RCP Seal Leakage Consensus Model for Westinghouse PWRs

NRC Meeting

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Westinghouse Owners Group

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RCP Seal Leakage Consensus Model for Westinghouse PWRs

AGENDA

- Introduction & Purpose - Mo Dingler
- RCP Seal Leakage Model - Ken Kiper
  - Scope
  - *WOG2000* Model
  - Clarifications & Modifications
    - Results
- Conclusion - Mo Dingler

RCP Seal Leakage Consensus Model for Westinghouse PWRs

INTRODUCTION

- Purpose of Meeting
  - Address current concern regarding multiple RCP seal leakage models in use across the WOG fleet.
  - Propose a consensus model acceptable to NRC & WOG that could be used in risk-informed regulatory applications.
    - Letter date January 5, 2000 to Andrew Drake from Stuart A. Richards

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SCOPE

- Boundary of the RCP Seal Leakage Model
  - Includes:
    - Combinations of seal failure modes (scenarios)
    - Seal leakage rate for each scenario
    - Probability of seal failure mode scenarios
    - Timing of seal failure scenarios
  - Excludes:
    - Time to core uncover calculations
    - System recovery probabilities

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WOG2000 RCP Seal Leakage Model

- Based on BNL Technical Report W6211-08/99 *with 3 modifications*
- Includes three failure modes:
  - Popping
  - Binding
  - O-Ring Extrusion
- Includes models for both "old" and "High Temperature" O-rings.

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FAILURE MODES

- Popping & Binding
  - Failure modes considered together because consequence is similar
  - No such events to date, but potential included in ***WOG2000***

- O-Ring Extrusion
  - High Temperature O-ring material much less susceptible to extrusion at high temperatures
    - 75% of RCPs have High Temperature O-rings.

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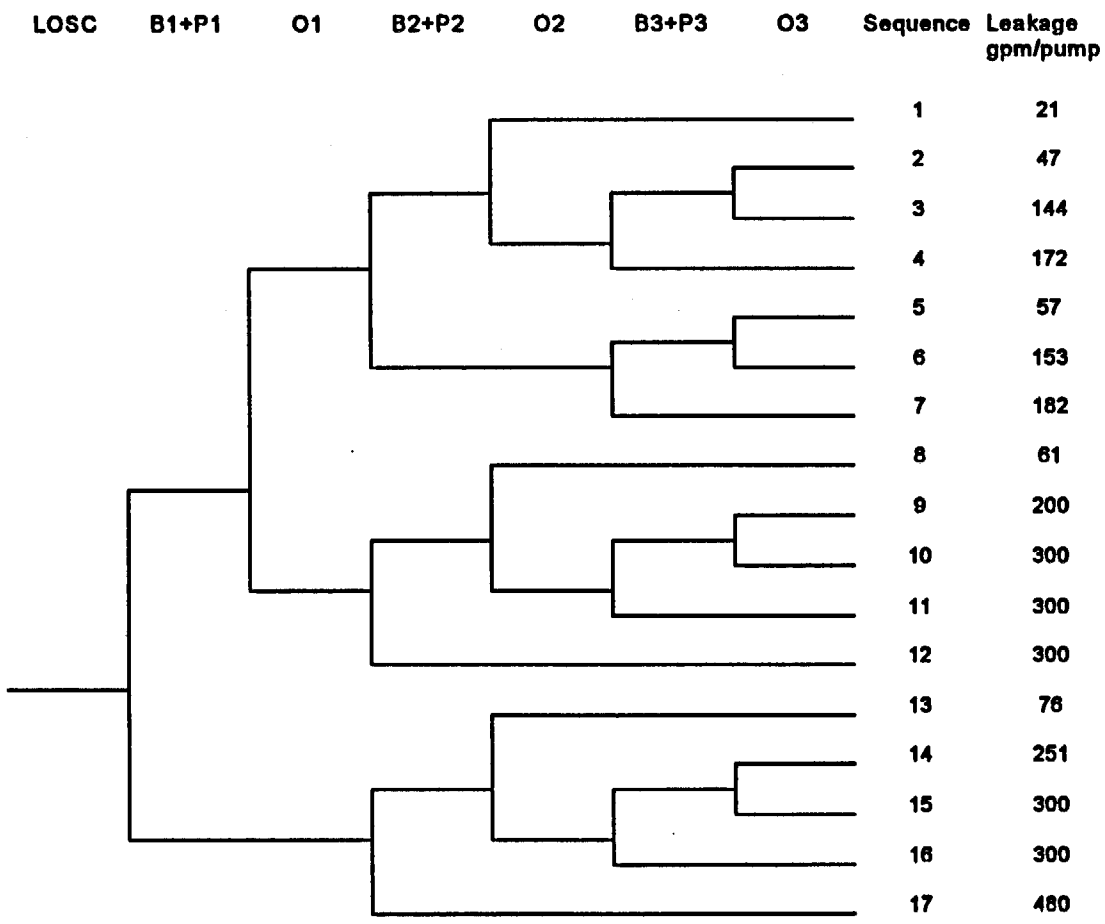
RCP Seal Leakage Scenarios (BNL)



