MICHIGAN MEMORIAL - PHOENIX PROJECT

The Ford Nuclear Reactor and Phoenix Memorial Laboratory are operated by the Michigan Memorial - Phoenix Project of the University of Michigan. The Project, established in 1949 as a memorial to students and alumni of the University who died in World War II, encourages and supports research on the peaceful uses of nuclear energy and its social implications. These laboratories, together with a faculty research grant program, are the means by which the Project carries out its purposes.

The primary purpose of the reactor and radiation laboratory 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, electric utilities, and by hospitals.

FACILITY LOCATION AND HOURS

The Ford Nuclear Reactor and Phoenix Memorial Laboratory are contiguous buildings located on the University of Michigan North Campus. Located in Ann Arbor, the University is in the heart of the mostdensely populated portion of the United States stretching from the East Coast to the Midwest. Ann Arbor is at the intersection of interstates 94 and 23, close to the Detroit Metropolitan Airport which has regular connecting flights to all major cities.

Normal facility hours for visitors and tours are weekdays from 9:00 AM to 4:00 PM. The facility is open 24 hours for researchers.

Michigan Memorial - Phoenix Project
Ford Nuclear Reactor
Phoenix Memorial Laboratory
2301 Bonisteel Boulevard
North Campus
University of Michigan
Ann Arbor, Michigan 48109

Director, Michigan Memorial - Phoenix Project	William Kerr	(313) 764-6213
Reactor Manager	Reed R. Burn	764-6223
Assistant Reactor Manager	Gary M. Cook	764-6223
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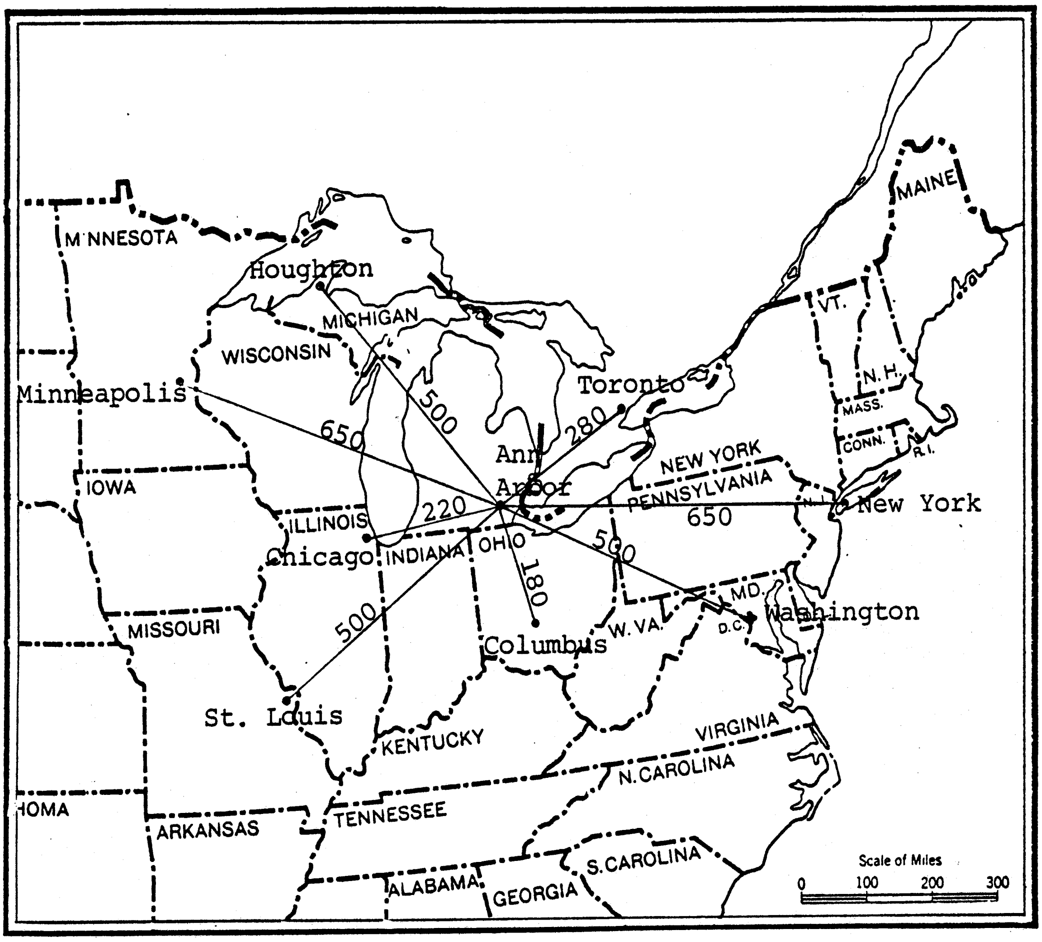
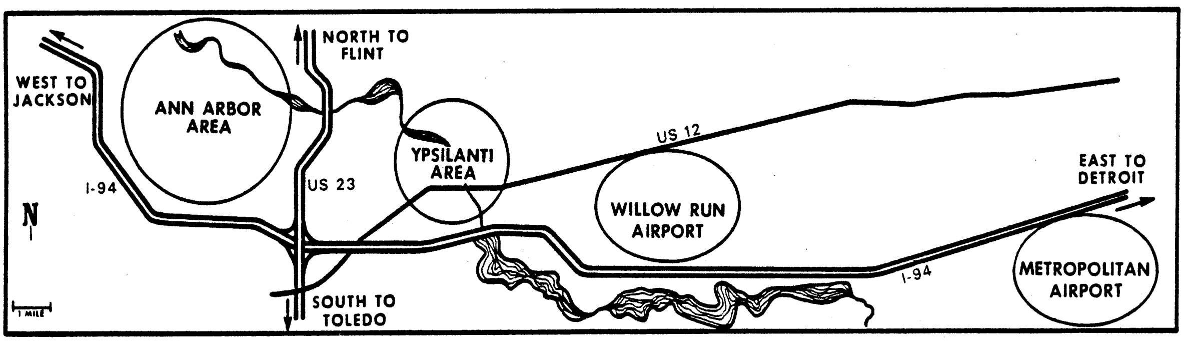
Tours	Receptionist	764-6220

