APR 1400 RCP Seal Design and ELAP Capability

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DRAFT

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

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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, passively
4. Aggressive cooldown ELAP response

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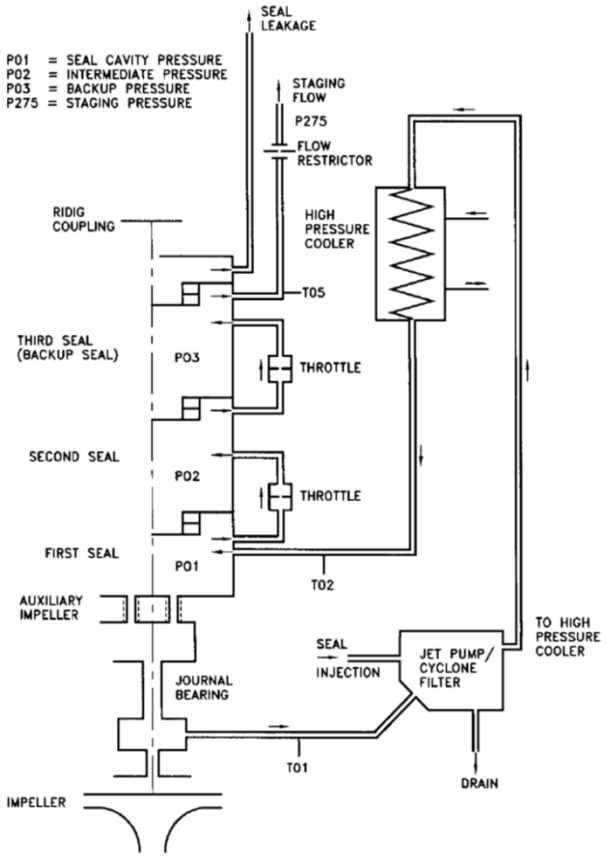
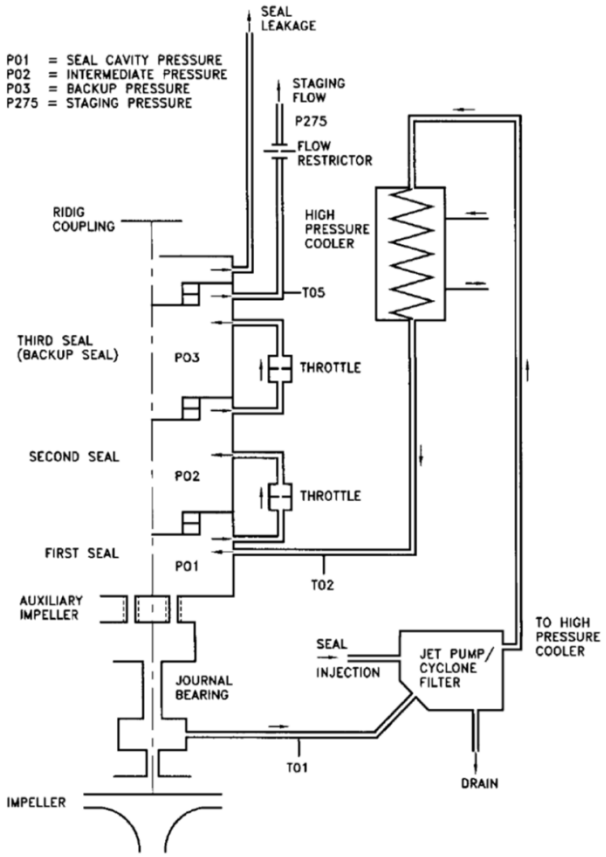
Seal Design and Normal Operation

- 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.