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CLARIFICATIONS/MODIFICATIONS

- Probability of ***popping-and-binding*** is reduced by a factor of 2 for seals with High Temperature O-rings
- Probability of ***O-ring failure*** is reduced by a factor of 2 for seals with old O-rings.
- ***Starting time*** of the time-independent seal face failures (popping-and-binding) is postulated to be 30 minutes after the loss of RCP seal cooling.

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POPPING & BINDING

- PROB("popping-and-binding" failure mode) from BNL Model:

P(PB1)	=	0.025
P(PB2)	=	0.20
P(PB3)	=	0.54

Where P(x) is the probability of popping and binding failure in the xth seal stage.

- The BNL model applies these same probabilities to both the old and the High Temperature O-ring materials.

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POPPING & BINDING

- *WOG2000* recognizes difference between popping and binding failure modes. These differences justify reducing the total popping-and-binding probabilities where the High Temperature O-rings have been installed. The rationale:

  - The "binding" failure mode is driven by premature extrusion failure of the o-rings or channel seal elastomers that make up the secondary seals (Section 2.2.1.1 of BNL Technical Report W6211-08/99). Since the o-rings are qualified in this case, this failure mechanism is effectively eliminated.

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POPPING & BINDING

- *WOG2000* modification: Reduce the "popping-and-binding" probabilities for stages 1 and 3 by a factor of two.

P(PB1)	=	0.0125
P(PB2)	=	0.20
P(PB3)	=	0.27

- This change reflects the benefit gained by the new material in reducing the "binding" probability. The factor of two decrease is a conservative estimate, based on the understanding that binding dominates the popping-and-binding failure mode for stages 1 and 3 (Section 3.1.1 of BNL Technical Report W6211 - 08/99).

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O-RING EXTRUSION

- For High Temperature O-Ring Material ...
  - BNL Model uses the following probability distribution for extrusion failure of the O-rings:
    - P(O1) = P(O2) = P(O3) = 0.0

      Where P(Ox) = probability of seal failure at the xth seal stage due to O-ring extrusion.
    - The High Temperature O-rings are designed to perform in the high temperature environment expected after loss of seal cooling. The BNL Model assumes the probability of O-ring failure to be zero. This assumption is adopted by the ***WOG2000*** Model.

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O-RING EXTRUSION

- For Old O-Ring Material…

  BNL Model

  $P(O1) = P(O2) = 1.0$ if time ≥ 3 hours

  $= 0.0$ if time < 3 hours.

  $P(O3) = 1.0$ if time is ≥ 2 hours after failure of first or second O-ring

  $= 0.0$ for other times.

- In the BNL model, old O-rings are assumed to fail with certainty during the 3 to 5 hour period following loss of cooling, leading to leakage scenarios with 300 gpm/pump.

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O-RING EXTRUSION

- Westinghouse/WOG position on this failure mode has been a gradual increase of this probability in time, with some residual probability that the 21 gpm per pump scenario will remain.
- This is consistent with the seal leakage model documented in NUREG/CR-4550.
- To recognize the possibility of the 21gpm scenario remaining, the O-ring failure probability is reduced by a factor of 2.

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O-RING EXTRUSION

- Old O-Ring Material - *WOG2000* Model

P(O1) = P(O2)	= 0.5 if time ≥ 3 hours
	= 0.0 if time < 3 hours.
P(O3)	= 0.5 if time is ≥ 2 hours after failure of first or second o-ring
	= 0.0 for other times.

