Nuclear Applications and Measurement of Radiation Effects.

Member, Review Committee on Energy Deposition in Fuel Rods During Power Facility RIA Testing.

Member, ASTM Subcommittee E10.05 on Nuclear Radiation Metrology.

Division 532, Technical and Professional Committee Participation and Leadership (cont'd)

Sydney Meshkov

Member, Advisory Board, Aspen Center for Physics. Actively participated in running the center during the summer months.

Organized the Program for the Orbis Scientiae (High Energy Conference) at the Center for Theoretical Studies at the University of Miami.

Session Chairman, Orbis Scientiae (High Energy Conference) at the Center for Theoretical Studies at the University of Miami, January 1982.

Member, Advisory Board for the Lewes Center for Physics at the Univ. of Delaware at Lewes, Delaware.

J. S. O'Connell

Member, Nuclear Science Advisory Committee to NSF and DoE.

Member, Program Advisory Committee for the MIT Bates accelerator.

Francis J. Schima

Vice-Chairman, Washington Area Data General Computer Users Group.

Roald A. Schrack

Member, Organizing Committee of Fifth International Conference on Quantitative Non-destructive Essaying in the Nuclear Industry, May 10-13, 1982, San Diego, CA.

Robert B. Schwartz

Member, International Standards Organization (ISO) Technical Committee on Nuclear Energy (ISO/TC 85).

Member, ISO Subcommittee 2 on Radiation Protection.

Member, ISO Work Group 3 on Neutron Reference Radiations.

Michael P. Unterweger

Member, American Society for Testing and Materials (ASTM) Committee D-22 on Methods for Sampling and Analysis of Atmospheres.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 532, Nuclear Radiation

1. J. W. Behrens consulted with Industrial Quality, Inc. on nuclear detection systems for neutron radiography and gauging.

2. A. D. Carlson organized the national effort for the Department of Energy to prepare the neutron cross section standards for the ENDF/B-VI evaluation.

3. B. M. Coursey and A. T. Hirshfeld provided assistance to the Nuclear Medicine Division at NIH in the calibration of several detectors used for fluorine-18 measurements.

4. B. M. Coursey and J. M. Calhoun provided calibration services and reviewed methodology for iodine-123 measurements at George Washington University.

5. M. Danos served as advisor and scientific consultant to the Chief of Nuclear Physics, Saclay, France.

6. Charles M. Eisenhauer and L. V. Spencer prepared a report for the Federal Emergency Management Agency (FEMA) which provides guidelines for research on the protection provided by various types of structures against initial radiations from nuclear weapons.

7. D. M. Gilliam advised Hanford Engineering Development Laboratory on fission chamber performance in high energy neutron fields.

8. J. Grundl consulted with Electric Power Research Institute (EPRI) on program directions in support of reactor pressure vessel dosimetry.

9. R. J. Johnson consulted with the Lawrence Livermore National Laboratory on neutron capture cross section measurements.

10. G. Lamaze led effort to revise ASTM Standard on definition for neutron dosimetry.

11. L. Maximon is consultant to two groups in the Department of Nuclear Physics at CEN, Saclay: The High Energy Nuclear Physics Group which does electron nuclear scattering and the Metrology and Fundamental Neutron Physics Group which does photo-nuclear physics.

12. E. D. McGarry provided planning and calibrations for in-situ neutron source strength measurement at SEFOR facility in Arkansas.

Division 532, Major Consulting and Advisory Services (cont'd)

13. E. D. McGarry served on management group for dosimetry characterization program at NRC/ORNL pressure-vessel mock-up facility.

14. E. D. McGarry and J. A. Grundl consulted with and acted as referee for EPRI on achieving optimal dosimetry results for pressure vessel cavity measurements.

15. S. Meshkov served as visiting professor at the California Institute of Technology, Pasadena, California and at the University of California, Irvine, California.

16. I. G. Schroder provided basic design study for Neutron Radiography Facility sponsored by the National Gallery of Art.

JOURNAL EDITORSHIPS

Division 532, Nuclear Radiation

R. S. Caswell, Member of Editorial Board, Journal of Physical and Chemical Reference Data.

B. M. Coursey, Editor, International Journal of Applied Radiation and Isotopes.

W. B. Mann, Editor, Environment International.

W. B. Mann, Editor, International Journal of Nuclear Medicine and Biology.

W. B. Mann, Editor-in-Chief for North America, International Journal of Applied Radiation and Isotopes.

TRIPS SPONSORED BY OTHERS

Division 532, Nuclear Radiation

R. S. Caswell, National Council on Radiation Protection and Measurements, Ad Hoc Committee on Potential New NCRP Publications, Chicago, Illinois, March 24, 1982.

R. S. Caswell, Annual Meeting of the International Commission on Radiation Units and Measurements, Reisensburg, Germany, September 16-25, 1982.

B. M. Coursey, College of American Pathologists, Nuclear Medicine Resources Committee Meeting, West Palm Beach, Florida, March 24, 1982.

B. M. Coursey, scientific exchange program with Országos Mérésügyi Hivatal, Budapest, Hungary, April 24-May 2, 1982.

B. M. Coursey, Editorial Board Meeting, International Journal of Applied Radiation and Isotopes, Oxford, United Kingdom, May 7, 1982.

M. Danos, Center for Nuclear Studies (CEN), Paris (Saclay) France to continue collaboration with Dr. V. Gillet and staff on relativistic nuclear physics, many-body correlations in nuclei, and heavy ion collisions, October 1-31, 1981; January 12-March 19 and May 1-June 12, 1982.

M. Danos, Duke University, collaboration with Prof. Biedenharn on nuclear physics, March 31-April 2 and September 15-20, 1982.

L. J. Goodman, International Commission on Radiation Units and Measurements Clinical Neutron Dosimetry Committee meeting, Houston, Texas, February 8-9, 1982.

E. V. Hayward, Argonne Universities Association Special Committee for the Medium Energy Electron Accelerator, Argonne, Illinois, November 9-10, 1981.

E. V. Hayward, American Physical Society Nomination Committee Meeting, Dallas, Texas, March 7-8, 1982.

E. V. Hayward, Argonne Universities Association Special Committee for the Medium Energy Electron Accelerator, Argonne, Illinois, May 19-20, 1982.

E. V. Hayward, Meeting to discuss photonuclear reactions, Université de Montréal, P. Q., Canada, May 31-June 2, 1982.

E. V. Hayward, Max-Planck Institut für Chemie, Mainz, Germany, collaborations with Prof. B. Ziegler on photon scattering experiments, September 1982.

Division 532, Trips Sponsored by Others (cont'd)

J. W. Lightbody, Jr., Duke University, to give talk, "Tests of the Coulomb Sum Rule in Electron Scattering," January 21, 1982.

J. W. Lightbody, Jr. Gordon Research Conference on Photonuclear Reactions, Colby-Sawyer College, New London, N.H., August 9-13, 1982.

W. B. Mann, Editorial Board Meeting, International Journal of Applied Radiation and Isotopes, Oxford, United Kingdom, May 7, 1982.

W. B. Mann, Executive Board Meeting, International Committee on Radionuclide Metrology, Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany, May 18-19, 1982.

X. K. Maruyama, University of Massachusetts, Amherst, Massachusetts, for a collaborative experiment, February 24-March 4, 1982.

X. K. Maruyama, Naval Postgraduate School, Dept. of Physics and Chemistry, Monterey, California to give talk, "Stretched Configuration States in Medium Weight Nuclei," January 8, 1982.

S. Meshkov, Elementary Particle Seminar, University of Wisconsin, Madison, Wisconsin, to give lecture, "Glueballs and Oddballs," May 10, 1982.

S. Meshkov, Elementary Particle Seminar, University of Minnesota, Minneapolis, Minnesota, to give lecture, "Glueballs and Oddballs," May 11, 1982.

S. Meshkov, Elementary Particle Seminar, Fermilab, Batavia, Illinois, to give lecture, "Glueballs and Oddballs," May 14, 1982.

S. Meshkov, California Institute of Technology, Pasadena, California and University of California, Irving, California, as visiting professor, September 1981-June 1982.

J. S. O'Connell, Physics Colloquium, Pennsylvania State University, University Park, Pennsylvania, to give lecture, "Unsolved Puzzles in Electronuclear Interactions," October 22, 1981.

R. A. Schrack, Argonne National Laboratory, Argonne, Illinois, to lecture on resonance neutron radiography, May 20-21, 1982.

STANDARD REFERENCE MATERIALS

Division 532, Nuclear Radiation

Standards Issued - 1 September 1981 through 31 August 1982

SRM	Radionuclide	Principal Use
4410H-G	Technetium-99m	Calibration of instruments for activity measurements of radiopharmaceuticals
4406L-E	Phosphorus-32	"
4407L-G	Iodine-125	"
4401L-H	Iodine-131	"
4412L-G	Molybdenum-99	"
4415L-F	Xenon-133	"
4416L-C	Gallium-67	"
4404L-E	Thallium-201	"
4400L-E	Chromium-51	"
4307-G	Xenon-133	Calibration of instruments for monitoring reactor off-gases
4310	Mixed-radionuclide gas	"
4275	Mixed radionuclide	Calibration of the efficiency of germanium gamma-ray or x-ray spectrometry systems as a function of energy
4276	Mixed radionuclide	"
4265-B	Iodine-125	"
4250-B	Cesium-134	"
4904-F	Americium-241	Calibration of alpha spectrometers

Division 532, Standard Reference Materials (cont'd)

SRM	Radionuclide	Principal Use
4949-B	Iodine-129	For use in monitoring long-lived radioactive waste
4350-B	Columbia River Sediment	Natural matrix materials for monitoring radioactivity in the environment
4352	Human Liver	"
4355	Peruvian Soil	"

CALIBRATION SERVICES PERFORMED

Division 532, Nuclear Radiation

Type of Service	Customer	SP 250	No. of Calib. or Tests	Income k$
Neutron Source Calib.	R. Schwartz, NBS	8.1 A	3*	NC**
Neutron Source Calib.	R. Schwartz, NBS	8.1 B	3***	NC
Neutron Source Calib.	NBS Health Physics	8.1 B	1	NC
Neutron Source Calib.	Lawrence Livermore Lab., Dr. C. Grahm	8.1 B	1	1.2
Neutron Source Calib.	Univ. of Arkansas SEFOR Fac.	Special****	2	--
Neutron Source Calib.	Los Alamos Lab. Dr. G. Eccelston	8.1 B	1	1.1
Neutron Source Calib.	Los Alamos Lab. R. W. Davis	8.1 A	1	0.7
Irradiation of dosimeters in thermal neutron density standard	Dept. of Army Lexington Cal. Lab.	8.1 H	3	0.3
Irradiation of gold foils in thermal neutron density standard	Cornell University Mr. Alder	8.1 P	4	0.3
Reactor pressure vessel irradiation surveillance dosimetry program special irradiations	Nuclear Regulatory Commission	N/A	50*****	4.0
^{252}Cf irradiation of titanium foils for measurements	CEN/SCK Mol, Belgium	N/A	2	NC

*NBS Sources SR-Cf-132, SR-Cf-136, NS-39
**NC=No Charge for Division Personnel
***NBS Sources NS-54, NS-79, NS-86
****NBS personnel (2) travel to Arkansas to on-site calibrate a source too large (>10^{10}n/s) to calibrate at NBS; this work led to FY-83 contract.
*****In excess of 300 hours of irradiations in neutron benchmark fields.

Division 532, Calibration Services Performed (cont'd)

Type of Service	Customer	SP 250	No. of Calib. or Tests	Income k$
Dosimeter Calibration	Dosimeter Corp.	8.1 H	32	.25
Dosimeter Calibration	DoE	NA	469	30
BF_3 Tube Calibration	US Army	8.1 H	4	.2
Remmeter Calibrations	Balto. Gas & Elec.	8.1 L	15	2.5
Remmeter Calibrations	Wash. Public Power Supply	8.1 L	6	1.0
Remmeter Calibrations	Philadelphia Electric	8.1 L	2	.4
Remmeter Calibrations	Rochester Gas & Electric	8.1 L	2	.4
Remmeter Calibrations	Mississippi Power & Light	8.1 L	9	1.3
Remmeter Calibrations	Carolina Power & Light	8.1 L	4	.75
Remmeter Calibrations	Duke Power	8.1 L	1	.25
Remmeter Calibrations	Omaha Public Power	8.1 L	1	.25
Remmeter Calibrations	US Army	8.1 L	14	1.8
Remmeter Calibrations	Duquesne Light	8 L	1	.25
Remmeter Calibrations	Knolls Atomic Power Lab.	8.1 L	1	.25
Dosimeter Calibrations	GPU Nuclear	8.1 L	28	1.0
Dosimeter Calibrations	Siemens Gommasonics	8.1 H	42	1.0
Dosimeter Calibrations	Siemens Gommasonics	8.1 L	20	.9
	Total		722	50.1

This summary is for the time period August 1, 1981 - August 1, 1982

Division 532, Calibration Services Performed (cont'd)

Radioactivity Calibrations for time period August 1, 1981 to August 1, 1982

	Scheduled Tests[1]		Non-scheduled Tests	
	Number of Sources	Total Fee $k	Number of Sources	Total Fee $k
Category				
Alpha-Particle Sources 8.2 H, I, J	42	23.2	1	1.5
Beta-Particle Point Sources and Gases (^{85}Kr) 8.2 P, Q, R	3	4.3	4	5.5
Gamma-ray Solutions, Point Sources, and Gases (^{133}Xe) 8.2 B, C, D	13	7.4	13	10.2
Mixed Radionuclide Sources, Solutions, Point Sources, and Gases[2]	--	--	22	8.6
Other Services	--	--	--	4.6
	58	34.9[3]	40	30.4[4]

Footnotes

(1) Four sources under one Test Folder are counted as 4 calibrations.

(2) Replicate samples are not considered as separate sources. For example, Amersham submits 2 each of 3 different source forms. This is counted as 3 samples.

(3) The average fee for a schedules test was $602 compared to $372 one year ago.

(4) The average fee for a non-scheduled test calibration was $644.

Summary

Aug. 1 - Aug. 1	Total Calibrations	Total $
'80-'81	79	40.5 k$
'81-'82	98	65.3 k$

TECHNICAL ACTIVITIES

Division 533, Radiation Physics

Introduction

The Radiation Physics Division consists of five groups,

- Radiation Theory (Non-Nuclear; M. J. Berger)
- Dosimetry (Photons, Electrons; R. Loevinger)
- X-Ray Physics (J. Motz)
- Vacuum Ultra-Violet Physics (includes the SURF II program; R. Madden)
- Electron Physics (R. Celotta)

The first three groups are largely concerned with radiation energies above about 10 keV, while the last two groups focus on lower, usually much lower energies.

The functional statement for the Division identifies the following types of activity:

- Provides the central national basis for the system of measurements of electron and photon radiation;
- develops advanced electron- and photon-based measurement standards and techniques;
- studies and measures the fundamental mechanisms by which electrons, photons, and other radiations transfer energy to gaseous and solid materials, and are transported in them;
- develops, operates, and maintains well-characterized sources of electrons and photons;
- establishes, verifies, and disseminates ultraviolet, x-ray and electron standards, calibrations and services for medical, industrial, and government users for applications in fields such as radiography, radiation protection and therapy, and fusion plasma diagnostics;
- maintains and acquires new competence, such as the development of new sources of positrons and polarized electrons for the investigation and measurement of the electronic structure of atoms, molecules, and solids.

As can be seen from the reports below, all of the groups in the Division have been active and productive.

RADIATION THEORY GROUP

Radiological Physics

Spectral Characterization of NBS X-ray Beams. In a collaborative effort involving S. M. Seltzer of the Theory Group, and M. Ehrlich and C. Soares of the Dosimetry Group, accurate determinations were made of the energy spectra from all the x-ray beams used at NBS for calibration purposes. This has involved the measurement of pulse-height distributions with intrinsic germanium detectors, the calculation of the detector response function (relation between pulse-height distribution and true energy spectrum), and the conversion (using a stripping procedure) of the measured pulse-height distributions into x-ray spectra. The output spectra include both the continuous bremsstrahlung spectrum, and characteristic x-ray lines, for various voltages and many conditions of beam filtration.

Ionization and Excitation Yields. L. V. Spencer has developed an approximate analytical solution of the Fowler equation in order to calculate the yield of excitations and ionizations in a medium irradiated with fast electrons. The first application has been made to electrons in a molecular-hydrogen medium, and results have been obtained that agree within 2 percent with the results of direct numerical calculations, for electron sources energies down to 300 eV. The extension of the method to other molecules, and to other charged particles, is discussed but has not yet been carried out.

Stopping Power Theory. The methods for computing the collision stopping power for charged particles have been reviewed and updated by M. J. Berger and S. M. Seltzer with emphasis on the region in which the Bethe stopping-power theory is applicable (above $\sim$ 10 keV for electrons, above $\sim$ 1 MeV/amu for heavy charged particles). Particular attention has been paid to the various quantities that enter into the Bethe formulas and must be evaluated with the use of empirical data. These include the mean excitation energy, the shell correction, the density-effect correction, and the z^3 and z^4 corrections (departures from first Born approximation). In regard to mean excitation energies, modified Bragg additivity rules have been derived from experimental data, with which the mean excitation energies for compounds can be estimated from the mean excitation energies of the atomic constituents, taking into account the effects of chemical binding and physical aggregation. Extensive stopping-power and range tables for electrons have been prepared for elemental substances as well as many compounds of dosimetric interest. Similar work for protons is now in progress. The electron stopping-power tables also include results for the radiative stopping power due to the emission of bremsstrahlung photons. These have been computed taking into account the new bremsstrahlung cross sections of Pratt and collaborators, and interpolated cross sections in the 2- to 50-MeV region, as described below.

Modeling of the Radioactive Decay of Iodine-125. The decay of this nuclide results in electron capture from the K, L, M, or N shell, the emission of internal conversion electrons from the K, L, M, and N shells, and the subsequent emission of a complex cascade of x-rays and Auger electrons. In order to characterize iodine-125 as a source of electrons for radiation transport calculations, the decay process has been modeled by M. J. Berger using the Monte Carlo method, taking into account the possibilities for the emission of a variable number of electrons per decay, with 11 possible electron energies between 0.3 and 35.3 keV. Due to the various branching ratios, the stochastic model allows for 700 possible outcomes whose relative probabilities have been computed. The electron source characteristics thus obtained will be used later to compute the stochastics of energy deposition in tissue-equivalent material as a function of distance from a point-isotropic Iodine-125 source. The product nucleus (Tellurium-125) is left highly charged due to the loss of electrons. The relative probabilities for charge states 1 to 17 have been calculated, and the mean number for electrons lost has been found to be 8.8.

Cross Sections

Form Factors. Tabulations have been prepared of new relativistic Hartree-Fock-Slater modified atomic form factors from $x = 0$ to $28\ \text{Å}^{-1}$ for all elements from $z = 1$ to 100. This work was done by M. Schumacher and colleagues of the University of Goettingen (West Germany) in collaboration with John Hubbell of CRR, NBS. The modification consists of the insertion of a factor $mc^2/(E - V(r))$ into the defining integral for the form factor, where E is the relativistic total energy of the bound electron $V(r)$ is the central potential, and mc^2 is the electron rest energy. The modified form factors are designed to represent the atomic Rayleigh scattering amplitudes with good accuracy at energies well above the K-shell binding energies and for small momentum transfers, and should be used in place of previously tabulated relativistic form factors.

Photon Attenuation and Energy Absorption Coefficients. Taking advantage of recent improvements in the knowledge of photon cross sections, John Hubbell has prepared improved tables of photon attenuation and energy absorption coefficients in the energy region from 1 keV to 20 MeV, for 40 elements and for 45 compounds and mixtures of interest in radiation dosimetry. The atomic photoeffect cross sections are taken from the 1973 computations of Scofield combined with more recent empirical modifications. The incoherent (bound-electron Compton) and coherent (Rayleigh) scattering cross sections, and the pair and triplet production cross sections are taken from recent results obtained at CRR in collaboration with scientists at Los Alamos, Livermore, Max Planck Institute (Mainz), and the University of Trondheim (Norway). The differences between the new attenuation and energy absorption coefficients and those in earlier tables are of the order of 1 percent or less over most of the element-energy range, but in some cases are as much as 5 percent.

Bremsstrahlung Cross Sections. As part of the updating of the widely used electron-photon transport computer program ETRAN, S. M. Seltzer and M. J. Berger have reviewed and improved the information on electron bremsstrahlung. Experimental data are scarce and reliance must be placed mainly on theoretical results. Reliable theoretical cross sections are available at electron energies below 2 MeV from recent numerical calculations of Pratt and collaborators, and above 50 MeV from the analytical high-energy approximation of Davies, Bethe, and Maximon. The systematic upward extension of the numerical calculations would be prohibitively expensive in computer time, and the downward extension of the analytical theory is not feasible. Up to now, it was necessary to use Bethe-Heitler Born-approximation theory, together with rough empirical correction factors, in the energy region from 2 to 50 MeV. It has now been found possible to obtain reliable cross sections (differential in the energy of the emitted photon) through an appropriate interpolation procedure which uses the low- and high-energy results below 2 and above 50 MeV as anchor points. The accuracy of these interpolations has been confirmed through comparison with the few cases (aluminum and uranium targets, 5 and 10 MeV electrons) for which accurate numerical calculations have been done. The groundwork has thus been laid for a planned systematic tabulation of the bremsstrahlung cross section for all elements, covering energies from 1 keV to 1 GeV.

Radiation Protection - Civil Defense

A paper by L. V. Spencer, delivered at a symposium held under the auspices of the NCRP, outlined the types of nuclear disasters and the radiation environment associated with them. The situations discussed include multi-weapon attacks on the U.S., single-weapon attacks, power reactor accidents (with or without core melt), accidents during the transport of weapons, or during the transport of spent fuel elements, and transoceanic fallout. In relation to these situations, summary information is provided regarding radioisotope hazards, radiation spectra and decays, counter measures, and dosimetry requirements.

A report by C. M. Eisenhauer and L. V. Spencer, prepared for FEMA, contains the first stage in the development of procedures for the routine evaluation of the protection provided by complex structures against initial radiations from nuclear explosions. The following radiation components were considered: early fission-product gamma rays, air-secondary gamma rays generated by neutron interactions in air, neutrons, and wall-capture gamma rays generated by neutrons through interactions with structural materials. The computer codes developed so far pertain mainly to the protection provided by elementary enclosures. However, the description of the programs also contains references to planned modifications, now in progress, to extend the applications to more complex shielding configurations.

DOSIMETRY GROUP

Use of ionizing radiation is becoming ever more widespread in modern society. The exposure of humans can be purposive (medical) or incidental (occupational), but both require close control in order to ensure that the radiation is efficacious in the one case, and harmless in the other. Such control can only be achieved with reliable measurement. With the increased use, and the improved knowledge of radiation effects, the need for more accurate and more precise measurements is constantly increasing. The measurement of ionizing radiation for the purpose of controlling a radiation effect falls in the field of radiation dosimetry. The Dosimetry Group has the responsibility for providing an up-to-date basis for reliable measurement of ionizing radiation, principally in medicine and radiation protection. This program involves establishment and maintenance of the national primary dosimetry standards, dissemination of the units established by those standards by means of calibration services and measurement quality assurance programs, other measurement assurance activities to test whether measurements by radiation users are in adequate agreement with NBS standards, research and development of measurement technology as necessary for any part of the program, and participation in the relevant national and international activities of the community of radiation users.

Calibration and Measurement Assurance Services

Calibration of x-ray and γ-ray measuring instruments has increased by about 40% compared to the previous fiscal year. Since other calibrations have remained at about the same level, the overall calibration activity of the Dosimetry Group -- counting only items listed in NBS Special Publication 250 -- has increased by only about 20%. The increase in calibration activity for photon-measuring instruments is the response to a need for increased calibration facilities expressed to the NBS Director by officials of the American Association of Physicists in Medicine. The increase was made possible by improved efficiency due to reassignment of responsibilities within the calibration project following loss of one person in the recent staff reductions, along with improved data acquisition and processing facilities. Additional memory has been added to the previously used dedicated minicomputer, and an additional data acquisition and processing system has removed the bottleneck caused by servicing five calibration ranges with a single data acquisition system.

