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Description of the High Flux Isotope Reactor and Future Upgrades

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General Description

Description of High Flux Isotope Reactor (HFIR)

The HFIR is a light-water-cooled, beryllium (Be) reflected, 85-MW research reactor. It is a flux-trap design giving a maximum flux of over 2×10^{15} n/cm^2-s in the flux trap located in the middle of the annular core (Fig. 1). The reactor went critical in 1966. In 1986 it was shut down due to vessel embrittlement concerns and restarted in 1989 with power reduced from 100 MW to 85 MW.

The reactor core is surrounded by a Be reflector ~1-ft (30 cm) thick. The core and Be reflector are located in a reactor vessel 8 ft (2.4 m) in diameter and 19 ft (5.8 m) high.

The vessel is pressurized to 468 psig (3.2 mPa). The light water flows downward through the reactor at ~16,000 gal/min (1009 l/sec). The inlet temperature is 120°F (48.9°C) and outlet at 155°F (68.3°C) (Fig. 2).

Control is achieved using four safety/shim plates surrounding a central cylinder. These are raised/lowered respectively to balance the leakage to the reflector. The plate and cylinder are sandwiched between the outer fuel element and the Be reflector (Fig. 3). The control plates are made up of 22 in. (55.9 cm) Eu_2O_3 (black section) followed by 5 in. (12.7 cm) of tantalum (gray section) followed by aluminum. Any of the five control plates can shut the reactor down. They system is fast acting with plate insertion accomplished in less than 0.5 sec.

The pressure is maintained using a feed and bleed process, and the system is "water solid." The pressure is controlled by use of one of two nine-stage centrifugal pumps [capable of producing over 1000 psia (6.8 mPa)] and a system of let-down values.

Heat removal is accomplished by three 600-hp (447.4 kW) primary pumps, resulting in a downward flow rate through the core of 13,000 gal/min (820 l/sec). A fourth pump is kept in standby and can be put on line during reactor operation. The heat is transferred to the secondary heat removal system by means of three primary heat exchangers (fourth in standby). The secondary coolant water dumps heat to the atmosphere using an induced-draft cooling tower [capacity of 375 million Btu/hr (109 MW)].

