AFRRI
TECHNICAL REPORT

AFRRI TR81-2

Reactor facility, Armed Forces Radiobiology Research Institute

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DEFENSE NUCLEAR AGENCY
ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
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Research was conducted according to the principles enunciated in the "Guide for the Care and Use of Laboratory Animals," prepared by the Institute of Laboratory Animal Resources, National Research Council.

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The Armed Forces Radiobiology Research Institute (AFRRI) reactor is a TRIGA (Training, Research, and Isotope Production General Atomics Reactor) Mark-F pool-type thermal research reactor, capable of both pulsed and steady-state operation at a variety of locations in the pool. Designed and built by General Atomics, it first achieved criticality in 1962 with aluminum-clad fuel. In 1965, stainless-steel-clad fuel was installed and is still in use today.

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20. ABSTRACT (continued)

The AFRRI reactor serves as a mixed neutron and gamma source for Department of Defense radiation research. Although most of this research involves radiobiology including radioisotope production, the AFRRI reactor has also been used in support of Federal criminal investigations, studies of transient radiation effects on electronics, and artifact analysis.

INTRODUCTION AND GENERAL DESCRIPTION

The Armed Forces Radiobiology Research Institute (AFRRI) reactor is a TRIGA* Mark-F pool-type thermal research reactor, capable of both pulsed and steady-state operation at a variety of locations in the pool (see Figure 1). Designed and built by General Atomics, it first achieved criticality in 1962 with aluminum-clad fuel. In 1965, stainless-steel-clad fuel was installed and is still in use today.

The AFRRI reactor serves as a mixed neutron and gamma source for Department of Defense radiation research. Although most of this research involves radiobiology including radioisotope production, the AFRRI reactor has also been used in support of Federal criminal investigations, studies of transient radiation effects on electronics, and artifact analysis.

The AFRRI reactor is licensed by the United States Nuclear Regulatory Commission to operate at steady-state power levels up to a maximum of 1.0 MW (thermal). For pulse operations, the maximum step reactivity insertion is limited to \$3.28 (2.3% $\Delta k/k$), which results in an approximate 10-msec full width at half maximum (FWHM) pulse with a peak power of ~ 2500 MW (thermal) and a yield or integrated energy of ~ 28 MW-sec.

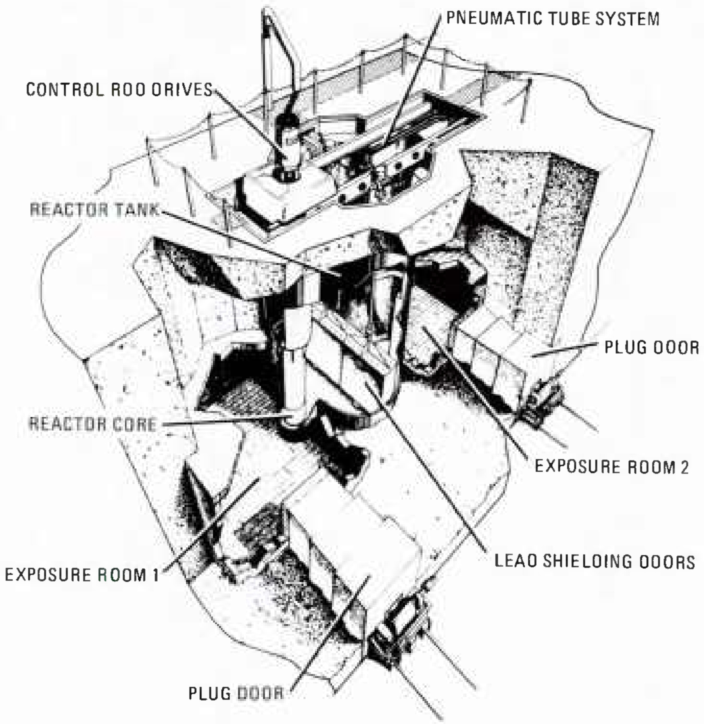

Figure 1. Cutaway view of the AFRRI TRIGA reactor

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* TRIGA stands for Training, Research, and Isotope Production General Atomics Reactor.

