PHÉBUS-FP PROGRAM

The Phébus-FP Facility

As illustrated in Figure 1, the test device in the Phébus-FP facility consists of a bundle of 20 fuel rods and 1 control rod that are 1 meter (39.37 inches) long, surrounded by an insulating ceramic shroud fitted into a pressure tube. The test device is inserted into a pressurized-water loop, located at the center of the 40-MW Phébus driver core.

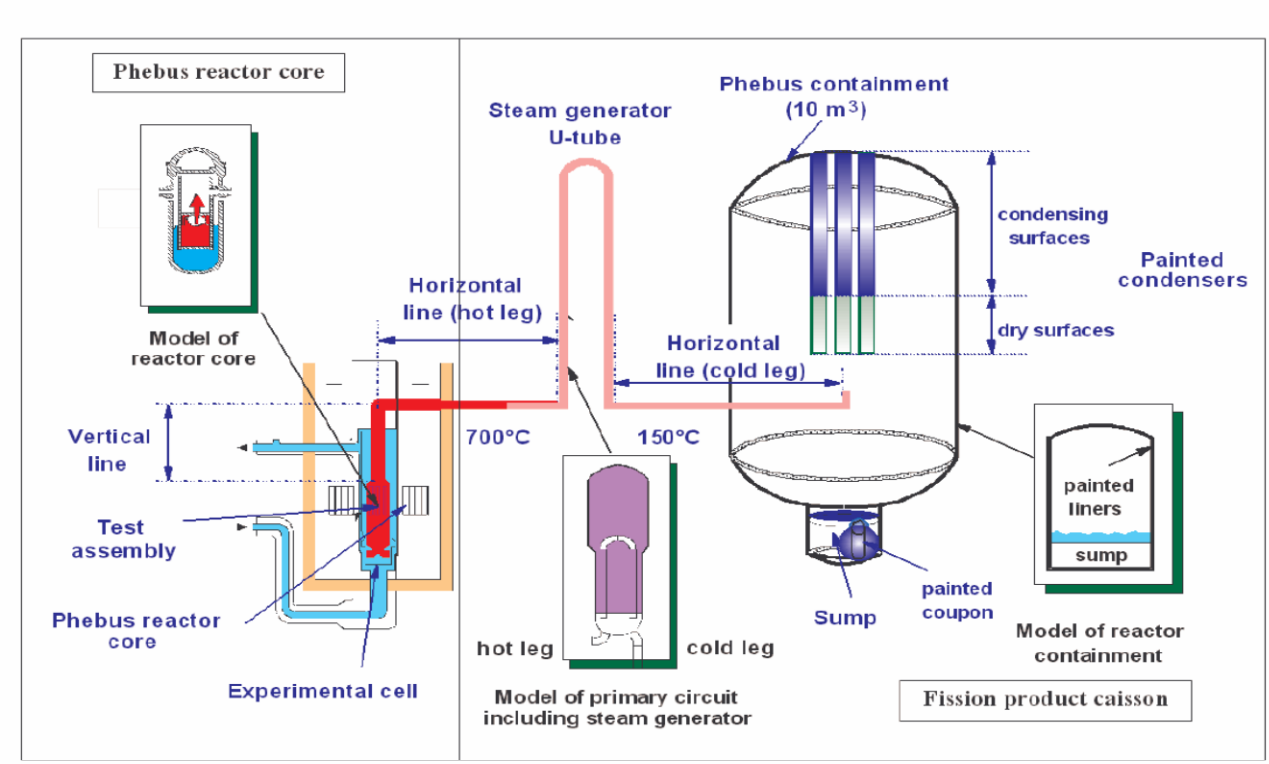

Figure 1. Schematic View of the Phébus FPT-0 and FPT-1 Experimental Circuit

The plenum above the test bundle is connected to a horizontal pipe, which simulates the hot leg and cold leg sections of the reactor coolant system, and a single inverted U-tube, which simulates a pressurized-water reactor (PWR) steam generator. The outlet of the U-tube is connected to a 10-m^3 (13-yd^3) vessel, which simulates the containment of a reactor. The containment vessel includes scaled, painted surfaces and a water-filled sump to investigate iodine behavior in the containment. The overall scaling factor is 1/5000 with respect to a 900-MWe French PWR. The facility is instrumented to allow measurement of fission product release, deposition in the primary circuit and release to the containment, and behavior in the containment. Extensive post-test examinations of the test bundle, circuit, and containment are carried out following each test.

Conduct of Test

Before each test (except FPT-4), test fuel from the BR3 reactor [a Belgian reactor that uses 1-meter (39-inch-) long fuel rods] was re-irradiated in the Phébus-FP in-pile section for up to 2 weeks using the existing pressurized-water loop in order to generate a sufficient inventory of short- and medium-lived fission products. The water level in the loop was then slowly dropped with simultaneous reduction of reactor power, with the in-pile section isolated from the loop.

During the test phase, the in-pile section was connected to a circuit and containment vessel, and the in-pile fuel bundle was heated by fission power from the driver-core at a rate typical of a severe accident up to temperatures at which the fuel is damaged. The test bundle was pushed to conditions in which fission product release takes place, and control rods and structural materials were vaporized to produce realistic quantities of aerosols. The fuel bundle was damaged to the extent necessary to release fission products and study the mechanical behavior of the fuel during extensive degradation.

The released fission products were swept by a flow of steam and hydrogen (H_2) into the circuit that simulates the primary cooling system up to the point of pipe break. The flow then entered the containment vessel.

Table 1 summarizes the conditions of four pertinent Phébus-FP tests. Three of the tests (FPT 0, 1, 2) involved the degradation of fuel rods along with a silver-indium-cadmium (Ag In Cd) control rod. The conditions of sump temperature and pH were varied among these tests to encourage either gaseous iodine accumulation in the sump or gaseous iodine partitioning from the sump. The fourth pertinent test (FPT-3) involved the degradation of irradiated reactor fuel rods in the presence of a boron carbide (B4C) control rod.

Test Matrix

Test	Objective	Fuel Bundle	Primary Circuit	Containment Vessel	Date
FPT-0	Degradation and fission product (FP) release from *fresh fuel*	Fuel degradation and FP release under steam-rich conditions	FP chemistry and behavior	Aerosol behavior and deposition Radiochemistry of iodine Sump pH = 5, 90°C	Dec. 12, 1993
FPT-1	Same as FPT-0, but with *pre-irradiated fuel* (23 GWd/tU)	Same as FPT-0	FP chemistry and behavior	Aerosol behavior and deposition Radiochemistry of iodine Sump pH = 5, 90°C	July 26, 1996
FPT-2	Same as FPT-1, but *with pre-irradiated fuel* (32 GWd/tU)	Same as FPT-1 under steam-starved conditions	FP chemistry and behavior w/boric acid injection	Aerosol behavior and deposition Radiochemistry of iodine Sump pH = 9, 90°C (degradation and aerosol phases), 120°C (chemistry phase)	Oct. 12, 2000
FPT-3	Same as FPT-1, but with B_4C control rod	Same as FPT-2	FP chemistry and behavior	Aerosol behavior and deposition Radiochemistry of iodine H_2 recombiner, Sump pH = 5, 90°C (degradation and aerosol phases), 120°C (chemistry phase)	Nov. 18, 2004
FPT-4	Late-phase core configuration using rubble bed EdF fuel (33 GWd/tU)	Release and transport of less-volatile FPs and refractory materials	N/A. Used integral filters in the test device, thereby bypassing the primary circuit and containment vessel.		Jul. 22, 1999