FRAMATOME ANP

An AREVA and Siemens company

FRAMATOME ANP, Inc.

prn 728

August 12, 2003
NRC:03:044

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Review of EMF-2310(P) Revision 1, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors"

Ref.: 1. Letter, J. F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Interim Report of Evaluation of a Deviation Pursuant to 10 CFR 21.21(a)(2)," NRC:01:017, April 27, 2001.

Ref.: 2. Letter, J. F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Closure of Interim Report 01-001, 'Boron Dilution Analyses - Instantaneous Mixing and Dilution Front Models'," NRC:02:008, January 31, 2002.

Framatome ANP requests the NRC's review and approval for referencing in licensing actions the topical report EMF-2310(P) Revision 1, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors." One CD containing a proprietary version of the report and one CD containing a non-proprietary version of the report are enclosed. We request that the NRC approve this report by December 31, 2003.

Section 5.6 "CVCS Malfunction That Results in a Decrease in the Boron Concentration in the Reactor Coolant (Boron Dilution)" of EMF-2310(P)(A) Revision 0 is the only portion of the approved topical report which has been revised. This section has been modified to address the three items listed below.

1. The dilution front model will be used when the RHR system is in operation.

2. All control rods will be assumed to be inserted in modes 4 and 5.

3. Complete mixing of the fluid is assumed prior to entry of the diluted fluid into the core. This assumption has been validated by computational fluid dynamics (CFD) calculations.

Framatome ANP provided an interim report of a deviation pursuant to 10 CFR 21.21(a)(2) in Reference 1. The deviation involved the methodology for evaluation of a boron dilution event described in EMF-2310(P)(A) Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors." In Reference 2, Framatome ANP reported that it had completed the evaluation of the deviation and had concluded the deviation was not reportable under 10 CFR 21. Framatome ANP also determined that the boron dilution methodology described in

FRAMATOME ANP, Inc.
2101 Horn Rapids Road - Richland, WA 99352
Tel.: 509-375-8100 Fax: 509-375-8402 www.us.framatome-anp.com

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EMF-2310(P)(A) Revision 0 needed to be revised. Section 5.6 of the topical report has been revised to reflect three assumptions to be used in future analyses.

The technical justification for changes 1 and 2 is provided in the topical report and the technical justification for change 3 (assumption of complete mixing of the fluid at the entrance to the core) is provided in Attachment A to this letter.

Framatome ANP considers some of the information contained in the enclosed report to be proprietary. As required by 10 CFR 2.790(b), an affidavit is enclosed to support the withholding of the information from public disclosure.

Very truly yours,

James F. Mallay, Director
Regulatory Affairs

Enclosures

cc: D. G. Holland
E. S. Peyton
Project 728

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is James F. Mallay. I am Director, Regulatory Affairs, for Framatome ANP ("FANP"), and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by FANP to determine whether certain FANP information is proprietary. I am familiar with the policies established by FANP to ensure the proper application of these criteria.

3. I am familiar with the FANP information provided with the letter number NRC:03:044 dated August 12, 2003, and referred to herein as "Document." Information contained in this Document has been classified by FANP as proprietary in accordance with the policies established by FANP for the control and protection of proprietary and confidential information.

4. This Document contain information of a proprietary and confidential nature and is of the type customarily held in confidence by FANP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure.

6. The following criteria are customarily applied by FANP to determine whether information should be classified as proprietary:

(a) The information reveals details of FANP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for FANP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for FANP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by FANP, would be helpful to competitors to FANP, and would likely cause substantial harm to the competitive position of FANP.

7. In accordance with FANP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside FANP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. FANP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 12th day of August, 2003.

Ella F. Carr-Payne
NOTARY PUBLIC, STATE OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/05

ELLA F. CARR-PAYNE
Notary Public
Commonwealth of Virginia
My Commission Exps. Aug. 31, 2005

Attachment A
Evaluation of Mixing during a Boron Dilution Event

Introduction and Summary

The analysis of a boron dilution event depends on the rate of dilution and the plant design. The plant layout dictates whether the dilution can be treated symmetrically or asymmetrically. In an asymmetric boron dilution event, the dilution takes place in only one of the cold legs of a PWR. If the charging line for residual heat removal flow is not in the same cold leg as the dilution flow, or if the RHR flow is distributed across the other cold legs, the boron dilution event is asymmetrical.

