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RAMONA-3B/MINET Composite Representation of BWR Thermal-Hydraulic Systems

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ABSTRACT

The modification and interfacing of two computer codes, RAMONA-3B and MINET, for the thermal hydraulic transient analysis of a Boiling Water Reactor nuclear steam supply system, is described. The RAMONA-3B code provides for multi-channel thermal hydraulics and three-dimensional (or one-dimensional) neutron kinetics analysis of a boiling water reactor core. The RAMONA-3B system representation terminates at the end of the steam line and at the junction of the feedwater line at the vessel inlet. By interfacing RAMONA-3B with MINET, a generic balance-of-plant systems analysis code, a complete BWR systems code with detailed core modeling was obtained. The result is a code of particular importance to the analysis of transients such as ATWS. A comparison between the 3-D and 1-D neutronics representation is provided, along with a test case utilizing the composite RAMONA-3B/MINET code.

INTRODUCTION

The RAMONA-3B code [1] is used by BNL for safety analysis of boiling water reactors (BWR), particularly for transients in which the coupling between the neutronics and thermal hydraulics is important. A RAMONA-3B validation study was performed using data from the Peach Bottom plant [2]. The code has recently been applied extensively in the Severe Accident Sequence Analysis (SASA) program [3] to analyze BWR behavior during postulated ATWS events. From these RAMONA-3B code applications, two limiting factors were considered for improvement. First, the need to better estimate transient boundary conditions from the balance-of-plant systems is essential, particularly for the longer and more complex transient events. Second, the use of three-dimensional neutron kinetics to determine the reactor power level is not always necessary, since radial effects are sometimes insignificant. Hence, to increase our BWR systems analysis capabilities: 1) RAMONA-3B was interfaced with the MINET code to extend the systems representation, and 2) a one-dimensional neutron kinetics method was implemented for use in analyzing those transients where radial symmetry exists.

The MINET code [4] was developed by BNL for the transient analysis of generic balance-of-plant systems. Originally part of the SSC code package [5] for LMFBR systems analysis, the MINET code was developed to easily interface with other codes. In support of the RAMONA-3B calculations, MINET can provide representations of the balance-of-plant and parts of the Emergency Core Cooling System (ECCS).

In Section 2, the RAMONA-3B Code will be discussed briefly, and the incorporation of the one-dimensional neutron kinetics option and its testing will be described. The MINET Code will be discussed in Section 3. The process of interfacing the two codes will be described in Section 4, and initial testing of the composite representation will be outlined in Section 5. The future plans for these codes will be discussed in Section 6. A summary is presented in Section 7.

THE RAMONA-3B CODE

RAMONA-3B is a best estimate BWR core and systems transient code with three-dimensional neutron kinetics coupled with multi-channel one-dimensional, nonhomogeneous, nonequilibrium thermal hydraulics. The code includes a boron transport model, and component models for the jet pump, recirculation pump, steam separator, steam line and valves, and a limited plant control and protection system (see Fig. 1). The code is used for the analysis of BWR transients such as Control Rod Drop Accidents [6], Anticipated Transients Without Scram (ATWS) [7], and any partial ATWS (e.g., an event where a fraction of the rods are driven in from a SCRAM signal) where spacetime neutron kinetics coupled with thermal hydraulics is required due to the strong spatial effects.

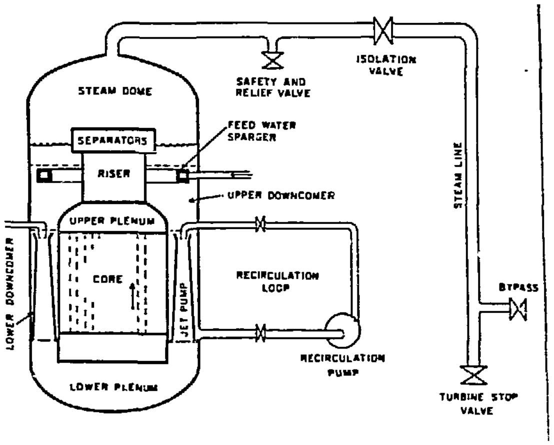

Figure 1
Schematic of BWR System and Circulation Loops

RAMONA-3B differs from most of the other advanced codes such as TRAC-BD1, TRAC-BF1, RELAP5, and RETRAN since it has both 3-D and 1-D neutronics, while the other codes use either point kinetics (i.e., TRAC-BD1, RELAP5) or 1-D neutronics (TRAC-BF1 and RETRAN) when modeling the reactor

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core. While RAMONA-3B uses a slip model thermohydraulic representation, which is different from some of the more detailed codes, it was found that RAMONA-3B can represent the system behavior quite accurately under most non-blowdown conditions [1,8].

