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Technical Activities 1981
Center for Radiation Research

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

November 1981

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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CENTER FOR RADIATION RESEARCH

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 1981 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, 1980 to September 30, 1981. 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

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The Office of Radiation Measurement promotes the dissemination to federal, state, and local regulatory bodies, and to the medical, industrial, and defense communities, of the measurement standards and technology required for reliable measurement of all types of radiation that may be biologically hazardous. The Office assists the technical organizational components of NBS in monitoring the radiation measurement needs of these national user groups, and in activities undertaken to meet national needs. It maintains liaison with other organizations concerned with related environmental, energy, health, or safety programs. Examples are the Nuclear Regulatory Commission, Bureau of Radiological Health, Environmental Protection Agency, Occupational Safety and Health Administration, National Institute for Occupational Safety and Health, National Council on Radiation Protection and Measurements, and the Conference of Radiation Control Program Directors.

In response to increasing concern about public exposure to hazards presented by ionizing radiation, NBS is making progress in providing new services essential for assuring the adequacy of measurements which are relied upon to protect workers and the general public from radiation hazards. It is important that such measurements be made with adequate accuracy and reliability to ensure public safety without unnecessary impediments to beneficial applications of ionizing radiation. Since national responsibility for actions based on radiation measurements is assumed by federal agencies, state and local governments, and industries which utilize radiation, it is convenient to consider office activities in terms of these three sectors.

In the state sector, the primary interaction organization is the Conference of Radiation Control Program Directors, specifically its Committee on Radiation Measurements. This Committee is sponsored by the Office, and represents the measurement interests of 58 state and local radiation control programs. As the result of a cooperative effort between NBS and the Committee, a comprehensive directory providing detailed information on the availability of commercial services for calibrating ionizing radiation survey instruments was published in April 1981. Previous to its publication there had been no single source of information on where appropriate calibrations could be obtained. For each company that provides instrument calibration services, the directory indicates the radiation type, energy and intensity ranges, calibration method, and estimated accuracy. Eighty-three companies which provide instrument calibration services are listed in the directory, along with 27 companies that sell calibrated radioactive sources.

Office of Radiation Measurement, Technical Activities (cont'd.)

The CRCPD Committee on Radiation Measurements has made significant progress on revision of its 1979 publication entitled "Ionizing Radiation Measurement Criteria for Regulatory Purposes". The revised material includes more specific references to measurement requirements stated in regulations, information on the use of radioactive check sources, and terminology for measurement of ionizing radiation.

The pilot project with the State of Illinois for development of a state-operated regional calibration laboratory has made significant progress. This laboratory is presently going through a verification process with its own instruments before offering its services to other state and local agencies. To enable calibrations at higher photon energies, two cesium-137 sources have been ordered.

Similar projects are well under way in South Carolina and the State of Washington. An x-ray machine has been delivered to South Carolina along with the necessary equipment to set up a calibration laboratory. Due to delays in space renovation being done by the state at the laboratory site, it is anticipated that the laboratory will not become operational until mid-1982. The Washington laboratory is being developed in cooperation with both the University of Washington and the state radiation control program. Cesium-137 gamma-ray sources and sufficient equipment to allow limited operation have been ordered and should be delivered by January 1982. It is planned to obtain the remainder of the equipment during fiscal year 1982. Preliminary discussions have been held with representatives of the State of California regarding the possibility of developing a regional laboratory in that state.

To ensure competent operation of the state regional calibration laboratories, a training program is being developed for the personnel operating them. This program will consist of two phases - a classroom review of the basic principles involved in radiation measurements and actual experience calibrating instruments at NBS and selected other institutions. Quality control procedures are also being developed to help ensure that the calibration process remains in statistical control. It is particularly important for the regional laboratories to develop as many control procedures as possible using existing equipment since they do not have redundant monitors to ensure that the calibration procedures are in control.

During the past year, the CRCPD Committee on Radiation Measurements, in cooperation with NBS, prepared criteria for the location of state regional calibration laboratories. In addition, the Committee has developed draft general criteria for the operation of such laboratories.

Various radon-related projects have continued to occupy an increasing part of the Office's activities during the past year. The EPA-sponsored project on radon transport in building materials is expected

to be terminated at the end of fiscal year 1981 due to lack of funds. This project has been conducted by a multidisciplinary team of staff members from the Office, Division 532 (Nuclear Radiation, Radioactivity Group), the Center for Materials Science, and the Center for Building Technology. One of the major phases of the project consisted of an extensive review and assessment of radon transport through and exhalation from building materials. Preparation of the resulting report, issued as Technical Note 1139, was coordinated by the Office. In addition, the Office assisted staff members of Division 532 in designing a radon chamber which can serve the dual purpose of measurement of radon exhalation rates from building materials and of providing an atmosphere with calibrated radon concentration. The Office has also participated in efforts to establish an ad hoc interlaboratory radon measurement comparison program with two EPA and several DOE national laboratories.

The CRCPD established a new subcommittee on radon measurements which is sponsored by the Office. The preliminary charge to the group is to (1) evaluate the types of radon and radon progeny measurements required in state programs; (2) assess the availability of instruments to perform those measurements; (3) assess the availability of calibration services in regard to accuracy, uniformity and agreement with national standards; (4) consider possible measurement intercomparisons or periodic testing programs; and (5) provide a statement of problems, needs, and possible solutions. As part of its first task, the subcommittee in collaboration with the Office conducted a survey of the state radiation control program directors to determine the radon measurement needs and present activities in the state programs. Forty-six program directors responded to the questionnaire, and a summary of the survey findings is in preparation. The subcommittee has also initiated a survey of commercially available instruments.

The Office has also begun to study the feasibility and design of a model intermediate calibration laboratory facility for radon measurements. This effort is of great interest to the CRCPD radon subcommittee, and the State of Wisconsin has already expressed an interest in possibly serving as a pilot regional calibration facility.

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

a preliminary study relating to task 3, development of an MQA service. To determine the need for, and interest in, such interactive services those laboratories which presently calibrate instruments for the NRC were contacted. They include Argonne National Laboratory, Brookhaven National Laboratory, Eberline Instrument Corporation, and Lawrence Livermore National Laboratory. Each laboratory was visited, with the exception of Brookhaven, during the past year. Although the Battelle Pacific Northwest Laboratory does not presently calibrate instruments for the NRC, it was also contacted and visited. It is encouraging that all five of these laboratories expressed an interest in participating with NBS in an interactive MQA program, and that several of them have a strong desire for a wide range of interactions of this type. The initial service will be limited to photon radiation.

As it has done for the past 35 years, NBS served during 1981 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 gamma radiography equipment was published in January as NBS Handbook 136. Of the 13 active projects that constitute Committee N43, nine have resulted in published standards and four made significant progress last year.

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 recommendations for use by international standardizing laboratories, and they will be submitted to the International Committee on Weights and Measures (CIPM) for ratification.

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. During the past year, initial planning for the program was done, and a successful proposal for funding was submitted to the NRC. The criteria for operating the laboratory that will periodically test the proficiency of individual processors are under development, including quality assurance procedures and monitoring of the testing laboratory by NBS. This program is expected to serve as a model for application in other areas of concern.

Other accomplishments during the past year include: publication of a report prepared for the U.S. Senate Committee on Commerce, Science, and Transportation; chairmanship of the Interagency Policy Committee for

Office of Radiation Measurement, Technical Activities (cont'd.)

Personnel Dosimetry; provision of financial support to the NCRP for preparation of a report on neutrons produced by medical accelerators; and assistance with the conduct of the 1981 Particle Accelerator Conference.

PUBLICATIONS

530, Center for Radiation Research

Eisenhart, C. and Collé, R., Postscript to Expressions of Imprecision, Systematic Error, and Uncertainty Associated with a Reported Value, NBS Communications Manual for Scientific, Technical, and Public Information, p 2-30, NBS (November 1980)

Collé, 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, 104 pages (1981).

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

Eisenhower, E.H., Traceability - A View From the NBS Center for Radiation Research, in Proceedings of a Seminar on Traceability of Ionizing Radiation Measurements, NBS Special Publication 609 (1981).

Heaton, II., H.T., (editor), Proceedings of a Seminar on Traceability of Ionizing Radiation Measurements, NBS Special Publication 609 (1981).

Heaton, II, H.T., NBS Services for Ionizing Radiation Measurements, NBS Special Publication 609 (1981).

Heaton, II, H.T., Review of Commercial Calibration Services for Ionizing Radiation Survey Instruments, Proceedings of the 12th National Conference on Radiation Control, to be published by the Department of Health and Human Services (in press).

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.

Member, Food and Drug Administration, Technical Electronic Product Radiation Safety Standards Committee.

Chairman, Interagency Policy Committee on Personnel Dosimetry Performance Testing.

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.

Member, Arrangements Committee, 1981 Particle Accelerator Conference.

MAJOR CONSULTING AND ADVISORY SERVICES

530, Center for Radiation Research

1. R. Collé advised Battelle Pacific Northwest Laboratory on the treatment of measurement uncertainties and reporting of environmental radiation data.

2. R. Collé consulted with Bechtel Power Corp. on instrument calibration procedures and interpretation of environmental exposure rate measurement data.

3. R. Collé advised Geomet Technologies in establishing a survey of radon in water.

4. R. Collé advised and assisted staff members in various NBS divisions on the treatment and reporting of measurement uncertainties.

5. R. Collé advised the Interagency Research Group on Indoor Air Quality in formulating the Interagency Indoor Air Quality Research Plan.

6. H.T. Heaton, II, advised ANSI Subcommittee N43-3.5 on the appropriate value of the exposure rate constant for iridium-192.

TECHNICAL ACTIVITIES

Division 531, Atomic and Plasma Radiation

The Atomic and Plasma Radiation Division carries out a broad range of experimental and theoretical research on atomic structure, primarily to generate atomic radiation and collision data. The division determines a large variety of such data, encompassing wavelengths of spectral lines; atomic energy levels; ionization potentials; atomic transition probabilities; plasma line broadening parameters; ionization 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. For example, 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. Two 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 18 professional physicists, among them 16 Ph.D.s, plus 3 postdocs and guest workers from France (2), China, Ireland, Poland, and Germany.

On the whole, the division has had a very productive year. In the following three sections, 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--Measurements for the Prediction of Forbidden Lines--The ground configurations of carbon-like, oxygen-like and nitrogen-like ions are of the type $2s^2 2p^N$ (with N = 2, 3, and 4), and the low excited configurations are $2s2p^{N+1}$ and $2p^{N+2}$. Transitions between levels of these configurations having different total spin are weak (LS coupling) and have not previously been observed or identified in many ions of importance for high-temperature plasma diagnostics (CTR), solar-flare spectra, etc. Such observations are particularly needed to allow accurate predictions of the wavelengths of basic parity-forbidden transitions between levels of the $2s^2 2p^N$ ground configurations. We have used laser-generated plasma sources and the NBS 10.7-m grazing-incidence spectrograph to excite and measure the parity-allowed but spin-forbidden lines for the ions of each of the above 3 types for the elements Cl, K, Ca, Sc, Ti, and V. The identifications of these intersystem lines ($\sim$ 90-200 Å) are new in all cases. Unified energy-level schemes have been derived for the 18 ions (ionization stages Cl^{9+} to V^{17+}). We also identified and measured intersystem lines of boron-like Sc^{16+}, which provides better predictions in this isoelectronic sequence.

We have also extended the fluorine isoelectronic sequence ($2s^2 2p^5$ $^2P^\circ$ ground term) to Y^{30+}. This extension is significant for diagnostics of plasmas in new-generation tokamaks, which are expected to contain components using Zr, Nb, or Mo. The data will permit accurate predictions of the magnetic-dipole transition $2s^2 2p^5\ ^2P^\circ_{3/2} - {}^2P^\circ_{1/2}$ in the F-like ions of these elements.

(b) Vacuum UV Spectra of Atomic Ions--Heavy Elements Strontium to Tungsten (Z = 38-74)--Our analyses of the spectra of copper-like ions as obtained with the Los Alamos Nd/glass laser were completed. Wavelengths, energy levels, and ionization energies were obtained for ten Cu-like ions from Ba^{27+} to W^{45+}. Our data for intermediate ions in the Cu-sequence (Ru^{15+} - Cs^{26+}) have been greatly extended through new observations with the (improved) NBS Nd/glass laser. Analysis of these data is in progress. Data reductions for the spectra of Na- and Mg-like ions made with the Los Alamos laser have been completed.

We have completed and have in the publication process work giving wavelengths and energy levels for Sr IX-XIII, Y IV, Y X-XIV, Zr XI-XV, Nb XII-XVI, Mo XIII-XVII, I VII through Ho XXI, and W XXVIII.

Division 531, Technical Activities (cont'd.)

(c) Resonant Laser-vapor Interactions--Absorption spectra of Ba^{2+} (Xe-like) have been obtained by use of laser-produced ionization techniques developed at NBS. The spectrum of doubly ionized Ba vapor in the 105-400 Å region is broadly divided into excitations from the 4d and 5p shells. Interpretation of the 4d spectrum and comparisons with Ba^{+} and neutral Ba results show striking effects of progressive collapse of the 4f shell in the Ba, Ba^{+}, Ba^{2+} sequence. We are analyzing the 5p absorption in Ba^{2+} using multichannel quantum-defect theory; a Lu-Fano plot showing the $5p^5ns$ and $5p^5nd$ channels has been developed. An experiment to explore these effects in Cs^{+} with high resolution is under way. Assembly of a heat-pipe and optics suitable for use in conjunction with our 10.7-m grazing-incidence spectrograph is almost complete.

(d) Atomic Energy Levels Data Center--The recent publications of our compilations of the energy levels for the 28 Ni spectra and for the 27 Co spectra completed our element-by-element project of new critical compilations for the entire iron group, K through Ni (Z = 19-28). Revisions and additions to these compilations have now been undertaken and their integration into a single volume covering all 235 spectra is prepared. The just-completed revision of our 1975 compilation for the 26 spectra of iron, now in press, represents significant progress on this major iron-group volume. Since our earlier Fe compilation was out-of-date for most of the spectra, the revised tables for this important element are also being published separately.

Our compilation of the levels for the sodium spectra (Na I-XI) was completed and published. In addition to critical evaluation and theoretical eigenvector percentages, the tables for several of these spectra include unpublished data; the Na I and Na X tables give levels based on series predictions, for example. We have critically evaluated and compiled the energy-level data for the first seven Si spectra and expect to complete similar compilations for the remaining spectra (through Si XIV) during the next year. The new Si tables, especially Si I, include extensive recent experimental and theoretical results (some unpublished) assembled for the first time. The Si compilations are part of a project covering the Na-through-Ar group (Z = 11-18), new compilations for all the Na, Mg, and Al spectra having been published so far.

We derived series formulae (equivalent to energy levels or wavelengths) for the He-like spectra Na X through Ar XVII (Z = 11-18). Most of these spectra are of interest for line identifications in spectra of high-temperature plasma or solar-flare spectra, and the predicted wavelengths are more complete and accurate than those generally available previously.

A volume of wavelength tables compiled under the coordination of the AEL Data Center was published in the NSRDS-NBS series last year. These tables are unique in their coverage of the first five spectra of all elements; wavelengths for about 47,000 lines (40 to 40,000 Å) are arranged both by element and in a finding list.

We continuously monitor the literature for all research papers on atomic energy levels, wavelengths, wavefunctions, etc., the resulting reference files and published bibliographies being available to a wide clientele. A report giving bibliographic and other information on laboratory atomic spectroscopy of interest for astronomy is being prepared for publication next year.

II. Atomic Radiation Data Group

(a) Theoretical Studies of Atomic Processes--Our theoretical work is concerned with producing data on basic atomic processes and with developing new theoretical methods for doing so. The important processes being studied are radiative transitions, electron impact ionization and dielectronic recombination. On the whole, this effort is directed toward atomic data important in plasmas, especially fusion plasma research.

Our research on electron impact ionization, after cross sections and rates were calculated for the H, He, Li, Be, Ne and Na sequences, has shifted its emphasis toward heavier ions and atoms for the purpose of assessing the effects of more complex target ion structure on the cross sections. Distorted wave calculations have been done on such ions as Ar^{+3}, Sb^{+3} and Hg^{+}. We also made a systematic study of the argon isoelectronic sequence and found that, as with photoionization, the cross section is sensitive to the details of the ejected electron partial wave. Term dependent effects are strong, especially in the ^1P channel, leading to cross sections differing by more than a factor of 2 over those computed in the conventional way. These term dependent effects decrease as one moves to higher ionization stages along the isolectronic sequence.

Another series of calculations has been performed on the photoabsorption spectrum of Ba III to assist in the interpretation of experiments currently being done by members of the Far Ultraviolet Group at NBS. It was found that the effects of intermediate coupling and intrachannel interaction combined lead to an unusual distribution of oscillator strengths for the $4d^9nf$ levels.

The emphasis of our work on dielectronic recombination has recently centered around a systematic study of approximation methods. Calculations

have been performed on the lowest doubly excited complexes of beryllium-like iron, Fe^{+22}, including the effects of configuration interaction on both the radiative and autoionizing rates. While configuration interaction is found to have a significant effect on individual processes, there are indications that the net effect on the overall recombination rate is not too significant. We have also studied the recombination of helium-like ions, and our results suggest that the dominant correction here is due to the intersystem radiative stabilizing transition. Our results indicate furthermore that the widely used Burgess-Merts formula is substantially in error.

The effort to upgrade our atomic structure codes is continuing and we should soon be in the position to make routine production calculations, non-relativistically, utilizing $\sim 10^3$ terms in the multiconfiguration expansion. The configuration interaction studies of dielectronic recombination drew on interim versions of these programs.

Our group hosted a workshop on electron impact ionization on November 5-7, 1980. This very productive meeting concentrated on assessing the current state of electron-ion ionization calculations and identifying promising future directions. A summary report will appear soon in Comments on Atomic and Molecular Physics.

(b) Critical Data Compilations--In the Data Center on Atomic Transition Probabilities and Line Shapes and Shifts, the comprehensive evaluation of all the elements in all stages of ionization from scandium through nickel is continuing. The last major separate part of this compilation comprising the elements Fe, Co, Ni was completed during the year and is in press. Revisions and updates of the earlier compiled data on Sc, Ti, V, Cr and Mn are now under way in preparation of a single volume covering all Fe-group spectra. For the first time these data are being keyboarded onto computer mass storage files, rather than being typewritten. This has resulted in the elimination of normal typesetting procedures, and has made possible the automatic generation of some auxiliary tables, which had previously been generated manually by data center personnel. A collaboration was started with computer scientists at Vanderbilt University to explore the possibility of developing a data base system for atomic spectroscopic data, and we are working on the preliminary design of files of atomic transition probability and energy level data and bibliographic information. We have also continued to co-edit, in collaboration with Oak Ridge National Laboratory, the bimonthly newsletter, "Atomic Data for Fusion."

Since one of our data center staff positions had to be abolished during the past year, we have ceased all activities of the data center on line shapes and shifts, i.e., we discontinued the searching and cataloguing of literature references on these subjects and the preparation of future bibliographies.

III. Plasma Radiation Group

(a) Collisional Rate Coefficient Studies with the 50 kJ Theta Pinch--Temporal histories of Ti VII through XII have been observed, and the diagnostic measurements of plasma electron temperature and density are under way. We thus expect to obtain very soon ionization rates for a selected number of these titanium ions. The temporal histories were obtained using a coaxial plasma gun fabricated of titanium electrodes. Besides the normal ionization phenomena that were observed for the Ti ions a yet unexplained reappearance of Ti X and XI at late times in the discharge was also observed. Preliminary investigations suggest that this may be a recombination phase of the plasma, and if so, will allow the determination of recombination rate coefficients of these Ti ions.

In a related plasma experiment, the Texas Experimental Tokamak (TEXT), a national users facility, is used to study magnetic dipole transitions in highly stripped ions of some important metals. Preparations of the instrumentation at NBS have been completed, and the experimental apparatus has been installed at TEXT. Observations of Fe and Ti in the B, C, N, O, and F isoelectronic sequences are under way. These new observations should yield data mainly for Doppler ion temperature diagnostics on fusion research plasmas. All of this experimental work is supported by the Department of Energy.

(b) Vacuum Ultraviolet Radiometry with Plasmas--We have completed all calibrations required for two types of VUV sources to be flown on the space shuttle. Both are intended to serve as on-board calibration sources for VUV spectrometers, which will be used to measure solar or stellar spectral radiation over long time intervals. The first project is the evaluation and calibration of several deuterium lamps for the NRL SUSIM (solar ultraviolet spectral irradiance monitor) experiment. We first constructed a test chamber in which the lamps could be tested in a "clean" vacuum environment. The spectral irradiance output in the vacuum ultraviolet region was repeatedly measured for all lamps. Measurements of stability, reproducibility, sensitivity to vibration, warm-up characteristics, all as a function of wavelength, were carried out. The results of these tests has been the selection of one lamp to be flown on the shuttle experiment. The second project is the evaluation of RF-excited dimer lamps, planned for use on the HRST (High resolution space telescope) shuttle experiment. Various properties of these lamps have been measured to determine their suitability as standard sources of radiance. Our measurements have revealed some limitations of this source, and further development is required before an entirely suitable radiance standard is realized.

A new type of radiometric source for the laboratory has been also investigated and has shown great promise. This source could greatly

extend the range of calibrations to much shorter wavelengths. It is a laser-produced plasma, created by a ruby laser hitting a rare earth (e.g., gadolinium) target. The spectral irradiance output of this pulsed source was found to be very strong and quite reproducible, making this source an excellent candidate for a new irradiance standard. The principal continuum emission of the plasma extends from 10 to 220 nm, of which the range from 10 to 115 nm is not covered by any other transfer source standard. It is just this wavelength range which is important in many high temperature plasma physics experiments. Since a ruby laser system is often in use for diagnostic measurements at many plasma laboratories, e.g., tokamaks or other machines for fusion research, far VUV calibrations could be performed in-situ. We intend to continue development of this very promising radiation source.

(c) Stark Broadening, Shifts and Asymmetries of Hydrogenic Ion Lines--Investigations of hydrogenic ion line profiles emitted from a medium temperature (4 eV) and electron density (10^{17} cm^{-3}) pulsed plasma source are continuing. The sensitivity of the Stark broadened line profiles to the plasma conditions makes them very attractive as non-perturbing plasma measurement and diagnostic probes. The widths at half-maximum intensity, shifts and asymmetries of the He II P_α, P_β, and P_γ lines have been observed and compared with theoretical predictions. The electron density of the source was independently determined using a He - Ne laser interferometer. Plasma boundary layers near the electrodes were found to be non-negligible in these observations, particularly for the interferometric measurements. Redesign of the electrodes is under way to reduce and minimize these end effects, in order to obtain improved line shapes and a more accurate density determination. In a new phase of this work, the pulsed arc source will be mounted on a 10.7 m normal incidence VUV spectrometer for detailed studies of the He II H_α line at 1640 Å. Recently there has been considerable theoretical effort to describe its line shape. For instance, new line broadening calculations based on the unified theory include, for the first time, ion dynamical corrections, and these were found to be significant for the He II H_α line. Furthermore, a new line shift mechanism involving strong electron impacts has been proposed. Its relationship with other line shift mechanisms due to profile asymmetries and plasma polarization effects could be sensitively determined through a systematic study of this line.

(d) Field Induced Autoionization--In the past year we have observed for the first time electric-field induced autoionization. The effect was observed by measuring the increase in the spectral width of an autoionizing level of strontium as the electric field strength was increased. The experiment was performed in an atomic beam apparatus with ion detection. The first observable broadening in the Sr 3d4d $^1D_2$ line occurred at a field strength of 50 KV/cm, and by 100 KV/cm the line reached a width of about one angstrom. This field-induced width is more

than an order of magnitude larger than any previously obtained in a uniform field, and represents the first observation of a monotonic field dependence. The width was observed to increase with the field F as $W = W_0 + \alpha F^X$, where W_0 is the zero field width, α is a constant, and $X = 1.8 \pm 0.2$. Work on the theoretical interpretation of our results is still in progress. Also, we have recently found in the literature the reported observation of an autoionization line that is very narrow in zero field, and accessible to laser excitation. We plan to study this line which should allow us to measure the field-induced width over a much broader range of width, obtain a significantly more precise value for the exponent in the field dependence, and observe a saturation of the effect at high fields.

(e) Radiation Scattering--We have investigated the effect of laser temporal pulse duration on Rayleigh scattering, which is commonly used as an absolute calibration to Thomson scattering systems to determine electron densities in plasma diagnostics. An experiment was set up by using a coaxial-flashlamp-pumped tunable dye laser, together with a Pockels cell, to deliver pulses from 3 ns to 110 ns duration and at a typical power of 1 MW. The incident beam monitor and the scattered signal were recorded photoelectrically by a fast phototube and photomultiplier. These two detecting channels are mutually independent, each having an effective time constant less than 600 ps. Relative Rayleigh scattering cross sections of nitrogen at filling pressure 40 - 140 kPa were measured as the laser pulse duration was varied from 5 ns to 110 ns. The experiment was carried out at several scattering angles, using two incident laser wavelengths at 590 nm and 486 nm. No dependence of the Rayleigh scattering on pulse duration was found for laser pulses ranging from 5 ns to 110 ns. We further found that the classical Rayleigh scattering cross section is still valid in this pulse width region by measuring the scattered dipole radiation pattern and its wavelength dependence (λ^{-4}), and both were found to be in agreement with theory to within 20 percent. This observation presents a significant contradiction to previous experimental results where the claim was made that the Rayleigh scattering cross section drastically deviates from the classical values when probing laser is shorter than 50 ns.

(f) Collisional Redistribution of Radiation--The collisional redistribution of radiation in a plasma was observed for the first time. Polarized radiation from a Nd-YAG pumped dye laser, tuned near the first Balmer spectral line of hydrogen (λ = 656 nm), was incident on a positive column discharge containing hydrogen. Light incident in the wing of the line was redistributed by collisions in the plasma and emitted in the line core. The intensity of this fluorescent radiation was observed as a function of laser wavelength. A study of this spectral profile and of the polarization of the fluorescent radiation will yield information concerning the collisions in the plasma.

After completion of the hydrogen experiment and analysis of the data, we expect to study a spectral line of helium ($2\ ^1S - 3\ ^1P$; λ = 502 nm). This line has two advantages; i.e., no fine structure and a metastable lower level. Both of these features simplify the interpretation of the data considerably.

SPONSORED CONFERENCES

Division 531, Atomic and Plasma Radiation

NBS Workshop on Electron Impact Ionization Theory, NBS, Gaithersburg, Maryland, S. M. Younger, November 5-7, 1980.

Third International NBS Workshop on Line Broadening in Plasmas, NBS, Gaithersburg, Maryland, Larry Roszman and W. L. Wiese, April 15-17, 1981.

INVITED TALKS

Division 531, Atomic and Plasma Radiation

Martin, W. C., Introductory remarks for A. G. Shenstone Memorial Symposium on High Rydberg States and Fano Interferences, Annual Meeting of Optical Society of America, Chicago, October 1980.

Martin, W. C., "Energy Levels of Highly Ionized Atoms," Workshop on Foundations of the Relativistic Theory of Atomic Structure, Argonne National Laboratory, December 1980.

Ott, W. R., "Ultraviolet Radiometry: Measurements and Applications," Technical University, Wroclaw, Poland, September 6, 1980.

Reader, J., "Spectroscopy of Highly Ionized Heavy Atoms with Laser-produced Plasmas," Division of Atomic and Molecular Physics, Canadian Association of Physicists, St. Johns, Newfoundland, October 23-24, 1981.

Roszman, L. J., "An Approach to the Calculation of Detailed Atomic Structure and Spectra in Moderately Dense Plasmas," Lawrence Livermore Laboratory, Livermore, California, June 1, 1981.

Roszman, L. J., "Dielectronic Recombination in Collisions of Electrons with Multicharged Ions," XII International Conference on Physics of Electronic and Atomic Collisions in Gatlinburg, Tennessee, July 17, 1981.

Weiss, A. W., "Review of Atomic Structure Calculations," Workshop on Foundations of the Relativistic Theory of Atomic Structure, Argonne National Laboratory, Argonne, Illinois, December 1980.

Wiese, W. L., "Overview of Production of Atomic Data for Fusion in the U.S.," US-Japan Workshop on Atomic Collision Data for Fusion, JILA, Boulder, October 27, 1980.

Wiese, W. L., "Atomic Structure and Oscillator Strengths," US-Japan Workshop at Atomic Collision Data for Fusion, JILA, Boulder, October 27, 1980.

Wiese, W. L., "Spectroscopy of Highly Ionized Atoms," University of Hannover, Institute for Plasma Physics, June 18, 1981.

Wiese, W. L., "Spectroscopy of Very High Temperature Plasmas," Technical University, Wroclaw, June 24, 1981.

Wiese, W. L., "Vacuum UV Radiometry with Plasma Sources," Physics Department, Jagellonian University, Krakow, June 26, 1981.

Division 531, Invited Talks (cont'd.)

Wiese, W. L., "Atomic Physics Data for Magnetic Fusion Research," Physics Colloquium, Ruhr University, Bochum, Germany, July 23, 1981.

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," Japanese Physical Society, Tokyo, Japan, October 3, 1981.

Younger, S. M., "Electron Impact Ionization of Positive Ions," 3rd Topical Conference on Atomic Processes in High Temperature Plasmas, APS, Louisiana State University, Baton Rouge, Louisiana, February 27, 1981.

Younger, S. M., "Theory of Electron Impact Ionization of Atoms and Ions," Physics Department, Oak Ridge National Laboratory, March 26, 1981.

Younger, S. M., "Calculations of Electron Impact Ionization Cross Sections in a Distorted Wave Approximation," ICPEAC Satellite Symposium, National Aeronautics and Space Administration, Greenbelt, MD, July 23, 1981.

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Acquista, N. and Reader, J., Spectrum and energy levels of nine-times ionized strontium (Sr X), J. Opt. Soc. Am. 71, 569 (1981).

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Burkhalter, P.G., Reader, J., and Cowan, R. D., Spectra of Mo XIII-XVIII from a laser-produced plasma and a low-inductance vacuum spark, J. Opt. Soc. Am. 70, 912 (1980).

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Greene, R. L., A Relaxation Theory of Stark Broadening by Ions, J. Quant. Spectrosc. Radiat. Transfer (in press, September 1981).

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Division 531, Publications (cont'd.)

Lucatorto, T. B., McIlrath, T. J., Sugar, J., and Younger, S. M., Radical redistribution of the 4d-oscillator strength observed in the photoabsorption of the Ba, Ba^{+}, and Ba^{++} Sequence, Phys. Rev. Lett. (in press, September 1981).

Martin, W. C. and Zalubas, R., Energy Levels of Sodium, Na I through Na XI, J. Phys. Chem. Ref. Data 10, 153-195 (1981).

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Martin, W. C., Series Formulae for the He I-like Spectra Na X through Ar XVII (Z = 11-18), Physica Scripta (1981) (in press, September 1981).

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Wyart, J.-F., Reader, J., and Ryabtsev, A., 3d-4p transitions in the zinclike and copperlike ions Y X, XI; Zr XI, XII; Nb XII, XIII; and Mo XIII, XIV, J. Opt. Soc. Am. 71, 692 (1981).

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Younger, S. M., Electron Impact Ionization Rate Coefficients and Cross Sections for Highly Ionized Iron, J. Quant. Spectrosc. Radiat. Transfer (in press, September 1981).

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Zalubas, R., and Albright, A., Bibliography on Atomic Energy Levels and Spectra (July 1975 through June 1979), NBS Spec. Publ. 363, Suppl. 2 (1980).