The long-awaited 300-kV x-ray generator arrived (about 15 months behind schedule) and at the time of writing awaited installation. It will replace an obsolete 250-kV x-ray generator that has provided NBS standard x-ray beams for more than 30 years. The new generator includes circuits that allow computer control. The properties of the new standard x-ray beams must be determined accurately, so the changeover is expected to require a downtime of about two months in FY83.

Measurement quality assurance services were provided for the three Accredited Dosimetry Calibration Laboratories (ADCL's) --formerly known as Regional Calibration Laboratories (RCL's) -- of the American Association

of Physicists in Medicine. The Victoreen ADCL stopped calibration in June 1982, and its place was taken several months later by K & S Associates, of Nashville, Because of the need for additional calibration facilities, technical help was provided by NBS to K & S Associates to prepare for AAPM accreditation. A representative of K & S Associates spent a day at NBS and was given an in-depth explanation of relevant NBS measurement and calibration techniques. Following a site visit to K & S Associates, a calibrated instrument was shipped by NBS to provide a measurement quality assurance test as the last step in qualifying K & S Associates for AAPM accreditation as an ADCL.

A measurement quality assurance program for a CaF(Mn) thermoluminescence (TL) dosimetry system has been operated for the Naval Electronic Systems Command. The program involves preparation by NBS of sealed boxes of 15 TL dosimeters, 12 of which have been given known exposures to ^{137}Cs γ rays. The boxes are dispatched to designated naval units for readout, the results of which are returned to NBS for comparison with the NBS exposures. TL readers that indicate exposures that differ from the NBS exposure by more than ±10% are repaired and recalibrated. About 200 such boxes, containing 2400 exposed dosimeters, were dispatched during FY82.

Collaboration with the 3M Company has continued in development of an exposure calibration service for the radionuclide iodine-125. The sources are in the form of titanium-clad seeds that have been measured using an NBS free-air ionization chamber, the calibration data then having been transferred to a re-entrant ionization chamber for routine calibration. The desired routine calibration service has been made available for the original type of seed (containing iodine-impregnated resin microspheres and a gold x-ray marker), which were somewhat geotropic, and for a second type of seed (containing an iodine-impregnated silver rod), which was less geotropic but the spectrum of which contained some silver lines. The 3M Company has developed a third type of seed, containing only iodine-impregnated resin microspheres in the titanium cladding. This last type has been measured with the free-air chamber and an independent calibration factor has been established. Improved measurement techniques allowed exposure calibration of the latest seed type to be performed more rapidly and accurately than for the two earlier types.

The spectrometry of all current bremsstrahlung sources used for instrument calibration was completed, including the unfolding of all pulse-height distributions. Before the final tabulations can be prepared for publication, it will be necessary (a) to average the spectra from repeated runs; (b) to interpolate spectral values for photon energies of multiples of, say, 5 keV; and (c) to verify that the spectra from the new 300-kV x-ray generator are comparable to the spectra from the 250-kV generator that is being retired from service.

Calorimetry

Early in FY82, S. R. Domen visited the Hungarian standards laboratory in Budapest and the Austrian standards laboratory at Seibersdorf to assist in proper operation of a copy of the NBS graphite absorbed-dose calorimeter that was built cooperatively by those laboratories and by the International Atomic Energy Agency (IAEA). Participants at these laboratories expressed their satisfaction at the speed and ease with which the calorimeter could be brought into accurate operation. Starting at room temperature, with the calorimeter at atmospheric pressure, it was possible to make 40 runs at a dose rate of 1.6 mGy/s (about 10 rad/min) with a standard deviation of about 1% for a single run, in 6 hours. As a result of this successful performance, it was decided to construct several more graphite calorimeters, so that each of these laboratoreis would have one, and possibly also supply calorimeters for the Italian and the G.D.R. standards laboratories. The increasing interest in graphite absorbed-dose calorimeters seems to be due to techniques developed at NBS for rapid control of the troublesome temperature drifts, which otherwise prevent these instruments from being adopted as convenient laboratory instruments.

During FY82 the focus of NBS calorimetry activity was on completion of a detailed description of the absorbed dose water calorimeter, now published in the NBS Journal of Research. This work has had considerable influence on other institutions: water calorimeters are being used for absorbed-dose measurements on electron and photon beams at the M. D. Anderson Hospital, the Massachusetts General Hospital, the Yale University Medical School, the Groote Schuur Hospital in South Africa, the Calgary Cancer Center in Canada, and the Sahlgrenska Hospital in Sweden. Interest has also been expressed at other institutions.

The main new activity in calorimetry at NBS has been, and will continue to be in the near future, investigating the 3.5% difference between the absorbed dose rate to water in a cobalt-60 gamma-ray beam, as determined by a graphite calorimeter and as determined by the water calorimeter. There appears to be a negative heat defect in water, i.e., the measured dose rate is higher in water than would be calculated from the graphite calorimeter. This result, first found at NBS, has been confirmed at other institutions. To investigate this matter, apparatus has been constructed for studying the heat defect in water. Absorbed dose rate will be measured in carefully isolated distilled water saturated with ultra-pure hydrogen, under which conditions there should in theory be no heat defect. By comparing the dose rates measured with the calorimeter using hydrogen and other gases, it is hoped to elucidate the source of the 3 to 4% discrepancy between water and graphite. Tests of the apparatus with available gases indicate that it will work satisfactorily.

J. W. Fletcher of Chalk River, Canada, has reported the results of extensive theoretical investigations of the heat defect in water, an investigation that was made in response to the NBS results with the two

calorimeters. His results indicate that the heat defect can vary depending on the conditions of irradiation and the radiation history of the water, but it is of interest that he finds a 2.6% exothermic effect in water with small initial concentrations of hydrogen and oxygen.

High-Energy Measurement-Assurance Services

The chemical (Fricke) dosimetry service for testing the uniformity of high-energy electron therapy dosimetry was carried out twice during FY82, the second time in two sections because the number of dosimeters requested exceeded the number available. A total of about 30 hospitals participated in each of the two tests. Holders were designed and built for use in a high-energy electron and photon measurement-assurance service using TLD that eventually is to replace (or supplement) the present Fricke-dosimetry service. A pilot test is planned for early in FY83.

Radiation Protection Dosimetry

Most of the extensive testing program carried out for the past two years on the Panasonic TLD system has been completed. The system is now being used by the NRC for environmental dosimetry. The tests were in accord with (and went beyond) the specifications of ANSI Standard N545 (1975).

Preparations have been made for a facility for the calibration of beta-particle instrumentation and sources used in radiation-protection dosimetry. An irradiation range has been designed and built for the beta-particle sources and the extrapolation chamber that have been ordered. Once this equipment arrives (early in FY83), it is planned to compare the PTB calibration of the sources with an independent NBS calibration in terms of absorbed dose to water. Preparations have also been made to supplement the envisaged beta-particle instrument-calibration service by response functions obtained on selected beta-particle instruments with monoenergetic electrons, over the range of electron energies of interest. For this purpose, equipmnt for scanning the monoenergetic electron beams from the 500-keV linear electron accelerator and the 4-MeV electron Van de Graaff has been assembled. A surface Si detector for use in the beam characterization has been ordered.

Work has proceeded on the development of high-energy photon-instrument calibration facilities. A photon beam of approximately 7 MeV was produced in the positive ion Van de Graaff using the $^{19}F(p,\alpha\gamma)O^{16}$ reaction. (This work is a joint venture of the Radiation Physics and the Neutron Physics Divisions.) The angular distribution of the photon beam has been measured. Preliminary measurements and computations have shown that beam intensities sufficient for instrument calibration will be achievable. A large high-resolution Ge-Li detector was rented (with rights for later purchase of an intrinsic Ge detector) and is being used for spectral characterizations.

Extensive work was done first in answer to the objections, and then in answer to the appeal, by the DOE against the ANSI Standard N.13.11 (Criteria for Testing Personnel Dosimetry Performance), developed by a HPSSC working group under M. Ehrlich's chairmanship.

Work proceeded on a cooperative effort between the CRR and NVLAP, on preparations for the selection of a testing laboratory that is to administer the mandatory tests to the organizations offering personnel-dosimetry services. (This testing program is to be in accord with the disputed ANSI Standard.) Progress also was made on the formulation of criteria for the selection of a peer group that is to carry out on-site inspections of the work of these organizations -- another step that would lead to their accreditation by NVLAP.

X-RAY PHYSICS GROUP

The X-Ray Physics program has been involved with problems arising out of the utilization of x rays in technological applications including medical and industrial radiology, radiation processing of materials and food, hot plasma nuclear energy sources, and applications which are concerned with radiation protection.

Medical Radiography

In medical radiology, the X-Ray Physics Group program has been concerned with a systematic examination of the transfer of image information through the individual components of an imaging system. This program has provided an assessment of the image information transfer efficiency for each component of a medical imaging system, and present efforts are now being focused on the image recording media. Of particular interest is the transfer of information from the intensifying screen to the recording device. Since photographic film is at present the most widely used image receptor, initial efforts are aimed at examining the response and noise properties of a variety of film types to determine whether significant improvements in image information transfer can be achieved.

In cooperation with the National Institute of Dental Research and with the U.S. Army Institute of Dental Research, the X-Ray Physics Group has initiated a program to develop non-film photoelectronic imaging systems for dental applications. These systems will be able to utilize digital image processing techniques and can be expected to provide new diagnostic information for the dentist. In the development of these systems, the X-Ray Physics Group will focus on any specific standards or calibration services that may be required by the user community and that can be provided by the NBS program.

The program to develop a new dental radiographic system to provide multiple projection angle geometrics and possible tomographical reconstructions is continuing. Detailed measurements indicate that of the possible

combinations of x-ray source and detector geometries, the most viable option is provided by a miniature extraoral x-ray source and an active extraoral detector. Preliminary designs have been completed on several possible detector configurations which utilize fibre optic bundles and either multichannel plates (MCP) or charge coupled devices (CCD) as the imaging element. In addition, several miniature x-ray fluence and projection geometries are being investigated. A new image processing system is in the final stages of testing. This system will provide the capability of digital image manipulation to enhance the dental pathologies of interest. Measurements on dental phantoms with simulated artifacts indicate that digital subtraction techniques can provide dramatic improvements in the diagnosis of dental disorders.

Industrial Radiography

The X-Ray Physics program in industrial radiography seeks to provide those standards and devices which will permit better nondestructive inspections of industrial output. The program is geared to providing in a more quantitative way the characterization of an image, or of the total x-ray system or any component. As mentioned in the last report, a standard for measuring equivalent image quality sensitivity at low energies has been published and the test device described in the publication is available through NBS as an SRM. Present effort is focused on producing an equivalent standard for high energy inspections. In a related activity, effort is being directed toward producing master patterns for a visual acuity standard according to the prescription given in an NBS publication. When completed, this is expected to fulfill an important need--the qualifications of the radiographic inspection.

In another project, an attempt was made to quantify radiographic definition (unsharpness) using standards published by others. The results revealed inadequacies in these methods and the continuing need for better measurement procedures for this quantity. Our efforts to provide a better way, or induce others to consider the problem, continues.

Digital techniques in radiographic inspection promises to provide improved methods for the detection and diagnosis of hidden flaws in industrial components. The past year has seen the installation of and initial applications to this work of a sophisticated digital image processing system having the ability to process an image in real time. In connection with this, we have engaged in a cooperative effort with other laboratories having similar equipment to ascertain their ability to process an image furnished by NBS.

The program to develop quasi-monoenergetic photon beams in the 100-300 keV range for the evaluation of radiographic systems is continuing. Measurements to date indicate that by an appropriate choice of incident electron energy, x-ray target materials, and beam filters, beams with sufficient intensity for the evaluation of the image information transfer properties of typical industrial radiography systems can be generated

utilizing the NBS 1.5 MeV electron accelerator. Efforts are at present underway to determine the spectral characteristics of these beams.

Dosimetry for Industry and Defense

The high-dose calibration services have broadened considerably to include the radiation hardness testing industry and national laboratories. These services have provided calibration of ^{60}Co irradiators and electron beam accelerators used in the testing of electron devices and systems employed in the missile systems of both DoD and NASA as well as other systems used by national laboratories such as Sandia. Efforts continue on the determination of complex photon spectra in various multilayer materials irradiated by ^{60}Co and flash x-ray machines, and the effects of these spectra on dose interpretations in multilayer semiconductor devices. New dosimetry standards have been adopted within the American Society for Testing and Materials (ASTM) that should help the industrial electronics facilities to maintain and improve their proficiency in dosimetry measurements. These ASTM standards recently approved include a method for calculation of absorbed dose in materials due to neutron irradiation, measurement of electron beam fluence with a Faraday cup, and a calorimeter standard for use in flash x-ray fields.

The standard service to radiation processing users has grown considerably especially in the area of radiation sterilization of medical suppliers. Some companies have reached 20 or 25 calibrations during the five-year listing of this service and require regular calibration of dosimeters as a means of quality control of the process and safe release of medical products to the customer. There is also the likelihood of an additional dimension to this service, with the recent disclosure by the FDA that there will be a relaxing of regulation in the use of ionizing radiation in the processing of foodstuffs. Dosimetry and traceability of measurement to NBS standards will undoubtedly be the means of quality assurance in food irradiation as discussed by W.L. McLaughlin at several Workshops on Food Irradiation Processing a DOADOE meeting, University of Maryland, and the 1982 Annual Meeting of the American Nuclear Society. Some of the most active participants in the present high-dose calibration service are Ethicon, Inc., Neutron Products, Inc., Brookhaven National Labs., Radiation Dynamics, Inc., IMED Corp., Radiation Technology, Inc., Howmedica, Inc., General Electric Co., Alza Corp., Tremco, Inc., Monoject Division of Sherwood Medical, National Semiconductor, Raychem Corp., Suragikos Division of Johnson and Johnson, IBM Research Lab., Becton Dickinson Co., Energy Sciences, Inc., Lederle Laboratories, Baxter Travenol, Inc. Lawrence Livermore Labs., Sandia Corp., Radiation Sterilizers, Inc., International Nutronics, Inc., and Texas Instruments. The most recent (Dec 1981) National Seminar of the Pharmaceutical Manufacturers Association made several strong recommendations to utilize the NBS Laboratories service to maintain quality control and safety of medical products.

Two new projects are being initiated relative to the high-dose dosimetry research effort. One project supported by the Federal Emergency Management Agency began in FY81, to investigate in detail the response characteristics, kinetics, and mechanisms of some radiochromic dyes in order to select a most stable, sensitive, and reproductible chemical system which can be developed into a suitable inexpensive fiber optics dosimeter for use in civil defense and military operations. The other project will begin in FY82 sponsored by Sandia Labs (DOE) to make an experimental study of the response characteristics of several key radiochromic film types, for electron and photon radiations. These films will be calibrated against a new thin-film calorimeter presently under development.

Several areas of international cooperation have helped fertilize development of the radaition measurement technology. McLaughlin initiated a new Research Agreement with the IAEA on dosimetry for food processing, with results to be published as a part of Proceedings of a 1983 IAEA Seminar on Radiation Processing Dosimetry. NBS-CRR continues to participate in an International Atomic Energy Agency Advisory Group on High Dose Standardization. This involves dose intercomparison studies and roundrobin intercomparisons with 14 other national laboratories and industrial radiation processing labs around the world (UK, Netherlands, Denmark, Austria, India, France, Yugoslavia, Hungary, Austria, Canada, Mexico, Egypt, Argentina, West Germany). The result of the second phase of these intercomparisons was published in 1982 by IAEA in the Proceedings of the IAEA Symposium on Biomedical Dosimetry held in Paris in Oct 1981. This international standardization program with NBS will continue until at least 1984, helping bring important measurement assurance on an international scale. Part of the efforts of NBS-CRR to this end is the design and implementation of a high-dose graphite calorimeter by J.C. Humphreys, W.L. McLaughlin, and S.R. Domen. This instrument proved its worth in a 4-nation intercomparison study (U.S., U.K., West Germany, and Denmark), when Humphreys and McLaughlin took the calorimeter as a primary standard to make absorbed dose intercomparisons in 10-MeV electron beams at PTB, NPL, and Risø National Laboratory. This work will be published in an IAEA document in 1983. Another international collaboration of note was with the Institute of Physics and the Institute of Nuclear Energy of the University of Mexico. McLaughlin was invited to the Physics Institute of the University of Mexico in Dec 1981 to give two weeks of lectures on dosimetry. Dosimetry developments between NBS and Mexico include ESR techniques for analyzing irradiated polymers and dye systems. Dr. Roberto M. Uribe of NCRRT is visiting NBS as a guest worker during 1982 to further develop this method as a promising technique in practical radiation processing applications. Some of the results of dosimetry collaboration will be published in the Transactions of the 4th International Meeting on Radiation Processing to be held in Dubrovnik, Yugoslavia in Oct 1982. In another international activity, McLaughlin is invited to give several academic courses on dosimetry at an IAEA Seminar on Radiation Processing held in Denmark in September 1982. He also served on the organizing and program committees for the 4th International Meeting on Radiation Processing mentioned above.

An interesting new type of dosimeter is being studied in collaboration with the U.S. Army Electronics R&D Command, for use as an emergency dosimeter. The new system was developed in this collaboration in 1981 and is based on fibre optics and offers biologically-relevant dose interpretations at dose levels encountered in radiation accidents. A U.S. patent has been filed by McLaughlin with an associated publication in Nuclear Instruments and Methods in Dec 1981. This work is generating much interest also in the areas of environmental dosimetry, medical applications (diagnosis and therapy), and personnel monitoring, and a new commercial product called "Opti-chromic" dosimeter will soon be marketed by Far West Technology, Inc. of Goleta, California.

Pulse Radiolysis

Instrumentation

The build-up of radiation facilities for use in radiation-chemical studies of the effects of ionizing radiations relevant to biological systems as part of the Ionizing Radiation Competence Program has continued.

1. The Febetron 705 pulse radiolysis system has been fully computerized using a Tektronix 7612D programmable digitizer which was interfaced to a Tektronix CP1164X minicomputer for processing, storing, and displaying of signal waveforms. Appropriate software was developed in order to measure absorption spectra of short-lived intermediates (0.1 μs and up) and the kinetics of their formation and subsequent reactions.

2. Capability to measure absorption spectra of transients in one pulse has been developed using a Jarrell-Ask Mark X spectrograph (No. 82-484) coupled to EG&G Princeton Applied Research Optical Multichannel Analyzer, OMA, system consisting of a Model 1420 silicon photodiode array and Models 1218 and 1215 controller and processor units. This enabled whole transient spectra to be recorded anytime greater than 1 μs after a single electron pulse.

3. The conversion of the 4 MeV Van de Graaff accelerator to a pulsed mode as well as a dc mode is 95% completed. This accelerator is now capable of producing electron beam pulses with pulsed currents in excess of 1 Ampere with pulse widths from 5 ns to 15 μs. The installation of a new accelerating tube, charging belt, and column resistors have increased the voltage stability of the accelerator. At the present time, efforts are underway to install a pulsed radiolysis experimental system on one output port of the accelerator.

Chemical Studies

1. GC and HPLC methods have been successfully developed for the study of free radical processes in amino acids, peptides and proteins, through the measurement of final radiolytic products. Coupling of pulse

radiolytic studies of the intermediates and the measurements of the resulting products provides pertinent information for complete kinetic and mechanistic understanding of radiation effects in proteins, nucleoproteins and symposes. Nature of crosslinks has been defined between Ala-Ala, Met-Met and Phe-Phe.

2. Pulse radiolytic studies of oxidizing radicals such as R•,ROO•, $\cdot CCl_3$, $OOCCl_3$, $\cdot Co_3^-$ etc. have been conducted in order to understand the rules governing their interaction with antioxidants. Intermediates of various antioxidants including Vitamin E were examined in collaboration with Dr. Ingold from NRC, Canada. Understanding of these reactions is crucial in comprehensive mechanistic studies of radiation induced and chemical carcinogenesis as well as of protection from carcinogenesis (anticarcinogens). These studies should be also useful in the unraveling of the synergism between radiation and chemical agents.

3. A new theory of chemical carcinogenesis has been developed based on the reactivities, i.e. selectivities, of free radicals in question. For example, OH radicals are highly reactive but totally unselective and are poor carcinogens. On the other hand, some radicals, e.g. ROO• are much less reactive and considerably more selective and could be much more damaging respective to the "target" molecule. Further experimental work is in progress to provide comprehensive experimental support.

4. Investigation of radioprotectors has been conducted by pulse radiolysis and the measurement of intermediates. Since most radioprotectors have sulfur as a reactive component (RSH, RSSSR etc.) and the information regarding reactivities of S radicals is rather poor, the emphasis of this project has been shifted to general studies of sulfur radicals.

FAR ULTRAVIOLET PHYSICS GROUP

Angle Resolved Photoelectron Molecular Spectroscopy

In the area of gas-phase photoionization, we have carried out angle-resolved, vibrationally-resolved, variable-wavelength photoelectron spectroscopy on six molecular systems this year using our two-inch mean radius hemisherical analyzer and our high-flux normal-incidence monochromator at SURF-II. (This instrument delivers up to 2×10^{11} photons/s-Å of monochromatic flux to an experimental sample--higher than that reported by any other synchrotron radiation laboratory.) These studies investigate the effects of resonance phenomena on the angular distribution parameters and on the branching ratios in molecular photoionization. We have found large departures from Franck-Condon predictions of relative vibrational intensity over an energy range of many electron volts in the case of shape resonances. Autoionization can also lead to transitions

within a vibrational progression which violate Franck-Condon predictions. Studies of such phenomena have been carried out for HCN, C_2H_2, BF_3, CO_2, CH_3CN, SF_6, and a number of diatomic molecules. For example in the case of acetylene, Franck-Condon considerations would predict that only a few vibrational modes would be expected to be excited. It was found that in the ground state of the ion, many vibrational modes were being excited. Furthermore, in the region of strong autoionization, bending modes of the ion were excited. Such modes are not usually excited in a linear molecule due to symmetry constraints.

An entirely new apparatus for SURF II has been constructed and is in the preliminary stages of testing. The instrument features two 4-inch mean radius hemispherical electron energy analyzers, one of which is rotatable. The sample inlet system has both effusive jets and a supersonic nozzle system. The chamber is triply magnetically shielded so that a residual field of less than 500 microgauss can be maintained. The chamber can be rapidly converted to accept a threshold photoelectron photoion coincidence spectrometer which is now being developed.

During FY 83, a new grazing-incidence monochromator will provide high flux dispersed radiation down to about 10 nm. This will permit the study of inner valence shell and core level excitations using both triply differential photoelectron and threshold photoelectron photoion techniques. Little is known about fragmentation kinetics, total and partial ionization cross sections, and angular distributions in this high energy region. Initial studies will be concerned with molecular systems such as CO_2, C_2H_2 and the C_3H_4 isomers. This work is a collaboration between CCP, SURF staff, SURF fellows, Argonne National Laboratory and SURF guest workers. 8 papers, 13 invited talks.

Photoelectron-Photoion Coincidence

The unimolecular fragmentation of the iodobenzene cation was studied by two distinct photoelectron-photoion coincidence techniques. One technique employed variable wavelength activation with threshold electron detection. The other approach involved constant wavelength activation coupled with variable electron energy detection. The former technique included both direct and autoionization processes and the latter included only direct ionization processes. A new, more detailed method of data analysis was developed. The experiments covered a much larger range of residence times than previous experiments, from 1 to 57 microseconds. The fragmentation rate-energy dependences deduced in the two experiments were in excellent agreement with one another and the resulting heat of formation determined for the phenyl cation was in agreement with results of earlier studies from this laboratory on the fragmentation of chlorobenzene and bromobenzene cations. The iodobenzene rate-energy dependence is proposed as an absolute benchmark for ion fragmentation rate measurements.

