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# LIFE ASSESSMENT AND AGING MANAGEMENT OF CERNAVODA UNITS 1 AND 2 REACTOR BUILDINGS

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## ABSTRACT

Life Assessments for Unit 1 and Unit 2 Reactor Buildings (RBs) of Cernavoda Nuclear Power Plant (NPP) have been performed by Candu Energy Inc, a Member of the SNC-Lavalin Group considering International Atomic Energy Agency (IAEA) guidelines and requirements of CSA N287.8 standard on aging management of concrete containment structures. Life Assessments (LAs) included the evaluations for aging management (referred to as ageing management reviews in IAEA documents) and the condition assessments of the RB containment structures as well as the safety related concrete structures located inside the containment.

Understanding the aging of concrete structures is essential to operate, monitor, inspect and maintain the structures so that effects of aging related degradation are controlled and mitigated as appropriate.

As a result of the life assessments performed, the aging mechanisms that can affect the performance of the RB structures have been identified and the risks associated with the effects of aging degradations were ascertained.

Considering results of the performed life assessments, aging management for Unit 1 and Unit 2 RB containment structures is being enhanced. As part of optimization of aging management activities, consideration is given to enhancing the monitoring program for the grouted post-tensioning system used as a principal reinforcement for the RB containment structures.

## INTRODUCTION

Cernavoda NPP produces about 18% of the Romanian electricity using Canada Deuterium Uranium (CANDU) ®[1] reactor technology. Currently, there are two units in operation (Unit 1 and Unit 2). Unit 1 has been operating since 1996, while Unit 2 started operating in 2007 (Figure 1). Construction of the RBs for both units, however, has started in early 1980s; thus, both buildings are currently about 40 years old.

The Containment Structure (CS) consists of a base slab, perimeter wall, ring beam and upper dome (Figure 2). These are all post-tensioned reinforced concrete elements. Figure 3 shows prestressing system of the containment structure. Functions of the containment structure include providing structural integrity, biological shielding; and leak-tightness.

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**Figure 1 Cernavoda 1 and 2 NPPs**

