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Technical Activities 1979
Center for Radiation Research

Chris E. Kuyatt and Wayne A. Cassatt, Editors

Center for Radiation Research
National Measurement Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

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CENTER FOR RADIATION RESEARCH

The Center for Radiation Research has a unique mission. It provides high accuracy radiation measurement techniques and quantitative data about atomic and nuclear radiation processes. These outputs are required for the safe and effective use of radiation in key technologies. Center activities cover the electromagnetic spectrum starting at the infrared, through the visible, the ultraviolet, and vacuum ultraviolet, to x-ray and nuclear gamma rays. Particle radiations include electrons, positrons, protons, deuterons and neutrons below 140 million electron volts. Our facilities include a 140 MeV electron linear acceleraor, a 240 MeV electron storage ring for synchrotron light, many lower energy accelerators, a polarized electron source, plasma devices and many sophisticated spectrometers with computer assisted data acquisition.

During the past year, CRR has directed special attention to several areas of growing national concern. One of these areas, ionizing radiation health and safety, has attracted a large amount of public and institutional concern. At the request of the Senate Committee on Commerce, Science and Transportation, the Center is cooperating with the Conference of State Radiation Control Program Directors. Together, we are reviewing the need for an intermediate level of calibration services such as regional facilities to better couple NBS laboratories with state and industrial needs. This review will contribute to an updated long-range plan and budget initiative for ionizing radiation measurements.

CRR is working with the State of Illinois to set up a pilot regional calibration laboratory, with Florida to set up a calibration facility for low-level survey instruments, and with the University of Michigan on the testing of personnel dosimetry performance. Special measurements were made on dosimeters used near the Three-Mile Island nuclear power plant. Natural matrix radioactivity standards, such as human lung and liver, are being prepared for environmental monitoring. We are working on dosimetry measurements and standards for radiation sterilization, a process which replaces the use of carcinogenic ethylene oxide. Measurements of the response of x-ray screens are part of our work on the technology for reducing patient exposure. Because of the need for increased cooperation between the various agencies concerned with ionizing radiation, the Center is represented on two recently-formed interagency committees on ionizing radiation.

CRR is working to improve the state-of-the-art in optical radiation measurements. Better measurements are needed, for example, in solar and atmospheric monitoring and by the electro-optics and lighting industries. To make available to the lighting industry the new radiometric scale, which will eventually replace the current scale based on the candela, 175 lamps are being calibrated on both scales for simultaneous distribution. Progress toward the 0.1 percent radiometry needed in solar monitoring is being made through quantum-based calibrations of silicon photodiodes, by improved characterization of black-body sources, and through intercomparisons of NBS radiometry standards. Improved measurements of UVB radiation are made possible by new source standards and by accurate measurements of spectroradiometer response. Provision of characterized detector packages on a rental basis enables users to measure the spectral response of their measurement systems. New measurement assurance programs are being developed for diffuse reflectance and for retroreflectance.

Several of our activities contribute to the nation's energy programs. Measurement and calculation of the spectra of highly-ionized heavy ions are essential to the diagnostics of fusion-plasma devices. Ionization rate measurements now in progress will provide benchmark data for analyzing heavy ion impurities in Tokamak fusion devices. Vacuum ultraviolet radiometric calibrations and portable transfer source standards provide the measurement base for accurate measurements of radiation from fusion plasmas. Radiation phenomena, such as plasma line broadening and dielectronic recombination, are being investigated as possible new plasma diagnostic techniques. Resonance neutron radiography is being developed as a non-destructive method for obtaining accurate values for the total mass of fissionable isotopes. This method is expected to be useful in calibrating measurement devices for nuclear fuel reprocessing plants. Accurate measurements of neutron cross sections are being made for both fission and fusion reactions. Integral and differential neutron fields continue to be developed for the calibration of neutron detectors used in fusion research, nuclear reactors, and personnel dosimetry.

The Center has a dedicated synchrotron radiation facility, SURF-II. This device produces electromagnetic radiation 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. This tunable, intense radiation is being applied to several new scientific and technical opportunities. Many of these activities involve collaboration with other Centers of NBS or with laboratories outside of NBS. Ultraviolet photodiode detectors are now being calibrated for photon energies up to 250 eV. This capability was used in a collaborative program with Los Alamos to measure photoemission yields of several promising cathode materials. Several calibrations were carried out on spectrometers for space experiments and fusion plasma diagnostics. A new spectrometer calibration facility, under construction with NASA funding, will give more accurate and convenient calibrations. During the past year our new high-flux normal-incidence monochromator came into full operation, and has been used to measure the angular distribution of photoemitted electrons from individual vibrational levels of highly excited molecules. This monochromator also has been used to study Stark mixing in high Rydberg autoionizing states of atoms and molecules. Further studies on excited state dynamics will utilize fluorescence measurements to investigate ion deexcitation processes. Using another monochromator, we have observed high pressure helium microbubbles in thin aluminum films by measuring the pressure-broadened helium resonance in absorption. Scientists from the Naval Research Laboratory are studying insulators by using reflection, photoemission and fluorescence. Scientists from Brookhaven National Laboratory are installing a circular dichroism apparatus for measurements of biomolecules. Apparatus is being built in collaboration with the Surface Science Division to study the photodesorption of ions from absorbates at surfaces. We do not have space to describe all of the activities of SURF-II, but these examples illustrate the wide range of activities being carried out with synchrotron radiation.

High energy photons and electrons are excellent probes of nuclear structure. The coupling of photons and electrons to charge, current, and magnetic moments of nuclear constituents is well known from quantum electrodynamics, and the flexibility of electron scattering allows energy and momentum transfer to the nuclear system to be varied independently. Using a high-current 140 MeV linear electron accelerator, CRR scientists have investigated nuclear structure using electron scattering, photon scattering, and electrodisintegration. Recent elastic photon scattering measurements from ^{12}C showed a surprisingly large electric quadrupole component. Similar measurements on ^{16}O will be of even greater theoretical interest. Elastic electron scattering has yielded an improved value for the ^{12}C nuclear radius which has become a world standard. Similar measurements on ^{4}He will provide a critical test of quantum electrodynamics.

In electron scattering, the cross section is measured as a function of energy and momentum transfer. In electrodisintegration, however, outgoing particles or induced radioactivities are integrated over all of the final states of the scattered electron. An entirely new type of experiment has recently been pioneered by CRR scientists in which the yield of particles is measured as a function of the incident energy. From analysis of such measurements it is possible to locate and measure the strength of the E1 and E2 giant resonances that result in proton and α particle emission. Results on ^{58}Ni, ^{60}Ni and ^{62}Ni show important E2 components in the α channel.

The ultimate experiment would detect both the scattered electron and outgoing particle in coincidence. Such experiments would require a 100 percent duty cycle (CW) electron accelerator and would be crucial in going beyond the classical description of nuclear structure and reactions in terms of elementary neutrons and protons, that is, in determining the effects of many-body correlations, virtual pions, and excited nuclear states on nuclear structure. These opportunities are important enough that we have begun, with DOE funding, the development of a prototype 185 MeV room-temperature CW electron accelerator. In addition to demonstrating the feasibility of building a 1 to 2 GeV machine using the same technology, the prototype accelerator will be a powerful tool in its own right for nuclear physics.

In the following pages the technical activities of the five divisions within the center for Radiation Research are described in more detail.

TECHNICAL ACTIVITIES

530, Office of Radiation Measurement

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. Because the states have the primary responsibility for making measurements that ensure public safety, the efforts of the Office of Radiation Measurement are concentrated on services for state radiation control programs. The primary interaction mechanism is the Conference of Radiation Control Program Directors, specifically its Task Force on Radiation Measurements. This task force is sponsored by the Office, and performs collaborative efforts of interest to state programs.

During 1978, the task force conducted an extensive study of accuracy requirements for the large variety of measurements made routinely by state personnel. The resulting report will be published soon by NBS. It references the regulatory motivation for the measurements, indicates the range of radiation parameters encountered, states the required accuracy, and outlines important instrument considerations.

Another collaborative effort with state programs is the development of a pilot regional calibration facility in the State of Illinois. It will test the concept of having an individual state program serve as a regional source of instrument calibrations for x-ray measurements up to 150 keV. The State is providing laboratory space and operating staff, while NBS will provide an x-ray machine and standard instruments on a loan basis, along with technical support. Essentially all of the instrumentation has been obtained and tested, the laboratory has been designed, and construction will occur in the fall of 1979. As of July 1, 1979, the state legislature provide operating funds and an operator.

The Office coordinated an interagency and multi-organizational project with broad national participation to develop a recommended national method for the reporting of environmental radiation data. Initiated in 1977 at the request of the Conference of Radiation Control Program Directors, the project is now nearing completion. A detailed Guide and Recommendations for Reporting of Environmental Radiation Measurements Data has been completed and distributed to a wide audience for review and comment. The Guide will be published as an NBS Special Publication in late 1979, and a condensed version will be published by the Health Physics Society.

During the past few years, potential health hazards associated with radiation exposure due to radon in buildings have received increasing attention. Many studies have indicated that indoor concentrations of radon and its radioactive-daughter products are frequently higher than outdoor concentrations. At the same time, there is an increasing interest in energy conservation in buildings. Conservation strategies such as reducing ventilation and infiltration rates may result in elevated radiation levels. It is becoming clear that radiation protection and building technology are in some cases interdependent. As a result of these concerns, a Roundtable Discussion of Radon in Buildings was jointly organized by the Office of Radiation Measurement and the Center for Building Technology, and held June 15, 1979, at NBS. Participants included individuals with programmatic as well as scientific and technical expertise in radiation protection, radiation measurement and building technology areas. They represented a wide range of private and government institutions with diverse radiation and building technology interests. The objective of the meeting was to bring together these participants to exchange information and to draw attention to some of the problems and research needs, and provide a forum for a general discussion of radon in buildings. At the same time, the meeting provided a focus for NBS to better understand its role in providing measurement support services for this serious problem in environmental radiation protection.

In the course of investigating the feasibility and efficacy of developing a distributed (large area) calibration source for instruments used to measure ambient environmental radiation levels, it became apparent that a much broader view of the measurement requirements is needed. To this end, the Office has initiated an expanded effort to examine the specific measurement needs and necessary measurement support services. This includes evaluation of the suitability of available field instruments to measure environmental gamma-radiation exposure rates, the characteristics and minimum performance criteria of the instruments, and development of appropriate measurement and calibration procedures.

In April 1979 the Office co-sponsored with the FDA Bureau of Radiological Health a Conference on Neutrons from Electron Medical Accelerators. The purpose of this conference was to acquaint members of the scientific, radiotherapy, regulatory, and accelerator manufacturing communities with the latest state-of-the-art information concerning neutron production during operation of medical accelerators. In spite of the highly specific topic of the conference there were 208 registrants with 22 participants from eight foreign countries. The proceedings of this conference were published in September 1979 as NBS Special Publication 554.

As a result of the Three Mile Island reactor accident, NBS was asked to calibrate and determine specific response characteristics of survey instruments used at the site. The Office coordinated four series of tests and calibrations for the Nuclear Regulatory Commission, the Department of Energy, and the Environmental Protection Agency, using xenon-133 as the radiation source. This work has led to proposals for additional studies and development of improved capability at NBS. It is expected that support will be provided by the NRC and EPA in FY 1980 for the necessary additional work.

During the past year a report was completed by the Committee on Radiation Calibration Needs in Therapy, of the American Association of Physicists in Medicine, on the subject of needs for additional regional calibration laboratories. The review was conducted under a two-year contract from the Office of Radiation Measurement. As indicated in the report, the committee concluded that one additional regional calibration laboratory is needed, located in the far west of the continental United States. A number of related highlights and recommendations are included in the report.

The Office provides the chairmanship and secretariat of the American National Standards Committee on equipment for non-medical radiation applications. During the past year a revised standard for design and operation of particle accelerators was published as NBS Handbook 107. Publication of Handbook 129, on radiation gauges, is scheduled for October 1979.

Other accomplishments during the past year include: collaborative efforts with the NRC that resulted in publication of a regulatory guide with a revised statement regarding traceability to NBS; cooperation with the CRCPD task force in conducting a survey that will document the availability of calibration services in the U.S.; and preparation of a draft report in response to a congressional committee request.

PUBLICATIONS

530, Center for Radiation Research

Cassatt, W. A., Atmospheric Particulate Measurement Development at the NBS, Proceedings of 25th Annual Technical Meeting, Institute of Environment Sciences, Seattle, Washington, April 30, 1979.

Collé, R., Treatment and Reporting of Uncertainties for Environmental Radiation Measurements, Proceedings of 23rd Conference on Analytical Chemistry in Energy Technology, to be published by Oak Ridge National Laboratory.

Collé, R., The Physics and Interaction Properties of Radon and Its Progeny, in Radon in Buildings, NBS Special Publication, to be published.

Collé, R. and Silberstein, S., (eds.), Radon in Buildings: A report on the Roundtable Discussion of Radon in Buildings held NBS-Gaithersburg, June 15, 1979, NBS Special Publication, to be published.

Heaton, H. T., II and Jacobs, R., editors, Proceedings of a Conference on Neutrons from Electron Medical Accelerators, NBS Special Publication 554, September 1979.

Kuyatt, C. E., Pierce, D. T. and Celotta, R. J., Spin and Energy Analyzed Photoemission: A feasibility analysis, Rev. Sci. Instr., (in press).

Kuyatt, C. E., Biondi, M. A., Herzenberg, A., Resonances in Atoms and Molecules, Physics Today, Vol. 32, 10, p. 44, October 1979.

INVITED TALKS

530, Center for Radiation Research

Cassatt, W. A., "Atmospheric Particulate Measurement Development at the NBS," sponsored by Institute of Enviornment Sciences - 25th Annual Technical Meeting held at Seattle, Washington, April 30, 1979.

Collé, R., "Reporting of Environmental Radiation Measurements Data," Special Session on Upgrading Environmental Radiation Data, 24th Annual Meeting of the Health Physics Society, Philadelphia, PA. July 12, 1979.

Collé, R., "The Physics and Interaction Properties of Radon and Its Progeny," review paper at A Roundtable Discussion of Radon in Buildings, NBS, Gaithersburg, MD. June 15, 1979.

Collé, R., "Practical Considerations of A Priori Detection Limits for Environmental Radioactivity," Virginia Chapter of the Health Physics Society, Richmond, VA. May 12, 1979.

Collé, R., "Reporting of Enviornmental Radiation Measurements Data," 11th Annual National Conference on Radiation Control, Oklahoma City, OK. May 10, 1979.

Collé, R., Measurement of Environmental Gamma-Radiation Exposure Rates, Florida Chapter of the Health Physics Society, St. Petersburg, FL. October 13, 1978.

Kuyatt, C. E., "Polarized Electron Sources," Joint Meeting, Electron Microscopy Society of America/Microbeam Analysis Society, San Antonio, Texas, August 13-17, 1979.

SPONSORED CONFERENCES

530, Center for Radiation Research

Roundtable Discussion of Radon in Buildings, held June 15, 1979, at NBS-Gaithersburg. Cosponsored by the Office of Radiation Measurement (530) and the Center for Building Technology (740).

Conference on Neutrons from Electron Medical Accelerators, held April 9-10, 1979, at NBS-Gaithersburg. Cosponsored by NBS and the FDA, Bureau of Radiological Health, with cooperation from the American Association of Physicists in Medicine.

Fifth Conference on Application of Small Accelerators, held November 6-8, 1978 at North Texas State University. Cosponsored by NBS, USDOE, NSF, IEEE, BRH, ANS, and the host.

JOURNAL EDITORSHIP

530, Center for Radiation Research

Chris E. Kuyatt, Editorial Board, The Review of Scientific Instruments.

ATOMIC AND PLASMA RADIATION DIVISION (531)

TECHNICAL ACTIVITIES DURING FY 79

The Atomic and Plasma Radiation Division, which consists currently of 20 professional physicists (17 Ph. D.s), carries out research in the fields of atomic and plasma spectroscopy with the principal objectives to advance our knowledge of the atomic radiation and collision processes in plasmas, to broaden and refine the relevant atomic data base, to utilize radiation processes, to advance plasma measurement science, and to provide plasma radiometric standards.

The division thus provides, through experimental and theoretical research as well as through critical data compilations, a significant part of the new atomic and plasma radiation data, such as wavelengths and relative intensities for spectral lines; atomic energy levels; ionization potentials; atomic transition probabilities; Stark broadening parameters; collision strengths and collisional rate coefficients; and dielectronic recombination rate coefficients. The division also carries out fundamental studies to explore the potential of radiation phenomena encountered in the plasma environment, such as plasma line broadening, for new plasma diagnostic techniques, and it develops well-defined steady state plasmas, such as the wall-stabilized hydrogen arc, as radiometric standards for the vacuum ultraviolet.

The main scientific and technological needs currently addressed by the division lie in the fields of thermonuclear fusion research (where radiation processes enter critically into the heavy ion impurity problem and plasma diagnostics); vacuum ultraviolet laser development; nuclear weapons simulation; fast high current switching and a variety of industrial applications of low temperature plasmas.

The principal facilities of the division are a 50 kJ θ-pinch device; a powerful Nd/glass laser (about 10 joules in 4 ns) for the generation of highly ionized spectra; two 10.7 m vacuum uv spectrographs in the normal and grazing incidence region, and 100 kW steady-state stabilized arc sources, and a pulsed high current arc.

The division is organized into three technical groups, whose principal work during the last year is highlighted in the three following sections.

I. Atomic Spectroscopy Group

(a) Vacuum UV Spectra of Atomic Ions--This work is focussed on isoelectronic sequences that include spectra of heavy ions occurring in or that are of interest to fusion-plasma devices (mainly Ti, V, Fe, Ni, Cu, Mo, Ta, W,). Analysis of spectra we obtained using a powerful Nd/glass laser at Los Alamos to generate plasmas has given wavelengths and levels up to 44- and 45-times ionized tungsten. The sequences involved are the longest known, and the ionization stages the highest observed with grating spectrographs. Our measurements and analysis of Y XI, Zr XII, Nb XIII, Mo XIV, and Zr V and La IV were completed; the results were published or are in press. The power of the NBS laser has been increased to produce the spectrum Fe XX. We expect to obtain accurate measurements of several lines important for tokamak diagnostics which could not previously be generated at NBS.

A new interpretation of strong tungsten radiation generated in the ORMAK and PLT tokamaks has resulted from our observations and identifications in the Pd I and Ag I isoelectronic sequences. The spectra have been obtained through Dy XXI and Ho XXI with a high voltage triggered spark discharge observed on the 10.7m grazing incidence spectrograph. Further experiments are planned to carry the observations through to tungsten (W XXVIII, XXIX) by means of laser-produced high temperature plasmas and thereby to confirm our new interpretation of the tokamak spectra.

(b) Resonant Laser-vapor Interactions--We have completed the experimental apparatus for generating absorption spectra of Ca I and Ca II by dye-laser pumping of a heat pipe vapor of calcium. The method includes the novel use of a small toroidal mirror near the spectrograph slit for collecting the continuum radiation. The apparatus consists of a triggered spark for generating the continuum, its vacuum connection through a capillary array to a heat pipe, followed by a housing containing the toroidal mirror and input window for the dye-laser radiation, which is reflected off the edge of the toroidal mirror back through the pipe. This housing is interfaced with the 10.7m grazing incidence spectrograph. We intend to study inner-shell absorption to auto-ionizing states of the neutral and singly-ionized atom, as well as photoionization cross-sections.

In studies intended to fully understand the ionization mechanism, a two-metal heat pipe is being designed, in which transfer of energy to a non-resonant metal through the collisionally heated electrons is expected. This will be built to conveniently replace the calcium heat pipe in the above arrangement.

(c) Atomic Energy Levels Data Center--In continuation of the program on new critical compilations of energy levels for atoms and ions of the first 30 elements, we completed work on magnesium (12 spectra), potassium (19 spectra), and scandium (21 spectra). This gives a total of 209 spectra in this region of the periodic table for which we have made available critically evaluated data on energy levels and their quantum properties. Work on the sodium and nickel atoms and ions is in progress.

A Bibliography on Atomic Energy Levels and Spectra covering the period July 1975 through June 1979 is almost ready to be submitted for publication. This includes some 1300 references covering the entire periodic table, with the references classified by spectrum and according to 14 different types of data.

II. Atomic Radiation Data Group

(a) Theoretical Studies of Atomic Processes--Our theoretical effort is predominantly directed towards obtaining data which are, in some way, pertinent to the fusion program. In addition to data production itself, a considerable effort is devoted to developing and exploring new theoretical methods. The basic atomic processes under study are: dielectronic recombination, emission and absorption of radiation, and collisional excitation and ionization. We also try to maintain some theoretical work on Stark line broadening.

During the past year calculations were begun on the dielectronic recombination rates of sodium-like ions (iron and molybdenum), and this work is still in progress. The emphasis of our dielectronic recombination studies, however, has shifted towards a more detailed study of satellite intensities rather than total rates, and towards a more fundamental study of the basic approximations used in formulating a description of such processes. In particular, we are developing a method for including the effects of the plasma environment on the recombination process. This involves separating the plasma Hamiltonian and the plasma-ion interaction into long-range field-like terms represented by collective coordinates and short range particle-like terms using ordinary spatial coordinates.

Our work on electron impact excitation of atomic ions has, until now, concentrated on systematic studies of the $\Delta n = 0$ transitions of highly stripped ions in the alkali and alkaline earth isoelectronic sequences, which are especially important for the impurity problem in fusion plasmas. Collision strengths were calculated in the Born, Coulomb-Born and distorted wave approximations, with and without exchange. In the case of the alkaline-earth-like ions, target state correlation was included in an approximate fashion and was found to affect the collision strength in a way very similar to the optical line strength. These excitation cross-section programs are now being rewritten in the distorted wave approximation, so as to include accurately the effects of target state correlation. We have also embarked on a study of the electron impact ionization problem, and preliminary exploratory calculations are now under way.

Calculations of the electron structure and oscillator strengths of the argon isoelectronic sequence have been completed. These calculations include both ground and excited state correlation and relativistic effects at the level of an ad hoc Pauli intermediate coupling approximation. A considerable effort has already been invested in a complete revamping of the atomic structure codes in order to take full advantage of the computing power of modern computers as well as recent developments in the methodology of calculating atomic structure. In the latter case, perturbation methods and Bethe-Goldstone techniques are being incorporated into large scale superposition of configurations programs. The possibility of including higher order Pauli approximation relativistic effects is also under study, and to this end the assistance of Dr. John Detrich, a visiting scientist last summer, has been most helpful.

We have also continued our beam-foil lifetime simulation studies, extending our theoretical simulation to zinc-like ions. An earlier study of copper-like ions elucidated the important role of cascades in extracting reliable f-value data from beam-foil decay curves, and the present study of the more complex zinc-like ions confirms the importance of the cascade problem, indicating that measured data are systematically off by about a factor of two. In this work we were ably assisted by Dr. Emile Knystautas, an expert in beam-foil spectroscopy who has been a visiting scientist this past year.

(b) Critical Compilation Work--In the Data Center on Atomic Transition Probabilities and Line Shapes and Shifts, we have completed a critical evaluation of f-value data for all ions of Fe, Co and Ni and a compilation, including about 3900 transitions, is in press. This compilation is as large as our earlier published Volume I. Work is also nearing completion on a revision and updating of previously published data on the ions scandium through manganese. When this is completed a comprehensive compilation of all the iron group elements, Sc through Ni, will be published as Vol. 3 of the NSRDS series on Atomic Transition Probabilities. A third supplement to the Bibliography on Atomic Line Shapes and Shifts, covering the literature 1975-1978, was also issued. Finally, the data center continues to co-edit the bimonthly newsletter "Atomic Data for Fusion", in collaboration with Oak Ridge National Laboratory.

(c) Atomic Lifetime Experiment--Much of the work in the lifetime laboratory has been temporarily suspended, due to a shift in personnel to assist with the UV radiometry effort. Some preliminary design studies have been made for upgrading the lifetime experiment to include an electron beam-tunable laser combination for exciting atomic states.

