Enclosure 2
Westinghouse APP-GW-GLY-010, (NONPROPRIETARY VERSION)
(43 pages including cover page)

AP1000® Containment Condensate Return to IRWST: December 18 Meeting to Discuss Approach / Status

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AP1000® Containment Condensate Return to IRWST

December 18 Meeting to Discuss Approach / Status

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December 18, 2013

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Agenda

- Wednesday December 18,2013

  2:00 – 2:15 Introductions, review agenda

  2:15 – 3:45 WEC present activities / status

  - Overview of Safe Shutdown operations
  - Plant changes
  - Analysis approach
  - Analysis status

  3:45 – 4:30 NRC present

  4:30 – 5:00 Discuss takeaways / actions

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Purpose

- Update design changes to improve containment condensate return to IRWST for long-term PRHR HX operation after station blackout event
- Update on calculations/analysis status that support the long-term PRHR HX operation:
  - What each calculation does and how they interrelate
  - Methodologies used, how they are similar / different from current calculations

Objective is to provide information that will make NRC review of this analysis more effective

Overview of **AP1000** Safe Shutdown operations

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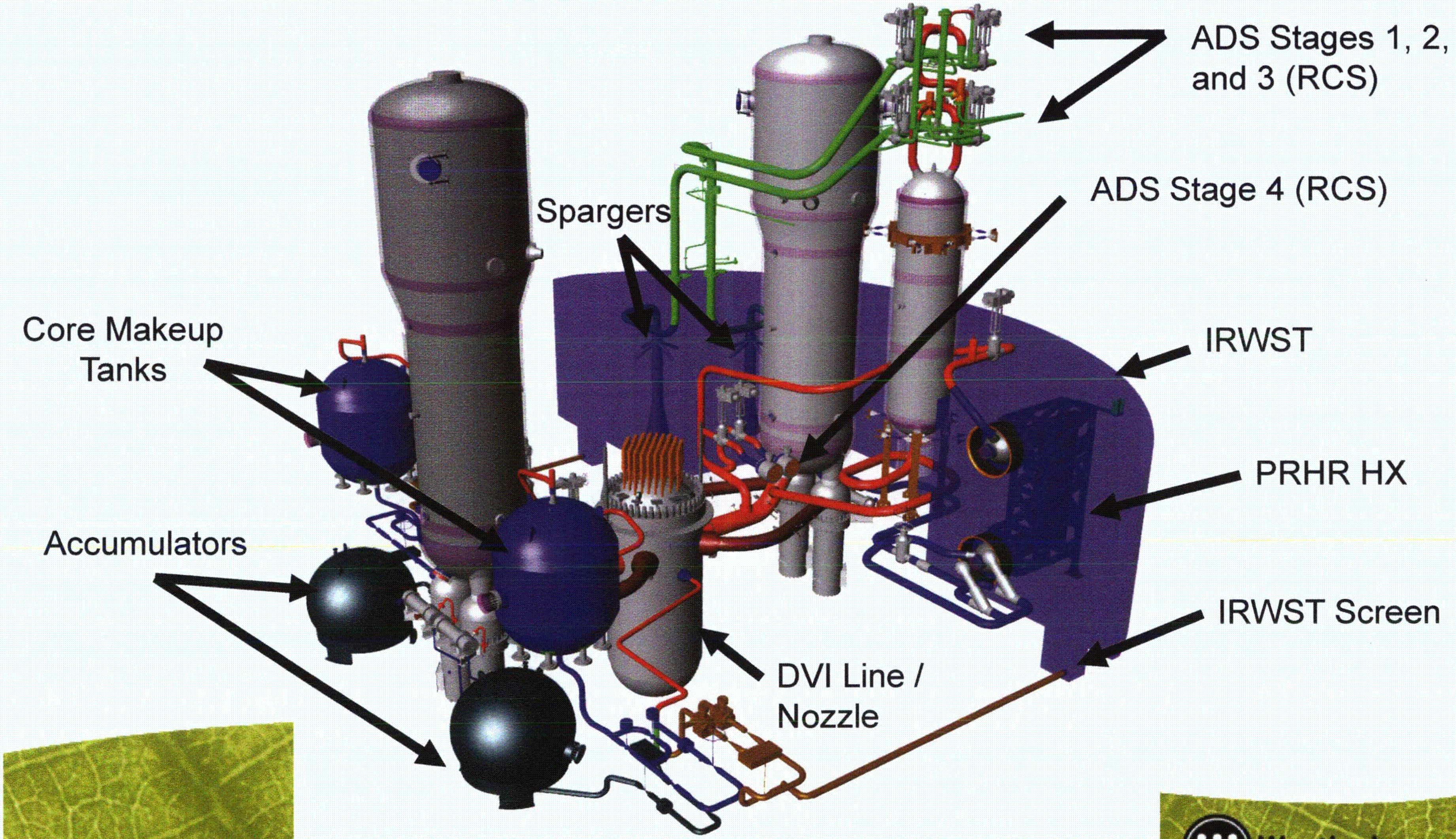
AP1000 Safe Shutdown