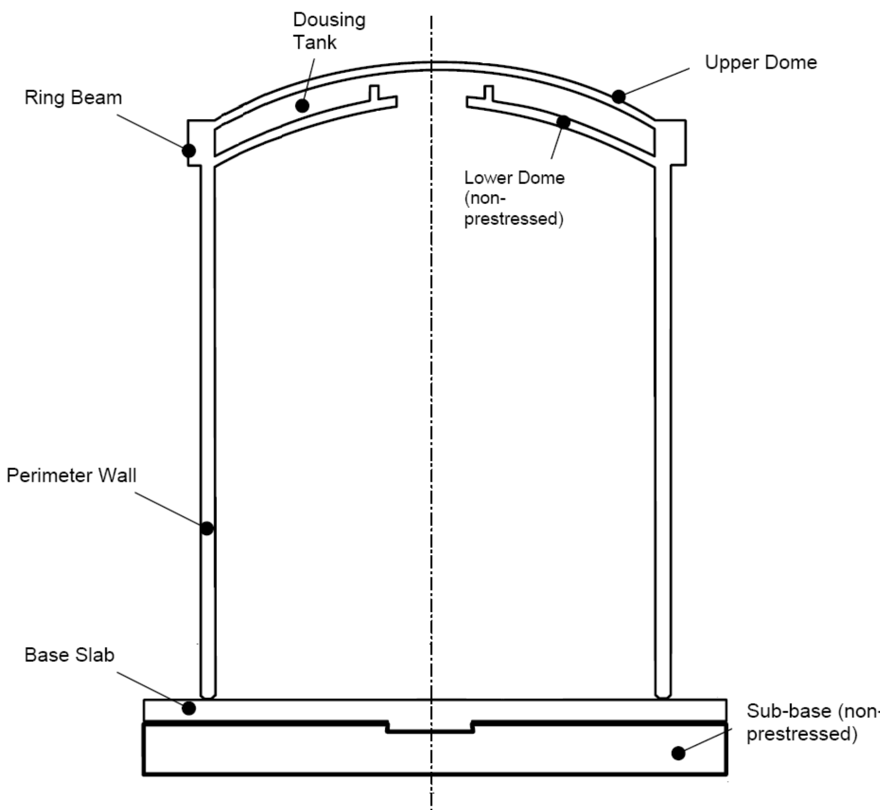


**Figure 2 CANDU 6 Containment Structure**

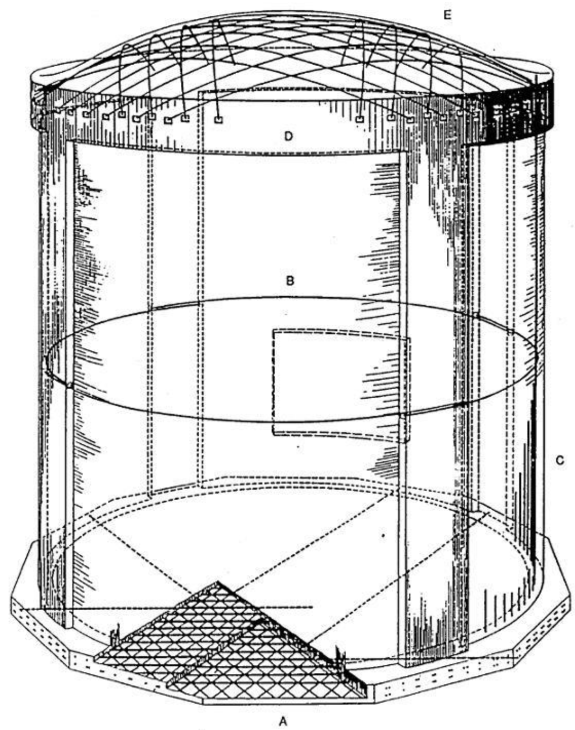


**Figure 3 CANDU 6 Containment Structure Prestressing**

## LIFE ASSESSMENT

### *Process*

Evaluation for aging management and condition assessment are typically performed in preparation for Long Term Operation (LTO). Evaluation for aging management also referred to as aging management review in IAEA documents (SSG-48, 2018) is a systematic assessment of aging effects and the related degradation mechanisms that have been experienced or are considered possible; the assessment includes an evaluation of the impact of the ageing effect on the structures' capabilities to perform their intended functions considering the current condition of the structures.

Condition assessment is typically performed as part of evaluation for aging management in preparation for LTO. As stipulated in CSA N287.8 (2015), condition assessment includes identifying and understanding degradation mechanisms, collecting data and evaluating the degree of degradation experienced, evaluating structure condition by comparing experienced degradation against established acceptance criteria, and establishing actions required to maintain acceptable condition of the structure. These activities together are referred to as Life Assessment (LA) or, more commonly may be called Condition Assessment (CA). Refer to Tcherner et al. (2016) for details of the process.

### *LA of Cernavoda 1 and 2 RBs*

All structural and non-structural elements of Cernavoda Unit 1 and 2 RB CSs have been assessed including concrete, reinforcing steel (prestressed and non-prestressed), non-metallic liners and joint sealants. The assessment has also included nuclear safety related structures located inside containment and their elements.

Reviewed information included design, construction, commissioning data as well as results of the Pre-operational Proof Test (PPT) and RB Integrated Leakage Rate Tests (ILRTs), results of in-service-examinations and tests, results of test beams testing, monitoring and instrumentation data collected over the life of the structures. In addition, measured and monitored parameters related to service conditions of the RB (inside and outside) including environmental and operating conditions have been collected for review and comparison with those considered in design. These included: temperature, radiation, humidity, as well as chemistry of the water where applicable. Some parameters of the water chemistry are very important for assessment of potential for degradation; for example, potential for degradation based on the pH of the water is illustrated in Table 1. There are also industry guidelines for the possibility of degradation of reinforced concrete structures based on the amounts of chlorides, sulphates, and carbon dioxide.

**Table 1: Type of Concrete Attack Depending on pH (Brueckner, 2015)**

| pH | Type of attack |
|---|---|
| >8.5 | Largely unaffected unless very strong alkaline solutions are present |
| 7.0–8.5 | Superficial leaching of calcium hydroxide |
| 6.0 | Attack is minimal unless the flow rate is significant |
| 5.0 | Serious attack, extent depending on flow rate |
| <4.0 | Hardened cement and calcareous aggregates are rapidly attacked |

Walkdowns have been performed to evaluate condition of the RB structures. A walkdown is an experience based visual inspection method, where most of the findings are based on actual structure condition and engineering judgement. Walkdowns have proven to be a very valuable source of information as they helped in identifying location of areas of distress and possible deterioration of the structure.

