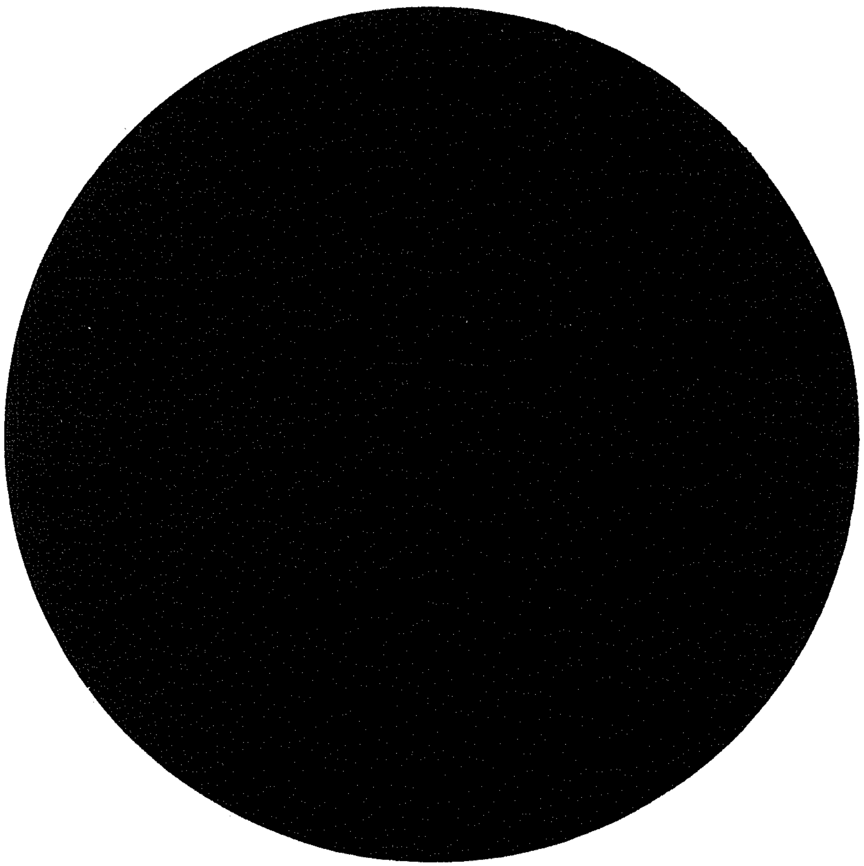
Phoenix Memorial Laboratory
and Ford Nuclear Reactor

RADIATION SERVICES



Michigan Memorial–Phoenix Project • The University of Michigan
Ann Arbor, Michigan

phoenix project laboratories

The Phoenix Memorial Laboratory is located on the University of Michigan's North Campus. The laboratory, completed in 1955, houses a cobalt-60 source, two hot caves, and laboratories equipped for isotope research in physics, chemistry, and biology. Special facilities include x-ray rooms, animal rooms, an aquarium room, and a greenhouse. The building also includes an AEC depository library and such research supporting services as a machine shop, an electronics shop, and photographic darkrooms.

Adjoining the Phoenix Memorial Laboratory is the Ford Nuclear Reactor, an open-pool research reactor. The FNR first went critical in 1957. In 1958, routine operation at 1 megawatt was initiated. In August, 1963, the power level was raised to 2 megawatts.

The primary purpose of these laboratories is to provide University faculty with the special facilities needed for nuclear energy research and teaching. In addition, the facilities and services of the laboratories are available for use by other schools, industry, and by hospitals.

research services

Isotope Preparation:

The laboratories provide custom labelling and preparation of short-lived radioisotopes. They are prepared on demand for medical and industrial research.

Neutron Irradiation:

The Ford Nuclear Reactor provides three main methods of neutron irradiation—beam ports, pneumatic tubes, and in-pool immersion. These methods may be used to irradiate experimental materials—such as chemical systems, fabricated machine parts, electronic components, and biological materials—that are compatible with safety and size limitations.

Activation Analysis:

The highly sensitive analytical technique of neutron activation analysis is available, either as a service performed by laboratory staff or to be performed by research groups using the laboratory's facilities.

Gamma Irradiation:

Two cobalt-60 sources, one of 4,000 curies and one of 5 curies for low level exposures, allow gamma irradiation of most types of material.

