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HEALTH AND SAFETY RESEARCH DIVISION PROGRESS REPORT FOR THE PERIOD JULY 1, 1984-SEPTEMBER 30, 1985

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Director

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MASTER

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FOREWORD

S. V. Kaye

Programs in the Health and Safety Research Division (HASRD) provide a focal point at the Oak Ridge National Laboratory (ORNL) for research and technical studies that complement basic biological studies and are necessary to facilitate the assessment of impacts of energy-related activities on human health. On the one hand, our long-term physical research studies form the foundation of the division's programs and are designed to create new basic knowledge rather than to solve specific energy technology problems. On the other hand, our life sciences effort is concerned largely with the biophysical processes of environmental transport of pollutants, exposure of workers and the public, nuclear medicine, and potential health impacts of energy related activities. The presence of strong fundamental and applied research programs in the division has often allowed us to demonstrate impressive overall problem solving capabilities.

This report summarizes the important progress we have made in our programs for the period July 1984 through September 1985. Our intention is that this progress report will serve as a guide to the extensive publications that fully document this work. A 1985 compilation by the ORNL Office of Program Planning and Analysis used data from 1979-1983 to evaluate productivity of ORNL research divisions. Based on the latest complete set of data (1983) the compilation showed that HASRD leads all other divisions at ORNL in two important categories: (1) total publications (3.0 publications per year per scientific staff member), and (2) oral presentations (3.2 talks per year per scientific staff member). We also led the Laboratory in total books published (19 books authored) during the five-year period covered in the compilation. The division's presentations and publications represented important contributions on the forefronts of many fields. Three of our staff's publications and two of our inventions were recipients of awards at the first annual Martin Marietta Energy Systems awards night.

A special new Excellence in Research Award was inaugurated in 1985 and will be presented to a HASRD staff member annually for either applied research (odd numbered years) or basic research (even numbered years). A panel selected Tuan Vo-Dinh as recipient of the first award for his work on establishing room temperature phosphorescence as an accurate and practical analytical methodology for pollutant monitoring. Vo-Dinh was also developer of the Light Pipe Luminoxcope which became the first product to be licensed by Martin Marietta Energy Systems for manufacture by an East Tennessee firm.

One measure of the division's creativity is shown in the record of patent activities for inventions since the last reporting period. Twelve invention disclosures were filed, five patent applications were submitted, and six patents were awarded. Energy Systems now provides incentives to staff who file for patents. It is the company's policy to transfer new technologies to the private sector more efficiently than in the past.

A significant increase in the experimental capabilities of our Health Studies Section was attained with the establishment of a new Biodosimetry Group under the leadership of A. W. Hsie who transferred from the Biology Division. The new group is using mammalian gene mutations both *in vivo* and *in vitro* to determine mutagen-induced alteration at the level of DNA sequences and the application of these indicators for biotesting and research related to screening

environmental samples. This experimental program brings together staff and resources of both the Biology Division and HASRD.

G. S. Hurst, Corporate Fellow in HASRD, retired after 33 years of highly productive company service. Holder of 17 patents and a pioneer in the development of neutron detectors and health physics instrumentation, Hurst's most recent major contributions were in resonance ionization spectroscopy (RIS) and one of its special applications, single atom detection. Shortly before his retirement he led a team of researchers that successfully used RIS to measure the age of all of the Kr-81 atoms in a sample of ancient ground water. An IR-100 Award was awarded to the team of C. H. Chen, S. D. Kramer, G. S. Hurst, S. L. Allman, R. C. Phillips, and M. G. Payne for the "ORNL Rare Gas Atom Counter" used in this work. Hurst will continue his association with HASRD through the ORNL/University of Tennessee (UT) Science Alliance Program. The Photophysics Group is now under the leadership of M. G. Payne.

Several other long-time staff members took retirement since our last reporting period. These include: S. R. Bernard, M. L. Randolph, W. H. Shimpugh, R. W. Shor, T. A. Butler, P. W. Reinhardt, and N. D. Brashier.

R. N. Compton also received an ORNL/UT Science Alliance appointment to help develop a graduate research program and curriculum in chemical physics. His efforts are expected to result in a formal program at UT in this important area which has been neglected. The division's Chemical Physics Section is expected to benefit by stronger research collaboration with the University.

The division's responsibilities to DOE under the Uranium Mill Tailings Remedial Action (UMTRA) program continued to increase in scope. C. A. Little is the division's site manager for 31 HASRD employees and more than 20 subcontractor employees at our office in Grand Junction, Colorado. The group completed inclusion recommendations for 1600 properties in FY 1985 and received an excellent rating by DOE for overall performance.

C. C. Travis was appointed Coordinator of the Office of Risk Analysis, replacing H. Ennaber who left the laboratory. The research funding for risk analysis increased during the reporting period and provided strong encouragement to establish ORNL as a center of excellence in risk analysis.

Under the leadership of A. R. Hawthorne, the Measurement Applications Group has developed a significant new program in indoor air measurements. The group has made many advances in methodology, instrumentation, and interpretation of pollutants found in the indoor air of homes in the southeast. The division's staff were instrumental in organizing the 7th ORNL Life Sciences Symposium, "Indoor Air and Human Health."

Our program in research related to dielectrics was greatly diversified during the reporting period. The excellent program on gaseous dielectrics continued to make important contributions to the field; but during the same time period we expanded our program into liquids, solids, and biotoxicity of dielectrics.

Conclusions drawn from our first major epidemiological field study under the sponsorship of the Environmental Protection Agency drew national attention. We found that for a population of Wisconsin farmers who obtain their drinking water from wells, cardiovascular disease was more associated with lower intakes of calcium and magnesium than with higher natural levels in drinking water. A follow-up study is now underway to examine in more detail the correlations of physiologic parameters and water chemistry.

We provided special assistance to the Nuclear Regulatory Commission by conducting a field investigation in the environs of the Rancho Seco Nuclear Power Plant in California to determine if the liquid effluent releases and subsequent doses to populations were below regulatory limits. Our

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comprehensive field sampling and analyses showed that the plant was in compliance with regulations.

Division staff received many types of recognition during the reporting period including appointments to national committees, editorships, "fellow" status in national scientific societies, etc. Three awards of particular note were the Jesse Beams Award (American Physical Society) received by R. H. Ritchie, the Distinguished Scientist Award (EPA) received by A. W. Hsie, and the Distinguished Service Award (Society for Risk Analysis) received by C. C. Travis.

The success of our many endeavors since the previous progress report demonstrates both the versatility and the effectiveness of the division in carrying out complex R & D programs in a very competitive environment. A number of our groups have national leadership positions in their specialties, while some even attained the same recognition on the international level. We are optimistic that we will continue to maintain these hard earned positions while we continue to improve and mature in new areas. The scientists, technicians, and clerical staff of HASRD are all exceptional people who will continue to work toward goals of improvement.

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Research in the Health Studies Section is organized under five groups which, together, provide capabilities to improve evaluation of human health impacts of technology implementation. The Advanced Monitoring Development Group develops instrumentation for monitoring exposure, dose and biological indicators related to human response to toxic materials. Emphasis is on real time or near real time field measurements of indicators of present or past exposures of individuals and populations. The Biodosimetry Group utilizes bioassays to obtain experimental data for use in analytic health hazard assessments. Results from basic research are adapted and developed further into improved methods for biotesting to support dose-response modeling. The group also provides biotesting capabilities for applied, Laboratory-wide multidisciplinary health assessment studies. The Health Effects and Epidemiology Group is conducting a major epidemiological study on the relationship of drinking water characteristics to cardiovascular disease. The group also conducts a variety of health effects assessment studies including screening level assessment systems for chemicals, ionizing radiation dose-response, electromagnetic field exposures and effects, and fusion energy-related issues. The Measurement Applications Group conducts experimental field studies of populations exposed in occupational and domestic settings. Laboratory studies of pollutant emission characteristics of a variety of consumer products, permeation of complex mixtures through candidate protective materials and model development are also ongoing. A major new activity is a 300-home indoor air quality study in the Oak Ridge area. The Nuclear Medicine Group designs and develops tissue-specific radiopharmaceuticals for *in vivo* nuclear medicine imaging and dynamic studies, prepares other radiolabeled substances for a variety of biomedical applications, and carries out preclinical testing of new agents in animals and various *in vitro* systems. An important feature of the nuclear medicine program is distribution of radiolabeled agents through 15 Medical Cooperative Programs for further preclinical testing and clinical evaluation.

ADVANCED MONITORING DEVELOPMENT

The Advanced Monitoring Development Group's research activities involve a multidisciplinary research program to develop or improve chemical sensors, screening methodologies, biological monitors and emerging monitoring technologies for human exposure to hazardous pollutants.

Recent fundamental investigations on room temperature phosphorescence (RTP) have shown that a heavy-atom salt, mercury chloride, has very selective properties in the enhancement of RTP of nitrogen containing polynuclear aromatic (PNA) compounds. These results will lead to the development of selective monitors for specific target pollutants of toxicological importance.

Laser-induced spectroscopy was used to provide the first observation of the phosphorescence line narrowing (PLN) effect on PNA compounds, such as coronene and phenanthrene adsorbed on filter paper. Extremely narrow phosphorescence emission lines ($<1\text{\AA}$) were successfully observed at 4K. This result is of great interest to fundamental research and also indicates that the filter paper substrates can be used for routine, rapid, and cost-effective analysis of environmental samples by

RTP, as well as for highly selective detection of specific PNA compounds in complex mixtures by laser-induced line narrowing spectroscopy at low temperatures.

Research and development work on surface-enhanced raman scattering (SERS), conducted under the joint sponsorship of the Department of Energy (DOE) and the Department of the Army, has led to the first publication on the analytical applications of SERS for a variety of PNA compounds. We have also demonstrated that the quartz post-based substrates, developed in the HASRD through collaboration of the Physics of Solids and Macromolecules Group and the Liquid and Submicron Physics Group, are the most strongly enhancing known SERS surfaces.

We continue a strong research program to expand the state-of-the-art in chemical monitors. The PNA passive dosimeters continue to receive further validation tests that will lead to acceptance of this device as an important personnel monitor in occupational and residential environments. The synchronous luminescence (SL) technique is becoming a critically important tool for cost-effective screening of complex mixtures. Recently, the SL screening tool has successfully been tested in an indoor air field study sponsored by the EPA. With regard to technology transfer, the DOE has given approval for Environmental Systems Corporation to acquire exclusive rights to manufacture and distribute the luminoscope. This agreement represents the first licensing agreement between Martin Marietta Energy Systems, Inc. and a private company in East Tennessee.

