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**The Development of a Realistic LOCA Evaluation Model
Applicable to the Full Range of Breaks Sizes:
Westinghouse Full Spectrum™ LOCA (FSLOCA™)
Methodology**

Dr. Cesare Frepoli
Fellow Engineer
Westinghouse Electric Company

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Outline

- Historical overview Westinghouse LOCA Safety Analysis Methodologies
- Industry and regulatory drivers for improved realistic (Best-Estimate) safety analysis methods
- Introduction to the Westinghouse Full Spectrum LOCA Evaluation Model:
 - Functional requirements
 - Major code models improvements and assessment
 - Approach to the uncertainties
- Conclusions

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FULL SPECTRUM LOCA



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Current (Licensed) Westinghouse LOCA Technology

Large Break LOCA

- Best-Estimate Methods Based on WCOBRA/TRAC (PD2)
 - ASTRUM (2004), CQD (1996)
 - Valid from 1 ft² (0.093 m²) to DEG (2 * 4.12 ft² (0.383 m²))

Small Break LOCA

- Appendix K Methods Based on NOTRUMP (1985)
 - Typical applications to 8 in (52 cm) only (0.35 ft² (0.033 m²))

Intermediate Break LOCA

- Not Analyzed, Historically Considered Non-Limiting

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Full Spectrum LOCA PIRT Scenario Identification and Partition

LOCA Scenario:

- *The break size considered includes any break size such that break flow is beyond the capacity of the normal charging pumps up to and including a double ended guillotine rupture with a break flow area two times the pipe area*
- **A Full Spectrum LOCA Integrated PIRT was developed**
- **Significant Improvement to WCOBRA/TRAC, in particular to handle smaller break LOCA scenarios**
 - **New code version renamed WCOBRA/TRAC-TF2**



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Code Development Overview

- **Coupling with TRAC-PF1(which now replaces TRAC-PD2)**
- Addition of Non-Condensable Transport Capability in the 3D Module of WCOBRA/TRAC-TF2
- Upgrades to several models in both 1D and 3D modules. Improvements include:
 - A new horizontal flow regimes map
 - Safety injection condensation and non-condensable condensation suppression models
 - Enhancement to the core heat transfer package



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Code Assessment Approach

- WCOBRA/TRAC was originally subjected to an extensive assessment against Large Break LOCA phenomena:
 - More than 100 experiments originally used to validate against key phenomena
 - WCOBRA/TRAC-TF2 is assessed against the same test matrix for the Large Break LOCA scenario/phenomena to confirm performances
- Assessment matrix now augmented with several SETs and IETs to cover SB and IB LOCA and scenario/phenomena
- The assessment also includes modeling of standard numerical problems and analytical benchmarks which are available in the literature



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Small Break LOCA SETs

Small Break Process	Test	Comments
Break Flow	EPRI-NP-4556 +additional Marviken Dataset represents more than 3500 points from 40 geom., and 10 facilities, containing data: 13 < P < 2500 psia (172.4 bar) 0 < L < 90.55 in (2300 mm), 0.018 in (0.464 mm) < D < 19.7 in (500 mm).	Available data appears to span PWR ranges of conditions for break area, upstream subcooling, flow quality. (V. Ilic, S. Banerjee and S. Behling, "A Qualified Database for the Critical Flow of Water", EPRI-NP-4556, May, 1986.)
Mixture Level	ORNL, Westinghouse G-1 Loop, GE Blowdown	Data covers PWR expected range of pressure and bundle power.
Horizontal Flow Regimes	JAERI-TPTF Tests	Horizontal stratified regime transitions predicted according to Modified Taitel-Dukler map.
Loop Seal Clearance	UPTF Loop Seal Tests	Data covers full scale geometry, provides information for range of Jg that covers PWRs.

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Small Break LOCA - SETs

Small Break Process	Test	Comments
Fuel Rod Models: Nuclear Rod Models Heat Transfer	Various sets of test data from LBLOCA assessment ORNL INEL Post-CHF Data	Fuel rod models were assessed and quantified for large break. Data representative of SBLOCA conditions added.
Steam Generator Hydraulics	ROSA NC	Prediction of flooding in SG tubes at PWR range of conditions.
Pump Performance	Pump Specific Data from LBLOCA	Empirical pump data; assessed for large break LOCA.
SI Condensation	COSI Tests, UPTF8, ROSA SB-CL-05	High pressure and Low Pressure SI condensation.