Based on the information evaluated as part of these LAs, the aging mechanisms that can affect the performance of the Cernavoda Unit 1 and 2 RBs' structures were identified and the risks associated with the effects of aging degradations were considered. As typically is the case, the main concerns have been associated with perceived differences between design and operating conditions and material properties.

## AGING MANAGEMENT

Based on results of the LA, aging management of RB CSs has been enhanced. It has been decided to develop a combined Aging Management Plan (AMP) for RB CSs of both units to take advantage of sharing some of the common elements, such as testing of the test beams, ground water monitoring program, etc.

The LAs provided a base for development of an AMP as in addition to assessments of the current conditions and ARDMs, they contain background information including review of design, construction, operation, inspection, monitoring & maintenance data that are necessary to develop appropriate methods for examinations and acceptance criteria.

An AMP is a set of procedures, arrangements, and activities that provides direction for managing the aging of RB CSs. The primary objective of an AMP is to ensure the timely detection and mitigation of degradation effects in structures and their elements to ensure their integrity and functional capability for the continued safe and reliable operation. This AMP has been intended to provide a framework for AM activities including inspection, testing, monitoring and maintenance activities already performed by Societatea Nationala Nuclearelectrica (SNN) supplemented by additional activities as applicable.

The following structural and non-structural elements of the Cernavoda Unit 1 and 2 RB CSs have been addressed in the AMP:

- Concrete;
- Reinforcement (pre-stressed and non-pre-stressed);
- Steel (e.g. embedded parts);
- Non-metallic liners; and
- Joint sealants.

As illustrated in Figure 4, an AMP has been established considering results of evaluation for aging management, condition assessment as well as Operating Experience (OPEX) and Research and Development (R&D) activities. As far as OPEX goes, in addition to the Candu Energy experiences performing CAs and LAs and developing aging management strategies for several other CANDU 6 NPPs, review of IAEA AMPs (IAEA SRS No 82, 2020) has been conducted and relevant elements have been considered for development of Cernavoda 1 and 2 AMPs for RB CSs. Review of relevant R&D activities including those by CANDU Owners Group (COG) has also been performed and considered for development of Cernavoda 1 and 2 AMPs for RB CSs.

