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PROPOSAL TO CONTINUE DEVELOPMENT AND APPLICATIONS OF SOME FAST NEUTRON DOSIMETRY TECHNIQUES UTILIZING PLASTIC TRACK DETECTORS FOR RADIOTHERAPY AND HEALTH PHYSICS

Submitted to the

U.S. Energy Research & Development Administration

by the

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PROPOSAL TO CONTINUE DEVELOPMENT AND APPLICATIONS OF SOME FAST NEUTRON DOSIMETRY TECHNIQUES UTILIZING PLASTIC TRACK DETECTORS FOR RADIOTHERAPY AND HEALTH PHYSICS

by

M. Sohrabi and K. Z. Morgan

Abstract

The research in the area of electrochemical etching is attracting widespread interest for many health physics and radiotherapeutic applications. A few of the many problems of interest which we propose to carry out in the coming year include fast neutron dosimetry intercomparison, neutron radiography, some radiobiological applications and exploration of some track reading techniques. The investigations of these problems are expected to be a major contribution to fast neutron dosimetry technology and radiography as well as radiobiological applications.

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Introduction

The results of interesting and exciting electrochemical etching of fast-neutron-induced recoil particle tracks in polymers, especially polycarbonate foils, were accumulated and reported in our recent progress report (ORO-4814-5). The results show the intensive research done by these investigators in this field as well as some recommendations on new problems to be solved for the advancement of this new and interesting avenue of approach for many neutron dosimetry applications. Some of the recommended studies have been investigated under this current contract and results of some of them are given in a progress report accompanying this proposal (ORO-4814-9, 1976) and in papers presented recently at scientific meetings (American Physical Society, Auburn, Alabama, 1975; Health Physics Society, Denver, Colorado, 1976, and San Francisco, 1976; International Radiation Protection Association, Amsterdam, The Netherlands, 1975; and American Industrial Hygiene Association, Atlanta, Georgia, 1976).

The reported problems under current investigation range from design and construction of electrochemical etching systems for large-scale neutron dosimetry applications especially in routine monitoring of personnel for large laboratories, to background track density comparison of different polycarbonate foils, to neutron contamination measurement inside high energy x-ray beams and their distributions for different medical electron accelerators, and to registration of charged particles produced by accelerators. The last problem is still in the preliminary stage of investigation which should be carried out in the remaining contract period, followed by continuation of some other interesting areas of research as proposed below.

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Proposed New Research

The following proposed studies are a few of many problems of interest that might be studied for the promotion of electrochemical etching amplification of charged particle tracks for further applications as well as obtaining basic information in the proposed areas. Each of these problems is briefly considered here; nevertheless, expansion and continuation of each part may be expected to result in major contributions to science and engineering. These problems are as follows.

1. Neutron Dosimetry

Although fast neutron dosimetry studies by recoil particle track amplification have proven its feasibility and superior characteristics for personnel dosimetry, its performance in the neutron environment of different neutron producing facilities requires field tests. Such field tests can only be achieved by providing this dosimetry system for practical tests at many neutron producing facilities. Here they would be exposed to unknown doses of fast neutrons used on personnel, as area monitors and as dosimeters to measure unknown doses of fast neutrons in neutron beams.

The polycarbonate dosimeters will be sent to a number of neutron producing facilities to be exposed to unknown doses of fast neutrons. The dosimeters will be collected, electrochemically treated and the results of track counting and neutron dose estimates will be compared to the reported doses by the facility of concern based on their evaluations using their methods of approach.

Attempts will be made to make improvements in the badge design so that the dosimeters can be sent inside a badge for convenient neutron dosimetry intercomparison.

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2. Neutron Radiography

Among various existing techniques to obtain neutron radiographs of biological or industrial objects, track etching methods provide many advantages over conventional methods under most circumstances. Especially, neutron radiography by registration of fast-neutron-induced recoil particle tracks produced directly in polymers such as cellulose nitrate and polycarbonate have been studied by several investigators, but the radiographs obtained by recoil particle track registration in polycarbonate have poor contrast for thorough analysis when they are etched by conventional methods. On the other hand, electrochemical etching amplification of recoil particle tracks which has been the subject of our research and many of our previous communications provides large tracks with high contrast making analysis of the radiographs possible by the unaided eye. Some of our preliminary investigations in this field gave some promise for such application. However, further detailed experiments are required to develop a method under best conditions to obtain high contrast radiography with high spatial resolution. This investigation is expected to be a major contribution to the field of neutron radiography of industrial and biomedical objects.

