UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 3 1 1978

MEMORANDUM FOR: Thomas E. Murley, Director
Division of Reactor Safety Research, RES

Roger J. Mattson, Director
Division of Systems Safety, NRR

FROM: S. Fabic, Chairman
Code Selection Committee, RSR

SUBJECT: COMMITTEE FINDINGS AND RECOMMENDATIONS CONCERNING SELECTION OF SIMPLIFIED ADVANCED SYSTEMS CODE.

1. INTRODUCTION

Three advanced systems codes are being developed under RES sponsorship: TRAC, THOR and RELAP-5. The TRAC code can be run under three-dimensional configuration for detailed analyses and, also, under the "collapsed noding" configuration for less accurate but faster computations. RELAP-5 and THOR codes are one-dimensional, hence potentially fast running. While the initial emphasis in development of these codes was on LWR LOCA (starting with PWR LOCA), RES plans indicate subsequent application to other accidents and to anticipated transients with and without scram.

RES has made commitments to develop an advanced Evaluation Model LOCA code for NRR use after 1982. During the intervening period NRR intends to freeze and use the WRAP-EM (BWR and PWR) packages developed by SRL under RES sponsorship.

The candidate advanced EM code was to be selected from among TRAC (collapsed noding version), RELAP-5 and THOR.

In his memo to Comissioner Gilinsky, dated May 30, 1978, Mr. E. Case has indicated that the candidate EM code selection will occur by the end of FY 1978.

On July 5, 1978 Dr. T. E. Murley issued a memo to Drs. L. S. Tong and D. F. Ross requesting that a Code Selection Committee be formed, chaired by S. Fabic, for the purpose of making the code selection recommendation to NRC management.

The committee was formed, beginning of July 1978, comprised of four RSR members (Fabic, Zuber, Shotkin and Lyon) and four NRR members (Rosztoczy, Lauben, Odar and Paulson). Three consultants were also chosen to aid the selection committee: Professors P. Griffith of (MIT), A. F. Henry (MIT) and T. Theofanous (Purdue). Professor Griffith is an acknowledged authority on thermal hydraulics of two-phase flow; Professor Henry is an expert in the area of reactor kinetics and numerical analysis. Professor Theofanous is also an expert in thermal hydraulics of two-phase flow, with excellent knowledge of reactor safety issues.

During the August 28, 1978 meeting of the ACRS subcommittee on LOCA-ECCS, RSR notified the ACRS of its plans to select the advanced EM code candidate and of its selection criteria. The subcommittee indicated its interest in this matter. RES staff presentation regarding implementation of the code selection committee conclusion has been scheduled for the November 3, 1978 session of the ACRS full committee.

2. PROCEDURE

The code selection committee (NRC members only) met twice (July 14, 1978 and September 1, 1978) followed by a joint meeting with consultants on September 5, 1978, for the purpose of arriving at the selection criteria. Items to be considered in this selection, agreed by the committee, are shown in Appendix I. Each item was to be rated on a 0 - 10 scale by each participant, following meetings with INEL, BNL and LASL personnel. These three laboratories were advised of the selection plans on July 17, 1978, at which time they were asked to each calculate three sample problems and compare them with test data. The sample problems comprised (1) Marviken vessel blowdown with critical flow through a 500 mm I.D. nozzle; (2) S-02-6 Semiscale small break LOCA; and (3) S-06-4 (200% break) Semiscale integral LOCA (blowdown + refill + reflood). These problems were chosen to examine both the simulation capability and code running times. INEL, BNL and LASL were asked to present the results of these calculations to the selection committee during the second week of September 1978, and answer questions concerning code features. Documentation of the code features was sent to committee members and consultants on August 22, 1978, per NRC request.

The meetings with contractors, attended by the committee members and consultants were held on September 6, 7 and 8, 1978. The meetings were also attended by Professor I. Catton who notified the committee chairman that he wished to observe the selection process on behalf of the ACRS. He was, therefore, provided with the same code documents sent to committee members and consultants.