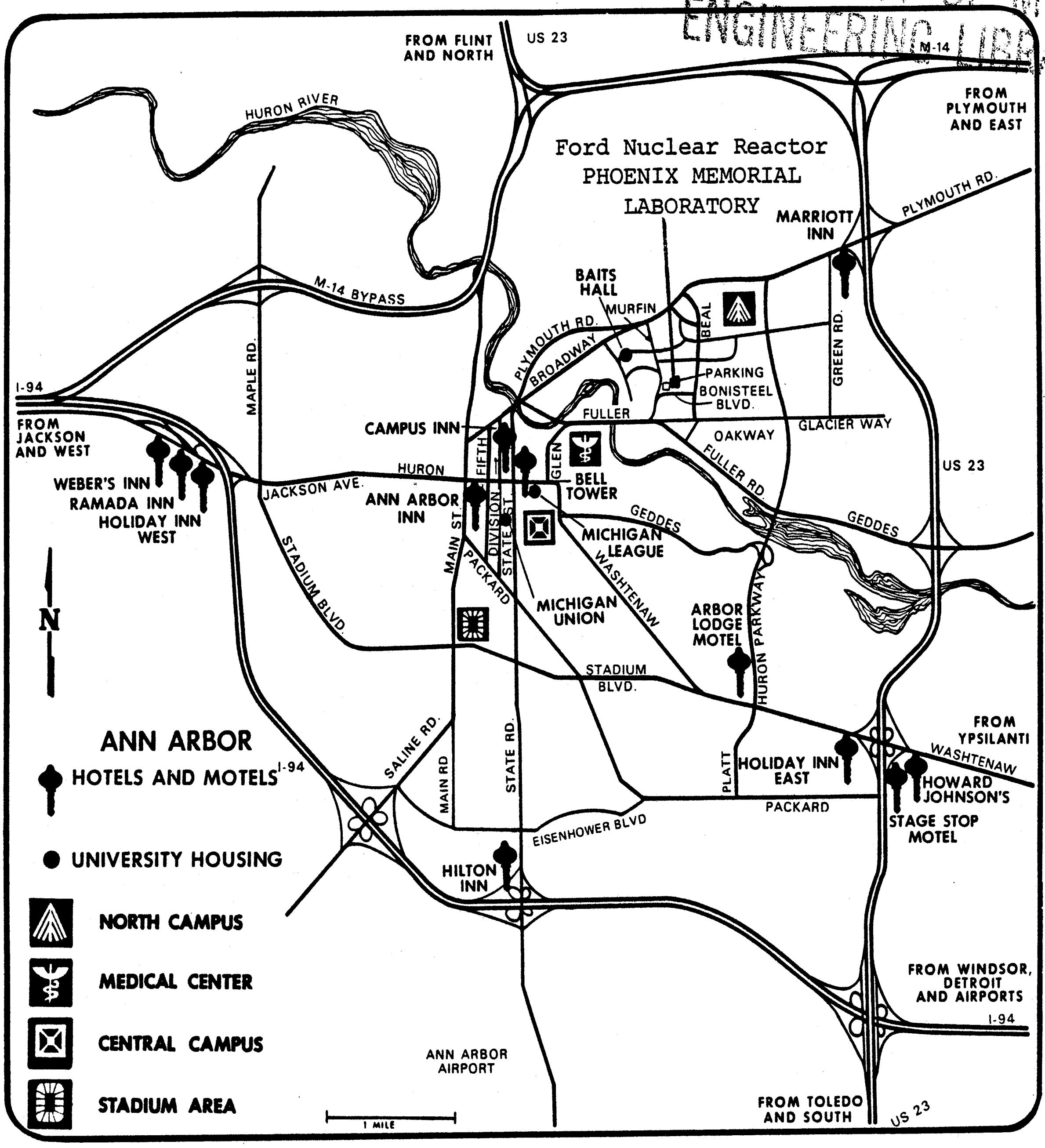


United States Map

Ann Arbor to Major Population Center Mileage



Ann Arbor Vicinity Map



ANN ARBOR HOTELS Area code(313)

Campus Inn 769-2210
615 East Huron & State(48104)

Ann Arbor Inn 769-9500
100 South 4th Ave. at Huron(48104)

Bell Tower Hotel 769-3010
300 South Thayer(48104)

ANN ARBOR MOTELS

Marriott Inn 769-9800
3600 Plymouth Rd. at US23(48105)

Red Roof Inn 996-5800
3621 Plymouth Rd. at US23(48105)

Holiday Inn, Ann Arbor-Ypsilanti 971-2000
3750 Washtenaw at US23(48104)

Holiday Inn, West 665-4444
2900 Jackson Rd. I-94(48103)

Ramada Inn 769-0700
2800 Jackson Rd. at I-94(48103)

Weber's Inn (Indoor Pool) 769-2500
3050 Jackson Rd. at I-94(48103)

Hilton Inn (Indoor Pool) 761-7800
610 Hilton Blvd. at I-94 & State(48104)

Wolverine Inn 665-3500
3505 South State Rd. at I-94(48104)

Howard Johnson's Motor Lodge 971-0700
2380 Carpenter Rd. at US23(48104)

Stage Stop Motel 971-1260
2443 Carpenter Rd. at US23(48104)
Family Unit with Kitchenette

FORD NUCLEAR REACTOR

The reactor operates on a fixed cycle at its licensed power level of two megawatts. The cycle consists of ten days at full power followed by four days of shutdown maintenance. A typical week consists of 120 full power operating hours.

Reactor operation at two megawatts produces a peak thermal flux of approximately 3×10^{13} n/cm^2/sec. A typical core configuration consists of 35-40, 93 percent enrichment, plate-type fuel elements. Standard elements contain 140 grams of U-235 in 18 aluminum-clad fuel plates. Control elements, which have control rod guide channels, have nine plates and contain 70 grams of U-235. Overall fuel element dimensions are approximately 3 inches by 3 inches by 26 inches long.

Standard fuel elements are retired after burnup levels of approximately 17 percent are reached. Control elements are retired after burnup levels of approximately 35 percent. Fuel burnup rate is approximately 2.46 gm/day at two megawatts. Under a two megawatt operating schedule, 18 fuel elements are required for one year of operation.

