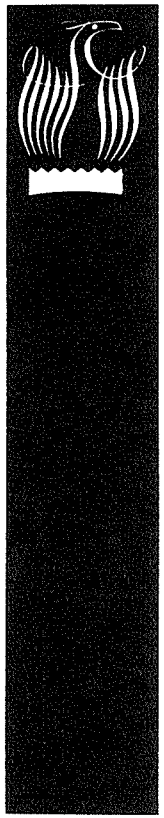
QUARTERLY REVIEW

FALL 1994

MICHIGAN MEMORIAL PHOENIX PROJECT
THE UNIVERSITY OF MICHIGAN

NUCLEAR REACTOR LABORATORY
FORD NUCLEAR REACTOR
PHOENIX MEMORIAL LABORATORY



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Seventh Year, No. 21

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The Nuclear Reactor Laboratory Quarterly Review is published and distributed to University of Michigan faculty and staff members to inform them of the unique research capabilities of the Nuclear Reactor Laboratory and to make them aware of the types of research in progress.

The Michigan Memorial Phoenix Project was founded on May 1, 1948, as a memorial to the 585 University of Michigan alumni, students, faculty, and staff members who died in World War II. The Project is devoted to peaceful, useful, and beneficial applications and implications of nuclear science and technology to the welfare of the human race. Research support and services provided by the Nuclear Reactor Laboratory and a research grant program are the means by which the Project fulfills its mission.

NEW RESEARCH

FORD NUCLEAR REACTOR

University of Michigan

Geological Sciences

Edward Van Hess is activating samples of biotite, muscovite, and horneblende separates utilizing high energy neutrons from the reactor and analyzing them for argon-39/argon-40 in order to establish the age of regional metamorphism in the Porcupine Mine, Ontario, Canada, relative to gold mineralization. The age of the samples in anticipated to be of the order $2x10^9$ years. The title of Mr. Van Hess' doctoral thesis is "Correlation of Gold Deposit Formation with Regional Metamorphism: Porcupine Gold Camp". His advisor is Professor Eric Essene.

Nuclear Engineering

Ram Venkataraman irradiated metal foils in the reactor heavy water tank to produce point sources of cadmium-111m, indium-114m, and selenium-75 as part of the experimental work associated with his doctoral project. Among the experiments was foil counting on a high-purity germanium detector at several distances away from the detector to measure loss of counts due

to angular correlation of gamma peaks. Another part of Mr. Venkataraman's experimental work involved irradiation and activation of small quantities of uranium dried on filter paper to measure the quantities of the various fission products that were produced. The title of Mr. Venkataraman's thesis is "Photo Fission Corrections in Fission Neutron Dosimeters". His advisor is Professor Ronald Fleming.

Yuni Dewaraja utilized the reactor to irradiate a variety of metal foils, wires, standards, and other solid materials to develop position sensitive neutron activation analysis methods and equipment. The title of her doctoral thesis is "Imaging Neutron Activation Analysis". Her advisor is Professor Ronald Fleming.

Shanka Guru irradiated gold-198 to produce a pure, strong source of medium energy gamma rays at 412 keV for a gamma camera test run. Mr. Guru is a doctoral candidate whose advisor is Professor David Wehe. The title of his doctoral thesis is "Fabrication of a Mechanically Collimated High Energy Gamma Camera".

Universite Blaise Pascal

Earth Sciences - Geochronology

Professor Nicolas Arnaud utilized the Ford Nuclear Reactor in-core irradiation facility to irradiate geological samples with high energy neutrons for argon-39/argon-40 age dating.

Eagle-Picher

Neutron Attenuation and neutron radiographs were made on a variety of borated aluminum products that may be used in reactor fuel shipping and storage casks. Eagle-Picher is the nation's leading supplier of boron enriched in boron-10, a strong neutron absorber. The enriched boron in the form of the compound, titanium diboride, is alloyed with aluminum. The tests conducted at the Ford Nuclear Reactor were to determine the uniformity of the boron-10 dispersion in the alloy.