Experimental work on the coincidence apparatus was completed on ionic fragmentation in azobenzene compounds and in acetone, acetic acid, and methyl acetate. The azobenzene results will give information on isomerization barriers in these ions. The other three compounds fragment to give the acetyl ion, which corresponds to protonated ketene. A determination of the heat of formation of the acetyl ion at 300K will lead to an absolute proton affinity of ketene for calibration of the gas phase proton affinity scale. The scale of relative proton affinities has been generated by measurements of equilibrium constants for proton transfer equilibria in the ion cyclotron resonance spectrometer and high pressure pulsed electron mass spectrometer.

Plans for photoelectron-photoion coinicidence studies during FY 83 include work on the fragmentation of the parent ions of dimethyl ether, phenol and anisole, to look for state-specific fragmentation processes. Studies of selected organic cations will be carried out to examine the competition between emission and fragmentation. This is a collaboration between SURF staff, CCP and the University of Basel in Switzerland. 7 papers.

Polarized Fluorescence

A series of studies has been carried out of polarized fluorescence from molecules excited by photons from SURF's high-throughput normal-incidence monochromator. The studies involved gases such as CO_2, COS and CS_2. Results demonstrate a wide range of polarization of the fluorescence over the wavelength range around autoionizing resonances. Information was obtained about the symmetry signatures and dynamical properties of the autoionizing resonances. Studies of the fluorescence excitation spectra of N_2 in the region of the $N_2^+ B\ ^2\Sigma_u^+$ threshold in an electric field of up to 6 KV/cm demonstrated the ability to use this technique to study shifts of threshold which lie above the first ionization potential. Such shift are difficult to measure by other techniques. This work is a collaboration between SURF staff, SURF guest workers, and Argonne National Laboratory.

Surface Science

We have also supported at SURF, the establishment by the Surface Science Division of CCP of an experimental capability to study adsorbed molecules on surfaces. These studies use several SURF monochromators and an ultrahigh vacuum system. Photon stimulated desorption of ions is being studied to understand the desorption mechanism and energetics. Variable wavelength ultraviolet photoemission spectroscopy is also utilized to characterize the surface species formed upon adsorption of the molecules on a clean metal substrate. Ion desorption mechanisms for ionically and covalently bonded adsorbates have been investigated. Results have been obtained for O, CO, H_2O and CH_3OH on Ti(001) and

Nb(001). In addition, H_2O, CH_3OH and C_6H_{12} have been studied as thick multilayers in an effort to understand the effects of layer thickness, hydrogen bonding and charge exchange reactions on ion desorption from condensed layers. 10 papers, 4 invited talks.

New High Energy Capability at SURF

The success of our programs utilizing the high-flux normal-incidence monochromator has led us to proceed with the extension of our capabilities to shorter wavelengths. We have designed and procured most of the components of a new high-throughput grazing-incidence monochromator for SURF II. Only the delay in delivery of the gratings has delayed completion of the monochromator. This instrument will use SURF's orbiting electron beam as its entrance slit--thus taking advantage of SURF's small vertical beam size and high brightness. The grating will be placed as close as possible to the orbit and will intercept 51 mrad of horizontal orbit and (for wavelengths below 500Å) the full vertical radiation output. Using three independently optimized gratings, the monochromator will cover the 30-600Å spectral range. Its resolution is expected to be about 0.6 eV at full intensity. This may be improved to, perhaps, 0.1 eV by stopping down the grating in experiments where the full intensity is not required. The new monochromator will allow us to extend our programs in surface science, ultraviolet photoemission spectroscopy, and gas-phase angle-resolved photoelectron spectroscopy to higher photon energies. 2 papers.

Electric Field Effects

The high-resolution 3-m grazing-incidence monochromator was used to study the effect of electric fields of strengths up to 30KV/cm on the absorption spectra of helium near the ionization limit. The results demonstrated a strong dependence on the polarization of the incident radiation, in contrast to previous work on the heavier noble gases. A simple model was used to explain the observations and the results have been published. Work is continuing to prepare for publication previously obtained results for the H_2 and N_2 molecules as well as the heavier noble gases. Additional experimental studies await the proposed installation of a 6.65m high-resolution spectrometer at SURF In the meantime, a series of measurements will be made to determine the absolute absorption cross section of atomic barium from threshold (2378Å) to about 400Å. This work is a collaboration between CAPQ, SURF staff, and a SURF guest worker. 3 papers, 1 invited talk.

The Angular Asymmetry Parameter of Silver

The angular asymmetry parameter, β, has been measured at SURF. The high-throughput normal-incidence monochromator was utilized over the energy range 14-20eV, to obtain the β parameter for the four J=1 levels associated with the ionization of the 4d core electron of silver vapor.

Solid State Studies

Our guest users from NRL have studied, at SURF, the vacuum ultraviolet reflectance, absorptance and photoelectron spectra of vitreous and crystalline BeF_2, allowing the first determination of its optical band gap and the Be^{++} 1s core exciton binding energy. The first allowed exciton reflectance peak in crystalline BeF_2 is at 12.9 eV, similar to the 12.8 eV peak found in the glass. Optical transmission extends at least to 9.5 eV, and can be assumed to be impurity-limited in available material. Since theory indicates that BeF_2 should have an optically forbidden band edge similar to that in SiO_2, the ultimate transparency range of purified BeF_2 will depend on the strength of the forbidden exciton absorption, not yet observable above the impurity background. Grazing-incidence reflectance spectra near the Be^{++} K edge are interpreted in terms of a core exciton state lying at or slightly below the conduction band minimum as determined from x-ray photoelectron data and the optical band gap. 1 paper.

He Microbubbles

Absorption measurements of high density helium in microbubbles in thin films of aluminum and tin continued. Recent low temperature absorption measurements suggest the solidification of helium in the microbubbles near 90°K. Measurements of the efficiency of electron beam excited fluorescence from helium microbubbles in metals by comparison to SURF through the 2.2 m grazing-incidence monochromator are encouraging for the development of a new ultra-high vacuum, molecular helium continuum source. This work is a collaboration between two guest workers (1 from the NRL group).

Laser Prepared States

While limited resources have delayed the implementation of a new class of experiments at SURF which utilize both lasers and synchrotron radiation, it was possible to continue a collaborative research program at LURE in Orsay, France. In one class of experiments, it was possible to produce even parity autoionizing resonances by step-wise excitation (laser plus VUV). These are detected by electron spectroscopy. It is also possible to determine the effective oscillator strength of these autoionizing states. Similar results have been obtained for barium. In sodium and barium, it was possible to obtain a population of 30% in the 3p state of sodium and of 50% in the 5d state of barium. Furthermore, it was possible to study collisional ionization in these vapors for a variety of pressures and a wide range of laser powers. We are continuing to search for funds outside of NBS and seeking collaborators within NBS in order to implement a similar program here. 3 papers, 5 invited talks.

The asymmetry parameter showed a large variation near autoionizing resonances, but off resonance, the value of β averaged over all four levels was in close agreement to a scaled relativistic random phase approximation calculation of the β parameter. The experiment was carried out by a collaboration of SURF staff and SURF fellows with Oak Ridge National Laboratory. One paper is being prepared.

Symmetry of n=2 State in Helium

The Coulomb field provides a unique opportunity to study different theoretical many-body formalisms because the Coulomb force governing the correlated motion of the atomic electron cloud is precisely known. Helium is the simplest system that exhibits correlation effects in the photoionization processes. Because of its general importance as a test case, the photoionization cross section has been studied in great detail over a broad energy range. As part of a continuing collaboration with LURE in Orsay, France, one of the SURF staff members participated in an experiment to use angle resolved photoelectron spectroscopy with synchrotron radiation to determine the ratio, R, of the 2p to 2s partial photoionization cross sections and the weighted angular asymmetry parameter, β, for these two states. The experimental values of R suggest that final-state correlation has a dominating influence on R as is shown by calculations that include final-state and ground-state correlation. These measurements of R are in close accord with the many-body calculation of T.N. Chung which suggests that the cross section is dominated by the photoionization process that leaves the ion in the 2s state at threshold. At high photon energies, the sudden approximation becomes more appropriate and R approaches zero as it becomes a measure of overlap between the hydrogenic 2s final state and the correlated initial state. The experiment is in agreement with both calculations at high energies. 1 paper.

Lithography

In collaboration with researchers from the Naval Research Laboratory (NRL), we have set up an experimental exposure system for studies of high resolution photoresists for lithography. This is part of NRL's comparative study of various UV, XUV and x-ray sources for lithography, particularly with regard to radiation damage. Preliminary exposures have been made with PBS and COP resists. Test masks supported on thin polyimide films have been replicated. The results extrapolate to quite reasonable exposure times. A new exposure chamber has been assembled and is slated for trials at SURF II in September 1982. This chamber accommodates a magnetic mask alignment clamp and will be used to fabricate test circuits in conjunction with the NRL microelectronics facility. 1 paper.

Photoabsorption Studies of Laser-Ionized Species

Off SURF, the technique of Resonant Laser-Driven Ionization (RLDI) discovered here, has been used to refine our understanding of 4f-shell collapse and the connection between electron-electron correlation and autoionization. Studies of the 4d-photoabsorption of the Ba, Ba^{+} and Ba^{++} isonuclear sequence has led to the discovery of shell "contraction". Unlike filled d-shell ground state atoms with configurations $4d^{10}4f^{N}5s^{2}5p^{6}5d^{X}6s^{2}$ which undergo a sudden 4f shell collapse at La(Z=57), the optically allowed photoexcited $4d^{9}4f\ ^{1}P$ terms in the Ba isonuclear sequence and in the Xe isoelectronic sequence undergo a more gradual "contraction". This work is expected to have important implications in molecular and solid state physics and has already been used as a model to explain valence fluctuations in solids. With the help of W. Johnson at Notre Dame and K.T. Cheng at Argonne, we have performed a thorough analysis of the 5p-photoabsorption of Xe, Cs^{+} and Ba^{++}. This analysis has demonstrated a very clear connection between a decrease in autoionizing rates in the $5p^{5}nd'$ Rydberg series and the decrease in electron-electron correlation associated with the increasing charge state of the nuclear core. Plans for the near term future include the conversion from the photographic recording of VUV spectra to the photoelectric recording with a specially designed, state-of-the-art, VUV optical multichannel analyzer. This new instrument will be used to enlarge our studies into the effects of "tuning" the strength of the nuclear attraction in atoms by selective ionization. New candidates for investigation are the Ca, Ca^{+} and Ca^{++} isonuclear sequence (Ca is on the edge of 3d collapse) and the Ar, K^{+}, Ca^{++} isonuclear sequence. 3 papers, 10 invited talks.

Improved Radiometric Accuracy

The principle uncertainty in specifying the irradiance from SURF at all but the shortest wavelengths comes from the determination of the orbital electron current (previously known to about 2% by means of visible radiometry). A new technique has been developed which reduces this uncertainty to less than 0.5%. It combines single electron counting which exactly counts the number of electrons orbiting at very low currents with a silicon photodiode which is known to be linear to within 0.2% over nine decades. Thus, the absolute uncertainty in the photon flux from SURF should be reducible to a value of 1.0% or less over the wavelength range 10-200 nm. In collaboration with the Radiometric Physics Division, an intercomparison is being made between SURF, the self-calibrated silicon photodiode, and other standards in the Radiometric Physics Division. It has been demonstrated that the SURF/silicon intercomparison can be made to a stability of better than one percent. Using the silicon radiometers as a transfer, SURF was compared with the tungsten-halogen lamps constituting the NBS spectral irradiance scale in the visible. Agreement was found to about 1%. Work is continuing on a direct comparison between SURF and the silicon photodiode. 2 papers, 1 invited talk.

Spectrometer Calibrations

The calculability of the irradiance from SURF II has been applied by means of the SURF spectrometer irradiance calibration beam line and its associated spectrometer calibration chamber to the calibration of spectrometer and photometer systems in the spectral region 4-400 nm. These calibrations are primariliy in support of the programs of NASA and the Department of Energy. For example, the NRL Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) was calibrated at SURF both before and after its flight on Space Shuttle earlier this year. Recalibration of SUSIM both before and after flight are expected to occur many times in the next decade. Other calibrations this year have been made for NASA/Goddard, NRL, Princeton Plasma Physics Lab, U. Colorado-LASP, and for three groups from Johns Hopkins University. 2 papers, 3 talks.

Transfer Standard Detectors

The far UV radiometry effort at NBS includes the calibration and supply of transfer standard photodiode detectors, some of which are fabricated in-house. Facilities both at SURF and in the laboratory are utilized. During FY 82, 29 outgoing calibrations were performed, serving such disciplines as aeronomy, astronomy, ICF, MFE, plasma solar and solid state physics, and furnishing the radiometric basis in the far UV for other standards laboratories. We also collaborated with Los Alamos National Laboratory in the characterization of photocathode materials used for laser fusion diagnostics. The design and construction of a new and improved detector calibration facility at SURF was initiated. 3 papers, 1 talk.

ELECTRON PHYSICS GROUP

The Electron Physics Group has ongoing research efforts in electron collision physics including electron-surface interactions, surface magnetism, electron interaction theory, electron polarization phenomena, electron-atom and electron-molecule collisions, and electron optics and instrumentation. The wide applicability of electron based measurement technologies allows us to contribute to the solution of many diverse scientific and technological problems.

Surface Magnetism and Electron Diffraction

Our work on the scattering of spin polarized electrons from surfaces continues with a high level of activitiy. As a consequence of our advancement of polarized electron source and detector technology, almost every experiment we do is breaking new ground and being done for the first time. This is particularly true of our most recent work on surface magnetism. By using our polarized electron gun to observe the effects

of the exchange interaction, we are able to sense the local net alignment of spins in the surface of a ferromagnet. The short mean free paths for elastically scattered electrons make this technique extremely surface-sensitive unlike neutron scattering.

During the past year we have extended our study of surface magnetism in a number of ways. We have used ferromagnetic glasses as targets in these investigations, so that our work no longer depends upon the effects of crystal diffraction. In one experiment we measured the temperature dependence of the surface magnetization near liquid nitrogen temperature. We found that the surface magnetization varied as $(1-BT^{3/2})$, the same power dependence as in the bulk magnetization except that the coefficient B is about three times the size as the corresponding bulk coefficient. It was predicted, about 15 years ago, that surface magnons would cause the temperature power law to be the same with a coefficient twice as large as that of the bulk. Our measurement substantially confirmed this theory but raised some questions of detail that must now be addressed.

In a second experiment we studied the polarization of secondary electrons emitted when a 500 eV unpolarized incident electron is scattered from a magnetic material. We made use of a new type of polarization detector developed at NBS last year and performed both energy and polarization analysis on the low energy (1-20 eV) secondary electrons. We found low energy secondary polarizations in rough agreement with the bulk valence band electron polarization. At higher secondary energies the polarizations decrease to about half the low energy values. For an iron based glass, polarizations of approximately 25% were obtained. These data have stimulated efforts among theorists interested in modeling the spin dependence of secondary electron production and have suggested to us a major, new avenue of experimental work. Up until now, our surface magnetism measurements have been made by observing the intensity variation in the scattered electrons when the polarization of the incident electrons is modulated. Now, as a result of these experiments, we could alternatively use an unpolarized incident electron beam and measure the magnetization by monitoring the polarization of the secondary electrons produced. Normally this would be a more difficult procedure but in one particular case it offers a substantial advantage. This situation occurs in scanning electron microscopy. It is very difficult to determine the size and direction of magnetization in microscopic magnetic samples. We envision a modification of a conventional scanning electron microscope to accomplish this task. In such a microscope the spatial resolution comes from the use of a highly focused, unpolarized incident electron beam. The beam is scanned in X and Y and the number of secondaries produced at any location is used to modulate the brightness of the picture element at that location in the final photograph. We would add polarization analysis to a conventional scanning electron microscope so that at each X,Y location in the final picture we will be able to measure the strength and direction of the magnetization. We hope to be able to

study very small magnetic structures and to probe the transition of spin directions as a domain wall is crossed. We are currently attempting to arrange for a one-year feasibility study of this promising new experimental method.

In our most recent experiment, we (in collaboration with Neville Smith and Peter Johnson of Bell Laboratories) performed the first spin polarized, inverse photoemission experiment. With the coming of high intensity UV storage rings, groups worldwide are beginning to tool up to measure spin polarized, angle-resolved, energy-resolved photoemission. Such measurements allow one to map out the spin dependent band structure. We have performed an inverse photoemission experiment prior to the measurement of the comparable direct process. In this experiment spin polarized electrons at a specific energy and angle to the crystal were scattered from a target and UV photons at a particular wavelength were collected. We successfully demonstrated that in nickel only minority spin electrons would give rise to absorption in the unfilled d-bands. This method allows measurement of the spin polarized density of unfilled states near the Fermi level. We will be using this technique during the next year to study the effect of adsorption on the unfilled d-band in nickel and the possible polarization of the unfilled states in the adsorbates.

High Energy Resolution Electron Scattering

During the past year we have used our high energy resolution electron spectrometer to resolve a dilemma which has occurred in the study of the diamond (111) surface. The difficulty was that LEED and photoemission studies showed that this surface had no atomic rearrangement while theory and our knowledge of other semiconductors predicted that a rearrangement should be expected. Our electron energy loss spectrometer (EELS) was used to observe the surface composition of a diamond (111) crystal used in other studies. We found that as prepared this diamond surface was terminated by hydrogen atoms. We could remove or replace these atoms with hydrogen or deuterium in a reproducible manner. Our discovery that hydrogen is hindering the reconstruction of the diamond surface explains all the conflicting experimental results to date. We have begun to revitalize our electron spectrometer system through various mechanical and electrical changes which should greatly enhance its performance in the future.

Theory

We have recently been studying theoretically the polarization of secondary electrons produced in ferromagnetic metals. A number of new experiments, e.g., photoemission and electron excitation on Co, Fe, and Ni in which the spin polarization of the low energy electrons is measured have exhibited very dramatic results. The electron spin polarization is found to increase rapidly with decreasing energy rising to several times

the bulk value at the lowest measurable energies. We have modeled these experiments by solving a Boltzmann-type transport equation that includes electron spin. We obtain results consistent with the experimental ones due to a physical mechanism that amounts to a spin flip. A minority spin electron has a higher probability of being scattered to an empty d state in a Coulomb collision than a majority spin electron due to the larger number of unfilled minority spin d states. The resulting minority to majority spin flips produce a large polarization at low energies where scattering is most probable. This mechanism also produces a spin dependent electron mean free path.

Electron Optics

Our electron optical design program has supported many of the new experimental efforts described above. Modification of our electron optics was made for the inverse photoemission experiment and for the secondary electron polarization experiment. In addition a complicated modeling of the trajectories of the secondary electrons in crossed magnetic and electric fields was used to interpret data on our secondary electron polarization measurements. The overall computer program used for electron optics calculations has been modified to allow greater flexibility and graphical output of the results of the calculation.

Electron-atom Collisions

Data accumulation on polarized electron-polarized atom scattering began in earnest this past year. We are investigating the electron-atom scattering problem in an experiment where all the parameters are determined so that we can make the step from measuring cross sections to the determination of quantum phases and amplitudes. For this purpose we have constructed a crossed beam, polarized atom, polarized electron scattering apparatus. Sodium atoms are polarized by optical pumping with a tunable CW-dye laser; even the nuclear spin will be aligned. The electron beam comes from our second GaAs polarized electron source, and will have an energy resolution less than 0.15 eV. The use of the laser to optically orient the sodium beam will also facilitate reading out the polarization of the beam through laser fluorescence or Faraday rotation measurements. We could also use the laser to study scattering from excited, oriented atomic states. During this past year we have been able to measure the asymmetry for ionization for the electron atom system in the singlet or triplet state. Our first results will soon be submitted for publication. We will then quickly move on to ionization from the first excited state of sodium and to ground state polarized electron-polarized atom elastic scattering.

SPONSORED CONFERENCES

Division 533, Radiation Physics

M. J. Berger organized and chaired a session on "Radiation Physics and Modeling" of a Workshop on the Interface Between Radiation Chemistry and Radiation Physics," held at the Argonne National Laboratory on September 9 and 10 under the sponsorship of the Department of Energy.

First Conference on Radioprotectors and Anticarcinogens, June 21-24, 1982, National Bureau of Standards, Gaithersburg, MD, Conf. Chairman, M. G. Simic.

Biological Effects of Radiation, American Nuclear Society Annual Meeting, Los Angeles, CA, June 7-11, Symposium Chairman, M. G. Simic.

Symposium on the "Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack," April 27-29, 1982, Reston, VA, L. V. Spencer, Chairman, NCRP Committee 63 sponsor.

INVITED TALKS

Division 533, Radiation Physics

Berger, M. J. and Seltzer, S. M., "Tables of Energy-Deposition Distributions in Water Phantoms Irradiated by Point-Monodirectional Electron Beams with Energies from 1 to 60 MeV, and Applications to Broad Beams," Presented at the Electron Dosimetry and Arc Therapy Symposium, Wisconsin Clinical Cancer Center, University of Wisconsin, Madison, Wisconsin, September 10-11, 1981. NBSIR 82-2451, January 1982.

Berger, M. J. and Seltzer, S. M. "Mean Excitation Energies for Use in Bethe's Stopping Power Formula," Proceedings of Seminar on Charge States and Dynamic Screening of Swift Ions in Solids; Honolulu, Hawaii, January 24-29, 1982.

Celotta, R. J., "Recent Applications of Electron Spin Polarization Measurements," Exxon Research and Development Laboratory, Linden, NJ, November 12, 1981.

Celotta, R. J., "The Use of Electron Polarization Measurements in Surface Physics," Materials Science Colloquium, Massachusetts Institute of Technology, Cambridge, MA, November 13, 1981.

Celotta, R. J., "Recent Advances in the Use of Electron Spin Polarization Measurements," Joint JILA-Physics Department Colloquium, University of Colorado, Boulder, CO, April 13, 1982.

Celotta, R. J., "Electron Spin Polarization Measurements: Applications in Surface and Atomic Physics," University of Oregon, Eugene, OR, April 15, 1982.

Celotta, R. J., "The Application of Electron Spin Polarization Measurements in Surface and Atomic Physics," Interdepartmental Physics Colloquium, Westinghouse Electric Corporation, Pittsburgh, PA, April 29, 1982.

Celotta, R. J., "Possibilities for the Use of Electron Spin Polarization in Scanning Electron Microscopy," Microbeam Analysis Society Conference, Washington, DC, August 11, 1982.

Celotta, R. J., "Application of Electron Polarization Technique to Surface Physics," XI Yugoslav Summer School and International Symposium on the Physics of Ionized Gases, Dubrovnik, Yugoslavia, August 25, 1982.

Celotta, R. J., "Use of Polarized Electrons in Atomic Physics," XI Yugoslav Summer School and International Symposium on the Physics of Ionized Gases, Dubrovnik, Yugoslavia, August 25, 1982.

Division 533, Invited Talks (cont'd)

Celotta, R. J., "Electron Polarization Phenomena at Surfaces," Physics Seminar City College of New York, New York, NY, September 22, 1982.

Domen, S. R., "Absorbed Dose Water Calorimeter," Hungarian and British National Standards Laboratories, and Ghent Univerity, Belgium, December 1981.

Ederer, D. L., "Observation of Ionization in Laser Excited Sodium Atoms by Synchrotron Radiation," Conference for Laser Techniques for Extreme Ultraviolet Spectroscopy, Boulder, CO, March 1982.

Ederer, D. L., "Photoelectron Spectroscopy in Atoms and Molecules," Yale University, New Haven, CT, May 1982.

Ederer, D. L., "Use of Synchrotron and Laser Radiation to Study Collisional and Photoionization Processes in Metalic Vapors," Eidgenossiche Technische Hochschule, Zurich, Switzerland, July 1982.

Ederer, D. L, "Studies on Photoionization Processes from Ground State and Excited State Atoms and Molecules," Workshop on Techniques for Production and Utilization of Polarized Radiation in the VUV, London, England, August 1982.

Hill, W. T., "Absorption Spectroscopy of Ions," Corning Glass Works, Corning, NY, November 1981.

Hill, W. T., "Quantum Defect Studies of the Rydberg Levels in Xe-like Ba^{++}," University of Maryland, College Park, MD, November 30, 1981.