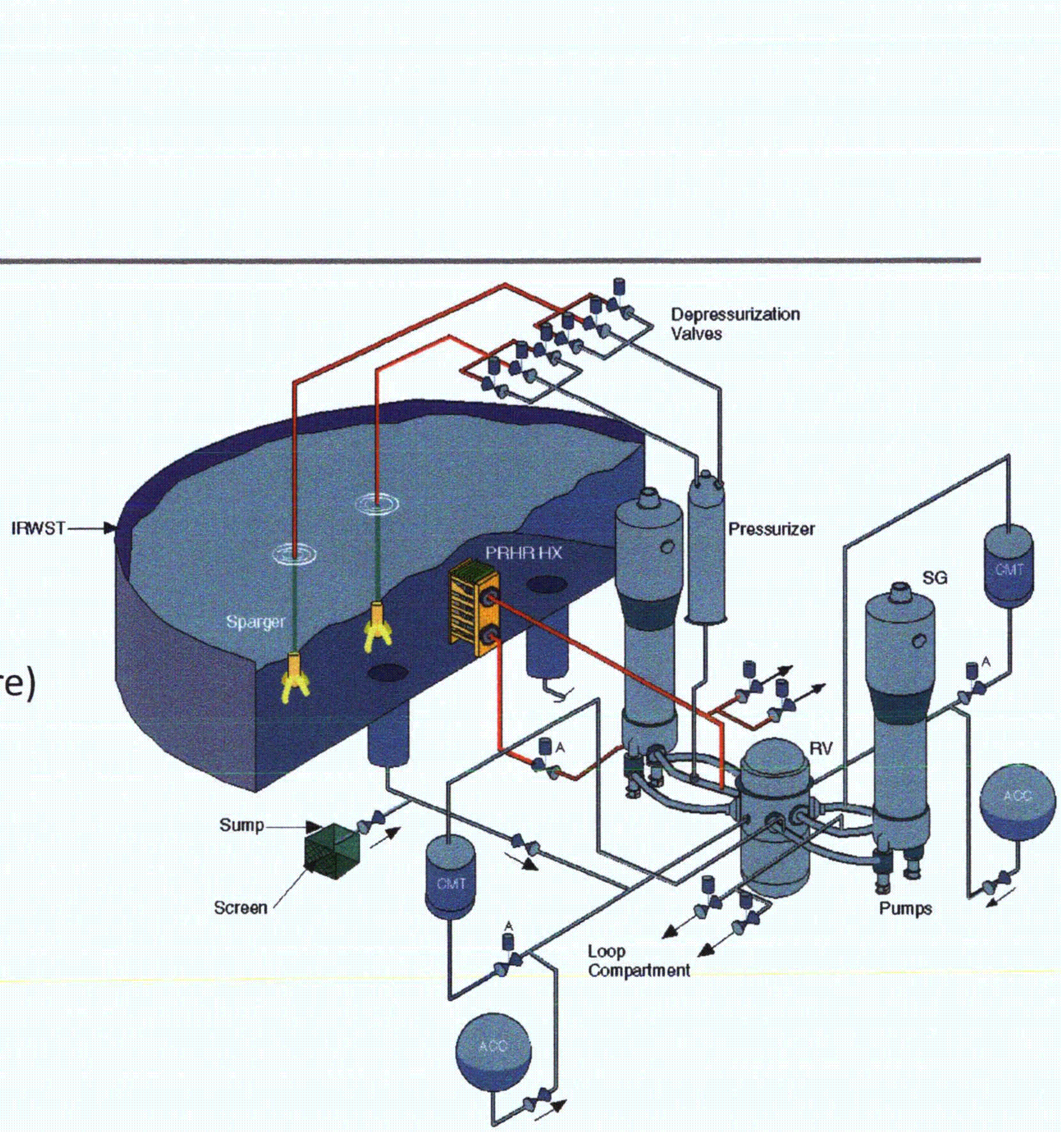
- In non-LOCA event, PRHR HX is designed to bring the plant to safe shutdown and to maintain plant in this condition
  - Safe shutdown is RCS temp ≤ 420°F in 36 hours
  - Duration of PRHR HX maintenance of safe shutdown not specified in DCD, referred to as "indefinite"
- Passive feed/bleed provides alternate safety-related means of providing/maintaining safe shutdown for LOCAs, large RCS leaks, long-term uncovery of PRHR HX
- IRWST inventory can deplete in the long-term due to
  - Steam lost to pressurize containment
  - Steam lost to heat up passive heat sinks (walls/floors, structures)
  - Splashes / drips from containment vessel bypassing IRWST gutter