NEUTRON ACTIVATION ANALYSIS

University of Michigan

Archaeology

Sarah Morgan participated in the Intercollegiate Program in Classical Art and Archaeology at the University of Michigan. She performed neutron activation analysis of Middle Kingdom ware from Coptos, Egypt, under the direction of Professor Sharon Hebert and Professor Henry Wright. The purpose of the project was to determine the chemical composition of pottery sherds from three loci of the Coptos excavation. Thin section analysis has suggested that this type of ware is homogeneous in compostion. If that proves to be true by neutron activation analysis testing, comparisons with the chemical compositions of other coarse wares from Coptos can be made.

Anthropology

Renato Kipnis utilized neutron activation analysis to detect trace elements in fossilized human skulls, extinct Pleistocene fauna, and sediment material from the state of Rondonia, Brazil. The project is part of his doctoral program. Its purpose is to examine diagenetic effects on bone in that part of South America and to test the utility of neutron activation analysis as a method for its examination. The study will address the question of potential association between humans and extinct mega-fauna during the late Pleistocene in the neotropics. Mr. Kipnis's advisor is Professor Jeffrey Parsons.

Andrew Darling and Helen Pollard performed a direct comparison general analysis of archaeological ceramics from the site of Izintzuntzan, Michoacan, Mexico. Trace element analysis utilizing neutron activation analysis serves to examine ceramic paste differences and compositions as part of a typological study of Tarascan ceramics. This is a pilot study the results of which may be compared to previous evaluations based on visible characteristics. Professor Jeffery Parsons and Professor Ronald Fleming are supervising the project.

Classical Archaeology and Chemistry

Darren Hillegonds is utilized neutron activation analysis to measure trace elements in pottery from ancient Lepti (Tunisia) to provenance the pottery to clay sources and specific work shops. Mr. Hilligonds is a doctoral candidate being advised by Professor John Humphrey. The title of his thesis is "Chemical Composition of Pottery Sherds Found in Lambta, Tunisia (Ancient Lepti)".

Geological Sciences

Gerald Dickens and his advisor, Professor Robert M. Owen, utilized neutron activation analysis to measure manganese depletion in water from the Indian Ocean. Manganese depletion correlates with oxygen minimum zones (OMZ) in the ocean. Oxygen minimization, in turn, is believed to be caused by decompostion of organic matter combined with density stratification. This work provided corroborative geochemical evidence to support theories based on benthic foraminiferal assemblage changes that OMZ was most extensive in the late Miocene - early Pliocene period in the earth's history.

Sharon Feldstein and Jean Tangeman utilized neutron activation analysis to conduct trace element analysis on whole rock basalt powders in support of their doctoral theses. The title of Ms. Feldstein's thesis is "Phiogopite in Nature and Experiments"; Ms. Tangeman's "Experimental Petrology Studies". Their advisor is Professor Rebecca Lange.

Pimbo Zhou, as part of his master's thesis, utilized neutron activation analysis to analyze rocks from multiple sites for preliminary characterization of the sites. Mr. Zhou's advisor is Professor Samuel Mukusa.

Kresge Hearing Research Institute

Jurgen Lautermann, a research fellow, and Professor Jochen Schacht analyzed dried blood for trace elements, platinum in particular. The purpose of their research is to determine the effect

of varying diets on ototoxicity as related to fluctuation in defense mechanisms.

Arizona State University

Botany

Ryan L. Bradley, a master's degree candidate in botany, utilized neutron activation analysis to quantify protein bound ions in the water oxidation process associated with the Photosystem II (PSII) reaction center. Ca^{2+} ions are involved in water oxidation. He has substituted Tb^{3+} ions for the Ca^{2+} ions, and he is attempting to analyze the effect. The title of Mr. Bradley's thesis is "Involvement of Ca^{2+} in PSII".