Recently, RAMONA-3B has been utilized in the Severe Accident Sequence Analysis (SASA) program, where the objectives included: 1) providing insights for probabilistic risk assessments (PRAs), 2) performing deterministic analysis of dominant accident sequences, 3) determining timings of significant events, and 4) evaluating the effects of operator actions on accident mitigation. RAMONA-3B was used to evaluate the most probable sequence which could lead to a core melt, the main steam isolation valve (MSIV) closure ATWS, as identified by an Interim Reliability Evaluation Program (IREP) for Browns Ferry Nuclear Plant Unit 1 [9].

The initial task of the RAMONA-3B analysis was to develop a set of cross sections for fuel cycle 5 of TVA's Browns Ferry, Unit 3. The macroscopic cross sections were generated using the CASMO [10] and BLEND2 [11] codes. The axial power distribution generated by RAMONA-3B using the 3-D cross sections is shown in Fig. 2, along with the plant data [12]. As can be seen, the calculated 3-D and measured power distribution agree within 2-5 percent for the central part of the core, while the region near the entrance (past the first cell) has a maximum error of about 12.6 percent. A combination of the following probably contribute to this discrepancy: 1) using 9 hydraulic channels instead of one for each computational channel (i.e., smearing of the spatial void effect), 2) uncertainties in the exposure and void history values supplied by the TVA process computer for this particular initial state, 3) the subcooled boiling model used in the code [1], 4) the uncertainties in the power measurements [13] near the edge or end points, and 5) the effect of modeling the core with a 1/8 symmetry rather than modeling the entire core. However, the above mentioned modeling simplifications are needed to obtain reasonable run times, and the uncertainties in measurements are considered unavoidable. The 3-D cross sections were then collapsed to an equivalent 1-D cross section set. The power distribution calculated by RAMONA-3B using the 1-D cross sections is also shown in Fig. 2.

A verification was conducted on the 1-D cross section set by performing a RAMONA-3B/1-D calculation and its identical RAMONA-3B/3-D counterpart. The transient selected involved an MSIV closure ATWS sequence, where the MSIV closes in 5 s, the feedwater flow rate coasts down in 8 s, the recirculation pump is tripped on high pressure, and the HPCI and RCIC systems are activated on a low water level signal. The two input decks were identical (e.g., 24 axial levels in the core), except for: 1) the number of fuel assemblies (FAs) simulated (the 3-D case had 101 FAs assuming a 1/8 core symmetry for a total of 2424 neutronic nodes, while the 1-D case had 24 neutronic nodes) and 2) the number of hydraulic channels simulated in the core (the 3-D used 9 for a total of 216 core hydraulic nodes, while the 1-D had 2 hydraulic channels and 48 core hydraulic nodes). The results of this test are shown in Figs. 3 and 4.

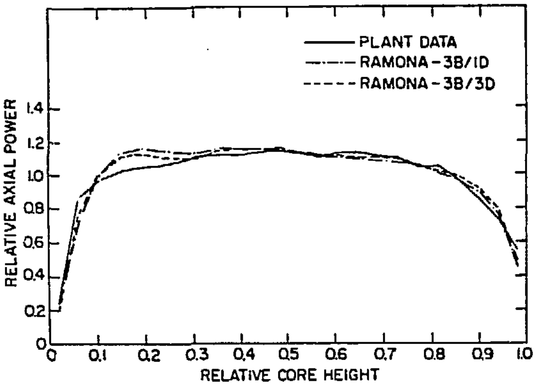

Figure 2
Browns Ferry (Unit 3) EOC5 (8876 MWD/MT) Axial Relative Power Distribution Plotted Against a RAMONA-3B/3D and Corresponding RAMONA-3B/1D Steady-State Calculations

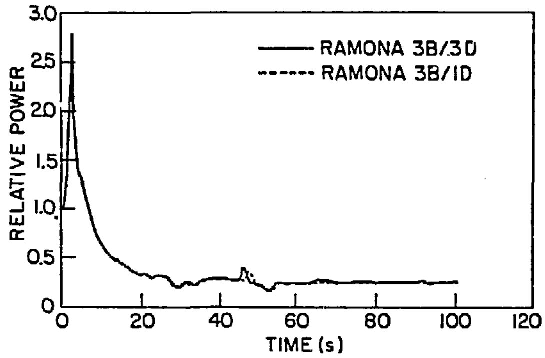

Figure 3
Relative Power, as Calculated by RAMONA-3B, Using the 1-D and 3-D Neutron Kinetics Model

