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NUCLEAR ENGINEERING RESEARCH OPPORTUNITIES AT BROOKHAVEN NATIONAL LABORATORY*

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Brookhaven National Laboratory (BNL) is a Department of Energy (DOE) multiprogram Laboratory, and is operated under contract with DOE by Associated Universities, Inc. (AUI). BNL conducts a wide range of basic and applied research and development in the physical and life sciences and designs, builds, operates and maintains a large array of very large research devices such as particle accelerators, nuclear reactors, and a synchrotron light source. These devices are used not only by the resident staff for its own research interests, but, more importantly, are made available to qualified users from the scientific and technical communities to an extent that far exceeds the in-house use. Thus, these specialized facilities are designated user facilities. In a similar manner, many smaller and less visible devices and laboratories are available to a large number of outside collaborators, including students, faculty, and practicing scientists and engineers. To illustrate this it can be noted that, while the Laboratory staff consists of approximately 3200 employees including 600 scientists and engineers, in any give year approximately 2000 visiting scientists and students hold appointments at the Laboratory. Or, to put it in other terms, approximately 80% of the running time on the Alternating Gradient Synchrotron (AGS) is devoted to outside use, and 90% of the experimental time at the National Synchrotron Light Source (NSLS) is also used by outside experimenters.

The Laboratory does not have a separate Engineering Department. However a good number of traditionally defined electrical, mechanical, chemical, and nuclear engineering studies are undertaken in such diverse Departments as the AGS, Accelerator Development, Nuclear Energy, the NSLS, Chemistry, Medical, Applied Science, Instrumentation, Computing and Communication, and Safety and Environmental Protection.

Brief descriptions of a variety of research and development areas involving nuclear engineering expertise are presented below. Also, various ways for students, faculty and practicing engineers to gain access to and become part of these activities are described.

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A number of studies devoted to improving the understanding of the behavior of various types of reactors under anticipated and hypothetical accident conditions are being pursued. Attention currently is focused on three advanced reactor designs: the Sodium Advanced Fast Reactor (SAFR); the Power Reactor Inherently Safe Module (PRISM); and the Modular High Temperature Gas-cooled Reactor (MHTGR). Efforts are directed towards developing, validating and maintaining independent computational capabilities with these systems. The major tools presently being utilized are the Super System Code (SSC), the MINET Code, and various other codes to analyze HTGR phenomenology.

Experimental Modeling

Studies are directed toward reactor safety issues involved in code development. These consist of both experiments and model development. Two major activities are presently underway: a "Severe Accident Phenomenology: Direct Containment Heating" investigation - directed towards studying containment loading due to thermal and chemical interactions between molten core debris and the containment atmosphere; and "Thermodynamic Core-Concrete Interaction Experiments and Analysis" - an investigation addressing the containment loading and source term issues during the core-concrete interaction phase of severe accidents.

Safety and Risk Evaluation

A number of analytical studies in the field of nuclear reactor safety are in progress. One broad area is probabilistic evaluations that assess the reliability of specific reactor systems and determine the frequency of core damage or meltdown for particular nuclear reactor plants. Probabilistic evaluations of standard nuclear reactor plant designs are also performed in connection with the accommodation of severe accidents.

An Accident Analysis Group performs analytical studies of the physical phenomena associated with postulated accidents, which involve severe damage to the reactor core and to the containment building. Particular emphasis is given to the calculation of radiological source terms for severe accidents and the evaluation of potential accident mitigation and actions that may reduce the risk from severe accidents.

A Safety Integration Group performs probabilistic evaluations that assess the safety impact of specific reactor systems under severe accident conditions, emphasizing the integrated analysis of plant design and operations, severe accident phenomena, and off-site radiological consequences.

Radioactive Waste Management

In the area of high level waste management, there are several studies underway. One is to develop procedure guides for performing a preclosure repository safety assessment using risk-based techniques. Another is the development of a set of generic data bases for use in the repository safety assessment. Since there is no experience in repository operation, the development of these data bases rely heavily on data from the nuclear (reactor and fuel cycle facilities), chemical and mining industries.

In the area of low-level waste a current major effort is devoted to modeling the radionuclide source term from a shallow land burial trench, involving an estimation of the contents of a typical trench, and the physical, chemical and hydrological processes that influence the release of radionuclides to the trench boundary.

Another effort is concerned with the management of reactor system decontamination wastes. During decontamination, organic chelating reagents are used to remove radioactive contamination resulting in a waste stream composed of chelating agents and radioactive constituents, frequently "cleaned" by ion exchange resins. Currently under experimental investigation are the thermal excursion/gas generation reactions of ion exchange resin wastes.