PXS 3D Layout



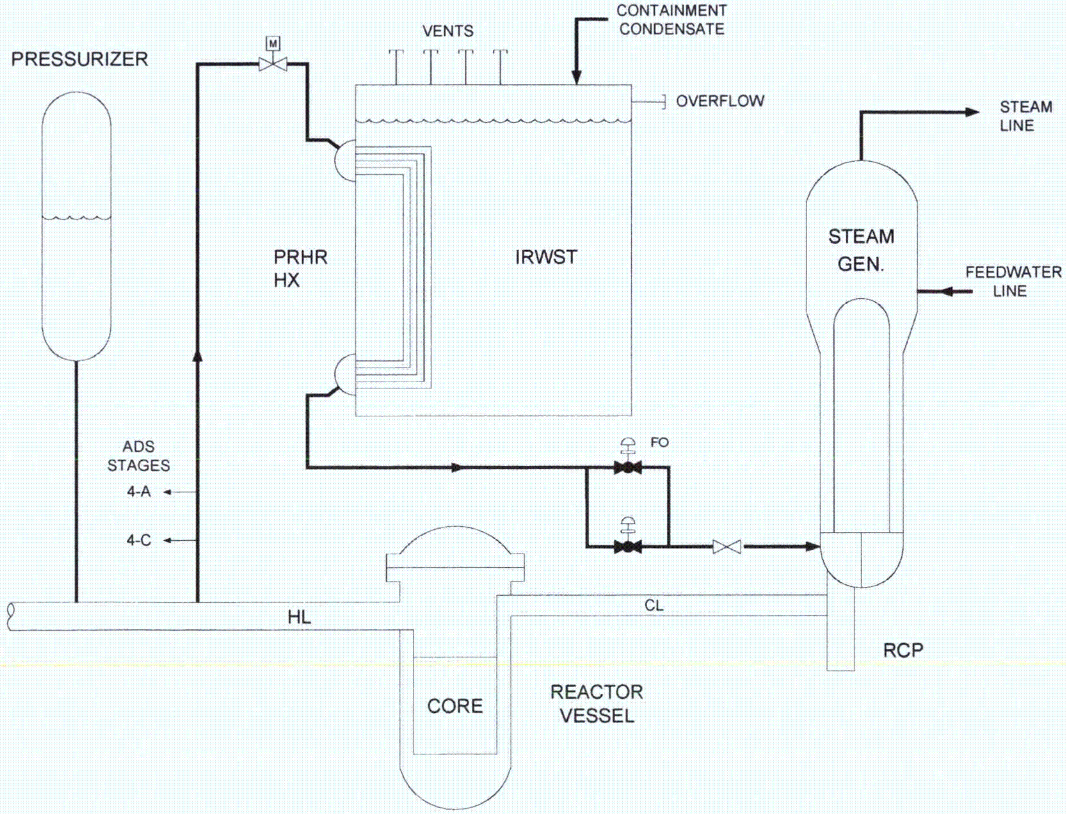
PXS Overview

- PRHR HX
  - Natural circ. Decay heat removal
  - Long term cooling for non-LOCA
- Passive safety injection
  - Core makeup tanks (High Pressure)
  - Accumulators (Intermediate Pressure)
  - IRWST Injection (Low Pressure)
  - Containment Recirculation
  - Automatic RCS depressurization
    - Staged, controlled depressurization
    - Stages 1-3 to IRWST, Stage 4 to containment



