EES NOTES

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APPLICATIONS OF THE REACTOR

The Georgia Tech reactor at the Frank H. Neely Nuclear Research Center has been in use for five years and operates at one megawatt power producing a flux of 2×10^{13} thermal neutrons per cm^2-second. The research reactor is used primarily as a source of neutrons. Because the reactor operates at one megawatt and is moderated by heavy water, the neutron flux is high relative to most research reactors, making possible many applications not feasible with a lower flux. The availability of the reactor at Tech provides a unique opportunity for research with one of the best neutron sources in the country.

The question is often asked: "What can I do with a nuclear reactor in the area of my research interests?" This would be more accurately phrased: "What can I do with neutrons to increase the scope or efficiency of my investigation?"

The full range of applications of neutrons is too broad to cover here. But, we can break down the applications of neutrons to scientific and engineering research into three groups based on the fundamental neutron properties utilized and discuss each briefly with specific examples.

In this discussion we shall consider the following classes of neutron interactions with matter and give examples of applications based on each class: neutron scattering (elastic collisions); neutron absorption; combined effects of these two interactions, referred to as neutron attenuation.

Neutrons scatter from nuclei in a manner somewhat analogous to X-ray scattering from atomic electrons. Because the neutron scattering efficiency of certain low-atomic-weight materials is high, neutron diffraction may be used to elucidate crystalline structures of these materials much as X-ray diffraction is used for higher atomic weight substances.

Many neutron absorption processes result in the formation of radioactive species of the irradiated elements. Such "activated" samples may then be used as radioactive tracers or as indicators for the presence of that element (neutron activation analysis, NAA). Tracer applications are well established in all fields of science and engineering. Determination of iodine uptake using iodine-131 tracer in the thyroid gland as a measure of the organ's function is a routine diagnostic procedure in hospitals around the world. Short-lived radioactive isotopes are used to evaluate the engineering parameters of catalytic cracking units in oil refineries. Short-lived sodium-24 can be pumped through a leaking pipeline and the location of the leak determined by the detection of accumulated radioactivity at the leaking point. Iodine-131 or phosphorus-32 incorporated into ink can make it possible to determine the flow rate of ink from pens by simply measuring the radioactivity in the ink deposit on the paper.

Neutron activation analysis can identify and quantitatively determine some 70 elements from a determination of the energy and intensity of gamma radiation emitted by the activated species of the elements present in a sample following irradiation with neutrons in a research reactor (see EESN-3-69). Detection limits as low as 10^{-11} gram are attainable for several elements. Many times NAA can be performed nondestructively with the sample remaining unchanged in appearance. Tissue samples as small as 10^{-4} gram (total sample weight) have been analyzed in the Georgia Tech Research Reactor for a mercury content of only 10^{-9} gram. Presently under way is a study evaluating the application of stable tracers followed by NAA in the measurement of high water-flow rates (10,000 cfs) in the discharge from dams.

Attenuation (both scattering and absorption) of neutrons in a collimated beam can be utilized to produce an image on film. Such neutron radiographs are capable of visualizing features not seen by conventional X-ray or gamma-ray radiographs. An example which demonstrates the unusual ability of neutron radiography is the clear imaging of a polyethylene vial half filled with water within a thick lead container. The transparency of lead to neutrons and the high neutron scattering efficiency of the hydrogen nuclei in the plastic vial and water make this imaging possible. Practical examples of neutron radiography are the examination of glue joints in adhesive-bonded metal aircraft structures and the quality-control inspection of all explosive bolts used in the Apollo program.

Radiation effects on materials may be used to gain an improvement of desirable properties. Catalytic effects of radiation may be applied in chemical synthesis. The heat resistance of many polymers may be improved by radiation-induced crosslinking of the polymer chains. Neutron transmutation (changing one element into another through the process of neutron absorption) may be used to dope semiconductor materials to improve or modify semiconductor properties.

The facilities at the Georgia Tech Research Reactor are available for any applications which may be of interest to staff or students. Inquiries may be directed to the author, Laboratory Supervisor, Frank H. Neely Nuclear Research Center.

Milton E. McLain, Jr.
Nuclear and Biological Sciences Division

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THERMOCHEMICAL RATE STUDIES ON SLIP-CAST FUSED SILICA

A primary technique for increasing the mechanical strength of a ceramic material is the application of energy in the form of heat. This is most readily accomplished in a furnace or a kiln designed for this purpose. The rate of heating, the temperature of the heat, and the time at temperature affect the development of the mechanical strength of the ceramic. This gain in strength results from increasing the bonding of the particles by melting and/or crystal grain growth (sintering).