Indiana University

Geological Sciences

Susan McDonald utilized neutron activation analysis in an attempt to determine if substitutional sodium and iron in quartz crystal is the cause of macroscopic fracture differences between different crystals. This is a senior research project under the direction of Professors Bruce Douglas and Jeremy Dunning.

Louisiana State University

Oceanography and Coastal Sciences

Professor Eugene Turner has analyzed over 200 samples in the past year as part of an investigation of changes in the

chemistry of the Mississippi River Drainage system and how the changes in the river have affected the continental shelf ecosystem.

Northern Illinois University

Geology Department

Robert L. Ward, a doctoral candidate working under the direction of Professor James Walker, is researching deep crystal growth and modification beneath the Trans Pecos Volcanic Province that covers sections of West Texas and Mexico. He used neutron activation analysis to analyze Cenezoic Granulite-facies xenoliths and associated mafic lavas for trace and rare earth elements. The analysis will provide information on elemental segregation that can be used to determine crystal growth rate.

San Jose State University

Geology Department

Professor Ellen Metzger utilized neutron activation analysis data provided by the Michigan Memorial - Phoenix Project for geochemical studies of granite gneisses from the Adirondack Mountains of New York and volcanic rocks of the Carolina Slate Belt of North Carolina and for the possible effects of trace element chemistry on the crystal habit of pyrite crystals.

University of Colorado

Geological Sciences

Professor Edwin Larson and two graduate students utilized neutron activation analysis to obtain trace element and rare earth information on Miocene volcanic rocks from Oregon, Precambrain lavas from the Belt Supergroup, Montana, and Eocene Sediments from Wyoming.

University of Toledo

Geology Department

Professor James Harrell, a fellow faculty member, and two graduate students performed neutron activation analysis on approximately 250 samples. About half were for a study of Precambrain volcanic rocks of the Saint Francois Mountains in Missouri, and the remainder were for a study of ornamental and building stones from ancient quarries in Egypt.

COBALT-60 IRRADIATOR

University of Michigan

Biological Chemistry

Dr. Arie Goldlust gamma irradiated human recombinant manganese superoxide dismutase protein at various doses. The molecular weight of the protein can be determined by radiation inactivation based on the damage in its structure caused by

ionizing radiation. The damage is reflected as a decrease in the biochemical activity and is directly proportional to the molecular weight and the dose received. Finding the molecular weight of the protein will help determine the functional size of this enzyme in humans.

College of Pharmacy

Louise Wilson, a consultant for the College of Pharmacy, is sterilizing GI tubes using the cobalt-60 gamma irradiator. The tubes have been previously sterilized. She attaches a new type of latex balloon to the tubes, tests the tubes after each irradiation, and continues gamma sterilization until the point of failure. The work supports an FDA study for approval of the new balloons that is being performed in the Clinical Research Center at the University of Michigan Hospital.

Internal Medicine

Deborah Cieslinski, the laboratory director for Dr. H. David Humes, is growing endothelial cells on polysulfone hollow fibers in order to study their permeability characteristics under perfusions. They are making single hollow fiber housing units and gamma irradiating them prior to cell inoculation.

Materials Science and Engineering

A student working for Dr. David C. Martin sterilized silicon implants for mice using gamma irradiation. The silicon implants are intercortical microprobes that are used when bypassing damaged auditory nerves and stimulating the central nervous

system artificially. Gel coating technology has been developed which allows thin porous films of protein polymers to be deposited on silicon devices. The silicon implants are coated with a nerve cell reagent which possesses the cell binding domain from the protein laminia. The researchers are then coating the implant with various protein polymers to find one that will work as a surgical adhesion barrier in conjunction with the nerve cell reagent. The goal of this research is to promote a cohesive cellular interface between the implant and surrounding nerve tissue while preventing the adhesion of connective tissue from the cranium.

Otolaryngology

Dr. Michael Disher utilizes the cobalt-60 gamma irradiator to sterilize operating room sponges.

Bowman Gray School of Medicine

Dr. Michael Morykwas, four faculty members, and three residents utilize the cobalt-60 irradiator to sterilize cartilage for use in craniofacial (nose and ear) reconstructive surgery.

