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

SEP 11 1981

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER - 125 - TRAC-PD2 "AN ADVANCED BEST-ESTIMATE COMPUTER PROGRAM FOR PWR LOCA ANALYSIS"

I. INTRODUCTION

TRAC-PD2 is the second in a planned series of three detailed accident analysis codes for PWR's. The first version, TRAC-P1A, was transmitted to the Office of Nuclear Reactor Regulation in Research Information Letter number 92 (Ref. 1), which identifies the user needs. TRAC-PD2 is currently being applied to the analysis of a variety of accidents in full-scale LWR's, including large-break LOCA, small-break LOCA and operational transients. The improvements of TRAC-PD2 over TRAC-P1A are documented in Section II, the results section. The evaluation of the code is given in Section III, while its application to problems of interest to NRC is detailed in Section IV. The evolution and mission of the various TRAC-PWR revisions are shown in Table I.

II. RESULTS: IMPROVEMENTS OF TRAC-PD2 OVER TRAC-P1A

The PD2 version of TRAC (Ref. 2) has many improvements over the original P1A version (Ref. 3):

1. A new reflood algorithm has been added to the TRAC-PD2 code to better model the axial conduction and precursory cooling effects in the local region around bottom refill and falling-film quench fronts. The algorithm uses an intermediate axial temperature noding (specified by the user) and a moving fine mesh centered around the quench fronts. This latter mesh is moved in a manner that conserves energy. Integrated heat transfer rates are then used to couple the temperature field solution to the fluid dynamics calculation. The temperature field solution is a mixed technique, implicit in the radial direction across the fuel rod and explicit in the axial direction around the quench fronts.

2. In TRAC-P1A the momentum source term for the connections to the vessel had a sign error that tended to reverse the flow at pipe-vessel junctions. In PD2 the signs are corrected so that the fluid momentum in the connecting pipes is conserved.

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3. In TRAC-P1A, the calculation of the wall friction pressure drop in cells containing area restrictions used the velocity at the minimum flow area and applied this velocity over the entire cell length. This over-estimated the frictional pressure drop, because the constricted flow area extends only for a small distance. The PD2 version of the code uses an averaged velocity to calculate the wall friction pressure drop and a local (orifice) loss to account for local flow restriction.

4. The condensation regime heat transfer model has been improved. The improved formulation is more realistic and alleviates the pressure spikes observed in the P1A calculations.

5. The solution strategy in the three-dimensional vessel component has been improved, thereby reducing the execution time and permitting tighter convergence criteria.

6. Conservation of mass is achieved in PD2; it was not achieved in P1A.

7. Improvements have been made in the wall-heat-transfer correlations, constitutive equations, metal properties evaluation, thermodynamic property evaluations, and water packing treatment.

8. A simple dynamic gap-conductance model has been included.

9. The programming of one-dimensional components has been simplified by using common subroutines wherever possible.

10. The types of boundary conditions that can be imposed at BREAKS and FILLS have been expanded to include more fluid properties, such as void fraction and fluid temperature.

11. Graphics output files are now produced that are compatible with the new graphics postprocessing programs, EXCON and TRAP.

12. A broader range of experimental results has been used to assess the code.

The EXCON and TRAP graphics postprocessors are significant improvements on the GRED and GRIT programs which were previously available. The improvements incldue:

(1) standard FORTRAN programming is used throughout, with a replaceable, high-level interface to the DISSPLA graphics software package,

(2) enhanced selection and merging facilities for information from multiple TRAC runs,

(3) varied presentation formats, including three-dimensional perspective plots, dependent-variable correlation plots, spatial independent variables, data comparisons capabilities, and motion picture capabilities,

(4) rod temperature plots utilizing variable mesh data during reflood,

(5) interactive command language, and

(6) user-defined functional capabilities.

II. EVALUATION: DEVELOPMENTAL ASSESSMENT OF TRAC-PD2 AGAINST DATA

Tests selected for the developmental assessment of PD2 are listed in Table II. This set includes most of the experiments used for P1A developmental assessment plus additional integral, systems, and heat-transfer tests. The assessment set includes separate effects (tests involving basically only one plant component and one LOCA phase), system effects (coupled components up to entire loops, but only one LOCA phase), and integral effects (system tests covering more than one LOCA phase) over a wide range of scales. Results indicate that PD2 does a reasonable job for all of these tests (Refs. 4 & 5). Improvements observed over P1A are mostly in the reflood heat-transfer area. However, as a result of numerous other improvements in solution strategy, numerics, and constitutive relations, PD2 is a much more reliable and smoother-running code than P1A. Running time is the same or improved over P1A even though the reflood heat-transfer treatment is more complex.