Seal Design and Normal Operation

- CBO flow of about 3.2 gpm passes through PBDs to VCT.
- Seal leakage (generally lower than 0.01 - 3 l/hr) 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 gpm



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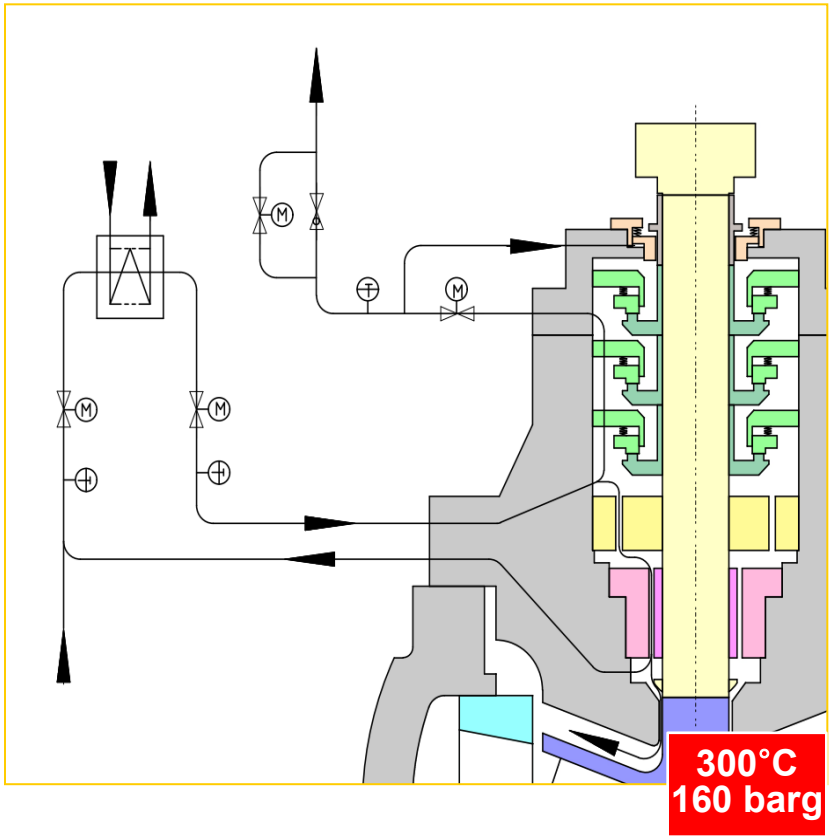
Features of APR1400 RCP Seal Installation

KSB Seal designed with extended high temperature operational capability in mind

a) mechanical seal : HDD 254 Type “F” designed with High temperature and high pressure capability
   - [Primary Seal designed to minimize thermal stress at high temperatures through enhanced manufacturing process and geometrical improvements]
   - [Secondary seals selection includes high temperature resistant EPDM.]

b) Highly reliable passive CBO isolation capability



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
- ✓[Geometrical improvements to primary seal to minimize high temperature thermal stresses]
- ✓Enhanced manufacturing process
- ✓Improved temperature resistance of seal and elastomers
- ✓Capable of extended operation at 300 ^{o}C @160 barg