Difco Laboratories

Drs. Leon F. Strenkoski and Marianne R. Plaunt are sterilizing polystryrene AST-ID cards. They are trying to determine if antibiotics/antimicrobials are sticking to their plates before/after sterilizing and/or before/after cleaning. They are using the cobalt-60 irradiator for sterilizing during their research

because of quick turn-around and the ability to offer various dose rates for study.

Eastern Michigan University

Professor Paul A. Volz, Mycology Laboratory, Biology Department, irradiated mutant strains of chaetomium globosum (a soil fungus) and saccharomyces cerevisiae (brewer's and baker's yeast) to study the effects of gamma irradiation as part of a student's master's thesis.

Michigan State University

Civil and Environmental Engineering

Xianda Zhao, a research assistant working for Professor Thomas C. Voice in the Civil and Environmental Engineering Department, is gamma sterilizing a biofilm-coated granular-activated-carbon (GAC). He is testing a pilot scale fluidized bed system used to treat ground water contaminated with three milligrams toluene per liter of water. The GAC is used as the carrier media for microbial growth. The biofilm-coated GAC is taken from the system each month and sterilized. The sterilized GAC will be used in an adsorption isotherm experiment to determine the remaining adsorption capacity.

Mara E. Hollinbeck, an environmental engineering graduate student, is gamma sterilizing soil filled columns. She is making a direct comparison between the two technologies commonly

used to remediate contaminated groundwater. Saturated soils will initially be contaminated with gasoline and two series of dynamic columns will be used to study the rate of removal during flushing with non-contaminated solutions. One set of columns will be seeded with microorganisms and enhanced using a nutrient/oxygen solution to simulate in-situ bioremediation. The second set of columns will be sterilized and kept free of oxygen and microorganisms to represent a pump and treat system.

Both influent and effluent liquid samples will be taken throughout the study and soil samples will be taken periodically by removing columns from operation. The biologically active system may be limited due to desorption of the contaminants from the soil if they are unable to be degraded in the solid phase. The inactive system, in which contaminants are removed to above-ground treatment systems, may also be limited by desorption since removal occurs in the liquid phase. This comparison in removal rates along with the effect microorganisms have on desorption will quantify a commonly debated issue. Sterilization of the soil filled columns will prevent changes in sorption characteristics of the soil which would occur if other sterilization methods were used.

Purdue University

Amy Nelson is testing the structural integrity of a sandwich board composed of carbon fiber/epoxy composite over Rohacell^{R} foam. The boards receive various cobalt-60 gamma doses corresponding to different lifetimes of use. Each board is tested using a 3-point bending tensile strength test to determine at what load failure occurs.

Quincy High School

A tenth grade student is irradiating Brasica rapa seeds for a Junior Academy of Science Presentation at Michigan State University in 1994.

USDA

Mr. Gerald Sims is sterilizing soil samples. He then tests the samples to find the extent and rate of degradation of pesticides in the soil. He is trying to determine what is responsible for the degradation of pesticides in soil.

NEUTRON RADIOGRAPHY

University of Michigan

Chemical Engineering

Christopher N. Fredd is utilizing neutron radiography as an analytical tool associated with his doctoral thesis, "Stimulation of Ethylenediaminetetraacetic Acid (EDTA)". Professor Scott Fogler is Mr. Fredd's advisor.

Fracture acidizing is a stimulation technique frequently used in the petroleum industry to improve well productivity in carbonate (limestone and dolomite) reservoirs. The process involves creating a fracture in the rock formation and injecting acid, usually hydrochloric. The acid dissolves the carbonate surfaces leaving a conductive channel through which reservoir fluids can flow. For an effective stimulation, live acid must

penetrate as far down the fracture as possible. Unfortunately, significant fluid loss occurs normal to the fracture surface which reduces the penetration distance.

