Published by Computer Simulation & Analysis, Inc.
for the Electric Power Research Institute

The RETRAN Newsletter

March, 1997

Summary of Activities

This issue of the RETRAN Newsletter contains information on the new RETRAN Mailing List, addition of CORETRAN to the CSA Web Page, and interesting articles from code users. Your contributions are greatly appreciated. We, EPRI and CSA, encourage everyone to participate in this newsletter.

Previous issues of the RETRAN Newsletter are available from the RETRAN Web Pages at http://www.csai.com/retran.

In This Issue . . .

RETRAN-3D Experience at Duke Power Company

G. Seeburger,
Duke Power

For many years now, Duke Power has done its own safety analysis with RETRAN-02 for four Westinghouse nuclear units and is currently preparing to submit a topical report to allow the same work on three B&W units. In an effort to gain experience with RETRAN-3D, and with an eye towards a possible upgrade to the licensed methods, the locked rotor event was recently analyzed with RETRAN-3D with the 3D kinetics option. The analysis was a best-estimate exercise of the technology, not a limiting FSAR-like worst case.

The RETRAN-3D system model was based on a four-loop Westinghouse plant. A two-loop model was used: one loop/steam generator was modeled individually for the pump with the locked rotor while the other three loops/steam generators were lumped into the other loop. The 3D kinetics model was taken from an ARROTTA core model that had been used previously for a rod ejection analysis. No adjustments were made to the cross sections of the core model, so the power distribution, reactivity coefficients, and shutdown margin are not at their limiting values.

RETRAN-3D was first initialized with a three-level point kinetics core model. Then an 18-axial level, 20 flow channel 3D core model was added. Eighteen-axial levels were chosen because the number must match the ARROTTA core model.

RETRAN-3D Experience at Duke Power Company (Cont'd)

One flow channel represents the core bypass and the remaining 19 flow channels represent the 193 fuel assemblies. Each of the 19 channels represents from one to six lumped assemblies. The choice of which assemblies to lump together was based on the assembly average power and the proximity to or presence of a control rod location. This choice of fuel assembly to lumping is specific to the power distribution and the transient to be simulated. Note that assemblies that are lumped together are not necessarily adjacent to each other. Since the locked rotor transient is symmetric as far as the core is concerned over the time period of interest (a few seconds), having lumped assemblies not adjacent to each other is acceptable. The 3D core was made hydraulically equivalent to the three-level point kinetics model that it replaced. Even so, some small adjustments were required to the core loss coefficients to get a converged flow solution.

8	13	11	12	7	10	1	4	18
9	11	11	9	7	5	4	6	14
10	12	9	8	6	17	3	8	16
11	7	7	6	17	3	2	19	16
12	10	5	17	3	8	19	15	
13	1	4	3	2	19	14	16	
14	4	6	8	19	15	16		
15	18	14	16	16				

RETRAN-3D Channel Layout

The transient was initiated by instantly setting the pump speed to zero on the single loop. The reactor tripped on the RPS low flow signal. The three remaining pumps on the lumped triple loop were tripped on the ensuing
turbine trip to simulate the loss of offsite power.

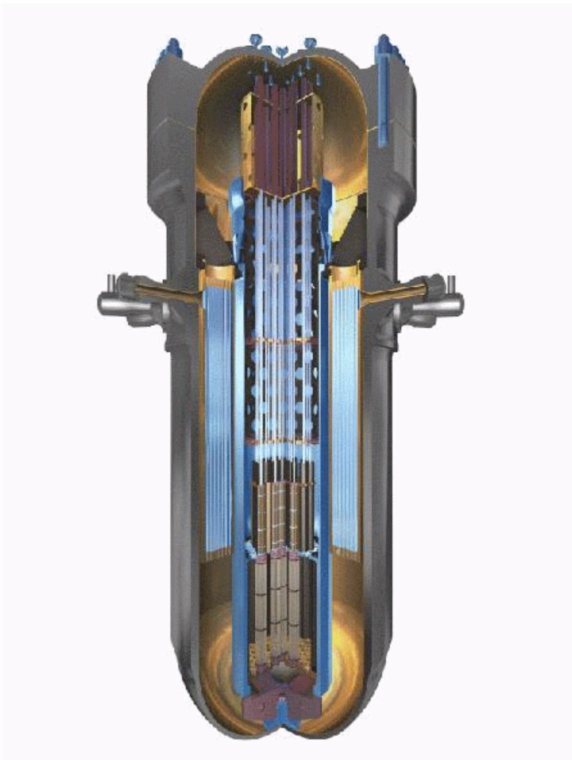
Once the transient was run, the core inlet flow versus time was taken from RETRAN-3D and input to an equivalent ARROTTA case. The minor core inlet temperature variation and the pressure variation were ignored. The ARROTTA assembly average power distribution closely matched the RETRAN-3D power distribution at the start of the transient, with the maximum error less than 1% of assembly power. By the end of the transient the agreement was not as good, with the maximum error about 7% of assembly power. However, the more important parameter of core power versus time matches very well between the two models, with the largest error being 1.5% of full power throughout the transient. The excellent agreement of core power versus time shows that the 19 core flow channels adequately model the thermal-hydraulic feedback, even though the power distribution comparison does degrade over the duration of the transient.