Hill, W. T., "Quantum Defect Studies of the Rydberg Levels in Xe-like Ba^{++}," Division of Electronic and Atomic Physics Meeting, New York, NY, December 1981.

Hill, W. T., "Laser-Assisted MQDT Studies in Xe-like Systems," Notre Dame University, Notre Dame, IN, March 1982.

Hill, W. T., "Laser-Assisted MQDT Studies in Xe-like Systems," Argonne National Laboratory, Argonne, IL, March 1982.

Hill, W. T., "Laser Generated Plasma Studies and VUV Photoabsorption," Stanford University, Stanford, CA, March 1982.

Hill, W. T., "Laser Generated Plasma Studies and VUV Photoabsorption," University of Southern California, Los Angeles, CA, March 1982.

Hill, W. T., "Absorption Spectroscopy of Ionized Vapors," Bell Laboratories, Murray Hill, NJ, April 1982.

Division 533, Invited Talks (cont'd)

Hill, W. T., "VUV Spectroscopy of the $5p^5\ ^2P_{3/2}$ ns, nd Discrete and Autoionizing Resonances in Ba^{++}," Workshop on Techniques for Production and Utilization of Polarized Radiation in the VUV, London, England, August 1982.

Hill, W. T., "VUV Spectroscopy of the $5p^5\ ^2P_{3/2}$ ns, nd Discrete and Autoionizing Resonances in Ba^{++}," VII International Colloquium on Ultraviolet and X-Ray Spectroscopy of Astrophysical and Laboratory Plasmas, University College, Dublin, Ireland, August 1982.

Hubbell, J. H., "Photon Attenuation Coefficients and Cross Section Data 100 eV to 100 GeV: Current Status and Prospects." Proc. 2nd International Symposium on Radiation Physics, Universiti Science, Penang, Malaysia, May 25-29, 1982.

Kelley, M. H., "Polarized Electron-Polarized Atom Scattering," University of Texas, Austin, TX, November 24, 1981.

Kelley, M. H., "Spin Dependence in Electron Atom Scattering," Rice University, Houston, TX, June 8, 1982.

Kelley, M. H., "Spin Dependence in Electron Atom Scattering," University of Texas, Austin, TX, June 9, 1982.

Loevinger, R., "Radiation Quantities and Units," preparation course for the American Board of Health Physics Certification Examination, Gaithersburg, MD, January 1982.

Loevinger, R., "Radiologic Physics Activities and Need at NBS," at a Workshop on Radiologic Physics Research and Support, National Cancer Institute, Bethesda, MD, May 1982.

Loevinger, R., "The NBS Program in Electron-beam Dosimetery," Symposium on Electron Beam Dosimetry at Memorial Hospital, New York, NY, June 1982.

Loevinger, R., "Audience Participation Presentation: Discussion and Vote on Exposure vs Air Kerma vs Water Kerma," a Continuing Education Lecture at the 24th Annual Meeting of the American Association of Physicists in Medicine, New Orleans, LA, August 1982.

Lucatorto, T. B. and Hill, W. T., "A Laser-Assisted Voyage Through Ba, Ba^+, and Ba^{++}: Shell Collapse, Term Dependence and Photoionization," Center for Absolute Physical Quantities Seminar, NBS, November 1981.

Lucatorto, T. B., "Effect of Valence Electrons on Core Absorption in Ba, Ba^+ and Ba^{++}," University of Maryland, College Park, MD, November 1981.

Division 533, Invited Talks (cont'd)

Lucatorto, T. B., "A Laser-Assisted Journey Through Ba, Ba^{+} and Ba^{++}: Shell Collapse Term-Dependence and Autoionization," University of North Carolina, Raleigh, NC, March 1982.

Lucatorto, T. B. and McIlrath, T. J., "Optical Studies of Atomic Systems: Do You Need Coherent Light to do Coherent Physics?," Bell Laboratories, Holmdel, NJ, April 1982.

Lucatorto, T. B. and McIlrath, T. J., "Resonant Laser-Excitation and Ionization of Dense Vapors: A Object of Study and as a New Tool in Atomic Physics," Princeton University, Princeton, NJ, April 1982.

Lucatorto, T. B., "The 4d Photoabsorption of Ba, Ba^{+} and Ba^{++}: A View of Shell Collapse vs. Contraction," X-82 Conference, Eugene, OR, August 1982.

Madden, R. P. Traveling Lecturer for Optical Society of America, Orlando, FL, October 1981; Norwalk, CT, December 1981; Rochester, NY, February 1982; and Phoenix, AR, April 1982.

Madden, R. P., "SURF-II Calibration Facility Users and Capabilities," NASA, Washington, DC, May 1982.

Madden, R. P., "Status Report: NBS Far Ultraviolet Transfer Standard Detector Program," Middle Atmospheric Program, Washington, DC, May 1982.

Madden, R. P., "Status Report: NBS/SURF Far UV Spectrometer Radiometric Calibration Facility," Middle Atmospheric Program, Washington, DC, May 1982.

Madden, R. P., "SR Radiometry at the National Bureau of Standards SURF Storage Ring", PTB, Berlin, W. Germany, August 1982.

McIlrath, T. J. and Lucatorto, T. B., "Observations of the Effect of Valence Electrons on Core Absorption Spectra in Alkaline Earths," Atomic and Molecular Physics Close to Ionization Thresholds in High Fields, CNRS International Colloquium, Savoie, France, June 1982.

McIlrath, T. J., "Pulsed Plasma Light Sources," Workshop on Techniques for Production and Utilization of Polarized Radiation in the VUV, London, England, August 1982.

McLaughlin, W. L., "Pulse Radiolysis of Triphenylmethane Dyes," Accelerator Department and Chemistry Department, Risø National Laboratory, Denmark, November 2, 1981.

McLaughlin, W. L., "Dosimetry for Quality Control of Radiation Preservation of Foods," Advisory Group on High-Dose Radiation Measurement, IAEA, Vienna, Austria, November 10, 1981.

Division 533, Invited Talks (cont'd)

McLaughlin, W. L., "Dosimetry for Quality Control of Radaition Sterilization of Medical Supplies," Advisory Group on High-Dose Radiation Measurement, IAEA, Vienna, Austria, November 13, 1981.

McLaughlin, W. L., "Fibre Optics for Ionizing Radiation Measurement," Institute of Physics, University of Mexico, Mexico., December 2, 1981.

McLaughlin, W. L., "Neutron Dosimetry With Radiochromic Dyes," National Institute of Nuclear Studies, University of Mexico, Mexico, December 7, 1981.

McLaughlin, W. L., "Ultra High-Dose Measurements in Charged-Particle Beams," Accelerator Group, Nuclear Center of Mexico, Salazar, Mexico, December 9, 1981.

McLaughlin, W. L., "Low-Energy Electron Beam Diagnostics and Industrial Quality Control,"TeleCom Product Division, 3M Company, St. Paul, MN, January 22, 1982.

McLaughlin, W. L., "Fibre Optics Dosimetry," Defense Nuclear Agency Planning Committee, March 30, 1982.

McLaughlin, W. L., "Dosimetry," DOA-DOE Workshop on Low Dose Irradiation of Agricultural Products, April 19-23, 1982.

McLaughlin, W. L., "Radiation Dosimetry in Food Irradiation Technology," American Nuclear Society Annual Meeting, The Western Bonaventure, Los Angeles, CA, June 8, 1982.

McLaughlin, W. L., "Electron Beam Dosimetry and Standardization," Becton-Dickinson Company Headquarters Staff and Quality Assurance Personnel, June 22, 1982.

McLaughlin, W. L., "Lyoluminescence and Free Radical Analysis in Radioprotectors," Radiation and Anticarcinogens Conference, NBS, June 23, 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," Georgetown University, Washington, DC, November 1982.

Parr, A. C., "Triply-Differential Photoelectron Studies of Autoionization and Shape Resonance Effects in Molecular Photoionization," Division of Electronic and Atomic Physics Meeting, New York, NY, December 1981.

Parr, A. C., "Triply-Differential Photoelectron Spectroscopy of Atoms and Simple Molecule," Center for Absolute Physical Quantities Seminar, NBS, January 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," University of Alabama, University, AL, March 1982.

Division 533, Invited Talks (cont'd)

Parr, A. C., "Resonance, Autoionization and Kinetic Effects in Photoionization," American Society for Mass Spectrometry Conference, Honolulu, HI, June 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," California Institute of Technology, Pasadena, CA, June 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," University of California, Santa Barbara, CA, June 1982.

Parr, A. C, "Photoelectron Spectrometer for High Resolution Angular Resolved Studies," International Conference on X-Ray and VUV Synchrotron Radiation Instrumentation, Deutsches Elektronen-Synchrotron, Hamburg, West Germany, August 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," University of Uppsala, Uppsala, Sweden, August 1982.

Parr, A. C., "Effects of Resonance in Molecular Photoionization Measured with Triply Differential Photoelectron Spectroscopy," 9th International Mass Spectrometry Conference, Vienna, Austria, August 1982.

Parr, A. C., "Resonance Phenomena in Molecular Photoionization," Centre National Researche Scientifique, SACLAY, France, September 1982.

Penn, D. R., "Surface Photoeffect in Small Spheres," American Physical Society, Dallas, TX, March 11, 1982.

Penn, D. R., "Surface Enhanced Photoabsorption in Small Spheres," Drexel University, Philadelphia, PA, April 15, 1982.

Penn, D. R., "Surface Photoeffect in Small Spheres," Xerox Corporation, Palo Alto, CA, August 13, 1982.

Pierce, D. T., "Spin Polarized Electron Studies of Surface Magnetism," Centro de Investigacion y de Estudios, Avanzados del Instituto Politechnico Natcional, Organization of American States, Mexico City, Mexico, December 7, 1981.

Pierce, D. T., "Spin Polarized Electron Scattering - A New Probe of Surface Magnetism," Physics Department Colloquium, University of Chicago, Chicago, IL, January 21, 1982.

Pierce, D. T., "Spin and Energy Analyzed Secondary Electron Emission from a Ferromagnet," Gordon Research Conference on Electron Spectroscopy, Wolfeboro, NH, July 19, 1982.

Pierce, D. T., "New Information from Electron Spin Polarization in Surface Studies," Korean Standards Research Institute, Seoul, Korea, August 31, 1982.

Division 533, Invited Talks (cont'd)

Pierce, D. T., "Spin Polarized Electron Scattering from Surfaces," Korean Advanced Study Institute, Seoul, Korea, September 1, 1982.

Pierce, D. T., "Spin Polarized Electron Scattering Studies of Surface Magnetism," International Conference on Magnetism, Kyoto, Japan, September 10, 1982.

Pierce, D. T., "Surface Magnetic Properties of Amorphous Ferromagnets Studied Using Electron Spin Polarization," 10th International Colloquium on Magnetic Films and Surfaces, Yokahama, Japan, September 14, 1982.

Pierce, D. T., "Spin Polarized Electrons in Condensed Matter Physics," Tribuvan University, Kathmandu, Nepal, September 23, 1982.

Pierce, D. T., "Electron Spin Polarization Probes of Surface Magnetism: Recent NBS Results," Swiss Federal Institute of Technology, Zurich, Switzerland, October 4, 1982.

Pierce, D. T., "Electron Spin Polarization Studies of Surface Magnetism," Solid State Physics Seminar, Cambridge University, Cambridge, England, October 7, 1982.

Rogers, W. T., "Polarized Electron-Polarized Atom Scattering," General Atomic Corporation, San Diego, CA, November 10, 1981.

Rogers, W. T., "Polarized Electron-Polarized Atom Scattering," Lawrence Livermore National Laboratories, Livermore, CA, November 12, 1981.

Rogers, W. T., "Polarized Electron-Polarized Atom Scattering," E. I. duPont de Nemours & Co., Inc., Wilmington, DE, November 19, 1981.

Simic, M. G., "Kinetics and Mechanisms of Auto-Oxidation Reaction," The University of Maryland Baltimore County, Catonsville, MD, November 9, 1981.

Simic, M. G., "Chemistry, Biological Effects and Dosimetry of Ionizing Radiation," University of Florida, Agricultural Research and Education Center, Lake Alfred, FL, November 24, 1981.

Simic, M. G., "Pulse Radiolysis and its Limitations in Autoxidation and Antioxidants," National Research Council, Ottawa, Canada, February 26, 1982.

Simic, M. G., "Radiation-Induced Racemization of Amino Acids," U.S. Department of Agriculture, Eastern Regional Center, Philadelphia, PA, March 31, 1982.

Simic, M. G., "Radiation-Induced Racemization of Amino Acids," Massachusetts Institute of Technology, Dept. of Nutrition and Food Science, Cambridge, MA, April 5, 1982.

Division 533, Invited Talks (cont'd)

Simic, M. G., "Mechanisms of Radiation-Induced Racemization and Dimerization of Aliphatic Peptides," Annual Radiation Research Society Meeting, Hotel Utah, Salt Lake City, UT, April 19, 1982.

Simic, M. G., "Radiation-Induced Autoxidation Processes", Lawrence Livermore Laboratory, Livermore, CA, April 22, 1982.

Simic, M. G., "Oxygen a Problem or a Detriment in Food Irradiation." Radiation in Food Processing Symposium, American Nuclear Society Annual Meeting, Los Angeles, CA, June 6-11, 1982.

Spencer, L. V., "Types of Nuclear Disaster and their Radiation Environment," Proc. NBRP Symp. The Control of Exposure to the Public to Ionizing Radiation in the Event of Accident or Attack, Reston, VA, April 27-29, 1982.

Waclawski, B. J., "Direct Verification of Hydrogen Termination of the Semiconducting Diamond (111) Surface," Ninth Annual Conference on Physics and Chemistry of Semiconductor Interfaces, Pacific Grove, CA, January 27, 1982.

PUBLICATIONS

Division 533, Radiation Physics

Berger, M. J. and Seltzer, S. M., Tables of Energy-Deposition Distributions in Water Phantoms Irradiated by Point-Monodirectional Electron Beams with Energies from 1 to 60 MeV, and Applications to Broad Beams, NBSIR 82-2451 (January 1982).

Berger, M. J. and Seltzer, S. M., Mean Excitation Energies for Use in Bethe's Stopping Power Formula, Proc. of Seminar on Charge States and Dynamic Screening of Swift Ions in Solids; Honolulu, Hawaii (January 24-29, 1982).

Berger, M. J. and Seltzer, S. M., Stopping Powers and Ranges of Electrons and Positrons, NBSIR 82-2550 (August 1982).

Berger, M. J. and Seltzer, S. M., Tables of Energy Deposition Distributions in Aluminum and Copper Irradiated by Point-Monodirection Electron Beams with Energies from 1 to 60 MeV. NBSIR (in press).

Celotta, R. J., Pierce, D. T., Kelley, M. H., and Rogers, W. T., Polarized Electrons, in Physics of Electronic and Atomic Collisions, S. Datz, ed., North Holland Publishing Co. (1982).

Celotta, R. J. and Pierce, D. T., Possibilities for the Use of Electron Spin Polarization in Scanning Electron Microscopy, Proc. of Microbeam Analysis Society (in press).

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Degraff, E., and McLaughlin, W. L., Quality Control for Electron Beam Processing of Polymeric Materials by End-Point Analysis, 3rd International Meeting on Radiation Processing, Tokyo, Radiat. Phys. Chem. 18, 975-985 (1981).

Dizdaroglu, M., and Simic, M. G., Hydroxycyclophexadienyl Peroxy Radicals, in Oxygen Radicals, Eds. M. A. J. Rodgers, E. L. Powers, Academic Press, p. 619 (1981).

Dizdaroglu, M., Krutzsch, H. C., Simic, M. G., Separation of Angiotensins by High-Performance Liquid Chromatography on a Weak Anion-Exchange Bonded Phase, Anal. Biochem. 123, 190-193 (1982).

Dizdaroglu, M., Krutzsch, H. C., Simic, M. G., Separation of Peptides by High-Performance Liquid Chromatography on a Weak Anion-Exchange Bonded Phase, J. Chromatogr., 237 417-428 (1982).

Dizdaroglu, M., Simic, M. G., Separation of Dipeptide Diastereomers by High-Resolution Gas Chromatography, J. Chromatogr. (in press).

Dizdaroglu, M., Simic, M. G., Isolation and Characterization of Radiation Induced Aliphatic Peptide Dimers, Biophys. Biochem. Acta. (in press).

Dizdaroglu, M., Simic, M. G., Rioux, F., and St-Pierre, S., Separation of Diastereomers and Analogues of Neurotensins by Anion-Exchange High-Performance Liquid Chromatography, J. Chromatogr. (in press).

Dizdaroglu, M., Gajewski, E., Simic, M. G., and Krutzsch, H. C., Radiolytic Products as Indicators of OH Radical Site of Attack on Lysozyme, Int. J. Radiat. Biol. (in press).

Domen, S. R., An Absorbed Dose Water Calorimeter: Theory, Design, and Performance, JRNBS (U.S.) 87, 211 (1982).

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Ederer, D. L., Parr, A. C., West, J. B., Holland, D. M. P., and Dehmer, J. L., Measurement of Spin-Orbit Branching Ratios and the Angular Asymmetry Parameter in the Region of the $4s4p^6 5p$ Resonances in Krypton and the $5s5p^6 6p$ Resonances in Xenon, Phys. Rev. A 25, 2006 (1982).

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TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 533, Radiation Physics

Martin J. Berger

Chairman, International Commission on Radiation Units and Measurements (ICRU), Committee on Stopping Power.

Member, National Council on Radiation Protection and Measurements (NCRP), Committee #52 on Conceptual Basis of Dosimetry.

Member, National Council on Radiation Protection and Measurements (NCRP), Committee #55 on Experimental Verification of Internal Dosimetry.

Robert J. Celotta

Chairman, NBS Research Advisory Committee

Editorial Board, Review of Scientific Instruments

Member, American Physical Society, Division of Electron and Atomic Physics Program Committee, 1982-1983.

Charles E. Dick

Member of the Technical Program Committee, Seventh Conference on the Application of Accelerators in Research and Industry.

David L. Ederer

Member, NSLS User Committee.

Member, Optics News Editorial Committee.

Margarete Ehrlich

Chairman, Health Physics Society Standards Committee, Work Group on Criteria for Testing Personnel Dosimetry Performance.

Member, ISO/TC 85/SC2, WG2, Photographic Dosimeters and Reference Radiation.

Member, Health Physics Society Standards Committee, Work Group on Criteria for Testing Environmental Dosimetry Performance.

Member, American Nuclear Society Work Group on revision of ANSI/ANS 6.1.1, Neutron and Gamma-Ray Flux-to-Dose Rate Factors.

Division 533, Technical and Professional Committee Participation and Leadership (cont'd.)

John H. Hubbell

Secretary, Commission on Crystallographic Apparatus, International Union of Crystallography, Task Group on X-ray Absorption Coefficients.

Chairman, Health Physics Society, Intersociety Liaison Committee (Assigned to Society of Nuclear Medicine).

Chairman, American Nuclear Society (ANS) Radiation Protection and Shielding Division ANS-6 Ad Hoc Committee on SI Units.

Member, Cross Section Evaluation Working Group (CSEWG) Subcommittee on Shielding.

Member, American Nuclear Society (ANS) Isotopes and Radiation Division Committee on Radiography and Gauging.

Jimmy C. Humphreys

Member, ASTM F-1.11 Subcommittee on Quality and Harness Assurance of the F-1 Electronics Committee.

Vice Chairman, ASTM Committee E.10 Nuclear Technology and Application E10.07 Subcommittee on Radiation Effects on Electronic Materials and Devices.

Robert Loevinger

Member, BIPM Consultative Committee for Standards for Measurement of Ionizing Radiation, Section I, X and Gamma Rays and Electrons.

Member, OIML, SP.16-SR.1, Performance of Dosimeters.

Member, OIML, SP.16-SR.2, Secondary Standard Dosimetry Laboratories.

Member, IAEA-WHO Network of Secondary Standard Dosimetry Laboratories, Advisory Council.

Member, IEC/TC 62/SC C/WG 3, Performance of Dosimeters.

Member, ANSI/N44 Equipment and Materials for Medical Radiation Applications.

Member, ANSI/N44/SC2 Therapeutic Radiology.

Member, Society of Nuclear Medicine, Medical Internal Radiation Dose Committee.

Division 533, Technical and Professional Committee Participation and Leadership (cont'd.)

Robert Loevinger (cont'd.)

Consultant, AAPM Radiation Therapy Committee.

Member, AAPM Radiation Therapy Committee Task Group 3, Regional Calibration Laboratories.

Member, AAPM Radiation Therapy Committee Task Group 21, High-Energy Photon and Electron Dosimetry.

Member, AAPM Radiation Therapy Committee Task Group 22, Brachytherapy.

Consultant, AAPM Radiation Therapy Committee Task Group 24, Physical Aspects of Quality Assurance in Radiation Therapy.

Chairman, AAPM Science Council Committee on the Effect of Si Units.

Thomas P. Loftus

Member, ANSI/N13, Radiation Protection.

Member, ANSI/N42, Working Group on Inspection and Test Specifications for Direct and Indirect Reading Quartz Fiber Pocket Dosimeters.

Robert P. Madden

Member, Advisory Committee for the Stoughton Storage Ring (Tantalus) of the University of Wisconsin.

Member, Advisory Editorial Board of Optics Communication.

Member, International Committee for the International Conference on VUV Radiation Physics.

President, Optical Society of America.

Member, American Institute of Physics (AIP) Board of Directors.

Member, Optical Society of America Committee on Finance and Investment.

Member, Council of Scientific Society Presidents, (CSSP).

Member, Middle Atmospheric Program (MAP) International Working Group on Solar Spectral Irradiance Measurements.

Member, Council of U.S. Synchrotron Radiation Laboratory Directors.

Robert P. Madden (cont'd.)

Visiting Lecturer, Local Sections of the Optical Society of America.

Member, Program-Advisory Committee of the International Conference on X-Ray and VUV Synchrotron Radiation Instrumentation, Hamburg, West Germany, August 1982.

Member, American Institute of Physics (AIP) Nominating Committee, 1982.

Thomas J. McIlrath

Member, Technical Council, Chairman Atomic Spectroscopy Technical Group, Optical Society of America.

Co-Chairman, OSA Conference on Spectroscopy in Support of Atmospheric Measurements.

Member, Program Committee, Optical Society of America, Annual Meeting.

Member, Program Committee, Division of Electron and Atomic Physics, American Physical Society.

Chairman, Conference on Use of Lasers for High Resolution Spectroscopy inthe Vacuum Ultraviolet.

Co-chairman, Workshop on Techniques for Production and Utilization of Polarized Radiation in the Vacuum Ultraviolet, London, England, August 1982.

Participant and Panel Chairman, Workshop on Current Trends in Atomic Spectroscopy, Tucson, AR, October 1982.

General Chairman, Optical Society of America, 1983 Annual Meeting.

William L. McLaughlin

Chairman, American Nuclear Society (ANS) 9, Nuclear Terminology and Units, Subcommittee 9.1, Health Physics and Dosimetry.

Member, ANS 6, Radiation Protection and Shielding Subcommittee 6.5, Units and Terminology.

Division 533, Technical and Professional Committee Participation and Leadership (cont'd.)

William L. McLaughlin (cont'd.)

Member, ASTM E10.07, Radiation Effects on Electronic Materials and Devices.

Member, Association for the Advancement of Medical Instrumentation Subcommittee on Radiation Sterilization of Medical Devices, Task on Radiation Dosimetry.

Member, ANS 9.2 Subcommittee on Shielding of the Nuclear Terminology and Units Committee.

Technical Advisor, ISO WG-1, Nuclear Energy Terminology Task on the ISO TC/85 Committee on Nuclear Energy.

Technical Advisor, Council of Europe Parliamentary Assembly Work Group on Aerospace Physiology and Medicine.

Technical Advisor, Council of Europe Parliamentary Assembly Work Group on Space Biophysics.

Member, ANSI N12, General Administration and Standards for Nuclear Energy.

Daniel T. Pierce

Local Committee for 1982 National Meeting of the American Vacuum Society.

Robert C. Placious

Chairman, ASTM E7.01.08, Subcommittee on Industrial Radiographic Film Classification.

