Application of CPSES Accident Analysis Methodologies to Replacement Steam Generators

TXU Power

October 18, 2005

TXU Power Participants

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Agenda

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Purpose of today's discussions

Overview of the Replacement SG Project

- Replacement SG design description
- Operating strategy changes
- Schedules

Background on TXU's analysis capabilities and methods

Application of TXU's non-LOCA transient analysis methods to the RSG

Application of TXU's LOCA analysis methods to the RSG

Concluding discussions

Purpose

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Familiarize NRC reviewers with TXU Power's LOCA and non-LOCA accident analysis methodology topical report supplements supporting TXU's Steam Generator Replacement Project

Answer questions to facilitate the review process as much as possible

Comanche Peak Steam Electric Station (CPSES) Unit 1

4-loop Westinghouse NSSS with large dry containment

Part of two-unit site with shared control buildings

Originally rated at 3411 MWth, now at 3458 MWth with MUR uprate

Current SG: Westinghouse D4 with integral preheater

- Alloy 600 SG tubes
- Approximately 3% tube plugging level

Replacement SG: Westinghouse Δ76 with feed ring

- Alloy 690 SG tubes

During same outage (1RF12 in Spring, 2007), replace reactor vessel upper head and support structures (missile shield, CRDM cooling ductwork, etc.)

Replacement SG Design Features

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Westinghouse Δ76 feed ring design

Similar to Δ75 design in use at Shearon Harris and V.C. Summer

Relative to D4 SG, the Δ76 SG has:

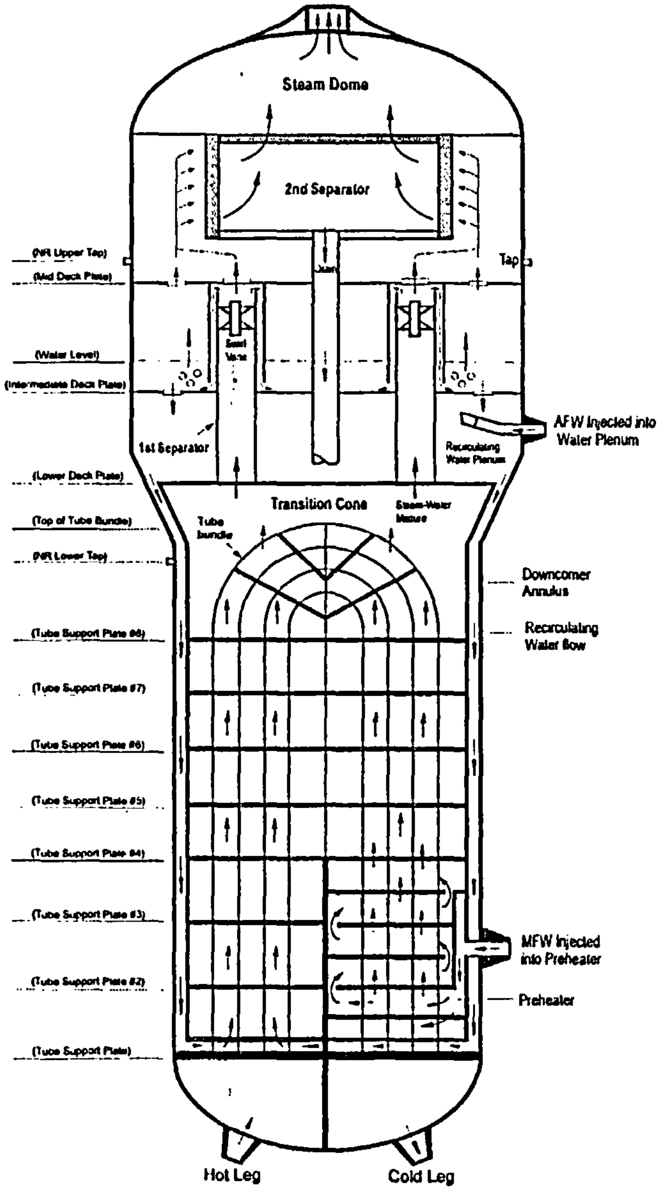
- 76,000 ft^2 heat transfer area (vs. 48,000 ft^2)
- 5532 U-tubes (vs. 4578)
- ¾" tube OD (same)
- 1.03" triangular pitch (vs. 1.0625" square pitch)
- Top of tube bundle 8 ft higher
- Separate Main feedwater and auxiliary feedwater piping nozzles
  - Eliminates delay time for purging AFW lines of hotter MFW fluid

Replacement SG Design Features

Relative to D4 SG, the Δ76 SG has:

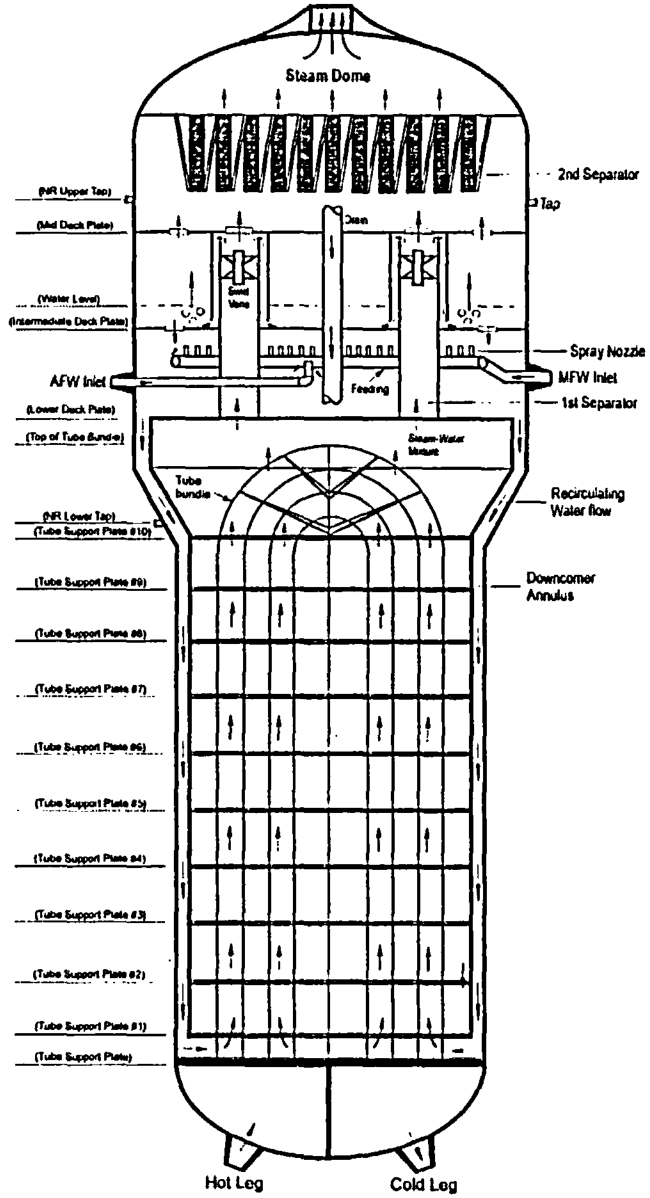
- Essentially the same exterior envelope
- 5330 ft^3 Shell-side volume (vs. 5954 ft^3)
- Increased Tube Side Volume
  - Approximately 825 ft^3 additional RCS volume
  - ~ 8% increase
- Circulation Ratio of ~ 4 (vs. ~2.4)
- Slightly larger secondary fluid mass
- 251" narrow range water level span (vs. 233")

