# IMPLEMENTATION OF THE RCP SHIELD® MECHANICAL SEAL MODEL IN THE COMANCHE PEAK PRA

Nathan Larson – Principal Engineer
Daniel Tirsun – Fellow Engineer
Aaron Moreno – Senior Engineer

Glen Rose, TX

# Purpose

- The purpose of this paper is to present lessons learned and challenges that were encountered during the application of the SHIELD mechanical seal model into the Comanche Peak PRA model.

# RCP Seal Failure Phenomenon

- Reactor Coolant Pump (RCP) Seal failures occur upon a loss of all seal cooling (thermal barrier and seal injection) and have plagued PRA models for years.
- WOG 2000 RCP seal model has been in use and adopted by (most) plants; which incorporated seal failures for a range of leakage sizes (21, 76, 182, or 480 gpm).
- As a result from a plant and PRA standpoint; equipment and operator responses are more complicated (LOCA vs. Transient)

**Seal Failures = Widespread Industry Issue**

Westinghouse

# Introducing the SHIELD Mechanical Seal!

- In response to the industry issue Westinghouse developed the RCP SHIELD mechanical seal that is capable of actuating to limit leakage from a failed RCP seal (< 1 gpm).
  - Important to note the distinction that the SHIELD mechanical seal only mitigates the leakage from a failed seal, it does not prevent the seals from failing.
- The SHIELD mechanical seal has been shown to vastly improve plant response and PRA models in situations where all seal cooling is lost, but there are certain limitations.

Westinghouse

# SHIELD Limitations

- The SHIELD mechanical seal is designed to maintain its integrity as long as secondary heat removal is available to maintain the RCS below its design limits; as discussed in PWROG-14006-P.
- If a steam generator(s) dries out during an event; natural circulation flow could cause the temperature in the cold leg to rise beyond the design specification of the SHIELD mechanical seal resulting in its assumed failure. Unless alternative methods are taken to prevent a SG dry-out (cross-ties, alternate equipment, etc.).

**Loss of SG can result in dry-out, asymmetric cooling and SHIELD mechanical seal failure.**

Westinghouse

# Methods for Mitigating Asymmetric Cooling Failures

- To prevent SHIELD mechanical seal failure RCS temperatures across the seal must remain below the design specifications.
- This can be achieved by:
  - Plant Specific Thermal Hydraulic (TH) analysis that demonstrates RCS temperatures at the seal do not exceed the design limits
  - Changes to operating procedures to perform alternate alignments; cross-ties, etc.
  - Implementing alternate equipment (FLEX?!?!)
- For Comanche Peak no plant specific TH was available and no other proceduralized actions were available to credit restoration of cooling to the affected SG(s).
  - Therefore, SHIELD mechanical seal failure had to be assumed on a loss of cooling to 1 or more SGs

