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Health and Safety Research Division Progress Report for the Period October 1, 1985–March 31, 1987

Phillip J. Walsh

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HEALTH AND SAFETY RESEARCH DIVISION PROGRESS REPORT FOR THE PERIOD OCTOBER 1, 1985–MARCH 31, 1987

Phillip J. Walsh

Date published: September 1987

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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 conducts a variety of health effects assessment studies including screening level assessment systems for chemicals, ionizing radiation dose-response, and electromagnetic field exposures and effects. The Measurement Applications Group conducts experimental field studies of populations exposed in occupational and domestic settings. Two major indoor air quality field studies were recently completed. A detailed investigation of radon entry into homes is currently under way in New Jersey with a follow-up study planned for the Tennessee Valley area. The Measurement Applications Group is increasing activities in the development and evaluation of screening level monitoring for hazardous waste sites. 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 approximately 20 Medical Cooperative Programs for further preclinical testing and clinical evaluation.

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[1]Biology Division.

[2]Engineering Physics Division.

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.

Indoor air quality research activities constituted the main thrust of the group's investigations during the reporting period. This work represents important collaborative research by several sponsors and was funded by a wide array of sponsors including the Environmental Protection Agency, the Consumer Product Safety Commission, the Tennessee Valley Authority, the Department of Energy, and private organizations such as the Electric Power Research Institute, Alabama Power Company, and Harvard University (via NIEHS funding).

Two major multipollutant indoor air quality field studies were completed during this period.

One study involved measurement of indoor air quality in 70 homes in four Tennessee Valley states over a one-year period. The initial focus of the study was on radon progeny. Results have identified the Huntsville, Alabama, area as having levels substantially above the national average. Broad surveys of radon levels in both Tennessee and Alabama are currently being conducted by EPA based partially on the results from our study. Additional pollutants monitored in this study included formaldehyde, nitrogen dioxide, polynuclear aromatic hydrocarbons, and volatile organic compounds. Initial results indicate higher formaldehyde levels in summer months, consistent with previous laboratory experiments of environmental dependence of emission rates. The experimental phase of a second major indoor air quality study was completed this year in 300 homes in the Kingston/Harriman communities. This study was a collaborative effort with Harvard University and represented one of the most intensive investigations of air quality yet conducted in occupied homes. Monitored pollutants included radon, formaldehyde, nitrogen dioxide, respirable particulates, polynuclear aromatic hydrocarbons, airborne microaerosols, and water vapor. Additional information obtained focused on house characteristics, including air exchange rates and occupant behavior, obtained primarily through questionnaires. Data from this study are currently being analyzed.

A new research effort begun during the period involves a detailed investigation of radon entry and mitigation measure effectiveness in homes with elevated radon levels. This work is being conducted in collaboration with Lawrence Berkeley Laboratory and Princeton University (through subcontract with ORNL) and with support from EPA and DOE. Time-dependent measurements of radon levels and important environmental parameters (temperature, differential pressures, precipitation, etc.) will provide a better understanding of radon entry mechanisms. Development and refinement of diagnostic measurements used to select appropriate mitigation measures are a major goal of the study. A better understanding of when and why specific mitigation measures fail will also result.

An increased involvement in hazardous waste research occurred during this reporting period. Emphasis was placed on the development and evaluation of screening methods that will allow a faster, more cost-effective evaluation of hazardous waste contamination. A major field study being conducted on the Oak Ridge Reservation involved screening of soil and soil gas for mercury, PCB, and vapors of degreasing solvents. New screening procedures were applied to samples taken along the 2.5-mile route of a Perimeter Intrusion and Detection Alarm System (PIDAS). The experience gained will benefit field surveys for chemical contaminants soon to be started in the Air Force Installation Restoration Program (IRP). This research represents an area of anticipated future focus.

HEALTH EFFECTS AND EPIDEMIOLOGY

The purpose of the Health Effects and Epidemiology Group is to draw together relevant laboratory and epidemiological data to develop methods for assessing health risks attendant to energy production and utilization. Fundamental long-term objectives include: (1) the placement of hazards from varying insults (e.g,. chemicals, injury radiation, nonionizing radiation) on a common scale; (2) the development of predictive tools for hazard analysis of complex mixtures of insults; and (3) the development of methods for evaluating actual levels of risk from exposures to hazardous substances. These objectives are supported by work related to more immediate needs, as described below.

Work for the Defense Nuclear Agency has continued with increased emphasis on the determination on LDN values where N may range from low to high. Studies conducted during the 1950s

and 1960s of radiation-induced mortality to diverse animal species under various exposure protocols were compiled into a mortality database. Some 24 variables were extracted and recomputed for each of the published studies. The important features of this compilation are: (1) an attempt to give an estimate of the uniform dose received by the bone marrow in each treatment so that interspecies differences due to body size were minimized and (2) a recomputation of the LD50 where sufficient experimental data are available. On the basis of this and past work, ORNL was requested to author the U.S. position on the LD50 for healthy young adults irradiated acutely with low-LET whole-body radiation for the NATO Research Scientific Group-5 Committee.

The relationship between chemistry of drinking water and cardiovascular disease has been examined in a population study of 46 Wisconsin communities, all of which used wells for drinking water. Half of the communities chlorinate drinking water, while half do not. Water hardness was classified as hard in about 50% of the communities and soft in about 50%. Initial results indicate that females living in communities with chlorinated water supplies have higher total serum cholesterol levels than do females in nonchlorinated communities; no difference was seen for men. Further, no differences were seen for serum triglyceride levels in either sex.

Public Law (P.L.) 99-145 directs the Secretary of Defense to carry out the destruction of the U.S. stockpile of lethal chemical agents and munitions by September 30, 1994. To assist in this process, group efforts have contributed to the environmental impact analysis of alternate disposal methods. Group activities have centered on researching available toxicological information on each stockpiled agent and this information has been used to consider occupational and public health effects of potential releases of each disposal alternative.

There is a real danger that the Federal Regulatory Program will bog down. In the last decade there were only a small number of agents that were regulated by all four of the responsible agencies. Today, there are about 500 agents for which there is substantial evidence for carcinogenicity. To assist in the deluge, the group has developed a rapid assessment methodology based on relative potency concepts. The relative potency values are derived from data presented in the Registry of Toxic Effects of Chemical Substances (RTECS). To date, nearly 200 chemicals have been evaluated and ranked quantitatively. Where possible, these rankings have been compared with recommendations of expert committees. In addition, a separate, more fundamental effort has examined many of the relationships used within this rapid assessment methodology. This investigation is proving to be valuable in understanding the predictive value of a battery of *in vitro* assays relative to laboratory animal assays.

The ubiquitous presence of 60 Hz electromagnetic fields and the possibility for biological interactions of these fields has prompted considerable concern about effects on humans. The group has addressed this question in two ways: (1) development of a resource guide for future epidemiological studies and (2) reanalysis of laboratory data by combining results of many laboratory experiments, each of which is smaller than necessary to allow for sufficient statistical strength. These two complementary efforts are directed at ultimately assisting the performance of a risk assessment evaluation for human exposure to 60 Hz electromagnetic fields.

ADVANCED MONITORING DEVELOPMENT

The research activities of the Advanced Monitoring Development Group are aimed to develop novel or improved chemical and biological monitoring technologies to measure human exposure to toxic chemical pollutants in energy-related technologies.

During this reporting period, we have demonstrated the analytical potential of cellulose substrates using the laser-induced fluorescence line-narrowing (FLN) technique. Although the FLN technique is known for frozen organic solvents, it has not been applied to practical cellulose substrates. The FLN technique was applied to analyze polynuclear aromatic (PNA) compounds such as benzo(a)pyrene (BP), chrysene and pyrene in complex mixtures. Our results show that the FLN technique may be successfully applied to complex samples adsorbed on filter paper. This adds further versatility to spectroscopy on cellulose substrates, which so far have been shown to be extremely useful in analytical applications of room-temperature phosphorimetry.

We have successfully adapted advanced spectrometric technologies for the study of biological and chemical dosimetry. The areas investigated include fluorescence of uracil derivatives in urine and synchronous luminescence of urine and DNA-adducts. Sensitivity potential to better than 1 in 10^9 DNA base pairs was obtained with laser-stimulated fluorescence.

We have also developed a new procedure based on the room temperature phosphorescence technique (RTP) to detect r-7, t-8-dihydroxy-t-9,10-epoxy-7,8,9,10-tetrahydrobenzo(a)pyrene (BPDE)-DNA adducts and BP metabolites adsorbed on filter paper. In this study we investigated whether it is possible to detect the RTP signal of biological systems derived from metabolic activation of PNA compounds. We have successfully detected BP metabolites in urine samples using RTP analysis. The RTP of benzo(a)pyrene-r-7,t-8,9,10-tetrahydrotetrol (BP-tetrol) has also been measured using laser excitation. BP-tetrol (BPT) is a product derived from BP-diolepoxide (BPDE), BPDE being the ultimate carcinogenic metabolite of BP. The detection limit of BPDE in *in vitro* modified BPDE-DNA was about 15 femtomoles. The method is characterized by its simplicity and does not require sophisticated and expensive instrumentation and cryogenic refrigerant. Thus it is well suited for routine analyses and screening procedures. The RTP approach could provide an additional practical tool to monitor human exposure to carcinogenic and mutagenic PNA species.

The discovery of the surface-enhanced Raman scattering (SERS) effect, which results in an enhancement factor of up to 10^7 in Raman signals from molecules adsorbed on rough metallic surfaces, has recently generated increasing interest in the Raman technique. A practical type of SERS-active surface based on cellulosic materials covered with silver was investigated to extend the general applicability of SERS by the use of a practical and easy-to-prepare substrate. The technique is used to analyze hazardous pollutants such as pesticides and compounds of biological interest such as BPDE-DNA adducts, DNA and BPT. Especially for biological samples, conventional Raman spectroscopy has the disadvantage of requiring large samples (usually 10-100 mg of the bulk pure specimens). The increased sensitivity provided by the SERS effect has eliminated this major limitation. For the sample analyzed in this study, the amount of BPT sample analyzed was only 30 picomoles. The technique for preparing the cellulose-based substrates here is simple and relatively efficient in producing SERS-active substrates. A cellulose surface consists of fibers and tendrils intertwined together providing tips, surface protrusions, and interstices of submicron sizes. Covered with silver, these surfaces can induce amplified local electromagnetic fields associated with surface roughness and induce the SERS effect.