Power Level

Licensed full power	2 MW
Volumetric power density	333 KW/ft^3 (11.8 KW/l)
Linear power density	1.54 KW/ft (5.06 KW/m)
Specific power	202 KW/lb (444 KW/Kg) U235

Core

Element configuration	35-40 elements in a 6 x 8 lattice
Mimimum critical mass	2,540 gm U235
Typical operating core	4,200 gm U235

Fuel

Element Description	18 curved, fueled plates (5.5 in (14.0 cm) radius containing a total of 0.31 lb. (140 gm) U235. 2.94 in (7.47 cm) x 3.25 in (8.26 cm) x 34.4 in (87.38 cm) long.
Average fission density	5.0×10^{21} fissions/in^3 (3.05×10^{20} fissions/cc)
Peak fission density	1.0×10^{22} fissions/in^3 (6.1×10^{20} fissions/cc)
Maximum allowed fission density	2.5×10^{22} fissions/in^3 (1.5×10^{21} fissions/cc)

Control

3 shim safety rods	.075 ΔK/K total
1 control rod	.003 ΔK/K

Neutron Flux

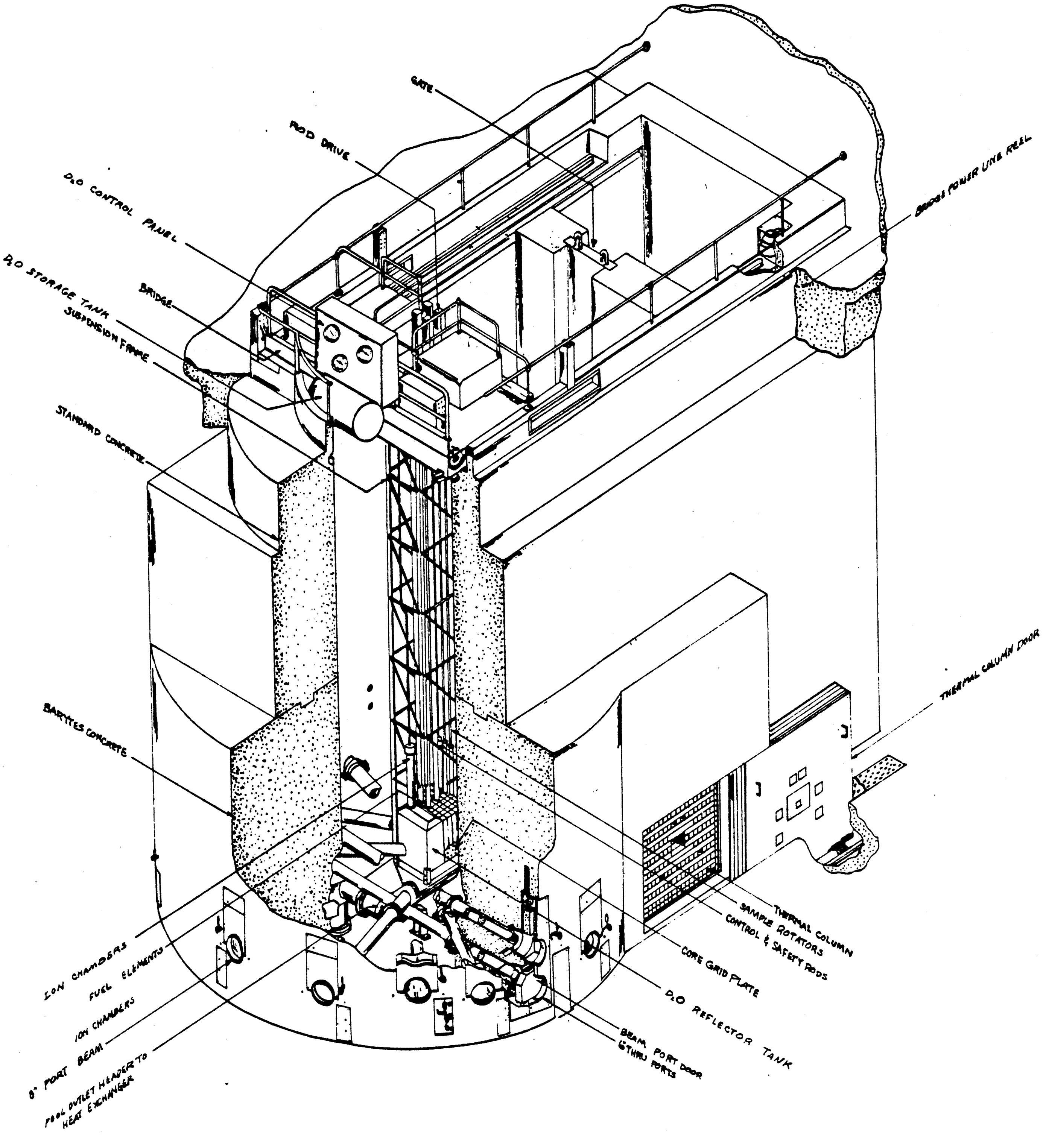
Steady state peak thermal	3.0×10^{13} n/cm^2/sec
Steady state average thermal	2.0×10^{13} n/cm^2/sec
Steady state peak fast	1.5×10^{13} n/cm^2/sec
Steady state average fast	1.0×10^{13} n/cm^2/sec