Our research programs on biomonitors are directed toward development of sensitive biological tools based on hybrid technologies integrating biotechnology and advanced sensing and spectroscopic detection techniques to monitor chemical species at trace levels in microsamples of body fluids. Among the various monitors under development is a unique fluoroimmunosensor (FIS) which derives its analytical selectivity through the specificity of antibody-antigen reactions. In this collaborative project with UT, antibodies are immobilized at the terminus of a fiberoptic within the FIS, and assay procedures will ultimately involve *in vivo* incubation followed by *in vitro* fluorescence measurement. High sensitivity is to be achieved through the combined utilization of europium chelate fluorotags, pulsed laser excitation, and signal recovery using a gated photon counter.

Experimental work is ongoing to develop antibodies to benzo(a)pyrene (BaP) for future incorporation onto the FIS and other antibody-based monitors. In this work BaP was covalently coupled to an immunizing protein by chemical synthesis and the resulting hapten-protein complex used to immunize rabbits for antibody production.

In the development of biomonitoring tools we have demonstrated that carcinogenic compounds such as BaP have a significant depression effect on interferon response in an *in vivo* system. We have also developed a simple and rapid procedure for urine cleanup that permits non-invasive and direct spectroscopic detection of important nucleosides and PNA metabolites as critical bioindicators of human exposure to toxic chemicals.

BIODOSIMETRY

The Biodosimetry Group uses biological and physical techniques to study the toxic and mutagenic effects of environmental chemical and physical agents as well as complex mixtures, ultimately leading to the assessment of risk to humans from exposure to these agents. We have devoted our efforts to the following three major projects.

First, Chinese hamster ovary (CHO) cells and their radiation-hypersensitive transformants (AS52 cells) have been used to provide experimental evidence that the mutagenic effects of ionizing

radiations (neutrons and x rays) and radiomimetic chemicals (streptonigrin and bleomycin) are mediated through oxygen free radicals. The hypermutability of AS52 cells would permit detailed mutagenesis studies at low dose and low dose-rate exposures by these agents.

Second, CHO cells have been used to demonstrate that UDP-glucuronyl- and glutathione-S-transferases play an important role in the detoxication of benzo(a)pyrene-induced cytotoxic and mutagenic effects. This should elucidate the roles of metabolic effectors which result in the modulation of the biological effects of benzo(a)pyrene, an important consideration in the assessment of the health hazard of this model suspected human carcinogen.

Third, bioassays needed to accurately estimate the health effects of wastewater effluents are being evaluated. This laboratory-wide project includes participation by investigators from five divisions (Analytical Chemistry, Biology, Chemical Technology, Environmental Sciences, and HASRD). This project demonstrates that ORNL has a unique interdisciplinary capacity to tackle an extremely complex environmental and health hazard problem at the national level. Similar efforts are underway to develop a division-wide project on human population monitoring as related to genetic bioassays and molecular epidemiological analysis. These areas are funded by the EPA.

HEALTH EFFECTS AND EPIDEMIOLOGY

Ongoing work for the Defense Nuclear Agency has examined dose-response models for hematologic depression and death in response to high dose-rate radiation exposures. Work being carried out in the area includes the development of a dose- and time-dependent model for biological mechanisms of hematologic mortality, and extension of the work into the area of gastrointestinal dysfunctions.

The group is examining the body of literature dealing with the effects in animals and humans of exposure to extremely low frequency electric fields, and developing techniques for comparing information from the variety of studies to carry out overall statistical tests of effect.

The group continues to develop and carry out epidemiological studies of environmental exposures and intakes of inorganic elements. One case-control study in the state of Wisconsin has been completed. The study was carried out in the population of Wisconsin farmers and found differences between calcium and magnesium intake in drinking water between the group with cardiovascular disease and the group without evidence of cardiovascular disease.

A new study has begun which further examines the possible effect of drinking water intakes on the cardiovascular system. This study will examine blood pressure, serum lipids, and thyroid function in 40 communities in the state of Wisconsin, with the communities having a broad range of water hardness (calcium and magnesium content) as well as both chlorinated and nonchlorinated supplies.

The U.S. Air Force's (USAF) Installation Restoration Program requires the identification and evaluation of past hazardous material disposal sites on Department of Defense property as well as the control of adverse effects on the environment and human health from contaminant migration. Phase I was completed with input from HASRD and Environmental Sciences Division (ESD) staff, and resulted in the development of a hazard assessment rating methodology (HARM) to use in prioritizing USAF sites for Phase II investigations. The HARM has since been modified to permit the use of site-specific monitoring data and is now known as HARM II.

Work requested from HASRD and ESD staff for FY 1986 includes production of a HARM II *Users' Manual* and a collaborative test of the system. Health Effects and

Epidemiology Group staff will prepare an appendix entitled *Health Effects Benchmarks* which will incorporate the use of T. Jones' relative potency schema to evaluate over 50 compounds and isomers identified by the USAF as materials of interest.

Occupational and population health and safety aspects of the fusion energy technology continue to be a focus of effort. Work is being carried out in conjunction with the Energy Division programs to evaluate health and safety concerns of fusion energy. Other work being carried out in conjunction with the Energy Division includes an evaluation of noise exposure work for two commands of the Air Force, the Tactical Air Command and the Strategic Air Command. Both commands have needs to establish new training routes or areas. Group tasks have been to assess health consequences of noise exposure to humans and domestic animals. More recently work has begun on vibration effects on ruins.

Other work has been on a multiple Air Force command user communications facility, the Northeast Regional Communications Facility. The focus here is health effects of microwave and radiofrequency transmitters.

MEASUREMENT APPLICATIONS

The Measurement Applications Group has two major objectives: (1) to obtain experimental exposure measurements to assist in health effects assessments; and (2) to test, refine, and validate new monitoring techniques for making exposure measurements.

During this reporting period efforts directed toward occupational health research, especially measurement activities associated with synfuel projects, have decreased due to shifting priorities by DOE. Laboratory investigations of protective clothing materials and complex mixtures of organic challenges have continued with support by the American Petroleum Institute and DOE's Office of Health and Environmental Research.

Indoor air quality research activities have grown to account for approximately 75 percent of the group's efforts. Activities include methods development, source characterization, modeling, research house studies, and field studies. Investigations address a variety of indoor pollutants including radon and radon progeny, formaldehyde, volatile organic compounds, aromatic organics, combustion gases, and particulate matter.

Indoor air quality research is supported by DOE/Conservation, Consumer Product Safety Commission, EPA, TVA, and EPRI. Collaborative efforts with support by Harvard University are an important component of our research.

Specific activities with multiple-sponsor support include a 70-home study of indoor air quality in residences of four states. Homes are being monitored for radon and radon progeny, formaldehyde, nitrogen dioxide, water vapor, PNA vapors, and volatile organic compounds during a one-year period. Housing characteristics, including air exchange rates, are also being obtained. Our study includes participants living in Oak Ridge and Chattanooga, Tennessee; Rossville, Georgia; Huntsville, Florence, and Birmingham, Alabama; and Tupelo, Mississippi.

Another indoor air quality field study that will be conducted during FY 1986 will involve 300 homes in the Kingston/Harriman communities of East Tennessee. This study will be done in conjunction with Harvard University, which has been monitoring air quality and respiratory health during the past decade. The Kingston/Harriman site is one of six cities in which indoor air quality will be measured during the next three years. In addition to monitoring for the above mentioned pollutants, this study will also investigate levels and types of airborne bacteria and fungi found in

the homes. A comparison of indoor air quality in homes with wood burning appliances and those without will be performed.

Our plans include efforts to increase research components supporting occupational health research and hazardous waste (especially mixed chemical and radiological wastes) research to obtain a better balance with our indoor air quality research.

NUCLEAR MEDICINE

The Nuclear Medicine Group consists of a multi-disciplinary team involved in the design and development of new radiopharmaceuticals for use in diagnostic nuclear medicine. Principal activities are the design and development of tissue-specific radiopharmaceuticals for *in vivo* nuclear imaging and the regional study of metabolism, biochemical studies to determine the mechanism of tissue specificity of the radiolabeled agents, preparation of other radiolabeled substances for a variety of biomedical applications, and preclinical testing of new radiolabeled agents in laboratory animals and various *in vitro* systems. Major emphasis is on the development of agents for the evaluation of heart disease, cerebral blood flow, and quantification of tissue metabolism. In conjunction with the development of radiopharmaceuticals, new, innovative radiolabeling techniques are being developed to incorporate radionuclides into the tissue specific agents. Distribution of radiolabeled agents through 15 Medical Cooperative Programs for further preclinical testing and clinical evaluation is also a major aspect of the program since these activities provide a rapid technology transfer.

A unique iodine-123-labeled methyl-branched fatty acid, 15-(para-iodophenyl)-3-(R,S)-methylpentadecanoic acid, developed at ORNL has entered clinical testing for the diagnosis and management of coronary artery disease, and for the early diagnosis of hypertensive disease. Normal patients and patients with coronary artery disease have been studied with this agent which shows excellent properties for the evaluation of myocardial disease not detected with currently available myocardial perfusion agents. A detailed biochemical evaluation of the distribution of radiolabeled fatty acid metabolites within the various lipid pools of heart tissue has been performed to identify the mechanism of localization and retention of this novel agent. In addition to studying the mechanism of transport and storage of methyl-branched fatty acids, major emphasis continues to be focused on new synthetic studies and preclinical testing to further evaluate structural features of the methyl-branched fatty acids that lead to optimal myocardial uptake and retention.

A new class of radioiodinated carbohydrates designed to metabolically trap tracers and enable the regional study of glucose metabolism in patients with very prevalent pathological disorders such as stroke, epilepsy and dementia by single photon techniques is under development. Radioiodide has been chemically stabilized as an iodovinyl moiety attached to 2- and 3-positions of the carbohydrate ring. Several model agents have been prepared and show low *in vivo* deiodination in experimental animals. The preparation of a variety of iodovinyl sugars with the active-D-glucose and D-mannose configurations required for active transport across the blood-brain barrier is now in progress.

A new strategy for the brain-specific delivery of radiolabeled agents to potentially measure regional cerebral blood perfusion has been achieved. This approach involves the chemical transformation of the quarternary charged form of a radiolabeled agent normally impermeable to the brain to a neutral lipid soluble form which readily crosses the blood-brain barrier with the resulting distribution pattern reflecting regional blood flow. Once within the brain the neutral form of the radiolabeled agent is oxidized to the original charged form and not released, resulting in prolonged retention. Several of these agents, iodine-123-labeled dihydronicotinamide analogues,

have been prepared and show pronounced brain uptake and low blood levels resulting in high brain to blood ratios. The synthesis of a variety of structural analogues is now under development to obtain structure-activity data to identify key structural features to optimize brain uptake and radiolabeling yields of this class of agents.