The final meeting of the code selection committee and consultants took place on September 22, 1978, for the purpose of examining the findings reached by the individual committee members and consultants, and to arrive at a joint recommendation to NRC management.

The purpose of this memo is to summarize the findings and give the committee's recommendations.

3. RESULTS OF CODES APPRAISAL

Written appraisals received from the individual members of the code selection committee and consultants are given in Appendix II. Table I below shows the scoring given by the individual members and consultants, for the major three groups listed in Appendix I, while the scores for subcategories are given in Appendix II. Mr. W. Paulson (committee member, NRR) was not present at the September 22 meeting and has excused himself from submitting appraisal and from voting.

Combining the individual scores for all three groups and dividing by the number of entries, the following statistics emerge:

	NRC Members	Consultants	Together
TRAC	21	25	22
RELAP-5	18	22	19
THOR	12	14	13

Six options were presented for code selection and laboratory work assignment combinations and offered for discussion and voting. These six options were enlarged to eight per participant's recommendations. All participants then indicated their first and second choices.

TABLE I

SCORING OF CODES CURRENT AND PROJECTED CAPABILITIES, OF THE CODE DEVELOPMENT TEAM AND FACILITIES

(For subcategories see Appendix I)

		NRC MEMBERS OF CODE SELECTION COMMITTEE								CONSULTANTS		
		S.F.	N.Z.	L.S.	W.L.	Z.R.	N.L.	F.O.	W.P.	P.G.	A.H.	T.T.
Group A Current capability of code	TRAC	7	8	8	8	2 1/2	6	6	Did not participate in all meetings. Excused himself from appraisal and voting.	8	7	9
	RELAP-5	5	7	5	8	3	6	6		7	6	7
	THOR	4	5	1	3	2	2	5		4	5	5
Group B Projected future capability of code	TRAC	8	8	8	8	7	6	7		9	8	9
	RELAP-5	8	7	7	8	7	5	7		7	6	9
	THOR	6	6	3	2	7	3	7		5	4	7
Group C Development team and facility	LASL	7	8	8	8	5	5	8		8	7	8
	INEL	8	9	7	9	5	5	7		7	6	9
	BNL	5	5	3	4	5	2	6		4	3	5

Description of each option is given in Table II while the committee member's and consultant's first and second choices are indicated in Table III. A note, indicated in Table III was added at Z. Rosztoczy's suggestion, amending slightly the option A. All participants found it acceptable.

4. RECOMMENDATIONS

The agreed upon (majority) recommendation to NRC management is to proceed per option A, as follows:

a) Proceed with development of BE TRAC, at LASL per current plans. This will result in (i) ability to perform detailed multidimensional analyses, and (ii) ability to collapse noding for less detailed, faster calculations.

b) The simplified (collapsed noding) TRAC has been selected for LWR LOCA EM conversion. However, this conversion is not to be performed, anywhere, during FY 79 and FY 80. Thereafter, INEL could undertake this task.

c) TRAC (BE) assessment to be performed at LASL, INEL, and BNL. The existing "independent verification" group at INEL to get involved in TRAC assessment beginning FY 79.

d) INEL code developers to become thoroughly familiarized with TRAC in order to be able to perform, during FY 79 and thereafter, (i) sensitivity studies in which effects of INEL's models for certain constitutive equations, break flow, and flow regime selection are examined (per NRC concurrence); and (ii) LWR sensitivity studies, per NRC requests.

