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ABSTRACT

Solid State Track Recorder (SSTR) Neutron Dosimeters have been developed for use in power reactors to provide information on the cumulative neutron dose received by the reactor pressure vessel during operation. The accumulation of neutron dose by the pressure vessel results in radiation damage in the form of steel embrittlement. In order to ascertain the safe operating lifetime of the reactor pressure vessel, the results of dosimeter measurements are evaluated and used to estimate the extent of radiation damage.

Among the requirements for SSTR neutron dosimetry are high accuracy and ability to provide useful data at high neutron fluences. To this end, ultra low-mass fissionable deposit preparation techniques have been developed, and the absolute accuracies of the measurements have been maintained at the 3-5% level.

The status of the deployment of SSTR dosimetry capsules in the reactor cavity region of operating power reactors will be summarized.

KEYWORDS

Solid State Track Recorders, Mica, Reactor Dosimetry, Neutron Dosimetry.

INTRODUCTION

The development and standardization of SSTR techniques for neutron dosimetry related to light water reactor pressure vessel surveillance have been described previously (Ruddy, et. al., 1985a; Ruddy, et. al., 1985b; Ruddy, et. al, 1984; Ruddy et. al., 1983). SSTR neutron dosimetry techniques have found widespread application for commercial pressure vessel surveillance applications and the number of SSTR dosimetry sets being prepared for such applications is steadily increasing.

The accumulation of neutron dose by the pressure vessel of a nuclear reactor results in radiation damage in the form of steel embrittlement. U. S. Federal codes require that reactor coolant pressure boundaries have sufficient margin to ensure that the boundary behaves in a non-brittle manner when stressed under operating, maintenance, testing, and postulated accident conditions and that the probability of rapidly propogating fracture is minimized. These requirements necessitate the prediction of the amount of radiation damage to the reactor vessel throughout its service life, which in turn requires that the neutron exposure to the pressure vessel be monitored.

SSTR Neutron Dosimetry

SSTR neutron dosimetry provides a method for passively monitoring the radiation dose to a pressure vessel on a reactor operational cycle-to-cycle basis. SSTR neutron dosimeters may be placed in key locations during normal reactor shutdown periods, and removed for analysis during the next convenient shutdown. Presently, SSTR dosimetry efforts emphasize measurements in the reactor cavity, which is the annular gap immediately outside of the reactor pressure vessel. Typical placement of dosimetry is shown in Figure 1, where dosimetry is indicated at approximately 0°, 15°, 30°, and 45° radial locations. These nominal locations are often chosen at the midplane elevation, with additional dosimeters at the ±210cm, 0° axial locations. Typical SSTR dosimetry for an operating LWR has consisted of six sets of six SSTR-fissionable deposit pairs. The fission rates of 235-U and 239-Pu are measured with no thermal neutron shielding and the fission rates of 235-U, 239-Pu, 237-Np, and 238-U are measured with cadmium shielding. SSTR dosimetry sets are combined with radiometric dosimeters and Helium accumulation fluence monitors as shown in Figure 2. A more complete description of all of the types of dosimeters deployed and their analysis is contained in Ruddy et. al., (1985b).

Typical fluences encountered in the reactor cavity during a cycle of operation are of the order of 10^{16} n/cm^2. This presents formidable problems associated with fissionable deposit preparation and calibration. In order to limit the track densities in the SSTRs to less than 10^6 tracks/cm^2 for ease of scanning, the deposit masses must be kept low. Typical midplane deposit mass requirements are 0.70 nanograms for 235-U, 0.20 nanograms for 237-Np, $1.5X10^{-4}$ nanograms and $1.4X10^{-3}$ nanograms for 235-U bare and Cd covered, and $8.9X10^{-5}$ nanograms and $8.9X10^{-4}$ nanograms for 239-Pu bare and cadmium covered, respectively. Production of these subnanogram and subpicogram deposits has resulted in the development of unique ultra low-mass preparation and calibration techniques at HEDL. High purity, dust-free handling conditions must be used during preparation, assembly, and disassembly of these dosimetry sets to prevent their contamination by environmental natural uranium which is present at the parts per million level in most naturally occuring materials.

The deployment to date of SSTR dosimetry in operating commercial power reactors is summarized in Table 1. Typically, six SSTR sets are irradiated during a reactor operating cycle, removed at the end of the cycle and replaced with six additional sets for the next cycle after which the original six fissionable deposits with new mica SSTRs are introduced for the subsequent cycle. Since the fissionable deposits are reusable, 12 deposits comprise a set for ongoing dosimetry at six locations in the reactor cavity.

CONCLUSIONS

At present a total of 163 SSTR dosimetry sets containing 924 SSTR-Fissionable Deposit pairs have been placed or ordered for placement in commercial power reactors.

SSTR neutron dosimeters provide a convenient, passive method for reactor pessure vessel monitoring. Furthermore, the SSTR neutron dosimeters provide permanent records of the neutron dose, which can be subjected to reanalysis at a later date, if inconsistencies in dosimetry data are encountered.