III. Plasma Radiation Group

(a) Collisional Rate Coefficient Studies with the θ-pinch--The major part of the group's current work is in support of the thermonuclear fusion research program, especially in providing benchmark atomic data for analyzing heavy ion impurities in Tokamak fusion devices. Data characterizing the atomic radiation and collision processes that heavy ion impurities undergo in fusion-type plasma are obtained experimentally using the NBS 50 kJ theta pinch. Work is now in progress on ionization rate measurements of heavier ions. A special plasma gun has been constructed and tested to reproducibly introduce titanium iron and nickel into the θ-pinch plasma. Time-histories of Ti III through Ti XII ions have been observed which together with the temporal and spacial distribution of electron density and temperature will yield ionization rates of selected titanium ions. Also on the θ-pinch facility, additional investigations of dielectronic recombination satellites of Li-like oxygen have been undertaken to study this important radiation loss mechanism in fusion-type plasmas. All this experimental work is supported by the Department of Energy.

(b) Vacuum Ultraviolet Radiometry with Plasmas--Our efforts to provide vacuum ultraviolet radiometric calibrations and portable transfer source standards have been a direct outgrowth of earlier vacuum ultraviolet plasma spectroscopy experiments. Our program involves calibrations of deuterium lamps and argon plasma arcs for both radiance and irradiance in the wavelength range from 350 nm to 110 nm. These sources are calibrated against a previously developed stabilized hydrogen arc primary source. The emphasis has recently turned to the further development of reliable, portable transfer sources and detailed investigations of convenient transfer sources that are compatible with space flight conditions. Newly developed deuterium and R-F discharge eximer lamps are being tested for stability, reliability, and space flight compatibility for in-situ calibrations aboard two Space Shuttle experiments. This represents the first in-situ calibration effort in the vacuum ultraviolet spectral region aboard a spacecraft. Various spectral irradiance calibration techniques at wavelengths shorter than 200 nm are currently being investigated and the uncertainty limits evaluated. In addition, an international intercomparison of spectral radiance and irradiance scales in the vacuum ultraviolet spectral region is being undertaken in cooperation with the National Physical Laboratory in England.

(c) Stark Broadening of Hydrogenic Ions--Hydrogenic species, by virtue of their high sensitivity, provide the most important spectral lines for plasma diagnostics. However, because of the required very high plasma temperatures, they have to be studied in pulsed sources, which are difficult to control in an accurate and reproducible manner. Therefore, we concentrated our efforts and refinements of the instrumentation and the acquition and analysis of data from the plasma source has been automated. This has facilitated more accurate data for the plasma polarization shifts, and we have been able to measure the shift of the He II P_α, P_β and P_γ lines, which show a pronounced quantum level dependence of the shift. A theoretical formalism for the polarization shift has been developed. To provide benchmark line broadening measurements of these lines, highly accurate determinations of electron density are required. A heterodyning laser-interferometry system has been built up. The present 10% accuracy is limited by a boundary layer in the plasma source. For this and other reasons a new source, essentially free of boundary layers, is presently being designed.

(d) Field-Induced Autoionization--Field induced autoionization of metastable ionization levels should provide a sensitive new diagnostic tool for local fields in a plasma. Initial studies of this effect are most readily performed in an atomic beam. In the past year we have built up an atomic beam device and designed and built two high-resolution pulsed dye lasers, pumped by a Nd: YAG laser. The ion detection system has recently been completed, and we have detected ions by photoionization of excited states in neutral calcium.

Division 531, Atomic and Plasma Radiation

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Martin, W. C., "Atomic Spectroscopic Data of Astrophysical Interest,", University of Montreal, Canada, August 15, 1979.

Reader, J., "Recent Progress in Spectra of Highly Charged Ions for Fusion Research," Second Topical Conference on Atomic Processes in High Temperature Plasmas, American Physical Society, Boulder, Colorado, January 18, 1979.

Roberts, J. R., "Diagnostic Techniques on NBS Plasma Experiments," 9th European Conference on Controlled Fusion and Plasma Physics, Oxford, United Kingdom, September 17-21, 1979.

Sugar, Jack, "Recent Work in the Pd I and Ag I Isoelectronic Sequences: Connection with Tungsten Radiation from Tokamaks," Symposium on Atomic Spectroscopy, The University of Arizona, Tucson, Arizona, September 12, 1979.

Weiss, Andrew W., "Review of Recent Progress at NBS on Atomic Data Pertinent to the Fusion Program," DOE meeting on High Energy Atomic Physics, Kansas State University, Manhattan, Kansas, April 5, 1979.

Wiese, W. L., "Radiation Data Needs for Highly Ionized Atoms," Institute of Applied Physics, Belgrade, Yugoslavia, September 28, 1979.

Wiese, W. L., "Spectroscopy Research for Magnetic Fusion Energy," Institute of Physical and Chemical Research, Tokyo, Japan, May 15, 1979.

Wiese, W. L., "Radiation Data for Highly Ionized Atoms--Status and Needs," U.S.-Japan Seminar on Plasma Spectroscopy, Kyoto University, Kyoto, Japan, May 8, 1979.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 531, Atomic and Plasma Radiation

1. During FY 79 the following VUV radiometric calibrations have been performed:

A. Seven calibrations of argon mini-arcs:

(1) Ball Brothers Aerospace Corporation (Space Astronomy)

(2) Institut für Physikalische Weltraumforschung in Freiburg (Space Sciences)

(3) California Institute of Technology (Atomic Physics)

(4) European Space Research and Technology Center-ESTEC (Space Sciences)

(5) Dr. Arnold Bass, 542.00 (Molecular Spectroscopy)

(6) Dr. Victor Kaufman, 531.00 (Atomic Spectroscopy)

(7) Robert Saunders, 534.00 (Radiometry)

B. About 20 calibrations of low pressure discharge lamps. These have been done in connection with service contracts with the Naval Research Laboratories and with the Goddard Space Flight Center and are representative of continuous consulting services extended throughout the year to these two agencies.

2. The Data Centers on Atomic Energy Levels and Transition Probabilities routinely fill requests for atomic data or literature information submitted by scientists in a wide range of research areas. The requests average about 15 per week. On occasion, special reports are prepared for particular user groups. Thus, W. C. Martin and W. L. Wiese wrote detailed reports on recent results of astrophysical interest, which have been published in the Transactions of the International Astronomical Union.

3. Dr. Joseph Reader, as Chairman of the NAS-NRC National Committee on Line Spectra of the Elements, organized the preparation by that group of extensive new tables of atomic spectral lines, which include wavelengths and transition probabilities. These much needed tables will probably be the most widely used atomic line lists. A revised version has been published in the newest edition of the Handbook of Physics and Chemistry of the Chemical Rubber Co. (60th Edition, 1979).

Division 531, Consulting & Advisory Services (cont'd.)

4. Dr. William Ott, as Treasurer on the National Committee for the organization of the 6th International Conference on Vacuum Ultraviolet Radiation Physics, has prepared and submitted proposals to national agencies for financial support of the conference, has prepared a budget, and is overseeing the financial aspects of the Conference organization.

5. Dr. W. L. Wiese served on a Department of Energy advisory committee to review and establish priority needs on atomic data for the national fusion program for the next five years. The advisory panel met at the Office for Magnetic Fusion Energy, DOE, Germantown, Maryland, and a draft report listing the high priority data needs is in preparation.

JOURNAL EDITORSHIP

Division 531, Atomic and Plasma Radiation

J. Reader, Editorial Advisory Panel, Optics Letters.

W. C. Martin, Associate Editor, Journal of the Optical Society of America.

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".

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, Differential Neutron Standards, 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 is attached to the Division Office. The Photonuclear Data Center is located in the Nuclear Research group.

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

We have undertaken several efforts at improvement of our scientific communications: a series of informal "chalk talks" in which all scientific staff members take part; and a renewed effort to bring in vigorous colleagues to work with us for short or long periods of time, which has already borne fruit. These include Brian Patrick, AERE Harwell, U.K.; James Kellie, University of Glascow, Scotland; Elisa Wolynec, University of Sao Paulo, Brasil; Raymond Moreh, Ben Gurion University of the Negev, Israel; Heinz Gimm and Rolf Leicht, Max Planck Institute for Chemistry, Mainz, Germany; Max Huber, University of Erlangen, Germany.

Nuclear Materials Safeguards Studies (attached to the Division Office). The Nuclear Materials Safeguards Studies project supports the safeguards program of the DOE Office of Safeguards and Security (DOE/SS). Systems analysis studies are performed leading to a more effective utilization of data and information from all sources for achieving safeguards goals. Inputs are made to a sound technical basis for design, development and operation of plant programs that will be effective in protection against covert diversion of special nuclear material by persons authorized access to the material.

A conceptual framework for an overall Safeguards Information System (SIS) has been revised to reflect recent organizational changes in the DOE Office of Safeguards and Security. The draft document describing the SIS has been extensively revised to reflect these changes and nears completion. While procedures for an initial implementation test of the SIS have been formulated, development of additional guidelines for plant SIS implementation has been delayed pending issuance of the draft document and the field test.

One component of SIS, developed for implementation before the framework was completed, is termed Diversion Path Analysis (DPA). This is a systematic procedure for directing a detailed examination of all conceivable possibilities for an insider to covertly divert material from nuclear plants. Potential weak points in the plant material control and material accounting (MC&MA) subsystems are identified as well as suggestions for remedial actions. Mechanisms for including additional aspects of the physical protection subsystem in the DPA methodology have been investigated. Analyses performed by personnel at two contractor facilities have been reviewed and a third awaits review. The two computer programs, written to assist in assembling analysis results, have been revised. These revisions were necessitated by special cases appearing in the results of contractor performed DPA's that were not anticipated when the original hypothetical test data were developed. A new DPA Handbook has been issued which includes the computer programs. This Handbook replaces the original edition issued in 1976 and reflects all revisions, based on contractor implementation experience, to the methodology. Implementation assistance to contractor personnel will continue as requested.

A member of the project staff served as the official DOE observer of the Diversion Path Survey, performed by NRC staff at the GE Vallecitos (California) plant, and as an expert member of the DOE assessment team during review of selected facilities under cognizance of the Richland (Washington) Operation Office. Diversion Path Survey is an evaluation technique developed by NRC that is based, in part, on DPA methodology.

Nuclear Theory. 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.

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.

The charmonium quark structure work by N.P. Samios of BNL and S. Meshkov of NBS, has continued with emphasis on the existence and masses of the pseudoscalar $c\bar{c}$ state (η_c) and its radial excitation η_c'. A reanalysis of the e^+e^- annihilation data from DASP which had led DASP to claim the existence of the η_c at 2.83 GeV led to the conclusion that the claimed state was at most a 2-3 standard deviation effect. Recent experimental searches at SPEAR have found no state at 2.83 GeV, but strong indications of a state at 2.98 GeV which may well be the η_c. Meshkov is working on the properties of the η_c and η_c' and is involved in proposing methods for their detection.

The next most important constituent of the nucleus beyond the nucleons is the Δ_3^3 baryon resonance. The strength of the interaction of this particle with the nucleus is a largely unknown quantity even though it is the key to the understanding of a large part of medium energy phenomena in nuclear physics. Theoretical estimations of the quantity are very uncertain and do not even predict whether this interaction is attractive or repulsive. An analysis was performed to extract the quantity from experimental data using the pion-nucleus scattering data as input. It was determined that the Δ-nucleus interactions can be represented by an attractive potential well of 150 MeV depth.

Neutron dosimetry of the kind required for biomedical uses is usually carried out using ionization chambers. To interpret the results in terms of energy deposited or dose, it is necessary to improve our knowledge of the average ionization per unit energy loss as a function of neutron energy. The latest data have been used to calculate secondary charged particle spectra. These spectra are combined with evaluated ionization yields for these secondary charged particles in order to calculate the average ionization for neutrons from 100 keV to 20 MeV. These values can now be used to average over any given neutron spectrum to give an improved value for W_n, the average energy per ion pair for neutrons.

The secondary charged particle spectra have also been used to calculate energy loss spectra in small spherical volumes. The calculational code has been modified so that one can also work with inhomogeneous chambers and compare with previous results from homogenous chambers. Also included in the calculations are the effects of biological saturation or overkill. The moments of these energy loss spectra with and without overkill have been used to specify the quality of various neutron fields and the effects of changes in the quality on the biological effectiveness of neutrons.

It is useful to understand the spatial distribution of energy from a beam of electrons for biomedical applications. An analytic expression has been developed which accounts for the main properties of the energy deposition with depth and radial distance for a narrow beam of electrons. The model applies to particles for which a large number of small-angle scatters is the predominant transport mechanism. Correction factors which vary slowly with position, source energy, and atomic number can be generated by tabulating numerical results of rigorous calculations in terms of the analytic model.

Detailed treatment of the currently used expressions for the positron bremsstrahlung background in photoneutron and photonuclear experiments using approximately monoenergetic γ rays from positron annihilation has been made, and a detailed analysis of the numerical uncertainties in the currently available theoretical expressions has been developed. In addition, improved and more accurate expressions for radiative tails for elastic and inelastic scattering have been derived, which are at the same time more simple and more useful to the experimentalist. A recent collaboration has been with the group doing total photon absorption measurements at Mainz. These measurements go from about 10 MeV to 30 MeV and include light as well as heavy nuclei. Detailed analyses have been made of all the atomic processes which must be corrected for, in order to extract the photonuclear cross-section.

Photonuclear Research. The study of the interactions of high energy photons and electrons with nuclei can lead to a basic understanding of nuclear physics. On the experimental side we are, and expect to be, involved in three main activities: 1) Photon Scattering using the positron annihilation beam and a large NaI(Tℓ) spectrometer, 2) Electron Scattering using the beam from the NBS Linac and the Electron Scattering Spectrometer with its dispersion matching system, and 3) Electrodisintegration Experiments in which (e,p), (e,α), etc. cross sections are measured and interpreted by means of the virtual photon theory.

Real photons in the energy range 10-30 MeV are traditionally used to study the electric dipole giant resonance, and, in fact, this labortory has contributed greatly to the development of this field of nuclear physics. A beam of quasimonochromatic photons, generated by the in-flight annihilation positrons, has recently been produced in the linear accelerator complex. These photons are being used to measure elastic photon scattering cross sections. We have just completed a measurement of the elastic scattering cross section of ^{12}C in the energy range 20-40 MeV in which we have found a surprisingly large electric quadrupole component. We have just begun a similar study of the nucleus ^{16}O which is of even greater theoretical interest.

During FY-79 the electron scattering group submitted two experimental papers for publication in Physical Review, one - already published - covering a study of the ^{22}Ne giant resonance, and the other - presently under consideration by Physical Review Letters - giving our new determination of the ^{12}C charge distribution. Two new in-house experiments were begun, one to investigate the structure of isospins forbidden magnetic transitions, the other a precise measurement of the ^{4}He charge radius which will provide a critical test of quantum electrodynamics. We have maintained continued outside user interest, performing collaborative study of magnetic transitions in ^{40}Ca and ^{32}S with the intermediate energy physics group at Catholic University, and providing detector calibration for high energy physics groups at William and Mary College and at NASA. This was done using the electron scattering beam line and monitoring equipment. We are involved in collaborative efforts with (i) the University of Massachusetts intermediate energy nuclear physics group to study the high spins magnetic excitations in medium-A atomic nuclei, and (ii) with electron scattering groups at the French and Dutch Centers for Nuclear Studies in a study of the nuclear charge distribution and structure of isotopes of chromium. In addition to this we did trace analysis development work, and performed a trace analysis of samples of semiconductor grade silican doped with boron using an electron scattering recoil difference method. This work was done in collaboration with the members of the Electronic Devices Section at NBS to establish the relation between actural dopent concentration, resistivity measurements, and Hall effect concentration measurements. Finally, an extensive orbit calculation code was developed and used in the design of new magnets to expand the electron scattering capability to include 180° scattering. Based on this work a proposal was made to the DOE for funding to construct and operate a 180° electron scattering user facility.

In electron scattering the scattered electron is detected and the cross section mapped out as a function of the electron's momentum transfer. In the electrodisintegration experiments, on the other hand, outgoing particles or induced radioactivities are detected; here the experiment integrates over all the final states of the electron. A whole new type of experiment has recently been initiated at NBS in which the yield of particles is measured as a function of incident electron energy. These excitation functions are then analyzed using the E1 and E2 virtual photon spectra. In this way we have been able to locate and measure the strength of the E1 and E2 giant resonances that result in proton and α particle emission. This important new work was begun using targets of ^{58}Ni, ^{60}Ni, and ^{62}Ni. We have also begun a study of ^{56}Fe, ^{59}Co, and ^{64}Zn. All six nuclei have important E2 components in the α channel.

The ultimate experiment, which finally unites the electron scattering and electrodisintegration experiments, is, of course, the coincidence experiment in which both electron and outgoing particle are detected. For this we await a C. W. Accelerator. At present, we need to perform experiments from which we can learn which are the most instructive coincidence experiments.

It would be unfair to overlook the importance of the Photonuclear Data Center to all of these, to say nothing of the outside world. This data center abstracts the world's literature on photonuclear reactions and maintains a file of digital cross section data. The data center's library is available for the use of this laboratory and provides a quick and ready access to relevant data and for background information in the preparation of experiments. Outside users have only to request this Center for raw data or for an evaluation that can help in the selection of the best data available for a specific purpose. In this way these files have provided information to further not only basic science but also medical physics, radiation shielding, environmental pollution control, nondestructive testing, and cosmology.

Differential Neutron Standards. The differential neutron standards program, which emphasizes the critical dependence of neutron interactions on neutron energy, has had a productive year. Significant progress has been made in differential nuclear data standards throughout the nearly ten decades of energy with direct impact on efficient fuel usage for commercial power reactors, the safeguarding of nuclear fuel in the fuel cycle, breeding ratio for fast breeder reactors, design of fusion reactor shielding and breeding blankets, fundamental cross sections for fusion reactors, neutron personnel protection, and nuclear weapons and effects. A larger portion of our effort this year has been focused on our Other Agency programs with significant progress in differential measurement methods for safeguarding nuclear material, for neutron dosimetry for testing the integrity of material, for fusion reactor construction, and for improvements in personnel neutron monitors. The wide recognition of NBS neutron measurement expertise is evidenced by major consulting and advisory services performed for the Los Alamos Scientific Laboratory, the Oak Ridge National Laboratory, Battelle Northwest Laboratories, Hanford Engineering Development Labs, Lawrence Livermore Laboratory, Babcock and Wilcox Corporation, and the Bureau of Radiological Health. In FY-79 the group has given ten invited papers in the U.S. and abroad, is represented on six technical and professional committees, and has 17 publications to its credit.

New developments in differential nuclear data standards include a remeasurement of the ^{235}U fission cross section standard in the 200 - 1500 keV range and new efforts in understanding the standards $^{10}B(n,\alpha)$, $^{6}Li(n,\alpha)$, and $^{3}He(n,\alpha)$ used for eV neutron flux measurement. For this low energy region the most important contribution was the recognition that molecular binding in the $^{10}BF_3$ molecule could have a significant effect on the cross section, and confirmation of the effect in experiments at NBS. This is a totally new phenomenon arising from our neutron standards work which is generally present in nuclear reactions involving molecular targets. The impact of this work is being assessed for other nuclear-based technology and measurement systems. Our standard cross sections measurements also are having a direct impact on the DOE program for enhancement of the U.S. light water reactor energy programs. For example, Dr. John Deutch, Undersecretary, Department of Energy, has stated the highest priorities for this program to be (1) "generic safety, (2) reduction of occupational radiation exposure, (3) improvement of plant reliability, and (4) the efficiency of uranium burnup in existing plants." The Differential Neutron Standard Group's work is directly related to items (2) and (4).

A greater emphasis was placed on Other Agency programs this year. Our largest effort has gone into the development of resonance neutron radiography. This method permits radiography of thick samples with both chemical and isotopic discrimination for elements as light as sodium. The objective is to measure not only the spatial distribution of material, but also to obtain accurate ($\sim$ 1%) values for the total mass of constituent isotopes of the sample. The method was first demonstrated in locating imperfections in a silver-solder joint containing about .001" of silver within half-inch thick plates of copper and stainless steel. To improve the quality of our radiographs, neutron position-sensitive detectors have been developed with $\sim$ 1 mm resolution - a factor of five better than previous technology. These improved detectors have been used to measure atom fractions for radiography of a fresh fuel pellet giving isotopic fractions of ^{234}U, ^{235}U, and ^{238}U

to an accuracy of 1%, which meets our accuracy goal. The method is being extended now to spent nuclear fuel analysis, to non-uniform samples such as nuclear waste and scrap, and to non-nuclear applications of this new radiographic method.

The accurately calibrated neutron beams required for the differential cross section standards work continue to be used extensively in improving measurements relating to personnel safety. This work, carried out in collaboration with the Neutron Field Standards Group, has been directed toward improved calibration of personnel dosimeter systems and to more accurate portable neutron field monitors.

The immediate future of the Differential Neutron Standards Group looks promising because of the new recently developed competences of the Group. The progress in resonance neutron radiography offers several attractive opportunities for interesting work with outside support. Our present accuracy achievement of 1% is well within the needs for most programs. Already spinoff from the primary direction for the program has been recognized in the application of position-sensitive neutron detectors for imaging the Fusion Materials Irradiation Test Facility neutron source. We have received many other inquiries on resonance neutron radiography which should be helpful in maintaining a steady flow of O.A. funding. Our established neutron beams and fields will be supplemented by the 14-MeV beam during the coming year. As the problems with existing neutron measurement method for personnel protection are more clearly recognized through these calibrations, the need for better systems will develop with a larger NBS role perhaps in both the development and testing of these sytems.

The NBS is now providing world leadership in the understanding of neutron interactions with matter at the nuclear physics-atomic physics interface. Recent papers have appeared from NBS on the effects of phonons in solids on fission cross sections, the effect of vibrations of gas molecules and molecular disassociation on reaction cross section, and molecular binding effects on fusion cross section measurements. The present base and extension of this work might lead to improved understanding of neutron damage mechanisms on structural materials and life systems. It also opens the possibility of changing or controlling nuclear cross sections with all the possibilities which might follow. The work might lead to improved methods for understanding the physical properties of materials and for radiation therapy.

Neutron Field Standards. Diversity of effort and outside interactions continue to be the clear programmatic characteristics of this group. Neutron field calibrations and related measurements were carried out to help solve standardization problems in reactor physics, materials integrity under radiation stress, personnel neutron dosimetry, new detector development, nuclear safeguards, and depth profiling of tritium in metals. Project personnel performed or directed neutron benchmark field measurements at the Oak Ridge National Laboratory and Arkansas Power and Light Co. for reactor pressure vessel irradiation fuels testing. Computation and evaluation efforts which complement these activities focused on detector response characterization and correction, documentation of benchmark referencing methods, and completion of the primary calculational program for the Intermediate Energy Standard Neutron Field (ISNF).

Facility and capability development moved forward in spite of the heavy measurement responsibilities: (1) the ^{235}U cavity fission source irradiation facility with fission neutron fluxes of 2 x 10^{10} n/cm^{2}sec, was brought to near-routine operation and a first set of twenty-five neutron fluence standards was prepared and distributed internationally; (2) in a complex experiment, the vintage neutron source-strength value for NBS-I, the National Standard Radium-Beryllium Photoneutron Source, was checked against modern experimental values of the number of neutrons per spontaneous fission of californium, (agreement is better than 0.5%); (3) a reference fissionable deposit of ^{240}Pu was mass assayed and became the fifth isotopic species in the NBS set of standard and working fissionable deposits; (4) ^{235}U fissionable deposits were intercompared and sent to the Analytical Chemistry Division for destructive analysis by isotope-dilution mass spectrometry; and (5) the ^{252}Cf-driven Intermediate-Energy Neutron Field (ISNF/Cf) was designed and fabrication of graphite pieces was completed.