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Small Break LOCA - IETs

Small Break Process	Test	Comments
Break Flow, entrainment at Break - Off Take	LOFT L3 Series ROSA: 10% CL (side), 5% CL (side), 2.5% CL (side), 2.5% CL (top), 2.5% CL (bottom), 0.5% CL (side)	Single and two-phase critical break flow measurements available. Orientation effect.
Mixture Level	ROSA: 10% CL, 5% CL, 2.5% CL, and 0.5% CL, Semiscale 7-10D	Range of break sizes. Vessel inventories and system wide mass distributions.
Steam Generator Hydraulics	ROSA NC LOFT L3 series	Provides information on system wide phase separation, primary-secondary heat transfer.
Loop Seal Clearance	ROSA: 10% CL, 5% CL, 2.5% CL, 0.5% CL, and additional 5% CL with higher Core Bypass	Provides information on Loop Seal Clearance phenomena.
Fuel Rod Models	LOFT (4 tests), ROSA SB-CLs	Nuclear rods. Clad heatup & PCTs.
IBLOCAs	LOFT L5-1/L8-2	A 14 in (356 mm) ACC line Break ¹²

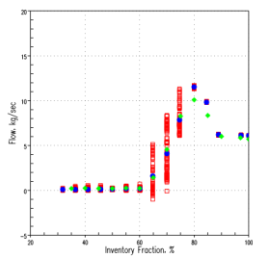
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FULL SPECTRUM LOCA

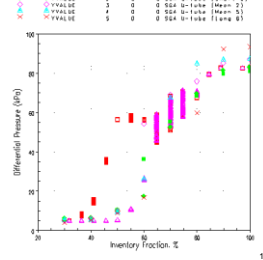


WCOBRA/TRAC-TF2 – Sample Results from IETs Assessment – Natural Circulation

Natural Circulation Test ST-NC-02 Simulation Loop Circulation Flows

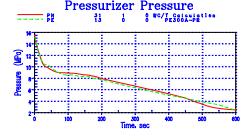


Natural Circulation Test ST-NC-02 Simulation Steam Generator U-tube Upflow Differential Pressure

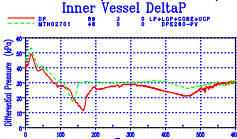


WCOBRA/TRAC-TF2 – Sample Results from IETs Assessment – SB-CL-18

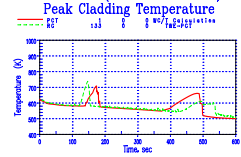
SB-CL-18 (5% CL Side Break)



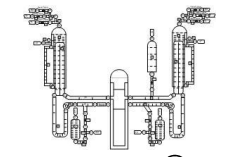
SB-CL-18 (5% CL Side Break) Inner Vessel Delta T



SB-CL-18 (5% CL Side Break) Peak Cladding Temperature



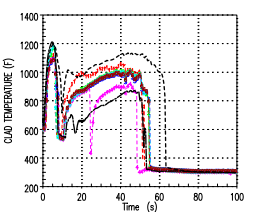
SB-CL-18 (5% CL Side Break) Inner Vessel Delta T



WCOBRA/TRAC-TF2 – Sample Results from IETs – LOFT L5-1: Intermediate Break

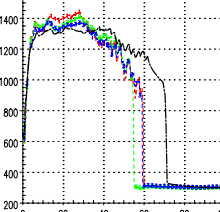
LOFT L23 TEST & WCT-TF2 COMPARISON

Legend	WCT-TF2	WCT-TF2	WCT-TF2	WCT-TF2
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	1	20	1100	ELEV. 2.29 FT. (TF2)
—	1	20	1100	ELEV. 2.29 FT. (TF2)



LOFT L25 TEST & WCT-TF2 COMPARISON

Legend	WCT-TF2	WCT-TF2	WCT-TF2	WCT-TF2
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	0	0	0	0
—	1	22	1100	ELEV. 1.36 FT. (TF2)
—	1	22	1100	ELEV. 1.36 FT. (TF2)



Treatment of Uncertainties

- Uncertainty methodology is based on a direct Monte Carlo sampling of the uncertainty contributors similar to previously approved method (ASTRUM), however implementation details have been re-worked to:
 - Properly address concerns relative to the sample size and variability of 95/95 estimator
 - Need of providing an adequate coverage and consideration of all break sizes which are considered by the Full Spectrum LOCA EM.

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Summary

- Westinghouse Full Spectrum LOCA Methodology was submitted to the US NRC on November 2010 for its review and approval.
- Licensing expectation: Realistic methods are in line with current regulatory practice and expectations (risk-informed regulatory environment) both in the US and abroad.
- Full Spectrum LOCA EM is expected to be aligned with such expectations

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