Westinghouse

# Comanche Peak Model Background

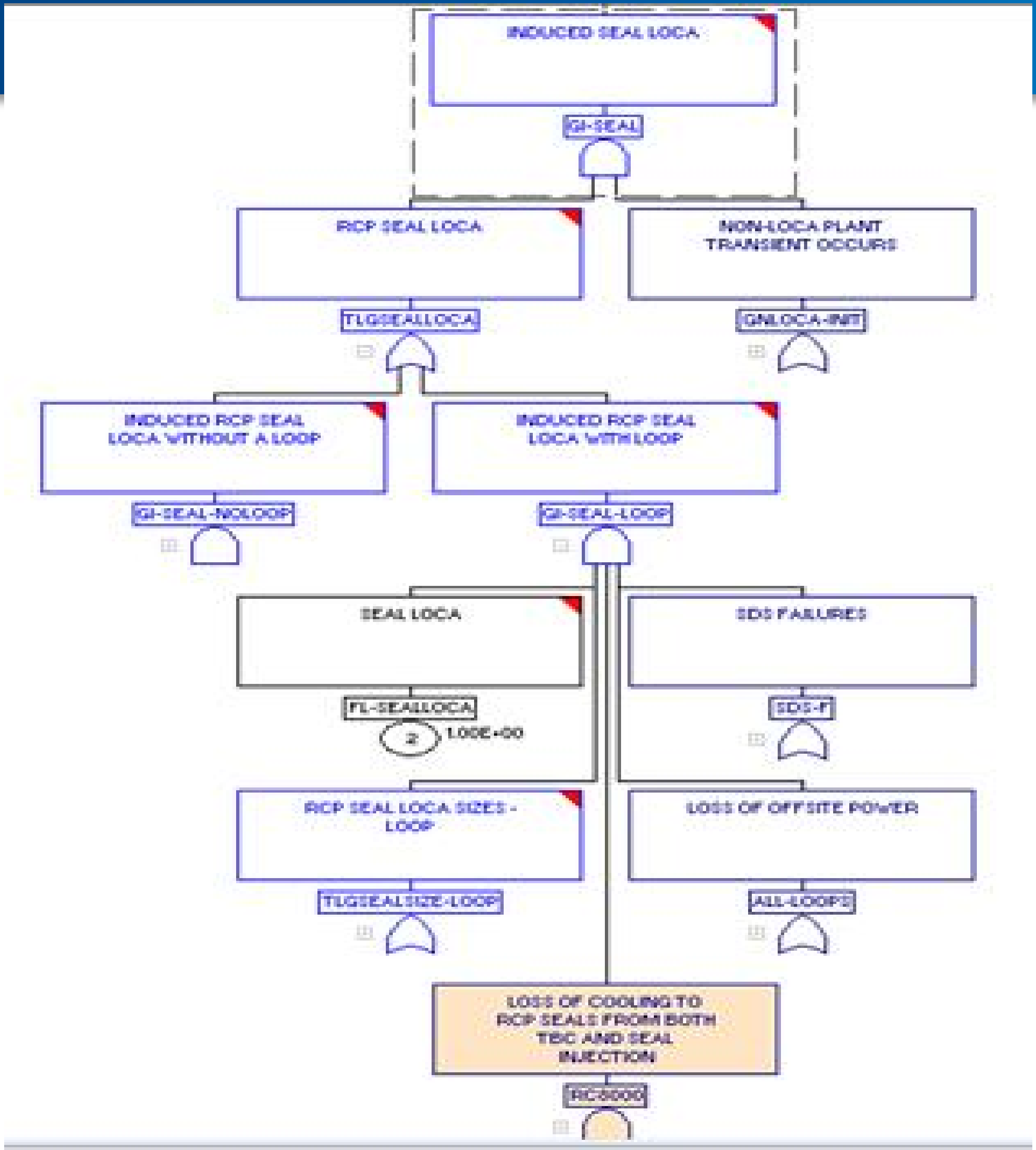
- CAFTA based PRA model with the WOG 2000 RCP seal model.
- RCP Seal failures are modeled as Very Small Loss of Coolant Accidents (VSLOCA); ½" to 2".
- Conditionally modeled using the existing VSLOCA fault trees; no separate event tree was developed for RCP seal failure.
- Mutually exclusive logic developed to ensure propagation of seal LOCAs through non-LOCA portions of the fault tree is prevented.

Westinghouse

# SHIELD Modeling

- Incorporation of the SHIELD mechanical seal was performed in accordance with PWROG-14006-P.
- Effectively, failure of the SHIELD mechanical seal is modeled under an ‘AND’ gate with the WOG 2000 seal model.
- Installation of the SHIELD mechanical seal does not remove the requirement for the WOG 2000 seal model, it supplements it.
  - It is noted that the leakage rates from the WOG 2000 seal model through the RCPs could be revisited. However for CP all RCP seal failures were classified as a VSLOCA and little benefit would be gained from this refinement. New leakage rates are bounded by the existing ones in the CP model.