EDTA is being investigated as an alternative stimulation fluid. Experiments with carbonate cores seem to indicate that EDTA could reduce the fluid loss by plugging fracture walls. The source of plugging is believed to be a precipitate that may be a dissolution product or an undissolvable component of the carbonate core. To determine the origin of this precipitate, samples of the carbonate and the precipitate are being analyzed with the aid of neutron activation. For further insight into the dissolution/precipitation in carbonates, images of treated cores have been obtained using neutron radiography. These tools are contributing to an understanding of the observed plugging and its usefulness in fracture acidizing.

FEATURE ARTICLE

DETERMINATION OF THE ABILITY OF LANDFILL COVERS TO ABSORB TOXIC HEAVY METALS USING NEUTRON ACTIVATION

by

Andrea Brown
Sophomore
University of Michigan

Tekeshia Bailey
Freshman
University of Michigan

Bridgette Marsh
Junior
Pioneer High School

INTRODUCTION

In landfills, rain water leaches metals and chemicals found in waste material into ground water. The Environmental Protection Agency (EPA) has set standards for limitations on pollutants that contaminate drinking water and may endanger public Health. The use of a spray-on landfill cover materials is part of the effort to reduce the amount of contaminants that leach into ground water.

This experiment was formulated to test the ability of one type of landfill cover, called Concover, to absorb heavy metal contaminants on the EPA drinking water standards list. This list includes the heavy metals: arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver and zinc. Concover is a recycled-newspaper-based covering that can be sprayed over landfill waste. Normally, it is used to assist in bio-degradation of landfill waste and to hold down dust and wind-blown garbage. The tests described in this report were conducted with two formulations of Concover and with mixtures of the two Concovers and natural, clay-base additives specifically intended to absorb heavy metal ions.

EXPERIMENTAL SETUP

Cylindrical columns of various formulations of Concover and the clay additives were prepared. Basic Concover is a mixture of shredded newspaper, water, and the Concover itself, a binding agent that acts as a "glue" to hold the mixture together. When dried, the result is a sort of papier-mache. Concover 180 was a second formulation tested. It is identical to base Concover with

a foaming agent added to expand the mixture with small air pockets. Concover mixtures with each of three clays added also were prepared, resulting in eight total formulations. The mass of the mixture in each column was kept constant in order to allow fair comparison between them.

A standard water solution of the heavy metals was prepared. The elemental parts per million (ppm) were adjusted based on the sensitivity of the elements to neutron activation. Sensitivity is the product of elemental isotopic abundance, nuclear cross section for neutron absorption, and decay gamma ray abundance.

PROCEDURE

After the Concover columns were dried, demineralized water was poured through each column to see if any of the EPA heavy metals washed out, particularly since newspaper with printers ink was a major constituent. In fact, considerable amounts of manganese and, in some cases, cadmium, along with sodium and chlorine were detected in the demineralized water leachates using neutron activation analysis.

Then, 200ml of the heavy metal standard solution was poured through each column and collected. The heavy metal concentration for each element in the standard solution is shown in Table 1. Approximately 5 grams of the standard solution and the collected leachate from each column were pipetted into polyethlyene vials, dried, and analyzed by neutron activation analysis.

Table 1
Removal of Heavy Metals From Solution by
Landfill Cover Materials

Heavy Metal Elements	STANDARD SOLUTION	CONCOVER 180		CONCOVER 180 EC-MCH	
	Heavy Metal Concentration (ppm)	Leachate Heavy Metal Concentration (ppm)	Heavy Metal Removal Fraction	Leachate Heavy Metal Concentration (ppm)	Heavy Metal Removal Fraction
Arsenic	50	18	0.64	0	1.00
Barium	9183	0	1.00	0	1.00
Cadmium	2449	4181	-0.71	1179	0.52
Chromium	140	104	0.25	43	0.69
Copper	64	47	0.26	0	1.00
Iron	478	0	1.00	0	1.00
Manganese	23	23	0.00	19	0.17
Nickel	2388	2027	0.15	0	1.00
Selenium	55	21	0.62	15	0.73
Silver	47	31	0.35	30	0.36
Zinc	500	41	0.92	18	0.96

Two irradiations and analyses were performed. Initially, the samples were irradiated for two minutes and analyzed two hours later at which time relatively short-lived nickel and manganese nuclides were identified. Following that, the samples were irradiated for six hours and analyzed approximately one week later at which time all of the remaining heavy metals were seen.