3. Radiobiological Applications

In many radiobiological applications, preparing high contrast, high resolution radiographs of biological specimens containing fissionable materials or alpha emitting radionuclides is of vital importance. By analyzing the radiographs, one can obtain some detailed information on the microdistribution of such elements to assess the dose rates received by critical tissues.

One such area of application is to determine the distribution of elements stated above in bone or in tissues adjacent to the bone to calculate

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the dose rates received by radiation sensitive tissues such as red bone marrow or periosteal and endosteal tissues of trabecular bone where most radiation induced bone tumors have their origin.

Track etching methods provide the advantage of insensitivity ot low-LET radiation such as beta, gamma and x rays, ease of handling the foils, no darkroom requirement, no track fading and radiographs may be prepared in a relatively short period of time, compared to autoradiographs obtained with photographic emulsions.

Electrochemical etching adds the advantage of having large size tracks and high track density which make image analysis easy by the unaided eye. Experiments will be carried out to investigate the feasibility of this approach for such applications. Bone sections containing the elements of interest for such applications will be requested for our studies from other laboratories involved in radiobiological experiments.

4. Track Reading Techniques

In our previous investigations, microscopic counting, visual counting in microfilm screen, optical densitometry, and light scattering measurements were used as track reading techniques. Nevertheless, visual counting under a microscope or on a microfilm screen have been used for most neutron dosimetry applications. The technique of visual counting of electrochemically etched tracks in polycarbonate is fairly simple, unlike the tedious counting of other types of tracks such as proton tracks in nuclear track emulsions or recoil particle tracks in polycarbonate etched by conventional methods. On the other hand, such a technique of interest for large scale dosimetry requires a complete assurance of a rapid reading procedure. Therefore, the reading techniques given above and some other possible methods will be explored for such applications.

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Proposed Budget

A. Direct Salaries and Wages		$23,200
Principal Investigators:		
Mehdi Sohrabi*	$6,000	
Karl Z. Morgan (~ 30% of academic yr)	8,200	
Shian J. Su** (part time support)	3,200	
Gary B. Stillwagon** (part time support)	5,200	
Machine Shop	600	
Retirement Benefits (9.1% of applicable Salaries and Wages		55
Total Direct Salaries, Wages and Retirement Benefits		$23,255
B. Materials and Equipment		2,500
C. Report and Publication Costs		775
D. Travel		850
E. Indirect Costs		
At a predetermined fixed rate of 68% of Salaries and Wages as established by the Naval Material Command upon advisory audit by the Defense Contract Audit Agency		6,120
TOTAL PROJECT COST		$33,500

*Consultant

**Graduate Students

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Duration of the Proposed Research

The proposed research is intended to be completed within a period of 12 months which will last from September 1, 1976 to August 31, 1977.

Project Personnel

Karl Ziegler Morgan was born in Enochsville, North Carolina on [redacted] He received the [redacted] and [redacted] degrees from the [redacted] respectively, and the [redacted] degree [redacted] From 1934 to 1943 he was chairman of the Physics Department of Lenoir Rhyne College, and during this period did research in cooperation with Duke University in the field of cosmic ray showers, the meson lifetime, etc. in Linville Caverns, on Mt. Mitchell, Beech Mountain, Mt. Evans, etc.

He joined the Metallurgical Laboratory staff at the University of Chicago in the spring of 1943. Here he was one of a group of six persons who developed and established the new science and profession of health physics. During the fall of 1943 he transferred to Oak Ridge National Laboratory where, until the latter part of 1972, he was director of the Health Physics Division which was engaged in research, engineering, and applied problems. Upon leaving Oak Ridge National Laboratory he joined the faculty of the Georgia Institute of Technology as Neely Professor in the School of Nuclear Engineering

In 1956 he was the first president of the Health Physics Society and from 1966 to 1970 was the first president of the International Radiation Protection Association which has about 10,000 members in some 65 countries. He now is President Emeritus of IRPA, an Emeritus member of the Main Commission of ICRP, and a member of NCRP. For 20 years he was chairman of the

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committees of ICRP and NCRP dealing with maximum permissible internal dose of radioisotopes. He has published over 300 papers dealing with subjects of cosmic rays, radiation protection, instrumentation, internal dose, and general health physics. He is editor of the journal HEALTH PHYSICS.