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FAILURE START TIME

- BNL Model assumes the following leakage start times:
  - 21 gpm "normal" leakage starts at the beginning of the scenario (t =0),
  - Binding-and-popping failures, if they occur, start at the beginning of the scenario (t =0), and
  - Old O-ring failures occur at the beginning of the third hour for O1 and O2, and at the beginning of the fifth hour for O3.

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FAILURE START TIME

- In *WOG2000* the binding-and-popping failures could occur at 30 minutes.
  - Based on analysis of the heatup rate: The occurrence time of such a failure can not physically be before the 15-minute time frame since the seals would not yet experience out-of design basis temperatures.

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FAILURE START TIME

- The BNL Report notes only that the failure is expected to occur sometime *during the first hour*:

  ".. the processes of binding and popping-open are not time-dependent, and the onset of the probability of opening of the face seals due to either process is assumed during the first hour of the LOSC event. For evaluating the probabilistic model, NUREG/CR-4906P does not state the specific time during the first hour of the LOSC event at which the face seals are assumed to fail; we interpret that NUREG/CR-4906P used time = 0, the onset of the LOSC event, as the time of possible failure."

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FAILURE START TIME

- *WOG2000* Model
  - Using 15 minutes and 60 minutes as the upper and lower bounds, the following approach is used to estimate a reasonable mean time of occurrence of the binding-popping failure mode:
    - The time of occurrence obeys the lognormal distribution;
    - The 05th percentile of the distribution is at 15 minutes;
    - The 95th percentile of the distribution is at 60 minutes.
  - Mean time of occurrence of 33 minutes.

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WOG2000 for High Temperature O-Rings

Leakage Scenarios with High Temperature O-Rings			
Leakage Rate (gpm/pump)			*Probability*
1st 30 Minutes	1st Hour	2nd and Following Hours	
21	21	21	0.79
21	57	57	0.1442
21	182	182	0.0533
21	76	76	0.01
21	480	480	0.0025
Total Probability			1.0

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BNL Model for High Temperature O-Rings

Leakage Scenarios with High Temperature O-Rings		
Leakage Rate (gpm/pump)		*Probability*
1st Hour	2nd and Following Hours	
21	21	0.78
57	57	0.0897
182	182	0.1053
76	76	0.02
480	480	0.005
Total Probability		1.0

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WOG2000 for Old O-Rings

Leakage Rate (gpm/pump)						Probability
1st 30 Minutes	1st Hour	2nd Hour	3rd Hour	4th Hour	5th and Following Hours	
21	21	21	21	21	21	0.1950
21	21	21	47	47	47	0.0449
21	21	21	47	47	144	0.0449
21	21	21	172	172	172	0.1053
21	21	21	61	61	61	0.1950
21	21	21	200	200	200	0.0449
21	21	21	200	200	300	0.0449
21	21	21	300	300	300	0.1053
21	57	57	57	57	57	0.0224
21	57	57	57	57	153	0.0224
21	57	57	300	300	300	0.0449
21	76	76	76	76	76	0.0100
21	76	76	251	251	251	0.0023
21	76	76	251	251	300	0.0023
21	76	76	300	300	300	0.0054
21	182	182	182	182	182	0.0527
21	182	182	300	300	300	0.0527
21	480	480	480	480	480	0.0050
Total Probability:						1.0

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BNL Model for Old O-Rings

Leakage Rate (gpm/pump)					*Probability*
1st Hour	2nd Hour	3rd Hour	4th Hour	5Th and Following Hours	
21	21	200	200	300	0.3588
21	21	300	300	300	0.4212
57	57	300	300	300	0.0897
182	182	300	300	300	0.1053
76	76	251	251	300	0.0092
76	76	300	300	300	0.0108
480	480	480	480	480	0.0050
Total Probability					1.0

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CONCLUSIONS

- WOG2000 is consistent with BNL Report
  - 3 Modifications/Clarifications
- If NRC agrees in principle with ***WOG2000***
  - WOG will develop a WCAP on ***WOG2000*** methodology
    - Submit to NRC no later than 12/31/00
    - Request SER on WCAP