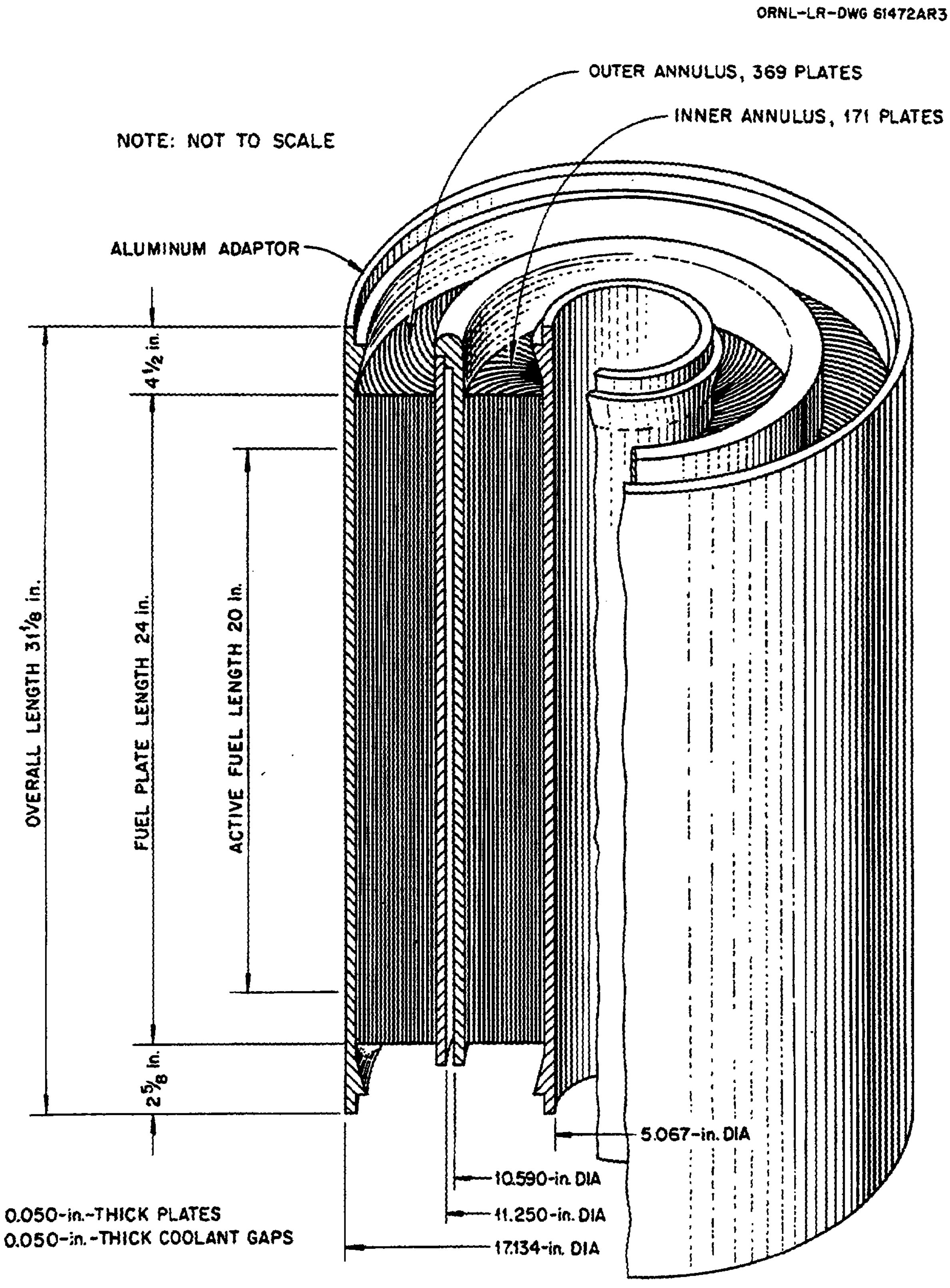

Fig. 1. HFIR Fuel element.