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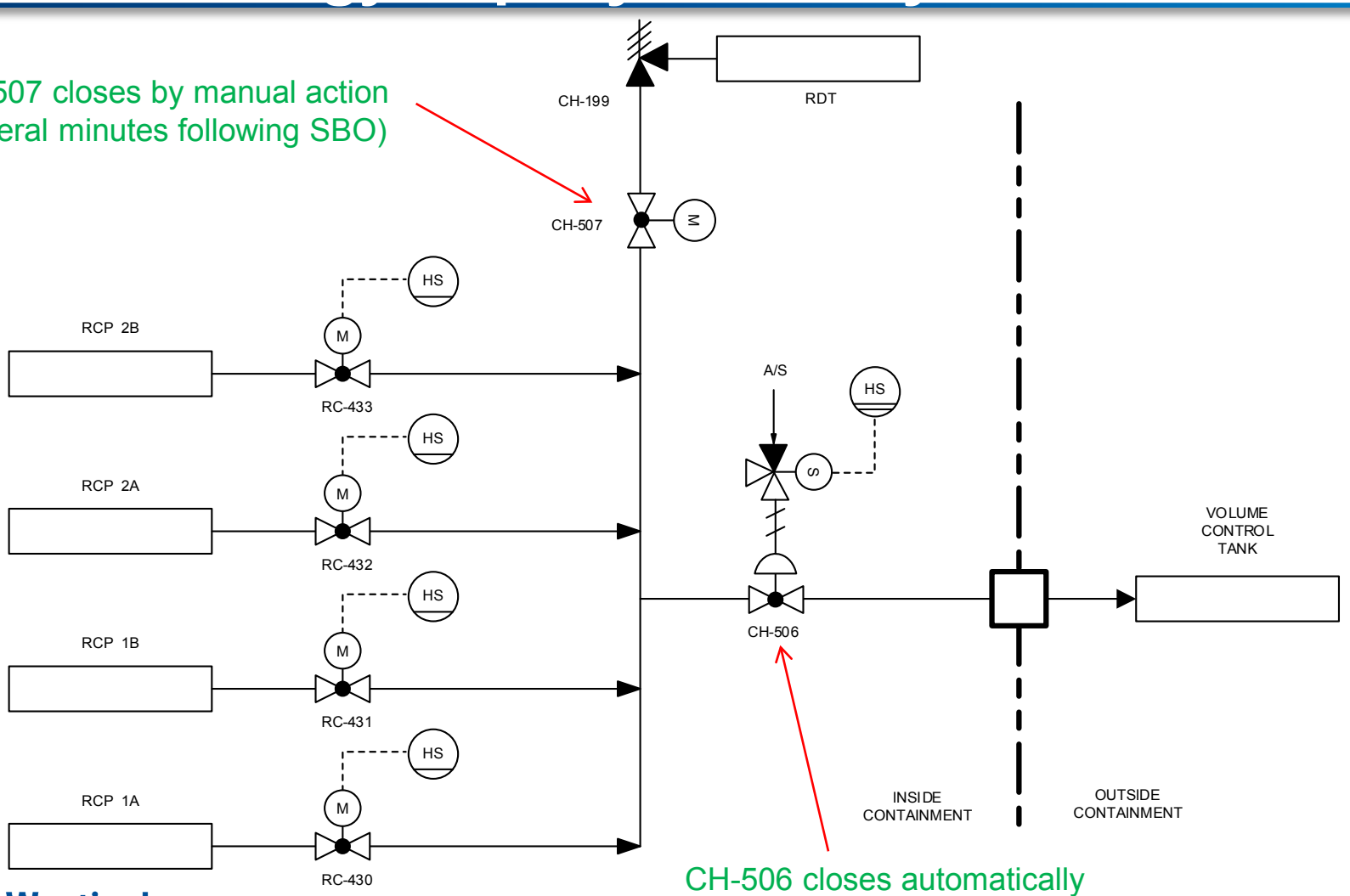
CBO Isolation Capability

- 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)

CBO Isolation Capability: SBO Strategy Rapidly and Fully Isolates CBO

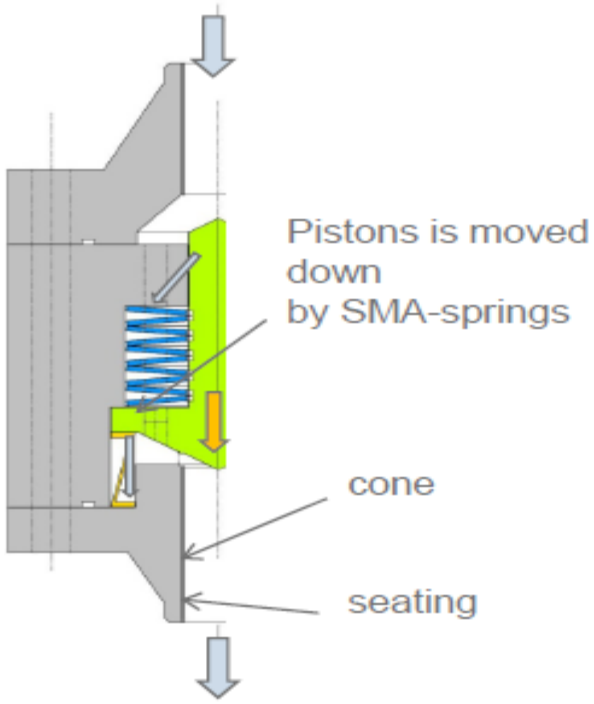
CH-507 closes by manual action (several minutes following SBO)