In 1962, K. Z. Morgan and W. Binks (England) were awarded the first gold medals for meritorious work in the field of radiation protection by the Royal Academy of Science of Sweden.

Morgan received the Distinguished Alumni Award and the honorary Doctor of Science Degree from Lenoir Rhyne College, honorary membership in Sigma Pi Sigma from Berea College, and the First Distinguished Service Award of the Western Chapter of the Health Physics Society. He is a member of the Health Physics Society, the International Radiation Protection Association, the American Public Health Association, the American Association for the Advancement of Science, the American Industrial Hygiene Association, the Research Society of America, the Radiation Research Society, the Society of Nuclear Medicine, the American Association of Physicists in Medicine, the American Association of Physics Teachers, an Associate Fellow of the American College of Radiology, a Fellow of the American Physical Society and of the American Nuclear Society, and an Affiliate of the Royal Society of Medicine.

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Major Publications of the Last Five Years

1. "Common Sources of Human Exposure to Ionizing Radiation in the United States," American Engineer, July 1968.
2. "Ionizing Radiation: Benefits Versus Risks," Annual Meeting of the Health Physics Society, June 16-20, 1968, Denver, Colorado; and published in HEALTH PHYSICS, Vol. 17, No. 4.
3. "Assumptions Made by the Internal Dose Committee of the International Commission on Radiological Protection," Sixth Annual Meeting of the Gesellschaft fur Nuclearmedizin, Wiesbaden, Germany, September 26-28, 1968; Published in Proceedings, 1969.
4. "Redirecting Health Physics Studies to Areas of Greatest Interest," First European Oongress of the International Radiation Protection Association, Menton, France, October 9-11, 1968; Published in Proceedings, 1968.
5. "The Need for Standardization Procedures in the Application of Ionizing Radiation to Medical and Dental Patients," Seminar sponsored by the National Center for Radiological Health, Rockville, Maryland, November 15, 1968, Seminar Paper 003.
6. "The Proper Working Level of Radon and Its Daughter Products in the Uranium Mines of the United States," Hearing on Radiation Standards for Mines, Washington, D. C., November 20, 1968; Congressional Record, 1968.
7. "Supplemental Statement on the Proper Working Level of Radon and Its Daughter Products in the Uranium Mines of the USA," Supplement to Testimony presented on November 20, 1968, Washington, D. C.; Congressional Record, 1968.
8. "Future Opportunities in Health Physics," Health Physics Society Midyear Topical Symposium, Los Angeles, California, January 29-31, 1969.
9. "Risks from Diagnostic X-Rays," Yale Scientific, Vol. XLII, No. 5, February 1969; Reprinted from Yale Scientific in the Journal of the American Radiography Technologists, Vol. XIV, No. 4, Winter 1969.
10. "Radiation Standards for Reactor Siting," Testimony presented before the Joint Committee on Atomic Energy at its Hearings on Environmental Effects of Producing Electrical Power, Phase 2, January 1970; Congressional Record.
11. "Energy Pollution of the Environment," Midyear Symposium of the Health Physics Society, Louisville, Kentucky, January 28, 1970; Proceedings published in USPHS-BRH Series.
12. "A Time of Challenge to the Health Physicist," Presidential Address presented before the Second International Congress on Radiation Protection, May 8, 1970, Brighton, England; Health Physics, Vol. 20, May 1971, pp. 491-498.
13. "My Opinion--You Can Drastically Cut X-Ray Exposure Below Today's Levels," Consultant, March/April 1970.
14. "History of the Health Physics Society," published as part of the RSNA Symposium on the Critical History of American Radiology (Nov. 1970).
15. "History of the International Radiation Protection Association," published in Proceedings of the RSNA Symposium on the Critical History of American Radiology, November 1970.
16. "Criteria for the Control of Radioactive Effluents," IAEA Symposium on Environmental Aspects of Nuclear Power Stations, UN Building, New York, August 1970, Proceedings published, this paper is IAEA-SM-146/10; synopsis published also in Environmental Studies, 1971.

