USERS HANDBOOK

FOR THE

Advanced Test Reactor

Idaho National Engineering and
Environmental Laboratory

INEEL
Home of Science
and Engineering Solutions

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THE ADVANCED TEST REACTOR

The Advanced Test Reactor (ATR) is the product of an evolution in nuclear test reactors. Located at the Test Reactor Area (TRA) at the Idaho National Engineering and Environmental Laboratory (INEEL) (Figure 1), the ATR was originally commissioned in 1967 with the primary mission of materials and fuels testing for the United States Naval Reactors Program. It is the highest power research reactor operating in the United States. Its large test volumes make it attractive for irradiations of materials and components. Though it has been operating for many years, the ATR is expected to remain operational until at least the year 2050. The ATR is designed to evaluate the effects of intense radiation on material samples, especially nuclear fuels. The principal customer for the reactor over most of its lifetime has been the U.S. DOE Naval Reactors Program. Other uses include isotope production for medical, industrial, environmental, agricultural and research applications. The ATR has provided a large fraction of the Ir-192 used in U.S. commercial radiography sources and high specific activity Co-60 for medical applications. Irradiation services are provided for government programs as well as private firms and consortiums.

The ATR was designed to provide large-volume, high-flux test locations. A unique serpentine fuel arrangement (Figure 2) provides nine high-intensity neutron flux traps and 68 additional irradiation positions inside the reactor core reflector tank, each of which can contain multiple experiments. Thirty-four more

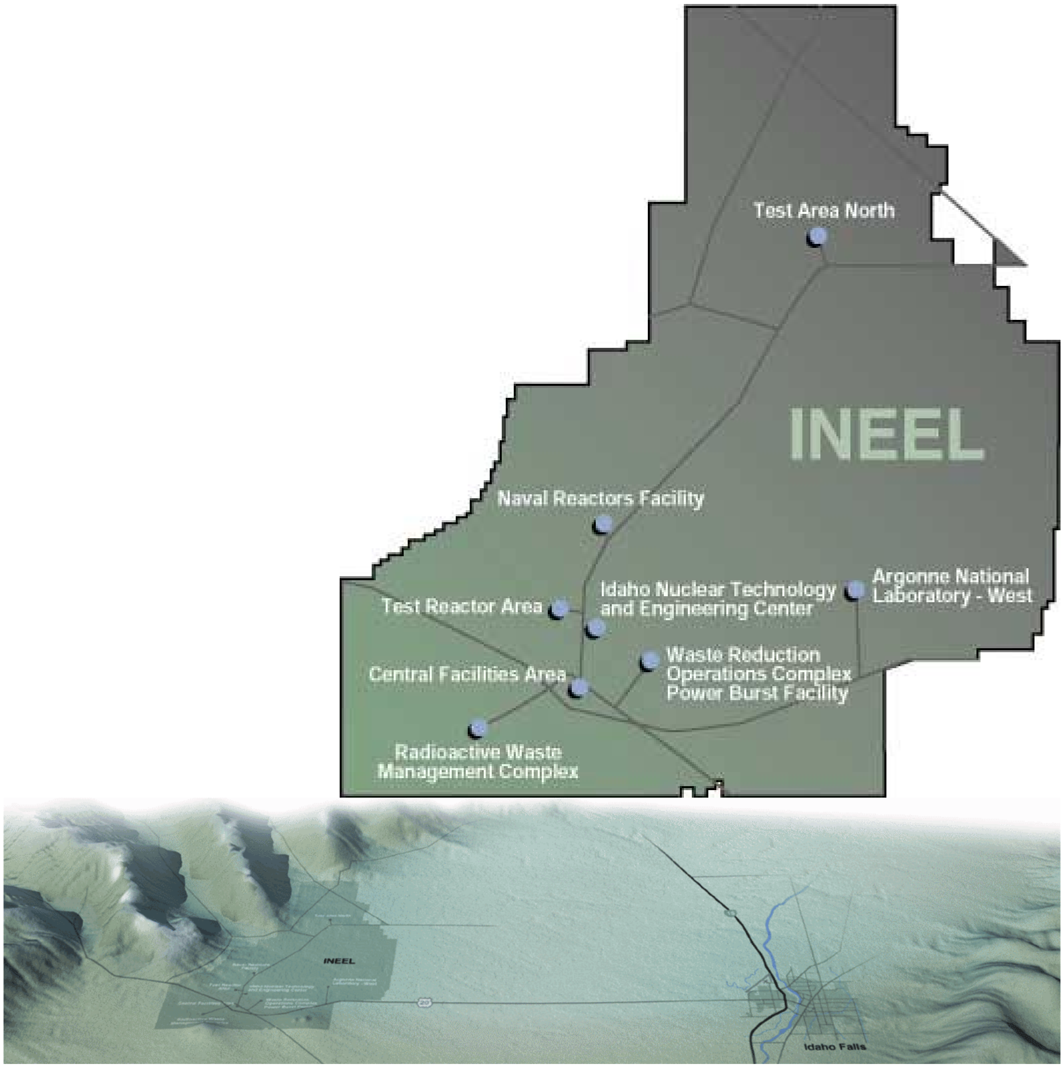


Figure 1. The Advanced Test Reactor is located at the Test Reactor Area at the INEEL.

low-flux irradiation positions are in the two capsule irradiation tanks outside the core. The four flux traps positioned within the corner lobes of the reactor core are almost entirely surrounded by fuel, as is the center position. Four other flux trap positions between the lobes of the core have fuel on three sides. The curved fuel arrangement brings the fuel closer on all sides of the flux trap positions than is possible in a rectangular grid. Effects from years of radiation in a normal power reactor can be duplicated in months or even weeks in the ATR.

The ATR's unique control device design permits large power shifts among the nine flux traps. The ATR uses a combination of control cylinders or drums and neck shim rods. The control cylinders rotate hafnium plates toward and away

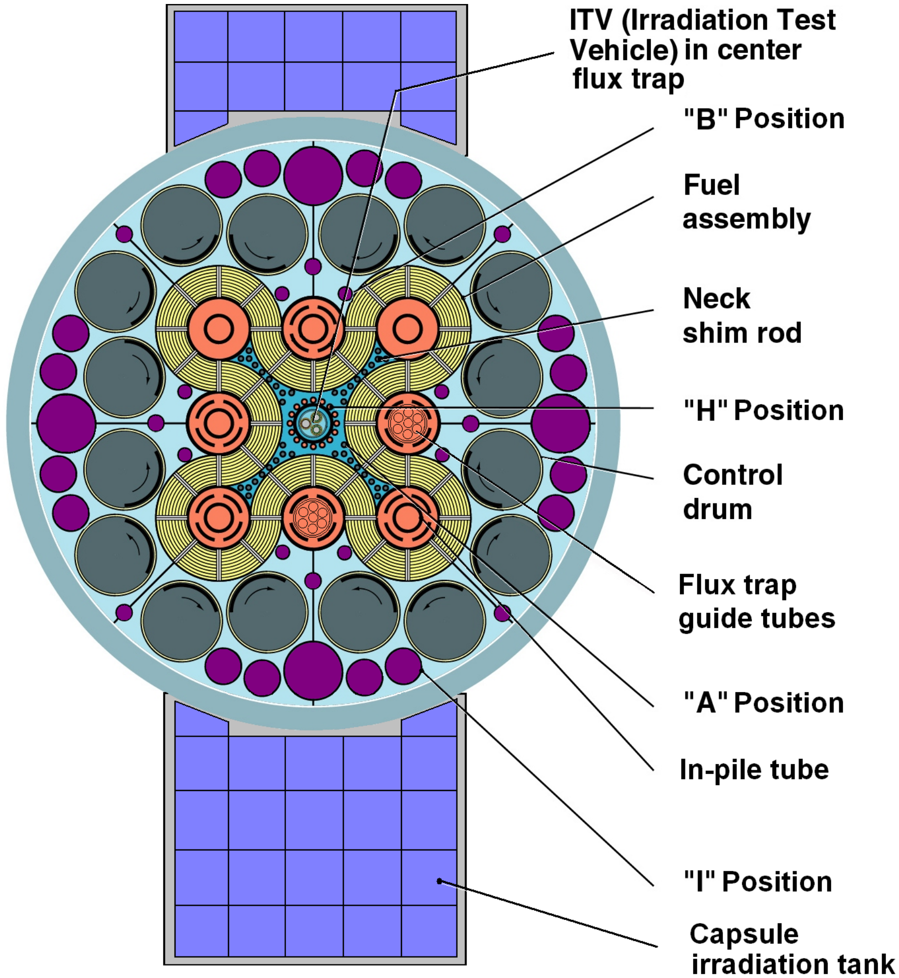


Figure 2. The Advanced Test Reactor has nine flux traps and 68 other irradiation test positions in or near the core.

from the core, and the shim rods, which withdraw vertically, are individually inserted or withdrawn to adjust power. Within bounds, the power level in each corner lobe of the reactor can be controlled independently.

Powered with highly enriched uranium, the ATR has a maximum thermal power rating of 250 MW_{th} with a maximum unperturbed thermal neutron flux rating of 1.0×10^{15} n/cm^2–s. While the ATR is capable of operation at that power, in recent years it has only occasionally operated at thermal powers greater than 110 MW_{th}.

The reactor operational availability is approximately 75% except during core internals change-outs, which require several months at nominally 8- to 10-year intervals. These periods are used to replace the beryllium reflector, outer shim control cylinders and certain other core components.

Testing can be performed in three major kinds of experiment facilities in the ATR: (1) pressurized water test loops installed in some flux traps that replicate a variety of reactor conditions; (2) instrumented lead experiments that provide real-time measurements and temperature and atmosphere control in the experiment capsules; or (3) simple drop-in capsule experiments in reflector or core irradiation positions.

REACTOR DESCRIPTION

The ATR is the most powerful research reactor operating in the U.S. It also has larger test volumes in high flux areas than any other reactor. General characteristics for the ATR are listed in Table 1.

Table 1. ATR general characteristics

Reactor	
Thermal Power	250 MW_{th}[a]
Power Density	1.0 MW/L
Maximum Thermal Neutron Flux	1.0×10^{15} n/cm^2-sec[b]
Maximum Fast Flux	5.0×10^{14} n/cm^2-sec[b]
Number of Flux Traps	9
Number of Experiment Positions	68[c]
Core	
Number of fuel assemblies	40
Active length of Assemblies	1.2 m (4 ft)
Number of fuel plates per assembly	19
Uranium-235 content of an assembly	1,075 g
Total core load	43 kg[d]
Coolant	
Design Pressure	2.7 MPa (390 psig)
Design Temperature	115°C (240°F)
Reactor coolant	Light water
Maximum Coolant Flow Rate	3.09 m^3/s (49,000 gpm)
Coolant Temperature (Operating)	<52°C (125°F) inlet, 71°C (160°F) outlet

a. Maximum design power. ATR is seldom operated above 110 MW_{th}
b. These parameters are based on the full 250 MWth power level and will be proportionally reduced for lower reactor power levels.
c. Only 66 of these are available for irradiations.
d. Total U-235 always less because of burn-up.

Reactor Configuration

Figure 3 shows a sectioned view of the ATR. Water enters the vessel at the bottom, flows up outside cylindrical tanks that support and contain the core, passes through concentric thermal shields, and enters the relatively open upper part of the vessel. The water then flows down through the core to a flow distribution tank below the core and exits the vessel.

Water inlet pressure is 2.5 MPa (360 psig). It enters the reactor vessel at 52°C (125°F) and leaves at an average temperature of 71°C (160°F) when the reactor is operating at full power.

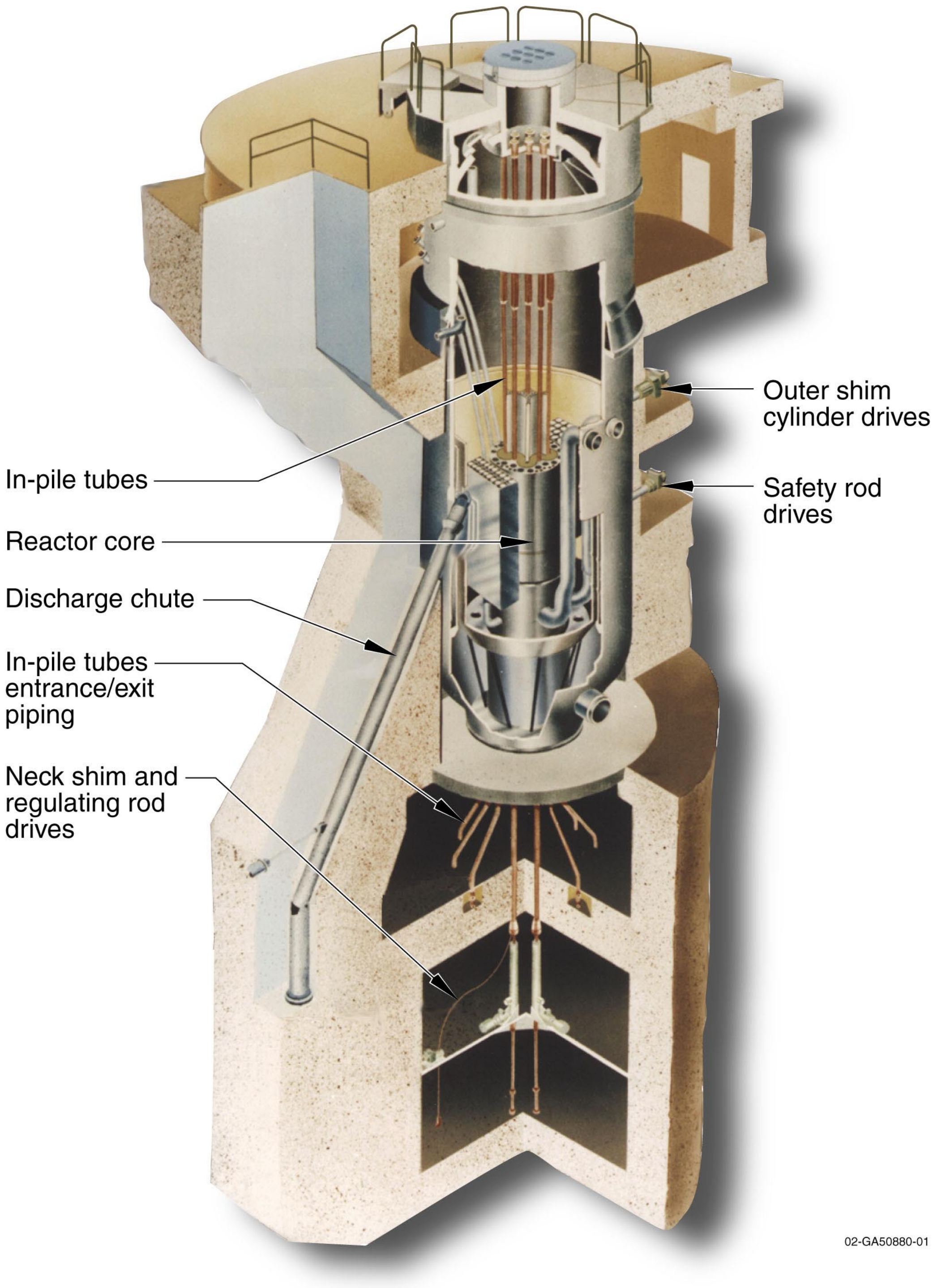


Figure 3. The Advanced Test Reactor.

The ATR operates in cycles that vary in duration, typically from 3 to 7 weeks. Experiments may be inserted or removed only during the shutdowns or outages between operating cycles, but those come relatively frequently. Experiments are inserted through the top head (Figure 4) or through the discharge chute (Figure 3). The top head itself is not removed during routine outages for refueling. Instead, cover plates are removed from five elliptical ports in the top head, each about 61 x 107 cm (2 ft x 3.5 ft). Operators reach down through the ports with long-handled tools to change fuel, irradiation capsules, and core components.

Following reactor shutdown and primary system depressurization, a discharge chute in the side of the vessel slightly above the top of the core, shown in Figure 3, can be opened. This chute is used for transferring used fuel, irradiated capsules, and miscellaneous radioactive hardware to the adjacent canal (Figure 5) during reactor outage periods. Irradiated items remain in the canal until they have cooled sufficiently to be removed and shipped elsewhere.

Figure 4. Top head of the ATR.

Figure 5. ATR canal where experiments are stored temporarily until they are moved to other facilities for examination.

Experiment Positions

The ATR has a wide variety of test positions available for experiments. Some of these are in flux traps. Others are in the beryllium reflector or the neck shim housing. Two of the flux traps (east and south) presently each contain 7 aluminum guide tubes with inside diameters of 1.76 cm (0.694 in). Capsules or lead experiments can be placed in those positions. The center flux trap houses the Irradiation Test Vehicle (ITV), which has three irradiation tubes with 2.51-cm (0.988-in) inside diameter. One design for thermocouple-holding jackets in ITV positions (shown in Figures 2, 7, 9, and 17) has an experiment size of 1.73 cm (0.681 in). Sizes and typical flux levels for these positions and for positions in the neck shim housing and in the reflector are listed in Table 2.

Table 2. Approximate peak flux values for various ATR capsule positions for a reactor power of 110 MW_{th} (22 MW_{th} in each lobe).