Neutron Radiography:

The use of neutron beams for nondestructive visualization of the interior of solid objects is relatively new. Services are available through an experimental facility operated by the Department of Nuclear Engineering.

Hot-Materials Handling and Storage:

The laboratory's hot caves are designed for remote manipulation, examination and limited machining of highly radioactive material. Wall ports are available for storage.

Consulting and Advisory Service:

Consultation on problems concerned with the use and handling of radioactive materials is available from the Project staff. This service covers such questions as choice of irradiation method, handling precautions, advice on special equipment necessary, and feasibility studies. Problems requiring extensive study may be handled as part of sponsored research contracts.

research services

How To Apply For Services

The services and facilities of the Phoenix Project laboratories are available to University research groups, University graduate students working on faculty-approved research, research groups at other universities and colleges, industrial research groups, and to hospitals.

Priority is given to University research and teaching, but space and facilities for outside research projects are generally available. The Phoenix Project will schedule exclusive use of its facilities for a non-University project, provided there is no interference with University research.

Requests for services should be sent to the Director, Michigan Memorial–Phoenix Project, Phoenix Memorial Laboratory, The University of Michigan, Ann Arbor, Michigan 48105. The telephone number is 313/764-6213.

Requests containing detailed information about a proposed experiment can be reviewed promptly. A preliminary contact can often provide the guidance necessary to expedite the conduct of the experiment or service.

Service Charges:

Fixed rate schedules for academic and industrial research are available. Projects should be discussed with a staff member to determine the appropriate rates.

General Regulations

The receipt, handling, and shipment of all radioactive materials are governed by regulations of the United States Atomic Energy Commission, the Department of Transportation, the Civil Aeronautics Board, and, in some states, e.g., Michigan, by state laws.

Radioactive materials shipped to the Phoenix Laboratory must conform to these regulations. Specific information can be found in the *Code of Federal Regulations, Title 49 — Transportation.* This booklet can be obtained from the Superintendent of Documents, Washington, D.C. Preliminary advice is available from staff.

Materials that have been irradiated in the reactor can be returned to the experimenter only in compliance with the regulations specified in Title 10, Part 30, of *The Federal Register*, entitled "Rules of General Applicability to Licensing of By-Product Material." Information can be secured from the Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545.

isotope preparation

Custom labelling and the preparation of short-lived radioisotopes are available for medical and industrial research.

Examples of Current Production:

^{18}F (1.83 hour half-life) sterile, carrier free—positron emitter (511 Kev gamma):

Prepared in approximately 4% saline solution in batch quantities of 10 mCi. This material has been used principally for tumor localization studies in bone and to help locate hairline fractures.

^{99m}Tc (6.0 hour half-life) sterile, produced by solvent extraction—(140 Kev gamma):

Prepared with a specific concentration greater than 20 mCi/cc. ^{99}Mo contamination less than 10^{-4}% of technetium activity. This material is supplied in 0.9% saline solution. It has been used as a scanning agent in nuclear medicine, particularly for brain scans and thyroid studies. The high specific concentration makes it ideal for circulatory studies. Unlike ^{99m}Tc produced by alumina generator systems, traces of aluminum are not present in the product, making it ideal for labelling procedures. The 140 Kev gamma emission and the absence of significant beta radiation suggests possible use of this material as a portable "x-ray" source for industrial uses in addition to the well-known medical uses.

^{99m}Tc-Albumin:

This material, which is used for lung scanning and placenta localization studies, is prepared by an electrolytic method using human serum albumin. The ^{99m}Tc is firmly bound to the albumin with less than 5% unbound ^{99m}Tc.

Industrial Special Preparations and Services:

^{82}Br Labelled Motor Oil:

This material is useful for oil economy tests performed by car manufacturers and the piston ring industry.

Special Counting Equipment:

The laboratory has special equipment for measuring radioactivity. This includes:

- —a 4096 channel pulse height analyzer with a high resolution Li-drifted germanium detector for gamma ray spectroscopy;
- —an automatic liquid scintillation counter with a 100 sample capacity used for beta counting and Cerenkov counting;
- —a radiochromatogram scanner which can be used with either paper chromatograms or thin layer chromatography strips, used to determine radio-chemical purity;
- —an ionization chamber isotope calibrator for routine calibration of radioisotopes used in medical applications.

gamma irradiation

Cobalt-60 Sources

The Phoenix Project has a 4,000 curie cobalt-60 source in the Phoenix Memorial Laboratory. This source is made of encapsulated cobalt-60 slugs arranged in a cylindrical configuration. Targets normally are placed around the source and in the annulus formed by the cobalt slugs.