Member, ASTM E10.07, Nuclear Technology and Application Subcommittee on Radiation Effects on Electronic Materials and Devices and Pulsed Radiation Effects.

Member, ANSI PH 2.31, Committee on Photographic Sensitometry Subcommittee on X-Ray Film Standards.

Member, ASTM F12.60, Controlled Access Security Search and Screening Systems.

Member, ASTM E7.01, Nondestructive Testing Committee on Radiographic Practice and Penetrameters.

Division 533, Technical and Professional Committee Participation and Leadership (cont'd.)

Daniel Polansky

Member, ASTM E07.01, Nondestructive Testing Committee on Radiographic Practice and Penetrameters.

Member, ASTM E07.02, NDT Committee on Radiographic Standards.

Member, ASTM E07.05, NDT Committee on Neutron Radiography.

Member, ASTM E07.91, ISO/TC135.

Member, ANSI PH2:31, Medical X-Ray Film Sensitometry.

Henry M. Rosenstock

Member, ASTM Committee E-14 on Mass Spectrometry.

Member, American Society for Mass Spectrometry (ASMS).

Member, Editorial Review Board of the International Journal of Mass Spectrometry and Ion Physics.

Member, American Association for the Advancement of Science.

Edward B. Saloman

Chairman, 5th Workshop on the Use of XUV and X-Ray Radiometry for Plasma Diagnostics 5 eV to 10 KeV.

Michael G. Simic

Member of the Military R&D Associates.

Member of the CAST (Council on Agricultural Science and Technology) Task Force.

Lewis V. Spencer

Consociate Member, National Council on Radiation Protection and Measurements (NCRP).

Chairman, National Council on Radiation Protection and Measurements (NCRP) Committee #63 on Emergency Radiation Exposure Control.

Member, National Council on Radiation Protection and Measurements (NCRP) Committee #52 on Conceptual Basis of Dosimetry.

Lewis V. Spencer (cont'd.)

Member, National Council on Radiation Protection and Measurements (NCRP) Committee #40, Task Group on A-Bomb Survivor Dosimetry Biological Aspects of Radiation Protection Criteria.

Member, Panel on the Re-assessment of A-Bomb Dosimetry, Advisory Committee on the Radiation Effects Research Foundation, National Academy of Science-National Research Council (NAS-NRC).

Member, American Nuclear Society (ANS) Shielding Glossary Committee.

Member, Interagency Committee on Federal Guidance for Occupational Exposure to Ionizing Radiation.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 533, Radiation Physics

1. M. J. Berger is a consultant to the ICRU committee on High Energy Electron Dosimetry.

2. M. J. Berger is a consultant to the AAPM Task Group on Photon and Electron Dosimetry.

3. R. J. Celotta and D. T. Pierce advised on construction and provided drawings of an electron polarization source which ANAC, Inc. will market as a commercial product.

4. S. R. Domen consulted on construction and operation of absorbed dose graphite calorimeters and water calorimeters, at the Hungarian standards laboratory in Budapest, the Austrian standards laboratory near Vienna, the British standards laboratory in Teddington, and the University of Ghent, Belgium.

5. S. R. Domen consulted at NBS on construction and operation of absorbed dose water calorimeters with representatives of the Massachusetts General Hospital; the Groote Schuur Hospital, Capetown, South Africa; the Tom Baker Cancer Center, Calgary, Canada; the Sahlgrenska Hospital, Gothenburg, Sweden; and the National Institute of Radiation Protection, Stockholm, Sweden.

6. S. R. Domen advised J. A. Mason from the University of London Reactor Centre on needed improvements on a calorimeter for absorbed dose measurement on neutrons in a reactor.

7. S. R. Domen advised J. C. McDonald and I-chang Ma on layout and construction of a spiral heater for a calorimeter for measurement of absorbed dose from high-LET radiations at Memorial Hospital in New York City.

8. J. H. Hubbell responded to inquiries to the X-Ray and Ionizing Data Center on matters pertaining to photon cross sections from over 300 scientists in the U.S. and abroad.

9. J. H. Hubbell is a consultant to the ICRU Task Group II-B-1 Radiation Dosimetry; X-rays from 5-150 keV. (Task Group Chairman: Dr. John Greening, Department of Medical Physics, University of Edinburgh, Edinburgh EH3 9YW, Scotland).

10. R. Loevinger and E. H. Eisenhower consulted with officials of the Nuclear Regulatory Commission concerning calibration aspects of proposed revisions of medical licensing regulations.

11. T. P. Loftus and R. Loevinger consulted with representatives of the 3M Company, and with medical physicists from George Washington Medical School and the Memorial Hospital, New York City, concerning development and calibration of iodine-125 brachytherapy sources for cancer therapy.

12. T. P. Loftus advised members of the Naval Electronics Command on establishment of a protection-level thermoluminescence dosimetry system for use on ships.

13. T. P. Loftus consulted on the final evaluation of a series of dosimetry measurement quality assurance tests, with representatives of the Lexington and Sacramento Signal Depots (Army), Charleston Naval Shipyard, Aberdeen Environmental Health Facility (Army), and the Armed Forces Missile Command.

14. W. L. McLaughlin gave advice to James Myron of Applied Radiation Energy Corp. on the effects of radiation on acrylic plastics and their prospects for dosimetry, as well as radiation damage.

15. W. L. McLaughlin gave advice to William Slauson of Texas Instruments on high-dose radiation dosimetry for quality control in treating electronic devices (also damage effects in solar cells, mosfits, diodes, etc.).

16. W. L. McLaughlin consulted with William Fitzgerald of Baxter Travenol, Chicago, IL on quality control and medical product release based on traceable dosimetry.

17. W. L. McLaughlin had extended discussions with Doug Weiss and group from 3M Co. on their plans to use electron beams to process thin laminated films for a number of products. They require high-resolution dose mapping for quality control of the new radiation-cured products.

18. W. L. McLaughlin discussed dosimetry with A. Scheve of Hercules Plastics, who plan use of gamma radiation and/or electron beams to cross-linking polymers, e.g. polyethylene, polyethylene-vinyl acetate, to improve their molding properties.

19. W. L. McLaughlin received a visit from Dr. Randy Culp and Dr. Ival Toepke of Bicron Corp., Cleveland, OH, who need assistance in radiation dosimeter design based on radiochromic dyes in liquid and solid phase (neutron dosimetry).

20. W. L. McLaughlin served as Chairman of IAEA Advisory Group Meeting on Dosimetry for Radiation Processing (IAEA, Vienna).

21. W. L. McLaughlin provided detailed advice to Bob Becker of Radiation Dynamics, Inc., Melville, NY, on electron beam mapping and high-resolution dosimetry as a means of quality control - depth data at 1.5 and 2 MeV.

22. W. L. McLaughlin assisted Dr. D. Ross and Vicki Spots of Research Reactor, Univ. of Missouri, with standardization of their high-dose dosimeters.

23. W. L. McLaughlin collaborated with Dr. S. Kronenberg of ERADCOM (Electronics Command), Ft. Monmouth, NJ, in development of tissue-equivalent fibre optics dosimeters for neutron measurements at low-dose equivalents.

24. W. L. McLaughlin provided lectures and assistance in setting up dye dosimetry project at Institute of Physics, University of Mexico.

25. W. L. McLaughlin consulted with Prof. A. Charlesby of UK Royal Military College of Science on radiation effects in polyethylene and means of analysis (ESR, NMR, infrared).

26. W. L. McLaughlin had discussions with Jim McKenzie of Sandia Labs on the possibility of designing thermochromic dye systems similar to radiochromic systems.

27. W. L. McLaughlin advised Joseph Rothleder, State Metrologist of Department of Food and Agriculture, California, on possibilities of use of dosimetry as a safe and effective means of quality control in food preservation by ionizing radiation (especially citrus fruits).

28. W. L. McLaughlin received visitors from Kal-Kan pet and stock food industrial, to discuss prospects for disinfecting and extending shelf life of animal foods.

29. W. L. McLaughlin provided advice and consulting to Donald Spaulding of USDA-Florida (tropical fruits) on radiation dosimetry as a means of quality control and release of wholesome and disinfested fruits to the market.

30. W. L. McLaughlin had an extended discussion with Dr. S. V. Nablo, VP of Energy Sciences, Inc., Woburn, MA, on ways to improve low-energy electron beam dosimetry for radiation curing industries (paints, inks, coil coatings, battery separators, thermal shields, building and insulating materials, etc.).

31. W. L. McLaughlin provided assistance to Jack O'Leary of IBM, San Jose, CA, on ways to thin films for standardizing radiation dose delivery to a variety of heterogeneous materials.

32. W. L. McLaughlin assisted Paula Wells (coop student in NBS Building Research) on ways to determine high resolution dose deposition profiles in honeycomb building materials.

33. W. L. McLaughlin received a one-week visit from Dr. K. Glover of AERE/Harwell, UK, to help them standardize their high-dose dosimetry system using ^{60}Co gamma radiation pool source at NBS.

34. W. L. McLaughlin assisted David Sieverdiz of Valleylab, Boulder, CO, with determinant of electron beam dose rates. He also provided electron collision stopping power data for various compounds.

35. W. L. McLaughlin consulted with William Owens of Isomedix, Inc., NJ, on NBS standard dose traceability for medical device sterilization by ionizing radiation, according to Assoc. for Advancement of Medical Instrumentation (AAMI) protocols.

36. W. L. McLaughlin assisted C. Pollock of NBS, Boulder, with standardization of irradiation of pure and doped alkali halide single crystals, and with analysis of color centers formed at very high doses.

37. W. L. McLaughlin assisted H. Turk of Tremco, Pittsburg, PA, with dose-level and dose-rate affects on irradiated duct-sealing materials used in reactor environments.

38. W. L. McLaughlin provided consultation with R. Novak and R. Morrisy of Johnson and Johnson on the role of standards in maintaining required radiation sterilization levels.

39. W. L. McLaughlin gave advice to Tom Simpson of 3M Company on photochromic systems for ultraviolet actinormity in UV curing of thin layers.

40. W. L. McLaughlin advised Dr. S. Tveekran, Firestone Tire and Rubber Company, on electron beam curing of elastomers and radiation dose distribution measurements in laminated multilayers.

41. W. L. McLaughlin provided consultation with Diane Lopez of Stanford Research Inst. International, to describe dosimetry protocols and regulations for food irradiation, especially at doses less than 100 krad (10^3 Gy).

42. W. L. McLaughlin provided assistance to Atomic Energy of Canada, Ltd., in intercomparison and standardization of their chemical dosimetry systems, so that they can take over regional calibration of high dose dosimeters and relieve overloaded NBS calibration services to U.S. and Canadian industries.

43. W. L. McLaughlin assisted Drs. Backenstow and Steven Resan of Carlisle Tire and Rubber Co., Carlisle, PA, with setting up traceable dosimetry for quality control of radiation processing of elastomers.

44. W. L. McLaughlin provided consultation with Dr. Donald Boure of Army Chemical Corp. (Aberdeen) on development of high-dose neutron dosimeters and standard fission spectrum radiation fields at high-dose rates.

45. W. L. McLaughlin consulted with Dr. Santanu Basu of RayChem Corp., giving him information on high-resolution imaging in dyed thin plastic films - a commercial development they would use in radiation treatment of plastic and electronic components.

46. W. L. McLaughlin consulted with Lt. Paul Blake of Armed Forces Radiological Research Institute on methods of electron beam calibration in Univac radiation fields.

47. W. L. McLaughlin assisted Steven Thomas of Radiation Technology, Inc., in design of special dosimeters for food irradiation quality control.

48. W. L. McLaughlin assisted Dr. M. Nakata of Energy System Group, Rockwell International, in setting up radiochromic dosimetry system for a more accurate radiation measurement capability in photon and electron beams.

49. W. L. McLaughlin provided assistance to Becton Dickinson Company in setting up standardized dosimetry for their new electron accelerator facility at Canaan, CT.

50. W. L. McLaughlin gave a talk and tour, with demonstrations of industrial radiation dosimetry for quality control, to NBS visitors from Plastic Products Manufacturing Association, Research Triangle Park, NC.

51. W. L. McLaughlin assisted Dr. J. Kennerly of Brookhaven National Laboratory's High-Intensity Research Laboratory in setting up a traceable dosimetry program based on NBS calibration and radiochromic systems.

52. W. L. McLaughlin provided Tom Ohlhaber of Bureau of Radiological Health with dosimetry for an Indiana radiation accident involving an x-ray crystallographic facility.

53. W. L. McLaughlin provided consultation with F. Deacon-Smith of Plessy Company (UK) on emerging dosimetry instrumentation and design of albedo dosimeters.

54. W. L. McLaughlin provided consultation for NCRP Committee in writing of proposed new handbook for Federal Emergency Management Agency: "Radiation Safety in Shelters".

55. W. L. McLaughlin provided a design for Laboratory for Radiation and Polymer Science University of Maryland quartz "suprasil" vacuum cells for real-time spectrophotometric and electron spin resonance analysis of thin films during irradiation.

56. W. L. McLaughlin consulted with Martin Bressler of IRT Corp., San Diego, CA, on radiochromic dosimetry and high-dose dosimetry standardization of 10-12 MeV electron beams for various industrial purposes.

57. W. L. McLaughlin provided consultation with Dr. J. McHenry of Houston University of Petroleum and Materials on use of radiation to treat petroleum and minerals as a means of radiation processing.

58. W. L. McLaughlin assisted Tom Fisher of Becton Dickinson Company, Sumpter, SC, Laboratory, in setting up a technician's course in radiation dosimetry for sterility control.

59. W. L. McLaughlin provided assistance to Charles Lawyer of Howmedica, Inc., Rutherford, NJ, in setting up traceable dosimetry and standardization for sterilization of prosthetic devices.

60. W. L. McLaughlin sponsored a high school student (Tom Preisinger) project involving high-dose dosimeter development.

61. W. L. McLaughlin was a host to Dr. J. G. Haides of the International Atomic Energy Agency, Vienna.

62. W. L. McLaughlin assisted J. A. Poublon of Poublon Associates, Inc., Yorba Linda, CA, in designing an indicator dye "go-no go" radiation monitoring system for radiation sterilization applications.

63. W. L. McLaughlin provided consultation to Dr. J. Blank of Radiation Technology, Inc., Rockaway, NJ, in selection of special dosimetry systems for proprietary new radiation industrial applications.

64. W. L. McLaughlin provided trouble-shooting for Dr. John Chasman of 3M Co., for the response in nitrogen of standard radiochromic film dosimeters to low-energy electron beams used for curing thin-film products.

65. J. W. Motz is collaborating with the research staff at Eastman Kodak Company on the development of medical x-ray film which will have the capability of storing more image information content than that contained in the present day medical x-ray films.

66. J. W. Motz consulted with University of Arizona Medical Center on comparisons of analog and digital image processing systems, and comparisons of digital and screen-film imaging systems.

67. R. C. Placious and D. Polansky, in support of other NBS programs, provided radiographic service and consultation to the NBS investigation of the Kansas City Hotel and the East Chicago Bridge disasters. There also exists a continuing service to the Department of Defense in maintaining and improving the radiological programs for the inspection of large diameter rocket motors by defense contractors.

68. S. M. Seltzer is a consultant to the ICRU Committee on Stopping Power.

69. S. M. Seltzer consulted and advised on radiation transport and space-shielding problems with members of the Radiation Effects Branch, Naval Research Laboratory; and with members of Goddard Space Flight Center, NASA.

70. S. M. Seltzer consulted with staff members of the Department of Therapeutic Radiology of the University of Minnesota Hospitals regarding the spatial patterns of energy deposited by electron beams.

71. M. G. Simic is a consultant of the Norris Cotton Cancer Center, Dartmouth Medical School, Hanover, NH.

72. L. V. Spencer and C. M. Eisenhauer prepared a report for the Federal Emergency Management Agency (FEMA) which provides guidelines for research on the protection provided by various types of structures against initial radiations from nuclear weapons.

JOURNAL EDITORSHIPS

Division 533, Radiation Physics

M. J. Berger, Editorial Board, Journal of Radiation Research, Japan Radiation Research Society.

R. J. Celotta, Co-editor, Methods of Experimental Physics, Academic Press.

R. J. Celotta, Member-Editorial Board, Review of Scientific Instruments, American Physical Society, 1982-1984.

W. L. McLaughlin, Editor, International Journal of Applied Radiation and Isotopes.

W. L. McLaughlin, Editor, Radiation Physics and Chemistry.

J. W. Motz, Editor, Computerized Radiology.

H. M. Rosenstock, Member-Editorial Board, International Journal of Mass Spectroscopy and Ion Physics.

CALIBRATION SERVICES PERFORMED

Division 533, Radiation Physics Division

Type of Service	Customer	SP 250 Item No.	Number of Calib'ns or Tests	Income
Calibration of x-ray and γ-ray measuring instruments	1-7	8.3B,C, D,H,I	417	$118K
Irradiation of TL dosimeters	2-6	8.3M,N	32	
Calibration of penetrameters	1	8.3K	1	
Calibration of γ-ray sources	2-4	8.4E,F	8	$ 5K
Calibration of β-particle sources	2,4-6	8.4K	7	
Chemical dosimetry measurement assurance service for electron beams	2	8.5B,C	55	$ 16K
High-dose irradiation	3-7	8.6B	314	
Dose interpretation	4-7	8.6C	26	$ 26K
Spectrophot. reading of dosimeters	4-6	8.6D	492	
Irradiat. of TLD dosims, & prep. of units for shipboard measurement	Navy	N.A.	180	$ 60K
Instrument calibration & evaluation	Nucl. Reg. Commission	N.A.	30	$ 25K
Far UV radiometric transfer standard detectors (photodiode calibrations)	1,3-8	N.A.	29	$ 34K
Totals			1590	$280K

Column 2: 1, calibration labs; 2, hospitals; 3, nuclear energy establishments; 4, industry; 5, US government labs; 6, DoD labs; 7, universities; 8, foreign governments.

Column 4: 8.3, 8.4, 8.6, number of calibrations or tests; 8.5, individual hospitals; N.A., estimates comparable to 8.3, 8.4, 8.6.

Columns 4&5: 8.3-8.6, from Sept. 1 computer print-out, extrapolated to end of FY 82; N.A., comparable estimates.

Division 534, Radiometric Physics

Task No. 11241 (new task no. 15241) - Advanced Optical Radiation Measurements

Task No. 11242 (new task no. 15242) - Maintenance and Dissemination of Optical Radiation Measurements

INTRODUCTION

The Radiometric Physics Division is the primary focal point within NBS for carrying out the traditional Bureau mission of promoting accurate, meaningful, and compatible optical radiation measurements in the wavelength region between 200 nm and 14 μm. The Division fulfills this mission by

- conducting fundamental research aimed at new approaches to optical radiometry,
- conducting applied research to extend existing radiometric standards and calibration procedures,
- maintaining and disseminating the U.S. radiometric scales,
- developing resources of expertise for the solution of radiometric problems within NBS, government, industry, and the public sector.

The Division's efforts are closely coupled to the radiometric programs of other CRR Divisions in the vacuum ultraviolet below 200 nm. The Division also interacts strongly with other programs at NBS, such as the Offices of Measurement Services and Standard Reference Materials, areas of CAC pursuing standards activities in analytical absorption spectrometry and spectrofluorimetry, areas of CBT pursuing vision research and illuminating engineering, and areas of CMS pursuing materials property research. Our staff is engaged in numerous interactions with professional societies and standards committees at the national and international level. These interactions, as well as the feedback received from calibration customers, are essential in ensuring the relevance of our programs.

Since radiometry involves the characterization of electromagnetic radiation generated by sources, propaged by optical systems components, and received by detectors, the research activities of the Division are organizationally subdivided in terms of these three categories of radiometric measurements:

Spectroradiometry and Optical Pyrometry (J. Shumaker, Group Leader) -- Responsible for the development of source standards and improving the accuracy of state-of-the-art radiometric and pyrometric measurements.

Spectrophotometry (J. J. Hsia, Group Leader) -- Provides high-accuracy spectrophotometric measurements and standards, and develops new methods for the radiometric characterization of optical media and components.

Electro-Optics and Quantum Radiometry (J. Geist, Group Leader) -- Develops new, detector-based radiometric standards and methods to complement and extend our traditional source-based capabilities.

The fourth Group serves the vital function of providing measurement services to the Radiometric community at large:

Photometric Radiometric Calibrations (D. A. McSparron, Group Leader) -- Provides, improves, and extends radiometric and photometric calibrations, implements measurement assurance programs, and participates in radiometric intercomparisons.

The following reports of the four Group Leaders show that important progress was made Division-wide during FY 1982. The Spectroradiometry and Optical Pyrometry Group completed applied research that will allow a more efficient realization of our spectral irradiance scale, and also finished a comprehensive study of the effects of coherence in high-accuracy radiometry. The Electro-Optics and Quantum-Radiometry Group gained further insight into semiconductor physics as an independent basis for absolute radiometry, and devised simplified detector configurations and calibration procedures that will facilitate the transfer of photodiode technology to radiometrists in general. Both Groups collaborated with the Far-UV Physics Group of the Radiation Physics Division in the radiometric intercomparison between the NBS synchrotron storage ring (SURF), self-calibrated silicon photodiodes, and blackbody radiation standards. A further effort to implement detector-based radiometry, aimed at allowing developing countries to realize their own photometric base units in terms of the recent redefinition of the candela, was initiated by the Calibrations Group in collaboration with the Egyptian National Standards Institute. The Spectrophotometry Group moved close to completing the development of measurement assurance packages for retroreflection and diffuse reflection, and has already started new programs in photoluminescence spectrometry and high transmission density measurements for non-destructive evaluation. The volume of Standard Reference Materials and special spectrophotometric calibrations provided by this Group increased again during FY 1982. Likewise, the Calibrations Group performed a large volume of pyrometric, photometric and spectroradiometric routine calibrations and, in addition, started a new calibration service in the long-wave infrared (LWIR) spectral region from 2 μm to 25 μm. This new service was developed in close collaboration with the Spectroradiometry and Optical Pyrometry Group, and aims at the accurate characterization of cryogenic blackbodies in a space-like environment.

Division 534, Technical Activities (cont'd)

The continuing evolution of the Division's programs received the full attention of upper NBS management during the fiscal year. Our calibrations and related R&D efforts were reviewed by the Director and won his approval. The Division submitted a major radiometric component to an FY'84 Budget Initiative for increased congressional funding of NBS base activities in measurement science. We also collaborated with the Council on Optical Radiation Measurements (CORM) in formulating the 1982 CORM Report on "Pressing Problems and Projected National Needs in Optical Radiation Measurements." In this report CORM presented, for the first time, a prioritization of needed efforts and urged industry and NBS to work together in solving the problems identified, thus establishing a cooperative "National Measurement System in Radiometry and Spectrophotometry."

SPECTRORADIOMETRY AND OPTICAL PYROMETRY

The program of this group in the Division focuses on providing the standards and techniques required for improving the accuracy of routine as well as state-of-the-art measurements in spectroradiometry and optical pyrometry. Our current efforts in this direction are of two kinds: advances in instrumentation and techniques, and an in-depth study of the theoretical and practical basis of optical radiometry. In the first area we are developing a new NBS pyrometer and improved transfer standards with which we hope to reduce by a factor of three the uncertainties of our temperature scales above 2000 K and of our spectroradiometric scales between 250 nm and 1600 nm. These developments are now possible because of improved facilities reported in previous years for spectral and flux responsivity measurements, advances in automation, and the experience of the Division with stable silicon photodiodes. In the second area we are thoroughly reviewing and systematizing the entire field of radiometry in a series of publications appearing under the general title of Self-Study Manual on Optical Radiation Measurements. In addition to these efforts a significant portion of our resources is devoted to providing measurement services, special calibrations, and consultation for a number of other government agencies and their contractors.

Instrumentation and Techniques

One of the major accomplishments this year was the completion of the basic research paving the way to a more efficient spectral irradiance scale realization process. The technique relies upon our ability to perform rapid, accurate determinations of radiometer linearity with an automated beam conjoiner. With this capability it is no longer necessary to perform the tedious flux matching which has been a characteristic of this scale realization process in the past. A forthcoming scale realization this fall will partially incorporate the new approach to verify its validity.