THEORY OF NEUTRON ACTIVATION

Consider an atom of barium. If a barium atom is placed near the reactor core, one of the trillions of fission neutrons from the core will be absorbed into the nucleus of the atom.

$$_{0}n^{1} + {}_{56}Ba^{130} = {}_{56}Ba^{131}$$

After this reaction, the resultant barium isotope is radioactive. In its unstable radioactive state, the barium decays to cesium by

capturing an electron and releasing a gamma ray.

$$_{56}Ba^{131} + _{-1}e^{0} = _{55}Cs^{131} + \text{gamma (496.3 keV, 41.3\%)}$$

The gamma ray is of a specific energy (496.3 keV) that is unique to the decay of barium and acts as a fingerprint for identifying barium. Measurement of fingerprint-like gamma rays from all of the elements in an irradiated sample allows the elements within the sample to be identified.

ANALYSIS

A computer-based multichannel analyzer utilizing a germanium detector was used to detect and identify the gamma rays emitted by the radioactive samples. After the system was calibrated using a National Institute of Standards and Technology (NIST) radioactive standard, the samples were placed in turn on top of the detector. Each sample was counted for five minutes.

RESULTS

The gamma rays emitted per gram of solution for the heavy metal standard solution and leachates were compared. Of the eight mixtures, the most effective heavy metal remover was Concover 180 with a clay identified as EC-MCH added. Table 1 shows the leachate heavy metal concentrations for Concover 180 alone and for the Concover 180 with EC-MCH. A removal fraction also is provided that is the fraction of the heavy metals in the standard solution that were removed by and remained in the filtering column.

Table 1 shows that 100% of the arsenic, barium, copper, iron, and nickel were removed by the Concover 180 EC-MCH, and that the mixture was relatively effective in removing significant fractions of all the other heavy metals tested.

CONCLUSION

Concover did absorb heavy metals from a water solution and presumably would be effective in landfill waste. Concover with natural clay additives was better than Concover alone in absorbing heavy metals. Some heavy metals are absorbed better than others by Concover, and some heavy metals were washed directly out of the Concover during the leaching process, probably from the ink in the shredded newspaper.

NUCLEAR REACTOR LABORATORY
Profile of Services

Neutron Irradiation Services

In-core, pneumatic tube, and beamport irradiations with high energy (fast) and low energy (thermal) neutrons. Thermal neutron range: $8x10^6$ to $1.5x10^{13}$ n/cm^2/sec.

Neutron Activation Analysis

Identification of trace quantities of sixty-two elements including most metals and rare earth elements utilizing a technique that is almost non-destructive and requires very small sample volumes.

Gamma Irradiation Services

Gamma irradiations utilizing a large cobalt-60 source to sterilize bone and cartilage for reconstructive surgery and to study radiation effects on materials.

Neutron Radiography

Radiographic imaging of low density materials such as plastic, oil, water, and gasoline contained in heavy materials and porous media that cannot be imaged with ordinary x-rays.

Radiopharmaceutical Preparation

Production and distribution of large quantities of investigational drugs containing iodine-123, iodine-125, and iodine-131 to more than 100 hospitals throughout the United States and Canada, as well as to medical research institutions for diagnosis and therapy of adrenal gland cancer and adrenomedulla diseases.

Radiochemical Production

Preparation of bromine-82 labeled motor oil for use in engine oil economy research programs, and bromine-82 labeled toluene, argon-41, sodium-24, and lanthanum-140 for use in oil refinery flow tests.

