Ford Nuclear Reactor
Phoenix Memorial Laboratory

THE UNIVERSITY OF MICHIGAN
NUCLEAR REACTOR LABORATORY
QUARTERLY REVIEW

Second Year, No. 5 North Campus Winter, 1989
2301 Bonisteel Boulevard
Ann Arbor, Michigan 48109-2100

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 of the types of research in progress. Research projects started within the preceding quarter are listed first. A feature article that provides in-depth information about one particular technique or program follows. Updated descriptions of the remaining Nuclear Reactor Laboratory programs complete the Quarterly Review.

NEW RESEARCH

Physics

Professor Henry Griffin of the Chemistry Department has been working in cooperation with members of the Physics Department to develop techniques for chemical separation of sodium-22 from an aluminum matrix as a means of producing intense positron sources for positron research. The work has involved the reactor and the facility's equipment for handling radioactive materials. Radioactive sodium is produced in an aluminum matrix. The most common isotope of sodium, Na-24, has a relatively short half-life and is allowed to completely decay. Radioactive sodium-22 remains. The sodium-aluminum composite is placed in a graphite cup and heated in an oven at 700 degrees celsius for one hour. The atmosphere in the oven is helium which prevents oxidation. The aluminum and sodium melt and separate because they have different densities. Following three hours of cooling, the separated solids are immersed in water. The sodium dissolves in water and produces a liquid solution that is ready for use.

Physics

Lead fluoride has been suggested as a suitable material for a Cerenkov radiation detector for the superconducting supercollider (SSC). The current irradiations were done to examine radiation hardness of lead fluoride to fast neutrons. Professor Byron Roe of the Physics Department sponsored the irradiations for the Enrico Fermi High Energy Physics Laboratory in Illinois.

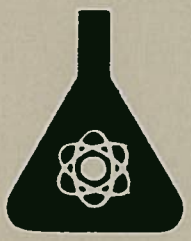
Pure samples of lead fluoride were irradiated in the reactor's pneumatic tube system. The objective was to attain fluences of approximately $1x10^{14}$ neutrons/cm^2 from neutrons with energies greater than 1 MeV. Thermal neutron activation was minimized by encapsulating the samples in boron nitride; boron has a high absorption cross section for thermal neutrons.

Physics

Barry Wissman, a graduate student working for Professor David Gidley and Dr. William Frieze of the Physics Department, irradiated sodium choloride crystals up to $1x10^9$ rads gamma to induce stresses along cleavage planes and make cleavage easier. The crystals are used as substrates for vapor deposition of thin metal films.

Chemical Engineering

Steven Blaine, a graduate student in the Chemical Engineering Department, is investigating reaction pathways in the degradation of lubricants for his Ph.D. thesis. Mr. Blaine is using the Nuclear Reactor Laboratory's neutron activation analysis capabilities to assist in measuring the amount of aldehyde buildup in lubricants. Aldehydes are oxidation products that result from the breakdown of hydrocarbon based lubricants. Samples of lubricant are treated with Tollen's Reagent which reacts with aldehydes to precipitate silver. The silver precipitate is separated and reacted with nitric acid to from an aqueous solution. The silver content of the solution is then quantified by neutron activation analysis. The silver values are used to back-calculate the amount of aldehyde in the lubricant and thus the extent of degradation of the lubricant. Mr. Blaine is working under the direction of Professor Phillip Savage.



FEATURE ARTICLE

MEASURING OIL CONSUMPTION WITH A RADIOACTIVE TRACER



Introduction

One of the services provided by the Nuclear Reactor Laboratory is the production of motor oil labelled with the radioactive isotope, bromine-82. Labelled motor oil is used by the General Motors Research Chemistry Laboratories to characterize automobile engine oil consumption.

Background

A major goal of automobile engine design, along with performance and fuel efficiency, is durability. One measure of durability is engine wear which, in turn, is measured by the amount of oil consumed in a running engine. Oil consumption measurements also are helpful in evaluating changes in design and materials in piston rings, cylinder walls, intake and exhaust valves, and valve guides.

In addition, the ability to accurately measure oil consumption is important in pinpointing potential operating problems. Excessive oil consumption causes spark plug fouling and carbon build-up within an engine's combustion chambers. That leads to poor engine performance, lowered fuel economy, and increased emissions. Left unchecked, these conditions can cause damage to the catalytic converter from the high temperatures generated in oxidizing unburned hydrocarbons. Engine damage caused by preignition or knocking and engine run-on, commonly known as dieseling, may also result.