The work currently being conducted on the ceramic material, slip-cast fused silica (SCFS), is directed toward determining the relative rates of sintering phenomena active during heating. The two predominant phenomena are densification and devitrification. The densification rate enhances the mechanical strength and density, while devitrification retards these two properties. Devitrification in SCFS is the conversion of a noncrystalline into a crystalline structure. These forms are respectively known as amorphous silica and cristobalite. The nucleation of the cristobalite occurs at impurity sites and is dependent on the impurity content of the fused silica slip.

The studies to date indicate that while both rates are temperature dependent, the densification rate is more sensitive to variations in firing temperature. Due to this unequal temperature dependence, it is possible to subordinate the dominant rate (devitrification) to densification by increasing the firing temperature.

As a result of these studies, it is possible to increase the mechanical strength of SCFS 50% by increasing the firing temperature 200°F.

V. C. Theiling
High Temperature Materials Division

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IMPROVING THE QUALITY OF AIR WITHIN HOSPITALS

Air is the most pervasive element of the intramural environment; it is especially important in hospitals where a hygienic and esthetically acceptable environment must be maintained for the safety and well-being of patients and for the prevention of transmission of infectious agents. For nearly ten years, the quality of hospital air has been the subject of investigations conducted by T. W. Kethley and W. B. Cown of the Bioengineering Laboratory, Nuclear and Biological Sciences Division. These studies were begun when aerial transmission of the causative agent of staphylococcal infections was recognized as a hazard within the hospital, and early efforts were directed toward improved methods of air handling to reduce the threat of cross-contamination by airborne disease agents. Currently, commercially available high-efficiency filters, increased volumes of diluting air, widespread use of total air conditioning, and improved methods of distributing ventilating air make possible the design of hospital ventilating systems in which the threat of aerial transmission of disease agents is minimal. Although this capability exists, it must be pointed out that practical application often lags far behind. When we became convinced that airborne particulate matter can be controlled, we turned to studies of control of gaseous contaminants in hospital air.

Gaseous contaminants in hospital air arise either extramurally or intramurally. The first type includes air pollutants such as oxides of sulfur and of nitrogen, hydrocarbons, and oxidants; the second case comprises volatiles such as ether or alcohol and odorants arising from patients. The practical situation is this: If extramural air pollution continues to rise in our metropolitan areas, it will be necessary for the hospital to treat "fresh air" to remove these contaminants. Then it may be simpler and more economical to recirculate hospital air and remove intramural gaseous contaminants. In response to this situation, we are evaluating the ability of commonly employed air-treatment systems to remove either class of gaseous contaminants. This knowledge will serve to indicate whether or not there may be a requirement for improved air-cleaning devices for hospital air.

We have selected test chemical compounds on the basis of water-solubility and vapor pressure; these parameters appear to encompass the characteristics most important in removing low concentrations of gases from the air. In general, the results have been those expected: high-vapor-pressure, low-water-solubility compounds (simple hydrocarbons) are not removed by any of the common air-treatment systems; high-water-solubility compounds are removed with appreciable efficiency by water-washers; low-vapor-pressure compounds are removed with considerable efficiency by sorption systems. The last-mentioned fact accounts for the lingering effect of many odorants -- they are sorbed on almost all surfaces and gradually desorb.

We also have found that several compounds of low vapor pressure are difficult to remove by dilution ventilation, even after allowing for desorption. Because dilution ventilation is the most direct and usually most economical method of removing odorants which arise intramurally, we have pursued this approach in some detail, employing a series of compounds of varying vapor pressure. The results show that the efficiency of removal of an odorant by dilution ventilation is markedly affected by the nature of the odorant, even though surface sorption and desorption are maintained at an insignificant level in the experimental design. The apparent efficiency of dilution ventilation ranges from nearly 100% for light gases to as low as 20% for iso-valeric acid when the ventilation rate is greater than 5-6 changes per hour. The practical consequence is that increasing volumes of fresh or equivalent fresh air will yield poor results in reducing levels of certain odorants in an enclosed space. This surprising result will require further work to determine the cause.

T. W. Kethley
Nuclear and Biological Sciences Division

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MATHATRON IN CSMD

BCS Associates of Huntsville, Alabama, has given Georgia Tech a Mathatron 8-48 Bio-Stat with paper-tape punch and typewriter. The computer has several pre-wired statistical programs which greatly facilitate statistical analysis of many types of engineering data. These programs permit calculation of sums of x, x^2, y, y^2, xy, in addition to calculation of average x, average y, correlation coefficient, variance, standard error, regression coefficients (for y + ax + b), chi square, and t-test statistics, etc., with a single entry of each data point.

The paper-tape punch permits programming a large variety of special or general calculations which can then be reused at will. Input to the machine is in simple algebraic notation. The equipment is located in the new EES building.