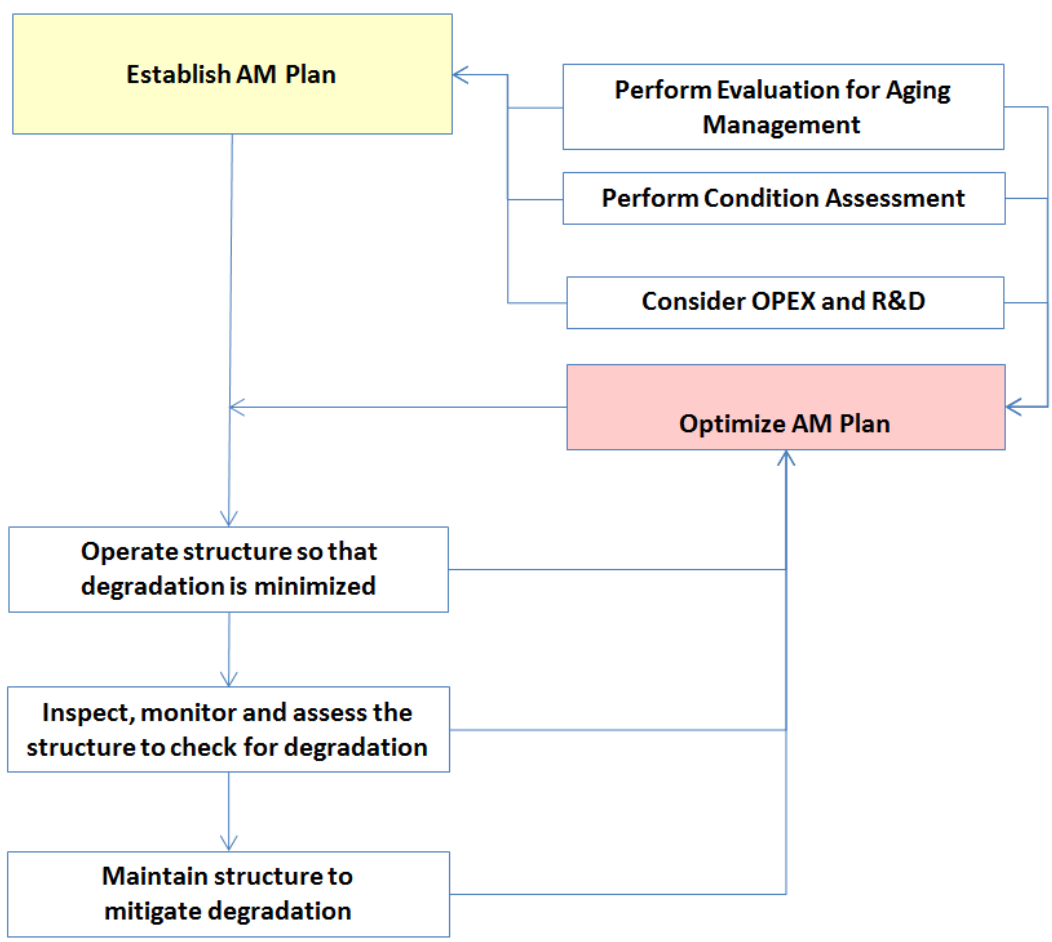


**Figure 4 Development and Optimization of AM Plan (Tcherner and Seto, 2015)**

An AMP for Cernavoda Unit 1 and 2 RB CSs has been developed in accordance with the requirements of CSA N287.8 (2015). The standard defines the requirements for aging management of concrete CS s and is consistent with the requirements of Canadian Nuclear Safety Commission (CNSC) Regulatory Document 2.6.3 (2014) and IAEA Safety Guide NS-G-2.12 (2009). NS-G-2.12 has recently been superseded by the IAEA Safety Specific Guide SSG-48 (2018). The updated document has also been considered in the AMP development.

As per IAEA SSG-48(2018), the nine attributes of an effective AMP are:

1. Scope of the AMP based on understanding ageing;
2. Preventive actions to minimize and control ageing effects;
3. Detection of ageing effects;
4. Monitoring and trending of ageing effects;
5. Mitigation of ageing effects;
6. Acceptance criteria;
7. Corrective actions;
8. Operating experience feedback and feedback of research and development results; and
9. Quality management.

The AMP was developed to meet the nine attributes of the effective aging management program listed above based on IAEA SSG-48 (2018). IAEA International Generic Ageing Lessons Learned (IGALL) documents including SRS-82 (2020), IGALL AMPs and Time Limited Aging Analysis (TLAAs) for civil structures have been considered in development of the AMP as applicable.

Preventive actions to minimize and control aging effects include determination and monitoring of service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at precluding potential degradation of the RB CSs and their elements. Preventive actions for RB CSs include monitoring of parameters related to service conditions, i.e. temperatures inside RBs, chemistry of the water in water retaining structures inside RB forming part of the containment, and ground water chemistry. Assessment of the monitored parameters is discussed in the AMP and associated acceptance criteria for each monitored parameter are identified.

It is necessary to use effective techniques (inspection, testing and monitoring, etc.) to detect aging effects before failure of the structure or its element will occur. Several programs and activities are necessary to be implemented to effectively detect aging effects. Periodic examinations of structures performed at regular intervals provide an effective aging management tool (CSA N287.7, 2019 and ACI 349.3, 2018). Therefore, to maintain structural integrity of Cernavoda 1 and 2 RB CSs, periodic examinations of structures should be undertaken and documented. Assessment of RB CSs at established intervals should be carried out to monitor the performance of the RB CSs, to identify the presence of aging-related deterioration and, if necessary, to propose mitigative and/or corrective measures. When warranted based on the LAs and follow up work; in addition to periodic aging management activities additional remedial or investigative measures have been recommended to be undertaken.

