April 26, 2000

MEMORANDUM TO: Chairman Meserve
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan
Commissioner Merrifield

FROM: William D. Travers ***/RA/***
Executive Director for Operations

SUBJECT: STATUS OF THE THERMAL-HYDRAULIC FIVE-YEAR RESEARCH PLAN (M000209 – WITS 2000-030)

This memorandum provides information requested in the Staff Requirements Memorandum (SRM) on the status of RES programs, performance and plans dated February 23, 2000. This request pertained to progress to date, training needs (including impact on schedule), and the projected completion date for the thermal-hydraulic infrastructure improvement program.

BACKGROUND:

In a memorandum from James M. Taylor, Executive Director for Operations, to the Commissioners dated September 6, 1996, "Thermal-Hydraulic Five-Year Research Plan," the staff examined the NRC's future thermal-hydraulic needs and outlined a five-year plan to satisfy these needs. The overall goal of the plan is to build, improve, and maintain the NRC thermal-hydraulic infrastructure. The plan encompasses (1) maintenance of core competency, (2) consolidation of the four thermal-hydraulic system analysis codes into one code and elimination of code deficiencies identified through assessment against data prototypical for the targeted applications, (3) maintenance of small experimental programs to collect data needed for model development and code assessment, and (4) development of technological bases for regulatory decisions involving thermal-hydraulics, e.g., use of computational fluid dynamic (CDF) codes.

DISCUSSION:

The staff met with the ACRS and its Subcommittee on Thermal-Hydraulic Phenomena on several occasions. The ACRS views are reported in a letter to Chairman Jackson dated October 21, 1996, and in NUREG-1635, "Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program," Vols. 1 & 2. In summary, the ACRS concludes that the code consolidation is timely and should lead to efficient use of resources. The ACRS

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emphasized the need for maintaining thermal-hydraulic capabilities and improving the consolidated code. The ACRS also indicated that more specific justification of new experiments and the expected payoff from their results is needed. This issue is discussed in the Attachment, which provides more detailed information on the code consolidation and experimental programs.

A status report is provided below on the thermal-hydraulic infrastructure improvement program. This includes progress to date, training needs (including impact on schedule), and projected completion dates for the four areas: (1) maintaining core competency, (2) code consolidation, (3) experimental programs, and (4) CFD codes.

1. Maintaining Core Competency

    a. Progress to Date

As stated in the plan, the RES strategy for maintaining core competency is to maintain a small, knowledgeable cadre of researchers in-house, complemented by limited contractor and university support in specialized skills. These experts will be available to respond to technical questions as they arise, to develop models that can be incorporated into NRC codes in order to ameliorate identified deficiencies, and to support new applications. Because of the agency’s commitment to improve its thermal-hydraulic infrastructure, RES has continued the Code Applications and Maintenance Program with 22 international organizations and entered into cooperative research agreements with France and Japan.

Prior to 1996, RES maintained little or no in-house research capability in the field of thermal-hydraulics code and model developments. Since then, RES has expended great effort in training the staff, who are now capable of performing tasks that have traditionally been performed by contractors. In addition, RES hired four engineers to perform the code consolidation in-house. However, because of the tight job market, all but one engineer with code development experience left the NRC during 1998–1999, which significantly impacted implementation of the plan. Recently RES has hired two new staff members with thermal-hydraulic expertise and is recruiting a senior level scientist to improve its in-house capability.

    b. Training Needs

The long-term focus will be on ensuring that the NRC continues to provide thermal-hydraulics support for regulatory decision making and continues to maintain core competency. Since NRC will rely on consultants who specialize in certain disciplines, the staff will gain expertise by working with these consultants. NRC will also rely on universities to run experimental programs to supplement the database in order to develop models for some high-ranked phenomena that are deficiently modeled in the codes. These activities will train engineering students who may become the junior staff of tomorrow and also will train staff who work with them on these programs. By developing in-house capability, RES will be better equipped to respond promptly, with a robust technical basis, to safety issues.

    c. Projected Completion Date

Thermal-hydraulics is a core research area essential for maintaining readiness to support risk-informed regulation, to respond to industry initiatives, and to respond to technical questions as they arise in an efficient and timely manner. As such, there is no projected completion date. There have been numerous examples where thermal-hydraulic codes and insights have played vital roles in support of the agency's mission, e.g., support the certification review of the AP600 design, evaluation of steam generator tube integrity, and assessment of pressurized thermal shock.