A new improved osmium-191/iridium-191m generator system which gives good iridium yields, low osmium-191 parent breakthrough, and has a useful clinical shelf-life of two-three weeks has been developed. The screening of several osmium species of various valence states with 39 potential adsorbents identified osmium(VI) potassium hexachloroosmate adsorbed on activated carbon as the most attractive generator system. The activated carbon osmium-191/iridium-191m generator system developed at ORNL may be of significant importance in the diagnosis of heart and vascular disease using nuclear medicine techniques. This system has entered clinical trials through our medical cooperative program in which 50 patients have been evaluated. Studies have been performed for the evaluation of both right and left ventricular ejection fraction; perfusion of the cerebral, femoral, and renal arteries; and evaluation of occlusions of the leg veins. The ultrashort-lived iridium-191m radioisotope (4.9 sec half-life) may also be used for the detection and evaluation of abnormal blood-flow (shunts) between the heart chambers of pediatric patients. The consistent performance of the generator over a two-three week period may make this system available to a large clinical population at a cost competitive with currently available nuclear medicine procedures. Presently a variety of carbon adsorbents and various generator geometries are being evaluated to increase yields to prolong the useful shelf-life.

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The objective of many of the section's research projects is the development, evaluation, and application of concepts for assessing health and safety impacts on man from energy technologies. For example, considerable effort is focused in the areas of describing the uptake and retention of ingested radionuclides and the resultant internal dose. Special emphasis is given to identifying processes that account for biological variability among humans as contrasted with standardized adult models. Another research focus is the development of quantitative models for the environmental transport of nuclear pollutants to humans. These models and strategies for use in decision making are provided to regulatory agencies to facilitate the development and implementation of exposure standards for protecting public health and safety. The theoretical methodology development and application activities are complemented by laboratory and field experimental activities. One such activity is measurements and surveys in support of DOE's Remedial Action Projects. The Health Physics Research Reactor, a heavily utilized DOE user facility in mixed-field (neutron plus gamma-ray) dosimetry research, is another experimental facility in the section. Grand Junction, Colorado continues to demonstrate cost-effective performance of the tasks for DOE's Remedial Action Projects. Other elements of the programs involve development of health risk estimates and implementation of models for quantitative

evaluation of potential impacts. Education, training, and university interactions are important parts of the section's activities.

DOSIMETRY APPLICATIONS RESEARCH

The Health Physics Research Reactor (HPRR) is the principal research tool of the Dosimetry Applications Research (DOSAR) Group. It is a fast pulse reactor which can be operated up to 10^{17} fissions in the pulse mode and to 10 kW in the steady-state mode. Because security-related changes affected the output of the HPRR, new reference dosimetry is being developed. A series of Bonner sphere neutron spectrum measurements was made during 85 reactor runs. Dose conversion factors are being meshed with unfolded spectra to provide new reference dosimetry.

Three mixed-field neutron and gamma-ray dosimetry studies, the Twenty-first and Twenty-second Nuclear Accident Dosimetry Intercomparison Studies and the Eleventh Personnel Dosimetry Intercomparison Study, were conducted using the HPRR. The large number of participants (57 organizations: 41-U.S., 16-foreign) indicates the continuing need for these internationally prominent experimental studies.

The HPRR was used by ORNL's Biology Division in ongoing neutron carcinogenesis studies, by four DOE labs to perform criticality alarm tests, by two universities for student training, and by ten different organizations for neutron dosimeter development.

The DOSAR staff organized and conducted the Personnel Radiation Dosimetry Symposium in Knoxville on October 15-18, 1984. This successful meeting was attended by 169 persons from 20 nations and had all 15 available vendor spaces filled.

METHODOLOGY IMPLEMENTATION

The principal DOE work performed by this group is described elsewhere in this report under the heading Advanced Liquid Metal Reactor Concepts Program. The group also contributed to DOE's Health and Environmental Risk Analysis Program for the Liquid Metal Fast Breeder Reactor (LMFBR) Fuel Cycle. This project was designed to provide DOE with an assessment of the risks associated with the operation of a mature LMFBR industry. The first LMFBR Health and Environmental Effects Document (HEED) focused on the human health and environmental impacts to the area within 100 km of routine radionuclide releases from a set of 51 power reactors dispersed throughout the country and three hypothetical fuel reprocessing facilities. The two major areas considered in the second HEED are the human health impacts due to routine radionuclide releases from fuel reprocessing facilities on the population of the contiguous U.S., and the human health impacts on selected local populations due to accidental radionuclide releases from breeder reactors. All of these studies include a quantitative analysis of the uncertainties in these risk estimates and a critical evaluation of areas of research needed to fill gaps in current assessment-related information.

The DOE work is complemented with projects supported by the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA). For the EPA, an entire suite of computer codes for agency use in standards development research related to atmospheric radionuclide releases has been developed. This suite of codes is currently undergoing an extensive peer review by a panel of outside experts appointed by EPA. A separate project is underway to

develop a computerized population and agricultural information data base for use with this suite of computer codes. Technical support has also been supplied to EPA through calculations made using the ORNL-developed AIRDOS-EPA computer code to assess the impact on man of radon releases from various sites in the western U.S.

The Methodology Implementation Group has been responsible for a number of Nuclear Regulatory Commission (NRC)-sponsored projects. The group had the lead responsibility for assessing the impact of liquid radioactive effluent releases from the Rancho Seco Nuclear Power Plant. This project also involved staff from the Radiological Survey Activities group and ORNL's Environmental Sciences Division. A draft generic environmental document has been prepared on potential risks associated with the recycle of contaminated materials from NRC-licensed facilities. Two projects are being carried out for NRC's Office of Inspection and Enforcement. The objective of the first project is to develop an emergency response training manual that will be used as the basic text for the training of NRC emergency response personnel. The second project involves refinement of the computer codes currently in use or under development for predicting the magnitude of the radionuclide releases associated with a severe reactor accident to ensure that these codes address the technical issues facing members of NRC's Emergency Response Organization. Work on site-specific environmental impact statements and appraisals continued in collaboration with the Energy Division at ORNL.

In addition to these activities, environmental assessment support has been supplied to other ORNL programs. These include dose calculations for various proposed radioactive waste management activities, and support of calculations for estimating the dose to persons from both current and previous radionuclide releases from DOE-contractor facilities managed by the DOE Oak Ridge Operations Office.

TRANSPORT PROCESSES RESEARCH

The DOE work performed by this group is described elsewhere in this report under the headings Advanced Liquid Metal Reactor Concepts Program and Waste Management Programs.

Two projects have been performed for the NRC's Office of Nuclear Reactor Regulation. In the first, an analysis was completed of uncertainties associated with site-specific applications of the CRAC2 (Calculation of Reactor Accident Consequences) computer code that result from uncertainties in models and their input parameters. The sources of uncertainty that were investigated include: (1) the model for plume rise, (2) the model for wet deposition, (3) the procedure for meteorological sampling of precipitation events, (4) dose conversion factors for inhalation, (5) the model for external ground-surface exposure, and (6) the model for intakes of radionuclides via terrestrial foodchain pathways. In the second project, evaluations of reactor accident consequences using the CRAC and CRAC2 codes have been performed for the NRC's use in preparing safety evaluation reports for near-term Operating License facilities.

Previous work for the EPA's Office of Radiation Programs has led to the development of the PRESTO-II model for estimating potential health effects from shallow-land disposal of low-level radioactive wastes. Documentation of this model has essentially been completed.

RADIOLOGICAL SURVEY ACTIVITIES

The Radiological Survey Activities (RSA) program performs three major functions: (1) identifies suspected locations of technologically-enhanced or anomalous radiation levels relative to

the natural radiation environment, (2) performs characterization of radiologically/chemically-contaminated sites, and (3) performs research and development of instrumentation and methodology to advance survey techniques. The primary focus of work has been in DOE's Division of Facility and Site Decommissioning Projects. The RASA program has had major involvement in the Uranium Mill Tailings Remedial Action Project (UMTRAP) and the Formerly Utilized Sites Remedial Action Project (FUSRAP), and lesser involvement in the Surplus Facilities Management Project (SFMP).

Involvement in the UMTRA project began in 1975 with the initial characterization of 22 inactive mill sites in the western states. Currently, the RASA program serves as the Inclusion Survey Contractor (ISC) whose function is to identify potentially contaminated properties in the vicinity of the primary mill sites and perform sufficient radiological measurements to determine whether the properties retain residual radioactive material in excess of appropriate EPA criteria to recommend inclusion or exclusion from UMTRAP. During this reporting period, mobile gamma scans have been conducted in Edgemont, South Dakota; Salt Lake City, Utah; and Lander, Wyoming. During the past 18 months, approximately 3,000 inclusion surveys have been conducted and reported to DOE/UMTRA. This project has a staff of 65 and funding of about \$6.5 million in both FY86 and FY87. An additional 6,000 inclusion surveys and recommendations will be conducted during the next two years. Major RASA/UMTRA accomplishments have been to open a Grand Junction, Colorado office; to develop a management/implementation plan; to prepare a quality assurance program plan; to prepare a procedures manual; to develop an automated graphics center; and to develop and implement a central database network involving about 30 microcomputers.

Recent work by the RASA/FUSRAP group has concentrated on identification and surveys to designate properties requiring remedial action in the vicinity of FUSRAP sites. Funding for this project has been constant over the last few years at about \$0.9 million each year. Mobile gamma scanning of transportation routes in hauling material to the Niagara Falls Storage Site in New York and the Weldon Spring/Latty Avenue storage sites in Missouri have revealed several hundred radiation anomalies requiring further investigation. A mobile gamma scan of Colebrookdale township in Pennsylvania showed dozens of homes located on a uraniferous-bearing geologic formation (Reading Prong) where significant interior concentrations of radon daughters may place residents at increased risks. During this reporting period, surveys have been conducted at the following FUSRAP locations: 120 properties in the vicinity of a former National Lead site in Colonie, New York; 30 properties in the vicinity of the former Maywood Chemical site in Maywood, New Jersey; a large parcel in the vicinity of the Niagara Falls Storage Site; and six major properties in the vicinity of the former Latty Avenue Storage Site. In addition to this, reports have been issued on a number of primary FUSRAP sites including Guterl Steel in Lockport, New York; W. R. Grace at Curtis Bay, Maryland; and the Havens/Bridgeport Brass Plant in Bridgeport, Connecticut. Recent directives by DOE/FUSRAP have led the RASA project into performing radiological surveys to assess the success of remedial action at vicinity properties in the Maywood, Hazelwood, and Colonie communities.