The reactor core, which is cooled by natural convection, is located under ~ 5 m of water, and is movable laterally within an open cloverleaf-shaped pool ~ 4.2 m across the major lobes, 3.9 m across the minor lobes, and 5.8 m deep. The reactor can be operated at any horizontal pool location along the axis of the major lobes. Core movement is accomplished via a motor-driven core support dolly carriage mounted on rails above the pool surface. Approximately 5 minutes is required to move the core between extreme pool locations. Since the core can be moved in a relatively short period of time, sequential irradiations involving different and varied exposure facilities can be performed. As a result, the AFRRI reactor facility provides the capability for efficient, flexible, and high use.

Exposure facilities presently available to users include two separate exposure rooms, a pneumatic transfer system, pool beam tubes and the pool itself, an in-core experiment tube, and a limited number of small in-core experiment locations. These are described further under <u>Exposure Facilities</u> below.

CORE

The AFRRI reactor core is formed by 86 cylindrical TRIGA stainless-steel-clad fuel elements, three standard aluminum-clad borated-graphite control rods with solid aluminum followers, and an air-filled aluminum core experiment tube (CET) arranged in five concentric rings about the centrally located transient control rod in position A1 (see Figure 2). The transient rod is identical in design to the other three standard

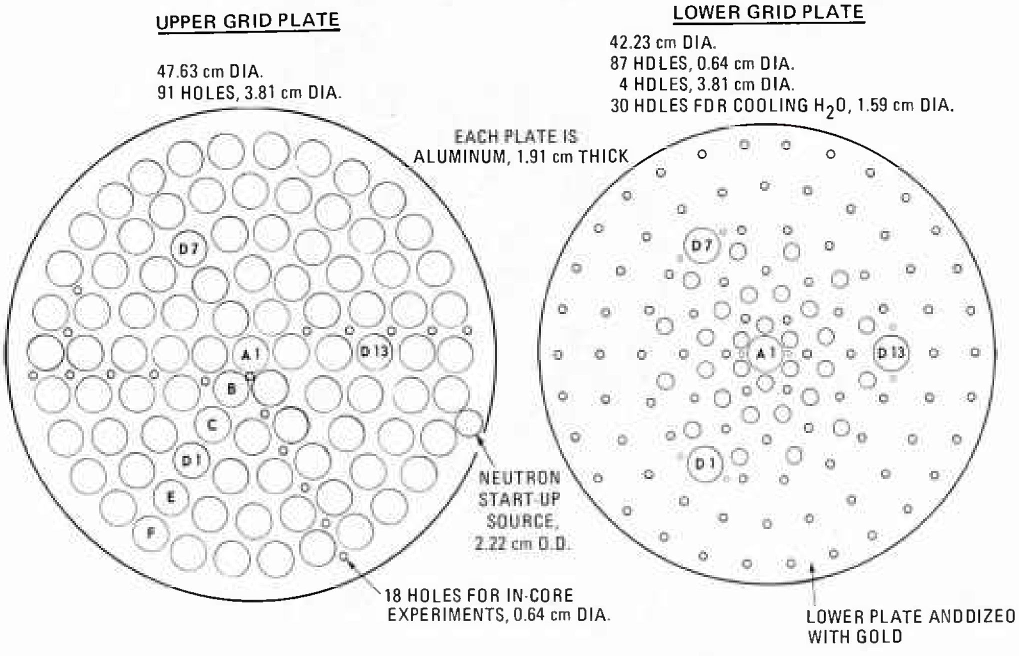

Figure 2. Upper and lower grid plates showing core lattice

absorber control rods (shown in Figure 3). The three standard control rods are located in the third concentric ring from the transient rod in locations D1, D7, and D13, equally separated from each other by 120 degrees (illustrated in Figure 2). Each standard control rod is operated individually by its own electromechanical drive, but only when current is applied and maintained to its electromagnet coupler. The transient control rod can also be driven electromechanically when pressurized air is supplied and maintained for coupling. However, the transient rod can additionally be driven out (pulsed) rapidly upward to a fixed position, using the pneumatic system alone. A reactor SCRAM (shutdown) is initiated simply by cutting the magnet current to the standard control rods while also venting the air supply to the transient rod.