2. Code Consolidation

As stated in the plan, the basis for the existing thermal-hydraulic codes was developed 20 to 30 years ago to analyze large-break loss-of-coolant accidents using coding architecture and numerical methods that are no longer state-of-the art. To accommodate emerging issues, these codes were modified in an ad hoc fashion, which resulted in difficulty in preparing or modifying plant input decks, difficulty in interpreting the results, and the need for frequent user intervention during the simulation of a transient because the codes are not robust and require large execution times (days to weeks) for detailed plant models.

a. Progress to Date

To accomplish the plan's goal of code consolidation, RES convened a group of experts to examine different approaches NRC could adopt to develop a single state-of-the-art thermal-hydraulic system analysis code that would meet NRC needs. To foster new ideas, RES ensured that this expert group had limited association with prior NRC thermal-hydraulic code development efforts. The general recommendation was to modernize the architecture of an existing code and to use this code as a base into which to consolidate the capabilities of the existing codes. Therefore, RES adopted the approach of consolidating the four thermal-hydraulic codes into a single code, rather than developing an entirely new code. In addition, RES also benefitted from interactions with an international expert group that was convened by NRC and OECD/CSNI in Annapolis, Maryland, November 5–8, 1996, and integrated the conclusions drawn by these experts in implementing the plan.

The staff is currently consolidating the capabilities of its four thermal-hydraulic codes into a single code, TRAC-M. The goal of the effort is to provide the functionality of the current suite of codes, while reducing the maintenance and development burden. NRC will then be able to focus on one code instead of four, thereby enhancing the knowledge base and allowing user-requested improvements to be made faster.

To date, the TRAC-M code is capable of performing the functionality of TRAC-P, TRAC-B, and RAMONA codes. In addition, several improvements have been made to the TRAC-M code, which will facilitate consolidating the RELAP5 functionality. A β-version of the TRAC-M Code will be released to NRR in May 2000.

b. Training Needs

RES staff has played an integral role in the consolidation process. The staff performs development work that would otherwise be assigned to contractors. Therefore, RES is beginning to develop the same skills that exist at a contractor, and by 2003, will perform the majority of code maintenance and development in-house. To broaden this knowledge-base, RES will provide training sessions on use of the code for the staff. The first session is scheduled for Fall 2000. These sessions will be regularly scheduled as needed, such as in the case of new hires.

c. Projected Completion Date

At the time the plan was written, RES envisaged consolidating the modeling attributes of the TRAC-P, TRAC-B, and RAMONA codes into a single TRAC-M code in two years. Although this intermediate milestone was delayed by approximately one year, because of budget short falls (total 20 percent over FY 1997–FY 2000) and loss of three staff members during the implementation phase, the overall code consolidation efforts will be completed in FY 2002.

The consolidated code will be maintained and developed in-house, resulting in savings to NRC. This savings allows RES to address other high priority issues. For example, some of the savings are now being used to support a new NRR user need to address uncertainties in analysis related to steam generator tube repairs.

3. Experimental Program for Model Development

System analysis codes like TRAC-M are used to calculate the behavior of nuclear power plants over a wide spectrum of conditions and they contain a large number of models and correlations to simulate the phenomena that occur. These models and correlations are developed from basic or separate-effects experiments. When incorporated into the systems code and used in a system calculation, many models come into play in a given calculation and interact with each other. The performance of the overall code is tested through comparison with integral system test data. Accordingly, the plan includes both separate and integral-effects tests.

a. Progress to Date

Separate-Effects Tests

Peer reviews have shown the need for RES to supplement the currently available database so that models can be developed to ameliorate significant known code limitations. For example, current codes are limited in their ability to calculate loss-of-coolant-accident reflood heat transfer, which directly affects the calculation of cladding temperature. The modeling deficiencies in this area limit the applicability of the codes, particularly in addressing risk-informed regulation and power rate increases. Four separate-effects tests (SETs) are being run, including (1) subcooled boiling at low pressure, (2) interfacial area transport, (3) phase separation at tees, and (4) rod bundle heat transfer. More detailed information concerning existing code limitations and each of these tests are given in the Attachment.

