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UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

March 1, 2000

MEMORANDUM TO: G. Wallis, T. Kress, D. Powers, R. Seale, V. Schrock, N. Zuber

FROM: P. Boehnert, Senior Staff Engineer

SUBJECT: ACRS THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE MEETING, MARCH 15, 2000 - BACKGROUND MATERIAL

The ACRS Thermal-Hydraulic Phenomena Subcommittee will hold a meeting on March 15[1], 2000 in our Rockville Maryland Offices. The purpose of the meeting is to (1) begin review of the thermal-hydraulic issues associated with the pressurized thermal shock (PTS) Screening Criterion Reevaluation Project being conducted by NRC Office of Nuclear Regulatory Research (RES); (2) begin review of the NRC staff acceptance review of the Siemens S-RELAP5 and GE Nuclear Energy TRACG codes; and, (3) discuss the status of the NRC staff's review of the EPRI RETRAN-3D code. A copy of a draft[2] meeting agenda is attached. (**Note**: I am estimating an adjournment time of ~ 5:30 PM.)

BACKGROUND

PTS Screening Reevaluation Project

Last year, RES initiated a project with the goal of promulgating a risk-informed revision to the PTS Rule (10 CFR 50.61). This is being done to address the known substantial conservatisms that exist in the current version of the Rule. This will, in turn, allow a significant increase in the PTS screening criteria that impact all PWR plant licensees. A

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[1] This meeting has been collapsed from two days to one due to the postponement of the discussion on the NRC staff's code review guideline documents. Specifically, ACRS review of these documents has been postponed from the April to the May meeting. Therefore, a Subcommittee meeting will be scheduled in mid-to-late April to continue review of the guideline documents.

[2] I am awaiting additional input from RES regarding the PTS presentation schedule.

copy of the set of slides that the staff used in its presentation to the Committee during the July ACRS meeting on this matter is attached for your perusal.

Regarding the thermal-hydraulic activities supporting the PTS reevaluation process, RES has as its primary objective to ensure that for risk-significant events (see below), the existing thermal-hydraulic inputs to the PTS calculations are still valid, or are corrected and updated as needed. To this end, RES has planned the following work (see attached slides):

- Perform experiments in the Oregon State University APEX facility (structurally modified to simulate a CE/Palisades plant configuration) to determine the effects of flow loop stratification and plume dispersal for the worse-case events (small hot -leg break, depressurization/repressurization transient, etc.)

- Perform code calculations (in-house) using plant-specific input decks (as available) Four events will be run with the goal to determine the threat posed from secondary side transients and determine which event(s) are bounding.

- Provide the results of the tests/analyses to industry for its review.

This is a multi-year effort and is not scheduled to be concluded until mid-2001.

S-RELAP5 and TRACG Code Acceptance Reviews

NRR has received submittals from Siemens Power Corporation and GE Nuclear Energy for review of its S-RELAP5 and TRACG codes, respectively.[3] Specifically, Siemens has requested staff review of S-RELAP5 for applications to transients (best-estimate basis) and small-break LOCAs (evaluation-model basis). GENE has submitted a version of TRACG for analysis of so-called Anticipated Operational Occurrences (best-estimate basis). Future submittals are expected from both vendors for application to large-break LOCA analyses on a "realistic" or best-estimate basis.

NRR has begun its acceptance reviews relative to the adequacy of the documentation submitted for both codes. I understand from NRR that the documentation provided appears to be adequate to support staff review, but shortcomings are evident. Specifically, both sets of documentation evidence shortcomings in the area of code assessment (this also was a problem with the RETRAN-3D documentation). For the TRACG code, the staff also has concern with the robustness of the kinetics models. Regarding the Siemens code, NRR noted that S-RELAP5 is a combination of models

[3] I have received copies of the S-RELAP5 code documentation, and am awaiting the TRACG topical reports. Copies of this material will be sent to you in a separate mailing upon receipt of the GE documents.

from the MOD 2.0, 2.5, and 3.0 versions of RELAP - including additional models inserted by Siemens. Given this, code assessment will take on a heightened importance. NRR has been provided a running version of S-RELAP5; GE has not yet provided a copy of TRACG for the staff's use.