New RASA work results from collaborative efforts with other HASRD groups, and from providing support to DOE/Oak Ridge facilities. Collaborative work includes radon monitoring of residential structures in the Tennessee Valley Authority region with the Measurement Applications Group, and food chain sampling and analyses in estimating radiological doses to residents near the Rancho Seco Nuclear Power Plant with the Methodology Implementation Group and

Environmental Sciences Division. A major RASA project has been initiated to characterize the chemical/radiological surficial environment of the Oak Ridge Y-12 reservation. Information collected from this survey effort will be made available to environmental managers on an integrated central database network. Additionally, radon monitoring networks have been established to plot isopleths of radon concentration on and around the Fernald, Ohio facility.

Research and development of new instruments and methodologies in survey techniques is an ongoing function of the RASA group. A new telemetry system has been developed to transmit location and survey data from the field to a microcomputer. The microcomputer is then able to reduce and format the data to provide real-time information in the form of data tables and graphics in the field. This development not only represents a cost savings over manual transcription and formatting of survey data, but also enhances survey quality by showing survey coverage in the field.

METABOLISM AND DOSIMETRY RESEARCH

The Metabolism and Dosimetry Research Group at ORNL serves as an international focal point for the development of dosimetric methods for use in setting radiation exposure guidelines. The main task of this group is establishing radiation exposure-dose relationships through modeling the metabolism of radionuclides taken into the body and modeling the interactions of emitted radiation with radiosensitive tissues to yield estimates of dose to these tissues. In addition, the dose to radiosensitive tissues from radiations incident upon the body (external radiation) is estimated.

Prior to the issuance of Publication 30 by the International Commission on Radiological Protection, most of the group's work has been the estimation of organ doses to Reference Man, a model of the human body that has generally been considered adequate for evaluation of occupational exposures. In recent years emphasis in radiation protection has shifted somewhat to public rather than occupational exposures. In response, the group is now involved in the development of metabolic and dosimetric models that allow consideration of important segments of the population other than the standard adult. For example, we have now adopted a mechanistic approach to metabolic modeling that is essential in dealing with biological variability among humans. This has required a departure from the empirical curve-fitting approach commonly used; instead of relying only on element-specific data, models now being developed are structured to accommodate basic physiological information as well. In addition to its advantages in characterizing biological variability among humans, such a physiological approach allows more meaningful extrapolation of data from animals to humans, permits more realistic treatment of daughter products of some nuclides, yields better estimates of activity in excreta, and potentially leads to an improved estimate of doses to heterogeneously distributed radiosensitive tissues within some organs. This new approach has been applied in developing metabolic models for a number of elements including the alkali metals and plutonium.

The group aids in establishing dose-response relationships through the evaluation of doses to sensitive tissues incurred by subjects of epidemiological studies who have been exposed to radiation in the past. We are now involved in a reevaluation of the gamma and neutron doses received by the A-bomb survivors. This study was needed primarily because of increasingly apparent uncertainties in the total yield of the blast at Hiroshima, as well as the relative gamma and neutron yields from that blast. It appears that there may be substantial modifications of earlier dose estimates; and subsequently, of the dose-to-risk conversion factors based on epidemiological studies of the A-bomb survivors.

In conjunction with the reassessment of dose to A-bomb survivors, a mathematical phantom representing a Japanese adult has been developed including the external dimensions of the neck region; this allows more realistic estimates of dose to the thyroid from external irradiation. Advances have also been made in modeling the energy deposition by secondary charged particles thus permitting more realistic estimates of the dose to the active marrow and endosteal tissues from phantom and neutron radiations.

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3. BIOLOGICAL AND RADIATION PHYSICS SECTION

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Activities within this section consist primarily of basic physics research studies directed toward providing new scientific knowledge of the fundamental properties of matter in all phases (gas, liquid, and solid) and of processes and mechanisms important in the interaction of pollutants with biological materials. Since pollutants interact at the surfaces of biological materials, we maintain an active surface physics program. Some of the research highlights during this year in each of the four groups in the section are reported below.

The section continues to have significant interactions with many other research institutions, both in the U.S. and abroad. Twelve visiting scientists from foreign institutions, 18 visiting scientists from U.S. institutions, and 27 students worked within the section at various times during this reporting period.

PHYSICS OF SOLIDS AND MACROMOLECULES

Electron attenuation lengths in amorphous carbon were measured using a new electron transmission apparatus with improved resolution. Surface-enhanced optical studies included plasmon resonance absorption measurements for a doubly corrugated bigrating made by a holographic method; surface-enhanced Raman spectra from benzoic acid and other organic molecules on well-characterized rough substrates; and resonant Raman scattering from high-frequency graphitic phonons in graphite- H_2SO_4 , an intercalation compound.

A very high efficiency, soft x-ray spectrometer to be used for fluorescence and absorption studies was installed at the SURF synchrotron light facility at the National Bureau of Standards, and soft x-ray emission spectra were obtained on samples of Al and Mg.

The optical properties of solid and liquid sulfur over a range of photon energies were obtained. These data are of basic interest and are also important in planetary studies, such as the study of the composition of Jupiter's satellite Io. The optical properties of poly(butene-1-sulfone) (PBS), a fast electron resist used in microlithography, were also obtained over a range of photon energies from 2.5–41.0 eV.

Using the photoacoustic method, the coupling of surface plasmons created on the two surfaces of free-standing thin silver films with periodic corrugations has been investigated. Also a cooperative program between HASRD and the University of Manitoba Cyclotron Laboratory was initiated to study the light emission from solid surfaces bombarded by swift neutral atoms.

LIQUID AND SUBMICRON PHYSICS

Microlithographic techniques have been used to produce large-area arrays of silver-coated, SiO_2 , conical microstructures. The individual microstructures are 100 nm in height, and the samples serve as substrates in experiments in which surface-enhanced Raman scattering is used to detect small fractions of a monolayer of organic species. The results are an improvement by factors of 30–100 over any data reported in the scientific literature.

An optical absorbance technique using surface plasmon excitation has been developed which allows optical determination of the shape of particulates smaller than the wavelength of light.

Electron beam microlithography has been used to produce ordered arrays of 100-nm microchannels of importance to the development of a photon scanning-tunneling microscope.

The first calculation of charged particle energy losses to a submicroscopic, polarizable sphere has been made. This fundamental result was obtained for arbitrary rectilinear trajectories and includes the contribution of all modes induced on the sphere.

The optical and photoemissive properties of four functionally related ethylene glycol liquids were studied over the range 0.5–25 eV. Current theories of photoemission are inadequate to explain the observed measurements.

ANALYTIC DOSIMETRY AND SURFACE PHYSICS

This group concentrates on important basic problems in dosimetry, microdosimetry, and surface physics. Fundamental studies in the interaction of radiation with matter have included a continuing development of our theory of track structure and high-energy sputtering from non-metallic solids and of the prediction of inelastic scattering probabilities in scanning transmission electron microscopy. Studies of a new approach to the calculation of relativistic corrections to stopping powers were completed. The role of damping in an electron gas in wake phenomena, including wake-binding energies and the vicinage effect, has been examined. Non-linear, density functional calculations were employed to study the energy loss, straggling, and effective charge of low-velocity ions in an electron gas. We have continued our theoretical investigation of transient conductivity in irradiated insulators and have begun a study of basic mechanisms leading to high-voltage breakdown in RF cavities.

In the surface physics area, efforts are directed at elucidating the fundamental physical mechanisms involved in interactions of microscopic and macroscopic particles with condensed-matter surfaces. Theoretical calculations of the interaction of charged particles with surfaces have included excitation of edge modes on a dielectric wedge, retardation effects in beam interactions with bounded media, and the excitation of ripplon fields at the surface of a non-polar liquid. A completely quantal theory of the interaction between atoms and between a charged particle and an atom, including recoil and finite-relative-velocity effects, has led to important, previously overlooked modifications of the theoretical representation of the van der Waals forces in these systems. We have continued studies of electrons tunneling through interfaces, including the generation of both real and virtual surface plasmons and surface phonons, and the role of these electrons in high-field dielectric breakdown phenomena. The path-length dependence of surface mode excitation of charged particles in aloof scattering has been evaluated. We have developed theory for the emission of optical radiation from solids under bombardment by neutral atoms.

In our microdosimetry program, we have performed calculations of yields of chemical species produced by protons and alpha particles in liquid water which are in good agreement with experimental data. We are collaborating with an experimental program at Lawrence Berkeley Laboratory for determining radiation-produced strand breaks in DNA in aqueous solution. For neutron dosimetry, a computer code was completed for calculating the complete slowing down of protons, carbon ions, and electrons in mixtures of methane and argon. The code will be used to analyze the digital information describing recoil-particle tracks in a time-projection chamber.

Collaborative studies are continuing with the Biology Division on the effects of metals on living organisms at the molecular and whole-animal level. Detailed calculations are being made of the binding of metal ions and other chemicals to single- and double-stranded polynucleotide structures

to simulate interactions with various forms of DNA and RNA. A study of bond characterization as a basis for understanding the detrimental effects of metals is underway. Experimental studies are being carried out to isolate and characterize a low-molecular-weight, metal-binding protein induced in *Drosophila* in response to metal ions. The induction of such a protein could provide a predictor of metal-ion toxicity. Parallel genetics studies using the same genotypes and metal ions are underway to elucidate the possible mechanisms involved in metal-ion toxicity in *Drosophila*. Correlations of our experimental data on metal-ion toxicity in Chinese hamster ovary cells are being analyzed in terms of metal-ion inhibition of calmodulin activity *in vitro*.

ATOMIC, MOLECULAR, AND HIGH VOLTAGE PHYSICS

The effect of temperature, T , on the dissociative and nondissociative electron attachment to molecules has been investigated. Extensive studies on CClF_3 , C_2F_6 , C_3F_8 , SO_2 , and C_6F_6 have been conducted which showed delicate and often profound effects of T on the corresponding cross sections. The results obtained, besides their intrinsic value, are of applied significance.

The isotopic dependence of the dissociative attachment cross section has been shown to be a function of T .

Studies have been initiated of electron-electronically excited molecule interactions and of laser-enhanced dissociative attachment processes.