Westinghouse

# Asymmetric Cooling Incorporation

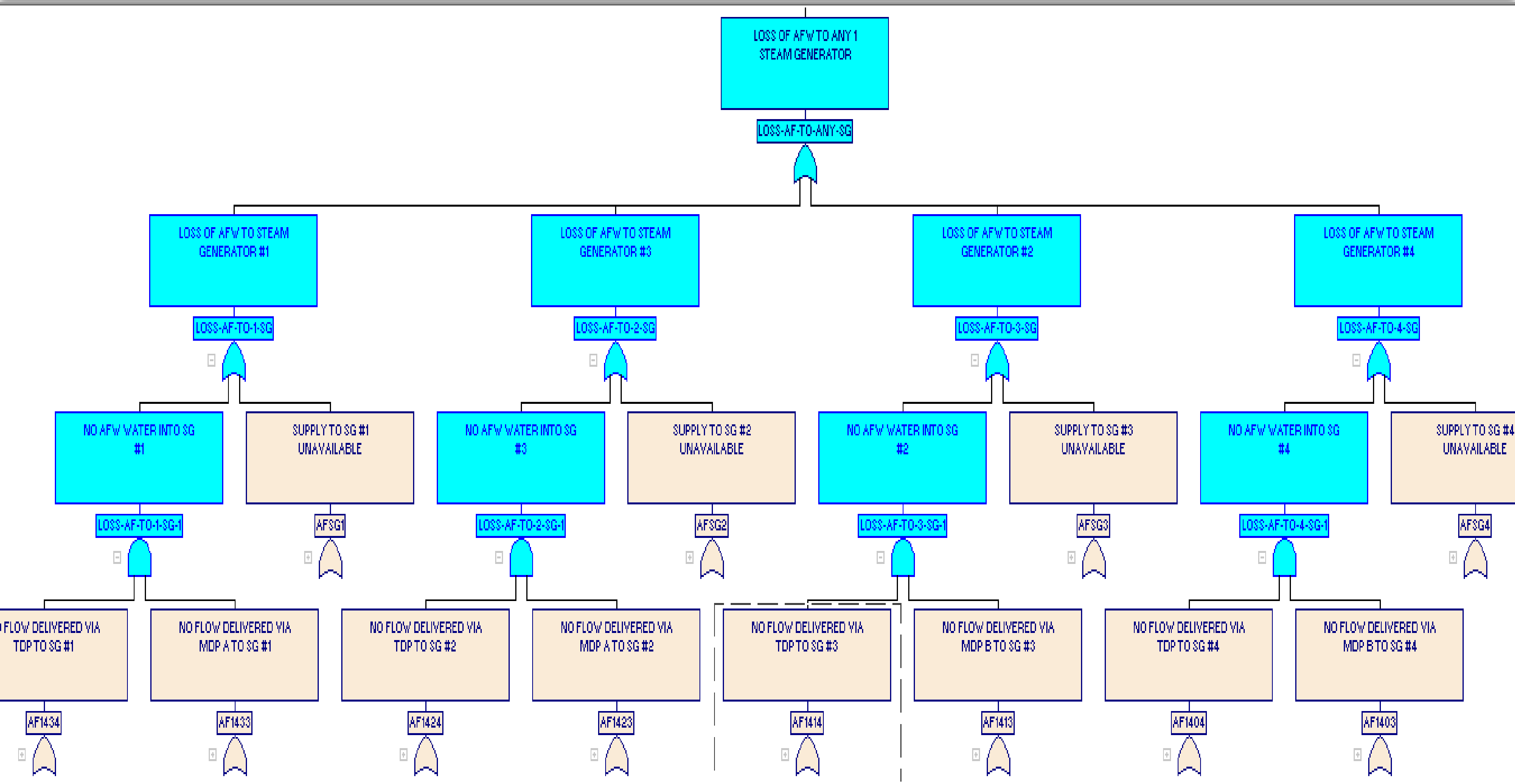
- In order to account for the asymmetric cooling issue, a fault tree was develop using the existing logic to indicate when one or more SGs was failed.
  - Decay heat steam release mechanism (condenser, SG atmospheric (power operated) relief valve, or main steam safety valves)
  - Source of feedwater (auxiliary/startup, main or condensate)
- Alternate means of decay heat removal via the main feedwater/condensate (or FLEX) was not included due to a lack of heatup information available.
  - Could not determine amount of time available before SHIELD mechanical seal failure would occur

Westinghouse

# Asymmetric Cooling Incorporation (Cont.)

- Steam relief was not modeled due to the large level of redundancy and diversity available.
- Initiating events that require isolation of a SG were included (FWLB, MSLBs, etc.)