The transient results are of little interest in absolute terms because it was done as best estimate and there is nothing to compare to. The next step in the process is to re-run the transient as a limiting, FSAR-type analysis. This will involve initializing RETRAN-3D with low flow, high vessel average temperature, high pressure (looking at peak pressure as opposed to DNBR). There will also be changes to the core model cross sections to obtain a limiting power distribution, limiting reactivity coefficients, a limiting delayed neutron fraction, and a limiting shutdown margin. These changes will facilitate a comparison to the current licensing basis analysis to determine the relative merit of the 3D kinetics option (for the locked rotor transient, at least). Along the way, some interesting experience should also be gained.

RETRAN-02 Activities in INVAP

C. Mazufri, INVAP

INVAP, under contract of CNEA (National Atomic Energy of Argentina), is developing an advance design of a nuclear reactor for electrical generation named CAREM. The main features of the reactor are: small size (25 MWe), core cooling by natural circulation, steam generator integrated into the pressure vessel, and selfpressurized.



According to its acceptable capability for licensing applications, the RETRAN-02 code was chosen to analyze the reactor behavior under transient and abnormal situations. Typical operation transients like power ramp, energy unbalances, load following; and abnormal events such as blackout, LOCA, reactivity insertions; have been analyzed and included in the Safety Analysis Report.

As part of the CAREM project, assessments of RETRAN-02 dynamic response predictions against experimental data in natural circulation conditions are now being carried out. Experimental results are obtained from a natural circulation loop developed ad hoc for CAREM thermal-hydraulic conditions by INVAP.

CORETRAN Added to CSA Web Page

J. Westacott, CSA

CSA is the contractor to EPRI for CORETRAN maintenance support. CORETRAN (developed by S. Levy and Battelle for EPRI) is designed to perform LWR core steady-state and transient analyses. CORETRAN is a product of combining the ARROTTA three-dimensional neutron kinetics and VIPRE-02 thermal-hydraulic codes into a unified package.

The CSA Web page now includes information of interest to CORETRAN users and is available on http://www.csai.com/coretran/index.html. The web page includes a summary of the CORETRAN-01 code, a list of trouble reports, and a form to submit CORETRAN trouble reports electronically.

Domain Decomposition Methods for 3-D Flow Simulation in RETRAN-3D

T. Downar and J.-Y. Wu, Purdue University

The simulation of Light Water Reactor transients has typically been limited to one-dimensional fluid dynamics modeling. For licensing based accidents in which spatial variations of the power, flow, or temperature in the core are important, conservative operating margins are imposed resulting in some degradation of plant efficiency. High fidelity, three-dimensional flow modeling can help reduce uncertainties in code predictions and can improve the basic understanding of transient phenomena.

One of the primary obstacles to 3-D flow simulation in the RETRAN-3D code has been the large computational burden incurred in solving the linearized fluid dynamics equations. Recent advances in semi-iterative solution methods and parallel computing has motivated an investigation into new methods for solving the RETRAN-3D fluid dynamics equations. The objective of this exploratory research project was to establish the computational feasibility of 3-D flow modeling in RETRAN-3D. Because cross flow between fuel assemblies has been shown to be important for the PWR steam line break transient [Dias, 1992], the SLB analysis was chosen as the application for demonstrating the methods developed here.