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 531, Atomic and Plasma Radiation Division

Charles H. Corliss

Member, Commission 14 of the International Astronomical Union.

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.

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

North-American Coordinator, 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).

MAJOR CONSULTING AND ADVISORY SERVICES

Division 531, Atomic and Plasma Radiation

1. Numerous evaluation tests and calibrations of eight deuterium lamps were performed throughout the year as part of contract work for Naval Research Laboratory. This work involved close consultations with NRL 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. Recently, W. C. Martin and W. L. Wiese have been asked by the International Astronomical Union to write updates on atomic data of interest for the astrophysical community for the 1982 IAU Transactions.

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 has in several recent meetings considered 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 EDITORSHIP

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

D. E. Kelleher, meeting at the Unizersity of Zagreb and Institute of Applied Physics in Yugoslavia, May 13-28, 1981. Sponsored by the Yugoslav Contract NBS-G-253 and NBS-G-258.

J. Reader, meeting of Division of Atomic and Molecular Physics, Canadian Association of Physicists, Memorial University of Newfoundland, St. Johns, Newfoundland, October 23-24, 1981.

W. L. Wiese, sponsored by Yugoslavian and Polish grants, visited Belgrade and Zagreb, Yugoslavia to review progress of two NBS cooperative programs. He also visited Wroclaw, Opole and Krakow, Poland to monitor scientific work being done under a grant from the Maria Sklodowska-Curie Foundation. (June 9-28, 1981)

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

S. M. Younger, traveled to Oak Ridge, Tennessee, to present a seminar entitled "Theory of Electron Impact Ionization of Atoms and Ions," at the Oak Ridge National Laboratory. This trip was paid for by ORNL. (March 25-27, 1981)

TECHNICAL ACTIVITIES

Division 532, Nuclear Radiation

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 Safeguards Studies project and a project on Dosimetry Standards for Neutron Radiation Therapy are attached to the Division Office. Photonuclear data collection 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).

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 SãoPaulo, Brazil; Li Linpei, National Institute of Metrology, Peking, China; Mauro Dias, Instituto de Pesquises Energéticas e Nucleares, São Paulo, Brazil; Johan Broerse and Hans Zoetelief, Radiobiological Institute TNO, Rijswijk, Netherlands; Hans-Georg Menzel, University of Saarlandes, Hamburg, West Germany; Bernd Siebert, Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany; Daniela Zanon, University of Rome, Italy; Bruno Chauvenet, LMRI, Saclay, France; Nancy Trahey, New Brunswick Laboratory, Argonne, Illinois; Joseph C. McDonald, Sloan-Kettering Institute, New York, New York.

Members of Nuclear Radiation Division staff on extended stays elsewhere include Henry Gerstenberg, Max Planck Institute for Chemistry, Mainz, Germany; Leonard Maximon and Michael Danos, Centre d'Etudes Nucléaires de Saclay, France; Evans Hayward and W. R. Dodge, University of São Paulo, Brazil; and Sydney Meshkov, California Institute of Technology and University of California, Irvine.

Division 532, Technical Activities (Cont'd)

Nuclear Materials Safeguards Studies (attached to the Division Office. These studies provide sound technical input for design, development and operation of safeguards programs directed by the DoE Office of Safeguards and Security (DoE/SS) and the US Initiative Program. Task activities addressed completion of the Concepts for Safeguards Information Systems (CSIS) study, modification of Diversion Path Analysis (DPA) Computer Program 2, and adaptation of DPA concepts to evaluation of International Atomic Energy Agency (IAEA) safeguards.

It has been decided by NBS management to terminate this program effective the end of fiscal year 1981, essentially because the program, although extremely valuable to the Department of Energy, is more of the nature of operations research than of traditional NBS measurement standards and supporting research. The program has produced several major outputs: a set of handbooks on Diversion Path Analysis, a report on Concepts for Safeguards Information Systems, and a report for IAEA, ISPO-153, Guide for Conducting Safeguards Approach Effectiveness Evaluations (in 4 volumes), 1981.

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.

Studies of the radiation responses of the six tissue-equivalent plastic ionization chambers, the two magnesium-walled chambers, and the Geiger-Müller (GM) dosimeter have been performed using ^{137}Cs and ^{60}Co calibrated photon fields and a ^{252}Cf field available at CRR. These studies included radiation sensitivity, wall attenuation and scattering, stem scattering, gas flow characteristics, ionization current saturation, collecting potential polarity effects, and resolving time for the GM dosimeter. A special electronic readout module was constructed for use with the digital electrometer to facilitate precision measurements of ionization charges.

Work has begun on the construction of a new charged particle beam line into the shielded room of the CRR's 3 MV Van de Graaff accelerator for use in producing moderately intense fields of monoenergetic neutrons. Three target holders and a target storage rack have been constructed and a number of target blanks have been fabricated. Several of these blanks have been sent to the Oak Ridge National Laboratory for tritiation and deuteration for use as water-cooled, neutron-producing targets. A target

service module has also been constructed for incorporation into the new beam line to direct and guide the high-power beam safely onto the target. A quadrupole doublet beam focusing magnet and its power supplies, two beam steering magnets and a turbomolecular vacuum pump have been acquired for the new beam line.

In support of the goals of this project, two reports titled "Comparison of Experimental and Theoretical Ionization Yield Spectra for Neutrons" and "Detailed Intercomparison of Calculated and Measured Ionization Yield Spectra for 20 MeV Neutrons and the Implication for High Energy Dosimetry" were given at the Fourth Symposium on Neutron Dosimetry, Munich.

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 on the initial studies carried out in the previous year, a more detailed study of composite gluon states was carried out in collaboration with P. Fishbane of the University of Virginia and C. Carlson and F. Gross of the College of William and Mary. In a series

of papers, it was shown that low-lying glueball states had extremely narrow widths of several MeV and that the oddball glueballs (those states not possible in a quark-antiquark coupling) have even narrower widths of less than 1 MeV. Using the flavor content of their decay products as a test of the presence of glueballs it was concluded that the E(1440) meson was not a glueball but more probably a simple composite of quark-antiquark. Finally, a detailed study was made of all possible hadronic decays of all low-lying glueball states. A rather long paper which spells out all the possible coupling for the various spin states has been written and a method has been devised to insure that all possible linearly independent couplings have been included. This paper will soon be submitted for publication.

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 extension of the formulation of relativistic nuclear physics to include the spin 3/2 field, a representation of the Δ_{33}, into the formalism developed earlier has been completed.

The elementary 3/2-field has up until now been used only in a non-relativistic approximation. The relativistic Rarita-Schwinger model, underlying the present semi-relativistic treatments, suffers from the well-known problems of a-causality. The Hayward 3/2 field allows a consistent formulation, which has to be developed beginning with NBS Monograph 154. This has been accomplished. However, the extension to QCD has not yet been completed.

A manuscript for a book on relativistic nuclear physics, in collaboration with Vincent Gillet of Saclay, has been completed.

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. The availability of electron accelerators with high duty cycle, such as the racetrack microtron currently under construction at the National Bureau

of Standards, makes it possible to determine the energy of the photon causing a nuclear event by measuring the inelastically scattered electron in time-coincidence with the nuclear event. These photons are called "tagged." A detailed report has been 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.

A second report on polarization effects in "tagged" photon experiments is being prepared. In addition, theoretical work continues on the photodisintegration of the few body system. This work is in collaboration with physicists from George Washington University. The effects of the Coulomb forces on the correlation of reaction products in the photodisintegration of ^{3}He has recently been investigated. A method has been developed for the numerical evaluation of integrals containing a spherical Bessel function and this technique will be used in studies of high momentum transfer effects in the photodisintegration of ^{6}Li.

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.

The quality of various radiation fields is studied by looking at the distribution of events of various energy loss within a small spherical cavity usually of 1 or 2 μm in diameter. A code which calculates these energy deposition distributions for neutrons has been modified to also calculate ion yield distributions. It is the ion yield distribution which is actually measured, but the energy deposition is what is desired. The differences between these two spectra have enabled us to better understand some of the differences between the measured ion yield spectra and the calculated energy deposition spectra. This work has been reported in two papers given at the recent international meeting on Neutron Dosimetry held in Munich in June. In addition, a Monte Carlo code is being developed to duplicate the calculation previously done by analytical means. The Monte Carlo code will then be modified to include effects (straggling and delta rays) which were not included in the analytic approach.

Neutron Personnel Monitoring. Under contracts with the NRC and DOE we have studied the problem of calibrating neutron monitoring instruments used in neutron fields of interest to these two agencies. In a paper accepted for publication in Health Physics we showed that the calculated dose equivalent in maintenance areas of nuclear power plants can vary by as much as 30%, depending on the type of interpolation used on the fluence-to-dose equivalent conversion factors.

In another paper accepted for publication in Health Physics we have treated the effect of neutrons reflected from the walls of a calibration room on the determination of calibration factors for various instruments. We have recommended an experimental procedure for determining a correction factor to account for the effect of reflected neutrons on the calibration of an instrument. We also have suggested a simple analytic expression for predicting this effect in an arbitrary calibration situation. The expression requires only simple parameters relating to the spectrum of the neutron source, the type of detector, and the size and composition of the walls of the calibration room. These recommended procedures were presented at a recent DOE workshop on neutron personnel dosimetry and are being incorporated into an ISO standard for calibration of neutron instruments.

Civil Defense. We have received final reports from the MAGI Corporation, under contract to NBS, concerning Monte Carlo calculations of shielding from neutrons from nuclear weapons. Calculations were made for benchmark structures specified by earlier agreements between NBS and the Federal Emergency Management Administration (FEMA). These calculations will be used to test approximate procedures devised at NBS for calculating protection from neutrons.

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 of 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

angles of 45°, 60°, and 135°. From both the angular distribution data and data taken at different energies we are able to extract an integrated E2 absorption strength. As in the case of ^{12}C studied in FY80, we have found significantly more E2 strength than current nuclear models would predict. More work needs to be done in this area.

Electron scattering experiments are now carried out with the new CAMAC/HARRIS data acquisition system. This new system has been developed into an almost totally hands-off operation which is extremely useful for this group considering manpower limitations. Our main activity during FY81 has been in data collection for precision measurement of the ^{4}He charge radius. In this effort we profited immensely from the help of visiting scientists from area universities including Catholic University and Montgomery College. The data taking operation is now almost complete. We have engaged in several electron scattering experiments at the MIT/Bates accelerator, a higher energy machine than the NBS linac. This work includes studies of high spin magnetic excitations, convection current transitions, and electron scattering sum rules. The high spin state work is yielding new spectroscopic information for medium A nuclei and the character of residual nuclear forces. The convection current work is aimed at understanding nucleon currents within nuclei, a subject about which we know very little. The sum rule work was done in collaboration with a group from the Lund Institute of Technology in Sweden. In this latter work, we have measured the Coulomb response functions of a variety of nuclei in the giant multipole resonance region and seek to answer the question, "Does the Coulomb sum rule work?" If it, as presently understood, does not work, our ideas concerning nucleonic properties within nuclear matter may have to be modified. We are now involved in a theoretical interpretation of the results.

Electrodisintegration as a tool for the study of the giant multipole resonances has the advantage over photodisintegration in that the virtual photon spectrum of the electron, in contrast to the real photon bremsstrahlung spectrum, is a strong function of the multipolarity of the induced nuclear reaction. Thus by measuring the yields of protons and alphas as a function of the incident electron energy, we have been able to locate and measure the strength of the proton and alpha decay channels of the giant E1 and E2 resonances. Thus far we have completed studies of ^{58}Ni, ^{60}Ni, ^{62}Ni, ^{56}Fe, ^{59}Co, and ^{64}Zn with the results published or in press. We have begun a study of the proton and alpha decay channels of ^{90}Zr and ^{92}Zr. An analogue state at 7.8 MeV in ^{90}Zr has been studied in both electrodisintegration and photodisintegration to verify the shape of the E1 virtual photon spectrum and the ratio of the real and virtual photon spectra. This work has benefitted tremendously from a collaboration with the University of São Paulo in Brazil sponsored by the NSF.

Complementary to the electrodisintegration experiment, measurements of electron-induced radioactivity are being done at the NBS linac. Measurements of $^{63}Cu(e,n)^{62}Cu$ in collaboration with a group from the University of São Paulo and $^{51}V(e,\alpha)^{47}Sc$ with a group from the Massachusetts Institute of Technology are presently being conducted. The resources of the Radioactivity Group of this division are utilized in these investigations.

During FY81, considerable work on our part has gone into the national effort to define future needs in electromagnetic nuclear physics. Members of this group participated in the year-long workshop held at various universities' sites on the east coast entitled "Future Directions in Electromagnetic Nuclear Physics." A book has been published containing (among others) our proposals for research with high duty factor electron beams in the next decade. We have participated in developing the nuclear physics justification of proposals for new electron accelerators in the 1-2 GeV range. We have also developed plans to use the NBS microtron in support of national goals in nuclear research. This accelerator is under construction and will provide a 100% duty factor beam of electrons, at several hundred MeV, with currents of several hundred μA. With this facility we anticipate doing coincidence measurements of scattered electrons and nuclear reaction products. This will provide new dimensions of understanding to many nuclear physics problems. A competence initiative to utilize this facility is being developed.

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 spectrocopic 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 section 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.

Probably the most important standards measurement of the past year was the determination of the fission cross section of ^{235}U at 14 MeV. The fusion process is a monoenergetic source of 14 MeV neutrons. Progress in fusion research and concern about effects of the tactical neutron warheads are driving the current interest in this standard. A careful evaluation of measurements at NBS and elsewhere was completed with a resulting accuracy of $\pm$ 0.7% at 14.1 $\pm$ .1 MeV. The 1% accuracy request for this cross section has existed for 20 years and it is a real boost to the NBS staff to see this objective realized. This cross section is now nearly as well known at 14 MeV as at thermal energy.

Upon completion of the 14-MeV ^{235}U measurement, our attention returned to the 200-1200 keV region. Two efforts were made in this area. First, our two earlier sets of data taken with the NBS Van de Graaff were reanalyzed in an attempt to understand the basis for a 2% difference in the absolute scale for these measurements. A thorough review of the experiments revealed two subtle corrections which enabled the data to be reconciled. These two data sets have now been prepared for final publication in a single paper submitted to Nuclear Science and Engineering.

The other effort is a second linac measurement of $^{235}U(n,f)$ in this energy range using a new measurement system. The data collection is expected to be completed in FY81. Upon completing the analysis of this data, the NBS will have completed four measurement efforts in this energy range on ^{235}U. It appears that the long existing objective of 1% for the cross section may also be within reach when the NBS data is combined with other data in the final evaluation. Thus, another long-standing request for high accuracy standards of great importance to the breeder reactor programs will be satisfied.

The search for possible molecular binding effects on the standard cross sections ^{10}B, ^{6}Li, ^{3}He, and ^{235}U continued in FY81. The most conclusive result of the FY80 effort was the discovery of a 2% variation in the (n,α) cross section ratio of ^{6}Li glass and solid ^{10}B found between 1 and 10 eV. This surprising result is being studied in further experiments including possible molecular and atomic binding effects on nuclear reaction cross sections.

These studies have led us to consider vibrations, rotations, and electronic excitations induced by neutron collisions in the eV and lower keV region. Experiments were devised and successfully completed on benzene and liquid N_2 targets. The expected vibrations and rotations were observed, and some evidence has been found for electronic excitations. These are the world's first measurements in this much discussed and promising field of inelastic scattering of eV neutrons. The experiments open up a wide range of studies with not only practical implications for standards measurement and other aspects of nuclear technology, but they represent a breakthrough into materials properties studies with the neutron probe extended into a new energy range.

Considerable effort was expended in FY81 in reviewing possible implications of the effect for the various branches of nuclear energy technology. It was found that calculated neutron spectra in critical assemblies and reactors are always significantly harder than measured spectra. Our discovery of new inelastic channels for neutron energy loss below the inelastic nuclear threshold provides an additional mechanism for neutron energy loss not presently taken into account.

Our study of new physical phenomena of importance to the standards program has helped reduce measurement uncertainties, but also has yielded another new technique for materials studies. We conducted a careful study of Bragg edges to understand better the highly anisotropic scattering from fission foil backings. The resolution on the Bragg edges was thirty times better than previous measurements. Where previously only two edges had been seen in iron, more than sixty were found in these experiments. It was immediately obvious that these steps were in every sense equivalent to the peaks observed in a neutron or x-ray powder diffraction experiment. Yet the method permits greatly improved resolution and statistical accuracy. It is projected that a run of typical length on the NBS linac would allow statistically significant powder diffraction data with a resolution of 0.05%--an order of magnitude better than the typical reactor-based crystal diffractometer. In simple terms, this means a capability for interpreting a unit cell containing ten times as many atoms as current techniques allow one to study.

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 in industrial and government programs. Dr. Allan Carlson is now 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 HEDL, BNL, ORNL, and Battelle-Columbus. The group has provided consulting services to LLNL and LANL on new neutron measurement methods, on the development of new methods for materials science studies using neutrons, and on γ-ray laser studies. Extensive consultation on preparation of large area deposits of fissile materials was provided to the ORNL for the Clinch River Breeder Reactor Program.

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. The latest measurement example is a round robin on 14-MeV flux measurements.

The continued availability of suitable accelerator sources of neutrons for NBS has been carefully studied this year. A report was prepared reviewing the future needs for accelerator-produced neutrons at NBS and the capabilities of the various accelerator systems to meet NBS needs. Several different accelerator possibilities were evaluated. Although in a draft status this report has been abstracted and a copy of this abstract is included in Appendix I.

While no attempt was made in the study to select or prepare the case for any type, the injector of the PIGMI accelerator offers many attractive features. The PIGMI accelerator is designed by LANL for cancer therapy in a hospital using mesons. The accelerator has the attractive features of simplicity in operation, low maintenance and power costs, and probably could be fitted into existing NBS space without major building modifications. Its neutron production capabilities appear to be an excellent match to the prospective NBS program.

IV. Neutron Field Standards Group

The objectives of this group are to provide neutron dosimetry standardization and neutron source and detector calibration for energy generation technology and radiation exposure monitoring. Activities are divided between response to calibration and measurement service requests and applying existing standard neutron fields and related capabilities to neutron reaction rate measurement standardization. Strong interactions with outside organizations, both federal and private sector, continue to be the main programmatic characteristics of this group.

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. Even the list of unusual and unpredictable places where the NBS double fission chamber has been employed for measurement saw another entry. This year it was the inside of the Army's new XM-1 battle tank!

Neutron personnel dosimetry activities involved hundreds of dosimeter and dosimetry instrumentation calibrations and 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 massive 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 program component. New impetus, in fact, appeared this year with the recognition of thermal shock potential in certain pressure vessels as a result of post-TMI changes in emergency reactor-shutdown procedures. In this latter regard a paper will be presented at the Ninth Water Reactor Safety Information Meeting examining

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. Power reactor development activities were a highlight this year. The long prepared-for fission rate measurements during start-up of DoE's Fast Test Reactor (FTR) at Hanford were completed. The challenge of this experiment was successfully met, with many firsts for a laboratory instrument adjusted to operate in the monumental and hostile surroundings of a 400 megawatt, sodium-cooled test reactor, the largest of its kind in the world. It was an exhilarating experience for our small staff, and not soon to be forgotten.

Less dramatic activities went their necessary way but they seemed less dominating after the FTR effort: (1) the new ^{252}Cf irradiation facility became operational and was immediately employed for the start of new isotopic fission cross section measurements; (2) absolute measurement of the neutron flux density at the center of the Intermediate-Energy Standard Neutron Field (ISNF) were initiated and completed; (3) type-testing of commercial neutron dosimetry got underway in earnest; (4) the dosimetry activation cross section, $^{63}Cu(n,\alpha)^{60}Co$, for ^{252}Cf spontaneous fission neutrons was published; (5) intercomparison of solid-state track recorder (SSTR) technique for fission rate measurements with the NBS fission chamber was completed after much delay; (6) neutron source calibrations at the Manganese Bath Facility continued. The last item, neutron source calibrations, created special problems this year because of the abrupt retirement of the staff person in charge of this facility.

Specific reference is made here to last year's narrative of technical activities (Annual Report 1980; Div. 532, p. 37-40). Most of the information provided there is applicable to this year's activities. Thirteen publications and reports were part of the Group's activities this year; the total for FY80 and FY81 is twenty-eight--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 interpretation. Participation at three symposia in radiation personnel dosimetry for specialists led in one case to a commitment to share in the drafting of a new IAEA Manual on Neutron Dosimetry Calibrations. Preparations for the Fourth ASTM/EURATOM Symposium Reactor Dosimetry, to be held at NBS next year, moved into mid-gear as we try to 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). 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. The NCRP Symposium on the Control of Radiation Exposure in the Event of Accident or Attack took place in April 1981 and was characterized by multi-discipline participation and a strong exchange of ideas. The Session on Public Information, organized and mustered by a member of the Neutron Field Standards Group was successful far beyond expectation in view of the unknowns regarding speakers and the outreach of subject matter. A proposal for establishing an Environmental Radiation Index, akin to the Air Quality Index was given an excellent airing by a university participant and enjoyed the expected criticism but also some unexpected support. The implementation of such an index for general dissemination--the idea for which originated here at CRR--hinges on the development of a set of understandable radiation exposure benchmarks. A candidate for identifying and explaining such benchmarks would be NBS/CRR.

V. Radioactivity Group

A. Standard Reference Materials and Calibration Services

From August 1, 1980 to August 1, 1981, 1288 standards and calibrated sources were issued to the public and government agencies, many in connection with various quality control or traceability programs. Details of the numbers of sources and the dollar value of these standards and calibrations are given in Table 1.

Table 1

Standards and Calibration Services	No. of Units	K$
Standard Reference Materials	1109	183.3
Atomic Industrial Forum, traceability tests of radiopharmaceutical manufacturers	11	4.5
College of American Pathologists	66	3.3
NRC (15) and EPA (8) Traceability Programs	23	--
Reports of Calibration (NBS 94)	46	28.2
Scheduled Calibrations (OMS)	33	12.3

A new booklet has been prepared describing radioactivity calibration services at NBS. This has been a great aid in explaining our services to the public. A reevaluation was also made of the time spent on calibrations, and the fees charged since June 1, 1981 are adequate to recover NBS' costs.

Special calibrations included (1) an iron-55 electroplated line source for use in calibrating a position-sensitive x-ray detector at Los Alamos, (2) filter-paper disk sources of ^{90}Sr-^{90}Y and ^{137}Cs for calibration of beta-particle detectors at Three Mile Island, and (3) millicurie sources of ^{22}Na and ^{134}Cs in steel capsules for use in calibrating detectors for short-half-life cyclotron-produced positron-emitting radionuclides.

Special calbirations also included continued testing of commercial mixed-radionuclide gamma-ray standards. During this period four companies submitted mixed standards in the form of solutions, point sources, and mixed gaseous sources.

The catalog describing SRM's was extensively revised and sent to an updated and enlarged mailing list.

Details of a new cost-recovery program were worked out with the Atomic Industrial Forum (AIF) for the radiopharmaceutical SRM's (4400 series). The goal is for the program to be self sustaining in two to three years. Prices on these SRM's have been increased about 70%, while sales have increased slightly due to better publicity.

A new long-lived mixed-radionuclide gamma-ray SRM was issued in both point source and solution form following almost two years of development work. The new standard is a mixture of ^{125}Sb, ^{154}Eu, and ^{155}Eu, and is intended for use in calibrating the efficiency of germanium spectrometers used in x-ray and gamma-ray spectrometry. Over 150 of these standards have been sold in three months. A booklet is provided with these SRM's describing the precautions to be observed in quantitative nuclear spectrometry.

Four natural-matrix radioactivity standards were prepared and calibrated. Rocky Flats Soil Number 1, Columbia River Sediment (re-issue) and Human Liver will be issued as SRM's, and Human Lung will be issued as a Research Material. Several laboratories were involved in the calibrations.

A new low-energy photon SRM, ^{49}V, was developed. This electron-capture radionuclide has K x-rays of about 5 keV and a half life of about 300 days.

Division 532, Technical Activities (Cont'd)

B. Basic Activity and Nuclear Data Measurements

Chemical techniques were tested for (1) separating ^{55}Fe from a manganese cyclotron target and (2) separating 58-day tellurium-125m daughter from 2.77-year antimony-125. Activity measurements were made of ^{125}Sb immediately after separation, and with ^{125m}Te in equilibrium, but the results were not consistent. Further investigations are planned.

An activity calibration was carried out for europium-154, using a $4\pi(PPC)$-γ anticoincidence technique.

An anticoincidence measurement of ^{51}Cr also tested two techniques for thin-source preparation. Electrosprayed ion-exchange resins will be investigated further, although initial results showed less improvement than that measured in other laboratories.

Half-life measurements made over the past several years in the Group were evaluated for 50 radionuclides and prepared for publication. Probabilities per decay of gamma rays measured for 7 radionuclides are included.

C. Other Agency Programs

A chamber has been constructed which can be used both for measuring radon exhalation rates from building materials and for providing a gaseous radioactive atmosphere in which monitoring instruments can be calibrated.

The literature concerned with the radon exhalation of, and diffusion through, building materials has been reviewed and a summary will be published shortly.

The following traceability test sources were provided to the EPA-Las Vegas: ^{14}C, ^{51}Cr, ^{65}Zn, ^{75}Se, ^{90}Sr, and ^{226}Ra. Samples of ^{60}Co, ^{110m}Ag, and ^{230}Th submitted by EPA were checked for correct activity calibration.

The following traceability test sources were provided to RESL (NRC), Idaho Falls: ^{3}H, ^{32}P, ^{51}Cr, ^{89}Sr and ^{90}Sr, ^{99}Tc, ^{127}Xe, ^{131}I, ^{133}Xe, ^{201}Tl, ^{207}Bi, ^{210}Po, and ^{242}Pu. NBS tested a spiked soil and a mixed-gamma-ray solution supplied by RESL.

Activity calibrations were developed for ^{210}Pb, and 200 ampoules of calibrated solution were prepared for EPA.

A pitchblende standard issued by the New Brunswick Laboratory was checked to see if the ^{226}Ra was in equilibrium with the ^{238}U and ^{234}U. NBS found that the standard was in equilibrium to well within the 2% uncertainty associated with the measurement.

D. International Activities

Ampoules of six radionuclides were sent to BIPM and the International Atomic Energy Agency for comparison in their ionization chambers with calibrations of other national and international laboratories.

The following bilateral intercomparisons were initiated or completed:

Nickel-63 was intercompared with IBJ (Poland).

Solutions of ^{109}Cd were exchanged with LMRI (France) for comparative measurements of gamma-ray-emission rate.

Antimony-125 and iodine-125 were intercompared with OMH (Hungary) as a part of a scientific exchange program involving working visits. Quantitative gamma-ray spectrometry is also being investigated cooperatively.

In addition, long-lived mixed-gamma-ray standards have been sent to OMH (Hungary), PTB (Germany), and LMRI (France) for comparative emission-rate measurements, and a carbon-14 solution has been received from the USSR.

A conference entitled Low Activities '80, cosponsored by NBS through the ICRM, was held in the High Tatras, Czechoslovakia, and was attended by approximately 190 scientists from around the world. The proceedings will be published in early calendar 1982.

SPONSORED CONFERENCES

Division 532, Nuclear Radiation

Eighth Annual Water Reactor Safety Information Meeting, NBS, Gaithersburg, Maryland. Liaison with Nuclear Regulatory Commission, James A. Grundl, October 1980.

International Program Review Meeting on Reactor Pressure Vessel Irradiation Surveillance, NBS, Gaithersburg, Maryland. E. Dale McGarry, October 27-31, 1980.

"Low-Level Radioactivity Measurements" High Tatras, Czechoslovakia. Cosponsored by NBS through the International Committee for Radionuclide Metrology (ICRM), J. M. R. Hutchinson, November 24-27, 1980.

International Forum on ^{252}Cf $\bar{\nu}$. Cosponsored with the Department of Energy Cross Section Evaluation Working Group, A. D. Carlson, April 20, 1981.

INVITED TALKS

Division 532, Nuclear Radiation

Ayres, Robert L., "Radiation and Radioactivity Measurements for Biology and Medicine," Nuclear Energy Mini-Plenary Sessions of the 1981 American Nuclear Society Annual Meeting, Miami Beach, Florida, June 1981.

Ayres, Robert L., "Radioactivity Standardization of ^{99m}Tc and ^{99}Mo, Nuclear Energy Mini-Plenary Sessions of the 1981 American Nuclear Society Annual Meeting, Miami Beach, Florida, June 1981.

Behrens, J. W., "Preparation of Accelerator Targets by Painting," Ninth International Conference of Nuclear Target Development Society, Gatlinburg, Tennessee, October 14, 1980.

Bowman, C. D., "Efficient Neutron Production Using 12 MeV Electrons," Sixth Conference on the Application of Accelerators in Research and Industry, North Texas State University, Denton, Texas, November 4, 1980.

Bowman, C. D., "Elastic and Inelastic Scattering of eV Neutrons," University of Kentucky, Lexington, Kentucky, September 25, 1981.

Caswell, R. S., "Some Problems in Neutron Microdosimetry Calculations," Radiobiological Institute TNO, Rijswijk, The Netherlands, June 11, 1981.

Caswell, R. S., Rapporteur of Poster Session on "Basic Data," Fourth Symposium on Neutron Dosimetry, Munich, Germany, June 1, 1981.

Coyne, J. J., "Proportional Counter Measurements of Energy Deposition Spectra for Neutrons in the Energy Region from 14 to 20 MeV," Institute fur Biophysik, Hamburg/Saar, W. Germany, November 1980.

Coyne, J. J., "Neutron Cross-Sections in Carbon and Oxygen in the Energy Region from 14 to 20 MeV," Physikalisch-Technische Bundesanstalt, Braunschweig, W. Germany, November 1980.

Danos, Michael, "Quarks in Nuclei", University of Maryland, January 14, 1981.

Danos, Michael, "Relativistic Heavy Ion Collisions," Colloquium at Saclay, France, May 1981.

Danos, Michael, "Nuclear Forces from Quark Dynamics," Workshop on Nuclear Physics with Real and Virtual Photons sponsored by the Italian Nuclear Energy Committee, Bologna, Italy, November 1980.

Division 532, Invited Talks (Cont'd)

Danos, Michael, "Nuclear Forces and Quark Dynamics," University of Milano, Italy, December 1980.

Duvall, K. C., "The NBS 14 MeV Absolute Neutron Beam Facility," Sixth Conference on the Application of Accelerators in Research and Industry, North Texas State University, Denton, Texas, November 4, 1980.

Gilliam, D., "Absolute Fission Rates in FFTF," American Nuclear Society, San Francisco, California, 1981.

Grundl, J., "Summary of Session on Public Information and Training," NCRP Symposium on Radiation Exposure Control in an Emergency, Reston, Virginia, April 1981.

Lightbody, J. W., Jr., "Electronuclear Reactions," Workshop on Nuclear Physics with Electromagnetic Probes, 1980 and Beyond, in the Canadian Context, Université de Montréal, P.Q., Canada, January 16, 1981.

Mann, W. B., "Standards, Traceability and Regulation," Nuclear Energy Mini-Plenary Sessions of the 1981 American Nuclear Society Annual Meeting, Miami Beach, Florida, June 1981.

Maruyama, X. K., "Radiative Tails and Distortion Effects in the Coulomb Sum Rule Experiment," University of Massachusetts, June 17, 1981.

Meshkov, S., "Glueballs and Oddballs," University of Florida, Gainesville, Florida, October 23, 1980.