We are currently developing a unique fiberoptics-based fluoroimmunosensor (FIS) which utilizes immobilized antibodies to detect chemical species, and couples this antibody-antigen reaction with laser-induced immunofluorescence spectroscopy, to provide exquisite detection sensitivity. Through use of small fiberoptic probes, this sensor can be used with microsamples of body fluids or can be applied to some tissue sites. Studies are continuing on development of a BP-specific fiberoptics probe of high selectivity and sensitivity. We have purified, using column chromatography and

affinity chromatography, a polyclonal anti-BP antibody from immunized rabbits and have successfully coupled this antibody to the quartz fiber probe. Experiments have demonstrated a very high level of sensitivity for detecting BP in microsized samples. We are currently expanding the concept of FIS to other specific chemicals, as well as investigating applications of monoclonal antibodies to FIS. Characterization of experimental parameters for the FIS system has been carried out using a fluorescein-labeled immunoglobulin G (IgG)/anti-IgG system. It has been found that a competitive binding immunoassay is practical using the optical fiber system. Typical limits of detection with our model FIS are 25 femtomoles of IgG antibody for a 20-minute incubation period.

We are continuing to investigate the toxic activity toward mammalian cells of SF_6 through which electrical sparks have been discharged. We have found that spark-decomposed SF_6 has a strong cytotoxic activity toward at least two different mammalian cell lines. Indirect experiments have suggested S_2F_{10} may be present in spark-decomposed SF_6. Direct cytotoxicity determinations of S_2F_{10} have been undertaken; it is active at lower concentrations than any other by-product of spark decomposition so far tested. Mutagenicity testing using an *in vitro* mammalian cell assay has been initiated.

The development of biological assay systems for assessing exposure to chemical mixtures has continued with the demonstration of an additive toxic response with Ni^{+2} and BAP exposure, and the demonstration that the response occurs to a broad range of chemical types.

A review of the literature has provided evidence for the existence of a common baseline level of arylhydrocarbon hydroxylase activity in nonexposed mammals. This observation may provide a reference value for assessment of risk in exposed human populations.

Other areas of work include the application of synchronous luminescence (SL) and HPLC to analysis of indoor air quality in a 300-home collaborative study with Harvard School of Public Health. The SL screening technology demonstrated several advantages including cost and rapidity of analysis for ranking air sample extracts according to their content in PNA pollutants.

We have developed a database for DNA adducts as part of a molecular epidemiology project with the U.S. Environmental Protection Agency. This information resource will be used to support prospective studies of select, exposed human populations.

A collaborative project with the Environmental Sciences Division at ORNL has been initiated to explore applications of our advanced spectrophotometric technologies to the measurement of bioindicators from field animal and fish exposure.

BIODOSIMETRY

The Biodosimetry Group focuses on biological studies to improve the experimental basis for health hazard assessment. Current activities involve mammalian cell survival and mutation and bacterial mutagenicity studies of complex mixtures. Wastewater and water from a variety of other sources have been studied with an emphasis on interpretation of the results in terms of potential human health hazard.

Use of short-term *in vitro* testing as a first stage or screening step in assessments will increase. It is therefore critical to examine the predictive power of these test systems in terms of animal or human toxicity. All aspects of sample collection, preservation and treatment (e.g. concentration), biological testing protocols, and data analysis are important in investigating the usefulness of *in vitro* biological systems for screening/ranking of samples of toxic chemicals. Thus, all of these areas are being investigated with a view towards testing samples as close to their natural state as possible.

We are preparing an interim document for EPA which will outline our current recommendations in regard to biological screening of complex mixtures. Our focus in the future will be on research to reduce uncertainties in the overall process. Additional areas of investigation may include complex mixtures of radiation and chemicals.

The emphasis of this work will be directed toward supporting the goal of several groups in the Health Studies Section to develop a more cost-effective framework for assessing potential health effects due to exposure to complex mixtures.

NUCLEAR MEDICINE

The principal goals of the Nuclear Medicine Program involve the design and development of new tissue-specific radiopharmaceuticals for use in diagnostic nuclear medicine. The Office of Health and Environmental Research (OHER) provides core support for this program and various aspects are also supported by three grants from the National Institutes of Health (NIH). In addition to the synthesis and testing of new radiopharmaceuticals for *in vivo* nuclear imaging, other activities include biochemical studies to determine the mechanism of tissue specificity of the radiolabeled agents and preclinical testing of new radiolabeled agents in laboratory animals and various *in vitro* systems. The major emphasis focuses on the development of agents for applications in cardiology, cerebral blood flow, oncology and quantification of tissue metabolism. In conjunction with the development of radiopharmaceuticals, new radiolabeling techniques are being developed to incorporate radionuclides into various tissue specific agents for both diagnostic and therapeutic applications. New radiolabeled agents are distributed internationally to approximately 20 Medical Cooperative Programs at clinics, universities, and other research institutions for further collaborative preclinical testing and clinical evaluation. A new research effort involves collaboration with the University of Tennessee Hospital (UT) on the development of new radiopharmaceuticals radiolabeled with positron-emitting radionuclides. The installation of a medical cyclotron at UT will allow research in this important new area. This balance between basic research and development and interaction with key programs at other institutions continues to form the basis of a strong Nuclear Medicine Program. Our collaborative programs bridge the gap between the conception and development of agents at ORNL and interaction with a variety of extramural programs with specific expertise in the areas of nuclear cardiology, cerebral metabolism, oncology, and other nuclear medicine applications.

The development of radioiodinated fatty acids as tools in cardiology research continues to be a major area of research, and various aspects of this work are supported by two NIH grants. Several iodine-123-labeled methyl-branched fatty acids (BMIPP and DMIPP) developed at ORNL have entered clinical testing for the evaluation of differences in regional myocardial blood flow (perfusion) and fatty acid energy substrate uptake by single photon computerized tomography (SPECT) at institutions in Boston, Massachusetts, Bonn, West Germany, Vienna, Austria, and Liege, Belgium. The increased retention of these agents in the heart muscle has allowed for the first time, effective SPECT studies which require a 15-20 minute data acquisition period. These agents are useful to evaluate the differences in uptake and flow in a variety of conditions such as studies of the molecular basis of cardiomyopathies, to evaluate the effects of calcium blocker therapy. Detailed biochemical evaluation of the distribution of radiolabeled fatty acid metabolites within the various lipid pools of heart tissue *in vivo* under various physiological conditions is being pursued. In addition, a new capability is the use of isolated perfused rat hearts which is allowing an evaluation of

the mechanism of localization and retention of these promising new agents for various interventions under carefully controlled conditions. In addition to studying the mechanism of transport and storage of methyl-branched fatty acids, major emphasis continues to focus on synthesis and preclinical testing to further evaluate structural features of methyl-branched fatty acids and other modified fatty acids that lead to optimal myocardial uptake and retention.

An improved method using N-substituted maleimides which bind to protein sulfur (thiol) groups has been pursued for the radioiodination of proteins. The goal of this work is the development of methods for radioiodination of antibodies and other proteins that overcome the problems encountered with methods currently used which show facile loss of radioiodine *in vivo*. The new agent actively binds to many proteins, and shows promise as a new protein label and may be useful for radiolabeling of proteins and monoclonal antibodies for both diagnostic (iodine-123) and therapeutic (iodine-131) applications. The use of substituted maleimides for radiolabeling of proteins with other radionuclides is being explored.

Radionuclide generator studies also continue to be a major focus of the program. The availability of iridium-191m (4.9 sec half-life) by rapid elution of the activated carbon osmium-191/iridium-191m generator system developed at ORNL has been shown to be of significant importance in the diagnosis of heart and vascular disease using "first-pass" nuclear medicine techniques. Clinical trials are in progress through our Medical Cooperative Programs in Belgium and West Germany. Over 250 patient cardiovascular studies have been performed. This area of research is now supported by NIH and new studies include optimization of the generator for use in the continuous infusion mode which may allow for the first time tomographic (SPECT) evaluation of organ perfusion. Several new collaborative programs with U.S. institutions have been initiated in anticipation of approval for human testing in this country, and a "Workshop" for radiopharmaceutical manufacturers will be held at ORNL in July 1987.

A new area of research that has been initiated involves studies with the tungsten-188/rhenium-188 (W-188/Re-188) radionuclide generator system. Rhenium-188 has a 17-hour half-life and high-energy beta emissions, is readily available from a generator system, and is an excellent candidate for a variety of therapeutic applications. The incorporation of Re-188 into antibodies and other proteins is being explored. Other applications include radionuclide treatment of arthritis of the knee joints where Re-188 would offer many advantages over the radioisotopes currently used.

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The section's research projects are focused primarily on evaluation of the health and safety impacts on man of energy technologies. For example, considerable effort is focused in the areas of describing the internal distribution and retention of ingested radionuclides and the resultant internal dose. Special emphasis is being given to quantifying 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 are provided to regulatory agencies for use in decision making and to facilitate the development and implementation of exposure standards for protecting public health and safety. The research 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.

[1]Part-time.
[2]Off-site assignment.
[3]Leave of absence.
[4]Operations Division.
[5]Instrumentation and Controls Division.
[6]Biology Division.
[7]Information Resources Organization.
[8]Finance and Materials Division.
[9]Environmental Compliance and Health Protection Division.
[10]Computing and Telecommunications Division.
[11]Environmental Sciences Division.

DOSIMETRY APPLICATIONS RESEARCH

The radiation dosimetry research, analysis, and experimental activities at the Dosimetry Applications Research (DOSAR) Facility are aimed at providing a better understanding of radiation effects and improving quantification of the radiation dose received by individuals. Such activities are in the mainstream of the HASRD mission of assessment of impacts of energy-related technologies on human health.

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 in the pulse mode or in the steady-state mode. New reference dosimetry was published for the HPRR during this reporting period. This new dosimetry was made necessary because of security-related changes in the reactor configuration in 1985.

The Twelfth Personnel Dosimetry Intercomparison Study (PDIS) was conducted using the HPRR. A total of 46 agencies (31-U.S., 15-foreign) participated in the study. Sixteen of the 46 were associated with commercial nuclear power plants. The results of the PDIS provided up-to-date knowledge of the worldwide status of mixed-field personnel dosimetry.

The HPRR was used by ORNL's Biology Division in ongoing neutron carcinogenesis studies, by two DOE labs to perform criticality alarm tests, by two universities for student training, by five different organizations for neutron dosimeter development, and by two organizations for the testing of equipment associated with the Strategic Defense Initiative.

A Radiation Calibration Laboratory (RADCAL) was designed to expand existing personnel dosimetry test and calibration capabilities. Construction of RADCAL at the DOSAR site will be completed in the second quarter of CY87.