Gamma irradiation is used for:

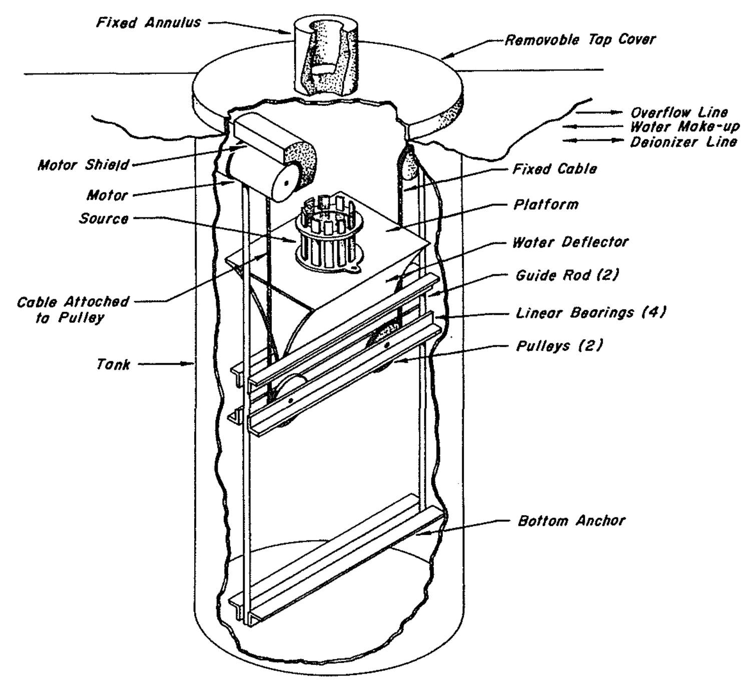
- —sterilization of bones and cartilage for human grafts;
- —sterilization of animal food for germ-free animal colonies;
- —radiation-pasteurization of food;
- —studies of radiation effects on chemical systems, electronic components, biological material, animal populations, and crystals;
- —irradiation of seeds and plants to change growth and develop mutants.

The Project also has a small 5 curie source for low level exposures such as those used in animal studies.

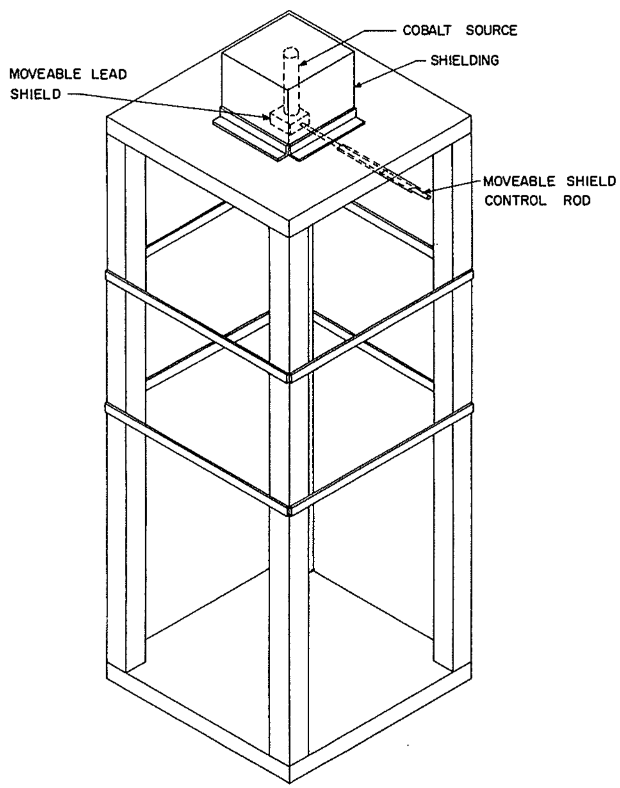
4,000 Curie Source Data:

Radiations	Gamma 1.17, 1.33 Mev
Source Strength (March, 1971)	4,374 curies
Maximum Exposure Dose Rate	378,000 rad/hr. (estimated)
Center Well Dimensions	
Inner Diameter	3″
Height	13 5/6″

schematic of 4,000 curie cobalt-60 source



schematic of 5 curie cobalt-60 source



ford nuclear reactor

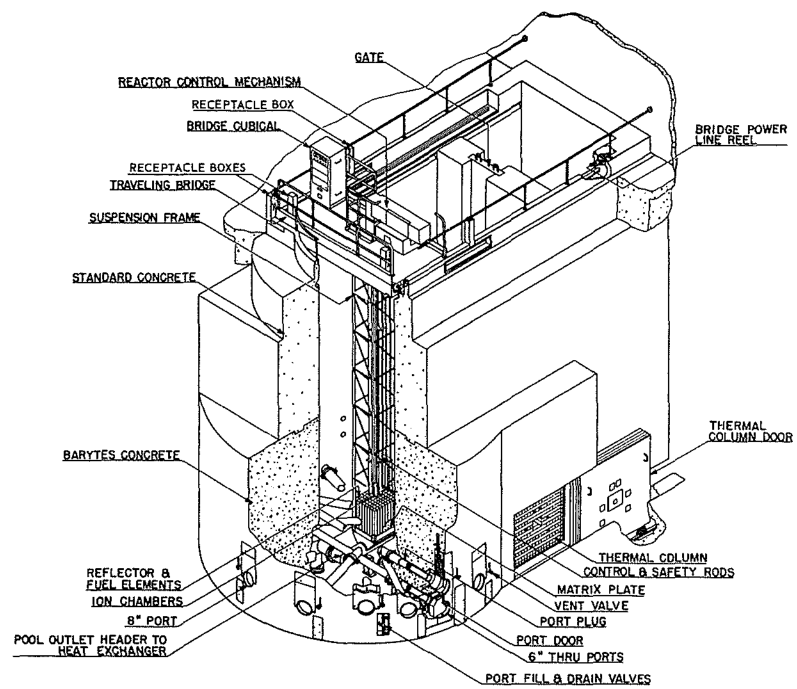
neutron irradiations

The Ford Nuclear Reactor

The Ford Nuclear Reactor is an open-pool research reactor presently operating at a maximum power level of 2 megawatts. The maximum accessible thermal neutron flux is 3 x 10^{13} neutrons/cm^2/sec.

Among the areas of research made possible by the reactor are: experimental reactor physics, neutron physics, neutron spectroscopy, solid-state studies based on neutron diffraction, activation analysis, isotope production, radiation chemistry, radiation-induced biological effects, radiation damage studies, direct conversion from nuclear to electrical energy, and γ—γ correlation studies.

schematic of ford nuclear reactor



Experimental Facilities in the Ford Nuclear Reactor

1. Ten Horizontal Beam Ports:

   The beam ports are used for long term irradiation and beam-extraction experiments. The ports penetrate the reactor's biological shield and terminate near the core face. Because of certain handling complexities with these facilities, it is recommended that plans for their use be discussed with a staff member early in the planning stage.

2. Four Pneumatic Tubes:

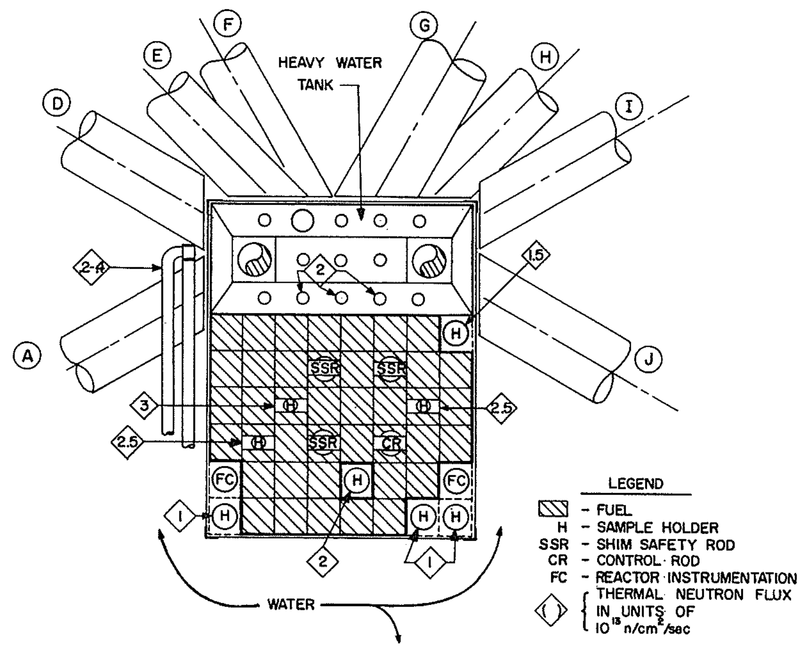
   The pneumatic tubes can be used for small targets that require an irradiation time of two hours or less. Minimum irradiation time is one second. The thermal fluxes available in the pneumatic tubes range from 2×10^{12} to 4×10^{12} n/cm^2/sec. Targets up to 15/16″ in diameter and 2″ in length can be packaged in polyethylene "rabbits." The pneumatic tubes originate in laboratories in the reactor building and in the Phoenix Memorial Laboratory.

