1967 coolant leak

In May 1967 the reactor was approaching the end of a scheduled fifty five day operating run when a detector in the primary vessel leak jacket indicated the presence of NaK. A normal shut down procedure was followed by analysis of the NaK taken from the leak jacket. None of the fission products in the NaK had a half life less than three months so the leak had been present for a considerable period and was therefore small and would be difficult to locate.

Shortly after shut-down, and with the circuit still pressurised, the leak appeared to stop. Attempts to re-open the leak were unsuccessful and, after serious consideration, it was decided to carry out a full refuelling programme and to restart the reactor having added further instrumentation to provide, for example, a more accurate method for measuring the leak rate.

After three weeks of full power operation the small leak rate began to increase and the reactor was again shut down normally and the leak thereupon stopped. During this brief operational period a strong correlation was established between the leak rate and reactor power.

This suggested that the leak depended on the coolant level in the circuit, which was power dependent, or that it was below coolant level and, being temperature sensitive, opened up as the result of thermal stresses. The latter was more probable because prior to the second shutdown sufficient coolant had been lost to lower the level in the vessel to that which would normally have been obtained at shut down; but the leak rate had remained constant right up until shutdown.

Suspicion was therefore directed at the primary circuit below coolant level. Pressurising the circuit to 200kPa, and raising the temperature to 2500C produced what appeared to be a small leak but this could have been drainage from the leak jacket. 100g of gold were added to the 50 tonnes of coolant and the pumps were run at full power. A sample of leaked NaK was activated in the Dounreay Materials Test Reactor and this showed a presence of gold indicating that the leak was open. The whole of the vessel and pipework was then subject to a gas leakage test. Having removed all the core elements and some breeder elements, the gas blanket was replaced by a 40/60 helium/argon mixture and the circuit pressure raised to 300kPa. The coolant level was steadily lowered and, when it was just below the twenty four outlet stubs, the helium concentration in the leak jacket suddenly increased. However, the lowering of the NaK level had reduced the temperature of the metalwork and the leak soon resealed.

Repeating this experiment but with the coolant rapidly dumped to the level of the bottom nozzles, the leak remained opened at a low level which was nevertheless sufficient to establish that the leak was either at one of the twenty-four outlet nozzles, or in one of the twenty-four 100mm outlet pipes connecting a nozzle to a thermocouple block where the leak jacket terminated. Pressurising the leak jacket and injecting radon cover gas while listening for bubbling noise, proved unsuccessful and it was decided that the offending crack would have to be opened up.

Laboratory experiments had shown that a crack, comparable in size to one which would give a leak rate similar to that observed, could be opened up by a factor of ten or more when subject to a strain small enough to be harmless to all adjacent pipework. Having removed the coolant and the active fuel elements, the radiation levels fell and access to the reactor vault became available. By manually deflecting each of the heat exchangers in turn, a significant increase in leak rate identified either 10A or 10B heat exchanger circuit as the leak site. A more precise location was obtained when the vessel was filled with eutectic NaK taken from the DFR thermal syphon and a number of microphones were clamped to each of the thermal couple blocks. Circuit 10A was readily identified as the source of the leak; much smaller signals were heard on the two adjacent circuits. Cross-correlation of the acoustic signals from the microphones attached to circuit 10A and its two adjacent circuits, indicated that the leak was not on the vessel itself but a short distance along an outlet pipe. To make an effective repair of the weld a 3m section of the leak jacket and pipe were cut out. Examination of the pipe exonerated the suspect weld identified by the crosscorrelation technique but revealed a thin crack 30mm long on an adjacent circumferential weld about 25mm from a tee connection which had been provided to return coolant from one of the six hot traps. These hot traps had not been used, consequently the 30mm pipe returned coolant at a temperature 1000C below that experienced in the main pipe.

Using liquid nitrogen, a thermal stress calculated to replicate the operating condition was applied to the cut-out section of the pipe section; this opened up the cracked pipe to an extent that could explain the observed leak rate.

The thermal stress, arising from the 100oC cooler inlet stream from the hot leg Tee at the point of failure, was calculated to be within normal design limits. However, the failed weld suffered several other major defects. There was misalignment of the pipes, straying of the weld bead and a lack of penetration and a stress raiser where the weld had been double started. It was probable that the leak was caused by a combination of all these factors.

Nevertheless, as the hot traps had never been used as such, it was decided to eliminate this Tee connection on each of the seven hot traps.

During the repair some 350 craftsmen were involved. It was a complex and, for the operators, a frustrating operation. It may be that a zealous interpretation of the instruction to apply a small deflection was applied in order to open up the elusive leak.

Among the many other constraints applying to the repair operation it was imperative to exclude air from entering the leak jacket or the main vessel. The environment of the vault was carefully monitored and none of the craftsmen experienced a dose in excess of the (then) ICRP three month radiation limit of 30mSv.

While access to the vault was available a number of additions and alterations were made to provide active storage facilities, and improve instrumentation including thermal couples and acoustic sensors for leak detection.

In June 1968 the reactor returned to full power. While the NaK was being returned to the vessel the re-filling operation was deliberately interrupted when the coolant level in the main tank was 50mm above the outlet stubs. The leak jacket was pressurised, but no signs of bubbling could be heard. This was reassuring and no further leaks occurred in the primary circuit.