Motor oil is consumed through three major pathways by operating engines. Oil is lost past the piston seal rings, past the intake and exhaust valve guide seals, and through the positive crankcase ventilation (PCV) system. All three pathways lead to the combustion chambers. As a result, minute amounts of motor oil are always burned along with fuel. Engine testing with a radioactive tracer in the motor oil allows the oil consumption through these pathways to be measured under various conditions of engine load and wear.

Labelling the Oil

The tracer labelled oil used by General Motors is prepared by the Nuclear Reactor Laboratory. Producing oil labelled with bromine-82 is a multi-step process that involves bromine preparation, irradiation in the reactor, chemical synthesis, and mixing the newly created bromine compound with motor oil.

Because of the highly volatile and reactive nature of elemental bromine, special precautions are taken in preparing it for irradiation in the nuclear reactor. For each batch of labelled oil, approximately 0.5 cubic centimeters of reagent grade bromine are first sealed in a high purity quartz vial. The sealed quartz vial is wrapped in aluminum foil and enclosed in a secondary capsule made of a steel pipe sealed with threaded end caps. If the quartz vial accidently breaks, the bromine released will react with the aluminum and be confined within the steel capsule as aluminum bromide. The steel capsule provides the integrity necessary to resist any forces generated from a bromine-aluminum reaction and prevents damage to the reactor during irradiation.

From the time shortly after the bromine capsule is inserted into the reactor until the time the oil is labelled, the capsule and the bromine are too radioactive to be handled directly by technicians. As a result, handling and processing are performed remotely.

The sealed pipe is irradiated in the reactor for approximately six hours. During the irradiation, a fraction amounting to only a few millionths of the total bromine atoms present becomes radioactive. However, this amounts to about 1×10^{16} radioactive bromine atoms which are sufficient to act as a tracer. The remaining non-radioactive bromine acts as a carrier.

Two radioactive bromine isotopes are produced during irradiation; each in a metastable (m) and ground (g) state. The isotopes are Br-80m, Br-80g, Br-82m, and Br-82g. The isotope used as the tracer in motor oil is Br-82g . The presence of the other isotopes does not create a problem because their half-lives are significantly shorter than 35.4 hour half-life of Br-82g. The capsule is kept in the reactor pool after irradiation for two to three days before any further processing to allow time for all isotopes except Br-82g to decay.

After the short lived isotopes have decayed away, the capsule is transferred to a shielded room called a hot cell. The hot cell acts as a giant hood that provides radiation shielding and physical protection from the bromine during the chemical synthesis. At this point, about 200 millicuries of Br-82g remain. They are used to produce 1,2-dibromooctadecane, the compound used to label the oil. The reagents needed to produce the compound are the irradiated bromine, 1-octadecene, and carbontetrachloride. The carbontetrachloride does not participate in the reaction but is mixed with the 1-octadecene to maintain the solution in a liquid state during the next phase.

Once the capsule is in the hot cell, it is immersed in liquid nitrogen to freeze the bromine. When the bromine has frozen, the capsule is opened. The quartz vial is removed and inserted into a stainless steel beaker with a premixed 1-octadecene and carbontetrachloride solution. The beaker is then placed under a pneumatically operated ram which crushes the quartz vial. As the bromine thaws it reacts with the 1-octadecene to form 1,2-dibromooctadecane. The reaction binds the bromine; thus, its chemical reactivity and volatility are no longer of concern.

The solution that results from the synthesis has a volume of about 50 milliliters. It is filtered to remove the broken quartz. About 150 millicuries of the solution are added to 200 milliliters of motor oil. The 1,2-dibromooctadecane solution is soluble in motor oil, so a uniform concentration of radioactive bromine is obtained. Labelling the oil is complete at this point. The labelled oil is packaged in a shielded container which is then shipped to the user.

The Engine Setup

Before testing can begin, the engine is set up in an engine test cell. The test cell used by General Motors is located at their Research Chemistry Laboratory in Warren, Michigan. This particular test cell is specially designed for testing engines with radioactive tracers. Among its features is a dilution stack that mixes the exhaust of an engine being tested with a large volume of fresh air before the exhaust is released from the laboratory. The large dilution factor keeps radioactive bromine released to the environment well below the permissible concentrations allowed by the U. S. Nuclear Regulatory Commission.

Inside the cell, the engine is set up on a test stand and connected to a dynamometer. The dynamometer gives the engineers the ability to run the engine under various conditions of load and speed and lets them monitor parameters such as horsepower, torque, coolant temperature and fuel consumption. The engine's exhaust is routed to a wye valve that selects where the exhaust is directed. It can be sent directly to the dilution stack or it can be diverted through a column containing a sodium hydroxide solution.