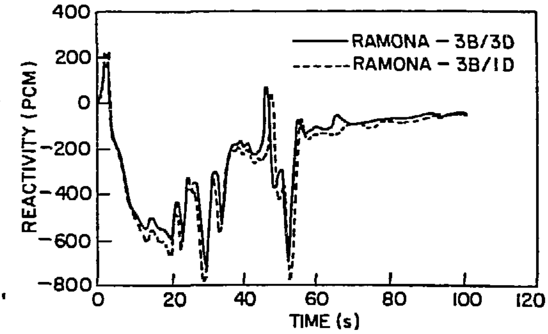

Figure 4
Reactivity, as Calculated by RAMONA-3B, Using the 1-D and 3-D Neutron Kinetics Model

The agreement between the 3-D and 1-D case is excellent, as exemplified in Fig. 3, where the relative power for the two cases is plotted as a function of time. It should be noted that a slight shift in the timing of events can be seen in Fig. 3 at about 46 s. This effect is a result of the spacial differences which occur when modeling the core with only one hydraulic channel as compared with one with 9 hydraulic channels. As an example, this difference in modeling results in a (slightly) different predicted steaming rate, which causes the water level history to be different enough to change the activation time of the HPCI and RCIC systems. In Fig. 4 the total reactivity (a highly sensitive parameter), including void, moderator-temperature, and fuel-temperature feedback for the two cases are plotted as a function of time. Again, the results are very good, which demonstrates that the 1-D model reacts to external stimuli in a way consistent with the 3-D case for a transient where there is radial symmetry. It should be noted, that since RAMONA-3B can be operated in either the 3-D or 1-D mode, the user has a tool that not only can run very detailed analyses using the 3-D option, but also, can run the 1-D version when appropriate (when no significant radial effects exist). In this comparison study, the 3-D case required 20.8 CPU seconds/real second, while the 1-D version of RAMONA-3B needed only 2.8 CPU seconds/real second, with no significant difference in accuracy.

With its 3-D and 1-D neutron kinetics and multi-channel thermal-hydraulic representations of a BWR, RAMONA-3B provides the capability to analyze complex systems transients, a capability unmatched by any of the other available "best estimate" codes. In order to provide a more complete systems representation, so that longer and more involved accident scenarios could be analyzed, the interface with MINET was implemented.

THE MINET CODE

MINET (Momentum Integral Network) is a computer code developed for the transient analysis of intricate fluid flow and heat-transfer networks, such as those found in the balance-of-plant in power generating facilities. It can be utilized as a stand-alone code, or interfaced to another computer code for concurrent analysis. Through such coupling, a computer code previously limited by either the lack of required component models or large computational needs can be extended to more fully represent the thermal-hydraulic system, thereby reducing the need for estimating essential boundary conditions.

The method employed in MINET is a major extension of a momentum integral method developed by Meyer [14]. Meyer integrated the momentum equation over several linked nodes, called a segment, and used a segment average pressure evaluated from the pressures at both ends. Nodal mass and energy conservation were used to determine nodal flows and enthalpies, accounting for fluid compression and thermal expansion.

In MINET, a network structure was built around Meyer's momentum integral model for the flow segment. In this extended method, a system is represented using one or more flow networks, connected to one another only through heat exchangers. Each network is composed of segments, volumes, and boundaries. Segments contain one or more pipes, pumps, turbines, heat exchangers, and valves, each of which is represented using one or more nodes. Volumes represent voluminous components and significant flow junctions. Volumes and boundaries are connected by segments.

A simple example of a MINET system is shown in Fig. 5, a schematic drawing of our example deck designated X1. This system is composed of two fluid networks, connected through the heat exchanger. There are four segments in this system, including the long one running through the pump and heat exchanger to the volume. Typically, a segment of this length would contain ten to twenty nodes, depending on the detail required in the heat exchanger.

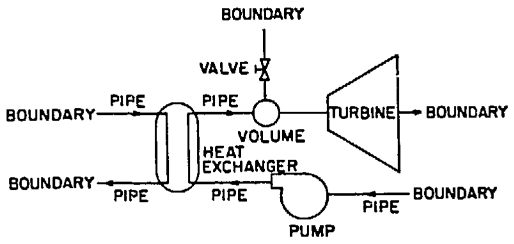

Figure 5
MINET Standard Deck X1, Example Case

While the momentum integral network method forms the basis for the MINET code, several component models, called "modules", are used to determine key parameters in the basic conservation equations. These parameters include the heating term in the energy equation and the pressure loss term in the momentum equation.