Replacement SG Design Features



← D4 SG

Δ76 SG →

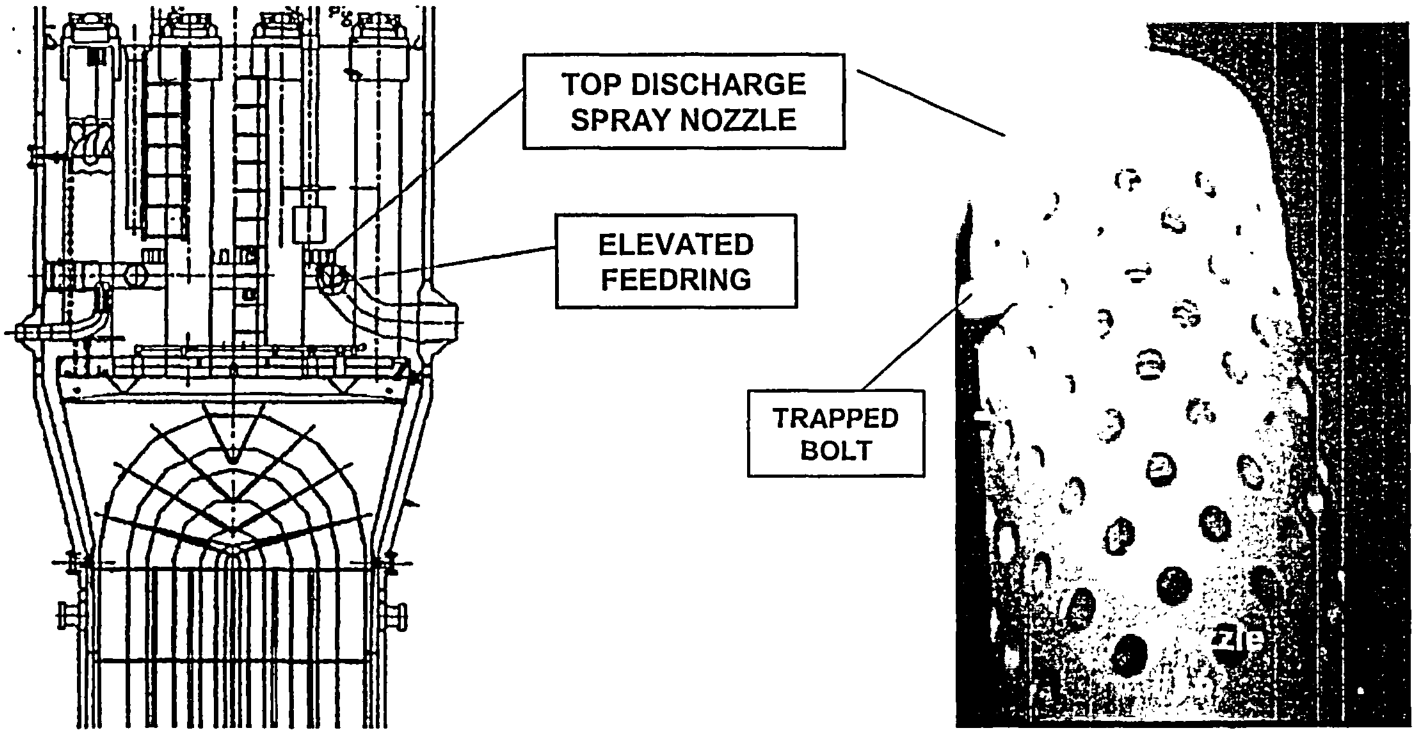


Replacement SG Design Features

Elevated feedring with top discharge nozzles

Nozzle holes sized to trap loose parts

- Hole diameter less than tube to tube clearance



Replacement SG Feedwater Distribution Ring

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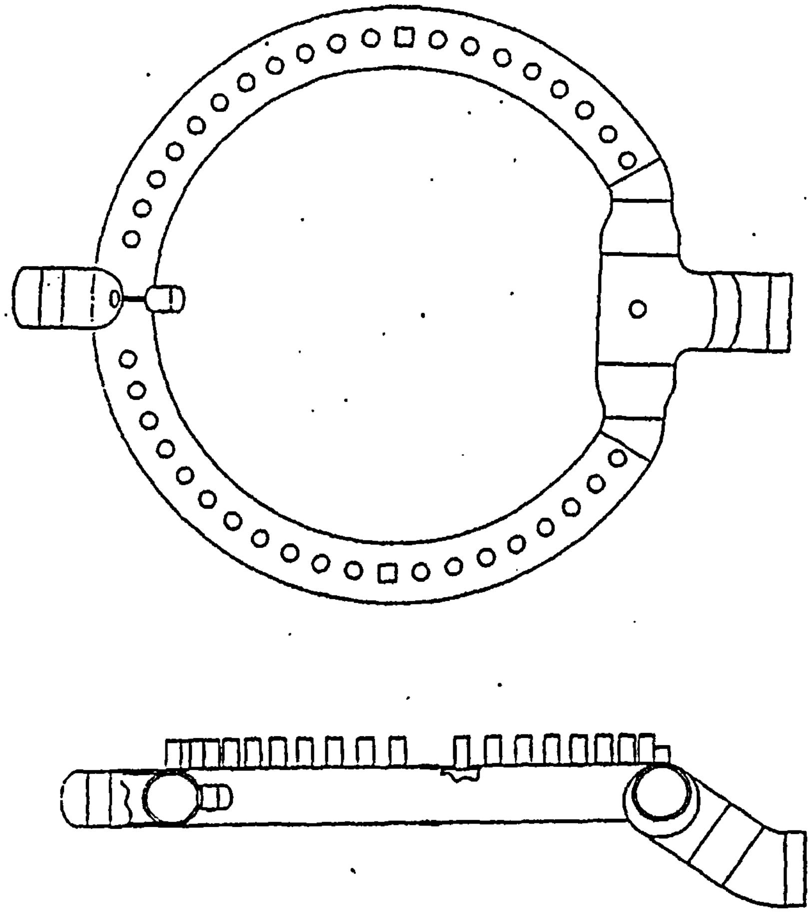

Operating Strategy Changes

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Generically, design for a Tavg range of 589.2°F to 574.2°F

Limit Steam Pressure to 1000 psia

- Initially, set full power Tavg ~ 585°F @ 3458 MWth
- Raise Tavg toward 589.2°F as SG heat transfer capability decreases (due to fouling or tube plugging)

Design to a much tighter Tavg range (e.g., ±1°F) on cycle-specific basis

Lower values of Tavg are intended for future use in Tavg coastdown

Schedules

March 2007	Steam Generator Replacement Outage Begins

Supporting Milestones:

January 2005	Submit Topical Report Supplements
October 2005	Significant "N-1" SGRO prep work during 1RF11
November 2005	Submit required changes to the Tech Specs
March 2006	NRC approval of Topical Report Supplements
May 2006	Submit any License Amendments identified through 10CFR50.59 Evaluations
February 2007	NRC Approval of RSG-related licensing actions

Background on TXU's Analysis Capabilities

TXU developed in-house core design and safety analyses methodologies

- CASMO/SIMULATE core design methods
- RETRAN/VIPRE non-LOCA transient analysis methods
- LOCA analysis methods derived from Siemens Power Corp. methods

Topical Reports reviewed and approved by NRC

- First topical report approved in 1988
- All were approved by 1993

Used to support 15 reload core configurations for Comanche Peak Steam Electric Station

Expertise and models applied to a wide variety of plant support issues including IPE/PRA success criteria, startup testing, simulator qualification, design modification evaluations, resolution of emergent issues, etc.

Background on TXU's non-LOCA Analysis Methods

TXU Power

Current Non-LOCA methods:

RXE-89-002-A, "VIPRE-01 Core Thermal-Hydraulic Analysis Methods for Comanche Peak Steam Electric Station Licensing Applications"

RXE-91-001-A, "Transient Analysis Methods for Comanche Peak Steam Electric Station Licensing Applications"

RXE-91-002-A, "Reactivity Anomaly Events Methodology"

TXX-88306, "Steam Generator Tube Rupture Analysis"

RXE-91-005-A, "Methodology for Reactor Core Response to Steamline Break Events"

RXE-94-001-A, "Safety Analysis of Postulated Inadvertent Boron Dilution Event in Modes 3, 4, and 5"

Background on TXU's non-LOCA Analysis Methods

Each topical report was individually reviewed and approved; however,…

Through the RAI process, the scope of RXE-91-001-A came to include the generalized non-LOCA accident analysis methodology

Now consider RXE-91-001-A to be the "umbrella" non-LOCA topical report

To address generic activities such as the replacement SG, consider a supplement to RXE-91-001-A to be appropriate

Background on TXU's non-LOCA Analysis Methods

Currently licensed approach to SG models:

- Single-node model used in SGTR and SLB analyses
- Three-node model used in other non-LOCA analyses
  - Internal recirculation loop is not modeled
- Detailed, multi-node model used to determine mass equivalency for simulating SG water level trip functions

Coarsely-noded model justified through comparisons of integrated system responses to CPSES transient data

Background on TXU's non-LOCA Analysis Methods

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Any Questions or Comments?