Passive Decay Heat Removal

- Normally isolated by two parallel AOVs, fail open
  - Opening 1 AOV actuates RCS cooling via natural circulation
  - AOVs actuated by PMS and by DAS
- IRWST absorbs heat
  - Takes several hours to heat up to saturated
  - Steaming is condensed by PCS and returned to IRWST by gutter



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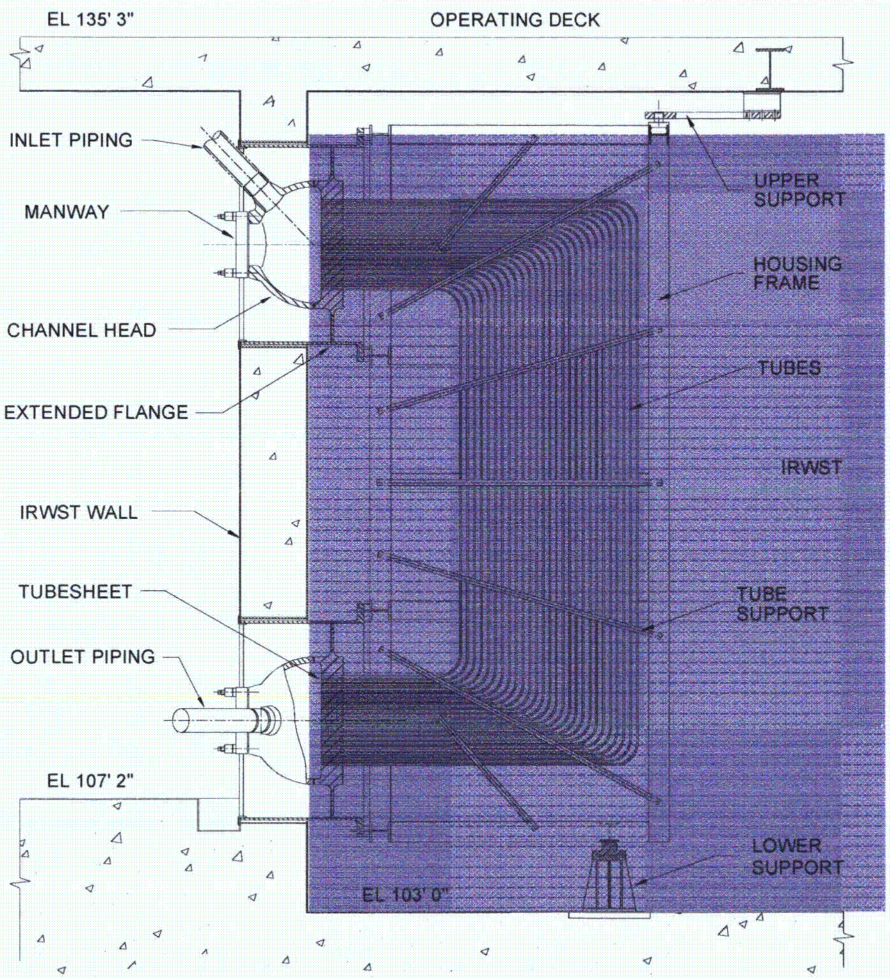
Passive Decay Heat Removal

- Safety Analysis assumes a constant fraction [90%][a,c] of steam to atmosphere is returned to the IRWST
- Return rate to the IRWST is really a function of time
- Multiple mechanisms for condensate losses
- Insufficient return will cause IRWST level to drop
- As PRHR HX tubes become uncovered, performance degrades



Containment Condensate Return

Problem Statement: Excessive condensate losses from the inside Containment Vessel (CV) shell prevent return of sufficient water to the In-Containment Refueling Water Storage Tank (IRWST) to keep the Passive Residual Heat Removal Heat Exchanger (PRHR HX) covered after steaming to meet safe shutdown licensing design criteria

Background:

- Design basis for condensate return was originally defined based on observations from AP600 test program
- Design calculations performed in support of **AP1000** design to confirm condensate return losses
- Calculations challenged by UK regulator as part of GDA assessment
- Confirmatory test program initiated to provide basis for analyses

