

FULL SPECTRUM™ LOCA Methodology

Background

Since the 1988 revision to the U.S. Nuclear Regulatory Commission (NRC) 10 CFR 50.46 requirements that allow the use of best-estimate (BE) models in realistic calculations of loss-of-coolant accidents (LOCAs), Westinghouse has been continuously developing, licensing and applying BE methodologies.

Following the NRC's approval of Westinghouse's first BE Large Break LOCA (LBLOCA) evaluation model (EM) in 1996 (Code Qualification Document, CQD), Westinghouse's next development in BE technology was the replacement of the uncertainty assessment step with the Automated Statistical Treatment of Uncertainty Method (ASTRUM), based on nonparametric statistical sampling techniques. In 2004, the NRC originally approved this method, which can be applied to Westinghouse two-, three- and four-loop, Combustion Engineering (CE), and **AP1000**® nuclear plant designs.

The latest evolution of Westinghouse's BE technology includes both improvements to the LBLOCA methods and the extension to intermediate and small break sizes with the **FULL SPECTRUM™ LOCA (FSLOCA™)** EM. As its name implies, this state-of-the-art EM resolves the full spectrum of LOCA scenarios that result from a postulated break in the cold leg of a pressurized water reactor (PWR), including any break size in which break flow is beyond the capacity of the normal charging pumps, up to and including a double-ended guillotine (DEG) rupture.

The FULL SPECTRUM LOCA EM, which has been approved by the NRC for application to 3-loop and 4-loop Westinghouse-designed PWRs, is intended to eventually be applicable to all Westinghouse and CE PWR fuel designs with zirconium alloy cladding. To date, Westinghouse has successfully applied its BE methodologies to more than 40 PWR units worldwide (Belgium, Brazil, China, Spain, Sweden, Taiwan and the United States). The FSLOCA EM has built on this success while expanding its offering to better support customer needs with 34 PWR units contracting for FSLOCA analyses to date.

Description

For the FSLOCA methodology, Westinghouse created a new version of its BE thermal-hydraulic code, which is named WCOBRA/TRAC-TF2 (WC/T-TF2). The code combines existing two-fluid, three-field, multidimensional fluid equations used in the vessel with an upgraded one-dimensional, two-fluid, six-equation formulation of the two-phase flow to model the loops, allowing for a complete and detailed simulation of a PWR. Additionally, a transport equation is included to model an explicit noncondensable field within the gas mixture.

WC/T-TF2 was subjected to a rigorous code assessment against a large number of separate and integral effect tests. Separate effect tests were used to characterize model biases and uncertainties. Four integral test facilities, specifically ROSA-LSTF (a full height, 1/48 scale of a PWR), LOFT and CCTF (respectively, 1/55 scale and 1/21 scale of a 4-loop PWR), and Semiscale (1/1,705 scale of a 4-loop PWR) provide full coverage of LOCA break sizes and scenarios.

Emphasis has been given to characterize complex thermal hydraulics of small, intermediate and large LOCA phenomena in an integrated fashion. The large test matrix provides validation of various models such as break flow, fuel rod behavior, core heat transfer, delivery and bypassing of the emergency core cooling (ECC), steam binding/entrainment, cold leg/downcomer condensation, noncondensable gases/accumulator nitrogen, core void distribution (mixture level), horizontal flow regime in the loops, loop seal clearance, and steam generator thermal hydraulics.

The uncertainty methodology is based on a direct Monte Carlo sampling of the uncertainty attributes. The overall uncertainty is bounded using a nonparametric statistical method similar to the ASTRUM EM. However, the FSLOCA EM utilizes a patent-pending uncertainty treatment method using large sample sizes that improves analytical margins.

Benefits

In addition to the currently realized benefits of BE LBLOCA technologies, a major advantage of the FSLOCA EM is that it is the first model in the industry to eliminate SBLOCA as a design constraint. The more robust uncertainty treatment along with many other improvements to fuel rod and nuclear design modeling results in additional LBLOCA margin. Combined, these factors better position the licensee to address and comply with an increasingly challenging regulatory environment. The additional margin obtained by the FSLOCA EM can be used to improve plant economics and operation in a number of ways, including:

- Increased rated power
- Improved fuel cycle economics (core operating limits and fuel cycle length)
- Relaxed operational restrictions (emergency core cooling system performance, emergency diesel generator start times and accumulator operating ranges)
- Accommodation of degradation in plant equipment (increased steam generator tube plugging and safety injection pumps)

The FSLOCA EM also fully resolves legacy regulatory issues such as the explicit modeling of fuel pellet thermal conductivity degradation (TCD) and positions the licensee to address the future 10 CFR 50.46c rulemaking via post-processing of existing analysis results.

Deliverables

A plant-specific summary report is provided for applications of the FSLOCA EM, which describes the methodology, the plant model, the analysis inputs, and the analysis results. Westinghouse also provides a recommended write-up suitable for inclusion in the owner's licensing submittal to the NRC. In addition, Westinghouse will provide verification that the acceptance criteria of 10 CFR 50.46 have been met, and that NRC Safety Evaluation Report requirements have been satisfied.

The following can also be supplied:

- Modified sections of the Updated Final Safety Analysis Report (UFSAR) incorporating the FSLOCA EM results and methods
- Technical specification markups

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