Position	Diameter (cm/in)[a]	Thermal Flux (n/cm^2-s)[b]	Fast Flux (E>1 MeV) (n/cm^2-s)	Typical Gamma Heating W/g (SS)[c]
Northwest and				
Northeast Flux Traps	13.3/5.250	4.4×10^{14}	2.2×10^{14}	
Other Flux Traps	7.62/3.000[d]	4.4×10^{14}	9.7×10^{13}	
A-Positions				
(A-1 - A-8)	1.59	1.9×10^{14}	1.7×10^{14}	8.8
(A-9 - A-16)	1.59/0.625	2.0×10^{14}	2.3×10^{14}	
B-Positions				
(B-1 - B-8)	2.22/0.875	2.5×10^{14}	8.1×10^{13}	6.4
(B-9 - B-12)	3.81/1.500	1.1×10^{14}	1.6×10^{13}	5.5
H-Positions (14)	1.59/0.625	1.9×10^{14}	1.7×10^{14}	8.4
I-Positions				
Large (4)	12.7/5.000	1.7×10^{13}	1.3×10^{12}	0.66
Medium (16)	8.26/3.500	3.4×10^{13}	1.3×10^{12}	
Small (4)	3.81/1.500	8.4×10^{13}	3.2×10^{12}	
Outer Tank Positions				
ON-4	Var[e]	4.3×10^{12}	1.2×10^{11}	0.15
ON-5	Var[e]	3.8×10^{12}	1.1×10^{11}	0.18
ON-9	Var[e]	1.7×10^{12}	3.9×10^{10}	0.07
OS-5	Var[e]	3.5×10^{12}	1.0×10^{11}	0.14
OS-7	Var[e]	3.2×10^{12}	1.1×10^{11}	0.11
OS-10	Var[e]	1.3×10^{12}	3.4×10^{10}	0.05
OS-15	Var[e]	5.5×10^{11}	1.2×10^{10}	0.20
OS-20	Var[e]	2.5×10^{11}	3.5×10^{9}	0.01

a. Position diameter; capsule diameter must be smaller.
b. Average speed 2,200 m/s.
c. Depends on configuration
d. East and south flux traps each contain 7guide tubes with inside diameters of 1.76 cm (0.694 in). The center flux trap holds the Irradiation Test Vehicle having 3 tubes, two with 1.73-cm (0.681-in) inside diameter and one with 2.24 cm (0.881-in) inside diameter.
e. Variable; can be either 2.22, 3.33, or 7.62 cm (0.875, 1.312, or 3.000 in)

The main radiation positions in the reactor for irradiation capsules are in four groups: “A”, “B”, “H”, and “I”. Group “A” positions are in the cruciform-shaped neck shim rod housing projecting above the reactor core, visible in Figure 6. Since the original construction, four additional “A” positions have been added. Figure 7 shows a more detailed mapping of the “A” position locations. The inner 8 of these positions (A1 to A8) are difficult to access, so they are used mainly for long-term irradiations.

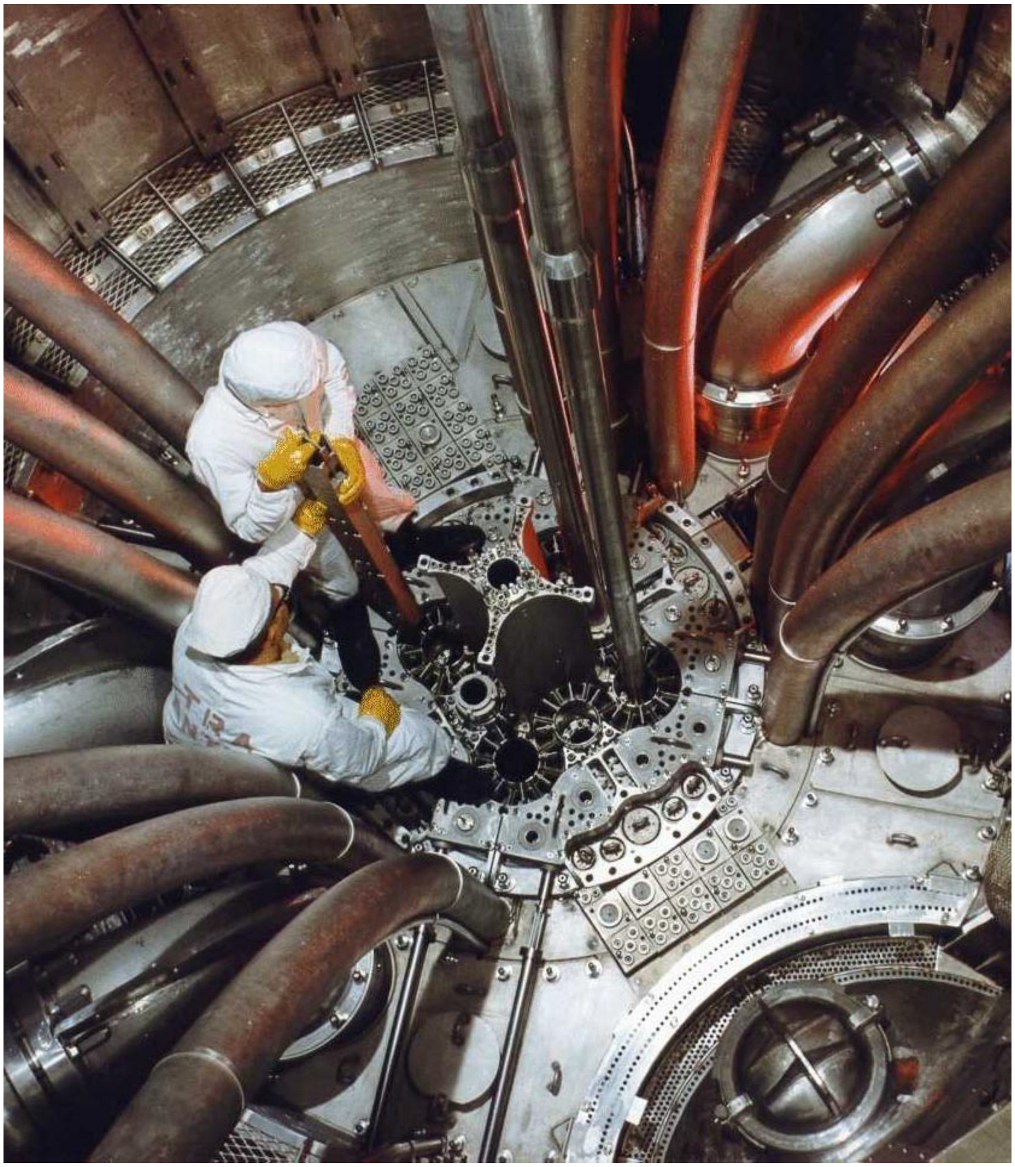


Figure 6. The neck shim rod housing lies at the center of the reactor core, shown here during initial reactor assembly.

Group “H” positions are in the center flux trap assembly that houses the ITV. These are also shown in Figure 7. Positions H-3 and H-11 are used for N-16 monitors and are not available for irradiations. The other 14 “H” positions extend 15.2 cm (6.0 in) below the active core for a total facility length of 2.718 m (107 in).

Groups “B” and “I” are located in the beryllium reflector surrounding the core (Figure 8). Their locations are shown in Figure 9. The “B” positions are located close to the fuel elements and, as indicated in Table 2, have considerably higher neutron flux than do the larger “I” positions.

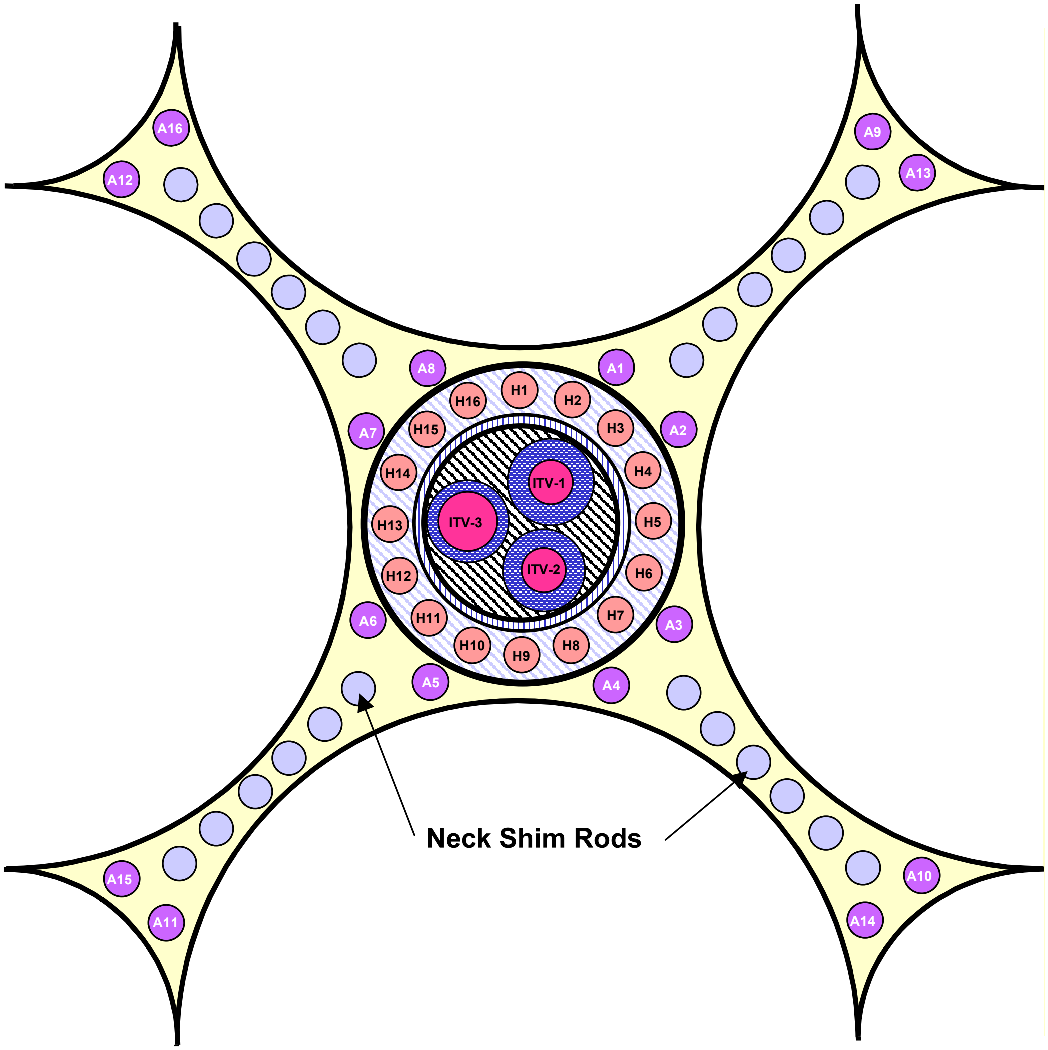


Figure 7. Irradiation positions in Group "A" are in the neck shim housing while Group "H" positions are in the center flux trap. The Irradiation Test Vehicle also has three irradiation positions.

Neutron Flux

The neutron flux in the ATR varies from position to position and along the vertical length of the test position. It also varies with the power level in the lobe(s) closest to the irradiation position. Thermal and fast flux intensity values listed in Table 2 are at the core mid-plane for a reactor power of 110 MW_{th} and assume a uniform reactor power of 22 MW_{th} in each lobe. Figure 10 shows the axial distribution of neutron flux for five different energy groups in the ITV, located in the center flux trap. These data are for a slightly higher total reactor power of 125 MW_{th}. Figure 11 shows the average unperturbed neutron energy spectrum for the same reactor power of 125 MW_{th}. Figure 12 illustrates the lateral variation in flux intensity at the mid-plane in the east quadrant of the core for a much higher

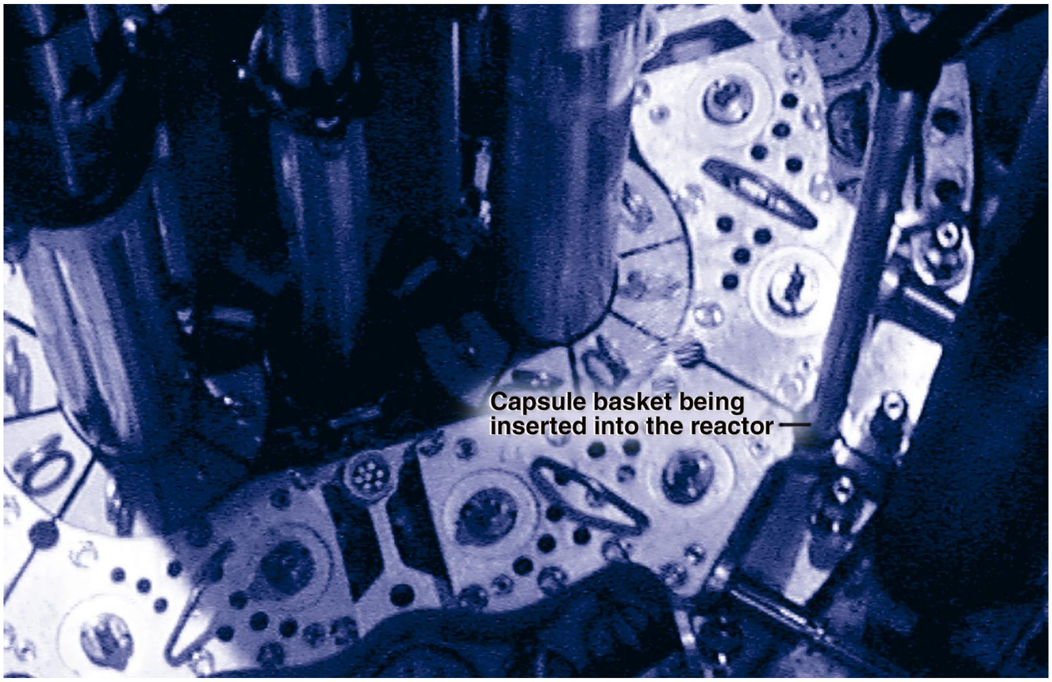


Figure 8. ATR beryllium reflector with irradiation capsule basket being inserted into a small "I" position.

reactor power of 220 MW_{th}. Lines of constant flux intensity for thermal neutrons are shown with a contour interval of 4 x 10^{13} n/cm^2–s. Locations of the OSCCs and many of the test positions are also shown.

Gamma Heating

Gamma heating in the ATR core is highest at the core mid-plane. It falls off with essentially a cosine distribution to the top and bottom of the core where the fuel elements end. Then it drops off with an exponential decay as one goes further and further from the core. Figure 13 shows typical gamma heating profile for a small (2.22-cm, 0.875-in) "B" position with the reactor operating at 125 MW_{th}.

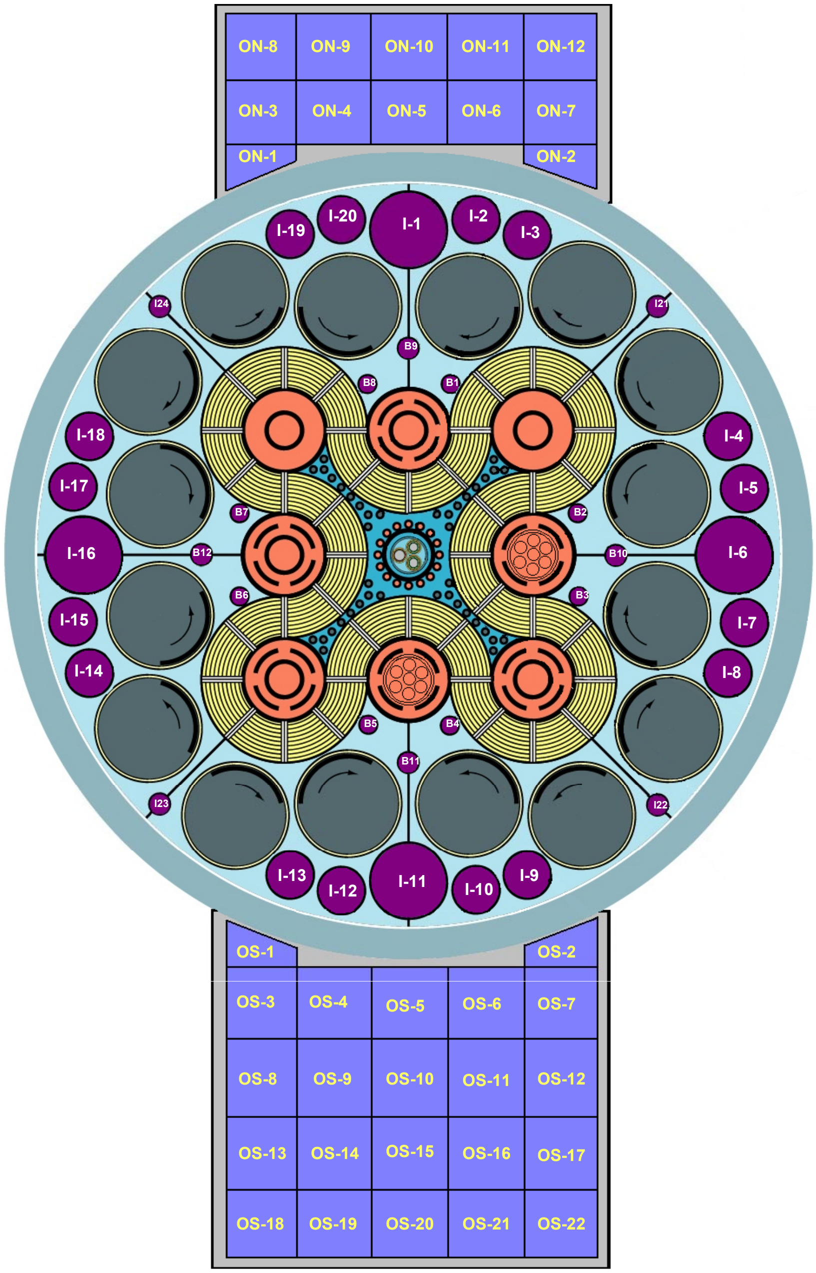


Figure 9. Small “B” positions are located close to the fuel elements, while “I” positions are in the periphery of the beryllium reflector. The Outer Irradiation Tank positions (ON-1 to ON-12 and OS-1 to OS-22) can be used with capsules of three different diameters.