Before testing can begin, the bromine labelled oil is mixed with the rest of the oil needed by the engine and loaded into the crankcase. The engine is run for about thirty minutes under a light load to warm it up to operating temperature and to ensure that the bromine is homogeneously distributed throughout the oil.

Measuring Oil Consumption

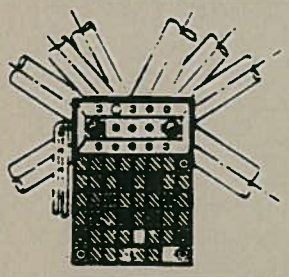
The combustion products of the ordinary burned oil are essentially identical with those of burned fuel and cannot be readily distinguished. When bromine labelled motor oil is burned in an engine, however, small quantities of hydrogenbromide (HBr) are expelled with the exhaust gasses. HBr is stripped from the exhaust by bubbling it through the column containing a one molar solution of sodium hydroxide. The amount of oil burned can be determined by quantifying the bromine collected from the exhaust.

The amount of HBr in the exhaust is too small to be measured reliably by ordinary physical or chemical means, which is where the radioisotope labelling comes into play. Bromine in very small quantities can be accurately measured even if only a small fraction of the total bromine is the radioactive isotope Br-82g.

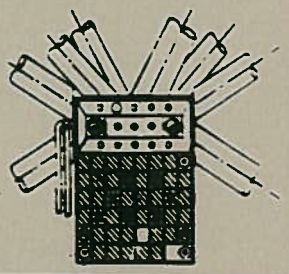
Both conceptually and in practice, the process is quite straight forward. An oil sample taken from the engine is put in a sodium iodide well type gamma-ray detector. The detector counts the gamma-rays emitted from the radioactive Br-82g in the oil. Based on this measurement, a specific activity of gamma-rays per second per milliliter of oil is calculated. Samples collected from the exhaust are counted using the same detector arrangement. The number of gamma-rays per second counted in the exhaust sample is divided by the total time the sample was collected. The resulting number, with the units gamma-rays per second per minute of engine operation, is divided by the specific activity of the oil. The resulting value is the oil consumption in milliliters per minute.

A recent test provides a good example of how the technique is applied. One of the ways automotive emissions are minimized is the positive crankcase ventilation system. When an engine is running, a small amount of fuel and exhaust called blow-by escapes from the cylinders past the piston rings and valve seals. The blow-by tends to have atomized oil mixed with it that has been thrown from moving parts within the engine. The PCV system scavenges the blow-by from the crankcase and valve covers and directs it back through the intake manifold to be burned. Typical stamped metal valve covers have baffles welded inside that separate oil from the blow-by before it vents to the PCV system. But, one of GM's new engines has a cast aluminum valve cover. It was impractical to use baffles on this cover because of the increased tooling and production costs that would be incurred. Therefore, as an alternative, various oil traps were designed that could be placed in the PCV line coming from the valve cover.

The engine was tested with the different prototype traps installed, with no trap, and with the PCV line disconnected. The oil consumption data that was obtained allowed GM engineers to determine how much oil was traveling through the valve cover vent. They also found which trap design was most effective at separating this oil from blow-by as it returned to the intake manifold.



FORD NUCLEAR REACTOR



The Ford Nuclear Reactor typically operates at full power, two megawatts, for ten days followed by four days of shutdown for maintenance. At full power, typical values of reactor neutron fluxes and gamma dose rates at experiment locations around the core are:

Thermal Neutron Flux ($n/cm^2/s$).....$1x10^{13}$
Fast Neutron Flux > 1 MeV ($n/cm^2/s$).....$3x10^{12}$
Gamma Dose Rate (rad/hr).....$6x10^7$

Much of the reactor utilization within the university of Michigan comes from the Nuclear Engineering Department, primarily because of laboratories and long term neutron beam experiments that involve continuous use of the reactor for gathering data. The Chemistry Department is also a regular user. A number of other departments use the facility for special projects.

The reactor is heavily utilized by other colleges and Universities, and for industrial research. Several other schools send chemistry, physics, and engineering classes for reactor and neutron activation analysis training laboratories. Neutron and gamma ray damage studies on materials such as vessel steels, neutron shield composites, and electric cable insulation used in power reactor construction are a major industrial research application.

Chemistry

Professor Henry C. Griffin is collaborating with Professor K. Rengan of Eastern Michigan University in setting up and utilizing a gas-jet system for collecting uranium-235 fission products at D beamport. the system is designed for the collection and study of low atomic mass (less than 120) fission products with half-lives as short as 0.2 second. Current studies emphasize isotopes of bromine, krypton, and selenium.

