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APR 1400 RCP Seal Design and ELAP Capability

Presented by

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Westinghouse Electric Company LLC

Presented to

US NRC Staff at PARM on APR1400 DCA

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APR 1400 RCP Seal Design and ELAP Capability

Agenda

- Overview
- APR1400 RCP Seal Design
- Seal Response to SBO conditions
- KSB RCP Seal Test Program
- ELAP Strategy
- Conclusions

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Overview

Defense in Depth Approach for RCP Seals

1. New KSB Type “F” RCP Seals for APR 1400 Design
2. High Temperature Capable Primary and Secondary Seals; confirmed by seal testing
3. Diverse and Redundant means to keep seal cool by isolating Controlled Bleed-off (CBO) early and/or availability of alternate seal injection
4. Aggressive cooldown ELAP response

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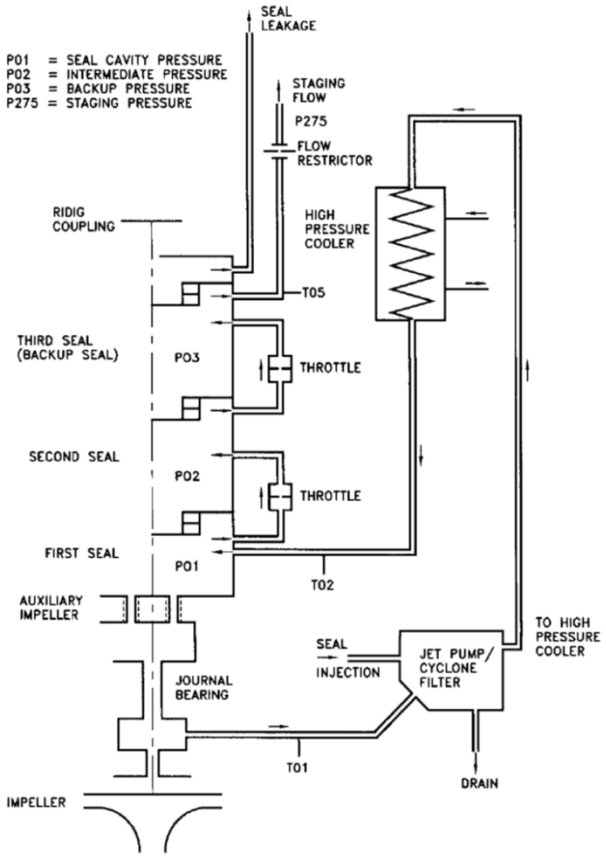
Seal Design and Normal Operation

- APR1400 uses KSB Type “F” Three stage RCP hydrodynamic Seal. Type “F” retains all positive features of the old Type “C” Seal and is robust to high temperature exposure.
- Seals have redundant cooling capability and are cooled by both seal Injection and CCW.
- 1) seal Injection water
- 2) recirculated seal water cooled by CCW.
- Seals can operate indefinitely with either cooling source.
- Seal stages operate with a 0.42:0.42:0.16 pressure breakdown via throttles and an exit flow restrictor.



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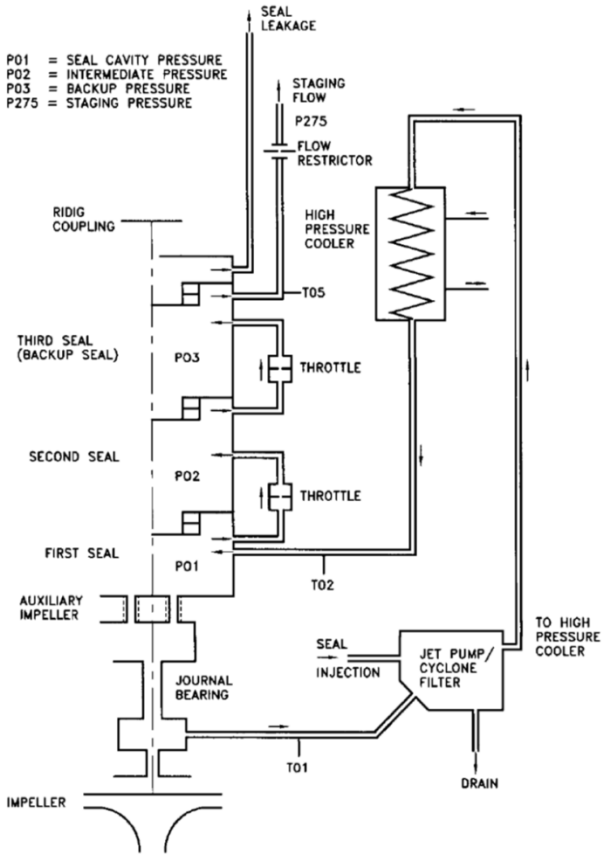
Seal Design and Normal Operation