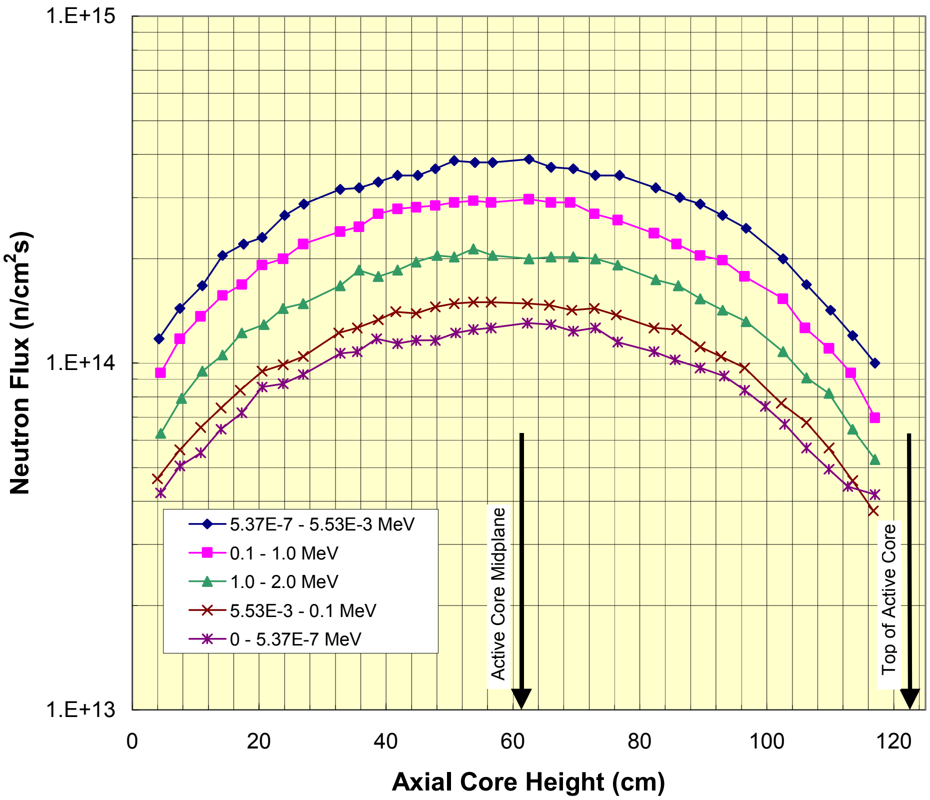


Figure 10. Unperturbed five-energy-group neutron flux intensity profiles over the active core length of the ITV in the ATR center flux trap for total reactor power of 125 MW_{th}.

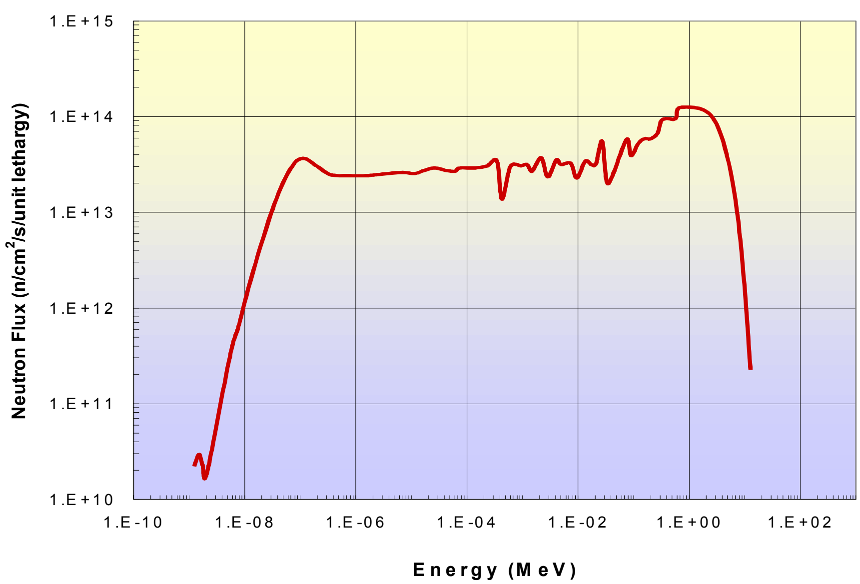


Figure 11. Unperturbed neutron energy spectrum for the ITV with the reactor operating at 125 MW_{th}.

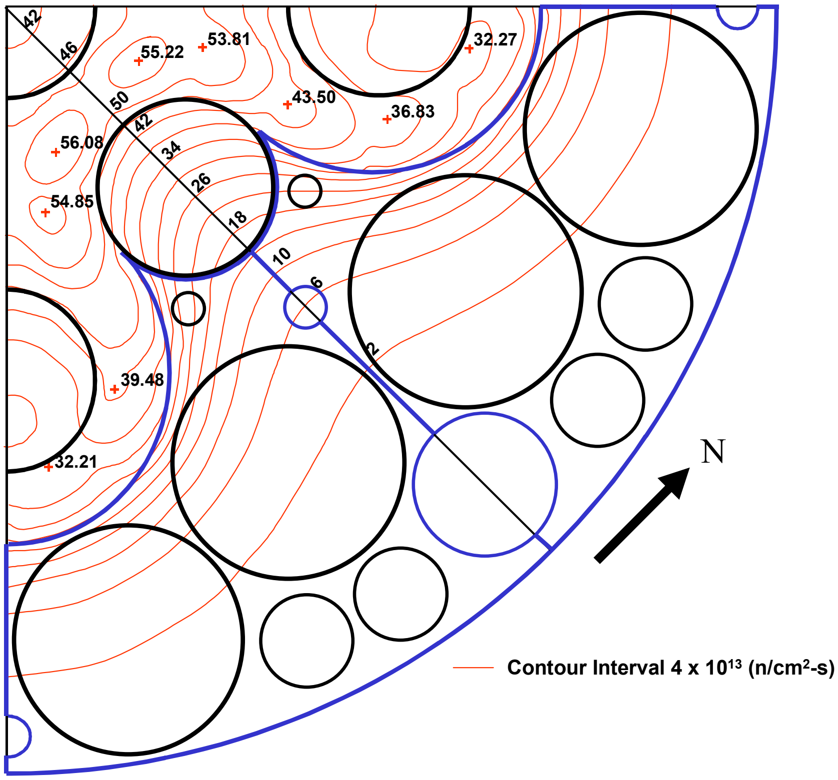


Figure 12. Unperturbed thermal neutron flux intensity distribution at the midplane in the east quadrant of the ATR for a reactor power of 220 MW_{th}.

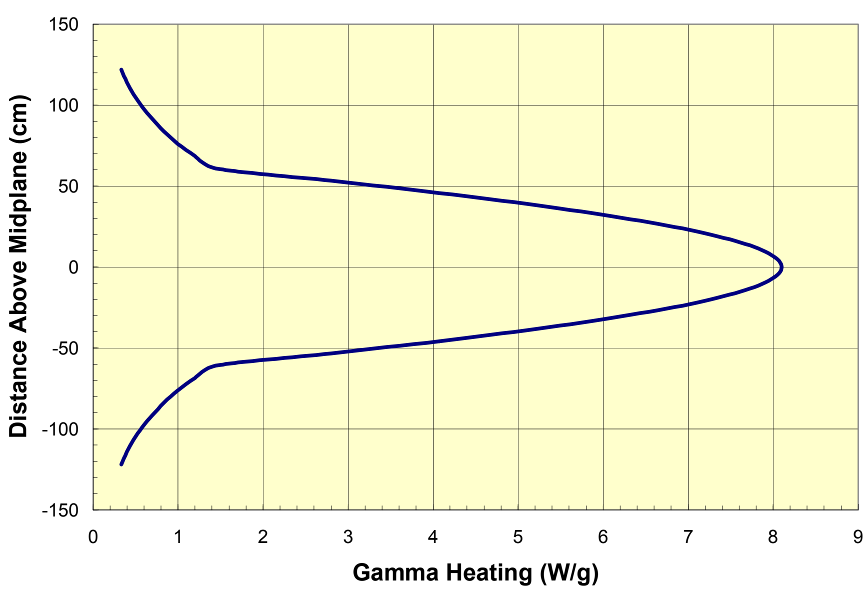


Figure 13. Typical gamma heating profile in a small “B” position with the reactor operating at 125 MW_{th}.

ATR IRRADIATION FACILITIES AND HARDWARE

Irradiations in the ATR are of three types, capsule, instrumented lead, and loop. These are of increasing complexity and cost.

Drop-In Capsules

A capsule experiment may contain a number of small samples, or, particularly if a large "I" position is used, it may contain engineered components. Temperature within the capsule is usually controlled by providing a gas gap with a known thermal conductance (Figure 14). Peak temperature is often indicated using a series of temperature sensitive paint spots or melt wires. Thermal bonding media such as liquid metals may be used in capsule experiments to keep temperatures uniform inside the experiment. Flux-wire activation monitors in the experiments can give good measurements of neutron fluence at particular locations. Figure 15 is an example of a drop-in capsule experiment.

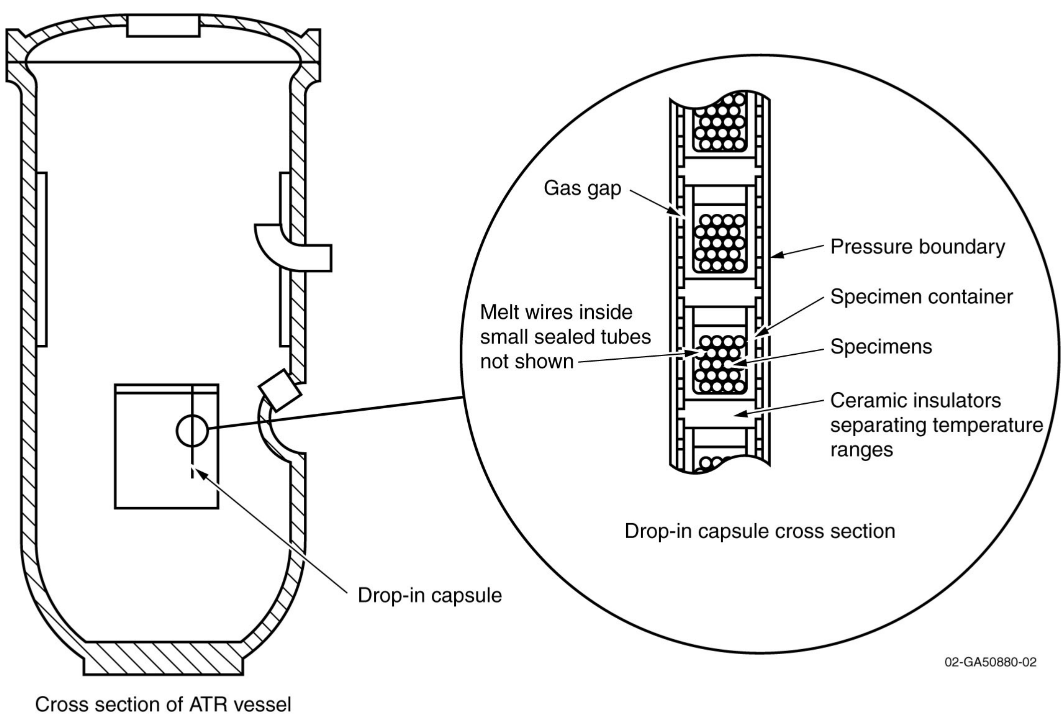


Figure 14. Drop-in capsule experiments are often stacked in aluminum baskets.

Capsule tests cost less than either instrumented-lead or loop tests but provide less flexibility and no dynamic control of the irradiation environment. Capsules may be any length up to 122 cm (48 inches). Uninstrumented capsules are typically 40.6 cm (16 inches) long and are stacked in aluminum baskets, for easy handling.

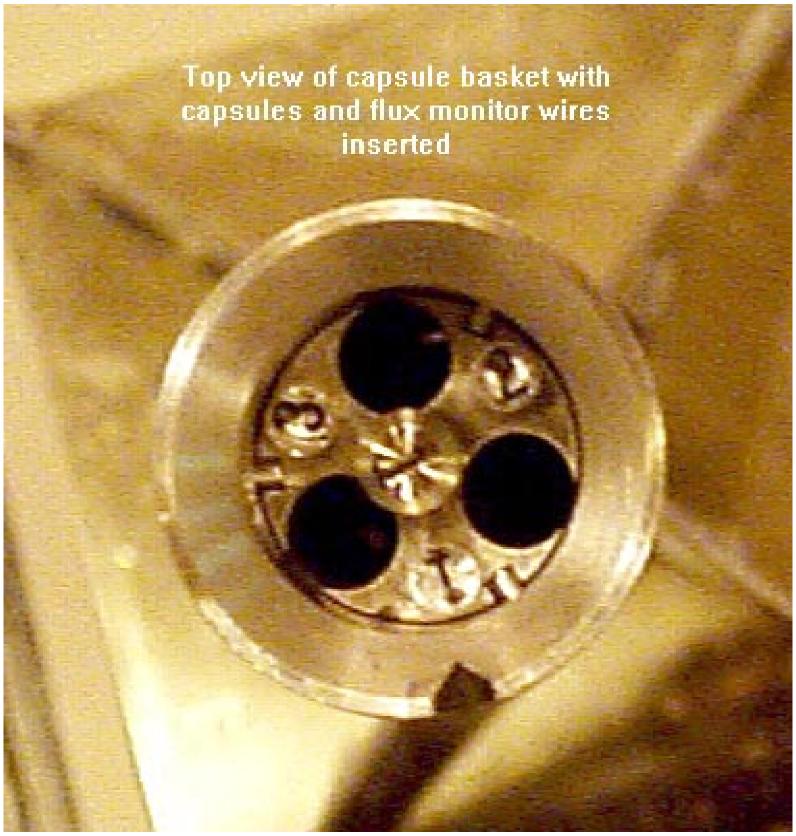


Figure 15. Typical experiment ready for insertion into one of the ATR's many test positions.

Instrumented Lead Experiments

Some capsules have lead tubes attached for carrying instrument wires and gases outside the reactor vessel. These are referred to as instrumented lead experiments. Figure 16 shows conceptually how an instrumented lead experiment is installed in the ATR.

Instrumented lead experiments are more complex than simple drop-in capsules. They may have a relatively large number of thermocouples, for example, connected to individual capsules or even single specimens. There may be active control and sampling of atmospheric composition inside the capsule. Experimenters can control temperature in individual zones by varying the gas mixture (typically helium and neon) in the gas gap that thermally links the capsule to the water-cooled reactor structure. Other electrical or pneumatic connections may also be used, subject to reactor safety requirements.

With the added complexity of these experiments, timing for installing and removing the experiment is not as flexible as for drop-in capsules. Costs for installing and operating the experiments are also higher.

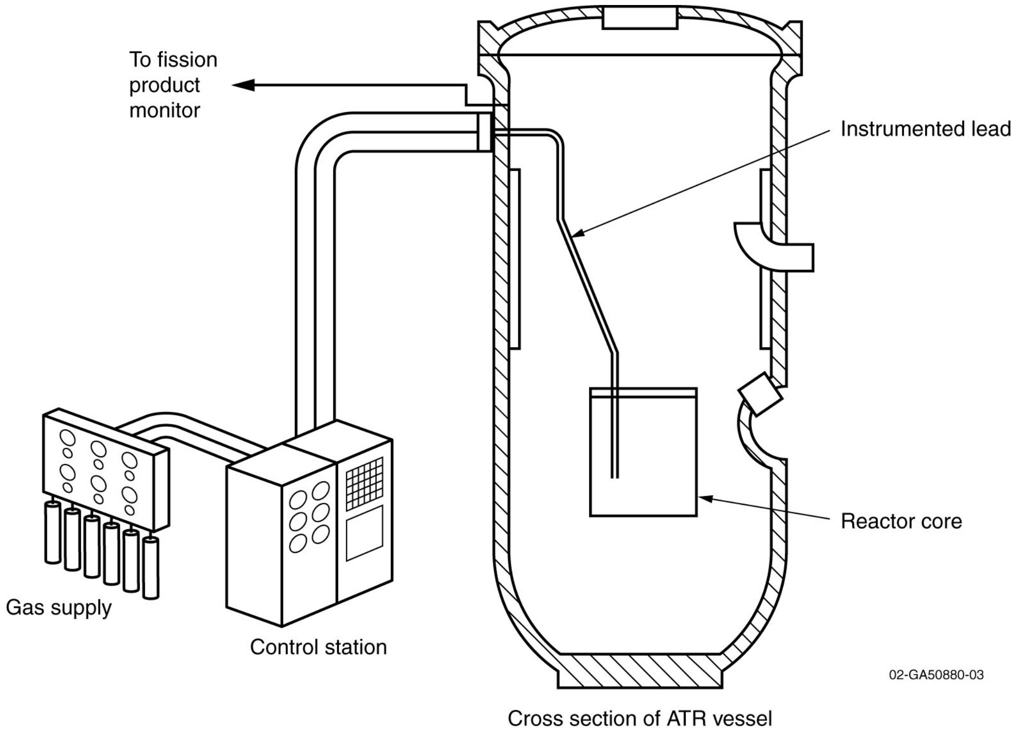


Figure 16. Instrumented lead experiments can have a controlled atmosphere as well as temperature monitoring and control and other instrumentation.

ITV

A specialized instrumented lead facility is the ITV, located in the center flux trap and shown in Figure 17. It is possible to provide neutron spectral tailoring in the ITV, and individual temperature control is possible for up to 15 experiment capsules simultaneously. The ITV consists of three in-pile tubes running the length of the reactor vessel. These in-pile tubes are kept dry, and test trains with integral instrumentation are inserted and removed through a transfer shield plate above the reactor vessel head. The facility is designed to irradiate specimens as large as 2.2 cm (0.881 in) in diameter, at temperatures of 250–800°C (480–1,470°F), achieving neutron damage rates in vanadium as high as 10 displacements per atom per year. The gas-blend temperature control system remains in place from test to test, thus hardware costs for new tests are limited to the experiment capsule train and integral instrumentation.

The high fast-to-thermal neutron flux ratio required for some irradiations is accomplished by using an aluminum filler to displace as much water as possible from the flux trap and surrounding the filler piece with a ring of replaceable neutron absorbing material. Figure 18 shows the suppression in thermal neutron flux calculated to be achieved by using a borated filter. Note that the ITV itself perturbs the flux energy spectrum somewhat, as may be seen by comparing the ‘without filter’ curve from Figure 18 with the curve in Figure 11.