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17. "Maximum Permissible Levels of Exposure to Ionizing Radiation," International Summer School on Radiation Protection, Boris Kidric Institute of Nuclear Sciences, Cavtat, Yugoslavia, September 20-30, 1970; Proceedings published in 1971 under title of "Radiation Dosimetry."
18. "President's Report to the General Assembly of IRPA," Brighton, England, May 1970, Health Physics, Vol. 20, No. 5, 1971.
19. "History of Radiation Protection," Symposium Commemorating the 75th Anniversary of the Discovery of X-Rays, Milwaukee, November 13-14, 1970; Materials Evaluation, Vol. XXIX, No. 3, March 1971.
20. "Why the 1968 Act for Radiation Control for Health and Safety Is Required," Radiology, Vol. 99, No. 3, pages 569-588, June 1971.
21. "Excessive Medical Diagnostic Exposure," Third Annual National Conf. on Radiation Control, Scottsdale, Arizona, May 3, 1971; Published in Proceedings.
22. "Health Physics and the Environment," International Symposium on Rapid Methods for Measurement of Radioactivity in the Environment, Neuherberg, Federal Republic of Germany (Proceedings published by IAEA).
23. "Adequacy of Present Radiation Standards," presented at the Environmental and Ecological Forum, Silver Spring, Maryland, January 20, 1971; Proceedings of Forum published in 1972.
24. "Proper Use of Information on Organ and Body Burdens of Radioactive Material," presented at the IAEA/WHO Symposium on the Assessment of Radioactive Organ and Body Burdens, Stockholm, Sweden, November 22-26, 1971, IAEA/SM/150-50; Proceedings of Symposium published by IAEA.
25. "Health Physics Measures to Implement New USAEC Regulations Relating to Radiation Exposure of the General Public," Budapest, May 1971; Proceedings published.
26. "The Need to Reduce Medical Exposure in the United States," outline of testimony presented before the Health and Welfare Subcommittee of the Senate Committee on Labor and Public Welfare on Senate Bill S.3327, May 15, 1972, Washington, D. C.; published in Congressional Record, 1972.
27. "Environmental Impact of Natural and Man-Made Ionizing and Non-Ionizing Radiations," Second Health Physics Summer School, Herceg Novi, Yugoslavia, August 1973; Proceedings published 1974.
28. "The Need for Radiation Protection," Radiologic Technology, 44, no. 6, 385-395, 1973.
29. "Possible Consequences of Excessive Medical Exposure in the United States," Given before the Fachverband für Strahlenschutz at the Bern, Switzerland meeting, March 21, 1973 and published in the Fachverband Proceedings 1973.
30. "Transportation of Radioactive Material by Passenger Aircraft," committee report to the Joint Committee on Atomic Energy of Congress, Congressional Record, Sept. 17, 1974.
31. "Biological Effects of Ionizing Radiation," published in Proceedings of Short Course, Sept. 9, 1974.
32. "Reducing Medical Exposure to Ionizing Radiation," J. Amer. Industrial Hygiene Assn., 36, 5, 358 (May 1975).
33. "Appropriateness of Regulations for Air Shipment of Radioactive Materials," Miami Beach, Fla., Sept. 23, 1974, International Conf. on Shipping of Radioactive Material, Proceedings to be published (1975).
34. "Health Physics--Past, Present and Future," Published in Proceedings of First Asian Congress of the International Radiation Protection Association, Dec., 1974.

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35. "Suggested Reduction of Permissible Exposure to Plutonium and Other Transuranium Elements," in press and to be published in J. of Amer. Industrial Hygiene Assn. (probably July 1975).
36. "Effects of Radiation on Man," Proceedings of Short Course on Energy and the Environment--Cost-Benefit Analysis to be published by Pergamon Press (1975).
37. Chapters on "Ionizing Radiation Exposure" and on "Exposure to Non-Ionizing Radiation" in text, Environmental Problems in Medicine, Ed. W. D. McKee; publisher, Chas. C. Thomas, 1974.
38. "Recent Developments in Fast Neutron Personnel Dosimetry Using Track Etch Methods," Proc. 3rd European Cong. IRPA, Paper 14, Amsterdam, The Netherlands (May 1975), with Mehdi Sohrabi.
39. "Development and Application of Some Fast Neutron Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics," USERDA Contract No. AT-(40-1)-4814 (1975), with Mehdi Sohrabi.

