NRC FORM 189 (Rev. 04-83)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

Date of Proposal: August 1983

■ New
□ Revision No.

Project Title: FUEL BEHAVIOR MODEL DEVELOPMENT

FIN: A6050

NRC Office: Office of Nuclear Regulatory Research (RES), Division of Accident Evaluation (DAE)

NRC B&R Number: 60 19 01 03

DOE Contractor: EG&G Idaho, Inc.

Contractor Account Number: I-309

Site: IDAHO NATIONAL ENGINEERING LABORATORY (INEL)

DOE B&R Number: 40 10 01 060

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER	PERIOD OF PERFORMANCE
NRC Project Manager: G. P. Marino	NRC/RES	427-4266	Starting Date: 10/01/83
Other NRC Technical Staff: J. T. Han	NRC/RES	427-4460	Completion Date: 09/30/84
DOE Project Manager: D. Majumdar	DOE-ID	583-1805	
Contractor-Project Manager: F. Aguilar	EG&G Idaho	583-9395	
Principal Investigator(s): F. Aguilar	EG&G Idaho	583-9395	

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)		FY -1983	FY -1984	FY -1985	FY -1986	FY -1987
Direct Scientific/Technical		2.5	2.7	2.5		
Other Direct (Graded)		0.1	0.1	0.1		
TOTAL DIRECT STAFF YEARS		2.6	2.8	2.5	2.5	2.5
COST PROPOSAL ($000)						
Direct Salaries		89	106	96		
Material and Services (Excluding ADP)		36	22	29		
ADP Support		46	48	82		
Subcontracts		0	0	0		
Travel Expenses	Foreign	0	0	0		
	Domestic	6	6	5		
Indirect Labor Costs	Direct Labor Overhead	74	90	83		
	Common Support	50	61	56		
Other (Specify)	(carryover)	0	0	0		
Other (Specify)		0	0	0		
General and Administrative (14.0 %)		39	47	49		
TOTAL OPERATING COST		340	380	400	400	350
Capital Equipment		0	0	0	0	0
TOTAL PROJECT COST		340	380	400	400	350

FY 19 84 MONTHLY FORECAST EXPENSE

Total Forecast Expense $ 380K

October	November	December	January	February	March
33	33	32	33	33	32
April	**May**	**June**	**July**	**August**	**September**
32	32	31	30	30	29

APPROVAL AUTHORITY-SIGNATURE: F. Aguilar by DV Clarn

Date: 8/12/83

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DOE Proposing Organization: IDAHO OPERATIONS OFFICE (ID)

FORECAST MILESTONE CHART: Scheduled to Start - △——▲ - Completed (Shown in Quarter Year)
PROVIDE ESTIMATED DOLLAR COST FOR EACH TASK FOR EACH FISCAL YEAR

TASK		FY -1983				FY -1984				FY -1985				FY -1986				FY -1987			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
FRAP-T6 Maintenance and Improvements	Schedule	△																▲			
	Cost	153K				147K				105K				89K							
MATPRO Maintenance and Improvements	Schedule	△																▲			
	Cost	41K				126K				160K				70K							
Transient Fuel Behavior Models	Schedule	△			▲																
	Cost	146K																			
SCDAP Assessment	Schedule													△				▲			
	Cost													138K				160K			
NRC Technical Assistance	Schedule					△												▲			
	Cost					107K				135K				103K				190K			
	Schedule																				
	Cost																				
	Schedule																				
	Cost																				
	Schedule																				
	Cost																				
	Schedule																				
	Cost																				
	Schedule																				
	Cost																				
SUBTOTAL		340K				380K				400K				400K				350K			
CARRYOVER		0K				0K				0K				0K				0K			
TOTAL ESTIMATED PROJECT COST		340K				380K				400K				400K				350K			

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Date: August 1983

Project Title

FUEL BEHAVIOR MODEL DEVELOPMENT

DOE Proposing Organization: IDAHO OPERATIONS OFFICE (ID)

PROJECT DESCRIPTION: (Provide narrative descriptions of the required topics in numerical order. If an item is not applicable, list title and so state.)