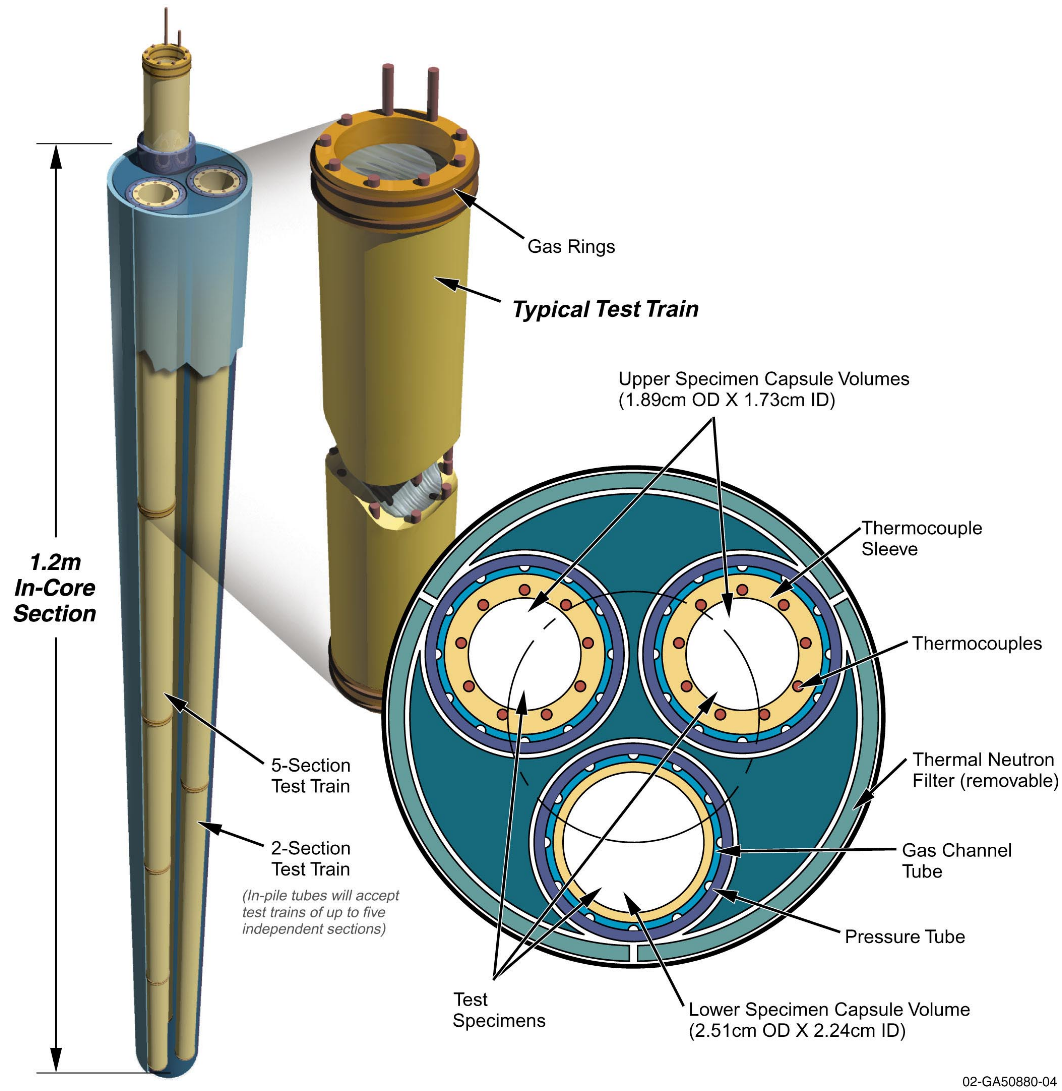


Figure 17. The ITV can accommodate up to 15 simultaneous instrumented-lead capsule experiments.

To minimize costs to customers, the following features were incorporated into the ITV design.

- Automated control and data acquisition was included to reduce operational staff requirements.
- No reactor vessel pressure boundary penetration is required to remove and replace tests.
- Equipment and methods used to install and discharge the ITV tests were previously developed for handling Naval Reactors Program experiments.
- Design and procedures maximize the amount of the irradiation facility left in place between tests.

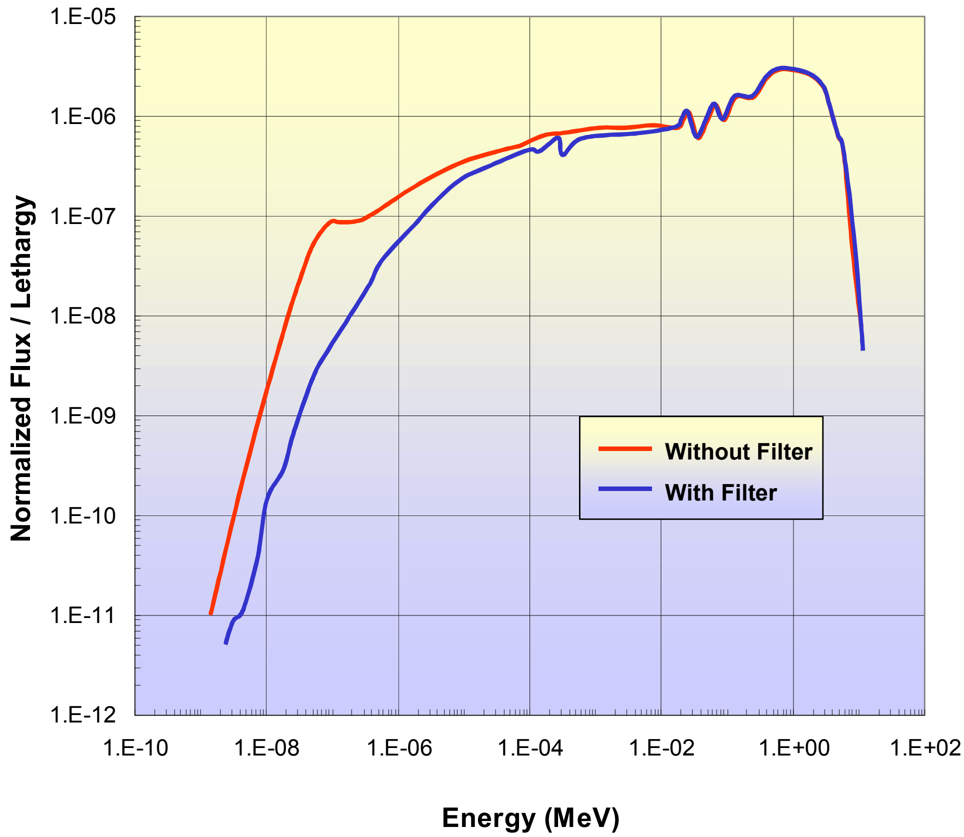


Figure 18. A filter may be used with the ITV to substantially reduce the thermal neutron flux density.

Pressurized Water Loops

Five of the nine flux traps in the ATR are equipped with pressurized water loops, which are used for materials and fuels testing. The great advantage of loop tests is the ease with which a variety of samples can be subjected to conditions specified for any pressurized water reactor design. Many samples can be tested at once (in several loops or one loop, depending on the size of samples) with variation in the samples, thickness of cladding, etc., and the samples can be compared afterward for optimum design. Materials and fuels designers rely heavily on such tests.

While there are variations in the designs of the various loops, Figure 19 shows a typical loop cross section. Three concentric tubes form the piping assembly for each water loop in the ATR. The assembly penetrates the vessel's bottom closure plate and has an inlet and an outlet below the vessel. Coolant comes up through the innermost tube, the flow tube, and passes the sample. Near the top of the vessel, on four of the five loops, the coolant passes through positions in the flow tube into the annulus enclosed by the pressure tube and returns down that annulus to the outlet. On the fifth loop, the water passes only one way, up through the in-pile tube and out.

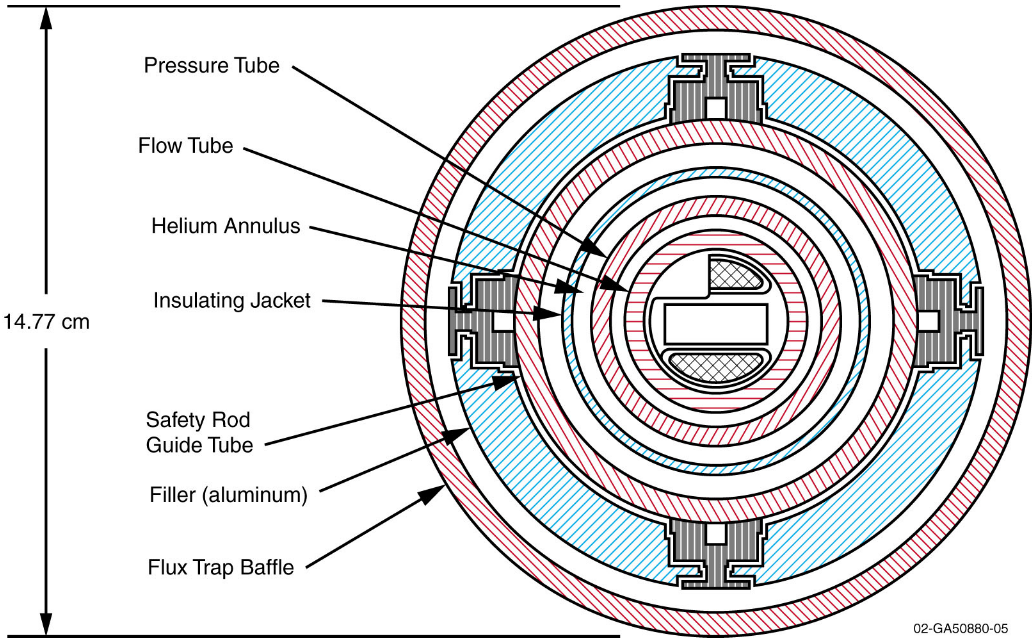


Figure 19. Cross section of the in-core portion of a typical pressurized water loop experiment.

Helium flows through the annulus enclosed by the outermost tube, the insulating jacket. Insulation is essential because the inside of the pressure tube is in contact with loop coolant at temperatures up to 360°C (680°F), whereas the outside of the insulating jacket is in contact with primary system coolant at 52°C (125°F). The helium is monitored for moisture to detect any leaks in the tubes.

Loop cubicles and equipment occupy the space around the reactor on two basement floors. The pressurized water loop equipment includes piping within the reactor vessel and pumps, heat exchangers, a pressurizer, and demineralizers within a shielded cubicle (Figure 20). The line heaters are capable of raising the loop coolant temperature from 38 to 360°C (100 to 680°F) in three hours. Normally, these heaters are used to capacity only when preparing the loop for startup. After the reactor comes into operation, fission and gamma heating of the samples provides much of the required heat.

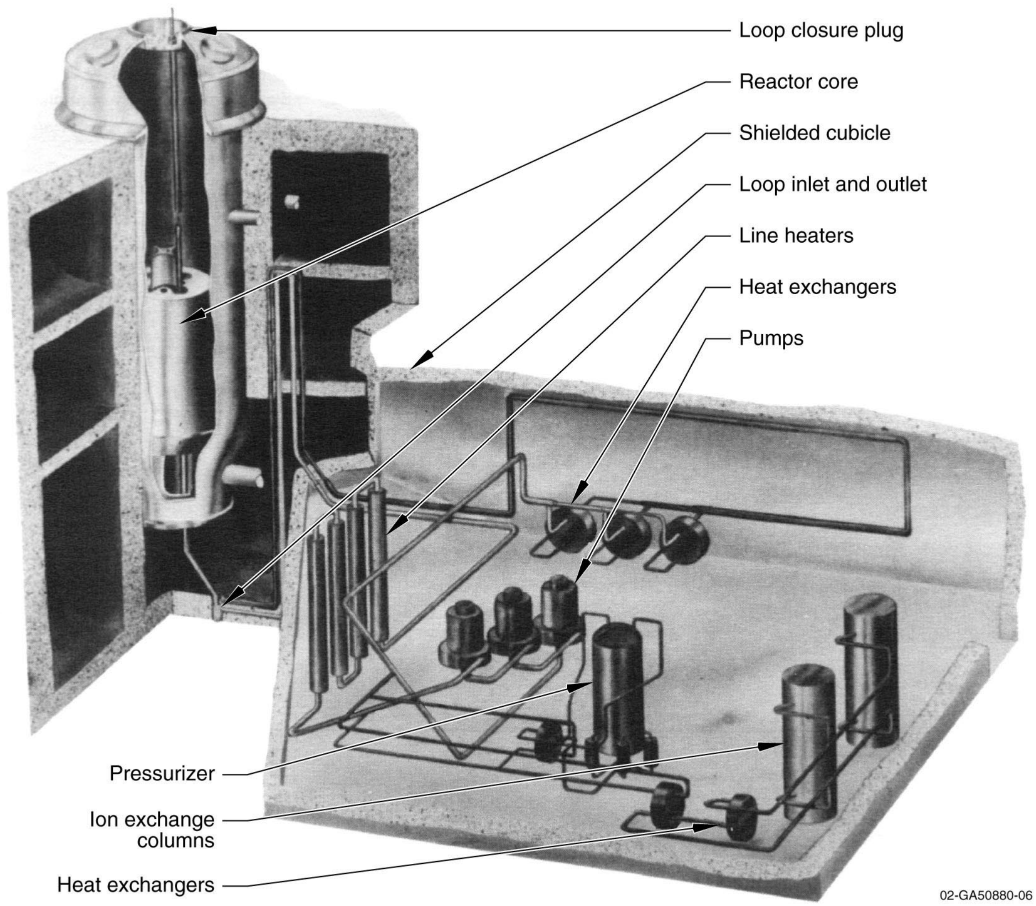


Figure 20. Pressurized water loop experiments provide environmental simulations for many different reactor conditions.

Each loop in the ATR is instrumented to measure coolant flows, temperatures, and pressures, and sample test data. Loop instrumentation and controls are located in the southwest portion of the ATR second basement in a controlled environment room. Precise control of the loop coolant temperature is achieved by automatic regulation of the amount of coolant bypassing the loop heat exchangers.

No loop instrumentation or control is duplicated in the reactor control room. However, loop parameters are displayed on the Loop Data Acquisition System located in the reactor control room. Setpoints in the loop circuitry such as loop pump failure, low coolant flow, or high temperatures are capable of causing reactor power reductions or scrams to protect the experiments. When any of these problems occur, trouble lights or annunciators light up on the panel of the reactor control room to indicate which loop is having trouble.

The ATR in-pile tubes can be subjected to high neutron fluxes, and the fluxes can be controlled. An added refinement is the ease of adjusting the neutron energy spectrum, using techniques similar to those described for the ITV. The ability to produce different neutron energy spectra in ATR loops can be valuable.

Another advantage of ATR loops is the ease with which samples can be changed. To remove a sample, it is necessary only to remove a shield plug from the transfer plate, disconnect the lead wires to the sample, unlock the closure plug, install a transfer sleeve, and draw the sample up into a removal cask.

Gamma Facility

In addition to the neutron irradiation facilities inside the ATR, the ATR Gamma Facility accommodates gamma irradiation experiments. Located in the ATR canal, the Gamma Facility is essentially an 12.7-cm (5-in) tube projecting from the spent fuel rack to the top of the ATR canal, as shown in Figures 21 and 22. A shielding plug on the top (not shown) blocks sky-shine of the gamma radiation passing up the tube. The intensity of the gamma irradiation that can be achieved in the gamma facility will depend on the freshness of the fuel and its proximity to the gamma tube. A typical value for fuel freshly removed from the reactor placed adjacent to the tube is 5×10^6 R/hr. That intensity will fall off at the rate of approximately 5% per day as the fission products in the fuel elements decay away.

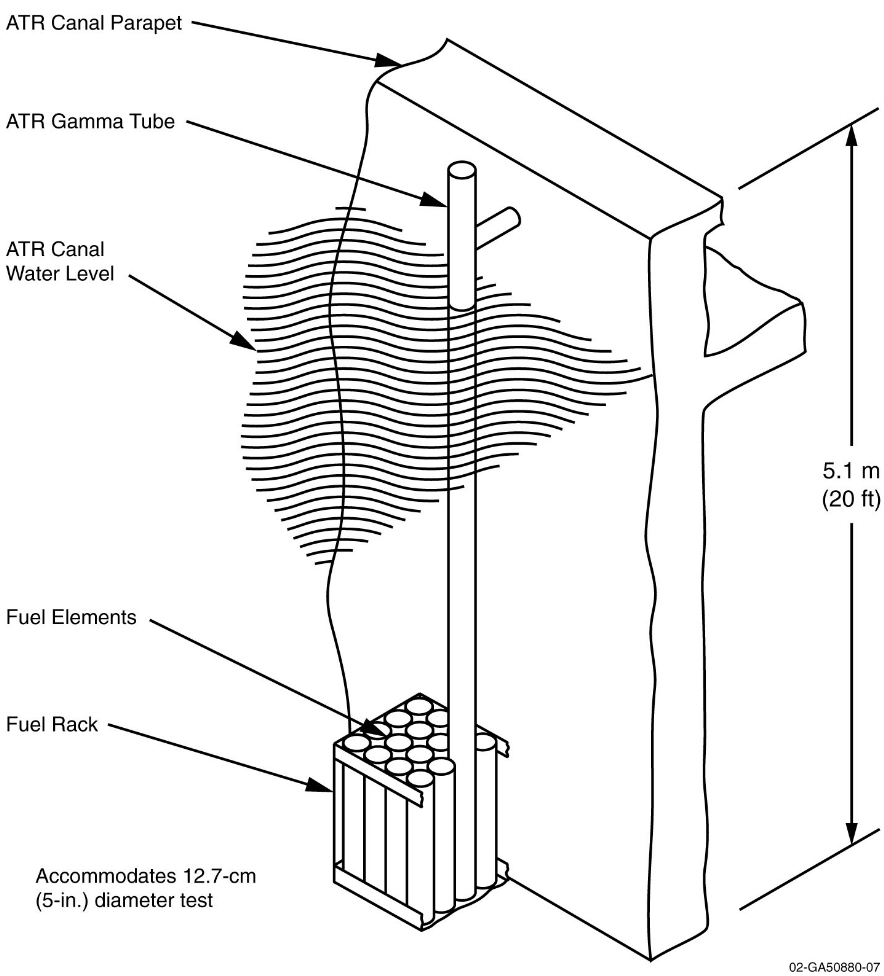


Figure 21 The ATR Gamma Facility allows gamma irradiations from spent fuel in fields up to 5×10^6 R/hr.