Integral-Effects Tests

In addition to the SETs, the plan indicates the need to maintain a pressurized-water reactor test facility at Oregon State University (APEX), a boiling water reactor test facility at Purdue

University (PUMA), and a B&W once-through steam generator test facility at the University of Maryland to provide integral thermal-hydraulic data for TRAC-M code validation. In addition, the integral test facilities are used to obtain essential data that can assist NRC in resolving important safety issues. For example, in FY 2000, the APEX facility is being modified to support the agency's effort to modify the pressurized thermal shock (PTS) rule.

b. Training Needs

No training is needed for this portion of the plan.

c. Projected Completion Dates

The low-pressure subcooled boiling heat transfer tests, the phase separation in tees tests, and rod bundle heat transfer tests are projected to be completed in FY 2001. The interfacial area transport test represents the cutting edge of two-phase flow modeling and is a long-term effort. It is expected to be completed in FY 2002–2003.

With regard to the integral-effects test program, RES will assess on a yearly basis the need to maintain the APEX and PUMA facilities. As discussed in the Attachment, RES identified the need to maintain these facilities in FYs 2001–2002.

4. Computational Fluid Dynamics (CFD)

a. Progress to Date

CFD will play an increasingly important role in the nuclear industry as CFD technology matures and the computational resources required become more affordable. RES has acquired the commercial CFD code, Fluent, along with the required computing power. RES is also supporting the development of advanced two-phase modeling techniques for nuclear systems application through two research contracts at the University of Florida and the Rensselaer Polytechnic Institute, thereby enhancing its available expertise.

b. Training Needs

A staff member was trained to use the Fluent code to perform in-house analysis to address emerging issues that require more resolution than can be provided by system-level codes. Examples of these issues include mixing phenomena in the reactor pressure vessel down comer, which is important in assessing the severity of PTS or boron dilution events.

c. Projected Completion Dates

The staff will continue small-level activities for five years at two universities to support cutting-edge research for developing two-phase flow for CFD codes.

SUMMARY:

In summary, RES developed a plan to maintain and update the agency's thermal-hydraulic codes. RES recruited and hired individuals with skills necessary to develop and maintain the consolidated code in-house and supplemented this in-house capability with university and contractor expertise, so that NRC can respond effectively and efficiently to emerging safety issues.

Significant progress has been made and the staff is confident that the code consolidation program will be completed in FY 2002. In May 2000, RES will release to NRR a β-version of the TRAC-M code that has the functional capabilities of the original TRAC-P, TRAC-B, and RAMONA codes. Future work will focus on RELAP5 functionality consolidation and developmental assessment. Test programs are currently under way to supplement the available database. Model development will be performed as a collaborative effort between RES staff and the university-based research team. RES has begun to utilize a commercially available CFD code in-house.

Attachment:
Update to the Thermal-Hydraulic Five-Year Research Plan

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Attachment

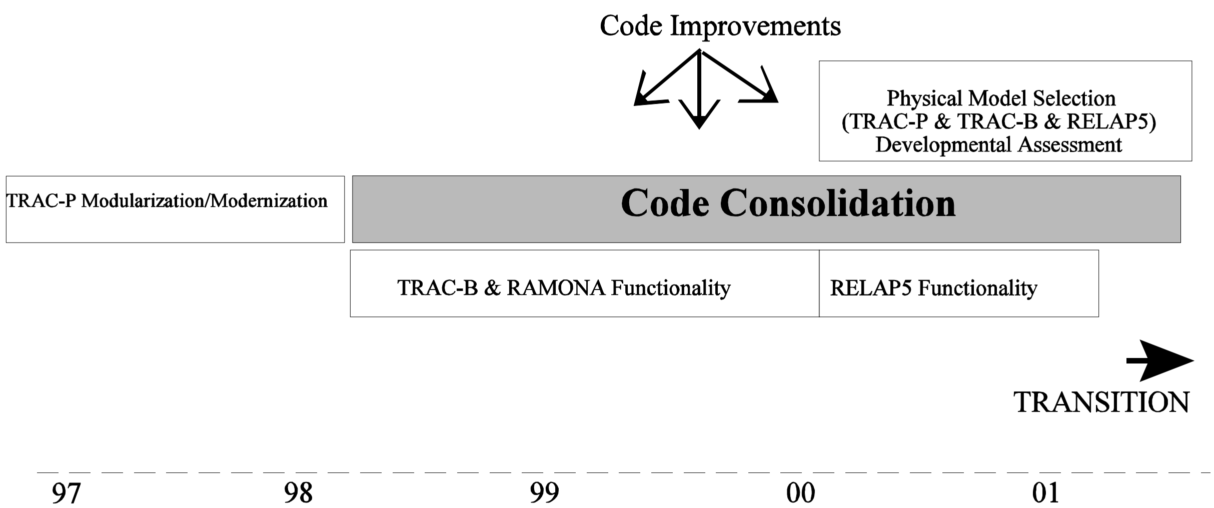
Update to the Thermal-Hydraulic
Five-Year Research Plan