Status of RETRAN-3D Code Review

The T/H Phenomena Subcommittee held three meetings on the issue of the staff's review of RETRAN-3D. Dr. Wallis performed a detailed review of the momentum equation model used in the code and identified several significant concerns. During the July 1999 ACRS meeting, Dr. Wallis provided a presentation that detailed his concerns with the RETRAN momentum equation model (see excerpt of meeting Minutes). Mr. J. Kelly, RES, was asked to review specific aspects of RETRAN. His report (copy attached) raised a number of concerns, some of which were identical to those of Dr. Wallis. Subsequent to this meeting, NRR transmitted a set of questions compiled by Dr. Wallis and Mr. Schrock, along with questions from the staff, to EPRI for response. The EPRI response (copy attached) was considered (by Dr. Wallis and NRR) to be insufficient. During its September 1999 meeting, the Committee agreed to NRR's suggestion that it not take any additional action relative to this review, pending the outcome of NRR's review.

The staff review has apparently reached an impasse. NRR is waiting for additional direction from EPRI, subsequent to taking additional action on this matter.

SUBCOMMITTEE DISCUSSION

A copy of the Presentation Schedule is attached. NRR will discuss the status of its code acceptance reviews and the RETRAN-3D code review. A brief presentation from Mr. Swindelhurst (Duke Power - representing EPRI) is expected relative to EPRI's plans regarding the RETRAN-3D code.

The bulk of the day's meeting presentations will involve the RES PTS Screening Reevaluation Project, specifically the T/H aspects of this effort.

OUTCOME

Time will be set aside during the April ACRS meeting for Dr. Wallis to provide a Subcommittee Report on the results of this meeting.

Attachments: As Stated

cc: R. Savio

cc w/o attach (via E-mail):
J. Larkins
S. Duraiswamy
ACRS Technical Staff & Fellows

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE MEETING:
ACTIVITIES ASSOCIATED WITH THERMAL-HYDRAULIC CODES/
REVISION OF PRESSURIZED THERMAL SHOCK RULE

MARCH 15, 2000

PROPOSED AGENDA (DRAFT)

TOPIC	PRESENTER	TIME
1. Introduction	G. Wallis, Chairman	8:30 AM
2. Status of RETRAN-3D Code Review		
• NRC Staff Presentation	R. Caruso, NRR	8:45 - 9:15 AM
• EPRI Presentation	G. Swindlehurst	9:15 - 9:30 AM
3. NRR T/H Code Acceptance Reviews		
• SRELAP5 Code	R. Landry	9:30 - 10:00 AM
	J. Mallay, Siemens Power Co.	10:00 - 10:15 AM
	BREAK	10:15 - 10:30 AM
• TRACG Code	R. Landry	10:30 - 11:00 AM
4. NRC-RES Presentation: PTS Rule Revision - T/H Activities		
• Introduction	F. Eltawila, RES	11:00 -
• Overview of T/H Input Into the PTS Reevaluation Program	D. Bessette, RES	
• Existing Fluid-Fluid Mixing Data Base	D. Bessette, RES	

- Results from Prior PTS Transient Analyses — D. Bessette
- Calculational Plans — D. Bessette
- Scaling of PTS Experiments — J. Reyes, OSU
- Planned Experiments in APEX, Analysis of Results, Schedule — D. Bessette
- Concluding Remarks — F. Eltawila

5. Subcommittee Caucus

- Follow-on Actions for the above topics
- Future Actions
- Committee Action

6. Adjourn — 5:30 PM (Est.)

David Bessette
Office of Nuclear Regulatory Research
US Nuclear Regulatory Commission

Status of Thermal Hydraulics Input to PTS Reevaluation Project

February 2-3, 2000
Washington, DC

Objective

- To ensure that for the risk significant classes of events, the thermal hydraulics inputs, developed at the time of the IPTS study, are still operative;

  or, are otherwise corrected and updated as needed.