The DOSAR staff helped organize and conduct the International Symposium on Radiation Dosimetry and Safety (RDAS 87) in Taipei, Taiwan, on March 2–4, 1987. Approximately 200 persons from six nations attended this successful meeting.

METABOLISM AND DOSIMETRY RESEARCH

The main task of the Metabolism and Dosimetry Research Group is the development of radiation exposure-dose relationships through modeling the behavior of radionuclides within the body and modeling the deposition of ionizing energy within radiosensitive tissues from these radionuclides or from radiation externally incident upon the body. Such exposure-dose relationships are a cornerstone for the development of radiation protection guidance and also serve an important role in evaluation of diagnostic procedures involving radiopharmaceuticals and diagnostic X-ray machines.

The present emphasis in our research is on exposure-dose relationships for evaluation of exposure of the general public. This focus has necessitated research directed to the development of detailed descriptions of the biokinetic behavior of radionuclides within the body and anatomical models to allow consideration of special characteristics of the exposed individuals or of a segment of the population.

The development of models for "nonreference" humans has required a departure from the curve-fitting approach commonly used to represent the behavior of most radionuclides in adult man. We have found that a mechanistic approach permits supplementing the limited information on a particular radionuclide in man with the more abundant physiological information thus allowing consideration of the variability among humans, more meaningful extrapolation of data from animal to man, better estimates of intake from measurements of excreta, and leads to improved estimates of dose to tissues of the body.

The reevaluation of the doses received by the A-bomb survivors, the shift in emphasis in radiation protection from occupational to environmental exposures, and the increasing application of organ dose estimates in such areas as risk assessment and probability of causation all have required improvements and refinements in methodologies for dose estimation for the appropriate tissues at risk from radiations emitted within or incident upon the body. In response to these needs, we have, for example, modified our mathematical representation of the body to include consideration of children of various ages, the adult female, and the Japanese adult male. We also have begun a program to acquire needed anatomical data from diagnostic images (computer-assisted tomography—CAT scan) of the body.

Members of the group are involved in work of various task groups of the National Council on Radiation Protection, the Medical Internal Dose Committee of the Society of Nuclear Medicine, and the International Commission on Radiological Protection. Of particular relevance to our research is the task group of ICRP Committee 2, formed to revise Publication 23 on Reference Man. In the revision, Committee 2 not only is seeking an update of the report's content but also requested that increased attention be given to variations in anatomical and physiological characteristics with age or sex, or of natural differences that may occur for persons of the same age and sex. This task group has met twice; at ORNL, July 8–11, 1986, and at the National Institute of Radiological Sciences, Chiba, Japan, March 10–14, 1987. Current plans call for working drafts to be circulated prior to the next meeting.

METHODOLOGY IMPLEMENTATION

The primary function of the Methodology Implementation Group is the application of various assessment tools developed by the research activities in the section to predict the impacts of technologies on man. In this role, the group applies various atmospheric dispersion, food chain, and dosimetric computer codes to specific problems. For some applications, the group may be required to evaluate, modify, or develop such computer codes, in conjunction with the Transport Processes Research and the Metabolism and Dosimetry Research Groups.

Several projects were performed for the Environmental Protection Agency (EPA). Work performed on the Computerized Radiological Risk Investigation System (CRRIS), a suite of computer codes for assessment of impacts from radionuclide releases to the atmosphere, included resolution of comments from a peer review and documentation of each computer code in the system. Work continued on efforts to develop a computerized population and agricultural database for use with the CRRIS. A sensitivity analysis was completed of the Inhalation Exposure Methodology, which uses ORNL-developed databases and a postprocessor with an EPA-recommended atmospheric dispersion

model, the long-term version of the Industrial Source Comple . Model. A guidance document on atmospheric model selection was prepared. Technical support also was provided to the EPA through calculations of potential radiological impacts from specific facilities using the ORNL-developed AIRDOS-EPA computer code.

Two projects were completed for the Nuclear Regulatory Commission (NRC) during this reporting period—the assessment of impacts associated with liquid radioactive effluent releases from the Rancho Seco Nuclear Power Plant and the preparation of a five-volume set of emergency response training manuals for use as the basic text for training NRC emergency response personnel. Work continues on a project for the NRC's Office of Inspection and Enforcement. The objective of this project is to refine or modify computer codes currently in use or under development for use by NRC emergency response personnel in predicting the magnitude of radionuclide releases associated with severe reactor accidents and to assure that these codes address the technical issues facing members of the NRC's Emergency Response Organization. Continued collaboration with the Energy Division at ORNL produced several site-specific environmental impact statements and appraisals for NRC-licensed nuclear fuel cycle facilities, other than reactors.

In addition to the above activities, radiation dose calculations have been made in support of past, present, and predicted radioactive waste management programs at all contractor-operated facilities managed by the DOE Oak Ridge Operations office. Similar calculations have been made for annual assessments of routine releases of radionuclides from the facilities.

RADIOLOGICAL SURVEY ACTIVITIES

The Radiological Survey Activities (RASA) measures radiological and chemical contaminants in the environment and assesses the impact of these contaminants on the health and safety of potentially exposed individuals. In the Health and Safety Research Division, the RASA Program provides the focus for application of new instrumentation and methodologies to measure and assess environmental hazards. The RASA Program performs three major functions: (1) identifies suspected locations of technologically enhanced chemical and/or radiological contaminants, (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 Office of Remedial Action and Waste Technology. The Radiological Survey Activities 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, and 30 square miles of Salt Lake City, Utah. During the past 18 months, approximately 5,000 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 3,000 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 35 microcomputers. A new RASA initiative has begun in verifying the success of remedial action in reducing radiation levels below EPA criteria at UMTRAP vicinity properties in Grand Junction, Colorado.

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 $1.0 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, has revealed several hundred radiation anomalies requiring further investigation. A mobile gamma scan of Colebrookdale township in Pennsylvania showed dozens of homes located on a uranium-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: 200 properties in the vicinity of a former National Lead site in Colonie, New York; 50 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. Recent directives by DOE/FUSRAP have led the RASA project into performing radiological surveys to assess the success of remedial action at vicinity properties.

New RASA work has resulted from collaborative efforts with other HASRD groups and from providing support to DOE/Oak Ridge facilities. Collaborative work includes assisting the Environmental Compliance and Health Protection Division in the DOE Environmental Surveys conducted at the 40 DOE reservations around the U.S. Sites visited include the Pantex facility near Amarillo, Texas, the Idaho National Engineering Laboratory near Idaho Falls, Idaho, Brookhaven National Laboratory in New York, and Lawrence Livermore Laboratory near Livermore, California. A major multidivisional initiative has begun to assist the Air Force in the Installation Restoration Program through ORNL's Nuclear and Chemical Wastes Program. The Health and Safety Research, Environmental Sciences, and Chemical Technology Divisions will form a team to perform environmental assessments of contaminated sites on assigned U.S. Air Force bases, and perform engineering design for any remediative measures appropriate for assessed contaminants. This effort will be coordinated through RASA's Grand Junction office.

A major RASA project has been completed in characterization of 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.

Research and development of new instruments and methodologies in survey techniques is an ongoing function of the RASA group. A new Ultra Sonic Ranging and Data 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.

TRANSPORT PROCESSES RESEARCH

The function of this group is to identify research needs in environmental transport with health impacts on man as the endpoint. These identified needs are then proposed to the funding agencies as research programs. Work performed by this group for the DOE includes technical support for

waste management programs and for revision of the DOE orders for Protection of the Public and the Environment. The first topic is described elsewhere in this report under the heading Waste Management Program. The group's work on the DOE orders centers on the derivation of external dose factors for exposures to contaminated air, water, and ground surfaces, and on preparation of derived concentration guides for air immersion. Also, analysis has begun of the exposures and radiation dose equivalents that could be received by railroad workers during the transport of casks containing spent nuclear fuel and other high-level waste materials.

Support activities performed for the Environmental Protection Agency (EPA) include an analysis of models used for simulating the transport of hydrocarbons leaking from underground storage tanks. Also, the EPA's ERAMS computer code has been installed on the ORNL computer system, and its data files have been updated and stored on the ORNL system. This code has been used to provide the EPA with estimates of radiation dose equivalents and risks to city and state populations in the U.S. due to fallout from the Chernobyl accident.

A special project was initiated to analyze aerosols deposited on a piece of wall from Hiroshima following the firestorm in August 1945. Particle sizes and the composition of the deposit are being determined by various physical, chemical, and radiographic techniques.

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 herein.

The section continues to have significant interactions with many other research institutions, both in the U.S. and abroad. Eleven visiting scientists from foreign institutions, 18 visiting scientists from U.S. institutions, and 23 students worked within the section at various times during this reporting period.

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[1]Part-time.

[2]Computing and Telecommunications Division.

ATOMIC, MOLECULAR, AND HIGH VOLTAGE PHYSICS

This research program is devoted to the study of electron-molecule interactions and negative ion processes, electron-excited molecule interactions, interphase physics, and the coupling of basic and applied research for the advancement of new energy-related technologies.

In our studies of electron-excited molecule interactions we have discovered the first optically enhanced electron attachment involving electronically excited molecules. We have observed up to 10^6 times larger electron attachment cross sections to electronically excited states compared to ground states for thiophenol (C_6H_5SH) and thioanisole ($C_6H_5SCH_3$) molecules. The metastable (triplet) states responsible for the photoenhanced electron attachment were produced indirectly via internal conversion from higher excited singlet states which are strongly optically allowed and are reached by excimer laser excitation. Besides their basic significance these studies open up new technological possibilities such as the optical control of the impedance characteristics of (gaseous) matter and repetitive switching—or modulation—of the electronic conduction/insulation properties of matter at times in the μs to the ns range.

The multiphoton ionization of fluoranthene in liquid tetramethylsilane (TMS) was studied as a function of laser intensity and wavelength. The ionization mechanisms operating at various laser wavelength regions were identified and the ionization threshold (I_L) of fluoranthene in TMS was determined to be ~5.7 eV. It was found that a gradual transition from a direct two-photon to a three-photon (via the first, S_1, and second, S_2, singlet states) ionization mechanism takes place for $400 < \lambda < 440$ nm. This important observation was developed into a novel technique for determining the I_L of a molecule dissolved in a nonpolar liquid. Additionally, the multiphoton ionization of azulene in various nonpolar liquids, with V_o values ranging from -0.7 to +0.21 eV, was studied and its I_L was determined in each liquid utilizing the aforementioned technique. A linear relationship between the I_L in each liquid and the corresponding V_o value was found.

Interphase studies on electron motion, attachment, and ionization in dense gases continued with emphasis on TMPD in ethane and SF_6 in Xe.