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BIOGRAPHICAL SKETCH

SOHRABI, MEHDI -- Research Scientist

Education

[redacted]

Employment History

National Iranian Oil Co., Trainee in Mechanics	1965
Army of Iran, 2nd Lieutenant	1966-1967
Tehran University Nuclear Ctr., in charge of reactor Hlth Phys	1967-1970
Officer's College, Instructor	1968
Oak Ridge National Laboratory, Alien Researcher	1970-1971
Georgia Institute of Technology	
Graduate Assistant and Co-Principal Investigator	1972-1975
Research Scientist	1975-Present

Experience Summary: While working at the Tehran University Nuclear Center, Sohrabi was responsible for personnel monitoring, calibration of instruments, shielding inspections of radiology departments of the hospitals, and dosimetry research. Since the Tehran Univ. Research Reactor, a 5 MW swimming pool type reactor, became critical, he was in charge of reactor health physics. Meanwhile, he was involved in teaching college physics, mechanics, and health physics at the University of Tehran and other colleges. He attended many programs such as Applications of Radioisotopes in Medicine, Agriculture, and Industry--Handling of Radiation Accidents--Dosimetry Intercomparison held by the International Atomic Energy Agency. He has been active in establishing the Iranian Radiation Protection Association and has been a member since its inception.

In August 1970, under the sponsorship of the IAEA and the National Academy of Sciences, Sohrabi was sent to the DOSAR, Health Physics Div. at ORNL where, under the direction of Drs. Karl Z. Morgan, John A. Auxier, and Klaus Becker, he did some solid state dosimetry research. During [redacted] he has been pursuing a [redacted] with a specialty in Health Physics. Meanwhile he has been studying, teaching, demonstrating laboratory experiments, and doing research. Since 1974 he has been serving as a co-principal investigator on ERDA projects with Georgia Institute of Technology.

Current Fields of Interest

Neutron dosimetry, radiation detection, registration of charged particle tracks, environmental impact of nuclear power, radiotherapy

Professional Activities

Member, Iranian Radiation Protection Association
Member, Health Physics Society
Member, Society of the Sigma Xi
Member, Atlanta Chapter, Health Physics Society
Member, International Radiation Protection Association

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Reports, Publications and Papers

1. "Electrodeposition of U-238 and Its Application in Fast Neutron Dosimetry by Fission Fragment Registration in Silver Activated Phosphate Glasses," M.S. Thesis, Tehran University Nuclear Center, 1969.
2. "Some Studies on the Application of Track Etching in Personnel Fast Neutron Dosimetry," M.S. Thesis, University of Tennessee, ORNL-TM-3605, 1971, with Klaus Becker.
3. "Fast Neutron Personnel Monitoring by Fission Fragment Registration from Np-237," Nucl. Inst. Methods, 104, 409 (1972), with Klaus Becker.
4. "Fading Characteristics of Various Films and Solid State Dosimeters in a Warm and Humid Climate," Paper 58, 17th Annual Meeting, Health Physics Society, Las Vegas, 1972, with others.
5. "Literature Review of the Proposed Research: Fast Neutron Microdosimetry by Plastic Track Detectors inside Heterogeneous Phantoms," in partial fulfillment of the Ph.D. degree, Georgia Institute of Technology, 1973.
6. "Electrochemical Amplification of Recoil Particle Tracks in Polymers and Its Application in Fast Neutron Personnel Dosimetry," Health Physics, 27, 598 (1974).
7. "Recent Developments in Fast Neutron Personnel Dosimetry Using Track Etch Methods," Proc. 3rd European Cong. IRPA, Paper 14, Amsterdam, The Netherlands (May, 1975) with Karl Z. Morgan. See also Trans. Am. Nuc. Soc. Student Conf., p. 24 (1975). (This paper was awarded Best Paper of the Health Physics Session at the Southeastern Section of the American Nuclear Society Student Conference, 1975.)
8. "Development and Application of Some Fast Neutron Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics," USERDA Contract No. AT-(40-1)-4814 (1975), with Karl Z. Morgan.
9. "Thickness Dependence of a Simple Fast Neutron Dosimeter," Paper CB7, Southeastern Section, American Physical Society, Auburn, Alabama, November 13-15, 1975, with Karl Z. Morgan.
10. "Electrochemical Etching Amplification of Fast-Neutron-Induced Recoil Particle Tracks in Polymers for Fast Neutron Dosimetry," Ph.D. Dissertation, Georgia Institute of Technology, November 1975. (This manuscript won The Society of the Sigma Xi Ph.D. Engineering Award, May, 1976, Georgia Institute of Technology Chapter.)
11. "Dose Levels Due to Neutrons in the Vicinity of High Energy Medical Accelerators," presented at the 9th Midyear Topical Symposium, Health Physics Society, Denver, Colorado, February 9-12, 1976, with others.
12. "The Effect of Polycarbonate Foil Thickness on the Electrochemical Etching Amplification of Recoil Particle Tracks," presented at the 9th Midyear Symposium, Health Physics Society, Denver, Colorado, February 9-12, 1976, with K. Z. Morgan.
13. "Some New Characteristics of a Polycarbonate Fast Neutron Dosimeter," presented at the American Industrial Hygiene Conference, Atlanta, Georgia, May, 1976, with Karl Z. Morgan.