To illustrate the performance of PD2, we have selected an integral test (S-06-3) in the Semiscale facility and an integral test (L2-2) in the LOFT facility. Test S-06-3 was a large-break LOCA test with accumulator and high- and low-pressure injection into the intact loop cold leg (Ref 6). There is good agreement between the calculated and measured mass flow rates on the vessel side of the break (Figure 1). In the intact loop, TRAC predicts the rapid decrease in mass flow rate due to two-phase degradation in the pump. As shown in Figure 2, TRAC tended to somewhat underpredict the peak clad temperature (PCT) but the overall comparisons were good except for the high-power rods at the top of the core.

Test L2-2, the first nuclear-powered test in the LOFT facility, was a large-break LOCA from an initial power of 25 MWt and an intact hot-leg temperature of 580 K. The calculated hydraulic response generally agrees very well with the data (Ref. 7). The primary discrepancy is an initial underprediction of the accumulator discharge rate which delays the start of refilling of the lower plenum. However, the core refill is predicted reasonably well and the PCT is close to the observed value. Figure 3 compares the break flow (vessel side of break) and shows good agreement except for the initial period of subcooled critical flow (first 10 s). The cause of the underprediction during the first 10 s is being studied at BNL as part of the independent assessment of TRAC-PD2.

Figure 4 shows typical results for the cladding temperature response for Test L2-2 at the core midplane for the central fuel bundle (high-power zone). The data shown are from three neighboring thermocouples. Other thermocouples in this same fuel bundle and at the same elevation show significantly different behavior so that the spread in the measurements is much larger than that shown in the figure. The TRAC-PD2 results shown are typical for all the rods in the central power zone except that the rods adjacent to the broken hot-leg do not experience the second dryout (this was also observed in some of the measurements). Both the calculation and data show a series of dryouts and rewets with the peak clad temperature occurring during blowdown. Comparisons at other elevations and in the intermediate- and low-power zones are similar to those shown in Figure 4.

IV. APPLICATION OF TRAC-PD2 TO FULL-SCALE LWR's

The primary mission of TRAC-PD2 is the analysis of large-break LOCA's in Pressurized Water Reactors. Enclosure 3 lists the variety of full-scale LWR analyses being performed with TRAC-PD2 at LANL. As can be seen, the code is being used for analysis of both large and small break LOCA's as well as operational transients.

DF Ross/for
Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosures:
1. "TRAC-PD2 An Adv. Best-Est. Prg. for PWR LOCA Analysis," NUREG/CR-2054, April 1981
2. J. C. Vigil, "TRAC-PD2 Dev. January 1981
3. Ltr., J. Ireland, LANL, to L. Shotkin, NRC, July 20, 1981

REFERENCES

1. Memorandum, R. Budnitz, RES to H. Denton, NRR, Research Information Letter No. 92, TRAC-P1A, June 18, 1980.

2. "TRAC-PD2, An Advanced Best-Estimate Computer Program for PWR LOCA Analysis," NUREG/CR-2054, April 1981.

3. "TRAC-P1A, An Advanced Best-Estimate Computer Program for PWR LOCA Analysis," NUREG/CR-0665, May 1979.

4. J. C. Vigil, "TRAC-PD2 Developmental Assessment Summary," Los Alamos National Laboratory informal report LA-UR-81-93, January 1981.

5. "TRAC-PD2 Developmental Assessment," Los Alamos National Laboratory report, to be issued in 1981.

6. B. L. Collins, M. L. Patton, Jr., K. E. Sackett, and K. Stanger, "Experiment Data Report for Semiscale MOD-1 Test S-06-3 (LOFT Counterpart Test)," EG&G Idaho, Inc. report NUREG/CR-0251, July 1978.

7. "Experiment Data Report for LOFT Power Ascension Test L2-2," Idaho National Engineering Laboratory report NUREG/CR-0492, 1979.