Periodic examinations of Cernavoda 1 and 2 RB CSs include visual inspections of all accessible areas of RB CSs inside and outside, Non-Destructive Tests (NDTs) as needed, testing of the containment liner systems inside RBs, and settlement monitoring. In addition, such activities as periodic leakage rate testing, periodic data collection and assessment using embedded and retrofitted instrumentation and periodic test beam testing are also addressed in AMP. Frequencies and acceptance criteria for each of these activities are defined in AMP.

Evaluating integrity of the RB CS post-tensioning system is achieved primarily by instrumented monitoring and periodic testing of the test beams. These methods are in line with the international practices employed for evaluating integrity of grouted (or bonded) post-tensioning systems as detailed in OECD

NEA/CSNI/R (2015). As far as instrumented monitoring goes, aging of vibrating wire strain gauges embedded in both RB CSs at the time of construction has been identified and recommendations were made to install additional instrumentation to supplement the data being collected. Establishing a baseline data for additional instrumented monitoring is shown schematically in Figure 5.

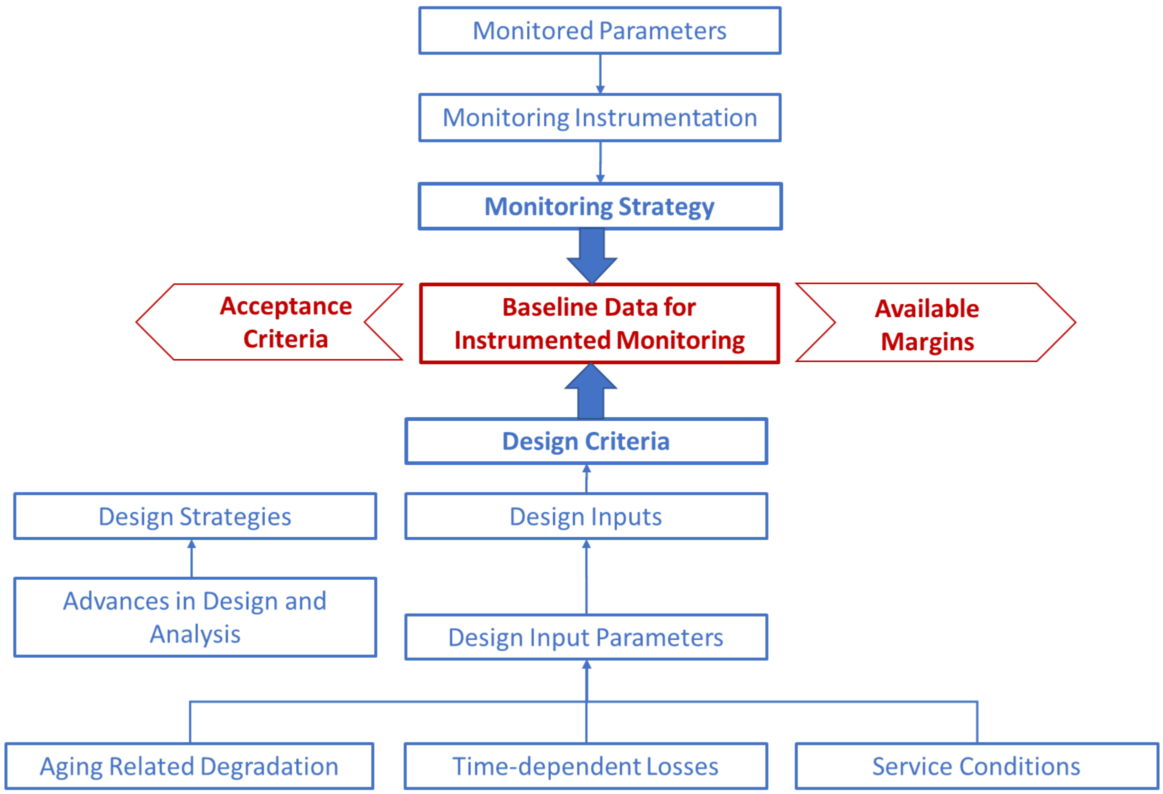


**Figure 5 Establishing Baseline Data for Instrumented Monitoring**

Operations, maintenance, repair and replacement actions to mitigate detected ageing effects and/or degradation of the structure or component typically include joint sealant maintenance, liner maintenance, maintaining concrete cover and maintaining leak tightness.

