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THE EBR-II BREACHED FUEL TEST FACILITY

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ABSTRACT

The Breached Fuel Test Facility (BFTF) is a multipurpose experimental facility, designed to provide the capability to conduct and monitor safety and fuel behavior experiments under move severe conditions than previously allowed in EBR-II. The facility consists of an outer thimble assembly with an internal instrument stalk which extends from the reactor floor through the primary tank cover to the top of the core. Coolant from a breached element test is directed upward to the instrument train above the core. The BFTF has the capability to measure flow, temperature, particle size distribution and deposition, and delayed neutron levels for breach site characterization. This paper describes the design, the instrumentation, the operational safety concerns and the initial experiments.

INTRODUCTION

The primary goal of LMFBR fuel designers is to provide fuel element and subassembly designs which can operate for extended periods without significant deterioration, i.e., breaching. In the event of breaching, it is still desirable to be able to operate those elements for significant times without compromizing safety. The competing requirements of breeding, high burnup, and intact element design tend to reduce reliability and increase the probability of breaching. The objectives then of the test programs are to provide the basic design data and demonstrate the benign behavior of breached element operation, as well as provide information on the degree of contamination of the coolant and primary system components following element rupture. The latter area has significant safety conotations in the event of a primary system sodium fire and a direct impact on the safe maintenance of plant components.

The BFTF has been designed to allow testing of severly breached elements and provides for incorporation of a deposition sampler experiment to obtain representative hot leg samples of debris which might be released from defected fuel. The sampler deposits provide a basis to determine the magnitude, nature and deposition behavior of released contamination. Correlation of breached fuel behavior and contamination data with BFTF diagnostic data will contribute to the support of viable fuel designs.