CH-506 closes automatically following onset of SBO

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 [(austenitic to martensitic structure change in shape memory alloy)]
- 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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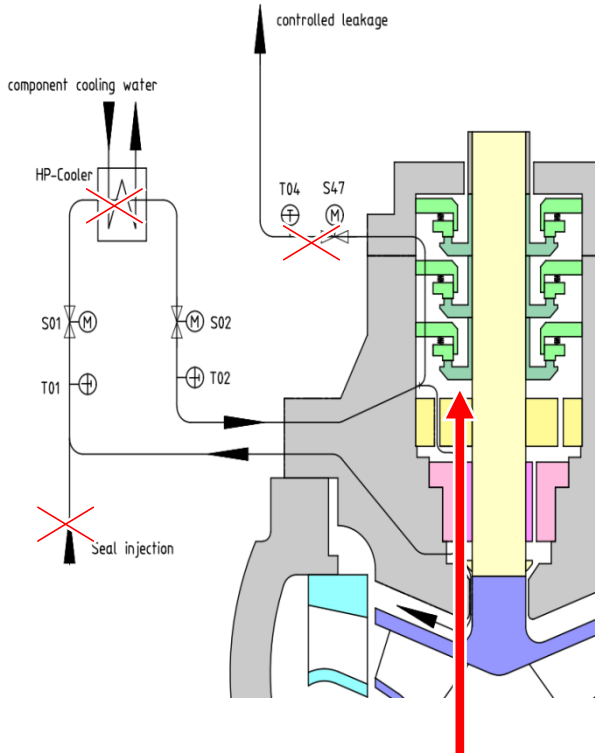
Response of KSB Seal to SBO induced LOSC



- 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 (~300 °C / 160 barg) begins to leak into the seal .

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

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SBO Condition: CBO Not Isolated

SBO Condition: CBO Not Isolated

SBO Condition: CBO Isolated Early

SBO Condition: CBO Isolated Early

PTCV passively isolates CBO at seal exit based on local CBO temperature

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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 300 ^{o}C at 160 barg) 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 ^{o}C.

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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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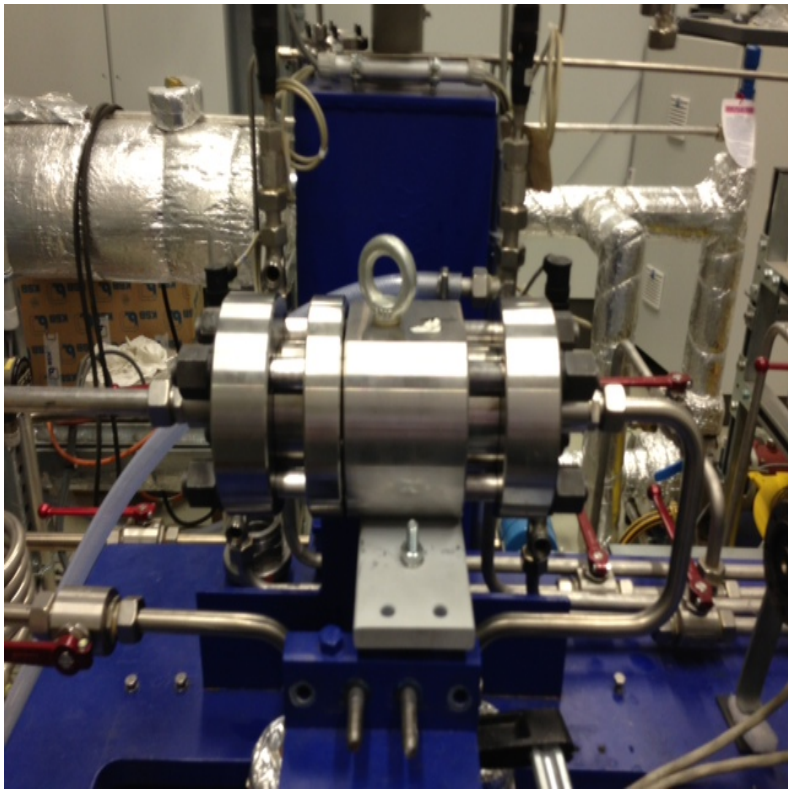
PTCV Tests