A strong negative effect of temperature, T, on the nondissociative electron attachment to molecules has been observed for a number of perfluorocarbons. The nondissociative attachment component of the total electron attachment to C_3F_8, n-C_4F_{10}, and n-C_6F_{14} extends from 0.4 to >5 eV, increases with the size of the molecule, and decreases precipitously with increasing T above room temperature. Similarly, the rate constant for electron attachment to molecules such as c-C_4F_8 and c-C_6F_6 which below ~1.0 eV attach electrons exclusively nondissociatively was found to decrease by two to three orders of magnitude when T was raised by 200 to 300 degrees above room temperature. Possible origins of the observed large negative effect of T on electron attachment have been investigated and the significance of these novel findings for certain applications such as spark gap and diffuse discharge closing switches has been established.

The uniform field breakdown strength of electronegative gaseous dielectrics has been shown to depend on T. It increases with T for those dielectric gases which attach electrons dissociatively and their attachment cross section increases with T, and it decreases with T for those dielectric gases which attach electrons nondissociatively and their electron attachment cross section decreases with T.

Accurate values of the electron drift velocity w have been measured in the rare gases Ar, Kr, and Xe over a wide range of the density normalized electric field strength ratio E/N and covering the mean electron energy $\langle\epsilon\rangle$ range from thermal energy $\langle\epsilon\rangle \sim 0.038$ eV to several eV. These measurements have been used in a Boltzmann equation analysis to determine the low energy electron momentum transfer cross section σ_m, the transverse diffusion to electron mobility ratio $D_T 3/\mu$ and $\langle\epsilon\rangle$ for these gases. The electron attachment rate constants $k_a(E/N)$ have been measured in SF_6/Xe gas mixtures, and these measurements along with the transport measurements in the pure rare gases are being used in analyses to calibrate the mean energy scale in rare gas liquids as a function of E/N.

The electron attachment coefficient η/N, ionization coefficient α/N, and w have been measured in SiF_4, BF_3, and several SiF_4/He gas mixtures over a wide E/N range. SiF_4 and BF_3 possess the highest known electron attachment thresholds ($\approx$10.5 eV) and these gases may be useful as constituents in gas mixtures for diffuse discharge closing switch concepts which are of prime importance in many pulsed power switching applications.

PHYSICS OF SOLIDS AND MACROMOLECULES

This group concentrates on making basic measurements, by a variety of techniques, of the optical and electronic properties of solids, macromolecules, liquids, and thin films over a wide range of photon energies and temperatures. Other areas of research include resonance ionization spectroscopy; photoacoustical measurements; and measurement and calculation of low-energy electron mean free paths in solids and macromolecules. Studies in this program should lead to a better understanding of biologically interesting materials and biological systems and to the development of new low-level pollutant detectors.

Electron inelastic mean free paths (IMFP's) and stopping powers were calculated for polymethylmethacrylate, an important electron resist, from a complex dielectric function determined from an insulator model, with parameters fixed using electron energy loss data. IMFP's were determined for the electrons through freestanding thin films of polystyrene and collodian. A

very effective, electrically conducting barrier to diffusion in thin film systems has been developed. It consists of a layer of refractory metal whose grain boundaries are blocked ("stuffed") by a metal oxide. No diffusion can be detected in Au-barrier-Si structures after several hours at high temperature.

Optical properties were measured for thin films of organic material (tholins) produced in an rf gas discharge plasma filled with simulated atmospheres of the planet Uranus. The optical data were found to agree well with the data obtained by the Voyager spacecraft and ground-based observations. Light emission from targets bombarded by high-energy (20–35 MeV) neutral atoms has been observed in the wavelength range from 200–800 nm using a neutral beam at the University of Manitoba Cyclotron Laboratory. Transparent targets of sapphire, quartz, polystyrene, and mylar produced easily detectable levels of light in this spectral region, while emission from aluminum, silver, and carbon was not observed. These results have been used to evaluate the use of this emission for target discrimination in the Strategic Defense Initiative Program. The measured optical response of surface-enhanced Raman spectroscopy (SERS) active substrates was compared with theory and with their performance as SERS enhancers. Prolate Ag deposits on the sides of SiO_2 posts provide extraordinarily large SERS enhancements.

The mass ablation rate and ablation thickness from rapid surface vaporization by a Nd:YAG laser on targets of Cr film, Ni sheet, and stainless steel sheet were measured with the resonance ionization time-of-flight mass spectrometer. A resonant signal of ^{138}Ba was measured with 2.5×10^2 ions per pulse deposited on the ion detector.

A very high efficiency soft x-ray emission (SXE) spectrometer was operated at the National Bureau of Standards (NBS) synchrotron source for calibration and performance studies. The instrument design received a 1986 I-R 100 Award. Since March 1986, SXE measurements have been carried out at the National Synchrotron Light Source at Brookhaven National Laboratory using e-beam and synchrotron light excitation. The measurements provide electronic density of states information localized near particular chemical species of the solid materials. These include Li-F, dilute Al-Mg alloys (model system for impurities), LiAl intermetallic compound (very unusual crystal structure with practical applications as a battery alloy), Al-Mn alloys (recently discovered icosohedral alloys), $Ga_{1-x}Al_xAs$ and $GaAs_{1-x}P_x$ (important semiconductor alloys), Fe-B alloys, and Kr in Al.

LIQUID AND SUBMICRON PHYSICS

This group's research is devoted to the basic physics of liquids and submicron structures. Allied investigations leading to applications in microscopy, the response of materials to radiation, detection of organic compounds, and development of new surface probes are carried out.

New types of microscopy and microlithography have been developed. Well-controlled microstructures have been fabricated for metal-oxide-metal tunnel junctions which are useful in obtaining spectra of organic compounds on surfaces. Other microstructures have been produced which are highly effective in surface-enhanced Raman scattering, enabling a portable instrument to be developed which utilized a low-power He-Ne laser. Pollutant screening has been investigated with this instrument.

A scanning tunneling electron microscope has been developed which operates at subatomic resolution, and several seminal studies have been conducted. The instrument operates under ultra-high vacuum and has been utilized not only as a microscope but also as a spectroscopic tool for analysis of surface composition.

Two students have completed M.S. degrees and three students completed Ph.D. degrees working on research in liquid and submicron physics.

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 included a continuing development of the theory of electron and ion interactions with the excitation modes of condensed matter, the theory of track structure and high-energy sputtering from nonmetallic solids and the prediction of inelastic scattering probabilities in scanning transmission electron microscopy. The role of damping in an electron gas on the vicinage effect in ion-cluster energy loss was evaluated for a stopping medium corresponding to solid carbon films. Studies of electron energy-loss rates and inelastic mean free paths in organic solids continued, with emphasis on materials used as photon and electron resists. The interactions of subexcitation electrons with SiO_2 were reexamined and new predictions made for energy-loss rates and transport mean free paths. We continued our theoretical investigation of transient conductivity in irradiated insulators and our 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 investigations of the interaction of probes, e.g., charged particles or atoms with surfaces and particulates included a completely quantal derivation of the polarization potential between an electron and an atomic or molecular system and the evaluation of higher-order corrections in a systematic evaluation of the spatial dependence of the self-energy of interacting systems. We are studying coherence effects in the energy losses of low-energy electrons in condensed matter and have evaluated the binding energy of wake-riding electrons in a self-consistent manner. We investigated quantitatively the surface contribution to the energy loss of slow ions in an electron gas using the Ritchie-Marusak quantal dielectric response model. We continued our investigation of the emission of optical radiation from solids under bombardment by neutral atoms. Theory for luminescence of a solid due to radiative transitions, as affected by the optical properties of the medium, was developed. The resulting general formulas should find application in many areas.

Development of our model for Monte Carlo calculations of the detailed sequence of events in irradiated water continued. Work was initiated to include dissolved oxygen and simple polyamino acids and oligonucleotides in order to study radiation damage to these systems. Experiments were initiated in collaboration with the Biology Division to measure the products of radiation damage for comparison with calculated quantities. Design of a basic chamber was completed for a digital characterization of charged-particle tracks. The device will have a number of uses including measurements made for neutron dosimetry. Monte Carlo calculations of the details of energy deposition in thin layers of Si and SiO_2 irradiated by X and gamma rays were completed. The dimensions of the layers were chosen to be of the order of those in integrated circuit memory devices.

Collaborative studies continued with the Biology Division on the effect of chemicals on living organisms at the molecular and whole-animal levels. Detailed calculations were made of the binding of metals and other chemicals, such as PAH's, PAC's, and aromatic amines, to single- and double-stranded polynucleotide structures to simulate interactions with various forms of DNA and RNA.

These studies are closely related to the recent Structural Biology and Human Genome initiatives. Studies continued of bond characterization as a basis for understanding toxic effects of metal ions. Experiments were performed to help elucidate the properties of a low-molecular-weight, metal-binding protein which is induced in Drosophila in response to metal ions in their diet. The induction of such a protein could provide a predictor of metal-ion toxicity. In parallel experiments, genetics studies were used to get closer to the location on the X chromosome of the allele associated with cadmium-ion toxicity in Drosophila. These experiments could lead to a better understanding of the basic mechanisms associated with metal-ion toxicity at the molecular level.

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Current 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 intensive use is made of laser-based spectroscopic techniques in many of the studies of physical and chemical phenomena. 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.

A new program has been initiated wherein use will be made of a high-power tunable, picosecond laser system for studies of chemical kinetics in gaseous, liquid, and clustered species. This new work will complement our ongoing activities which involve the use of molecular beams, mass spectroscopy, resonance ionization spectroscopy, and other nonlinear optical techniques for the studies summarized herein.

The following brief 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.

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[1]Off-site assignment.

[2]Instrumentation and Controls Division.

[3]Analytical Chemistry Division.

MOLECULAR PHYSICS

Multiphoton ionization (MPI) of gaseous atoms and molecules has developed into a major area of chemical physics which encompasses both basic and applied research. The Molecular Physics Group has continued extensive experimental and theoretical studies of MPI of gaseous atoms, molecules, and clusters. In most cases, the experimental studies at ORNL have been combined with theoretical collaborations at other institutions. In particular, detailed comparisons between experiment and theory have been completed for MPI photoelectron angular distributions. A major article has been completed which reviews multiphoton ionization photoelectron spectroscopy.

