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ASSESSMENT OF THE RELAP4/MOD6 REACTOR TRANSIENT THERMAL-HYDRAULIC CODE

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SUMMARY

The RELAP4/MOD6 transient analysis code is the most recently released of a set of computer programs designed for calculation of the thermal-hydraulic behavior of a light water reactor (LWR) during the transient phases of a postulated loss-of-coolant accident. Earlier versions of RELAP4 primarily had capability for analysis of blowdown and refill phenomena. With RELAP4/MOD6, this capability has been extended through the core reflood range, uniquely providing a best estimate analysis code for the entire accident period.

The code has been assessed by comparing and evaluating calculations with results of a broad selection of reactor safety experiments. This assessment represents a new procedure that incorporates the results of code-data comparisons and evaluations made under controlled user-oriented conditions and introduces a conventional statistical approach to the analysis of code prediction uncertainties. The assessment procedure quantifies the uncertainties in the code in application to the modeling of experiments varying in size, scale, and scope.

Code assessment is achieved by comparing calculated results with experimental data or suitable analytical solutions; the assessment objective is to provide tested and evaluated codes usable in the analysis of hypothesized LWR accidents. An independently assessed code is one that has been evaluated against experimental data and has had its uncertainty, in application to experimental data, adequately defined.

The reported study was conducted by the Code Assessment and Applications Program of EG&G Idaho, Inc. under the sponsorship of NRC/RES. The assessment was made against a broad spectrum of experimental data. Experimental complexity ranged from the study of system component phenomena to the simulation of complete reactor primary coolant systems. The scope of calculations performed included base-case analyses in which code calculations are compared with the results of completed experiments and test predictions in which calculations were made prior to obtaining experimental results.

Some of the representative code-data agreement uncertainties and error-characteristics derived are listed in Table I. The figures are given for both blowdown and reflood phases of the postulated accident and were obtained from comparisons of base-case and test prediction calculations with experimental data. They do not reflect the considerable improvements realizable using modified code user guidelines developed as one of the principal products of code assessment.

Capabilities and deficiencies inherent in recommended code input guidelines and in code internal model structure were defined as a direct result of the assessment study. Some of the more significant code capabilities demonstrated were (1) the adequate analytical representation of the hydraulics throughout the modeled systems for both blowdown and reflood, and (2) the matching of calcu.ated and measured peak cladding temperature in blowdown separate-effects and systems-effects experiments and in reflood systems experiments. The success of the reflood analytical modeling in the code, new with the development of RELAP4/MOD6, is reflected in the successful application of modified user guidelines developed in this study. Among the deficiencies identified were inadequacies of specific empirical models, such as those governing entrainment and phase separation for reflood calculation, and those comprising the critical flow user guidelines and equilibrium assumptions used primarily in blowdown analyses. Both capabilities and deficiencies are discussed and summarized in concluding statements.

TABLE I

REPRESENTATIVE CODE-DATA DIFFERENCES
FOR BASE-CASE AND TEST PREDICTION ANALYSES

Separate Effects Analyses

Phase	Component	Parameter	Uncertainty or Error
Blowdown	Pressurizer	Pressure	<5%
	Fuel Rods	Time to CHF	<0.2 s
		Temperature Rise	<50 K
	Core	Cladding Temperature	
		Short Core	Mean Error = 124 K Std Dev = 103 K
		Full-Length Core	Mean Error = 110 K Std Dev = 77 K
Reflood	Core	Cladding Temperature, Lower and Middle Core	<100 K
		Liquid Inventory at Midplane Quench	<4%

Systems-Effects Analyses

Phase	Parameter	Uncertainty or Error
Blowdown	System Pressure Prior to Accumulator Flow	<2%
	Cladding Temperature	
	Short Core	<70 K
	Full-Length Core	Mean Error = -39 K Std Dev = 34 K
Reflood	Cladding Temperature, Lower and Middle Core	<100 K