Current Problem: **Testing performed to quantify losses from obstacles - showed condensate return losses exceeded the [ ]a,c design calculation value. Plant changes have been developed to ensure adequate condensate return.**

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Overview of **AP1000** Changes to Improve Long-Term PRHR HX Operation

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Design Changes To Improve Long-Term PRHR HX Operation After Station Blackout

- Design changes made to PXS to increase condensate return to the IRWST
  - Polar Crane Girder and Internal Stiffener holes blocked and downspouts to IRWST added
    - Additional downspouts added to lower part of PCG
  - Containment Gutter optimized
  - Routing of cables to H2 sensors changed
- Chapter 19E shutdown temperature evaluation needs to be updated to confirm acceptability
- Will be addressed in License/COLA change request

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Design Changes To Improve Long-Term PRHR HX Operation After Station Blackout

- Changes to improve IRWST steam condensate return
  - Block holes in crane girder and stiffener
  - Add down spouts to crane girder and stiffener and route to gutter/IRWST collection boxes
    - Add small downspouts to bottom of polar crane girder
  - Re-route cables to H2 sensors
  - [ ]a,c
  - Modify gutter routing around equipment and personnel hatch

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Current PCG with Downspouts from Top

- PCG is about 8' high

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PCG Revised Design

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Overview of **AP1000** Long-Term PRHR HX Operation Analysis Methodology / Status

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Four Calculations Support The Long-Term Station Blackout Response

1. Containment Response Analysis for the Long Term PRHR Operation
   - New analysis using existing WGOTHIC peak pressure model
   - Revised inputs to maximize IRWST losses
2. Condensate Return to IRWST for Long-Term PRHR Operation
   - New [ ]a,c calculation
3. PRHR HX Sizing / Performance
   - Revision of existing [ ]a,c calculation
4. **AP1000** Safe Shutdown Analysis
   - Revision of existing LOFTRAN analysis
   - Provides input to DCD Chapter 19E

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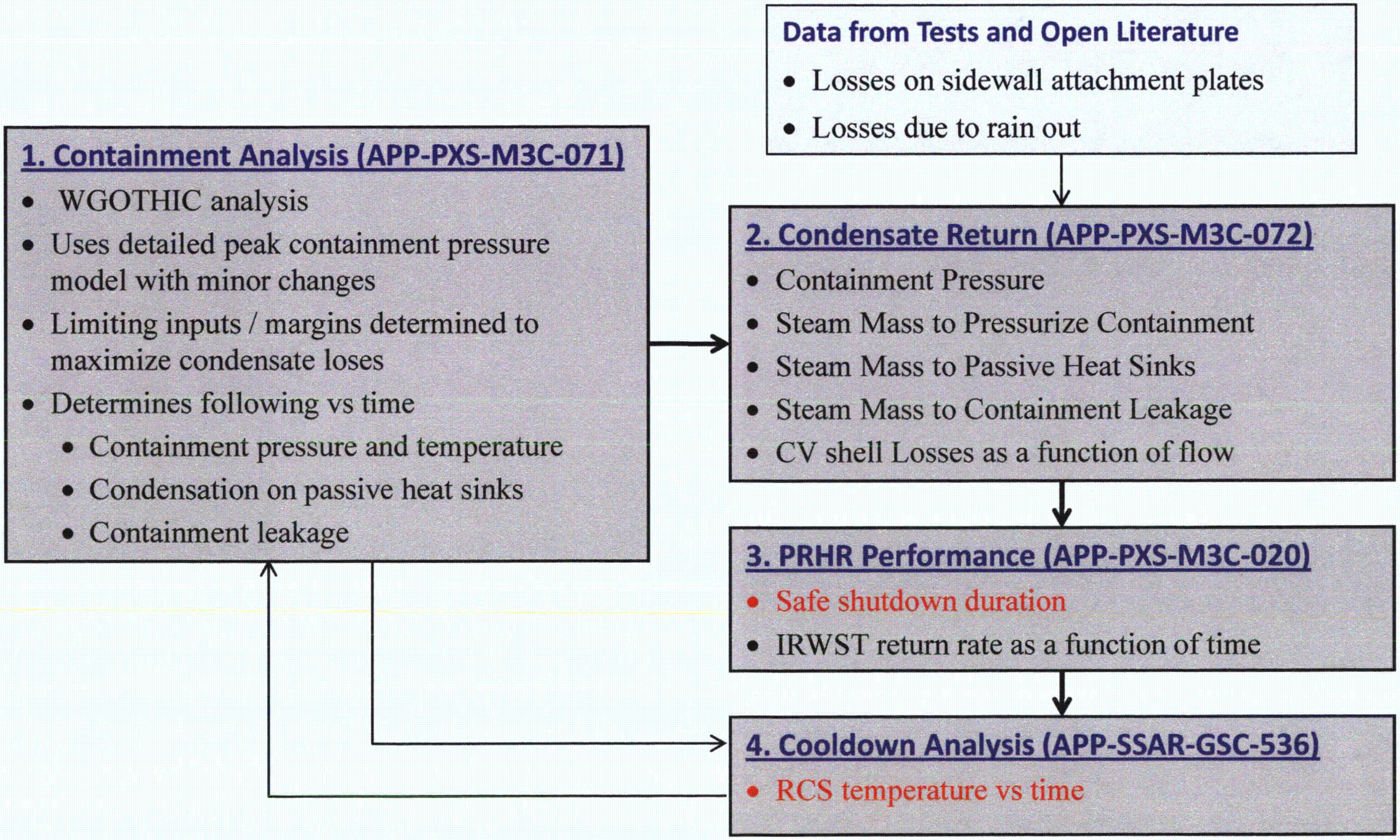
Diagram of Calculation Note Interfaces