Experiment Reactivity Limits

Moveable experiments	.0001 ΔK/K
Unsecured (subcritical to load and unload)	.002 ΔK/K
Secured	.012 ΔK/K
Total in core	.012 ΔK/K

Reactivity Coefficients

Temperature	-5.5×10^{-5} ΔK/K/F (-9.9×10^{-5} ΔK/K/C)
Void	-1.0×10^{-4} ΔK/K/in^3 (-6.4×10^{-6} ΔK/K/cc)

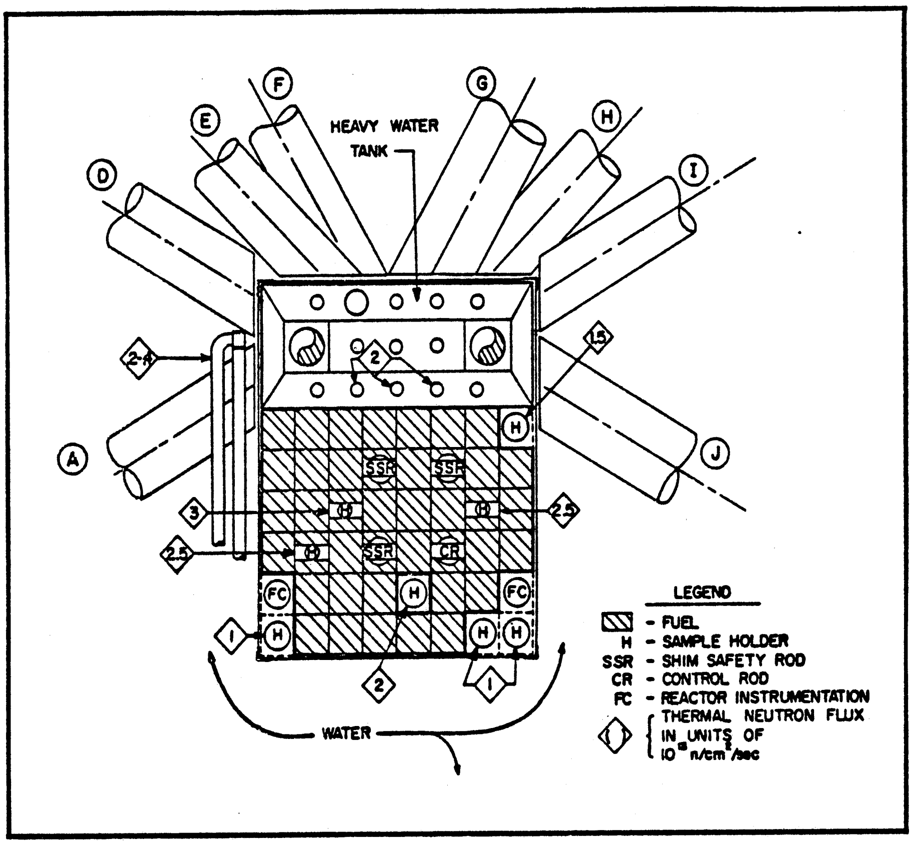


FORD NUCLEAR REACTOR

THE UNIVERSITY OF MICHIGAN

NEUTRON IRRADIATION SERVICES

The Ford Nuclear Reactor provides three methods of neutron irradiation: in-core, pneumatic tubes, and beamports.