A number of studies of high-power laser interaction with dense alkali vapors have been performed. The alkali vapors are contained in optical heat pipes. In addition to basic research into the mechanisms of MPI harmonic generation and stimulated Raman processes, which is the main focus of the work, applications of the tunable infrared (IR) radiation are being pursued. For example, detection techniques utilizing IR absorption due to gaseous impurities in the air (NO, HF, NO_2, etc.) are being developed with success. A more recent novel application of optical heat pipes has been in the area of dosimetry. Studies are being directed toward the measurement of w values (energy required to produce an ion pair) for alkali vapors. A long-range goal of this research is to use lasers to study energy deposition mechanisms in the interaction of ionizing radiation with matter.

Excimer laser emission has been observed for the first time between the lowest triplet states of Na_2 and Li_2 ($^3\Sigma_u^+ \leftarrow {}^3\Sigma_g^+$). Both theory and experiment show that the upper $^3\Sigma_g^+$ state is populated by two-photon excitation of Na_2 $^3\Delta_g$ followed by cascading emission to Na_2 $^3\Pi_u$ and finally emission to Na_2 $^3\Sigma_g^+$. These studies may lead to the development of a simple discharge sustained alkali excimer laser. The results will allow for more precise location of the potential energy curves for the bound $^3\Sigma_g^+$ and repulsive $^3\Sigma_u^+$ states.

A major part of this effort is devoted to understanding molecular clusters as a bridge between gaseous and liquid states. Recent experimental work has included MPI studies of simple van der Waals molecules and the autodetachment spectroscopy of helium negative ion dimers. Theoretical studies of evaporation dynamics in molecular clusters have uncovered important regularities, identified experimental tests of them, and shown how small "magical" properties may be magnified to macroscopic proportions.

Our longstanding interest in third harmonic generation (THG) in rare gases led to studies of the effect of a second strong, resonant laser on THG in xenon. We find that through coupling by the second laser, THG can occur in normally forbidden regions of a nonlinear medium. Even in normally allowed regions, the THG conversion is altered by the second laser.

A tunable, picosecond dye laser system is being acquired. The high-peak power of such a system (10^{12}-10^{14} W/cm^2) will make possible the observation of high-order multiphoton processes in dense atomic and molecular gases. The short pulse time ($\sim 5 \times 10^{-12}$ s) will allow study of very fast chemical dynamics of liquids and clusters which is important in radiation chemistry and physics. In both cases, the ability to tune the wavelength of the laser will allow state specific studies.

PHOTOPHYSICS

In the Photophysics group continued emphasis is placed on quantitative measurements of processes involved in advanced laser techniques for sensitive chemical analysis. Our studies of nonlinear optical effects in metal vapors have led to the discovery of several very novel effects. For instance, in alkali atoms when a strong two-photon resonance is pumped by a relatively narrow bandwidth laser source with power densities $>10^7$ W/cm^2 and angular frequency ω_L, it is found that for concentrations above 10^{12}/cm^3 every two-photon absorption leads to a photon of angular frequency ω_E being emitted and to the atom ending up in a lower excited state of excitation energy $\hbar(2\omega_L - \omega_E)$. The mechanism for the photon emission is amplified spontaneous emission (ASE) when the laser is tuned on resonance, or stimulated Raman generation when tuned off resonance. The stimulated processes have long been known to be important around two-photon resonances, but it was not known that these processes can play such a dominant role at low concentrations. In the situation described above, the ASE intensity increases with increasing concentration until the intensity of the emitted light becomes so large that several saturation effects limit both the ASE intensity and the two-photon absorption.

Also coming into play at high concentrations is a four-wave mixing phenomenon which serves to permit stimulated Raman emission without filling up the lower state. In fact, at high concentrations nearly all of the two-photon absorption leads to stimulated Raman emission which is not resonant with the three-photon resonance and leads to a four-wave mixing photon for every stimulated Raman photon. The required phase matching for such an efficient conversion of stimulated Raman to light at $2\omega_L - \omega_E$ is achieved both by Δk being zero at a point between fine structure levels, and by the emissions occurring into a conical region about the laser beam. Resonant ionization through the two-photon states is also drastically affected by the same processes, greatly decreasing resonant ionization yields. These results are relevant to development of certain mass spectrometer ion sources.

In other studies we have used the combination of a dye laser and the ninth harmonic of a Nd-YAG laser in order to explore high-lying two-photon resonances in several atoms and molecules. These studies make use of the fact that in a two-photon resonant excitation with a weak vacuum ultraviolet (VUV) beam at ω_{VUV} and an intense dye laser beam at ω_d to a state with excitation energy $\hbar(\omega_{VUV} + \omega_d)$, nearly all of the VUV beam can be absorbed at concentrations $\sim 10^{16}$/cm^3, thereby, leading to an ion for nearly every photon in the weak beam. In principle, this concept can permit high-resolution two-photon spectroscopy of very high-lying atomic and molecular resonances.

A considerable part of the Photophysics group's effort has been devoted to preliminary investigations related to the development of liquid phase studies. One of the planned studies involves

the production of transient species by picosecond two-photon absorption. The product is probed by a time-delayed picosecond infrared (IR) absorption technique, where the IR is generated by stimulated Raman processes from a part of the original picosecond dye laser beam, and the absorption is monitored by comparing the spectrum of the unattenuated IR with that of the beam which has passed through the region of the transient species. The time-resolved fingerprints show up as dips in the rather broad spectrum (due to the short pulses) of the transmitted IR.

5. OFFICE OF RISK ANALYSIS

C. C. Travis

The Office of Risk Analysis (ORA) was organized to assist in the coordination of risk-related activities at ORNL. A primary goal of ORA is to initiate and develop risk-related funding for the laboratory from a variety of government agencies.

The ORA is involved in several risk-related projects. ORNL is providing assistance to the Office of Science and Technology Policy and the National Science Foundation in an evaluation of the scientific basis for assumptions used in risk assessment. The assumption areas being considered are interspecies, low-dose, dose-route, and dose-rate extrapolations. For the EPA, ORA is evaluating the use of pharmacokinetic models in risk assessment. ORA has developed pharmacokinetic models in mice, rats, and humans for tetrachloroethylene, methylene chloride, and methyl chloroform. The ability of physiologically based pharmacokinetic models to extrapolate between species provides a major tool for improving the estimation of human cancer risk based on animal cancer bioassays. ORA is also evaluating the use of pharmacodynamic models in the risk assessment process. These models relate fundamental cellular processes to the epidemiology of cancer in animal and human populations. They are based on the assumption that cancer is a two-stage process, and incorporate data on genetic mutation frequencies and cell turnover dynamics. These models appear to have excellent possibilities of producing more realistic estimates of risk associated with hazardous substances. For DOE, the ORA is evaluating rapid methods for prioritizing chemicals with respect to their potential threat to human health. Attributes of these methods are that they provide estimates of the potential human toxicity of organic chemicals for which little toxicological data exist, and they work equally well for carcinogens and noncarcinogens.

6. CONTRIBUTIONS TO NATIONAL AND LEAD LABORATORY PROGRAMS AND ASSIGNMENTS

NUCLEAR REGULATORY COMMISSION

R. O. Chester

At the request of the NRC, modifications to codes on their Emergency Operations Center computer were made. A users' manual for MENU-TACT, an interactive dose estimation code for use in real time during an emergency, has been issued. The code provides the NRC Center personnel with information to guide them in making recommendations to civil authorities when an evacuation of an area is deemed necessary or to the plant operators that initiate those actions. Extensive documentation of the NRC's internal emergency operational procedures has been completed. The five-volume manual is to be used in training NRC staff and distributed to responsible state and utility personnel to assist them in their interactions with the NRC staff.

WASTE MANAGEMENT PROGRAM

D. C. Kocher

The Dosimetry and Biophysical Transport Section has been active in four major projects within the laboratory's radioactive waste management program. The first project has involved a cooperative effort with the Chemical Technology Division for the DOE's Defense Programs to develop generally applicable and risk-based definitions of high-level and other radioactive wastes, i.e., transuranic waste and equivalent and low-level waste. This activity was undertaken to assist the DOE in formulating a response to an anticipated rulemaking by the NRC on defining high-level waste, which could have a significant impact on management and disposal of wastes generated in atomic energy defense activities. The results of this activity also may be used as support for modifying existing DOE policies on waste management and disposal. In the second activity, the Section has continued to support the laboratory's program for development of new disposal facilities for low-level radioactive wastes by further development of models for evaluating potential radiation doses to inadvertent intruders and by developing preliminary criteria for defining concentrations of man-made and naturally occurring radionuclides that would be below regulatory concern and, thus, could be disposed of as if they were nonradioactive. The third activity has involved calculation of

potential radiation doses to workers in support of ongoing studies of alternatives for improving the laboratory's capabilities for management and storage of radioactive wastes. These dose analyses are used as part of an analysis to ensure that doses to workers shall be maintained as low as reasonably achievable (ALARA). The fourth activity is a new initiative in the laboratory's remedial action program and involves the development of simple analytical decision tools for prioritizing existing radioactive waste disposal sites at the laboratory for future detailed investigations and cleanup efforts.

CHEMICAL HAZARDOUS WASTE INITIATIVE

R. B. Gammage

A program has been initiated to identify, promote, and coordinate division skills and new activities relating to chemical hazardous waste. The division is building an interactive program involving field survey activities and applied and basic research. The objective is to produce new and improved devices and techniques for monitoring hazardous waste chemicals and their effects on exposed humans.

Groups engaged in radiological survey activities and, in particular, the Uranium Mill Tailings Remedial Action (UMTRA) project, are entering a phase of active transition. Skills are being expanded for dealing with chemical hazardous waste materials. Valuable experience has been gained recently by monitoring contaminated soil and soil gases along the 2.5-mile route of the Perimeter Intrusion Detection Alarm System (PIDAS) at Y-12. The much larger, and soon to be started, field survey work associated with the Air Force Installation Restoration Program (IRP) will profit by the PIDAS experiences.

A main purpose of our intended research and development is to identify and indicate how best to fill niches whose needs are not being adequately met by others. One such niche, and a long standing forte of the division, is the development of new instruments and measuring techniques for cost-effective field survey work and for evaluating potential impacts on human health. We are making the production of innovative and cost-effective screening tools, both chemical and biological, the cornerstone of our research and development program. These products will give those individuals engaged in field survey activities the skills and measuring devices that are the best state-of-the-art. A document was formulated detailing a two-year planning strategy for achieving these ends. The strategy has the goal for the division to become a center of excellence in screening technology and to apply this capability to field survey studies both on and off the Oak Ridge reservation. Improved cost effectiveness is anticipated to result in long-term savings of millions of dollars compared to the current analytical laboratory analyses of environmental samples.