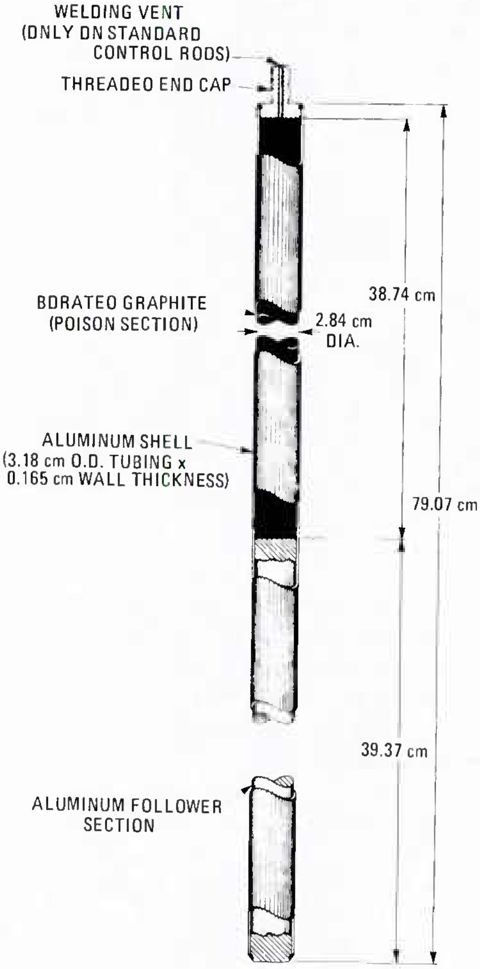

Figure 3. Transient and standard control rod design

The fuel material is uranium-zirconium hydride (U-$ZrH_{1.7}$) with 8.5 weight percent uranium and a nominal 20 percent uranium-235 enrichment. The fuel is contained within TRIGA fuel elements ~ 72 cm long (see Figure 4). The fueled region of each