Current techniques for realizing the International Practical Temperature Scale (IPTS) at 2500 K are accompanied by uncertainties of about 1 kelvin. We expect to improve this by a factor of three (resulting in a 0.1 percent inaccuracy in terms of spectral radiance) by using a new NBS pyrometer now being developed. This instrument uses automation and computer techniques to permit frequent, rapid scale realizations for optimum accuracy. Between scale realizations the scale will be carried on detectors instead of on lamps as at present. Progress on the assembling of the system has been slowed somewhat due to staff shortages and the press of other tasks: continuing maintenance of gold-point blackbodies and the existing pyrometry temperature scale, expansion of the long-wave infrared program, and the continuing administrative overburden.

Nevertheless this instrument system should be undergoing preliminary testing and evaluation within the next month or two.

Studies of the Basis of Accurate Radiometry

Complementing our experimental program to achieve improved accuracies in radiometric measurements is our preparation of a Self-Study Manual on Optical Radiation Measurements (SSM) in which we are attempting to write a thorough treatise on the science of accurate optical radiometry. Although intended primarily to be a means of improving the competence and techniques of the radiometry community within the national measurement system, a vital benefit to NBS of such a complete study is the quantitative delineation of the physical, mathematical, and instrumental approximations and compromises which are inevitable in these measurements, and the resulting refined estimates of accuracy and increased measurement confidence. This project has been under way for half a dozen years now and many fundamental subjects have been treated and published: the distribution of radiation with position, direction, wavelength, and polarization; beam-defining apertures; the slit-scattering function and deconvolution; and the over-all measurement equation.

Chapters on coherence in radiometry and the measurement of solar terrestrial spectral irradiance in the ozone cut-off region have been completed this year. Chapters on blackbody radiation and temperature scales, thermal radiation properties of materials, spectrophotometry, linearity, and the time variable in radiometry have been started this year. These latter two subjects are particularly appropriate now because of the importance of the measurement of detector linearity in our efforts to improve the accuracy of our temperature and spectroradiometric scales and because of the Division's growing interest in pulse radiometry.

Other Agency Projects

Other government agencies continue to provide valuable support in the form of specific tasks which, from our point of view, enable us to acquire equipment or experience which is important to our program.

In previous years the EPA has generously funded research directed toward accurate ground level solar irradiance measurements in the 285-340 nm spectral region. A draft of a description of this work has been prepared for journal publication.

We are continuing to provide BRH with radiometric consultation and instrument evaluation in order to insure a sound spectroradiometric measurement base for their regulatory responsibilities. One

such activity was the calibration of an infrared thermovision camera as a quantitative thermometer.

Our facility for calibrating 200 K-400 K blackbodies in a space-like environment (20 K and high vacuum) was used early this year for performing a special calibration for a DoD contractor. This facility uses an electrically calibrated black detector operating below the lambda point of helium with germanium resistance thermometers for temperature sensing. We have also undertaken two calibrations of 200 K-400 K blackbody sources in a dry nitrogen purged chamber for a DoD contractor. In this chamber a narrow pass band infrared radiometer directly compares the test source with a high-quality variable temperature blackbody whose temperature is measured by platinum resistance thermometry. A feature of this facility added this year is a vacuum chamber to permit operating test sources in a vacuum with a 77 K background.

SPECTROPHOTOMETRY

This group:

(1) establishes and improves high-accuracy spectrophotometric and densitometric scales in the National Measurement System by developing new instrumentation, establishing new measurement capabilities, and improving basic standards;

(2) disseminates these scales by developing measurement assurance programs (MAP), developing transfer standards and standard materials, performing calibration services, and providing consultation to the measurement community; and

(3) studies and develops new methods for radiometric characterization of optical media and components for scientific research and for emerging technologies.

Major achievements were made during FY 82 in the areas of diffuse reflection, retroreflection, transmission, densitometry, and luminescence.

Diffuse Reflection

The diffuse-reflectance standards for the Measurement Assurance Program (MAP) have been recalibrated. The diffuse-reflectance MAP transport package consists of one set of neutral-density filters, one set of 45°/0° and one set of 6°/hemispherical diffuse reflectors. Two completed diffuse-reflectance transport packages were sent to two instrument manufacturers to serve as a pilot MAP.

The Group Leader has been appointed International Chairman of the CIE Subcommittee on Standards and Technique in the Committee on Characterization of Materials. He has served as discussion leader of Session 5 on wavelength selection during the 1982 USDA Conference on Diffuse Reflectance Spectroscopy.

Retroreflection

Studies on the MAP transport package reached the final stage. A fractional factorial design experiment requiring 486 measurements was performed on the two-orientation hexagon cube corner reflector. This study permits estimation of errors due to geometrical setting errors. Measurements were performed on the complete package periodically to establish an internal NBS MAP by means of control charts. One MAP transport package was sent to an instrument manufacturer, and one

package was sent to a manufacturer of retroreflectors to serve as a pilot MAP. The package was received favorably by the two laboratories.

The instrument has been put under control of a dedicated microcomputer with increased measurement efficiency.

A light source and a detection system have been prepared for the purpose of making spectral measurements of chromaticity of retroreflectors under night-time geometry. However, due to other projects with higher priority this project is to be postponed.

Group personnel consulted with ASTM Committee E-12 on the statistical data analysis of an intercomparison, and on the preparation of a precision statement for an ASTM test method for measuring retroreflectors.

Transmission

Several sets of neutral density filters have been re-calibrated. These filters are for linearity checking in the diffuse reflectance MAP package.

The CCG Project 81-153, with the assistance of a guest worker, is near completion. The purpose of this project was to extend the range of our high-accuracy reference spectrophotometer from 800 to 2500 nm. This required changing the source, grating, and detector. Construction of an averaging sphere with a bell assembly to contain a new thermoelectrically cooled PbS cell was completed. Also, we required a chopped system utilizing a lock-in amplifier. A microcomputer system with an NBS developed interfaced system was connected to the spectrophotometer for data acquisition and data analysis. Software was developed to acquire data for different characterization needs, and data were analyzed. Characterizations included instrument sensitivity functions, uniformity of the receiver system, beam stability of the system, wavelength calibration, stray light, and linearity (using the double aperture system). The latter was accomplished by using two lenses of equal focal length to image the tungsten source on the chopper blade and then re-collimate the beam.

Staff members consulted with Rensselaer Polytechnical Institute on spectral transmittance of liquid filters for realizing one of the standard CIE Illuminants. Staff members also participated in the determination of transmittance of some fused quartz windows to be used for the radiometric intercomparison with SURF.

Densitometry

Development of high optical density (up to approximately 5.8) standards is under way. Automation of the inverse fourth apparatus

is nearing completion. This experiment will be controlled by means of a microcomputer. The sample will be moved step-by-step and inserted into the beam automatically as well as automation of the photometric measurement. Characterization of the color temperature of the light incident on the sample has been completed. It was found that the source complies with ANSI specifications.

Luminescence

The NBS reference photoluminescence spectrometer has been moved from the Chemistry Building to a laboratory of the Radiometric Physics Division in the Metrology Building. The process of putting it into working status is underway. It is anticipated that a new program on fluorescence will be initiated in FY83.

ELECTRO-OPTICAL AND QUANTUM RADIOMETRY

The Electro-Optics Group is responsible for (1) providing the basis for photophysical process characterization in the National Measurement System, (2) developing a new detector based radiometry that is different both in conception and execution than the classical approach based on standard sources of optical radiation, and (3) de-developing new electro-optical technology for radiometric application. As was the case last year, the major part of the Group effort was devoted to studies of silicon junction diode physics as a basis for accurate radiometry.

The analysis of the silicon quantum yield spectra taken a year and a half ago in Australia has been completed. The possibility (mentioned in last year's report) that the prominent feature in spectra near 4.5 eV was an artifact of the reflectance measurements has been ruled out. The average of the quantum yields for the three diodes measured in Australia is shown in fig. 1. Also shown there is the result of a new calculation done by Geist in collaboration with C. S. Wang of the University of Maryland and R. C. Alig of RCA, Princeton. Most of the differences between the two spectra can be understood in terms of the differences between the band structure of silicon and the self consistent, first principles band structure used in the calculation. In connection with these calculations, Gladden and Geist also completed a study of Kane's random k approximation to the transition rate for impact ionization that verifies its usefulness at least for indirect gap semi-conductors.

One possible cause (other than experimental error) of the diode-to-diode differences in quantum yield that were discussed in last year's report has been discovered. J. R. Lowney of the NBS Center for Electronic and Electrical Engineering has suggested that the screening of the electron-electron interaction, which determines the matrix elements for impact ionization, might depend upon dopant density and the condition of accumulation or depletion near the oxide-silicon interface where the ultraviolet radiation is absorbed. We intend to study this possibility experimentally and theoretically next year.

If the quantum yield does turn out to be sensitive either to doping or to the net charge density near the interface, silicon photodiodes will not be suitable as high accuracy standards in the ultraviolet. However, GaP, which has a band gap twice as large as silicon, is being studied as a material for electronic devices that operate at high temperatures. Devices with very favorable properties have already been constructed, and high quality GaP photodiodes seem within the state-of-the-art of current technology. Because of its large band gap, the quantum yield of such diodes should be unity

below about 6 eV (above about 200 nm). Thus the prospects for a high accuracy absolute detector standard in the near ultraviolet remain promising.

In this connection, it is of interest that during the last year, we were able to negotiate a collaborative research grant with Prof. R. J. Schwartz of the Purdue University School of Electrical Engineering to develop standards grade Ge photodiodes. If this project succeeds, we would use these photodiodes to extend self-calibration into the near infrared. Also, if this project succeeds, Prof. Schwartz has indicated a desire to continue the joint project with GaP in an attempt to extend self-calibration into the near ultraviolet.

During the last year, Schaefer and Zalewski concluded a study of minority carrier recombination in the region between the junction and the rear of the diode, and its role in non linearity, spatial non-uniformity of response, and reduced quantum efficiency When these occur in the infrared, they are all symptoms of the same problem, a high recombination center count in the region between the junction and the rear of the diode. Therefore, part of the self-calibration procedure, the measurement of photoresponse as a function of reverse bias, turns out to be a simple test with which to screen silicon photodiodes for linearity and uniformity of response in the red.

During the last year, Booker and Geist studied the physics of new off-the-shelf inversion layer photodiodes from UDT. These are improved versions of devices that we investigated during their development by UDT. We have verified that oxide bias is not needed in order to obtain above 99.9% collection of the photogenerated minority carriers in these devices. Reverse bias is still needed with red and infrared radiation to extend the depletion region toward the rear of the diode in order to collect all of the minority carriers created by penetrating radiation, and also at moderately high flux levels in order to keep the relatively high I·R drop across the inversion layer from forward biasing the diode. At the sub-tenth percent level, we see effects that we do not yet understand, but nevertheless, these diodes make a very suitable high accuracy standard for the visible spectral region.

In this connection, Zalewski tested a multiple reflection configuration of inversion layer photodiodes from UDT that, with sufficient reverse bias, provides 99.9 ±0.2% external quantum efficiency for low level laser power measurements throughout the visible. With this type of standard, self-calibration is not necessary. Reverse bias is applied and the measurements made. Zalewski has also optimized the design of the multiple reflection configuration for increased quantum efficiency while accommodating higher solid angle radiation, and will test it next year.

Also last year, Booker and Geist discovered the mechanism by which ultraviolet radiation causes the response of the EG&G UV 444A photodiodes to increase for a period lasting from hours to days after sustained irradiation. It turns out that ultraviolet radiation photoexcites electrons from interface traps into the silicon dioxide conduction band. The electrons then cross the ∿30 Å thick oxide and are stored on the oxide surface in the same way as if they had been deposited there by a corona discharge to the surface. Once there, the stored electrons repel minority carriers from the oxide-silicon interface where they would recombine. The proof that this was indeed the mechanism was simple once it had been proposed (by a group at Fort Monmouth, N.J., to explain some anamolous results in electron-spin-resonance studies of the oxide-silicon interface). A drop of ethylene glycol was put on the oxide surface of the UV 444A diode, and the quantum efficiency of a region of the diode under the drop was enhanced by ultraviolet irradiation. The drop was then grounded, and the quantum efficiency was observed to decrease to the pre-irradiation value within a few minutes. This period is consistent with the capacitance of the oxide and the resistance of the ethylene glycol drop, and contrasts strongly with the tens of hours decay period of an ungrounded surface. The latter period is consistent with the capacitance and surface resistance of the oxide.

During last year, Zalewski observed the existence of an oxide bias induced hysteresis effect that was also described to us by Peter Key of the UK National Physical Laboratory. Figure 2 shows the quantum efficiency of a photodiode as a function of time while its surface is subjected to repeated cycles of OV and - 46 V bias. This effect was also observed at the PRC National Institute for Metrology by a former NBS guest worker, Li Tong-Bao. It is as if the passivation (rendering ineffective for recombination) of surface states involves a complex consisting of a mid-gap state, an electron and some neutral species, where the complex is stable even when the Fermi energy is well below the level of the un-occupied surface state. Apparently, the electron can be ejected from the complex by absorption of a sufficiently energetic photon or by stimulation by a sufficiently strong field (caused by negative charge on the oxide surface). Once the electron is ejected from the complex, the neutral species is presumably free to diffuse through the silicon and/or the oxide, and if the surface state is above the Fermi level, it increases the recombination rate. As a result, the self-calibration procedure must be carried out after a measurement of radiant flux, rather than before, if the highest accuracy is desired. This problem with oxide bias makes the inversion layer diodes all the more desirable as absolute standards since they require no oxide bias.

The intercomparison between silicon self-calibration and electron counting on the NBS SURF II finally took place this year. The quantum efficiencies of two photodiodes with nominal 10 nm band pass filters centered at 600 nm were calibrated against a self-calibrated photodiode at ∿ 1 Å intervals by Schaefer and R. J. Saunders of the Spectroradiometry Group. The radiation was obtained from an amplitude stabilized dye laser; the wavelength was measured interferometrically at each wavelength

with a wavemeter. The intercomparison between the filtered photodiodes and the SURF monitor diode was conducted with about 100,000 electrons circulating in the ring. The SURF monitor diode was calibrated by counting down from about 400 to about 300 electrons. The linearity of the monitor diode was tested by comparing its response when unfiltered to its response when filtered with a $V(\lambda)$ filter.

At the time of this writing, the two filtered photodiodes agree to within about 1% in their assessment of the radiant power per electron from SURF II, but differ by about 6% from the power assessment based on electron counting. Because they differ by the same amount in their assessment of the spectral irradiance from a calibrated standard lamp, it is clear that the fault lies with the calibration of the filtered photodiodes. Since this type of calibration has been carried out successfully in the past, the 6% discrepancy does not indicate a fundamental problem with the procedure for calibrating the filtered photodiodes, but rather seems to be the result of an isolated, non-essential error. Currently, we suspect deterioration of the interference filters between the time of the filtered diode calibration (late May) and the time of the SURF II intercomparison (late August).

There is a brighter side. Consider the filtered photodiodes as transfer standards used to measure the irradiance from SURF II one week and the irradiance from the standard lamps the next. The result is that the blackbody theory based standard agrees with the synchrotron theory based standard at the 1% level, which is the precision of the comparison. As pointed out below in connection with the silicon detector based calibration of FASCAL, we also know that the quantum yield theory based and blackbody theory based standards agree to at the 1% level. The demonstration of this level of agreement between the three scales is in itself useful.

In connection with the SURF II intercomparison, Fowler developed a detector-op-amp configuration that provides greater immunity to pick-up noise than those that we used previously. He also tested the feasibility of digital measurement and control of an electrically calibrated pyroelectric radiometer with an 8 bit microcomputer. However, to get sufficient precision and dynamic range, it was necessary to use a 16 bit A-to-D converter. The overhead in reading and processing the 16 bit words on an 8 bit machine slowed the system too much to be practical. He will test the concept with a 16 bit computer when one becomes available to us. Also this year, Fowler has designed and prototyped a versatile, dual channel, current-to-voltage converter/ratio meter with variable voltage supplies that is specifically designed to facilitate silicon based radiometry. Next year he will have a number of units built for routine application in various Division projects.

The first full recalibration of the DRIP radiometers since their initial distribution was completed this year by Gladden and Zalewski.

They measured both spectral response and the reflectance of the radiometers at several of the laser lines readily accessible in the detector characterization facility. They showed that reflectance interpolation based on published optical constants worked reasonably well over the visible, but was a more severe problem in the ultraviolet.

They also continued their detector based measurement of spectral irradiance, repeating both the silicon spectral response recalibration of FASCAL and the measurement of lamp irradiance with FASCAL. At the time of this writing there appears to be a 1% discrepancy between the source based and detector based measurement of spectral irradiance. However, the source based recalibration of the lamps used in this intercomparison is not yet complete.

Zalewski also assembled and characterized several detector-diffuser assemblies for the self-calibration intercomparison that he is coordinating for the CIE. He tested the feasibility of measuring the quantum yield of the luminol chemical fluorescence against silicon photodiode standards of spectral response in collaboration with Ian Matheson of the University of Georgia. The preliminary results were very promising and we expect the chemistry, rather than the radiometry, to limit the accuracy of the final results.

Finally, Cohen has completed his review of noise in general and noise in photodiodes in particular, and has written up his findings in three reports which have stimulated considerable thought and discussion about these topics. During the last year he started a study of infrared thermography for non-destructive testing under the sponsorship of the NBS NDE program.

PHOTOMETRIC-RADIOMETRIC CALIBRATIONS AND MAP

This group provides a firm measurement base for the Nation's optical radiation community (defense and aerospace, instrument manufacturers and commercial calibration laboratories, lighting and photographic industries, research institutions, etc.). To accomplish this objective, the group:

(1) maintains the U.S. photometric and radiometric scales and provides, improves and extends the NBS calibration services for the basic photometric and radiometric quantities--radiance temperature, spectral radiance, spectral irradiance, detector spectral responsivity, luminous intensity, luminous flux and color temperature.

(2) engages in activities such as intercomparisons, measurement assurance programs, consultations and ad hoc experiments that will insure that measurements made in laboratories outside NBS are being made at acceptable levels of accuracy.

As in the past, much of the group's activity has been devoted to the calibration program during FY 1982. Calibration volume increased about 10 percent during the year and now consumes about 50 percent of the group's effort. Several improvements were made in the facilities devoted to calibration services. New microcomputers have been installed on the Facility for Automatic Spectral Calibrations (FASCAL) and the software conversion is substantially complete. A FASCAL compatible, variable high temperature blackbody for pyrometric calibrations has been designed and construction is about 50 percent complete.

Improved documentation of the routine calibration services received considerable attention. New write-ups describing the calibration procedures have been prepared and issued for the spectral radiance and the luminous flux standards. The availability of appropriate personnel outside the Division's regular staff permitted additional effort toward meeting the documentation guidelines of the NBS Calibration Advisory Group. As a result of this additional effort an NBS Technical Note describing the realization of the spectral radiance scale is now in draft form.

International acceptance and compatibility of the NBS radiometric and photometric scales is a concern of the group. A considerable effort was devoted to preparations for the September 1982 meeting on the Consultative Committee on Photometry and Radiometry (CCPR). The CCPR, an advisory committee functioning under the Treaty of the Meter, addresses optical radiation measurement problems at the international level, primarily by organizing intercomparisons. Of particular note

in the NBS preparations for this meeting was a bilateral spectral radiance intercomparison conducted with the National Physical Laboratory, England. Two specially built British tungsten strip lamps have been evaluated and proposals for their use in an international intercomparison will be presented to the CCPR.

The calibration program of the Radiometric Physics Division is constantly being updated. At the beginning of this year, the luminous directional transmittance standards were identified for possible phase-out. The availability of an alternative standards base (the NBS scale of spectral radiance) and the low volume in recent years (approximately 5 items per year) suggested this action. Input from the user community has been solicited through articles and talks. A decision will be made shortly as to whether to begin a three-year phase-out period.

The technical opportunities offered by the development of silicon cell technology have continued to receive attention, particularly in the area of the realization, maintenance, and dissemination of photometric scales. Mosaically-filtered, photopically-corrected silicon cells have been examined for $V(\lambda)$ response at several laser wavelengths (maximum deviation observed: 1.25 percent) and for linearity (maximum deviation observed: less than 0.2 percent). Testing, particularly with respect to long-term stability will continue into the coming year. An experiment designed to realize photometric scales through silicon cells and filter radiometry has been planned and procurement begun. It will be carried out next year in collaboration with a guest worker from Egypt.

A major expansion of the infrared activities of the group has been initiated. Optical systems operating in the 2 to 25 micrometer, long wave infrared (LWIR) spectral region are becoming increasingly important to the nation's defense effort. Such systems are used for weapons guidance and surveillance. The low signal levels involved pose extremely severe calibration problems. LWIR calibrations and other agency projects totaling more than $75K were performed during the year. A five-year program to upgrade the NBS calibration facilities, investigate error mechanisms, and extend the capabilities of the NBS equipment to lower input signal levels has been formulated. A major attempt to obtain other agency funding for this program is now underway.

SPONSORED CONFERENCES

Division 534, Radiometric Physics

Council for Optical Radiation Measurements, NBS Gaithersburg, May 11-12, 1982.

INVITED TALKS

Division 534, Radiometric Physics

D. A. McSparron, "The Future of Luminance Standards", Electronics Industries Association, Committee on Optical Characteristics of Display Devices, Washington, D. C., March 5, 1982.

D. A. McSparron, "DoD and the NBS Optical Radiation Program", 1982 Measurement Science Conference, San Diego, California, January 22, 1982.

A. R. Schaefer, Invited Lecture Tour of People's Republic of China, State Bureau of Metrology - Beijing, Chengdu, Wuhan, and Shanghai, June 17 -July 4, 1982.

A. R. Schaefer, "Characterization of a Silicon Filter Radiometer and Intercomparison with NBS SURF", Electro Technical Laboratory, Tsukuba City, Japan, July 6, 1982.

E. F. Zalewski, "The Quantum Yield of Silicon Photodiodes - A New Basis for Absolute Photon Flux Measurements and Spectrofluorimetry", Dept. of Chemistry, University of Maryland, College Park, MD, March 5, 1982.

E. F. Zalewski, "Calibrations and Corrected Spectra - Tried, True and New", ASTM Symposium on New Direction in Molecular Luminescence, Atlantic City, NJ, March 10, 1982.

PUBLICATIONS

Division 534, Radiometric Physics

Apel, C. T., Keller, R. A. and Zalewski, E. F., "Optogalvanic Effect in a Hollow Cathode Discharge with Non Laser Sources", Appl. Opt. 21, 146 5 (1982).

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Booker, R. L. and Geist, J., "Photodiode Quantum Efficiency Enhancement at 365 nm: Optical and Electrical", Appl. Opt. (Accepted for Publication).

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Eckerle, K. L. and Hsia, J. J., "Proposed Standards for NBS Retroreflection MAP", Color Research and Applications 7, 235 (1981).

Geist, J., Liang, E. and Schaefer, A. R., "Complete Collection of Minority Carriers from the Inversion Layer in Induced Junction Diodes", J. Appl. Phys. 52, 4879 (1981).

Geist, J., Farmer, A. J. D., Martin, P. J., Wilkinson, F. J., and Collocott, S. J., "Elimination of Interface Recombination in Oxide Passivated Silicon p^+n Photodiodes by Storage of Negative Charge on the Oxide Surface", Appl. Opt. 21, 1130 (1982).

Geist, J., Gladden, W. K., and Zalewski, E. F., "Physics of Photon-Flux Measurements with Silicon Photodiodes", J. Opt. Soc. Am. 72, 1068 (1982).

Hsia, J. J. and Weidner, V. R., "NBS 45°/Normal Reflectometer for Absolute Reflectance Factors", Metrologia 17, 97 (1981).

Hughey, L. R. and Schaefer, A. R., "Reduced Absolute Uncertainty in the Irradiance of SURF-II and Instrumentation for Measuring Linearity of X-ray, xuv and uv Detectors", Nuclear Instruments and Methods 195, 367 (1982).

