Chapter 12
Other Research and Tracks of New Research

IRSN also conducts research of varying scope in many other technical areas related to PWR safety, including:

- the reliability of critical codes in the code-based digital instrumentation and control systems used in N4 series and EPR reactors;
- the behavior of materials subjected to seismic loads with the proprietary development, *via* numerical simulation, of material "fragility" curves that can be implemented in probabilistic assessments of seismic hazards. Determination of fragility curves *via* numerical simulation is an alternative to the American method (EPRI curves based on a lognormal model and predetermined parameter sets) and could also make it possible to determine in a most suitable way the parameters of EPRI's lognormal model. To achieve this, IRSN developed Interactive Seismic Analysis of Fragilities of Equipment and Structures (ISAFES), a simulation code that makes it possible to conduct dynamic time simulations using representation objects of structural components referred to in France as MARC (Weight, Damper, Stiffness, Criterion). This development thus addresses the fields of dynamic numerical simulation of equipment with uncertainties as well as soil-structure interaction with seismic excitation;
- in-vessel mixing phenomena in PWRs, which could occur, for example, if borated water is diluted with clear water, a situation that can lead to reactivity accidents;

– airborne contamination. This research, apart from that on filtration systems, is more specifically geared to the issues encountered in fuel cycle facilities and dismantling operations.

Furthermore, the designers of the Generation III[248] and III+ reactors, as well as of projects for integral or modular reactors (SMR[249]), are increasingly emphasizing passive systems[250]. There has been renewed interest in passive systems since the Fukushima Daiichi accident. Needless to say, the accident's consequences led researchers to look at prolonged loss of electrical power and LOCA. Passive systems may be solutions for handling such situations. However, the increasing use of passive systems reveals that more needs to be known about their use in deterministic safety demonstrations and PSAs. Indeed, questions remain to be answered about their reliability, their effectiveness, the possibility of "recovery" in case of failure, and the verification of their performance from reactor design to reactor operation.

IPSN (and after IRSN) addressed the subject of passive systems during assessments conducted in the 1980s and 1990s on the PHENIX and SUPERPHENIX fast neutron reactors and, more recently, for the ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) project. These systems related specifically to the possibility of removing the residual heat from the reactor *via* natural convection of the sodium in the reactor vessel—primary circuit—and in the secondary circuits, which also contained sodium. At the same time, IRSN was involved in the European Thermal-Hydraulics of Innovative Nuclear Systems project (THINS), particularly for the numerical simulation of natural convection tests conducted at PHENIX in the late 1990s (as part of its "end-of-life tests") and for the qualification of the CESAR module of the ASTEC simulation code. However, proposals for research projects (extending beyond sodium-cooled reactors and spanning prestandardization research, testing of components, numerical simulation, etc.) are being prepared following the European Commission's H2020 call for projects. These projects include REPASS[251] and NUSMOR[252], in which IRSN may participate with partners such as ENEA[253], KIT and GRS.

248. The use of passive systems in an EPR is limited to gravity drop of the control rods, pressurized accumulators to reflood the core, the possibility of thermosiphon cooling of the reactor following failure or voluntary shutdown of the primary pumps—to be checked in the reactor itself as well as in the case of reactors in operation—, hydrogen recombiners, and the core catcher in the event of a core melt accident.
249. Small Modular Reactors.
250. The concept of a passive system is broad: spanning systems that make limited used of components requiring mechanical movement to perform the systems' functions, the supply of outside power or support functions, human intervention (to activate and operate the system for the appropriate period), and systems that use natural phenomena (gravity, heat transfer by conduction, natural convection, or radiation, pressure differences, etc.).
251. Reliability Evaluation of Passive Safety Systems.
252. NUgenia Small Modular Reactor with passive safety features.
253. Italian National Agency for New Technologies, Energy and Sustainable Economic Development.