The mean energy of excess electrons in liquid Ar as a function of the density-reduced electric field has been determined and used to obtain the energy dependence of the rate constant for electron attachment to N_2O in liquid Ar. The latter has been compared with that in gaseous Ar.

Electron drift velocity and attachment measurements have been performed in the pure gases CF_4 , C_2F_6 , C_3F_8 , and $n\text{-C}_4\text{F}_{10}$ in order to observe the influence of pressure dependent attachment processes on the shape of the electron energy distribution functions in these gases.

Two-photon laser excitation of benzene, toluene, and fluoranthene in a number of nonpolar solvents has been studied and the effect of solvent on higher-excited states investigated. Similarly, the multiphoton ionization of benzene in n -pentane and tetramethylsilane has been studied, and the multiphoton ionization mechanism investigated.

Studies have been made of the pressure and isotopic dependence of the dielectric strength of gases. The synergism exhibited by the dielectric strength of binary gas mixtures has been explained from basic data. The major decomposition products produced by electrical discharges in SF_6 have been identified and studied quantitatively both with respect to discharge energy and with respect to impurities (mainly moisture). A high pressure negative ion swarm technique has been developed for analysis of SF_6 and its spark decomposition products; it has potential as a diagnostic tool for fault detection in SF_6 gas-filled equipment.

The electron drift velocity and attachment and ionization coefficients were measured in $\text{C}_2\text{F}_6/\text{Ar}$ and $\text{C}_2\text{F}_6/\text{CH}_4$ gas mixtures at 500 K in order to study the effect of elevated gas temperatures on the repetitive operation of diffuse discharge switches. Studies of the electron transport properties and breakdown strength characteristics of several gas mixtures for use in diffuse discharge opening switches at room temperature have been completed. The measurements included the electron drift velocity, transverse diffusion coefficient, attachment and ionization coefficients, and the high voltage breakdown field strengths. Several gas mixtures were recommended for use in prototype switches now in operation at other laboratories. In this regard

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ternary gas mixtures which optimize the electron production in binary gas mixtures which have conduction and insulation properties appropriate for use in e-beam sustained diffuse discharge switching applications have been found. Penning ionization processes in such mixtures have been studied.

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4. CHEMICAL PHYSICS SECTION

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Research activities in the Chemical Physics Section encompass a variety of basic experimental and theoretical studies that are relevant to energy-related problems in atmospheric physics and chemistry, radiation chemistry, advanced instrumentation technology, laser development, and analytical applications of laser techniques. Emphasis is placed on gaining detailed understanding of fundamental physical and chemical processes at the molecular level and on developing advanced experimental techniques which find applications in other areas of energy-related research. In this

work heavy use is made of laser-based spectroscopic techniques in many of the physics studies. Complementary to these efforts, major components of the program are also directed toward development of advanced laser-based instrumentation techniques for characterization and detection of various chemical species.

Most of the studies are conducted in gas phase media with use being made of molecular beams, mass spectroscopy, multiphoton photoelectron spectroscopy, resonance ionization spectroscopy, and resonance ionization mass spectroscopy. New detailed information on doubly excited metastable atomic and molecular negative ions is being gained through a new technique of autodetachment electron spectroscopy.

The following summaries of activities in the Molecular Physics and Photophysics groups provide general information on the accomplishments in the chemical physics program. More detailed information on all of the research can be found in the open literature references at the end of this report.

MOLECULAR PHYSICS

The Molecular Physics Group has continued extensive experimental and theoretical studies of multiphoton ionization (MPI) of atoms and molecules. In particular, we have made detailed studies of alkali atoms. These studies include: (1) MPI photoelectron angular distributions, (2) angular distributions for above threshold or "continuum-continuum" MPI, (3) DC electric field effects upon MPI, (4) the role of stimulated Raman processes in nonlinear generation of new laser frequencies and in MPI, and (5) simultaneous MPI and third-harmonic generation. Future studies will be directed toward MPI photoelectron angular distributions for molecules. Preliminary measurements have been completed for a few resonant intermediate states in nitric oxide.

Considerable effort has been devoted to bridging our knowledge of the gaseous and liquid state. Theoretical studies of the pH of steam and evaporative cooling of molecular clusters have been published. Investigation of MPI of rare gas-nitric oxide clusters has provided new information on van der Waals interactions of both valence and Rydberg electronic states in cluster species.

We have continued our studies of the production and uses of tunable vacuum ultraviolet radiation generated from frequency tripling dye lasers in rare gas media. The utility of this new source of radiation is amply demonstrated through its use in our program for ionization studies of cold nitric oxide emitted from pulsed sonic nozzles.

In collaboration with members of the Physics Division, we have characterized new states of metastable Be^- , He_2^- , and NH_2^- . Using autodetachment spectroscopy of fast moving Be^- and He_2^- with lithium vapor, we have determined the electron affinities for Be^- ($1s2s2p^2$) and He_2^- ($^4\pi_g$) to be 0.195 eV and 0.172 eV, respectively. Two distinct autodetachment channels are observed in the electron energy spectra of He_2^- . The production of very low energy electron (~ 0.011 eV) involves vibrational autodetachment [e.g., $\text{He}_2^- (^4\pi_g)_{v=1} \rightarrow \text{He}_2 (a^3\Sigma_u^+)_{v=0} + e$] while a second broad group of electrons centered at ~ 15.85 eV is attributed to autodetachment of He_2^- into the $\text{He}_2 X^1\Sigma_g^+ + e$ repulsive continuum.

PHOTOPHYSICS

The resonance ionization spectroscopic "Maxwell demon" apparatus has been used to analyze the ^{81}Kr extracted from a modern water sample. Before isotopic enrichment the water sample was

expected to contain ≈ 1300 ^{81}Kr atoms and about 2.5×10^{15} atoms of the stable krypton isotopes. Our measurements of the number of ^{81}Kr atoms in the sample yielded the expected result and therefore demonstrated the feasibility of using ^{81}Kr for purposes of dating old groundwater and polar ice caps. This new development avoids the necessity of collecting and processing many tons of water in order to permit standard radioactive decay counting of ^{81}Kr concentrations.

A very simple method has been developed for recording the three dimensional energy density of a high-power laser beam. The method is based on changes in the optical properties of a salt crystal as a result of the production of color centers by a high intensity laser beam. The color-center record can be stored for very long time periods or erased by red light absorption in a very short period of time. Since color centers in alkali halide crystals, for example, are formed in about 20 picoseconds the phenomenon suggests the possibility of operating an optical switch with a switching time as short as 20 picoseconds. The latter possibility has not been pursued due to our lack of access to a picosecond laser.

Our studies of the effects of laser-induced interference phenomena on MPI at concentrations above 10^{12} atoms/cm³ have continued. We have shown that the cancellation of odd-photon resonant enhancements occurs for five-photon resonances, and for the general case of two-color three-photon excitation of single photon allowed transitions. The resonances appear in the presence of counterpropagating beams, as predicted by theory. Our studies have shown that the reported suppression of a.c. Stark shifts in the MPI of nitric oxide, as observed by a group at Stony Brook, are an experimental artifact due to space charge effects on the measurement of ionization produced with focused laser beams. Many of the ways which space charge affect ionization measurements have been demonstrated. The potentially significant collective effect suggested by other workers to explain their observations was shown to be nonexistent.

Last year we made the first measurements on the self-broadening of resonance spectral lines. The measurements, which are based on a three-photon excitation method, are very simple, but the method avoids the problem of radiation trapping which has made all previous attempts at such measurements fail. The data have now been analyzed and shown to be in excellent agreement with theory.

The development of a new facility for extending our resonance ionization spectroscopic methods to ultrasensitive detection of small molecules is nearly complete. We expect to have the facility in full operation within the next three months.

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5. OFFICE OF RISK ANALYSIS

C. C. Travis

The Office of Risk Analysis (ORA) was organized to help coordinate activities related to risk analysis at ORNL. Risk-related research at ORNL ranges from the study of carcinogenesis, mutagenesis, and damage to biological systems in the Biology Division to the collection of data pertinent to probabilistic risk analysis of nuclear reactor accidents in the Engineering Physics Division. A primary goal of ORA is to initiate and develop risk-related funding for the laboratory from a variety of government agencies. To this end, the ORA promotes the flow of information between the laboratory and funding agencies, thus producing a better understanding of risk at the federal level.

The ORA is involved in several risk related projects. ORNL will assist the Office of Science and Technology Policy and the National Science Foundation in development of a document outlining the scientific bases for assumptions used by federal agencies in assessing risk. For the EPA, ORA is developing and implementing computer models to predict the transport and fate of chemical substances in the environment. In another EPA project, ORA is evaluating the use of pharmacokinetic models for improving interspecies extrapolations and dose-response estimates. For DOE, the ORA is developing a data base which will provide DOE with the ability to make risk estimates for various hazardous materials associated with energy production in a comparative way.

6. CONTRIBUTIONS TO NATIONAL AND LEAD LABORATORY PROGRAMS AND ASSIGNMENTS

NUCLEAR REGULATORY COMMISSION (NRC)

R. O. Chester

The ORNL NRC Program organization corresponds to the organization of the agency. The ORNL NRC Program Director, A. P. Malinauskas, has program managers for each of the divisions in the Office of Nuclear Regulatory Research (RES), as well as two program managers for the Office, Nuclear Material Safety and Safeguards. The ORNL NRC Radiation Programs and Earth Sciences division/RPS Program Manager is R. O. Chester for the ORNL programs sponsored by that RPS Division. Oak Ridge National Laboratory has projects in each of the three program areas of NRC Radiological Programs and Earth Sciences—Waste Management, Earth Sciences, and Occupational Radiation Protection. Individual projects within this program are conducted principally in four ORNL Divisions—Environmental Sciences, Energy, HASRD, and Chemistry.

Within the Health and Safety Research Division there are fourteen NRC-sponsored projects in both the research and technical assistance categories. Eleven of these projects are technical assistance and three are research. The technical assistance projects utilize a cross-section of the diverse technical staff of the division. The projects include: Age-Specific Dose Factors, CRAC Code Analysis, Support to the NRC Emergency Operation Center, Revision of ICRP 23 Reference Man, Internal Dose from Occupational Exposures, Survey of Metabolic Data for High Level Waste, Examining Source Term Assumptions for Operating Reactors, Generic Study of the Recycle of contaminated Material, and Analysis of IAEA Transactions. The research projects, however, are primarily in the areas of dosimetry modeling and radionuclide transport in the biosphere.