# Asymmetric Cooling Failure Fault Tree




Westinghouse

# Quantification Insights

- Existing model used mutually exclusive logic to force the logic model to quantify the model through the VSLOCA portion of the tree on a loss of seal cooling.
- New mutually exclusive logic was known to be required, however for the initial quantification all seal LOCA mutually exclusive logic was removed to ensure the new logic was appropriate.
  - This step was found to be important as it led to a few unexpected insights

# Complete Loss of Secondary Heat Removal

- Initial quantifications revealed (as expected) some cutsets retained were not propagated through the VSLOCA portion of the fault tree as they should have been, due to the asymmetric cooling logic.
- Namely, scenarios where a loss of all AC power had occurred coincident with a failure of the turbine driven auxiliary feedwater pump were being generated through the general transient portion of the fault tree.
  - Complete loss of seal cooling and secondary cooling, so SHIELD failure should have occurred

# Complete Loss of Secondary Heat Removal (Cont.)

- Initial thoughts were to leave the results as is, since propagation through the VSLOCA tree would not result in any different combinations of equipment failure.
- However, closer examination of the results revealed that this would produce an incorrect offsite non-power recovery probability that was much lower than what it should have been.
- The time available to recover offsite power in a transient compared to a VSLOCA are much different and if not binned correctly would lead to an under conservative estimate of CDF/LERF.
- Similar results were noted (again as expected) for conditions where asymmetric cooling only (no loss of all SG cooling) occurred.

# CP Offsite Power Recovery

- Uses a convolution methodology that looks at availability and failure times for diesel generators and the turbine driven AFW pump.
- It should be noted that Comanche Peak offsite power recovery does differ from other plants with regards to offsite power recovery.
  - CP has a ‘Black Start’ switchyard that is independent of plant resources to realigned and connect to the grid.
  - Separate diesel generators are available along with a dedicated long duration set of batteries.
  - Switchyard breakers are sealed type breakers that only require DC power to operate, no compressors.
- Essentially offsite power recovery can occur up to and well beyond 24 hours.

# Mutually Exclusive Logic Development

- CP desire to continue to use the conditional logic method in lieu of additional event tree development, therefore new mutually exclusive logic was developed.
- Logic created to retain asymetric cooling cutsets through the VSLOCA portion of the tree. This essentially tells the quantifier to delete the non-VSLOCA cutsets when the following occurs:
  - Asymmetric or complete loss of SG cooling
  - Loss of all RCP seal cooling
  - Flag indicating propagation through the Transient portion of the fault tree
- Other minor non-minimal cutsets were also found and resolved via mutually exclusive logic changes.

# Model Results Impact

- SHIELD mechanical seal modeling was found to have a dramatic effect on the results; even with the incorporation of asymmetric and complete loss of SG cooling.
  - ~50% reduction in CDF (low E-06 range)
- CP CDF was relatively low prior to implementation prior to SHIELD installation in the mid to low E-06 range. Due to dual unit cross-tie capabilities and other design mods.
- Drastic change in the top cutsets was seen. New dominant scenarios included:
  - Feed and bleed successful but lost after the batteries failed due to a train related complete loss of power; 2 PORVs required.

Westinghouse

# Model Results Impact (Cont.)

- Further investigation still required into top cutsets that are likely to change based on TH analysis, but could not be investigated at this time.
- To steal a phrase from one of our recently retired personnel
  "Important systems are now AFW all the time, especially the TD AFW pump; there is no other answer."
- Much work still to be done to refine and review what appears to be a whole new model from the results standpoint.

**Results landscape shifted as expected but what came up is no longer 'low hanging fruit.'**

Westinghouse

# SHIELD Modeling Improvements?!?!

- Some preliminary research was performed (in the form of sensitivity studies) as to what the impact would be if the asymmetric cooling issue could be removed:
  - Approximately a 30-50% (mid E-07 range) additional decline in CDF could be seen; dependent on how much asymetric cooling can be sustained (4 loop plant)
  - Even more low contributors become dominant such that the risk results landscape become more ‘flat’; large number of cutsets makeup the top 95%
  - No credit was taken in this research to credit alternate methods for re-establishing full SG cooling (other systems/operator actions/etc.)

**More work could be done to refine the model, but at what cost? $$$**

Westinghouse

# Conclusion

- SHIELD was demonstrated to have significant benefit to the Comanche Peak PRA model.
  - 50% currently but could be even more if asymetric cooling can be further refined (30-50%).
- Impacts of the implementation need to be carefully reviewed to make sure the SHIELD mechanical seal and overall PRA model are doing what they are expected to do.
- Results of the new model will likely not be what you expect:
  - Vast change in the results were noted
  - Further refinement may become limited at a certain point, diminishing returns for risk improvement (beyond some initial simple cases or asymmetric cooling changes) in terms of cost and level of effort.

Westinghouse

# Questions?