Application of TXU's non-LOCA transient analysis methods to the RSG

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During initial RSG project planning, all topical reports reviewed to assess effects of RSG on approved analysis and model methods

- Analysis and modeling methods remain applicable
- For those analyses which are relatively insensitive to the SG model, still required to update SG model with replacement SG geometrical attributes
- For those analyses which show some sensitivity to the SG model, require a different SG model (preheater vs. feed ring)
  - Conforming modifications to SG water level trip functions

Also assessed the effects of the replacement SG on the course of transients and accidents

- Only feedwater line break has any relevant differences
  - Due to elevated feed ring, early transient response similar to steam line break

Application of TXU's non-LOCA transient analysis methods to the RSG

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Due to extensive discussions of preheat SG design in RXE-91-001-A, decision made to submit topical report **supplement** to describe application of approved TXU methods to feed ring SG design

Current methods will continue to be used to support Unit 2

Topical Report Supplement

ERX-04-005, "Application of TXU Power's Non-LOCA Transient Analysis Methodologies to a Feed Ring Steam Generator Design"

ERX-04-005 supplements the approved TXU non-LOCA transient analysis methodology topical reports (via RXE-91-001-A)

Included in the supplement:

- Assessments of effects of the replacement SG on the transient-specific methodology
- Identification of new models required for specific analyses
- Assessment of transients with different phenomena or sequence of events
- Demonstration analysis of the feedwater line break accident

Assessments of effects of the replacement SG on the non-LOCA analysis methodology

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General analysis methodology remains applicable

For each transient or accident:

- Ensure important phenomena are modeled
- Identify conservative initial conditions and equipment performance characteristics for each relevant event acceptance criterion
- Consider loss of offsite power where required
- Identify limiting single active failure

Identification of different required models

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Generically:

- Modify coarse-node SG to remove preheater (if previously modeled)
- Update model to reflect replacement SG geometry

Feedwater line break (FLB) - specific

- Replacement SG blowdown is predominantly steam (vs. liquid for D4 SG)
- Necessitates a different SG model

Assessment of transients with different phenomena or sequence of events

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Only feedwater line break identified as different

FLB with a preheat SG:

- Initially, saturated liquid blowdown through preheater box with integral flow restrictors in the feedwater nozzle
- Essentially, the SG inventory is being drained
- Relatively little heat removal due to low-quality fluid discharge

FLB with a feed ring SG:

- Short duration of saturated fluid relief through flow distribution nozzles and into the feed ring, exiting the SG through a nozzle with no flow restrictors
- Once flow distribution nozzles uncover (very quickly in accident), saturated steam blow down (similar to steam line break)
- After inventory is exhausted, heatup is similar to preheat SG, but greater RCS cooldown has previously occurred

SG model changes

For FLB analyses, chose to adopt feed ring SG model developed by Westinghouse

- Relatively detailed model including the internal recirculation loop
- Based on RETRAN-02
- Benchmarked against plant data
- Model methodology reviewed and approved by NRC
  - WCAP-14882-P-A
- Widely used by Westinghouse
- Demonstrated to be robust through internal testing

Noding diagram is contained in WCAP-14882-P-A (Westinghouse proprietary)

For configuration control convenience, chose to use this model for all non-LOCA transients and accidents except for SGTR and SLB

SG water level model changes

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For the LOAC and LOFW analyses, detailed vendor design information used to assess the mass equivalency for the SG water level –low-low trip functions

- Essentially the same as current practice for determining mass equivalency

For the FLB analysis, SG water level indication based on ΔP between instrument tap locations

- Corrected for limitations of the model
  - Lower tap is near bottom of a homogenous volume, which results in an artificially high mass between tap elevations
- Approach is essentially the same as that currently used with TXU's detailed SG model when determining the mass equivalency for the coarsely-noded SG model

RSG Feedwater line break

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Due to early uncovery of elevated feed ring, early transient response similar to steam line break

The RSG feedwater line break event results in:

- Initial cooldown as faulted SG depressurizes
- Subsequent Reactor Coolant System heatup due to degradation of heat sink
- Ultimate mitigation when auxiliary feedwater flow is sufficient to remove decay heat

Limiting single failure remains in the Auxiliary Feedwater System where:

- One motor-driven auxiliary feedwater pump is assumed to feed only the faulted SG, with no credit for heat removal
- The second motor-driven auxiliary feedwater pump (feeding two intact SGs) is the assumed single failure
- The turbine-driven auxiliary feedwater pump requires a steam generator water level –low-low signal in two or more SGs to start

RSG Feedwater line break

For larger break sizes, the rapid steam pressure decrease leads to early steam line isolation and safety injection actuation

- Significant delay in obtaining 2nd steam generator water level – low-low signals from intact, isolated steam generators

For smaller break sizes, the low steam pressure setpoint may not be reached for several minutes, but MFW can still be delivered to intact steam generators