3. In-Pool Irradiations:

   This method enables the irradiation of targets of various sizes and shapes by placing them in or near the core. Polyethylene containers are usually used for short term irradiations and aluminum containers for long term irradiations. Water-tight containers are required for certain target materials.

   The pool as an irradiation area shows the great versatility of this type of reactor. Small samples (1″ diameter x 6″ long) can be exposed in the core at a flux of 3×10^{13} n/cm^2/sec, while large experimental apparatus can be lowered into the pool next to the core for exposure at lower flux levels.

Core Configuration and Available Flux Levels



(Fluxes quoted are for core conditions with no sample present. Represent average results — may vary 20% from cycle to cycle.)

analytical services

Neutron Radiography

The neutron radiography facility of the Phoenix Memorial Laboratory is based on a three-inch diameter vertical neutron beam of extremely good collimation (.076 degrees). The facility is operated by the Department of Nuclear Engineering in research programs directed toward the development of neutron microradiography in medicine. Services are available to companies who wish to pursue problems in nondestructive testing under a program designated to define new industrial applications. Recent neutron radiography inspections have defined defect areas in electronic diodes used in automobile components, in small diameter cables, and in thermal batteries. Radiographs are taken with a 25-micron thick gadolinium converter foil exposing Type R industrial x-ray film which has a resolution capability of approximately 20 microns when used with the present beam configuration. Current research is aimed at reducing this resolution limitation down to the limits of optical reading devices, i.e., about one micron.

Activation Analysis

A typical analysis made with this technique is the determination of mercury in biological specimens. The sensitivity is great enough to detect 10 parts per billion. Mercury in water samples has been determined with a sensitivity of less than 0.5 parts per billion.

The technique is particularly useful for analyzing environmental samples to determine pollution and to analyze industrial samples to maintain quality control. Typical determinations include analysis of mercury in fish, human tissue (hair, fingernails), caustic soda, and most chemicals.

special purpose laboratories

Special purpose facilities are maintained in the Phoenix Memorial Laboratory to serve the various scientific disciplines that use the Phoenix Project.

Hot Caves:

The Phoenix Memorial Laboratory has two hot caves for remote handling of radioactive materials with source strengths up to 10,000 curies, cobalt-60 equivalent.

One hot cave is connected to the reactor pool by a waterlock system that allows the transfer of irradiated material from the pool to the hot cave.

Each hot cave is equipped with a remotely operated hoist, with master-slave manipulators and with ports for service connections.

Chemistry Laboratories:

There are eight chemistry laboratories. In addition to standard equipment such as air, gas, vacuum, and water lines, these laboratories are equipped with hot drains that go to retention tanks, hoods that are vented through "absolute" particulate filters and utility supplies for portable glove boxes. Two of these laboratories have walk-in hoods and three have pneumatic tube stations from which samples can be sent to the face of the reactor core for irradiation.

Physics Laboratories:

There are two laboratories equipped for physics experiments. One has a pneumatic tube station. The other houses the photoneutron laboratory.

Special Laboratories

There are a variety of specially equipped laboratories within the Phoenix buildings. These include:

- —an aquarium
- —an animal room
- —a greenhouse
- —bacteriological laboratories
- —an x-ray room.

Support Facilities:

On-site services are available from the laboratory's machine shop and electronics shop.

ford nuclear reactor data

General

Reactor Type: Pool-type, highly enriched uranium, light water moderated, cooled and reflected, with heavy water reflector on one face of core.