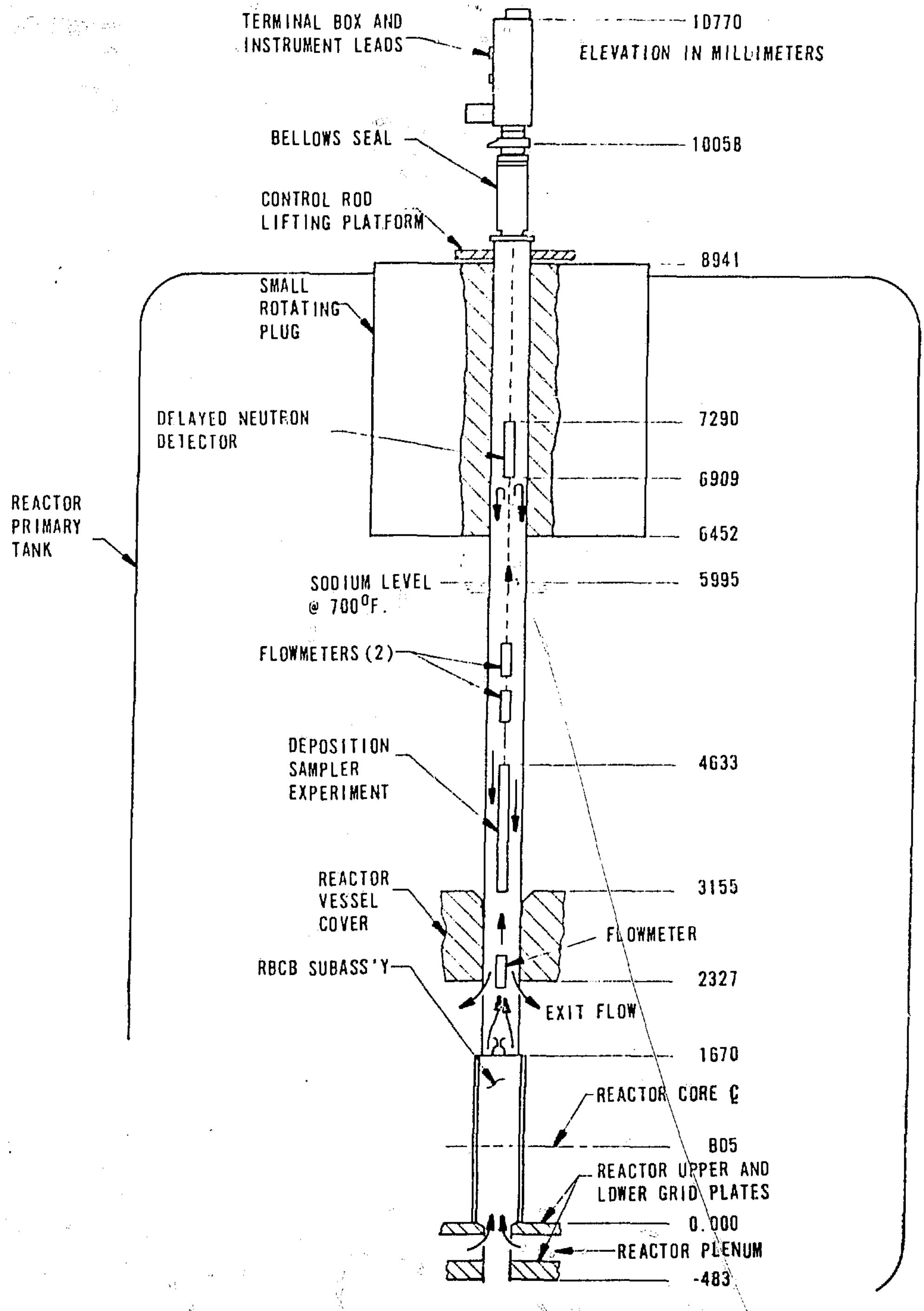
DESCRIPTION OF THE FACILITY

The EBR-II BFTF is an in-reactor safety and fuel behavior test facility designed to conduct and monitor breached fuel experiments under more severe conditions than previously allowed. Fueled experiments are positioned in-core while deposition samples are contained above core. Instrumentation for control and diagnostic purposes is provided. The location of the BFTF in the EBR-II is shown in Figure I. The assembly is inserted through the rotating plug in a converted control rod location and extends through the reactor vessel cover to the top of the core where it mates with an in-core experiment. Instrument leads are routed internally to the terminal box on top of the facility. The entire device is 7.9 m (26 ft) long.

The facility is made up of an outer, double-walled thimble assembly, 63.5 mm (2.5 in.) in diameter. It contains an inner instrument stalk and a delayed neutron detector in an upper drywell. Figure II shows the details of the facility and their relationship to the in-core experiment. The internal instrument stalk contains the deposition sampler experiment, temperature sensors and two flometers to measure total flow and deposition sampler flow. An additional flowmeter and temperature sensors are located in the thimble assembly below the instrument stalk. The entire facility is lowered to mate with the in-core test. Limit switches are incorporated to indicate proper positioning and inadvertent binding between the test and thimble assembly. There are a total of five chrom-alumel thermocouples provided to monitor sodium temperatures at the inl t (outlet of test assembly) and above the upper flowmeter and at the location of the neutron detector. In addition, sodium leak detectors (contact type) are provided in the detector drywell and terminal box.

Primary coolant flow is directed upward from the in-core test past the lower flowmeters to the deposition sampler and past the upper flowmeters. Continuing upward, the coolant flows in an inner annulus to

Figure 1. Schematic of the BFTF in EBR-II



TERMINAL BOX AND INSTRUMENT LEADS
10770
ELEVATION IN MILLIMETERS
BELLOWS SEAL
10058
CONTROL ROD LIFTING PLATFORM
8941
SMALL ROTATING PLUG
DELAYED NEUTRON DETECTOR
7290
6909
REACTOR PRIMARY TANK
6452
SODIUM LEVEL @ 700°F.
5995
FLOWMETERS (2)
DEPOSITION SAMPLER EXPERIMENT
4633
REACTOR VESSEL COVER
3155
FLOWMETER
RBCB SUBASS'Y
2327
EXIT FLOW
1670
REACTOR CORE ℄
805
REACTOR UPPER AND LOWER GRID PLATES
0.000
REACTOR PLENUM
-483