A major program involves the behavior of low-level waste barrier materials. Included are experimental studies of the biodegradation of ion-exchange resins, the effect of sulfate solutions on the expansion and failure of concrete barrier materials, and the effects of chemical and radiation environments on the mechanical integrity of high-density polyethylene, frequently used for low-level waste containers.

Safeguards and Security Evaluations

A Technical Support Organization (TSO) is a multidisciplinary group that provides assistance to a number of Department of Energy Offices, the Air Force, several other Federal Agencies, and, through appropriate channels, the International Atomic Energy Agency in matters concerning nuclear safeguards, security, and classification issues. Its areas of current capability and interest are:

Material Control and Accountability
Statistical Analysis
Security Systems
International Safeguards Systems
Education and Training
Arms Control Verification
Information Control
Hardware Development
Inspection and Evaluation

Its staff expertise covers such disciplines as chemistry, physics, engineering, applied mathematics, computer technology, law and economics.

Radiation Protection

The Radiation Protection Group is responsible for the Laboratory's (ALARA) Center which serves as an information gathering, analysis, and dissemination resource for DOE, NRC and industry. The Center staff is currently reviewing ALARA practices and equipment at DOE facilities in order to extend the usefulness of the Center's activities to DOE facilities. Technical assistance is provided to the NRC for licensing irradiated gemstones, evaluation of radiation risks from "hot particles" produced in nuclear reactors, and the development of quality assurance programs for medical users of radioisotopes.

Nuclear Data Evaluation and Management

The Laboratory operates a National Nuclear Data Center (NNDC) for the Department of Energy. The services include information on nuclear structure and decay data, neutron physics, and charged particle interactions. The NNDC has more than 20 years experience in organizing inter-agency, interlaboratory and international groups, e.g. the Cross Section Evaluation Working Group and the Nuclear Data Network, which has resulted in the international standards, the Evaluated Nuclear Data File (ENDF/B) and the Evaluated Nuclear Structure Data File (ENSDF). When a theoretical or experimental basis for a phenomenon has not been established, NNDC personnel are experienced in providing educated answers via model codes or from systematics derived from the large store of nuclear data maintained by the NNDC.

Nuclear Medicine

Nuclear engineers may not be aware of the emerging need for their expertise in the field of nuclear medicine, one of the largest and rapidly expanding areas of use of stable and radioactive nuclides. What follows is not intended to be an exhaustive review of nuclear medicine, an undertaking that would far transcend the purpose of this paper. Instead, it is a brief description of a few nuclear medicine techniques presently practiced and under development at the Laboratory, in keeping with the title of this paper.

In general terms, the techniques revolve around detecting the presence, and distribution in time and/or space, of a "label," where the label is either intrinsically radioactive or can become so by a superimposed technique. The former instance generally involves a radioisotope that has been produced by some means, usually incorporated into a biocompatible molecular species, and then injected into a living organism. The latter case consists of tagging a biocompatible molecule with a naturally non-radioactive species, injecting this into a living organism, and then subjecting the organism to an external stimulus that will render the non-radioactive species radioactive. An example of this is boron neutron capture therapy, in which the boron-10 isotope is activated, in situ, by thermal neutrons, causing the boron-10 to undergo a neutron capture-alpha particle emission process.

A third technique involves the direct use of external radiation, e.g., electrons, x-rays, protons, etc. to produce the desired therapeutic effect.

A role for nuclear engineers is emerging in the first area mentioned above. Consider the steps that are involved:

Choice of desired radioisotope
* Method of production
* Separation of desired species
* Incorporation into suitable vehicle
* Delivery of labelled material to site of application

Detection

In at least four of the six independent but interrelated steps engineering expertise is needed, particularly if the process is to proceed from a laboratory bench-scale process to a larger scale, practical process.

Once the decision has been made as to the radioisotope that will be used, it is then necessary to develop a method to produce that isotope. In general, the desired isotope usually cannot be made by the simple activation of an isotopically pure predecessor. Hence, one is faced with devising a separation scheme for the desired species. Before that, however, and, in many instances, contingent on a proposed separations scheme, a method of activation must be decided upon. Will it be simple (?) neutron activation and, if so, what is the desirable energy or energy spectrum available? Will it be charged particle bombardment? If so, what particle? Monoenergetic? Etc., etc.

