N184. Designing Radiation Protection Into Sizewell B

In achieving the extremely low dose targets that have been set for Sizewell B in the UK, the plant's designers have been fortunate in that they have been able to draw on a vast body of international experience. They have reduced the levels of cobalt in components and materials, made extensive provision for robotics, and added formal ALARP review procedures to the design process.

The whole-body dose targets adopted for Sizewell B were derived from consideration of operator doses at UK gas-cooled reactors, and from the requirements of the NII and the public inquiry for planning consent. The most important targets are an individual annual target of 10 mSv (1 rem) and a collective annual dose target of 2.4 manSv (240 man-rem). These are extremely demanding targets for a PWR, with the individual dose target being regularly exceeded on operational PWRs around the world.

Minimizing Radiation Sources

The most important contributor to operator doses on PWR plant is cobalt, which accounts for 85% of the total dose uptake. The sources of cobalt are nickel, which is irradiated to Co-58, and natural cobalt, which is irradiated to Co-60. The following measures are being used to reduce radiation sources:

- Stellite Replacement - Proven alternatives to stellite for the faces of the flow control valves in the chemical and volume control system are to be used.
- Steam Generator Tubing - Thermally treated Inconel 690 has been adopted in place of the original Inconel 600 for the steam generator tubes. This will reduce maintenance and also has a much lower nickel content and lower corrosion release rate.
- Materials Impurities - A cost-benefit analysis was carried out addressing the cobalt impurity specifications of materials. It resulted in a reduction for the components directly in the core flux and for the steam generator tubing.
- Operational Chemistry - Strict flushing and chemistry controls will be in place from the initial filling of all the circuits. This ensures that the systems are kept clean and that the build up of oxide layers is minimized, reducing activated cobalt deposition. In addition, the inside surfaces of the primary circuit will be preconditioned before operation to passivate the surfaces and minimize the formation of corrosion products. During operation, the primary circuit chemistry will be tightly controlled at a constant pH to minimize the transport of corrosion products around the circuit. At the moment the pH is specified as 6.9 (300°C), but this will be reviewed before initial fill of the circuit.

Design Approach

The building and system designs have also been significantly reviewed to reduce operator dose uptake. The following are system and layout improvements:

- The reactor pressure vessel (RPV) cavity has been made smaller to reduce dose rates at the RPV flange during refueling work.
- A permanent RPV cavity seal has been included to remove the dose uptake received when fitting the temporary seal.
- An integrated head package has been included which reduces the preparation time for head removal.
- The RPV O-ring seals have been designed to be quickly removed and replaced.
- The reactor coolant pump (RCP) seals are a removable cartridge design, allowing inspection and repair in a low dose-rate area.
- The RCP seal change platform has been made a shielded platform to reduce the dose from the RCP bowl and reactor coolant system pipework.

- An additional shield has been included between the RCP and steam generators to reduce the background dose rate from the other components.
- Many platforms have been included to improve access for maintenance.
- The resistance temperature detector (RTD) system has been replaced by a dry cold leg measurement and an N-16 monitor to predict hot leg temperatures. The RTD system is a major contributor to dose rates in the steam generator and RCP cells, and its removal will significantly lower background dose rates and remove many radiation hot spots.

Remote Equipment Provisions:

- A multi-stud tensioner will be used to detension and remove RPV studs.
- Automatic equipment will be used for RPV flange and stud hole cleaning.
- All RPV and nozzle volumetric in-service inspection will be carried out by a submersible robot.
- All steam generator inspection and tube plugging will be carried out automatically without the need for personnel to go into the steam generator bowl.
- Automated sludge lancing of the steam generator secondary side will be carried out.
- All volumetric inspection of welds on high dose-rate systems will be carried out by automatic equipment.

ALARP Design Reviews:

- The chemical volume and control system regenerative heat exchanger, which has high dose rates, has been moved from the RCS loop cells to dedicated shielded cells outside the secondary shield wall.
- The reactor coolant drain system components, which are subject to very high hot spot radiation, have been housed in dedicated shielded cells.
- All valves requiring maintenance have been moved from the auxiliary building pipe chase area where dose rates are very high.

The initial indications are that the individual dose target of 10 mSv (1 rem) will be easily met, with maximum individual dose to be around 8 mSv (0.8 rem). The current prediction for the station collective dose is about 2.0 man-Sv (200 man-rem), which is within the target of 2.4 man-Sv (240 man-rem). Both the source minimization and the design approach are showing significant improvements in occupational radiation exposure. When taken together, it is expected that the station will achieve all its dose targets. In particular, if full improvement from the source reduction is achieved, this would indicate a station collective dose of 1.33 man-Sv (133 man-rem).

Taken from "Designing in Radiation Protection to Sizewell B," A. Willcock and A.M. Zodiates, Nuclear Engineering International, April 1992, pp. 44-46.