Chapter 2
Some of the Research Facilities Favored by IRSN in the Field of Nuclear Power Reactor Safety

2.1. The CABRI reactor

The CABRI safety test reactor, together with SCARABEE, its former twin reactor now disused, is the basic nuclear installation (INB 24) at the Cadarache research center. CABRI is operated by CEA for IRSN.

CABRI was commissioned in 1964. It is a pool-type reactor consisting of a 25 MW, water-cooled driver core[5] that uses slightly enriched uranium oxide (UO_2) fuel since the 1970s.

It is used to study the impact on fuel of reactivity-initiated accidents that may occur in various types of reactors. The experiments consist in very rapidly increases of reactor power above its normal operating level. The power peaks, which last only a few milliseconds, may reach 20 GW and are achieved by the more or less rapid and sequential emptying of control rods filled with a neutron-absorbing gas, the helium-3 isotope. The

5. The driver core produces neutrons for conducting experiments on the test fuel, which is placed in a loop that contains its own coolant, and crosses the core along its central axis.

65 cm width and 80 cm high reactor core is made up of 40 fuel rod assemblies designed to withstand the impact of these power peaks.

From 1978 to 2001, CABRI was used for research on reactivity-initiated accidents in sodium-cooled fast neutron reactors (SFR), using single fuel pins (or rods) placed in a sodium test loop. From 1993 to 2000, the sodium loop was also used for carrying out tests to simulate the first phase of a reactivity-initiated accident in pressurized water reactors. These were known in France as REP-Na (i.e. PWR-sodium) tests. CABRI is now equipped with a pressurized water loop for the purposes of a new research program comprising ten tests on pressurized water reactors, under conditions that are more representative of a PWR[6]. This program, called the CABRI International Program (CIP), was launched in 2000 (Figure 2.1).

The CABRI reactor includes a device called a hodoscope, which consists of several tens of fission and recoil proton ionization chambers positioned at the end of a collimator passing through the core. The hodoscope is designed to detect and precisely measure the solid or molten fuel movements in the test rods during the experiment.

SCARABEE, which is no longer used, shared its cooling systems with CABRI. Unlike CABRI, it was not used to produce rapid power transients. Equipped with a sodium loop with a larger diameter than that of the CABRI loop, it was used mainly for the study of hypothetical accidents involving fuel assembly blockage and

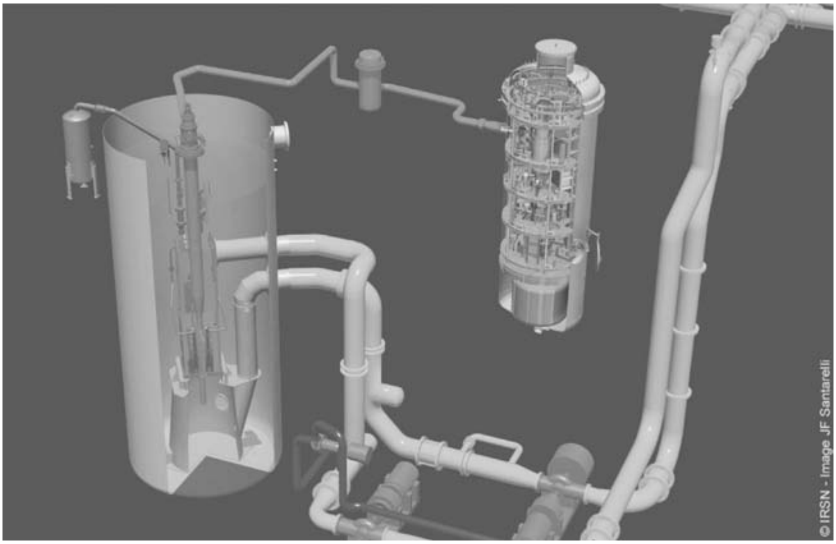

Figure 2.1 Diagram of the CABRI safety test reactor with its pressurized water loop.

6. The pressure and temperature in the water loop are respectively 155 bar and 350° C.

meltdown in high-power fast neutron reactors (SUPERPHENIX, “RNR 1 500” project), from 1983 to 1989. The tests were performed on small assemblies comprising up to 37 fuel pins.

2.2. The PHEBUS reactor

PHEBUS was an experimental nuclear reactor (INB 92) also located at the Cadarache center and operated by CEA. Commissioned in 1978, it was intended for research on accidents liable to affect pressurized water reactors. It has not been used since 2010.

PHEBUS was a pool-type reactor consisting of a 40 MW drive core, equipped with a cooling tower that enabled it to operate at high power for several days, unlike CABRI, whose operating time cannot exceed tens of minutes. It was used to provide neutron flux to heat the test fuel that was inserted into the pressurized test loop at the center of the core and produce radioactive substances, whose behavior was studied during a subsequent phase of the experiment.

It was mainly used as the experimental tool for a Fission Product program (Phebus-FP), which was aimed at studying what became of fission products from a pressurized water reactor core in the event of core melt. This program was launched by IPSN in 1988 under a partnership with EDF and the European Commission, and with a number of other countries (United States, Canada, Japan, South Korea and Switzerland). It lasted from 1988 to 2010. PHEBUS had previously been used for the Phebus-LOCA and Phebus-CSD programs.

CEA plans to file an application with the French Nuclear Safety Authority (ASN) in 2017 for the final shutdown of PHEBUS.