Treatment of the asymmetric behavior of boron dilution becomes a consideration only when the reactor coolant system flow rate becomes small enough that the instantaneous mixing model can no longer be applied. For conditions where the dilution front model applies, the behavior of asymmetric boron dilution is no different than the symmetric boron dilution event if the diluted sector is adequately mixed with the undiluted sectors at the core inlet.

The purpose of this analysis is to demonstrate that sufficient mixing exists to permit the symmetric dilution front model to be applied under asymmetric boron dilution conditions. The criterion used to demonstrate adequate mixing is to show that at least 85 percent mixing of the diluted flow with the remainder of the reactor coolant has occurred at the core inlet using a computational fluid dynamics code.

Analysis Results

Computational fluid dynamics (CFD) has been used to determine the degree of steady-state mixing during an inadvertent initiation of a charging pump resulting in a boron dilution event. CFD has been shown to adequately predict dilution and STAR-CD has been benchmarked by Framatome ANP against an International Standard Problem, ISP-43 (discussed later), to confirm the applicability of the model to boron dilution.

A simple model is built of a typical PWR that does not include any of the internals. A cross sectional view of a typical model is shown in Figure 1. All cells are fluid cells and the model is extended past the lower plenum to allow the use of a pressure boundary at the exit.

The STAR-CD default turbulence model is used and the fluid properties are held constant with no buoyancy effects. The dilution of borated water is simulated by thermal mixing. Thus, the property of interest is the temperature of the region. That is to say, the boron concentration is not modeled, only the fluid enthalpy as mixing takes place. This approach is consistent with ISP-43. The analysis is performed as a steady-state analysis where cold water is introduced into one leg of the plant with RHR cooling flow equally distributed in all cold legs.

The result of importance is the temperature profile at the exit of the lower plenum. An example of the temperature distribution is shown in Figure 2. For a 4-loop plant the region is divided into quadrants, for a 3-loop plant it is divided into thirds. The average temperature is calculated for each region and the percent mixing is determined based on the ratio of the worst case sector temperature to the perfectly mixed temperature; i.e.,

$$\%Mixed = (1 - \frac{T_{totally\_mixed} - T_{worst\_case}}{T_{totally\_mixed} - T_{cold\_leg}}) * 100$$

The results of the mixing calculations are summarized in Table 1.

The use of the 85 percent value to show satisfactory mixing is based on the following considerations. The CFD model used to analyze the mixing is conservative. It does not account for mixing caused by buoyancy effects that result from density differences as a function of boron concentration and temperature. The modeling of ISP-43 showed that buoyancy effects enhanced the mixing, and inclusion of these effects was necessary to obtain good agreement with the experiment. The model also does not account for mixing caused by wake turbulence and jets from support structures in the lower plenum, or the mixing that results from flow interaction with the lower tie plate and core support plate below the core. Finally, in the LOFT boron dilution experiments, L6-6, the experimentalists went to considerable lengths to set up the experiment to be as isothermal as possible, and to eliminate loop flow effects that would enhance mixing by conducting the experiment with the reactor coolant system drained so that the surface of the water was at the level of the tube sheet. Despite these measures, the estimate of the time to criticality was significantly underestimated – by 30% – as a consequence of unanticipated mixing. Because of the inherent conservatisms in the CFD boron dilution model and calculation, it is reasonable to assume that complete mixing has taken place at the core inlet if the sector average mixing from the CFD simulation exceeds 85 percent.

<u>Benchmark Results</u>

The nuclear industry routinely uses standard problems to demonstrate the adequacy of computer codes for predicting plant transients. The Committee on the Safety of Nuclear Installations within the Organization for Economic Cooperation and Development (OECD) sponsors these International Standard Problems and they are based on tests performed in research facilities around the world. One of these International Standard Problems, ISP-43, was used to demonstrate the ability of computational fluid dynamics (CFD) techniques to predict the boron mixing in the downcomer of a reactor vessel.

The ISP-43 test was performed at the University of Maryland 2x4 Thermal-Hydraulic Loop. This loop is a scale model of the Three Mile Island Unit 2 pressurized water nuclear reactor. The test was performed by holding the reactor coolant in the reactor vessel at 347 K and injecting water into one cold leg at a colder temperature and then using thermocouples to determine the mixing. Note that no boron was injected into the vessel; mixing was determined strictly by the change in temperature. The measure of success was the ability to predict the transient average temperature as measured at the exit of the downcomer, labeled in the test as Level 4.