The first phase of the research focused on the parallelization of the RETRAN-3D transient algorithm. Spatial domain decomposition methods were applied in which groups of contiguous volumes and junctions were assigned to separate processors for a sequence of computations. The parallelized program was tested for a typical 1-D flow problem on the distributed memory INTEL Paragon. Only moderate speedups were achieved primarily because of the heavy overhead in message passing and the difficulty of balancing the computational load among the processors. It became apparent that the tightly coupled thermal-hydraulic algorithms in RETRAN-3D could more efficiently be parallelized on a shared memory multiprocessor in which message passing overhead is eliminated.

The second phase of the work focused on the RETRAN-3D linear solver which consumed over 99% of the CPU time for reactor models with 3-D flow channels such as depicted in Figure 1. The existing direct solver in RETRAN was optimized for 1-D flow and employs a Sparse Block Elimination scheme which takes advantage

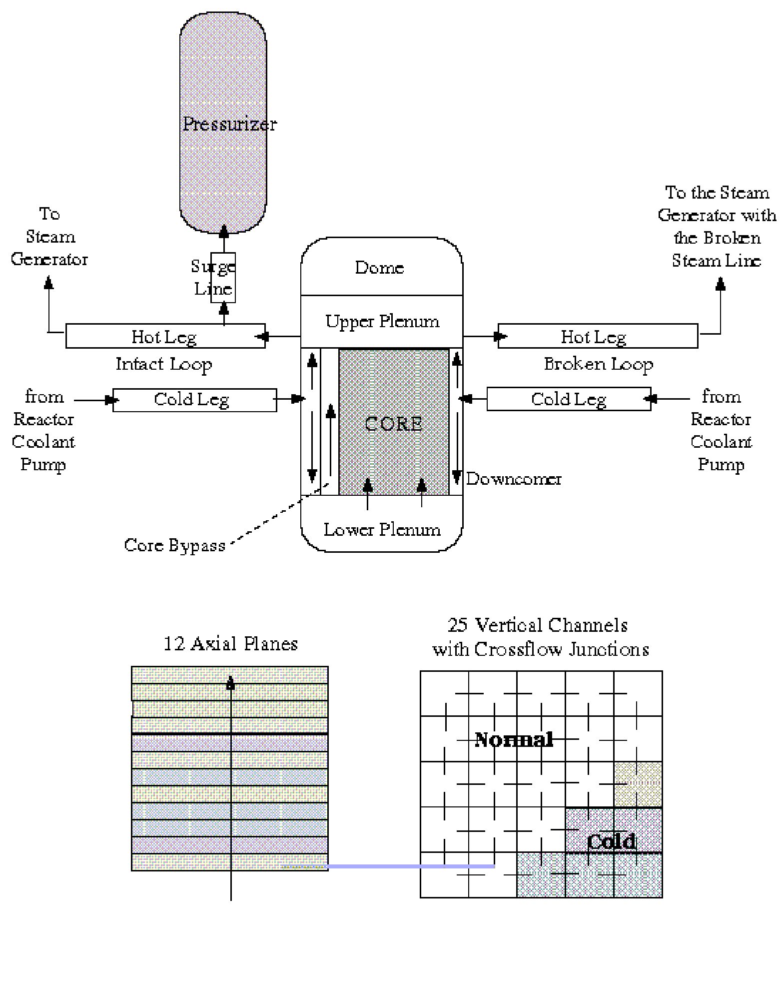


Figure 1. A PWR SLB Analysis Model

Domain Decomposition Methods for 3-D Flow Simulation in RETRAN-3D (Cont'd)

of the tridiagonal matrix structures encountered in 1-D flow models. For 3-D flow this method was very inefficient and the computational time increased as the cube of the matrix size. An innovative iterative linear solver was developed based on the Generalized Minimum Residual (GMRES) method and accelerated with a domain decomposition preconditioner in which the core and the ex-core blocks of the linear system were solved separately. The 3-D core flow problem was solved by a second level GMRES and accelerated using a Schwarz preconditioner consisting of overlapping subdomains with multiple channels.

The performance of the new iterative solution algorithm was studied using a PWR SLB model with explicit cross flow modeling between fuel channels as shown in Figure 1. The core in the model shown consists of 25 channels and 12 axial planes. A second model was also examined in which each assembly in a half-core was modeled separately as a total of 104 channels. The solution with the direct solver was reproduced by the iterative solver for both the 25- and 104-channel models. The computational time for the 25-channel model was reduced by a factor of 44, whereas comparisons to the direct solver time for the 104-channel model were not meaningful because the memory requirements of the direct solver exceeded the workstation core memory capacity. The direct solver required an excess of 1 GB whereas the iterative solver required less than 100 MB. Since the CPU time of the direct solver increased as the matrix order cubed, a reasonable estimate of the reduction in the execution time for 104-channel problem would be more than a factor of two orders of magnitude.