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



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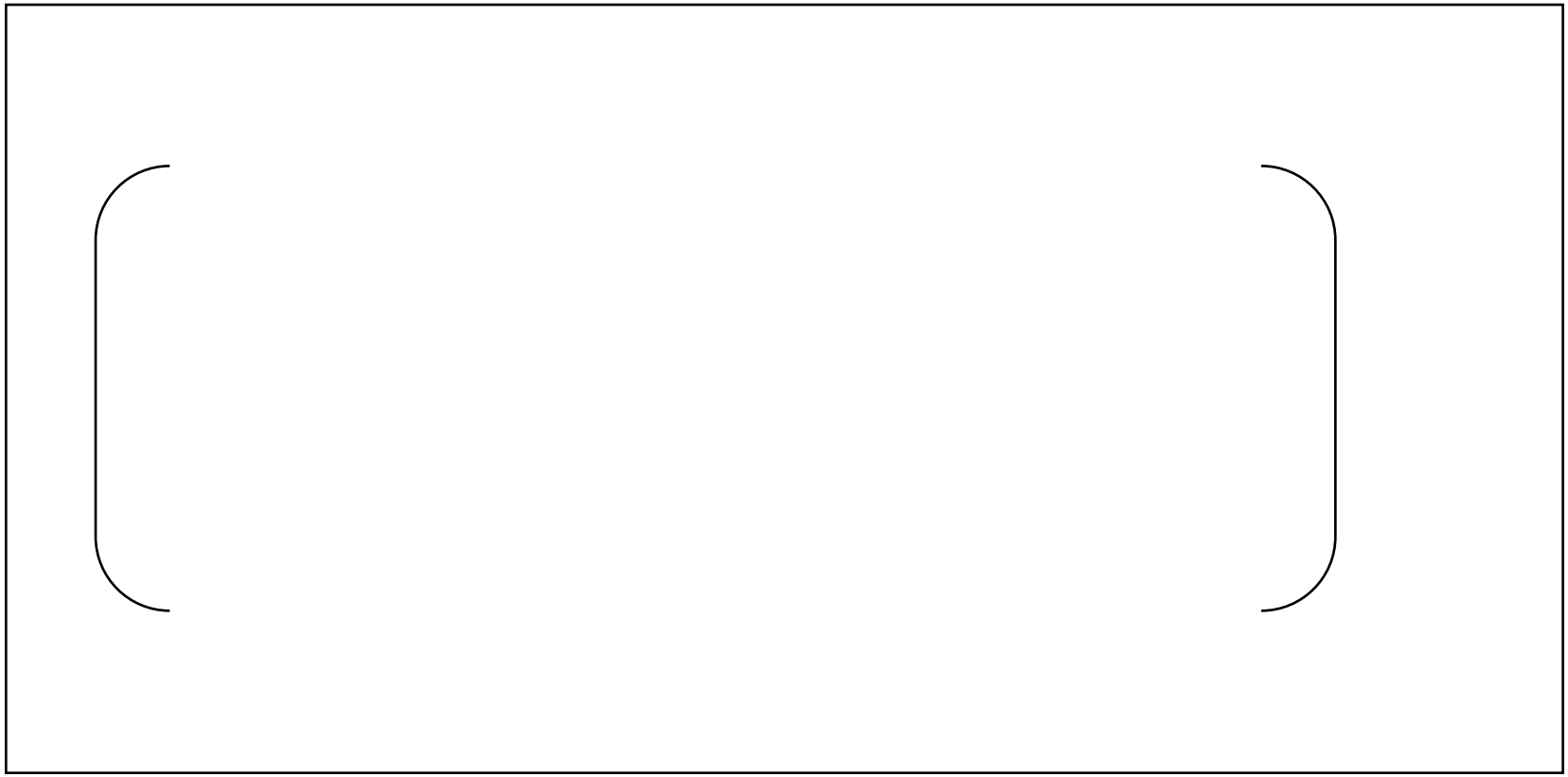
Elastomer High Temperature Performance Test Results



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 300 °C
  - **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

Verification Test

Verification Test

Integral SBO/ELAP Performance Test Proposed Test Conditions

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KEPCO ELAP Strategy

- **Strategy for APR1400 to follow general PWROG Guidance**
  - Early CBO isolation
  - Short duration high pressure hold for about 8 hours

- **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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KEPCO ELAP Strategy (Cont'd)

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

Seal design

- includes three independent stages with a design goal of full pressure (160 barg) operation at 300 ^{o}C for 72 hours

CBO isolation

- APR1400 uses AOV and battery powered MOV to fully isolate CBO within several minutes of event onset

Seal injection flow

- Auxiliary charging pump provides seal injection flow when AAC power is available during an SBO