TABLE I

EVOLUTION AND MISSION OF TRAC-PWR VERSIONS

EVOLUTION OF ADDED CAPABILITIES		PRIMARY MISSION
DETAILED VERSION	FAST-RUNNING CAPABILITIES	
TRAC-P1A		LARGE-BREAK LOCA
TRAC-PD2		LARGE-BREAK LOCA
	TRAC-PF1	SMALL-BREAK LOCA
	TRAC-PF1/MOD1	OPERATIONAL TRANSIENTS
TRAC-PD3		ATWS/RIA

TABLE II

TRAC-PD2 DEVELOPMENTAL ASSESSMENT EXPERIMENTS

No.	Experiment	Scale	Thermal-Hydraulics Effects
1	Edwards Horizontal Pipe Blowdown (Standard Problem 1)	1/100[a]	One-dimensional separate effects during blowdown including critical flow, flashing, slip, and wall friction.
2	CISE Unheated Vertical Pipe Blowdown (Test 4)	1/1200[a]	Same as 1 plus pipe-wall heat transfer, flow area changes, and gravitational effects.
3	CISE Heated Vertical Pipe Blowdown (Test R)	1/1200[a]	Same as 2 plus critical heat flux (CHF).
4	Marviken Vessel Blowdown-Long Nozzle (Test 4)	1/1[b]	Same as 1 plus full-scale effects and delayed nucleation effects.
5	Marviken Vessel Blowdown-Short Nozzle (Test 24)	1/1[b]	Same as 4 plus nonequilibrium, two-dimensional nozzle flow.
6	THTF Blowdown Heat-Transfer Test 177	1/1[c]	Separate effects during blowdown including rod heat transfer with dryout and rewet.
7	Creare Downcomer tests (3) - Low ECC Subcooling	1/15[d]	Two-dimensional separate effects during refill including countercurrent flow, interfacial drag, and downcomer penetration.
8	Creare Downcomer tests (3) - High ECC Subcooling	1/15[d]	Same as 7 plus condensation effects.
9	FLECHT Forced Flooding Tests (PWR Tests 4831 and 17201, SEASET Test 4)	1/1[e]	One-dimensional separate effects during reflood including heat transfer, quench-front propagation, liquid entrainment, and carryover.
10	Bennett Vertical Tube CHF (Tests 5336, 5431, and 5442)	1/1[f]	One-dimensional pipe-wall steady-state heat transfer over the entire range of the boiling curve.
11	Semiscale Heated Blowdown Test S-02-8	1/2000[g]	Synergistic and systems effects during blowdown in a multiloop PWR simulator.
12	Semiscale Integral LOCA Test S-06-3	1/2000[g]	Integral effects during a complete LOCA in a multiloop PWR simulator.
13	Nonnuclear LOFT Blowdown (Test L1-4)	1/60[g]	Integral effects during isothermal blowdown and refill in a PWR simulator (nuclear core not in place).
14	Nuclear LOFT Integral LOCA (Test L2-2)	1/60[g]	Integral effects during a large-break LOCA in a scaled PWR.
15	CCTF Reflood Test C1-1	1/1[h]	Multidimensional and system effects during refill and reflood.

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[a] Scale given is based on pipe flow area.

[b] Scale based on vessel and break pipe dimensions.

[c] Full-scale 7x7 array of electrically heated rods.

[d] Linear downcomer dimensions.

[e] Single bundle of ~ 100 electrically heated full-scale rods.

[f] Full-scale compared to fuel rod dimensions -- flow inside the tube is nonprototypic.

[g] Power and volume scaling.

[h] Full-height components; radius of electrically heated core is 1/5 scale.

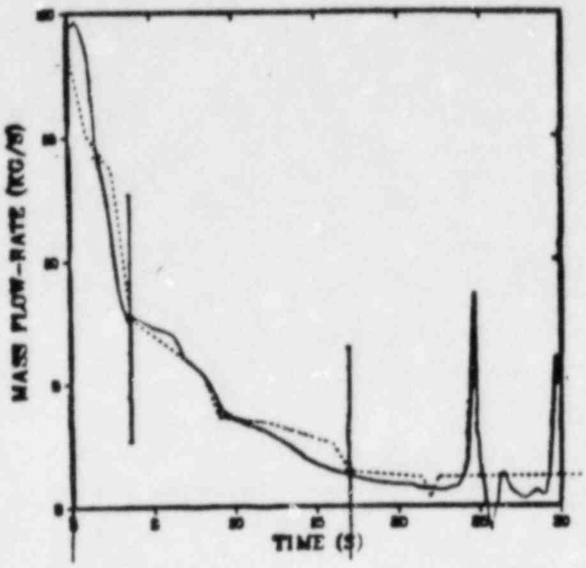

Fig. 1. Break flow (vessel side) for Semiscale LOCA test S-06-3 (solid = PD2, dash = data).