Segment modules include pipes, pumps, turbines, valves, and heat exchangers. The pump and turbine models are based on known performance at some reference condition, and utilize minimal geometric detail. The valve model is based on a user-input loss coefficient and the flow area through the valve opening. If choking is indicated by the extended Henry-Fauske, Moody, or isentropic models, the flow rate across the valve opening is automatically limited. Heat exchangers are treated as two pipes linked via heat transfer through the tube wall. The heat transfer from the tube to the fluid is calculated at each time step and used in the nodal energy equations. A fixed mesh nodalization is used, with any change in heat transfer regime within nodes factored into the nodal heat flux calculation, i.e., heat flux is piecewise averaged.

Volume modules are used to represent voluminous system components, as well as locations in a network where pressure must be accurately monitored, e.g., significant flow junctions. For example, one would use one or more volumes (connected by short, wide pipes) to represent a pressurizer or steam drum, or for a header between flow paths of unequal resistance. Currently, one can specify the geometry as a box shape, a vertical or horizontal drum, or a partial box or drum, as well as the operating conditions, i.e., whether the contents are distributed homogeneously or, if saturated, divided into liquid and vapor regions. A cover gas option is available, whereby a noncondensible gas can be specified in the upper region with subcooled fluid in the lower region.

External interfaces to the MINET system representation are provided through the boundary modules. At each boundary, two conditions are required: 1) pressure or flow, and 2) temperature, enthalpy, or quality (if saturated). These are supplied by the user or another computer code (such as RAMONA-3B). Generally, the temperature parameter will be used in the MINET calculations only when flow is entering the system. MINET will always calculate the unspecified flow/pressure parameter and the temperature of the flow exiting the system.

In addition to the basic MINET method and the supporting component models, various constitutive relations are needed for fluid properties and heat transfer. Currently, MINET contains properties and correlations for water/steam, air, sodium, eutectic NaK, and helium. The water/steam property functions are based on polynomial fits of the 1967 ASME steam tables, and are accurate between .7 KPa and the critical pressure. The heat-transfer correlations include those for subcooled convection, subcooled nucleate boiling, forced convection vaporization, film boiling, superheated convection, and filmwise condensation. Water/steam mixture flows are represented through either a homogeneous, equilibrium model or a drift flux model.

The MINET code is relatively small and fast running (approx. 15000 lines of FORTRAN, faster than real time on CDC-7600 for a typical 200 node system), due to modular programming, careful data structuring, and an underlying numerical method that allows a large problem to be broken down into several small ones. In addition, steps have been taken to maximize the range of problems that can be analyzed, as well as the potential for concurrent analysis, i.e., with another computer code, such as RAMONA-3B. One such step was the development of major driver subroutines, which control large portions of the calculational process, whether called from the main MINET program (a small coordinating module), or another computer code driver, such as the one in RAMONA-3B.

The MINET code has been validated using test data from both LWR [15] and LMFBR [16] systems. In particular, the heat exchanger module has been tested in several cases [15-17], and the basic models and methods have been widely tested and applied [18-20].

INTERFACING RAMONA-3B AND MINET

When using RAMONA-3B, one specifies as boundary conditions: the feedwater flow rate and temperature, the behavior of the ECCS system (tabular data or control system parameters), and the turbine/condenser pressure. In MINET applications, the user always specifies the pressure or flow rate and the temperature or enthalpy at each system boundary, in tabular (vs. time) form.

An extensive representation of the BWR system, i.e., one that would be quite complete (regardless of cost) for all types of transient analysis, would be as shown in Fig. 6. To accomplish this, one would represent the BWR system as indicated, using RAMONA-3B to represent the immediate reactor system, and MINET to represent the balance-of-plant and ECCS systems, in such a way that both codes were always informed as to the conditions at the common system border, i.e., at the edge of each code's representation. There are essentially three RAMONA-3B/MINET interface areas: 1) at the location where the feedwater line (also ECCS) enters the vessel, 2) at the outlet of the safety/relief valves, which release steam into the pressure suppression pool, and 3) in the steam lines to the turbine and the turbine bypass.

It was a high priority that the calculations could be performed quickly and accurately. It was considered highly desirable that the two codes remain as independent as possible, so both could be further developed independently, and that the input decks remain independent, so various MINET decks could be switched in and out-representing the system in various degrees of detail.