- Loss of heat sink effects bounded by maximum break size

Feedwater line break – Comparisons to D4 analyses

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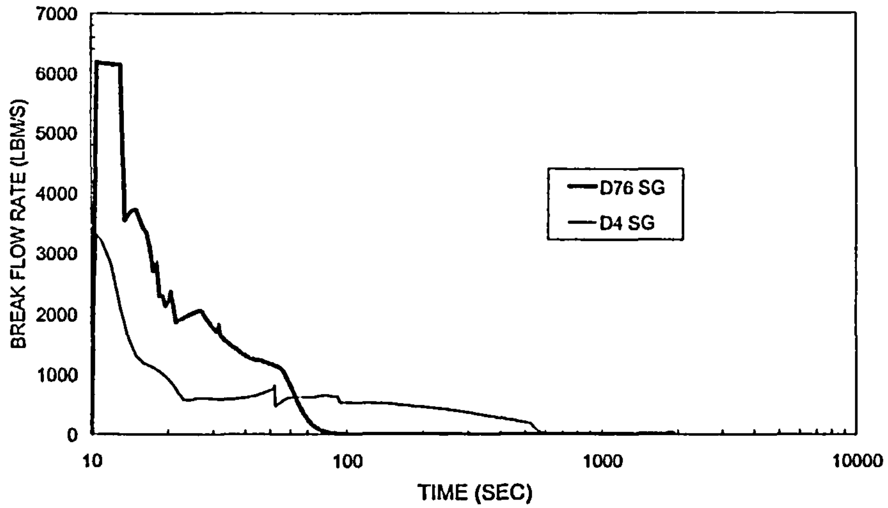
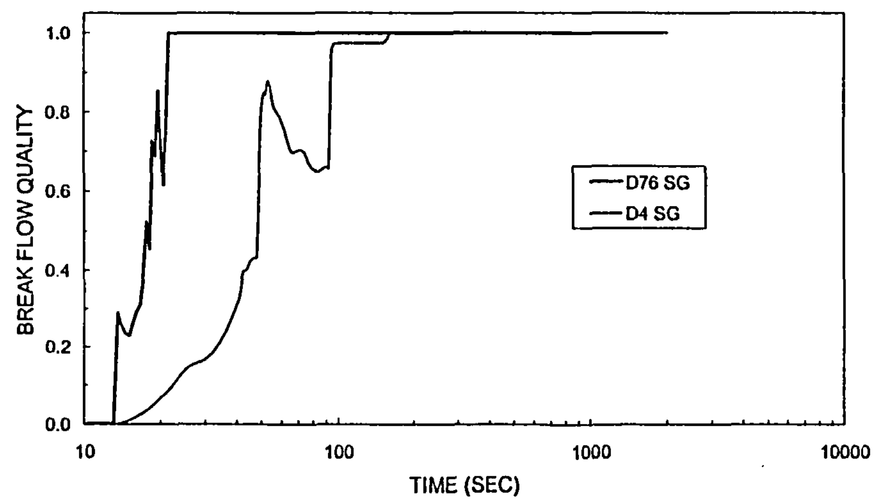
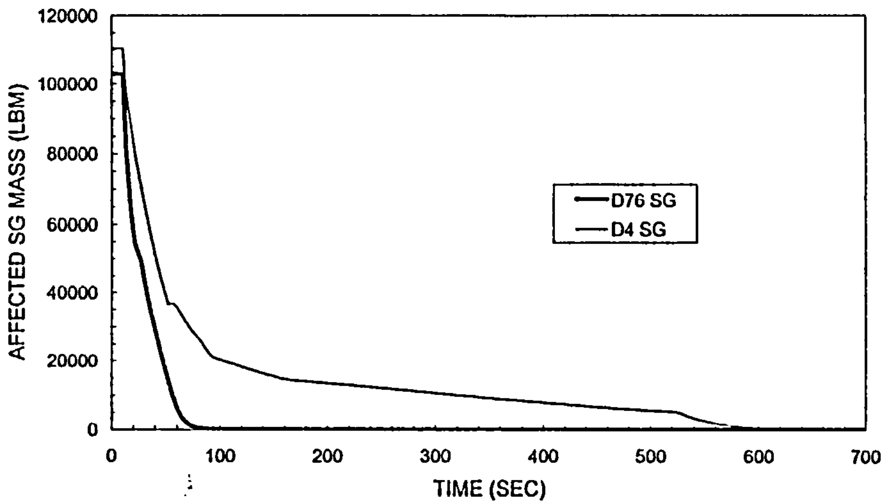
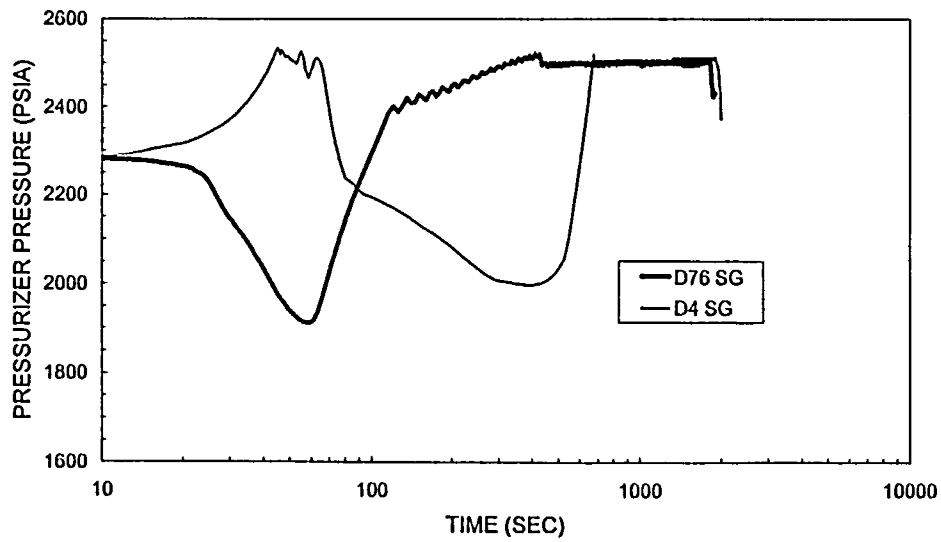