The measurement highlight this year, and long anticipated, was a determination of the ^{238}U capture to ^{235}U fission cross section ratio in the NBS Intermediate-Energy Standard Neutron Field (ISNF). Carried out in collaboration with Argonne National Laboratory, the result will contribute to the difficult evaluation of the energy dependent capture cross section for ^{238}U. A notable facet of these measurements was a careful experimental verification of proper boron-10 shell closure to epithermal neutrons in the ISNF. Equally important this year, though less dramatic, was a difficult and seemingly interminable series of fission chamber measurements in PCA, the reactor pressure vessel benchmark at Oak Ridge National Laboratory.

Documentation preparation and committee work formed a larger than usual share of our activities this year. For the Third ASTM-EURATOM Symposium on Reactor Dosimetry, we provided an organizing secretary and a workshop chairman. For the ASTM Subcommittee E10.05 on Neutron Dosimetry, a general secretary and a subtask chairman. For the Nuclear Regulatory Commission, our participation was three-fold: (a) a chairman for the steering committee on ASTM Standards Development, (b) organization help for a "blind test" of neutron transport calculations for reactor pressure vessel irradiation surveillance, (c) liaison for the Seventh Annual Light-Water Reactor Safety Information Meeting. The documentation highlight this year was the distribution of the first two sections of a "Compendium of Benchmark Neutron Fields for Pressure Vessel Irradiation Surveillance," and the preparation of an exploratory report applying the measurement principles and information given in the Compendium. The latter report, entitled "Neutron Flux Measurements in the Pressure Vessel Cavity of an Operating U. S. Power Reactor," is a first attempt to provide elementary methods for benchmark neutron field referencing of neutron dosimetry, including appropriate error assessment and propagation.

Last year's annual report may be consulted for an extended outline of interactions with other Divisions inside of NBS and with outside agencies, institutions, and laboratories. The level and extent of those interactions were essentially unchanged in FY-79.

Plans for FY-80 will be influenced largely by responsibilities surrounding the U. S. Fast-Test-Reactor start-up measurements at Hanford, Washington, and the growing need for neutron fluence standards for surveillance of reactor pressure vessel steel embrittlement.

Radioactivity. Approximately 1500 radioactivity standards and calibrated sources were issued to the public and government, in connection with various quality control or traceability programs. In such programs a calibrated source of one or more radionuclides, of undisclosed value, is sent to each participating laboratory which receives the calibration value, in order to revise the calibration of its measuring systems if necessary, after the laboratory has submitted its results of measurement.

Included in the above figure are sources issued in connection with traceability programs supervised and administered by NBS for the Atomic Industrial Forum, the Food and Drug Administration, the Environmental Protection Agency, the Nuclear Regulatory Commission, and the College of American Pathologists. In addition, under the scheduled testing and special services programs, 100 alpha-particle, beta-particle and gamma-ray emitting sources submitted to NBS by outside laboratories were calibrated.

New standards issued this year using recent calibrations were ^{111}In, ^{133}Ba, ^{169}Yb, ^{195}Au, ^{201}Tl, ^{242}Pu and fly ash certified for ^{226}Ra and ^{228}Ra. Numerous other sources using calibrations obtained on a high pressure ionization chamber were also issued. A considerable amount of progress has been made toward the homogenization of human lung and liver samples using techniques borrowed from powder mixing technology.

A new anticoincidence system was used with a pressurized proportional counter and NaI(Tl) detectors to remeasure ^{54}Mn and ^{134}Cs, and develop an activity calibration for ^{137}Cs. A similar system using a liquid scintillation detector was used to calibrate ^{155}Eu.

A blender facility has been constructed that can handle 10 cubic feet of natural matrix standard material at one time.

Soil from Rocky Flats has been successfully processed and the final blend shown to be homogeneous by gamma-ray counting.

International activities designed to check and improve our activity calibrations included participation in International Bureau of Weights and Measures (BIPM) intercomparisons of ^{55}Fe, ^{134}Cs and ^{137}Cs. In addition, ampoules of 9 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. We contributed to the following International Committe for Radionuclide Metrology (ICRM) exercises designed to improve the measurements of photon emission rates: an intercomparison of ^{133}Ba; a test of dead-time and pile-up corrections; studies of the reliability and sensitivity of impurity searches using Ge(Li) detectors and a study of detector response stability. Nuclear data used in the development of emission-rate or radioactivity standards were compiled at NBS.

A seminar, cosponsored by ICRM, NBS and PTB, was held at Braunschweig, West Germany, to determine needs in quality assurance and traceability in low-level radioactivity measurements. Part of the discussions centered on regulatory requirements for traceability and the possibility that traceability could be instituted internationally through the Office of International Legal Metrology.

Computer-based procedures have been developed for calculating coincidence summing effects in semiconductor detectors as a function of nuclear decay-scheme parameters and detector efficiencies. These calculations will allow standards of multiple-gamma-ray emitting radionuclides, such as ^{133}Ba and ^{152}Eu, to be used for improved efficiency calibration of gamma-ray spectrometry systems. A mixture of ^{125}Sb, ^{154}Eu and ^{155}Eu is being tested as a long-lived standard for routine calibration of such systems.

Commercially prepared mixed-gamma-ray standards, which are a copy of previous NBS standards, are routinely checked against NBS calibrations in order to ensure traceability of the mixture.

PUBLICATIONS

Division 532, Nuclear Radiation

A Manual of Radioactivity Measurements Procedures, NCRP Report 58, extensively contributed to by member of the Radioactivity laboratory (532). (Supersedes NCRP Report 28/NBS Handbook 80) Dec. 1978.

Behrens, J.W., Schrack, R.A., Bowman, C.D., Resonance Neutron Radiography Using a Position-Sensitive Proportional Counter, Transactions of American Nuclear Society, 32, 207, 308 (1979) (Am. Nuclear Society Annual meeting, June 3-7, 1979.

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Division 532, Nuclear Radiation

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Division 532, Nuclear Radiation

Babcock and Wilcox. Measures for safeguarding nuclear fuel. Roald A. Schrack.

Battelle Northwest Laboratory. Development of a ^{3}He neutron spectrometer. Robert B. Schwartz.

E.G.&G.-Idaho, Loss of Coolant Accident Tests - Power Burst Facility. Evaluation of Uncertainties in determining burst energy desposition. Edward D. McGarry.

Hanford Engineering Development Laboratory. Fusion Materials Irradiation Test Facility (FMIT), review of neutron dosimetry methods and recommendations. Charles D. Bowman.

Hanford Engineering Development Laboratory, FTR Operations. Development of accurate power level monitoring scheme for reactor physics measurements during FTR start-up. David M. Gilliam.

IAEA and U.S. Department of State, International Safeguards Program Office. Development of tamper-proof power rector level monitor. Ivan G. Schroder.

Lawrence Livermore Laboratory, Experimental Physics Division. Photonuclear and neutron physics, accelerator development, and γ-ray lasers. Charles D. Bowman.

Los Alamos Scientific Laboratory. Fission foil preparation for fission physics studies. James W. Behrens.

Nuclear Regulatory Commission. Measurement problems related to the Three Mile Island accident. Frank J. Schima, Michael Unterweger, and Robin Hutchinson (members of the Radioactivity laboratory).

Nuclear Regulatory Commission, Division of Operating Reactors Office of Standards Development and Division of Regulatory Research. Task Action Plans for Unresolved Safety Issues. Edward D. McGarry and James A. Grundl.

Nuclear Regulatory Commission, Office of Standards Development. Performance testing of personnel dosimetry services. Val Spiegel and Charles M. Eisenhauer.

Oak Ridge National Laboratory, Neutron flux measurement methods and the consequences of chemical binding. Charles D. Bowman.

Division 532, Major consulting and advisory services (Cont'd.)

President's Commission on the Accident at Three Mile Island. Task Group on Health Physics and Dosimetry, May 1979-October 1979. Charles Eisenhauer.

Sandia Corporation, Applied Physics Division. Investigation of possible depth-profiling techniques for tritium in metals. Ivan G. Schroder.

Division 532, Nuclear Radiation

The radioactivity group supplied standard reference materials (SRM's) of the following radionuclides: ^{3}H, ^{32}P, ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{75}Se, ^{85}Kr, ^{99}Mo, ^{99m}Tc, ^{125}I, ^{127}Xe, ^{131}I, ^{133}Ba, ^{133}Xe, ^{201}Tl, ^{203}Pb.

JOURNAL EDITORSHIPS

Division 532, Nuclear Radiaton

Bowman, C.D., Editor of the Proceedings of the International Conference on Nuclear Cross Sections for Technology. University of Tennessee, Knoxville, Tennessee, Oct. 22-26, 1979

Caswell, R.S., Associate Editor, Radiation Research

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

Hayward, E.V., Editor of Physical Review C

Mann, W.B., Editor, Environmental International

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

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

Division 533, Radiation Physics

Introduction

The Radiation Physics Division consists of five groups, two from the previous Optical Physics Division (Electron Physics and Far UV Physics), and three from the previous CRR organization (Dosimetry, X-Ray Physics, and the non-nuclear part of Radiation Theory.) The functional organization effective for most of FY 79 is listed after the summaries of technical activities for the five groups. The functional statement for the Division is as follows:

"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 ionizing 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."

This Division combines three groups concerned with photon and electron energies above about 10 keV, with two groups concerned largely with energies below about .25 keV. It is important not only that there develop suitable activities from .25 to 10 keV, but that there be activities somewhat independent of energy region, in which different groups have joint concerns and interest.

A major step towards activities with relevance to all groups was the decision to fund (with $300 K per year for five years) a Competence Proposal on Physical and Chemical Effects of Ionizing Radiation on Matter. Leader of this project is to be Dr. Pierre J. Ausloos, of CTMS. The group itself will be about evenly divided between CTMS and CRR personnel. Much of the experimentation will take place in Bldg. 245, where some of the main radiation sources to be used are located: the SURF II, the 4 MeV Van de Graaf, and the Febetron 705. The studies will be largely directed to radiation effects in selected materials in liquid or solid state. More details on the goals of this project are given in the descriptive statement on New Competence.

We are also pleased to report a $200 K base increase in the funding of SURF II. Part of this increase will be used to augment the support staff for the facility, while another part will be used to encourage new users, particularly within NBS. Dr. Ausloos' new group plans to be among the new users of the facility, hopefully beginning sometime in FY 80.

Some unusual recognitions this year for exceptional work performed by scientists in this Division have occurred; and we would like to call attention to the awards and honors given to R. J. Celotta, S. R. Domen, R. P. Madden, W. L. McLaughlin, and S. M. Seltzer, as recorded later in this report.

Radiation Theory

Work by the Radiation Theory Group has included two principal components: a) the critical evaluation and compilation of photon and charged particle cross sections; and b) the use of these cross sections to determine the penetration, diffusion, and degradation of radiation in bulk matter, with emphasis on medical, national defense, space, and industrial applications.

The X-ray and Ionizing Radiation Data Center has published tabulations of relativistic Hartree-Fock atomic form factors for all elements from Z = 1 through Z = 100, based largely on the work of Øverbø, Doyle and Turner, and Cromer and Waber. These form factor data are in turn being used to develop improved and extended mass absorption coefficients and energy-absorption coefficients for materials of general interest as well as materials of special biomedical interest. The data on energy-absorption coefficients are required by two ICRU task groups concerned with radiation dosimetry in biological applications.

Tables of electron stopping power and range have been prepared covering the energy region 0.1 to 1000 MeV, and more than 50 materials of dosimetric interest. Up-to-date values were used of the mean excitation energy, derived from the analysis of heavy-particle stopping power and range data, and from the analysis of oscillator strength distributions. The density effect correction to the collision stopping power was evaluated according to the formulation by Sternheimer and Peierls. The radiation stopping power was thoroughly revised to take account of fundamental advances in bremsstrahlung cross section theory by Tseng and Pratt, and by Haug. Screening factors for the bremsstrahlung cross section have been reevaluated using form factors and incoherent scattering functions recently developed by Hubbell at NBS.

Turning to radiation transport studies: exploratory track-structure calculations have been carried out for electrons, x-rays, and Co-60 gamma rays in water. Although the ionization yield (per unit absorbed dose) is the same for all three types of radiations, there are significant differences in the spatial pattern of the ionization events. This provides a physical basis for explaining observed differences in biological effectiveness between low-energy x-rays and Co-60 gamma rays.

Ionization yield calculations for molecule hydrogen have been completed on the basis of a set of cross sections due to Gerhart, and also a modified set of cross sections agreeing equally well in regards to fundamental integrals over the oscillator strength but in better agreement with experimental data on low-energy excitations. It turned out that Gerhart's cross sections gave ionization yields in much better agreement with experiments . A theory of the ionization yield was also developed which gave results in close agreement with the numerical studies.

Transport studies for specific applications include the development of electron, bremsstrahlung, and proton depth dose data for space-shielding requirements. The longer-lasting duration of present and planned satellite missions, and the increasing use of radiation sensitive metal-oxide semi-conductor devices, make it important to have accurate estimates of radiation dose levels inside spacecraft. A set of depth-dose distributions has accordingly been developed for omni-directional electron and proton fluxes incident on aluminum shields. The main feature of this work is the accurate Monte Carlo treatment of the electron-produced bremsstrahlung component. In addition to the absorbed dose at different depths, the dose to thin tissue-equivalent detectors was also obtained.

Studies of shielding against nuclear radiations, primarily resulting from detonation of nuclear weapons, has continued. Various transport calculations and critical data evaluations pertinent to shielding against the initial gamma rays and neutrons from nuclear detonations have been carried out, partly in-house and partly through subcontracts. A short paper has been completed which describes methods for estimating initial gamma ray penetration into structures, and comparisons with analogous Monte Carlo studies. Extended studies include both gamma rays and neutrons incident on walls and roofs, and gamma rays generated by neutrons in structures, with procedures to take account of complexities resulting from windows and internal walls and floors. In addition to these developments, a book on shielding against fallout gamma rays has been revised to include recent data on fission spectra. This definitive treatise, which sums up many years of research by NBS and many other laboratories, is undergoing final editorial revisions.

An unusual byproduct of S. Seltzer's transport computations occurred this past year: a hand-held readily portable x-ray fluoroscopic system has been developed in a collaborative effort by L. Yin and J. Trombka of NASA, and S. Seltzer of NBS. Called the Lixiscope, the system has an x-ray image intensifier tube roughly the size and shape of a hand-held magnifying glass and powered by a 3 volt battery. The sensitivity of this intensifier makes possible real-time x-ray examinations using low-intensity, commercially available radioisotopes in lieu of an x-ray machine. Given much publicity, the device has been selected by the Industrial Research/Development magazine as one of the 100 most significant "new technology" advances of 1979.

Dosimetry

The program of the Dosimetry Group is to provide a reliable basis for radiation dosimetry, principally in medicine and radiation protection. This program involves establishment and maintenance of the NBS dosimetry standards, dissemination of the units established by those standards by means of calibration services and development of necessary measurement technology, and measurement assurance activities to test whether measurements by radiation users are in adequate agreement with NBS standards.

The NBS ionometric standards of exposure are periodically checked for constancy, but no other development or test of these standards has been carried out in FY 79. The NBS calorimetric standards of absorbed dose have been tested by comparison with the NRC in Canada, showing agreement within 0.3%, and with VNIIFTRI in the USSR, showing agreement within about 2%. The latter incomparison, considered unsatisfactory, is now being repeated due to differences in the laboratory conditions at the time of measurement. The use of a graphite calorimeter as a standard of absorbed dose to water presents a special problem. It has been studied for a cobalt-60 γ-ray beam by ionization measurements in water and in graphite phantoms over a range of distances, depths, and field sizes that allow comparison with a theory based on the predominance of Compton interactions. The theory, with certain corrections, has been verified and will serve to provide a flexible and reliable basis for relating absorbed-dose calibration in water to the NBS graphite calorimeter.

Because the pi meson beam used for radiation therapy at LAMPF contains a variety of ionizing particles in addition to pi mesons, and because pi mesons react with matter in a complex manner, the radiation dosimetry cannot be simply based on a standard of absorbed dose. The NBS graphite calorimeter was taken to Los Alamos for measurement in a pi meson beam, at the same time that measurements were made with a calorimeter made of "tissue-equivalent" plastic, various ionization chambers, and other radiation detectors. The necessary dosimetry information is obtained by comparing the response of these different detectors. In order to improve the accuracy of this work, a new calorimeter is under construction made of A-150 tissue-equivalent plastic, at the Memorial Sloan-Kettering Cancer Center. A member of the Dosimetry Group took part in the design studies for this calorimeter, carrying out heat-flow calculations and measurements of thermal diffusivity and conductivity of the A-150 plastic, these measurements leading to a publication that is now in press. That calorimeter is nearing completion, and will be compared with the NBS calorimeter both in the NBS cobalt-60 beam and at the LAMPF pi meson beam.

The NBS graphite calorimeter is believed to be at least the equal of any other graphite calorimeter designed for absorbed-dose determination, but because of certain essential construction details, and because the information wanted is absorbed dose to water, the existing graphite standard is not, in principle, an ideal standard. Work is now underway on a water calorimeter that should in principle be very close to an ideal absorbed-dose standard. Preliminary tests have been satisfactory and design and construction are proceeding on an instrument that, it is hoped, will serve as a new NBS standard of absorbed dose in water, and will also be useful for measurement in the field in a variety of practical situations.

With regard to calibration services, the regular services provided by the Dosimetry Group have continued during FY 79. About 40 instruments have been calibrated in terms of exposure, involving about 300 calibration points. Approximately 30 irradiations of passive dosimeters were carried out, involving 560 separate dosimeters. Programming for on-line data processing using the mini-computer is now complete for all x-and gamma-ray sources. A calibration service for small sealed sources of iridium-192 is now routinely available, and sources have been calibrated for both manufacturers of the sources and for a number of medical physics laboratories. It is expected that the number of iridium-192 sources submitted for calibration will grow during the current year. In response to a rapidly growing use in cancer therapy, it is planned to establish a routine calibration service for sealed sources of iodine-125, though the low energy and short half-life present special problems.

The measurement assurance activities of the Dosimetry Group take a variety of forms. Work was completed on the technical aspects of preparations for a survey of the dosimetry of high-energy x-ray beams used in radiation therapy. Thermoluminescence dosimeters were calibrated in a selected irradiation geometry with low-energy x-rays, with cobalt-60 gamma radiation, and with x-rays generated at 4, 6, and 10 MV. These irradiations were tied to the NBS calorimetric absorbed-dose standard where possible, and also to the NBS exposure standards. The pilot study will be carried out by the Bureau of Radiological Health during FY 80. Approximately 60 measurements were made for the dosimetry of high-energy electron therapy beams, employing Fricke ferrous sulfate chemical dosimeters. Initial steps were taken to investigate the feasibility of producing a Fricke dosimeter of sufficient stability to function as a standard reference material. Assistance and advice were continued to the University of Michigan School of Public Health in connection with the pilot study of personnel-dosimetry performance. Tests were carried out to ensure traceability to NBS of the irradiation of dosimeters performed by the University of Michigan for the processors participating in the pilot study. The three regional calibration laboratories accredited by the American Association of Physicists in Medicine have been again tested by circulating calibrated dosimeters, and their traceability to NBS standards continues to be excellent.

X-Ray Physics

The x-ray physics program involves three main areas, including radiology for medical, industrial, and defense applications, high radiation dose measurements for industrial and defense applications, and plasma x-ray measurement systems for the development of nuclear fusion energy sources.

In the area of radiology, the program is directed toward the evaluation and improvement of the components of the x-ray imaging system such that with a given x-ray exposure, the available image information content is increased. In this program, we have developed an experimental method to evaluate the propagation of noise in the fluorescent x-ray screen which is the x-ray sensitive component in medical imaging systems. Based on this method, which employs sophisticated light photon counting techniques, we have formulated a "Figure of Merit" which for the first time will permit a quantitative comparison of the information transfer properties of different commercial x-ray screens. We have introduced this method to the University of Arizona medical physics group who are now extending the measurements for evaluating the noise propagation properties of x-ray image intensifiers. Also, these screen measurements provide basic data on the number conversion factor from x rays to light photons, which is an important parameter related to screen speed. In anticipation of the development of new types of digital and computerized x-ray imaging system, we have determined the image information storage requirements for any given x-ray exposure, spatial resolution, and image size. For the evaluation of high energy industrial radiographic systems, we have initiated a program to develop standard x-ray beams with quasi-monoenergetic energies in the region from approximately 0.1 to 1.0 MeV with accurately determined flux densities, fluences, and spatial uniformity of the beam intensity over a given area. We have played a major role in developing an official ASTM radiographic standard for measuring image quality response of industrial x-ray film. We are developing an ANSI standard for medical x-ray screens related to spectral radiometry and to the new ANSI film sensitometry standard. We have evaluated an industrial image quality indicator for the purpose of developing a standard for the measurement of radiographic definition (unsharpness).

In cooperation with the fracture mechanics and ultrasonics groups at NBS and the radiographic groups at Rockwell International (Rocky Flats) and Southwest Research Institute, we are providing consulting services for pipeline inspection to the Department of Transportation, in which we (a) provide radiographic data needed for considering waiver requests for questionable welds, (b) compare the diagnostic accuracy of the available nondestructive evaluation techniques, and (c) recommend improvements in pipeline radiographic inspection procedures. At the request of the Department of Defense, we have accepted a program to assess the qualifications of laboratories assigned to carry out the radiographic and real-time inspection of strategic missiles. Finally, we provide radiographic inspection services for NBS and outside users, for many types of objects such as handcuff locks for the Law Enforcement Assistance Agency, or rodent and pest repellant devices for the Consumer Affairs Agency.

In the area of high-dose measurement technology, calibration service to industrial laboratories and national programs has expanded to more than 50 participants during the past year. In the use of ionizing radiation for sterilizing products, the successful use of dosimetry for sterility assurance and product release by the manufacturers (under the endorsement of the FDA) is largely due to the efforts of the NBS-CRR standardization program. The many hospital and medical supply industries now widely using gamma rays and electron beams to sterilize goods safely depend on the NBS calibration service to standardize their radiation fields and measurement devices. The use of electron beams for this purpose is expanding. For example, Radiation Dynamics, Inc., IRT Corp., Johnson & Johnson, Electronized Chemicals, Inc., Columbia Research, Inc., and Energy Sciences, Inc. are among the companies employing high-intensity electron beams for industrial sterilization. All these industries use NBS assistance for dosimetry problems that are generally more difficult than those encountered in gamma-ray sterilization. Dosimetry methods have been established for detailed and accurate determination of absorbed dose distributions in heterogeneous products irradiated with electrons of 0.4 to 4 MeV from accelerators available at the CRR. Traceability to NBS standards is essential for measurement assurance, which is the chief factor in the release of safe products to the public. NBS continues to participate in the International Atomic Energy Agency Dose Intercomparison Study for Radiation Processing (at dose levels of 10^3 - 10^5 Gy). The study is being expanded in 1979-80 to include lower dose levels for applications in the areas of agriculture, public health, and medicine (dose levels of 10 to 10^3 Gy). In a national dosimetry intercomparison program to be completed in 1980, NBS-CRR is the central standard reference laboratory in the round-robin study conducted by a consortium of U.S. and Canadian companies engaged in radiation sterilization of hospital and health care goods (Association for the Advancement of Medical Instrumentation). Also initiated this year was the project monitoring for several collaborative international programs between NBS and Poland, Egypt, and Yugoslavia dealing in general with industrial radiation processing.

In addition to the national and international standards for the processing industries, dosimetry measurement standards have been developed for users in NASA, DOD, and national laboratories sponsored by DOE concerned with radiation damage effects in electronic semiconductor devices and systems. Three standards addressing the dosimetry of photons and electrons have been published (by ASTM) this year and three others addressing the measurement of neutron spectra are in the final steps of the approval process. These standards are particularly important to industrial radiation-hardness testing facilities that are concerned with supplying electronic systems used in tactical and strategic weapons systems as well as in deep-space probes. These standards should improve the reliability, reproducibility, and uniformity of the dosimetry employed by such facilities. In addition to these standards, a new isotope source calibration service will be made available to the hardness-testing facilities based on the existing industrial-processing calibration service but tailored to the needs of electronic semiconductor radiation hardness testing. A new program, in collaboration with the Naval Research Laboratory, will be initiated next year to develop dosimetry techniques for measurements on low-energy flash x-ray machines used in electronic device hardness testing.

