National Nuclear Safety Administration (NNSA) Questions and U.S. Nuclear Regulatory Commission (NRC) Responses Regarding AP1000 Reactor Coolant Pump Flywheel Integrity July 2017

NNSA Question

U.S. Standard Review Plan subsection 5.4.1.1 recommends that the design of flywheel should meet the following criteria: 4.a) The combined stresses at the normal operating speed due to centrifugal forces and the interference fit of the wheel on the shaft should not exceed 1/3 of the minimum specified yield strength or 1/3 of the measured yield strength. 4.c) The combined stresses at the design overspeed, due to centrifugal forces and the interference fit of the wheel on the shaft, should not exceed 2/3 of the minimum specified yield strength or 2/3 of the measured yield strength.

AP1000 primary pump geometry is different from the other simple geometric shape and it contains flywheel hub, heavy alloy segments and outer retainer cylinder. The interference fit of outer retainer cylinder provides the preload force that holds the flywheel together as a wheel assembly. NNSA found that the calculation report of AP1000 flywheel do not analyze or evaluate the combined stress. For the stress calculation of AP1000 flywheel, WEC considered stress limits in SRP are applied only to primary stress in the outer retainer cylinder due to rotation of heavy metal alloy and outer retainer cylinder, not include any of the stresses due to component shrink fits of flywheel assembly on the shaft. APP-MP01-GLR-001NP (structural analysis summary for flywheel) Section 5.1 indicated the results of primary stressed analyses for outer retainer cylinder meet the stress limits in SRP. In addition, Section 5.1.4 WEC respectively evaluated flywheel hoop stresses at assembly conditions and 125-percent overspeed at 70°F and the results indicated the calculated stresses is less than yield stress of material.

NNSA considers the stress calculation of AP1000 flywheel do not meet the SRP requirements since WEC do not evaluate the combined stresses. With regards to this, WEC issued DCP APP-GW-GEE-5408 to modify and clarify the acceptance criteria in October 2016. The DCP proposed change that the stress evaluated is the maximum primary stress due to centrifugal acceleration instead of the combined stresses.

Taking into account the flywheel acceptance criteria in SRP for the NRC to develop, NNSA would like to consult the following questions:

1) Is SRP 5.4.1.1 suitable for AP1000 primary pump flywheel with complex split structure?

NRC Response

The AP1000 reactor coolant pump (RCP) flywheel is a bi-metallic complex design with heavy tungsten alloy inserts, and is not addressed by SRP 5.4.1.1, which is only for simple alloy steel flywheel designs. Therefore, while SRP 5.4.1.1 was used as a guideline for designing the flywheel, it is not applicable to preventing missiles from the AP1000 flywheel. The NRC staff's evaluation in NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," does not cite SRP 5.4.1.1. The conclusion of the NRC staff's evaluation regarding the AP1000 flywheel is based only on material selection, preservice inspections, and containment of the flywheel by RCP pressure boundary structures in order to prevent missile generation as addressed in NUREG-1793 which states:

> [T]he staff finds that the material specifications used and the preservice inspections provide reasonable assurance of the flywheel integrity, and that the Curtiss-Wright Electro-Mechanical Corporation Report AP1000 RCP-06-09 demonstrates that if the flywheel assembly fails, the flywheel components will not penetrate the pump pressure boundary structures. Therefore, the staff finds the RCP flywheels acceptable since they meet the requirements of [general design criteria] GDC 1, GDC 4, and [American Society of Mechanical Engineers] ASME Code, Section III.

NNSA Question

2) Whether the DCP APP-GW-GEE-5408 is acceptable to the proposed change of acceptance criteria?

NRC Response

As discussed in the response above, SRP 5.4.1.1 is not directly applicable to the AP1000 RCP flywheel and was only used as a guideline for designing the flywheel, not for the prevention of missiles as required by GDC 4 of Appendix A in Title 10 of the *Code of Federal Regulations* Part 50.

Westinghouse Design Change Package (DCP) APP-GW-GEE-5408 was initiated to correct a perceived inconsistency in the licensing documentation in the Updated Final Safety Analysis Report (UFSAR) and the incorporated by reference technical report (Curtiss-Wright Electro-Mechanical Corporation Report AP1000 RCP-06-09, Revision 2). The inconsistency is in Section 4.2.3, "Standard Review Plan," of the technical report AP1000 RCP-06-09, which states, "These limits [SRP 5.4.1.1 stress limits for combined stresses] are satisfied for the outer retainer cylinder." However, it is clearly documented in the remainder of the technical report that only the primary stresses are included to meet the SRP 5.4.1.1 stress limits and that the secondary (interference fit) stresses are not included. In addition, Curtiss-Wright Electro-Mechanical Corporation Report AP1000 RCP-06-09, Revision 2, Section 4.2.1, states:

> An additional acceptance criterion is a limit of S_y for the primary plus secondary membrane plus bending stress intensities in the main shrink-fit areas. This

> ensures that the flywheel will remain elastic in these areas and prevent a loss of shrink fit due to tensile yielding.

It should be noted that Curtiss-Wright Electro-Mechanical Corporation Report AP1000 RCP-06-09, Revision 2 uses the same methodology as technical report APP-MP01-GLR-001, which is the flywheel analysis for the original depleted uranium AP1000 flywheel design. Section 4.2.3, "Standard Review Plan," in technical report APP-MP01-GLR-001 states:

> These limits [SRP 5.4.1.1 stress limits for combined stresses] are satisfied for the uranium alloy flywheel away from localized areas at the shrink-fit bands on the inside diameter. The shrink-fit bands areas have high localized stresses, which are evaluated to the ASME Code, Section III, Subsection NG limits described in subsection 4.2.1.

This statement, as it applies to the bi-metallic flywheel, could have been carried over to Section 4.2.3 of Curtiss-Wright Electro-Mechanical Corporation Report AP1000 RCP-06-09, Revision 2 to be consistent with the rest of the report. This change could be made to AP1000 RCP-06-09, Revision 3.

DCP APP-GW-GEE-5408 adds a sentence in Appendix 1A, Table 1.6-1, "Conformance with Regulatory Guides," of the UFSAR, that states, "The stress evaluated is the maximum primary stress" to correct this inconsistency along with a proposed change to include a new revision (RCP-06-09, Revision 3) of the flywheel analysis report that has not been completed. However, for the UFSAR change to be completely consistent with the flywheel analysis report, the added statement in the UFSAR could state that the primary stresses are evaluated against the recommended stress limits in Positions 4.a and 4.c of SRP 5.4.1.1, and that the combined stresses are evaluated to the ASME Code, Section III, Subsection NG stress limits.