1. Thermal-Hydraulic Code Consolidation

   a. Consolidation Plan

At the time the Thermal-hydraulic Research Plan was written, the NRC supported the development and maintenance of the RELAP5, TRAC-P, TRAC-B, and RAMONA codes at INEEL, LANL, Penn State University, and BNL, respectively, with little opportunity to consolidate the available talent base and minimize costs. The plan to consolidate the capabilities of the four thermal-hydraulic codes into a single code is intended to minimize the dilution of resources that occurs with the development of four separate codes. As a result, user needs will be accommodated more expediently since effort will not be distributed among the four codes. Additionally and perhaps most importantly, the consolidation will enhance analysis capabilities, as the NRC and users can focus their attention on one code, thereby developing collective expertise far more efficiently than is possible when four codes are utilized. Input deck construction will not be duplicated, as all transients for a plant would be performed with one code instead of two. The consolidation process consists of five distinct stages, as depicted in Figure 1.

2. TRAC-P modularization/modernization
3. TRAC-B and RAMONA functionality



4. RELAP5 functionality consolidation
5. Developmental assessment and constitutive model selection
5. Code Improvements

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Figure 1: Consolidation Time Line

Stage 1 involved revamping the architecture of the TRAC-P code, which served as the basis for the consolidation. The language was converted from Fortran77 to Fortran90 and the architecture modified to enhance modularity. The code is now denoted TRAC-M. Stage 2 work recovered the capabilities of the 3-D neutronic capabilities of the RAMONA code and the boiling water reactor capabilities of TRAC-B codes. In consolidating the TRAC-B components, the technical approach taken also made some progress that will facilitate the RELAP5 functionality consolidation. Therefore, Stage 3, which will be concurrent with Stage 4, now primarily involves resolving additional input options. It should be noted that, since the TRAC-M, TRAC-B, and RELAP5 codes use different physical models, different answers are to be expected at this juncture of the consolidation efforts. Therefore, in Stage 4, the staff will perform assessment of all available physical models and select the best ones that must be imported from either TRAC-B or RELAP5 to allow TRAC-M to perform analyses for the targeted applications. Assessment will also ensure that kinetics and stability capabilities are sufficient. Throughout the consolidation program, improvements will continue to be made to the TRAC-M code. These improvements are merged with TRAC-M when logistically feasible (Stage 5).

The plan of the consolidation stresses the importance of documentation and version control. Each activity has been documented in separate completion reports containing a Software Requirements Specification, Testing Plan, Software Development and Implementation Document, and Verification Test Report. To manage the versions created during the consolidation, the staff has developed a configuration control system utilizing Concurrent Versions System and maintains a development web site, which provides the developers remote access to the source code, test sets, user error reports, correction reports, and details of the development history and plan.

It should be noted that RES is not simply combining existing codes and models into one consolidated code (TRAC-M). If this were done, the consolidated code would be the same size as the current suite of codes, and it would still be necessary to know each of the four codes in order to use, maintain and develop the consolidate single code. In contrast, the consolidation involves using TRAC-B philosophy to develop BWR components out of TRAC-M components.

b. Status

To date, Stages 1, 2, and a significant portion of the Stage 3 planned accomplishments have been completed. The BWR components and models installed and tested in the TRAC-M code include the jet pump, level tracking, turbine, BWR Fuel channel, separator/heater, feedwater heater, control system, containment (for BWRs and PWRs), 1-D kinetics, and input processing capability for TRAC-B input decks. To recover the functionality of RAMONA, a 3-D kinetics capability and a less diffusive numerical scheme have been incorporated in order to perform stability analysis.

Therefore, the TRAC-M code now has the same functional capabilities as the TRAC-P, TRAC-B, and RAMONA codes. Over the past two months, RES has been performing extensive assessment and debugging of the TRAC-M code. Approximately 200 test problems were executed to verify the consolidation of the TRAC-B components and models into TRAC-M. The consolidation also resulted in major improvements to the TRAC-M code and included a containment model that is capable of simulating both PWR and BWR containment behavior. In May 2000, a TRAC-M β version will be issued to NRR.

c. Current and Future Activities

The staff is now working on Stages 3 and 4 and is expecting to complete the code consolidation activities in FY 2002.