Meshkov, S., "Glueballs and Oddballs," University of Michigan, Ann Arbor, Michigan, February 2, 1981.

Meshkov, S., "Glueballs and Oddballs," Purdue University, Lafayette, Indiana, February 4, 1981.

Meshkov, S., "Glueballs and Oddballs," Duke University, Durham, North Carolina, April 29, 1981.

Meshkov, S., "Glueballs and Oddballs," University of North Carolina, Chapel Hill, N.C., April 30, 1981.

O'Connell, J. S., "Coincidence Measurements with High Energy Electrons," Workshop on Nuclear Physics with Real and Virtual Photons, Bologna, Italy, November 25-28, 1980.

O'Connell, J. S., "Coincidence Measurements with High Energy Electrons," Lund Institute of Technology, Lund, Sweden, December 2, 1980.

Division 532, Invited Talks (Cont'd)

O'Connell, J. S., "Unsolved Problems in Electromagnetic Nuclear Reactions," Rensselaer Polytechnic Institute, Troy, N.Y., March 26, 1981.

O'Connell, J. S., "Unsolved Problems in Electromagnetic Nuclear Reactions," Nuclear Laboratory, Triangle Universities, Durham, N.C., April 10, 1981.

O'Connell, J. S., "Photonuclear Reactions Above the Pion Threshold," three lectures at the International School of Nuclear Physics at Intermediate Energies, Verona, Italy, July 16-26, 1981.

Schrack, R. A., "Resonance Neutron Radiography Using an Electron Linac," Sixth Conference on The Application of Accelerators in Research and Industry, North Texas State University, Denton, Texas, November 4, 1980.

Schwartz, R. B., "Effects of Room-Scattered Neutrons on the Calibration of Radiation Protection Instruments," Fourth Symposium on Neutron Dosimetry, Munich, Germany, May 1981.

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Division 532, Nuclear Radiation

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Behrens, J. W., Schrack, R. A., and Bowman, C. D., Nondestructive Examination of a Defective Silver Braze Using Resonance-Neutron Radiography, Nuclear Technology 51, No. 1, 78-82 (Nov. 1980).

Behrens, J. W., Browne, J. C., and Walden, J. C., Measurement of the Neutron-Induced Fission Cross Section of ^{237}Np Relative to ^{235}U from 20 keV to 30 MeV, Lawrence Livermore National Laboratory Report UCRL 86397 (July 1981).

Behrens, J. W. and Browne, J. C. (Lawrence Livermore National Laboratory), Measurement of the Neutron-Induced Fission Cross Sections of Americium-241 and Americium-243 Relative to Uranium-235 from 0.2 and 30 MeV. Nucl. Sci. Eng. 77, 444-453 (1981).

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Division 532, Publications (Cont'd)

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Cauvin, M., Gillet, V., Soulmagnion, F., and Danos, M., Mass Formula Based on SU4, Nucl. Phys. A361, 192 (1981).

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Dodge, W. R. and Bertsch, D. L., Calibration of a Gamma-Ray Telescope Using Tagged Positron Annihilation Photons, Nuclear Instruments and Methods 185, 439-448 (June 1981).

Dodge, W. R., Hayward, E., Leicht, R. G., and Wolynec, E., Electrodisintegration of ^{56}Fe, ^{59}Co, and ^{64}Zn, to be published in Phys. Rev.

Duvall, K. C. and Wasson, O. A., The NBS 15 MeV Absolute Neutron Beam Facility, Proceedings of 1980 Conference on the Application of Accelerators in Research and Industry held at North Texas State University, Denton, Texas, Nov. 3-5, 1980, IEEE Transactions on Nuclear Science, NS-28, No. 2, 1488-1489 (April 1981).

Eisenhauer, C. M. and Grundl, J., Benchmark Referencing of Neutron Dosimetry Measurements, LWR-PV Irradiation Surveillance Dosimetry, Prog. Report, NUREG/CR-1240, Vol. II (January 1981).

Eisenhauer, C. M. and Schwartz, R. B., Difficulties in Calculating Spectrum-Averaged Values of Neutron Dose Equivalent, Health Phys. (in press).

Eisenhauer, C. M., Schwartz, R. B., and Johnson, T., Measurement of Neutrons Reflected from the Surfaces of a Calibration Room, Health Phys. (in press).

Eisenhauer, C. M. and Schwartz, R. B., Analysis of Room-Return Effects. Proc. 8th DoE Workshop on Personnel Neutron Dosimetry, Louisville, Ky., June 18 and 19, 1981 (in press).

Eisenhauer, C. M. and Schwartz, R. B., The Effect of Room-Scattered Neutrons on the Calibration of Radiation Protection Instruments, Proc. 4th Symp. on Neutron Dosimetry, GSF, Munich-Neuherberg, Germany, June 1-5, 1981 (in press).

Division 532, Publications (Cont'd)

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Gilliam, D. M., Fuller, J. L., Grundl, J. A., and Daughtry, J. W., Absolute Fission Rates in the FFTF, Trans. Am. Nucl. Soc. 37 (November 1981).

Gilliam, D. M. Fuller, J. L., Grundl, J. A., and Rawlins, J. A., FFTF Reactor Characterization Program: Absolute Fission Rate Measurements, TC-1963, Hanford Eng. Dev. Lab. (May 1981).

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Golas, D. B., Traceability Programs for Nuclear Medicine, Proceedings of the Symposium on Traceability for Ionizing Radiation Measurements, Gaithersburg, Maryland, May 1980 (in press).

Grundl, J. A., Eisenhauer, C. M., McGarry, E. D., and Spiegel, V., with McElroy, et al., LWR Pressure Vessel Surveillance Dosimetry Program, Eighth Reactor Safety Research Information Meeting, NRC Annual Report, NUREG/CR-1747 (April 1981).

Haight, R. C., Grimes, S. M., Johnson, R. G., and Barschall, H. H., Charged-particle Emission in Reactions of 15-MeV Neutrons with ^{89}Y, ^{90}Zr, and $^{92,94,95,96}Mo$, Physical Review C23, No. 2 (February 1981).

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Hayward, E., Photonuclear Reactions, Encyclopedia of Physics, 750-751 (January 1981).

Hayward, E., Photon Scattering Experiments, Future Directions in Electromagnetic Nuclear Physics (1981).

Hoppes, D. D. and Schima, F. J., Eds., Nuclear Data for the Efficiency Calibration of Germanium Spectrometer Systems, NBS Special Publication (in press).

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 (in press).

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

Division 532, Publications (Cont'd)

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, Int. J. Appl. Rad. Isotopes (in press).

Johnson, R. G. and Bowman, C. D., High Resolution Powder Diffraction by White Source Transmission Measurements, Proceedings of the IPNS Symposium on Neutron Scattering, Argonne National Lab., Argonne, Il., August 12-14, 1981 (in press).

Johnson, R. G., Behrens, J. W., and Bowman, C. D., Source Imaging Using Neutron Pinhole Cameras Based on Position-Sensitive Proportional Counters, Nuclear Technology (in press).

Kopp, M. K. (ORNL), Behrens, J. W., Meacham, M. A. (ORNL), and Williams, J. A. (TEC), Development of Proportional Counter Cameras for Neutron Imaging with 1-mm Resolution, Rev. Sci. Instrum. (in press).

Lehman, D., Parke, W. C., and Maximon, L. C., Numerical Evaluation of Integrals Containing a Spherical Bessel Function by Product Integration, J. Math. Phys. 22, 1399 (1981).

Lightbody, J. W., Jr., A(e,e'2-nucleon)A-2 Reaction Studies, Future Directions in Electromagnetic Nuclear Physics (1981).

Mann, W. B., Hutchinson, J. M. R., and Edgerly, D. E., National and International Traceability in Radioactivity Measurements, Proceedings of the International Atomic Energy Agency Symposium on Low-Level Counting and Spectrometry, West Berlin, W. Germany, April 1981 (in press).

Mann, W. B., Standards, Traceability and Regulation, 27th Annual Meeting of the American Nuclear Society, Miami Beach, Florida, ANS Abstracts (June 1981).

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Maruyama, X. K., Lindgren, R. A., Flanz, J. B., Hicks, R. S., Parker, B., Peterson, G. A., Lawson, R. D., Teeters, W., Williamson, C. F., and Kowalski, S., Comparison of Inelastic Electron Scattering with $[g_{9/2} \otimes (f_{7/2}^{-3})_J]_{8^-}$ Shell-Model Calculations for the T = 1 and T = 2, 8^- States in ^{58}Fe, Phys. Rev. Letters 46, No. 11, 706-709 (March 16, 1981).

Maruyama, X. K., Lindgren, R. A., Plum, M. A., Hicks, R. S., Parker, B., Peterson, G. A., and Williamson, C. F., Comparisons of M8 Transitions to $(g_{9/2} f_{7/2}^{-1})_{8^-}$ States in ^{54}Fe, ^{58}Ni, and ^{60}Ni, Proceedings International Conference on Nuclear Physics, Berkeley, California, 79 (1980).

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Prats, F., Harper, E. P., and Maximon, L. C., Reaction $^3He(\gamma,2p)n$ at Intermediate Photon Energies, Phys. Rev. C22, 7 (1980).

Maximon, L. C., de Miniac, A., and Aniel, T., Tagged Photons, An Analysis of the Bremsstrahlung Differential Cross Section in the Range of Interest for a Tagged Photon System, NBSIR 81-2262 (April 1981).

Eskandarian, A., Lehman, D. R., Gibson, B. F., and Maximon, L. C., Momentum-Space Solution of the Bound Three-Body Problem with Two Charged Particles, Bull. Am. Phys. Soc. II (Session DG12) 26, 566 (1981).

McGarry, E. D., Fabry, A., Gold, R., Kellogg, L., and Kam, F., Current PCA Specifications for Transport Theory Validation, LWR-PV Surv. Dos. Improvement Program, NUREG/CR-1861, Section 8 (1981).

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McGarry, E. D., Tests of Radiation Exposure Calculations for Reactor Pressure Vessels, NBS Dimensions (October 1980).

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Motz, J. W. and Danos, M., Towards Safer Medical X-ray Examinations, NBS Dimensions 64, 16 (August 1980).

Noyce, J. R., Evaluation of Methods for the Assay of Radium-228 in Water, NBS Technical Note 1137 (February 1981).

O'Connell, J. S., Coincidence Measurements with High Energy Electrons, Proceedings of the Workshop on Nuclear Physics with Real and Virtual Photons, Bologna, Italy, 286-295 (1981).

O'Connell, J., Coeditor, Report of the Workshop on Future Directions in Electromagnetic Nuclear Physics (1981).

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Division 532, Publications (Cont'd)

Schleter, J. C. and Baloga, S. M., Guide for Conducting Safeguards Approach Effectiveness Evaluations, ISPO-153, Vols. 1-IV (May 1981).

Schrack, R. A., Behrens, J. W., Johnson, R. G., and Bowman, C. D., Resonance Neutron Radiography Using an Electron Linac, Proceedings of the Sixth Conference on the Application of Accelerators in Research and Industry, North Texas State University, Denton, Texas, November 3-5, 1980; IEEE Trans. on Nucl. Sci. NS-28, No. 2, 1640-1643 (April 1981).

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Spencer, L. V., Chilton, A. B., and Eisenhauer, C. M., Structure Shielding Against Fallout Gamma Rays for Nuclear Detonation 967 p., NBS Special Publication (September 1980).

Spiegel, V., Eisenhauer, C. M., Winkler, G., and Smith, D. L., Measurement of the Average Activation Cross Section for the Reaction $^{63}Cu(n,\alpha)^{60}Co$ in the Spontaneous Fission Neutron Field of Californium-252, Nucl. Sci. & Eng. 78, No. 4, 415 (1981).

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

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. Engr. (in press).

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Division 532, Nuclear Radiation

Stephen M. Baloga

Member, American Nuclear Society, Isotopes & Radiation Division's Technical Committee on Nuclear Safeguards.

James W. Behrens

Member, DoE Cross Section Evaluation Working Group (CSEWG), Standards Subcommittee.

Charles D. Bowman

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.

Randall S. Caswell

Member, Program Committee, Fourth Symposium on Neutron Dosimetry, Munich, Germany, June 1-5, 1981.

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.

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

Member, NCRP Board of Directors.

Chairman, NCRP Ad Hoc Committee on SI Units.

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

Randall S. Caswell (Cont'd)

Chairman, NCRP Ad Hoc Committee on Publications.

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

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

Member, Subcommittee on Federal Strategy for Research into the Biological Effects of Ionizing Radiation.

Alternate Delegate, Committee on Federal Guidance for Occupational Exposure to Ionizing Radiation (chaired by EPA).

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.

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.

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.

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

Charles M. Eisenhauer

Member, President's Commission on the Accident at Three Mile Island, Dosimetry Task Group.

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

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 Fourth ASTM-EURATOM Symposium on Reactor Dosimetry, NBS, March 1982.

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

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

Member, Organizing Committee for National Council on Radiation Protection and Measurements (NCRP) Symposium on Radiation Exposure Control, April 1981.

Evans V. Hayward

Member, Maryland Governor's Science Advisory Council.

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.

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

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.

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.

George Lamaze

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

J. W. Lightbody, Jr.

Chairman, 1982 Gordon Research Conference on Photonuclear Reactions.

Member, Scientific Advisory Committee to Southeastern Universities Research Association.

Wilfrid B. Mann

Member, Executive Board, International Committee for Radionuclide Metrology.

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

Wilfrid B. Mann (Cont'd)

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 INMM8.04 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 Fourth ASTM-EURATOM Symposium on Reactor Dosimetry, NBS, March 1982.

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.

Sydney Meshkov

Trustee and General Consultant, Aspen Center for Physics. Actively participated in running the center during the summer months.

Organized the Program for the High Energy Conference at the Center for Theoretical Studies at the University of Miami.

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

Sydney Meshkov (Cont'd)

Member, Advisory Board for the Summer Physics Center to be established by the University of Delaware at Lewes, Delaware.

J. S. O'Connell

Member, Nuclear Science Advisory Committee to NSF and DoE.

Francis J. Schima

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

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 advised the Oak Ridge National Laboratory on the preparation of large fission deposits for the Clinch River Breeder Reactor Program.

2. C. D. Bowman advised the Lawrence Livermore National Laboratory on γ-ray laser devices and on neutron measurement methods.

3. C. D. Bowman reviewed γ-ray laser concepts for the Los Alamos National Laboratory and advised on the implementation of neutrons for materials science studies using the WNR.

4. C. D. Bowman consulted with the Hanford Engineering Development Laboratory, Richland, Washington, on the nondestructive analysis of spent fuel from the FFTF.

5. C. D. Bowman advised the Electric Power Research Institute on the nondestructive assay of spent power reactor fuel.

6. A. D. Carlson organized the national Department of Energy effort for evaluation of measurements on neutron cross section standards.

7. J. J. Coyne advised the ICRU Report Committee on Microdosimetry and prepared and completed a final draft of the report for submission to the Commission.

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

9. C. M. Eisenhauer acted as a consultant to John Auxier of ORNL concerning calculations of the T65 neutron and gamma doses assigned to survivors of Hiroshima and Nagasaki.

10. C. M. Eisenhauer is participating in an American Nuclear Society Standards Committee that is reviewing published and unpublished gamma ray buildup factors, including those generated at NBS, in order to publish a set of recommended values for the nuclear engineering community.

11. D. M. Gilliam oversaw performance characteristics for on-line, one-shot fission rate experiments at the Fast Test Reactor, Hanford Engineering Development Laboratory.

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

12. D. M. Gilliam and E. D. McGarry established blind test procedures for SSTR fission detector test at Hanford Engineering Development Laboratory.

13. D. M. Gilliam provided essential follow-up consultation for the reduction of fission rate data taken during the Fast Test Reactor experiments by Hanford Engineering Development Laboratory.

14. D. M. Gilliam consulted with U.S. Army Proving Ground, Aberdeen, Maryland, to maintain operation of NBS fission chamber at the Pulsed Reactor Facility.

15. D. M. Gilliam and R. Dallotore provided fission chamber operation information for pilot effort to calibrate $^{252}Cf/D_2O$ Dosimeter Calibrated Source at the University of Arkansas.

16. J. Grundl served as an advisor in program information for NCRP Symposium on Radiation Exposure and Control in an Emergency.

17. G. Lamaze and D. M. Gilliam provided a neutron beam flux for the Small-Angle Neutron Scattering Facility (SANS) at the NBS Reactor.

18. J. W. Lightbody, Jr. and X. K. Maruyama performed electron scattering measurements to determine target composition for UCLA Particle Physics Group.

19. L. C. 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.

20. E. D. McGarry served on a management group for a dosimetry characterization program at the NRC pressure-vessel mock-up facility.

21. J. S. O'Connell performed neutrino-nucleus reaction cross section calculations for the Los Alamos National Laboratory, Physics Division.

22. R. A. Schrack advised the Brookhaven National Laboratory Safeguards staff on the nondestructive assay of spent commercial reactor fuel.

23. I. G. Schroder tested track-etch thermometers applicable to thin-film semi-conductor technology for Pennsylvania State University.

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

24. I. G. Schroder consulted on the design of the neutron beam system for NBS depth-profiling initiative.

25. R. Schwartz is a primary program consultant for the DoE Personnel Neutron Dosimeter Improvement Program.

26. R. Schwartz is consultant to ISO Committee TC85 concerned with a new Draft Standard on calibration of neutron dose equivalent meters, ratemeters, and monitors.

27. W. Slater and D. M. Gilliam evaluated isotope mass of Np deposit for Phoenix Memorial Laboratory, University of Michigan.

JOURNAL EDITORSHIPS

Division 532, Nuclear Radiation

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

C. D. Bowman, Los Alamos National Laboratory, Los Alamos, N.M. to consult with staff on physics of neutron scattering, gamma-ray laser development, neutron production with advanced accelerator technology, September 14-19, 1981.

C. D. Bowman, University of Kentucky, to give a talk to Dept. of Physics and Astronomy on inelastic scattering of eV neutrons, September 24-27, 1981.

R. S. Caswell, Standards Laboratories in the People's Republic of China, sponsored by NBS Director's Office, October 21-November 11, 1980.

R. S. Caswell, National Council on Radiation Protection and Measurements, Meeting of the Board of Directors, Provincetown, Massachusetts, September 24-26, 1980.

R. S. Caswell, Symposium on Neutron Dosimetry, Munich, Germany sponsored by the Commission of the European Communities, June 1-5, 1981; also Annual Meeting of the International Commission on Radiation Units and Measurements, Brussels, Belgium sponsored by ICRU, June 15-23, 1981.

R. S. Caswell, Consultative Committee for Measurement Standards for Ionizing Radiations (CCEMRI), Paris, France sponsored by NBS Director's Office, August 27-29, 1981.

R. S. Caswell, National Council on Radiation Protection and Measurements, Meeting of the Board of Directors, Burlington, Vermont, August 19-20, 1981.

J. J. Coyne, Physikalisch-Technische Bundesanstalt (PTB) to give a talk on "Kerma Factors for Neutrons in the Energy Region, 14 to 20 MeV," November 24, 1980; and Homburg/Saar Institut fur Biophysik, University of Saarlands to give a talk on "Quality of Neutrons from Energy Deposition Spectra," November 26, 1980. His expenses were paid in part by the two institutions visited.

J. J. Coyne, Stockholm, Sweden to complete the first draft of a report for the ICRU Report Committee on Microdosimetry, November 15-30, 1980.

M. Danos, Duke University, to give a lecture, "How do We Describe Nuclear Forces in the Presence of Quarks?", October 1980.

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

M. Danos, Center for Nuclear Studies (CEN), Paris (Saclay), France, to continue collaboration with Dr. V. Gillet and staff on relativistic nuclear physics and discussions with experimentalists concerning medium energy physics, February and May-July, 1981.

M. Danos, Institute for Theoretical Physics, Erlangen, W. Germany, to have discussions on medium energy nuclear physics and on questions of finite relativistic quantum field theory, November 1980.

M. Danos, Bologna, Italy, to act as a session chairman at the Workshop on Nuclear Physics with Real and Virtual Photons, November 1980.

M. Danos, Institute for Theoretical Physics, University of Frankfurt, W. Germany, to discuss theory of weak interactions, heavy ion collisions and field theory with Drs. Greiner, Rafelski, et. al., December 1980.

C. Eisenhauer, Oak Ridge National Laboratory, to act as a consultant to John Auxier regarding the T65 neutron and gamma doses assigned to survivors of Hiroshima and Nagasaki, May 10-12, 1981.

E. V. Hayward, LEP, Geneva, Switzerland, to attend workshop to discuss the research possibilities of a photon beam at the large electron storage ring, December 8-9, 1980.

E. V. Hayward, American Physical Society Nomination Committee Meeting, Phoenix, Arizona, March 14-16, 1981.

E. V. Hayward, American Physical Society Meeting, Baltimore, Maryland, April 20-23, 1981.

E. V. Hayward, SURA Search Committee, Blacksburg, Virginia, June 5-6, 1981.

E. V. Hayward, Argonne Universities Association Special Committee for the Medium Energy Electron Accelerator, Argonne, Illinois, July 27-29, 1981.

D. D. Hoppes, scientific exchange program with Országos Mérésügyi Hivatal, Budapest, Hungary, April 19-May 2, 1981.

G. Lamaze, ASTM Subcommittee E10.05 Meeting, Myrtle Beach, South Carolina, June 1981.

J. W. Lightbody, Jr., Gordon Research Conferences Chairperson's Orientation Meeting, New York, N.Y., February 28, 1981.

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

J. W. Lightbody, Jr., Université de Montréal, Montréal, P.Q., Canada, to attend Workshop on "Nuclear Physics with Electromagnetic Probes, 1980 and Beyond, in the Canadian Context," January 16-17, 1981.

W. B. Mann, at the invitation of the International Atomic Energy Agency, Vienna, Austria, for consultations on the authorship by W. B. Mann of a proposed manual for use by the Network of Secondary Standard Dosimetry Laboratories. This group of laboratories is sponsored by the IAEA and the World Health Organization, May 5-10, 1981.

X. K. Maruyama, Bates Laboratory, Middleton, Mass., and the University of Massachusetts, Amherst, Mass., to work on collaborative research, June 15-23 and September 11-21, 1981.

L. C. Maximon, Center for Nuclear Studies (CEN), Paris (Saclay), France, to act as consultant to the High Energy Nuclear Physics Group and the Metrology and Fundamental Neutron Physics Group, July 1-August 3, 1981.

J. S. O'Connell, Triangle Universities, Durham, N.C., to give invited talk, April 10, 1981.

J. S. O'Connell, MIT, Cambridge, Mass., for meeting and writing session of the editorial board and writers panel on the report, "Future Directions of Electromagnetic Nuclear Physics," to be submitted to DoE/NSF, November 1-4, 1980.

J. S. O'Connell, Workshop on Neutrino Physics, Los Alamos Scientific Laboratory, Los Alamos, N.M., June 7-10, 1981.

J. S. O'Connell, International School of Nuclear Physics at Intermediate Energies, Verona, Italy, to give invited lectures, July 16-26, 1981.

J. S. O'Connell, Lund Institute of Technology, Lund, Sweden, to lecture on Electron Scattering Coincidence Experiments at the Department of Nuclear Physics, December 1-4, 1980.

J. S. O'Connell, Rensselaer Polytechnic Institute, Troy, N.Y., to give invited talk, March 26, 1981.

R. B. Schwartz, Fourth Symposium on Neutron Dosimetry, Munich, Germany, June 1981.

STANDARD REFERENCE MATERIALS

Division 532, Nuclear Radiation

Standards Issued -- 1 September 1980 through 31 August 1981

SRM	Radionuclide	Principal Use
4410H-F	Technetium-99m	Calibration of instruments for the activity of radiopharmaceuticals
4402L-C	Tin-113	"
4407L-F	Iodine-125	"
4408L-C	Cobalt-57	"
4401L-G	Iodine-131	"
4412L-F	Molybdenum-99	"
4415L-E	Xenon-133	"
4404L-D	Thallium-201	"
4400L-D	Chromium-51	"
4409L-D	Selenium-75	"
4309-E	Xenon-127	Calibration of instruments monitoring reactor off-gases
4307-F	Xenon-133	"
4275	Mixed radionuclide	Calibration of the efficiency of germanium gamma-ray or x-ray spectrometry systems as a function of energy
4276	" "	
4266	Vanadium-49	"
4206-C	Thorium-228/Thallium-208	"
4209-C	Yttrium-88	"
4999-F	Cerium-139	"

Division 532, Technical Activities (Cont'd)

SRM	Radionuclide	Principal Use
4338	Plutonium-240	Calibration of instruments measuring the activity of plutonium-240 in the nuclear power cycle
4361	Hydrogen-3	Standard for monitoring tritium in water

CALIBRATION SERVICES PERFORMED

Division 532, Nuclear Radiation

Type of Service	Customer	SP 250	No. of Calib. or Tests	Income k$
Alpha-Particle Sources	Military, nuclear power	8.2 H,I,J	25	9.5
Beta-Particle Sources	Commercial standards suppliers, nuclear power	8.2 P,Q,R	4	2.2
Gamma-Ray Sources	Commercial standards suppliers, medical users, nuclear power	8.2 C,D	8	2.8
Gamma-Ray Sources	Commercial standards suppliers, medical users, nuclear power	N.A.	42	23.6
Neutron Source Calib.	DOE	8.1 B	3	1.38
Neutron Source Calib.	Univ. of Michigan	8.1 B	2	1.36
Neutron Source Calib.	Univ. of Calif.	8.1 B	1	.68
Irradiation of dosimeters in thermal neutron density std.	Dept. of Army	8.1 P	4	1.1
Irradiation of sulfur pellets at Cf-252 standard neutron field	Dept. of Army	8.1 P	1	.34
Reactor pressure vessel irradiation surveillance dosimetry improvement	NRC	N.A.	44	.90

Division 532, Calibration Services Performed (Cont'd)

Type of Service	Customer	SP 250	No. of Calib. or Tests	Income k$
Reactor Materials Dosimetry Standardization	DOE	N.A.	18	.7
Isotopic Fission Rate Measurements	HEDL (DOE Contractor)	N.A.	17	.3
Remmeter Calibration	Balto. Gas & Electric	8.1 A	15	1.05
Dosimeter Calibration	EG&G, Idaho Falls	8.1 H	120	.40
Remmeter Calibration	Carolina Power & Light	8.1 A	3	.40
Dosimeter Calibration	DOE	N.A.	914	70.00
Dosimeter Calibration	Siemens Gammasonics	8.1 H	18	.80
Dosimeter Calibration	Univ. of Oklahoma	8.1 H	3	.40
Remmeter Calibration	Philadelphia Elec.	8.1 A	2	.20
Dosimeter Calibration	Metropolitan Edison	8.1 H	80	.40
Dosimeter Calibration	Philadelphia Elec.	8.1 H	5	.20
Remmeter Calibration	Duquesne Electric	8.1 A	1	.20
Remmeter Calibration	Triangle Resource Industries	8.1 A	2	.40
Fission Chamber Calib.	Gamma-Metrics	8.1 A	1	.20
		Total	1,333	119.51

This summary is for the time period August 1, 1980 - August 1, 1981

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

Photon Cross Sections

Photon attenuation and energy-absorption coefficients are required in a wide variety of industrial, medical, and scientific applications. An updated and improved tabulation has recently been completed that contains pair, triplet, and total atomic cross sections for the elements Z = 1 to 100, for photon energies from 1 MeV to 100 GeV. In this work, pair and triplet production cross sections were obtained from Born-approximation calculations, without the high-energy approximation, using atomic form factors and incoherent scattering functions data recently compiled by the NBS Theory Group. The new tables remove discrepancies of as much as 4% between earlier calculations and recent high-precision total absorption measurements in the photonuclear giant dipole resonance region (5 to 30 MeV). This work, by Hubbell, Gimm, and Øverbø, has recently been published in the J. of Phys. Chem. Ref. Data.

An interim set of new low-energy attenuation coefficient tables for the energy region 1 keV to 1 MeV has been compiled, using theoretical photoeffect cross sections of Scofield (Livermore), in which the electrons are treated relativistically, with use of a Hartree-Slater central potential, and with use of subshell renormalization factors (for Z = 1 to 54) from relativistic Hartree-Fock calculations. Cross sections for some low-Z elements (C,N,O,Ar) important in biomedical dosimetry applications, have been further adjusted below 10 keV using available measured attenuation data.

Serious discrepancies (up to 5%) persist among the measured photon attenuation coefficients below 10 keV. A task group of the International Union of Crystallography, with Hubbell of NBS a key participant, is engaged in an effort to resolve these discrepancies by further measurements and theoretical analysis.

The experimental data file on x-ray attenuation data, previously kept on hand-written index cards, has been computerized. This involved approximately 500 papers, 1500 data sets and 20,000 data points. The data have been converted to a standard format and made available in a data-base stored locally in a microprocessor and on the NBS central computing facility (Gerstenberg, Nguyen).

Electron Dosimetry

As a contribution to radiation treatment planning in cancer therapy, a superposition method has been developed for calculating the spatial distribution of absorbed dose in a water medium irradiated by high-energy electron beams. According to this method, the electron beam of interest is treated as a superposition of narrow-pencil beams, and the

absorbed-dose distribution from the beam is obtained by a corresponding summation over the elementary absorbed-dose distributions from narrow-pencil beams. Extensive Monte Carlo calculations have been carried out to obtain the required elementary three-dimensional absorbed dose distributions from monoenergetic narrow-pencil beams with energies between 60 MeV and 1 MeV. Such data have been obtained for a water target (with a view toward biomedical applications) but also for aluminum and copper media (with a view toward radiation damage analysis).

Preliminary applications of the superposition method have been made to determine central-axis depth dose curves, radial dose distributions and isodose patterns in water phantoms irradiated with electron beams with circular cross sections, for various field sizes. These results have been presented at an Electron Dosimetry and Arc Therapy Symposium, U. of Wisconsin, Madison, September 1981 (Berger and Seltzer).

The measurement of absorbed-dose distributions with air-filled ionization chambers requires ionization-to-dose conversion factors, which are proportional to medium-to-air stopping-power ratios, suitably averaged over the electron flux spectrum at the point of measurement. These stopping-power ratios depend sensitively on the density-effect correction to the stopping power for the dense medium (water, graphite, polystyrene, PMMA, etc.). New and improved theoretical information on the density effect correction has led to revisions, which in turn result in a modification of previously calculated stopping-power ratios, by amounts ranging up to 1%. The result is that the calculated stopping-power ratios no longer agree as well as earlier calculations with experimental stopping-power ratios based on the intercomparison of ionization chamber and calorimeter or ferrous sulfate dosimeter data, for the case of irradiation by high-energy electron beams. It appears, however, that there may be 1-2% uncertainties in the calibrations of the detectors used in the experiments, so that the discrepancies are within the combined limits of experimental and theoretical uncertainty (Berger).

Dosimetry Data

In biomedical and industrial radiation dosimetry, one must have accurate information about the interaction of photons and charged particles with a large number of compounds. In order to supply some of the needed information, three contributions have been prepared by the Radiation Theory Group for inclusion in a special issue of the International Journal of Isotopes and Applied Radiation, which will also be issued separately in book form.

The first contribution pertains to the evaluation of the collision stopping power for electrons, and gives tables of material properties and auxiliary quantities from which the collision stopping power can be evaluated quickly with only a minimal amount of further arithmetic. The key quantity tabulated is the mean excitation energy, which has been

determined from a critical analysis of all available stopping-power data, oscillator strength distributions and dielectric response functions. Material data have been supplied for almost 200 compounds and mixtures, and rules are given for estimating the data for other materials (Seltzer and Berger).