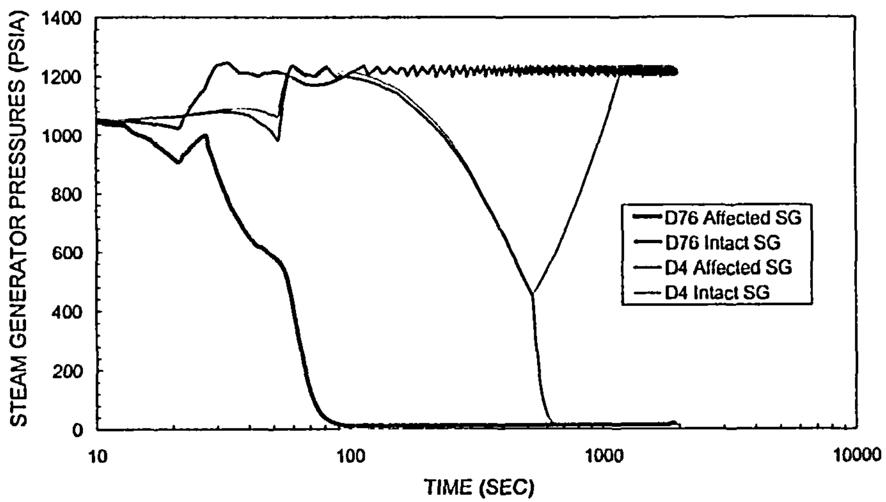
Feedwater line break – Comparisons to D4 analyses





Feedwater line break – Comparisons to D4 analyses

TXU Power



Summary of non-LOCA Topical Report Supplement

TXU Power

Descriptions of original and replacement SG designs and characteristics

Assessments of the effects of the replacement SG on the approved non-LOCA accident analysis methodologies

Discussion of the replacement SG model

Description of the revised feedwater line break analysis methodology

- Including comparisons of sample analysis results to results with original SG

RSG Supplement to TXU's LOCA Methodologies

TXU Power

Hugo C. da Silva

October 18, 2005

Purpose:

Familiarize NRC Reviewers with TXU's LOCA Topical ERX-04-004 entitled:

*"Replacement Steam Generator **Supplement** to TXU Power's Large and Small Break Loss-of-Coolant Accident Methodologies"*

- TXU already has NRC-approved ECCS Evaluation Models for Large and Small Break LOCA
  - TXU is requesting that this topical be considered as a **supplement** to be applied only to Unit 1 with the Replacement Δ-76 SG's
    - The methodology changes proposed are simply due to the new RSG design
  - The existing NRC-approved methodologies will continue to be applied **unchanged** to Unit 2 with the current D-5 SG's

Approach:

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- A differential approach was adopted for the Topical Report.
  - Only the methodology changes are presented. The unchanged parts of the methodology are not repeated. The changes are those required by the new RSG design.
  - This approach was intended to streamline the topical and its review.
  - This approach also avoids the need to make portions of this topical proprietary by referencing proprietary figures and statements in previously NRC-approved topical reports.

- Still, this Topical Report includes a complete set of demonstration analyses for both Large Break and Small Break LOCA.
  - The demonstration analyses have the same scope, i.e., include all the same relevant sensitivities, as the analyses submitted to the NRC with the original methodologies.

Affected Elements:

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- Small Break LOCA
  - Only the system thermal-hydraulic response was potentially affected. Therefore, the ANF-RELAP input was the only thing changed.

- Large Break LOCA
  - Only the system thermal-hydraulic response was potentially affected. Thus, only RELAP4 and REFLEX inputs were affected.

LBLOCA (RELAP4 & REFLEX) Model Changes:

TXU Power

- Replaced existing steam generator geometry with Δ-76 geometry
  - The existing nodalization structure was preserved.
- The Large Break remains the LIMITING LOCA

LBLOCA Demonstration Analyses:

TXU Power

- Break spectrum (required by Appendix K)
  - 3 Split breaks cases were run (A = 2.0, 1.6 & 1.0 x Cold Leg Area).
  - 3 DEG breaks cases were run (C_D = 1.0, 0.8 and 0.6).
    - C_D = 1.0 was limiting and became the "Base Case"

- Single failure
  - Loss of 1 ECCS train vs. Loss of 1 train of LPI (RHR)
    - Loss of 1 train of RHR was limiting

- Convergence criterion (Optional)
  - Varied RELAP4 convergence criterion, ESPW = 0.5 -> 0.25
    - Little difference between cases, shows robustness.

LBLOCA RSG Δ-76 vs. D-4 Results :

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- Effect of SG type on LBLOCA response is predictable and small
  - PCT occurs slightly earlier in the Δ-76 than in the D-4
    - This is due to the larger RCS volume inventory in the Δ-76, which retains more water at the end of blowdown and therefore quenches sooner.
      - As a result, the PCT is lower in the Δ-76 than in the D-4.
  - Sensitivities lead to the same conclusions in the Δ-76 and the D-4
    - Break Spectrum: DEG break with C_D = 1.0 remains limiting
    - Single Failure: Loss of 1 train of RHR remains limiting
- LBLOCA remains limiting with respect to SBLOCA

SBLOCA (ANF-RELAP) Model Changes:

TXU Power

- Replaced existing steam generator geometry with Δ-76 geometry
  - The existing nodalization structure was preserved.
  - No MFW "purge" flow in the RSG. Might impact loop seal clearing.

- Minor change in the upper downcomer (Fig. 2.3 of RXE-95-001-P-A)
  - Combined previously-split volumes to improve robustness

SBLOCA Demonstration Analyses:

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- Break spectrum (required by Appendix K)
  - 3 inch, 4 inch and 5 inch breaks were run.
    - 4 inch was limiting and became the "Base Case"
- Cross-flow sensitivity study (required by Methodology)
  - Same as in previous topical report (RXE-95-001-P-A).
    - Study was performed for the "Base Case" .
    - Little difference from varying the X-flow K. Nominal "K" was limiting.
- Time step sensitivity study (optional)
  - Only required by the methodology if certain criteria are met. They were not. However, this study was performed anyway.
    - Study was performed for all break sizes.
    - Little difference between cases, shows robustness.
    - Selected time step was limiting.