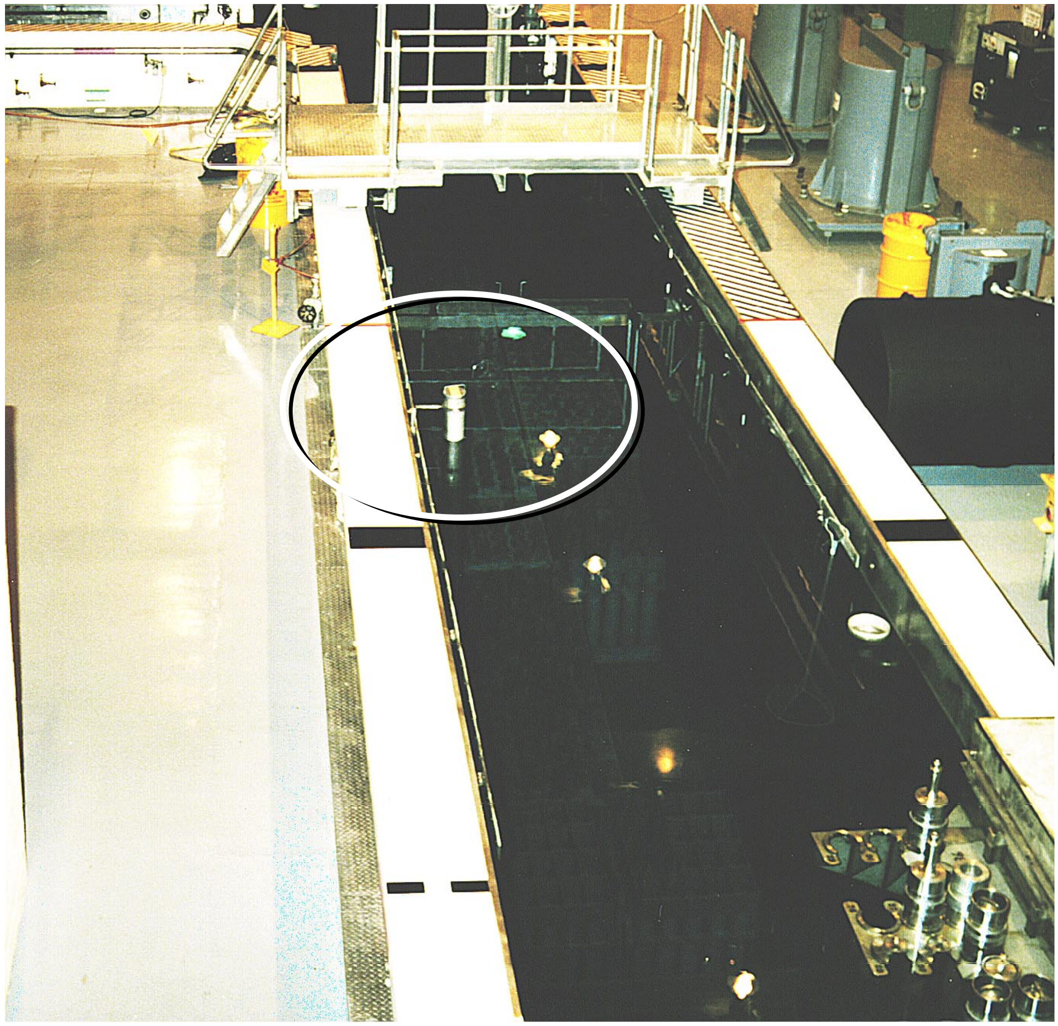


Figure 22. The Gamma Facility is in the ATR canal fuel rack.

ATR Critical Facility

Before an experiment can be placed in the ATR core, its effect on core reactivity must be known with good accuracy and precision. Sometimes it is necessary to determine that experimentally in the ATR Critical (ATRC) facility.

The ATRC is a low-power; full-size nuclear replica of the ATR, designed to evaluate prototypical experiments before irradiation of the actual experiments in the ATR. The ATRC provides valuable reactor physics data that contribute to evaluating (a) control element worths and calibrations, (b) excess reactivities and charge lifetimes, (c) thermal and fast neutron distributions, (d) gamma heat generation rates, (e) fuel loading requirements, (f) effects of inserting and removing experiments and experiment void reactivities, and (g) temperature and void reactivity coefficients.

Depicted in Figure 23, the ATRC is a pool type reactor located in an extension of the ATR canal. Normal power level is about 100 W; maximum power is 5 kW.

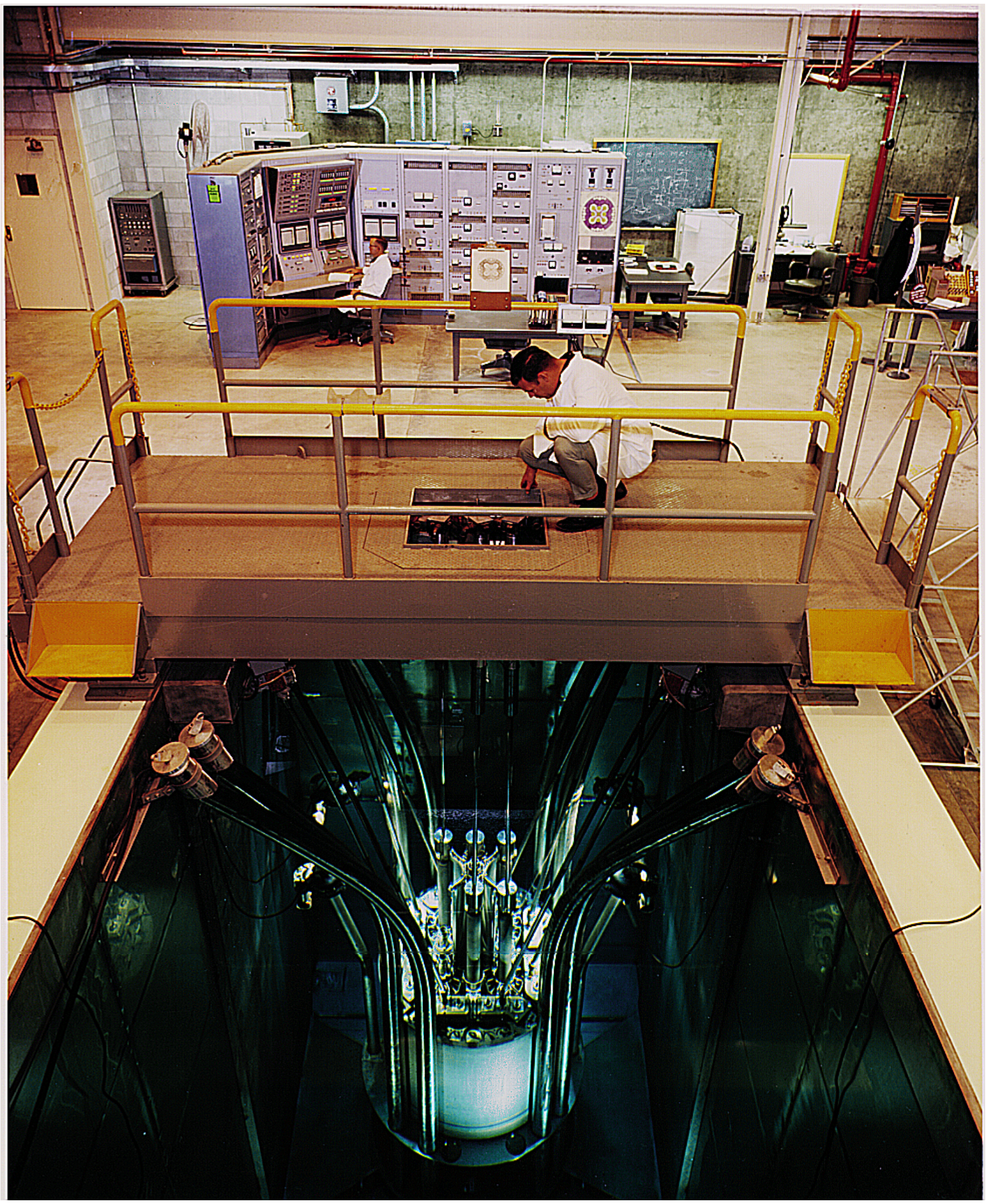


Figure 23. The Advanced Test Reactor Critical Facility is used to verify reactivity of experiments placed in the reactor and core configurations.

When ATRC testing is necessary, experimenters are required to furnish prototypes of capsule experiments. It is not unusual to test these designs in the ATRC prior to each ATR cycle to ensure the reactivity effects are known.

Canal Operations

Experiments are removed from the reactor and lowered through the discharge chute (Figure 3) into the ATR canal. Once there, they are moved to an appropriate location for temporary storage. There are facilities in the canal where underwater operations with long-handled tools can be conducted. Such operations may include rearranging capsules in a basket, experiment examination, or removal of the experiments. For example, an experimenter may wish to remove a capsule for experiment examination partway through a test program. The basket may be opened and reassembled on an underwater workbench, then the basket can be retrieved through the discharge chute or moved into a transfer cask and re-inserted into the test position.

Hot Cells

Hot cell facilities are available at the Test Reactor Area (Figure 24), and a shielded cask is available to transport experiments from the ATR canal to the hot cells. The TRA hot cells are furnished with shielded viewing windows, remote manipulators, and basic utilities including appropriate atmospheric controls. Functions performed in these hot cells in the past have included assembly/disassembly, storage, inspection, and examination, including metallography, of radioactive or other hazardous material. Specialized activities in the TRA hot cells required by users should be discussed with the ATR New Business Office (NBO).

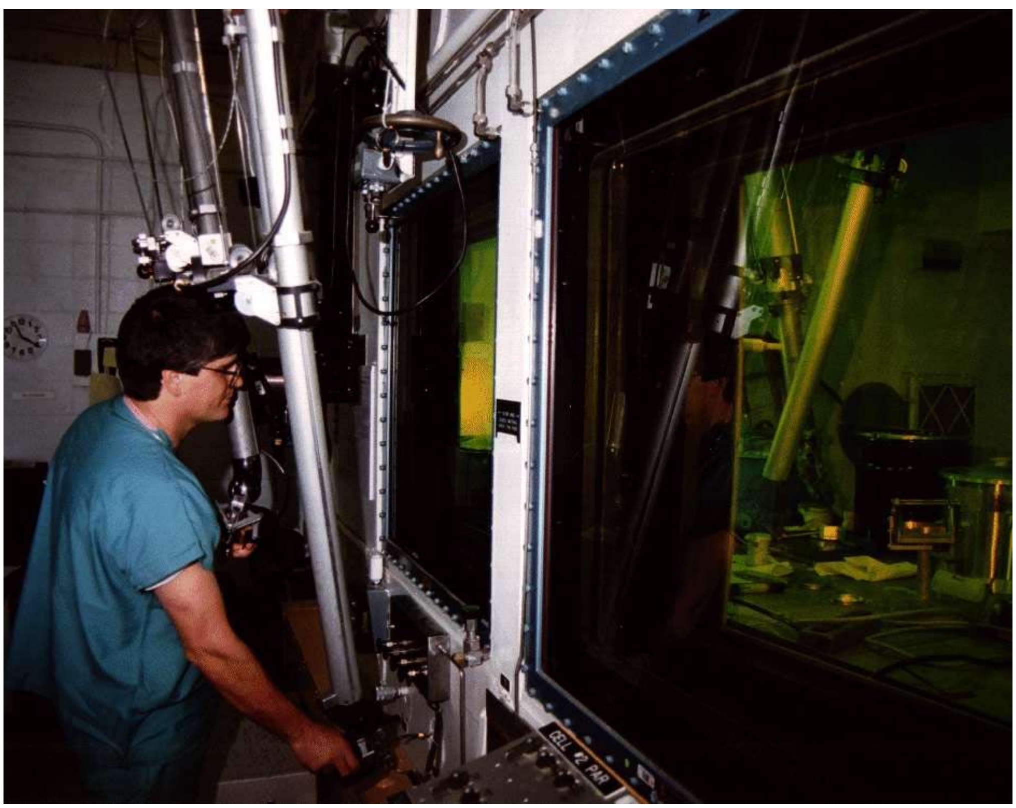


Figure 24. Hot cell facilities are available at the Test Reactor Area.

Availability

The Naval Reactors Program (NR) is the primary customer for the ATR and makes continuous use of all the flux traps except the East, South, and Center flux traps (see Figure 2). All of the “A”, “B”, “H”, and “I” positions identified in Table 2 and Figures 7 and 9 (except H3 and H11) are normally available, subject to utilization by other experiments. Essentially all of the outer tank positions are available. A few of those are used for reactor diagnostics.

The ATR operates in cycles that may be as short as three weeks but are usually about seven weeks in duration. Those times include the typical outage or down time of one week during which experiments are inserted and removed, fuel is replaced, and any other preparations needed for the next cycle are performed. Appendix D lists a typical operation schedule over the course of a year. Scheduling of ATR operating cycles is normally controlled by the needs of the Naval Reactors Program. A current ATR Operations Plan can be obtained from the ATR New Business Office at http://www.INEEL.gov/energy/nuclear. Counting the outages, the overall availability of the reactor is about 75%.

USING THE ADVANCED TEST REACTOR

As with any highly technical facility, there are certain aspects of ATR utilization and making use of other INEEL facilities that require careful coordination and controls.

ATR User Policy

The Advanced Test Reactor is a United States Department of Energy facility operated primarily for materials research and materials testing for the primary support customer, the US Naval Reactors Program. The facility is available on a full cost recovery basis to other federal agencies, states, universities and other qualifying non-governmental and industry users.

Department of Energy Work

Irradiation services and support services acquired at INEEL for Department of Energy funded work is processed in the same manner as all other DOE work at INEEL. Particulars of intellectual property rights, data rights, and funding issues are those required by the DOE.

Work-for-Others Process

Irradiation services and support services acquired at INEEL for non-Department of Energy funded work are governed by the requirements of the DOE Order *DOE O 481.1, Work for Others (Non-Department of Energy Funded Work)*. A Work-for-Others Agreement including terms and conditions applicable to the work will be developed. Approval of work for non-foreign Sponsors is provided by the DOE Idaho Operations Office. Work-for-Others agreements with foreign sponsorship require DOE Headquarters approval.

Patent Rights

The rights in inventions of the INEEL Contractor's employees are governed by the provisions of the Management and Operations (M&O) prime contract. The Sponsor may elect to obtain the entire right, title, and interest throughout the world to each invention and any patent application filed in any country on an invention and in any resulting patent secured by the Sponsor. Other provisions for assignment of patent rights to the INEEL M&O Contractor and the Government are applicable if the Sponsor does not elect to retain all rights to inventions.

Data Rights

The Sponsor may designate as Proprietary Information any generated information where such data would embody trade secrets or would comprise commercial or financial information that is privileged or confidential if it were obtained from the Sponsor. Such Proprietary Information will, to the extent permitted by law, be maintained in confidence and disclosed or used by the INEEL Contractor only for the purpose of carrying out the Contractor's responsibilities under the WFO Agreement. Upon completion of activities under the WFO Agreement, Proprietary Information will be disposed of as requested by the Sponsor. Subject to invention disclosure considerations, the government normally reserves unlimited rights to all information generated during the course of Agreement activities.

General Facility Availability Schedule

As noted earlier, the typical ATR operating-cycle is typically from three to seven weeks with the longer ones being more normal. The stability of the operating plan is of critical importance to all users, since it impacts the planning and execution of all activities performed prior to and after the irradiation period. For planning purposes, customers should expect seven cycles to be completed in a year's time. Appendix D is an example of a typical operations plan for the ATR. Periodic special maintenance, special reactor shutdowns or operations and miscellaneous contingencies result in an annual reactor availability of approximately 75%.

The accommodation of different experiments each operating cycle requires a substantial analytical effort to ensure that the core environment is properly established. Changes in the core loading each cycle require careful attention to impacts by each experiment. Therefore it is necessary to have all experiment information to support core safety analysis and fuel selection provided in sufficient time that required analysis can be completed six weeks prior to the beginning of the cycle scheduled for experiment insertion. The actual lead time required depends on the complexity of the experiment.

This requirement, in turn, dictates that all equipment, hardware, procedures, data packages, quality assurance items, and definition of special requirements for a given irradiation experiment must have high assurance of being completed prior to the scheduled installation date. All experiment assemblies to be loaded for a given cycle must be approved for insertion and available to reactor operations at least seven days prior to the scheduled beginning of the cycle.

Cost of Services

The INEEL is funded through specific Federal programs. All operational and support costs are borne by programs sponsoring defined work at INEEL, including ATR and TRA support facilities. The ATR Primary Sponsor, the DOE Office of Naval Reactors, does not normally require all ATR irradiation services capacity. This circumstance provides an opportunity for others to employ the unique facility and staff capabilities in their business plans. The full range of the TRA facility capabilities can be made available on a cost sharing basis to any entity wishing to do so. The Federal Government continues to pay the full cost of keeping the facilities operational and properly maintained. Customers will pay for only the portion of facility and staff used. The actual cost is dependent upon the defined customer requirements and is established via contract negotiations.

The ATR irradiation space charges are based upon space occupied by the experiment, irradiation time, and thermal flux. Details of these charges are available in the ATR Pricing Policy available through the NBO.

Charges for a given irradiation space will vary with the total reactor power level. The charges for each test space are forecast at the beginning of the fiscal year for each cycle in that year. Irradiation costs are approved by the Department of Energy (DOE).

It is impossible to provide a generic cost table for the various kinds of experiments because of the differences in experiment configuration, irradiation conditions, operating cycle times, etc. that will pertain to the various experiments performed. Typically, the total cost for a drop-in capsule experiment will range from $200,000 to $800,000. Lead-times required for drop-in capsule experiments will generally be those shown in Figure 25. Instrumented-lead experiments will typically be up to a factor of 5 more costly and require lead times of 15 months or more. Pressurized water loop experiments are more expensive yet and may cost in the tens of millions of dollars, depending on complexity. Lead-times required for these experiments are also longer and can be several years. Experiments with flux augmentation by including fuel in the test article are more costly yet.