- CBO flow of about 3.2 gpm passes through PBDs to VCT.
- Seal leakage (less than 0.05 gpm) routed to RDT
- Multi-stage seal design with PBD devices make seals robust to stage failures
- During normal operation seal stages operate with pressure differentials between 300 and 950 psid
- Each stage capable of operating at full RCS pressure for prolonged periods under rated conditions.
- Seal leakage given two seal stages fail <10.2 gpm



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Features of APR1400 RCP Seal Installation

- KSB Type “F” Seal designed with extended high temperature operational capability in mind
- KSB mechanical seal : HDD 254 Type “F” designed with High temperature and high pressure capability
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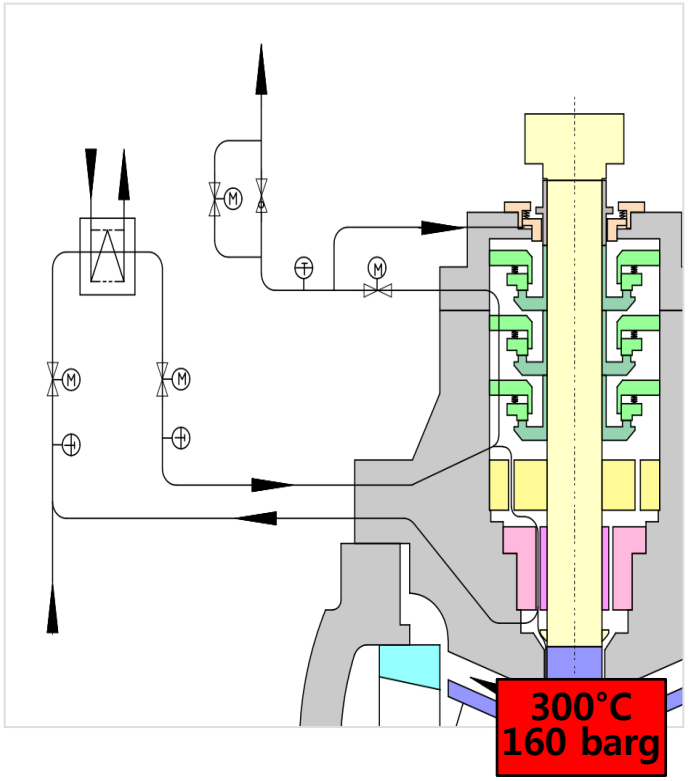
- Highly reliable CBO isolation capability



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Mechanical Seal HDD 254 Type "F"

Design Goals:

- ✓Interchangeability (no modification to interface)
- ✓ Same performance for normal operation as prior Type "C" seals with excellent history
- ✓Material combination unchanged from Type "C" seal
- ✓ [

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- ✓Enhanced manufacturing process
- ✓Improved temperature resistance of primary seal and elastomers (secondary seal)
- ✓Capable of extended operation at 572 °F @2335 psia

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CBO Isolation Capability

- **APR1400 Seal system/installation designed with diverse and redundant means to isolate controlled bleed-off following SBO**
  - Seal injection water can be provided by Auxiliary Charging Pump which is a dedicated pump to supply seal injection for loss of normal charging pump and powered by EDG and AAC Generator.
  - External CBO line isolation using an Air Operated Valve (AOV) and a battery powered Motor Operated Valve (MOV)
  - KSB seal design includes an option for a Passive Thermal Check Valve (PTCV), although not credited for ELAP analysis.