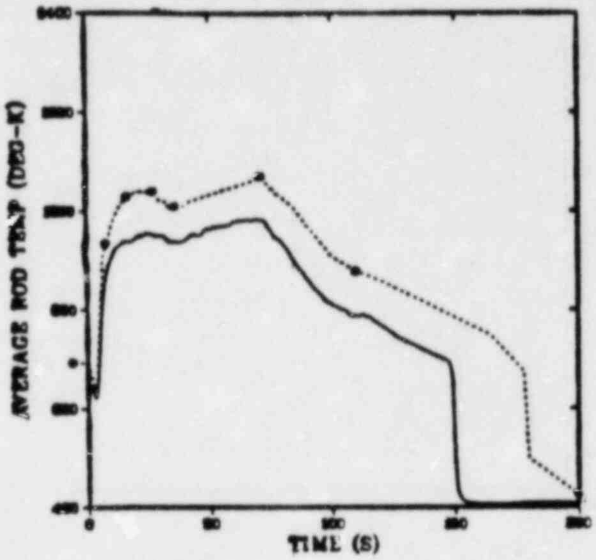

Fig. 2. PCT for Semiscale LOCA test S-06-3 (solid = PD2, dash = data).

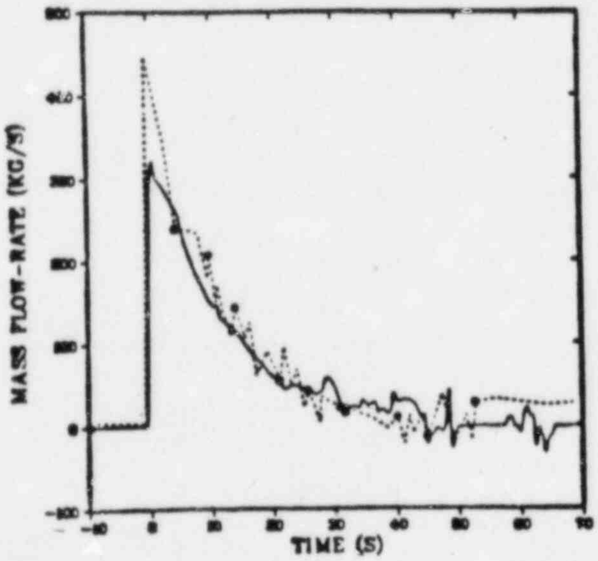

Fig. 3. Break flow (vessel side) for LOFT LOCA test L2-2 (solid = PD2, dash = data).

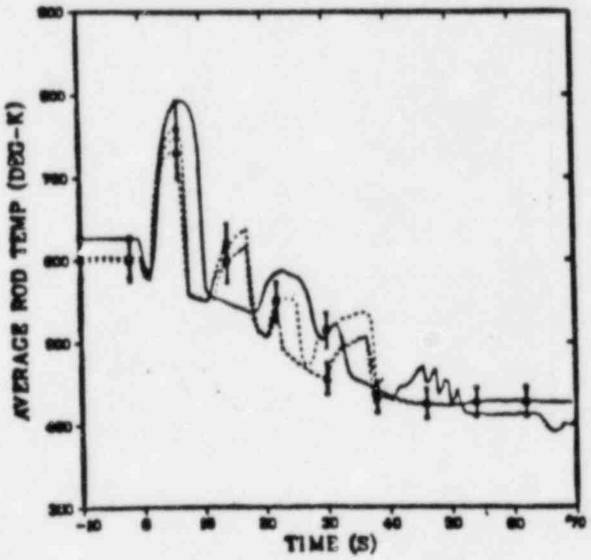

Fig. 4. PCT for LOFT LOCA test L2-2 (solid = PD2, dash = data).