The second contribution gives a procedure for calculating the radiation stopping power of electrons. It is based on the latest theories of bremsstrahlung production, and on a new interpolation procedure connection available theories in the low-energy region (below 2 MeV), and in the high-energy region (above 50 MeV). The radiation stopping powers in the energy region from 1 keV to 10 GeV have been fitted by a nine-parameter approximation formula. These parameters depend on the atomic number Z, are given for all Z from 1 to 100, and can readily be applied to compounds via a Bragg additivity rule (Seltzer and Berger).

The third contribution pertains to mass attenuation and energy absorption coefficients for photons in the energy region from 1 keV to 20 MeV, which have been tabulated for 40 elements and for 45 mixtures and compounds of interest in dosimetry (Hubbell).

Civil Defense Shielding

A 967-page book, entitled "Structure Shielding Against Fallout Gamma Rays from Nuclear Detonations" has been published by L. V. Spencer A. B. Chilton, and C. M. Eisenhauer as NBS Special Publication 570 (1980). This book summarized the research and development carried out at NBS and elsewhere during the past 20 years to evaluate protection against gamma radiation from nuclear fallout by existing or planned structures. Measurements and calculational procedures are described for elementary as well as complex structures.

The book is written so as to serve several functions: 1) as a reference for engineering students, 2) as a reference and source book of ideas for engineers engaged in research and development on radiation protection, 3) as a basic reference for architects and engineers concerned with the design of buildings with protective features, and 4) as a reference handbook for government officials responsible for protection of the civilian population in nuclear emergencies.

The book is organized into twelve chapters, as follows: Historical introduction; physical and biological aspects of the fallout phenomenon; elementary concepts of photon transport; transport problems and shielding concepts; penetration data for shielding applications; free-field experiments; shielding analysis for simple structures in an idealized field; experimental data on simple blockhouses; shielding analysis for complex situations; experimental data on complex structures; problems in the application of the fallout shielding methodology; shelter programs and systems. Appendices give mathematical background, penetration data for cobalt-60 and cesium-137 gamma rays, and charts from the Office of Civil Defense method of fallout gamma radiation shielding analysis.

Molecular Ionization and Fragmentation

An invited critical review was prepared covering all aspects of the dynamic behavior of excited $C_6H_6^+$ ions, including isomerization and structural stability, location of excited electronic states, fragmentation mechanisms, kinetics and energetics, and radiative processes. It turns out that this comprehensive discussion will be useful in understanding new experimental results on multiphoton ionization and fragmentation (Rosenstock, Dannacher, Liebman).

A new systematic approach to estimation of thermochemical properties of gaseous neutral and ionized molecules was developed and applied to acyclic strainless hydrocarbon and C,H,O, compounds. Ionization energies of 31 compounds have been measured by threshold photoelectron spectroscopy, and will be used in preparing a comprehensive review of reference and estimated ion energetics of the classes of compounds (Liebman, Rosenstock, Buff, Parr, Stockbauer).

A precise benchmark value of the absolute proton affinity of propylene has been determined by threshold photoelectron-photoion coincidence mass spectrometry (Rosenstock, Buff, Parr, Ferreira, Lias, Stockbauer, Holmes).

A new class of slow fragmentation processes has been discovered in normal and isopropyl bromide and iodide ions. The processes involve slow decomposition of essentially vibrationless propyl halide ions formed in the upper component of the ion spin-orbit doublet state.

A preliminary theoretical study of polyatomic Franck-Condon envelopes has been carried out. With suitable approximations a number of interesting relationships between bandwidths, maximum quantum number and adiabatic ionization energy can be derived.

The lowest energy fragmentation process of iodobenzene cation has been carefully investigated using the two different versions of the electron-ion coincidence experiment. The complementary character of the NBS- and the Basel-experiment allows a detailed and accurate study of a dissociation process employing data from independent sources, which can serve as a reference point for related experimental and theoretical work (Dannacher, Buff, Parr, Rosenstock).

Coincidence data have been obtained for two C_4H_6 isomers (1,3-butadiene and the commercially nonavailable bicyclobutane), again with both the NBS and Basel coincidence machines (Dannacher, Rosenstock).

Microdosimetry

A paper entitled "On the Spatial Correlation of Ionization Events in Water" by M. J. Berger has been presented at the VIIth Symposium on Microdosimetry and published in the proceedings (Harwood Academic Publishers for the Commission of the European Communities, 1980). This paper introduces the concept of a restricted ionization yield which is defined as the number of ionizations per 100 eV which are preceded by another ionization on the track within a given distance s. For large values of s the restricted ionization yield goes over into the usual total ionization yield. Restricted ionization yields have been computed for a water-vapor medium irradiated with monoenergetic electrons, beta particles, x rays and cobalt-60 gamma rays. Whereas the total ionization yield is almost the same for various low-LET radiations, the restricted yield is found to depend markedly on the radiation quality. For small and moderate separation distances it can become almost 2 times larger for 1-keV electrons than for 1-MeV electrons, and 1.5 times larger for low-energy x rays and tritium beta rays than for cobalt-60 gamma rays. These yield ratios are consistent with observed differences in radiobiological effectiveness between various low-LET radiations.

The best available cross sections for the electron-impact ionization, excitation, and dissociation of water molecules have been used for the Monte Carlo simulation of ionization cascades in water vapor. These calculations follow all generations of secondary electrons in a water-vapor medium irradiated with electrons with energies ranging from 1 MeV down to 12.6 eV (ionization threshold).

Three kinds of results have been obtained: (a) the mean number of ionization events in the cascade, $\bar{n}(T_0)$, resulting from the release of a single electron of initial kinetic energy T_0; (b) fluctuations of the number of ionizations, expressed in terms of the Fano factor $f = n^2(T_0)/\bar{n}(T_0)$; (c) the probability distribution $P(n)$, i.e., the probability that the release of a single electron of energy T_0 will give rise to $0,1,2,\ldots,n,\ldots$ ionization events (Berger).

Germanium-Detector Spectrometry

Intrinsic Ge detectors are the most accurate devices currently available for the measurement of x-ray spectra. The pulse-height distributions recorded by such detectors must be converted into actual photon spectra, taking into account the detector efficiency and the escape of energy from the detector. Based on extensive Monte Carlo calculations, a semi-analytical method has been developed for generating response functions for intrinsic Ge detectors of any size commonly used. This work has been written up in a paper in Nuclear Instruments and Methods (in press) by S. M. Seltzer.

Intrinsic Ge detectors are currently being used by the NBS Dosimetry Group to measure the spectral output of the NBS x-ray machines whose beams are used for the calibration of dosimeters and other detectors. A large series of such spectral measurements has been converted from pulse-height distributions to x-ray spectra.

DOSIMETRY GROUP

Use of ionizing radiation is becoming ever more widespread in modern society. The intentional 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 and taking new forms. The measurement of ionizing radiation for the purpose of controlling a radiation effect falls in the field of radiation dosimetry. The Dosimetry Group has then the responsibility of providing a reliable and up-to-date basis for the radiation dosimetry 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

Overall calibration activity this year has been about the same as the preceding year. The Dosimetry Group issued approximately 190 calibration reports during FY 81. This number covers calibration of instruments for measurement of exposure and absorbed dose, irradiation of thermoluminescence dosimeters, calibration of gamma-ray brachytherapy sources, and calibration of beta-particle sources and applicators. The number cited is the number of formal, serially numbered reports issued. These reports contain one or more, and sometimes many, calibration points. Calibrations performed on other-agency contracts, for which numbered reports were not issued, are not included.

Measurement quality assurance audits have been carried out for the three regional calibration laboratories of the American Association of Physicists in Medicine, for five Department of Defense radiation instrument calibration laboratories, and for the Bureau of Radiological Health.

Suitable instruments are calibrated at NBS, circulated for calibration at the laboratory being audited, and then returned to NBS for a final check. The audit consists of comparing the calibration reported by the laboratory with the calibration established by NBS. A constancy-check method for the instrument being circulated has been developed, whereby redundant chambers are circulated along with sufficient information to allow the laboratory to verify the constancy of the instrument. This constancy check allows the instrument to be circulated to several laboratories before being returned to NBS for remeasurement. This work is part of a program to establish measurement traceability to NBS dosimetry standards in place of instrument traceability, for the intermediate-level dosimetry calibration laboratories.

A 300-kV x-ray generator has been purchased to replace the obsolete 250-kV generator that has provided NBS standard x-ray beams for more than 30 years. The new generator will include circuits that allow computer control. The facilities necessary for the new generator have been provided, and delivery and installation are expected early in FY 82. Because the properties of the new standard photon beams must be determined with great care, the changeover will require a downtime of many months.

About a dozen radiation-protection survey instruments have been calibrated and evaluated for the Nuclear Regulatory Commission and the Navy, using photon beams with energies from about 40 to 660 keV. The low radiation levels required development of some special measurement techniques and made necessary some changes in the NBS standard photon beams.

The program to update the automatic acquisition and reduction of calibration data has continued, with further improvement in the efficiency of operation. Calibration data are now stored in the floppy disk memory of a dedicated minicomputer, edited as necessary, and transmitted via a dedicated telephone line to the NBS central computer. The final report is processed in the central computer and is printed out on a terminal in the Radiation Physics Building.

In collaboration with the 3M Company, work has been carried out to provide an exposure calibration service for the radionuclide iodine-125. 3M has provided groups of sources in the form of titanium-clad seeds and these have been measured using one of the NBS standard free-air chambers. The calibration data is transferred to a re-entrant ionization chamber for routine calibration. The initial group of seeds was found to exhibit geotropic variability as great as 10 percent. A newly designed seed has been developed by 3M, which minimizes the geotropic problem and appears to make possible establishment of a standard with satisfactory accuracy of a few percent.

Division 533, Technical Activities (cont'd.)

Calorimetry

The NBS graphite calorimeter has served as a highly successful standard of absorbed dose, and in previous fiscal years it has strongly influenced absorbed dose calorimetry in national standards laboratories and other institutions in Belgium, Canada, France, Holland, United Kingdom, and South Africa. The interest has continued during FY 81. The International Atomic Energy Agency, the Austrian standards laboratory in Vienna, and the Hungarian standards laboratory in Budapest, have finished construction of graphite calorimeters using the NBS design, and S. R. Domen has been invited to Vienna and Budapest early in FY 82 to assist them in proper operation of their calorimeters as absorbed dose standards. A representative of the South African standards laboratory visited NBS to confer on details of construction and operation, and another visitor from South Africa is expected early in FY 82. Detailed drawings of the graphite calorimeter were sent to the standards laboratory of the Peoples Republic of China at Beijing, and their calorimeter is already under construction. There have been expressions of similar interest from the U.S.S.R. and the G.D.R.

During FY 81 the focus of NBS calorimetry activities in dosimetry has been the water calorimeter. This instrument makes use of the low thermal diffusivity of water and the electrical isolation provided by thin polyethylene sheets to measure the temperature rise directly in water with very small thermistors. The work has been performed using a cobalt-60 gamma-ray beam and a 30-cm cubical phantom. Thermal drifts in the water are controlled by changing small currents between electrodes on opposite sides of the water tank, which is thermally isolated. Extensive theoretical and experimental studies have been carried out to determine the reliability and precision of the instrument. At a dose rate of about 1 Gy/min (100 rad/min) the standard deviation of a single 3-min measurement is about 0.6 percent. The measured, apparent absorbed dose represents a temperature rise due to the energy imparted by the beam plus the energy due to endothermic or exothermic reactions. The absorbed dose rate measured in distilled water is independent of agitation by oxygen or very pure nitrogen, and is about 3.5 percent higher than the rate calculated from measurements with the graphite calorimeter at the same position in the cobalt-60 beam. Less pure water gives a rate about 0.5 percent lower. Measurements have been made as a function of dose using various solutes, and in general the initial apparent dose rate may be a few percent higher or lower than the stable dose rate arrived at after a few tens of grays (kilorads). Some of these results with solutes are influenced by agitation with oxygen or pure nitrogen. The initial studies of the water calorimeter are considered completed, and a manuscript has been prepared for submission to the NBS Journal of Research. It is concluded that the water calorimeter is a stable and reliable instrument with adequate sensitivity for many uses in radiation therapy and radiation biology, but that it cannot be used as an NBS standard until further studies either remove or explain the difference that has been observed between the water calorimeter and the graphite calorimeter in the NBS cobalt-60 gamma-ray beam.

There has been considerable interest outside NBS in the water calorimeter. Since it is considerably easier to construct and operate than the graphite calorimeter, water calorimeters modeled on the NBS instrument are already in operation at the M. D. Anderson Hospital in Houston and at the Yale University School of Medicine, and are under construction at the Massachusetts General Hospital in Boston and at the University of Edinburgh in Scotland. It is expected that an instrument will soon be under construction at the Calgary Cancer Center in Canada. In addition to other institutions in the U.S., interest has been expressed at standards laboratories and other research institutions in Austria, Egypt, Hungary, Thailand, the U.K., and others. During FY 81 S. R. Domen has been invited to talk on the water calorimeter at the National Research Council in Ottawa, at the Massachusetts General Hospital in Boston, and at the University of Wisonsin Medical School in Madison.

Thermoluminescence Dosimetry

The study of the feasibility of a thermoluminescence dosimetry (TLD) system to survey radiation therapy dosimetry of high-energy electron beams was completed. Depth versus TL response was determined in water and polystyrene phantoms in the NBS cobalt-60 gamma-ray beam, and in electron beams with energies of 7, 11, 15, and 18 MeV, at the National Cancer Institute and at Georgetown University Hospital. Absorbed dose was determined with a calibrated ionization chamber at the depth of peak TLD response. Random uncertainty in the data was of the order of ±1 percent. In the water phantom, the ratio of TLD response per unit of absorbed dose to water for high-energy electrons and for cobalt-60 gamma radiation showed the usual trend with electron energy, a decrease from about 0.99 to 0.97 for electron energies from 7 to 18 MeV. No trend was observed in the polystyrene phantom, where the ratio was about 0.95 ±0.01 over the entire electron-energy range. It is concluded that the proposed system is well suited for radiation therapy dosimetry surveys for electron energies at least up to 18 MeV. Once the relationship between the response to high-energy electrons and cobalt-60 gamma radiation has been established, a calibration of the system with the cobalt-60 gamma radiation is sufficient.

Some progress has been made on the study of neutron dosimetry using thermoluminescence. Preliminary irradiations were performed in the 144-keV scanned neutron beam and a cobalt-60 gamma-ray beam, for both ^{7}LiF and ^{6}LiF bare extruded thermoluminescence dosimeters. Glow curves were then obtained with a hot-plate reader rather than a hot nitrogen reader, because the hot-plate reader allows wide variations in heating rate and maximum readout temperature, while it is difficult to vary these parameters in the hot nitrogen reader. The difference observed in the shape of the resulting glow curves was marginally significant. A new power supply was constructed for the heater to give a more nearly linear and reproducible heating ramp. Operating parameters have been optimized, and the neutron irradiation will be repeated.

Radiation Protection

Since most photon measurements for radiation protection are performed in terms of exposure in air, it is necessary to have agreed-on conversion factors for obtaining absorbed dose to tissue. No recommendations for such factors exist at present. M. Ehrlich is chairman of a working group of the Health Physics Society that is writing a standard on performance testing of the suppliers of personnel dosimetry services. In this capacity, she was invited to attend a seminar on radiation protection quantities (including conversion factors) organized by the Commission of European Communities in collaboration with several European centers active in radiation protection, to report on the problems encountered in her working group. Later, after the working group had chosen a set of photon conversion factors for the standard, she prepared a detailed summary of recent experimental and theoretical conversion factors to explain and justify the choice of the working group. This summary will appear as an appendix to the standard, and has been separately submitted elsewhere for publication.

Fricke Chemical Dosimetry

The chemical dosimeter service for comparing high-energy electron dosimetry performance in medical therapy departments has been provided twice during FY 81, each time with about 30 participants, including some from Canada. The inclusion of Canadian participants has resulted from temporary suspension of a similar service by the National Research Council of Canada. The new unit for automatic sealing of spectrophotometer cells and glass vials was found to be in need of some redesigning, and is now performing satisfactorily. A set of reusable spectrophotometer cells with graded quartz-to-glass seals is being procured for the study of the deaerated Fricke dosimeter system. If the system turns out to be sufficiently stable, it will be proposed for production as an SRM.

NBS participated in an international comparison of Fricke chemical dosimetry conducted under the auspices of the BIPM by Section I of CCEMRI. This comparison was in two phases, a spectrophotometry check using NBS acid dichromate standard reference material, and preparation of Fricke dosimeters for irradiation at the BIPM and subsequent readout and dose interpretation at each national laboratory. In the first part, NBS results indicated a correction of at most 0.001 at the optical density (0.3) used for Fricke dosimetry, which is considered satisfactory. For the second part, the NBS value of absorbed dose to water in the cobalt-60 gamma-ray beam differed by 2.6 percent from that calculated, again considered a satisfactory result in view of the quite different irradiation geometries and methods of calculation used at different national laboratories.

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 at lower exposures. In addition a program has been initiated to develop a real-time imaging system for use in dental applications. This system will provide multiple geometric views of the dentition and surrounding tissue and will enable the diagnostician to detect caries and septal bone deterioration using image processing techniques. It is expected that this system will provide considerably enhanced diagnostic ability at patient exposures less than those currently being delivered in ordinary dental radiographs.

Industrial Radiology

In industrial radiography, the X-Ray Physics program is aimed at improving and maintaining high quality industrial radiological systems by developing suitable radiographic standards and standard procedures for evaluating the performance of these systems for quality control. An important part of this program is to carry out an analysis of existing standards for measuring image quality and to help develop and recommend an image quality indicator that can be used as an international standard. Also, there is a continuing effort to provide standards for assessing x-ray equivalent penetrameter sensitivity. The ASTM standard E-746-80 for evaluating image quality response of industrial x-ray film for 200 kV x-ray sources has been published, and studies are in progress to extend this standard to higher energy x-ray sources. Round robin testing demonstrated that previous test devices provided by NBS to cooperative laboratories were unsuitable. New ones have been designed here and are now undergoing extensive testing around the country. In other activities, contributions have been made to several ASTM documents, including a tutorial document on real-time radiography and drafts of proposed documents on x-ray film processing and storage. Also, studies are in progress to provide suitable measurement standards for pipeline weld inspection.

In a parallel effort, measurements are underway to develop quasi-mono-energetic photon beams in the 100-300 keV range for the purpose of evaluating the image information transfer properties of industrial radiographic systems. Initial efforts will focus on the evaluation of the transfer properties of the fluorescent, metallic, and fluoro-metallic screens currently in use. In addition, a real-time radiography system based on a state-of-the-art image processor is being developed to investigate the measurement difficulties associated with real-time imaging which is becoming increasingly important in industrial evaluation. In a related quality assurance program for the Department of Defense, the industrial radiological program provides an NBS staff member to monitor and approve the procedures employed by industry to inspect the propulsion units of large diameter missiles with high energy real-time radiological systems.

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 and measurement of electron beam fluence with a Faraday cup. Nearing final approval is 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 15 or 20 calibrations during the four-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 consumer. There is also the likelihood of an additional dimension to this service, with the recent disclosure in the Federal Register, 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 July 17 Workshop on Food Irradiation Processing at the University of Maryland. Some of the most active participants in the present high-dose calibration service are Isomedix, Inc., Ethicon, Inc.,

Neutron Products, Inc., Crown Zellerback, Buckeye Cellulose, Inc., Alza Corp., Tremco, Inc., Monoject Division of Sherwood Medical, National Semiconductor, Raychem Corp., Surigkos Division of Johnson and Johnson, IBM Research Lab., Becton Dickinson Company, Energy Sciences, Inc., Lederle Laboratories, Baxter Travenol, Inc., Lawrence Livermore Labs., Sandia Corporation, Radiation Sterilizers, Inc., International Nutronics, Inc. This NBS work was featured in the June 1981 issue of Medical Device trade journal, Medical Device and Diagnostic Industry, in a 4-page article entitled "Radiation Dosimetry" and written by Claude Anger.

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 reproducible 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.

Several areas of international cooperation have helped fertilize development of the radiation measurement technology. McLaughlin supervised a Research Agreement with the IAEA on the measurement of dose distribution in radiation processing, with results to be published as a part of proceedings of the 1st International Symposium on Radiation Processing of Plastics and Rubber. NBS-CRR continues to participate in an International Atomic Energy Agency Advisory Group on High Dose Standardization. This involves dose intercomparison studies and round-robin 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 first phase of these intercomparisons was published in 1981 by IAEA as a book (IAEA Technical Report Series 205, edited by McLaughlin entitled "High Dose Measurements in Industrial Radiation Processing." This international standardization program with NBS particularly will continue until at least 1983 and helps bring important measurement assurance on an international scale. Another area of international cooperation during 1981 was a UNDP mission by W.L. McLaughlin to the Egyptian National Center for Radiation Research and Technology. The purpose of this technical mission was to assist Egyptians in Cairo, in setting up a dosimetry program in their new 1.5 MeV electron beam industrial facility. There presently is a close collaboration between NBS and NCRRT, with a plan for technical visits to NBS from several of their scientists within the next three years, as NBS guest workers. This cooperation involves also the visit (FY81) to NBS of guest worker physicists from NCRRT of Egypt (Dr. Amin El-Behay and Dr. Mustaffa Rageh). Another international collaboration of note was with the Institute of Physics and the Institute of Nuclear Energy of the University of Mexico. Dosimetry developments include ESR techniques for

analyzing irradiated polymers and dye systems. Dr. Roberto M. Uribe of NCRRT will visit 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 were given in the magazine R&D Mexico, July 1981, in an article entitled "Sterilizing Pharmaceuticals with Errant Electrons."

An interesting new type of dosimeter has been developed in collaboration with the U.S. Army Electronics R&D Command, for use as an emergency dosimeter. The new system is based on fibre optics and offers biologically-relevant dose interpretations at dose levels encountered in radiation accidents. U.S. patent has been applied for by McLaughlin with an associated publication in press with Nuclear Instruments and Methods. This work is generating much interest also in the areas of environmental dosimetry, medical applications (diagnosis and therapy), and personnel monitoring.

Another promising new dosimeter has been developed by McLaughlin and Simic, involving solutions of blood by-products in the porphyrin family (e.g., hemin). This is another biologically significant dosimeter that should be expected to cover a broad range of radiation doses, with a response that does not vary with radiation energy or LET. A publication is in press as part of the Proceedings of the International Symposium on Radiation Chemistry.

In the development of new systems for high-dose dosimetry, a collaboration of McLaughlin with Harry Levine, a chemist formerly with the Bureau of Radiological Health, led to a promising new chemical dosimeter. This new system is a tissue-equivalent (muscle, bone, fat, etc.) liquid dosimeter for the measurement of doses in the range of 1 to 40,000 Gy. This is the first broad-range chemical dosimeter having multi-uses in radiation therapy, food preservation, radiation processing, etc., that is capable of measuring absorbed doses in biological tissues from broad photon and electron spectral radiations.

Radiation Chemistry

In a new NBS competence-building program, the X-Ray Physics Group under the supervision of M. Simic, has developed new facilities for radiation chemistry studies These facilities include:

1. A pulse radiolysis system has been designed and built in conjunction with the Febetron 705 pulsed electron accelerator. This provides a new capability for kinetic absorption spectrophotometry with a time resolution of 0.1 μs. The system is operational for analysis in the 220-700 nm region of the optical spectrum.

2. A pulsing conversion kit has been acquired for the 4 MeV van de Graaff accelerator. This will permit pulse radiolysis to be performed with single 4 to 5 MeV electron pulses, with a high degree of precision and penetration in condensed matter.

3. An analytical lab consisting of a gas chromotograph, high performance liquid chromatography and general instrumentation has been established with the assistance of academic consultants and graduate students (including Dr. Miral Dizdaroglu from the Univ. of Maryland-Baltimore and Ewa Gajewski from American University).

Radiation effect studies in complex organic systems are underway related to medical physics and chemistry, as well as food preservation. The following specific radiation chemistry projects have begun:

1. Reactions of free radicals with vitamin E in micellar systems are leading to new theories of the physiological role of vitamin E in nutrition and disease control.

2. General outlines of the radiation chemistry of DMSO were obtained indicating a major role of methyl radicals. Favorable conditions were found for utilization of DMSO in fiber optics dosimetry.

Plasma X-Ray Calibration Facility

The low-energy x-ray calibration facility was developed to support the radiometric measurement needs of the laboratories involved in the development of nuclear energy fusion reactors. The facility presently provides six steady state or pulsed x-ray line sources in the energy range of from 0.3 to 8.0 keV which can be continously varied in flux densities from 10^3 x 10^{10} x rays per steradian per second. The estimated accuracy of the x-ray line flux density measured by gas-flow proportional counter is ±7%. The facility can and has been utilized for the calibration of photoelectric diodes and other experimental detector systems. At the present time, this facility will be maintained to provide the calibrations described above as may be requested by the various laboratories involved in nuclear fusion research.

FAR ULTRAVIOLET PHYSICS GROUP

Molecular Kinetics

The experimental program utilizing our high-flux normal-incidence monochromator at SURF II continues to yield important results. This instrument delivers up to 2 x 10^{11} photons/s-Å of monochromatic flux to an experimental sample--higher than that reported by any other synchrotron radiation laboratory.

In the area of gas-phase photoionization, we have carried out angle-resolved, vibrationally-resolved, variable-wavelength photoectron spectroscopy on eight molecular systems. These studies investigate the effects of resonance phenomena on the angular distribution parameters and on the branching ratios in molecular photoionization. We have found, for example, that in acetylene autoionization populates vibrational modes in the ground state of the ion that are not normally observed in photoelectron spectroscopy. These modes are bending modes with diminishingly small Franck-Condon probability for direct transition but with significant intensity when populated via autoionization. A technique called Constant Electron Energy Spectroscopy has been employed in the acetylene study which involves analyzing electrons of a fixed kinetic energy as a function of excitation wavelength. It will enable us to obtain previously unavailable information about the photoionization process: the effect of autoionization and the state of the remaining ion as a function of electron excess energy. This area of study is expected to be fruitful for the next several years. A new apparatus is being constructed to carry out future gas phase photoionization experiments at higher resolution and efficiency. A photoelectron-photoion coincidence experiment is being built which can also be used in this apparatus. It will allow the measurement of breakdown curves for the study of fragmentation of polyatomic molecules. This work is a collaboration between CCP, SURF staff, SURF fellows, Argonne National Laboratory, and SURF guest workers. 10 papers, 3 invited talks.

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. The adsorption of O_2, CO, H_2O, H_2 and methanol on niobium, titanium and gold has been studied over the 13-75 eV photon energy range. Both the high-flux normal-incidence monochromator and a toroidal-grating monochromator were utilized. The effort has led to one publication with six more on the way. The work of SURF Fellow David Hanson has been chiefly responsible for the high productivity. We also helped support guest worker, Anders Flodström, who assisted this project.

Division 533, Technical Activities (cont'd.)

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 are in the process of procuring a new high-throughput grazing-incidence monochromator for SURF-II. 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 energy. 1 paper, 1 invited talk.

High Resolution Atomic Studies

In other work, the absolute cross section of atomic lithium has been measured between 110-175Å. The autoionizing resonant structure excitation between 160-176Å has been measured and line profile parameters obtained. The resonant structure for excitation associated with N = 3 and N = 4 inner quantum numbers is found to bear a close relationship to the analogous excitations in helium. This work, a collaboration between CAPQ, SURF staff, and a SURF guest worker was carried out on the SURF high-resolution 3-m grazing-incidence monochromator. This instrument was also used for a study of the Stark effect on the absorption spectra of helium states near the ionization limit. Electric field strengths up to 30KV/cm were applied to the helium atoms. In contrast to previous work on the heavier noble gases, the results show a strong dependence on the polarization of the source. A simple theoretical model has been developed to explain the results. 1 paper, 1 invited talk.

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 after the current upgrade of electron energy at SURF.

Division 533, Technical Activities (cont'd.)

Solid State Studies

Our guests from NRL have also continued their studies of II-VI compounds using laser and synchrotron radiation cooperatively. Their program involves two-photon photoelectron spectroscopy, surface photovoltage spectroscopy, and surface photochemistry. This year's work primarily involved photo-oxidation studies. They continue their ultraviolet reflectance studies and have confirmed in a reflectance spectroscopy study of BeF_2 and LiF that BeF_2 has a wider band gap than any other normal solid. The NRL group also extended their wide ranging study of radiation damage in MOS capacitor structures to the XUV. This study works from cobalt-60 X-rays on down. It tended to confirm theoretical predictions of the damage by demonstrating the reversal predicted by the theory in the monotonic dependence of damage on photon energy in the XUV. Other outside users have carried out extensive optical property studies utilizing SURF's 2.2 m grazing incidence monochromator. 13 papers, 6 invited talks.

Laser Prepared States

We are planning to begin a new class of experiments at SURF--studying photoionization from laser-excited atoms using synchrotron radiation. Excited state photoionization studies have been carried out by our group using laboratory light sources. The first such study using synchrotron radiation was carried out this year by a staff member of the Far UV Physics Group working with a group at LURE. We plan to begin such studies at SURF next year. 1 invited talk.

Double Ionization of Barium

Off-SURF, resonant laser excitation-ionization of dense vapors, previously discovered here and applied to the production of singly and multiply charged ions, has been used in a quantitative fashion to observe partial collapse of high angular momentum orbitals. The absorption spectrum of the inner shell $4d^{10}$ electrons in Ba was observed as the valence $6s^2$ electrons were sequentially removed. The data was quantitive, giving absolute absorption cross sections. A dramatic change in character of the spectrum from a continuum to a predominantly line spectrum was observed in going from neutral Ba to Xe-like Ba^{++}. With the help of theoretical calculations done in collaboration with the Atomic and Plasma Radiation Division, this change was interpreted in terms of partial collapse of the 4f orbitals. This work is now being compared to absorption by $4d^{10}$ electrons in solids, on surfaces or in molecular vapor phase to see if information about electron distributions in these states can be deduced. Work has also progressed on analysis of $5p^6$ absorption in Ba^{++} in terms of Multichannel Quantum Defect Theory. Preliminary experiments have been performed on the effect of electron cooling by buffer gases on laser-driven ionization. This work is continuing. 2 papers, 6 invited talks.

Division 533, Technical Activities (cont'd.)

Fluorescence in Barium

We have completed the first study of a fluorescence spectrum of a metal vapor resonantly excited by VUV radiation. This study in Ba II identified seven fluorescent transitions when 584Å excitation was used to excite the Ba 5p inner-shell excitation. No detectable Ba II fluorescence was observed when 736-742Å excitation was used. Using a fluorescence monochromator radiometrically calibrated at SURF, it was determined that the intensities of the observed fluorescent transitions are consistent with population distributions of excited Ba II obtained using photoelectron spectroscopy. 1 paper.

Improved Radiometric Accuracy

The principal 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. When other planned improvements are completed, 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. This work is being carried out in collaboration with the Radiometric Physics Division.

Spectrometer Calibration Chamber Activated

Until recently, all VUV spectrometer calibrations required the user to supply a vacuum chamber with all the required motions to translate his instrument and rotate it to obtain an efficiency map over its solid angle of acceptance. This required a large duplication of effort. In connection with space shuttle missions, several spectrometers will have to be calibrated. As a result, NASA supported the construction of a large spectrometer calibration facility at SURF. This facility is now operational. The chamber is all stainless steel and measures 1.2 m X 1.2 m X 2.5 m long. It is coupled to the beamline by a 40 cm ID welded bellows which allows the chamber to travel about 40 cm in either X or Y direction perpendicular to the beam line. Spectrometers are mounted in the chamber in a gimbal which permits the needed angular motions. All motions take place under computer control. SURF compatible pumping systems are provided to enable operation at 10^{-8} torr. The chamber has already been used for several calibrations including the prelaunch calibration of the Space Shuttle's Solar Ultraviolet Spectral Irradiance Monitor (SUSIM). Other users make use of our calibration beamline using their own vacuum systems. Groups from Cal. Tech., NASA-GSFC, NRL, LANL, Johns Hopkins University and University of Colorado-LASP have calibrated instruments this year. Calibrations involved both space and plasma diagnostic instruments. 9 papers.