- To, additionally, provide and estimate of the uncertainty of these values..

Thermal Hydraulics Input to Fracture Mechanics

- As a function of time;
  1. System Pressure (p)
  2. Downcomer Temperature (T)
  3. Fluid-to-Wall Convective Heat Transfer Coefficient (h)
- Time-dependent uncertainty estimates for the three parameters
- Note that p, t, and h are not independent parameters.
- Over the region of interest, sensitivity of temperature distribution in the reactor vessel to variations in h shown to be small (NUREG-1667)
- System pressure is generally calculated reasonable well from TRAC or RELAP.
- Downcomer temperature can also be calculated reasonably well, either using TRAC and RELAP or REMIX

Thermal Hydraulics Input to Fracture Mechanics (cont'd)

- Plumes, when they occur, are expected to have dissipated (mixed) before reaching the beltline region, based on experimental data, leaving only an axial temperature gradient

Thermal Hydraulic Codes in Use

- Systems Codes

  TRAC
  RELAP5

- Special Purpose Code

  REMIX

- CFD Codes

  FLUENT
  CFX

Currently Available Input Decks

Code				
TRAC	HB Robinson	Oconee	Calvert Cliffs	
RELAP	HB Robinson	Oconee	Calvert Cliffs	Palisades
REMIX	HB Robinson		Calvert Cliffs	Palisades
FLUENT				
CFX				

Current Plans for RELAP/TRAC Calculations
(subject to revision)

- First priority

  1. Small hot leg break.

  2. Depressurization/repressurization transient (e.g. a stuck open PORV which depressurizes the primary system, allows HPI to initiate, natural circulation to stop. Then the block valve is closed and the system begins to repressurize).

- Next priority

  3. Main steam line break. This was one of the most risk important sequences in the IPTS studies but has not apparently disappeared due a change in logic for tripping the reactor coolant pumps.

  4. Small cold leg break. The results appear to be similar to the small hot leg break, but other things being equal, less severe.

Current APEX PTS Test Matrix

- Inject HPI into cold legs and measure plume effects in the vessel downcomer. The loop flow conditions will be stagnant.
- A depressurization/repressurization test simulating one of the most risk dominant sequence from the IPTS studies.
- Flow interruption in one steam generator prior to the other.
- Small (2 inch) hot leg break where the operator is assumed to follow the emergency operating procedures.
- Small hot leg break similar to preceding test, but simulating Westinghouse HPI, accumulators, and LPI, instead of Combustion Engineering.
- Small cold leg break. Similar to hot leg break, but to assess the difference between the same break in the hot leg versus the cold leg.

Current APEX PTS Test Matrix (cont'd)

- Main steam line break from full power initial conditions.
- Main steam line break from hot standby conditions.

APEX PTS Testing Status

- Facility is currently being modified to add loop seals, HPI connections to cold legs, additional thermocouples in cold legs and downcomer
- Testing is scheduled to take place during the summer 2000:

Information Received From Industry

1. Review by Oconee of the IPTS Oconee study (NUREG/CR-3770, NUREG/CR-3703, NUREG/CR-3761

2. Palisades input deck

Information Still Being Sought From Industry

1. Review by H.B. Robinson of the IPTS H.B. Robinson study (NUREG/CR-3935, NUREG/CR-3977, NUREG/CR-4183) and updated analysis NUREG/CR-5452

2. Review by Calvert Cliffs of the IPTS Calvert Clifffs study (NUREG/CR-4022)

Information Still Being Sought From Industry

- Emphasis should be on control systems, e.g.
  1. auxiliary feedwater
  2. high pressure injection
  3. makeup
  4. tripping/restart of reactor coolant pumps
- and operator procedures for
  1. main steam line break (also stuck open steam dump valves, safety valves and PORVs.
  2. small break LOCA in primary system