As stated earlier, in Stage 1, additional effort was spent modifying TRAC-M to facilitate the conversion of RELAP5 input decks. This effort was originally planned to commence after the consolidation of the TRAC-B, TRAC-P, and RAMONA capabilities in the TRAC-M code. However, for efficiency, RES has completed them ahead of schedule. For example, adding a single junction component, enabling the semi-implicit numerical scheme, and adding an exterior communication interface will speed up the remaining consolidation.

d. Code Improvements

Throughout the consolidation, improvements have been made to the TRAC-M code and merged whenever logistically feasible. Therefore, Stage 5 activities take place concurrently with other stages. As users request additional code capabilities in response to emerging issues and take advantage of increases in available computing power, the danger exists to complicate the code and its architecture, hindering further development and maintenance. To prevent this, the staff has adopted the design strategy of coupling the code across a well-defined interface. This strategy was used in providing the code with a 3-D kinetics capability. To allow this logic to be extended to other functional models and to make its implementation consistent in each case, an exterior communication interface has been developed. In addition to facilitating the implementation of RELAP5 functionality, the exterior communication interface will facilitate coupling to other codes, such as CFD codes, sub-channel analysis codes, or more detailed containment codes.

e. Graphical User Interface

One of the major obstacles complicating the switch to the reliance on the consolidated code is the existence of a large number of input decks for RELAP5, TRAC-B, and TRAC-P. The ability to import and initialize these old input decks, and export a file that can be used with the consolidated code, was one of the motivating factors in developing a generic graphical user interface, now referred to as SNAP (Symbolic Nuclear Analysis Program). In 1999, the staff completed the development and issued an α version of SNAP, which allows the user to build and edit input models by manipulating icons and through user-friendly interactive command. This SNAP version is also capable of converting the existing RELAP5 ascii-based input format into a graphical display and will soon be able to generate files that can be used with the computational engine of the TRAC-M code with a minimal amount of user intervention. In FY 2000, we are developing a runtime processor for problem submission, reporting and plotting of results, and job status monitoring.

The SNAP front end will replace current text-based input deck preparation and will assist the analyst in executing the model. Expert systems will provide default nodalization and other user conveniences. Component templates will be available to simplify the construction of plant models. Analysts will only have to make plant-specific modifications to system loss coefficients or other geometric details. Furthermore, the user effect will be minimized, as SNAP will report any modeling practices that are not recommended. The SNAP back end will serve as the output visualization tool. The back end capabilities will include a 3-D representation of the piping system and components, a simulator-like mask of the system with animation (colors represent temperatures, trips enunciated, strip charts depicting time traces of system parameters, etc.), and runtime control system linkage. The latter feature will allow the user to interact with the model/execution of the code as is common with simulators, thereby having the capability to change things, such as positions of valves, pump speeds, and trip settings during runtime. The back end will also have multiple masks, allowing the analyst to run and display different models simultaneously with the ability to pause and resume each calculation. A β version of the SNAP back end capabilities will be available in FY 2000, and it will be released in FY 2001.

2. Experimental Program for Model Development

Since code limitations and deficiencies have been identified, the staff has initiated work to ameliorate these limitations and deficiencies. These new features will be merged with the consolidated code when available and when logistically feasible. This approach was adopted since it was necessary to supplement the currently available database before some models could be developed. Therefore, four separate effects tests are being run in an attempt to minimize the time required before these deficiencies can be improved.

A. Subcooled Boiling at Low Pressure

In two-fluid codes, only one temperature is specified for each phase in a cell. Therefore, in order to predict boiling on the heated surface when the volume averaged temperature is subcooled, a special model is required to predict vaporization in the superheated near wall region. TRAC-M and most two-fluid codes use a model that utilizes a liquid-to-vapor density ratio to suppress nucleation. At low pressures, the density ratio is huge (0.2 MPa, the ratio is 1300 vs. a ratio of six at 15 MPa) and the net vapor generation is dramatically under-predicted. This limits the code's ability to predict two-phase pressure drop through the core, which can lead to inaccuracies in the core flow rate and in turn, clad temperature. The AP600 analysis proved that the subcooled boiling model at low pressure requires improvement.