WASTE MANAGEMENT PROGRAM

D. C. Kocher

The Dosimetry and Biophysical Transport Section has been active in three major projects within the laboratory's radioactive and chemical waste management programs. The first involves a cooperative effort with the Energy Division to evaluate and select reasonable alternatives for greater confinement disposal of transuranic wastes that currently are being stored at the laboratory but cannot be certified for shipment to the Waste Isolation Pilot Plant facility in New Mexico. Important contributions to this work include the development of performance objectives for TRU

waste disposal, the development of a hazard index for ranking disposal alternatives, scoping studies of potential hazards for TRU waste disposal, and an assessment of the chemical toxicity of radionuclides in TRU waste. The second activity involves technical support to current efforts within Martin Marietta Energy Systems to develop a new low-level radioactive waste disposal facility on the Oak Ridge Reservation. Contributions have included the development of performance objectives for low-level waste disposal, evaluation of potential doses to inadvertent intruders, and the development of preliminary waste acceptance criteria. The third activity involves a cooperative effort with the Office of Risk Analysis and Environmental Sciences Division to develop a risk assessment methodology for DOE hazardous chemical waste sites. The work in the initial phases of this project has involved a review of existing hazard ranking and risk assessment methodologies and recommendations for future methodology development.

FOSSIL ENERGY TECHNOLOGY ENVIRONMENTAL PROGRAM

P. J. Walsh

Funding for health and environmental activities related to synthetic fuels within the Fossil Energy Technology Environmental Program has decreased due to the uncertain future of the Synthetic Fuels Corporation. Work on an assessment framework for prioritizing health and environmental monitoring around synfuels facilities was completed. Proposals focusing on occupational health concerns have been submitted in coordination with the Occupational Health Research Program in HASRD.

ADVANCED LIQUID METAL REACTOR CONCEPTS PROGRAM

D. E. Fields and C. W. Miller

Technical support has been supplied to DOE's Advanced Liquid Metal Reactor Concepts Program. Liquid-metal cooled nuclear reactors often use large quantities of sodium or sodium-potassium alloy, and evaluation of the possible consequences of a liquid metal fire, henceforth referred to as a sodium fire, is an important consideration of the design process. One facet of this evaluation is to determine the sodium aerosol concentration at the air intake ports. These ports are used for heat exchanger cooling, and blockage of a critical number of ports would lead to a significant cooling problem. To provide an added safety margin, extra cooling ports are included in the reactor design.

A methodology has been developed to estimate the sodium aerosol concentrations at selected air intake ports of a liquid-metal-cooled nuclear reactor under medium wind-speed conditions during sodium aerosol fires. Building wake effects, which in many cases dominate the dispersal of aerosols near buildings, are included in this methodology. This methodology has been applied to a

variety of advanced concept power pack configurations. A proprietary reactor design was obtained, and the methodology was parameterized using architectural blueprints. These calculations suggest that reactor cooling at safe levels may be possible even in the event of a major sodium fire.

OCCUPATIONAL HEALTH RESEARCH PROGRAM

R. B. Gammage

The plan on needs for occupational health research for emerging energy technologies that was prepared in 1984 for DOE's Office of Health and Environmental Research (OHER) has been incorporated into OHER's overall initiatives for health and environmental research on complex organic mixtures. In support of this activity, proceedings were published of a DOE-OHER Workshop on Monitoring and Dosimetry in an Occupational Health Research Program for Synfuel Technologies. Efforts were initiated to start new research for measuring and interpreting dermal exposure to complex mixtures of organic compounds. A complementary program in applied research has been carried out under the sponsorship of the American Petroleum Industry. The permeation was measured for glove materials challenged by complex hydrocarbon liquids ranging from gasoline and kerosene to highly viscous synfuel and oil refinery products. In addition to measuring volatile organics measurements were made, for the first time ever, of permeating polynuclear aromatic hydrocarbons. If breakthrough occurred, volatile components generally permeated prior to the polynuclear aromatic hydrocarbons. Latex and neoprene provided the least protection. Butyl rubber and PVC were slightly better. The benzene and toluene components of some of the lighter hydrocarbon liquids were responsible for a selective attack and permeation; the concentration of benzene and toluene was enhanced in the permeated vapors. Nitrile was generally adequate except for severe corrosion caused by a phenolic component of coal liquefaction products. Viton, Tyvek, and PVA fabrics were not penetrated within 24 hours by any of the challenge liquids.

APPENDIX A. BUDGET AND SUPPORT DISTRIBUTION

	Actual FY 84 (\$K)	Actual FY 85 (\$K)
American Petroleum Institute	63	120
Army	45	80
Consumer Product Safety Commission	408	176
Defense Nuclear Agency		94
Department of Energy		
Basic Energy Sciences	87	80
Biological & Environmental R&D	4,635	4,425
Breeder Reactors		70
Building & Communications		62
Coal	192	105
Conservation & Renewable Energy	82	
Defense Waste Management	69	164
Electric Energy Systems	636	781
Life Sciences	727	729
Remedial Action Programs	2,040	5,315
Environmental Protection Agency	754	1,201
EG & G	84	71
Food & Drug Administration	10	40
Massachusetts General Hospital	52	
National Heart, Lung, & Blood Institute	53	
National Lead of Ohio		88
National Science Foundation		85
National Security Agency		200
Naval Surface Weapons Center	125	130
Navy		90
Nuclear Regulatory Commission	1,050	744
Office of Naval Research	135	99
Tennessee Valley Authority	125	255
U.S. Air Force	165	307
Y-12 Plant		140

Other	10	66
In-House Total	11,547	14,737
Outside Subcontracts	769	980
Total Division	12,316	15,717

APPENDIX B. PERSONNEL SUMMARY

	Technical		Support		Total	
	1984	1985	1984	1985	1984	1985
Permanent employees	81	77	24	22	105	99
Temporary, >10 months	17	26	0	4	17	30
Division-supported loanees	1	2	0	0	1	2
Loaned out	1	0	0	0	1	0
Part-time	10	7	0	1	10	8
Assigned guests	69	71*	0	0	69	71
Co-ops	2	1	0	0	2	1

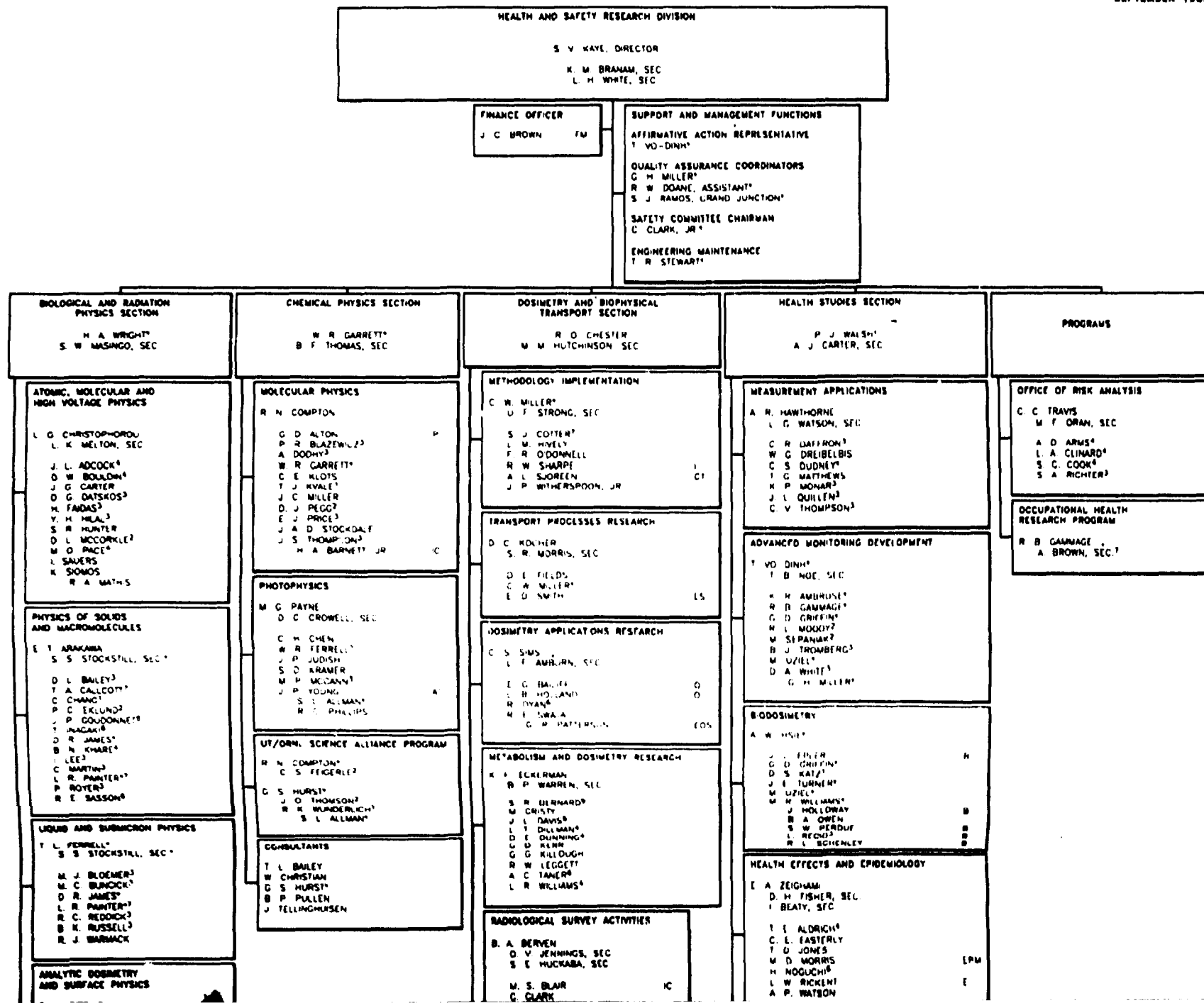
*Assigned guests through 9/30/85.

To run the division efficiently and effectively requires many types of employees. The various sources used to staff the division are shown in the table. We experienced a net increase of seven in our permanent and temporary staff.

Through September 30, 1985, there was a total of 71 guests assigned to the division. The guests were from universities, other laboratories, and private companies. Assignment terms vary in duration from a few months up to a year or more. We view the use of assigned guests as an economical way to bring different and diversified talents to the division.

APPENDIX C. ORGANIZATION CHART

SEPTEMBER 1985



[illegible]

APPROVED: SUKanya 9/25/85

APPENDIX D. SEMINAR PROGRAM

P. C. Srivastava

The coordinator of the Health and Safety Research Division's seminar program works with division staff to identify distinguished seminar speakers from various disciplines of research interest to the division.