Maximum Reactor Power: 2 megawatts thermal.

Location: North Campus, Ann Arbor, Michigan.

Owner and Operator: The University of Michigan.

Designer and Supplier: Babcock and Wilcox (reactor)
Leeds and Northrup (control)

History:	Start of construction	July, 1955
	Reactor critical	September, 1957
	100 kw operation	January, 1958
	1 MW operation	August, 1958
	2 MW operation	August, 1963

Reactor Vessel: Reactor pool, barytes concrete and ordinary concrete, thickness 6.5 ft. at the bottom, 1.5 ft. at the top, lined on the inside with ceramic tile. 24 x 10 x 27 ft. deep (core covered by 20 ft. of water).

Core

Shape and Dimensions: Parallelpiped 24 x 18 in., 24 in. high.

No. of Channels and Subassemblies: Grid plate with 8 x 10 lattice (pitch=3.035 x 3.189 in.). Normal operating core of 35 to 40 fuel elements.

Minimum Critical Mass: 2540_g U^{235}.

Typical Operating Core: 4200_g U^{235}.

Average Specific Power in Fuel: 480 kw/kg U^{235}.

Average Power Density in Core: 15 to 18 kw/liter.

Burnup: Approximately 10% average to 17% maximum.

Average Thermal Neutron Energy: 0.040 ev.

Prompt Neutron Lifetime: 60 microseconds.

Reactivity Balance: Maximum Allowable: 3.50% $\Delta K/K$

Allowance for Equil. Xenon: 2.2% $\Delta K/K$

Allowance for Temperature: 0.25% $\Delta K/K$

Allowance for Operation (Burnup): 0.75% $\Delta K/K$

Allowance for Experiments: 0.30% $\Delta K/K$

Moderator: Light water, average temperature 116°F.

Fuel Element

Form and Composition: MTR-type, curved plates (.06 x 3 x 24⅝ in.), using 14.1% uranium (>90% enriched —~7.8 gms U^{235}/plate) alloyed with aluminum.

Cladding: 0.02 in. aluminum, hot rolled.

Subassemblies: 18 plates forming standard fuel element, control rod fuel elements with 9 plates.

Control

Control, Regulating and Safety Rods: 3 shim-safety rods, bar shaped Boron SS, active length 24 in., and 1 regulating rod, elliptical, stainless steel tube, active length 24 in., operating in special fuel elements.

Total worth of shim-safety rods:	~7.5% $\Delta K/K$
Worth of regulating rod:	~0.3% $\Delta K/K$
Speed of shim-safety rods:	2.66 in./min.
Speed of regulating rod:	26.8 in./min.

Scram Mechanism: Electronic actuated magnetic release, gravity fall.

Core Heat Transfer and Cooling System

Heat Transfer Area:	Per standard fuel element	2520 in.^{2}
	Per control rod fuel element	1260 in.^{2}

Fuel Element Temperatures:	Maximum fuel	~197°F
	Maximum cladding	~194°F
	Film drop	~55°F

Coolant Flow Rate: 1000 gpm.

Coolant Pressure and Temperatures:

Atmospheric pressure + 20 ft. pool head

Inlet 115°F } Maximum Bulk
Outlet 129°F }

Heat Exchangers: U tube and shell type, 304 stainless steel, 354 U-shaped tubes, 0.5 in. od., 0.05 in. wall thickness, secondary in tubes.

Primary Coolant Purification: Mixed bed ion exchanger in 20 gpm by-pass loop(total primary 48,000 gal.). Nominal pool water conductivity .5 micro-Mho/cm^3.

Shut-Down Heat Removal: Natural convection of pool water.