Assuming that more than one activation route is available, what will be the separations problems, including chemistry, radioactive half-life, etc.

Once having isolated the desired radioisotope, what molecular vehicle will it be attached to? On a scale larger than bench-scale, what engineering problems are involved?

Having incorporated the radioisotope into the desired vehicle, how will it be efficiently delivered from its point of origin to its point of use?

These questions, and others, require engineering expertise and practice. I submit that, as the field of nuclear medicine expands, the need for nuclear engineering expertise will grow.

Shielding

At any Laboratory involved in designing, operating, and maintaining nuclear reactors and various accelerators for research applications, there is a constant need for people to help in the design and fabrication of shielding and other safety and health areas.

Access to BNL Programs

At this point, I turn to the question of how students, faculty and practicing engineers can participate in the research and development programs at BNL referred to above. There are several established, organized, and funded routes, as well as innumerable informal routes.

Supported by the DOE's Division of University and Industry Programs, the following formal routes exist:

Summer Student Program - Undergraduate students receive ten-week research appointments during the summer, generally from mid-June to mid-August

Eligibility requirements:

a) at least 18 years old
b) at least junior year level status at time of appointment
c) U.S. citizen or permanent resident alien.

Conditions:

a) weekly stipend
b) free housing on Laboratory grounds
c) round-trip transportation reimbursement.

Science and Engineering Research Semester (SERS) - Undergraduate students receive sixteen-week academic semester research appointments, generally late-January to mid-May or late August to mid-December.

Eligibility requirements:

a) at least 18 years old
b) at least junior year level status at time of appointment
c) U.S. citizen or permanent resident alien.

Conditions:

a) weekly stipend
b) free housing on Laboratory grounds
c) round-trip transportation reimbursement.

Brookhaven Semester Student Program - Undergraduate students receive sixteen-week academic semester research appointments, generally late-January to mid-May or late August to mid-December. Targeted for students from historically black colleges and universities

Eligibility requirements:

a) at least 18 years old
b) at least junior year level status at time of appointment
c) U.S. citizen or permanent resident alien.

Conditions:

a) weekly stipend
b) free housing on Laboratory grounds
c) round-trip transportation reimbursement.

Faculty/Student Research Support - designed to provide short-term access to specific Laboratory equipment or facility to faculty-student research teams, in which the faculty involved does not have DOE research funding, nor travel funding from another Federal Agency.

Eligibility requirements:

a) faculty member submits research proposal
b) team must consist of at least one faculty person and usually no more than two students
c) financial need (see above).

Conditions:

a) round-trip travel, housing, and per diem, limited to twenty days per year for two years.

In addition to these programs centrally coordinated by the Office of Educational Programs at the Laboratory, there are a number of established ways for students and faculty to participate in the Laboratory's research and development activities. These are briefly described below:

Post-Doctoral Appointments - Each Department administers its own Post-Doctoral appointments. These appointments are renewable for up to three years total. It is generally expected that a Fellow will leave the Laboratory at the expiration of the appointment; in some cases Fellows remain at the Laboratory and receive appointments to the Scientific Staff.

Graduate Student Research - As was implied earlier, a large number of graduate students do their thesis research at the Laboratory. This can be either a short term (Thesis Parts) stay, or the entire research project may be done here. In the latter instance, the Laboratory Staff member collaborates closely with the university research advisor, and is generally a member of the Dissertation Review Committee. Financial support may be supplied by the Laboratory, the university, or some combination.

Sabbatical Leave Appointments - The Laboratory generally welcomes requests for research appointments from faculty who are on sabbatical leave. Since the financial support for such an appointment must come from current research funds, the number of appointments is governed by how an individual Department wishes to employ its resources.

On-Leave from Industry - When interests coincide and no legal barriers are raised, the Laboratory welcomes qualified practicing industrial scientists and engineers to collaborate with the staff on problems of mutual interest. it is generally expected that most, if not all, of the financial burden be borne by the outside employer.

Following is a list of contacts for those interested in gaining additional information, either about program content or access.

For programs funded by DOE's Division of University and Industry Programs, contact

Dr. Donald J. Metz, Head
Office of Educational Programs
Telephone: 516-282-3054

For other information, contact

Dr. Walter Kato, Chairman
Department of Nuclear Energy
Telephone: 516-282-2444

Dr. Norman Sutin, Chairman
Department of Chemistry
Telephone 516-282-4301

Dr. Arjun Chanana, Chairman
Medical Department
Telephone: 516-282-3568

Mr. William R. Casey, Head
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