NBS-CRR has been enlisted, partly by industry and partly by DOD, to develop practical dosimetry for emergency use by military and civilian personnel. This will be supported in part by a new NBS Research Associate Program in which two research scientists for Bicron Corp. will spend a year at NBS-CRR to assist in the development program. The dosimetry system will be designed to demonstrate several practical features: tissue equivalence, stability, small size, ruggedness, simple visual readout of dose between 0.3 and 10 Gy, and large batch uniformity.

In the area of plasma diagnostics, one of the most important tools for the determination of plasma temperature and other parameters is a measurement of the x-ray spectra emitted by the plasma. Recent advances in this technology indicate the need for the calibration of the x-ray detectors used in the energy region from 0.1 to 5 keV. In addition, the intensity levels must be sufficiently high to permit these calibrations to be performed on detectors which have very small single photon response and high background levels. To facilitate this task, NBS is continually improving and expanding the monoenergetic x-ray sources in this region. In the past year, the absolute spectra of monoenergetic K lines generated by the bombardment of carbon, aluminum, iron, and copper targets have been measured. When added to the previously available sources from beryllium and titanium targets, NBS can now provide approximately 6 calibration energies in the region from 100 eV to 6 keV. These sources are now being used to calibrate solid state x-ray detectors used in the PLT and TFTR inertial confinement experiments at Princeton and the ISX facility at Oak Ridge. In addition, NBS has been engaged in a round robin detector calibration program which includes seven government and university laboratories. This program is aimed at providing a consistent detector calibration program among those laboratories engaged in laser fusion experiments and requires that NBS calibrate the round robin detectors and coordinate the calibration by the other laboratories. At the present time, the detectors have been circulated and data compilation and comparison have begun. These data will provide essential measurement assurance for the intercomparison of x-ray diagnostic data reported by the participating laboratories.

Far Ultraviolet Physics

Experiments utilizing our new high-flux normal-incidence monochromator at SURF were initiated in the fall of 1978. This instrument delivers up to 2×10^{11} photons/sec-Å of monochromatic flux to the experimental sample, higher than that reported by any other synchrotron radiation laboratory. Therefore SURF staff and collaborators have been able to initiate several new and innovative experiments. A photoelectron spectrometer capable of 100 meV resolution and also allowing the angular distribution of electrons to be measured is currently installed on this monochromator and is being successfully used to study small molecules. It is the first such experimental system to be put into operation with a continuum source and having such angular and resolution capabilities. Initial photoionization studies on N_2 and CO have yielded new and significant results on the effects of shape resonances upon vibrational transition intensity distributions and upon angular asymmetry parameters. Studies also include the effect of autoionization upon photoionization partial cross sections and angular asymmetry parameters. These experiments are being done as a collaboration between SURF staff, the first SURF Fellow, Argonne National Laboratory, and the University of Alabama.

A preliminary experiment on the high flux instrument was carried out by SURF staff to prove the feasibility of studying fluorescence in atomic metal vapors (Ba). This work will be continued when a new fluorescence monochromator is obtained in late 1979. Still another experiment on this new instrument has been the study of Stark mixing in high Rydberg autoionizing states of atoms and molecules. First results of this pioneering work have been obtained for selected rare gases and molecular nitrogen. Concurrent theoretical development seeks to explain the effects in terms of Stark mixing of the optically forbidden absorption channels with the optically allowed channel. These Stark experiments have also been performed on our 3-meter high resolution monochromator. Here the trade-off is to accept lower counting rates for higher resolution in selected cases where the resolution is required. This effort is a collaboration between SURF staff and CAPQ in the person of John Cooper. Overall, our work on the high flux instrument this year has resulted in six talks, three manuscripts submitted for publication (one Phys. Rev. Lett. in print), and four manuscripts in preparation.

In other activities at SURF, Jack Rife, using our 2.2 m grazing-incidence monochromator, has succeeded in detecting helium microbubbles in thin aluminum films by measuring the pressure-broadened helium resonance line in absorption. Preliminary results show that for heavily bombarded films (2.7 atomic percent helium and 100 Å mean bubble diameter) the helium resonance line broadens to ∿ 30 Å FWHM and is blue shifted as theoretically expected. Direct comparison of the broadening with that observed in the reflectance from liquid helium (12 Å FWHM) suggests that the helium density in the microbubbles is very high indeed, and that shifts due to a distribution of bubble diameters and isolated atoms trapped interstitially may contribute to the broadening. Annealing effects will be studied in the near future to shed light on these phenomena. This has been the first successful absorption measurement on helium microbubbles and was performed in collaboration with the University of Notre Dame de La Paix in Belgium.

Our guest workers from the Naval Research Laboratory have had a very productive program running at SURF on our beam line #8 torroidal monochromator. They have been studying mainly insulator materials in reflection, photoemission and fluorescence, have a paper in publication, two others in progress and have given several talks on their work. They have just installed a Nd-Yag laser to attempt two photon absorption (one laser photon, one SURF photon) in wide band gap insulators. Guests from Oak Ridge National Laboratory visited once again to continue the work on soft x-ray absorption and emission edges in metals, and we had visitors from Goddard Space Flight Center, Johns Hopkins University and the Naval Research Laboratory at SURF to use the spectrometer calibration beam line for space experiments and fusion plasma diagnostics. Components of the large calibration chamber for spectroscopic instruments, funded by NASA are now arriving daily. We expect this facility to be functioning by the end of 1979. Guests from the University of Virginia have made several visits to SURF to test a Redicon detector in the soft x-ray region. The latest configuration using a phosphor overcoating has proved quite successful. Our collaborative program with Los Alamos on the measurement of photoemission yields in the soft x-ray region has continued to produce new results.

Laboratory activities off-SURF include the completion of the first stage of the program to develop a technique of trace impurity analysis. This stage consisted of reliably detecting small numbers of atoms of a selected species by resonant laser-ionization in a proportional counter. Sodium was chosen to demonstrate the technique: less than 50 Na atoms cm^{-3} were injected into the proportional counter and irradiated by two collinear lasers, one tuned to the 3s-3p transition at 5896 Å and the other to the 3p-4d transition at 5686 Å. From the 4d state, a photon absorbed from either laser will produce ionization. Pulses proportional to the number of laser-produced electron-ion pairs were obtained only when the two lasers were tuned close to the atomic resonances. The next stage will involve the introduction of a solid sample in the proportional counter, the controlled ablation of part of the sample, and the elemental analysis by resonant laser ionization of the material in the ablation cloud. This work is a collaboration involving T. B. Lucatorto of the Radiation Physics Division and S. Mayo of the National Engineering Laboratory.

In another effort the technique of resonant laser excitation-ionization of dense vapors, discovered here several years ago, has been applied to Ba in an experiment designed to extend the technique to produce doubly-ionized atoms. We have now successfully produced and studied a dense column of Ba^+ ions as the first step in the two-stage experiment. The next step will involve irradiating the Ba^+ column with intense laser radiation tuned to the 6s-6p resonance of Ba^+ (at λ = 4935 Å). Initially it is expected that the laser will produce a large excited state population of Ba^+ (6p); subsequently, through the transfer of this excitation energy to the free electrons in the plasma by the process of superelastic collisions, it is expected that the absorbed laser energy will ionize the Ba^+ into Ba^{++}. This phenomenon will provide a unique opportunity both to study the laser excitation-ionization mechanism itself and to study the energy levels and photoionization of Ba^{++}. This project is a collaboration between Far UV Physics Staff and the Atomic and Plasma Radiation Division.

An important aspect of our VUV radiometric activity is the calibration and supply of transfer standard photodiodes. Much of this activity is off-SURF at present. We have recently overhauled our calibration facilities, interfacing the experimental apparatus with microcomputers and developing software to operate switching functions and the acquisition and reduction of data. This year we completed 46 outgoing far UV detector calibrations, the largest output since the program was initiated in 1971. These transfer standards were deployed to a broad constituancy including solar physics. MFE, astrophysics/astronomy, aeronomy, standards laboratories, space simulation facilities and plasma and solid state physics. We also co-organized a workshop on the VUV Radiometric Calibration of Space Experiments in March 1979 and hosted and organized a National Conference on Synchrotron Radiation Instrumentation which met in June 1979.

Electron Physics

The Electron Physics Group has ongoing research efforts in high resolution electron scattering, uv photoemission, electron optics and instrumentation, electron interaction theory, and electron polarization phenomena. It is the interaction of electrons with matter and the common instrumentation which unites this group, rather than a focus on a specific problem.

Our work on the study of electron polarization phenomena continues to explore new areas of research. We have made a leap in the technology of producing polarized electron beams that enables us to perform many desirable experiments for the first time. Two classes of such experiments are the scattering of a spin polarized electron beam from heavy atoms to observe the effect of the spin orbit interaction, and the scattering from an oriented spin system to observe effects due to the exchange interaction. This year we were able to do both types of scattering experiments for the first time with a polarized electron gun. Our targets were clean, single crystal metal surfaces, tungsten for the spin-orbit scattering and nickel for the exchange interaction. In the tungsten work, we have demonstrated a symmetry principle and obtained a set of polarization data that is extremely sensitive to the exact diffraction conditions. This should enable theorists to provide better, more reliable determination of surface structure through a comparison of our data with polarization calculations based upon assumed structural models. Further work on different crystals and studies of electronic surface resonance scattering and of surface reconstruction are planned.

Our most recent measurements have demonstrated that the exchange interaction may be used to observe the surface magnetization of a nickel single crystal. This opens the door to studies of surface magnetism and how it differs from bulk magnetic phenomena. A parallel can be drawn to neutron scattering which has been very successful in understanding bulk magnetism. Whereas neutrons are weakly interacting and probe the bulk, electrons are strongly interacting and probe only the first few angstroms of a material. This permits us to study the temperature and magnetic field dependence of the surface magnetization.

This measurement technique is, in effect, a very sensitive surface magnetometer. With it, we plan to measure surface critical phenomena, to determine whether or not the surface layers are magnetically active or "dead", and to investigate the role of the magnetic d electrons in chemisorption and catalysis.

Our expertise in the use of electron beams with very narrow energy distributions has been focused recently on the interaction of monochromatic beams with single metal crystals and adsorbed molecular layers. A technique that is now finding wide application in surface chemistry is the observation of vibrational excitation of a substrate-adatom normal mode by monitoring the exciting electron's energy loss. While this technique is usually used as a "fingerprint" technique, we are interested in understanding the physics of the excitation process. We are studying the probability of electron energy loss as a function of the incident electron energy. There are a number of possible mechanisms that would provide a resonant enhancement of the vibrational excitation at specific incident energies. Our apparatus has been modified to observe and to discriminate among the possible effects. We have obtained ultrahigh vacuum, high angular and energy resolution, and clean single crystal surfaces and are about to begin the first measurements.

In our photoemission work a study of the metallic glasses has been performed from both the experimental and theoretical point of view. In a collaborative effort with the Allied Chemical Company, we have used uv-photoemission to determine the electronic structure of this new class of materials. The photoelectron spectra of 5 different palladium-silicon alloys taken both below and above the glass transition temperature have been analyzed and will soon be submitted for publication.

A previously developed theory of the satellite that has been observed in Ni valence band photoemission experiments has been extended to include the resonant behavior of the satellite which exhibits a maximum at a photon energy of 67 eV. Satellites have also been observed in the core level spectrum of Ni as well as several other transition metals and we have developed a theory to account for them. The physical mechanism is different from that causing the Ni valence band satellite. The theory has been used to calculate the Ni 3p spectrum and represents the first such calculation. Agreement between theory and experiment is very good.

The electron optical design program has progressed in two directions over the last year. Detailed transport calculations were made for high current, heavy-ion beams where space charge is an important consideration. For this purpose codes were developed for the Texas Instrument ASC computer, a very high speed, vector machine located at the Naval Research Laboratory. Also, progress was made in augmenting our computer system for the design of low energy electron optics and monochromators. The quick access and graphical display now available aid significantly in the development and use of new, state-of-the-art electron optical devices.

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Celotta, R. J., "Low Energy Electron Diffraction with Polarized Electrons," Greater Washington Surface Science Seminar, NBS, 11/8/78.

Celotta, R. J., "A Polarized Electron Gun: Its Application in Surface Physics," RCA David Sarnoff Laboratories, Princeton, New Jersey, 4/5/79.

Celotta, R. J., "Recent Experiments with Spin Polarized Electrons," Physics Department Colloquium, University of Chicago, Chicago, Illinois, 6/7/79.

Celotta, R. J. "Scattering Experiments with Polarized Electrons at NBS," Johannes Gutenberg-Universitat, Mainz, West Germany, 9/11/79.

Celotta, R. J., "Magnetic Scattering of Polarized Electrons," University of Bielefeld, Bielefeld, West Germany, 9/12/79.

Celotta, R. J., "Polarized Low Energy Electron Diffraction: The Magnetic and Non-Magnetic Cases," IFF der KFA, Julich, West Germany, 9/14/79.

Dick, C. E. and Motz, J. W., "Number Distribution of Photons Emitted from X-ray Screens, 21st Annual Meeting of American Association of Physicists in Medicine at Atlanta Hilton Hotel, Atlanta, Georgia, July 29 - August 2, 1979.

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Hubbell, J. H., "A New Extended-Range NBS/NSRDS Evaluation and Compilation of X-Ray Cross Sections and Mass Attenuation Coefficients for Z = 1 to 100." 5th European Crystallographic Meeting, International Union for Crystallography (IUCr), Special Session on X-Ray Attenuation Coefficient Project, Ørsted Institute, Copenhagen, Denmark, 8/17/79.

Hubbell, J. H., "Radiation Physics Programs at the National Bureau of Standards," Lebedev Physical Institute, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R., 8/22/79; Joint Institute for Nuclear Research, Dubna, U.S.S.R., 8/28/79; and Leningrad Institute of Nuclear Physics, U.S.S.R. Academy of Sciences, Gatchina, U.S.S.R., 9/12/79.

Loevinger, R., "International, National, and Regional Dosimetry Standardization Programs," American Association of Physicists in Medicine, San Francisco, California, August 1978.

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Loevinger, R., "The Role of the Standards Laboratory in Brachytherapy," Workshops in Advances in Brachytherapy, American Association of Physicists in Medicine, Sturbridge, Massachusetts, October 1979.

Lu, T.-M., "Lattice Gas Models and Surface Phase Transitions," Solid State-Surface Physics Joint Seminar, Physics Department, University of Maryland, College Park, Maryland, 3/14/79.

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Madden, R. P., "New Radiometric Calibration Facility for SURF II," Vth International Workshop of the VUV Calibration of Space Experiments, NCAR, Boulder, Colorado, March 1979.

Madden, R. P., "A Status Report on the SURF II Synchrotron Radiation Facility at NBS," National Conference on Synchrotron Radiation Instrumentation, NBS, Gaithersburg, June 1979.

McIlrath, T. J., "Spectroscopy of Laser Driven Plasmas," Colloquium at University of Virginia, April 1979.

McLaughlin, W. L., "Dosimetry for Industrial Applications," 6th Conference of Nordic Society for Radiation Research and Radiation Technology, Hirtshals, Denmark, August 1978.

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McLaughlin, W. L., "A National Standardization Programme for High-Dose Radiation Measurement," International Atomic Energy Agency, Advisory Group Meeting on High-Dose, Intercomparison and Standardization, Vienna, Austria, September 1978.

McLaughlin, W. L., "Standardization of Dosimetry for Radiation Processing," IAEA, Advisory Group Meeting on High-Dose Intercomparison and Standardization, Vienna, Austria, September 1978.

McLaughlin, W. L., "Dose Distributions in Irradiated Wire Insulation, 6th Conference of Nordic Society for Radiation Research and Radiation Technology, Hirtshals, Denmark, August 1978.

McLaughlin, W. L., "The Response of Plastic-Dosimeters to Gamma and Electrons at High Absorbed Dose Rates," 2nd International Meeting on Radiation Processing, Miami, Florida, October 1978.

McLaughlin, W. L., "Electron and Gamma-Ray Dosimetry Using Radiation-Induced Color Centers in LiF," 2nd International Meeting on Radiation Processing, Miami, Florida, October 1978.

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McLaughlin, W. L., "Temperature and Humidity Effects on the Gamma Ray Response of Plastic and Dyed Plastic Dosimeters," 2nd International Meeting of Radiation Processing, Miami, Florida, October 1978.

McLaughlin, W. L., "Commissioning Dosimetry in a Versatile Irradiation Plant," 2nd International Meeting of Radiation Processing, Miami, Florida, October 1978.

McLaughlin, W. L., "The Measurement of Absorbed Dose and Dose Gradients," at University of Lowell Seminar on Radiation Sterilization of Plastic Medical Devices, Lowell, Massachusetts, March 1979.

McLaughlin, W. L., "New Standard Methods for Radiation Industries," Department of Industry Seminar, National Physical Laboratory, Teddington, England, 9/19/79.

McLaughlin, W. L., "Tissue-equivalent Dosimetry in Radiation Theory," Seminar at Mt. Vernon Hospital, Northwood, England, October 1979.

McLaughlin, W. L., "International Dosimetry Intercomparison Studies at High Radiation Dose Levels," Radiation Chemistry Symposium of Polish Institute of Nuclear Research, Warsaw, Poland, October 1979.

McLaughlin, W. L., "Radiochromic Imaging Systems for Medical Diagnostics, Colloquium of Risø National Laboratory, Roskilde, Denmark, October 1979.

McLaughlin, W. L., "Radiation Dosimetry at Interfaces of Different Materials, Advisory Group Meeting International Atomic Energy Agency, Hungarian Academy of Sciences, Budapest, Hungary, November 1979.

McLaughlin, W. L., "A National Calibration Service for Radiation Processing Industries, talk to Dosimetry Section, International Atomic Energy Agency, Vienna, Austria, November 1979.

McLaughlin, W. L., "Muscle- and Bone-Equivalent Radiation Dosimeters for Radiation Therapy Studies," Seminar of Department of Clinical Physics, University of Glasgow, Scotland, September 1979.

Penn, D. R., "Panel Discussion: Polarization of Electrons Emitted from Ferromagnets," Transition Metals 1977, Conference Series No. 39, 1978.

Pierce, D. T., "Spin Polarized Low Energy Electron Scattering from Surfaces," Physics Colloquium, University of Maine, Orono, Maine, 5/11/79.

Pierce, D. T., "A Polarized LEED Study of Surface Magnetism," 1979 International Magnetism Conference, Munich, West Germany, 9/6/79.

Pierce, D. T., "Polarized LEED (PLEED): A New Tool for the Measurement of Surface Magnetism," E.T.H. Laboratory, Zurich, Switzerland, 9/10/79.

Pierce, D. T., "Polarized Electron Scattering Studies of W(100) and Ferro-magnetic Ni(110) Surfaces," Physikalisches Institut der Universitat Munster, Munster, West Germany, 9/13/79.

Pierce, D. T., "Surface Physics Studies with Spin Polarized Electrons," Stanford University Solid State Seminar, 11/27/78.

Pierce, D. T., "Spin Polarized Low Energy Electron Scattering from Surfaces, "Bell Labs. Surface Science Seminar, Murray Hill, New Jersey, 3/16/79.

Pierce, D. T., "Spin Polarized Low Energy Electron Diffraction, University of Wisconsin, Madison, Wisconsin, 5/2/79.

Placious, R. C., "Sizing Pipeline Girth Weld Flaws from Field Radiographs," ASNT Spring Conference, San Diego, California, April 1979.

Placious, R. C., "The Development of Industrial Radiographic Film Standards," ASNT Topical Conference, Asheville, North Carolina, August 1979.

Placious, R. C., "Evaluation of X-Ray Variables Using the ASTM Image Quality Indicator," ASNT Topical Conference, Asheville, North Carolina, August 1979.

Saloman, E. B., "Study of Practical Extreme Ultraviolet Photocathode Materials," Vth International Workshop in the VUV Calibration of Space Experiments, NCAR, Boulder, Colorado, March 1979.

Seltzer, S. B., "Electron, Electron-Bremsstrahlung and Proton Depth-Dose Data for Space Shielding Applications," IEEE (Institute of Electrical and Electronics Engineers) Annual Conference on Nuclear Space and Radiation Effects, University of California, Santa Cruz, California, 7/17/79.

Wang, G.-C., "Quantitative Island Size Determination and Phase Transition in an Overlayer Oxygen on W(110)," Solid State Physics Seminar, University of Maryland, 1/31/79.

Wang, G.-C., "LEED-A Probe to Study Defects, Islands and Phase Transitions on Surfaces," Metallurgical and Material Sciences Seminar, Brookhaven National Laboratory, Upton, New York, 8/9/79.

West, J. B., "Photoelectron Spectroscopy of Molecules using Synchrotron Radiation," Colloquium given at University of Virginia, March 1979.

SPONSORED CONFERENCES

Division 533, Radiation Physics

Conference on Synchrotron Radiation Instrumentation, NBS June 4-7, 1979.

Vth International Conference on VUV Radiation, University of Virginia, Charlottesville, VA, June 1980.

Fifth Workshop on the VUV Radiometric Calibration of Space Experiments, NCAR, Boulder, CO, March 1979.

SURF User Meeting, NBS, Gaithersburg, December 1978.

CONSULTING AND ADVISORY SERVICES

Division 533, Radiation Phyics

1. C. E. Dick consulted with R. Deslattes and E. Kessler on use of the 4 MeV Van de Graaff as a radiation source for various experiments utilizing a high precision gamma ray spectrometer. These experiments are now underway with the following goals in mind: 1) Measurements of the K absorption edge of medium to high Z nucleii, 2) Precise determination of the negative kaon mass.

2. S. R. Domen has provided consultation and technical advice on construction and operation of absorbed-dose calorimeters to individuals at several national standards laboratories (including Holland, Belgium, U.K., USSR), as well as to the Memorial Sloan-Kettering Cancer Center on construction of a calorimeter suitable for measurement of pi mesons.

3. J. C. Humphreys began participation in joint NBS-Egypt Special Foreign Currency project, "Development of Ionizing Radiation Dosimetry Systems and Standards for Application in Industrial Radiation Processing," in collaboration with Egyptian National Center for Radiation Research and Technology, Cairo, Egypt.

4. J. C. Humphreys performed 3 MeV electron beam irradiations and related dosimetry measurements on prototype polyethylene ion chamber caps for RADEF Instrumentation Test Facility, Washington Navy Yard, Washington, D.C.

5. J. C. Humphreys assisted in planning of dosimetry for collaborative project with Sandia Labs., Albuquerque, New Mexico, for upcoming underground nuclear tests.

6. J. C. Humphreys advised on dosimetry techniques for calibration of 30 MeV electron beam at White Sands Missile Range, New Mexico.

7. J. C. Humphreys participated in dosimetry intercomparison study for U.S. Association for the Advancement of Medical Instrumentation, Arlington, Virginia, in connection with their program to improve and standardize radiation sterilization procedures.

8. J. C. Humphreys advised Converters, Inc. (American Hospital Supply Corp.), El Paso, Texas, on their dosimetry procedures and calibration needs.

9. W. L. McLaughlin assisted in commissioning of a UN-sponsored radiation facility at the Boris Kidric Institute of Nuclear Science in Yugoslavia for sterilization of medical supplies. NBS-CRR contributed technical assistance and dosimetry planning to the Yugoslavia scientists.

10. W. L. McLaughlin consulted and advised on dosimetry measurements and calibration of White Sands Missile Range, New Mexico, 30 MeV electron beam accelerator.

11. W. L. McLaughlin consulted on radiation dosimetry program for the Burn Treatment Center, Armour Foundation, Phoenix, Arizona.

12. W. L. McLaughlin consulted on the measurement of large radiation dose for Battelle NW Labs., Seattle, Washington.

13. W. L. McLaughlin consulted on radiation dosimetry for radiation preservation of food for U.S. Army Natick R & D Command, Natick, Maine.

14. W. L. McLaughlin consulted on design of new personnel dosimeters for U.S. Army Electronics Command and Defense Civil Preparedness Agency.