By irradiating high purity nickel oxide (NiO) in the reactor and chemically purifying the products, Professor Griffin has prepared extremely pure samples of nickel that contain radioactive nickel-65. These samples were used in a search for low intensity gamma rays; preliminary results indicate that about 3 gammas of 2094 keV are emitted in one million decays.

Under the sponsorship of Ann Arbor Nuclear, Professor Adon A. Gordus has been carrying out a research program on the production of titanium trichloride from titanium tetrachloride using radiation. The object of the work is to produce high grade chemical energy from low grade radiation energy. The project has used both the reactor and the facility's cobalt-60 irradiator.

Nuclear Engineering

The largest departmental research commitment at the Laboratory facilities is maintained by the Department of Nuclear Engineering. During 1987-1988, this department used the laboratory and reactor for ten formal University courses and conducted extensive, on-going research projects in the areas of neutron spectroscopy, radiation effects in materials, development of low enrichment uranium reactor fuel for research and test reactors, and cross section measurements.

Under the neutron spectroscopy program directed by Professor John S. King, a wide angle, two-circle, powder diffraction spectrometer has been modified for utilization as a fully computerized, single crystal, four-circle diffractometer. Recent studies have involved powder diffraction on order-disorder alloys. A change in the powder diffraction pattern is expected in association with heat treated metal alloys.

Under sponsorship by the U.S. Department of Energy, Professor Glenn F. Knoll directs the cross section measurements activities. This is a large project involving the absolute measurement of fast fission and capture cross sections of several different isotopes. The reactor is used to irradiate sodium, gallium, and antimony sources to produce activities ranging from 10 to 40 curies each. These gamma sources are then coupled with targets of deuterium or beryllium to produce monoenergetic neutrons. Current work is focused on the measurement of neutron capture cross sections in uranium-238 and in thorium-232.

Professor Knoll also investigated a new type of neutron deteector. Tests consisted of placing samples of several different scintillation materials in a neutron beam to measure detection efficiency and pulse height spectra. The samples consisted of dispersions of small glass microshells (about 100 micron diameter) in plastic scintillators. The shell walls were about 1 mircron thick. Helium-3 gas was trapped inside the microshells at high pressure. Protons produced in the neutron-induced reaction in the helium pass through the shell walls and create light pulses in the scintillator.

Professor David Wehe supervised students who used the reactor for projects involving response of rhodium self-powered neutron detectors in steadily changing fluxes, in gamma ray spectroscopy, and in two dimensional radiation imaging of one of the reactor demineralizers.

Professor Wehe and a nuclear engineering student, Jim Fox, performed fast flux measurements in the reactor's vertical neutron beam tube. The fast flux will ultimately be used to test proton recoil detectors. Neutron flux was measured by neutron activation of cadmium covered indium and nickel foils.

In addition, the Department of Nuclear Engineering used the Nuclear Reactor Laboratory facilities for tours, classes, laboratories, and preparation of radioactive sources associated with the following courses:

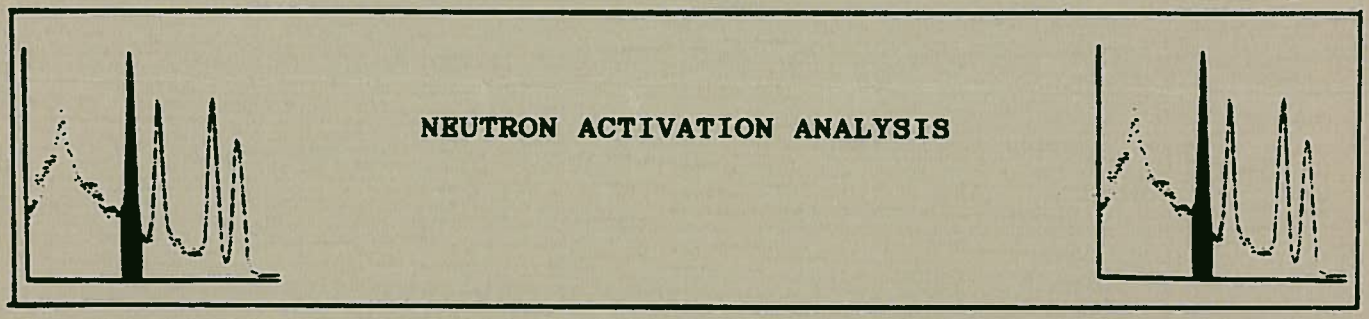
Nuclear Engineering 100	Nuclear Energy in Modern Society
Nuclear Engineering 311/312	Elements of Nuclear Engineering
Nuclear Engineering 315	Nuclear Instrumentation Laboratory
Nuclear Engineering 400	Elements of Nuclear Energy
Nuclear Engineering 445	Nuclear Reactor Laboratory
Nuclear Engineering 499	Research in Nuclear Engineering
Nuclear Engineering 515	Nuclear Measurements Laboratory

Physics

Professor Joachim Janecke used the reactor to produce radioactive argon-41 for calibration of a Physics Department beta particle detector.