We chose to make a "modular" interface, where the RAMONA-3B driver program and major subroutines called the four major MINET sub-drivers for: 1) input processing, 2) steady-state calculations, 3) transient calculations, and 4) output processing. Further, data belonging to each code were kept separate, and modules were developed to 1) take information from the RAMONA-3B data and load it into the MINET boundary condition tables and 2) take information from the MINET calculations and load it into the RAMONA-3B boundary condition tables.

In order for the two codes to march through time together, it was necessary to properly coordinate the calculation to avoid inaccuracies and instabilities. Fortunately, at the interfaces under consideration, the coupling between the RAMONA-3B and MINET calculations was quite loose, i.e., changes in conditions calculated in one code did not impact severely on the other code over the time frame of one step, say 0.5 seconds. Thus, we were able to perform the MINET calculations for a given time step using boundary conditions from the RAMONA-3B calculations at the beginning of the step, i.e., explicitly. Once MINET completed the time step, RAMONA-3B boundary condition tables were loaded using beginning and end of step values from MINET. These tables were then interpolated as RAMONA-3B advanced through the time step, to assure smooth stable progress.

Currently, the RAMONA-3B and MINET codes are interfaced only at the feedwater line junction with the vessel. RAMONA-3B sends the steam dome pressure to MINET, which returns the temperature and flow rate at the vessel inlet, including contributions from the feedwater and ECCS systems. The interface in the line to the pressure suppression pool has been planned, and will be implemented in the near future. Here, because the flow through the safety/ relief valves is generally choked, the numerical coupling between the RAMONA-3B and MINET calculations is expected to be loose, and no problems are anticipated. Interfacing in the lines to the turbines and turbine bypass is considered to be a straightforward extension of the above efforts.

TESTING THE INTERFACE

In the first test of the interface at the feedwater line junction with the vessel, we used a simple MINET representation, containing only a

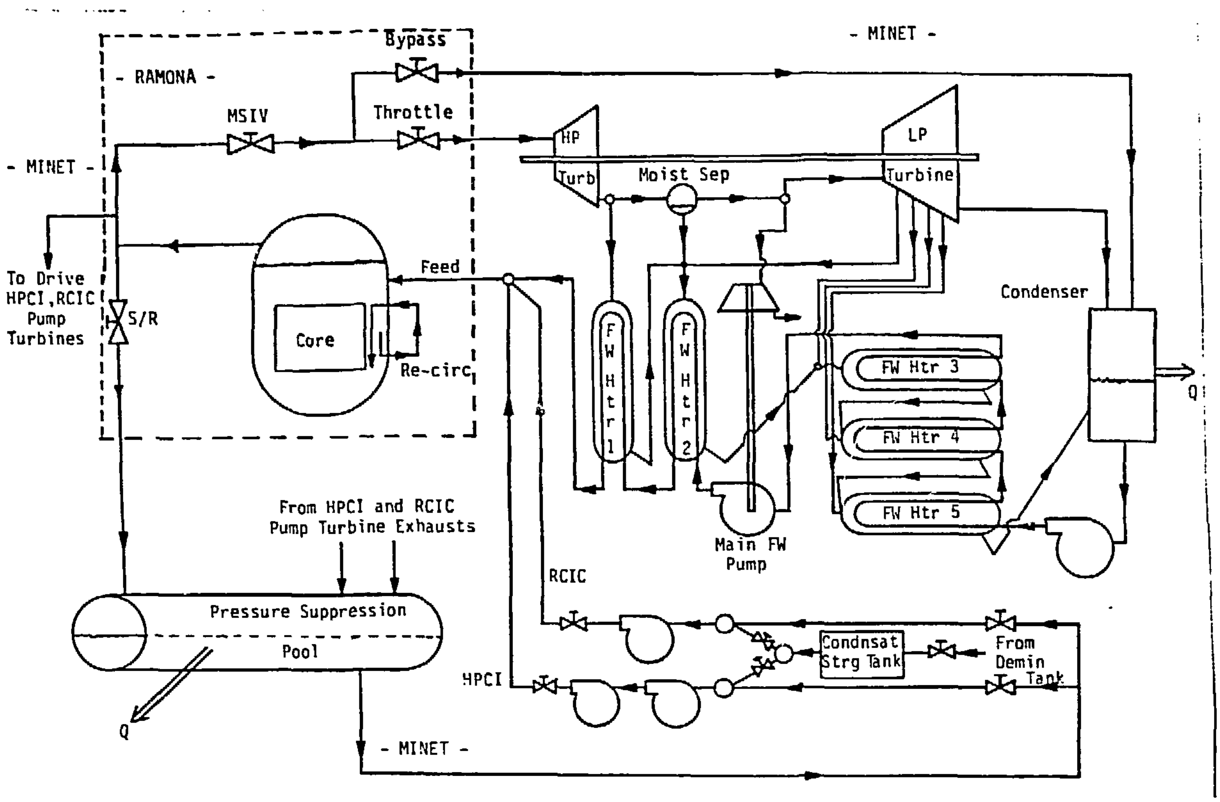

Figure 6 Planned RAMONA/MINET Representation of Browns Ferry BOP and Auxiliary Systems

1-node pipe, and boundaries at both ends. We found that we could control the feedwater flow rate and temperature at the (RAMONA-3B) vessel inlet by adjusting the flow and temperature entering the 1-node pipe (MINET), a highly simplified, but important test.

