Re-Analysis of In-Service Inspection of Pressure Tubes and Feeder Pipes in Wolsong Unit 1

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1. Introduction

Since the first commercial operation in 1983, Wolsung unit 1 has experienced several aging phenomena, especially in pressure tubes and feeder pipes. In case of pressure tubes, in-service inspections (ISI) revealed that a major portion of inspected tubes was in contact with calandria tubes. The likelihood of blister formation was a safety concern because it is a potential threat to pressure tube integrity. Wolsung unit 1 was, therefore, subjected to the SLAR (Spacer Location And Reposition) work to separate the contacted pressure tubes from calandria tubes. In this paper, experience of in-service inspection to the pressure tubes will be discussed including the irradiation creep elongation and CIGAR (Channel Inspection and Gauging Apparatus for Reactors) examination of pressure tubes. On the other hand, the problem of wall thinning in the feeder pipes became of great concern since 1996. Inspections, in compliance with CSA N285.4, were conducted in the upper portions of the feeders close to the headers. Wall thinning at outlet feeder bends was detected so that in-service inspection program was strengthened. The analysis of in-service inspection for the pressure tubes and feeder pipes was already done in 2001. In this paper, re-analysis of in-service inspection will performed using the new data since 2001[2], and the experience of in-service inspections and the associated measures to reduce the aging phenomena in Wolsung unit 1 will be discussed.

2. Methods and Results

In this section the experience and methodologies used to inspect the pressure tubes and feeder pipes are described, and results of the integrity assessment are discussed.

2.1 Pressure Tubes – ISI history

Since the CIGAR (Channel Inspection and Gauging Apparatus for Reactors) - special inspection tool for pressure tubes - was not available at 1980s, the authority allowed the continued operation until April of 1990 when the first overall inspection of pressure tubes was carried out at Wolsong unit 1[1].

A total of 26 reportable indications were found over 11 fuel channel inspections during the 1990, 1st overhaul. The 1992 inspection revealed that there were 14 reportable indications at 8 channels and two flaws greater than code allowable at M-11 and O-08, and contact between pressure tube and calandria tube took place at seven channels. 3rd ISI, 1994 overhaul, revealed that one pressure tube had many reportable indications including one exceeding code limit. Consequently, this tube was replaced so that a total of three tubes were replaced. They were pulled out in March 1994 and the removed pressure tubes were subject to metallurgical and mechanical investigation in Canada[4].

95% of the inspected tubes were found to have mis-located garter springs and a large number of inspected tubes was in contact with calandria tubes, including some inner surface debris damage. It was necessary to reposition the garter springs by performing Space Location And Reposition (SLAR) on all the fuel channels to minimize the likelihood of blister formation on pressure tubes contacting with calandria tubes. So, pressure tubes have been subjected to SLAR every overhaul since 1995 and full coverage will be done by 2005 outage. The blister formation was not found through eight years of SLAR works and the mis-located garter springs seem to be successfully repositioned.

Table 1 Summary of SLAR operation

SLAR year	Number of SLAR tubes (repeat)	Number of contacted tubes (%)
1995	48	37 (77%)
1996	73 (3)	55 (72%)
1998	91 (2)	59 (65%)
1999	84	52 (62%)
2000	80 (11)	54 (68%)
2001	79(71)	4(5%)
2003	47(44)	2(4%)
2005	To be performed in Sept. – Oct. 2005	

2.2 Pressure Tubes – Elongation and LBB Assessment

Pressure tubes of Wolsong unit1 were elongating somewhat faster than had previously been predicted. So, some channels can reach the total allowable elongation before design life of 30 years. Since the analysis in 2001, the maximum elongation rate is somewhat increased from 6.69 to 7.8mm/EFPY. It shows that the maximum elongation rate is somewhat accelerated with increasing the operating time and the power. As of May 2005, H-16 channel shows maximum elongation and rate. Figure 1 is total elongation of Wolsong unit 1 pressure tubes. It is closely related with CANDU fuel channel refurbishment which is planning by utility. So an appropriate life time management program (such as, less than full power operation) is needed before the refurbishment. Also, the effect of thermal expansion of Zr pressure tube alloy will be discussed in this section.