15. W. L. McLaughlin provided advise to the following organizations in their plans to use radiation for industrial applications: ENCO Corp., Asheville, North Carolina, Miami-Dade Sewer and Water Authority, Miami, Florida, Baxter Travenol, Chicago, Illinois, Johnson & Johnson, Lamont, Illinois, Radiation Dynamics, Inc., Melville, New York, IRT Corp., San Diego, California, International Nutronics, Palo Alto, California, Converters (American Hospital Supply Corp.), El Paso, Texas, Atomic Energy Agencyof Canada, Ltd., Ottawa, Canada, Risø National Laboratory, Roskilde, Denmark, Ray Chem Corp., Menlo Park, California, Radiation Sterilizers, Inc., Los Angeles, California, and Innovative Chemicals, Inc., Baton Rouge, Louisiana.

16. R. Loevinger has continued to served as a member of the Advisory Group of the IAEA/WHO Network of Secondary Standard Dosimetry Laboratories, Vienna, Austria. In this capacity he has provided editorial assistance and has helped plan the training of individuals who will take charge of the Secondary Standard Laboratories.

17. R. C. Placious served as radiographic member of advisory team to NASA Langley, Virginia, on the safety inspection of a cryogenic wind tunnel prior to recommissioning.

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

18. D. T. Pierce, C. E. Kuyatt and R. J. Celotta consultated with groups from Bell Labs, IFF of the KFA (Germany) and ETH (Zurich) on the practicality of and best approach for spin polarized photoemission experiments.

19. D. T. Pierce and R. J. Celotta consulted on the design, construction, and operation of GaAs polarized electron sources with a number of universities and laboratories both in the U.S. and Europe.

JOURNAL EDITORSHIPS

Division 533, Radiation Physics

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

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

TECHNICAL ACTIVITIES

Division 534, Radiometric Physics

INTRODUCTION

The major program directions of the Division are spectroradiometry and optical pyrometry, spectrophotometry, electro-optical (detector-based) radiometry, and photometric-radiometric calibrations. The Division is organizationally subdivided into four Groups, with one corresponding to each of these program directions. Research and services in all these areas is restricted to the wavelength range above 200 nm. The Division coordinates very closely with other Divisions in CRR having some radiometric programs in the vacuum ultraviolet portion of the spectrum below 200 nm. This coordination within the Center has been particularly strong recently in connection with planning for the potential role of CRR in providing measurement support for the National Climate Program.

The Division has several broad objectives:

(1) Provides the National Measurement Laboratory with resources of talent and expertise on general problems involving the measurement of optical radiation.

(2) Conducts research to improve the accuracy and extend the range of optical radiation measurements.

(3) Develops methods and standards for both detector and source based radiometry and provides technical resources in this area for the solution of problems in other government agencies, industry, and the public sector.

(4) Develops calibration procedures, standards of reflectance and transmittance, and highly accurate reference instrumentation for spectrophotometry.

(5) Conducts research in electro-optical technology and the associated radiometric measurement problems.

(6) Characterizes quantum detectors and slitless spectroradiometers by use of tunable lasers and electrically calibrated pyroelectric detectors.

In the last ten years, the economic and social impact of radiometric and photometric measurements has increased significantly. Optical radiation measurements are required in many manufacturing processes (e.g. lamps, automated cameras, copying machines, color TV). Our energy problems are creating new measurement needs. Twenty-five percent of the U.S. electrical power is used for lighting, and developing higher efficiency lamps requires the best photometry available. The development of more efficient solar collectors and solar cells will be affected by the accuracy of the radiometry employed. Optical radiation measurements are required for health and safety. Phototherapy is used almost exclusively in the treatment of some diseases (e.g. jaundice in prematurely born infants). Regulatory agencies in the government are concerned with the hazardous effects of UV on the eyes and skin (skin cancer). Considerable time and money are spent on the radiometry and photometry associated with these problems. The electro-optical industry now has annual sales of about 15 billion dollars. A leading instrument manufacturer has estimated that about 200 million dollars are spent each year in calibrating radiometric systems or resolving discrepancies in these measurements.

The effectiveness of the Division's program in improving radiometric and photometric measurements in the NMS is estimated from various laboratory intercomparisons, feedback from calibration customers, and interaction with the Council for Optical Radiation Measurement (CORM), the Lamp Testing Engineers Conference (LTEC), a number of governmental laboratories, and various national and international committees such as those of the CIE, ASTM, ANSI, IES, and MCCA.

SPECTRORADIOMETRY AND OPTICAL PYROMETRY

This program 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. Optimizing the accuracy of these measurements also requires a thorough understanding and characterization of instruments and the radiation field itself. Therefore, there are activities in this program under all four of these categories: Instruments, Standards, Techniques, and the Radiation Field. These activities are listed in Table I and positioned horizontally so as to indicate the portion of FY 1979 and/or FY 1980 for which they have been or are intended to be pursued. For example, the first item in the table, "New laboratory for coherence and polarization studies", was completed in FY 1979 while the last activity listed under Standards, "Development of an improved IPTS", will be initiated about the middle of FY 1980. The four categories and the activities associated with them that are listed in Table I will be discussed approximately in the order in which they appear.

Instruments

There are two types of instruments which we usually investigate and characterize in great detail. One type constitutes instruments that we ourselves have developed in order to realize a particular scale or perform a particular calibration. The second type consists of instruments that we are asked to evaluate for other government laboratories.

A new facility in the Division for coherence and polarization studies has been set up because we expect in the next few years to be

TABLE I. ACTIVITIES IN THE SPECTRORADIOMETRY AND OPTICAL PYROMETRY PROGRAM

	FY 1979 / FY 1980
INSTRUMENTS	New laboratory for coherence and polarization studies
	Improved (0.01 deg) large area blackbody calibration facility - DOD
	Portable spectroradiometer/computer interface - Measurement Assurance Program, EPA. DOD
	Evaluation of UV Hazard Meter and UV-Visible-IR Scanning Spectroradiometer - BRH
	Spectroradiometer Characterization Facility - EPA
	New State-of-the-art, Automated NBS Optical Pyrometer
STANDARDS	Realization and maintenance of International Practical Temperature Scale (IPTS) and scales associated with spectral radiance and irradiance
	Resolve differences between the NBS and National Physical Laboratory (England) Spectral Irradiance Scales
	Detector Stabilized Tungsten Strip Pyrometer Lamps
	Development of an improved IPTS
TECHNIQUES	Characterization of and new technique for determining the slit-scattering function of monochromators
	Radiometric guidelines for plant scientists working in controlled environments
	Development of a model demonstrating that large errors in radiometry are often due to the variation of the instrument responsivity with respect to various radiation parameters
	New state-of-the-art for solar terrestrial spectral irradiance measurements between 280 and 320 nm - EPA
	Compilation and detailed description of techniques for determining departure from linearity for radiometers - Self-Study Manual (SSM) - DOD
RADIATION FIELD	Polarization characteristics of a variety of light sources - CIE
	Determination of the effect of coherence on radiometric measurements
	Detailed treatment of time as a radiation parameter (SSM)
	Chapter in Self-Study Manual (SSM) on Blackbody Radiation & Temperature Scales - DOD

concerned with uncertainties of 0.1% in spectroradiometric measurements and standards. As a result, we will have to make a more accurate correction for polarization effects than was necessary in the past. This laboratory will provide the tools required to do this. The principles utilized for such corrections were developed in Chapter 6 of our Self-Study Manual on Optical Radiation Measurements* that was published about two years ago. Coherence is a radiation parameter than has been given little attention in radiometry. We do not expect the effect of coherence to be significant with other than laser sources except when the optical beam is confined to a very small solid angle or cross-sectional area. Nevertheless, we need to address this question more quantitatively as we move towards requirements for smaller and smaller uncertainties in spectroradiometric measurements. In addition, we are beginning to use lasers in characterizing the responsivity function of spectroradiometers and must demonstrate that the resulting function may be used with high accuracy when performing measurements of highly incoherent sources.

The large-area blackbody calibration facility was developed to calibrate blackbodies at temperatures between about 225 K and 350 K with an uncertainty of 0.2°. These blackbodies have been used for calibrating radiometers used in remote sensing. The Navy now needs a one-inch-square blackbody calibrated as a FLIR radiance standard with a relative accuracy approaching 0.01°. We have improved the above-mentioned facility sufficiently for this requirement and began the required calibration in September, 1979.

The portable spectroradiometer/computer interface refers to developing a computer-controlled, portable spectroradiometer for use in an NBS Measurement Assurance Program, in a program with the Environmental Protection Agency (EPA) that will be discussed below, and for the DoD primary standards laboratories. The effort involves modifying commercially available monochromators, photometers, and microcomputers and developing the necessary interface and computer programs to operate these together as an easy-to-use, versatile, and automated spectroradiometer. Though entire systems of this type are now becoming commercially available, they are still very expensive and not sufficiently versatile for our needs. Our first system is now complete and is being used in a variety of experiments. This experience will be used in developing the computer controlled spectroradiometer required for the EPA work to be described below.

The UV Hazard Meter is an instrument designed by the Bureau of Radiological Health (BRH) and built commercially for the purpose of

*For those not familiar with this publication it is a comprehensive treatise on radiometry which is detailed enough for self-instruction and is being published one or a few chapters at a time as an NBS Technical Note in the 910 series.

measuring the biologically weighted irradiance of a variety of sources for safety and regulatory purposes. We have determined the accuracy of the instrument when viewing a number of common sources having different spectral distributions in the UV and have also characterized the relative responsivity function and linearity of the instrument. We also expect to characterize the UV-Visible-IR Scanning Spectroradiometer when it is delivered to BRH by the manufacturer. In general, we are continuing to provide BRH with radiometric consultation and instrument evaluation required by them in order to insure a sound spectroradiometric measurement base for their regulatory responsibilities.

We are in the process of setting up a laboratory for characterizing the responsivity function of UV spectroradiometers designed to measure the solar terrestrial spectral irradiance between 280 and 320 nm. The heart of this facility is a frequency-doubled dye laser with an output power of a few milliwatts in this spectral range. The EPA is supporting this effort because such measurements provide a method of determining the atmospheric concentration of ozone. This will be discussed in more detail below.

A new state-of-the-art automated NBS optical pyrometer is being designed for realizing the International Practical Temperature Scale (IPTS) between 200 K and 2600 K with an accuracy in terms of spectral radiance of about 0.1%. Determining the temperature of blackbodies in this temperature range is one of the major limitations in the uncertainty currently associated with spectral radiometric standards. This instrument is intended to be the first step in reducing the uncertainty of these standards by a factor of about 3 (from 1% and 3% in the visible and UV respectively to about 0.3% and 1%).

<u>Standards</u>

The Spectroradiometry/Optical Pyrometry Program is responsible for performing the basic experiments for realizing the standards associated with the IPTS above the melting point of gold and spectral radiance and irradiance standards from 200 nm to 1.6 μm. These standards are then used in the Division's extensive program of calibration services.

During an informal spectral irradiance intercomparison between 200 and 250 nm carried out with the National Physical Laboratory (NPL) in England, a 10% difference at 200 nm has been observed. Our standard in this region is based on a wall-stabilized hydrogen arc maintained by the Atomic and Plasma Radiation Division while NPL's standard is based on synchrotron radiation. An effort will be made in FY 80 to resolve this difference.

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 have performed some preliminary research a few years ago in utilizing silicon detectors for monitoring these lamps and correcting 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 improving spectroradiometric source standards by a factor of three, more stable lamps are required. We plan to develop a simple radiometer utilizing a silicon detector to monitor tungsten lamp standards in order to correct them for any observed instabilities. This will be tried first with tungsten ribbon filament lamps used as transfer standards in optical pyrometry.

Current techniques for realizing the IPTS at 2500 K are limited to about 1 kelvin. We plan to try to improve this by a factor of three (resulting in a 0.1% effect in terms of spectral radiance) by using the new automated NBS pyrometer now being developed and an automated beam conjoiner developed in this Program a few years ago. The new Spectroradiometer Characterization Facility referred to under Instruments is also vital for this effort in order to accurately determine the relative spectral responsivity function of the new pyrometer. It will be possible to perform a new IPTS realization utilizing the above instruments in a short enough time (15-30 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 changes will be reduced.

Techniques

"Precise Instruments and Accurate Standards do not Insure Accurate Measurements" is the title of a paper published in "Optical Radiation News" during the past year. This paper emphasizes that special techniques in handling the data and sometimes additional experiments are necessary because the radiation field being measured and that of the standard are frequently quite different, and the responsivity function of the measuring instrument is usually sensitive to these differences. Radiation fields may differ relative to flux level and to the so-called radiation parameters. These are position and direction at the receiving aperture of the radiometer, wavelength, time and the polarization and coherence character of the flux. The activities listed in the Techniques category of Table I are associated with ways of dealing with these differences.

These differences and resulting errors if they are not taken into account was the central theme in a paper delivered by our Division to plant scientists working in controlled environments at a conference held this past year at the University of Wisconsin. The Division is helping organize and will participate in a radiometric round-robin involving major laboratories in this discipline to assist them in documenting their measurement differences and uncertainties.

The slit-scattering function of a monochromator, from which the spectral responsivity function may be obtained, has traditionally been determined by spectrally scanning an isolated spectral line. Research performed in the Division during the past year has demonstrated that the accuracy of such a determination is very poor except for approximately one spectral slit width on either side of the peak of the function. In addition, we have extended the traditional technique by using several spectral lines which significantly improves the accuracy some distance from the peak. This work was reported at the 1979 Annual Meeting of the Optical Society of America and will be particularly useful in obtaining an accurate relative spectral responsivity function for monochromators used in improving the state of the art for solar terrestrial measurements in the 290 nm region.

Accurate solar terrestrial spectral irradiance measurements between 280 and 320 nm are needed because the UV in this region is detrimental to most living things. We estimate that the current uncertainty of measurements below 295 nm is 50% or more. EPA would like to determine any changes in the solar terrestrial irradiance in this region much more accurately than this. Spectral measurements in this region can also be used to determine the amount of atmospheric ozone between the sun and the point of observation. We have been conducting an extensive developmental program for the EPA aimed at producing a new state of the art for spectral irradiance measurements in this region (uncertainties of about 5%). The effort involves utilizing a newly developed double monochromator with significantly higher wavelength accuracy, accurately determining the spectral responsivity function of this instrument, making field measurements to test the instrument, deconvoluting the resulting data to correct for spectral scattering and spectral curvature, and finally, preparing a detailed monograph describing the instruments and procedures used so that they may be set up and used routinely at UV monitoring stations throughout the U.S.

The final activity listed under Techniques in Table I is determining the departure from linearity for radiometers. This is a well-known source of error in radiometry. It is a particular case of responsivity variance where the flux responsivity varies with the magnitude of flux incident on the radiometer. In most modern day instruments this is only a problem when trying to limit errors to about one percent or less. It will be of prime importance in trying to develop an improved IPTS. With financial support from DoD, where non-linearity problems are frequently encountered, we are preparing, in FY 80, a chapter in the Self-Study Manual on techniques for determining the amount of linearity in radiometers.

<u>Radiation Field</u>

Since for reliable radiometry the differences between the radiation field being measured and that of the standard must be known when the responsivity function is not invariant with respect to all radiation parameters, a detailed characterization of these fields is required. Table I lists the work associated with this activity that has been conducted in FY 79 and that is planned for FY 80.

The report on polarization characteristics of light sources has been prepared for the Commission Internationale de l'Eclairage (CIE). If this organization does not publish it in its entirety, we will probably include it as a chapter in the Self-Study Manual.

We have been performing a comprehensive study of the principles of and recent experimental developments in the subject of coherence. During FY 1980 we plan to determine whether or not coherence effects will be significant in our effort to reduce the uncertainty of spectroradiometric standards by a factor of three and begin to develop techniques for correcting for these effects.

Characterizing a radiation field relative to the radiation parameter "time", indicated next in Table I, will enable us to generalize the Measurement Equation introduced in Chapter 5 of the SSM to include time. This is essential in any definitive measurements involving rapidly varying radiation fields. For example it will be of great importance when developing standards and measurement techniques for pulsed radiometry which we are considering starting in FY 1981, subject to funding and staff availability.

Finally, relative to the activities under Radiation Field, a chapter in the Self-Study Manual on blackbody radiation and temperature scales, supported by DoD, is planned for FY 1980. This will be one of the few recent chapters of the SSM that is almost completely tutorial. Chapters 5 through 8 developed new ideas and approaches that are important for developing a new state of the art in spectroradiometry. The material in this new proposed chapter, particularly that on temperature scales, has been lacking in the background of many radiometrists, and, to the best of our knowledge, is just not available in the published literature.

Before ending this presentation of the Spectroradiometry/Optical Pyrometry program, we would like to make a few brief comments about the direction the program will probably take in FY 81 and beyond. By the end of FY 81 we expect to have completed a new improved IPTS, a method of handling coherence effects in radiometry and a complete analytic treatment of time as a radiation parameter. We expect to have initiated experimental studies on measuring and improving the quality of our high temperature blackbody and on extending the concept of detector stabilized lamps from pyrometer lamps to radiometric lamp standards that are used over a much broader spectral range. By FY 82 it should be possible to use the results of all the activities described in this review of the Spectroradiometry/Optical Pyrometry program to obtain spectroradiometric standards and techniques with uncertainties significantly less than 1%

and to begin to apply these to high-accuracy, long-term measurements required in the U.S. Climate program.

SPECTROPHOTOMETRY, MAP & RESOURCE RECOVERY

Establishing, improving and disseminating the spectrophotometric scales in the National Measurement Systems are the main objectives of the spectrophotometry program. The program is being pursued through:

(1) Development of new measurement capabilities and techniques;

(2) Development of Measurement Assurance Programs (MAP's) and Standard Reference Materials (SRM's); and

(3) General consultation and services to the spectrophotometric measurement community.

Current and planned activities in the above three areas will be discussed below.

In the area of new measurement capabilities, the spectral range of the NBS reference spectrophotometer has been extended from the ultraviolet and visible regions out to 2500 nm during FY79. Evaluations were performed for stray light, linearity and wavelength accuracy.

A specular reflectometer has been constructed and tested for calibrating the reflectance of mirror standards over the spectral range 250 nm to 2500 nm with an uncertainty of about ±0.2%. This instrument is a measurement accessory to the reference spectrophotometer, which is also used for measurements of diffuse hemispherical spectral reflectance and 45°/0° spectral reflectance. The specular reflectometer is designed to measure mirror reflectances at angles of incidence between 5° and 80° using a beam tracking system with a stationary detector. An NBS Technical Note documenting the instrument is in the process of editorial review. This new NBS capability generated considerable interest when a technical paper on it was presented at the recent annual meeting of the Optical Society of America.

The newly developed hazemeter has been evaluated to have an uncertainty of ±0.2%. A description of the development and testing of the instrument was published in Applied Optics this year.

The reference retroreflectometer has also been improved in electronics, source and detector optics. The instrument has been completely characterized for source and detector spectral distributions, angular setting, linearity and over-all performance. The uncertainty for luminous retroreflectance measurement is about 1 to 2%. The technical paper describing the instrument and its performance is in the process of editorial review and will be submitted for journal publication.

In the area of MAP/SRM, a five-year plan for new MAP development has been completed and approved by the NBS Office of Measurement Services. The objectives of the five-year plan are to make the following MAP Services routinely available:

(1) Coefficient of luminous intensity (CIL) and chromaticity for retroreflectance, and

(2) The 6°/hemispherical, 45/0, and translucency for diffuse reflectance.

The CIL and chromaticity MAP development is planned for testing laboratories, manufacturers of retroreflecting materials, big buyers, and state highway departments as a means of ensuring equity in domestic and international trade and of ensuring accuracy for retroreflectance measurements. This MAP service is intended to replace the special calibration service for CIL. The 6°/hemispherical and 45/0 diffuse reflectance MAP service is planned for testing laboratories, instrument manufacturers, and central laboratories of multicompanies as a way of diagnosing their measurement problems, and to ensure accuracy and equity in trade. This MAP service is intended to replace the currently available calibration services for these types of diffuse reflectances. The translucency MAP development is planned in anticipation of growing measurement problems on translucent materials.

Effort has been started and will be devoted in FY80 to investigate parameters influencing measurements on candidate MAP materials. These parameters include temperature, pressure, incidence angle, observation angle, cleaning, stability, humidity, etc. A Diffuse Reflectance MAP package is planned to be completed at the end of FY80 and a Retroreflectance MAP package is planned to be completed at the end of the first quarter of FY81.

Wavelength standards have been produced as SRM 2009, 2010, 2013, and 2014. Wavelengths of minimum transmittance and inflection points in the transmittance curve of didymium glass filters provide a convenient basis for calibrating the passband centroid of spectrophotometers with bandwidths between 1.5 and 10.5 nm. The publication, describing the calibration, uncertainty, and use of didymium as wavelength standards is in press and will be published as NBS SP260-66.

Efforts were initiated in FY79 and will continue into FY80 to select and produce SRM's for the solar energy community. Reflectance and transmittance are two of the key optical properties identified for performance tests for materials commonly used in solar heating and cooling systems such as glass and plastics for cover plates, absorptive coatings, and reflective and anti-reflective coatings. For a mirror solar concentrator system, one of the key optical properties is specular reflectance. We have started the solar energy SRM project on diffuse reflectance. The

SRM's consist of one white and one black diffuse reflector calibrated in the solar wavelength range and at several angles of incidence. The solar energy SRM's on specular reflectance will be started in FY80 for both first-surface and second-surface mirrors.

A NSF/AU High-Ability Summer Program student, Mr. Richard W. Watkins, joined us in July and August this year. Mr. Watkins assisted us in the solar energy SRM project with computer programming and measurements.

Reflectance standards are used to establish accurate photometric measurements of diffuse reflectance. Such materials as white opal glass, procelain enamel, or ceramic tiles are useful because they possess the required reflectivity and durability characteristics needed for everyday use as working standards. Unfortunately these materials do not work well as ultraviolet reflectance standards. By nature most materials absorb strongly at these shorter wavelengths. The few materials that do possess a high reflectivity in the ultraviolet are powders such as barium sulfate which are inconvenient for use as every day working standards. Such materials are easily contaminated, and fresh specimens cannot always be prepared with reproducible results.

The spectrophotometry group has developed an experimental permanent working standard of diffuse reflectance for the ultraviolet spectral range. The standard combines the use of a high purity polytetrafluoroethylene powder and an ultraviolet transmitting quartz cell. This white powder has a higher reflectivity in the ultraviolet than any other known material. The all-quartz cell has a cavity into which the powder is pressed. An ultraviolet transmitting window on the cell is designed to allow the cell to be fitted to the reflectometer integrating sphere so that the total reflectance of the powder in the cell and the window reflectance are included in the measurement. The ultraviolet reflectivity of this experimental working standard is being studied in order to determine its stability. The absolute reflectance techniques required to check the stability, will have to be repeated over a period of at least two years in order to establish these results. The fabrication of the quartz cell was funded by NASA. The calibrations of certain ultraviolet instrumentation being used on orbiting satellites are traceable to absolute reflectance measurements at NBS. Due to increasing requests, a comprehensive study has been started on the reflective properties of the high purity polytetrafluoroethylene powder in the wavelength region 250 nm to 2500 nm. The study includes absolute scale of directional-hemispherical reflectance with several angles of incidence, goniodistribution, and influence of density and method of preparation on reflectance.

Optical transmittance density SRM's are produced for photographic and related industries: x-ray film step tablets (non-destructive testing); microcopy resolution test charts; and photographic step tablets. Two new SRM's are planned to start in FY80: reflectance step tablets and reflectance density card SRM's.

In the area of consultation and services, the expertise of the Spectrophotometry group staff is called on regularly, and last year more than one hundred calls and letters for consultation have been answered and over forty special spectrophotometric tests and calibrations have been carried out. These consultations are with individuals in the measurement community who have specific questions or who are developing new measurements. Special measurements are performed for industrial laboratories and other government agencies, such as USDA, EPA, and CPSC, when these measurements are not available commercially. Staff members have been actively involved in committees in the CIE, ASTM, ISCC, and VESC sun screening committee. Measurements have also been provided for a Collaborative Reference Program jointly sponsored by NBS/NEL and MCCA.