In pursuing a second test, we made an interesting observation about the boundary conditions for RAMONA-3B, regarding the feedwater and ECCS contributions. As can be seen schematically in Fig. 6, the High Pressure Coolant Injection (HPCI) and Reactor Core Isolation Cooling (RCIC) systems connect with the feedwater line some distance (approximately 70 meters in the Browns Ferry Plant) from the vessel inlet. These are fairly large pipes (multiple parallel feedwater lines are represented as one in Fig. 6), and contain approximately 27,000 kg of 464 K feedwater in the Browns Ferry Plant under normal operating conditions. When the feedwater trips off and ECCS flow comes on, at a total (RCIC + HPCI) flow of 360 kg/s at 294 K, it takes about 75 seconds at full flow to clear the hot feedwater from the line before the colder ECCS water reaches the vessel. The physical representation was not explicitly modeled in the RAMONA-3B calculations, so the delay had to be estimated, based on how we expected the ECCS systems to perform, and factored into the boundary conditions.

Because the impact of the delay before cold ECCS water reached the vessel was potentially significant, we embarked on the second test of the interface, which involved three cases, designated A through C. Boundary conditions for the RAMONA-3B calculation were the MSIV closure and the scram failure. RAMONA-3B controller models opened the safety/relief valves at 3 seconds and tripped the recirculation pumps around 3.7 seconds into the transient.

For case A, MINET was used to represent the feedwater line, the header where the ECCS lines feed in, and boundaries for specification of 1) feedwater flow rate and temperature, 2) the HPCI flow rate and temperature, and 3) the RCIC flow rate and temperature. The transient boundary conditions were: 1) feedwater flow rate ramped down to 0 kg/s during the first eight seconds, 2) HPCI flow rate increased to 330 kg/s between 33 and 58 seconds, and 3) RCIC flow rate increased to 30 kg/s during the 33 to 58 second period. The transient was run to 150 seconds, and the results were plotted and reviewed. The ECCS cold front reached the vessel (RAMONA-3B inlet) approximately 80 to 90 seconds after initiation (in MINET), consistent with results from hand calculations.

A second case, "B", was then run for the same transient, in which RAMONA3B was run without MINET, with the transport delay for the cold ECCS waterfront, as observed in case A, input as a transient boundary condition. The results of cases A and B were essentially the same, again verifying the composite RAMONA3B/MINET code was performing correctly.

A third case, "C", was then executed using RAMONA-3B stand-alone, for the same transient, but without accounting for the transport delay. Thus, cold ECCS water was injected into the vessel immediately upon initiation. Results for case "C" were judged to be consistent with the premature injection of cold ECCS water.

Results for cases A and C were plotted against each other in Figs. 7-9. In all three plots, the results for cases A and C are identical until 50 seconds into the event. For the first 33 seconds, there is no ECCS flow, and once the ECCS flow starts, there is some delay while the cold water mixes in the core inlet plenum. Thus, until 50 seconds, the reactor is relatively uneffected by the colder ECCS flow.

The subcooling of the reactor inlet flow is shown in Fig. 7. In the RAMONA-3B run without delay (case "C"), the cold ECCS flow begins entering the plenum around 34 seconds, and reduces the core inlet temperatures by about 20 K during the 1 to 2 minute period. In the RAMONA-3B/MINET composite run (case "A"), the cold front is still in the piping during this period, and the plenum water remains near saturation.