In addition to actual irradiation costs, the sponsor of an experimental program will be charged a substantial demurrage fee if technical difficulties with his experiment result in a significant extension of the critical-path time schedule for the reactor. For that reason, it is essential that, in addition to the actual test article, a neutronically similar but otherwise dummy experiment be prepared and provided along with the actual test article. Then, if a problem develops, the dummy can replace the actual experiment, and the costs of ATR operations schedule delay can be avoided.

Access to INEEL facilities, staff and materials is available on a full cost recovery basis. If ancillary facilities or laboratories are needed, specific charges are determined and negotiated during the preparation of irradiation services contracts. INEEL labor rates charged will be the individual's hourly rate times the company burden rate (established annually) times the hours recorded on the individual's time card. Actual costs, not estimated costs, are billed to the customer unless otherwise negotiated. Materials obtained are billed at actual cost including a nominal material burden charge. Funds unused will be returned to the sponsor.

Obtaining Irradiation Services

The ATR irradiation facilities and supporting INEEL staff and facilities are available through the DOE Work-for-Others process. A flow diagram of the process for obtaining irradiation services is provided in Figure 25. These steps are discussed in detail below.

Contacting the ATR New Business Office

To initiate acquisition of irradiation services and other INEEL services, the interested User or Sponsor will need to contact the ATR New Business Office (NBO). A web site for initial contact is http://www.INEEL.gov/energy/nuclear. This contact should be made from 9 months to 2 years ahead of the intended start of irradiation, depending on the complexity of the experiment. The NBO will integrate all activities leading to irradiation services contracts at ATR. The NBO will also coordinate activities for use of support facilities and personnel at TRA and the INEEL. The NBO will examine the technical and scheduling needs for irradiation services.

Informal Technical Discussions

Normally within 30 days of the initial contact with the NBO, a meeting will be held involving both the new program applicant, the NBO, and technical support persons brought in by the NBO. At this meeting, the proposed program Sponsor will present informally the experiment program being considered (see Appendix A for information that will be sought) together with any specialized requirements for the irradiation or other support. Discussions will clarify availability and requirements for ATR utilization. Following this informal discussion, the NBO will conduct a compatibility analysis to ensure that customer requirements can be adequately served by ATR technical capabilities and within schedule constraints. Based on the compatibility analysis, the NBO will recommend or discourage continued discussions.

Program Requirements Meeting

This meeting is where the sponsor formally presents requirements and plans for the proposed program. It would normally be held from 20 to 60 days following the informal discussions. An experiment data sheet is prepared that documents these requirements. A preliminary 'go/no-go' decision is made at this time on

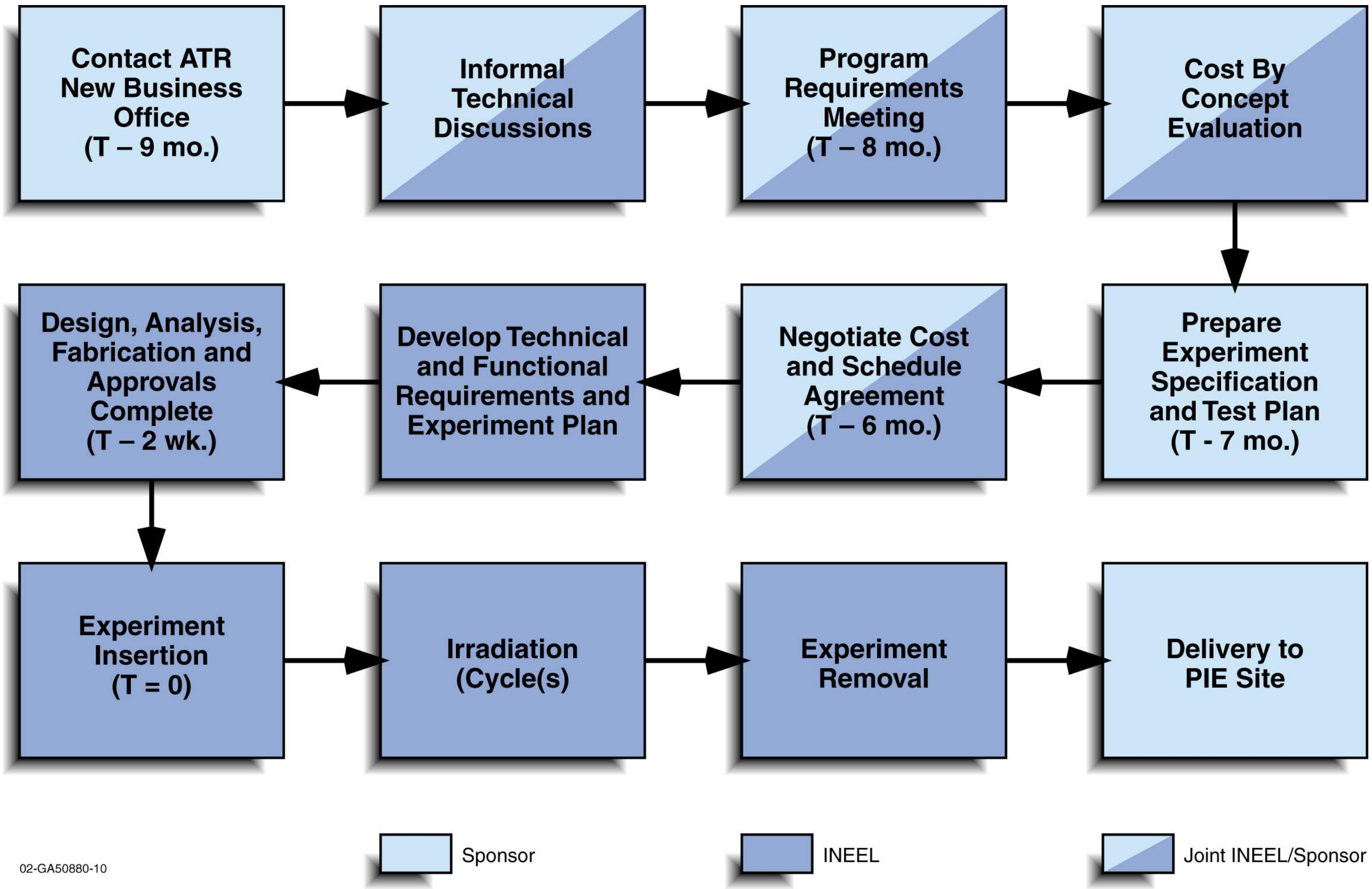


Figure 25. Sequence of actions in a simple irradiation experiment.

the program. A recommendation may also be made as to whether or not it will be necessary to provide a test article for ATRC evaluation. Following this meeting, a specification will be developed that provides the basis for a cost and schedule estimate.

Cost-By-Concept Evaluation

Working with the Sponsor, the NBO directs participants with knowledge of the ATR, prior experience, and engineering judgement to explore various alternatives for achieving the objectives of the proposed program. Each alternative will consider at the minimum the following:

- Technical design requirements
- Safety requirements
- Security requirements
- Flux levels and profile
- Operational requirements
- Cost
- INEEL and Sponsor roles in design, fabrication and analysis
- Mockup or prototype testing at ATRC
- Insertion, irradiation, and removal schedule
- Handling and transportation requirements.

The Cost-By-Concept Evaluation formally considers these alternatives, and a selection of the preferred alternative is made jointly by the INEEL and the Sponsor.

The sponsor and INEEL technical staff will begin the process of documenting specific technical requirements in an Experiments Requirements Data Sheet. Examples of the data typically required for neutron irradiation and gamma irradiation experiments are provided in Appendix B and Appendix C.

During the Cost-By-Concept process, it is important to factor in INEEL lessons learned and other INEEL corporate knowledge acquired over three decades of irradiation services at ATR. Significant design simplification, cost reduction and schedule acceleration can be achieved at this stage of the experiment definition process.

Rough order-of-magnitude (ROM) estimates of cost and schedule will be developed. These will provide the basis for development of a Sponsor specification document.

Prepare Experiment Specification and Test Plan

In these documents, the Sponsor defines in detail the technical specifications that must be met for the irradiation program and a proposed test plan for the conduct of the program. These documents reflect the results of all prior discussions, the evaluations of alternatives, and the planned operations schedule for the ATR. The Sponsor specification document will formally prescribe and, if applicable, prioritize the needs as identified in the Cost-of-Concept process. For routine, non-complex or previously analyzed experiments, the specification document requirement can be met via normal communications processes (e.g., e-mail, letter). For more complex experiments requiring significant analysis, design and fabrication or special considerations, the Sponsor will prepare and formally transmit the specification document, including a preliminary test plan.

Cost and Schedule Agreement

Based on the Sponsor specification document, INEEL technical staff will prepare a Work-for-Others agreement that will be the formal contractual mechanism for the irradiation and supporting services. The contractual agreement for the irradiation program is prepared by the INEEL based on the information in the Experiment Specification and the Test Plan. This plan is negotiated with the Sponsor, finalized, and agreed upon by both parties. It constitutes the legal authority to proceed with the program and obligates funding. Work can be initiated after DOE approval of the WFO package and receipt of initial funding. Normally, this agreement must be in place at least 6 months before the intended commencement of irradiation. A Project Engineer is assigned following contract signature.

Develop Technical and Functional Requirements and Experiment Plan

The Technical and Functional Requirements (T&FR) document is the official INEEL description of the program containing all the requirements that must be met by the various functional groups and offices within the INEEL. It is prepared under the direction of the Project Engineer. The official Experiment Plan is prepared at the same time, also under the direction of the Project Engineer. It serves to identify the specific activities that must be performed to execute the irradiation program and delineates and justifies quality requirements, inspections that must be performed, and any special processes or procedures that must be followed. These two documents together form the bases for the analyses and approvals to follow.

Design, Analysis, Fabrication, and Approvals

Once requirements are in place, the design of the experimental hardware can be completed. This will have been begun earlier in the process, once a contract is in place and there has been a determination to proceed. The Sponsor will be intimately involved with the design process, but the design will be performed (in most instances) and approved by the INEEL.

A number of functional and safety analyses must be performed once the design is finalized. Among these are the Criticality Safety Analysis and the Experiment Safety Analysis. Reactivity and criticality valuation in the ATRC will normally be completed at this stage. These analyses are required to support reviews by the necessary safety committees and to obtain the necessary approvals to proceed with the irradiation program. These must be approved at least two weeks prior to the beginning of activity to install the test article in the reactor.

Experiment Insertion

Test train assembly and preparation must be completed before the commencement of the outage during which it will be inserted into the ATR. Activities during the outage are complex and generally hurried to minimize the time the reactor is down. It is essential that the test train or capsule be ready for installation at the time it is planned for. Unavailability of experiment hardware will not normally justify altering the restart schedule. Billing for reserved but unused reactor space may be negotiated.

Irradiation Cycle(s)

Experiments can only be inserted and removed during outages between irradiation cycles. These cycles are normally planned at least a year in advance and are strongly influenced by the needs of the ATR's primary customer, the Naval Reactors Program. Other users should plan for irradiation cycles that best suit their needs. It is possible to remove a test article for examination and re-insert it during a single outage where several cycles are required to complete the planned program of irradiation.

Experiment Removal

Capsules are lifted from the core using long-handled tools and lowered through the discharge chute into the ATR canal. Longer test trains may be removed using a transfer cask that fits onto the ATR head-piece and into which the test train can be lifted. The cask is then moved to a location over the canal outside the reactor, near the discharge chute opening, and the test train is lowered to the bottom of the canal. Items removed from the reactor are then moved to a predetermined temporary storage location where they are allowed to cool prior to further movement. If post irradiation examination is to be performed by the Sponsor, INEEL Operations will transfer the experiment to a shipping cask normally provided by the Sponsor. This will complete the contractual agreement for irradiation services. Other INEEL technical support may continue as defined in the Work-for-Others agreement.

Delivery to PIE Site

Shipment to the Sponsor's facility for post-irradiation examination (PIE) is normally the responsibility of the Sponsor, though the INEEL can assist in accomplishing that shipment. When preparation for shipment will require special assembly, disassembly or other processes that can be performed in the ATR hot cells, a transfer cask can be used for transportation from the ATR canal to the ATR hot cells.

SUPPORT FOR ATR EXPERIMENTS

The ATR continuing mission is fully supported by the overall INEEL mission. The DOE Lead Secretarial Office for the INEEL is DOE Nuclear Energy (NE). DOE NE has designated the INEEL as the DOE Nuclear Technology Center. INEEL research and development capability is managed through the DOE Idaho Operations Office. Complementary to the INEEL nuclear research capability, the University of Chicago conducts advanced nuclear research and development at the Argonne-West facilities located on the INEEL site. Argonne-West research and development activities are managed through the DOE Chicago Operations Office.

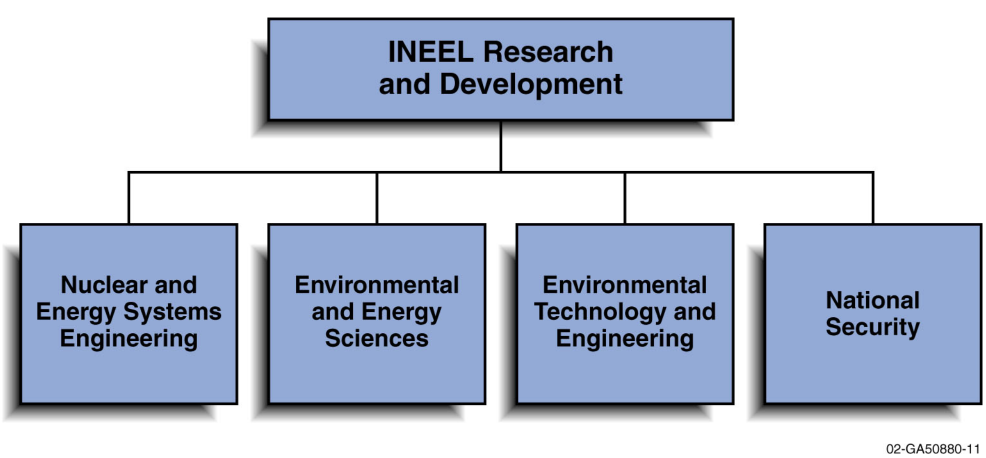
Building on the prior fifty year mission in nuclear technology development, the INEEL has numerous support services available to facilitate the work of experimenters. These include not only support for the experiments themselves but many other kinds of resources that can be applied to a wide variety of pursuits.

INEEL Organization

The INEEL is a Government-owned, contractor-operated facility under the DOE Idaho Operations Office. The INEEL conducts fundamental and applied science and engineering to develop, demonstrate, and deploy new technologies that address the needs of the Department of Energy and other customers.

INEEL Research and Development

The structure of INEEL's Research and Development organization mirrors the DOE's four mission areas of Environmental Management, Energy Resources, National Security, and Science.



The Nuclear and Energy Systems Engineering Division is developing and deploying new nuclear energy systems and practices that will provide current and future generations with energy that is clean, reasonably priced, and reliable. Nuclear energy research centers around Generation IV reactor design, including nuclear systems design and analysis, safety analysis and risk assessment, fuels and materials analysis, and advanced computing. Non-nuclear energy research includes bioenergy, methane hydrates and hydrogen as fuel sources, ultra-clean fossil fuels and processes, hydropower, and geothermal energy. In addition, the INEEL leads the DOE's Field Operations Program by managing the testing of advanced technology vehicles. For program and contact information on this division, visit http://www.INEEL.gov/energy/

The Environmental and Energy Sciences Division conducts fundamental and applied science and engineering to support the INEEL research divisions, and DOE and industry customers. Disciplines include geoscience, chemistry, materials science, applied physics, prototype engineering and electronics. The organization also provides a full spectrum of analytical chemistry services for the Laboratory's waste operations activities. For program and contact information on this division, visit http://www.INEEL.gov/env-energyscience/

The Environmental Technology and Engineering Division plays a major role in improving the effectiveness of waste management operations, safety, and deployment of new technologies; developing alternative energy sources; extending the capabilities of robotic, intelligent machines; and enhancing computer applications for science and operations. For program and contact information on this division, visit http://www.INEEL.gov/env-techengineering/

The National Security Division delivers science and engineered solutions to counter threats to the security of the nation - its people, infrastructure, and environment. Research focus areas include nonproliferation and demilitarization, counter-terrorism and law enforcement, integrated defense systems, and environmental security. For program and contact information on this division, visit http://www.INEEL.gov/nationalsecurity/

Inland Northwest Research Alliance

The Inland Northwest Research Alliance (INRA) is a consortium of eight universities dedicated to enhancing the quality of life in the Inland Northwest through collaborative educational and research enterprises.

INRA was formed to facilitate the leveraging of new research and national partnerships between the member institutions and the private sector, federal agencies and federal laboratories.

INRA is a partner with the management and operations contractor responsible for running the INEEL for the Department of Energy. As a managing partner, INRA plays a strategic role in the education and research decisions at the laboratory. INRA's missions for the INEEL are to:

- Establish, develop and strengthen multidisciplinary research and educational programs;
- Collaborate with business and government agencies to develop and strengthen such programs;
- Utilize its resources in such a way as to maximize the performance of its partners, be they other educational institutions, business enterprises, or government agencies.

The consortium partners cutting-edge capabilities with INEEL research staff and shares large and complex research facilities, thereby fostering collaborations and joint activities. Such relationships will help build a sustaining work force for the INEEL by attracting and retaining world-class research talent, building continuity in knowledge, and fostering career growth. The consortium also positions the INEEL, INRA university members, and regional universities to compete nationally for research funding. For contact information visit http://www.INEEL.gov/inra/

INEEL Technical Capabilities

The INEEL has a full complement of technical capabilities to support research and development, including experiments in the ATR and elsewhere. Many of these are located at the TRA, site of the ATR. A description of major INEEL facilities and operational capabilities are available at the following web site: http://www.INEEL.gov/facilities/default.shtml

Radioanalytical Measurements and Development

TRA has several chemistry and physics laboratories equipped to handle radioactive samples. Collectively, the laboratories offer a full cadre of analytical services, ranging from analyses of trace quantities in environmental samples to intense radiation levels from reactor samples.