Corrective action program includes documenting occurrences where acceptance criteria was not met, documenting methods to address degradation (e.g: evaluation and acceptance, evaluation and monitoring, repair or replacement), and documenting modifications made to AMP, plant programs, plant operations, etc.

The flow of information and AMP documentation requirements are illustrated in Figure 6.

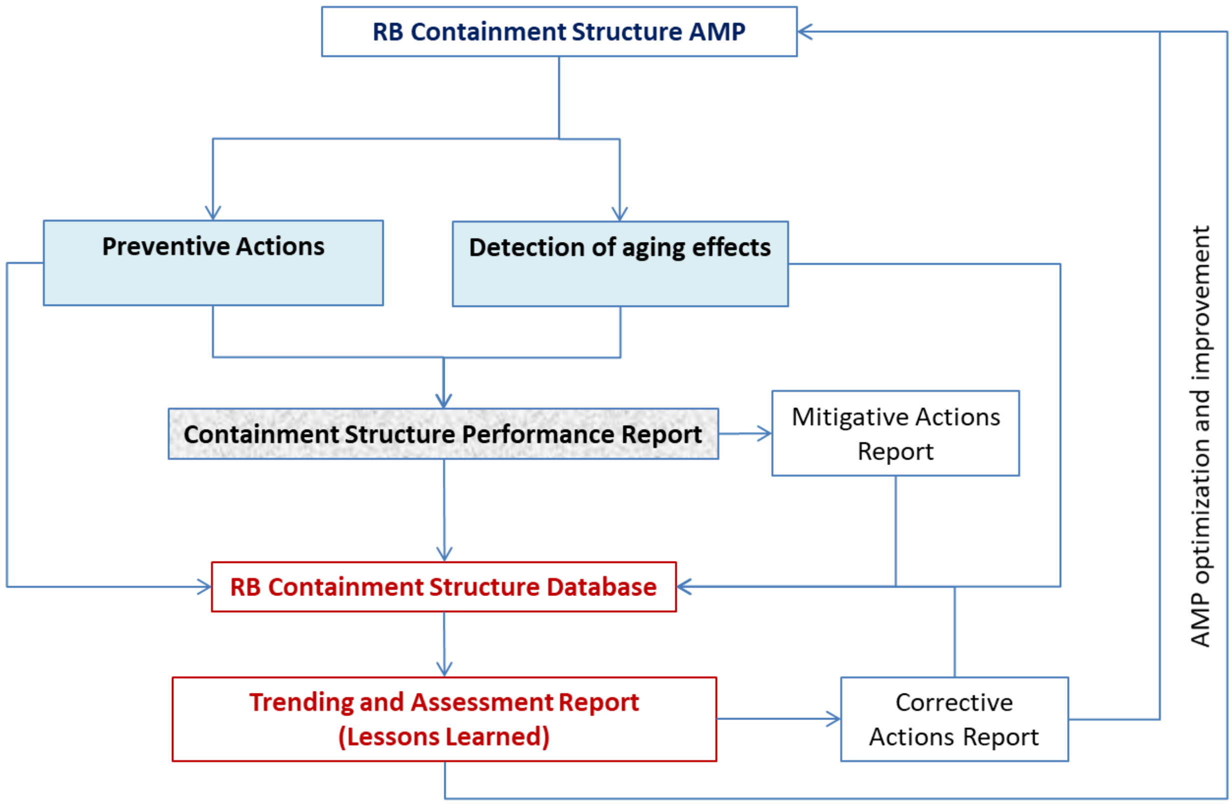


**Figure 6 AMP Documentation Flow**

## CONCLUSION

Based on the reviewed information, the Cernavoda Unit 1 and 2 RB structures are expected to continue meeting their intended functional requirements for the design life (30 years), and, for an extended life (additional 30 years); however the effects of operating conditions where they differ from the values considered in design shall be ascertained and the integrity of some elements not readily accessible for inspections should be ensured. Other recommendations have been provided to support results of the assessment and to ensure that aging of structures is maintained.

Enhancing aging management of RB CSs and implementing the recommended activities under the framework of AMP is expected to improve and help maintaining leak tightness of the RB CSs. This is also expected to provide several economic opportunities.

## ACKNOWLEDGEMENT

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