Jack Kinney
Chemical Sciences and Materials Division

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ADVANCES IN ELECTRON SPIN RESONANCE SPECTROSCOPY

Electron spin resonance (ESR) spectroscopy has been employed in nondestructive testing of biological materials for over a decade. The advent of manned space flights has emphasized the need for continuing study to determine the effects of both ionizing and non-ionizing radiation on biological materials; ESR techniques are well suited to analysis of these effects.

Early applications of ESR were confined to solid derivatives of tissues because the presence of water, with its high dissipation factor, reduces the sensitivity of ESR spectrometers. This limitation has precluded many valuable experiments which otherwise could be made with functional (water-containing) biological samples. Improvements in microwave instrumentation now make possible the limited use of water-containing samples in ESR experiments.

One of the major instrumentation problems encountered in this application is the design of a low-loss microwave cavity which will provide an adequate transmission window for sample irradiation. Although the sophistication of ESR instrumentation has grown since its inception by Zavoisky in 1945, development of the microwave cavity has proceeded slowly. An experimental program in the Electronics Division has concentrated on the design and testing of two open-boundary microwave cavities. These cavity designs differ from the standard metal waveguide cavity in that the electromagnetic boundaries are formed by conducting walls on two sides with an open dielectric medium in between, whereas the waveguide cavity is completely enclosed by metal walls. In the open-boundary resonator, the sample is positioned at the proper point in the dielectric medium, allowing irradiation with a high radiation flux for wavelengths which lie within the transmission band of the dielectric.

One design that has shown great promise is the dielectric cavity resonator (DCR). The DCR is formed by terminating a low-loss dielectric tube with two circular metal end plates at right angles to the tubing axis. Although the geometry is relatively simple, the resonator mode structure is complex and offers excellent flexibility in positioning of the biological sample for ESR coupling. A DCR utilizing a single-crystal sapphire tube was shown to have an order of magnitude improvement in signal-to-noise ratio over a commercial waveguide cavity designed for the study of photosensitive processes in biological materials. In addition, sapphire has a transmission band extending into the near ultraviolet, and the open-boundary design permits a much higher radiation flux than is possible with a waveguide cavity equipped with a slotted radiation window.

The Fabry-Perot resonator utilizing an air dielectric between two reflectors also has been investigated. This design offers a broad transmission band for sample irradiation, but requires a magnet of much larger dimensions for sensitivity comparable to that obtained with the DCR or standard waveguide cavity. In addition to the emphasis on sample irradiation, optimum sample placement for water-containing samples has been investigated with both the Fabry-Perot and the dielectric cavity resonator.

Much work remains before the open-boundary resonator is accepted as a complete replacement for the standard closed-boundary resonator. The study of low-temperature photochemical processes currently occupies a high priority with many researchers in the field. The DCR has been shown to offer improved performance in sample irradiation, and the design of a suitable cryogenic sample holder for the open-boundary resonator would fulfill an instrumentation need which at present cannot be realized with the closed-boundary resonator.

R. G. Shackelford
Electronics Division

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NUMERICAL INTEGRATION METHODS FOR SYSTEMS OF ORDINARY DIFFERENTIAL EQUATIONS

When faced with a problem involving the solution of a differential equation, most engineers and scientists are aware that there are standard techniques for obtaining numerical solutions and that, if other methods fail, one can always use a computer to obtain numbers representing the solution. For example, the classical 4th-order method of Runge and Kutta has been used for generations, on desk calculators before the days of computers, and by hand calculation before that, to obtain these numerical approximations. There are other, generally less well-known numerical methods for solving differential equations, some predating Runge-Kutta, others described quite recently. Adam's method was published in 1883; Cowell's method was devised to study the orbit of Halley's comet at the time of its last appearance in 1910. More recently, E. B. Shanks has published improved versions of the Runge-Kutta method; Gragg and Setter, and Butcher have published schemes which show promise.

The Georgia Tech study of numerical methods consists of testing as many of these integration schemes as possible on various problems to determine under what circumstances some are more efficient or more accurate than others. Computer programs have been written for each of the different methods (and the different orders within the method). These programs are general-purpose subroutines, having automatic error and step-size control, and can be used with any number of equations or any kind of differential equation system.

The tests are conducted by integrating a system of equations for each of the methods with a given accuracy request and observing the number of steps taken, accuracy obtained, time taken, and other characteristics of the integration scheme.

The tests suggest that, while most of the methods tested work well, high-order methods are superior for high accuracy. For example, at error tolerances of less than 10^{-11}, often desired in precise satallite orbit or other astronomical calculations, the high-order methods of Butcher, Adams, or Cowell can be up to two orders of magnitude faster than the traditional 4th-order Runge-Kutta. These high-order methods are longer, more complicated, and more difficult to program, but in terms of reducing computing costs in high-accuracy calculations, they are well worth it.