Transfer Standard Detector

An important aspect of our VUV radiometric activity is the calibration and supply of transfer standard photodiodes. This activity takes place both at SURF and off SURF. This year we completed 23 new outgoing far-UV detector calibrations. These detectors and the large number in service from the calibrations of previous years serve a broad constituency including solar physics, MFE, ICF, astrophysics/astronomy, aeronomy, standards laboratories, space simulation facilities, and plasma and solid state physics. 3 papers, 2 invited talks.

Calibration Workshops

We organized the fourth in our series of workshops on the use of XUV and X-Ray radiometry for plasma diagnostics which met in April 1981. This workshop provides a major communications channel within the plasma diagnostic community as well as between NBS and the diagnosticians. This meeting brought to NBS magnetic and inertial fusion diagnosticians from ten institutions. Increased dependence on NBS radiometric capabilities was evidenced at this meeting. In addition, we shared in the organization of the sixth in a series of workshops on the VUV Radiometric Calibration of Space Experiments. This workshop is a major communications channel between NBS and the atmospheric, solar and stellar physics communities. It was well attended particularly with groups planning space shuttle experiments. Continued dependence on NBS radiometric standards and calibrations was demonstrated.

ELECTRON PHYSICS GROUP

The Electron Physics Group has ongoing research efforts in electron collision physics including electron-atom and electron-molecule collisions, electron-surface interactions, surface magnetism, electron interaction theory, electron polarization phenomena, 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 activity. As a consequence of our advancement of polarized electron source 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.

In our first experiments we observed surface hysteresis curves from a nickel single crystal. We showed that there was an approximate linear temperature dependence for the surface magnetization; this is a very different variation than that for the bulk. We also have made measurements on the influence of adsorbates on surface magnetism. Future work on nickel will test models of two-dimensional critical phenomena with accurate measurements of the temperature dependence of the magnetization in the region of the Curie temperature.

We were able to demonstrate that we could make the same sorts of magnetic measurements on amorphous magnetic materials, thus greatly expanding the applicability of the technique. We used a metallic glass, Fe(40%) - Ni(40%) - B(20%), and in addition to measuring hysteresis curves and the temperature dependence, we were able to observe the effect of the exchange interaction for inelastic scattering as well. We also found that these devices can be operated in a way to produce very simple and effective spin polarization detectors by observing the net current absorbed at an energy near that at which the net absorption is zero. Here, the small spin dependent effects dominate. We have made measurements on W(110), Au(111), Au(110) and Au polycrystalline films in an effort to optimize this device. Further, we have completed a detailed analysis of the statistics of its operation to better facilitate its application.

In our non-magnetic, polarized electron scattering from surfaces, we completed an extensive study of the spin-orbit scattering from W(100) and investigated TaS_2, Au(110) and Au(111) in an attempt to find a favorable alternative to W(100) as a PLEED polarization detector. Our study of W(100) included a demonstration of the application of Constant Momentum Transfer Averaging to the analysis of PLEED data. We also investigated, in depth, the formation of electron-surface resonance states in collaboration with E.G. McRae of Bell Labs. Our data have been made available to LEED theorists and we look forward to seeing what effect the polarization parameter has on surface structure determinations.

High Energy Resolution Electron Scattering

Our experiment on high-energy-resolution electron scattering from surfaces has made significant progress during the past year. The apparatus has been partially converted from its previous use with gas phase targets to accept a solid target. Pressures of 6×10^{-11} Torr and an energy resolution of 8 meV have been obtained. We completed a study of the adsorption of ethelyne and acetylene on W(100). The vibrational energy losses were observed as a function of scattering angle and adsorbate coverage. The dissociation of the molecule was observable and our analysis of the momentum transfer occurring during the scattering process permitted a fuller determination of the molecule-substrate geometry. We began a study of the possible role of atomic hydrogen in the stabilization of the surface of diamonds against an energetically favorable reconstruction. This work will continue interspersed with the planned upgrading of this instrument.

Electron Optics

In our electron optical design program, Annija Galejs has completed the design of a complex beam transport system for our electron-atom scattering apparatus. In addition to this design, which was highly successful, she took part in many other design and analysis programs, e.g., secondary detector, Mott detector, etc. Work is now underway on a modular electron optics program which will greatly simplify the design process. This program will allow a choice of the level of accuracy required, include graphic output, be readily transported and upwardly extensible.

Theory

The theoretical effort has been concentrated on the recently discovered quantum Hall effect, which offers the potential for a new precision determination of the fine structure constant and establishment of a quantum standard of resistance. As a step toward understanding the experimental limitations of the effect, a calculation of end effect errors for MOSFET devices within a simple model of an inversion layer was carried out. It was found that the shorting effect of the source and drain introduces negligible error for the device geometries currently in use. Also calculations of the photoabsorption and yield for small metal spheres have been carried out. These calculations include the effects of electron-hole excitations in the sphere which have previously been neglected. The excitations are shown to result in very large enhancements in both the photoyield and photoabsorption. The optical properties of such spheres are of interest in a number of contexts, particularly in atmospheric physics.

Electron-Atom Collisions

Last year we began a new experiment which we have had under consideration for a few years. We wish to study the electron-atom scattering problem in an experiment where all of 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 are constructing a crossed-beam, polarized-atom, polarized-electron scattering machine. Sodium atoms are polarized via 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 $<.15$ eV. The use of a laser to optically orient the Na 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. The apparatus construction phase has been successfully completed and data taking will begin shortly.

PHYSICAL AND CHEMICAL EFFECTS OF IONIZING RADIATION ON MATTER

P. Ausloos*, H. Rosenstock, M. Simic, S.G. Lias*, M. Mautner*,

A. Parr, F. Schwarz*, E. Hunter*, E. Gajewski*, C. Lutz*

(8 staff years)

Long Term Goals

This is a joint competence building program of the Center for Chemical Physics (CCP) and the Center for Radiation Research (CRR) to investigate the fundamental mechanisms of chemical and physical processes induced by the interaction of ionizing radiation with matter; to obtain experimental and theoretical results which contribute to the understanding of the response of matter to ionizing radiation in sufficient detail for application to radiation biology, radiation dosimetry, and radiation processing.

Introduction

The experimental program at CCP on the effects of ionizing radiation on matter includes (a) the use of vacuum ultraviolet radiation to trace the events resulting from activation (excitation and ionization) as a function of energy, and (b) an experimental effort aimed at a quantitative exploration on the effects of solvation on the chemistry and thermochemistry of radiation-generated reactive intermediates (i.e. an exploration of the differences between systems irradiated in the gas and the liquid phases). Work at CRR includes detailed examinations of the ionization process (SURF), and work on the lifetimes, and mechanisms of fragmentation, of excited ions. There is active collaboration between CRR and CCP personnel on radiation effects in biochemical systems and the development of radiation dosimeters. Details of these efforts are given below, along with descriptions of some related activities in which competence personnel are involved.

Recent Accomplishments and Future Plans

a) Molecular Ionization Processes (A. Parr, CRR, and R. Stockbauer, Div. 541, in collaboration with J. Dehmer, Argonne Laboratories)

Photoionization at a given wavelength is a combination of direct ionization and autoionization (formation of superexcited neutral states which spontaneously eject an electron). One generally assumes that the accompanying vibrational excitation is governed by the Franck-Condon

*CCP

principle, which is based on separability of electronic and nuclear motions. A few years ago, it was pointed out that in some cases, this separability does not occur when the outgoing photoelectron has to pass through a centrifugal barrier. As a result, strong departures from Franck-Condon intensity distributions might occur. The general phenomenon is called shape resonance. To investigate this, an experiment was set up on the NBS storage ring (SURF) to study the vibrational excitation distribution as a function of photon energy and polarization angle. The experiment consists, in essence, of a variable angle photoelectron spectrometer coupled to polarized, monochromatic radiation from the NBS storage ring.

Accomplishments

Studies on the effects of autoionization and shape resonance upon the angular distributions and branching ratios in molecular photoionization have been performed on N_2, O_2, CO, CO_2, C_2H_2, C_2N_2, CH_3CN, HCN, BF_3, and SF_6. There are approximately 10 papers in print describing this work, and about another 12 papers in various stages of preparation.

Future Plans

Installation of new experimental apparatus, including a magnetically shielded chamber, cryogenic and turbomolecular pumps, a system of double 4"-mean-radius electron energy analyzers, and computer automation. After updating, the chamber will support experiments in photoelectron-photoion coincidence spectroscopy, angle-resolved photoelectron spectroscopy, and laser-excited fluorescence.

Studies of the effects of inner valence shell and inner level excitation on the fragmentation of organic molecules. For example, extensive data on C_3H_4 isomers has already been obtained at energies less than 20 eV. An extension of this work to higher energies will allow an investigation of the carbon-carbon bond rupture processes, which do not occur at energies lower than 20 eV.

Many chemical species do not have sufficient vapor pressure to be studied by normal photoelectron spectrometric techniques. A variety of molecular beam sources will be developed for use at SURF to allow the investigation of such compounds. This facility will include expansion nozzles.

b) Fragmentation of Molecular Ions (H.M. Rosenstock, CRR, in collaboration with R. Buff, IPA, and J. Dannacher, guest worker from the University of Basel)

In the variable residence time photoelectron-photoion coincidence technique, ions of known excitation energy can be sampled by selecting ionization events producing near-zero energy photoelectrons at known (variable) photon energy. The molecular or fragment ions produced in the chosen event are analyzed by coincidence time-of-flight techniques. The time available for ion fragmentation can be varied from about 0.7 to 7 microseconds. For ions with lifetimes in this microsecond range, pronounced effects on fragmentation yields can be observed by this variable residence time technique. A theoretical model has been developed which can be used to extract kinetic parameters (activation energies and entropies) for the non-thermal fragmentation processes. The parameters can be used to predict ion lifetimes at various excitation energies, to make quantiative comparisons of analogous thermal decomposition processes, and to deduce whether or not internal conversion to the ion ground state has taken place.

Accomplishments

An invited critical review was prepared covering all aspects of the dynamic behavior of excited $C_6H_6^+$ ions, including isomerization and structural stability, location of excited electronic states, fragmentation mechanisms, kinetics and energetics, and radiative processes. It turns out that this comprehensive discussion will be useful in understanding new experimental results on multiphoton ionization and fragmentation (Rosenstock, Dannacher, Liebman).

A new systematic approach to estimation of thermochemical properties of gaseous neutral and ionized molecules was developed and applied to acyclic strainless hydrocarbon and C,H,O compounds. Ionization energies of 31 compounds have been measured by threshold photoelectron spectroscopy, and will be used in preparing a comprehensive review of reference and estimated ion energetics of the classes of compounds. (Liebman, Rosenstock, Buff, Parr, Stockbauer).

A precise benchmark value of the absolute proton affinity of propylene has been determined by threshold photoelectron-photoion coincidence mass spectrometry (Rosenstock, Buff, Parr, Ferreira, Lias, Stockbauer, Holmes).

A new class of slow fragmentation processes has been discovered in normal and isopropyl bormide and iodide ions. The processes involve slow decomposition of essentially vibrationless propyl halide ions formed in the upper component of the ion spin-orbit doublet state.

A preliminary theoretical study of polyatomic Franck Condon envelopes has been carried out. With suitable approximations a number of interesting relationships between band widths, maximum quantum number and adiabatic ionization energy can be derived.

Future Plans

Detailed coincidence study of iodobenzene fragmentation to a) compare accuracy of rate-energy determination with those of other techniques, b) develop a model for in-flight ion dissociation on the coincidence machine.

Coincidence study of phenol and dimethyl ether to search for cases where electron impact and photon impact show different fragmentations due to population of optically forbidden states.

Coincidence study of diazabenzene isomers, a case where isomers do not freely interconvert prior to fragmentation.

Further development of estimation schemes for ion energetics of cyclic and polyfunctional species.

Completion of study of photoelectron band envelope properties. Initial study of feasibility of photoelectron spectroscopy of laser-excited molecules.

c) Excitation and Ionization in Organic Liquids Induced by High Energy Photons (P. Ausloos, F. Schwarz, M. Mautner, C. Lutz, CCP)

Measurements of ion currents, fluorescence quantum yields, and yields of photofragments in irradiated organic liquids provide information about the nature of the excited state formed by direct excitation, and, at energies above the ionization onset, about the nature of the excited molecules resulting from ion-electron recombination. Such measurements, carried out as a function of the energy of the irradiating light, lead to a comprehensive picture of the photophysical and photochemical phenomena occurring. This information can then be applied to the interpretation of systems irradiated by electron beams or gamma rays.

Accomplishments

Completion of a comprehensive study of the energy-dependence of fluorescence quantum yields in liquid alkanes (n-hexane, n-decane) and cyclic alkanes (cyclopentane, cyclohexane, bicyclohexyl, and trans-decalin) at energies above and below the ionization threshold. For cyclopentane and cyclohexane, these data were used in conjunction with information about the energy dependence of the modes of photofragmentation (photochemistry experiments carried out in collaboration with R. Rebbert and S. Lias) to derive information about the ionization quantum yields as a function of energy in the liquid phase. The study elucidated details of the mechanism of charge neutralization in the liquid phase.

Completion of a study of the energy-dependence of fluorescence quantum yields in alkyl benzenes, which provided insight into charge recombination mechanisms in aromatic hydrocarbons.

Future Plans

Studies of the energy-dependence of fluorescence quantum yields in ketones and cyclic ethers are in progress. Preliminary results indicate that light emission occurs as a result of direct irradiation as well as charge recombination. In the case of para-dioxane liquid, there is a strong emission at 250 nm which shifts towards longer wavelengths upon addition of water and alcohols. The emission which can be ascribed to an aggregate involving the boat form of para-dioxane, decreases sharply with an increase in photon energy as a result of a shortening of the dissociative lifetime of the excited molecule.

Determination of relative photoionization quantum yields in the liquid phase can also be obtained from photoconductivity measurements. A photoconductivity cell is presently being fabricated for this purpose. A major research effort will be made next year in photoconductivity studies of liquid alkanes, aromatics, and ethers exposed to far ultraviolet radiation.

Efforts will be made to extend the energy range of the condensed phase fluorescence measurements, which are currently restricted to the energy range below 11.6 eV (because of the transmission characteristics of the lithium fluoride window material). A cryostat will be interfaced with a vacuum monochromator; thin films of sample compounds condensed on a cold surface could then be exposed to vacuum ultraviolet radiation through aluminum windows. Since, in the energy range 15-20 eV, the photoionization efficiency is unity for most compounds, one would observe fluorescence from charge recombination only. Under these conditions, the longer-lived phosphorescence can also be observed, so information can be obtained about the ratio of triplet vs. singlet states formed during the charge recombination process.

Absolute fluorescence yields of liquids exposed to 0.6 MeV β particles from a Sr^{90} source will be measured and interpreted in terms of charge recombination.

d) Ion-Molecule Interactions; Ion Solvation (P. Ausloos, S.G. Lias, M. Mautner, and E. Hunter, CCP, in collaboration with L.W. Sieck, CCP)

Radiation with energy above the ionization threshold produces positive ions which may react with neutral molecules to form the ultimate products of ionizing radiations. The reactivities of the ionic species are determined by the structures of the ions and the thermochemistry (stability) of the ionic reactants and products. The thermochemical properties are affected both by intrinsic molecular parameters and by the interactions of ions with solvent molecules which may substantially alter the charge distribution on the ionic species.

Accomplishments

The energies of ionization and the corresponding values of $\Delta S°$ associated with the ionization process have been measured for a number of alkyl cyclohexanes and other cyclic alkanes in the high pressure photoionization mass spectrometer through charge transfer equilibrium constant determinations. Certain consistent patterns observed in the thermodynamic network found for the substituted cyclohexanes have permitted evaluation of the relationship between methyl substitution at various skeletal sites and the entropy of ionization, and a predictive scheme has emerged which should be applicable to branched alkanes as well.

Fundamental studies exploring the effect of temperature on ion-molecule reaction rate constants, and the effect of other thermochemical parameters on ion-molecule reactions have been completed. Two manuscripts have been submitted for publication.

A study has been carried out using the ion cyclotron resonance spectrometer which uses changes in chemical reactivity as a function of ΔH of reaction to estimate the proton affinities of various free radicals. This study establishes a new primary standard, the benzyl radical, for the proton affinity scale. A manuscript has been submitted for publication.

Studies elucidating the structures of $C_3H_3^+$ and $C_4H_4^+$ ions formed in the fragmentation of various organic ions have been completed. The different isomers were distinguished through differences in chemical reactivity, as observed in the ion cyclotron resonance spectrometer. The $C_3H_3^+$ ion has been proposed to be an important precursor in the mechanism leading to soot formation in fuel-rich flames. An outgrowth of the study of the reactivities of the cyclic and linear $C_3H_3^+$ ions was a collaborative effort with Kermit Smyth of the Center for Fire Research exploring the details of the proposed initiating steps in the soot-formation mechanism. One publication has appeared and two are in press.

Future Plans

It is possible using pulsed high pressure (1-10 torr) mass spectrometry to study quantitatively the kinetics and thermochemistry of the stepwise solvation of positively-charged ions. In this way, the gap between gas phase and solution phase chemistry of ions can be bridged. The concentration of a pulsed high pressure mass spectrometer which will allow kinetic and equilibrium studies on ion solvation is now under way. The new instrument will allow time-resolved kinetics measurements over the temperature range 200-550 K. The reaction chamber will be equipped with solid, liquid, and vapor introduction ports, and will be capable of operation at pressures up to several torr. The temporal history of the ions generated in the system will be monitored by a newly-acquired

digital detection system and multichannel scaler, which is directly interfaced to a dedicated computer. When operational, by the end of 1981, the new pulsed high pressure system will be the only instrument with these combined capabilities in the U.S. and only the third instrument worldwide.

The new pulsed high pressure mass spectrometer will be used to study the interactions of radical ions with solvent molecules, since such solvation effects affect condensed phase ionization potentials and the mobilities of positive holes in liquids. The interaction of benzene and substituted benzene ions with solvent molecules will be examined to identify the contributions of molecular geometry, polarizability and dipole moments on non-covalent ion-solvent bonding. Another initial effort will involve an examination of the kinetics and thermochemistry of the formation of cluster ions such as $C_2H_6 \cdot C_2H_6^+$ and $C_3H_8^+ \cdot C_3H_8$, in alkanes. Ion-neutral interactions of selected alkylpyridines will be investigated to quantify the thermodynamic and kinetic consequences of steric hindrance of the active sites in solvated ions.

Ion cyclotron resonance studies on the structures of ions are continuing. A study in progress elucidates the details of the isomerization mechanism involving benzyl ions and tropylium ions.

A new capacitance bridge detector has been constructed for the ion cyclotron resonance instrument. This detector, which is currently being installed and de-bugged, will permit the study of ions of molecular weight as high as 1000 and as low as 2; current mass limitations are $\sim$20 to 200 amu. A computerized data acquisition system is also being installed.

Investigations will be initiated to explore the role of Franck-Condon restrictions on electron transfer processes in the gas, liquid, and solid phases. These processes govern the mobility of positive holes in irradiated matter. Current understanding of the action of Franck-Condon restrictions in electron transfer phenomena is incomplete; while theoretical predictions of lowered efficiencies appear to be fulfilled for some reactant pairs, in other cases, effects of the restrictions apparently can not be discerned, especially in the liquid phase. Gas phase charge transfer rate constants for pairs predicted to have such restrictions will be measured in the up-dated ion cyclotron resonance instrument. The pulsed Van de Graaff generator will be used to carry out time resolved studies of electron transfer processes in liquids and glasses.

e) V. Radiation-Induced Damage in Bio-Systems (M. Simic, CRR, E. Hunter, E. Gajewski, CCP, in collaboration with M. Dizdaroglu and W. McLaughlin)

Since most living systems have water as a major component, it is water which absorbs most of the energy when living cells are irradiated. The irradiation of water leads to the formation of reactive transient

species, called "water radicals" such as O_2^-, OH, or hydrated electrons, e_{aq}, which ultimately attack dissolved biochemical material to cause radiation damage. Physiological radiation damage results in part from such indirect effects of radiation. Direct effects, which result from the direct interaction of the radiation with the biochemical molecules themselves, can be studied using the approaches described above. Indirect effects are best studied in situ using a high energy pulsed electron beam coupled with time-resolved observation of both the water radicals and the biochemical species activated by the attack of these reactive transients. Transient species are observed by absorption spectroscopy while the stable end-products formed in irradiated systems can be identified by a variety of analytical techniques. Studies of indirect effects are the major focus of that portion of the competence program being carried out in the Radiation Physics Building.

Accomplishments

A kinetic spectrophotometric system was assembled and combined with a Febetron 705 Pulser to monitor transient species formed in pulse radiolysis. Gating and timing circuits were fabricated so that optical transmission changes of 1% can be detected.

Disodium-4,4'-trithiobis(butane sulfinate) has been suggested as a radiation protective agent. The Febetron 705 and associated kinetic spectrophotometric system has been used to measure the rate constants for reduction of this compound by hydrated electrons, CO_2^-, and $CH_3C(OH)CH_3$.

Reactions of free radicals with vitamin E in micellar systems led to a new understanding of the physiological role of vitamin E.

General outlines of the radiation chemistry of DMSO were obtained, indicating a major role of methyl radicals. Favorable conditions were found for utilization of DMSO in fiber optics dosimetry.

Future Plans

Radioprotectors. Various sulfur compounds (polysulfides and thioles) will be subjected to pulse radiolytic investigations in order to understand the parameters which govern their radiation protective properties (inactivation and repair of free radicals).

Chemical dosimetry. Studies of DMSO will be extended to encompass quantification of all radiation-generated species. DMSO solutions of dyes and metallo porphyrins will be investigated for their suitability in fiber optics dosimetry.

Autoxidation processes. The chemistry of diverse peroxy radicals with selected antioxidants will continue to be investiaged in order to elucidate the nature of these reactions (electron vs H atom transfer).

SPONSORED CONFERENCES

Division 533, Radiation Physics

4th Workshop on the Use of XUV and X-Ray Radiometry in Plasma Diagnostics 5 eV to 10 KeV, Gaithersburg, MD, April 24, 1981.

6th Workshop on the VUV Radiometric Calibration of Space Experiments, Boulder, CO, April 1-3, 1981.

International Symposium on Correlation and Polarization in Electron-Atom Collisions, NBS, Gaithersburg, MD, July 13-14, 1981.

First National Workshop on Radiation Processing of Food, Chairman, M.G. Simic, Univ. of Maryland, College Park, Maryland, July 16, 1981.

INVITED TALKS

Division 533, Radiation Physics

Berger, M.J., "Theoretical Aspects of Electron Dosimetry," Electron Dosimetry and Arc Therapy Symposium, University of Wisconsin-Madison, September 10, 1981.

Celotta, R.J., "Electron Scattering in the NBS Electron Physics Group," The Institute of Physics, Belgrade, Yugoslavia, September 18, 1980.

Celotta, R.J., "Spin Polarization Effects in Electron Impact Spectroscopy," Symposium on Electron Impact Spectroscopy, Bull. Am. Phys. Soc. 26, 438 (1981).

Celotta, R.J., "Polarized Electrons," XIIth Int. Conf. on Phys. of Electronic and Atomic Collisions (ICPEAC), Gatlinburg, TN, July 21, 1981.

Dick, C.E., "Utilization of Monoenergetic X-Ray Beams to Examine the Properties of Radiographic Intensifying Screens," 6th Conference on the Use of Small Accelerators in Business and Industry, North Texas State University, Denton, TX., November 4, 1980.

Dick, C.E., Sparrow, J., Motz, J.W. "A proposal to develop a multiple exposure geometry real-time radiographic imaging system for dentistry", Advisory Group to the National Institute for Dental Research, December 15, 1981.

Domen, S. R., "The Remodeled NBS Absorbed Dose Water Calorimeter," National Research Council of Canada, October 1980.

Domen, S. R., "Performance and Preliminary Results with the NBS Absorbed Dose Water Calorimeter," Massachusetts General Hospital, Boston, MA, November 1980.

Domen, S. R., "Theory, Performance, and Measured Results with an Improved Absorbed Dose Water Calorimeter," Electron Dosimetry and Arc Therapy Symposium, University of Wisconsin, Madison, September 1981.

Ederer, D., "The Franck-Condon Separation and New Insights in Molecular Photoionization Dynamics", University of Connecticut, Storrs, CT, April, 1981.

Ederer, D., "The Franck-Condon Separation and New Insights in Molecular Photoionization Dynamics," Virginia Polytechnical Institute, Blacksburg, VA, April, 1981.

Division 533, Invited Talks (cont'd.)

Ederer, D., "Photoionization of Laser Excited States in Sodium by Synchrotron Radiation," Howard University, Washington, DC, June 1981.

Ederer, D., "Advance in Monochromator Designs for Synchrotron Radiation," National Conference on Synchrotron Radiation Instrumentation at Cornell University, Ithaca, NY, July 1981.

Ehrlich, M., "Choice of Radiation Protection Quantities for a Personnel Dosimetry Performance Standard," European Seminar on Radiation Protection Quantities for External Exposures, Braunschweig, Germany, October 1980.

Hubbell, J.H., "Recent Tabulations (X-Ray Mass Attenuation Data)." 12th Congress & General Assembly of the International Union of Crystallography, Ottawa, Canada, August 16, 1981.

Humphreys, J.C., "Dye Film Dosimetry for Radiation Processing", 6th Conf. on Application of Accelerators in Research and Industry, North Texas State University, Denton, TX, November 3, 1980.

Kelley, M.H., "Polarized Electron-Polarized Atom Scattering," Seminar on Collision Experiments in Their Theoretical Frame, University of Chicago, May 1981.

Loevinger, R., "Calculation of Absorbed Dose in High-Energy Photon and Electron Beams Using a Calibrated Ionization Chamber," International Symposium on Biomedical Dosimetry, International Atomic Energy Agency, Paris, France, October 1980.

Loevinger, R., "Radiation Quantities and Units," preparation course for the American Board of Health Physics Certification Examination, Gaithersburg, Maryland, January 1981.

Lucatorto, T., and Hill, W., "Laser Excitation and Ionization of Dense Atomic Vapors-Absorption Spectroscopy of Ions the Easy Way," Howard University, April, 24, 1981.

Lucatorto, T., and McIlrath, T., "Quantitive Inner Shell Absorption Spectroscopy Using Ionic Vapors," 5th International Conference on Laser Spectroscopy, Jasper Park, Canada, July 3, 1981.

Madden, R.P., "Resonance Phenomena in Molecular Photoionization - Impact of Synchrotron Radiation," John Strong Symposium, University of Mass. Amberst, MA, March, 1981.

Madden, R.P., "Storage Rings as Sources for Soft X-Ray Emission," Topical Conference on Low Energy X-Ray Diagnostics, Monterey, CA, June, 1981.

Division 533, Invited Talks (cont'd.)

Madden, R.P., Conference Summary, Second National Conference on Synchrotron Radiation Instrumentation, Cornell, NY, July 1981.

Madden, R.P., "Harnessing Luminous Electron For Science and Technology, The Story of Synchrotron Light," A talk given to local sections of the Optical Society of America in Ann Arbor, Chicago, Detroit, Minneapolis, Philadelphia, Pittsburg, Rochester, Norwalk, and Schenectady in 1981.

McIlrath, T., "Generation of VUV Radiation by Resonant Up-Conversion in Noble Gases," U.S.-Japan Seminar on Production and Applications of High Power Levels in the Extreme Ultraviolet, Sendai, Japan, October, 1981.

McIlrath, T. "The BRV as a Light Source from 100A to 600A," U.S.-Japan Seminar on Production and Applications of High Power Levels in the Extreme Ultraviolet, Sendai, Japan, October, 1981.

McIlrath, T., "Generation of Intense Far UV Continua Using Laser Plasma from High Z Target," U.S.-Japan Seminar on Production and Applications of High Power Levels in the Extreme Ultraviolet, Sendai, Japan, October 1981.

McLaughlin, W.L., "The Gamma Ray Response of Radiochromic Dye Films at Different Absorbed Dose Rates," 3rd International Meeting of Radiation Processing, Science Council of Japan, Tokyo, Japan, October 27, 1980.

McLaughlin, W.L., "Radiation Sources for Industrial Processing," 3rd International Meeting of Radiation Processing, Science Council of Japan, Tokyo, Japan, October 27, 1980.

McLaughlin, W.L., "Liquid Radiochromic Dosimetry," 3rd International Meeting on Radiation Processing, Science Council of Japan, Tokyo, Japan, October 28, 1980.

McLaughlin, W.L., "Quality Control for Electron Beam Processing of Polymeric Materials by End-Point Analysis," 3rd International Meeting on Radiation Processing, Science Council of Japan, Tokyo, Japan, October 29, 1981.

McLaughlin, W.L., "Use of Electron-Spin Resonance of Polymer Films Containing Leucodyes for Dosimetry," 3rd International Meeting of Radiation Processing, Science Council of Japan, Tokyo, Japan, October 30, 1980.

McLaughlin, W.L., "Radiochromic Dyes as 1-hit Detectors," Risø National Laboratory, Roskilde, Denmark, November 14, 1980.

McLaughlin, W.L., "National High Dose Intercomparison," IAEA Advisory Group Meeting in High Dose Standardization in Industrial Radiation Processing, Vienna, Austria, November 17, 1980.

Division 533, Invited Talks (cont'd.)

McLaughlin, W.L., "Protocol for International Dosimetry Intercomparison for Industrial Application," IAEA Advisory Group Meeting in High Dose Standardization in Industrial Radiation Processing, Vienna, Austria, November 21, 1980.

McLaughlin, W.L., "Dosimetry for Industrial Radiation Processing," Center for Nuclear Research, Mexico City, Mexico, December 11, 1980.

McLaughlin, W.L., "Fibre Optics Dosimetry," Institute of Physics, Universidad Nacional de Mexico, Mexico City, Mexico, December 11, 1980.

McLaughlin, W.L., "Chemical Dosimetry," International Sumposium on Nuclear Chemistry Radiochemistry, and Radiation Chemistry, Congress Center, Mexico City, Mexico, December 10, 1980.

McLaughlin, W.L., "Radiation Chemistry of Triphenylmethane Dyes," Faculty of Cairo, Giza, Cairo. March 16, 1981.

McLaughlin, W.L., "Electron Beam Dosimetry," National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt, March 17, 1981

McLaughlin, W.L., "Chemical Dosimetry for Radiation Emergencies," Radiation Protection Department, Nuclear Research Centre, Atomic Energy Establishment, Cairo, Egypt, March 18, 1981.

McLaughlin, W.L., "Radiation Dosimetry with Metalloporphyrins," Department of Nuclear Engineering, University of Alexandria, Egypt, March 21, 1981.

McLaughlin, W.L., "End Point Analysis for Quality Control in Radiation Processing of Plastics," Chemistry Department, Ain Shams University, Cairo, Egypt, March 23, 1981

McLaughlin, W.L., "X- and Gamma-Ray Dosimetry for Industrial Applications," National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt, March 24, 1981.