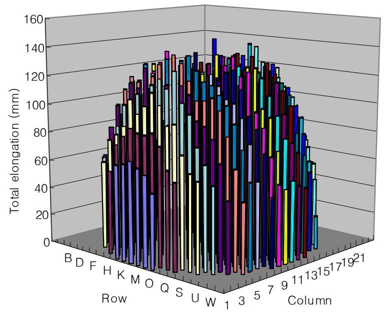

Figure 1. Total elongation of Wolsong unit 1 pressure tubes

On the other hand, the LBB assessment of Wolsong Unit 1 reactor is shown in Fig. 2. As shown in this figure, the LBB can be satisfied not only for 15-year but also for 30-year operation whereas it is barely marginal for a 30-year operation case. The background of LBB assessment , leak detection and location will be presented in this paper[5].

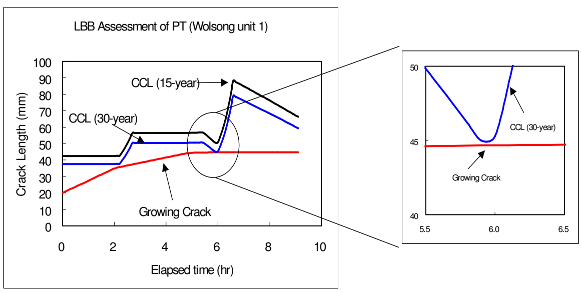

Figure 2. LBB assessment of Wolsong Unit 1

2.3 Feeder Pipes – Wall Thinning Assessemtn

According to the Station Bulletin 96-02[3], the Wolsong Unit 1 has measured the wall thickness for the first bend extrados of feeder pipes since 1996. Figure 3 shows a schematic position for thickness measurement.

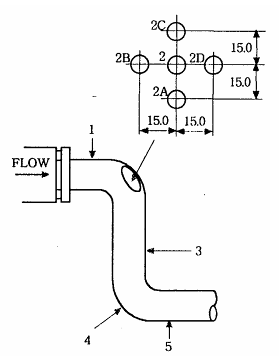

Figure 3. Schematic position for thickness measurement

The results with the recent in-service inspection data show that the wall thinning degradation in feeder pipes is still progressing, and it can be reached the minimum allowable thickness calculated by the ASME Section III NB-3640 before the design lifetime. Figure 4 is the distribution of thickness measurement for the 2000 and 2004 outage. It shows that the distribution shape is shifted to the minimum allowable thickness.

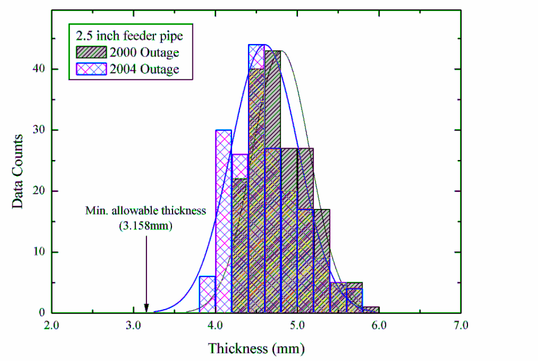

Figure 4. Distribution of thickness measurement in 2.5 inch feeder pipes

In this paper, the criteria for the minimum allowable thickness and estimation of residual life time for the feeder pipe will be discussed.

3. Conclusion

The degradation phenomena, such as elongation of pressure tube by irradiation creep and wall thinning of feeder pipe by FAC, are critical issues in CANDU reactor. It is closely related with the fuel channel refurbishment. It is, therefore, necessary to take a very extensive lifetime management program to cope with these concerns.

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