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Reports, Publications and Papers (continued)

14. "The Effect of Etchant Parameters on the Electrochemical Etching of Recoil Particle Tracks in Polycarbonate," to be presented at the 21st Annual Meeting, Health Physics Society, San Francisco, California, June 27 - July 2, 1976, with Karl Z. Morgan.
15. Book Review of "Nuclear Tracks in Solids," Robert L. Fleisher, P. Buford Price, and Robert M. Walker, Editors; University of California Press, Berkeley, 1975 in Health Physics (1976) in press.

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Support Facilities at Georgia Tech

The facilities most closely related to teaching and research in the nuclear engineering programs at Georgia Tech are located in the Cherry L. Emerson Building and the Frank H. Neely Nuclear Research Center.

Cherry L. Emerson Building

The School of Nuclear Engineering occupies about 24,000 square feet in the Emerson Building. This space contains ample classrooms, student laboratories and offices, as well as a periodical library, staff machine shop, electronics shop, seminar room, computation lab and a large, two-story bay with a ten ton crane. The latter space houses the nuclear engineering laboratory. The counting rooms and other laboratories have been well equipped with conventional radiation detection instruments (including several multichannel analyzers) in sufficient numbers to accommodate laboratory sections of 12-15 graduate students.

Specialized equipment available in the Emerson Building to nuclear engineering students includes:

an AGN-201 training reactor

a natural uranium-light water subcritical assembly

100 μgram Cf-252 source

Korad K-15 pulsed ruby laser

three EAI Model TR-20 analog computers

a 12,000 curie Cs-137 gamma source

a one MeV Van de Graaff positive particle accelerator with beam analysis system

50 and 250 KVP X-ray machines

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several gas chromatographs

eleven radioisotope fume hoods and three glove boxes

vacuum deposition system

The training reactor is located in the nuclear engineering laboratory. It is used in laboratory exercises and for special student problems and theses. The GTRR continues to be available for all pedagogical experiments and research which require its higher flux.

Nuclear Research Center

The Frank H. Neely Nuclear Research Center, valued at $4,500,00, was completed in 1964. The Georgia Tech Research Reactor (GTRR) which serves as the key component of the Center is a heterogeneous, heavy-water moderated and cooled type, fueled with enriched uranium. It is similar in design to the Argonne Research Reactor, CP-5, which has demonstrated excellent research capability and dependable service. The GTRR has been designed to develop a sustained power output of five megawatts with a corresponding thermal neutron flux of about 10^{14} neutrons/cm^2. The reactor has a variety of experimental facilities (such as beam tubes, through-tubes, pneumatic tubes, fast flux facility, biomedical facility, thermal column, and gamma facility) to provide for a wide range of experiments. The GTRR currently operates at a power of one megawatt two or three shifts per day. It currently is undergoing modification to increase power to the full, rated level of 5 megawatts.

The reactor and associated systems are housed in a steel containment building eighty feet in diameter and sixty-five feet in height. The adjoining 24,000 square foot, two-story, air-conditioned laboratory and office building contains laboratories for radiochemistry, health physics, materials preparation, nuclear spectroscopy, low-level counting, radiobiology, electronics, as well as a machine shop and a large animal quarters.