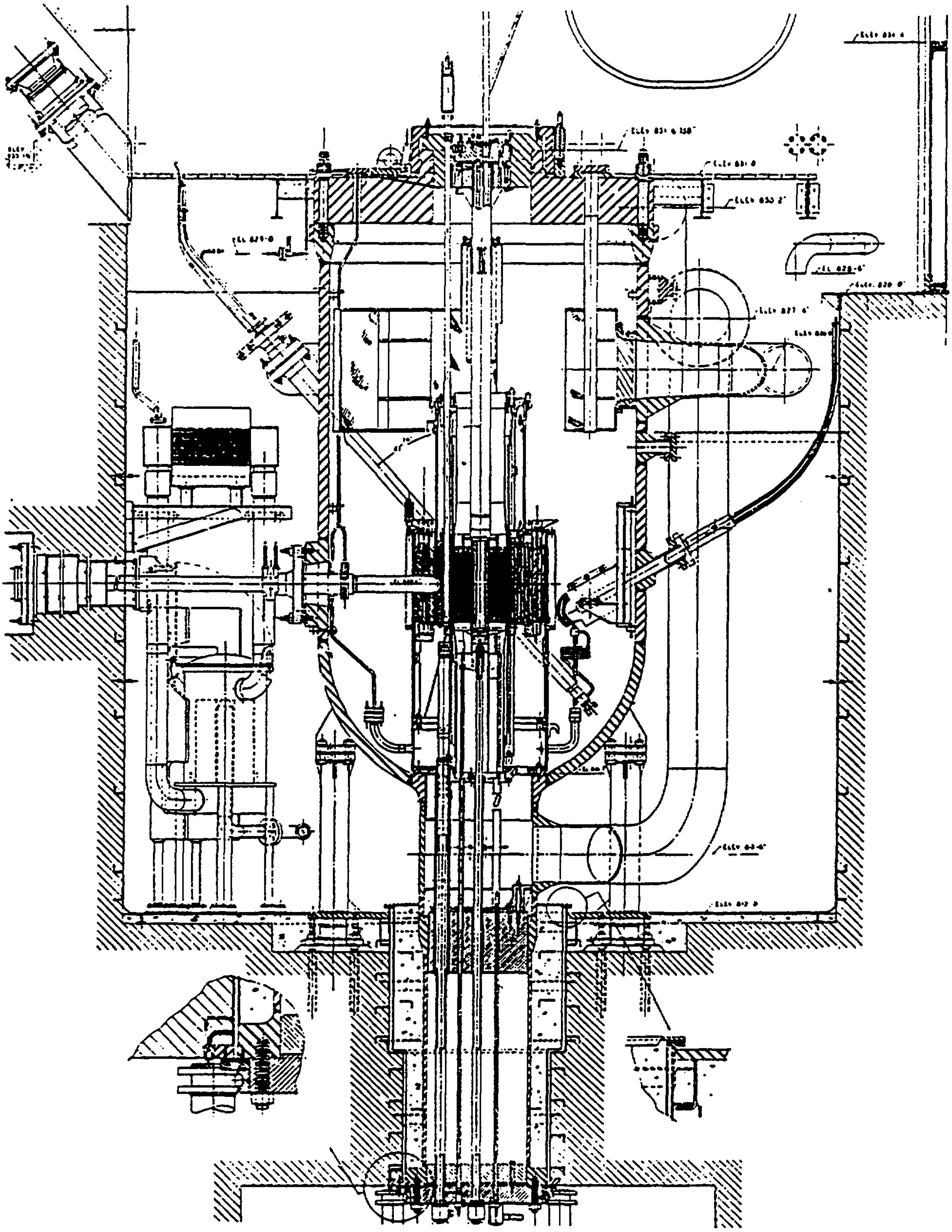

Fig. 2. Centerline view of reactor.