Professors Michael Bretz and Ctirad Uher are investigating the use of high energy neutron irradiation effects to produce room-temperature superconductors in ceramic materials. Current interest is centered on yttrium(1) - barium(2) - copper(3) oxide compacts.

Mr. Joseph Rogers, a graduate student working under the direction of Dr. William E. Frieze and Professor Arthur Rich, has begun irradiation of high purity nickel to establish the potential of nickel as a positron source. When nickel-58 absorbs high energy neutrons in the reactor core, cobalt-58 is produced. Cobalt-58 is a positron emitter. Major problems associated with nickel as a positron source are high levels of radioactive interference from cobalt isotopes other than cobalt-58 that occur as a result of nickel activation and depletion of the cobalt-58 itself by thermal neutron absorption.



Neutron activation analysis is an analytical technique for identifying and measuring trace quantities of a large number of elements in many types of materials. Sixty-seven common and rare earth elements become radioactive when exposed to the neutron flux in a reactor. The subsequent radiation emitted by the decay of activated nuclei is different for each element and its measurement permits identification. Of the 67 radioactive elements, over 50 can be identified and measured quite readily. The method permits measurement of all detectable elements simultaneously; it is rapid and non-destructive.

Table 1 Neutron Activation Analysis Elements

Aluminum	Dysprosium	Lanthanum	Praseodymium	Terbium
Antimony	Erbium	Lutetium	Rhenium	Thulium
Argon	Europium	Magnesium	Rhodium	Thorium
Arsenic	Gadolinium	Manganese	Rubidium	Tin
Barium	Gallium	Mercury	Ruthenium	Titanium
Bromine	Germanium	Molybdenum	Samarium	Tungsten
Cadmium	Gold	Neodymium	Scandium	Uranium
Calcium	Hafnium	Nickel	Selenium	Vanadium
Cerium	Holmium	Niobium	Silver	Xenon
Cesium	Indium	Osmium	Sodium	Ytterbium
Chlorine	Iodine	Palladium	Strontium	Yttrium
Chromium	Iridium	Platinum	Tantalum	Zinc
Cobalt	Iron	Potassium	Tellurium	Zirconium
Copper	Krypton			

The highly sensitive analytical technique of neutron activation analysis is available as a service performed by the laboratory staff. Alternatively, it can be performed directly by investigators using the laboratory's facilities. In addition, samples can be irradiated and returned to users so that they may perform their own analyses on their own equipment.

The Nuclear Reactor Laboratory has two primary analysis systems: (1) Nuclear Data 6660 - a single user system capable of simultaneously analyzing many parameters associated with a single experiment and (2) Nuclear Data 6700 - a multi-user system which can receive inputs from many detectors associated with many experiments, but can analyze only a single parameter associated with any experiment.

There are practical limits to neutron activation analysis. A number of elements are relatively insensitive to neutron absorption. Calcium is an example. Others, such as rhodium, decay rapidly and make the analysis that follows activation difficult. For other elements including argon, boron, holmium, krypton, lithium, neon, oxygen, silicon, sulfur, thalium, and xenon, techniques such as chemical concentration, filtration, special encapsulation, and special irradiation methods are necessary to perform neutron activation analysis.

Biology

Professor Wayne Frasch used neutron activation analysis to determine the manganese content of proteins associated with photosynthesis in plants.

Professor Peter Kaufman, in an on-going program, analyzed hundreds of leaf samples from various cultivars of rice plants by neutron activation analysis for silicon uptake. The program seeks the relationship between silicon uptake and photosynthetic productivity.

Chemical Engineering

Amit Sachdev, under the direction of Professor Johannes W. Schwank, performed neutron activation analysis of platinum-tin bimetallic catalysts.

An alumina supported platinum-tin system is used in the petroleum industry as a reforming catalyst (i.e., in the production of aromatic and cyclical hydrocarbon compounds from a crude oil feed). The relative amounts of platinum and tin can affect the microstructure of the metal particles in the catalyst, which in turn can influence the product distribution, stability, and activity of the system. A small amount of chlorine, which is always present in the catalyst as a remnant of the preparation procedure, can also alter the product distribution towards isomeric compounds.