McLaughlin, W.L., "New Concepts in Chemical Dosimetry," Nuclear and Radiological Physics Seminar, Radiation Physics Bldg., NBS, May 14, 1981.

McLaughlin, W.L., "Dosimetry," International Conf. on Radiation Processing and Rubber, Brighton, England, June 15, 1981.

McLaughlin, W.L., "Electron Beam Diagnostics and Imaging," Division of Radiation Science and Acoustics, National Physical Laboratory, Teddington, UK., June 19, 1981.

Division 533, Invited Talks (cont'd.)

McLaughlin, W.L., "Fibre Optics System for Radiological Measurements," Radiation Physics Department, St. Bartholomews Hospital, Radiotherapy Department, West Smithfield, London, UK, June 22, 1981.

McLaughlin, W.L., "Radiochromic Dye Dosimetry," Department of Biophysics and Bio-Engineering, University of Aberdeen, Scotland, UK, June 23, 1981.

McLaughlin, W.L., "Dosimetry in Quality Control of Irradiated Foods," Workshop on Radiation Processing of Food, University of Maryland, College Park, MD, July 16, 1981.

Penn, D.R., Chaired session on transition metals at Conference on Magnetism and Magnetic Materials, Dallas, Texas, November 12, 1980.

Penn, D.R., "Resonant Satellites in Metals with Filled d-Bands," Xerox Research Labs, Palo Alto, California, November 13, 1980.

Penn, D.R., "Enhanced Photoyield from Small Particles," Solid State Seminar, LURE, O'rsay, France, March 31, 1981.

Pierce, D.T., "Spin Polarized Electron Scattering at Magnetic Surfaces," Naval Research Laboratory, Magnetics Branch Seminar, March 2, 1981.

Pierce, D.T., "Electron Scattering Studies of Surface Magnetism," Greater Washington Surface Science Seminar, November 17, 1980.

Rosenstock, H.M., "Fragmentation of Large Molecular Ions," City University of New York, December 1980.

Rosenstock, H.M., "Chemistry at NBS," City University of New York, December 1980.

Rosenstock, H.M., "Recent Coincidence Studies of Ion Fragmentation," Brooklyn Polytechnic Institute, December 1980.

Rosenstock, H.M., "Coincidence Studies of Alkyl Iodide Ion Fragmentation," 4th Annual Meeting of the Portuguese Chemical Society, Lisbon, Portugal May 1981.

Rosenstock, H.M., "Formation of Ethyl and Propyl Ions From C_2H_5I, 1-C_3H_7I, and 2-C_3H_7I," 29th Annual Conference on Mass Spectrometry and Allied Topics, Minneapolis, Minnesota, May 1981.

Saloman, E., "Radiometry Using Synchrotron Radiation," Society of Photo-Optical Instrumentation Engineers Technical Symposium East '81, Seminar on Ultraviolet and Vacuum Ultraviolet Systems, Washington, DC, April 1981.

Division 533, Invited Talks (cont'd.)

Saloman, E., "Far Ultraviolet Detector Calibration at the National Bureau of Standards," 4th Workshop on the Use of XUV and X-Ray Radiometry in Plasma Diagnostics 5 eV to 10 KeV, Gaithersburg, MD, April, 1981.

Simic, M.G., "Kinetics and Mechanism of Free Radical Reactions with Vitamin E, Committee on Diet, Nutrition and Cancer," National Academy of Sciences, Washington, DC, November 6, 1980.

Simic, M.G., "Vitamin E," Department of Nutrition and Food Science, MIT, Cambridge, MA, November 17, 1980.

Simic, M.G., "Kinetics and Energetics of Autoxidation Reactions," MIT, Cambridge, MA, November 25, 1980.

Simic, M.G., "Vitamin E and Antioxidants," Radiological Group, Case Western University, Cleveland, OH, December 22, 1980.

Simic, M.G., "Radiation Chemistry A Base for Safety and Technological Assessments," Workshop on Radiation Processing of Food, University of Maryland, College Park, Maryland, July 16, 1981.

Soares, C. G., "A Thermoluminescence Dosimetry System for Use in a Survey of High-Energy Bremsstrahlung Dosimetry," Sixth Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 1980.

Sparrow, J.H.. "The NBS Low Energy X-Ray Calibration Program," Fourth Workshop on the Use of XUV-X-Ray Radiometry. April 1981.

Sparrow, J.H., "General Details of Several Alternate Approaches to Achieve a Dental Radiographic System Capable of Selective Geometry for Dental Radiography," presented to the National Institute of Dental Research Advisory Panel, held at NIH, April 1981.

Sparrow, J.H., "Details of the NBS Proposal to the National Institute of Dental Research on a Selective Geometry Radiographic System for Dental Radiograph," presented to the NIDR nationally selected project evaluation panel, held at NBS, December 1980.

Spencer, L.V., "Future Plans Relative to Committee SC 63," Council Meeting of the National Council on Radiation and Measurement, August 19, 1981.

Spencer, L.V., "Assumptions about the Characteristics and Environments after Nuclear Accidents and Nuclear Attacks," The Control of Exposure from Ionizing Radiation in the Event of Accident or Attack, Symposium April 27, 1981.

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Division 533, Radiation Physics

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Ederer, D.L., Cole, R., Stockbauer, R., Codling, K., Parr, A., West, J., Poliakoff, E.D., Dehmer, J., Wavelength and Vibrational-State Dependence of Photoelectron Angular Distributions. Resonance Effects in the 5σ Photoionization of CO. J. Chem. Phys. 72, 6308 (1980).

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Division 533, Publications (cont'd.)

Ederer, D.L., The Development of Far UV Spectrometers for Synchrotron Radiation Facilities, to be published in Nucl. Inst. and Methods.

Ehrlich, M., Choice of Radiation Protection Quantities for a Personnel Dosimetry Performance Standard, Proceedings of European Seminar on Radiation Protection Quantities for External Exposure, Braunschweig, Germany, 1980 (in press).

Hamilton, J.C., Swanson, N., Waclawski, B.J. and Celotta, R.J., Specular and Off-Specular High Resolution Electron Energy Loss Spectroscopy of Acetylene and Ethylene on Tungsten (100), J. Chem. Phys. 74, 4156 (1981).

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Hughey, L.R., Shaefer, A.R., Reduced Absolute Uncertainty in the Irradiance of SURF-II and Instrumentation for Measuring Linearity of X-Ray, XUV and UV Detectors. To be published in the 2nd National Conference on Synchrotron Radiation Instrumentation.

Loevinger, R., A Formalism for Calculation of Absorbed Dose to a Medium from Photon and Electron Beams, Med. Phys. 8, No. 1, 1-12 (1981).

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Division 533, Publications (cont'd.)

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Lucatorto, T.B., and McIlrath, T.J., Radical Redistribution of the 4d-Oscillator Strength Observed in the Photoabsorption of the Ba, Ba^{+}, and Ba^{++} Sequence, Phys. Rev. Lett., to be published.

Madden, R.P., Availability of NBS Radiometric Standards for Solar Irradiance Studies, Proceedings of the Workshop on Solar UV Irradiance Monitors, held July 31 - August 1, 1980, pp. 79-86.

Madden, R.P., Timothy, G., Photon Detectors for the Ultraviolet And X-Ray Regions, To be published Handbook on Synchrotron Radiation

Madden, R.P., and Parr, A.C., Resonance Phenomena in Molecular Photoionization - Impact of Synchrotron Radiation, to be published Applied Optics.

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McLaughlin, W.L., Jarrett, R.D., and Olejnik, T.A., "Dosimetry," Chapter 7 in Preservation of Food by Ionizing Radiation, Editors: E.S. Josephson and M.S. Peterson, CRC Press (in press).

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Rogers, W.T., Dunn, G.H., Ostgaard Olsen, J., Reading, M., and Stefani, G., Absolute emission cross sections for electron impact excitation of Zn^+ ($4p\ ^2P$) and ($5s\ ^2S$) terms, Phys. Rev. A, 1981 (in press).

Rogers, W.T., Stefani, G., Camilloni, R., Dunn, G.H., Msezane, A.Z., and Henry, R.J.W., Electron-impact ionization of Zn^+ and Ga^+, Phys. Rev. A, 1981 (in press).

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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 on Dose Calculations. (Chairman deceased: committee in abeyance).

Member, NCRP Committee #55 on Experimental Verification of Internal Dosimetry Calculations.

Member, NCRP Committee #52 on Conceptual Basis of Dosimetry.

Robert J. Celotta

Chairman, NBS Research Advisory Committee.

Charles E. Dick

Member of the Technical Program Committee for Biannual Conference on the Industrial and Scientific Utilization of Small Conference (J. Duggan and L. Morgan Co-Chairman).

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.

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).

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

Chairman, ANS Radiation Protection and Shielding Division ANS-6 Ad Hoc Committee on SI Units.

Member, ANS Isotopes and Radiation Division Committee on Radiography and Gauging.

Jimmy C. Humphreys

Member, ASTM F-1.11 Subcommittee on Quality and Hardness 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 Dosemeters.

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, NCRP Scientific Committee 26, High Energy X-Ray Dosimetry.

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

Member, ANSI/N44/SC2 Therapeutic Radiology.

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

Robert Loevinger (cont'd.)

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

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.

Member, AAPM Science Council ad hoc Task Group on Radiation Quantities and Units in Medicine.

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 Communications.

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

Pres-Elect, Optical Society of America.

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

Member, Program Committee, Conference on Reflecting Optics for Synchrotron Radiation, Brookhaven, November 1981.

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

Robert P. Madden (cont'd.)

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

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 Committe, Optical Society of America, Annual Meeting.

Member, Program Committee, Div. Atomic and Electron Physics, Amer. Phys. Soc.

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

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.

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.

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

William L. McLaughlin (cont'd.)

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

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

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, Non Destructive Testing Committee on Radiographic Practice and Penetrameters.

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, American Society for Mass Spectrometry (ASTM), Committee E-14 on Mass Spectrometry.

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

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

Edward B. Saloman

Chairman, 4th Workshop on the Use of XUV and X-Ray Radiometry for Plasma Diagnostics 5 eV to 10 KeV.

Lewis V. Spencer

Consociate Member, National Council on Radiation Protection and Measurements.

Member, American Nuclear Society (ANS) Standards Committee, Working Group 6.5 on Shielding Glossary.

Member NCRP Committee #52 on Conceptual Basis of Dosimetry.

Acting Chairman, NCRP Subcommittee #63, Emergency Radiation Exposure Control.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 533, Radiation Physics

1. M. J. Berger and S. M. Seltzer, consulted on problems in electron-beam transport for the Chair Heritage Program administered by the Naval Surface Weapons Center, White Oak, Maryland.

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

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

4. R. J. Celotta and D. T. Pierce advised on construction and provided drawings of a spin polarized electron source to Rice University, Yale University, and Naval Research Lab., Arlington, VA.

5. C. E. Dick serves as technical liaison and advisor to the members of the Polymers Group who are utilizing the 500 keV electron accelerator to investigate electron charge deposition in thin polymeric films.

6. C. E. Dick serves as a technical consultant to members of the Electron Devices Characterization Group on the development of proportional counters designed to measure extremely small sulfur-atom concentrations by photoionization.

7. C. E. Dick served as consultant with members of the National Security Agency and the University of Maryland to develop a program to measure accurately the electron dose delivered by a time-dependent electron beam in electronic components.

8. C. E. Dick was consulted by members of the American University to examine the utilization of the NBS low energy accelerators to fundamental problems in weak electromagnetic interactions.

9. C. E. Dick served as a technical consultant to members of the Quantum Metrology Group, which is utilizing the NBS Van de Graaff for precision measurements of the K x-ray energies of high-Z nuclei.

10. C. E. Dick served as the technical consultant and liaison for the planned pulsed conversion of the 4-MeV Van de Graaff accelerator for use by members of the Center for Radiation Research and the Center for Thermodynamics and Molecular Science. These modifications will permit use of this facility for problems in chemical kinetics and radiation chemistry.

Division 533, Consulting and Advisory Services (cont'd.)

11. C. E. Dick and J. W. Motz consulted with H.M. Cleare from Kodak Laboratories on the transfer of a new method and installation of equipment required for the measurement of the image information transfer efficiency and light output properties of the medical x-ray screens developed and manufactured by Kodak.

12. J. H. Hubbell responded to inquiries to the X-Ray and Ionizing Data Center on matters pertaining to photon cross sections from approximately 250 scientists in the U.S. and abroad.

13. J. H. Hubbell collaborated on calculations of photon pair-production with scientists at University of Mainz, W. Germany, and University of Trondheim, Norway.

14. 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)

15. R. Loevinger has twice served as a member of a Special Review Group of the National Cancer Institute to evaluate research proposals.

16. T. P. Loftus consulted with the Naval Surface Weapons Center, White Oak, MD, regarding construction of a new facility for routine testing of the Navy TL Dosimetry System, and regarding procedures for establishing traceability to NBS standards for the dosimeters in routine use.

17. W. L. McLaughlin gave talks and demonstrations to NBS tour of Tri-Service Clinical Medical Students from Bethesda Naval Hospital as part of NBS Tour Program, December 1980.

18. W. L. McLaughlin gave advice to Greg Morgan, Becton Dickinson Co., NJ, on proposed guidelines for evaluating polymeric materials being processed by radiation sterilization, December 1980.

19. W. L. McLaughlin. Advice to Joel Mattsson of Brooks AF Base on accurate and precise methods of dosimetry and dose distribution methods in high-intensity pulsed radiation fields, December 1980.

20. W. L. McLaughlin. Assisted Irving Serlin (Monsanto Research, Indian Orchard, MA, in devising methods of producing radiographic imaging materials with dye incorporated in plastics, January 1981.

Division 533, Consulting and Advisory Services (cont'd.)

21. W. L. McLaughlin. Assisted Russel Sacrato (EPA, College Park, MD) with technology information on radiation sterilization industry, methods, quality control, entire list of products, companies engaged in the industry, and breakdown of types.

22. W. L. McLaughlin. Assisted Noel Spanggard of Crown Zellerbach, San Leandro, CA, with dosimetry quality control advice for radiation effects in plastics and solid state materials, January 1981.

23. W. L. McLaughlin. Assisted William Fitzgerald of Baxter-Travenol (Chicago) with study of temperature dependence of response of radiochromic dye systems, January 1981.

24. W. L. McLaughlin. Supervised Ph.D. Thesis of N.H. Ahmed Taher, Cairo University, Prof. El Hussein Youssef, Physics Department, Title: Radiation Modifications of Industrial Polymeric Materials." January 1981.

25. W. L. McLaughlin. Supervised Ph.D. Thesis of Roberto Uribe, University of Mexico, Department of Physics, Title: ESR Spectrometry of Dyes. January 1981.

26. W. L. McLaughlin. Assisted AAMI (Association for Advancement of Medical Instrumentation, Trade Association for Medical Device manufacturers and processors) in establishing quality control in radiation dosimetry by dose intercomparison studies. Participants: Isomedix, Inc.; Ethicon Corp.; Surgikos, Inc.; American Hospital and Supply Corp.; Baxter Travenol; Johnson and Johnson; Becton Dickinson Company; Sherwood Medical; Radiation Dynamics, Inc.; Atomic Energy of Canada, Ltd.; University Hospital, London, Ontario.

27. W. L. McLaughlin. Assisted IBM Research (Jane Shaw) in designing an electronic lithographic material using radiochromic dyes to be presented at Electron Lithography National Conference, January 1981.

28. W. L. McLaughlin. Assisted Art Lucas of Harshaw Chemical Company, Solon, OH. in designing applications and improving accuracy and reproducibility of color-center dosimeter consisting of optical quality LiF chips as possible dosimeters.

29. W. L. McLaughlin. Assisted Prof. Walter Bremer, NYU, Department of Chemical Engineering with design of radiation sensitive plastic materials for high-resolution imaging. January 1981.

30. W. L. McLaughlin. Assisted George Gough, Pfizer Medical Systems, with advice on radiation sterilization dosimetry for quality assurance, January 1981.

Division 533, Consulting and Advisory Services (cont'd.)

31. W. L. McLaughlin. Advised Dr. Wasserman, Department of Agriculture, Philadelphia, PA, on setting up new Interdepartment Committee on Food Irradiation. January 1981.

32. W. L. McLaughlin. Assisted Sydney Breshears of Space Science Services, Inc., Laurel, Maryland, with calibration methods for electron beam irradiated space vehicle components and provide data for their paper to be given at IEEE meeting in July 1981. February 1981.

33. W. L. McLaughlin. Assisted Laboratory for Radiation and Polymer Science, U. of Maryland (Dr. Walter Chappas) with characterization of ^{60}Co gamma-ray field and electron beam for 14 MeV Linac. February 1981.

34. W. L. McLaughlin. Consultation with Van Gunten (NSA) on dosimetry and electron beam and spectrum for special test studies to develop a program to measure accurately the electron dose delivered by a time-dependent electron beam in electronic components. February 1981.

35. W. L. McLaughlin. Assisted Lehigh University, Dr. Dale Zurawski (Chem. Engineering Dept.) with mapping of 2.5 MeV electron field. February 1981.

36. W. L. McLaughlin. Assisted Dr. Joseph Holland, Texas A&M University with advice on high-dose dosimetry project there involving large ^{60}Co gamma ray source. February 1981.

37. W. L. McLaughlin. Advised Prof. J.F. Merklin, Department Nuclear Engineering, Kansas State University in new LiF dosimetry methods for high dose applications, February 1981.

38. W. L. McLaughlin. Advised Dr. Patrick Walsh (Union Electric Co. in dosimetry for reactor cores very high neutron doses). February 1981.

39. W. L. McLaughlin. Assisted Mr. Jack Dempsey of Stieff R&D and Taggant Inc. of Bethesda, Maryland with air infiltration radiation monitors (using electrets), Radiation and Radar dosimeters, as well as Nuclear emulsion Nucclion track dosimeters. February 1981.

40. W. L. McLaughlin. Advised Dr. Sedgewick Berggren, Hughes Aircraft, on methods of intense beam radiation dosimetry for radiation effects studies. March 1981.

41. W. L. McLaughlin. Assisted Robert Wood of FAA (New Jersey) with fast response data on emission of LaOBr radiographic screens. March 1981.

Division 533, Consulting and Advisory Services (cont'd.)

42. W. L. McLaughlin. Advised Kim Butler, Goodyear Tire and Rubber Co. Akron, OH on radiation dosimeters for dose distribution measurements in radiation processing of rubbers. March 1981.

43. W. L. McLaughlin. Assisted Jeff Williams, Huttman Nuclear Co., Columbia, MD, on methods of analysis of high-density polyethylene stored for long times in the presence of nuclear waste. March 1981.

44. W. L. McLaughlin. Assisted Mr. Bracco, Pierelli Cable Corp., New York, NY, on high dose dosimetry for large insulating cable applications using electron beams for industrial processing. April 1981.

45. W. L. McLaughlin. Assisted Far West Technology Inc. with traceability of gamma-ray dose to primary NBS standards. April 1981.

46. W. L. McLaughlin. Assisted Mr. Dominique Gignoux (Industrial Gauging and Control Inc., Gaithersburg, MD) with quality control advice on radiation thickness gauges. May 1981.

47. W. L. McLaughlin. Assisted Carl Siebentritt Federal Emergency Management Agency with design and testing of dosimeters for radiation emergencies and environmental monitoring. May 1981.

48. W. L. McLaughlin. Advised Mr. Michael Noble, Wyle Laboratories, Huntsville, Alabama, on details of radiation effects in PVC, including toxicity data. May 1981.

49. W. L. McLaughlin. Consultation with Sandia Labs, (Mr. J. Plimpton) on underground nuclear testing dosimetry results. May 1981.

50. W. L. McLaughlin. Assisted Mr. Randy Culp, Bicron Corp., Cleveland, OH, with irradiations at NBS of Bicron dosimeters for DOE dose data being compiled by Bicron. May 1981.

51. W. L. McLaughlin. Advised David Ciarlione (Pennsylvannia State University Reactor) on high-dose dosimetry and reactor field dose mapping. July 1981.

52. W. L. McLaughlin. Assisted Doris Boesch of ALZA Corp. with a special irradiation to trouble shoot problematic dosimeters from the UK-Harwell, that radiation sterilized product may be released safely to the market. August 1981.

53. W. L. McLaughlin. Assisted Jeffrey Beck of Isomedix, Inc.. Whippany, NJ, with dosimetry for determination of dose distributions in heterogeneous product, as well as to compute gamma-ray source augmentation from uniform dose distributions in medical product carriers. August 1981.

Division 533, Consulting and Advisory Services (cont'd.)

54. W. L. McLaughlin. Assisted Dr. Donald Theisser and Doug Weiss of Telcom Products Div. of 3M Co. to establish new high-dose dosimetry procedures for radiation processing of cable and wire insulation using electron beams. August 1981.

55. W. L. McLaughlin. Assisted Dale Von Behrens, Sterling Drug Inc., New York, NY, begin procedures for instituting dosimetry as sterility assurance in the radiation sterilization of pharmaceuticals. August 1981.

56. 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.

57. J. W. Motz consulted with Philips Medical Systems, Inc., on experimental methods for evaluating the image information transfer efficiency of various x-ray fluorescent screens.

58. J. W. Motz consulted with the University of Arizona Medical Center on the dependence of image information transfer on the kilovoltage of x-ray machines in diagnostic radiology.

59. D. R. Penn, served as a consultant to members of Laboratorie pour L'Utilisation du Rayonnement Electromagnetique (LURE), Orsay, France, on pursuits in solid state, atomic, and molecular physics. Consulting time was from March 21 - April 4, 1981.

60. S. M. Seltzer is a consultant to the ICRU Committee on Stopping Power.

61. S. M. Seltzer consulted and advised on radiation transport and space-shielding problems with members of the Radiation Effects Branch, Naval Research Laboratory; with members of Goddard Space Flight Center, NASA.

62. S. M. Seltzer as an invited co-investigator on experiments proposed for scientific missions sponsored by NASA, advised and collaborated in studies of x-ray measurements of aural bremsstrahlung in Halley's ionosphere, of the fluorescence from the surface of the nucleus of Tempel 2 on the International Comet Mission, and of the x-ray imaging experiment to study global particle precipitation from Polar Plasma Laboratory, one of four satellites in the Origin of Plasmas in Earth's Neighborhood Mission.

63. M. G. Simic served as consultant on radiation sensitization and protection for radiation induced mutagenesis, Dartmouth Medical School, Hanover, New Hampshire.

Division 533, Consulting and Advisory Services (cont'd.)

64. M. G. Simic served as consultant on polymers to Prof. J. Silverman, University of Maryland, College Park, Maryland.

65. M. G. Simic served as consultant on GC and HPLC methods for proteins and sugars to J. Schubert, University of Maryland, College Park, Maryland.

66. M. G. Simic served as consultant on autoxidation to Prof. M. Karel, MIT, Cambridge, MA.

67. M. G. Simic was a member of the advisory panel to Prof. E.L. Powers on pulse radiolysis and radiation biology, University of Texas, Austin, TX.

68. M. G. Simic was consulted on protection from radiation by J. Biaglow, Case Western Reserve University, Cleveland, OH.

69. M. G. Simic was consulted by D. Davidson at Walter Reed Hospital, Washington, DC, on protection from radiation.

70. M. G. Simic was consulted by G. Bohn, Firestone, Ohio on radiation effects in polymers.

71. M. G. Simic was consulted by H. Krutch, at NIH, Bethesda, Maryland on separation of peptides.

JOURNAL EDITORSHIPS

Division 533, Radiation Physics

Martin J. Berger, Editor, Journal of Radiation Research (Japan).

Robert J. Celotta, Editor, Methods of Experimental Physics, Academic Press.

W.L. McLaughlin, Editor, International Journal of Applied Radiation and Isotopes.

W.L. McLaughlin, Editor, Radiation Physics and Chemistry.

H. M. Rosenstock, Member-Editorial Board, International J. Mass Spectrometry and Ion Physics.

TRIPS SPONSORED BY OTHERS

Division 533, Radiation Physics

S. R. Domen traveled to Ottawa, Canada to present a lecture on the present status and performance of the remodeled NBS absorbed-dose water calorimeter, sponsored by the National Research Council, October 1980.

S. R. Domen traveled to Boston to present an invited lecture at the Massachusetts General Hospital, November 1980.

S. R. Domen traveled to Madison, Wisconsin, to present an invited lecture at the Electron Dosimetry and Arc Therapy Symposium, University of Wisconsin, September 1981.

S. R. Domen traveled to Vienna and Budapest in October 1981 to consult on construction and operation of graphite calorimeters to be used as standards of absorbed dose.

D. L. Ederer traveled to the Laboratoire pour 'l Utilisation du Rayonnement (LURE) to collaborate with Francois Wuilleumier, who is a world recognized leader in the application of photoelectron spectroscopy to the study of excitation dynamics in the soft x-ray range. He also visited with Dr. West of Daresbury Laboratory, England and Dr. K. Codling at Reading University, England. September 1979 - October 1980.

R. Loevinger gave an invited lecture at an IAEA Symposium on Biomedical Dosimetry: Physical Aspects, Instrumentation, Calibration. Paris, October 27-31, 1980.

R. Loevinger participated in a meeting of the Medical Internal Radiation Dose Committee of the Society of Nuclear Medicine. Chicago, May 7-8, 1981; and New York, August 27-28, 1981.

R. Loevinger served as a consultant to the Dosimetry Section of the IAEA, Vienna, June 10-12, 1981; and served as a consultant to the Dosimetry Department of the Hungarian National Standards Laboratory. Budapest, June 15-18, 1981.

R. P. Madden traveled to the John Strong Symposium, University of Mass. to give a lecture and attend an AIP Governing Board Meeting. March 1981.

W. L. McLaughlin, as editor of book being published, Pergamon Press Ltd., Oxford, England, to discuss progress and planning of book.

W. L. McLaughlin, consultation as Chairman of IAEA Advisory Group to write synopsis of meeting and plan further international radiation dosimetry, Vienna, Austria, November 17-21, 1980.

Division 533, Trips Sponsored by Others (cont'd.)

W. L. McLaughlin gave invited lectures on chemical and radiation dosimetry at University of Mexico, Institute of Physics, Mexico City, Mexico, December 8-12, 1980.

W. L. McLaughlin assisted Egyptians in Cairo, Egypt in setting up dosimetry program in their new 1.5 MeV electron beam industrial facility, March 12-27, 1981.

W. L. McLaughlin attended dosimetry meeting at Sandia Laboratories, Kirkland Air Force Base, Albuquerque, NM, April 22-24, 1981.

D. R. Penn presented two talks on synchrotron photoemission experiments at Laboratorie pour L'Utilisation du Rayonnement Electromagnetique (LURE), Paris, France, and discussed in detail the ongoing activities of LURE of importance to our program in Electron and Radiation Physics, March 21 - April 4, 1981.

R. C. Placious, Cleveland X-Ray Inspection Company, Cleveland, OH, invited lecture entitled "Radiographic Standards for Pipeline Weld Inspection", November 1980.

R. C. Placious travelled to American Science and Engineering Corp., Boston, MA, to serve as x-ray consultant for the FAA on a new automated x-ray baggage inspection system, May 1981.

W. T. Rogers visited Joint Institute for Laboratory Astrophysics, Boulder, Colorado, February 2-9, 1981, for professional collaboration with Dr. Gordon H. Dunn, sponsored by University of Colorado.

CALIBRATION SERVICES PERFORMED

Division 533, Radiation Physics Division

Type of Service	Customer	SP 250	Number of Calib'ns or Tests	Income
Calibration of x-ray and γ-ray measuring instruments	1 Calibration labs 2 Hospitals 3 Nuclear energy establishments 4 Industry 5 US Gov't labs 6 DoD labs	*8.3B,C, H,I	**135	$69K
Irradiation of TL dosimeters	2,3,4,5,6	*8.3M,N	** 25	
Calibration of γ-ray sources	2,3,4	*8.4E,F	** 18	$ 8K
Calibration of β-particle sources	2,4,5,6	*8.4K	** 15	
Chemical dosimetry measurement assurance service for electron beams	Hospitals	*8.5B,C	** 50	$17K
Calibration of x-ray and γ-ray measuring instruments	Army, Navy	*N.A.	** 20	$15K
Radiation MQA service for calibration labs	DoD & AAPM calbration labs	*N.A.	** 30	$25K
Far Ultraviolet radiometric transfer standard detectors	1,3,4,5,6 plus Universities, and Foreign gov'ts	***N.A.	23	$25K
Totals			318	$134K

* Column 4: 8.3 & 8.4, numbered reports of the Dosimetry Group; 8.5, individual hospitals; N.A., estimates comparable with 8.3 to 8.4.

** Column 5: 8.3, 8.4, & 8.5, computer print-out, extrapolated to end of FY 81; N.A., estimates comparable to 8.3, 8.4, 8.5.

***Photodiode calibrations.

TECHNICAL ACTIVITIES

Division 534, Radiometric Physics

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.

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 (H. J. Kostkowski/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:

Division 534, Technical Activities (cont'd)

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 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.

The Division program is continuously monitored and reviewed to ascertain trends and update activities. For example, a survey of our calibration services in FY's 1978 through 1980 indicated two important trends:

- Almost one-half of the calibration load now occurs in the area of spectroradiometry. This reflects a growing emphasis throughout the radiometric community on obtaining spectral information as the most reliable method of characterizing modern sources and detectors. We expect this trend to continue, and will respond by strengthening our spectroradiometric research. In addition to improving traditional techniques by controlling polarization, partial coherence, and similar limiting factors, we hope to examine the potential of entirely new approaches. One of these is Fourier transform spectroscopy, a technique used extensively in analytical spectrometry but not yet adopted in radiometry.

- Independent calibration laboratories and optical instrument manufacturers have surpassed the lighting and photographic industries as our second most customer (defense and aerospace communities remaining the foremost constituent). This shows that the Division's broad approach to the solution of radiometric problems has been successful. Some years ago the decision was made, not to provide standards for every feasible type of radiometric measurement, but to concentrate on a relatively small number of stable incandescent lamps for spectroradiometric calibrations. Thus the burden of providing transfer standards for the lighting industry has been shifted, to a substantial degree, from NBS to independent and corporate calibration laboratories. Since instrument manufacturers and the detector industry have traditionally depended less on standards from

NBS, and since commercial spectroradiometers and calibrated detectors now offer the advantage of simplified calibration methods, we expect that secondary calibration laboratories will play a still greater role in disseminating NBS standards in the future.

In addition to the requirements of our traditional constituents, the rapid growth of electro-optic technologies poses new radiometric problems. National needs, such as defense, energy issues, and radiation safety concerns, also create new measurement challenges. We are currently assessing all of these needs and will submit an FY 1984 budget initiative to obtain Congressionally appropriated funds for implementing the required new programs.

Overall, FY 1981 has been a year of consolidation, review and planning for the future. Reductions in staff and restrictions on hiring have made it impossible to reach all planned goals. Nonetheless, the work of the Four Groups, as described in the following Technical Reports, has been productive. In addition to the research accomplishments evidenced by publications and talks, calibration volume increased to $160K in FY 1981 and sales of spectrophotometric SRM's through July 1981 stood at $92K.

Division 534, Technical Activities (cont'd.)

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

Spectroradiometric and pyrometric scales are usually maintained on tungsten lamps. Instability in these lamps has been the second major limitation in the uncertainty of these standards (temperature being the first). We performed some preliminary research a few years ago utilizing silicon detectors to monitor these lamps and correct for any instabilities--typically a long-term drift or a change on relighting the lamp. Though the results were very promising, the lack of staff and the urgency of other problems prevented this research from being pursued to completion. If we are to be successful in significantly improving spectroradiometric source standards, lamps with greater stability are required. We have constructed this year a simple radiometer utilizing a silicon detector to monitor tungsten lamp standards in order to correct them for any observed instabilities. Preliminary results with this instrument suggest that lamp control in the neighborhood of 0.02 percent in radiance reproducibility will probably be achievable.