The work on RELAP-4/MOD 7 development and development checkout to be completed as scheduled.

e) BNL personnel currently involved in THOR development is to be redirected as follows: (i) To install the non-LOCA codes ALMOD, ALMOS, and RAMONA-3, and implement modifications requested by NRC; (ii) To install TRAC and perform assessment and sensitivity studies indicated by NRC.

f) Two of the code selection committee members and all three consultants urged that a very low level (about 3 man years/per year) on THOR development continue at BNL. In their opinion, THOR's methodology is quite different from that of TRAC and has sufficient

TABLE II

OPTION DETAILS	OPTIONS A	B	C	D	E	F	G	H
TRAC B.E. development at LASL	yes	yes	yes	yes	yes	yes	yes	yes
TRAC EM development at LASL	no	yes	no	no	no	no	no	no
TRAC EM development at INEL	yes	no	no	no	no	no	no	no
TRAC EM development at BNL	no	no	no	no	no	no	no	yes
TRAC B.E. assessment and sensitivity studies at following laboratories, including work at BNL on selected existing non-LOCA codes, such as ALMOD, ALMOS, RAMONA-3	LASL INEL BNL	LASL INEL BNL	LASL BNL	LASL INEL	LASL	LASL BNL	LASL INEL BNL	LASL INEL BNL
Continue one more year work on RELAP-5, then re-appraise	no	no	yes	no	yes	yes*	yes	no
Continue one more year work on THOR, then re-appraise	no	no	no	yes	yes	no	no	no

* But do not stop after one year. Also, stop development of RELAP-4/MOD 7

TABLE III

MEMBERS AND CONSULTANTS VOTING ON OPTIONS

I = FIRST CHOICE, II = SECOND CHOICE

OPTIONS	NRC CODE SELECTION MEMBERS								CONSULTANTS			
	S.F.	N.Z.	L.S.	W.L.	Z.R.	N.L.	F.O.	W.P.	P.G.	A.H.	T.T.	
A	I	I	I		I	I	I	DID NOT PARTICIPATE IN ALL MEETINGS, EXCUSED HIMSELF FROM APPRAISAL AND VOTING	I	II	II	
B			II				II		II	I		
C	II			II		II					I	
D												
E												
F												
G				I	II							
H		II										

NOTE: IN OPTION "A" THE DECISION OF WHETHER TRAC WITH COLLAPSED NODING IS TO BE USED BY NRR FOR SIMPLIFIED ATWS AND OTHER TRANSIENTS NOT INVOLVING PRIMARY PIPING BREAKS, IS TO BE POSTPONED FOR 2 YEARS, PENDING ASSESSMENT OF EXISTING CODES SUCH AS IRT, ALMOS, ALMOD, RAMONA-3.

merit to deserve further exploration. The other five code selection committee members disagreed since (i) the additional cost of THOR development could not compensate for the cost savings accrued by faster computations, and (ii) serious problems are anticipated in development of generalized "profiles" which THOR needs for analyses of a variety of postulated PWR and BWR accidents. The committee decided to notify the NRC management of this tie vote.

g) The decision as to whether simplified analyses of LWR anticipated transients with or without scram need to be performed with the collapsed noding TRAC is to be postponed for about two years, pending assessment of the currently available or acquired codes such as IRT, ALMOD, ALMOS, and RAMONA. RSR will, in the meantime, proceed with the development of the detailed versions of TRAC capable of analyzing LWR LOCA (including plants with alternate ECCS Systems), and other LWR accidents and transients.

5. JUSTIFICATION

The following summarize the majority findings that led to the above stated recommendations:

1) Some situations in postulated LWR plant accidents are likely to produce significant multidimensional hydraulic transients. Strong evidence of multidimensional flow patterns was seen even in some tests conducted with what one may term "one-dimensional" test facilities such as Semiscale/MOD 1 (e.g. effects of steam generator tube breaks). Calculations will have to be first performed with a detailed, multidimensional TRAC and, for subsequent repetitive calculations, a collapsed noding would have to be obtained through a systematic study of consequences, of gradually removing the degrees of freedom. The acceptable collapsed noding may show, for some cases, that a purely one-dimensional representation is inadequate. The concept employed at LASL that uses the same code (TRAC) to collapse the noding offers a very important advantage over THOR and RELAP-5, which are one-dimensional. Since TRAC will, eventually, have a three-dimensional neutronics capability, it is clear that the ability to collapse the noding and study its consequences will offer unique advantages also for other accidents and transients in which important neutronics feedback effects need to be considered.