ELECTRO-OPTICAL RADIOMETRY

The Electro-Optics Group is responsible for 1) providing a more fundamental basis for photoprocess 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 group currently consists of three physicists, an electronics engineer, and a mechanical engineering technician. This size is below critical mass to fulfill the responsibilities described above due to the large number of new needs and new opportunities that have grown up over the past few years as a direct result of the electro-optics revolution. Despite this fact, the group has been highly productive since its creation in 1975 and extremely significant developments in radiometry have come from this group over the last five years. Before reviewing last year's achievements, we will give an overview of the E-O group programs.

The group's efforts on behalf of photo-physical, -chemical and -biological process characterization fall within four program elements, 1) the Detector Response Transfer and Intercomparison program, 2) a recalibration of the potassium ferrioxalate chemical actinometer in collaboration with R. Velapoldi of the NBS Center for Analytical Chemistry and J. Demas of the University of Virginia, Chemistry Department, 3) development of a characterization capability to assure the accuracy of NASA and NOAA solar constant monitoring programs to within an uncertainty of ±0.1% over periods long compared to a solar cycle, and 4) the calibration of solar cells for other government agencies to use as standards in their solar energy conversion programs.

The group's efforts in introducing new technology into radiometry include: 1) the development and application of electro-optical modulators in feedback loops for amplitude stabilization of lasers, and the demonstration that amplitude stabilized, cw lasers are virtually ideal radiometric characterization tools, 2) the refinement and application of AC-DC flux superposition techniques to a wide variety of linearity and additivity studies, 3) fundamental studies of laser induced opto-galvanic effects in hollow cathode lamps for application to dye laser wavelength calibration, and 4) the development of more accurate, convenient, and/or versatile absolute radiometric components such as the electrically calibrated pyroelectric radiometer. The latter was developed in collaboration with R. Phelan, C. Hamilton, and G. Day of NBS, Boulder, B. McIntosh of Laser Precision, Inc. and W. Blevin, of Australia's National Measurement Laboratory. This work received an IR 100 award for 1975.

The introduction of lasers into radiometry allows a considerable simplification of the conceptual basis for radiometric calibrations. For most radiometric applications, laser radiation can be considered a Dirac delta function distribution with respect to the radiation parameters, wavelengths, position, direction and polarization. Therefore, it is possible to conceive of various radiometric calibrations based on lasers in terms of direct measurements of radiant power, rather than comparisons of various radiant power concentrations, such as radiance, irradiance, and intensity, but there are a number of aspects of this approach that require a more detailed investigation. The coherence of the radiation field is a problem only in those cases where diffraction introduces a serious source of error. All radiation fields are, in fact, partially coherent and judicious experimental design is required to eliminate or account for such errors even if the source is not a laser.

Having covered the general framework of the E-O group programs, we now turn to a review of specific achievements in various of these program areas during FY 1979.

Measurements and Standards for Photoprocess Characterization

During the last fiscal year, twenty-two laboratories participated in the Detector Response Transfer and Intercomparison Program: a novel and well-received calibration program developed by the E-O group. The initial problems encountered in 1978 have been eliminated from both the instrumentation and the procedures.

The structure of this detector calibration program was designed to achieve three principal objectives: (1) to maximize the accuracy of the transfer of spectral response calibrations from the NBS radiant power measurement base, (2) to assess the calibration transfer capabilities of the participating laboratories, and (3) to provide these calibrations to the greatest number of laboratories in the shortest possible time and at reasonable cost.

To satisfy the first objective the radiometer was designed and the detector selected to fulfill specific radiometric requirements. A rather detailed study was then made of various critical electronic and radiometric properties. The third objective was satisfied by limiting the number of radiometers that were built and characterized. Because of the limited number of well characterized radiometers available they could not be sold as is the case with standard lamps. Instead, the radiometers are leased to each participating laboratory for a period of a few weeks. The leasing arrangement has several obvious advantages: The rental cost to each user is much lower than would be the purchase price of the calibrated radiometer. The radiometers are returned to NBS so that they can be remeasured and their stability checked. And a "fresh" calibration can be obtained as often as deemed necessary by the individual laboratory.

The second program objective, that of assessing the overall state of the art of detector spectral response calibrations, was achieved by requesting feedback information from each participating laboratory. Several diagnostic and intercomparison experiments were designed to assess the magnitude of suspected problems in detector spectral comparison measurements. The E-O group is currently working with the Dissemination Group of the Division to transfer the responsibility for this calibration to them.

Due to staff limitations, we were unable to provide continuous calibrations on the DRIPs throughout the entire silicon spectral range. At present the calibrations are limited to the region between 390 nm and 860 nm. Isolated calibration points are provided at a few wavelengths outside of this region, but an interpolation scheme has yet been developed. The extension of this service down to 200 nm and up to 1600 nm utilizing similar systems based on germanium photodiodes, for the long wavelengths, will require considerable future effort.

During this same period, we assisted in verifying the 0.4% change in solar luminosity measured by Dr. R. C. Willson of the Jet Propulsion Laboratory (JPL) on sounding rocket flights in June 1976 and November 1978. We independently analyzed the pre- and post-flight intercomparison data, and provided consultation in studies of the radiometric parameters of his instrument. We also acquired an electrically calibrated solar pyrheliometer from the Physicalisch-Meteorologisches Observatorium in Davos (PMOD) for use by NBS in monitoring pre- and post-flight intercomparisons. This instrument was provided in recognition of our past assistance to PMOD's solar meteorology and climatology programs. As discussed in the next section, we also developed a new reflectometer for measuring cavity reflectance.

Research, Development and Application of New E-O Technology

Silicon photodiodes are the detectors most widely used for optical radiation measurements in the visible region of the electromagnetic spectrum. When employed in this capacity, their calibration is based on electrical substitution radiometers or on thermal physics of blackbodies.

The possibility of basing these calibrations directly on the quantum physics of the internal photoelectric effect in silicon has been suggested frequently. As a result, the E-O group has undertaken a program in this area as an outgrowth of the characterizations of silicon photovoltaic diodes for the detector response transfer program.

Considerable progress in understanding the details of the photovoltaic effect in real silicon photodiodes was achieved during the last year. A new model of the front region collection efficiency has been derived. It is appropriate to devices in which a pronounced maximum doping concentration occurs between the front surface of the device and the junction. Devices based on boron diffusion followed by thermal oxidation as well as ion implanted devices can have this type of doping distribution. In conjunction with this work, we have demonstrated the feasibility of basing a scale of spectral radiant power on the quantum physics of commercially available silicon photodiodes. The ultimate goal of this program is the development of self-calibrating silicon photodiodes employing test pattern structures which allow non-radiometric measurement of the parameters that determine the device's radiometric properties.

During this same period, we have also developed a new reflectometer for measuring the reflectance of cavity receivers for electrically calibrated radiometers. This work was carried out in collaboration with Y. M. Liu of the NBS Electron Devices Division. With this device cavity reflectances were measured in the 100 to 200 ppm range with an accuracy of 20 ppm and precision of 2 ppm. The cavities under investigation had been provided by Willson of JPL to test various ways of improving cavity absorptance, based partially on previous collaboration with our group. As a result of this collaboration, cavity reflectance should no longer be a problem for solar constant monitoring programs.

The radiometric properties of an acoustically tuned optical filter were studied in collaboration with members of our group by a guest worker from INTI (Argentina) during the last year. The results show that significant problems associated with field of view and temperature coefficient must be solved before these devices can be used in general radiometric work. However, in special applications such as solar radiometry they show more promise. An ideal application is as an extra-cavity filter element to decrease the effect of dye fluorescence in applications of dye lasers that demand extreme spectral purity. The measurement of the absorption coefficient of silicon is a good example of a future application to which we expect to apply the device.

<u>New Conceptual Basis for Radiometric Calibrations</u>

The routine issuance of the detector response transfer radiometers has started the process of transferring the conceptual basis of spectral response calibrations to a more fundamental basis. In the past, these calibrations were viewed as a two-step process involving a determination of relative spectral response, and an absolute calibration in μA/(μW/cm^2) derived from a lamp calibrated for spectral irradiance, and a filter of measured spectral transmittance. Now the calibration is a one step process providing absolute spectral response data directly in terms of current out per power in (A/W). This unit can be realized more accurately than any of the units involving concentrations, and the latter can be easily derived from the former by the use of apertures of measured area or filters of measured spectral transmittance, with an increased uncertainty determined by the accuracy of the measurement of the area or transmittance.

Intercomparisons form a very important method by which we verify our new approaches to radiometry and by which the new conceptual basis is propagated.

During the past year, work was initiated on a Director's Reserve sponsored project to measure the synchrotron radiation from the NBS SURF II storage ring using a well characterized silicon radiometer. The results of this measurement can be compared with the synchrotron flux predicted from a knowledge of the ring parameters and the number of electrons in the beam current.

The radiometer consists of a silicon photodiode coupled with two filters to restrict the spectral response to a finite and convenient spectral region for the measurement. The response of this radiometer is to be calibrated at many wavelengths through its bandpass using a tunable cw dye laser. The facility necessary for characterizing the radiometer at accurately known wavelengths has been constructed, and the necessary filters and silicon photodiodes are being procured.

Work in determining the number of electrons in the storage ring beam using analog techniques has progressed to the point that approximately 1000 electrons can be counted. Work is progressing to apply digital techniques, which should result in at least another order of magnitude of counting ability. This corresponds to a flux level well within the linearity scaling requirements of our silicon photodiodes.

Preparations for another intercomparison of considerable importance were also partially completed during the last year. A liquid-helium-temperature, electrically calibrated radiometer originally developed at NPL, Teddington, England, for temperature scale studies will be used to measure the radiant power in the 675 nm wavelength radiation from a krypton ion laser, also to be measured with one of our high accuracy silicon photodiodes. The largest source of error in the measurement by the NPL radiometer will be the reflection and scattering from a Brewster's angle window especially designed to admit radiation to the radiometer for this experiment. During the last year we have been working on techniques to measure the transmittance of this window with an uncertainty of between 10 and 100 ppm.

In conclusion, we point out that we expect the focus of our program in the 1980s to be the replacement of thermal physics by quantum physics as the basis of radiometric measurements in the U.S.

PHOTOMETRIC-RADIOMETRIC CALIBRATIONS AND MAP

The objectives of this group are: a) to maintain the U.S. photometric and radiometric scales, and provide, improve and extend the NBS calibration services for the basic photometric and radiometric quantities of radiance temperature, spectral radiance, spectral irradiance, luminous intensity, luminous flux and color temperature; and b) to engage 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. It is a major objective of this group to provide a firm measurement base in support of the nation's $15 billion optical radiation industry (lighting, photography, aerospace, etc.).

In the past year more than $100,000 of calibrations were issued. The facilities used for these calibrations took about 30 staff-years of senior personnel to develop and incorporate an investment of about $200,000 in capital equipment. It requires about $30K per year to reestablish the scales and maintain the various standards, and it would require considerably more if highly trained, experienced staff were not available. A major extension of the routinely available calibrations services was begun this year. The silicon cell Detector Response Intercomparison Program has been until this year an activity of the Electro-Optical Radiometry group. The enthusiastic response of the U.S. and international radiometric communities to the program has exceeded expectations. To satisfy the need for this program, therefore, it was decided to transfer the activity to the group under discussion here and to set up a dedicated facility for carrying out the program. A monochromator-based transfer instrument has been designed and equipment procurement begun to establish this facility. It is envisioned that the next year will see this service available on a fully routine basis.

Considerable effort this year has been devoted to preparing for the redefinition of the photometric units, which was adopted by the 16th General Conference on Weights and Measures in October, 1979. It has been agreed internationally to replace the current platinum point definition of the photometric units with an agreed value for K_m, the coupling constant between photometric and radiometric units, and with a redefinition of the candela in terms of the watt. At NBS the photometric and radiometric scales have been derived and maintained independent of each other. In order to implement the redefinition, it was necessary to make a high-accuracy determination of the practical K_m's relating the present NBS scales to each other. A new, highly automated gonio-spectroradiometer was designed and constructed. The NBS scales of luminous intensity and luminous flux were compared with the high accuracy spectral irradiance scale. This work is complete and a paper describing it is in preparation. In order to facilitate the transition to the new scale, all the major lamp companies and commercial calibration laboratories have been contacted and are submitting lamp standards of luminous flux for calibrations. Approximately 200 such lamps will be calibrated early in FY80 and results will be reported on both the old and new scale. Thus the U.S. will be in an excellent position to implement the international redefinition on a timely basis.

The Division participated in two international intercomparisons during this year. Such work is undertaken to insure international acceptance of measurements made at NBS and to assist in the development of new, more stable transfer standards. The first intercomparison is sponsored by the National Physical Laboratory (Great Britain) and involves the calibration for luminous intensity of three lamps of a new design. It is hoped that the intercomparison will show these lamps to be sturdier than lamps used in previous intercomparisons and thus provide a more accurate transfer vehicle for photometric scales. The second intercomparison is sponsored by the Comite Consultatif de Photometrie et Radiometrie and coordinated by Physikalisch-Technische Bundesanstalt (Federal Republic of Germany). It involves the calibration for luminous intensity of three lamps and, simultaneously, the calibration for luminous responsivity of three photopically corrected silicon cells. This intercomparison is the beginning of an NBS effort to assess the possibilities for supplementing or replacing the present photometric lamp standards with photopically corrected silicon cells. NBS measurements for both intercomparisons are complete and results will be available early in 1980.

This past year saw a continuation of the five year program to provide the Bureau of Radiological Health with a legally defensible measurement capability in the optical radiation area. This program is nicely on schedule, having just completed its fourth year. Intercomparisons of spectral irradiance measurements made at NBS and BRH showed a significant reduction in the 5-10% discrepancies seen in previous years. At present, NBS and BRH measurements are in agreement, except in the 200-250 nm region, to within the NBS uncertainties (1-2%). As part of the program with BRH, NBS agreed to undertake special tests on objects of immediate regulatory concern in areas where BRH has not yet demonstrated an adequate measurement capability. During FY79, NBS made uv spectral irradiance measurements on 10 commercially marketed sun lamps. With the NBS measurements for backup, BRH has published in the Federal Register, draft regulations governing the manufacture of all sun-lamps marketed in the U.S.

Every year, this Group undertakes a limited number of calibrations to support research activities in other divisions of NBS and/or to resolve discrepancies in the optical radiation community. During the past year calibrations were performed for the Atomic and Plasma Radiation Division (D_2 lamp work), the Radiation Physics Division (SURF II work) and the Nuclear Radiation Division (detector efficiency for x-ray intensifying screens). In addition, a special test was undertaken to resolve a 10% discrepancy in luminance measurements between Newark Air Force Base and Gamma Scientific, Incorporated.

PSYCHOPHYSICAL PHOTOMETRY

A program in psychophysical photometry, conducted in cooperation with the Optics Section of the National Research Council of Canada, was completed in 1979. In this program, photometric luminance and perceived brightness were compared in experiments using observers in order to investigate the adequacy of the present photometric system. Results of the initial work at both NBS and NRC have been published and demonstrate that there can be substantial differences between photometric luminance based on the $V(\lambda)$ function and brightness as perceived visually.

In the most recent phase of this work at NBS, the differences between photometric luminance and perceived brightness were investigated with nine observers in a brightness matching experiment at suprathreshold levels using 20 chromatic stimuli covering a large portion of the chromaticity diagram, including the non-spectral purple region, and were also investigated as a function of source size using four of the stimuli. Deficiencies in the present photometric system were studied through the use of the so-called brightness-to-luminance (B/L) ratio where B is the luminance of the adjustable white stimulus used by the observer in obtaining a brightness match and L is the fixed luminance of the chromatic stimulus. B/L ratios were obtained with the chromatic stimuli at a luminance of 100 cd/m^2 while subtending angles of 1°, 20' and 6'. The amount of white light required to make a brightness match increased as saturation increased and decreased as stimuli size decreased. A more complete description of this investigation is contained in an article submitted to the Journal of the Optical Society of America.

OPTICAL RADIATION NEWS

In order to rapidly disseminate information on new NBS standards and calibrations, progress reports on the Division's research activities, and other information of general interest in the field of optical radiation measurements, the Division is continuing to prepare and send out gratis a quarterly newsletter to about 1,200 subscribers.

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Conference on the Department of Defense Calibration Coordination Group (CCG), NBS, Gaithersburg, MD, May 1, 1979.

MAJOR CONSULTING AND ADVISORY SERVICES

Division 534. Radiometric Physics

1. J. Geist, Flight Technology Improvement Workshop, invitation to participate in this three day workshop sponsored by NASA and NOAA for identifying required radiometric improvements for future flights associated with the Climate Program, July 31, August 1 and August 2, 1979.

2. J. Geist, Invitation to serve on a NOAA sponsored committee to set up a general climate monitoring program, Boulder, CO, September 19, 1979. CONTACT: Dr. John DeLuisi.

3. J. J. Hsia, Invitation to provide advice on spectrophotometric concepts and measurement techniques on vehicle sun screening devices for the Vehicle Equipment Safety Commission (VESC) Sun Screening Committee in Phoenix, Arizona on April 9 and 10, 1979 and in Baltimore, Maryland on June 7, 1979. CONTACT: Dairl Bragg, Executive Director, VESC, Washington, DC.

4. J. J. Hsia, Consultation with Professor William C. Cutis of the Chemistry Department, University of District of Columbia on reflectance measurement techniques and calibration of instrument. These measurements are for monitoring oil films on water surface. (June 8 and 9, 1979).

5. H. J. Kostkowski, consulting and advisory services on radiometric system for calibration of missile seekers, March 16, 1979. CONTACT: E. J. Bevan, Naval Weapons Center, China Lake, CA.

6. H. J. Kostkowski, Flight Technology Improvement Workshop, invitation to participate in this three day workshop sponsored by NASA and NOAA for identifying required radiometric improvements for future flights associated with the Climate Program, July 31, August 1 and August 2, 1979.

7. D. A. McSparron, consultation and collaboration with Dr. Tibbits, University of Wisconsin. An intercomparison program was established to insure measurement uniformity of spectral irradiance measurements in plant growth chambers at 10 institutions throughout the country.

8. F. E. Nicodemus, Division technical representative and technical consultant to NBS Library.

9. C. H. Popenoe, Member of Microprocessor Subcommittee of the NBS Electronics Storeroom Committee.

10. R. D. Saunders consulted with K. Mohan of BRH on spectral data taken in Arizona.

11. R. D. Saunders consulted with Robert James of BRH on modification of MIDAS controller to run with Data General terminal.

12. J. L. Tech, continued consulting with the U.S. State Department and other government agencies on scientific and technological interactions with the U.S.S.R.

13. C. R. Yokley, consultation at various times throughout FY 1979 on special state-of-the-art cryogenic blackbody standard with Mr. Fred G. Sherrell, ARO, Inc., Arnold AFS, Tennessee.

14. E. F. Zalewski, consultation with Dr. Richard A. Keller of the Los Alamos Scientific Laboratory on laser amplitude stabilization techniques and applications to laser analytical chemistry; also collaboration on the study of laser radiation effects on minority species in hollow cathode discharges. September 1-7, 1979 at Los Alamos, NM.

Division 534. Radiometric Physics

1. SRM 1001, X-Ray Film Step Tablet

   Used in the calibration of optical densitometers and similar equipment used in the photographic, graphic arts, and x-ray fields. Certified for optical densities from 0 to 4.

2. SRM 1008 and 1009, Photographic Step Tablets

   Used in the calibration of optical densitometers and similar equipment used in the photographic and graphic arts fields. SRM 1008 is certified for optical densities from 0 to 4 and SRM 1009 from 0 to 3.

3. SRM 1010a, Microcopy Resolution Test Charts

   Used for determining the resolving power of microcopy systems.

4. SRM 2009, 2010, 2013, and 2014, Didymium Glass Filters

   Used as reference filters for calibrating the wavelength scale in the visible wavelength range of scanning spectrophotometers. These four SRM's differ only in physical size and in the accuracy of the associated table of spectral transmittance. SRM 2009 and 2010 are individually measured, whereas only a representative filter of the melt from which SRM 2013 and 2013 are produced is measured, and all others from the melt are assumed to have the same characteristics.

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 1979 included programs in neutron cross section standards, radiography, high energy electron scattering, photonuclear research and activation analysis. (The last is an activity of the Center for Analytical Chemistry, the others are activities of the Nuclear Radiation Division.) Other, occasional users of the linac include groups from the College of William and Mary, NASA, and our own Division. This is in addition to a large number of outside collaborators and guest workers who participate in the programs mentioned above.

The Linac Operations staff consisted of three engineers, seven technicians, an an upward mobility trainee. 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 the beam handling systems as well as designing, constructing, and installing mechanical components for both the Linac and beam handling system. Table I shows the distribution of the total Linac operations staffing time in the operation of the facility for FY 1979 (through August). For the first three-quarters of the fiscal year, maintenance was alternately two and one-half shifts one week followed by one shift the next week. Setup for experiments normally began at 11:30 a.m. on the Tuesday following a long maintenance and at 3:30 p.m. on the Monday following a short maintenance. The facility runs for experiments until 7:30 a.m. Saturday. For the last quarter of the fiscal year, maintenance was scheduled for one week out of every four. The facility was shutdown for part of the month of November and all of the month of December for its yearly general maintenance as well as inventorying spare components as recommended by DOC. During the months of March and April, several gun changes were made in order to improve beam quality.

Experiment time on the facility was requested by and allocated to the users at scheduling meetings, which were held every four weeks. Table II shows the distribution of time by experiment for the fiscal year.

The unscheduled maintenance of 733.0 hours is broken down and summarized by system in Table III. This 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, both financial and personnel, which were starting to be rectified during the later part of the fiscal year.

Plans for upgrading the Linac include:

1. Complete installation of the new R.F. Drive System to improve beam stability and reduce maintenance.

2. Complete installation of components to improve front-end beam optics. This modification is expected to substantially increase the currents available in short pulse mode (for neutron production) and in positron operation.

3. Complete beam transmission optimization study of the Linac to improve beam quantity and quality for all experiments.

4. Complete study and analysis of the Model 12 Electron Gun to improve its performance and obtain a source of reliable guns. Benefits the neutron cross section program.

5. Rework of MG Sets to improve regulation - benefits all experimenters.

6. Continue switch tube rebuild program - anticipated initial cost savings approximately $70,000.

7. Install new air compressor system for vacuum valves. Benefit to all experimenters due to marginal operation and downtime.

LINAC OPERATIONS

FY 1979 (through August)

	Scheduled Hrs.	Actual Hrs.
Maintenance	1069.5	1069.5
Unscheduled Maintenance	--	733.0
Beam Time	2927.5	2173.0
Set-Up*	197.0	213.0
Experimental Down-Time**	--	5.5
Installation	246.5	246.5
Total Hours***	4440.5	4440.5

*Includes lock-up after scheduled maintenance.

**Linac available for operation, but experiment either not ready or breaks down during scheduled run.

***Total staffing hours.

Efficiency = 74.2%.

Table II

Linac Operations
FY 1979 (through August)

Distribution of Time by Experiment

	*Scheduled Beam Hours	Actual Beam Hours	**Setup Hours	Unscheduled Maintenance Hours	***Experiment Downtime Hours	Total Scheduled Beam %	Total Actual Beam %
Electron Scattering	668.5	378.5	53.0	236.0	1.0	21.4	17.4
Neutrons	1076.0	772.5	49.5	252.5	1.5	34.4	35.6
Photonuclear Spectrometer	548.0	468.0	22.5	56.5	1.0	17.5	21.5
Activation Analysis	226.5	169.0	22.0	35.5	-	7.3	7.8
Linac	108.0	76.5	9.5	22.0	-	3.5	3.5
Positrons	458.0	281.0	51.0	126.0	-	14.6	12.9
William & Mary	30.0	23.5	3.5	1.0	2.0	1.0	1.1
NASA	9.5	4.0	2.0	3.5	-	.3	.2
	3124.5	2173.0	213.0	733.0	5.5	100	100

*Machine time assigned to experiment, includes scheduled setup time of 197.0 hours.