Since July 30, 1984, HASRD has hosted 13 seminar speakers representing industry, research institutions, and universities. The following is a list of the seminar speakers and their topics.

Richard J. Bull

Health Effects Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, "Potential Health Risks Associated with the Chlorination of Drinking Water," August 3, 1984.

Eduardo Gaitan

Endocrinology Section, Veterans's Administration, University of Mississippi Medical College, Jackson, Mississippi, "Kentucky-Appalachia Goiter: A Public Health Puzzle Requiring a Multi-Disciplinary Approach," September 11, 1984.

Lyman W. Condie

Toxicology Branch, Toxicology and Microbiology Division, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, "Water Quality Based Approach for Controlling Toxic Substances Discharge to the Environment," November 2, 1984.

Gerald Stubbs

Department of Molecular Biology, Vanderbilt University, Nashville, Tennessee, "Structure of Intact Tobacco Mosaic Virus," December 4, 1984.

Anthony Zawadzki

Department of Chemistry, University of Colorado, Boulder, Colorado, "Kinetic Modeling of Chemical Vapor Deposition," February 11, 1985.

P. C. Srivastava

Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Colloquium Talk for SCUU-Oak Ridge Science Semester," March 19, 1985.

Roger M. Wartell

Physics and Biology Departments, Georgia Institute of Technology, Atlanta, Georgia, "The Interaction of the Catabolite Activator protein and Its DNA Gene Regulatory Site: A Physical View," May 8, 1985.

Steve Schery

Physics Department, Geophysical Research Center, New Mexico Institute of Mining and Technology, Socorro, New Mexico, "Modeling and Measuring Thoron and Its Progeny in the Indoor Environment," May 20, 1985.

Larry C. Waters

Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Genetic Regulation of Cytochrome P-450 Expression in *Drosophila*," May 22, 1985.

Tito Cascieri

FMC Corporation, Chemical Research and Development Center, Princeton, New Jersey, "Applications of *In Vitro* Bioassays in Industrial Toxicology," August 14, 1985.

Edmond LaVoie

American Health Foundation, Naylor Dana Institute for Disease Prevention, Valhalla, New York, "Structural Requirements Favoring the Mutagenicity of Methylated Polynuclear Aromatic Hydrocarbons," September 17, 1985.

M. D. Waters

Genetic Toxicology Division, EPA Environmental Research Center, Research Triangle Park, North Carolina, "Genetic Activity Profiles of Known or Suspected Human Carcinogens," September 19, 1985.

Elisabeth Pate'-Cornell

Department of Industrial Engineering, Stanford University, Stanford, California, "Risk Analysis and Uncertainty in Nuclear Safety Decisions," September 19, 1985.

**APPENDIX E. LIST OF HONORS AND AWARDS FOR STAFF MEMBERS OF
THE HEALTH AND SAFETY RESEARCH DIVISION
JULY 1, 1984-SEPTEMBER 30, 1985**

IR-100 AWARDS

C. H. Chen, S. D. Kramer, G. S. Hurst, S. L. Allman, R. C. Phillips, and M.G. Payne
IR-100 Award for Rare Gas Atom Counter, 1984

COMMITTEE NOMINATIONS

R. O. Chester

Member, Executive Committee of the Environmental Sciences Division, American Nuclear Society, 1985-88

R. B. Gammage

Member, Workplace Environment Exposure Level Committee, American Industrial Hygiene Association, 1982-1984

A. W. Hsie

Member, ASTM E47 Task Group on Forward Gene Mutation Assay in CHO Cells, 1985-present

T. D. Jones

Member, National Council on Radiological Protection, Scientific Committee 57, Task Group 8 on Estimation of Leukemia from Internal Emitters, 1979-1984

Member, National Council on Radiological Protection, Scientific Committee 3, Task Group on Relationships Between Field and Dose Quantities, 1979-1984

Member, Governor Thornburgh's Blue Ribbon Advisory Panel on Health Research Studies on Three Mile Island, 1979-1984

Member, National Health Physics Society Nominating Committee, 1980-1984

G. D. Kerr

Member, Standards Committee of the American Nuclear Society, 1982-1984

Member, Working Group on Reassessment of A-Bomb Radiation Dosimetry, U.S. Department of Energy, 1982-1984

Chairman, Committee on State and Federal Regulations, East Tennessee Chapter of the Health Physics Society, 1983-1984

F. F. Knapp, Jr.

Member, Nuclear Medicine Peer Review Committee, U.S. Department of Energy, 1982-1984

D. C. Kocher

Member, Performance Assessment National Review Group, U.S. Department of Energy, 1983-1984

C. W. Miller

Member, National Council on Radiological Protection, Scientific Committee 64, Task Group on Environmental Screening Models, 1983-1984

J. E. Turner

Member, National Council on Radiation Protection and Measurements, 1978-1984

A. P. Watson

Member, State Reclamation Committee for Rural Abandoned Mine Program, 1979-1984

Member, Task Force on Energy and Jobs for Minorities and Women, The National Urban Coalition, 1980-1984

APPRECIATION AWARDS**T. G. Matthews**

Appreciation Award for Distinguished Service, Washington State University, International Symposium on Particleboard, 1984

C. C. Travis

Distinguished Service Award, Society for Risk Analysis, 1984

JOURNAL ACKNOWLEDGEMENTS**R. N. Hamm**

Associate Editor, *Radiation Research*, 1985-1988

A. W. Hsie

Member, Editorial Board, *Fundamental and Applied Toxicology*, 1983-present

Member, Editorial Board, *Teratogenesis, Carcinogenesis, and Mutagenesis*, 1983-present

C. C. Travis

Editor-in-Chief, *Risk Analysis*, 1983-present

A. P. Watson

Associate Editor, *Environmental Management*, 1984

PUBLICATION AWARDS**W. R. Emanuel, G. G. Killough, and W. M. Post**

Martin Marietta Energy Systems 1984 Publication Award for "Modeling Terrestrial Ecosystems in the Global Carbon Cycle with Shifts in Carbon Storage Capacity Due to Land-Use Change."

T. D. Jones

Martin Marietta Energy Systems 1984 Publication Award for "A Unifying Concept for Carcinogenic Risk Assessments: Comparison with Radiation-Induced Leukemia in Mice and Men."

J. E. Till, H. R. Meyer, K. H. Galloway, N. K. Hardin, and M. M. Hutchinson,

1985 Technical Communication Award in Recognition of Merit in Books for the publication "Radiological Assessment: A Textbook on Environmental Dose Analysis."

T. Vo-Dinh

Martin Marietta Energy Systems 1984 Publication Award for "Room Temperature Phosphorimetry for Chemical Analysis."

UNIVERSITY APPOINTMENTS

L. G. Christophorou

Professor of Physics, The University of Tennessee, 1979-present

R. N. Compton

Adjunct Professor of Physics, Vanderbilt University, 1983-present

Professor of Chemistry, The University of Tennessee, 1985

T. L. Ferrell

Professor of Physics, The University of Tennessee, 1979-present

A. W. Hsieh

Professor of Biomedical Sciences, The University of Tennessee, 1976-present

Adjunct Professor of Biological Sciences, Fordham University, 1981-present

Adjunct Professor of Toxicology, University of Kentucky, 1983-present

R. H. Ritchie

Professor of Physics, The University of Tennessee, 1979-present

J. E. Turner

Professor of Physics, The University of Tennessee, 1979-present

M. Uziel

Professor (part-time), The University of Tennessee, Oak Ridge Graduate School of Biomedical Sciences, 1968-present

R. J. Warmack

Professor of Physics, The University of Tennessee, 1983-present

J. P. Witherspoon

Professor of Ecology, The University of Tennessee, 1979-present

OTHER**R. B. Gammage**

Honorary D.Sc. Degree, Exeter University (England), 1984

A. W. Hsie

Distinguished Visiting Scientist, U.S. Environmental Protection Agency, 1985-1988

G. S. Hurst

Martin Marietta Energy Systems 1984 Inventor Award for achievement of isotopically selective detection, storage, and retrieval of small numbers of noble gas atoms, based on the technique of Resonance Ionization Spectroscopy.

T. D. Jones

Consultant, Armed Forces Radiobiology Research Institute's Studies on Human Health Effects Deriving from Weapons Radiations, 1979-1984

G. D. Kerr

Consultant, Armed Forces Radiobiology Research Institute's Studies on Human Health Effects Deriving from Weapons Radiations, 1979-1984

Consultant, Radiation Effects Research Foundation, Hiroshima and Nagasaki, Japan, 1979-1984

Representative, Oak Ridge National Laboratory to Coordination and Information Center, U.S. Department of Energy, 1983-1984

F. F. Knapp

Martin Marietta Energy Systems 1984 Inventor Award for development and testing of a new clinical radioisotope generator that allows safe and prolonged use of iridium-191m to evaluate cardiovascular defects and blood flow in young patients.

Board of Directors, Radiopharmaceutical Science Council, Society of Nuclear Medicine, 1982-1984

R. H. Ritchie

Recipient, Jesse W. Beams Award, American Physical Society, 1984

J. E. Turner

Elected Fellow, American Association for the Advancement of Science, 1985

T. Vo-Dinh

Health and Safety Research Division Excellence in Research Award, 1984

**APPENDIX F. PATENTS GRANTED TO STAFF MEMBERS OF THE
HEALTH AND SAFETY RESEARCH DIVISION
JULY 1, 1984-SEPTEMBER 30, 1985**

PATENTS ISSUED

- J. L. Adcock, L. G. Christophorou, M. O. Pace, "Contaminant Trap for Gas-Insulated Apparatus," U.S. Patent No. 4,480,147, 1984.
- L. G. Christophorou, S. R. Hunter, J. G. Carter, "Gas Mixture for Diffuse-Discharge Switch," U.S. Patent No. 4,490,650, 1984.
- M. M. Goodman, F. F. Knapp, Jr., "Heart Testing Compound," U.S. Patent No. 4,523,033, 1985.
- M. O. Pace, J. L. Adcock, L. G. Christophorou, "Method for Minimizing Contaminant Particle Effects in Gas-Insulated Electrical Apparatus," U.S. Patent No. 4,464,417, 1984.
- R. K. Robins, P. C. Srivastava, "2- β -D-Ribouranosylthiazole-4-Carboxamidine Compounds and Their Production and Use," U.S. Patent No. 4,461,891, 1984.
- R. K. Robins, P. C. Srivastava, "Novel 2- β -D-Ribofuranosylselenazole-4-Carboxanide Compounds and Their Production and Use," U.S. Patent No. 4,531,001, 1985.