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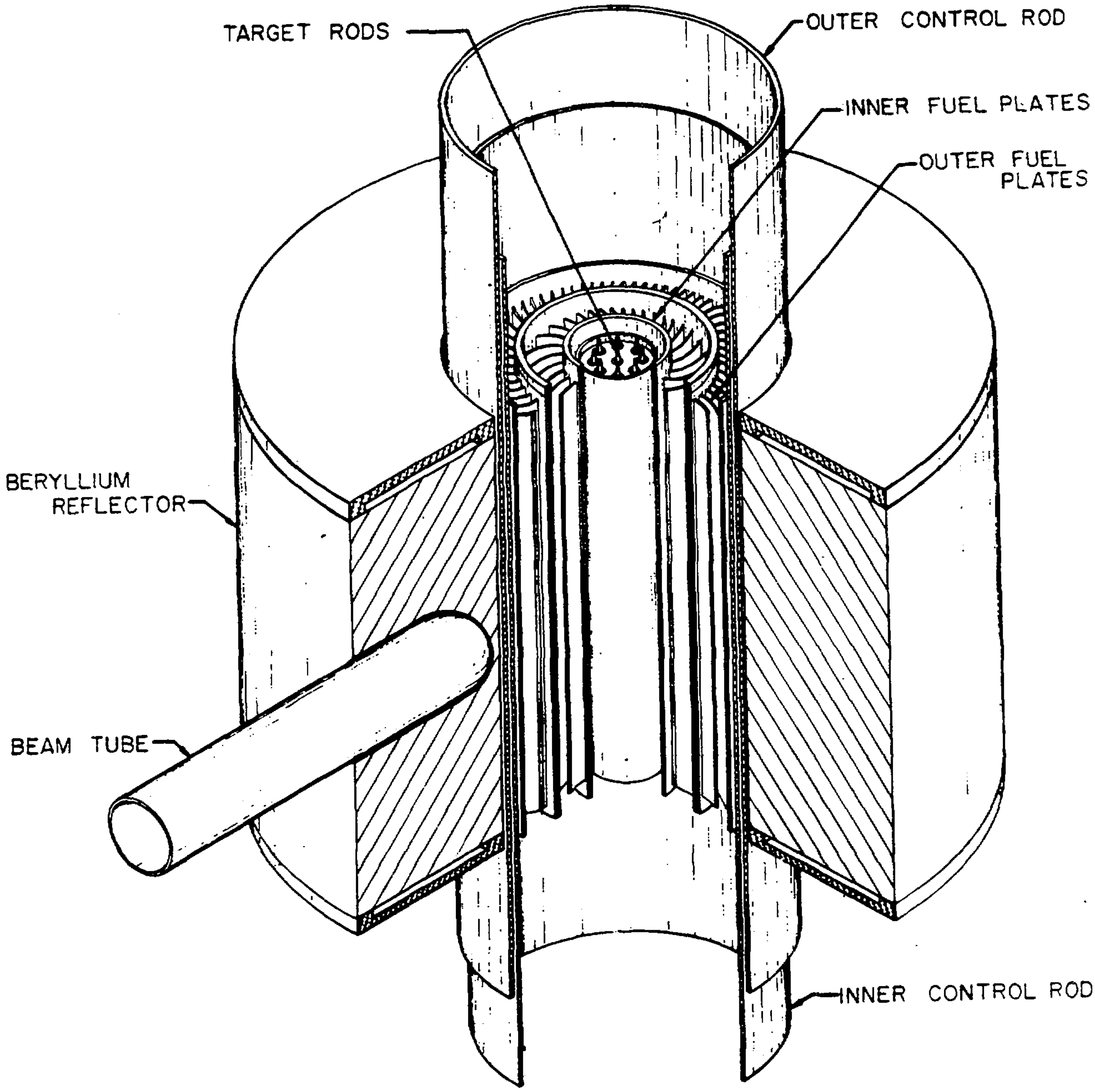

Fig. 3. Schematic of High Flux Isotope Reactor core.

Decay heat removal is generally accomplished using the normal primary/secondary cooling systems. If off-site power is lost to the primary pumps, decay heat can be removed using a DC pony motor system attached to the main coolant pump drives. Each pony-motor-driven pump is capable of supplying 1300 gal/min (82 l/sec) of flow through the core.

It has been demonstrated that the secondary heat removal system is not needed to remove decay heat. The primary piping and reactor pool have adequate heat capacity to prevent reaching saturation conditions.

The power to the DC pony motors is supplied by a dedicated battery system for each of the four pony motors, backed up by one of two on-site diesels that in turn is backed by one of two portable diesels (auxiliary electric power generators) stored off-site.

The primary and secondary heat removal systems are schematically shown in Fig. 4.

The reactor building is 128 ft × 160 ft × 86 ft in height. The building constitutes a dynamic confinement system with one of three exhaust fans continuously pulling air through the building through a series of high-efficiency and carbon filters and exhausts the air up the 250-ft (76.2 m) stack at a rate of ~28,000 cfm (13.2 m^3/sec).

The fuel is a U_3O_8/Al ceremet clad in aluminum [fuel ~30 mils (7.6410^{-2} cm) with 10 mils (2.54×10^{-2} cm) of cladding]. The active core length is 20 in (50.8 cm). Each 50-mil (0.127 cm) plate is separated by a 50-mil (0.127 cm) cooling channel. There are two concentric elements in each core assembly, the inner having 171 plates, the outer 369 plates. The two concentric cylinders have a diameter of 17.5 in (44 cm) and surround a 5-in. (13 cm) diameter flux trap target region. The fuel contains about 9.4 kg of 93-percent enriched uranium (Fig. 1).

An average fuel cycle is 26 or 27 days (at 85 MW) and can be shorter depending on the experimental loadings and target loadings in the core.