**Includes lock-up after scheduled maintenance.

***Linac available for operation, but experiment either not ready or breaks down during scheduled run.

Table III

Linac Operations
(FY 1979 through August)

Summary by System of Unscheduled Maintenance

Linac: Total unscheduled maintenance 470.0 hours.

System:

Modulators	125.75 hours	26.8%
R. F. Drive	80.25 hours	17.1%
Vacuum	30.0 hours	6.4%
Positron	44.0 hours	9.4%
Injector	70.5 hours	15.0%
Preamplifiers	19.5 hours	4.1%
Trig. Gen.	26.0 hours	5.5%
View Screens	27.5 hours	5.9%

No other system or item over 3%.

BHS: Total unscheduled maintenance 224.0 hours.

System:

Cooling	.5 hours	.2%
Vacuum	91.0 hours	40.6%
Magnet Power Supplies	113.0 hours	50.5%
Slits	19.5 hours	8.7%

Balance of total unscheduled maintenance, 39.0 hours, due to air conditioning, chilled water, and Pepco related.

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, 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 can now support as many as seven simultaneous users, with two additional ports under development. Operation for three or four users at a time is now routine. Since different users may have conflicting beam requirements, a formal scheduling system has now been set up, replacing the rather informal arrangements of the past.

The program to upgrade SURF to 280 MeV in underway. New power supplies, racks and cable trays are in place, AC power and output cables are installed. Delivery of the new correction coils and auxiliary windings has been delayed by protracted procurement procedures and by long lead times in copper deliveries to the coil manufacturers. Delivery is now expected around November 1979. Prototype current regulator modules have been tested and most of the hardware for the microprocessor-driven controller has been ordered. Shutdown for installation of coils will probably take place in early 1980.

Plans for FY 1980 include the design and installation of a combination bump coil and third harmonic RF cavity, to replace the present bump coil. Its function, in addition to deflecting the injected beam into a closed orbit at injection time, would be to deliver a harmonic accelerating voltage to the beam, phased in such a way as to cause elongation of the electron bunches. This bunch stretching in turn would result in increased beam lifetime. The device will be water cooled and will be driven by a frequency multiplier followed by a commercial UHF power amplifier.

Automatic RF cavity tuning, originally planned for FY 1979, will be inplemented in FY 1980.

The operational statistics show a dramatic increase in the number of beam hours over FY-78, with a corresponding decrease in unscheduled downtime, maintenance and studies. This increase in efficiency has been mainly due to the fact that there were no major breakdowns and no lengthy shutdowns this year. The repairs done on the corrections coils last year have held us so far. Their life has been prolonged by restricting the maximum operating energy of SURF to 243 MeV, thereby limiting the thermal stress on the coils.

The increase in beam time was also due to a concerted effort on the part of the operations staff to meet the increasing demand. Although SURF has just one operator working one shift, it has been possible to operate more than eight hours a day by (a) calling on two other qualified staff members to stagger their work hours and to work occasional evenings and Saturdays as substitute operators, and (b) by training several experimenters to monitor the control console in the absence of a operator and to shut the machine down at the end of the evening, or in an emergency. The latter mode of operation relies on good beam lifetime and long-term stability of all subsystems of the electron storage ring. As a result, actual beam hours exceeded 150 hours for each of the past six months. The total for April 1979 was 178 hours of beam.

The SURF operations group still has only three people: an engineer, an operator/technician and a user-interfacing specialist. In addition, a physicist from the UV Physics group (Division 533) continues to serve as vacuum specialist. An electronic technician has recently joined the facility to install and operate the NASA-sponsored Optical Calibration Chamber. He is formally assigned to Division 533. Tentative approval has been received to hire a technician or junior engineer to be assigned to the experimental facilities of SURF. This position is also in Division 533. Both of these people could provide occasional assistance on specific projects or emergencies, but they do not represent direct relief to the personnel shortage in SURF operations.

SURF Operations Statistics

	FY-78	FY-79	% Change
Beam to users	914 hours	1612 hours	+ 76%
Standby (beam available)	185	232	+ 25%
Studies & Maintenance	540	252	- 53%
Unscheduled downtime	658	198	- 70%
Total hours	2297 hours	2294 hours	~ 0%

SURF Users During FY-79

533 Radiation Physics Division, Far UV Section (R.P. Madden, D.L. Ederer, E. Saloman, J. Rife, B. Cole, L. R. Hughey)

520 Center for Absolute Physical Quantities (J. Cooper, R. LaVilla).

534 Radiometric Physics Division (R. Schaeffer).

541 Surface Sciences Division (T. Madey).

543 Chemical Thermodynamics Division (R. Stockbauer).

Naval Research Labs (D. Nagel, R. T. Williams, V. Bermudez).

NASA Goddard (B. Guenther, D. Williams).

Los Alamos (R. Day).

Argonne National Lab (J. Dehmer).

Brookhaven National Lab (J. Sutherland, P. Takacs).

Oak Ridge National Lab (E. Arakawa).

U. of Tennessee (T. Calcott).

U. of Virginia (S. Schnatterly, F. Zutavern, C. Frank, T. Aton, E. Käellne).

Johns Hopkins U. (W. Moos, W. Hodge, J. Castrecane).

Westinghouse Research Labs (J. Schreurs, M. Peckarar).

Guest Workers:

C. Mehlman, CNRS, France.

J. West (SURF Fellow), Daresbury Lab. England.

A. C. Parr, U. of Alabama.

K. Codling, U. of Reading, England.

Division 535, Radiation Source and Instrumentation

Control Instrumentation

Numerous control instruments and systems have been designed and constructed for various groups in the Center for Radiation Research. Among these are a 20 ma loop interface for a PDP 11/03-HP Coupler-3TTY setup used with an existing data acquisition system for dosimetry calibration, a bakeout controller to speed up vacuum pump-down, a triple pulse delay module, multi-target controller for use with linac experiments, and various modifications to DVMs, gauges, and other instruments used in control systems.

Data Acquisition System for the NBS Linear Accelerator (LINAC)

A computer system has been designed for accumulation of experimental data from the NBS Linac. The system is designed around CAMAC modular hardware. In this module concept a number of CAMAC modules constitute the interface to the computer (CAMAC Branch Driver), while other CAMAC modules drive specialized input and output devices. A branch driver for interfacing the CAMAC system to a Harris Slash 5 computer has been completed and the computer system reconfigured to accommodate new peripheral devices. The system will be expanded in the near future to permit operation in the three counting rooms, replacing the obsolete XDS-920 systems.

Electronic Instrumentation Maintenance and Construction

Instruments serviced during FY 1979 numbered approximately 230 and approximately 70 instruments were designed and constructed. The corresponding figures for FY 1978 were 200 serviced and 50 designed and constructed. These services have regularly been provided for the Center for Radiation Research. With the recent considerable increase in the size of the Center as a result of the reorganization, the requests for such services have increased accordingly.

Instrumentation Support for Various Physics and Chemistry Projects

Assistance and apparatus is being provided to surface electron physics, plasma diagnostics and vacuum UV standards measurement programs. Apparatus for low-level current measurements noise, and interference suppression (using active circuits), high voltage isolation of low-level signals and photon counting is being designed and integrated into measurements systems. Consulting services are provided on projects origianlly associated with and supported by the NBS Office of Environmental Measurement. Current projects include ozone photometric standards relating to atmospheric and ambient ozone levels. Also, we are assisting with the electronics for a gas-phase reaction quadrupole mass-spectrometer measurement system associated with atmospheric pollution studies. A joint project was undertaken with the Center for Analytical Chemistry on the transient measurement of flash plasmas. Work proceeded on this project on development of flat uniform current microsecond pulses through a triggered spark gap. Also, a staff member (J. Whittaker) is supervising the work of a University of Maryland graduate student on developing a controller for an environmental particulate sampler to be used to monitor pollution measurements.

Mechanical Instrumentation Services

Mechanical Instrumentation design, construction, and maintenance services were provided for all of the particle accelerators of the Center for Radiation Research and for the numerous experimental programs of the center. This is a continuing function and involves cooperation and coordination with the various experimental groups in the center. We still have not replaced the people that were lost in the previous year. This has made it necessary to work overtime to try to provide services on a timely basis, however it is becoming more and more difficult to keep up with the heavy work load.

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 of this work, with the Section Chief, 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 Section has similar responsibility is the FASTBUS high speed modular data acquisition system for high energy physics and other applications.

The preparation of reports for the above systems involves a number of individuals and laboratories. Coordination and processing, as well as writing of some sections, is handled by the National Bureau of Standards. The documents are usually issued initially as Reports of the Department of Energy and then processed as Standards of the Institute of Electrical and Electronics Engineers, (IEEE), the American National

Standards Institute (ANSI), and the International Electrotechnical Commission (IEC). Such reports issued (or on the verge of issuance) in FY 1979 are:

ANSI/IEE Std. 675-1979, Multiple Controllers in a CAMAC Crate.

ANSI/IEE Std. 680-1978, Determination of Germanium Semiconductor Detector Gamma-Ray Efficiency Using a Standard Marinelli (Reentrant) Beaker Geometry.

ANSI N42.13-1978, Calibration and Usage of "Dose Calibrator" Ionization Chambers for the Assay of Radionuclides.

ANSI N42.14-1978, Calibration and Usage of Germanium Detector for Measurement of Gamma-ray Emission of Radionuclides.

ANSI N322-1977, Inspection and Test Specifications for Direct Reading Quartz Fiber Pocket Dosimeters.

ANSI N323-1978, Radiation Protection Instrumentation Test and Calibration.

ANSI N320-1979, Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation.

ANSI N317-1979, Performance Criteria for Instrumentation Used for Inplant Plutonium Monitoring.

Documents approved in FY 1979 but to be published in FY 1980 are:

IEC Standard, Multiple Controllers in a CAMAC Crate.

IEC Standard, Block Transfers in CAMAC Systems.

IEEE Std. 726-1979, Real-Time BASIC for CAMAC.

IEEE Std. 758-1979, Subroutines for CAMAC.

IEEE Std. 583A-1979, Supplement to CAMAC Standards and Reports.

(b) National Voluntary Standards - The Section plays an active role in IEEE and ANSI standards activities with the Section Chief 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 about six ANSI and IEEE standards in FY 1979. J. Whittaker serves on ASTM Committee D-22 on Methods of Sampling and Analysis of Atmospheres.

(c) International Electrotechnical Commission - The Section Chief 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 are to be published in early FY 1980.

Division 535, Radiation Source and Instrumentation

CW Microtron Project

The Division of Nuclear Physics of the Department of Energy has approved a proposal entitled "Research in CW Electron Accelerators Using Room Temperature RF Structures." This proposal was submitted to DOE jointly by the Radiation Source and Instrumentation Division of CRR and the Accelerator Technology Division of the Los Alamos Scientific Laboratory (LASL). 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 accelerator of sufficient size to provide a meaningful test of components and beam performance. The demonstration accelerator 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 for the 4-1/2 years needed to design, build, and demonstrate the operation of the accelerator. The collaboration between NBS and LASL brings together the unique expertise of LASL in the area of rf accelerator structures and systems with the expertise at NBS in particle beam dynamics and accelerator technology.

The project is now underway, under the direction of S. Penner. The The NBS Director has approved six new slots for the project, and we are actively recruiting accelerator physicists and engineers for the project, while beginning conceptual design work with existing staff. The demonstration microtron will be assembled in MR2 of the linac complex (the room presently occupied by E. Hayward's photon scattering setup), beginning in the first half of 1981. The first attempt to recirculate a beam in the microtron is scheduled for January 1983.

Linac Improvements

It has become apparent that the beam current limitation of the linac in short pulse operation for neutron production is due to the focusing properties of the linac. The same properties result in poor beam quality (large emittance) for other modes of operation when the high current (Arco Model 12) electron gun needed for short pulse operation is in use. A computer study of possible improvements has been undertaken, which should lead to a design and cost estimate for improved focusing. Recent operational results clearly show that the linac beam performance using the electron gun (Arco Model 10) for which the linac was designed is very good. Using a Model 10 gun, recent operation for electron scattering using the dispersion matching system and for activation analysis work is far superior to what was previously obtainable.

High Current Beam Transport

In several applications, it is necessary to transport charged particle beams of extremely high current. An example is heavy ion beams for inertial confinement fusion. Recent theoretical work at LBL has predicted certain instabilities in the transport of space charge limited beams. The theory is only capable of examining small perturbations and a very restricted class of beam charge density distributions. We have, therefore, developed a computer program which can simulate the transport of space charge limited beams in the most general case. Due to the importance and difficulty of this problem it is being done independently at NBS and at NRL. In the cases studied to date, some of the predictions of the LBL theoretical work have been verified, and the agreement between the NBS and NRL computer simulation work is excellent. Our program has been developed with a large amount of flexibility so that it can be used to study a wide variety of beam transport problems. This program has been used to study the design of a high current cesium ion beam transport system being built at LBL for heavy ion fusion. First results of this study were presented at the U.S. National Particle Accelerator Conference in March 1979. Further studies including the effects of quadrupole magnet fringing field are in progress.

Induction Accelerator Research and Intense Relativistic Electron Beam Propagation Studies

A unique, long pulse induction linear accelerator built earlier as part of a DOD sponsored feasibility study is being used to generate high current electron beams for propagation studies in low-pressure gas. Over the past three years, problems of focusing and stability in different types of charge neutralizing background gases have been addressed. Stable, well-focused electron beams of several hundred amperes have been propagated over extended distances.

The results of the beam propagation studies and induction accelerator development are presently being applied to the question of the technical feasibility of a recirculating induction linear accelerator.

If proven successful, such a technique would significantly reduce the cost, size and weight of an induction accelerator by passing the beam through the accelerating unit several times during the same voltage pulse for multiple energy gain. The addition of a charge-neutralizing gas reduces the complexity of high current beam transport during recirculation. Under DOD sponsorship, a small 2-pass recirculation induction accelerator test module has been designed, constructed and installed at the output of the Prototype NBS Induction Linac as a proof-of-principle demonstration. This unit has added 25 keV per pass to the intense 750 keV electron beam. Problems due to the effects of reduced symmetry on beam steering have been solved by shielding techniques. However, considerable attenuation of the initial 500 A beam has been observed to occur during two passes through the recirculator. This beam loss has been attributed to radial beam growth in the accelerating gaps. These results have been reported at a classified workshop on Experimental Beam Propagation held at the Naval Research Laboratory April 30, 1979. A computer simulation of the beam envelope has been used to redesign the accelerator gaps to considerably reduce radial beam growth. Beam tests with the new gaps are due to begin by the middle of October. This same computer model is also being used to help design a larger recirculation induction accelerator which will go much further toward establishing the technical feasibility of accelerating intense electron beams by this compact, efficient method.

Interest continues to be strong for research in induction accelerator technology. A test facility for a heavy ion fusion driver is being constructed at Lawrence Berkeley Laboratories, incorporating an induction linac to accelerate several amperes of Cesium ions to 25 MeV. A high current induction linac is being built at Lawrence Livermore Laboratories to study intense beam propagation. Accelerator research personnel at NBS are contributing expertise to both projects.

To keep NBS current on progress in fusion energy research, a member of the accelerator research staff at NBS attended the Minicourse on Inertial Confinement Fusion held at the University of Montreal June 12-14, 1979. A synopsis of the material presented at this minicourse was given at a CRR seminar on July 18, 1979.

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 will be to a large extent arranged by NBS personnel. S. Penner has been designated Chairman of this conference.

PUBLICATIONS

Division 535, Radiation Source and Instrumentation

Louis Costrell

Paper accepted for publication in Health Physics Journal Germanium Semiconductor Detector Efficiency Determination Using a Standard (Marinelli) Beaker Geometry, Louis Costrell (co-author with D. E. Persyk, Searle Radiographic Inc., Colin Sanderson, Environmental Measurement Laboratory, DOE; G. Walford and F. J. Walter, E.G. & G - ORTEC).

Samuel Penner

Transport Calculations for Very High Current Beams, Samuel Penner and Annija Galejs, IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979.

George Rakowsky

SURF'S Up at NBS: A Progress Report, George Rakowsky and Lanny R. Hughey, IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979.

Division 535, Radiation Source and Instrumentation

Louis Costrell.

"The Development and Implementation of Standardized Instrumentation Systems for Nuclear Applications," January 29, 1979, Department of Energy, 20 Massachusetts Avenue, Washington, D.C. (before Scientific Delegation of Peoples Republic of China).

Samuel Penner

"High Duty-Cycle Accelerator and New Experimental Possibilities," International Conference on Nuclear Physics with Electromagnetic Interactions, Mainz, Germany June 5-9, 1979.

"The NBS-LASL CW Microtron Project," CRR Seminar, September 6, 1979.

Mark A. Wilson

"Propagation Experiments with Microsecond Pulse - Length Relativistic Electron Beams in Low Pressure Gas," Naval Research Laboratory, Main Site, Washington, D.C., April 30, 1979.

"Inertial Confinement Fusion - An Alternate Energy Source?" CRR Seminar, July 18, 1979.

Division 535, Radiation Source and Instrumentation

Samuel Penner

Consulting services provided to Austin Research Associates, Austin, Texas in connection with program review of the Auto-Resonant Accelerator effort.

530, Center for Radiation Research

Chris E. Kuyatt

NBS liaison, National Council on Radiation Protection and Measurements.

NBS representative, Interagency Committee on Federal Research into the Biological Effects of Ionizing Radiation.

Member, Interagency Radiation Protection Task Force.

530, Office of Radiation Measurement

Ronald Collé

Member, Committee for Upgrading Environmental Radiation Data, Subcommittee on Reporting of Environmental Radiation Data

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.

Delegate, ISO TC85 Nuclear Energy, SC4 Radioactive Sources,

Chairman, Committee for Upgrading Environmental Radiation Data, Subcommittee on Reporting of Environmental Radiation Data.

Member, Health Physics Society Committee for Upgrading Environmental Radiation Data.

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

Chairman, Interagency Policy Committee on Personnel Dosimetry Performance Testing.

H. Thompson Heaton, II

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

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

TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Charles H. Corliss

Member, Commission 14 of the International Astronomical Union.

Georgia A. Martin

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

William C. Martin

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

Member, U.S. National Committee for the International Commission for Optics.

Member, IAEA Network of Atomic Data Centers for Fusion.

William R. Ott

Treasurer, National Committee for the VI International Conference on VUV Radiation Physics (1980, U.S.A.).

Joseph Reader

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

Member, National Academy of Sciences-National Research Council Committee on Atomic and Molecular Physics.

Wolfgang L. Wiese

North-American Coordinator, Program Committee for the series of International Conferences on Spectral Line Shapes.

Member, International Astronomical Union Commission 14, Organizing Committee.

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

Member, Ad-hoc DOE Panel on Atomic and Molecular Data for Fusion Research.

Division 531, Technical and Professional Committee (cont'd)

Member of Organizing Committee, 1979 Symposium on Atomic Spectroscopy.

Member, IAEA Network of Atomic Data Centers for Fusion.

Member of Organizing Committee, Conferences on Atomic Processes in High Temperatures Plasmas (a topical conference of APS).

Alternate member, User's Committee of TEXT (Texas Experimental Tokamak, a national plasma research facility).

Division 532, Nuclear Radiation

Robert L. Ayres

Deputy Delegate, International Committee for Radionuclide Metrology (ICRM) Life Sciences Working Group

James A. Behrens

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

Member, Safeguards Committee, Institute for Nuclear Materials Management

Charles D. Bowman

Member, Program Committee, International Conference on Nuclear Cross Sections for Technology

Technical Advisor, Department of Energy (DOE) Nuclear Data Committee

Technical Advisor, DOE Cross Section Evaluation Working Group (CSEWG), Standards Subcommittee

Allan D. Carlson

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

Randall S. Caswell

Member, EURATOM Program Committee, Symposium on Neutron Dosimetry in Biology and Medicine

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

Chairman, Conference Générale des Poids et Mesures, Section on Neutron Measurements (Section III), CCEMRI

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

Randall S. Caswell (Cont'd.)

Member, NCRP Board of Directors

Chairman, NCRP Ad Hoc Committee on SI Units

Secretary, International Society of Radiology, International Commission on Radiation Units and Measurements (ICRU)

Member, Radiation Research Accelerator Facility (RARAF) Scientific Advisory Committee, Brookhaven National Laboratory

Member, Radiation Research Society, Board of Editors, Radiation Research

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

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

Lucy M. Cavallo

Member, Atomic Industrial Forum (AIF) Committee on Radioisotopic Production and Distribution, Standards Steering Subcommittee

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

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

Member, College of American Pathologists (CAP), Nuclear Medicine Resource Committee

Bert M. Coursey

Deputy Delegate, International Committee for Radionuclide Metrology (ICRM) Life Sciences Working Group

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

Alternate Representative, ASTM Subcommittee D-22.10 on Sampling and Analysis of Atmospheres for Radioactivity

Bert M. Coursey (Cont'd.)

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

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

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

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

Charles M. Eisenhauer

Member, National Council on Radiation Protection and Measurements (NCRP) Task Group on Atomic Bomb Survisor Dosimetry

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

Member, ASTM Subcommittee E10.05 on Neutron Dosimetry

Everett G. Fuller

Member, Fachbeirat Kenphysik for the Max-Planck Institutes of Nuclear Physics at Heidelberg and Chemistry (Otto Hahn Institute) at Mainz

Member, National Council on Radiation Protection and Measurements (NCRP) Committee on Dosimetry of Leakage Neutrons from Medical Accelerators

Member, Advisory Committee for the Giant Multipole Resonance Topical Conference, Oak Ridge, Tennessee, Oct. 15-17, 1979

James A. Grundl

Member, Organizing Committee for Third ASTM-EURATOM Symposium on Reactor Dosimetry, Ispra, Italy, Oct. 1-4, 1979

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

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

Member, ASTM Subcommittee E10.05 on Neutron Dosimetry

Evans V. Hayward

Member, American Physical Society (APS) Program Committee of the Division of Nuclear Physics

Member, APS Editorial Board of Physical Review C

Dale D. Hoppes

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

J.M. Robin Hutchinson

Chairman, International Committee of Radionuclide Metrology (ICRM) Subcommittee on Low-Level Techniques Group

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

Secretary, ANSI Subcommittee N42.2 on Precedural Standards for Calibration of Detectors for Radioactive Measurements

Wilfrid B. Mann

President, International Committee for Radionuclide Metrology

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

Member, Department of Energy (DOE) Half-Life Evaluation Committee for Pu Isotopes Physical Constants

Wilfrid B. Mann (Cont'd.)

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 Materials Control

Member, ANSIINMM Work Group INMM8.04 on Calibration Techniques for Calorimetric Assay of PlutoniumBearing Solids

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

Member, College of American Pathologists (CAP), Nuclear Medicine Resource Committee

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

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

Emmert D. McGarry

Secretary, Organizing Committee for the Third ASTMEURATOM Symposium on Reactor Dosimetry, Ispra, Italy, Oct. 1-4, 1979

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

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

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

Secretary, ASTM Subcommittee E10.05 on Neutron Dosimetry

Sydney Meshkov

Trustee, Aspen Center for Physics

James R. Noyce

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

Member, ASTM Subcommittee E10.01 on Nuclear Fuel Burnup

Member, ASTM Subcommittee E10.05 on Radiation Dosimetry

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

Val Spiegel

Member, ASTM Subcommittee E10.05 on Neutron Dosimetry

Michael P. Unterweger

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

Division 533, Radiation Physics

Martin J. Berger

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

Technical Advisor, ICRU Committee on High Energy Electron Dosimetry.

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

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

David L. Ederer

Chairman, Organization/Program Committee, National Conference on Synchrotron Radiation Instrumentation, June 1979.

Margarete Ehrlich

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

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

Executive Secretary, Interagency Policy Committee on Personal Dosimetry Performance Testing.

John H. Hubbell

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

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

Technical Advisor, ICRU Task Group II.B.1. Radiation Dosimetry; X-Rays from 5-150 keV.