2) TRAC offers more degrees of freedom to model thermal hydraulics of two-phase flow, without imposing thermal or mechanical restrictions concerning interactions between vapor and liquid While it may be argued that our current knowledge in specifying the physical details of field interactions greatly lags the ability to numerically solve them, it is clear that one can easily (a) force, in TRAC, if necessary, either thermal or mechanical equilibrium, or both, and (b) improve the physics of interactions as further knowledge is gained through basic research.

3) TRAC (collapsed noding) comparisons with test data pertaining to all of the assigned sample problems were satisfactory. The committee has noted (and LASL agreed) that in some cases better schemes for the collapsed noding could have been employed, potentially further improving the comparison results. However, a systematic study of the collapsed noding was not required for this exercise.

RELAP-5 also gave satisfactory comparisons in the blowdown and refill regimes, (in some cases superior to those of TRAC). Reflood capability in RELAP-5 does not yet exist.

THOR could only address the vessel blowdown (Marviken III test) case, with severe limitations, and the results were unacceptable.

4) TRAC employs the same hydraulic model at the pipe break as in the pipe interior. This requires a detailed nodalization (i.e. many cells) in the vicinity of the break, for representation of steep profiles. RELAP-5 solves a different set of the governing equations (and with certain imposed restrictions) at the break as compared to those for the pipe interior. This technique removes the need for a detailed nodalization at the break. However, it can lead (and has) to situations where the interior pipe exhibits self-choking, inconsistent with that obtained at the break. There are, therefore advantages and disadvantages associated with both codes with respect to discharge flow calculations.

5) The CDC 7600 CPU (execution) times, the transient times, and the number of cells employed in running the three sample problems are tabulated below for TRAC and RELAP-5 codes.

Code Running Times as Announced at the Review Meetings, September 6, 7 and 8.

Sample Problem	Code	Total Number of Cells	Transient duration (secs)	CPU computer running time (mins)
Marviken-III	TRAC	60	48	3.9
	RELAP-5	28	50	4.0
S-02-6 (Small break)	TRAC	75 (36 near break)	500	85.3
	RELAP-5	43	600	100
S-06-4 integral LOCA)	TRAC	112 (18 near break)	250	169.3
	RELAP-5	100	150	360

It can be seen that the running times of TRAC and RELAP-5, on the same computer (CDC 7600), were comparable for the first two sample problems. However, for the third, most demanding sample problem TRAC ran over two times faster than RELAP-5. Future addition of the quench front tracking capability in RELAP-5, which did not exist at this time, would only increase the difference (everything else remaining the same).

NRR stated a desired goal to have an advanced EM code that runs a complete LOCA calculation in approximately one hour. Both LASL and INEL claim that further improvements in the solution technique are envisaged to reduce the running time. However, the current work on introducing the droplet and the noncondensible gas fields in TRAC (deemed necessary for B.E. calculations of LWR reflood) will impose a limit to the degree of TRAC running time reduction. RES estimates that analyses of the most complex accidents or transients, with a

"collapsed noding TRAC," may require between 2 and 4 hours of CPU on CDC 7600 computer.

NRR members indicated that reasonable running times will be acceptable, especially if the concurrent developments in the computer hardware show promise that one hour running times will be feasible three to four years from now.

The committee consultants suggested that the real question should not be how short is the running time but how reliable are the calculated results.

6) The WRAP-EM package, for both BWR and PWR LOCA will be available fairly soon and will be "frozen" for NRR's LOCA audit calculations to be performed over the next three years or so. Therefore the work on conversion of the collapsed noding TRAC BE version into the EM version can be deferred until further code improvements and a substantially larger amount of TRAC assessment has been performed, over the next two years.