Over the course of several years, G. E. Duncan, H. L. Durham, Jr., O. B. Francis, Jr., L. J. Gallaher, J. M. Gwynn, Jr., H. G. Hale, Jr., E. M. Pass, W. T. Wall, and S. Filippi (of the University of Aachen, West Germany) have participated in this work under my direction.

I. E. Perlin
Rich Electronic Computer Center

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SURFACE SCIENTIST APPOINTED TO PHYSICAL SCIENCES DIVISION ADMINISTRATION

Dr. E. J. Scheibner has announced that Dr. Raymond K. Hart has been appointed Head of the Surface Science Section and Associate Chief of the Physical Sciences Division. This assignment will combine active research in the fields of surface science and electron optics with administrative responsibility at the divisional level. As Head of the Surface Science Section, he will have specific responsibility for existing programs in the areas of surface physics and applications, surface chemistry, vacuum technology, and high stability quartz crystal oscillators.

Dr. Hart comes to Georgia Tech from Argonne National Laboratory, where he has been actively engaged in the study of metal surfaces for more than a decade. These investigations were focused on both the physical nature of surfaces, including work function and particle scattering phenomena, and their chemical reaction kinetics in various environments. For the detailed investigation of surfaces he has made extensive use of a wide variety of electron optical techniques. Besides their application, he has played an active part in advancing the design and instrumentation of electron microscopes to meet new levels of performance.

In 1966 he served as chairman for the Joint Associated Midwestern Universities-Argonne National Laboratory Workshop on High Voltage Electron Microscopy. Later that year, he was appointed Project Leader of a program to develop a high-voltage electron microscope (1 to 5 MeV) facility at Argonne.

Dr. Hart attended Sydney University, Australia, Imperial College, London, and Cambridge University. He is a member of the American and British Physical Societies, Faraday Society, and Royal Australian Chemical Institute. In the Electron Microscopy Society of America, he is Director for Physical Sciences, and he is a past president of the Midwest Society of Electron Microscopists. He has published 34 papers and review articles.

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PROFESSIONAL ACTIVITIES

Papers and Presentations

At the Symposium on Research on Uranium Plasmas and Their Technological Applications held at the University of Florida in Gainesville January 7-10, two papers by NBSD personnel were presented: "Gaseous Reactors for MHD Power" by J. R. Williams and S. V. Shelton and "A Study of Thermal Radiation Absorption Processes in Gas Core Reactors" by J. R. Williams, J. D. Clement, and W. L. Partain. Edward Keng, CSMD, read a paper entitled "Application of Zoning Techniques in Practical Radiation Energy Transport Problems."

Fred Bellinger, Chief, CSMD, recently went on an AIChE Speaker's Tour, giving five talks on "The Future of Chemical Engineering" in five days to local sections in Louisiana and Texas.

D. A. Sparrow, RECC, is conducting a training course in computing at Berry College, Rome, Georgia, January 5-March 31, 1970.

W. R. Tooke, Jr., CSMD, attended the Highway Research Board meeting in Washington, D. C., on January 13, and gave a talk on "Electrochemical Properties of Coatings."

O. M. Wellslager and John Frazer, IDD, testified January 15 before the Directors of the Georgia State Game and Fish Commission on the need for more than one commercial alligator farming venture in the state, and the Commission authorized a second such venture.

"An Electronically Scanned Geodesic Luneberg Lens" by R. P. Zimmer, ED, was presented at the Conformal-Array Antenna Conference, which was held at the Naval Electronics Laboratories Center, San Diego, California, January 13-15.

Publication

Charles Poole, IDD, "Coated Blades," Mobile Home/Recreational Vehicle Dealer, December 20, 1969.

Honors and Awards

Fred Bellinger, Chief, CSMD, was appointed by Gov. Maddox to a six-year term as Trustee of the Ocean Science Center of the Atlantic.

The State Committee of the Georgia Cooperative Area Manpower Planning System (CAMPS) has asked William C. Howard, IDD, to serve on its Manpower Problems Subcommittee. CAMPS is developing comprehensive manpower plans for fiscal year 1971.

L. T. Murphy, Jr., IDD, was general chairman of a seminar presented on January 23 by the Augusta Chapter of the AIIE on "The Profitability Index (Calculating Rate of Return on Proposed Projects, Equipment and Plant Facilities)."

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SUBMISSION OF ARTICLES

Contributors in the divisions should submit their articles to the appropriate division coordinator listed below. Others may send their contributions via campus mail to Martha Ann Deadmore at the Industrial Development Division.

Division Coordinators

Chemical Sciences and Materials Division	Walter H. Burrows
Electronics Division	H. A. Corriher, Jr.
High Temperature Materials Division	Nick E. Poulos
Industrial Development Division	Martha Ann Deadmore
Nuclear and Biological Sciences Division	Geoffrey G. Eichholz
Physical Sciences Division	Robert L. Bullock
Rich Electronic Computer Center	John P. McGovern