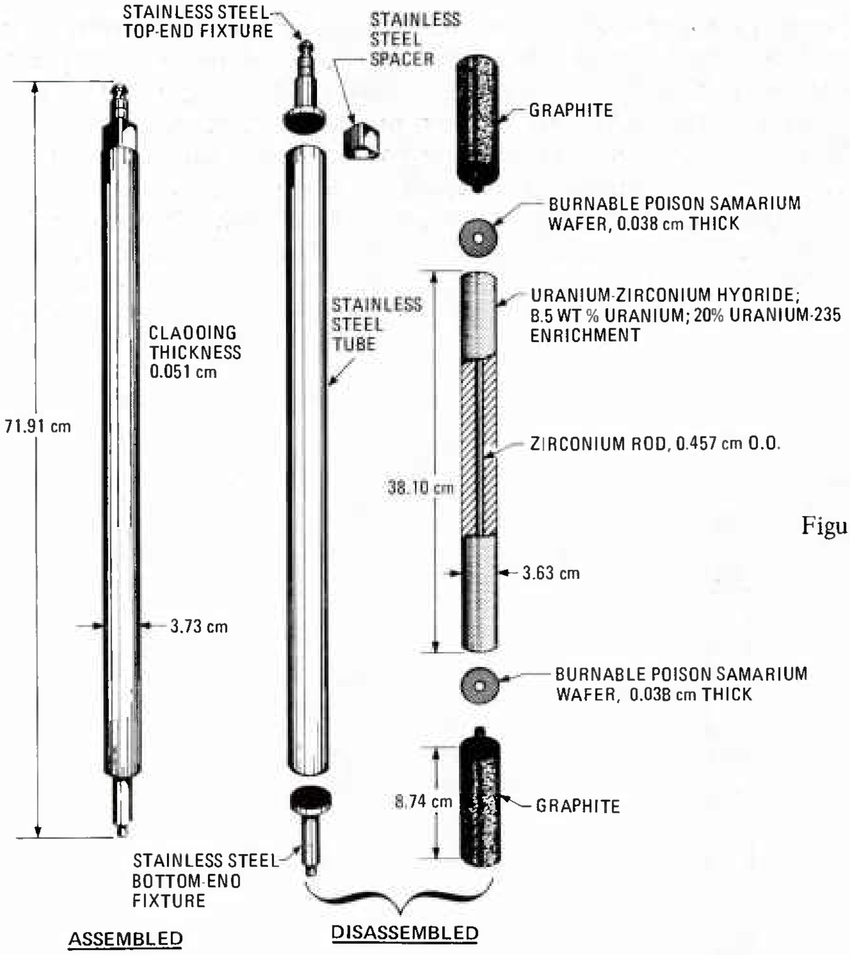

Figure 4. Standard AFRRI TRIGA fuel element design

TRIGA fuel element is 3.63 cm in diameter and 38.1 cm in length, and contains approximately 38 g of uranium-235. Graphite end plugs located above and below the fueled region within each TRIGA fuel element serve as axial neutron reflectors while water outside the active core region serves as the radial reflector. The zirconium hydride in the fuel matrix, together with the water that exists between the fuel elements, provides the necessary neutron moderation.

The TRIGA fuel elements used in the AFRRI reactor were designed and verified for safe operation at temperatures up to 1000°C. To provide assurance that the fuel temperature safety limit of 1000°C is never approached, AFRRI has incorporated an automatic SCRAM if fuel temperatures reach or exceed 500°C, even though AFRRI is currently licensed to operate up to a maximum fuel temperature of 600°C.

The inherent safety of the AFRRI TRIGA reactor derives from its large negative prompt and steady-state temperature coefficients of reactivity, which automatically accommodate (i.e., reverse) and limit reactivity additions during pulse and steady-state operations, respectively. Intrinsic characteristics of the uranium-zirconium hydride fuel during heat-up (primarily zirconium hydride excitation and Doppler broadening of the uranium-238 resonance peaks) account for this unalterable self-limiting safety feature.

PERFORMANCE CHARACTERISTICS

Maximum nominal operating parameters listed below are for free-field conditions in the CET at the core midplane with infinite water reflection.

Steady-State Operation

Power		1.0 MW (thermal)
Fuel Temperature		440°C
Neutron Flux (all energies)	~	1.5×10^{13} n/cm^2/sec
Thermal Neutron Flux (<0.4 eV)		8.0×10^{12} n/cm^2/sec
Gamma Dose Rate	~	4.0×10^{3} rads (H_2O)/sec

Pulse Operation

Step Reactivity Insertion		\$3.28 (2.3% $\Delta k/k$)
Peak Power	~	2500 MW (thermal)
Pulse Width (FWHM)	~	10 msec
Reactor Period		2.44 msec
Maximum Integrated Energy Release (0.9-sec rod holdup)		28 MW-sec
Peak Temperature Rise	~	500°C
Neutron Fluence (all energies)	~	4.2×10^{14} n/cm^2
Thermal Neutron Fluence (<0.4 eV)	~	2.2×10^{14} n/cm^2
Peak Neutron Flux (all energies)	~	3.8×10^{16} n/cm^2/sec
Peak Thermal Neutron Flux (<0.4 eV)	~	2.0×10^{16} n/cm^2/sec
Gamma Dose	~	1.1×10^{5} rads (H_2O)
Peak Gamma Dose Rate	~	1.0×10^{7} rads (H_2O)/sec

EXPOSURE FACILITIES

Exposure facilities currently available for irradiations using the AFRRI reactor consist of Exposure Room number 1 (ER #1), Exposure Room number 2 (ER #2), an in-pile core experiment tube (CET), portable beam tubes that can be placed in the reactor pool, the pneumatic transfer system (PTS), a limited number of small in-core experiment locations, and the pool itself. A brief description of each of these experimental facilities is presented below.