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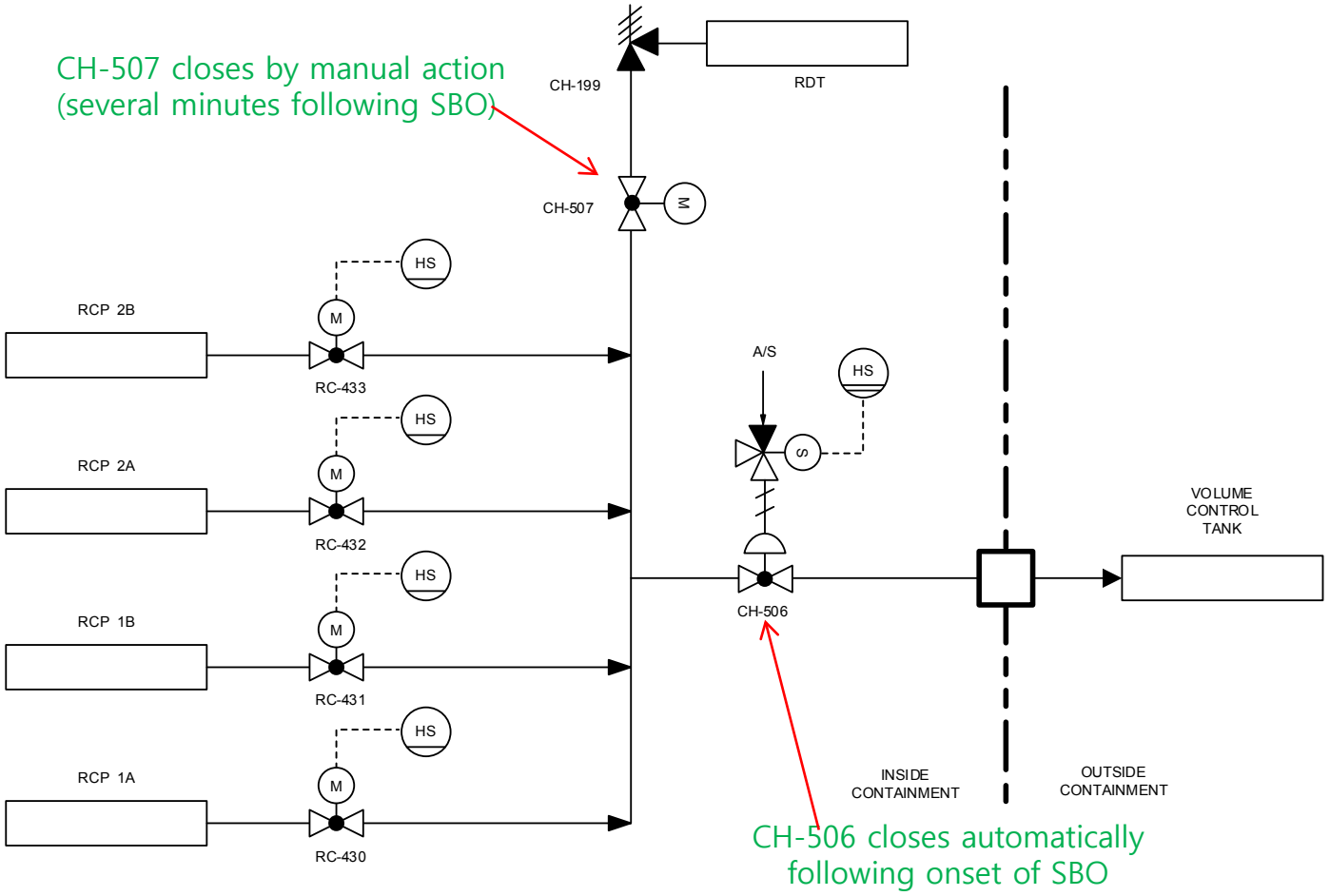
SBO Strategy Rapidly / Fully Isolates CBO