SBLOCA RSG Δ-76 vs. D-4 Results :

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- Break Spectrum (Required by Appendix K)
  - 4 inch limiting for Δ-76 whereas 3 inch limiting for D-4.
    - This is due to differences in transient liquid distributions, consistent with the Δ-76's larger RCS volume & taller tube bundle

- Cross-flow sensitivity study
  - Similar conclusions to previous (D-4) topical report:
    - Nominal K remains more limiting than 10xK and K/10
    - Differences between results varying K were not significant

- Time step sensitivity study
  - Similar conclusions to previous (D-4) topical report:
    - Differences between results varying time step were not significant.
    - Selected time step remains limiting

SBLOCA RSG Break Spectrum Results:

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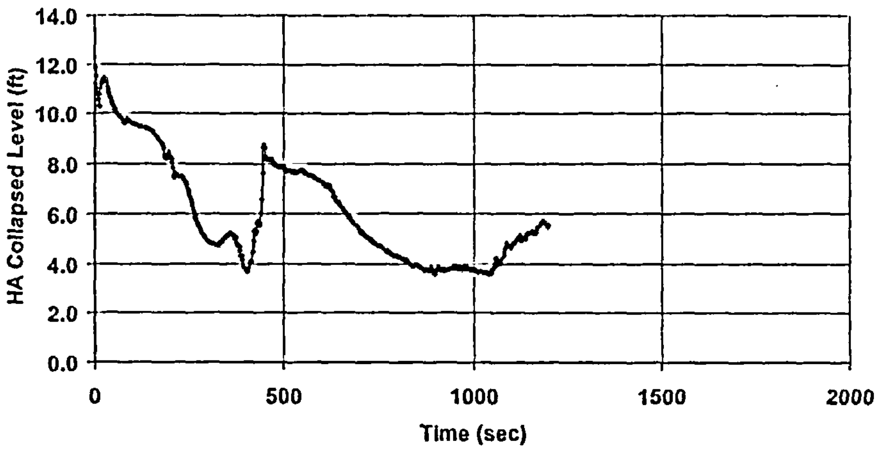
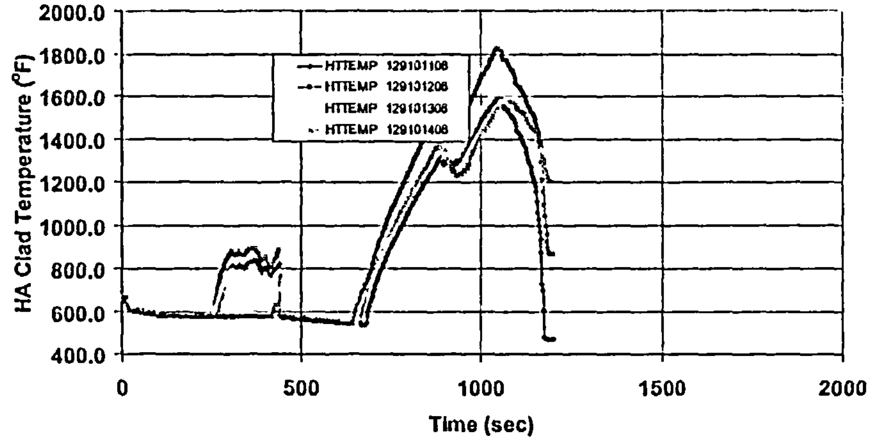
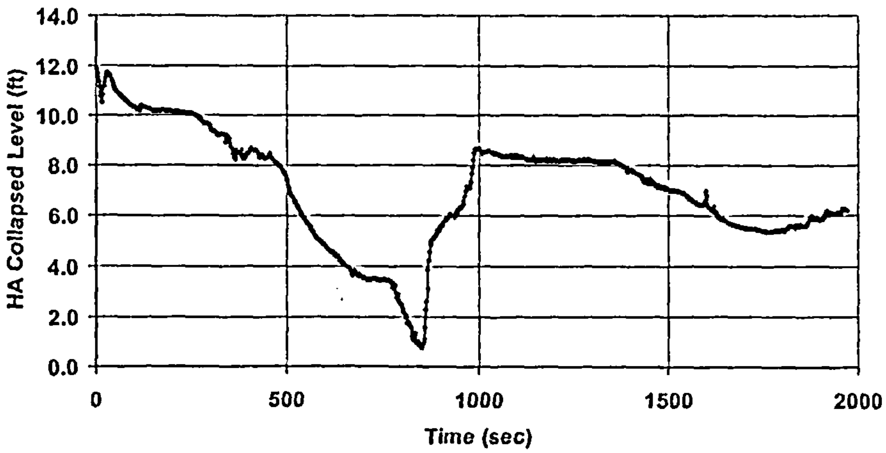
CPSES-1 SBLOCA D76 RSG - 4-Inch Break