STAR-CD's meshing program, Pro-am, was used to model the vessel. This program permitted the sizing of the cells needed to model the flow phenomena through various area changes. The model contains about 640,000 hexahedral cells. A cross-sectional view is shown in Figure 3. STAR-CD's AMG solver and the RNG k-epsilon turbulence model were chosen.

The benchmark transient calculation was performed using two different treatments for fluid modeling. In the first case, constant fluid properties (independent of temperature) were used and buoyancy was turned off. (This treatment is the one used for analysis of the boron dilution event.) The second case

uses temperature dependent viscosity and density, and the buoyancy is optionally turned on. When comparing these modeling assumptions to the measurements of ISP-43, it is found that the first case conservatively underestimates the amount of mixing and the second case, with buoyancy included, agrees with the experimental results. A comparison of the two cases with the benchmark test results at Level 4 is shown in Figure 4.

Table 1 Summary of Results

Plant Type	RHR Flow (gpm)	Charging Flow (gpm)	Mixing %
3 Loop Westinghouse	2800	250	88.3
	1200	132	88.4
	1200	321	93.1
4 Loop Westinghouse	2800	250	97.2
	1200	132	95.1
CE	3000	147	86.9
	600	98	93.3

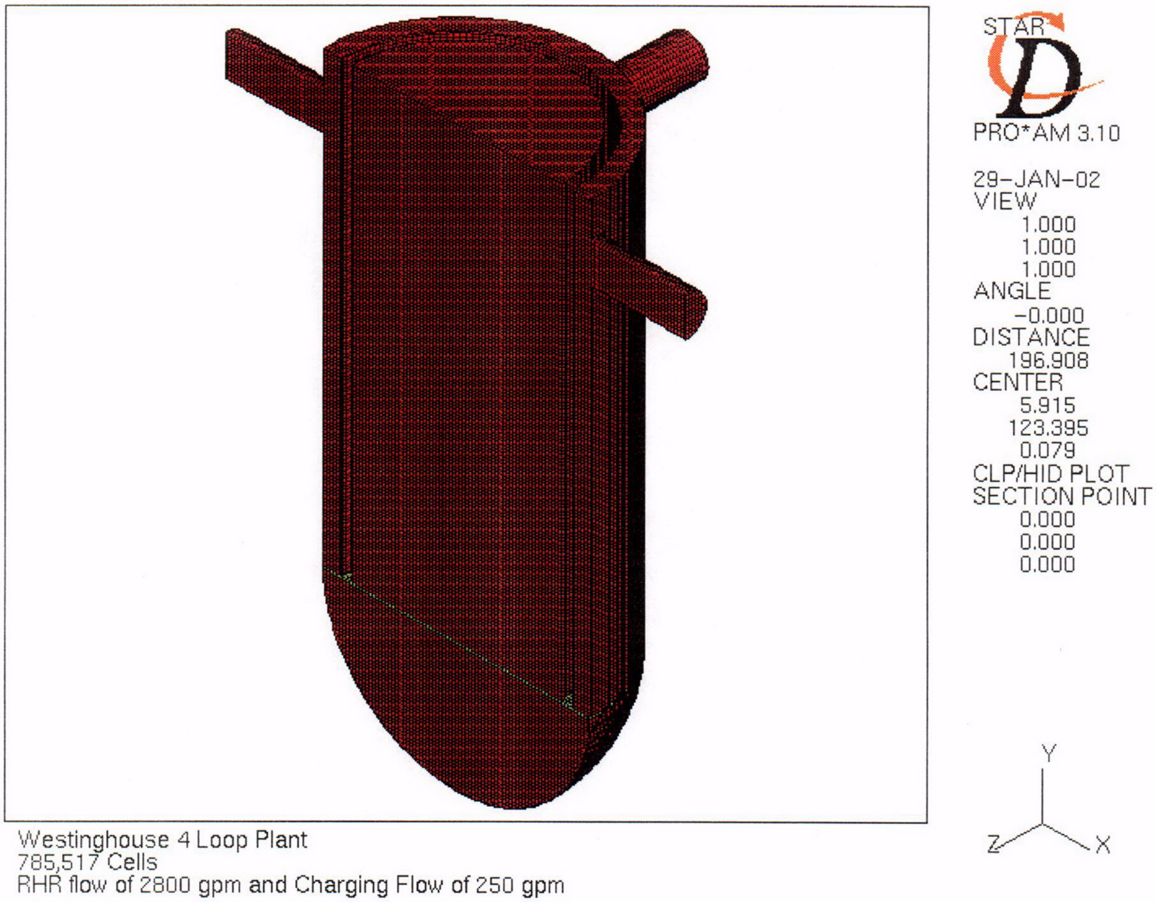

Figure 1 Cross Section of the Vessel Model

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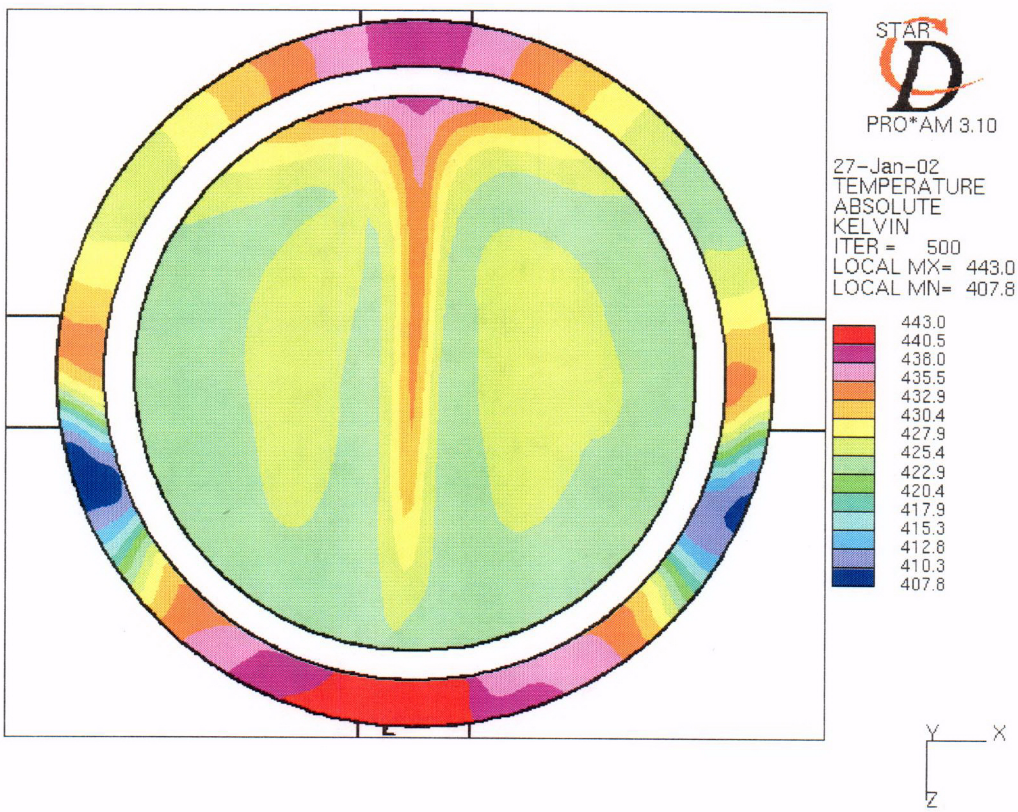