Work to develop an improved subcooled boiling model for low pressure conditions began in January of 1998 at UCLA. The main objectives of this study are to develop an experimental database and to augment and validate available experimental data and to develop a mechanistic model for wall heat transfer and void fraction during subcooled boiling. Extensive review of the open literature revealed that most previous studies were performed under high-pressure conditions and do not provide enough information to develop mechanistic models. The main issue to be resolved is how the wall heat flux is partitioned during subcooled boiling, i.e., how much is used to generate vapor and how much goes into single-phase forced convection.

UCLA is currently in the process of analyzing the data collected on the flat plate and comparing them with any available experimental data or models and correlations. Data collection using the rod bundle is continuing. New models and correlations will be developed if necessary. The project is expected to conclude in FY 2001.

B. Phase Separation at Tees

During depressurization, phase separation at tees can dominate the course of a transient, since the effluent quality determines how fast the system depressurizes and the liquid inventory decreases. Perfect separation will maximize depressurization while minimizing the loss of inventory, resulting in a non-conservative result. During AP600 analysis, the phase separation at tee model in RELAP5 or TRAC-M was proven to be of limited applicability, since data only covered a limited range of conditions. Research was begun at Oregon State University in Fall 1997 to collect the available data and to review existing models. It was concluded that a test facility was necessary to supplement this database with data that covered the complete range of conditions prototypic of nuclear reactor operation. Because of loss of graduate students, the project was delayed and construction on a scaled air-water facility was completed in November 1998. Data have been taken for the horizontal stratified and wavy flow regimes and is now being taken for the intermittent regime. A model has been developed and preliminary analysis shows good agreement with the stratified and wavy data. Effort is now focusing on taking data for the intermittent flow regime and extending the model to cover these conditions. A model is expected to be incorporated into the consolidated code in FY 2001.

C. Rod Bundle Heat Transfer Program

Previous tests to study reflooding phenomena were conducted to prove that fuel cladding temperatures will not exceed regulatory limits and the test facilities were not instrumented to produce detailed information required for model development. Current flooding models incorporate too many adjustable parameters and do not account for the effect of spacer grids. These modeling deficiencies limit the applicability of the codes, particularly for risk-informed regulation and power rate increases, where the need may exist to use the model outside its range of applicability.

A program was initiated in November 1998 at Pennsylvania State University to develop a more mechanistic model for reflood heat transfer in an aim to reduce the uncertainty inherent in current reflood analysis. A test facility will generate data in a manner that will help isolate each of the many phenomena that affect reflood. For example, data on convection heat transfer and radiation heat transfer alone will be taken, as well as the effect of drops (induced turbulence, distributed heat sink, etc.). The facility will also measure detailed data on drop size distribution, drop velocity, vapor superheat, and void distribution in the froth region to help identify the effect of void fraction on heat transfer. The facility will have instrumented spacer grids to measure rewetting and droplet break up. Expert opinion was solicited to identify the deficiencies in the current database and a facility was designed to collect these additional data. The facility construction will be completed in July 2000, and the test series will be completed in 2001. In coordination with RES staff, a model will be developed to be incorporated into the consolidated code at the end of 2002.

D. Interfacial Area Transport

TRAC-M and most two-fluid codes use interfacial area to determine the total force between phases for heat transfer and drag. Currently the codes use static flow regime maps and deduce the representative interfacial area. As mass flux and void fraction change, the flow regimes change instantaneously with no regard of the physical time and length scale of flow regime development. This approach causes instabilities and limits code accuracy, particularly at low pressure conditions important to advanced light-water reactor safety. An alternative approach is to use a transport equation for interfacial area, with source and sink terms representing the actual processes that govern the change in interfacial area.

In Fall 1997, carefully scaled air/water test facilities were constructed at Purdue University and the University of Wisconsin, Madison, to study interfacial area transport in vertical and horizontal pipes. To date, detailed experiments have been performed for the bubbly flow and bubbly-slug flow transition. The data are representative of low-to-high-pressure conditions in relatively small-to-medium-sized pipes or channels. A one-dimensional one-group interfacial area transport equation has been developed using a mechanistic modeling approach and benchmarked against the experimental data. For cap, slug, and churn-turbulent flow, the mathematical framework for two-group interfacial area transport equations has been completed. The necessary constitutive relations have been identified based on physical processes that dominate the transfer of interfacial area. New experimental data at higher gas fluxes will be used to benchmark the constitutive models. In order to replace the current flow regime maps, the model must be extended to cover all conditions and geometries prototypic of reactor designs. Therefore, data will be taken using rod bundles and in channels with elbows and cross-sectional area deviations. The NRC has entered into a collaborative research agreement with Japan and France in an effort to extend the available database and to obtain access to diabatic steam/water data.