Kostkowski, H. J., Saunders, R. D., Ward, J. F., Popenoe, C. H., and Green, A. E. S., "Self-Study Manual on Optical Radiation Measurements, Part III --Applications, Chapter I, Measurement of Solar Terrestrial Spectral Irradiance in the Ozone Cut-Off Region", to be published as an NBS Tech Note in the 910-series.

Mielenz, K. D., Weidner, V. R., and Burke, R. W., "Heterochromatic Stray Light in UV Absorption Spectrometry: A New Test Method", Appl. Opt. 21, 3354 (1982).

Mielenz, K. D., "Measurement of Photoluminescence", in Optical Radiation Measurements, Vol. 3, (K. D. Mielenz, editor), Academic Press, NY, 1982.

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Mielenz, K. D., Costa, L. F. and Grum, F., "Correction of Emission Spectra", in Optical Radiation Measurements, Vol. 3 (K. D. Mielenz, editor), Academic Press, NY, 1982.

Shumaker, J. B., "Self-Study Manual on Optical Radiation Measurements, Part I--Concepts, Chapter 10, Introduction to Coherence in Radiometry", to be published as an NBS Tech Note in the 910-series.

Weidner, V. R. and Hsia, J. J., "Standard Reference Materials: Preparation and Calibration of First-Surface Aluminum Mirror Specular Reflectance Standards", NBS Special Publication 260-75 (May 1982).

Zalewski, E. F., "Radiometry: New Developments Relating to Spectrofluorimetry and Photon Yield Measurements", in Optical Radiation Measurements, Vol. 3, (K. D. Mielenz, editor), Academic Press, NY, 1982.

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 534, Radiometric Physics

Robert L. Booker

Member and Secretary, U.S. Panel of CIE TC-1.6 on Fundamentals of Visual Signalling.

Member, U.S. Panel of CIE TC-1.4 on Vision: Photopic, Mesopic, and Scotopic.

Member, U.S. National Committee of the CIE.

Robert J. Bruening

Secretary, National Capital Section of the Optical Society of America.

Jon C. Geist

U.S. Representative of TC-2 - Photon Detectors Committee of the International Measurement Confederation (IMEKO).

Member, Program Committee for the 1982 International Electron Devices Meetings (iedm).

Jack J. Hsia

Chairman, International Subcommittee on Standards and Techniques of CIE TC-2.3 on Properties of Materials.

Member, U.S. Panel of CIE TC-2.3 on Properties of Materials.

Member, ASTM D-1.26 Subcommittee on Optical Properties of Paint, Varnish, Lacquer and Related Products.

Member, ASTM E-12 Committee on Appearance of Materials.

Member, ASTM E-37 Committee on Thermal Measurements.

Delegate from ASTM to ISCC.

NBS Representative, ANSI Committee PH2 on Sensitometry and Subcommittee PH2-28 on Densitometry.

Donald A. McSparron

Member, ANSI Z311 on Photobiological Safety of Lamps.

Member, Lamp Testing Engineers Conference.

Member, Illuminating Engineering Society (IES) on Testing Procedures.

Member, U.S. Panel of CIE TC-1.2 on Photometry and Radiometry.

Klaus D. Mielenz

Secretary, U.S. National Committee of the CIE.

Chairman, CIE International Technical Committee TC-2.3 on Properties of Materials.

Member, ASTM E-13 on Molecular Spectroscopy

Member, ASTM E-13.06 on Luminescence.

Member, Comite Consultatif de Photometrie et Radiometrie

Board of Directors (ex officio), Council on Optical Radiation Measurements.

Robert D. Saunders

Member, IES Committee on Photobiology.

Member, Illuminating Engineering Research Institute (IERI) Committee on Extra Visual Effects.

A. Russell Schaefer

Member, U.S. Panel of CIE TC-2.2 on Detectors and Photometric Instruments.

Member, Teller's Committee of Optical Society of America

John B. Shumaker

Member and U.S. Coordinator of U.S. Panel of CIE TC-2.3 on Polarization.

Edward F. Zalewski

Chairman, U.S. Panel of CIE TC-2.2 on Detectors.

Member, U.S. Panel of CIE TC-1.2 on Photometry and Radiometry.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 534, Radiometric Physics

1. R. L. Booker assisted the NBS Center for Building Technology and the Naval Coastal Systems Center in planning and conducting a field experiment to determine the difference at sea in the visual range of surfaces illuminated by known amounts of either low pressure sodium (LPS) or red light. Recommendations were also made regarding a land-based experiment, with observations over water, that offers better control over the experimental variables.

2. K. L. Eckerle provided consultation to ASTM Committee E-12 on statistical analysis and precision statement for ASTM method on retroreflectance measurements.

3. K. L. Eckerle provided consultation to Ellen Gerrity and Prof. Fred Billmeyer, Jr. on spectral transmittance measurements of liquid filters.

4. J. B. Fowler provides ongoing consultation in the area of microcomputer hardware and software to other divisions within NBS.

5. J. B. Fowler is a member of the Microprocessor subcommittee of the NBS Electronics Storeroom Committee.

6. J. J. Hsia provided consultation to EPA-ESRL Peer Review Program on "Evaluation of Trained (Method 9) VE Observers for Fugitive Emission Opacity Measurements" (Contact: Barbara Framer, Jeffalyn Johnson and Associates, Inc., Falls Church, VA.) January 15, 1982.

7. E. Lewis and J. H. Walker provided consultation and a special calibration of a novel prototype optical pyrometer operating in the near infrared to personnel from Leeds and Northrup Corporation.

8. D. A. McSparron provided consultation to NASA (Goddard) and to the Aerospace Division of Ball Brothers (Prime Contractor) on the calibration of a Solar Backscatter Ultraviolet Radiometer (SBUV) for use in the NASA/NOAA solar monitoring program.

9. D. A. McSparron provided consultation to Jerry Terrell of the Naval Avionics Facility (Indianapolis) on traceability and measurement consistency to meet photometric and colorimetric Mil specs.

10. D. A. McSparron provided consultation to Frank F. Koblitz of AMP Corporation on optical characterization of the photo-polymerization of dental materials.

11. D. A. McSparron and K. D. Mielenz consulted with Charles Showalter and Robert Landry of the Bureau of Radiological Health on the calibration of sensitometers as a control method for limiting x-ray dosage in medical diagnosis.

12. K. D. Mielenz visited the National Institute for Standards (NIS) in Cairo, Egypt, from May 15 to 21, 1982, to assist the Photometry Laboratory of NIS in establishing a standards base traceable to NBS.

13. C. H. Popenoe, Member of Microprocessor Subcommittee of the NBS Electronics Storeroom Committee.

14. J. H. Walker and D. A. McSparron provided consultation and a special calibration of the Faint Object Spectrograph for the Space Telescope to John McCoy of Martin Marietta Corporation.

15. V. R. Weidner provided consultation to Dr. Elian Greenbaum of the Oakridge National Laboratory regarding the design of instrument and measurements of absorption for liquid with particles.

16. C. R. Yokley consulted with Todd Gilmore of Lockheed and Willard Birtley of Rockwell International on the design, construction and calibration of cryogenic blackbodies for long wave infrared DoD research program.

17. E. F. Zalewski is providing consultation on the measurement of absolute photon yields of chemi-luminescence reactions to members of the Department of Biochemistry of the University of Georgia.

18. E. F. Zalewski is providing consultation on the optogalvanic effect to staff members of the Los Alamos National Laboratory.

TRIPS SPONSORED BY OTHERS

Division 534, Radiometric Physics

R. L. Booker, airfare and per diem supplied by the Naval Sea Systems Command through the Center for Building Technology to plan and conduct a visual range experiment, Panama City, FLorida, Oct. 21-22 and Dec. 14-19, 1981.

A. R. Schaefer, Lecture Tour of the People's Republic of China, sponsored by Protocol Agreement between NBS and Chinese State Bureau of Metrology, National Institute of Metrology, Beijing; Institute of Measurement and Test Laboratories, Dayi County and Chengdu, Sichuan Province; Hupei Provincial Bureau of Metrology, Wuhan; and Shanghai Bureau of Metrology, Shanghai.

STANDARD REFERENCE MATERIALS

Division 534, Radiometric Physics

1. SRM 1001, X-Ray Film Step Tablet

   Used in the calibration of optical densitometers and similar equipment used in the photographic, graphic arts, and x-ray fields. Certified for Optical Densities from 0 to 4.

2. SRM 1008, Photographic Step Tablets

   Used in the calibration of optical densitometers and similar equipment used in the photographic and graphic arts fields. Certified for Optical Densities from 0 to 4.

2. SRM 1008, Photographic Step Tablets

   Used in the calibration of optical densitometers and similar equipment used in the photographic and graphic arts fields. Certified for optical densities from 0 to 4.

3. SRM 1010a, Microcopy Resolution Tests Charts

   Used for determining the resolving power of microcopy systems.

4. SRM 2061, Reflection Step Tablets

   Used in the calibration of reflection densitometers and similar equipment used in the photographic and graphic arts fields. Certified for optical density from 0 to 2.

5. SRM 2019 and 2020, White Ceramic Tile for Directional-Hemispherical Reflectance from 250 to 2500 nm,
   SRM 2021 and 2022, Black Porcelain Enamel for Directional-Hemispherical Reflectance from 250 to 2500 nm.

   For use in calibrating the reflectance scale of integrating sphere reflectometer.

6. SRM 2003a, First Surface Aluminum Mirror for Specular Reflectance from 250 to 2500 nm.

   SRM 2023, Second Surface Aluminum Mirror for Specular Reflectance Specular Reflectance from 250 to 2500 nm.

   For use in calibrating the photometric scale of specular reflectometers

7. SRM 2009, 2010, 2013, and 2014 Didymium-Oxide glass as Wavelength Standards between 400 and 760 nm.

CALIBRATION SERVICES PERFORMED

Division 534, Radiometric Physics

Type of Service	Customer	SP 250	Number of tests	Income	
Pyrometry		7.4 A thru G	30		$30K
	Defense & Aerospace		13	$12K	
	Instrument & Cal labs		6	$ 5K	
	Lighting & Photography		3	$ 4K	
	Foreign		1	$ 1K	
	Electrical & Materials		7	$ 8K	
Spectroradiometry		7.5 A thru H	38		$88K
	Defense & Aerospace		12	$46K	
	Instrument & Cal labs		13	$17K	
	Lighting & Photography		4	$ 6K	
	Foreign		9	$19K	
Photometry		7.6 A thru M & 7.7 B thru F	16		$25K
	Defense & Aerospace		6	$ 7K	
	Instrument & Cal labs		5	$ 3K	
	Lighting & Photography		3	$ 6K	
	Foreign		2	$ 9K	
Spectrophotometry		7.8 A thru I	25		$17K
	Defense & Aerospace		7	$ 7K	
	Instrument & Cal labs		5	$ 2K	
	Lighting & Photography		5	$ 3K	
	Foreign		1	$ 2K	
	Electrical & Materials		7	$ 3K	
			109		$160K

TECHNICAL ACTIVITIES

Division 535, Radiation Source and Instrumentation

Task No. 11252 (new task no. 15252) - Provide linac beam
Task No. 11253 (new task no. 15253) - FASTBUS instrumentation specification
Task No. 11254 (new task no. 15254) - Design, install and test microtron components

CW Microtron Project

This project, sponsored by the Division of Nuclear Physics of the Department of Energy is a joint effort of the Radiation Source and Instrumentation Division of CRR and the Accelerator Technology Division of the Los Alamos National Laboratory. The goal of this project is to determine the feasibility of building a 1 to 2 GeV, 100% duty factor electron accelerator with a beam current in excess of 100 μA using beam recirculation and room temperature rf technology. An accelerator with these operating parameters has been identified as a major need of the national nuclear physics community by serveral high level committees charged with determining future needs and priorities of the national effort in nuclear physics.

An essential part of the program is the design, construction and operation of a demonstration racetrack microtron (RTM) of sufficient size to provide a meaningful test of components and beam performance. The RTM will be built and operated at NBS. Its design calls for a beam energy of 185 MeV and a current of 550 μA. This machine, in addition to demonstrating the feasibility of building a 1 to 2 GeV machine using the same technology, will be a powerful tool in its own right for nuclear physics research and several other NBS programs.

The total estimated cost of this project is $10.4 million for the 5-1/2 years needed to design, build, and demonstrate the operation of the accelerator. The collaboration between NBS and Los Alamos brings together the unique expertise of Los Alamos in the area of rf accelerator structures and systems with the expertise at NBS in particle beam dynamics and accelerator technology.

At the end of the third year of this project most systems of the RTM are well into the construction and/or installation phase. Thus far, no insurmountable technical problems have arisen. Operation of the 100 keV injector beam has begun, as has construction of the end magnets. An important but unexpected result during the past year was the discovery by Los Alamos that the disc and washer accelerating structure is unsuit-

able for cw electron accelerators. An alternative structure (side-coupled) is being developed by Los Alamos for the RTM with no relaxation of performance specifications. A one-year delay of the project completion date to May 1985 will be necessary to accomodate the extra rf structure development work.

Planning for New Facility

We are designing a 800 MeV CW microtron. This accelerator is a scaled up version of the present 200 MeV RTM design. The two accelerators used in combination would then produce a 1000 MeV continuous duty electron beam of up to 300 μA for use in nuclear reaction studies of the type (e,e'x) and (γ, x) with tagged photons. We are also designing a building to house the 800 MeV accelerator and two new experimental halls. Together with the nuclear research group (532), who are designing the experimental equipment for a 1000 MeV resarch program, we will make a proposal to the DoE and NSF for construction and operation of a national user facility for electromagnetic nuclear research.

Consulting and Advisory Services

The application of accelerators and accelerator technology is growing at a tremendous rate, as evidenced by the fact that there is at present a severe nationwide shortage of trained accelerator physicists and engineers. Older applications of accelerators in fields such as cancer therapy, medical diagnostics, curing of paints and plastics, nuclear and high energy physics research, and many others are well known. Newer applications in such areas as fusion energy sources (both magnetic and inertial confinement fusion schemes do or might employ particle accelerators), weapons, weapon effects simulation, and materials research demand new types of accelerators with performance characteristics far beyond what was thought possible a few years ago. NBS has an excellent reputation in the accelerator community, based largely on important contributions made in the past, and therefore we are constantly being called on to provide consulting and advisory services, as well as specific research work. Requests for our services in this area have come from many agencies including DoD, DoE, NSF, NASA, as well as a number of universities and industrial organizations. In the past year, P. Debenham has served as a consultant to the University of Maryland on the design of a magnetic spectrometer to be installed at the University of Indiana. He has also advised the University of Illinois on the design of end magnets for a racetrack microtron. Although our in-house research programs on DoD accelerator needs have been phased out, both M. Wilson and S. Penner will continue to provide consulting services as requested.

LINAC OPERATIONS

Division 535, Radiation Source and Instrumentation

The NBS Electron Linac was designed in 1960 with maximum flexibility in order to support a wide variety of program activities of interest to NBS. Major users of the linac in FY 1982 included programs in neutron cross section standards and radiography, high energy electron scattering, electron activation, photonuclear research, and activation analysis. The last is an activity of the Center for Analytical Chemistry. In addition, a number of outside collaborators and guest workers participated in the above mentioned programs.

The Linac Operations staff normally consists of three engineers and seven technicians. At present the staff consists of only two engineers and four technicians. In spite of its relatively small size this group has achieved a highly commendable operating efficiency as described below. The staff operates and maintains the facility as well as designs, constructs, and installs new equipment to improve operations and extend the capability of the Linac and the beam handling system. The mechanical instrumentation group within the Division provides help by maintaining the integrity of the vacuum and cooling systems of both the Linac and beam handling system as well as designing, construction, and installing mechanical components. Table I shows the distribution of the total Linac Operations staffing time in the operation of the facility for FY 1982 (through August 1982). The facility is staffed from 7:30 am Monday morning and runs for experiments until 6:30 am Saturday. Scheduled maintenance hours have varied throughout the year.

Experiment time on the facility was requested by and allocated to users at scheduling meetings, which were held every four weeks. Time requested by experimenters has continued to run over 150% of that which is available. Table II shows the distribution of time by experiment for the fiscal year.

The unscheduled maintenance of 837.5 hours, through September 1, is broken down and summarized by system in Table III. The large amount of unscheduled maintenance is due, in the main, to three factors: (1) the facility is old, having begun operation for experiments in 1965, (2) the lack of resources, especially in FY 1981 and 1982, both financial and personnel wise, and (3) due to #2 we were unable to have a scheduled shut down for annual preventive maintenance.

Division 535, Linac Operations (cont'd.)

TABLE I

LINAC OPERATIONS

Month/Year FY82	Scheduled Hours	Actual Hours
Maintenance	396.0	396.0
Unscheduled Maintenance	---	837.6(1)
Beam Time	4066.5	3203.5
Set-up*	165.5	186.5
Experimental Down-Time**	---	5.5
Installation	32.0	32.0
Inventory	---	---
Total Hours***	4660.0	4660.0

*Includes lock-up after scheduled maintenance.

**Linac available for operation, but experiment either not ready or breaks down during scheduled run.

***Total staffing hours.

(1) Includes 65 hours of Plant down time.

TABLE II

Linac Operations

FY 1982

Distribution of Time by Experiment

	[1]Scheduled Beam Hours	Actual Beam Hours	[2]Setup Hours	[3]Unscheduled Maintenance Hours	[4]Experiment Downtime Hours	Total Scheduled Beam %	Total Actual Beam %
Electron Scattering	667.5	400.0	36.0	218.0	3.0	15.8	12.5
Neutrons	2293.0	1874.0	59.5	356.6	2.0	54.2	58.5
Photonuclear Spectrometer	864.5	659.5	74.0	83.0	---	20.4	20.6
Activation Analysis	229.0	115	17.0	99.5	.5	5.4	3.6
Linac	155.0	155.0	---	---	---	3.7	4.8
Positrons	---	---	---	---	---	---	---
Electron Activation	23.0	0	---	23.0	---	.5	0
	4232.0	3203.5	186.5	780.0	5.5	100	100

[1]Machine time assigned to experiment, includes scheduled setup time of 165.5 hours.
[2]Includes lock-up after scheduled maintenance.
[3]Includes 65.0 hours plant related unscheduled maintenance.
[4]Linac available for operation, but experiment either not ready or breaks down during scheduled run.

$$\text{EFFICIENCY} = \frac{3203.5 + 5.5 + 65.0}{4232.0 - 186.5} \times 100 = 80.9\%$$

*Through August 1982

TABLE III

LINAC OPERATIONS

FY 82

LINAC: Total unscheduled maintenance 380.0 hours.

System:

Modulators	115.0 hours	30.8%
R.F. Drive	49 hours	12.9%
Injector	65 hours	17.1%
M.G. Sets	73 hours	19.2%
Vacuum	56.5 hours	14.9%

No other system or item over 2%.

BHS: Total unscheduled maintenance 382.5 hours.

System:

BHS Mag.	170.0 hours	44.4%
Magnet P.S.'s	12.5 hours	3.3%
Vacuum	142 hours	37.1%
Water	47.5 hours	12.4%

No other system or item over 2%.

Balance of total unscheduled maintenance, 65.0 hours, due to air conditioning and power outage.

SURF OPERATIONS

Division 535, Radiation Source and Instrumentation

SURF-II is a dedicated synchrotron radiation facility, consisting of the recently upgraded 280 MeV electron synchrotron storage ring, a 10 MeV microtron injector and associated synchrotron radiation beamlines. It produces light in a narrow, intense, highly polarized beam with a continuous and accurately known spectrum from the infrared through the visible and into the extreme ultraviolet. SURF-II is unique among synchrotron light sources by virtue of its uniform and precisely known electron orbit.

SURF-II serves users from the Radiation Physics Division (533) as well as from other NBS divisions and outside users, in radiometric standards and calibration work, optical physics research, surface science, biochemistry, spectroscopy and other areas involving ultraviolet radiation. It fills a growing demand for radiation in the ultraviolet and soft x-ray region of the electromagnetic spectrum. The multiple ports at SURF now serve eight active experimental stations of which seven can run simultaneously. Three beamlines are especially active, with several research groups using them on a rotating basis. The Optical Calibration Facility on beamline 2 is also operating on a full schedule for outside user groups. Three additional beamlines are in the planning stage.

The project to upgrade SURF operating energy from 240 to 280 MeV has been successfully completed. Electrons were accelerated in the reassembled machine on February 9, 1982 and limited operation for users resumed on February 17, although at a slightly reduced energy. After optimization of the magnetic field profile and ramping program, as well as a 25% boost in RF power, regular operation at 282 MeV commenced on May 3.

In the course of the shutdown, detailed mechanical and magnetic measurements were performed on the magnet to verify pole circularity and gap uniformity, and to map the magnetic field radially and azimuthally. An inherent azimuthal non-uniformity of the field on orbit of up to $\pm$ 0.5% was discovered. These field variations would be expected to cause local variations in bending radius of about the same magnitude, and a corresponding variation in the synchrotron radiation spectrum from port to port. The detailed field maps will now permit appropriate corrections to be made in the calculation of the photon flux at any port, if necessary.

Field measurements and thermal calculations predicted that the new correction coils and power supplies should enable the magnet to support a circulating beam of up to 300 MeV. This has been demonstrated. However the available RF power is insufficient to maintain the beam with

reasonable lifetime. Operation at 300 MeV would necessitate a major modification of the RF system to increase its power capability by a factor of two.

Electron counting is now a routine procedure for calibrating the beam current monitor and for calculating the photon flux in the calibration beamline. This technique provides the basis for intercomparison between SURF and the self-calibrated silicon diode standards, as reported elsewhere.

Other improvements and enhancements are still in the works, having been delayed by lack of manpower, lack of funds, and/or late vendor delivery. These include the second harmonic RF system, the optimization of flight apertures in the microtron accelerating cavity, and microcomputer control of the correction coil system. The first two should be completed in FY 83; the last item will require six months of software development, by an experienced programmer.

Operational statistics for FY 82 reflect the shutdown which lasted nearly six months. The second half of FY 82 saw nearly normal operation again. Beam hours to users averaged 141 hours per month, peaking at 187 hours for the month of July. On the other hand downtime was up too, due as much to understaffing as to normal bugs in the newly installed systems.

A number of challenging opportunities exist for further enhancing SURF performance and exploiting its known potential, such as:

- operation at up to 300 MeV;
- beam currents of up to 50 mA, with the present injector;
- beam currents in excess of 50 mA, using a higher-energy injector system;
- computer control of machine parameters.

Efforts will be made to implement these improvements which would benefit current users and would make possible experiments currently deemed impractical or marginal.

SURF serves a large user community, as shown in the list below. It provides essential services and resources which, in many instances, are not available anywhere else. The facility represents a sizable investment by NBS and other agencies. The responsibilities of the SURF Operations Group include supporting full and efficient utilization of this investment, and maintaining its performance and capabilities at the current

state of the art. Without additional engineering and technical staff and appropriate funding, these responsibilities cannot be adequately met.

SURF Operations Statistics

	FY 81	FY 82
Beam to users	1872 hours	855 hours
Standby (beam available)	267	81
Studies and Maintenance	216	136
Unscheduled downtime	126	159
Total hours	2481	1262 (6 mos.)

SURF Users During FY 82

R.P. Madden,* D.L. Ederer, L.R. Hughey, A.C. Parr, E. Saloman, N. Swanson (533 Radiation Physics Division, Far UV Physics Group)
*Principal Scientist

J. Cooper (520 Center for Absolute Physics Qunatities)

J. Geist, R. Schaeffer (534 Radiometric Physics Division)

T. Madey (541 Surface Sciences Division)

R. Stockbauer (543 Chemical Thermodynamics Division)

D. Holland (Reading University, England)

E. Bertel (Innsbruck University, Austria)

G. Leroi, '82 SURF Fellow (Michigan State University)

R.M. Catchings (Howard University)

C. Mehlman (CNRS, France)

S. Donnelly (University Notre Dame de la Paix, Belgium)

G. Carruthers, J. Rife, M. VanHoosier (Naval Research Lab)

Division 535, SURF Operations (cont'd.)