Neutron activation analysis enables the determination of an accurate value of the bulk composition of the catalyst. This information is crucial in the quantitative analysis of the various characterization techniques used to understand the catalyst mechanism. Also, it is of interest to compare the amount of these elements present in the bulk with that of surface compositions determined by other methods.

Chemistry

Professor Adon A. Gordus used neutron activation analysis to determine the yield of alkali elements reduced from alkaline chloride solutions by gamma induced radiolysis. The research is directed at finding suitable compounds for direct conversion of electromagnetic radiation (gamma radiation) into chemical potential energy.

Neutron activation analysis was performed on metal rubbings from ancient and medieval coins by Professor Gordus to determine elemental content. This can provide information about the origin of the coins, the contained metals, and the cultures associated with them.

Neutron activation analysis also was performed by Professor Gordus on hair samples to obtain information on body chemistry and the impact of environmental pollution on hair chemistry.

Dr. Richard Fronko, a research fellow in the Chemistry Department, in association with Professor James Penner-Hahn, utilized neutron activation analysis to determine manganese content in Mn-Catalase protein. The analysis was used to help characterize Mn-Catalase. The goal of Dr. Fronko's research was to describe the structure of the Mn-Catalase protein.

Ms. Lorraine Yu, under the direction of Professor A.H. Francis, is investigating the physical properties of semi-conductor materials for her Doctoral thesis. Transition element impurities are known to change the physical properties of semi-conductor materials. Ms. Yu is using neutron activation analysis to determine the concentrations of various transition elements in crystals of SnS_2 and $CdPS_3$ semi-conductor. The crystals, some of which are doped with transition elements, are grown in Ms. Yu's laboratory. The types and levels of impurities will be related to changes observed in physical properties such as conductivity of the semi-conductors.

Geological Sciences

Annette Olivarez and Professor Robert M. Owen studied the trace and rare earth element content of Eolian sediments using activation analysis as part of her doctoral research.

Mr. Andrew Zimmerman, a graduate student in Geological Sciences working under the direction of Professor Robert M. Owen, is using instrumental neutron activation analysis to investigate the geochemistry of marine sediments from the Indian Ocean basin to establish their geological history. This study is a part of Mr. Zimmerman's doctoral research.

Medical School - Biological Chemistry

Dr. William Epperly, as part of research funded by the National Institutes of Health, had activation analysis performed on samples of the enzyme, threonine dehydrogenase. It is believed that the enzyme requires bound metallic ions such as zinc for it to function as a metabolic agent. The analysis will be used to help characterize threonine dehydrogenase by providing qualitative and quantitative information on the metals present in the enzyme.

Ms. Sonya Roman is studying the concentration of platinum in the ear and in kidneys that is a side effect of the administration of the cancer treatment drug, cisdiaminedichloroplatinum. Elevated levels of platinum in the cochlea of the inner ear and in the kidneys are known to cause both hearing loss and kidney damage. Neutron activation analysis is being used by Ms. Roman to determine the platinum uptake in the cochlea and in kidneys of guinea pigs as a function of dosages of cisdiaminedichloroplatinum. Ms. Roman is a Biological Chemistry Department doctoral student under the direction or Dr. Jochen Schacht.

Medical School - Pediatric Cardiology

Quantative analyses for aluminum in laboratory animal pericardium tissue using neutron activation are being performed for Dr. Catherine Webb, Department of Pediatric Cardiology. Calcification of pericardium tissue is a major problem affecting the longevity of artificial heart valve implants in children. Aluminum is known to inhibit calcification. The analyses are being used to find the level of aluminum in pericardium tissue that will inhibit calcification thus leading to development of longer lasting artificial heart valves.

Medical School - Pediatric Surgery

An extensive project using neutron activation analysis to compare trace element levels in the blood of normal newborns, premature newborns, and newborns that had required intravenous feeding during their first weeks had been ongoing for several years. The project, under the direction of Dr. John Wesley and Robert Drongowski, Pediatric Surgery, sought the trace element nutritional requirements of newborns and relationships between trace element levels and premature birth. Unfortunately, because of the small sizes of the blood samples and the minute levels of most important trace elements, the investigation has not produced useful results.

Medical School - Pharmacology

Soheil Meshinchi and Dr. William B. Pratt utilized neutron activation analysis to determine molybdate concentrations in tissue samples. Molybdates may inhibit receptor dissociation in cells and subsequent entrance into cell nuclei.

