

Although not much publicised because of their low rate on the INES scale – based on immediate radiological risk rather than intrinsic safety criteria – many significant events occur in nuclear reactors and fuel-chain facilities that show serious flaws of design, quality, procedures and systems, with the potential to trigger a dramatic event. France is no exception to that rule. The 2007 *Residual Risk* report, by an international team of independent experts, obtained from IRSN a selection of some of the most significant of those near-miss and precursor incidents in France for the period 1986-2006. Below is the summary by the report authors of these 18 selected events, presented in chronological order:

■ **12 January 1987, Chinon-B3** (not rated on INES scale). The particularly cold conditions during the winter 1986-87 led to the freezing of several materials and systems significant for the safety of the unit, in particular at the level of feed water intake from the Loire river.

■ **16 August 1989, Gravelines-1** (INES Level 3). The mounting of an inappropriate type of screws onto pressure relief valves on the primary circuit would have rendered the overpressure protection system inefficient. The valves would have opened and closed significantly later than under design basis conditions. The operators did not agree to the Level 3 rating and initiated, in vain, a procedure to get it downgraded to Level 2.

■ **30 October 1990, Cruas-4** (INES Level 1). The explosion of a 6.6 kV commutator caused a fire that entailed the loss of one of the two electrical safety circuits. The destruction of the commutator was caused by the degradation of elastic washers due to the exposure to heat. Subsequently, the second line was found to be affected in the same way.

■ **23 September 1991, Bugey-3** (INES Level 2). A leak was identified during the decennial primary circuit pressure test on the support of the control rod drive mechanisms that was going through the reactor vessel head.

■ **29 January 1994, Bugey-5** (INES Level 2). The reactor was shut down and the primary coolant level was decreased to working level in order to carry out some maintenance operations. The water flow level at the primary pumps and the motor intensity fluctuated for eight hours without any operator intervention. The technical specifications explicitly require close supervision of these parameters under these operational conditions because fluctuation can indicate the degradation of the primary pumps leading to their potential loss and thus the risk of core degradation. The safety authorities identified “significant malfunctioning”: the manual was erroneous, the operators had not received any specific training for this “particularly delicate” operation, the situation has been considered falsely as “normal and safe”, the visit of the safety engineer in the control room did not lead to any corrective action.<sup>66</sup> The event had originally been given an INES 1 rating.

■ **12 May 1998, Civaux-1** (INES Level 2). While the unit was shut down, a 25 cm diameter pipe cracked open due to thermal fatigue and a large leak (30 m<sup>3</sup> per hour) occurred in the primary cooling circuit. It took 10 hours to isolate the leak. An 18 cm long crack was on a weld was identified. The unit, which is one of the four most modern French reactors (N4, 1500 MW), had been operating only for six months.

■ **10 June 1999, Tricastin, then identified on all 58 EDF units** (INES Level 1). Polyamide cages, non-qualified for accidental situations, instead of metal cages have been built onto ball bearings of coolant safety injection pumps. First identified at the Tricastin site, the problem turned out to be spread over all of EDF’s nuclear power plants.

■ **11 March 1999, Tricastin-1** (INES Level 1). Following a series of organizational and human errors, a technician has penetrated into a protected, highly radioactive area of the reactor (red zone) and has received a dose of about 340 mSv (17 times the current legal limit for worker exposure).

- **27 December 1999, Blayais-2** (INES Level 2). The unusual storms at the end of 1999 led to the flooding of the Blayais nuclear power plant site. Certain key safety equipments of the plant were flooded, for example the safety injection pumps and the containment spray system of units 1 and 2. The electrical system was also affected. For the first time, the national level of the internal emergency plan (PUI) was triggered.
- **2 April 2001, Dampierre-4** (INES Level 2). Following human and organizational errors, the correct core loading scheme has not been implemented. The situation could have led to a criticality risk.
- **21 January 2002, Flamanville-2** (INES Level 2). The installation of inappropriate condensers due to an inappropriate procedure led to the simultaneous loss of several control-command boards and systems while the unit was operating as well as to the destruction of two safety significant pumps during the shut down sequence.
- **24 December 2003, all 900 MW reactors** (INES Level 2). The misconception of the reactor sump filters induced the potential risk of debris blocking the cooling function in case of the need for recirculation under post-accident conditions. The problem has been subsequently identified not only in all of the French 900 MW reactors but also in many other plants around the world.
- **24 January 2004, Fessenheim-1** (INES Level 1). Following the erroneous operation of an auxiliary circuit valve, ion exchange resins<sup>68</sup> have been introduced into the primary cooling circuit. Their presence could have threatened the integrity of the primary pump joints as well as the proper functioning of the control rods. Both elements are essential to control and shut down the reactor.
- **22 March 2004, all 58 EDF reactors** (INES Level 2). An insulation default at an electrical switchboard, experienced on unit 2 of the Penly nuclear power plant, was triggered by a steam leak close to electrical equipment that was to be qualified to resist accidental conditions. The non-conformity of the cabling has been subsequently identified on all of the French nuclear power plants and led to large-scale verification and remediation operations.
- **16 May 2005, Cattenom-2** (INES Level 1). The sub-standard of the secondary coolant pump power supply cabling led to a fire in the electricity funnel. As a consequence one of the two safety circuits had to be disconnected. The operator EDF triggered its local (Level 1) internal emergency plan (PUI) The technical emergency center (CTC) has been activated for a few hours. The nuclear safety authorities issued a nine-line press release. Details of the event have never been published.
- **7 April 2005, Gravelines-3** (INES Level 1). During the year 2006 the operator has noticed the presence of provisional pieces of equipment on both of the reactor protection control command lines. These pieces were applied during the previous reactor outage and had been left there by mistake. Under accidental conditions certain automatic sequences would not have taken place in a normal way.
- **30 September 2005, Nogent-1** (INES Level 1). A certain number of material failures added to a human error during the restart of the reactor led to the hot water and steam penetrating the four rooms containing the control command boards of the reactor protection system. Under normal conditions these rooms are independent from each other and should never be put in danger simultaneously. In the case of an accident, this incident could have made it difficult for the operator to bring back the reactor into safe state. EDF has activated its internal emergency plan and the nuclear safety authority ASN activated its national emergency organisation for a few hours. ASN issued a 10-line press release.
- **21 December 2005, Chinon-B, four units** (INES Level 1). An ill-conceived surveillance of the tertiary cooling water intake canal led to its significant silting up. The collapse of the sand hill could have led to the heat sink loss of all four reactors.