Parallel performance of the iterative solver was examined only on the distributed memory INTEL Paragon. The speedup compared to the serial performance was again modest because of the fine graining of the algorithm and the heavy message passing overhead. The best parallel efficiency achieved with the 104-channel model was about 50% on three processors. A considerably better parallel efficiency for the iterative solution method can be expected on shared memory workstations which are more suitable for fine grain parallelism.

Future work will examine the adaptation of the methods developed here onto a shared memory multiprocessor with the expectation of further performance improvement. However, the results of the work appear to establish the computational feasibility of three-dimensional flow modeling and provide encouragement for practical three-dimensional coupled thermal-hydraulics and neutronics in RETRAN-3D.

This research is sponsored by the Strategic R&D Group at EPRI.

Responses to EPRI Survey on RETRAN-02 and RETRAN-3D Software Experience Still Needed

G. Swindlehurst, Duke Power

By letter dated January 8, 1997, from Lance Agee to the members of the RETRAN User Group, your response to a survey regarding your use of RETRAN-02 and RETRAN-3D was solicited. EPRI and the RETRAN Steering Committee are still very much interested in receiving your completed survey forms. The results will be used to improve how EPRI software and, in particular, the RETRAN codes are developed, distributed, and maintained. Please send your responses in at your earliest convenience.

RETRAN-02 Trouble Reports

The following is a summary of RETRAN-02 Trouble Report/Code Maintenance Activity.

Unresolved Trouble Reports

- 1 From MOD001
- 5 From MOD002
- 4 From MOD003
- 3 From MOD004
- 8 From MOD005

A list of trouble reports and the status can be obtained directly from the EPSC.

Additional information is available from the RETRAN-02 Trouble Report Page at http://www.csai.com/retran/r02trpt/index.html.

Summary of RETRAN-02 Code Trouble Reports

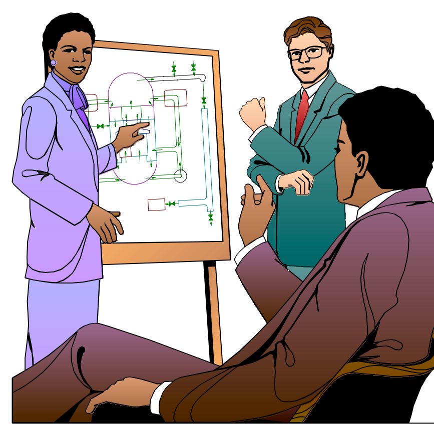
NO.	TROUBLE REPORT TYPE OF PROBLEM	CORRECTION NO.	IDENT	COMMENTS
1	Error 209 in TEMZ	***	*******	MOD001 Error
61	Delta T for Conductor with TDV	***	*******	Need Input Deck
121	OTSG Low Power Initialization	***	*******	
139	Failed Using Large Time Step	***	*******	Need Input Deck
140	Spurious Trips on High Level	***	*******	Need Input Deck
177	Overflow in WAT9	***	*******	Need Input Deck
209	Pump Coast Down Rates	***	*******	Need Correct Deck
272	Junction Properties at Break	***	*******	Need Input Deck
317	Junction Property Error	***	*******	
334	Time-Dep. Volume Input	***	*******	
342	Control Block Output near Zero	***	*******	Cannot Reproduce Error
354	Large Step Change in PHIR	***	*******	
366	Mixture/Liquid Level Difference	***	*******	Need Input Deck
376	Control Reactivity, No Motion	***	*******	
394	Anomalous Heat Trans. Behavior	***	*******	
408	OTSG Heat Transfer Problems	***	*******	
413	Incorrect Vsn No. in IBM Output	***	*******	Cannot Reproduce Error
436	Prandtl Number is Discontinuous	405	MOD005P3	
437	Heat Transfer Logic/CHF	-----	-----------	Not a Code Error
438	Restart Failure/Pipe Transport	407	MOD005P3	
439	Decay Heat Input	***	*******	
440	Kinetic Energy/Time Dep Area	***	*******	
*441	Anomalous Power Increase	-----	-----------	Not a Code Error

Summary of RETRAN-3D Code Trouble Reports

RETRAN-3D MOD002.0 has been completed and transmitted to the Electric Power Software Center. A total of 122 trouble reports had been filed as of February 28, 1997. Of these, 103 reports have been resolved, while 19 remain unresolved. A summary of the unresolved trouble reports is shown below. Additional information for RETRAN-3D trouble reports is available at http://www.csai.com/retran/r3dtrpt/index.html.