Re-evaluation of the Pressurized Thermal Shock Screening Criteria (10 CFR 50.61)

Michael E. Mayfield
Division of Engineering Technology

Farouk Eltawila
Division of Systems Analysis & Regulatory Effectiveness

Mark Cunningham
Division of Risk Analysis & Application

Office of Nuclear Regulatory Research
US Nuclear Regulatory Commission

Presentation to ACRS

July 14, 1999

PTS RE-EVALUATION PROJECT

- Goal
- Is there a success path?
- Approach to re-evaluation
- Milestones and schedule

PTS RE-EVALUATION PROJECT

Background: IPTS (Integrated Pressurized Thermal Shock) Studies

- In 1985 NRC promulgated PTS rule -- 10 CFR 50.61
  - Established embrittlement screening criteria
  - If RPV projected to exceed screening criteria, lecensee to implement flux reduction
  - If screening criteria still projected to be exceeded, analysis required 3 years in advance to demonstrate continued safety of RPV
- During 1982-86, RES funded 3 full-scale PWR plants PTS studies ("IPTS" studies)
- Results from the studies were used in developing PTS RG-1.154 analysis methodology

PTS RE-EVALUATION PROJECT

Background : IPTS (Integrated Pressurized Thermal Shock) Studies

- Initiating events that caused PTS transients generally involved --
  - Small-break LOCA
  - Steam line break
  - Steam generator overfeed
  - Reactor-trip with stuck-open secondary valves

PTS RE-EVALUATION PROJECT

Background : IPTS (Integrated Pressurized Thermal Shock) Studies

- It was found that dominant PTS transients had re-pressurization during the last portion of the transients
- Sensitivity analyses showed that --
  - Flaw (Crack) related variables had the most significant effect on P[F|E]
  - Level of conservatism in these variables was significant

PTS RE-EVALUATION PROJECT

Background : IPTS (Integrated Pressurized Thermal Shock) Studies

- Several other factors were found to also be important
  - Embrittlement variables (ΔRT_{NDT}, RT_{NDTo})
  - Fracture Toughness, K_{Ic}
  - Thermal-Hydraulics transients data

PTS RE-EVALUATION PROJECT

OVERALL GOAL: Promulgate a risk-informed revision to 10 CFR 50.61

RES Project Goals

- To develop the technical basis for a fundamental revision to the PTS rule, 10 CFR 50.61
- To approach this project as a full-participatory project with the public and technical experts
- To achieve common understanding among stakeholders that the proposed revisions are practical, technically credible, cost effective, and scrutable

PTS RE-EVALUATION PROJECT

Is There a Success Path?