Nuclear Engineering

The Nuclear Engineering Department utilized the Laboratory's gamma energy spectroscopy facilities for two formal courses. The NE 445, Reactor Laboratory, under Professor John King performed activation analysis on bare and cadmium shielded iron wires in order to characterize the axial neutron flux of the Ford Nuclear Reactor. NE 499, Research in Nuclear Engineering, taught by Professor Dietrich Vincent, performed two experiments using the Laboratory's spectroscopy facilities. One experiment was performed to familiarize students with qualitative and quantivative analysis utilizing gamma ray induced x-ray fluorescence. The second experiment determined the diffusivity of gold in copper by neutron activation analysis of sections of a copper ingot into which gold had been diffused.

Physics

Professor Joachim Janecke has performed neutron activation analysis of osmium and rhenium solutions that are used in chemical deposition processes of these elements. Before and after deposition solutions were analyzed to measure the magnitude of the deposits.

Professor Ronald Clark used neutron activation analysis to measure the degree of intercalation of elemental cesium, potassium, and rubidium into graphite.



COBALT-60 IRRADIATION SOURCE



The cobalt-60 source of approximately 10,000 curies is available for gamma irradiations. Typical applications include sterilization of bone and cartilage for human grafts and transplants; sterilization of animal food for germ-free animal colonies; studies of radiation effects on mutation of cells, chemical systems, electronic and reactor components, food, seeds, and plants.

The peak dose rate at the center of the source is about 1.5×10^6 rad/hour. Typical dose rates at distances near 25 centimeters from the source are of the order of 100,000 rad/hour and typical sterilization doses are 2×10^6 rad.

Biology

Professor John Pringle is advising a graduate student who is observing the mutagenesis of S-Cerevisiae yeast cells by gamma radiation.

Professor Alfred Sussman irradiated oat, soybean, and corn seeds from low to high gamma doses for use in class projects for course Biology 301.

Chemical Engineering

Professor Dale Briggs and a graduate student, Steven Roeder, is investigating coal liquification. A liquid slurry of coal is irradiated in a sealed container at elevated temperature in the center well of the Cobalt-60 irradiator. Radiation acts as a catalyst to promote total liquification of the slurry.

Chemistry

Professor Adon A. Gordus is working in collaboration with Ann Arbor Nuclear on an extensive, ongoing project that involves conversion of low grade radiation energy to high grade chemical energy. A solution of liquid titanium tetrachloride is pumped in a closed system past the cobalt-60 irradiator. Some of the tetrachloride is converted to trichloride. The titanium trichloride can be extracted. It can be made to react exothermally to provide concentrated chemical energy.

In related work, graduate students are testing other chlorine compounds including cesium tetrachloride, tin dichloride, and zirconium tetrachloride.

Dr. Gordus is sponsoring another graduate student in a coal liquification project. A coal-cyclohexane solution is irradiated at ambient temperature. Hydrogen transfers from the cyclohexane to the coal. This assists in coal liquification during subsequent processing.

Professor Paul G. Rasmussen is sponsoring a graduate student on a project involving solid-state polymerization of dicyanomidazole by gamma ray radiation.

Mechanical Engineering

Dr. Massoud Kaviany is sponsoring a graduate student who is irradiating porous stainless steel blocks to determine the amount of ethanol present. The volume of ethanol can be determined using gamma attenuation data. These blocks will be used as wicks in a combuster.

Medical School - Internal Medicine/Gastroenterology

Cell sterilizations are performed for Professor Tadataka Yamada on a regular basis for studies involving collagenase.

School of Public Health - Epidemiology

Professor G. I. Higashi is conducting an ongoing test program involving schistosomiasis cercariae in an attempt to develop a live vaccine.

University Hospital - Pediatrics

Dr. Madhavan Nair sponsors a graduate student who is using HIV^+ serum in research involving killing assay work. Co-60 irradiation is used as a second method of inactivation of the serum which has been heat inactivated prior to irradiation.

University Hospital - Plastic and Reconstructive Surgery

Dr. Jeffrey Kyllo irradiated human cartilage for implantation in human reconstructive surgery.

University of Michigan Dearborn - Natural Sciences

Professor Miriam Zolan of the Biology Department irradiates cell cultures to various gamma doses for a study involving radiation repair and meiosis of coprinus cinereus, an ashen colored spore found on the underside of mushroom caps. Meiosis is the process used by eukaryotic organisms to produce gametes, specialized cells with half the normal complement of chromosomes that combine in sexual reproduction to create new, genetically unique individuals.

Professor Zolan is studying the molecular regulation of meiosis. She has isolated several mutant strains of coprinus cinereus that cannot repair cell damage from radiation. Two of these mutant strains also have defects in meiosis, suggesting that the two processes are linked.