Member, Cross Section Evaluation Working Group Subcommittee on Shielding.

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

John H. Hubbell (cont'd)

Member, American Nuclear Society (ANS), Radiation Protection and Shielding Division, Working Group ANS-6.1 on Shielding Cross Sections.

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 Applications, E10.07 Subcommittee on Radiation Effects on Electronic Materials and Devices.

Robert Loevinger

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

Member, International Organization for Legal Metrology (OIML), SP.16-SR.1, Performance of Dosimeters.

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

Member, American Association of Physicists in Medicine (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, ANSI N44, Equipment and Materials for Medical Radiation Applications.

Member, ANSI N44/SC2, Therapeutic Radiology.

Member, Bureau International des Poids et Mesures (BIPM) Consultative Committee for Standards for Measurement of Ionizing Radiation, Section I, X and Gamma Rays and Electrons.

Robert Loevinger (cont'd)

Member, IAEA-World Health Organization (WHO) Network of Secondary Standard Dosimetry Laboratories, Advisory Council.

Member, ICRU Report Committee, Methods of Assessment of Dose in Trace Investigation.

Member, NRCP Scientific Committee 26, High Energy X-Ray Dosimetry.

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

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.

Member, ANSI N43/SC 1, X-Ray Diffraction and Fluorescence Analysis Equipment.

Thomas Lucatorto

Member, Local Organizing Committee for VI International Conference VUV Radiation Physics.

Robert P. Madden

Member, DEAP ad hoc Study Committee to Investigate the (National) Advisory Structure for Atomic Physics.

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.

Chairman, National Committee for the VI International Conference on VUV Radiation Physics (1980, U.S.A.).

Member Optical Society of America Publications Committee.

Member, Optical Society of America Committee on William F. Meggars Award.

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

Thomas J. McIlrath

Member, Local Organizing Committee for VI International Conference VUV Radiation Physics (June 1980).

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.

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

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

Vice Chairman, Interdepartmental Committee on Radiation Preservation of Foods.

Robert C. Placious

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

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

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

Robert C. Placious (cont'd)

Member, ASTM E10.07, Nuclear Technology and Applications 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.

Lewis V. Spencer

Member, Federal Preparedness Agency (FPA) Interagency Working Group on Federal Response Plan for Peacetime Nuclear Emergencies.

Consociate Member, National Council on Radiation Protection and Measurements.

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

Member, ANS-6, Radiation Protection and Shielding Standards Subcommittee.

Member, Environmental Protection Agency (EPA) Interagency Committee on Federal Guidance for Occupational Exposures to Ionizing Radiation.

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.

Jon C. Geist

U.S. representative to TC-2 - Photon Detectors Committee of the International Measurement Confederation (IMEKO).

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

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

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 Committee on Paint, Varnish, Lacquer, and Related Products (Subcommittee on Optical Properties).

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

Henry J. Kostkowski

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

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

Member, IES Committee on Photobiology.

D. A. McSparron

Member, ANSI Z311 on Photobiological Safety of Lamps

Member, Lamp Testing Engineers Conference

Member, Illuminating Engineering Society (IES) on Testing Procedures

F. E. Nicodemus

Consultant, U.S. Panel of 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, Countermeasures Subgroup of the Joint Technical Coordination group on Aircraft Survivability (DoD).

D. Nyyssonen

Member, ANSI Task Force of Subcommittee PH3-2 on Optics, Printing and Projection Equipment.

R. D. Saunders

Member, IES Committee on Photobiology

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

A. R. Schaefer

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

J. B. Shumaker

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

J. L. Tech

Secretary, U.S. National Committee of the CIE

Member, CIE International Executive Committee

U.S. Member, Comite Consultatif de Photometrie et Radiometrie

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

J. L. Tech (cont'd)

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

Member, International Astronomical Union Commission 14 (Fundamental Spectroscopic Data) and Commission 19 (Stellar Spectra).

U.S. Member, International Action Committee of the CIE.

E. F. Zalewski

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

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.

Chairman, U.S. Department of Energy National Instrumentation Methods (NIM) Committee.

Member, IEEE Automated Instrumentation Technical Committee, Instrument/Computer Interface of the IEEE Instrumentation and Measurements Society Subcommittee, and U.S. Advisory Group to IEC/TC66/WG3).

Member, Nuclear Standards Measurement Board, American National Standards Institute.

Member, U.S. National Committee of International Electrotechnical Commission (IEC).

Member, IEEE Technical Meeting Committee.

Chairman, Nominating Committee, IEEE Nuclear and Plasma Sciences Society.

Meetings Coordinator, IEEE Nuclear and Plasma Sciences Society.

Chairman, NBS Microprocessor Standards Action Group.

Division 535, Technical and Professional Committee Participation and Leadership (cont'd.)

Samuel Penner

Member, Program Committee for the 1979 Linear Accelerator Conference.

Chairman, 1981 Particle Accelerator Conference.

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.

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CENTER FOR RADIATION RESEARCH

Chris E. Kuyatt, Acting Director
S. M. Thomas, Secretary
Wayne A. Cassatt, Acting Deputy Director
J. P. Ulvedal, Secretary
J. A. Hormuth, Assistant to the Director
M. B. Hale, Administrative Assistant
K. L. Fritz, Administrative Aid
M. H. Phillips, Administrative Aid*

530

OFFICE OF RADIATION MEASUREMENTS

E. H. Eisenhower, Chief
H. T. Heaton, II
R. Colle

531

ATOMIC AND PLASMA RADIATION DIVISION

W. L. Wiese, Chief
L. Gallahan, Secretary

532

NUCLEAR RADIATION DIVISION

R. S. Caswell, Chief
N. Wilson, Secretary*

533

RADIATION PHYSICS DIVISION

L. V. Spencer, Act. Chief
M. Ahalt, Secretary

534

RADIOMETRIC PHYSICS DIVISION

J. L. Tech, Chief
C. Stroup, Secretary

535

RADIATION SOURCES AND INSTRUMENTATION DIVISION

S. Penner, Chief

*Part time

531

ATOMIC AND PLASMA RADIATION DIVISION

Wolfgang L. Wiese, Chief
L. Gallahan, Sec. (1/2)

ATOMIC SPECTROSCOPY

W. C. Martin
L. Ambush, Sec. (1/2)

M. Acquista
A. F. Albright
C. H. Corliss
V. Kaufman
#A. M. Malvezzi
J. Reader
J. Sugar
R. Zalubas

ATOMIC RADIATION DATA

A. W. Wiess
L. Gallahan, Sec. (1/2)

J. R. Fuhr
/R. L. Greene
J. Z. Klose
G. A. Martin
B. J. Miller
L. J. Roszman
+M. L. Thompson
/S. M. Younger

PLASMA RADIATION

J. R. Roberts
L. Ambush, Sec. (1/2)

M. Bassin
J. M. Bridges
D. E. Kelleher
E. Knystautas
+F. W. Lee
T. J. Nee
W. R. Ott
T. Pittman
T. E. Sellner
+J. Weiner

Guest Worker
+ WAE
/ Postdoctoral Fellow

532

NUCLEAR RADIATION DIVISION

Randall S. Caswell, Chief
*N. L. Wilson, Sec.

NUCLEAR THEORY

J. J. Coyne
*G. Wiersma, Admin. Aide

Elementary Particle Physics
- S. Meshkov

Theoretical Nuclear Physics
- M. Danos
- L. C. Maximon
- #D. Lehman

Neutron Standards and Dosimetry
- C. M. Eisenhauer
- J. J. Coyne

NUCLEAR RESEARCH

E. V. Hayward
G. L. Wood, Clerk Typist
*C. Campbell, Librarian

High Energy Electron Scattering
- J. W. Lightbody
- X. K. Maruyama

Photonuclear Data Center
- E. G. Fuller
- H. M. Gerstenberg

Photonuclear Research
- W. R. Dodge
- #R. Leicht
- /R. Starr
- #E. Wolynec

DIFFERENTIAL NEUTRON STANDARDS

C. D. Bowman
J. S. Marks, Sec.

Van de Graaff Neutron Standards
- K. C. Duvall
- A. Wasilewski
- O. A. Wasson

Linac Neutron Standards
- A. D. Carlson (1/2)
- R. A. Schrack (1/2)
- R. B. Schwartz
- R. G. Johnson (1/2)
- G. P. Lamaze

Nuclear Materials Safeguards
- J. W. Behrens
- A. D. Carlson (1/2)
- M. M. Meier
- R. A. Schrack (1/2)
- R. G. Johnson (1/2)

NUCLEAR MATERIALS SAFEGUARDS STUDIES

- J. C. Schleter, Leader
- J. D. Maltese
- V. W. Myers
- S. M. Baloga

RADIOACTIVITY

W. B. Mann
P. S. Pierce, Sec.

- *A. C. Walley, Admin. Aide
- *J. Seymour, Clerk Typist
- ##P. Gelfeld, Clerk Typist
- ##A. Roberts, Clerk Typist

Radioactivity Standards
- R. L. Ayres
- L. M. Cavallo
- B. M. Coursey
- **D. B. Golas
- A. T. Hirshfeld
- D. D. Hoppes (1/2)
- J. Calhoun

Gaseous Radioactivity Standards
- F. J. Schima
- J. E. Harding
- M. P. Unterweger

Environmental Radioactivity Measurements and Standards
- J. M. R. Hutchinson
- P. A. Mullen
- J. R. Noyce
- K. Inn

Nuclear Spectroscopy
- D. D. Hoppes (1/2)

Nuclear Materials Safeguards
- L. Lucas

NEUTRON FIELD STANDARDS

J. A. Grundl
*M. H. Baier, Admin. Aide

Neutron Source Standards
- V. Spiegel (1/2)

Neutron Standard Fields
- R. A. Dallatore (1/2)
- D. M. Gilliam
- E. D. McGarry
- I. G. Schroder (1/2)
- W. E. Slater
- V. Spiegel (1/2)

Reactor Neutron Nuclear Physics
- I. G. Schroder (1/2)
- R. A. Dallatore (1/2)

* Part time
** Research Associate
\# Guest Worker
\## Stay-in-School Program
\+ WAE
/ Postdoctoral Fellow

533

RADIATION PHYSICS DIVISION

Lewis V. Spencer, Acting Chief
M. Ahalt, Sec.

RADIATION THEORY

M. Berger
M. Jones, Admin. Aide

- Transport Theory & Radiation Effects
  - S. Seltzer
- X-ray & Ionizing Radiation Data Center
  - J. Hubbell

FAR UV PHYSICS

R. Madden
C. Maria, Admin. Aide

- Far UV Radiometry
  - R. Canfield
  - L. Hughey (1/4)
  - R. Falge
  - E. Saloman
  - T. Hall
- Dynamics of Excited States
  - B. Dole
  - D. Ederer
  - T. Lucatorto
  - ÷T. McIlrath
  - ≠G. Mehlman
  - °A. Parr
- Far UV Optical & Photoelectric Properties
  - L. Hughey (1/4)
  - J. Rife

SURF Operations (535)

L. Hughey (1/2)

DOSIMETRY

R. Loevinger
J. Shorten, Sec.

- Dosimetry Standards
  - S. Domen
  - P. Lamperti (1/2)
  - T. Loftus (1/2)
  - J. Pruitt
  - J. Weaver (1/2)
- Calibration Services
  - P. Lamperti (1/2)
  - T. Loftus (1/2)
  - H. Walker
  - J. Weaver (1/2)
- Measurement Technology & Assurance
  - M. Ehrlich
  - C. Soares

X-RAY PHYSICS

J. Motz
V. Varone, Sec.

- Plasma X-ray Standards
  - J. Sparrow
- Measurement Techniques for High Radiation Dose
  - J. Humphreys
  - W. McLaughlin
- Radiology
  - C. Dick
  - R. Placious
  - D. Polansky
- Electron & X-ray Irradiation Services
  - J. Mills

ELECTRON PHYSICS

R. Celotta
*T. Barlow, Admin. Aide

- Electron Scattering & Polarization
  - /J. Hamilton
  - °M. Kelley
  - S. Mielczarek
  - D. Pierce (3/4)
  - °G. C. Wang
  - N. Swanson
- Electron Physics Theory
  - ≠T. M. Lu
  - D. Penn
  - R. Rendell
- Electron Optics
  - A. Galejs

- WAE
* Part time
= Guest Worker
° IPA

534
RADIOMETRIC PHYSICS DIVISION

Jack L. Tech, Chief
C. W. Stroup, Sec.
D. L. Butler, Admin. Aide (1/2)

SPECTRORADIOMETRY AND OPTICAL PYROMETRY

H. J. Kostkowski
B. Castle, Admin. Asst.

Spectrophotometry
- H. Kostkowski (1/2)
- *C. Popenoe
- R. Saunders
- J. Shumaker (3/4)
- *J. Ward
- W. Waters (1/4)

Optical Pyrometry
- H. Kostkowski (1/4)
- E. Lewis (1/2)
- W. Waters (3/4)
- R. Yokley (1/2)

Self-Study Manual on Optical Radiation Measurements (SSM)
- H. Kostkowski (1/4)
- F. Nicodemus
- J. Shumaker (1/4)
- Division Staff

Infrared Radiometry
- R. Yokley (1/2)

ELECTRO-OPTICAL RADIOMETRY

J. Geist
D. Butler, Admin. Aide (1/4)

Electrically Calibrated Radiometry
- A. Crigler (1/2)
- J. Fowler (1/4)
- J. Geist (1/4)
- E. Zalewski (1/4)

Silicon Detector Radiometry
- A. Crigler (1/4)
- J. Fowler (1/4)
- J. Geist (1/2)
- A. R. Schaefer (1/4)
- E. Zalewski (1/2)

Electro-Optical Applications
- A. Crigler (1/4)
- J. Fowler (1/2)
- J. Geist (1/4)
- #O. Nejamis
- A. R. Schaefer (3/4)
- E. Zalewski (1/4)

SPECTROPHOTOMETRY, MAP AND RESOURCE RECOVERY

J. J. Hsia
*B. Hendrick, Clk. Steno (3/4)

Diffuse and Specular Reflectance
- L. Fink (1/8)
- M. Freund (1/4)
- J. Hsia (1/2)

Retroreflectance
- θR. Booker (1/2)
- K. Eckerle (1/2)
- L. Fink (1/8)
- M. Freund (1/2)
- J. Hsia (1/4)
- V. Weidner (1/4)

Diffuse Transmittance
- θR. Booker (1/4)
- M. Freund (1/4)
- J. Hsia (1/4)
- V. Weidner (1/4)

Regular Transmittance
- θR. Booker (1/4)
- K. Eckerle (1/2)
- V. Weidner (1/4)

Densitometry
- L. Fink (3/4)

PHOTOMETRIC-RADIOMETRIC CALIBRATIONS AND MAP

D. A. McSparron
*B. Hendrick, Clk. Steno (1/4)
D. Butler, Admin. Aide (1/4)

Radiometric Calibrations
- R. Brown (1/2)
- W. Gladden (3/4)
- J. Jackson (1/4)
- J. Walker (1/2)

Photometric Calibrations
- R. Brown (1/4)
- J. Jackson (1/4)
- E. Lewis (1/2)

MAP Development
- R. Bruening (1/2)
- D. McSparron (1/2)

Photometric-Radiometric Unit System
- R. Brown (1/4)
- R. Bruening (1/2)
- W. Gladden (1/4)
- J. Jackson (1/2)
- D. McSparron (1/2)
- J. Walker (1/2)

* Part time
\# Guest Worker
θ Temp. Assign. to DOE

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RADIATION SOURCE AND INSTRUMENTATION DIVISION

Sam Penner, Chief

ACCELERATOR PHYSICS

E. R. Lindstrom
M. A. Wilson
+J. K. Wolford

SURF OPERATIONS

S. Ebner
A. Filipovich
G. Rakowsky
L. Hughey (1/2) (533)

LINAC OPERATIONS

J. E. Rose
L. M. Cline, Admin. Aide

J. B. Broberg
W. J. Dobbie
C. G. Keys
I. J. Livant
A. S. Lopez
W. H. Page
S. P. Sirkis
S. C. Strumsky
J. A. Winpigler

ELECTRONIC INSTRUMENTATION

L. Costrell
V. R. Lenhart, Admin. Aide

P. H. Beachley
S. Careathers
R. M. Graves
D. C. Green
A. B. Marella
A. A. Raptakes
F. R. Saunders
J. K. Whittaker
R. C. Wilkinson

MECHANICAL INSTRUMENTATION

D. L. Mohr

C. D. Bostian
P.Jackson
H. Lantz

+ WAE

CENTER FOR RADIATION RESEARCH

GUEST WORKERS

Division	Name	Outside Sponsor	Scientific Area
531	Malvezzi, A.	Centro Informazioni Studi Experienze, Milan	Spectra of highly ionized atoms.
531	Manley, O.	Dept. of Energy	Magnets for Fusion Machines-Tokamaks.
531	Priester, D.	Dept. of Energy	Plasma Physic Properties.
531	Stone, P.	Dept. of Energy	Magnetic fusion energy research.
532	Burt, P.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Cardman, L.	Univ. of Illinois	Electron Scattering using NBS Linac.
532	Crannell, H.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Drake, T.	Univ. of Toronto, Toronto, Canada	Electron Scattering using NBS Linac.
532	Fagg, L.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Flanz, J.	Univ. of Massachusetts	Electron Scattering using NBS Linac.
532	Leicht, R.	Deutsche Forschungsgemeinschaft, Germany	Photon Scattering (Elastic).
532	Lindgren, R.	Univ. of Massachusetts	Electron Scattering using NBS Linac.
532	Meshkov, N.	National Sci. Foundation	Women in Science Career Project.
532	O'Brien, J.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Pal, R.	Howard University	Penetration and Energy Deposition of Fast Charged Particles in Matter.
532	Peterson, G.	Univ. of Massachusetts	Electron Scattering using NBS Linac.
532	Sober, D.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Sobie, R.	Univ. of Toronto, Toronto, Canada	Electron Scattering using NBS Linac.
532	Stapor, W.	Catholic Univ.	Electron Scattering using NBS Linac.
532	Wolynec, E.	Univ. of Sao, Brazil	Electron Scattering using NBS Linac.

Center for Radiation Research, Guest Workers (cont'd.)

Division	Name	Outside Sponsor	Scientific Area
532	Yen, S.	Univ. of Toronto, Toronto, Canada	Electron Scattering using NBS Linac.
532	Zanon, D.	Dr. A.M. Malvezzi	Field theory of composite systems & weak interactions.
533	Codling, K.	Univ. of Reading, England	Studying excitation dynamics in atoms at SURF-II.
533	Dehmer, J.	Argonne National Lab.	Variable wavelength photoelection angular & energy distribution at SURF.
533	Lehman, D.	George Washington Univ.	Scattering problems in nuclear physics.
533	Levine, H.	Bur. of Radiological Health, Food & Drug Admin.	Radiation Dosimetry.
533	Lu, T.M.	- - -	Electron-surface interaction.
533	Markovic, V.	Boris Kidric Inst. of Nuclear Science & Univ. of Maryland	Radiation Dosimetry.
533	Mehlman, G.	Laboratoire des Hautes, Bellevue, France	Far UV Absorption Spectra of Atoms and Molecules.
535	Parrington, J.	Univ. of Maryland	Environmental Monitoring System.

INDUSTRIAL RESEARCH ASSOCIATE

Division	Name	Outside Sponsor	Scientific Area
532	Golas, D.	Atomic Industrial Forum.	Radiopharmaceutical Standards.

CENTER FOR RADIATION RESEARCH

INTERGOVERNMENTAL PERSONNEL ACT

Division	Name	Outside Sponsor	Scientific Area
533	Kelley, M.	Univ. of Texas	Spin polarized electron scattering from atoms & metals.
533	Parr, A.	Univ. of Alabama	Measurements on atomic, molecular & surface systems using SURF II.
533	Wang, G.	Univ. of Wisconsin	Spin polarized electron scattering from single crystals of metals.

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, measurement methodology, and measurement services in the areas of optical radiation, ultraviolet radiation, and ionizing radiation (x-ray, gamma rays, electrons, neutrons, radioactivity, etc.); 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; participates in collaborative efforts with other NBS centers in the interdisciplinary applications of radiation.

ATOMIC AND PLASMA RADIATION DIVISION: Provides a central coordination for the Nation's research into the spectroscopic and radiative properties and characteristics of atoms and ions; provides an essential resource of competence for the solution of problems involving the measurement, assignment, and detailed analysis of spectra and atomic processes; carries out basic theoretical and experimental research on the spectra and radiative and collisional rates of atomic and ionic species; develops new measurement techniques and methods for spectral analysis and for the measurements of plasma properties; collects, compiles, critically evaluates, and supplements the existing spectroscopic data base in order to meet the major demands of the Nation for such data; participates in the interdisciplinary applications of atomic and plasma radiation to the extent necessary to insure that the resources of the Division are most efficiently used to meet the needs of measurement and data users in these areas.

NUCLEAR RADIATION DIVISION: Provides the central national basis for the system of measurements of nuclear radiations, and coordinates this system with the systems of other nations; develops national standards, provides dissemination and measurement assurance services leading to accurate and uniform measurements of nuclear radiations throughout the Nation for radiation user communities such as nuclear energy and environmental protection, medicine, industry, and national defense; conducts research leading to improved methods of measurement, measurement standards, and highly accurate standard reference data for nuclear radiations; develops increased understanding of the properties of radiation fields and of nuclei, and determines needed nuclear and radiation data.

RADIATION PHYSICS DIVISION: 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 ionizing 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.

RADIOMETRIC PHYSICS DIVISION: Provides the National Measurement Laboratory with resource of talent and expertise on general problems involving the measurement of optical radiation; conducts research to improve the accuracy and extend the range of optical radiation measurements; develops methods and standards for both detector and source based radiometry, and provides technical resources in this area for the solution of problems in other Government agencies, industry, and the public sector; develops calibration procedures, standards of reflectance and transmittance, and highly accurate reference instrumentation for spectrophotometry; conducts research in electro-optical technology and the associated radiometric measurement problems; characterizes quantum detectors and slitless spectroradiometers by use of tunable lasers and electrically calibrated pyroelectric detectors.

RADIATION SOURCE AND INSTRUMENTATION DIVISION: Operates, maintains, and improves major NBS radiation facilities including the electron linear accelerator (LINAC) and synchrotron ultraviolet radiation facility (SURF) in order to provide the radiations required by the users of these facilities, both inside and outside of NBS; develops, designs, and builds electronic and mechanical instrumentation needed for the operation of the radiation facilities, and for the programs of the other divisions in the Center for Radiation Research; provides national leadership in standardizations of nuclear and radiation instrumentation; maintains and acquires new competence in the areas of accelerators and instrumentation in order to satisfy future needs of the Center, of NBS, and of outside agencies for advanced accelerators, radiation sources, and instrumentation.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)* The FY 79 technical activities of the Center for Radiation Research are described. New work in Division 531 has focused on development of plasma diagnostic techniques, spectral identification in highly ionized isoelectronic atoms, theoretical studies of atomic processes, and photoionization of excited atoms. Division 532 activities include investigations in quantum chromodynamics, positron bremsstrahlung production, nuclear electric dipole giant resonances, nuclear charge distributions, differential neutron cross-sections, resonance neutron radiography, international neutron fluence standards and high pressure ionization chambers. Division 533 work is highlighted by a new radiation effects program and studies of ion-track structure, water calorimeters, x-ray imaging, start mixing, surface magnetism, and electronic structure of metallic glasses. In Division 534 a coherence and polarization laboratory, computer-controlled spectroradiometer, specular reflectometer and large-area blackbody calibration facility were completed. Instrument response functions for spectral line width, polarization, coherence, etc., were determined. Division 535 operated NBS LINAC and SURF facilities, designed computer data acquisition and research instruments, initiated a room temperature CW accelerator development project and demonstrated stable induction linac beam recirculation. Office of Radiation Measurement activities include designing a pilot regional calibration laboratory, coordinating an environmental radiation data reporting method, organizing a "Radon in Buildings" roundtable discussion, and a medical accelerator conference.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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