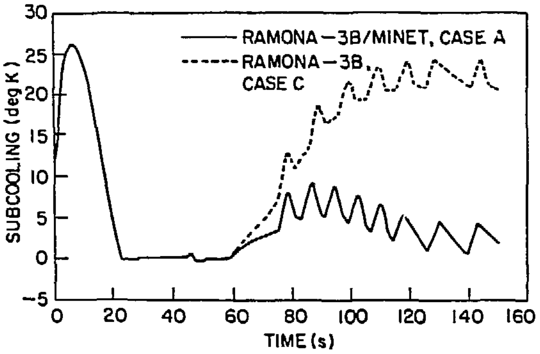

Figure 7
Reactor Inlet Subcooling as Calculated by RAMONA-3B (No Feedwater Transport Delay) and by RAMONA-3B MINET

The relative power levels are plotted in Fig. 8. In a BWR core, the reactivity is very sensitive to the void fraction, i.e., the more steam, the less water, and therefore reduced neutron moderation, reduced reactivity, and reduced power. The power fluctuations are in response to safety/relief valve cycling. In the RAMONA-3B run without the transport delay (case "C"), the power level initially is somewhat higher due to more subcooling at the reactor inlet, and the power fluctuations are smaller because there is less saturated coolant present. In the composite run (case "A"), the power level is lower, due to greater voiding, and the fluctuations are much wider because most of the coolant is saturated and hence, void collapse has more effect on power. Both curves in Figure 8 were then integrated numerically between 60 and 150 seconds. The average power levels were 25.9% for case A and 32.4% for case C. Thus, properly accounting for the feedwater line transport delay provides a 6.5% (of full power) reduction in average power level during what could be an important portion of a BWR ATWS event.

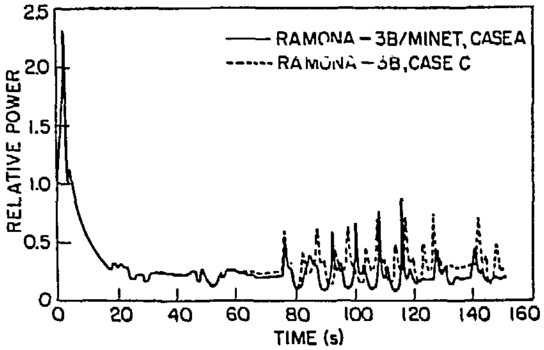

Figure 8
Relative Reactor Power as Calculated by RAMONA-3B (No Feedwater Transport Delay) and by RAMONA-3B/MINET

Maximum fuel temperatures are plotted in Fig. 9. Because of the higher power levels, the fuel temperatures are about 160 C higher for case "C", due to the colder water entering the reactor and pushing the power upward.

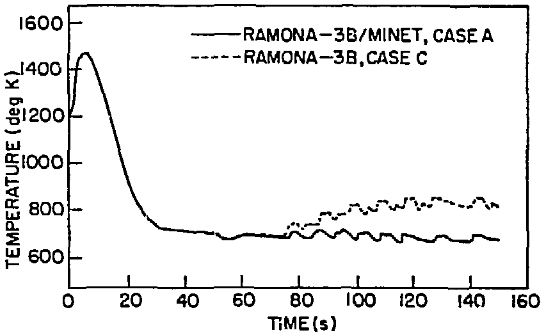

Figure 9
Maximum Core Fuel Temperature as Calculated by RAMONA-3B (No Feedwater Transport Delay) and by RAMONA-3B/MINET

From this analysis, we can make two observations. First, the transient response is influenced by the feedwater line transport delay, and therefore this delay is a significant factor in BWR ATWS analysis. Secondly, interfacing of the RAMONA-3B and MINET codes has already resulted in a modeling improvement, while utilizing only a simple representation of a very small portion of the BWR thermal-hydraulic system. Finally, it should be noted that these cases were all run using the 3-D neutron kinetics, and that the MINET calculations caused only very small increases (less than 10%) in computer CPU time requirements.

PLANS FOR RAMONA-3B/MINET

In the near future, a RAMONA-3B/MINET composite code with interfaces at the feedwater line/vessel inlet and in the relief line to the pressure suppression pool, along with the 1-D/3-D neutron kinetics option, will be completed and tested. MINET decks representing an increasingly larger portion of the BWR thermal-hydraulic systems are being developed.

Further validation efforts must be performed to fully substantiate the RAMONA-3B/MINET simulation of a BWR systems. However, the type of data needed to do such validation work is very difficult to find, and many times it involves usage of proprietary data. The effort to do this work may well depend on a cooperative venture with a utility that operates a BWR plant.

SUMMARY

Our BWR safety analysis capacity has been significantly improved by incorporating a 1-D neutron kinetics option into RAMONA-3B, and by interfacing it with the MINET code, in order to represent a larger portion of the BWR system. Both codes have been used and tested prior to the interface, so that much of our recent testing has been of the interface itself. In one such test application, it was determined that the feedwater line transport delay, and the resulting hold-up of the cold ECCS system water, does significantly effect the reactor power and temperatures during an ATWS event, particularly in the 1 to 3 (approx.) minute period of the transient.