PATENT APPLICATIONS

- M. M. Goodman, F. F. Knapp, Jr., "A Radioiodinated Iodovinyl Methyl-Branched Fatty Acid for Applications in Nuclear Cardiology," 1985.
- F. F. Knapp, Jr., T. A. Butler, C. Brihaye, "Improved Osmium-191/Iridium-191m Radionuclide Generator," 1985.
- I. Sauers, "Method for Measuring Degradation of Sulfur Hexafluoride in High Voltage Systems," 1985.
- T. Vo-Dinh, "Continuous Monitor for Trace Organic Compounds by Surface-Enhanced Raman Spectroscopy," 1985.
- T. Vo-Dinh, "Surface-Enhanced Raman Spectroscopy Substrate for Trace Organic Analysis," 1985.

INVENTION DISCLOSURES

- (Inventors not determined), "3-D Digital Neutron Dosimeter," 1985.
- M. C. Buncick, R. J. Warmack, T. L. Ferrell, "Substrate for Use in Raman Spectroscopy," 1985.
- C. H. Chen, W. R. Garrett, M. G. Payne, "Tunable Vacuum Ultraviolet Laser Amplifier," 1984.
- C. H. Chen, S. D. Kramer, M. G. Payne, "Vibrational Excitation Induced Desorption Spectrometer," 1985.
- C. H. Chen, M. P. McCann, S. D. Kramer, "Ultraviolet Laser Beam Monitor Using Alkali Halide Crystals," 1985.

- R. N. Compton, W. R. Garrett, M. J. Shea, "Monoenergetic Photoelectron Beam Source," 1984.
- D. E. Fields, "Pulsed, Self-Triggered, Radioisotope-Powered Gas Laser," 1985.
- S. D. Kramer, C. H. Chen, "Dual Solvent Use in Oscillator/Amplifier Configured Dye Laser," 1984.
- S. D. Kramer, C. H. Chen, "Phase Sensitive Ionization Source for a Quadrupole Mass Spectrometer," 1984.
- I. Sauers, "Ultrasensitive Detection of By-Products Formed by Electrical Discharges in Sulfur Hexafluoride," 1984.
- I. Sauers, "Method for Measuring Degradation of Sulfur Hexafluoride in High Voltage Systems," 1984.
- P. C. Srivastava and F. F. Knapp, Jr., "Radiopharmaceutical Agent for Brain Imaging," 1985.
- T. Vo-Dinh, "Surface-Enhanced Raman Spectroscopy Substrate for Trace Organic Analysis," 1984.

**APPENDIX G. MEETINGS AND CONFERENCES SPONSORED
BY THE HEALTH AND SAFETY RESEARCH DIVISION
JULY 1, 1984-SEPTEMBER 30, 1985**

DOE Workshop on Charged Particle Track Structure, Oak Ridge National Laboratory, August 21-22, 1984; H. A. Wright, organizer and host. Sponsored by the Department of Energy.

International Conference on Multiphoton Processes III, Crete, Greece, September 5-11, 1984; R. N. Compton, co-organizer. Sponsored by the Department of Energy-Office of Health and Environmental Research.

Personnel Radiation Dosimetry Symposium, Knoxville, Tennessee, October 15-18, 1984; C. S. Sims, organizer, host and chairman. Sponsored by the Health and Safety Research Division, Oak Ridge National Laboratory.

Seventh ORNL Life Sciences Symposium on Indoor Air and Human Health, Knoxville, Tennessee, October 28-31, 1984; S. V. Kaye, co-chairman, R. B. Gammage, member-organizing committee. Sponsored by the Department of Energy, Environmental Protection Agency, Tennessee Valley Authority, and Electric Power Research Institute.

Indoor Air Quality Data Bases: Needs, Issues, Directions, Knoxville, Tennessee, October 31, 1984; A. R. Hawthorne, organizer. Sponsored by the Health and Safety Research Division, Oak Ridge National Laboratory.

Indoor Air Quality, Oak Ridge, Tennessee, November 1, 1984; A. R. Hawthorne, organizer. Sponsored by the Health and Safety Research Division, Oak Ridge National Laboratory.

Symposium on Polynuclear Aromatic Hydrocarbons (PAH) in the Workplace, Honolulu, Hawaii, December 16-21, 1984; R. B. Gammage, co-organizer. Sponsored by Chemical Institute of Canada, Chemical Society of Japan, and American Chemical Society.

Eleventh Personnel Dosimetry Intercomparison Study, Oak Ridge National Laboratory, May 22-23, 1985; C. S. Sims, organizer and host. Sponsored by the Department of Energy-Office of Health and Environmental Research.

Twenty-second Nuclear Accident Dosimetry Intercomparison Study, Oak Ridge National Laboratory, August 12-16, 1985; C. S. Sims, organizer and host. Sponsored by the Department of Energy-Office of Health and Environmental Research.

APPENDIX H. ADVISORY COMMITTEE

A. R. Buhl, Ph.D.
Energex, Incorporated

**Engineering Science and
Technology Transfer**

W. C. Lineberger, Ph.D.
University of Colorado

Chemistry and Physics

W. A. Mills, Ph.D.
ORAU/CIRRPC

**Health Physics and
Risk Analysis**

J. W. Palms, Ph.D.
Emory University

**Radiological Physics and
Instrumentation**

APPENDIX I. PUBLICATIONS AND PRESENTATIONS

BOOKS, BOOK CHAPTERS, AND JOURNAL ARTICLES

Allman, S. L.

Hurst, G. S., Payne, M. G., Kramer, S. D., Chen, C. H., Phillips, R. C., Allman, S. L., Alton, G. D., Dabbs, J. W. T., Willis, R. D., and Lehmann, B. E., "Method for Counting Noble Gas Atoms with Isotopic Selectivity," *Rep. Prog. Phys.* **48**, 1333-70 (1985)

Lehmann, B. E., Oeschger, H., Loosli, H. H., Hurst, G. S., Allman, S. L., Chen, C. H., Kramer, S. D., Payne, M. G., Phillips, R. C., Willis, R. D., and Thonnard, N., "Counting Kr-81 Atoms for Analysis of Groundwater," to be published in *J. Geophys. Res.*

Ambrose, K. R.

Knapp, F. F., Jr., Goodman, M. M., Ambrose, K. R., Som, P., Brill, A. B., Yamamoto, K., Kubota, K., Yonekura, Y., Dudczak, R., Angelberger, P., and Schmoller, R., "The Development of Radioiodinated 3-Methyl-Branched Fatty Acids for Evaluation of Myocardial Disease by Single Photon Techniques," to be published in *Noninvasive Imaging of Cardiac Metabolism*, Martinus Nijhoff Medical Publ., Amsterdam

Vo-Dinh, T., Griffin, G. D., and Ambrose, K. R., "A Portable Fiberoptic Monitor for Fluorimetric Bioassays," to be published in *Clin. Chem.*

Arakawa, E. T.

Arakawa, E. T., Dolfini, S. M., Achley, J. C., and Williams, M. W., "Arc-Evaporated Carbon Films: Optical Properties and Electron Mean Free Paths," *Phys. Rev. B* **31**, 8097-101 (1985)

Chang, C. C., Callcott, T. A., and Arakawa, E. T., "Barrier Diffusion and Optical Properties of the Au-Al₂O₃-Al Thin Film System," to be published in *Phys. Rev. B*

Goudonnet, J. P., Inagaki, T., Little, J. W., Begun, G. M., and Arakawa, E. T., "Plasmon Resonance Contribution to Surface Enhanced Raman Scattering on Oblate Spheroids: Experimental Estimation," to be published in *Phys. Rev. B*

Inagaki, T., Goudonnet, J. P., and Arakawa, E. T., "Nearly Total Absorption in Silver Island Films in the ATR Geometry," to be published in *Phys. Rev. B*

Inagaki, T., Goudonnet, J. P., and Arakawa, E. T., "Plasma Resonance Absorption in Conical Diffraction: Effects of Groove Depth," to be published in *J. Opt. Soc. Am.*

Inagaki, T., Goudonnet, J. P., and Arakawa, E. T., "Optical Absorption in a Thin Nickel Wire," *J. Appl. Phys.* **P85-2861**,

Inagaki, T., Goudonnet, J. P., Little, J. W., and Arakawa, E. T., "Photoacoustic Study of Plasmon-Resonance Absorption in a Bigrating," *Phys. Rev. B* **2**, 433-9 (1985)

Inagaki, T., Motosuga, M., Arakawa, E. T., and Goudonnet, J. P., "Coupled Surface Plasmons in Periodically Corrugated Thin Silver Films," to be published in *Phys. Rev.*

Inagaki, T., Motosuga, M., Arakawa, E. T., and Goudonnet, J. P., "Coupled Surface Plasmons Excited by Photons in a Free-Standing Thin Silver Film," *Phys. Rev. B* 31, 2548-50 (1985)

Martin, C., Arakawa, E. T., and Callcott, T. A., "Low Energy Electron Attenuation Length Studies in Thin Amorphous Carbon Films," *J. Electron Spectrosc. Related Phenom.* 35, 307-17 (1985)

Sasson, R., Wright, R., Arakawa, E. T., Sagai, C., and Khare, B. N., "Optical Properties of Solid and Liquid Sulfur at Visible and Infrared Wavelengths," to be published in *Icarus*

Williams, M. W., Beckman, D. W., Swan, J. B., and Arakawa, E. T., "Detection of Trace Elements with Resonance Ionization and Time-of-Flight Mass Spectrometry," *Anal. Chem.* 56, 1348-50 (1984)

Williams, M. W., Young, D. W., Ashley, J. C., and Arakawa, E. T., "Optical and Electronic Properties of the Electron Beam Resist PBS," to be published in *J. Appl. Phys.*

Ashley, J. C.

Arakawa, E. T., Dolfini, S. M., Ashley, J. C., and Williams, M. W., "Arc-Evaporated Carbon Films: Optical Properties and Electron Mean Free Paths," *Phys. Rev. B* 31, 8097-101 (1985)

Ashley, J. C. and Echenique, P. M., "Influence of Damping in an Electron Gas on Wake-Binding Energies," *Phys. Rev. B* 31, 4655-6 (1985)

Ashley, J. C. and Ferrell, T. L., "Evaluation of a Fourier Transform Involved in the Interaction of a Moving Charge with a Polarizable, Spherical Body," to be published in *Math. Comput.*

Ashley, J. C., Ritchie, R. H., Echenique, P. M., and Nieminen, R. M., "Non-Linear Calculations of the Energy Loss of Slow Ions in an Electron Gas," to be published in *Nucl. Instrum. Methods*

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