In-Core Irradiations

Targets of various sizes and shapes can be irradiated by placing them in or near the reactor core. The thermal neutron flux level at the center of the core is approximately 3 x 10^{13} $n/cm^2/sec$ and at the edge of the core is approximately 1 x 10^{13} $n/cm^2/sec$. Sample irradiations can be conducted for periods as short as a few minutes and for as long as a year or more.

Pneumatic Tubes

Four horizontal and two vertical pneumatic tubes can be used to irradiate small targets for up to two hours. Minimum irradiation time is one second. The thermal neutron flux in the pneumatic tubes ranges from 2 x 10^{12} $n/cm^2/sec$ to 4 x 10^{12} $n/cm^2/sec$. Targets up to 15/16 inch in diameter and 2 inches long can be irradiated in polyethylene rabbits.

Beamports

Ten horizontal beamports can be utilized for long term irradiations and neutron beam extraction experiments such as neutron radiography and neutron spectroscopy. The beamports penetrate the reactor pool wall and terminate at a heavy water tank adjacent to one face of the core. The heavy water tank provides a cadmium ratio of approximately 11. Thermal neutron flux from the beamports varies between 1×10^6 $n/cm^2/sec$ and 1×10^7 $n/cm^2/sec$.

NEUTRON ACTIVATION ANALYSIS

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

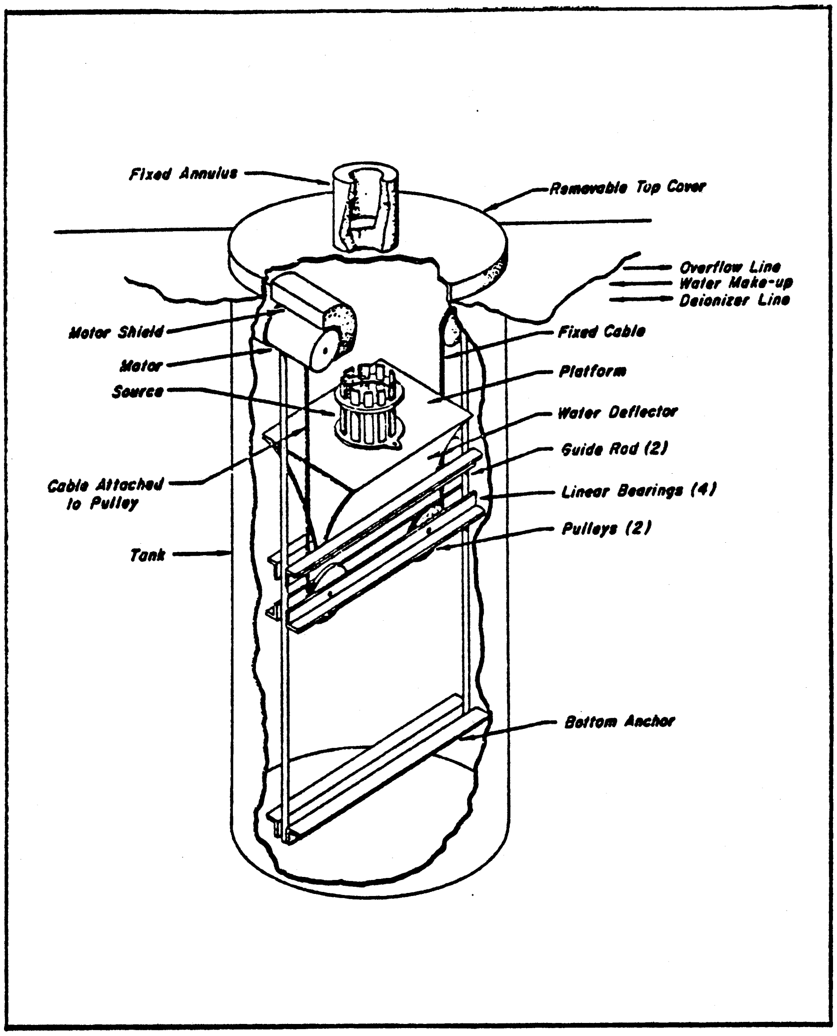
Neutron activation analysis is a method of identifying and measuring minute quantities of certain trace elements in many types of materials. Approximately 39 common elements become radioactive when exposed to the neutron flux in the reactor. The subsequent radiation produced by the decay of the activated nuclei is characteristic for each element and permits identification. The technique is particularly useful for analyzing environmental samples and to analyze industrial samples for maintaining quality control. The sensitivity, accuracy, variety of types of materials that can be analyzed, large number of elements that can be detected, and essentially non-destructive nature of the technique make neutron activation analysis an excellent analytical tool.