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1. WGOTHIC Containment Response Analysis

- Purpose is to quantify maximum IRWST losses
  - Mass of steam condensing on heat sinks
  - Mass of steam in atmosphere
  - Mass of steam lost due to containment leakage
- Uses WGOTHIC peak pressure model
  - Thoroughly reviewed, verified model
    - Confirmed by audit calc performed by NRC and UK regulator
  - Minor additions were made to the model
  - Sensitivity studies performed to identify most conservative inputs and heat transfer assumptions
  - [

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1. WGOTHIC Containment Analysis Inputs / Assumptions

	Peak Pres Analysis	Max IRWST Loss Analysis
Objective	Determine peak containment pres.	Determine maximum IRWST losses
Accident	LOCA (or MSLB)	Loss MFW
M&E input	LOCA & ADS4 mass and energy input	PRHR HX heat input to IRWST
M&E release location	Loop compartment below operating deck	IRWST vents above operating deck

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1. WGOTHIC Containment Analysis Inputs / Assumptions

	Peak Pres Analysis	Max IRWST Loss Analysis
Initial cont. pres.	15.7 psia	15.7 psia[ ]c
Initial cont. temp.	120°F	85°F[ ]c
Initial cont humidity	0%	0%[ ]c
Initial IRWST level	Min.	Min.
Outside air temp	115°F	115°F

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2. Condensate Return to IRWST for Long-Term PRHR Operation

- Purpose is to quantify losses from IRWST:
  - Detailed hand calc note
  - Steam to pressurize containment
  - Steam that condenses on heat sinks other than containment vessel

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2. Condensate Return to IRWST for Long-Term PRHR Operation

- Provides input to 3rd calc which determines the IRWST level vs time

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3. PRHR HX Sizing / Performance

- Purpose is to determine:
  - PRHR HX performance at fixed conditions with natural and forced flow conditions
  - Long-term PRHR HX operation including RCS cooldown to safe shutdown conditions
- Existing calculation
  - First part not changed; second part revised to update losses from IRWST as determined in calc #2
  - Provides input to DCD safe shutdown analysis (calc #4)

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3. PRHR HX Sizing / Performance
Conservative Performance Case

	Current Calc	Revised Calc
Pre-trip core power	102%	102%
Decay heat	ANS'79 + 2 sigma	ANS'79 + 2 sigma
Initial IRWST level	Min	Min

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3. PRHR HX Sizing / Performance Best Estimate Performance Case

	Current Calc	Revised Calc
Pre-trip core power	100%	100%
Decay heat	ANS'79 + 0 sigma	ANS'79 + 0 sigma
Initial IRWST level	Nominal	Nominal