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Isolation of CBO via PTCV

- Passively isolates CBO line and minimizes the impact of an SBO event. PTCV directly attaches to CBO discharge.
- Actuation temperatures in excess of pump trip value (no inadvertent actuation during operation)
- Inherently safe: Actuation through physical principle [

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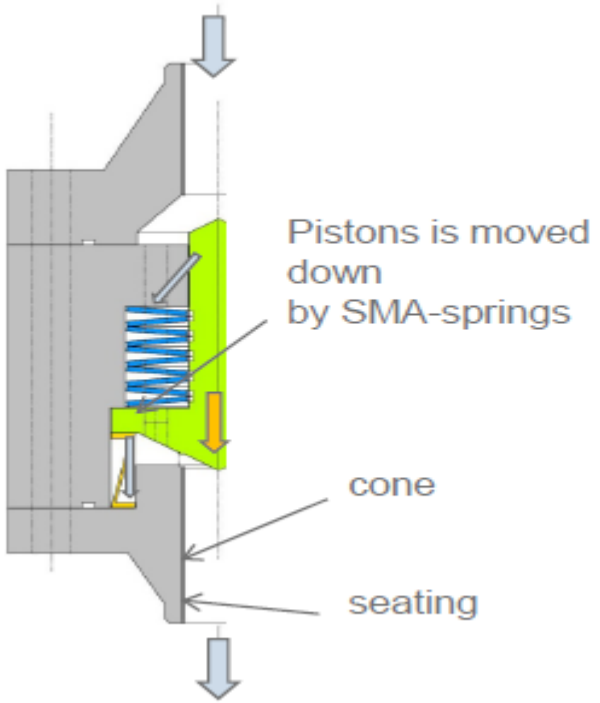
- Re-opens only, if system pressure has dropped below 20 barg (unless intentionally vented)
- Based on KSB NUCA© valve technology



Tested successfully over 100 times

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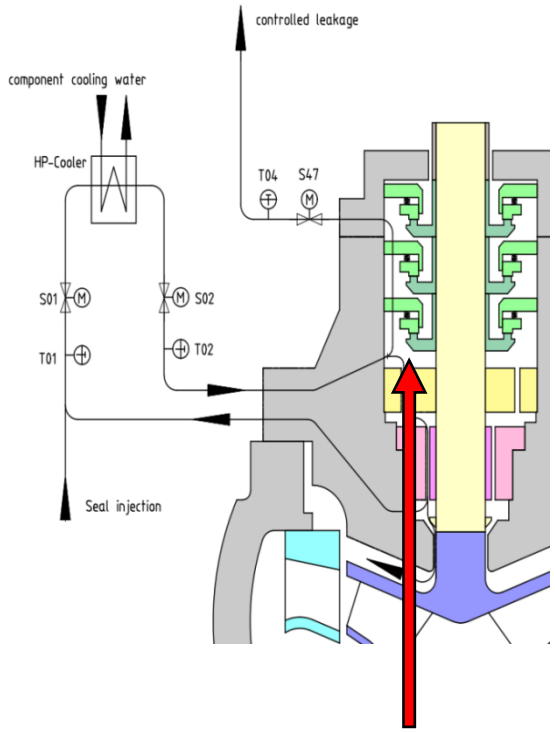
Response of KSB Seal to SBO induced LOSC



If isolation of CBO is delayed, a rapid temperature increase in seal cavity results.

- SBO implies:
  - Power not available
  - Component cooling water (CCW) not available
  - Seal injection water not available
- Without Seal Injection, RCS fluid at full RCS pressure and temperature (~572 °F / 2335 psia) begins to leak into the seal.