2.3. The GALAXIE experimental facility

GALAXIE is an IRSN-operated experimental facility that is also located at the Cadarache center. It groups together experimental facilities with various capabilities, designed for conducting experimental research on fire risk control in nuclear facilities (see details in Chapter 7). A brief description of the two main GALAXIE test facilities is given below.

► DIVA (Fire, Ventilation and Airborne Contamination Device)

The DIVA facility (Figure 2.2) is used for performing tests on fires that may occur at fuel cycles facilities as well as pressurized water reactors. The tests are performed in configurations involving several ventilated rooms. DIVA consists of three 120 m^3 rooms, a 150 m^3 corridor, another room with a volume of 170 m^3 on the second floor, and a ventilation network. It is very well-instrumented, with up to 800 measuring channels. Its reinforced concrete structure and its equipment have been designed to withstand a gas pressure range of – 100 hPa to + 520 hPa. Leakage between rooms and ventilation configurations can be adjusted to study fire in situations involving several confined and ventilated rooms.

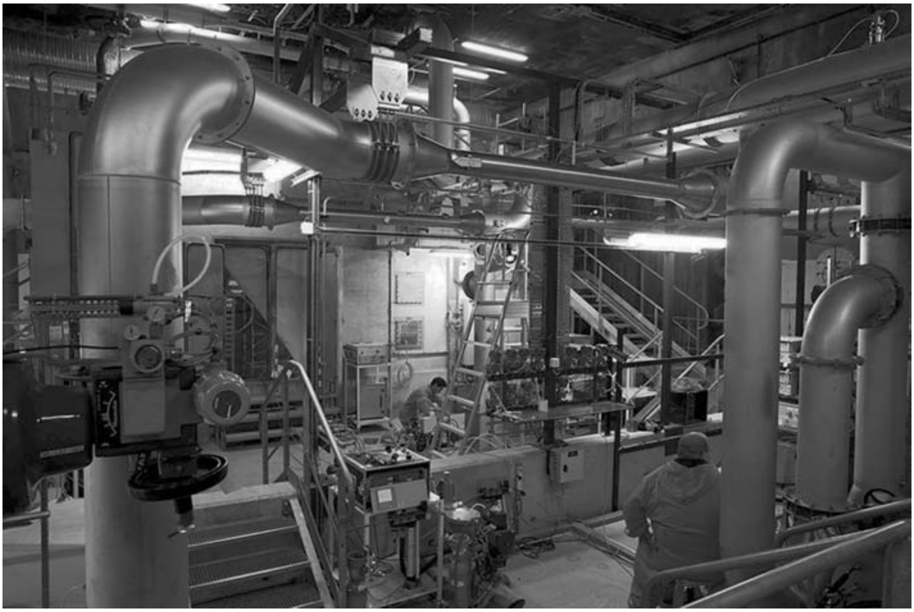

Figure 2.2 The DIVA facility © Jean-Marie Huron/Signatures/IRSN.

► SATURNE

The SATURNE calorimeter cone (Figure 2.3) is a facility used to determine characteristic variables of a fire, such as its heat release rate and mass flow. The capacity of the hood and ventilation network (maximum capacity of 30,000 m^3/h) is suitable for studying fires with heat release rates of up to 3 MW.

2.4. Other facilities

IRSN uses five other experimental facilities in the field of pressurized water reactor safety.

► The CALIST experimental facility (Saclay)

The CALIST (Characterization and Application of Large and Industrial Spray Transfer) experimental facility was designed to characterize the size and velocity of drops from one or more spray nozzles and for the study of air entrainment by the sprays.

► The TOSQAN facility (Saclay)

The TOSQAN facility is used to simulate the thermal-hydraulic conditions inside the containment building of a nuclear reactor in the event of a core melt accident. This facility is designed for the analytical study of physical phenomena influencing hydrogen

Figure 2.3 The SATURNE facility. © Olivier Seignette/Mikaël Lafontan/IRSN.

distribution in a reactor containment: wall condensation, exchanges induced by the containment sump or the containment spray system.

► The CHIP facility (Cadarache)

The CHIP[7] facility is used for physical-chemical studies. It consists of ovens in which chemical reagents are placed, and temperature-controlled axial profile tubes through which these reagents and a carrier gas are injected. It is used in the CHIP research program, which focuses on iodine chemistry far from thermodynamic equilibrium (impact of chemical kinetics) in the reactor coolant system of a water reactor during a core melt accident.

► The EPICUR facility (Cadarache)

The EPICUR[8] facility is a panoramic irradiator composed of cobalt sources (^{60}Co). It emits γ radiation characterized by an average dose rate of 10 kGy/h. It consists of an experimental chamber used to study the effect of radiation emitted by the radioactive substances found in the containment of a pressurized water reactor during a core melt accident. It is used for the program of the same name, which studies iodine chemistry in a reactor containment in an accident situation.

7. Iodine Chemistry in the Reactor Coolant System.
8. Physical and Chemical Studies of Contained Iodine under Radiation.

► The IRMA Irradiator (Saclay)

IRMA[9] is a panoramic irradiator used to irradiate materials. It consists of cobalt sources (^{60}Co) and emits γ radiation characterized by an average dose rate of 20 kGy/h. Various scientific and technical experiments are carried out at the facility. By nature, they concern the study of radiation/material interaction mechanisms and, more especially, the response of materials and components to gamma radiation and any related degradation. IRMA is also used in the study and design of biological shielding and protection for various types of nuclear facilities. Its research potential (high γ flux) is also compatible with accident studies.

9. IRradiation of MAterials.