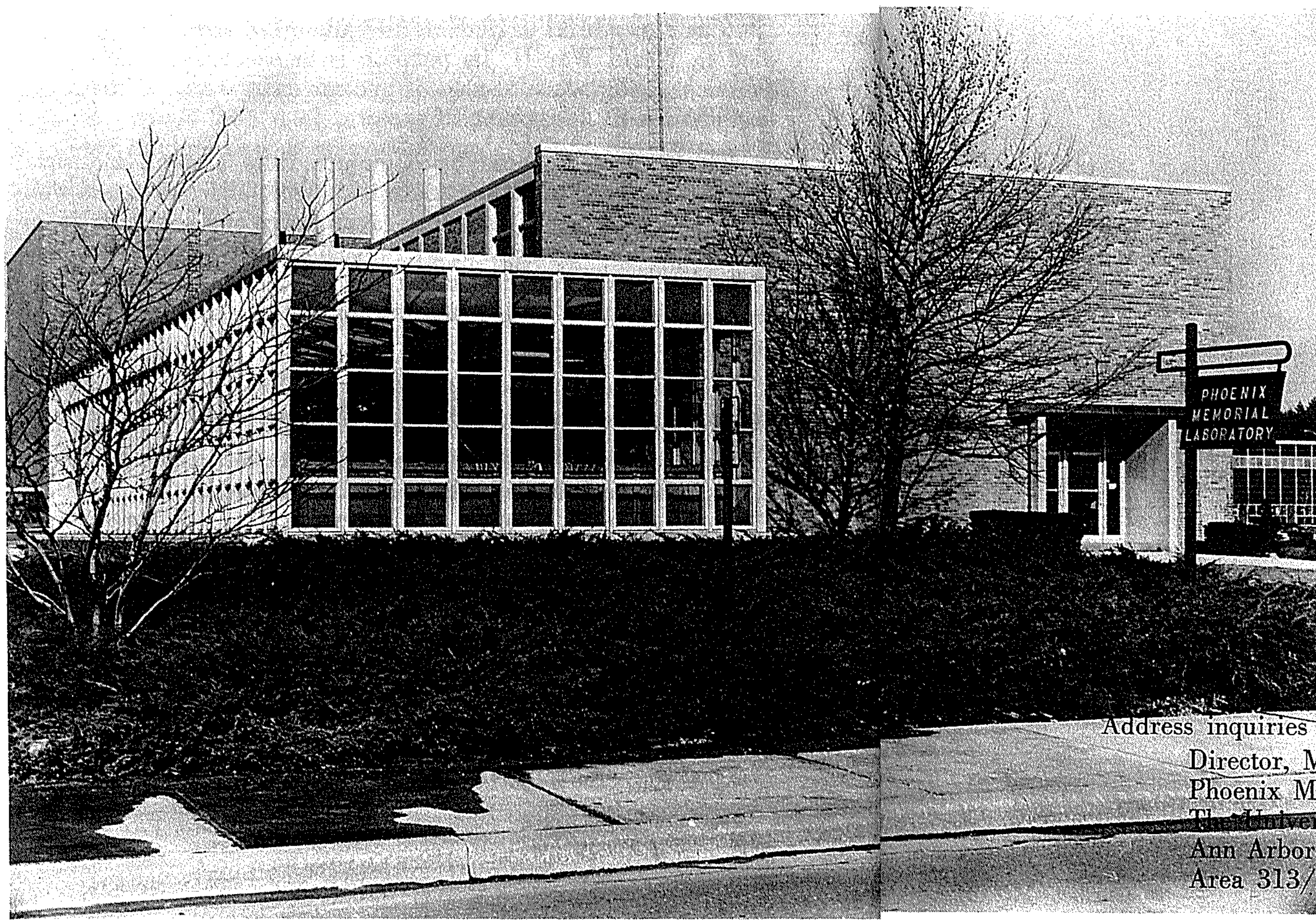
the michigan memorial-phoenix project

The Michigan Memorial–Phoenix Project was established in 1949 as a memorial to students and alumni of the University who died in World War II. Its purpose is to encourage and support research on the peaceful uses of nuclear energy and on the social implications of this source of power.

The Project, financed by donations from alumni, industrial organizations and philanthropic foundations, allocates funds within the University to: 1) establish laboratories and purchase equipment for radiation research; 2) support faculty research projects; 3) initiate new areas of teaching that use nuclear energy; 4) disseminate technical and general information about the peaceful uses of nuclear energy.

Research laboratories operated by the Project are the Phoenix Memorial Laboratory and the Ford Nuclear Reactor.

To date, more than 440 research projects, originated by faculty members at the University, have been sponsored by The Michigan Memorial–Phoenix Project. Typical studies are the investigation of radiation effects on biological and physical systems, the environmental problems associated with nuclear energy, and the use of radioisotopes in medical diagnosis and therapy.



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