M.O. Krause (Oak Ridge National Lab)

R. Day, R.J. Bartlett, D. Lear (Los Alamos National Lab)

E. Poliakoff (Argonne National Lab)

B. Guenther, J. Mentall, D. Williams (NASA Goddard)

W. Hodge, J. Castracane, S.T. Durrance, T.N. Woods, T. Yu (Johns Hopkins University)

G. Mount, R. Jakoubek (LASP, Colorado)

D. Hwang (Princeton University)

N.V. Richardson (Liverpool University, England)

INSTRUMENTATION SERVICES

Division 535, Radiation Source and Instrumentation

Electronic Instrumentation Maintenance and Construction

Provision of electronics instrumentation maintenance and construction services for the experimental program of the Center for Radiation Research is a continuing responsibility of the Division. Instruments designed and constructed during 1982 number about 105 and maintenance has involved about 225 instruments. Increasing complexity of the instruments requires increasing amounts of highly-trained technicians time. More advanced support instrumentation is still urgently needed for use in this maintenance although some instruments have been purchased through FY 1982.

Although the Center has almost doubled in size over the past few years due to internal reorganization, technician support manpower has remained static at a lower level than in 1980. It is presently impossible to provide all the services required by Center personnel for presently instituted programs.

Control Instrumentation Design and Construction

Design and construction of many types of Control Instrumentation has been undertaken for the Division of the Center for Radiation Research. Typical examples of instrumentation included; a control and data acquisition system for pulse radiolysis measurements using the NBS 2 MeV flash electron accelerator; a CAMAC target control system for an electron spectrometer used with the NBS linac; a neutron beam scanner; a controller and data acquisition system for temperature and humidity measurements.

Instrumentation Support for Physics and Chemistry Projects

Consulting and systems instrumentation has been provided to scientists in programs relating to neutron physics, electron physics, surface electron physics, X-ray dosimetry, radiation chemistry, vacuum ultraviolet physics (SURF), analytical chemistry, physical chemistry and photometry.

Instrumentation also has been provided for the States Regional Calibration Centers. Instrumentation supplied includes; a novel track and hold pulse amplifier for pulsed radiolysis measurements, neutron dosimetry instrumentation, low-noise current amplifiers, analog signal-processing circuits, pulse detection, counting and processing devices, microcomputer circuits, complex NIM modules.

An important, continuing and growing problem is the lack of adequate modern instrumentation to complement and support the efforts of the electronic instrumentation design engineering staff. This concern has been noted in previous years but sufficient funds have not been available to overcome the problems. At present, as last year, the Radiation Instrumentation Laboratory is ill-equipped to provide adequate support to the Center in the following areas; radio-frequency circuit characterization and systems measurement, transient analysis, measurement of very short time intervals, microcomputer development and microcomputer software development, CAMAC development and clibration. This lack of instrumentation affects the innovation, efficiency and productivity of the Instrumentation Group. When coupled with a severe staff shortage, this combination adversely affects the programs of the Center on a continuing basis.

Consultation continues to be provided to the Center for Chemical Physics (ozone measurements, ion cyclotron resonance), the Center for Analytical Chemistry (metal sampling techniques, ion time-of-flight mass spectrometry, low-level counting measurements), Center for Building Research (humidity measurements). One staff member (Whittaker) continues the joint project with the Chemistry Department of the University of Maryland on air particulate measurements supervising the work of a graduate student. A new AID sponsored cooperative project with the Eqyptian National Institute of Standards has been started and presently two Egyptian scientists are studying electronic repair and maintenance techniques in the Instrumentation Laboratory.

The Radiation Instrumentation Group has provided a large amount of support to the racetrack microtron project relating to the design of sensitive current amplifiers, pulse data acquisition, high-voltage terminal design, test instrumentation, wiring and interlock support and general instrumentation consultation.

Mechanical Instrumentation Services

Mechanical instrumentation services were provided for the Center for Radiation Research in connection with the particle accelerators of the CRR and the experimental programs of the Center. The services provided consist of design and construction of new equipment and facilities as well as maintenance, and modification of existing equipment. This past year the major effort was the NBS-Los Alamos racetrack microtron accelerator. The viewscreens, wire scanners and water cooled chopping aperature were designed and prototype assemblies built and tested. The precision, moveable "turn around" magnet support design has been completed.

RADIATION INSTRUMENTATION STANDARDS

Division 535, Radiation Source and Instrumentation

Standards work falls into three categories as follows:

(a) NIM Committee Standards - This involves development and maintenance of instrument standards, in cooperation with the National Laboratories, primarily for use in nuclear applications. NBS has the management responsibility for this work, with L. Costrell serving as Chairman of the NIM Committee. The Nuclear Instrumentation Module (NIM) system has been adopted nearly universally in the US and is the predominant system in nuclear laboratories throughout the world. There is a continuous coordination requirement involving contact with numerous laboratories and manufacturers. Similar management, direction and maintenance are provided in the US with regard to the international CAMAC (Computer Automated Measurement and Control) system that is utilized in the National Laboratories and in a large number of other laboratories and installations throughout the world. A third system now being developed and for which the Division has similar responsibility is the FASTBUS high speed modular data acquisition system for high energy physics and other applications. The FASTBUS development has been a major effort and preparation of the final specifications is now underway.

The preparation of reports for the above systems involves a number of individuals and laboratories. Coordination and processing, as well as writing of some sections, is handled by the National Bureau of Standards. The documents are usually issued initially as Reports of the Department of Energy and then processed as Standards of the Institute of Electrical and Electronics Engineers (IEEE), the American National Standards Institute (ANSI), and the International Electrotechnical Commission (IEC). There are currently sevel CAMAC standards. These have been updated and the updated documents issued in FY 82. Some additions to the basic NIM standard, such as specifying the "IEEE Standard Interface for Programmable Instrumentation" (IEEE Std 488) as a digital data bus for NIM instruments, are now in process.

(b) National Voluntary Standards - The Division plays an active role in IEEE and ANSI Standards activities with L. Costrell serving as Chairman of ANSI Committee N42 on Radiation Instruments and as Secretary of the IEEE Nuclear Instruments and Detectors Committee. In these capacities he has processed several ANSI And IEEE standards in FY 1982. J. Whittaker serves on ASTM Committee D-22 on Methods of Sampling and Analysis of Atmospheres.

(c) International Electrotechnical Commission - L . Costrell serves as Technical Advisor to the US National Committee of the IEC for IEC

Committee TC45 on Nuclear Instruments. He serves as Chief US Delegate to TC45, as Chairman of the Working Group on Detectors and as a member of the working groups on Interchangeability and on Terminology. Numerous IEC draft documents were prepared and reviewed resulting in a number that were published and others that are to be published in FY 1983.

INVITED TALKS

Division 535, Radiation Source and Instrumentation

Ayres, R. L., Lecture on "Practical Gamma Counting in our course Rad Sci 230 Radioimmunoassay," George Washington University Medical Center, Washington, DC, October 19, 1981.

Ayres, R. L., "Microcomputers - How They Function and How They are Used," Winston Churchill High School, Potomac, Maryland, December 4, 1981.

Costrell, L., "FASTBUS Modular High Speed Data Acquisition System," Franklin Plaza Hotel, Philadelphia, Pennsylvania, June 16, 1982.

Penner, S., "NBS-LANL Racetrack Microtron Project," Triangle Universities Nuclear Laboratory Seminar, Durham, North Carolina, November 5, 1981.

Penner, S., "Next Generation Accelerators - An Overview," Conference on New Horizons in Electromagnetic Physics, Charlottesville, Virginia, April 22, 1982.

Wilson, M. A. D., "The Induction Linac - A New Concept in High Current Charged Particle Accelerators," Electrophysics Physics Seminar, College Park, Maryland, December 4, 1981.

PUBLICATIONS

Division 535, Radiation Source and Instrumentation

Ayres, R.L., Radioactivity Standardization of ^{99m}TC and ^{99}Mo, International Journal Applied Radiation and Istopic (in press).

Costrell, L. and Dawson, W.K., "FASTBUS Modular High Speed Data Acquisition Systems, published in Conference Records of 1982 IEEE International Conference on Communications, ISSN 0536-1486, IEEE Catalog Number 82CH1766-5, June 1982.

Debenham, P.H., Homogenizing the Field in a Picture-Frame Magnet, Proceedings of Workshop of High-Resolution, Large-Acceptance Spectrometers, Argonne, Illinois, September 8-11, 1981.

Debenham, P.H., Understanding the Purcell Filter, Proceedings of Workshop on High-Resolution, Large-Acceptance Spectrometers, Argonne, Illinois, September 8-11, 1981.

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 535, Radiation Source and Instrumentation

Louis Costrell

Chairman, ANSI Technical Committee N42, Nuclear Instruments.

Member, ANSI Technical Committee N41, Controls, Instrumentation, and Electrical Systems for Nuclear Power Generating Stations.

Chief U.S. Delegate, International Electrotechnical Commission (IEC), Technical Committee on Nuclear Instruments (IEC/TC45).

Chairman, IEC/TC45 Working Group-9 on Radiation Detectors.

Member, IEC/TC45 Working Group-3 on Interchangeability.

Member, IEC/TC45 Working Group-1 on Classification and Terminology.

Technical Advisor, U.S. National Committee of IEC.

Secretary, Institute of Electrical and Electronics Engineers (IEEE)/NPSS Nuclear Instruments and Detectors Committee of IEEE Nuclear and Plasma Sciences Society.

Member, IEEE Standards Review Committee.

Member, U.S. National Committee of International Electrotechnical Commission (IEC).

Chairman, U.S. Department of Energy National Instrumentation Methods (NIM) Committee.

Chairman, NBS Microprocessor Standards Action Group.

Philip H. Debenham

Member, 1983 Particle Accelerator Conference Program Committee.

Samuel Penner

Member, 1983 Particle Accelerator Conference Program and Organizing Committees.

Division 535, Technical and Professional Committee Participation and Leadership (Cont'd.)

Julian K. Whittaker

Member, ASTM Committee D-22 on Methods of Sampling and Analysis of Atmospheres.

Member, U.S. Department of Commerce, Industry and Trade Administration, Electronic Instrumentation Technical Advisory Committee.

Chairman, Electronics Storeroom Committee, NBS.

Chairman, Electronics Storeroom Committee Microprocessor Subcommittee, NBS.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 535, Radiation Source and Instrumentation

1. R. L. Ayres serves as a consultant on the design and development of a microprocessor based automated humidity calibration system for the NBS Thermal Processor Division.

2. P. Debenham serves as a consultant to the University of Maryland on the design of a magnetic spectrometer to be installed at the University of Indiana.

3. P. Debenham serves as an advisor to the University of Illinois on the design of end magnets.

4. S. Penner serves as a member of the DoE-sponsored Nuclear Physics Major Facilities Review Panel.

5. S. Penner and M. Wilson continue to provide Accelerator Technology and Assessment and Oversight for DARPA.

6. J. Whittaker serves as a consultant on instrumentation and instrumentation maintenance and repair to AID for the Egyptian Government Standards Laboratories.

7. J. Whittaker serves as an advisor to two Eqyptian visiting scientists in the field of repair and maintenance services.

8. J. Whittaker serves as an advisor to a graduate student in the Department of Chemistry, University of Maryland.

9. J. Whittaker serves as a consultant on electronics instrumentation and instrumentation repair and maintenance to the University of Petroleum and Minerals, Dhahran, Saudi Arabia.

STANDARD REFERENCE MATERIALS

Division 535, Radiation Source and Instrumentation

1. SRM 4949B, Preparation of I-129 Radioactivity

SPONSORED SEMINARS & COLLOQUIA

CENTER FOR RADIATION RESEARCH

F. Wuilleumier, Universite Paris-Sud, Orsay, France, "New X-Ray Sources and New Experimental Studies Involving Synchrotron and Laser Radiation," October 8, 1981.

H. G. Ebert, Biology, Radiation Protection and Medical Research, Commission of the European Communities, Brussels, Belgium, "Radiation Protection Research Program of the Commission of the European Communities," October 8, 1981.

Michael Danos, Nuclear Radiation Division, Center for Radiation Research, NBS, "Nuclear Quarks According to Versailles," October 15, 1981.

Kurt Behringer, Max Plank Institut fur Plasma Physik, Garching, Germany, "VUV and X Ray Spectroscopy of Impurity Ions in the ASDEX Tokamak," October 19, 1981.

Samuel Penner, Radiation Source Instrumentation Division, Center for Radiation Research, NBS, "The Future of Nuclear Physics Research at NBS," October 22, 1981.

A. Carillon, University of Paris-Sud, Orsay, France, "Some Aspects of the Production of Multicharged Ions in Dense Laser Produced Plasma," November 12, 1981.

S. J. Wallace, Guest Worker, Center for Radiation Research (on leave from the University of Maryland,) "Bright Spots in High Energy Proton Scattering," November 12, 1981.

Stephen W. Lovesey, Neutron Division, Rutherford Appleton Laboratory, England, "Dynamic Properties of Electrons in Materials by Neutron Scattering," November 19, 1981.

R. R. Silbar, Nuclear Physics Division, Department of Energy, "The Nucleon-Nucleon Interaction at Medium Energies," December 3, 1981.

Martin Lingare, Princeton University, "Photoproduction of Spin Polarized Hydrogen Atoms in Mixtures of Cs Vapor and Hydrogen Gas," December 8, 1981.

Michael Simic, Radiation Physics Division, Center for Radiation Research, NBS, "Radiation Biological Mechanisms," December 10, 1981.

Arthur Charlesby, Professor Emeritus, Royal Military College of Science, Shrivenham, Great Britain, "The Use of Pulsed NMR for Characterization of Polymers," December 14, 1981.

John Leonard Holmes, University of Ottawa, "Phenomenology of Slow Ion Fragmentation Processes," December 14, 1981.

S. J. Wallace, Guest Worker, Center for Radiation Research (on leave from the University of Maryland,) "Dynamics of High Energy Proton Scattering," December 17, 1981.

W. R. Cooke, University of Southern California, Los Angeles, California, Multi-channel Quantum Defect Theory on the Back of an Envelope," December 18, 1981.

J. Tersoff, University of California, Berkeley, "Substrate Effects in Thin N_i Films," December 28, 1981.

Walter Johnson, Dept. of Physics, University of Notre Dame, Notre Dame, IN, "New Theoretical Insights into the Photoionization Process," January 8, 1982.

Emanuel Riklis, Nuclear Research Center, Negev, Israel, "Mechanisms of DNA Repair as a Probe to Radiation Sensitivity," January 15, 1982.

Santos Alvarado, Inst. Sol. State, Res., KFA, Julich, Germany, "Surface Magnetism of Ni(100) Near the Critical Region by Spin Polarized Electron Scattering," January 26, 1982.

Peter Smith, Harvard Smithsonian Center for Astrophysics, Cambridge, MA, "Measurements of f-values of Intersystem Lines Used in Astrophysical Plasma Diagnostics," January 27, 1982.

Carl Bigging, Uppsala University, Sweden, "Solar Selective Properties of Oxidized Steel and Copper," February 4, 1982.

Gary Prinz, Naval Research Laboratory, Washington, DC, "Properties of Single Crystal Fe Films Grown on GaAs by Molecular Beam Epitaxy," February 9, 1982.

Kamil V. Ettinger, Department of Biomedical Physics and Bioengineering, University of Aberdeen, Scotland, "Free Radical Dosimetry Using Organic Systems," February 12, 1982.

Klaus W. Geiger, National Research Council of Canada, "Electron Dosimetry," February 18, 1982.

Donald Lehman, George Washington University, Washington, DC, "What Do We Learn About the Structure of ^{6}He and ^{6}Li from Three-Body Models?" February 23, 1982.

Richard Ellis, University of Maryland, Laboratory for Plasma and Fusion Energy, "Synchrotron Emission as a Diagnostic for Magnetic Mirror Machine Plasmas," March 9, 1982.

Wilfrid B. Mann, Nuclear Radiation Division, Center for Radiation Research, NBS, "Radio- (and other) Activities in China," March 11, 1982.

David Holland, Radiation Physics Division, Center for Radiation Research, NBS, "Photoionization of Atoms and Molecules," March 15, 1982.

K. G. W. Inn, W. S. Liggett, Jr., Nucear Radiation Division, Center for Radiation Research, NBS," NBS Natural Matrix Radioactivity Standards," March 18, 1982.

H.P. Baltes, Landis and Gyr Central Research Laboratory, Zug, Switzerland, "Magnetic Field Microsensor Based on a Magnetoresistive Comparator," March 22, 1982.

H.P. Baltes, Swiss Federal Institute of Technology, Laussanne, Switzerland, "Multiplex Version of the Generalized Van Cittert-Zernike Theorem," March 23, 1982.

James E. Lawler, Department of Physics, University of Wisconsin, "Applications of Hollow-Cathode Discharges in Laser Spectroscopy," March 24, 1982.

Roger Falcone, Ginzton Laboratory, Stanford University, Stanford, CA, "XUV Spectroscopy and Source Development at Stanford University," March 26, 1982.

Jeff Linsky, JILA, University of Colorado, Boulder, CO, "UV Observation of Stars with the International UV Explorer Spacecraft," March 29, 1982.

V. I. Mishin, Institute for Spectroscopy, Moscow, USSR, "Laser Photo-ionization Detection of Impurities in Solids and Studies of Hyperfine and Isotope Structures of Radioactive Atoms," April 5, 1982.

Kwok Tsang Cheng, Department of Physics, Argonne National Laboratory, Photochannel Quantum Defect Analysis of the Absorption Spectrum of Ba," April 5, 1982.

Aryeh Frimer, Department of Chemistry, Bar-Ilan University, Israel, "Autoxidation by Superoxide Radical Anion," April 12, 1982.

Claude Fleurier, University of Orleans, Cedex, France, "Some Aspects of the Atomic and Plasma Physic Research at the University of Orleans," April 12, 1982.

S. C. Roy, Department of Enmgineering and Applied Science, Yale University, New Haven, CT, "Neutron Detection Using Superheated Liquids," April 16, 1982.

Helmut Herminghaus, Institut fur Kernphysik dur Johannes, Gutenberg-Universitat, Mainz, W. Germany, "The Mainz CW Racetrack Microtron," April 20, 1982.

C. von Sonntag, Max Planck Institut fur Strahlenhemie, Mulheim, Germany, "Mechanisms of Radiation Induced DNA Strand Breaks," April 30, 1982.

David Herrick, University of Oregon, "Approximate Symmetries in Doubly Excited States of Helium," April 27, 1982.

Stephen M. Younger, Atomic and Plasma Radiation Division, Center for Radiation Research, NBS, "Dividing the Indivisible: Selected Topics in Modern Atomic Physics," May 4, 1982.

John R. Calarco, Department of Physics, University of New Hampshire, Burham, New Hampshire, "^{238}U(e,e'f) Cross Section Measurements at 80, 120 and 160 MeV," May 4, 1982.

Jurio Avoitinsh, Department of Physical Chemistry, Latvian State University Chemistry Department, University of Colorado, Boulder, Colorado, "Lyoluminescence Alkali Halides," May 11, 1982.

H. Zacharias, Universitat Bielefeld, Bielefeld, West Germany, "Spectroscopy of Hydrogen Atoms with VUV Lasers," May 11, 1982.

Susumu Namba, Osaka University, Toyonaka, Osaka, Japan, "X-Ray Lithography at the Toyko Synchrotron Radiation Source," May 17, 1982.

Charles Clark, Atomic and Plasma Radiation Division, Center for Radiation Research, NBS, "Atomic Diamagnetism," May 18, 1982.

W. Timothy Elam, Physics Dept., University of Washington, Seattle, WA, "EXAFS Measurements of the Oxygen - Transport Protein Hemerythrin," May 21, 1982.

John F. Ward, Professor of Radiology, Chief of Radiobiology, School of Medicine, University of California, San Diego M027, La Jolla CA, "Does Rate of DNA Repair Affect Cell Survival?" May 21, 1982.

Peter Rosen, National Science Foundation, "Double Beta Decay and Marjorana Neutrinos," May 25, 1982.

Sydney Meshkov, Nuclear Radiation Division, Center for Radiation Research, NBS, "An Update on the Status of Glueballs and Oddballs," May 26, 1982.

Michele Crance, Laboratory Aime Cotton, Orsay, France, "Fluorescence Induced by Resonant Multiphoton Ionization Near an Autoionizing State," May 26, 1982.

D. E. Murnick, Bell Laboratories, Murray Hill, NJ, "Laser Optical Pumping in Nuclear Physics," June 3, 1982.

Josh Halpern, Chemistry Department, Howard University, "Photodissociation of Cyanogen," June 9, 1982.

Donald Schran, Eidenhoven University of Technology, Eidenhoven, Holland (on sabbatical leave at the University of Montreal,) "Non-Equilibrium in Pulsed Cascaded Arcs and Medium Density Cathode Discharges," June 10, 1982.

Leonard Maximon, Nuclear Radiation Division, Center for Radiation Research, NBS, "Radiative Tail from Elastic Eletron Scattering," June 23, 1982.

K. T. Lu, Argonne National Laboratory, Argonne, Illinois, "Chemical Physics of Highly Excited States," June 24, 1982.

Gian-Paulo Tozzi, Institute fur Astronomie, ETH, Zurich, Switzerland, "Measurements of UV Branching Ratios at ETH," June 30, 1982.

Nikola Konjevic, Institute of Applied Physics, Belgrad, Yugoslavia, "Stark Broadening of Non-hydrogenic Atom and Ion Lines in Plasmas-Critical Review of Experimental Data for the Period 1976-1981," July 8, 1982.

Goran Pichler, University of Zagreb, Yugoslavia, "Spectroscopy of Alkali Metal Vapors," July 9, 1982.

Johann Rafelski, Institute for Theoretical Physics, University of Frankfurt, Frankfurt, Germany, "Quark-Gluon Plasma," July 15, 1982.

Volkmar Helbig, Institut fur Experimentalphysik, Universitat Kiel, West Germany, "Atomic Transition Probability Studies on Rare Gases," July 20, 1982.

Johann Rafelski, Institute for Theoretical Physics, University of Frankfurt, Frankfurt, Germany, "Strange Particle Production in High Energy Nuclear Collisions," July 22, 1982.

Erhard Kisker, Institute fur Festkorperforschung, Julich, West Germany, "Ennancement of the Spin Polarization of Secondary Electrons from Ferromagnets," August 2, 1982.

Takeshi Namioka, Research Institute for Scientific Measurements, Tohoku University, Japan, "High Resolution Spectrometers for Synchrotron Radiation," August 3, 1982.

John Umbarger, Bruce Erkilla, Los Alamos National Laboratory, Los Alamos, New Mexico, "Radiac Instrumentation - New Directions for the '80s," August 12, 1982.

Walter Greiner, University of Frankfurt, Germany and Yale University, Connecticut, "Evidence for Giant Nuclei from Supercritical Field Positron Emission Spectra," August 19, 1982.

Gerhard Wiech, Sektion Physik der Ludwig-Maximilian-Universitat Munchen, Munich, FRG, "Angular-Resolved X-Ray Emission Spectroscopy," September 7, 1982.

Gunter Baum, Fakultat fur Physik, Universitat Bielefeld, Bielefeld, West Germany, "Ionization and Excitation of Atoms with Polarized Electrons," September 24, 1982.

Andrew C. Tam, IBM Research Laboratory, San Jose, CA, "Laser-Induced Plasmas and Shock Waves in Atomic Vapors," September 25, 1982.

Sybille Krummacher, National Synchrotron Light Source, Brookhaven National Laboratory, Upton, NY, "News from the National Synchrotron Light Source Facility at Brookhaven," September 27, 1982.

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7. Contract/Grant No.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report summarizes research projects, measurement method development, testing and data evaluation activities, carried out during Fiscal Year 1982 in the NBS Center for Radiation Research. These activities fall in the areas of radiation measurements, atomic and plasma radiation, nuclear radiation, radiation physics, radiometric physics, and radiation sources and instrumentation.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Atomic radiation; nuclear radiation; plasma radiation; radiation instrumentation; radiation measurement; radiation physics; radiation sources; radiometric physics.

13. AVAILABILITY

☐ Unlimited

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