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STATUS OF SSTR CAVITY DOSIMETRY SETS FOR OPERATING POWER REACTORS

Location	Reactor Type*	Time of Exposure	Isotopes Included	Number of Sets
Browns Ferry 3	BWR	Dec. 1978 – Aug. 1979	232-Th, 235-U, 238-U 237-Np, 239-Pu	4
Tihange 1 (Belgium)	PWR	Jan. 1980 – Jan. 1981	235-U, 238-U, 237-Np	4
McGuire 2	PWR	Feb. 1981 – Feb. 1982	232-Th, 235-U, 238-U, 237-Np	4
HB Robinson 2	PWR	Aug. 1982 – Jan. 1984	235-U, 238-U, 237-Np	1
Maine Yankee	PWR	Dec. 1982 – Mar. 1984	235-U, 238-U, 237-Np	5
Turkey Point 3	PWR	Dec. 1983 – Apr. 1984	235-U, 238-U, 237-Np 239-Pu	6
Brunswick	BWR	Aug. 1984 – (Feb. 1986)	235-U, 238-U, 237-Np 239-Pu	2
HB Robinson 2	PWR	Feb. 1985 – (Apr. 1986)	235-U, 238-U, 237-Np 239-Pu	6
Diablo Canyon 1	PWR	May 1985 – (Aug. 1986)	235-U, 238-U, 237-Np 239-Pu	6
Zion 1	PWR	Jun. 1985 – (Sept. 1986)	235-U, 238-U, 237-Np 239-Pu	6
Turkey Point 3	PWR	(Jun. 1985) – (Sept. 1986)	235-U, 238-U, 237-Np 239-Pu	12
Diablo Canyon 2	PWR	(Sept. 1985) – (Nov. 1986)	235-U, 238-U, 237-Np 239-Pu	6
Zion 2	PWR	(Oct. 1985) – (Dec. 1986)	235-U, 238-U, 237-Np 239-Pu	6
Davis-Besse 1	PWR	(Jan. 1986) – (Jan. 1987)	235-U, 238-U, 237-Np 239-Pu	21
Brunswick	BWR	(Feb. 1986) – (Apr. 1987)	235-U, 238-U, 237-Np 239-Pu	2
Diablo Canyon 1	PWR	(Sept. 1986) – (Dec. 1987)	235-U, 238-U, 237-Np 239-Pu	6
Zion 1	PWR	(Oct. 1986) – (Dec. 1987)	235-U, 238-U, 237-Np 239-Pu	6
Diablo Canyon 2	PWR	(Jan. 1987) – (Apr. 1988)	235-U, 238-U, 237-Np 239-Pu	6
Zion 2	PWR	(Jan. 1987) – (Mar. 1988)	235-U, 238-U, 237-Np 239-Pu	6

* BWR = Boiling water reactor, PWR = Pressurized water reactor.

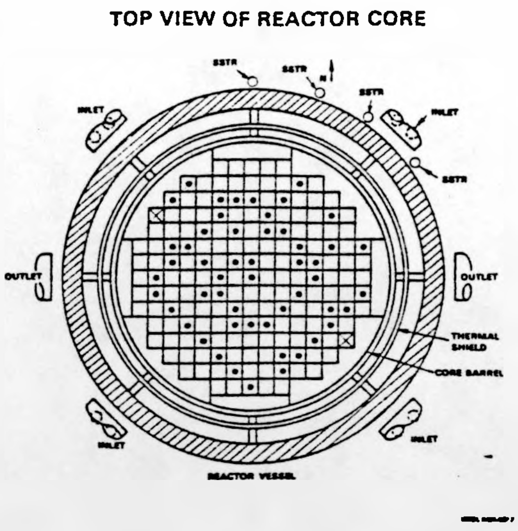

Figure 1. Top view of Reactor Core showing appropriate locations of SSTR Cavity Dosimetry Capsules.

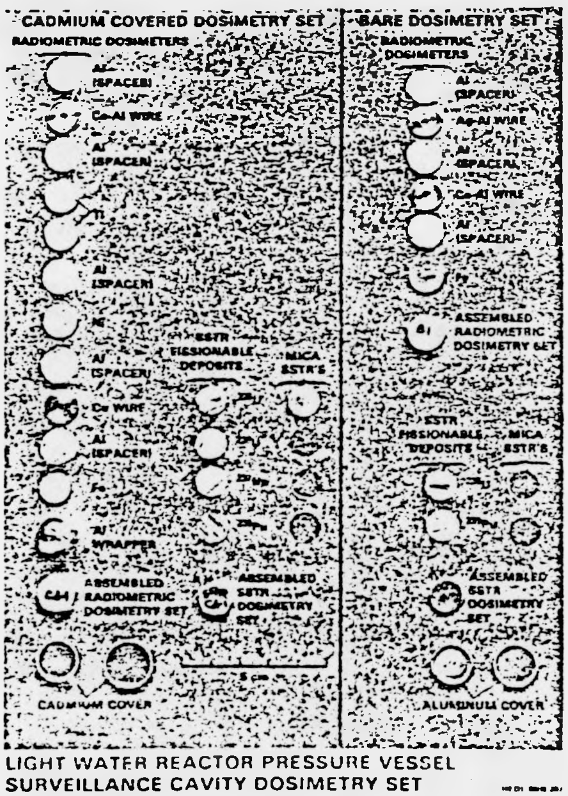

Figure 2. Light Water Reactor Pressure Vessel Surveillance Cavity Dosimetry Set.