Radiation Measurements Laboratory

The Radiation Measurements Laboratory (RML) is a modern, well-equipped radioanalytical laboratory specializing in qualitative and quantitative measurements of alpha, beta, gamma, and neutron radiation. It develops and uses state-of-the-art radiation measurement instrumentation and analysis techniques to support a broad variety of INEEL programs. A staff of internationally known professionals oversees the laboratory. RML capabilities include four working groups: Radiation Measurements, Analytical Radiochemistry, Radiochemical Research and Development, and Field Measurements and Site Characterization. Most of the RML capabilities are applied to the analyses related to reactor operations, reactor experiments, radioactivity effluent monitoring, environmental monitoring, environmental restoration monitoring, waste characterization monitoring, and radiological safety monitoring. In addition to these analyses, the RML performs measurements and analyses related to research and development programs that establish new capabilities for measurement techniques and the electronic and digital systems needed to apply the research and development.

Radiation Measurements

Samples with various geometries, matrix types and activity levels are measured for gamma-ray emitting radionuclides. Specialized gamma-ray spectrometer systems are designed and implemented for applications in the laboratory, remote online monitoring of effluents and processes, portable field measurements, special experiments measurements and control, and post-irradiation scanning and assay of irradiated materials.

Special systems are developed and used for gross alpha and beta counting. Such processes measure the alpha and beta emission rates of samples related to effluent, environmental and reactor systems monitoring. These systems include computer controlled sample changers, data acquisition, and analyses.
Special systems are developed and used for neutron monitoring in neutron fields ranging from those associated with high power test reactors like the ATR to those associated with low power critical facilities like the ATRC or isotopic neutron sources such as ^{252}Cf. The neutron monitoring includes fast, intermediate and thermal energy neutrons, reaction rate measurements, fission rate measurements, and neutron spectrum measurements and analyses. These measurements are related to reactor experiments, radionuclide production, reactor materials damage, and reactor neutron level monitoring systems.

Equipment and expertise exist for measuring gamma-ray dose rates ranging from 1 mR/hour to 10^7 R/hour levels. These measurements are related to the assay of radionuclides produced in the ATR and the gamma-ray fields associated with the Gamma Facilities of ATR.

Samples or specimens irradiated in various neutron fields are counted by radiation spectrometry to determine the radionuclides associated with them. Radiochemical separations and counting are used for radionuclides without distinctly observable energy levels. From these measurements the production of desired and impurity radionuclides are determined. Also, these measurements are frequently used to identify unknown materials and their elemental constituents.

Electronic circuits and radiation detection systems are designed and developed for use in special applications. This development work specializes in miniaturized digital systems and programmable gate arrays and uses computer-aided design and layout of the circuit boards. Circuits and systems are implemented, tested, and put into application for the customer (either in-house or with commercial partners).

Special computer programs are written for gamma-ray and alpha particle pulse height spectral analyses on small to mid-size computers. Programs are also written to provide computer operational control, data acquisition, and analyses for radiation measurement systems. Programs are developed that produce special format reports from these systems. Computer system development and management are performed for efficiency, speed, and economy in the laboratory environment.

Analytical Radiochemistry

Radiochemists at TRA are responsible for the routine analytical determinations for the alpha and beta emitters on many types of sample matrices, preparation of standards containing known quantities of homogeneously distributed radionuclides, as well as research and development of new analytical techniques. Analytical Radiochemistry also provides radioanalytical support to the RML. Investigations are under way to produce and purify radioisotopes, study the effects of radiation on hazardous waste, and partition actinides from highly radioactive fission product waste for long-term management of nuclear waste. Nine laboratories and a special chemical hot cell provide facilities for these efforts.

Samples that contain radionuclides that decay only by beta emission and require radiochemical treatment and separation (^{3}H, ^{55}Fe, ^{63}Ni, ^{89}Sr, ^{90}Sr, etc.) for isolation and measurement are prepared and counted by liquid scintillation or proportional counting.

Various sample types that contain alpha-emitting radionuclides and require radiochemical treatment and separation (Th, U, Am, Pu, Cm, Np, etc.) for isolation and measurement are prepared and counted using alpha spectrometry systems and techniques. Solutions and sources are prepared for radiochemical treatments, check sources, and detector calibrations using certified radioactivity materials.

Elemental analyses are performed using gas chromatography, atomic absorption, inductive coupled plasma and various wet-chemical methods.

Radiochemical Research and Development

Methods and systems are developed to establish new and better separations for all radioactive elements, especially rare earths, actinides, and tritium. Laboratory hot cells allow separations and preparation of high-level radioactive sources. Mass spectrometers and the radiochemistry for preparing samples allow the determination of isotopic ratios for actinides, lanthanides, and other elements. Studies are made to determine the effects of high gamma-radiation doses on polychlorinated byphenyls, pesticides, and halocarbons.

Field Measurements and Site Characterization

Mobile laboratories are available for in-field analyses of air, soil, and smear samples for transuranic and gamma-emitting radionuclides. Special equipment and expertise for mapping the radiation of contaminated areas, assessment of radioactivity in waste containers and spectral surveys of contaminated soil areas are developed and applied.

Equipment and expertise for sampling air for stable tracers, radionuclides, and iodine forms are developed and applied. Measurements to profile the air velocity in stacks and ducts are performed. Filter efficiencies, sampler calibrations, and monitoring parameters are determined for various air systems. Alpha constant air monitor systems are developed, tested, and calibrated.

Leaching of radioactive materials from solids are also studied and quantified.

Safety and Tritium Applied Research Facility

The Safety and Tritium Applied Research (STAR) facility is a National User Facility equipped with a variety of experimental systems that have been used in analyses of irradiated and non-irradiated material specimens. The laboratory is classified as a low-hazard, non-nuclear facility, and it can handle tritium experiments involving up to 1.6 g (16,000 Ci) of tritium.

Among the specialized systems in the STAR facility are two ion implantation systems to investigate hydrogen/material interactions in materials. In one, experiments are performed with deuterium and tritium. Ion beams with energies from a few hundred eV to 10 keV are produced with flux densities up to 10^{16} D/m^2-s over a few-mm diameter area. Another system, the Tritium Plasma Experiment is capable of ion current densities of 1 A/cm^2 at energies up to several hundred eV over an area of approximately 10 cm^2. It typically uses a mixture of deuterium and tritium as a working gas.

Thermal desorption measurements and specific surface area measurements are made with separate specialized systems. Other kinds of research conducted in the STAR facility include an experiment (Figure 26) for measuring the reactivity of materials exposed to steam at temperatures ranging from 300°C to 1100°C (572 to 2,012°F) and other systems for investigations on the properties of molten salts, particularly their interactions with tritium. STAR has its own tritium cleanup system and a storage and assay system.

Another unique gas-analysis system is set up in this laboratory for measuring gases trapped in target particles (Figure 27). This system is equipped with the means to fracture target particles at ambient temperature or at temperatures up to 900°C (1650°F) and to measure the released gas species and quantities. Quadrupole mass spectrometers are used for gas analyses, and capacitance manometers are used for absolute pressure measurements. Test chamber volumes are accurately determined. The system includes the capability for thermal-desorption mass spectroscopy with temperatures variable from 20 to 900°C (70 to 1,650°F).

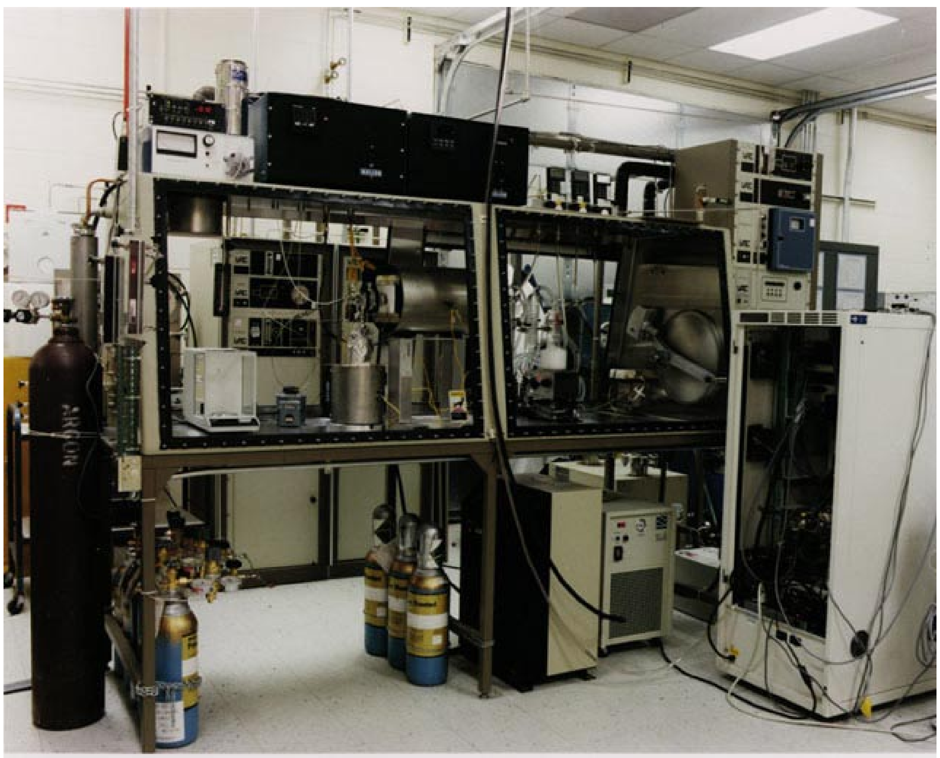


Figure 26. This system in the Safety and Tritium Applied Research facility explores interactions of various materials, including irradiated materials, with high-temperature steam.

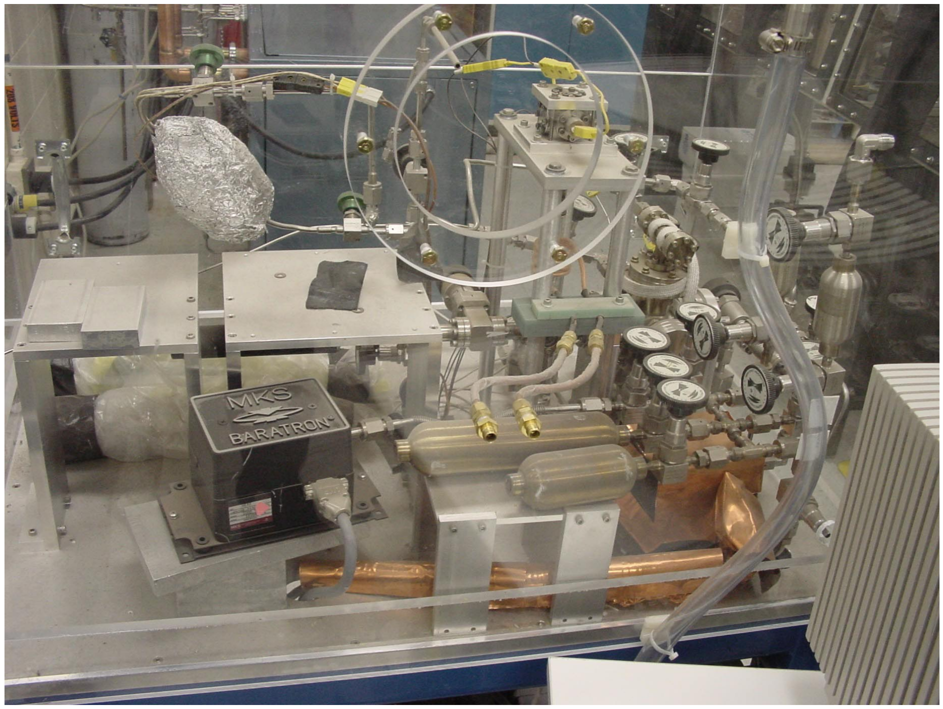


Figure 27. System for measuring gases trapped in irradiated target particles.

Mass Separator Laboratory

The Mass Separator Laboratory houses an electromagnetic isotope separator with a 90°, 150-cm (59-in) radius of curvature electromagnetic sector and electrostatic beam formation optics for producing 50-keV energy ion beams (Figure 28). The system is suitable for isotope (or mass) separation and implantation of both stable and radioactive ion beams for basic and applied science experiments.

Figure 28. The magnetic sector mass separator laboratory is used in isolating many different isotopes including some with very short half-lives.

The mass separator is equipped with an ultra-high vacuum beam line and target chamber. This system is used for implantation of test specimens with mass-separated, stable, or radioactive, probe atoms with energies selectable from 100 eV to 100 keV. A vacuum interlock is used to transfer specimens to and from a support fixture located in the ultra-high vacuum test chamber. The ion beam can be scanned to provide uniform implantation over a 2 x 2-cm (0.8 x 0.8-in) area on a test specimen. The system is of particular importance to investigations of defect behavior using techniques like Mossbauer Spectroscopy and Perturbed Angular Correlation Spectroscopy, which require incorporating radioactive probe atoms in materials.

Quality Assurance

Quality assurance and quality control are maintained in all disciplines to ensure product quality to NQA-1 standards. In addition to internal quality programs, the laboratory participates in the EPA-EMSL/LV Inter-laboratory Inter-comparison Program, the DOE-EML/NY Quality Assessment Program, the DOE-RESL/ID Inter-comparison Program, and the NIST Neutron Fluence Standards Program.

INEEL Technical Support Capabilities

Various other areas and programs of the INEEL support the ATR and TRA, including engineering, fabrication, laboratory, and computer facilities.

- INEEL engineering organizations offer reactor expertise in nuclear, electrical, mechanical, architectural, quality, safety, and operations engineering.

- TRA fabrication facilities include an instrument shop, machine shop, carpenter shop, and weld shop.

- To help operators prepare for an emergency, the Test Reactor Area includes a training center equipped with a full mockup of the reactor control rooms. The training center's design and operation are geared to reduce shutdown time and to maintain regular reactor uses.

- The INEEL Radioactive Waste Management Complex (RWMC) and supporting technical staff in INEEL Waste Generator Services provide customer support for the disposal of low-level radioactive waste and other mixed or hazardous waste generated at the INEEL. Sponsor needs for waste disposal can normally be addressed during planning phase of the experiment definition.

- The INEEL Research Center (IRC) in Idaho Falls conducts government-based technology research in materials science, physical sciences, chemistry, biotechnology, environmental sciences, and electronic development. The IRC provides some capabilities to conduct independent research and development activities for, and in cooperation with, a number of government agencies, private companies, universities, and nonprofit organizations. Seven facilities make up the IRC:

    1. A single-story structure (IF-601) includes offices and light laboratories with low power requirements.

    2. A three-story office building (IF-602) houses IRC technical and support personnel. A small amount of space is used for light laboratories, including equipment used to monitor seismic activity in southeast Idaho.

    3. The Laboratory Building (IF-603) is the primary laboratory facility in the IRC complex, and also contains office space and mechanical support areas. Of 58 laboratories in IF-603, the 20 on the east corridor are wet-laboratory modules. They contain fume hoods, sinks and other equipment, and house such activities as chemical analysis, materials research, geochemistry, biotechnology and other small-scale projects. Another 20 modules on the west corridor are for heavy-duty experiments with larger power requirements. Included are laboratories

for welding research, instrumentation and engineering development, ceramics research, thermal fluids experiments, lasers and electric vehicle testing. The remaining 18 general-purpose modules on the central corridor are for electronics design, optics, lasers or materials testing, and nondestructive examination research and development. A biotechnology laboratory/greenhouse addition on the east side is designed for research with microorganisms.

4. The Energy Storage Technology Laboratory (IF-605) contains experimental electric vehicles, components and batteries.

5. The Systems Analysis Facility (IF-627 and IF-611) houses classified projects, including some light electronics work.

6. The Physics Building (IF-638) contains office space, a computer laboratory and a heavy-duty magnet laboratory.

7. The INEEL Engineering Demonstration Facility (IF-657) houses several prototypical-scale research and development projects that support programs in military munitions assay, advanced sensor systems, environmental restoration, subsurface investigation, and materials science.

Argonne National Laboratory-West

Argonne National Laboratory–West (ANL-W) is the prime testing center in the United States for demonstration and proof-of-concept of nuclear energy technologies. Operated by the University of Chicago, ANL-W is fully integrated with Argonne National Laboratory–East (ANL) in Illinois. ANL-W is 61 kilometers (38 miles) west of Idaho Falls, 81 kilometers (50 miles) northwest of Blackfoot, and 61 kilometers (38 miles) south east of Arco.

Current Mission

The mission at ANL-W emphasizes technologies associated with nuclear fuel, including advanced fuel treatment methods, fuel efficiency enhancements, and fuel performance testing. This mission also includes nuclear material characterization technologies, environmental technologies, and technologies and processes requiring remote handling of nuclear materials. ANL-W provides strong technical and scientific research support to DOE’s mission to provide the nation with safe, clean, economical energy sources for the future.

Employees

Approximately 700 employees work at ANL-W, with a broad range of skills and expertise in nuclear energy technology research and development. These include expertise in nuclear materials, nuclear fuels, analytical chemistry, nuclear fuel treatment, materials characterization, and remote handling and operations with nuclear materials.

Programs and Facilities

There are several major program at ANL-W.

Electrometallurgical Treatment

Electrometallurgical treatment is an advanced method of preparing unstable nuclear fuels for permanent geologic disposal. Developed through research integrated at both ANL-W and ANL, electrometallurgical treatment uses an electrolysis-based process to reduce the volume of material to be disposed while sealing the waste materials in a ceramic that is impermeable to air and water. It was developed for application to the spent fuel from Experimental Breeder Reactor-II (EBR-II), the fuel from which is unstable both mechanically and chemically without treatment.

Fuel Conditioning Facility

The Fuel Conditioning Facility (FCF) is where electrometallurgical treatment is performed. It consists of two heavily shielded hot cells, one with an air atmosphere and one with an inert argon atmosphere. Process operations are conducted remotely using manipulators that allow operators outside the hot cell to work with materials in the cell. In this way, work can be done on extremely radioactive materials with no radiation exposure to workers or visitors. There is no human entry into the hot cell, and all operations are performed remotely.