Figure 2 Temperature Distribution for the Lower Plenum

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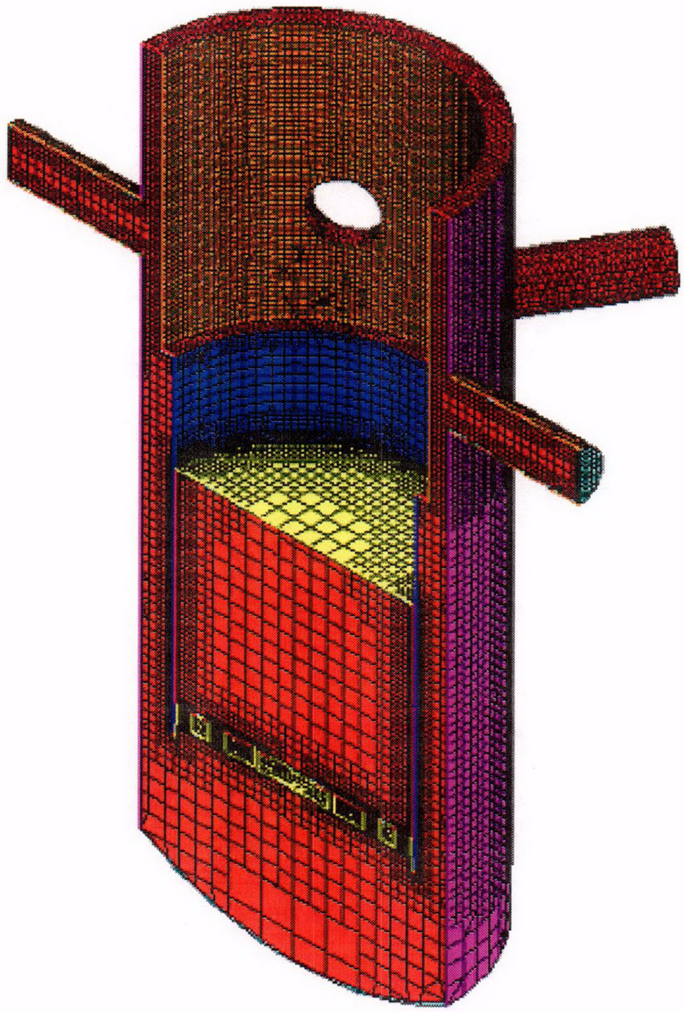

Figure 3 Clipped View of the ISP-43 Test Vessel Model

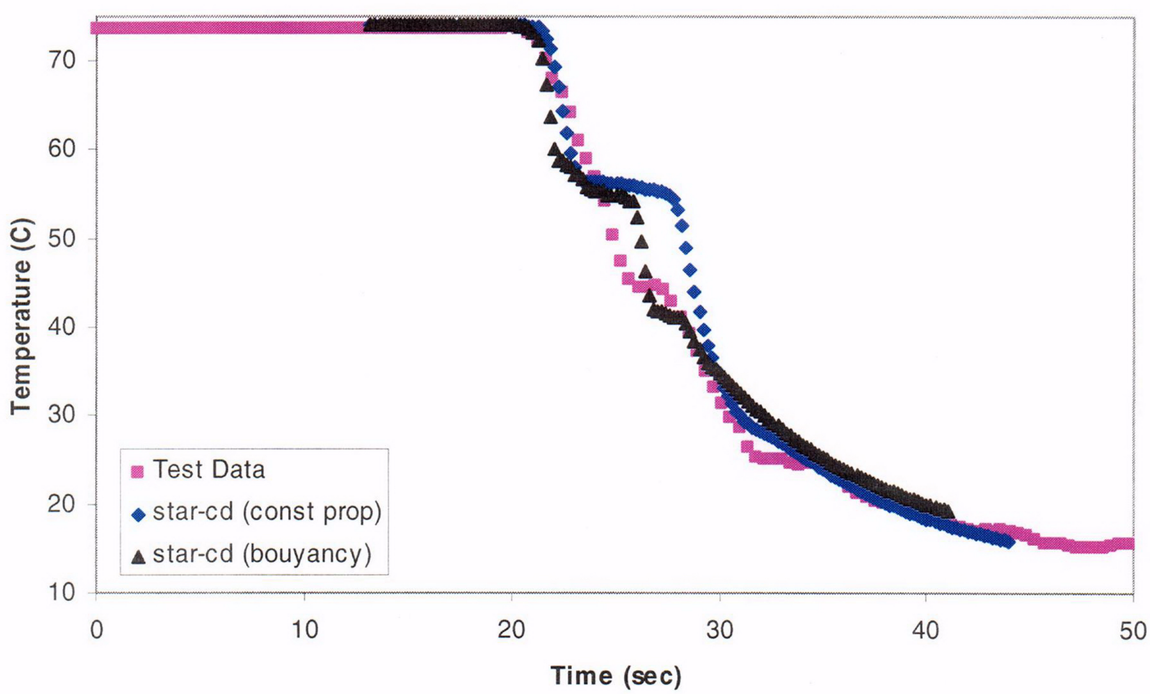

Figure 4 Test Results Compared to Analysis

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