Figure 11. Schematic of the Breach Fuel Test Facility

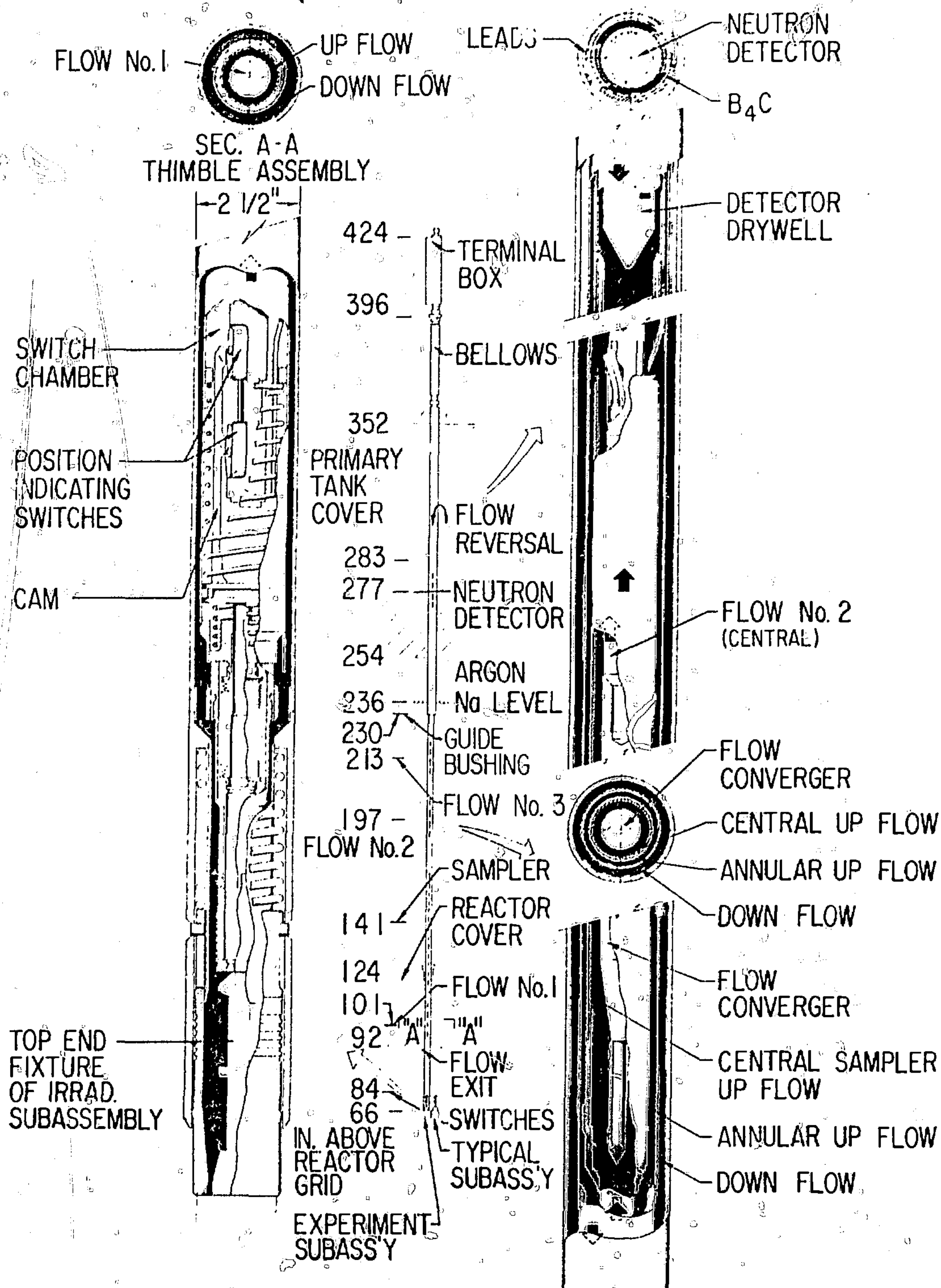


FIG. 2 SCHEMATIC OF BFTF

the delayed-neutron detector drywell located at an elevation of 457 mm (18 in) from the bottom of the rotating plug. After passing the DN detector, the flow is reversed and flows down the outer annulus back to the upper plenum of the reactor vessel. The flowmeters are arranged to measure the total flow as well as the flow split in the deposition sampler.

The flow meters are of the eddy current type and have a range from 6.3×10^{-2} to 1.28 l/s (1 to 20 gpm). They have been calibrated for use at temperatues up to 538°C (1000°F).

The delayed neutron detector is a ^{235}U fission chamber having a fissile loading of 312.3 mg as U_3O_8 plated on stainless steel anodes. It measures 25.4 mm dia. x 377.8 mm in length (1 x 14.9 in.) and is designed to operate at temperatures up to 550°C (1025°F). The measured sensitivity to thermal neutrons is 0.36 ± 0.04 cps/nv. The detector is surrounded by ^{10}B shielding to reduce the background from core neutrons. The gamma signal at the detector due to core and capture events is insignificant. A Monte Carlo calculation of the detector sensitivity using the Morse Code [1], indicates a signal-to-noise ratio of about 50 to 1, depending on the source of delayed neutrons. The source strength at the detector is a function of the breach site parameters (size of breach etc.) and the facility flow rate.