The spent fuel is stored in one of two spent fuel pools adjacent to the reactor pool. The storage capacity of these pools is being increased to 210 core assemblies (currently have 65 assemblies stored) due to the shut down of the Savannah River Reprocessing Plant.

Experimental Capabilities

The HFIR has six major experimental missions (Fig. 5).

1. Production of transuranic isotopes [primarily californium-252 (^{252}Cf)] in the target region.

2. Production of industrial isotopes in various Be reflector locations (42 locations).

3. Production of medical/industrial isotopes in a hydraulic rabbit (allows capability of insertion and removal during operation) in the target region.

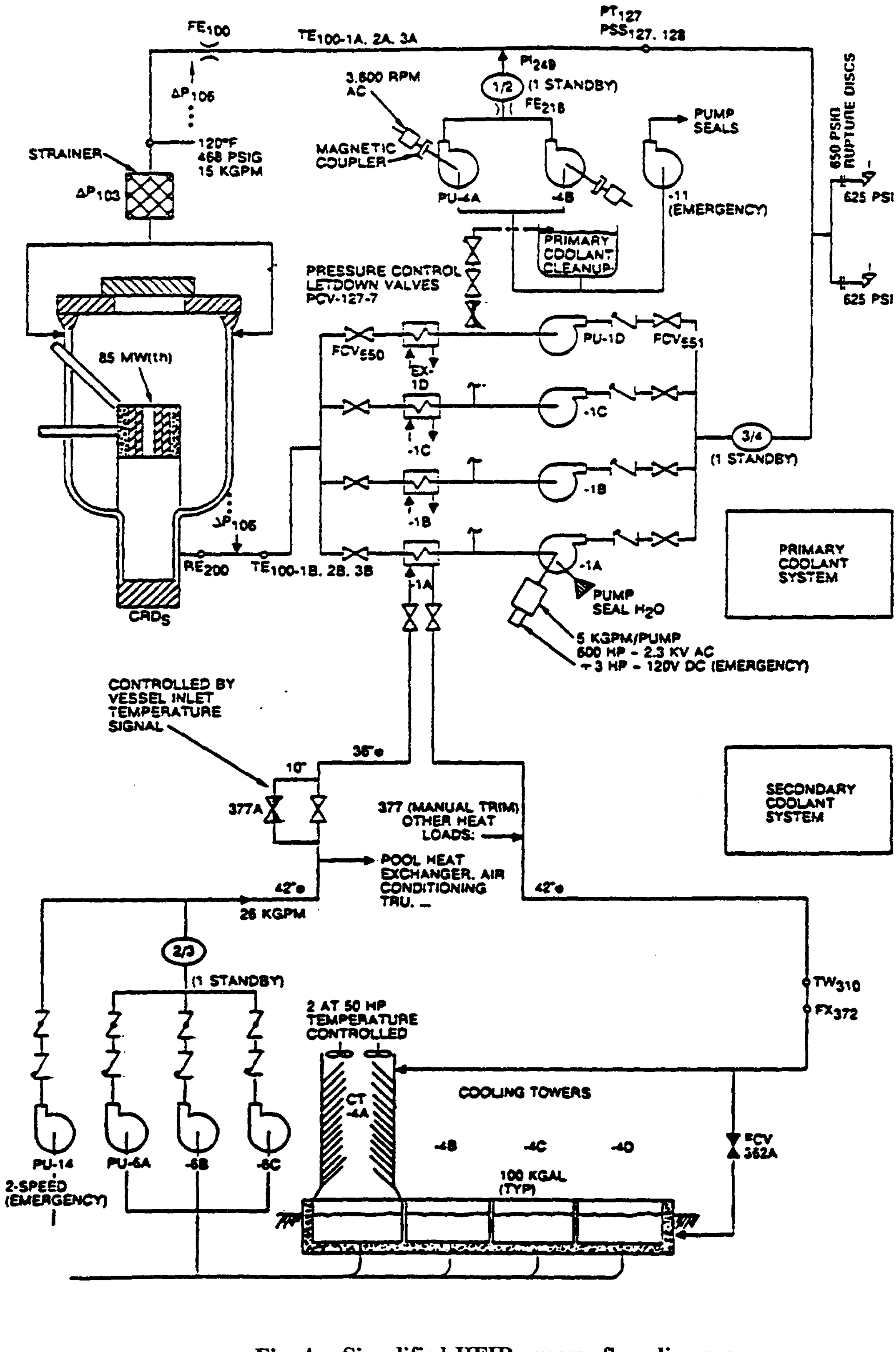

Fig. 4. Simplified HFIR process flow diagram.