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Equipment at the Frank H. Neely Nuclear Research Center includes:

5 megawatt, heavy-water research reactor

three neutron diffractometers

time-of-flight neutron spectrometer

experimental set-up for pile oscillator measurements

50,000 curie hot cell with master-slave manipulators

20' x 6' x 18' deep storage pool joined to hot cell by transfer chute

neutron generator--200 keV TMC Activatron Model 211, (d,n) reaction with tritium producing 14 MeV neutron peak intensity of 2×10^{14} n/sec

gamma facility--spent fuel element storage in pool provides gamma rates to 10^6 R/hr depending on sample geometry

100,000 curie cobalt irradiation source

intermediate level radiochemistry laboratory (18' x 26') with radioisotope hoods, shielded glove boxes

facilities for treatment, storage, and handling of solid and liquid radioactive wastes, including retention tanks of 8,000 gallon capacity

Model 33 teletype terminal providing remote computer access on and off campus

PDP-8 computer system

PDP-12 computer

The data acquisition system consists of two data processors (PDP-8, PDP-8/I), with appropriate peripheral devices for use in sophisticated experiments requiring on-line analysis and control, as well as data collection. One of the processors is located within the reactor containment building and is intended for use by experimenters with a minimum of setup time. A rather sophisticated interface for accepting both digital and analog signals is operational. There is a communications link to the other processor, located in the laboratory portion of the Center, which acts as a data collection center for several experiments and a secondary processor. Both processors function (with lower priority) as a data reduction and preprocessing facility, and as such are generally available for use 24 hours a day. The PDP-12 computer is also available to this project if required.

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Computer Facilities

The Rich Electronic Computer Center is housed in a modern reinforced concrete and brick building. Especially designed to accommodate computer facilities, the plant contains approximately 6,000 square feet of space used for equipment and offices.

Two computers with associated card and tape-handling capabilities are presently in operation at the Computer Center. These are:

1. Burroughs B-5500 with 32,000 48-bit words for core memory and 3.6 million 48-bit words of disc memory. High speed card readers and line printers are also provided. This machine also has multiplexing capability.

2. In 1975, a Control Data Corporation CYBER 70 Model 74-28 replaced Univac-1108 Shared Processor system. Also a Control Data Corporation 6400 replaced an IBM 360/30. Both computer systems are dedicated to the support of education and research.

The Computer Center maintains an extensive library of frequently used computer programs. In addition to the programs available for immediate use in the library, the Center participates in program-sharing plans with other computer users, which effectively increases the extent and scope of its own library.

Library

The Price Gilbert Memorial Library is a centralized scientific, technical, and management collection of 679,000 volumes plus six hundred thousand microtext and other bibliographic units. Outstanding collections in the fields of science and engineering have been developed to support graduate study and research. It is housed in adjoining structures totaling 240,000 square feet of space. It can house over one million volumes and can seat two thousand users. The library's United States Patent specification collection is the only one in the Southeastern area. In 1962, the library was designated one of twelve Federal Scientific Report Centers and its collection of reports from the Atomic Energy Commission, the Department of Defense, the National Aero-

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nautics and Space Administration, and the Clearinghouse for Scientific and Technical Information now totals over 490,000 titles. Extensive files of standards issued by American associations and societies and a complete file of U. S. Military Standards and Specifications and of British Standards are maintained. The Library is also a depository for United States government publications issued by the Government Printing Office, and for maps issued by the Army Map Service. Available on microfilm are more than 6,000 company catalogs providing information on industrial components.

Other Facilities

Georgia Tech has many other facilities closely allied with the nuclear engineering program including, for example, various facilities operated by Divisions of the Engineering Experiment Station. Among these are specialized laboratories utilizing X-ray equipment, optical and electron microscopes, emission and absorption spectroscopes, analog computers, microwave systems, cryostats and many other research devices. In addition, close cooperation exists between the School of Nuclear Engineering and other Schools of the Engineering College and the School of Physics.

In addition to the facilities available on the Georgia Tech campus, Oak Ridge National Laboratory, which is located about three hours driving time from Atlanta, has radiation sources of our interest and, under a subcontract No. 3921, we have easy access to these facilities. In particular, the Health Physics Research Reactor, which is a bare, unmoderated reactor facility having a neutron leakage spectrum of 1.5 MeV average energy, is available to us. This facility and the DOSAR low-energy neutron generator are considered as two sources of neutrons in addition to those at Georgia Tech.

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