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 automated NBS pyrometer now being developed. This instrument includes micrometer adjustable tungsten strip lamp mounts, temperature-controlled lamp bases, a state-of-the-art current measuring

system, a double monochromator and a microcomputer for control and on-line computations. The improvement in accuracy of the instrument stems primarily from the following: improved and more frequent spectral pass-band determinations due to the availability of our CW dye laser spectroradiometer characterization facility, rapid (15 minutes) flux responsivity measurements (i.e., determination of departures from linearity) using an automated beam conjoiner, and reliance upon short-term photomultiplier stability and long-term silicon photodiode stability instead of lamp stability for carrying the scale between scale realizations. We hope it will be possible to perform a new IPTS realization utilizing the new instrument in a short enough time (30 minutes) so that whenever optimum accuracy is required a new scale may be realized just before a temperature measurement is performed. In this way the effects due to lamp and other component change will be reduced significantly. All major components of this instrument were received and tested this year and we expect that the completed instrument will be undergoing testing by the end of FY 82.

During FY 81 we have begun a long-overdue modernization of the pyrometry calibration laboratory with the purchase of solid state replacement power supplies, amplifier, and strip chart recorder, and with the introduction of some remote control capability. This modernization should be complete early in FY 82.

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 already 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. The past year has seen drafts of chapters on coherence and on solar ultraviolet irradiance measurements completed. It is expected that both chapters will be published early in FY 82. Further plans for FY 82 include the preparation by the spectroradiometry group of a long-postponed chapter on linearity and, probably, participating in writing a chapter on the time variable in radiometry. These 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. For the past several years the EPA has generously funded research directed toward accurate ground level solar irradiance measurements in the 285-340 nm spectral region. The experience gained in this work forms the basis for the SSM chapter mentioned above and the details of the measurements taken using the newly developed technique and instrument are being readied for publication as an NBS Tech Note and, in a shortened version, as a journal publication. This measurement capability, generating the most accurate measurements ever in this region of the solar spectrum, promises to provide improved means of determining the atmospheric ozone concentration and is of direct interest to photobiologists because of the harmful effects of this component of sunlight on life forms. An essential element of this solar UV work was the establishment of a spectroradiometer characterization facility which contains a tunable dye laser with a frequency doubling capability for UV work. In this facility we can determine spectrometer slit-scattering functions with precision and ease and over a range which we could not previously hope to cover. This facility has not lived up to the contractor's promised power levels in the UV, but we are attempting to improve its performance in this region by substituting a ring dye laser for the standing-wave dye laser supplied with the original system. In the meantime the facility has been used for the complete characterization for the EPA of a spectroradiometer, i.e., determining its slit-scattering function, wavelength accuracy, and absolute signal output calibration including linearity. In the coming years we expect this important facility to be heavily used in the characterization of new spectroradiometric instruments and for monitoring the behavior of existing instruments.

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 to be commenced late this year or early next is the evaluation of a new automated laboratory spectroradiometer designed for BRH. The evaluation will be similar to that described above for the EPA instrument.

During the past year we have been assembling an automated spectroradiometer for the CCG. This is a portable, computer driven double monochromator complete with keyboard and disk drive. The goal is to produce a well-documented, thoroughly characterized spectroradiometer

which can be used by the armed services in their measurement assurance programs. The work remaining is to characterize the radiometer--measure the slit-scattering function, wavelength accuracy, and linearity--and to improve the computer program documentation.

Our facility for calibrating 200 K - 400 K blackbodies in a space-like environment (20 K and high vacuum) is continuing to be used a few months each year for performing special calibrations for DoD. This facility uses an electrically calibrated blackbody detector operating below the Lambda point of helium with germanium resistance thermometers for temperature sensing. There is no other facility like it in the USA.

SPECTROPHOTOMETRY AND MAP

The objectives of this group are:

(1) to establish and improve high accuracy spectrophotometric and densitometric scales in the National Measurement System by developing new instrumentation, establish new measurement capabilities and improving basic standards,

(2) to disseminate 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) to study and develop new methods for radiometric characterization of optical media and components for scientific research and for emerging technologies.

The achievements during FY81 are reviewed in the areas of retroreflection, diffuse reflection, and specular reflection, bidirectional reflection, transmission, and densitometry.

Retroreflection

The package for the MAP consists of high and low intensity bead sheeting retroreflectors, a prismatic retroreflector, and seven colored glass filters. The glass filters have been measured using the high accuracy reference spectrophotometer. The luminous transmittances have been calculated from the spectral transmittances using CIE Illuminant A and CIE $V(\lambda)$, and can be used to check the combined spectral distribution of source and responsivity of the receiver. Computer simulations have been done. The results show that if a color correction filter is not carefully chosen, large errors may result.

The effect of the size of source and detector apertures on high and low intensity bead sheeting have been studied. The effect of changing of angles of incidence and observation on high and low intensity bead sheeting have been measured and the data have been analyzed for significant coefficients.

The effect of changing of the angle of incidence, two angles of observation and the angle of rotation of the sample (on its own axis) on the prismatic retroreflector is being studied using the one-third factorial experimental design which requires 54 runs with nine measurements in each run.

The status of the retroreflection measurement assurance program at NBS, including some investigations on proposed standards has been reported at the International Conference on Optical Radiation Measurement

of Fluorescent and Retroreflective Materials at Bloomington, Minnesota on June 18, 1981.

The staff has been consulted on the design and construction of retroreflectometer and measurement method by the Avery International.

Diffuse Reflection

An international intercomparison of the absolute diffuse reflectance scales has been conducted among our group, NRC, Ottawa (Canada), and PTB, Braunschweig (FRG). The results have showed that the reflectance factors of the three measurement geometries used at the three laboratories agree to within ±0.1% for the near 100% reflectance for the wavelength range of 500 nm to 800 nm.

The important 6°-hemispherical, directional-hemispherical, and bidirectional reflection properties of pressed polytetrafluorethylene powder have been investigated in the wavelength range of 200 nm to 2500 nm and the results have been published in the Journal of the Optical Society of America.

The 45°/normal reflectometer has been characterized for calibrating the absolute reflectance factor of diffuse samples over the 380-770 nm spectral range using polarization radiation and the details will be published in Metrologia, September issue.

The diffuse reflectance MAP package consists of one didymium glass filter for checking wavelength accuracy, and one set of neutral density filters and one set of reflectors for checking linearity accuracy. The reflectors have been calibrated in the visible spectral region. The neutral density filters were first surveyed on the transfer transmittance instrument to determine at which wavelengths the transmittance would be least effected by the spectral passbands. Three sets of neutral density filters have been measured on the high accuracy transmittance instrument with narrow passband. Transmittances have been computed for various passbands.

This group has developed white and black diffuse reflectance standards (SRM's 2019-2022) for calibrating reflectometers used in evaluating solar properties of solar energy materials for the wavelength range of 250 nm to 2500 nm.

Specular Reflection

For the solar specular reflectance standards, second surface specular reflectance standards (SRM 2023) similar in construction to that of the heliostat mirrors, have been calibrated and certified. Each standard consists of one thin fused quartz front plate with a vacuum deposited aluminum coating on its back. A thin protective layer of S_iO is evaporated over the aluminum. Another thin quartz plate is then

bound on to serve as the base plate. The total sample thickness is about 5 mm. The first surface specular reflectance standards (SRM 2003a) for calibrating specular reflectometers have been calibrated and certified. Both the first and second surface specular reflectance standards were calibrated for the wavelength range of 250 nm to 2500 nm.

Bidirectional Reflection

A survey of the bidirectional reflectance distribution function measurement methods has been performed and the overview has been presented at the minisymposium on standards for the specification of optical surface finish. The minisymposium was sponsored by ASTM subcommittee F-1.02 on lasers.

The staff has been consulted on bidirectional reflectance measurement methods and available data by the Center for Manufacturing Engineering. These informations are needed for distance judging by a robot sensor.

Transmission

This group participated in the international comparison on transmission filter measurements in May. The data are still being analyzed. This international comparison was handled by the National Office of Measures at Budapest and under the sponsorship of CIE Technical Committee TC-2.3 on Materials.

The wavelength range of the high accuracy spectrophotometer for transmittance is being extended from 800 nm to 2500 nm. The electronics as well as the automation and data acquisition equipment have been received and integration of these equipment into the high accuracy spectrophotometer has begun. Design and construction of an averaging sphere has been completed. It was coated with polytetrofluoroethylene powder and a PbS cell has been attached and is ready for testing.

The staff has performed measurements for the Center for Analytical Chemistry to help investigate the polarization problem of metal-on-quartz filters, to study methods for stray light determination and to verify photometric scales on high transmitting fused quartz filters.

The staff has been consulted on high accuracy measurement method and design of spectrophotometers by Hoya and Barr Associate Inc.

Densitometry

Optical transmission density SRM's are produced for the photographic, printing, and non-destructive testing industries. These are comprised of x-ray film step tablets (SRM 1001), photographic step tablets (SRM 1008), and microcopy resolution test charts (SRM 1010a).

Division 534, Technical Activities (cont'd.)

This year this group has developed the reflection step tablet standard reference material (SRM 2061) for calibrating reflection densitometers used in photographic applications requiring color balance or separation. The calibrated reflection step tablet has 12 steps that cover the optical density range from 0 to 2 on gray scale paper from white to black. The reflection density scale was transferred from the reference 45°/normal reflectometer developed by this group. The total SRM sales including didymium filters for wavelength calibration this fiscal year is $92K.

ELECTRO-OPTICAL AND QUANTUM RADIOMETRY

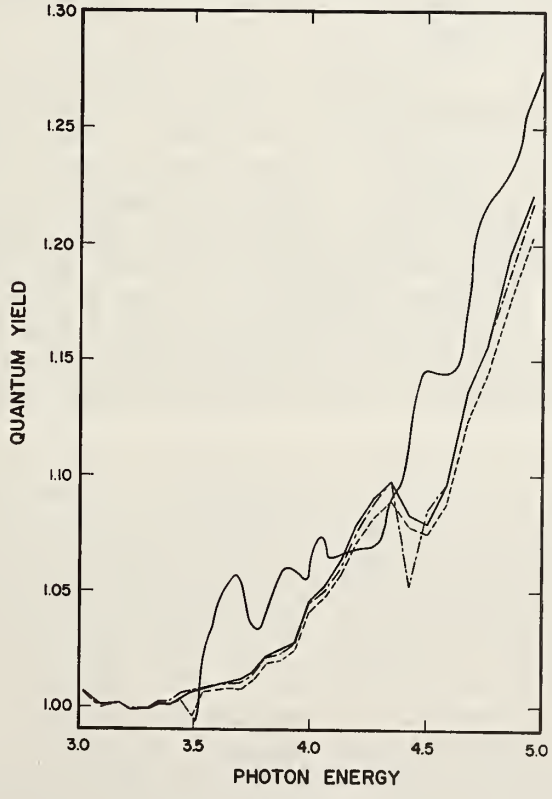
The Electro-Optics Group is responsible for 1) providing a more fundamental basis for photophysical process characterization in the National Measurement System, 2) developing new electro-optical technology for radiometric applications, and 3) developing a new conceptual basis for radiometric calibration. The major part of the total Group effort this year was devoted to studies of silicon junction diode physics as a basis for accurate radiometry. However, a doubling of the Group's size during the year with support from the Quantum Radiometry competence building program expansion, made it possible to vigorously pursue these studies without sacrificing other important Group programs.

Silicon Junction Photodiode Physics:

In collaboration with members of the Optics Section of Australia's CSIRO Division of Applied Physics, Jon Geist studied various replacements for the water drop electrode used in photodiode self calibration. The alternate approaches included condensing water from a saturated air flow, a tin oxide electrode, and a corona discharge to the diode surface. Only the latter technique offered significant advantages over the water drop. The most important disadvantage of the water drop as an electrode is that repeated application and removal create a dirt film on the diode surface that reduces its optical quality and increases the uncertainty in the diode reflectance measurements. No similar effect on the optical properties of the oxide was observed following repeated charging and discharging of the oxide surface with a corona discharge. This advantage is important enough that the corona technique was used instead of the water drop in monochromator based measurements of the uv quantum yield of silicon that were also made in Australia. The results, which are shown in fig. 1, have not been completely interpreted, nor have all radiometric corrections been applied. The differences from detector to detector that are evident in fig. 1 are not yet understood. If they represent fundamental variations in material properties from device to device, then they would present a severe limit to the accuracy achievable in the uv with photo-diode self-calibration, and could reduce our interest in pursuing this research direction in the uv. However, if the differences represent a defect in the diodes or an as yet undiscovered systematic error in radiometry, then there would still be considerable potential for self-calibration to have a very important impact on the accuracy and ease of uv radiometry. Even if these results turn out to be of little use to radiometry, they are of considerable use for comparison with theoretical calculations of the uv quantum yield of silicon. Also shown in Fig. 1 is our synthesis of recent theoretical results of Alig, Bloom and Struck at high photon energy based upon the free particle band structure, and earlier, low energy calculations of Antoncik and Gaur based on the band structure of silicon, including corrections to the latter by us. Some earlier measurements by Ed Zalewski and Li Tong Bao using our laser based facility are also shown in the figure. While, the quantitative agreement between the three data sets is not good at the

Figure Caption

Fig. 1 A comparison of a calculation of the near ultra-violet quantum yield for electron-hole pair production in silicon (upper curve) with measurements on three different detectors (lower solid and dashed lines). One bad data point is evident on each of the dashed curves. Most of the features on the calculation are artifacts; a recalculation is needed. The prominent feature on the measured curves near 4.5 eV is also likely to be an artifact associated with errors in the reflectance measurements.



one percent level, there are some tantalizing correlations in the details of the features of the two spectra, and the agreement is much better then previously reported due to improvements in both the theoretical and the experimental results.

Warren Gladden and Ed Zalewski completed a study of the angular dependence of the quantum efficiency of silicon photodiodes that was prompted by a recent letter in the Journal of the Optical Society (JOSA) claiming that variations in external quantum efficiency as a function of angle do not scale with diode absorptance. The study included the type of diode that was the subject of the study reported in JOSA and the type of diode usually employed in our research. A theoretical model of the angular dependence of the quantum yield based on the rise in collection efficiency from the diode's oxide/silicon interface to the depletion region was also derived. Our experimental results did not confirm those reported in JOSA, but did agree quite well with the prediction of a very small effect derived from the theoretical model. We discovered two possible sources of error that might explain the results in the JOSA letter, (multiple reflections at the window and nonlinearity), but personal communication with one of the authors of the letter seems to rule them out.

Joel Fowler has started a study of noise in our photodiodes and operational amplifiers from the point of view of the electronics engineer. He also guided Gyorgy Eppeldauer, a guest worker from the Hungarian Academy of Sciences, Institute of Physics in Budapest in the design of a higher gain detector head for the Detector Response Transfer and Intercomparison Package (DRIP). Julius Cohen has also started a study of noise in photodiodes, but from the point of view of the fundamental physics. As a result of these programs we hope at least to understand in great detail the causes of the current limitations on photodiode signal to noise, and hopefully, what can be done to improve it.

Russ Schaefer has continued to prepare for the intercomparison between photodiode self-calibration and electron counting on the NBS SURF II synchrotron facility. On the negative side, we have not been able to develop a computer implemented algorithm that can unambiguously identify an electron loss event even though human observers can easily do this from the graphical records. For this reason, and because it takes so long to lose 10^4 electrons from the ring at a rate low enough to identify each loss event, we no longer plan to count 10^4 electrons. The current plan is to count a few hundred electrons at 3×10^4, 10^4, 3×10^3, 10^3 and 300 electrons and to compare the step size at the different electron numbers. Since we can independently verify photodiode linearity with the ac/dc flux superposition technique that we developed previously, this approach is viable. If we were to find a systematic change in step size with electron number, it would bring into question the applicability of the Schwinger theory of single electron synchrotron radiation to multi-electron radiation. However, very careful study of all aspects of the linearity question would be necessary before this possibility could be addressed.

An absolute spectral response calibration based on a photodiode self-calibration was carried out on a photodiode filtered with the 600 nm interference filter that was used in the 1976 feasibility study. An absolute accuracy of ± 0.3% was indicated, and numerous possible improvements in experimental design were apparent. A new dye laser configuration is being set up to allow higher wavelength accuracy, and positioning stages to allow more convenient comparison between the filtered photodiode and the self-calibrated reference photodiode have been built and set up. However, it is proving difficult to obtain interference filters of quality equal to that of the 600 nm interference filter left over from the feasibility study.

Other Electro-Optics Group Activities:

During the last year, Ed Zalewski and Bob Booker both made reflectance measurements in support of electrical substitution cavity radiometer characterizations. Zalewski measured the reflectance characteristics of a mock-up of the NPL electrically calibrated cryogenic cavity radiometer with which he had compared the NBS silicon self-calibration capability last year. The purpose of the measurement was to better characterize errors associated with the cavity reflectance loss for new high accuracy measurement of the Stefan-Boltzmann radiation constant by Terry Quinn (BIPM) and John Martin (NPL). They reported on these measurements at the recent NBS sponsored Conference on Precision Measurements and Fundamental Constants.

Bob Booker measured the reflectance distribution from 180 nm to 220 nm of a black paint used in sattelite borne cavity radiometers. The purpose was to verify that the paint is as specular and absorptive at these short wavelengths as it is in the visible where it has been characterized previously. These measurements were performed at the request of solar physicists who wanted to know whether or not current satellite borne solar constant experiments were sensitive to the radiation in solar flares.

Joel Fowler has designed a microcomputer based control system for the electrically calibrated pyroelectric radiometer, and Pat Tobin, under Fowler's supervision, has done the board layout for modules that will plug into the S-100 bus of our Cromemco microcomputer system in the same way our experimental interface boards do. This prototype system will be used to test the practicality of microcomputer control for this type of instrument.

Also during this year, Miguel Tufino, a guest worker from the National Polytechnical Institute in Mexico City, used the Silicon self-calibration procedure to determine the radiant power to electrical power calibration factor of our electrically calibrated pyroelectric radiometer. He checked its linearity by comparison with a silicon photodiode, and then used it with a monochromator based detector comparator to calibrate the spectral response of silicon photodiodes over the 350 to 980 nm spectral region.

Comparison with previous spectral response measurements using cw laser radiation and our thermopile electrically calibrated radiometer showed agreement to better than 1%.

Finally, Ed Zalewski, with substantial assistance from Warren Gladden, continued to do absolute spectral response measurements in support of the detector calibration program.

Division 534, Technical Activities (cont'd.)

PHOTOMETRIC-RADIOMETRIC CALIBRATIONS AND MAP

The objective of this group is to provide 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.

Much of the group's activity in the past year has been devoted to the calibration program. Calibration volume increased to $160 K in billings (up from $125 K in FY-80). Early in the year the NBS Director, Dr. Ambler, expressed concern that the NBS calibration programs should continue to be first rate and progress with the times. This concern led to the establishment of several review committees culminating in the permanent formation of the NBS Calibration Advisory Group. Extensive interaction with these committees led to an internal review of the Division's calibration programs. As a result of this review, plans have been formulated to upgrade the existing documentation and to implement new technology in an orderly manner. An immediate positive result of the Director's interest was the allocation of $50 K of general purpose equipment money to replace aging and obsolescent instruments presently used for routine calibrations. Procurement of this equipment has been completed and integration of the new equipment has begun.

Several projects were finished by completing experiments begun in previous years. NBS completed measurements for the second half of the international intercomparison of luminous intensity measurements sponsored by the National Physical Laboratory (Great Britain). The three lamps involved in this intercomparison have now made two trips around the world and results of the intercomparison are expected early next year. The luminous flux calibrations (approximately 200 lamps for 15 customers) performed to implement the international redefinition of the photometric units were completed and reports have been issued. The Detector Response Intercomparison Program (DRIP) has been established on a routine basis. The four rental packages are now issued to customers quarterly and at present the backlog is six months.

Every year, this group undertakes a limited number of special, ad hoc calibrations to support research activities in other divisions of NBS and/or the optical radiation community in general. In the past year three sun lamps of two different types were evaluated for the Bureau of Radiological Health to determine their ultraviolet emission and hence their potential health hazard. Two self-luminous sources (tritium activated phosphor luminance standards) were calibrated for the U.S. Army. These sources are used to provide the measurement base for radioluminescent source procurement in the U.S. Measurement uniformity in plant growth chambers was supported through NBS calibration of two quantum-flat silicon cell radiometers. These radiometers are being circulated among ten university and government laboratories to insure uniform optical radiation measurements in the plant biology community.

Looking to the future, several efforts were initiated. Phototopically corrected silicon cells have been procured and experiments planned to assess their potential as photometric transfer standards. Proposals to initiate a new program to calibrate spectrally rich sources, such as metal-halide lamps, were prepared and presented to management. Finally, plans were initiated to revamp the pyrometric lamp calibrations by transferring the measurements to the automated spectroradiometer used for spectral irradiance and spectral radiance calibrations.

SPONSORED CONFERENCES

Division 534, Radiometric Physics

UV-B Irradiation Experiments International Workshop, jointly sponsored by NBS-EPA, NBS Gaithersburg, April 6-8, 1981.

INVITED TALKS

Division 534, Radiometric Physics

K. L. Eckerle (co-author J. J. Hsia), "Status of the Retroreflection Measurement Assurance Program at NBS, Including Some Investigation on Proposed Standards", International Conference on Optical Radiation Measurement of Fluorescent and Retroreflective Materials, Bloomington, Minnesota, June 18, 1981.

J. Geist, "Modern Developments in Radiometry of Interest to Meteorology and Climatology", Symposium, Fifth International Comparison of Pyrheliometers, Physikalisch-Meteorologisches Observatorium, Davos, Switzerland, October 5, 1980.

J. Geist, "Silicon Device Physics: The p-n Junction as a Radiometric Standard", Central Research Laboratory Colloquium, Landis and Gyr A.G., Zug, Switzerland, October 9, 1980.

J. Geist, "The Physics of the p-n Junction in Silicon as an Absolute Radiometric Standard", Optics Division Colloquia, Physikalish-Technische Bundesanstalt, Braunsweig, West Germany, October 13, 1980.

J. Geist, "Review of Flight Instrumentation for Solar Constant Measurements", Workshop on Variations of the Solar Constant, NASA Goddard Space Flight Center, Greenbelt, MD, November 5, 1980

J. Geist, "The Physical Basis of the Self-Calibration of Silicon Photodiodes", Electro-Optics/Laser 80 Conference and Exposition, Boston, Nov. 20, 1980.

J. Geist, "Physics of Silicon Photovoltaic Junction Diodes in Short Circuit Operation", Division Colloquium, CSIRO Div. of Appl. Phys., West Lindfield, NSW, Australia, May 28, 1981.

J. Geist, "Blackbody Theory", Radiometry Group Informal Colloquium, CSIRO Div. of Appl. Phys. West Lindfield, NSW, Australia, June 16, 1981.

J. Geist, "Review of p-n Junction Physics Research at the U.S. National Bureau of Standards", Sydney Area Solid State Colloquium Series, University of New South Wales, Sydney, NSW, Australia, July 7, 1981.

J. Geist, "Quantum Efficiency of p-n Junctions in Silicon Photodiodes", Symposium on the Optical and Electronic Properties of Insulators and Semi-conductors, Hotel Hacienda Cocoyoc, Morelos, Mexico, August 4, 1981.

Division 534. Invited Talks (cont'd.)

J. J. Hsia, "Bidirectional Reflectance Distribution Function Measurements Methods", ASTM Committee FL.02 Minisymposium on Standards for Specifying the Surface Finish on Optical Components, NBS, Gaithersburg, MD, June 9, 1981.

H. J. Kostkowski, "New State-of-the-Art Instruments and Techniques for Solar Terrestrial Spectroradiometry below 300 nm", Meeting of the American Society for Photobiology, Williamsburg, Virgina, June 15, 1981.

A. R. Schaefer, "Recent NBS Research in Heavy Doping Effects", Workshop on Heavy Doping Effects in Silicon Devices, Dept. of Electrical Engineering, University of Florida, Gainesville, FL, May 9, 1981.

E. F. Zalewski, A. R. Schaefer and J. Geist, "Absolute Radiometric Standards based on the Physics of Silicon Photodiodes", Annual Meeting, Optical Society of America, Chicago, IL, October 17, 1980.

E. F. Zalewski, "Description and Verification of the Silicon Photodiode Self-Calibration Procedure", Electro-Optics/Laser 80 Conference and Exposition, Boston, November 20, 1980.

E. F. Zalewski and M. Tufino-Velazquez, "Silicon Photodiode Self-Calibration as a Basis for Radiometry in the Infrared", 25th Annual International Technical Symposium and Exhibit, Society of Photo-Optical Instrumentation Engineers, San Diego, August 25, 1981.

PUBLICATIONS

Division 534, Radiometric Physics

Baltes, H. P. and Geist, J., "Kirchhoff's and Planck's Radiation Laws for Small Particles", J. Quant. Spect. and Rad. Trans. (accepted for publication).

Booker, R. L., "Luminance-brightness Comparisons of Separated Circular Stimuli", J. Opt. Soc. Am., 71, 139 (1981).

Demas, J. N., Bowman, W. D., Zalewski, E. F. and Velapoldi, R. A., "Determination of the Quantum Yield of the Ferrioxalate Actinometer with Electrically Calibrated Radiometers", J. Phys. Chem. (accepted for publication).

Geist, J., Zalewski, E. F. and Schaefer, A. R.., "Spectral Response Self-calibration and Interpolation of Silicon Photodiodes", Appl. Opt. 19, 3795 (1980).

Geist, J. and Lowney, J. R., "Effect of Band-gap Narrowing Phenomena on the Built-in Field in n-type Silicon", J. Appl. Phys. 52, 1121 (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. (accepted for publication).

Hsia, J. J. and Weidner, V. R., "Reflectance Properties of Pressed Tetrafluoroethylene Powder", Laser & Electro-Optik, No. 1, 14-15 (1981).

Hsia, J. J. and Weidner, V. R., "NBS 45°/Normal Reflectometer for Absolute Reflectance Factors", accepted for publication in Metrologia (September 1981).

Keller, R. A. and Zalewski, E. F., "Noise Considerations, Signal Magnitudes and Detection Limits in a Hollow Cathode Discharge by Opto-galvanic Spectroscopy", Appl. Opt. 19, 3301 (1980).

Richmond, J. C., Hsia, J. J., Weidner, V. R., and Liggett, W. C. Jr., "Standards Reference Materials: Preparation and Calibration of Standards of Absolute Directional-Hemispherical Reflectance Factor", to be published in Nat. Bur. Stand. (U.S.) SP-260 series.

Schaefer, A. Russell, "Measurement of Synchrotron Radiation from the NBS SURF II Using a Silicon Radiometer", Nucl. Inst. and Meth. 172, 89 (1980)

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.

Division 534. Publications (cont'd)

Weidner, V. R. and Hsia, J. J., "Reflection Properties of Pressed Polytetrafluoroethylene Powder", J. Opt. Soc. Am. 71 (7), 856 (July 1981).

Zalewski, E. F., Keller, R. A. and Apel, C. T., "Opto-galvanic Effect as a Detector for Intra-cavity Atomic Absorption in a cw Dye Laser", Appl. Opt. 20, 1584 (1981).

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).

Jack J. Hsia

Member, U.S. Panel of CIE TC-2.3 on Methods of Measuring Photometric Characteristics of Materials.

Member, ASTM E-37 Committee on Thermal Measurements.

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; E-12.01 Editorial and Terminology, E-12.02 Colorimetry and Spectrophotometry, E-12.03 Geometric Properties.

Delegate from ASTM to ISCC.

Representative, ANSI Committee PH2 on Sensitometry and Subcommittee PH2-28 on Densitometry.

Henry J. Kostkowski

Member, U.S. Panel of CIE TC-1.2 on Photometry and Radiometry.

Division 534, Technical Professional Committee Participation and Leadership (cont'd)

Henry J. Kostkowski

Alternate representative/delegate, ANSI Committee Z311 on Photobiological Safety of Lamps.

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

Member, ASTM E-13 on Molecular Spectroscopy.

Member, ASTM E-13.06 on Luminescence.

Member, U.S. Panel of CIE TC-2.3 on Properties of Materials.

Member, U.S. National Committee of the CIE.

Fred E. Nicodemus

Consultant, CIE TC-1.2 on Photometry and Radiometry.

Member, U.S. Panel of CIE TC-1.1 on Definitions and Vocabulary.

Member, U.S. National Committee of the CIE.

Technical Advisor, Joint Infrared Standards Working Group, Countermeasures Subgroup of the Joint Technical Coordination Group on Aircraft Survivability (DoD)

Robert D. Saunders

Member, IES Committee on Photobiology

Member, Illuminating Engineering Research Institute (IERI) Committee on Extra Visual Effects.

Division 534. Technical Professional Committee Participation and Leadership (cont'd)

A. Russell Schaefer

Member, U.S. Panel of CIE TC-2.2 on Detectors and Photometric Instruments.

John B. Shumaker

Member and U.S. Coordinator of U.S. Panel of CIE TC-2.3 on Polarization.

Jack L. Tech

Secretary, U.S. National Committee of the CIE.

Member, CIE International Executive Committee.

U.S. Member, Comite Consultatif de Photometrie et Radiometrie.

Member, U.S. Panel of CIE TC-1.2 on Photometry and Radiometry.

Member, International Astronomical Union Commission 14 (Fundamental Spectroscopic Data) and Commission 29 (Stellar Spectra).

U.S. Member, International Action Committee of the CIE.

Edward F. Zalewski

Chairman, U.S. Panel of CIE TC-2.2 on Detectors.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 534, Radiometric Physics

1. R. L. Booker and D. A. McSparron provided consultation and measurement assistance to W. J. Boettinger of the Metallurgy Division in making a low level luminance measurement of an x-ray phosphor. The measurement established the relationship between x-ray flux and phosphor luminance and will be used to specify equipment for x-ray studies of phase transformation and defect motion in alloy crystals.

2. R. L. Booker consulted with B. Schwartz of the Army Mobility Equipment Research and Development Command at Ft. Belvoir regarding the photometric measurement of low-level flashing mine-field lights.

3. K. L. Eckerle, consulted on design and construction of retroreflectometer for the Instrument Development Engineering Associates, Inc. (Mr. David L. Fridge, President) and Avery International (Dr. Karl Josephy).

4. K. L. Eckerle, consulted on design and construction of transmittance spectrophotometers for the Barr Association, Inc., Concord, Massachusetts.

5. J. J. Hsia and V. R. Weidner, consulted on pressing technique of polytetrofluoroethylene powder and on method of measuring diffuse reflectance for the Labsphere Co., North Sutton, NH (Dr. Philip B. Lape and D. J. Lovell).

6. J. J. Hsia and V. R. Weidner, consulted on bidirectional reflectance measurement method and available data. Information is needed to help judge distances of an object by a robot sensor. This is for Dr. Robert Houser, Automation Sensors Group, Center for Manufacturing Engineering.

7. D. A. McSparron provided consultation to NASA (Goddard) and to the Aerospace Division of Ball Brothers (Prime Contractor) on the design, construction and calibration of a Solar Backscatter Ultraviolet Radiometer (SBUV) for use in the NASA/NOAA solar monitoring program.