7) Hydraulic models in the THOR code and their solution technique is quite different from those in TRAC and RELAP-5. The technique offers potentially accurate and fast calculation for small break LOCA and certain other accidents and transients. Unfortunately, the code is not yet operational (after four years of development) and the estimated costs for completion of development, checkout and assessment very greatly exceed the potential cost savings accrued by the faster running time. For example, the current cost of one year development time for THOR (and more than that would be needed) could pay for running the TRAC code,at LASL,every work-da for 5 1/2 years, assuming an average 2 hours run duration on the C 7600 computer (for which LASL currently charges NRC $400/hr). The committee also noted that the need to select profiles of fluid properties - for improved accuracy - for every new situation, together with the code's inherent one-dimensionality impose important drawbacks. It was also felt that sufficient, if not as accurate or rigorous, level tracking capability exists in TRAC.

8) In addition to development costs, code assessment (verification) is also expensive and time consuming. The committee felt that it would be more cost effective if a large effort were focused on thorough assessment of one code (TRAC), rather than development and assessment of alternate codes.

9) The committee is aware of the considerable knowhow in the matters of reactor safety acquired by INEL engineers over the years. That knowhow could be utilized by helping with TRAC assessment and applications.

10) Important and urgent work needs to be done in installing and adapting the imported non-LOCA codes (ALMOS, ALMOD and RAMONA-3) to NRR needs in the area of BWR anticipated transients. Such work has already been initiated at BNL but could be significantly accelerated, in lieu of continuing THOR development. BNL should also participate in TRAC assessment, to give it a broader coverage.

At a round table discussion during the committee's final meeting the participants summarized their reasons for the scores indicated in Table I and for option preferences indicated in Table III. These are given in Appendix III.

Issue of this report concludes the activities of the code selection committee. Detailed documentation of code calculation results pertaining to the three sample problems is available upon request.

S. Fabic

S. Fabic, Chairman
Code Selection Committee
Division of Reactor Safety Research

Enclosures: as stated

cc w/encls: S. Levine
H. R. Denton
L. S. Tong
F. Schroeder
Prof. H. Isbin , U. of Minn.
Prof. M. Plesset, Cal Tech
Code Selection Committee Members
Professors T. Theofanous
A. F. Henry
P. Griffith
Public Document Room (2)
ACRS

APPENDIX I

Contents:

1) Items to be Considered During Code Selection

2) Information from contractors concerning estimates of man-years needed to complete (a) PWR-BE LOCA code that can meet the one hour running time goal on the CDC 7600 computer; (b) extension of that code to description of BWR non-LOCA transients. (Some committee members felt that INEL and LASL estimates were too low.)

ITEMS TO BE CONSIDERED DURING SELECTION OF SIMPLIFIED ADVANCED CODE

GROUP A: CURRENT CAPABILITIES

- MODELING OF THERMAL-HYDRAULICS
- GEOMETRIC DESCRIPTION; ADAPTABILITY
- NEUTRONICS
- USER CONVENIENCE
- COMPUTATION EFFICIENCY
- VERIFICATION (PERFORMED THUS FAR)

GROUP B: ADAPTABILITY TO FUTURE NRC NEEDS AND PROJECTIONS OF DEVELOPMENTAL EFFORT

- STEAM GENERATOR TUBE BREAKS
- STEAM LINE BREAK
- ALTERNATE ECCS (E.G., UHI)
- PWR LOCA - EM
- BWR LOCA - BE AND EM

- ATWS (PWR AND BWR)
- RIA (PWR AND BWR)
- OPERATIONAL TRANSIENTS (PWR AND BWR)

ITEMS TO BE CONSIDERED DURING SELECTION OF SIMPLIFIED ADVANCED CODE (CONT.)

GROUP C: ASSESSMENT OF CODE DEVELOPMENT TEAM AND FACILITY

- RECORD OF PAST PERFORMANCE
- KNOWLEDGE OF INFORMATION OBTAINED IN REACTOR SAFETY RESEARCH
- PERSONNEL POOL ACCESS (WITH KNOWLEDGE IN THERMAL HYDRAULICS, REACTOR SAFETY INFORMATION, LICENSING REQUIREMENTS)
- COMPUTER ACCESS (ABILITY TO PERFORM ON-CALL ASSISTANCE)