Currently she is working to locate the defective gene or genes that give these mutant strains their radiation sensitivity. Once she identifies the gene, she plans to clone the gene and use it to study the genetic and biochemical control mechanisms of meiosis. She also can produce large quantities of the protein produced by the cloned gene. These biochemical tools will permit her to trace the gene's expression and its role in meiosis.



NEUTRON RADIOGRAPHY



Neutron radiography is analogous to x-ray radiography in that a beam of radiation is used to create images, generally on film. Images are formed by placing objects in the beam that alter the intensity of radiation reaching the film.

Neutron radiography can be used to complement x-ray radiography. X-rays interact with electrons in matter. The heavier the element, the larger the number of electrons around the nucleus, and the greater the amount of x-ray attenuation. While x-rays will easily penetrate light materials such as water, oil, and human tissue, they are readily absorbed by heavier materials such as aluminum, iron, and lead.

Neutrons interact with the nuclei of atoms. The effect on neutrons of a specific atom is not as predictable as is the effect

on x-rays. If a general rule can be made for neutrons, it is that lighter elements tend to stop them, and they more easily penetrate heavier elements. There are many exceptions to the rule. Cadmium, gadolinium, hafnium, indium, and silver are all relatively heavy elements, and they also are excellent neutron absorbers. From an imaging point of view, neutrons tend to act just the opposite of x-rays.

Neutrons are uniquely suitable for imaging many heavy materials and for imaging light materials within heavy materials. Paint within a metal can, oil inside a steel pipe, and polyethylene imbedded in lead cannot be seen by taking and an x-ray radiograph. All three can easily be imaged using neutron radiography.

Chemical Engineering

Professor Scott Fogler, Chairman, Chemical Engineering, used Real Time Neutron Radiography (RTNR) to study flow through porous media. Water and oil flow through porous sandstone, water replacing oil, oil replacing water, gas replacing water, and water replacing gas in porous sandstone have been observed. RTNR was also used to image acidizing of sandstone and the injection of woods metal into the acidized structure. These experiments model oil recovery methods and techniques.

Civil Engineering

Professor Steven Wright has used real time neutron radiography to study water flow through soil. His interest is primarily in the progression of contaminants into a water system.

Nuclear Engineering

The vertical neutron radiography port was utilized by Professor Dietrich Vincent for cross section measurements as part of course NE425, Nuclear Materials Laboratory.



RADIOPHARMACEUTICAL PRODUCTION



Two radioiodine compounds, NP-59 and MIBG-diagnostic, are produced regularly by the radiopharmaceutical program at the Nuclear Reactor Laboratory.

NP-59, a derivative of cholesterol, is an adrenal scanning agent used in the detection of abnormalities in the adrenal gland. NP-59 is synthesized monthly for distribution within and outside the University.

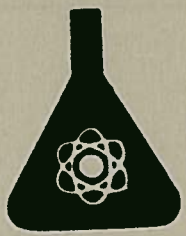
MIBG-diagnostic, a radioiodinated analog of guanethidine, an antihypertensive drug, is an adrenal medulla scanning agent used in the detection of disease in the adrenomedulla. MIBG is synthesized twice monthly for distribution within and outside the University.

Radiopharmaceutical Production Summary

Diagnostic radiopharmaceutical samples are produced four times monthly and shipped to 136 hospitals in 34 states, the District of Columbia, and Puerto Rico in the United States and 12 hospitals in three provinces in Canada. Larger quantities of radioiodine compounds are produced as therapeutic radiopharmaceuticals for use in hospitals in Michigan and Pennsylvania.



RADIOCHEMICAL PRODUCTION



Preparation of radioisotopes for research is performed at the Laboratory. Elemental bromine-82 is produced by irradiating liquid bromine in the reactor. The radioactive bromine is combined with motor oil and used in engine wear tests. Currently, engine wear tests using brominated motor oil are being conducted on the General Motors Saturn engine.

NUCLEAR REACTOR LABORATORY

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

Mondays-Friday 9:00 a.m.-4:00 p.m.
Tours should be scheduled at least 24 hours in advance.

Telephone Numbers

Director	William Kerr	(313) 764-6213
Manager	Reed Robert Burn	764-6224
Assistant Manager, Operations	Gary M. Cook	764-6222
Assistant Manager, Research Neutron Activation Analysis Radiation Damage Studies Radiochemical Production	Philip A. Simpson	764-6221
Senior Research Associate Neutron Radiography	John T. Lindsay	936-1583
Research Associate Cobalt-60 Sterilization Radioisotope Preparation	Robert B. Blackburn	936-1582
Information and Tours		764-6220 764-6223

Further information and assistance can be obtained by calling any of the staff members listed above.