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4. Safe Shutdown Analysis

- Purpose
  - Verify the PRHR HX can cool the reactor coolant system to long-term safe shutdown temperature of 420°F in 36 hours
- Methodology
  - Revision of existing LOFTRAN analysis
    - Includes detailed model of the PRHR HX and the IRWST
    - Uses best estimate assumptions consistent with current DCD analysis in Section 19E

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4. Safe Shutdown Analysis - Assumptions

	Current Calc DCD Rev 19	Revised Calc Departure Analysis
Pre-trip core power	100%	100%
Decay heat	ANS'79 + 0 sigma	ANS'79 + 0 sigma

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Analysis Summary

- WEC is performing detailed analysis of the IRWST condensate return and PRHR HX performance based on approved computer analysis models and test data
  - #1 calc is new analysis that uses WGOTHIC peak pressure model to determine IRWST losses to containment pressurization, passive heat sinks and containment leakage, outputs to calc #2 & #4
    - Systematic study determined what inputs/assumptions are conservative
    - [ ]a,c
  - #2 calc is new hand calc using WGOTHIC results and test results - outputs to calc #3
  - #3 calc is revision of existing calc that determines IRWST level behavior considering losses from IRWST, outputs to calc #4
  - #4 calc is revision of existing LOFTRAN analysis with more detailed / revised input from calc #1 and #3

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AP1000 Long-Term PRHR HX Operation Recent Activity / Status

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Recent Activities

- APOG utilities audited initial versions of calc

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- Detailed design change packages have been developed and are in review / approval process

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Summary of Margin Included in Analysis

- One plant analysis being performed for all **AP1000**s, includes

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Safe Shutdown Criteria With PRHR HX

- DCD Chapter 19E.4.10.2 says
  - PRHR HX cools RCS to 420F in 36 hours
  - *"As discussed in subsection 7.4.1.1, this mode of operation can last for up to 72 hours. However, in about 22 hours after the event, if no ac power is available, or if condensate return is not available, then the operator is instructed to actuate the ADS. Operation of the ADS in conjunction with the CMTs, accumulators, and IRWST reduces the RCS pressure and temperature to below 420°F."*
- DCD Chapter 6.3.1.1.1 says
  - *"The passive residual heat removal heat exchanger, in conjunction with the passive containment cooling system, is designed to remove decay heat for an indefinite time in a closed-loop mode of operation"*
  - The term "indefinite" is used throughout the DCD in this context

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Safe Shutdown Criteria With PRHR HX

- Licensing Background
  - Safe shutdown was discussed for AP600
  - Staff recommended in SECY-94-084 that
    - *"Commission approve the EPRI's proposed 215.6C (420F) or below, rather than cold shutdown condition required by RG 1.139, as a safe stable condition, which the passive decay heat removal systems must be capable of achieving and maintaining following non-LOCA events"*
    - *"That the passive safety injection system and the associated depressurization system can also protect against the loss of reactor coolant inventory during long-term passive RHR operation"*
  - Staff recommended in SECY-95-132 that
    - *"No requirement with respect to the supporting systems to replenish the water pool will be imposed if the plant is design so that sufficient pool water can be maintained for long-term operation of the PRHR without being replenished by support systems. For example, a plant may be designed to maintain the pool water through a closed loop operation in which the steam from boiloff of the pool water is condensed and the condensate is returned to the water pool."*

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Safe Shutdown Criteria With PRHR HX

- It is proposed that a quantitative criteria be adopted for "indefinite" / "long-term" safe shutdown operation using PRHR HX
  - Recognize that ADS based safety-related feed / bleed provides alternate means of maintaining safe shutdown
  - Therefore, safe shutdown using PRHR HX operation only needs to last long enough to reduce probability of need to resort to ADS

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Safe Shutdown Criteria With PRHR HX

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Summary of **AP1000** Long-Term PRHR HX Operation Changes / Analysis

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Summary

- Some additional plant changes will be made to add margin
  - Capture condensate that forms on containment vessel inside polar crane girder

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- Supporting plant analysis will incorporate conservative margin assumptions

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- Final plant change packages and supporting analysis packages are nearing completion

Future Activities / Dates

- Complete review / sign off plant change packages (early January 2014)
- Complete review / sign off analysis packages (early January 2014)
- Present analysis packages to NRC and make available for their audit (1/23/14)
- NRC issue RAIs - TBD
- RAI responses - TBD

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