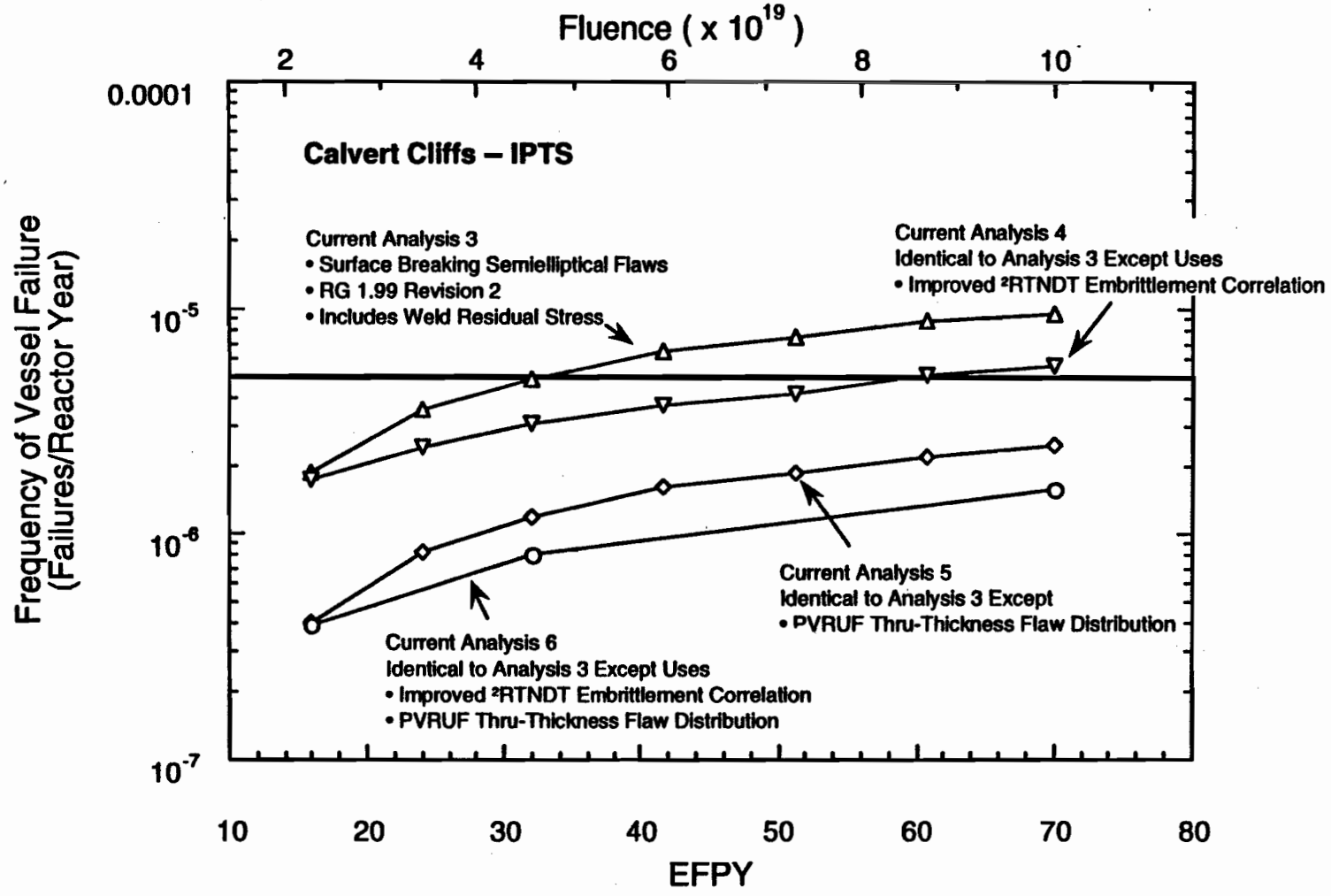
- Recent staff and contractor analysis demonstrates reduction of one order of magnitude in P(F|E) mostly due to treatment of flaws
  - Additional conservatisms are known
    - Flaw density and size distribution in plate material (90% of the volume)
    - Flaw density in welds
    - Up-to-date fluence map
    - Accurate chemistry data (RT_{NDTo}, ΔRT_{NDT})

PTS RE-EVALUATION PROJECT

Is There a Success Path?

- There is reason to believe that screening criteria can be increased significantly by reducing excessive conservatism