	TROUBLE REPORT	CORRECTION		
NO.	TYPE OF PROBLEM	NO.	IDENT	COMMENTS
7	Steam separator model fails	***	*******	
30	2-loop Oconee w/5-eq. fails in steady state	***	*******	
33	000040 data not read during restart	***	*******	
39	Time-step error; pressure is 5997 psia	***	*******	
40	Results do not agree with data	***	*******	
41	Anomalous downcomer level	***	*******	
43	Steady-state convergence error	***	*******	
45	Restart incorrect transient values	***	*******	
47	Standard Problem One difference	***	*******	
48	Steady state fails after 6 iterations	***	*******	
		006	MOD001g	(partial fix)
51	Pressure search failure for two-phase MOC	***	*******	
52	MOC does not return to the initial temp.	***	*******	
54	MOC solution; no null transient for two-phase	***	*******	
60	Anomalous countercurrent flooding	***	*******	
70	Fails in subroutine DERIVS	***	*******	
		052	MOD001g	(partial fix)
116	Fails in steady-state initialization	***	*******	
119	SS fails to converge for some cases (algebraic)	***	*******	
121	Calculation failure on second time step	***	*******	
122	Problems with EOS convergence	***	*******	

Announcing the RETRAN Mailing List



G. Gose and K. Kvarfordt, CSA

An internet mailing list has been established for the purpose of exchanging ideas on RETRAN related issues. The mailing list is intended to provide a forum for an on-going group discussion of RETRAN methods, models, ideas, or other related topics.

A mailing list is similar to a news group because when a member of the group posts a message to the list address (defined below), it is distributed to all of the members or subscribers to the list. The list is different from a news group because access to the list is controlled and the discussion will be moderated.

While the moderator will reject nonappropriate or offensive postings, a free idea exchange is encouraged. Subject matter related to thermal hydraulics or core physics methods are sought, but any topic that may enable engineers to better model the plant are valid. Please keep the discussion to technical issues.

Announcing the RETRAN Mailing List (Cont'd)

To subscribe, send email to

majordomo@domo.srv.net

leave the subject line blank and enter

subscribe retran

in the body of the message.

A digest version of the list is also available by entering

subscribe retran-digest

in the body of the message.

For more information, contact Garry Gose at gag@csai.com or Kent Kvarfordt at kek@csai.com.

Calendar

Basic RETRAN Training
Idaho Falls, ID
June 16-20, 1997

Advanced RETRAN Training
Idaho Falls, ID
June 24-27, 1997

RETRAN User Group Meeting
September - October, 1997
Location To Be Announced

International RETRAN Meeting
1998
Location, Date To Be Announced

About This Newsletter

RETRAN Maintenance Program

The RETRAN Maintenance Program is part of a program undertaken by EPRI to provide for the support of the software developed in the Nuclear Power Division. The main features of the Subscription Service include:

- the code maintenance activities for reporting and resolving possible code errors,
- providing information to users through the User Group Meetings and this newsletter, and
- preparing new versions of RETRAN.

The RETRAN Maintenance Program now has 31 organizations participating in the program, including 23 member utilities, 5 organizations from outside of the U.S., and 3 nonmember utilities from the U.S. A Steering Committee, composed of representatives from the participating organizations, advises EPRI on various activities including possible enhancements for the code and the scheduling of future code releases. Information regarding the Maintenance Program can be obtained from

Lance Agee
Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 94303
lagee@epri.com or (415) 855-2106

Newsletter Contributions

The RETRAN Newsletter is published for members of the Subscription Service program. We want to use the newsletter as a means of communication, not only from EPRI to the code users, but also between code users. If this concept is to be successful, contributions are needed from the code users. The next newsletter is scheduled for June 1997 and we would like to include a brief summary of your RETRAN activities. Please provide your contribution to CSA, P. O. Box 51596, Idaho Falls, ID 83405, or to the E-mail addresses below by June 1, 1997. ***Contributors will receive a RETRAN mouse pad.*** We are looking forward to hearing from all RETRAN licensees.

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Garry Gose	gag@csai.com
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The RETRAN Web Page is located at http://www.csai.com/retran/index.html.