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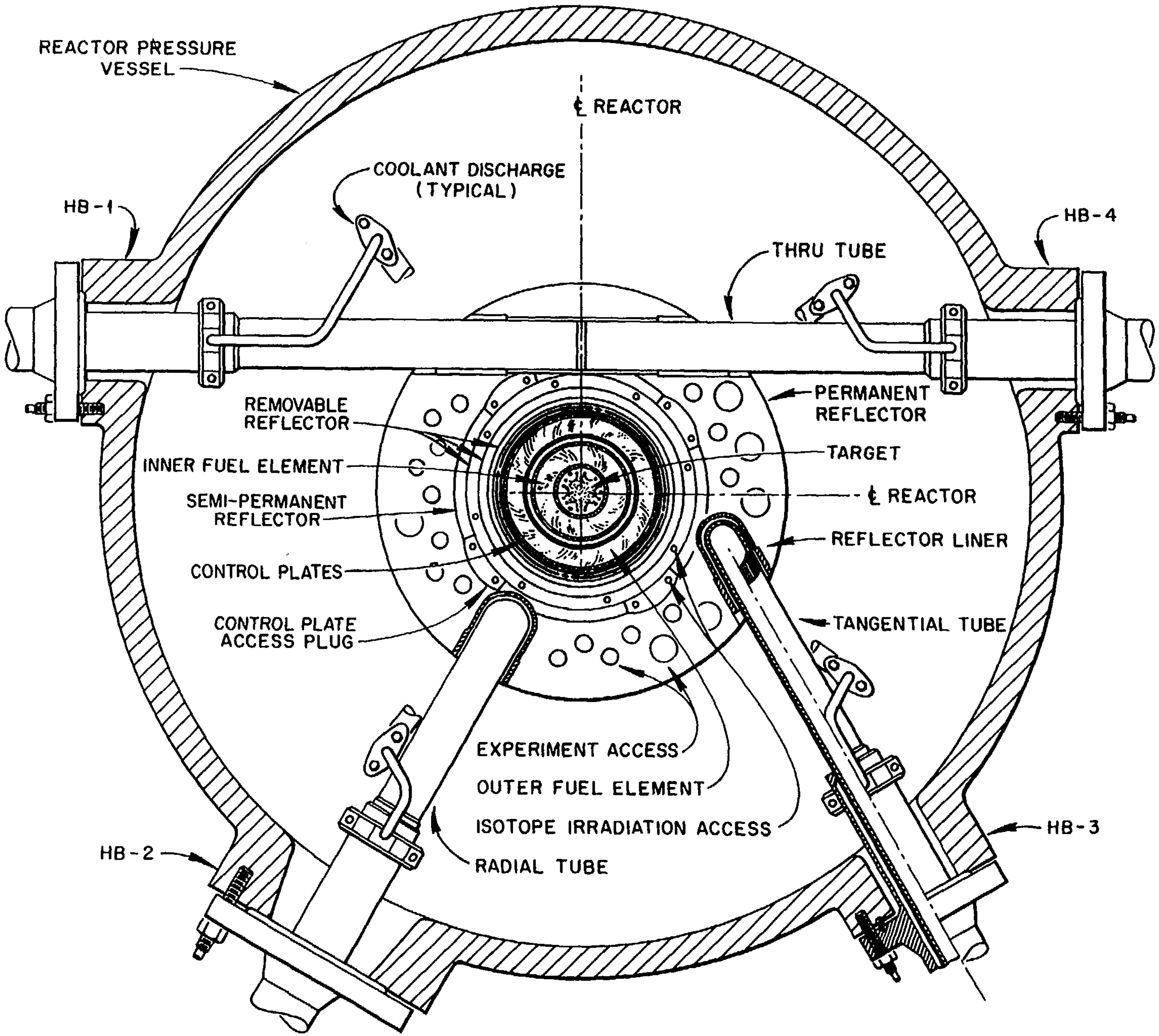

Fig. 5. Cross section of HFIR at core centerline.