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SBO Condition: CBO Not Isolated

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SBO Condition: CBO Not Isolated

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SBO Condition: CBO Isolated Early

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SBO Condition: CBO Isolated Early

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APR 1400 RCP Seal Design and ELAP Capability

SBO Condition: CBO Isolated Early

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Key Insights of RCP Type "F" Seal System

Seal design allows for effective ELAP response:

- Seal designed to accommodate high RCS pressures (up to 572 °F at 2335 psia) for extended periods
- Early CBO isolation (either via AOV/MOV or PTCV) keeps seals relatively cool for an extended period and limits seal temperature rise to < 210 °C (410 °F) .

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KSB Type "F" Seal Test Program

Test program includes separate effects and full scale tests

- PTCV Tests completed
- Seal Elastomer temperature response tests completed
- Seal Separate effects single stage tests in progress
- Integral seal performance tests scheduled to begin during first quarter 2015.

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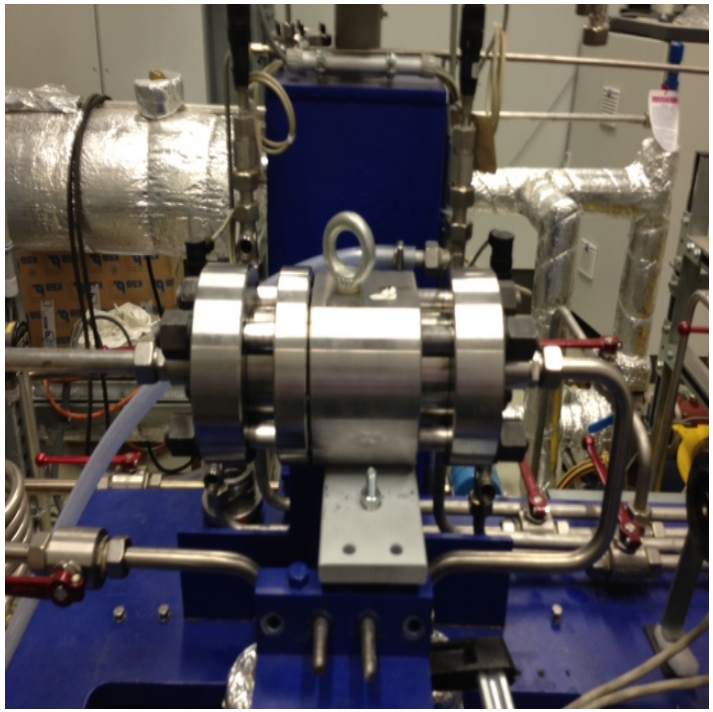
PTCV Tests

- Test program successfully completed
- No pre-mature actuations
- No failures to actuate
- Over 100 tests completed



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Elastomer Performance Test Results

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Seal Assembly Test: In Progress

- New test rig especially designed for high temperature & pressure test
- Full scale testing of one seal stage under SBO Conditions
- Leakage measurement
- Additional o-ring testing at 572 °F
  - Temperature: 20-300° C
  - Pressure: 0-160 bar at high temperature
    0-250 bar at ambient temperature

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Seal Assembly Test: Preliminary Results

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Verification Test

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Verification Test

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Integral SBO/ELAP Performance Test

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APR1400 ELAP Strategy

- Strategy for APR1400 to follow general PWROG Guidance

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- Strategy Results in relatively low temperature, low pressure seal exposure for most of the ELAP duration
- Very low RCP seal leakage expected for ELAP conditions

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Defense in Depth for APR1400 ELAP Strategy

Defense in Depth Response to ELAP Scenarios for APR1400 due to:

Seal design

- includes three independent stages with a design goal of full pressure (2335 psia) operation at 572 ^{o}F for 72 hours

CBO isolation

- APR1400 uses AOV and battery powered MOV to fully isolate CBO within several minutes of event onset
- PTCV passively isolates CBO at the RCP seal bleed-off line

Seal injection flow

- While not part of ELAP strategy, the auxiliary charging pump seal injection backs up the normal seal injection system using an independent power supply (AAC power), thereby extending coping time.