REFERENCES

1. W. Wulff et al., "A Description and Assessment of RAMONA-3B MOD.0 Cycle 4: A Computer Code with Three-Dimensional Neutron Kinetics for BWR System Transients," Brookhaven National Laboratory Report NUREG/CR-3664, BNL-NUREG-51746, January 1984.
2. L.A. Carmichael and R.O. Neimi, "Transient and Stability Tests at PeachBottom Atomic Power Station Unit 2 at End of Fuel Cycle 2," Electric Power Research Institute Report EPRI NP-564, 1978.
3. "Safety Research Programs Sponsored by Office of Nuclear Regulatory Research," Brookhaven National Laboratory Quarterly Progress Report, NUREG/CR-2331, BNL-NUREG-51454, Vol. 4, Nos. 1-4, 1984.
4. G.J. Van Tuyle, T.C. Nepsee, J.G. Guppy, "MINET Code Documentation," Brookhaven National Laboratory, NUREG/CR-3668, BNL-NUREG-51742, February 1984.
5. J.G. Guppy et al., "Super System Code (SSC, Rev.0), An Advanced Thermohydraulic Simulation Code for Transients in LMFBRs," Brookhaven National Laboratory Report NUREG/CR-3169, BNL-NUREG-51650, April 1983.
6. D.M. Cokinos, P. Neogy, J.F. Carew, "Comparison of a Center and Off-Center BWR Control Rod Drop Accident," <u>ANS TRANSACTIONS</u>, <u>47</u>, p. 405, 1984.
7. G. Slovik et al., "RAMONA-3B Applications to Browns Ferry ATWS," Proc. of U.S. NRC 12th Water Reactor Safety Research Information Meeting, NUREG/CP-0058, Vol. 3, Oct. 22-26, 1984.
8. C.J. Hsu, L. Neymotin, and P. Saha, "Analysis of a Typical BWR/4 MSIV Closure ATWS Using RAMONA-3B and TRAC-BD1 Codes," Joint ANS/ASME Nuclear Engineering Conference, Portland, Oregon, August 4-8, 1984, also BNL-NUREG-34942, August 1984.
9. S.E. Mays et al., "Interim Reliability Evaluation Program: Analysis of the Browns Ferry, Unit 1, Nuclear Plant, NUREG/CR-2802, EGG-2199, July 1982.
10. A. Ahlin, M. Edenius, H. Häggblom, "CASMO A Fuel Assembly Burnup Program," STUDSVIK Report AE-RF-76-4158, June 1978.
11. G. Slovik et al., "BLEND 2 Users Manual," Brookhaven National Laboratory Report to be published.
12. Private Communication, T A Keys of the Tennessee Valley Authority to John Carew of Brookhaven National Laboratory, March 6, 1984.
13. J.F. Carew, "Process Computer Performance Evaluation Accuracy," Licensing Topical Report, June 1974, NEDO-20340.
14. J.E. Meyer, "Hydrodynamic Models for the Treatment of Reactor Thermal Transients," Nucl. Sci. Eng. 10, 269, 1961.
15. G.J. Van Tuyle, "MINET Validation Study Using Steam Generator Test Data," Proc. International Conference on Power Plant Simulation, Cuernavaca, Morelos, Mexico, Nov. 1984, also NUREG/CR-3813, BNL-NUREG-51775.
16. G.J. Van Tuyle, "MINET Validation Study Using EBR-II Transient Data," Second Proceedings of Nuclear Thermal Hydraulics Division, American Nuclear Society, New Orleans, LA., June 1984, also NUREG/CR-3603, BNL-NUREG-51733.
17. G.J. Van Tuyle, "MINET Simulation of a Helical Coil Sodium/Water Steam Generator, Including Structural Effects," Brookhaven National Laboratory Report NUREG/CR-3765, BNL-NUREG-51766, April 1984.
18. G.J. Van Tuyle, "Analysis of a CRBRP Station Blackout Event Using SSC/MINET," 2nd Joint ASME/ANS Nuclear Engineering Conference, Portland, Oregon, ASME Paper No. 82-NE-19, BNL-NUREG-31110, July 1982.
19. P.G. Kroeger and G.J. Van Tuyle, "Assessment of Modelling Needs for Safety Analysis of Current HTGR Concepts," Brookhaven National Laboratory Report to be published.
20. B. Schubert, "Analysis of Decay Heat Removal in KNK-II," Proceedings of the Second Specialists' Meeting on Decay Heat Removal and Natural Convection in LMFBRs, April 17-19, 1985, Long Island, NY.