Exposure Room Number 1 (ER #1)

ER #1 is located on the first-floor level of the AFRRI Reactor Building at the north end of the reactor tank (see Figure 1). A semicylindrical portion (lobe) of the reactor tank projects through the south wall of ER #1. When the reactor core dolly is moved to its extreme north location, the core is adjacent to ER #1 and a water gap of ~ 2.54 cm exists between the aluminum core shroud and the inside surface of the 0.64-cm-thick aluminum tank projection into ER #1. The internal physical dimensions of ER #1 are approximately 6.1 m by 6.1 m by 2.6 m high. A 0.3-m-thick wood lining covers all six interior surfaces of ER #1 to minimize fast neutron and secondary gamma activation of the 3.66-m-thick concrete biological shield that encases ER #1. Masonite panels painted with gadolinium oxide and a cadmium-gadolinium shield in ER #1 reduce the thermal neutron flux and thereby enhance (i.e., in a relative sense) the fast neutron flux component in ER #1. A portable shield frame that accommodates up to 0.3 m of lead can be rolled between the experiment and the ER #1 tank projection, if desired, to obtain the desired neutron-to-gamma ratio.

Exposure Room Number 2 (ER #2)

ER #2, located at the south end of the reactor tank on the first floor of the AFRRI Reactor Building, is smaller but similar to ER #1 (see Figure 1). The internal dimensions of ER #2 are approximately 4.6 m by 4.3 m by 2.44 m high. No cadmium-gadolinium shield is present in ER #2, making the thermal neutron flux higher in ER #2 than in ER #1. Access to ER #1 and ER #2 is gained through separate 3.66-m-thick and 3.05-m-thick concrete plug doors, respectively, that are driven in and out on rails. These plug doors are stepped on the top and sides to reduce radiation streaming from the exposure rooms.

Core Experiment Tube (CET)

The CET is an air-filled aluminum tube that can be placed in any single fuel location within the core lattice. Currently, the CET is positioned in a fuel location of the outermost ring of core fuel elements. The inner diameter of the CET is ~ 3.33 cm, and polyethylene irradiation capsules called "rabbits" have been designed for specific use with the CET. A maximum of five of these "rabbits" can be irradiated simultaneously in the CET, with precise axial positioning of the "rabbits" possible. The CET has a gradual S-bend above the core region to reduce radiation streaming from the core to the pool surface.

Portable Beam Tubes and the Pool

Several portable beam tubes have been constructed for irradiations in the pool proper. Beam tubes can vary greatly, depending on their intended purpose. In general, though, they are evacuated or air-filled tubes that are placed against the core shroud at the bottom of the pool to get an unattenuated beam of neutrons and gamma rays for subsequent experimental use. Water-proofed samples also can be simply lowered into the pool itself against or near the core for direct irradiation without the use of a beam tube.

Pneumatic Transfer System (PTS)

The AFRRI TRIGA reactor facility is equipped with two separate banks of pneumatic tubes, which are used primarily for isotope production and activation of small samples. The in-pool tube termini are located at fixed positions within the reactor tank in two separate banks of four tubes each in such a way that the core can be placed between the two banks. The out-of-pool PTS sender-receiver stations are located in the Radiochemistry Lab, and diversion to the adjoining AFRRI Hot Cell is possible using four of the eight pneumatic tubes. The inside diameter of the pneumatic tubes is ~ 2.54 cm, and specially designed "rabbits" must be used. A "rabbit" is inserted or withdrawn simply by applying a partial vacuum between the "rabbit" and the appropriate terminus. An in-line absolute filtration system is used to scavenge particulates from the air supply for the PTS.

Small In-Core Experiment Locations

Eighteen small holes (0.64 cm diameter) exist in the upper grid plate of the AFRRI TRIGA reactor (see Figure 2). Although primarily for core physics measurements using foil activation, these locations can be used for irradiation of small experiment samples. A sample placed in one of these small core locations will actually be located between fuel elements in the core. Not all 18 of these small in-core locations are readily accessible for use, however, because the core instrumentation chambers are located just above the core.

For more information about the AFRRI Reactor Facility or to inquire about possible use, contact the Chief, Radiation Sources Division at (202) 295-1048, or the AFRRI Reactor Physicist-In-Charge (PIC) at (202) 295-1290, or write to:

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