APPENDICES

APPENDIX A. BUDGET AND SUPPORT DISTRIBUTION

	FY85 ($K)	FY86 ($K)	FY87 Oct-Mar ($K)
DEPARTMENT OF ENERGY			
Fossil Energy – Coal	104	–	–
Nuclear Energy – Breeder Reactor	87	–	–
Nuclear Energy – Remedial Action	4697	7238	3386
Conservation & Renewable Energy – Electric	739	631	240
Defense – Defense Waste	159	178	46
Energy Research – Fusion	–	–	74
Conservation & Renewable Energy – Building	55	33	–
Environmental & Biological Research	5299	4688	2512
Energy Research – Nuclear Physics	80	–	–
Energy Research – Multilab Facilities	–	95	58
DEPARTMENT OF DEFENSE			
Navy (including DSRD)	319	383	140
Air Force	397	515	123
Army (including SDI)	78	283	122
National Security Agency	139	218	131
Defense Nuclear Agency	63	96	136
Other DOD	–	19	
OTHER FEDERAL AGENCIES			
Nuclear Regulatory Commission	651	248	59
Environmental Protection Agency	728	1517	610
Consumer Products Safety Commission	120	164	43
National Heart, Lung and Blood Institute	87	168	129
Tennessee Valley Authority	143	214	21
National Bureau of Standards	5	–	–
Food & Drug Administration	39	–	–
Department of Treasury	–	136	–
National Science Foundation		4	14
NIEHS			33
OTHER DOE			
Lawrence Livermore Laboratory	13	–	
Argonne Laboratory	15	–	
Battelle Pacific Laboratory	1	14	54
Westinghouse Materials Corporation/ National Lead	88	122	64

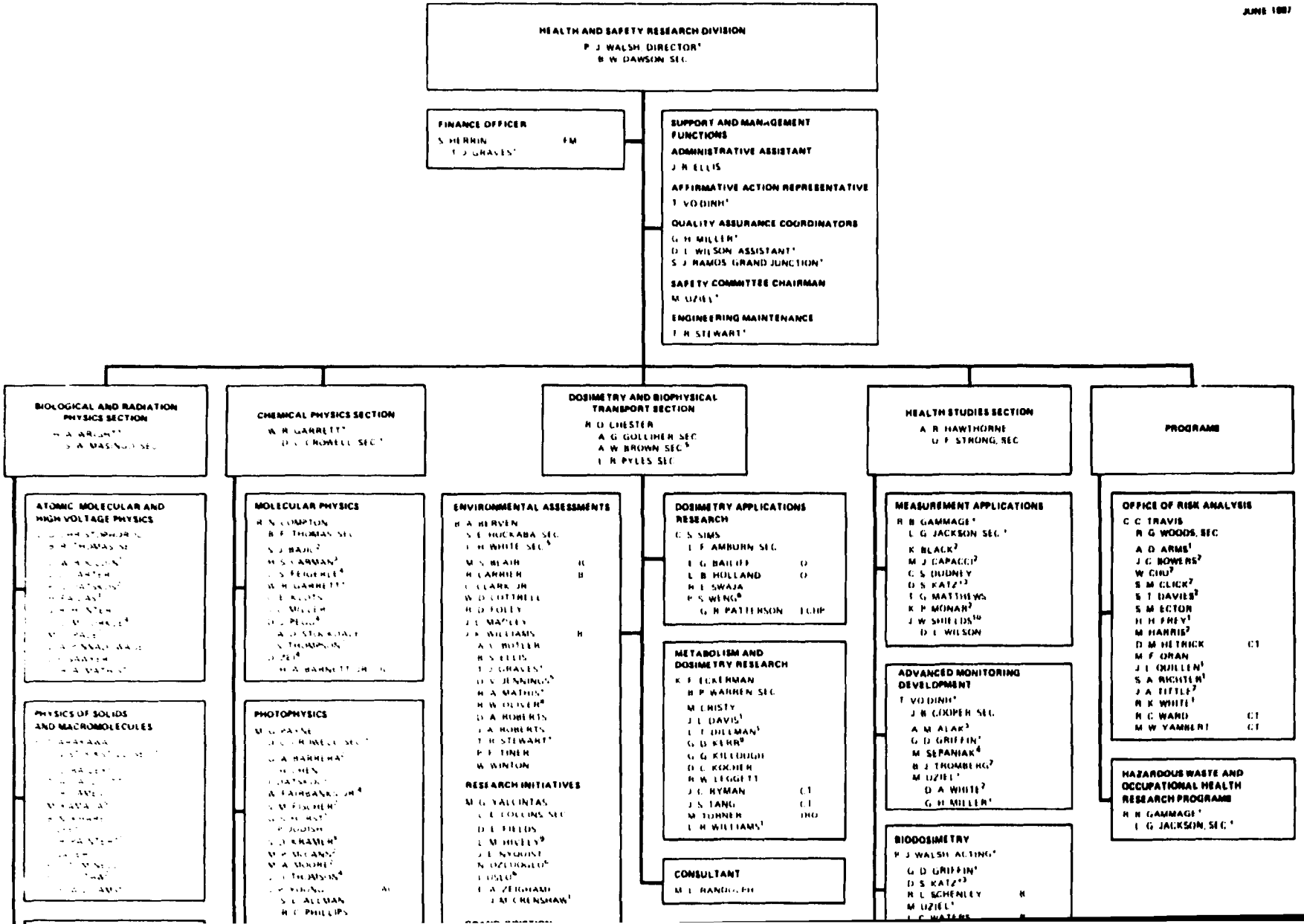
FMC		15	8
Other	60		
Y-12	168	300	225
ORO		38	
PRIVATE, STATE & LOCAL GOVERNMENT			
Universities			
University of Tennessee	31	66	10
Harvard University	–	54	9
New York University	13	18	9
University of Southern California	–	–	63
Alabama Power		32	29
Tetra Tech	–	–	25
Children's Hospital		9	45
EG&G		10	
National Academy of Science		17	58
EPRI		137	16
Nichols Research		–	8
API	118	2	
Other	45	40	
Total	14496	17697	8540
Less - Outside Subcontracts	974	2898	952
Total Division	13522	14799	7588

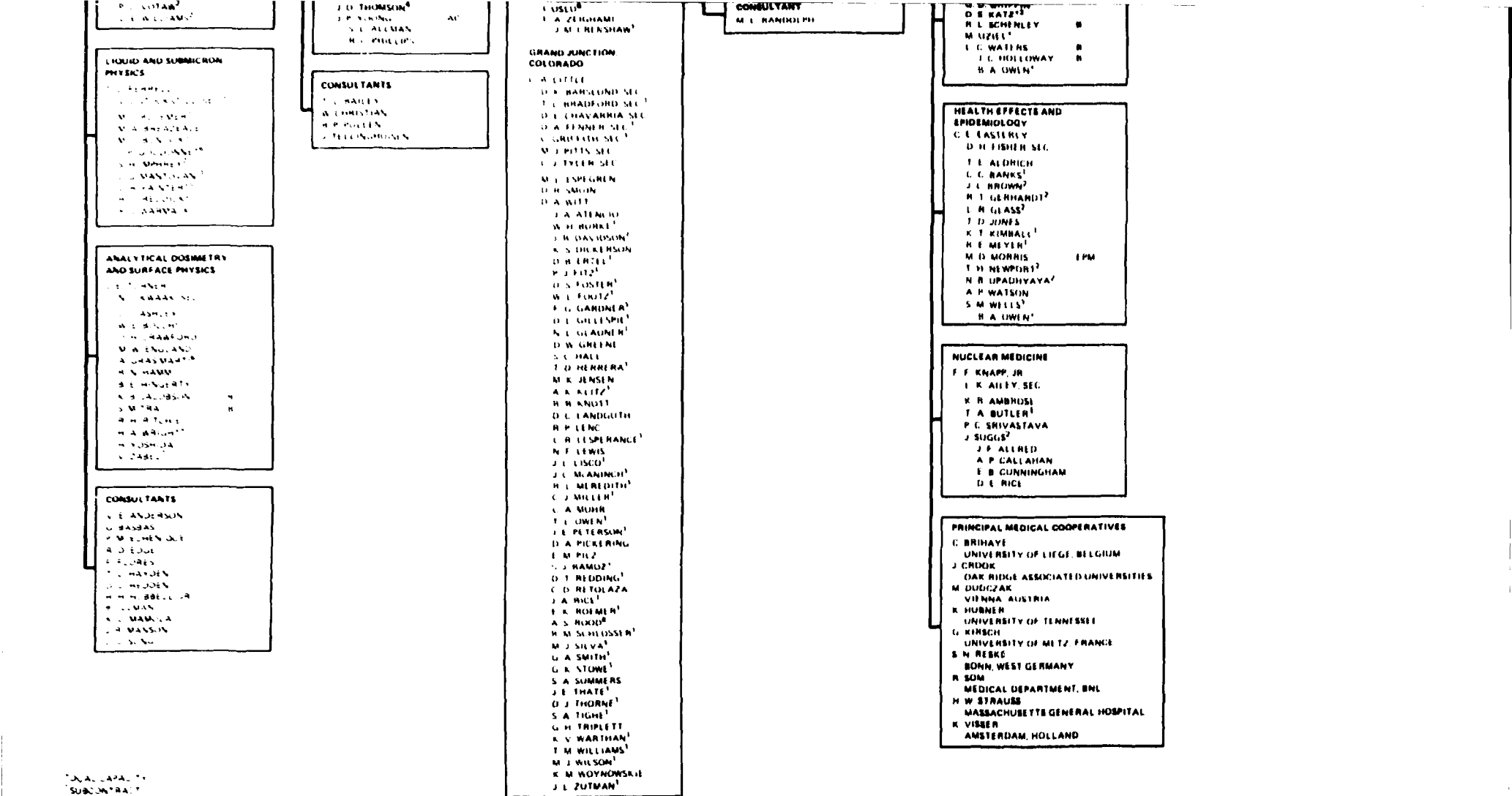
APPENDIX B. PERSONNEL SUMMARY

	Permanent	Technical Support	Administrative Support	Total
Permanent	58	18	21	97
Temporary	10	12	9	31
Part-time	1	3	2	6
Division-supported loanees	13	3	0	16
Leave of Absence	1	2	0	3
Off-site Assignment	2	0	0	2

Many types of employees are required to run the division effectively and efficiently. We use several sources to staff the division to maintain high standards. During this reporting period, we have had a total of 102 assignments to the division in the following categories: consultants; subcontractors; guests from universities; visiting scientists from other laboratories as well as private companies; postdoctoral fellows; and students who come to us under several different programs. Assignment terms vary in duration from a few months to a year or more. We view this as a very economical way to bring different and diversified talents to the division.