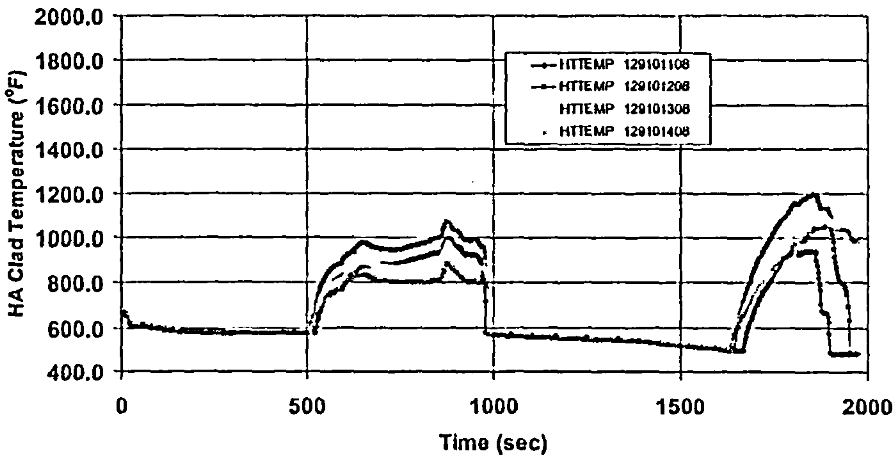
CPSES-1 SBLOCA D76 RSG - 4-Inch Break



CPSES-1 SBLOCA D76 RSG - 3-Inch Break



CPSES-1 SBLOCA D76 RSG - 3-Inch Break



SBLOCA RSG X-Flow & Time Step Sensitivities:

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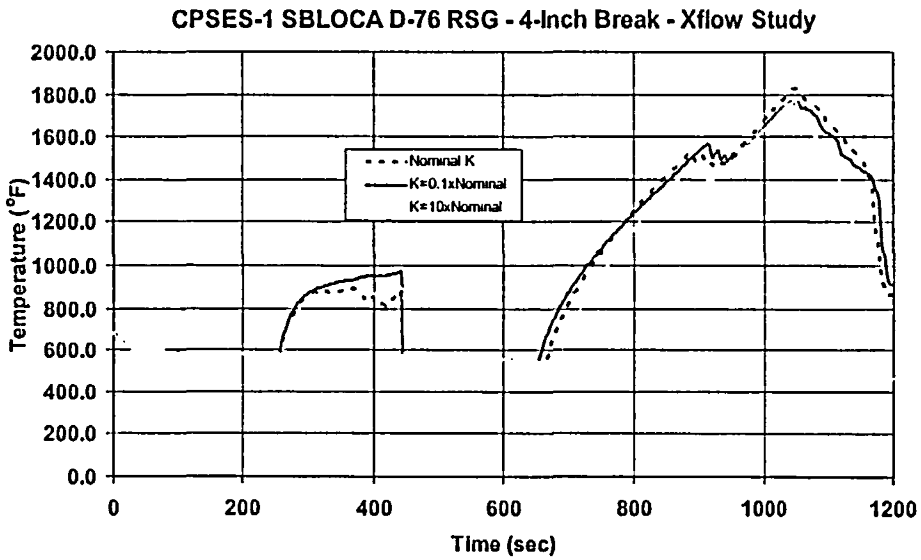

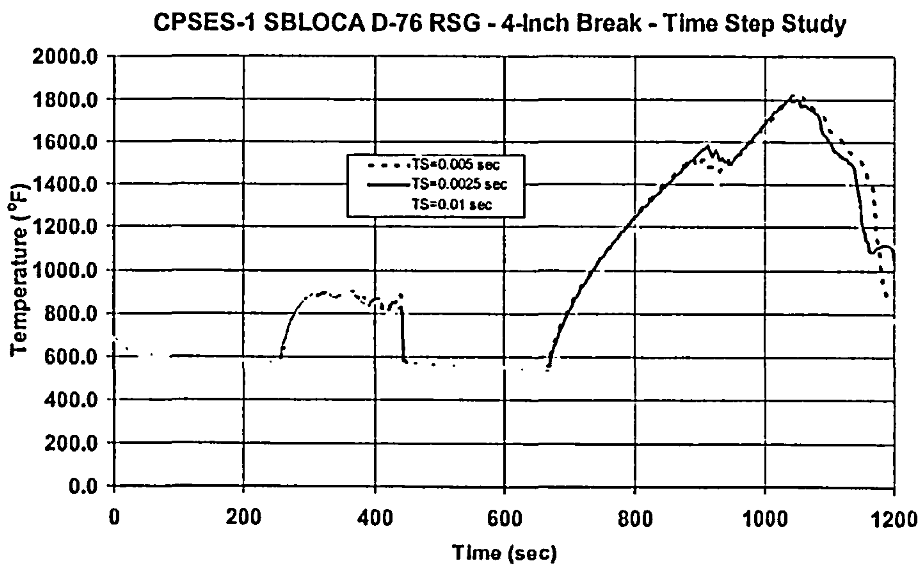

LOCA Overall Conclusions

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- For **BOTH** the Large and Small Break LOCA:
  - Only system thermal-hydraulic response was potentially affected
    - RELAP4 and REFLEX SG input change for LBLOCA
    - ANF-RELAP SG input change for SBLOCA (downcomer node change)
  - A complete set of demonstration analyses was performed
    - LBLOCA PCT occurs sooner and is lower in the Δ-76 vs the D-4
      - Larger RCS volume → higher post-blowdown lower plenum inventory
    - SBLOCA limiting break 4 inch in the Δ-76 vs 3 inch in the D-4
      - Δ-76's larger RCS volume & taller tube bundle → differences in RCS transient liquid distributions
    - All Other SBLOCA and LBLOCA analyses show similar trends and conclusions in the Δ-76 as in the D-4
  - The proposed methodologies are essentially the same as those previously approved and extensively used for both CPSES units with Model D SGs

General Discussions

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Any Comments or Questions?

Summary

TXU Power's non-LOCA and LOCA analysis methods have been reviewed and approved by the NRC

Analysis methods have been applied to support 15 reload core configurations for CPSES since 1993

Similar methods and models have been used extensively for a variety of plant-support applications

TXU engineers are well-versed in the use of these tools, which provide good representation of the design and operation of CPSES

Extending the application of these methods to feed ring SG design

Assessed the continued applicability of the methods

Updated models where appropriate

Continue to apply same proven methods and modeling approaches to RSG