ISOTOPE PREPARATION AND RADIOCHEMICAL PRODUCTION

Preparation of and custom labeling with radioisotopes is available for medical and industrial research. Five radioisotopes and radiolabelled chemicals are routinely produced by the laboratory. Elemental bromine-82 is produced for pharmacological research. Bromine-82 labeled motor oil is prepared for use in research programs to help improve engine oil economy. Fluorine-18 in saline solution is used for tumor localization studies in bone. NP-59, an iodine based investigational drug approved by the Food and Drug Administration, is produced in large quantities for use in the diagnosis of adrenal gland diseases. Nearly 100 hospitals in the United States, Puerto Rico, Canada, and Scotland receive regular shipments of NP-59 from the facility. Sodium-24 is supplied by the laboratory to the University's Physiology Department for brain capillary permeability studies.

GAMMA IRRADIATION SERVICES

A cobalt-60 source of approximately 10,000 curies is available for gamma irradiations. Typical applications include sterilization of bones and cartilage for human grafts, sterilization of animal food for germ-free animal colonies, radiation pasturization of food, studies of radiation effects on chemical systems, electronic components, biological material, animal populations, and crystals, and irradiation of seeds and plants to change growth and develop mutants. The peak dose rate in the center well of the cobalt-60 source is approximately 1×10^6 rad/hour.



Gamma irradiations can also be performed in the reactor spent fuel storage racks where the peak dose rate is approximately 1 X 10^5 rad/hour. The fuel storage racks are particularly useful for irradiating large objects.

NEUTRON RADIOGRAPHY

Neutron radiography services are available to researchers who wish to pursue problems in non-destructive testing. Neutron radiography is a technique similar to X-ray radiography except that neutrons, unlike X-rays, interact with atomic nuclei rather than outer electrons. Whereas dense materials such as lead, iron and uranium are opaque to X-rays, they are easily penetrated and examined with neutrons. Neutron radiography also reverses to an extent the relative order of imaging possibilities. For example, details of plastics, oil, water, and fractures or voids inside heavy materials can be determined with good resolution.

The facility currently operates two neutron radiograph facilities. A three inch diameter facility with a length to diameter ratio of 300 provides extremely fine resolution of small objects. A larger facility associated with a beamport can produce full eight by ten inch radiographs with excellent resolution. The facility has a length to diameter ratio of 50 and neutron intensity variations of not more than ten percent over the exposed film.

RADIATION, CHEMICAL, AND MECHANICAL TESTING SERVICES

Complete materials testing programs can be conducted at the laboratory. Neutron and gamma radiation damage studies can be performed in the reactor core, in spent fuel storage, and in the cobalt-60 source. Neutron attenuation tests through shielding materials are performed utilizing beamport spectrometers and neutron radiography. Gamma attenuation tests are performed with small, well collimated gamma sources.

Mechanical and chemical tests include tensile strength, cantilever flexure, dimensional stability, weight changes, specific gravity, hardness, and gas evolution and analysis.

TRAINING PROGRAMS

Training programs are offered in neutron activation analysis and reactor operations and instrumentation.

One and two week reactor operator and instrument technician training sessions have been developed for electric utility companies. These sessions are combinations of lectures, problem sessions, reactor experiments, and operational training.

Lectures are presented to familiarize trainees with the Ford Nuclear Reactor facility, process systems, and nuclear instrumentation and control systems. Additional lectures provide background for experiments, reactor operations, and maintenance sessions. The heart of the lecture series is designed to provide the operators with essential background information in reactor physics and kinetics, reactor fuel and core parameters and operating characteristics, reactor operations, nuclear instrumentation and control, health physics, and radiation shielding.