Plant response

- APR1400 ELAP strategy demonstrates acceptable plant response following aggressive cooldown and depressurization to SIT setpoint with assumed 25 gpm/pump seal leakage

Expected leakage rate low (under 2 gpm/pump)

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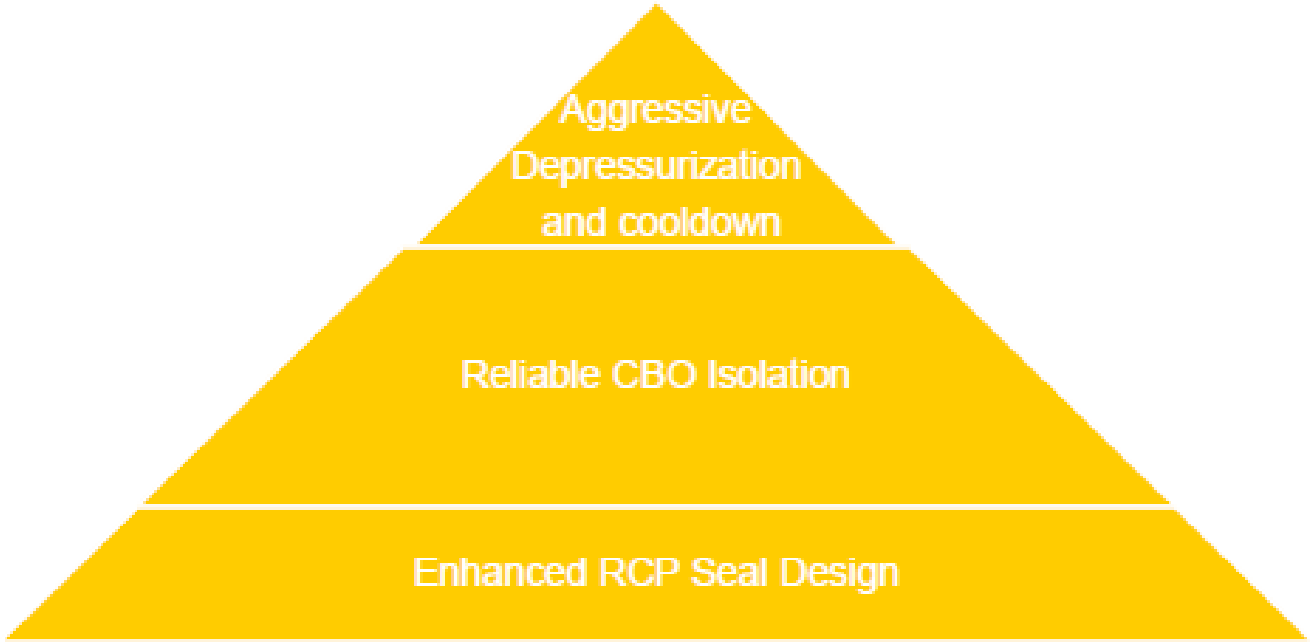
Defense in Depth for APR1400 ELAP Strategy



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Conclusions

- The APR1400 RCP seals, KSB Type F seal, is designed to accommodate high temperature and high pressure operation for extended period of time (~72 hrs).
- Secondary seals (elastomers) use EPDM material and have been tested at high temperatures (~572 ^{o}F) for greater than 72 hours.
- The CBO line is isolated early during an ELAP scenario
- ELAP strategies further reduce the challenge to the RCP seals via planned cooldown and depressurization of the RCS.
- For the ELAP scenario, with early isolation of the CBO line, the seal leakage rates would be less than 2 gpm per pump. ELAP strategies have been evaluated by conservatively assuming 25 gpm per pump seal leakage.
- The capability of the Type F seal to maintain RCP seal integrity during an ELAP scenario will be further confirmed via single stage and multi-stage seal tests to be completed by KSB in Germany.

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Questions