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Lay-up During Retubing Outage at Wolsong Unit 1

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1. Introduction

Due to the intrinsic design of CANDU reactors, their horizontal fuel channels should be replaced for another 30 years of service. During this 'retubing' outage, it is essential to have the guidelines for maintaining chemistry control of systems (lay-up). Wolsong Unit 1, a Korean CANDU reactor, which started its commercial operation in 1983, has a plan to replace its fuel channels in April 2009 for almost 20 months. Since this retubing is the first time in Korea and the period of time is exceedingly long, Korea Hydro Nuclear Power (KHNP) has asked KEPRI and AECL to establish the guidelines for lay-up during Wolsong Unit 1 retubing outage. This paper presents the results of the joint project between KEPRI and AECL [1].

2. Background

2.1 Purpose of Lay-up

Lay-up is aimed at protecting systems from degradation during outage, mainly by minimizing corrosion. Particularly, when the outage is longer than 16 weeks, the implementation of the lay-up is more important [2]. Usually, the lay-up focuses on the protection of carbon steel, as it can be readily corroded. The purpose of lay-up can be fulfilled by deleting or minimizing factors of corrosion, such as dissolved oxygen in water, oxygen or moisture in air.

2.2 Categories of Lay-up

Lay-up usually falls into two distinct categories; wet lay-up and dry lay-up. The former fills a system with chemically treated water. Usually, the water is circulated to facilitate obtaining representative samples, based on which the chemistry of the system is controlled within specifications. Typically, pH and dissolved oxygen are controlled to minimize corrosion. If continuous circulation is not feasible, at least periodic circulation should be performed for sampling. That is, wet lay-up under stagnant condition is the worst.

Dry lay-up preserves a system in a dry state maintaining the relative humidity below 40 %. For this, continuous flow of dehumidified air and/or dehumidifying equipments can be used. Dry lay-up is employed when the system should be drained due maintenance or repair activities or when wet lay-up cannot be used. However, a complete draining and drying is not easy. In this case, the system is sealed with N_2 gas (N_2 blanket) after draining to expel O_2 from the system. It is recommended to add hydrazine to areas that still contain residual water after draining (so called 'dead legs') to suppress dissolved oxygen level.

It should be noted that there are many variations that are based on these two major categories.

2.3 Lay-up During Retubing Outage at Wolsong Unit 1

The retubing outage at Wolsong Unit 1, which will last for almost 20 months, gives two special conditions. First, the long period of time necessitates the implementation of lay-up. Second, the replacement of fuel channels limits lay-up methods available. For example, in order to replace fuel channels, primary heat transport system and moderator system should be drained, leaving dry lay-up as the sole choice for them.

3. Lay-up Methods by System

The recommended lay-up methods for only seven systems appearing in Table I are described here because of their importance in lay-up of CANDU reactors. Other systems not dealt here are omitted just because no special lay-up conditions are required for them except for normal lay-up conditions. Table I summarizes recommended lay-up methods for the selected systems.

3.1 Primary Systems

3.1.1 Primary Heat Transport (PHT) System

Apparently, due to the replacement, only dry lay-up with continuous flow of dehumidified air is applicable to this system where the relative humidity is monitored and kept below 40 %. For better management of corrosion, the system should be drained and dried completely considering that this system is made mainly of carbon steel. However, there is a concern for dead legs because rather complicated design of this system makes draining difficult. Systems with the dead legs should be under N_2 blanket and hydrazine added to the dead legs.

3.1.2 Moderator System

Due to the same reason with PHT system, only dry lay-up with continuous flow of dehumidified air is feasible for this system. However, since this system is made mostly of stainless steel, the potential risk of corrosion is less. Also systems having the dead legs

should be under N_2 blanket with hydrazine added to the dead legs.

Table I: Recommended Lay-up Methods by System

System		Lay-up
Primary Systems	Primary Heat Transfer System	Dry Lay-up with Dehumidified Air & Dry Lay-up with N_2 Blanket
	Moderator System	
	End shield Cooling System	Wet Lay-up under Circulation
	Liquid Zone Control System	Wet Lay-up under Normal Operating Conditions
Secondary Systems	Steam Cycle	Dry Lay-up with Dehumidified Air
	Steam Generator	Wet Lay-up under Circulation with N_2 Blanket
	Recirculating Cooling Water System	Wet Lay-up under Normal Operating Conditions

3.1.3 End Shield Cooling (ESC) System

The principal concern during outage is degradation of the extensive carbon steel surface in this system. This system will be maintained under wet circulating conditions during outage because of its function to cool moderator system. If, however, it is required to stop the system recirculation, it is recommended that the system be circulated on a periodic basis and the chemistry monitored and adjusted as required.

3.1.4 Liquid Zone Control (LZC) System

It would be preferable to maintain this system under normal operation conditions during outage. Thus, it is recommended to maintain the system under normal operating conditions for as long as possible. In case of system shutdown, it is recommended to fill the in-core spaces with demineralized water, and to isolate the rest of the system and air dry.

3.2 Secondary Systems

As opposed to the primary systems, the secondary systems of CANDU reactors are basically identical to those of other reactor systems such as PWRs and BWRs, and even fossil reactors. Since most secondary systems are made of carbon steel, careful attention should be given to these systems. Steam generator, one of the most expensive components, is dealt separately below.

3.2.1 Steam Cycle

For steam cycle consisting of a lot of equipments, dry lay-up with continuous flow of dehumidified air is recommended. For this, it would be needed to purchase or rent dehumidifying equipments. It is noted that an independent flow path for dehumidified air should be made for tube sides and shell sides of the feedwater heaters, respectively.

3.2.2 Steam Generator (SG)

The recommended lay-up method for SG is wet lay-up with N_2 blanket as SG will be partially drained with its water level above upper bundles. Thus, the part filled with water will be under wet lay-up where the chemistry of the bulk water is adjusted within specifications by adding chemicals. For this chemistry control, it is strongly recommended to install a recirculation loop that allows obtaining representative samples. However, since Wolsong Unit 1 has no such a loop, it is recommended that the bulk water is periodically circulated via N_2 sparging from the blowdown sampling points.

On the other hand, the gas space above the water level is filled with N_2 gas. Since Wolsong Unit 1 has no main steam isolation valve (MSIV) needed for this N_2 blanket, the installation of 'bungs' at the joint where the steam piping coming from the SG head is connected to the common steam header is recommended to isolate SG from other systems as in Point Lepreau nuclear plant.

3.1.3 Recirculated Cooling Water (RCW) System

This system should be in service while end shield cooling system and other systems that need operation this system in also service. Therefore, this system is expected to be in service for the most of the outage. If, however, this system needs opening, after draining, the system should be under dry lay-up with continuous flow of dehumidified air.

4. Conclusions

Based on the results for the KEPRI and AECL joint project to prepare lay-up guidelines for Wolsong Unit 1, this paper illustrated lay-up methods recommended for some selected systems. It was shown that dry lay-up was the sole choice for PHT system, moderator system, and steam cycle. Also wet lay-up under circulation was recommended for ESC system, LZC system, RCW system and the water-filled part of SG. For the gas space of SG, N_2 blanket with the installation of bungs was recommended.

REFERENCES

[1] C.R. Stuart, M. Ajersch, Chemistry Design Manual for the Lay-op of Systems During the Retubing Outage, 59RF-03081-DM-001, AECL, Ontario, Canada, 2007.
[2] G.C. Allen, Sourcebook for Plant Layup and Equipment Preservation (Rev.1), EPRI NP-5106, Palo Alto, California, USA, 1992.