Testing Programs

Accelerated neutron and gamma aging of reactor materials; fast neutron damage effects in reactor vessel steels; and quality assurance tests of irradiated materials including neutron attenuation properties, strength, gas evolution, radionuclide content, and changes in physical parameters.

Training

Neutron activation analysis and reactor operations laboratories for university students, advanced high school students, and electric utility engineers and reactor operators.

NUCLEAR REACTOR LABORATORY DIRECTORY

Hours of Operation:

Monday-Friday 8:00 a.m.- 5:00 p.m.

Facilities can be made available 24 hours a day, if required.

Tours: Monday-Friday 9:00 a.m. - 4:00 p.m.

Tours should be scheduled at least 48 hours in advance.

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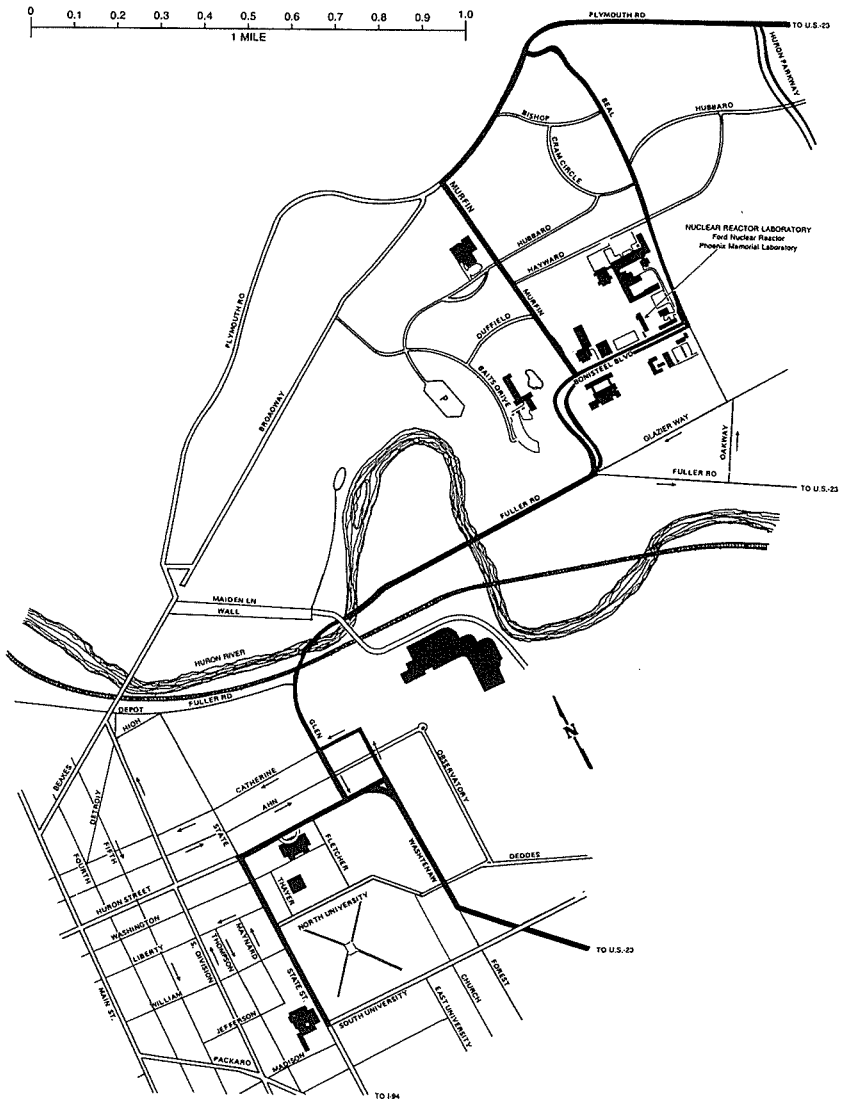

Nuclear Reactor Laboratory Location
University of Michigan Central and North Campus

The Regents of The University of Michigan:

Deane Baker, Ann Arbor;
Paul W. Brown, Mackinac Island;
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Shirley M. McFee, Battle Creek;
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