The deposition sampler is shown in Figure III. The sampler is a replaceable unit located in the BFTF above the reactor vessel cover. It guides the effluent from a fuel assembly containing breached fuel elements through two concentric flow paths. The outer annular path directs part of the flow (higher velocity) across test deposition surfaces of various compositions and surface finishes. The parallel inner flow path (lower velocity) directs the remaining flow through a sintered 316 stainless steel filter with nominal pore size of 10 μm to retain particulates. The flow rates and temperatures in the sampler are monitored using the permanent instrumentation in BFTF. There are a total of 40 deposition rings in the unit made of 304SS, 316SS, nickel and Inconel 718. Surface finishes vary from 1×10^{-4} to 1.27×10^{-2} mm (4 to 500 μ in.) rms. Provision is also made to vary the flow area around each of several deposition surfaces to gather data on velocity affects on particle deposition. The entire sampler is removable for analysis.

SAFETY ANALYSIS

Because of the uniqueness of the facility and the potential for conducting experiments with grossly defected fuel, a more than routine safety analysis of the facility and its operation was performed. Of major concern is the potential for flow blockage, gas entrainment in the BFTF due to test failure, and the coolability of the test under loss-of-flow conditions. Overall system contamination, while not a direct safety problem, was also a consideration. Analysis of the above events established design criteria for the facility.