4. Four horizontal beam tubes (three tangential, one radial, located at the core centerline) for materials research and four engineering facilities (slant tubes) immediately outside the Be reflector region.

5. Two pneumatic tubes, one in the reflector region and one in use, in the engineering facilities, which are used for neutron activation analysis.

6. Materials irradiation in the 42 penetrations in the Be reflector.

HFIR was designed and built to produce research and commercial quantities of transuranic isotopes and is the Western World's only supplier of significant quantities of ^{252}Cf, ^{253}Es, ^{259}BK, and ^{257}Fm. The principal transuranic isotope is ^{252}Cf, which is separated and processed by the Radiation Engineering Development Center (REDC) located adjacent to the HFIR facility. Californium-252 is used for medical, defense, industrial, and research purposes. To date HFIR and REDC have produced the following quantities of each:

	To date	**Current annual rate**
^{244}Cm	2.2 Kg	50 g
^{245}Bk	0.7 g	50 mg
^{252}Cf	7 g	0.5 g
^{253}Es	30 mg	2 mg
^{255}Fm	16 pg	1 pg

Future Upgrades at the HFIR Facility

HFIR has an ongoing aging management program. It consists of an active In-service Inspection Program (ISI) and a preventative/predictive maintenance program. Several major improvements to the facility have occurred over the last few years. These improvements include replacement of all four heat exchangers, rebuilding the four primary coolant pumps, upgrades to the electrical supply systems to the plant and improved irradiation facilities in the reflector region closest to the core. There was also a major seismic analysis and upgrade, a Probabilistic Risk Assessment (PRA) was produced along with a new Safety Analysis Report (SAR), including re-analysis of all accident analyses using state-of-the-art codes.

Near-term plans include replacement of the primary pressurizer pumps, refurbishment of the cooling tower, replacement of the diesel generators, and upgrade of the Instrumentation and Controls (I&C) systems in the facility.

Until this year, the HFIR was scheduled to be replaced with the Advanced Neutron Source (ANS). However, now that DOE has dropped its support for the ANS, a revised look at the long-term prospect for HFIR has been initiated by a multi-disciplined team chaired by C. D. West (head of ANS project) and composed of users and Research Reactors Division staff. The HFIR

Futures Group has prepared three major classes of upgrades for the facility with the goal of improved availability, predictability, and experimental capability.

The three groupings are:

1. those improvements that can be made with existing funds by rearranging resources,

2. those improvements that can be accomplished in the short term and whose costs are greater than existing funds but less than $5M, and

3. long-term improvement that will require significant planning, funds, and possible lengthy outages.

Examples of the types of improvements in category 1 are a return to 100-MW operation, installation of a new gamma irradiation facility, redesign of the reflector to enhance materials irradiation and production of ^{238}Pu, upgrades to enhance availability, relocation of current scattering instrumentation, increase in neutron activation analysis capability.

Examples of the items being considered in category 2 would include the addition of an hydrogen-cooled cold source in use of the beam tubes, an expanded neutron scattering guide hall, longer fuel cycles, addition of more hydraulic rabbit facilities for isotope production.

Items in category 3 include the replacement of the Be reflector with a D_2O reflector and large cold source, addition of a hot cell accessible to the reactor pool, and a positron source.

The upgrade suggestions have been presented to Laboratory management for consideration and prioritization.

It is anticipated that several of these upgrades will be supported in the upcoming years since there are only a few neutron sources available for scientific research in the United States.