PTS RE-EVALUATION PROJECT



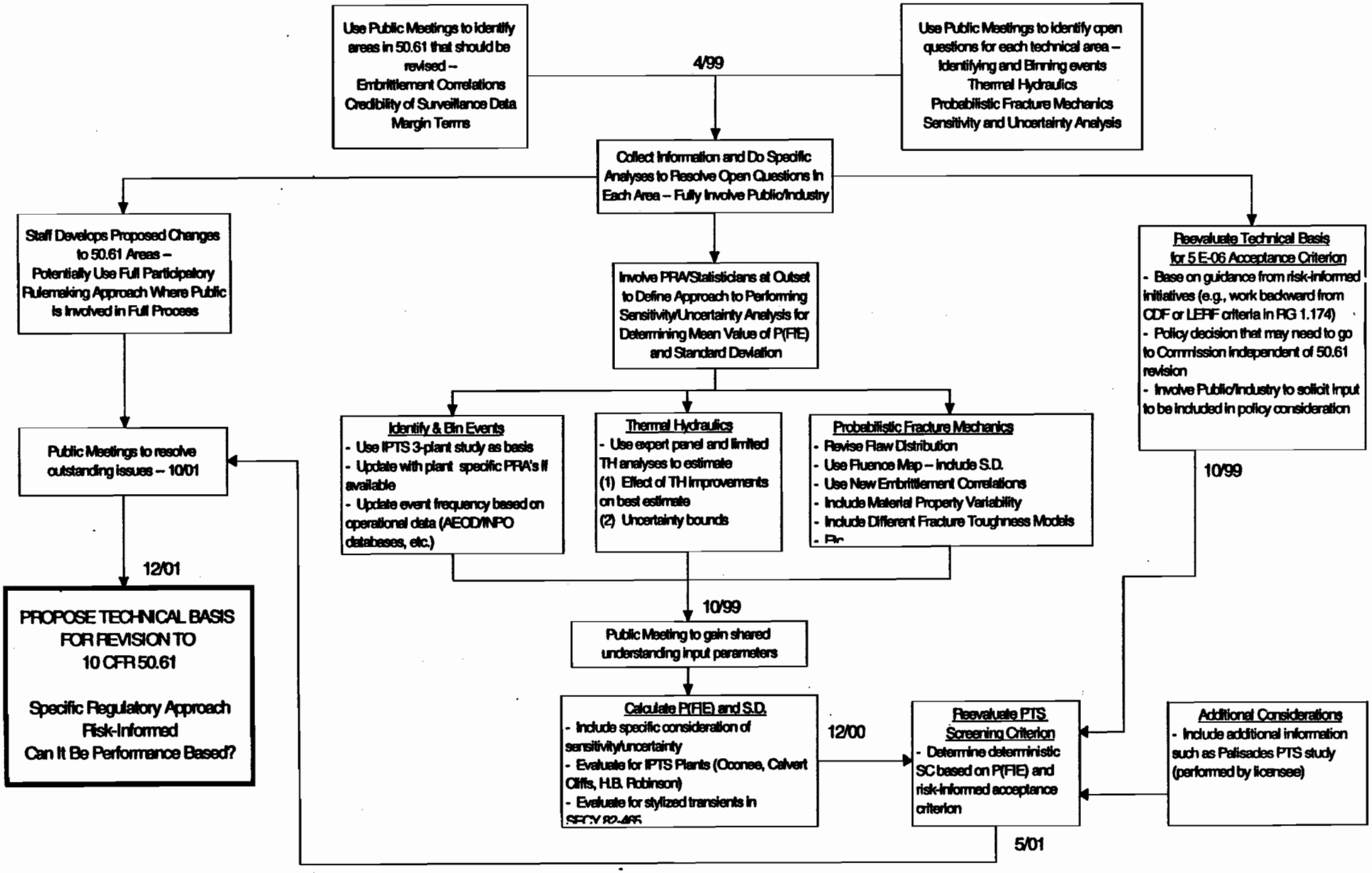
Frequency of thru-thickness vessel failure as a function of EFPY and neutron fluence for current analyses 3, 4, 5, and 6

PTS RE-EVALUATION PROJECT

Approach to Re-evaluation

- Two-track approach
  - Bulk of work will be in determining appropriate screening criteria
  - Numerous aspects of existing rule must also be reassessed and revised
    - Embrittlement correlations
    - Margins
    - "Credibility criteria" for surveillance data
    - Etc.
- Fully participative process -- involve public and industry at each stage
- Brief ACRS -- Additional status briefings during project