This work represents the cutting edge of two-phase flow modeling and is a long-term effort. A preliminary model was incorporated into a test version of the TRAC-M code by NRC staff to predict the development of interfacial area in a vertical pipe. Good agreement with data was achieved. This study helps prove the feasibility of the approach. Although subject to the progress made by the other countries, it is estimated that the flow regime maps will be replaced in FY 2003 in a developmental version of the code. RES will continue to implement the preliminary models into test versions of the code in an effort to resolve issues associated with how the model works with the code numerics and to help focus the experimental effort. At this stage of the work, RES is unable to predict precisely when the model will be perfected and distributed to the user community as a code release.

E. Integral-Effects Test Facilities

In addition to the separate-effect tests, the Plan articulated the agency strategy for maintaining a boiling water reactor test facility at Purdue University (PUMA), a pressurized-water reactor test facility at Oregon State University (APEX), and a B&W once-through steam generator test facility at the University of Maryland (THECA) to provide integral thermal-hydraulic data for the TRAC-M code validation. Systems codes, e.g., TRAC-M code, which are used to calculate the behavior of nuclear power plants under a wide spectrum of conditions, contain large numbers of models and correlations. These models and correlations are developed from basic or separate-effects experiments and validated and assessed against similar experiments. When incorporated into the systems code and used in a system calculation, many models come into play in a given calculation and interact with each other. The performance of the overall code is tested through comparison with integral system test data. As part of our continued assessment of the need for these facilities, it was planned that support for the THECA facility would be terminated in FY 2000. However, in response to the ACRS concerns over the PTS issue, RES will reevaluate the capabilities of the THECA facility to determine if it can help reduce the uncertainties in the current understanding of PTS phenomena. Therefore, RES is currently assessing the role the THECA facility will play in the thermal-hydraulic research program. The test programs at the other two facilities are summarized below.

The APEX facility is of unique importance in improving the NRC's data bank in the area of integral systems tests. The facility can also function in a quasi separate-effects mode to study certain important modeling issues such as phase separation at flow junctions and counter-current flow. In FY 2000, the APEX facility is being modified to support the agency's effort to modify the pressurized thermal shock rule. RES has not previously run an integral system to provide PTS data. CFD codes have never been exercised or compared with cold leg/downcomer data. The use of CFD and high-quality experimental data will enable the staff to quantify safety margins. In FY 2001–2003, RES will use the APEX facility to obtain data to evaluate the overall system response to steam generator tube failure, fluid-fluid mixing and thermal stratification in the cold leg, the effect of stepped inventory reductions and competing loop effects and interruption of natural circulation flow, phase separation at junctions (this will supplement the data from the separate-effect test discussed above), and noncondensable transport, which has a significant effect on plant response during shutdown conditions.

The PUMA facility is unique in that it provides integral data of coupled RCS thermal-hydraulics with the containment thermal-hydraulic phenomena. Coupling the thermal hydraulics of the reactor coolant system to the thermal-hydraulics of the reactor containment remains difficult in current generation thermal-hydraulic codes. As stated earlier, the TRAC-M code was improved to incorporate containment models for both PWRs and BWRs. The PUMA data will be used to produce the data needed to assess the TRAC-M code.

In FY 2000, the staff is using the PUMA facility to provide separate-effects data on critical flow at low pressure conditions to be used in model improvement. The work done as part of the evaluation of RELAP5 adequacy for simulating the AP600 system demonstrated the deficiency of the choking models currently utilized in the fluid codes, including the TRAC-M code. In FY 2001, the PUMA data will be used to produce data needed to assess the containment modeling in the TRAC-M code. During the consolidation of the TRAC-B capabilities, a BWR containment model was incorporated into the TRAC-M code and was extended to be applicable to a PWR plant design. Coupling the thermal-hydraulic response of the RCS to that of the reactor containment continues to challenge the current generation of thermal-hydraulic codes. The PUMA facility is unique in that it can provide integral data for situations in which the RCS and containment response is tightly coupled.