Emphasis is placed upon experiments and reactor operations that illustrate reactor operating principles and provide the trainees with maximum hands-on experience. In addition to performing reactor startups and shutdowns, trainees perform sub-critical multiplication, control rod calibration, power level determination, negative temperature coefficient measurement, power defect measurement, reactor flux profile, radiation shielding, and radioactive contamination detection and cleanup experiments. These experiments utilize operating equipment and instruments which are unique to reactor operation.

Maintenance training is geared toward operations with which reactor operators must be familiar or which pose special hazards such as exposure to radiation. Maintenance sessions include startup reactivity checks, rod release and drop time measurement, detector and instrument channel checks, and demineralizer operation and recharge.

LABORATORIES

Chemistry and Physics Laboratories

The facility offers eight chemistry and two physics laboratories. In addition to standard equipment such as air, gas, vacuum, and water lines, the laboratories are equipped with radioactive drains to retention tanks, hoods that exhaust through absolute particulate filters, and utility supplies for portable glove boxes. Two of the laboratories have walk in hoods and four have pneumatic tube stations from which samples can be sent to the face of the reactor core for irradiation.

Special Laboratories

The facility offers a variety of specially equipped laboratories including a greenhouse, organic synthesis laboratories, an X-ray room and a photographic darkroom. Services are available from machine and electronics shops.

RADIOACTIVITY HANDLING AND STORAGE

Hot Caves

The laboratory has two hot caves for remote handling, examination, and limited machining of radioactive materials. Source strengths of up to 10,000 curies cobalt-60 equivalent can be handled with ease. One hot cave is connected to the reactor pool by a water-lock system that allows the transfer of irradiated material from the pool to the hot cave. Each cave is equipped with master-slave manipulators, a remotely operated hoist, and ports for service connections.

Storage

Wall ports are available in the reactor building and in the laboratory for storage of highly radioactive materials.

CHARGE SCHEDULE

The facility operates under a fixed rate charge schedule for irradiations, analytical services, and use of facilities.

MICHIGAN MEMORIAL-PHOENIX PROJECT

Phoenix Memorial Laboratory and Ford Nuclear Reactor

July 1, 1980 - June 30, 1981

CHARGE SCHEDULE

Service Provided	Unit of Service	Charge Rate University/ Federal	Charge Rate Commercial/ Industrial
Staff Assistance			
A. Administrative	Man-Hour	$33.12	$33.81
B. Reactor Technical	Man-Hour	16.67	17.02
C. Radiation Laboratory Technical	Man-Hour	13.59	13.87
D. Machine Shop	Man-Hour	17.22	17.58
E. Electronics Shop	Man-Hour	17.33	17.70
Reactor			
A. Exclusive Use	Reactor-Hour	$91.04	$144.70
B. Neutron Irradiations at 2 MW			
1. South Core Face Exclusive Use	Experiment-Hour	45.52	72.35
2. Pneumatic Tube	Tube-Hour	18.75	29.80
3. In-pool Sample	Sample-Hour	18.75	29.80
4. Sample Stringer Sample	Sample-Hour	14.20	22.58
5. Beam Port	Experiment-Hour	10.92	18.11
C. Gamma Irradiation in Spent Fuel	Megarad-Liter	4.51	4.61
Radiation Laboratory			
A. Cobalt-60 Irradiations	Megarad-Liter	4.51	4.61
B. Hot Cave	Cave-Hour	37.53	38.32
Laboratory and Reactor Space			
A. Support Charges	Ft^2 Year	30.54	31.18
Radioactive Storage			
A. Wall Port	Port-Day	1.91	1.96
Radioactive Waste Disposal			
A. Packaging Material, Shipment, and Burial Ground Fee	55 Gal. Drum	100.00	100.00

NOTES:

1. Special materials for experiments, packing and shipping will be charged at actual cost.
2. Minimum charge for services in any month, $40.00.
3. All charges computed to the nearest 1/4 hour above actual service period.
4. For In Pool Samples, Sample Stringer Samples, and Beam Port usage, the rate will be 50% of above rates for 11-100 hours of continuous irradiation or usage and 25% of above rates for 101 or more hours of continuous irradiation or usage.