APPENDIX C. ORGANIZATION CHART





[1] PART TIME
[2] GUEST ASSIGNMENT
[3] VISITING SCIENTIST
[4] LEAVE OF ABSENCE
[5] OFF SITE ASSIGNMENT

AC ANALYTICAL CHEMISTRY
B BIOLOGY
CT COMPUTING AND TELECOMMUNICATIONS
ECHP ENVIRONMENTAL COMPLIANCE AND HEALTH PROTECTION
EPM ENGINEERING PHYSICS AND MATHEMATICS
FM FINANCE AND MATERIALS
I INSTRUMENTATION AND CONTROLS
IRO INFORMATION RESOURCES ORGANIZATION
O OPERATIONS

APPROVED: P. J. Walsh 6/15/87

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.

During the period October 1, 1985–March 31, 1987, the Health and Safety Research Division has hosted ten seminar speakers representing industry, research institutions, and universities. The following is a list of the seminar speakers and their topics.

Anders L. Colmsjo

Department of Analytical Chemistry, University of Stockholm, Sweden, "Detection of Polynuclear Aromatic Hydrocarbons by High-Resolution Shpolskii Luminescence Spectrometry," October 28, 1985.

Fu-Ming Chen

Department of Chemistry, Tennessee State University, Nashville, Tennessee, "Binding of Benzo[a]pyrene Metabolites to Polynucleotides," November 20, 1985.

Norman G. Anderson and *Leigh Anderson*

Proteus Technologies, Inc., Rockville, Maryland, "Protein Mapping of Mouse Liver: Mutation Detection and Toxicological Studies," December 20, 1985.

Miral Dizdaroglu

Center for Radiation Research, National Bureau of Standards, Gaithersburg, Maryland, "Radiation-Induced Damage to DNA and Its Detection at Low Radiation Doses," April 21, 1986.

Jochen Booz

Commission of the European Communities, Brussels, Belgium, "Implications of Some Proposed New Formulations of Quality Factor Versus LET," April 29, 1986.

Joyce E. Penner

Geophysical and Atmospheric Sciences Division, Lawrence Livermore National Laboratory, Berkeley, California, "Progress in Developing the Smoke Source Term for 'Nuclear Winter' Studies: Major Uncertainties," July 8, 1986.

Ronald L. Iman

Sandia National Laboratories, Albuquerque, New Mexico, "A Matrix Approach to Fault Tree Risk Analysis," September 16, 1986.

Geoffrey G. Eichholz

Georgia Institute of Technology, Atlanta, Georgia, "Views on the Radon Problem," January 12, 1987.

Keith Baverstock

Medical Research Council Radiobiology Unit, Chilton, Didcot, United Kingdom, "Human LD50 and How Chernobyl Has Changed Life in the United Kingdom," March 6, 1987.

Alan G. Underbrink

Department of Botany, Southern Illinois University of Carbondale, Carbondale, Illinois, "The *Tradescantia* Stamen Hair System: Some Radiobiological Experiments with Emphasis on Very Low Doses," March 10, 1987.

APPENDIX E. LIST OF HONORS AND AWARDS FOR STAFF MEMBERS OF THE HEALTH AND SAFETY RESEARCH DIVISION OCTOBER 1, 1985–MARCH 31, 1987

I·R 100 AWARD

T. A. Callcott, D. L. Ederer (NBS), E. T. Arakawa, and K. L. Tsang (UT)
Soft X-ray Emission Spectrometer

PUBLICATION AWARDS

S. L. Allman, C. H. Chen, G. S. Hurst, S. D. Kramer, M. G. Payne, and R. C. Phillips,
Martin Marietta Energy Systems 1985 Publication Award for "Method for Counting Noble Gas Atoms with Isotopic Selectivity"

D. L. DeAngelis, W. M. Post, and C. C. Travis
Martin Marietta Energy Systems 1986 Publication Award for "Positive Feedback in Natural Systems"

R. B. Gammage, S. V. Kaye, and V. B. Jacobs (Editors)
1986 Technical Communication Award in Recognition of Merit in Books for the publication "Indoor Air and Human Health"

C. C. Travis (Editor)
1987 Technical Communication Award in Recognition of Merit in Whole Periodicals for the publication "Risk Analysis"

J. P. Witherspoon
1986 Technical Communication Award in Recognition of Merit in Whole Periodicals for the publication "Nuclear Safety"

SPECIAL AWARDS

M. S. Blair, T. Vo-Dinh, and E. J. Soderstrom
Special Award for Excellence in Technology Transfer from the Federal Laboratory Consortium for Technology Transfer for noteworthy contributions toward the commericalization of the fiberoptics luminoscope resulting in a licensing agreement with Environmental Systems Corporation of Knoxville.

T. A. Callcott and E. T. Arakawa
Martin Marietta Energy Systems 1986 Inventor Award for design, construction, and testing of a new type of soft X-ray emission spectrometer that is the most efficient instrument of its type in the world.

L. G. Christophorou

Martin Marietta Energy Systems 1986 Inventor Award for continued, innovative development of gaseous media for advanced technologies that led to 13 patents and, particularly, for the patents on repetitive pulsed-power switches.

R. N. Compton

Martin Marietta Energy Systems 1985 Technical Achievement Award for development of accelerator-based autodetachment spectroscopy for the study of metastable negative ions and for subsequent use of the technique in fundamental studies of "exotic" atomic and molecular ions and "particle beam" neutralization.

Health and Safety Research Division Excellence in Research Award, 1986

Corporate Fellow, 1987

F. F. Knapp, Jr.

Health and Safety Research Division Excellence in Research Award, 1987

S. J. Ramos

Martin Marietta Energy Systems 1986 Operational Performance Award for organizing and leading a PIP Team that significantly reduced the probability of incorrect exclusion recommendations on property surveys at Grand Junction, Colorado.

I. Sauers

Martin Marietta Energy Systems 1985 Inventor Award for developing a technique that significantly improves by three orders of magnitude the sensitivity for the early detection of incipient faults in compressed, SF_6-gas-insulated, high-voltage systems.

C. S. Sims

Martin Marietta Energy Systems 1986 Operational Performance Award for materially expanding the research and technology transfer applications of the Health Physics Research Reactor and for establishing international leadership in neutron dosimetry.

P. C. Srivastava and F. F. Knapp, Jr.

Martin Marietta Energy Systems 1986 Inventor Award for development of an innovative new approach for the brain-specific delivery of diagnostic radiopharmaceuticals.

T. Vo-Dinh

Martin Marietta Energy Systems 1985 Technical Achievement Award for development of the simple, cost-effective, Synchronous Luminescence Technique for screening important bioindicators--carcinogen-DNA interactions--in biological samples.

R. J. Warmack and T. L. Ferrell

Martin Marietta Energy Systems 1985 Inventor Award for development of a unique microlithography technique for producing the best surfaces known for surface-enhanced Raman spectroscopy and many other applications.

COMMITTEE APPOINTMENTS

E. T. Arakawa

Member, International Advisory Board, Vacuum Ultraviolet Radiation Physics Group, 1986 - 1989

B. A. Berven

Chairman, Environmental Section of the Health Physics Society Standards Committee, 1985 - present

R. O. Chester

Member, Executive Committee, Environmental Sciences Division, American Nuclear Society, 1985 - 1988

Member, Technical Journals and Critical Reviews Committee, American Nuclear Society, 1984 - present

R. N. Compton

Member, Executive Committee, Atomic, Molecular, and Optical Physics Division, American Physical Society, 1983 - 1986

Member, Executive Committee, Division of Electron and Atomic Physics, American Physical Society, 1984 - 1987

M. T. Cristy

Member, Task Group on Dose Calculations, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1985 - present

Vice-chairman, Task Group on Revision of Reference Man, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1984 - present

K. F. Eckerman

Member, Task Group on Modeling and Scaling to Humans, DOE, 1985 - present

Member, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1982 - present

Chairman, Task Group on Dose Calculations, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1982 - present

Member, Scientific Committee 57, Internal Emitter Standards, National Council on Radiation Protection and Measurements, 1979 - present

Member, Scientific Committee 64, Task Group 5, Public Exposure from Nuclear Power, National Council on Radiation Protection and Measurements, 1979 - present

Member, Scientific Committee 64, Task Group 6, Screening Models, National Council on Radiation Protection and Measurements, 1979 - present

Member, ASTM Committee 10-E on Nuclear Technology and Applications Subcommittee on Radiation Risk, 1984 - present

Member, Advisory Group, Health Effects Model Revision, Nuclear Regulatory Commission, 1980 - present

D. E. Fields

Member, Research Committee, Tennessee Academy of Science, 1985

Member, Executive Committee, Tennessee Academy of Science, 1986 - 1988

R. B. Gammage

Chairman, Indoor Air Quality Committee, American Industrial Hygiene Association, 1987 - 1988

Member, Workplace Environmental Exposure Level Committee, A6-American Industrial Hygiene Association, 1982 - present

A. W. Hsie

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

G. D. Kerr

Member, Task Group on Revision of Reference Man, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1985 - present

Member, Ad Hoc Committee on Neutron Quality Factors, DOE, 1985 - present

D. C. Kocher

Member, Review Committee on Low-level Waste Pathways and Dose-to-man Assessment, DOE, 1985

Member, Standards Committee, Health Physics Society, 1987 -

R. W. Leggett

Member, Task Group on Dose Calculations, Committee 2 on Secondary Limits, International Commission on Radiological Protection, 1985 - present

C. A. Little

Chairman, Awards Subcommittee, Manpower and Professional Education Committee, Health Physics Society, 1986 - 1987

F. R. O'Donnell

Member, Scientific Committee 74, National Council of Radiation Protection and Measurement, 1985 - present

R. H. Ritchie

Member, Executive Council, Southeastern Section, American Physical Society, 1986 - present

C. S. Sims

Chairman, Technical Committee on Procedures and Data for the Intercomparison of Personnel Dosimeters, IAEA, 1984 - present

Chairman, Technical Committee on Assessment of Occupational Exposure to External Radiation for Monitoring Purposes, IAEA, 1985 - present

Chairman, ANSI N13.11 Review Working Group, Health Physics Society, 1987 -

R. E. Swaja

Member, ANSI N319 Committee on Personnel Neutron Dosimetry, Health Physics Society, 1986 - present

Chairman, ASTM E10.04 Committee on Criticality Accident Dosimetry, 1986 - present

C. C. Travis

Member, Los Angeles City Energy Recovery Project (LANCER) Peer Review Committee, City of Los Angeles, CA, 1986 - present

Chairman, Scientific Bases for Risk Assessment Assumption, Office of Science and Technology Policy, 1986 - present