8. D. A. McSparron consulted with Irving Sochard of Naval Security (White Oak) and Mr. Weinstein of the CIA on the use and measurement of phosphorescent paints for surveillance of high security areas.

Division 534. Major Consulting and Advisory Services (cont'd)

9. D. A. McSparron consulted with Frank Carlen of the Army Environmental Hygiene Agency on standards, instruments and measurements of ultraviolet optical radiation.

10. D. A. McSparron consulted with Mr. Rudy of RCA (Lancaster, Pennsylvania) on luminance measurements problems associated with characterizing color TV picture tubes.

11. D. A. McSparron consulted with Terry Smalley of the City of Oakland, on illuminance measurement problems associated with the acceptance testing of high pressure sodium and multi-vapor street lighting.

12. K. D. Mielenz and K. L. Eckerle, consulted on high accuracy transmittance measurement method for the Hoya Co.

13. F. E. Nicodemus, Division technical representative and technical consultant to NBS library.

14. C. H. Popenoe, Member of Microprocessor Subcommittee of the NBS Electronics Storeroom Committee.

TRIPS SPONSORED BY OTHERS

Division 534, Radiometric Physics

J. Geist, Return airfare to Europe, and per diem supplied by NOAA to support participation in the Fifth International Comparison of Pyrheliometers (and Absolute Radiometers) held under the auspices of the World Meteorological Organization at the Physikalisch-Meteorlogisches Observatorium, Davos, Switzerland, September 28 to October 7, 1980.

J. Geist, Train tickets from Davos to Zug to Zurich in Switzerland, and assistance in kind to support a trip to the Central Research Laboratory of Landis and Gyr, AG to present an invited paper, October 7 to October 11, 1980.

J. Geist, Train tickets from Zurich, Switzerland, to Braunsweig, West Germany, and assistance in kind to support trip to the Physikalisch-Technische Bundesanstalt to present an invited paper, October 11 to October 14, 1980.

J. Geist, Return airfare to Denver, and per diem supplied by the U.S. Solar Energy Research Institute through the NBS Electron Devices Division to support consultation on radiometric measurements for solar conversion, October 29 to October 31, 1980.

J. Geist, Return airfare to Sydney, Australia, and per diem supplied by the CSIRO, Division of Applied Physics to support guest worker status at the National Measurement Laboratory in West Lindfield, May 23 through July 23, 1981.

J. Geist, Return air tickets and assistance in kind to support trip to present invited paper at a symposium celebrating the 20th anniversary of the School of Physics and Mathematics of the Institute Politecnico Nacional, Mexico City, Mexico, August 2 to August 5, 1981.

H. J. Kostkowski, Trip sponsored by the American Society for Photobiology to present an invited paper at the annual meeting in Williamsburg, Virginia, June 14-17, 1981.

STANDARD REFERENCE MATERIALS

Division 534, Radiometric Physics

1. SRM 100k, 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.

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.

   SRM 2023, Second Surface Aluminum Mirror for Specular Reflectance Specular Reflectance from 250 to 2500 nm.

CALIBRATION SERVICES PERFORMED

Division 534, Radiometric Physics

Type of Service	Customer	SP 250	Number of Calib'ns or tests	Income
Pyrometry		7.4 A thru G	39	$27K
	Defense & Aerospace		13	$9K
	Instrument & Cal labs		8	$5K
	Lighting & Photography		7	$4K
	Foreign		2	$1K
	Electrical & Materials		9	$8K
Spectroradiometry		7.5 A thru H	61	$69K
	Defense & Aerospace		20	$28K
	Instrument & Cal labs		23	$20K
	Lighting & Photography		1	$1K
	Foreign		15	$16K
	Electrical & Materials		2	$4K
Photometry		7.6 A thru M & 7.7 B thru F	124	$47K
	Defense & Aerospace		22	$10K
	Instrument & Cal labs		47	$9K
	Lighting & Photography		31	$16K
	Foreign		15	$8K
	Electrical & Materials		9	$4K
Spectroradiometry		7.8 A thru I	120	
	Defense & Aerospace		20	$4K
	Instrument & Cal labs		41	$4K
	Lighting & Photography		23	$3K
	Foreign		10	$3K
	Electrical & Materials		26	$3K
			344	$160K

ACCELERATOR RESEARCH

Division 535, Radiation Source and Instrumentation

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 several high level committees charged with determining future needs and priorities of the national effort in nuclear physics.

An essential part of the program will be the design, construction and operation of a demonstration race-track 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 $6.2 million, in FY 1980 dollars, for the 4-1/2 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.

We are now two years into this project and it is proceeding on schedule and on budget. Major successes to date include the development (at Los Alamos) of a new type accelerating structure with remarkably high shunt impedance, and a novel design for the RTM end magnets that promise greatly improved field uniformity at reasonable cost. The injector system of the RTM is now being installed, with initial beam operation (at 5 MeV) expected in August 1982.

Linac Improvements

Matching focus solenoids were installed before Accelerator Section No. 1, between Accelerator Sections No. 1 & No. 2, and between Accelerator Sections No. 2 & No. 3. The solenoids have made a definite contribution to increasing beam current, but additional study time is needed to effectively evaluate the improvement. A new Injector Power Supply was installed to improve reliability, reduce downtime, and reduce the time to activate a new Electron Gun, which was demonstrated, as a rebuilt Model 12 Electron Gun was installed at the same time. New Quadrupole Power Supplies were installed to improve reliability and reduce downtime of the beam handling system. A large part of the Beam Monitoring T.V. System was replaced with new cameras and controllers to improve reliability. Finish of the installation of components for the R.F. Drive System was completed, controls checked, and a number of units checked for R.F. output. The part of the system for control of the Buncher Section of the Linac has been in use this fiscal year. Balance of units are being checked for R.F. output before the total system is put into operation.

Induction Accelerator Research and Intense Relativistic Electron Beam Propagation Studies

The unique, long pulse induction linear accelerator built at NBS as part of a DoD-sponsored feasibility study has been moved to NRL. NBS personnel are assisting in the installation at the new site. This high current accelerator will be used to support research into recirculation acceleration techniques as well as for Free Electron Laser Studies.

A final report on the work at NBS with the induction linac covering a feasibility study of the recirculating acceleration of high current electron beams using a charge-neutralizing gas transport system was issued in May of this year.

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. As an example, the 1981 U.S. National Particle Accelerator Conference was arranged by NBS personnel. S. Penner was Chairman of this highly successful conference which attracted over 750 participants from all over the world. Although our in-house research programs on DoD accelerator needs are being 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-1981 included programs in neutron cross section standards and radiography, high energy electron scattering, electron activation, photonuclear research, positron annihilation, 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. For all of this fiscal year, the technician staff was short by two people, putting a greater demand on the operating staff. 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, constructing, and installing mechanical components. Table I shows the distribution of the total Linac operations staffing time in the operation of the facility for FY-1981 (through August 21). The facility is staffed from 7:30 a.m. Monday morning and runs for experiments until 6:30 a.m. Saturday. Scheduled maintenance hours have varied throughout the year. The facility was shut down April 20th for the installation of the new Injector Power Supply, matching focus solenoids, new Quadrupole Power Supplies, and a rebuilt Model 12 Electron Gun, all to improve beam quality and reliability. The scheduled shut-down of five weeks was extended because of a fire which destroyed the Deflecting Magnet Power Supply and associated beam handling system wiring just prior to the scheduled shut-down. The facility was shut down again August 10th for two weeks in order to rebuild the shielding wall between the Magnet Room and Measurement Room 3 in preparation for the installation of the RTM.

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.

Division 535, Linac Operations (cont'd.)

The unscheduled maintenance of 664.5 hours, through August 21, is broken down and summarized by system in Table III. The large amount of unscheduled maintenance is due, in the main, to two factors: 1) the facility is old, having begun operation for experiments in 1965, and 2) the lack of resources, especially in FY-1981, both financial and personnel wise.

Plans for upgrading the Linac include:

1. Complete study and analysis of the Model 12 Electron Gun to improve its performance and learn to rebuild the gun to provide reliable performance. This benefits the neutron cross section program.

2. Continue improvement of MG Sets regulation - benefits all experimenters.

3. Continue the switch tube rebuild program - anticipated total cost savings of approximately $70,000. Four re-built tubes are presently in sockets, with one tube having over 5,750 high voltage hours.

4. Continue Driver tube rebuild program initiated late in FY-1981 to save money.

5. Complete installation of new air compressor system for vacuum valves. Benefit to all experimenters due to marginal operation and downtime.

6. Complete installation of new Activation Analysis facility in the drift section of the Linac. Will provide more efficient use of the Linac for this activity.

7. Complete the now totally funded installation of the new Beam Monitoring T.V. System. The system is now approximately 75% complete. Improves Linac set-up time and reduces downtime due to obsolete system.

TABLE I

LINAC OPERATIONS

FY 1981

	Scheduled Hrs.	Actual Hrs.	
Maintenance	401.5	401.5	
Unscheduled Maintenance	------	781.0	
Beam Time	3993.0	3100.0	
Set-Up*	188.0	225.5	(1)
Experimental Down-Time**	------	74.5	
Installation	324.5	324.5	
Total Hours***	4907.0	4907.0	

*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 35.0 hours of Operator Training.

TABLE II

LINAC OPERATIONS

FY 81

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	1010.0	681.5	66.0	191.5	71.0	24.2	22.0
Neutrons	1466.5	1160.0	60.0	245.0	1.5	35.1	37.4
Photonuclear Spectrometer	366.0	243.5	26.5	94.0	2.0	8.7	7.9
Activation Analysis	181.0	105.5	17.5	58.0	---	4.3	3.4
Linac	187.5	187.5	---	---	---	4.5	6.0
Positrons	876.5	680.0	51.5	145.0	---	21.0	21.9
Electron Activation	93.5	42.0	4.0	47.5	---	2.2	1.4

[1]Machine time assigned to experiment, includes scheduled setup time of 188.0 hours.
[2]Includes lock-up after scheduled maintenance.
[3]Includes 36.5 hours plant related unscheduled maintenance.
[4]Linac available for operation, but experiment either not ready or breaks down during scheduled run.

$$\text{EFFICIENCY} = \frac{3100 + 74.5 + 36.5}{4181.0 - 188.0} \times 100 = 80.4\% \text{ (Increase of 9.4\% over FY 80)}$$

TABLE III

LINAC OPERATIONS

FY 1981

LINAC: Total unscheduled maintenance 296.5 hours

System:

Modulators	164.0 hours	43.2%
R.F. Drive	46.5 hours	12.2%
Injector	61.0 hours	16.1%
Cooling	22.0 hours	5.8%
Vacuum	19.5 hours	5.1%
Trigger	17.0 hours	4.5%
Pre-Amplifiers	13.0 hours	3.4%

No other system or item over 3%

BHS: Total unscheduled maintenance 335.5 hours

System:

Collimator	144.0 hours	39.5%
Magnet P.S.'s	111.0 hours	30.5%
Vacuum	59.5 hours	16.3%
Slits	13.5 hours	3.7%
Magnets	12.0 hours	3.3%

No other system or item over 2%

Balance of total unscheduled maintenance, 36.5 hours, due to air conditioning (28.5 hours) and power outage (8 hours).

SURF OPERATIONS

Division 535, Radiation Source and Instrumentation

SURF-II is a dedicated synchrotron radiation facility, consisting of a 240 MeV electron synchrotron storage ring fed by a 10 MeV microtron. 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 principally the Radiation Physics Division (533) as well as other NBS divisions and outside users, in optical 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 support ten active experimental stations of which eight can run simultaneously. Three beamlines are especially active, with several research groups using them on a rotating basis. The new Optical Calibration Facility on beamline 2 has already been utilized by three outside user groups since its commissioning in February. Development of three additional beamlines is underway. During FY-81 SURF counted approximately 44 active users.

Beam intensity reached a new high this year. We achieved 47 mA of stored beam, exceeding last year's record of 40 mA. Routine currents, however, remain in the 10-20 mA range due to less than optimum microtron output.

Improved beam stability in the "fuzzed" mode has been demonstrated by use of a white noise source, instead of a sinusoidal oscillator, to enlarge the beam in the vertical dimension.

The project to upgrade SURF to 280 MeV is underway. The shutdown is scheduled from August 24 to October 23. Detailed measurements of magnet pole circularity and alignment will be made, as was done initially in 1975. At the same time the harmonic RF cavity will be installed in the ring vacuum chamber. Certain modifications will be made to the chamber to minimize internal light scattering. After reassembly, extensive magnetic measurements will be performed to develop the programming for the new correction coil power supplies. Acceleration of beam to 280 MeV will be attempted in November.

Division 535, SURF Operations (cont'd.)

This year's improved machine performance and operational statistics were due in large measure to the efforts of the two SURF Operators. Not shown in the statistics is the effort they contributed to direct support of users: maintenance of vacuum equipment, assistance in assembly and disassembly of users' hardware, etc. It is therefore most regrettable that the junior SURF operator was one of the casualties in the recent NBS reduction-in-force. In the face of the growing utilization of SURF and demand for beamtime, SURF should be expanding operations to two shifts. This possibility has now been precluded.

Operational statistics continue to show increasing beam time to users and low downtime. Actual beam hours to users averaged 156 hours per month for the past 12 months, topping last year's figure of 145 hours. Unscheduled downtime increased over last year, but was still only 5% of the total. The statistics are summarized in the table. Data for FY-79 and FY-80 are shown for comparison.

SURF Operations Statistics

	FY-79	FY-80	FY-81	% Change
Beam to users	1612 hours	1748 hours	1872 hours	+ 7%
Standby (beam available)	232	220	267	+ 21%
Studies & Maintenance	252	322	216*	- 33%
Unscheduled downtime	198	58	126	+117%
Total hours	2294	2348	2481	+ 6%

SURF Users During FY-81

533 Radiation Physics Division, Far UV Physics Group (R.P. Madden, Principal Scientist; D.L. Ederer, L.R. Hughey, A.C. Parr, E. Saloman, L.R. Canfield, N. Swanson)

520 Center for Absolute Physical Quantities (J. Cooper)

534 Radiometric Physics Division (R. Schaeffer)

541 Surface Sciences Division (T. Madey)

543 Chemical Thermodynamics Division (R. Stockbauer)

Division 535, SURF Operations (cont'd.)

Naval Research Lab (D. Nagel, R.T. Williams, M. Kabler, J.C. Rife, J.P. Kirkland, C.M. Brown, M. VanHoosier, D.L. Blizzard, C.M. Dozier, V. Bermudez, W.R. Hunter, Bruckner)

NASA Goddard (B. Guenther, D. Williams)

Argonne National Lab (J. Dehmer, E. Poliakoff)

Brookhaven National Lab (J. Sutherland, P. Keck, P.Z. Takacs, K. Griffin)

Los Alamos National Lab (K.B. Mitchell, N. Lemma)

California Institute of Technology (G.P. Garmire, N. Bobroff, M. Juda)

Johns Hopkins University (W. Hodge, R. Bell, J. Castracane, B. Stratton)

University of Colorado (G. Mount, G. Timothy, R. Jakoubek)

Guest Workers:

R.M. Catchings, Howard University

S. Donnelly, University of Notre Dame de la Paix, Belgium

A. Flodstrom, Linkoping University, Sweden

D.M. Hanson, SUNY Stony Brook

D. Holland, Reading University, England

A. Jahnke,* Technische University Munchen, W. Germany (arriving September 1981)

C. Mehlman, CNRS, France

F.P. Netzer, Innsbruck, Austria

H. Onuki, Japan

J. West, Daresbury Lab, England

*Sponsored by SURF Operations Group.

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 FY 81 number about 102 and maintenance has involved about 315 instruments. Increasing complexity of the instruments requires increasing amounts of highly-trained technicians time. More advanced support instrumentation is urgently needed for use in this maintenance.

Although the Center has almost doubled in size over the past few years due to internal reorganization, technicians support manpower has decreased. 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 Divisions of the Center for Radiation Research. Included are a new Thermoluminescence Dosimeter Heater/Reader Controller, High Voltage X-ray Shutter Timing and Controllers (used in CRR and at the Regional Calibration Centers elsewhere in the USA), vacuum bakeout controllers and many CAMAC interfaces including a stepper motor controller to the Harris computers. The 1 megaword mass memory for a Harris computer has finally been installed. This will particularly benefit neutron spectroscopy programs which generate vast amounts of data at high rates.

Instrumentation support in the form of consultation on digital control systems, microprocessor and related hardware, procurement of computer equipment, and preparation of specifications has been done in the past year for the NBS-Los Alamos Racetrack Microtron Accelerator project.

Instrumentation Support for Physics and Chemistry Projects

Consulting and systems instrumentation has been provided to scientists in programs in neutron physics, electron physics, surface electron physics, X-ray dosimetry, radiation chemistry, electronic physics, ion cyclotron resonances, vacuum ultraviolet physics (SURF). Apparatus currently under design and construction includes a special controller for a very low energy electron spectrometer (surface physics), mass memory

controller/interface, high-speed NIM modules, specialized analog signal-conditioning devices and various instruments for pulse detection, counting and processing.

An important and growing problem is the lack of adequate modern instrumentation to complement and support the efforts of the electronic instrumentation design engineering staff. Presently the Radiation Instrumentation Laboratory is ill-equipped to provide adequate support to the Center in the following areas; radio-frequency circuit characterization and system measurement, transient analysis and microelectronic and microcomputer applications and development. There is also a lack of CAMAC equipment and calibration equipment. Presently this lack of instrumentation is affecting the innovation, efficiency and productivity of the Instrumentation Group and the effects will be felt more in the future unless remedial action can be taken, particularly since there is presently a staff shortage, to compensate for the increased responsibilities from a large Center.

Continued consultation has been provided and continues to be provided (at a much reduced level) to projects originally associated with and supported by the NBS Office of Environmental Measurement. Continuing projects are in ozone standards measurements and gas-phase reaction studies. Work still continues on a current-controlled arc for spark emission spectroscopy. Flat-topped 90 ampere, 100 μsecond arcs at a repetition rate of 200-400 cps can be maintained. One staff member (J.K. Whittaker) continues to supervise a graduate student in a joint project with the Chemistry Department of the University of Maryland on the design and construction of air particulate sample controllers. One such controller, installed at the Mauna Loa Environmental Observatory has functioned without failure for nearly two years. Another controller was installed at the South Pole in November 1980 and has been performing perfectly since.

There has been great success in bringing the CRR Pulse Radiolysis project on line. Particular difficulty was experienced due to the high electrical noise environment generated by the 2 MeV pulsed electron accelerator. We can now routinely measure pulsed radiolysis decay times with signal amplitude levels within the residual microvolt noise levels due to the illuminating lamp source.

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 several projects received major efforts. These were the multiple magnet assembly for activation analysis experiments which was completed; five new focus coils with precision adjustable supports which were installed on the NBS linac; the design work for the "turn around" magnets for the NBS-Los Alamos Racetrack Microtron accelerator which was completed; and the design work which has begun on the vacuum system and support structure for the Racetrack Microtron injection linac.

Radiation Instrumentation Standards

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 U.S. 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 U.S. 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 with tentative specifications being completed and issued and Prototype testing is underway. Many features of the specification are now firm and preparation of the final specifications will begin in FY 82.

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. There are currently seven CAMAC standards. These have been updated in FY 81 and the updated documents are to be 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 being investigated.

Division 535, Instrumentation Services (cont'd.)

(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 1981. 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 U.S. National Committee of the IEC for IEC Committee TC45 on Nuclear Instruments. He serves as Chief U.S. 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 1982.

SPONSORED CONFERENCES

Division 535, Radiation Source and Instrumentation

1981 Particle Accelerator Conference, Shoreham Hotel, Washington, DC, Samuel Penner, March 11-13, 1981.

INVITED TALKS

Division 535, Radiation Source and Instrumentation

Debenham, P.H., "End Magnet Design for the NBS-LASL CW Microtron," 1981 Particle Accelerator Conference, Washington, DC, March 11, 1981.

Penner, S., "The NBS-LASL Racetrack Microtron Project," Argonne National Laboratory, Argonne, IL, October 7, 1980.

Penner, S., "The NBS-LASL Racetrack Microtron Project," University of Illinois, Champaign, IL, October 9, 1980.

Penner, S., "The NBS-LASL CW Microtron," Sixth Conference on the Application of Accelerators in Research & Industry, Denton, Texas, November 4, 1980.

Penner, S., "The NBS-LASL Racetrack Microtron," Naval Research Laboratory Lectures Series on Conventional Particle Accelerators, Washington, DC, January 7, 1981.

Penner, S., "CW Electron Accelerators for Nuclear Physics," 1981 Particle Accelerator Conference, Washington, DC, March 11, 1981.

Penner, S., "Future Directions of Electromagnetic Nuclear Physics," American Physical Society Spring Meeting, Baltimore, MD, April 21, 1981.

Penner, S., "NBS-LASL Microtron Project," Information Meeting on a National GeV Electron Research Facility at Argonne National Laboratory, Chicago, IL, May 1, 1981.

Penner, S., "CW Electron Accelerators," Brazilian National Workshop on Nuclear Physics, Cambuqueira, MG, Brazil, September 10, 1981.

Penner, S., "Beam Particle Optics," Lecture Series, Institute of Physics, University of Sao Paulo, Sao Paulo, Brazil, September, 1981.

Penner, S., "NBS-Los Alamos Racetrack Microtron Project," Second Electronuclear Physics Workshop, Williamsburg, VA, September 25-26, 1981.

Wilson, M., "Recirculation Acceleration of High Current Relativistic Electron Beams - A Feasibility Study," 1981 Particle Accelerator Conference, Washington, D.C., March 12, 1981.

Wilson, M., "Recirculation Acceleration of High Current Relativistic Electron Beams - A Feasibility Study," Technical Interchange Meeting, (Classified), NSWC, White Oak, Silver Spring, MD, May 20, 1981.

PUBLICATIONS

Division 535, Radiation Source and Instrumentation

Debenham, P.H., End Magnet Design for the NBS-LASL CW Microtron, Proceedings of the 1981 Particle Accelerator Conference, Washington, D.C., March 11-13, 1981, IEEE Transactions on Nuclear Science, NS-28, pp. 2885-2887, June 1981.

Parr, A.C., Rakowsky, G., Ederer, D.L., Stockbauer, R.L., West, J.B., Dehmer, J.L., Current Research at NBS Using Synchrotron Radiation at SURF-II, Proceedings of the 1980 Conference on the Application of Accelerators in Research and Industry, Denton, Texas, November 3-5, 1980, IEEE Transactions on Nuclear Science, NS-28, pp. 1210-1214, April 1981.

Penner, S., Cutler, R.I., Debenham, P.H., Lindstrom, E.R., Mohr, D.L., Wilson, M.A.D., Yoder, N.R., Young, L.M., Boyd, T.J., Knapp, E.A., Martin, R.E., Potter, J.M., Schneider, C.M., Swenson, D.A., and Tallerico, P.J., The NBS-LASL CW Microtron, Proceedings of the 1980 Conference on the Application of Accelerators in Research and Industry, Denton, Texas, November 3-5, 1980, IEEE Transactions on Nuclear Science, NS-28, pp. 1526-1530, April 1981.

Penner, S., CW Electron Accelerators for Nuclear Physics, Proceedings of the 1981 Particle Accelerator Conference, Washington, D.C., March 11-13, 1981, IEEE Transactions on Nuclear Science, NS-28, pp. 2067-2073, June 1981.

Rakowsky, G., NBS-SURF II: A Small, Versatile Synchrotron Light Source, Proceedings of the 1980 Conference on the Application of Accelerators in Research and Industry, Denton, Texas, November 3-5, 1980, IEEE Transactions on Nuclear Science, NS-28, pp. 1519-1521, April 1981.

Whittaker, J., Book Review, Principles of Nuclear Radiation Detection and Principles of Nuclear Radiation Detection Laboratory Manual, Medical Physics, Vol. 7, No. 6, November/December 1980, pp. 735-737.

Wilson, M.A.D., Recirculation Acceleration of High Current Relativistic Electron Beams - A Feasibility Study, Proceedings of the 1981 Particle Accelerator Conference, Washington, D.C., March 11-13, 1981, IEEE Transactions on Nuclear Science, NS-28, pp. 3375-3377, June 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).

Member, Instrument/Computer Interfaces of the IEEE Instrumentation and Measurements Society (Serves also as U.S. Advisory Group to U.S. representatives on IEC/TC66/WG3).

Chairman, U.S. Department of Energy National Instrumentation Methods (NIM) Committee.

Chairman, NBS Microprocessor Standards Action Group.

Samuel Penner

Chairman, 1981 Particle Accelerator Conference.

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

S. Penner served as a reviewer for the superconducting electron accelerator programs at Stanford University and the University of Illinois for the Division of Physics, National Science Foundation.

S. Penner and M. Wilson continue to provide Accelerator Technology Assessment and Oversight for DARPA.

J. Whittaker served as a consultant on instrumentation and instrumentation maintenance and repair to AID for the Egyptian Government Standards Laboratories.

J. Whittaker serves as an advisor to a graduate student in the Department of Chemistry, University of Maryland.

M. Wilson has been assisting the Navy Research Laboratory in the installation and operation of the high current electron induction Linac originally designed, built and operated at NBS.

TRIPS SPONSORED BY OTHERS

Division 535, Radiation Source and Instrumentation

S. Penner, Argonne National Laboratory, Argonne, Illinois, October 7-8, 1980.

S. Penner, Institute of Physics, University of Sao Paulo, Sao Paulo, Brazil and Brazilian National Workshop on Nuclear Physics, Brazilian Physical Society, Cambuqueira, MG, Brazil, trip sponsored by Institute of Physics, University of Sao Paulo and the Brazilian Science Foundation, September 5-21, 1981.

SPONSORED SEMINARS & COLLOQUIA

CENTER FOR RADIATION RESEARCH

J.C. White, Bell Laboratories, Holmdel, New Jersey, "Recent Progress in Laser Induced Collisions," October 2, 1980.

Bryan Henry Patrick, United Kingdom Atomic Energy Authority, A.E.R.E., Harwell, Didcot, Berkshire, England, "Neutron Measurement Plans for the New Harwell 140 MeV Low Duty Cycle Electron Linac," October 2, 1980.

H.-J. Kunze, Institut fur Experimentalphysik V, Ruhr-Universitat, Bochum, Federal Republic of Germany, "Measurement of High Frequency Electric Fields in Plasmas," October 14, 1980.

G. Rosen, Department of Pharmacology, Duke University, Durham, NC, "Generation of Free Radicals in Biological Systems," October 16, 1980.

G.J. Lutz, Inorganic Analytical Research Division, Center for Analytical Chemistry, NBS, "Photon Activation Analysis - A Review," October 16, 1980.

John Rumble, Office of Standard Reference Data, NBS, "Rigorous Upper and Lower Bounds to Atomic Transition Probabilities - Real Results," October 21, 1980.

Jean Francois Wyart, (Guest Worker at NBS), Laboratoire Aime Cotton, C.N.R.S., France, "Theoretical Analysis of Lanthanide and Actinide Atomic Spectra: Some Recent Results," October 28, 1980.

Michael Danos, Nuclear Radiation Division, Center for Radiation Research, NBS, "Nuclear Forces from Quark Dynamics," October 30, 1980.

J.A. Purdy, Washington University School of Medicine, St. Louis, Missouri, "A Computer File of X-Ray and Election Depth Dose Data for Use in Radiation Therapy," November 3, 1980.

Jean Claud Gauthier, Institut D'Electronique Fondamental, Laboratoire associe' au CNRS, ORSAY, France, "Stark Broadening of He I Lines in a CO_2 Laser Produced Plasma," November 4, 1980.

J.W. Van Orden, Physics Dept., University of Maryland, "Meson Exchange Currents & Deep Inelastic Electron Scattering," November 13, 1980.

Einar Hinnov, Plasma Physics Laboratory, Princeton University, "Spectroscopy of Tokamak Discharges," November 18, 1980.

Harry Ing, Atomic Energy of Canada Ltd., Chalk River Nuclear Laboratory, Chalk River, Ontario, Canada, "Techniques of Neutron Dosimetry," November 20, 1980.

A. Szorenyi; R. Jedlovszky, National Office of Measures (OMH), Budapest, Hungary, "Radionuclide Metrology and Dosimetry in the National Office of Measures (OMH), Hungary," December 1, 1980.

Dave Gilliam, James Grundl, Dale McGarry, Nuclear Radiation Division, Center for Radiation Research, NBS, "Isotopic Fission Rate Measurement at the Fast Flux Test Facility --- R & D in a Reactor Operations Environment ---," December 4, 1980.

B.F. Gibson, Nuclear Physics Division, Department of Energy, "Electromagnetic Disintegration of the Mass 3 and 4 Nuclei," December 11, 1980.

G. Franklin, Bates Accelerator Laboratory, Massachusetts Institute of Technology, "Electroproduction of Low Energy Pions from Deuterium," December 15, 1980.

Cliff Strawitch, University of Wisconsin, Physics Department, "Plasma Transport in a Simulated Magnetic Diverter Configuration," December 18, 1980.

Oren A. Wasson, Nuclear Radiation Division, Center for Radiation Research, NBS, "^{235}U Neutron Induced Fission Cross Section Measurements at the 3 MV Van de Graaff Laboratory," January 8, 1981.

R.A. Schrack, Nuclear Radiation Division, Center for Radiation Research, NBS, "Neutron Radiography," January 22, 1981.

R.S. Caswell, Nuclear Radiation Division, Center for Radiation Research, NBS, "Technical and Social Impressions from the NBS Team Visit to the People's Republic of China," January 29, 1981.

Joseph C. McDonald, Memorial Sloan-Kettering Cancer Institute, New York, N.Y., "Calorimetry Measurements of Neutron Dose," February 3, 1981.

Robert Contolini, Department of Chemistry, Ohio State University, "The Spectroscopy of $AlCl_3$ in Absorption, Emission, and Laser-Induced Fluorescence," February 3, 1981.

M.V. Samii, Department of Physics, Johns Hopkins University, "Relativistic Study of One-Photon Transitions in Highly Ionized Atoms," February 3, 1981.

D.A. Swenson, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, "PIGMI - A New Development in Ion Accelerator Technology," February 6, 1981.

G.M. Temmer, Dept. of Physics, Rutgers State University, New Brunswick, New Jersey, "Particles - Crystals - Photons The interaction of charged particles with crystals)," February 13, 1981.

Ken R. Shortt, X-Rays and Nuclear Radiation, Division of Physics, National Research Council, Ottawa, Canada, "Physics and Dosimetry of Pion Therapy at SIN, TRIUMF, and LAMPF," February 18, 1981.

Gerard D. O'Sullivan, University College, Dublin, Ireland, "Far UV Continuum Generation in Laser-Produced Plasmas," February 24, 1981.

R. Feder, University of Duisburg, West Germany, "Surface Analysis by Spin-Polarized Low-Energy Electron Diffraction," February 27, 1981.

Walter Greiner, Institute for Theoretical Physics, University of Frankfurt, Frankfurt, Germany, "Discovery of the Decay of the Vacuum and of Super Heavy (Z-184) Nuclear Systems??," March 5, 1981.

J.M. Salome, Central Bureau for Nuclear Measurements, Geel, Belgium, "New Neutron Measurement Capabilities of the Geel Electron Linac," March 10, 1981.

Mireille Aymar, Laboratoire Aime Cotton, Orsay, France, "Analysis of Perturbed Rydberg Series by Multi-Channel Quantum Defect Theory," March 17, 1981.

K.T. Chung, North Carolina State University, "Saddle-Point Technique to Autoionizing States of Atomic Systems," March 18, 1981.

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This report summarizies research projects, measurement method development, testing and data evaluation activities, carried out during Fiscal Year 1981 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.

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