Hot Fuel Examination Facility

The Hot Fuel Examination Facility (HFEF) is a large, highly versatile hot cell facility. It features an air cell and argon cell, superb overhead crane capacity, large floor space with high ceiling clearance, and versatile access ports. In-cell equipment includes a wide variety of machining equipment used for destructive testing of nuclear materials, as well as a wide variety of non-destructive testing equipment. HFEF also has neutron radiography capability with a functioning TRIGA reactor as the neutron source. The high bay area of HFEF is home to the Waste Characterization Area which performs remote characterization of material to be shipped to the Waste Isolation Pilot Plant in New Mexico for disposal. In the WCA, transuranic nuclear waste is removed from drums it currently is stored in, examined and sampled, and repackaged for shipment to WIPP. This work is being done in support of INEEL's efforts to remove its transuranic waste from the state of Idaho.

Transient Reactor Test Facility

The Transient Reactor Test Facility (TREAT) is a pulsed reactor designed to produce short, controlled bursts of nuclear energy for safety testing of waste materials in a ceramic that is impermeable to air and water. It was developed for application to the spent fuel from experimental Breeder Reactor-II (EBR-II), the fuel from which is unstable both mechanically and chemically without treatment.

Zero Power Physics Reactor

The Zero Power Physics Reactor (ZPPR) is an extremely low power test reactor used to test various reactor design features with different materials and configurations. It is in stand-by status.

Sodium Processing Facility

The Sodium Processing Facility is where the primary and secondary coolant from EBR-II is converted from its elemental, chemically unstable form, to a chemically stable compound suitable for landfill disposal. Taken together, these and the other ancillary facilities at Argonne-West provide all the necessary steps to take a nuclear reactor power station from design to demonstration. For nearly 50 years, this was the primary function of ANL-W.

VISITING INEEL

Sponsors visiting the INEEL will normally travel to the Eastern Idaho area through several major airline transportation hubs, including the Salt Lake City International Airport. Several incoming and departing flights to and from major hubs are available from early morning through late evening, seven days a week. The eastern Idaho region is served by Interstate Highways 15 and 86 and several major US highways and by rail transportation.

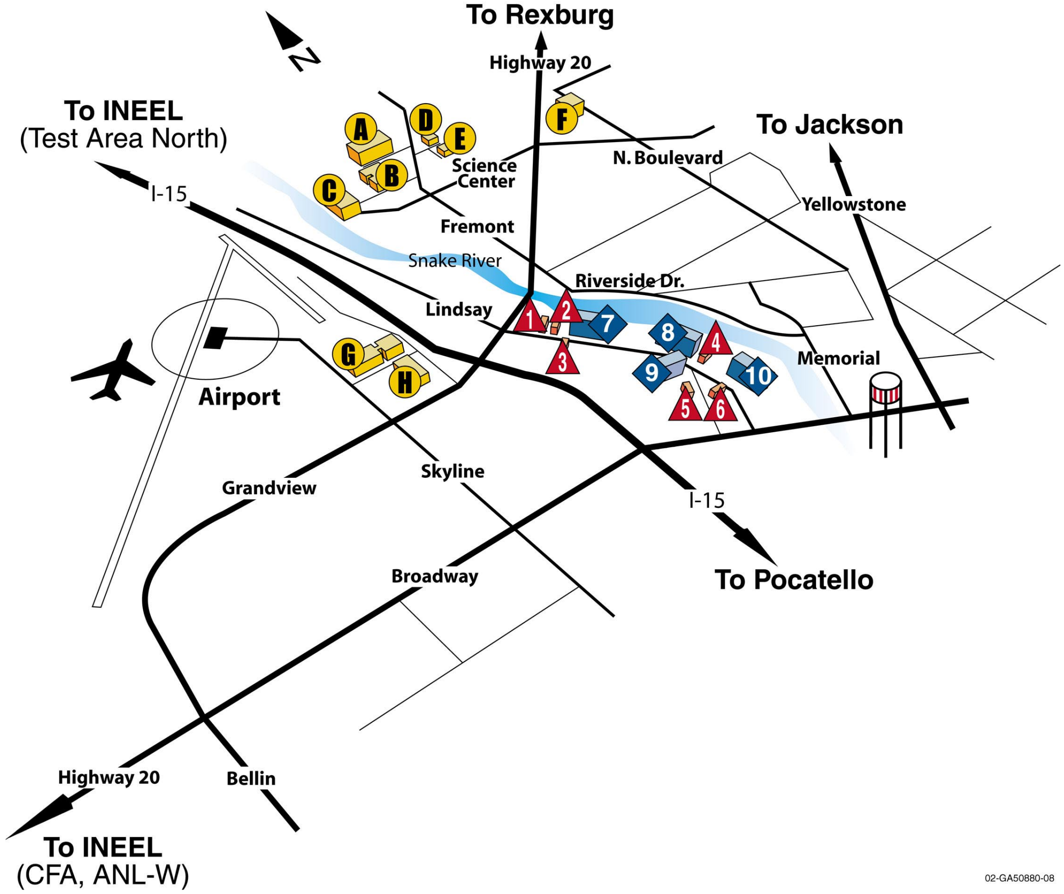
The nine county area nominally surrounding and supplying services to the INEEL is primarily agricultural with light industry. The highly technical nature of INEEL business provides for a higher than normal percentage professional and technical population. The nine county area provides several regional medical facilities and all other services normally expected in major metropolitan areas.

Sponsors visiting the INEEL will normally travel to Idaho Falls, Idaho via Interstate 15 or through the Idaho Falls Regional Airport. The ATR NBO is located in the INEEL Engineering Research Office Building, less than 3 kilometers (2 miles) from I-15 or the regional airport. Most major food service and lodging accommodations are located within one mile of the airport and the EROB. ATR NBO staff will coordinate access requirements needed to conduct meetings with INEEL R&D technical staff and ATR Operations Engineering at the INEEL Idaho Falls offices and at the INEEL site.

Figure 29 depicts Idaho Falls and INEEL site locations in relation to major highways and the Idaho Falls Regional Airport. Figure 30 locates Idaho Falls in the Eastern Idaho region. For further information visit the web site http://www.INEEL.gov/contact/directions.shtml

The Eastern Idaho region is high desert plain surrounded by scenic mountainous areas. Major summer and winter resort areas, millions of acres of national forests and major national parks such as Yellowstone and Craters of the Moon National Parks are within three hours driving distance from the INEEL. Idaho State

University in Pocatello, 80 kilometers (50 miles) south, and BYU Idaho in Rexburg, 40 kilometers (25 miles) north, as well as the University of Idaho in Moscow, ID are represented at the Eastern Idaho Center for Higher Education in Idaho Falls. The community also has excellent hospitals and other medical facilities. Information for areas of local and regional interest can be accesses at the following web sites: http://www.eastidaho.org, http: www.ci.idaho-falls.id.us/, http://www.idahoparks.org/, http://www.state.id.us/, http://www.idahofallschamber.com/



INEEL Facilities

A. Engineering Research Office Building
B. Willow Creek Building
C. University Place
D. DOE North
E. DOE South
F. INEEL Research Center
G. Technical Support Building & Annex
H. INEEL Supercomputer Center

Restaurants

1. Outback Steak House
2. Denny's
3. Jaker's Steak House
4. Sandpiper Restaurant
5. Applebee's
6. Chili's
7. Rutabaga's

Hotels/Inns

8. Best Western Cotton Tree
9. Shilo Inn
10. Ameritel
11. Cavanaugh's

Figure 29. INEEL and other facilities in the Idaho Falls area.

Figure 30. Idaho Falls is located in Eastern Idaho, not far from Yellowstone National Park.

APPENDIX A
EXPERIMENT FEASIBILITY FACT SHEET

EXPERIMENT FEASIBILITY FACT SHEET (Enter a short, descriptive title)

1. Objectives and Scope

   a. Objectives
   Clearly identify the objectives of the experiment.

   b. Scope
   Summarize the range of materials and test variables.

2. Summary Description of Experiment
Provide a summary description of the experiment. Include, where appropriate, predictions of plant state, power level, temperatures, flow rates, and so on.

3. Desired Experimental Conditions
Define, as appropriate or possible, the following:

   a. Desired irradiation environment for the experiment. Target reaction rates and acceptable variations should be outlined and basis given.

   b. Duration of experiment [effective full-power days (EFPD)].

   c. Coolant flow requirements.

   d. Goal fluence [in n/cm^2 (E > 0.1 MeV)] or burn up in at. %, etc.

   e. Experimental component temperature.

   f. Element/capsule pressure (initial operating and at experiment conclusion).

   g. Estimated reactivity burden that the proposed experiment will place on the reactor. This may be either a calculated reactivity burden or enough information about the fissile or absorber loading to allow a calculation by INEEL.

   h. Data-collection requirements.

   i. Off-normal reactor operation requirements--special reactor power levels, transients, mid-run shutdowns--both planned or possible.

4. Summary of Prior Experience
Any similarity with prior experiments (either in ATR or other facilities) should be summarized. Difficulties or abnormalities that may have been encountered should also be discussed.

5. Desired Out-of-Reactor Service
Identify desired services. This users Handbook should be consulted for information on the services routinely available. NOTE: The services should be specifically listed. The listing shall include the following, as applicable:

a. Special handling requirements for insertion.

b. Special handling requirements for removal, interim storage, and so on.

c. Estimate of disassembly and examination requirements.

d. Interim examination requirements.

6. Summary Conceptual Design Description
To permit the INEEL to determine feasibility and make an early judgment on the level of review that will be required include, as appropriate, the following:

a. A summary of required experimental components (capsule design, etc.), and who is responsible for design and fabrication of the various components.

b. Schematic drawings of the design features.

c. Proposed subassembly design, i.e., currently available INEEL approved subassembly design or a new or modified design.

d. The number of experiment capsules.

e. Tabular summaries of the design and functional requirements.

f. Design operating conditions.

g. Flow and temperature requirements.

h. Any required modifications to systems or existing special facilities.

i. Listing of all anticipated materials to be used.

7. Discussion of Nuclear Safety Considerations
Sufficient information must be provided to permit an initial assessment of nuclear safety considerations by the INEEL. Information that will allow the INEEL to address the following questions is needed:

a. Can the experiment be safely conducted, handled, and reconstituted?

b. Will the experiment require a change to the ATR Technical Specifications?

c. Does the experiment impact the facility or safety requirements?

d. Will the experiment introduce an unreviewed safety question?

During the technical and program feasibility review, the subject of nuclear safety is to be addressed in broad, general terms. For most experiments, it is expected that this early assessment of nuclear safety can easily be made. Obviously, the assessment is only a preliminary one that can later be modified as the design and safety analyses mature. An ATR unreviewed safety question may exist if the experiment causes any limit or criteria defined in the ATR Technical Specifications to be exceeded.

The INEEL recognizes that the experimenter may not have a thorough knowledge of the ATR Technical Specifications. However, the experimenter should provide his best assessment of the potential impact of his experiment on reactor/plant safety.

8. Schedule

A brief table should be included that shows anticipated calendar dates for the following:

a. Beginning and completion of experiment fabrication.

b. Completion and transmittal of the design description and safety analyses documents to ATR.

c. Completion and transmittal of an experiment procedure (when applicable) to ATR.

d. Shipment of experimental components to TRA.

e. Beginning of experiment and effective full power days of exposure.

f. Beginning and completion of post experiment disassembly and examination.

9. Responsibilities

Where possible, responsibilities (by person and/or organization) for all major activities should be listed.

APPENDIX B
EXPERIMENT DATA PACKAGE REQUIREMENTS CHECKLIST FOR NEUTRON IRRADIATION IN THE ADVANCED TEST REACTOR

Sponsor: ______________________________ **Phone:** ____________________

Mailing Address: ____

Date Requested: ____

Experiment Description/Objective: ____________________________________
____
____
____
____

Enter the following data requirements below or indicate applicable documentation.

	Data Requirement	Experiment Data
	Physics and Thermal Hydraulics	
1.	Coolant Flow	
2.	Thermal Conductivity of all Material	
3.	Surface Temperatures in °F	
4.	Internal temperature distribution	
5.	Fissionable material in grams	
6.	Heat output in Watts/length or Watts/gram	
7.	Peak Heat Flux (BTU/hr-ft^2)	
8.	Thermal Flux	
9.	Fast Flux	
10.	Gamma Heat	
11.	Reactor Location preference	
12.	Reactivity worth	
13.	Experiment Pressure	
14.	Irradiation time (cycles or MWd)	
15.	Thermal hydraulic analysis	

	Data Requirement	Experiment Data
16.	Departure from Nucleate Boiling Ratio (DNBR)	
17.	Flow Instability Ratio (FIR)	
18.	Stress Analysis	
19.	Activity of experiment when irradiation complete	
	Operations/Administrative	
20.	Handling requirements	
21.	Disassembly/Reconfiguration requirements	
22.	Interim Examinations	
23.	Number of experiments/capsules	
24.	Off-Normal Reactor Operation Requirements	
25.	Data Collection	
26.	Detailed drawings with dimensions and materials	
27.	Handling and Operating Instructions	
28.	Utility requirements	
29.	Wiring Diagrams	
30.	Experiment holder or capsule OD and overall length	
31.	Weights of all material in grams	
	Quality	
32.	Radiographs of assembled capsules from two directions (90º apart)	
33.	Sponsor testing descriptions and results	
34.	Material certifications	
	ATR Critical Facility Mockup	
35.	Supporting Calculations demonstrating nuclear equivalency of mockup	
36.	ATRC Mockup configuration drawings, sketches, etc.	
37.	Mockup materials	
38.	Water volume fraction/length	
39.	Handling and shipping instructions	

	Data Requirement	Experiment Data
40.	Radiographs of assembled capsules from two directions (90º apart)	
41.	Sponsor testing descriptions and results	
42.	Material certifications	
	Customer/Sponsor	
43.		
44.		
45.		
46.		
47.		
48.		
49.		
50.		

APPENDIX C
DATA PACKAGE REQUIREMENTS FOR IRRADIATION IN THE TRA GAMMA FACILITY

Sponsor: ________________________________**Phone:** ______________________

Mailing Address: ____

Date Requested: _______________________

Experiment Description/Objective: ____

____

____

____

____

Enter the following data requirements below or indicate applicable documentation.

	Data Requirement	Experiment Data
	Physics and Thermal Hydraulics	
1.	Detailed sketch or drawing showing dimensions and orientation of the experiment.	
2.	List of all materials and quantities (grams) in the test train.	
3.	Gamma heating in each material.	
4.	Heat flux	
5.	Chemical reactions and rates.	
6.	Corrosive materials (target or product).	
7.	List all gases produced by quantity and maximum possible pressure.	
8.	Identify effects of moisture (due to canister flooding or leaking) on experiment.	
9.	Criticality evaluation	
	Operations/Administrative	
10.	List all instrumentation	
11.	Operating instructions.	
12.	Wiring diagrams	
13.	Discuss sequence of insertions and removals as a function of exposure for each target item (capsules, holder, etc.).	
14.	Desired dose rate and acceptable range for each target item.	
15.	Desired total dose and acceptable range for each target item.	

	Data Requirement	Experiment Data
16.	Desired gamma field and acceptable range for test duration.	
17.	Effects of gamma irradiation on the target and also on the associated equipment, i.e., vessel walls, seal rings, hanger assembly, etc.	
18.	Utility requirements	
19.	Data acquisition requirements and method(s) of obtaining.	
20.	Special precautionary safety measures required in handling or irradiating the test train	
21.	Special tools necessary for test train handling and assembly/disassembly	
22.	Special precautions necessary for shipping, storage, and post irradiation disposition	
	Customer/Sponsor	
23.		
24.		

APPENDIX D
TYPICAL ATR OPERATIONS SCHEDULE

					Lobe Power[a] (MW_{th})					
Cycle	Outage Start Date	Outage Duration (days)	Reactor Run Start Date	Run Duration (Days)	NW	NE	C	SW	SE	Cycle End Date
126A-1	09/11/01	13	09/24/01	40	17.0	15.9	23.1	23.0	25.0	11/03/01
126B-1	11/03/01	14	11/17/01	50	18.0	16.0	23.8	23.0	25.0	01/06/02
127A-1	01/06/02	7	01/13/02	56	18.1	16.0	23.5	23.1	25.1	03/10/02
127B-1	03/10/02	6	03/16/02	1	17.8	16.1	32.0	46.3	49.9	03/17/02
127C-1	03/17/02	5	03/22/02	51	18.0	16.0	23.3	25.0	25.0	05/12/02
128A-1	05/12/02	32	06/13/02	59	18.0	18.0	24.0	23.0	25.0	08/11/02
128B-1	08/11/02	7	08/18/02	15	18.0	18.0	33.0	49.0	45.0	09/02/02
129A-1	09/02/02	6	09/08/02	56	18.0	18.0	24.0	25.0	25.0	11/03/02
129B-1	11/03/02	14	11/17/02	49	18.0	18.0	24.0	25.0	25.0	01/05/03
130A-1	01/05/03	7	01/12/03	49	18.0	18.0	24.0	23.0	25.0	03/02/03
130B-1	03/02/03	14	03/16/03	49	18.0	18.0	29.0	23.0	25.0	05/04/03
131A-1	05/04/03	7	05/11/03	56	18.0	18.0	24.0	23.0	25.0	07/06/03
131B-1	07/06/03	7	07/13/03	14	18.0	18.0	29.0	40.0	40.0	07/27/03
132A-1	07/27/03	5	08/01/03	44	18.0	18.0	24.0	23.0	25.0	09/14/03
132B-1	09/14/03	14	09/28/03	14	18.0	18.0	34.0	50.0	50.0	10/12/03
132C-1	10/12/03	5	10/17/03	51	18.0	18.0	24.0	23.0	25.0	12/07/03
133A-1	12/07/03	7	12/14/03	1	18.0	18.0	34.0	50.0	50.0	12/15/03
133B-1	12/15/03	5	12/20/03	50	18.0	18.0	24.0	23.0	25.0	02/08/04

a. Powers listed for Northwest (NW), Northeast (NE), Central (C), Southwest (SW), and Southeast (SE) reactor lobes.

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