Member, Science Advisory Board, Food and Drug Administration, 1987 -

President-elect, Society for Risk Analysis, East Tennessee Chapter, 1987 - 1988

Member, Delivered Dose Work Group, American Industrial Health Council, 1987 -

J. E. Turner

Member, Comprehensive Certification Panel of Examiners, American Board of Health Physics, 1987 -

T. Vo-Dinh

Co-chairman, International Committee on Polycyclic Aromatic Compounds, 1985 - present

Secretary, Technical Committee TT-6 on Energy-Environmental Interactions, Air Pollution Control Association, 1984 - present

Member, Technical Committee on Indoor Air Quality, American Industrial Hygiene Society, 1984 - present

Member, Executive Committee, Air Pollution Control Association, East Tennessee Chapter, 1986 - present

M. G. Yalcintas

Chairman, Organ Dose Committee, Biology and Medicine Division, American Nuclear Society, 1980 - present

Chairman, Program Committee, Biology and and Medicine Division, American Nuclear Society, 1984 - present

JOURNAL ACKNOWLEDGMENTS

K. F. Eckerman

Member, Editorial Board, *Radiation Protection Dosimetry Journal*, 1980 - present

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, Carcinogensis, and Mutagenesis*, 1983 - present

G. G. Killough

Editor, *Mathematics and Computer Science Journal,* Tennessee Academy of Science, 1984 - present

C. E. Klots

Associate Editor, *Journal of Mass Spectrometry and Ion Physics,* 1983 - present

C. C. Travis

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

A. P. Watson

Book Review Editor, *Environmental Management,* 1984 - present

J. P. Witherspoon

Editor, *Environmental Effects,* Nuclear Safety, 1983 - present

M. G. Yalcintas

Editor, *Biology and Medicine Division Newsletter,* American Nuclear Society, 1985 - present

UNIVERSITY APPOINTMENTS

T. E. Aldrich

Assistant Professor of Public Health, The University of Tennessee, 1985 - present

Adjunct Professor of Epidemiology, The University of Miami, 1984 - present

Adjunct Professor of Epidemiology, The University of Texas, 1985 - present

Adjunct Professor of Epidemiology, The University of Utah, 1986 - present

E. T. Arakawa

Adjunct Professor of Physics, The University of Tennessee, 1982 - present

L. G. Christophorou

Professor of Physics, The University of Tennessee, 1969 - present

R. N. Compton

Adjunct Professor of Physics, Vanderbilt University, 1983 - present

Professor of Chemistry, The University of Tennessee, 1985 - present

T. L. Ferrell

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

A. W. Hsie

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

C. A. Little
Adjunct Professor of Radiology and Radiation Biology, Colorado State University, 1987

J. C. Miller
Professor (part-time) of Chemistry, The University of Tennessee, 1986

R. H. Ritchie
Professor of Physics, The University of Tennessee, 1965 - present

J. E. Turner
Professor of Physics, The University of Tennessee, 1981 - present

Adjunct Professor of Environmental Engineering Sciences, The University of Florida, 1985 - present

M. Uziel
Professor of Biomedical Sciences, The University of Tennessee, 1968 - present

T. Vo-Dinh
Professor of Biomedical Sciences, The University of Tennessee, 1987 -

R. J. Warmack
Professor of Physics, The University of Tennessee, 1983 - present

J. P. Witherspoon
Professor of Ecology, The University of Tennessee, 1979 - present

M. G. Yalcintas
Adjunct Professor of Radiation Biology, Tennessee Technological University, 1985 - present

OTHER

K. F. Eckerman
Consultant, Sloan-Kettering Memorial Medical Center, 1981 - present

D. E. Fields
President-elect, Tennessee Academy of Science, 1986

R. D. Foley
Treasurer, East Tennessee Chapter, Health Physics Society, 1986

B. E. Hingerty
Elected Fellow, American Physical Society, 1985

L. M. Hively
Full-time Advisor to Office of Energy Research, Office of Fusion Energy, DOE, 1986 - 1987

S. V. Kaye

Elected Fellow, American Association for the Advancement of Science, 1987

G. D. Kerr

Visiting Scientist, Radiation Effects Research Foundation, Japan, September 1986 - August 1987

R. H. Ritchie

Recipient, NATO Research Grant, 1987 - 1988

Recipient, Research Grant, US-Spain Joint Committee for Scientific and Technological Cooperation, 1985 - 1986

C. S. Sims

U.S. Dosimetry Contact for the Joint Standing Committee for Civil Nuclear Cooperation with Taiwan, Republic of China, 1985 - present

J. E. Turner

Elected Fellow, Health Physics Society, 1986

A. P. Watson

AAAS Environmental Science and Engineering Fellowship, First Alternate, 1986

APPENDIX F. PATENTS GRANTED TO STAFF MEMBERS OF THE HEALTH AND SAFETY RESEARCH DIVISION OCTOBER 1, 1985–MARCH 31, 1987

PATENT ISSUED

I. Sauers, "Process for Measuring Degradation of Sulfur Hexafluoride in High Voltage Systems," 1986, U.S. Patent No. 4,633,082

PATENT APPLICATIONS

L. G. Christophorou, D. L. McCorkle, S. R. Hunter, "Gas Mixtures for Spark Gap Closing Switches," 1987.

P. C. Srivastava, F. F. Knapp, Jr., "Radiopharmaceutical Agent for Brain Imaging," 1986.

INVENTION DISCLOSURES

T. A. Callcott, D. L. Ederer, E. T. Arakawa, "Fully Adjustable Multiple Grating Mounting for a Vacuum Spectrometer," 1986.

C. H. Chen, M. P. McCann, "Photoelectronic Ionizer," 1986.

C. H. Chen, M. P. McCann, "Pulzed Nozzle Source Mass Spectrometer," 1986.

C. H. Chen, M. P. McCann, M. G. Payne, "Pulsed Nozzle Vacuum Ultraviolet Light Source," 1987.

L. G. Christophorou, S. R. Hunter, "Penning Ionization Ternary Gas Mixtures for Diffuse-Discharge Switch," 1986.

L. G. Christophorou, S. R. Hunter, "Optical Switch," 1986.

R. N. Hamm, S. R. Hunter, G. S. Hurst, J. E. Turner, H. A. Wright, "Digital Optical Ionizing Radiation Particle Track Detector," 1986.

S. R. Hunter, L. G. Christophorou, "Gas Mixtures for Diffuse Glow Discharge Closing Switches," 1986.

M. M. Goodman, F. F. Knapp, Jr., "Radiohalogenated Branched Carbohydrates," 1986.

F. F. Knapp, Jr., M. M. Goodman, G. Kirsch, "Radiohalogenated Dimethyl-Branched Fatty Acids and Use to Evaluate Regional Myocardial Fatty Acid Uptake," 1986.

P. C. Srivastava, "Radioiodinated Maleimides, and Use as Agents for Radiolabeling Thiol Containing Biological Substrates," 1986.

APPENDIX G. MEETINGS AND CONFERENCES

MEETINGS NOT PREVIOUSLY REPORTED

Fourth International Symposium on Gaseous Dielectrics, Knoxville, Tennessee, April 29 - May 3, 1984; L. G. Christophorous, organizer and host. Sponsored by the Health and Safety Research Division, Oak Ridge National Laboratory.

The Werner Brandt Workshop on Penetration Phenomena: Photon Emission from Irradiated Solids, Oak Ridge, Tennessee, April 15-16, 1985; H. A. Wright, R. H. Ritchie, and J. C. Ashley, organizers. Sponsored by the Health and Safety Research Division, Oak Ridge National Laboratory.

MEETINGS HELD DURING REPORTING PERIOD

Twelfth Personnel Dosimetry Intercomparison Study, Oak Ridge National Laboratory, April 14-18, 1986; C. S. Sims, organizer and host. Sponsored by the Department of Energy-Office of Health and Environmental Research.

Fourth International Radiopharmaceutical Dosimetry Symposium, Oak Ridge, Tennessee, November 5-8, 1986; K. F. Eckerman, member-planning committee. Sponsored by Oak Ridge Associated Universities, U.S. Food and Drug Administration, and the Department of Energy.

Epidemiologic Studies on Electromagnetic Fields and Cancer in Humans, Denver, Colorado, November 15-23, 1986; T. E. Aldrich and C. E. Easterly, organizers. Sponsored by the Department of Energy-Office of Storage and Development.

The Werner Brandt Workshop on Penetration Phenomena: Dynamic Interactions of Energetic Probes with Condensed Matter, Alicante, Spain, January 7-9, 1987; R. H. Ritchie, J. C. Ashley, R. Garcia-Molina, E. Louis, and A. Gras-Marti, organizers. Sponsored by the Department of Energy-Health and Safety Research Division, the Spanish CAICYT, and the Generalitat Valenciana with additional support from Diputacion de Alicante, IBM-Spain, the British Council, Universidad de Alicante, and the CAAM.

International Symposium on Radiation Dosimetry and Safety (RDAS 87), Taipei, Taiwan, March 2-4, 1987; C. S. Sims, coordinator/organizer and R. E. Swaja, technical program committee chairman. Sponsored by the Nuclear Energy Society of the Republic of China, American Nuclear Society of Taiwan Section, and the Health and Safety Research Division, Oak Ridge National Laboratory.

APPENDIX H. ADVISORY COMMITTEE

1986

A. R. Buhl, Ph.D. International Technology Corp.	Engineering Science and Technology Transfer
W. C. Lineberger, Ph.D. University of Colorado	Chemistry and Physics

1986-1987

W. A. Mills, Ph.D. ORAU/CIRRPC	Health Physics and Risk Analysis
J. W. Palms, Ph.D. Emory University	Radiological Physics and Instrumentation

1987

J. N. Bardsley, Ph.D. Lawrence Livermore Laboratory	Atomic Physics and Quantum Chemistry
A. W. Castleman, Ph.D. Pennsylvania State University	Chemical Physics

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Aldrich, T. E.

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Aldrich, T. E. and Meyer, R. E., "Birth Defects and Electromagnetic Fields", presented at Birth Defects Monitoring Program, Centers for Disease Control, Atlanta, January 23, 1987

Aldrich, T. E., Wilson, C. C., and Easterly, C. E., "Population Surveillance for Rare Health Events", presented at National Center for Health Statistics 24th Annu. Symp., Bethesda, MD, August 19, 1985 and published in *Proc. Public Health Conf. on Records and Statistics*, Washington, DC, August 19, 1985, DHHS Publication No. 86-1214, U.S. Dept. of Public Health and Human Services, Hyattsville, MD, 1986, pp 215-20

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