Plant response

- APR1400 ELAP strategy demonstrates aggressive depressurization and cooldown to SIT setpoint with assumed [ ] seal leakage

Expected leakage rate low (under 2 gpm/pump) based on test results

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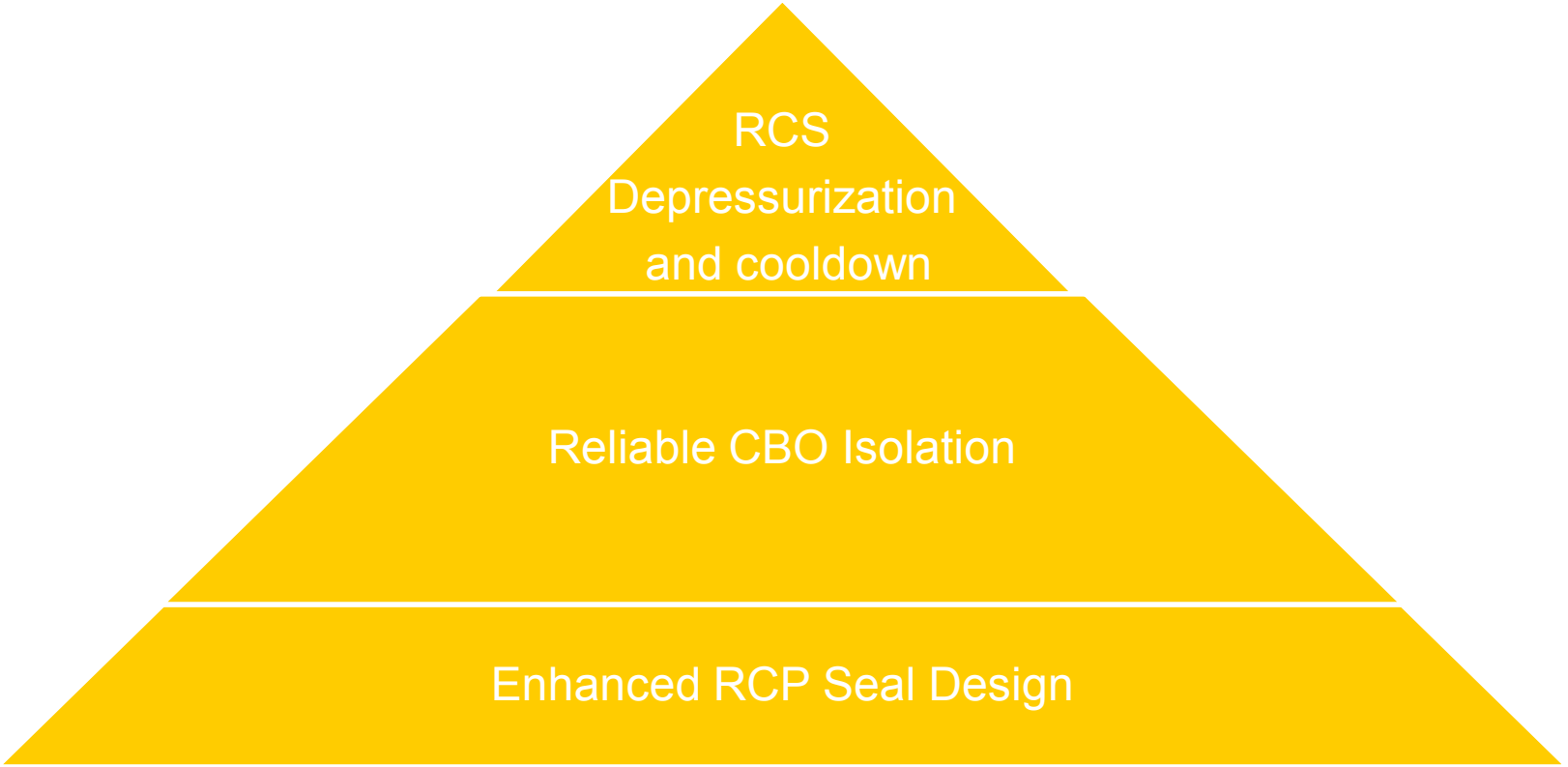
KEPCO ELAP Strategy (Cont'd)



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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 (~300 °C, 572 °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 [ ] 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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