DEVELOPMENT OF TECHNICAL BASIS FOR REVISION OF PTS RULE



PTS RE-EVALUATION PROJECT

- Research results have significantly improved understanding of these variables
  - Can develop technically defensible approach to dealing with flaw variables
- Expert elicitation will be used to develop "generic" flaw distribution

Thermal-Hydraulic Support for PTS Issue

T/H Activities

- Goal is to identify transients conducive to PTS; rank them by relative risk potential
  - insights from previous studies
  - potential of "new" scenarios
- Scenario identification and ranking (in cooperation with PRA group)
  - support from UMD

T/H Activities contd.

- T/H predictions (downcomer P, T, h), loop circulation
  - support from integral test facility (OSU)
- Support to UCSB for integrated approach to issue resolution

T/H Predictions

- Tools include:
  - system codes and validation techniques
    - incorporate plant specific features
  - integral test facilities and scaling considerations
  - specific local phenomena modeled as needed
    - local mixing/downcomer plumes
    - CFD

Oregon State University (APEX Facility)

- Experimental results from UMD and APEX indicate 1 of 2 cold legs (same loop) will stagnate early in natural circulation conditions (pressure still high)
  - how downcomer mixing is affected?
- Integral test planned to provide insights on loop flow stagnation in 2x4 plant arrangement

Summary of Efforts

- 1st step involves scenario identification, grouping of scenarios, and ranking
  - characteristics/groups of PTS transients to be identified
  - UMD support
  - "new" scenarios possible

Summary of Efforts contd.

- 2nd step involves T/H calculations
  - codes and model adequacy will be addressed
  - OSU support
  - prediction of uncertainty required
- Alternative approach by UCSB

Acceptance Criteria

- Current probabilistic acceptance criterion:
  - 5×10^{-6} per reactor year of through-wall crack
- Applicability of and consistency with RG 1.174 guidelines
  - cdf, Δ cdf
  - lerf, Δ lerf

PTS RE-EVALUATION PROJECT

Major Milestones and Schedule

- Public meeting to identify areas and open questions for resolution — 4/99
- Public meetings/workshops to resolve — 5/99-8/99
- Public meetings to gain common understanding on analysis input parameters — 9/99 -10/99
- Public meeting to discuss acceptance criteria — 12/00
- Propose revised screening criterion — 9/01
- Public meeting to resolve outstanding issues — 10/01
- Provide paper to RES/NRR management on proposed revisions to 10 CFR 50.61 — 12/01

II. Electric Power Research Institute (EPRI) RETRAN-3D Thermal-Hydraulic Transient Analysis Code (Open)

[Note: Mr. Paul A. Boehnert was the Designated Federal Official for this portion of the meeting.]

G. Wallis's Comments on RETRAN-3D Code

Dr. G. Wallis, Chairman, Thermal-Hydraulic Phenomena Subcommittee, provided comments on the EPRI RETRAN code, based on his selected review of the EPRI code documentation. He focused his remarks on the methodology used to model momentum and the associated equations, details of the modeling geometry used for various flow paths, the generalized momentum equation employed in the code, and the volumes and flow junctions noted in the documentation were discussed. Dr. Wallis expressed a number of fundamental concerns from his review of the models incorporated in the EPRI code which included:

- The global momentum equation cannot by used directly to compute the "rate of change of flow rate" in a control volume, unless it is a straight pipe.
- All system components cannot reasonably be modeled as area changes joining two straight pipes.
- Flow rate is a scalar quantity. It cannot be treated as a vector.
- Forces associated with the (pipe) wall must be included in a global momentum balance. They cannot generally be modeled as "energy dissipation" as is done in RETRAN.
- The rationale for reducing a three dimensional momentum balance to a one dimensional formula contains statements that may be inconsistent.