Figure III. The BFTF Deposition Sampler

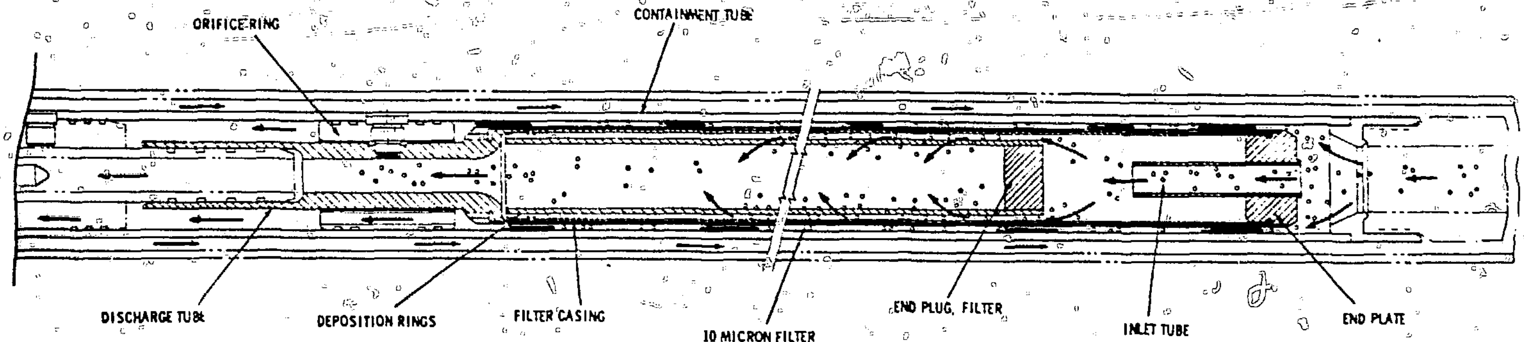


FIG. 3 BFTF DEPOSITION SAMPLER

Sodium flow is upward in the facility and at the elevation of the neutron detector in the rotating plug, the flow reverses and flows downward in an outer annulus and exits below the level of the sodium inside the reactor vessel. (The EBR-II core is contained in the reactor vessel which in turn is inside the primary tank.) The increased hydraulic resistance of the facility and the potential flow reduction due to gas entrainment from breached elements were evaluated as to their effects on temperatures of fuel and in-core components. The analysis was done using the THHB code [7]. The test assembly below the BFTF and the surrounding six subassemblies were modeled for the calculation. Temperatures were calculated for postulated loss-of-flow events taking into account gas entrainment, etc. For these events, temperatures were within the Technical Specificaiton limits; however, the size of the test subassembly must be restricted to less than 19 full power pins without coolant bypass at the test-facility interface to increase the test flow rates. Consequently, provision is made in the design to include bypass holes.

Bypass is also required to assure release of tag gas from experimental pins to the cover gas for sampling and analysis.

Sodium contamination was considered in light of previous experience with other RBCB experiments. The major contaminant in the primary Na following cladding breach is ^{137}Cs. Other fission products, such as Ba and Zr, appear to plate out and behave similarly to activated stainless steel corrosion products. The ^{137}Cs is very effectively removed and controlled by the graphite nuclide trap. Iodine is also removed by the trap, but is less of a problem due to its short half-life. Other impurities are controlled by the cold trap.

On two occasions, following cladding breach in experimental subassemblies, Pu has been detected in the primary sodium. Levels have been of the order of 10^{-10} gm-Pu per gm-Na. If this were uniformly distributed, the total amount of Pu involved would be about 30 milligrams total per release. The levels were observed to decrease linearly over a period of 3-to-4 weeks at which time they were below detectable levels. This would seem to indictate that plateout or settling of the Pu was occurring. The linear behavior is typical of other isotopes which are known to settle out with time.

System contamination, while not a direct threat to the public, is important from a maintenance and operations viewpoint. To date, the RBCB program has not added significantly to the levels of contaminants.

EXPERIMENTAL PROGRAM

The experimental program centers around three experiments; the first, designated XY-1, is a fission-product, recoil source assembly used to calibrate the delayed neutron detector and to compare results with the existing EBR-II fuel-element-rupture-detector; the second,

CONCLUSIONS

Installation of the Breached Fuel Test Facility provides an expanded capability for irradiation of run-beyond-cladding-breach experiments and provides a capability for direct experimentation in areas of fission product contamination and particulate behavior in sodium systems. The capability for RBCB operation is increased several fold over that of an open core experiment. Diagnostic capability has been included which will generate quantitative information regarding breach parameters and fission product deposition.

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