Dr. Wallis suggested that the mechanical energy conservation equation might form the basis for developing a self-consistent code.

EPRI Presentation

Messrs. M. Paulsen and L. Agee made brief presentations in response to Dr. Wallis's comments. Mr. Paulsen said that their review of the momentum equation

used in RETRAN leads them to believe that there is a misunderstanding regarding the modeling of the velocity vector at the surface of the momentum cell. Further, EPRI does not believe that the equation and modeling are in error; therefore, no safety concern exists. During discussion, Dr. Wallis took exception to EPRI's claim that use of not adequately supported engineering judgment was an acceptable practice for dealing with problems of this type.

Dr. L. Agee noted the following points with regard to the RETRAN code:

- The code was created to provide predictions of overall plant behavior for transients and accidents. The code is not designed to provide detailed phenomenological modeling.

- RETRAN relies on use of available plant and transient data. It has been used successfully for over 20 years by utilities in the U.S. and overseas in the modeling of plant analyses.

- The documentation supporting RETRAN, while thorough, is lacking adequate justification for EPRI's approach with regard to extending one-dimensional modeling to the entire plant system.

- EPRI has made a series of first-order corrections/improvements to the momentum equation used for the RETRAN code.

There was extensive discussion centering on the concerns cited by Dr. Wallis. Dr. Apostolakis urged EPRI to provide a detailed response to Dr. Wallis's concerns to aid the Committee's review of this code. Dr. Powers noted that Dr. Wallis's critique is aimed at the intellectual foundations of the RETRAN code, and stated that EPRI provide a detailed response to Dr. Wallis' concerns. Dr. Shack, acknowledging that the thermal-hydraulic (T/H) codes cannot obtain closure to the energy and momentum equations from first principles, agreed that approximations are needed to successfully model mass and energy phenomena. He said that EPRI needs to clarify its closure methodology in light of Dr. Wallis' concerns regarding the approach taken in RETRAN.

NRC Staff Presentation

Mr. R. Landry, NRR, provided a brief presentation on the status of the staff's review of the RETRAN code. He discussed the review background, and staff review

approach. The review is being done totally within the NRC and includes the use of the RETRAN 3D code by the staff. Regarding the current review status, Mr. Landry noted that additional concerns with the code are being raised by both the staff and Dr. Wallis. In response to of Dr. Wallis's concerns cited today, the staff's review focus may change from an evaluation of just the new material submitted by EPRI to a more general review of the code.

In response to Dr. Powers, Mr. Landry said the staff does not want the review dominated by scheduler concerns. The current schedule calls for a staff safety evaluation report by the end of this year. However, he noted that the schedule may slip.

Conclusion

The Committee considered submitting formal comments on this matter. Following a discussion, the Committee action was postponed pending receipt and response to the concerns noted above.

III. Proposed Revision to Appendix K of 10 CFR Part 50 (Open)

[Note: Mr. Paul A. Boehnert was the Designated Federal Official for this portion of the meeting.]

[Dr. Uhrig noted that has a conflict in that he is a Project Manager to a DOE project that is a potential competitor to one of the flow measurement methods to be discussed today. Dr. Uhrig limited his participation to the regulatory aspects of this review.]

Dr. Wallis introduced this topic to the Committee. He noted that the staff is proposing to allow a reduction in the margin assumed for emergency core cooling system (ECCS) analysis given that the uncertainty associated with the margin has been reduced. Dr. Wallis stated that the key issue that the Committee should focus on for this discussion is: if information is available that allows one to reduce uncertainties, how does one, in turn, apply this to the reduction of margins? Dr. Wallis also stated that the staff needs to consider what requirements licensees will need to meet in order to demonstrate that uncertainty and the corresponding margin has been adequately reduced, since the connection between uncertainty and margin has not been adequately addressed by the NRC.

II. Electric Power Research Institute (EPRI) RETRAN-3D Thermal-Hydraulic Transient Analysis Code (Open)

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