(1) Objective of Proposed Work

The Fuel Behavior Model Development Project provides for development and maintenance of (a) a "best estimate" computer code (FRAP-T) which calculates the thermal-mechanical-chemical behavior of light water reactor (LWR) fuel rods during anticipated transients and postulated accidents including fuel rod failure probabilities and the associated release of fission products from the fuel rod after such events, and (b) LWR fuel rod materials properties models which serve as an environmental package (MATPRO) for the fuel behavior computer codes (FRAP-T, FRAPCON, and SCDAP). Experimental data and analytical models from the Idaho National Engineering Laboratory (INEL) and other national laboratories, industry, etc., are reviewed and incorporated in the computer codes as appropriate. The project provides independent assessment of the Nuclear Regulatory Commission (NRC) fuel behavior codes which are being used to audit licensee submittals, to plan and interpret fuel behavior experiments, to support NRC's safety goal and fission product source term program etc. The project also provides an on-call calculational support for the NRC as technical assistance for FRAP-T and SCDAP.

(2) Summary of Prior Efforts

FY-1983:

MATPRO Maintenance and Improvements

Maintenance of existing versions of MATPRO models was provided but new model development was delayed pending analysis of sensitivity studies to determine which models have a significant effect on key calculational results of the SCDAP code. Models for thermal properties of water were added to support the SCDAP simplified boiloff thermal-hydraulics model. Quality assurance procedures similar to those of FRAP-T were followed.

Transient Fuel Behavior Models

A version of PARAGRASS revised by ANL to be compatible with SCDAP was incorporated into the code. This provides SCDAP with the capability to analyze both intact regions and debris regions using a mechanistic gas release model. The BALON2 model used in SCDAP/MOD0/V0 was reviewed to identify alternatives for simplifying the mechanical model. A design report was written which describes the proposed changes and was attached as an Appendix to the SCDAP/MOD1 development planning document.

(3) Work to be Performed and Expected Results

FY-1984:

Summary

The project consists of maintaining the FRAP-T6 code and the MATPRO package. Several updates will be added to FRAP-T6/MOD1 which will enhance the FRAP-T6 pellet cladding mechanical interaction (PCMI) modeling, so that the code

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(3) Work to be Performed and Expected Results (Continued)

FY-1984: (Continued)

Summary (Continued)

accurately calculates fuel rod cladding stresses. FRAP-T6/MOD1/V1 will be created by including this additional modeling. A limited developmental assessment will be performed, and the code will be transmitted to the NESC. MATPRO maintenance will consist primarily of work in support of both FRAP-T6 and SCDAP. For FRAP-T6, the zircaloy cladding plastic deformation models will be revised, the fuel creep and hot pressing subcodes will be modified for use in FRAP-T6, and a model for tensile cladding creep will be developed. For SCDAP, several subcodes will be produced in support of adding models from the TRAP-MELT code to SCDAP. NRC technical assistance will be provided including assembling a library of SCDAP/MODO input decks, a calculation of the Three Mile Island (TMI) event of 1979, and one special project creating a core damage map.

MATPRO Maintenance and Improvements

Maintenance including correction of identified deficiencies in the subcodes describing fuel restructuring (FRESTR), zircaloy-helium accommodation coefficients (GTHCON, GJUMP), and uranium-zircaloy-oxygen compound solidus and liquidus temperatures (PSOL and PLIQ) will be provided.

The zircaloy cladding plastic deformation routines (CKMN, CMLIMT) will be revised to consider yield point data as well as ultimate strength data using the method developed in IS-NSMD-83-009[a] for stainless steel data. This will improve PCMI calculations and all other low-strain cladding deformation calculations with FRAP-T. The fuel creep and fuel hot pressing subcodes (FCREEP and FHOTPS), which calculate strain rate as a function of stress will be augmented with subcodes which calculate stress as a function of strain rate so that the fuel creep and hot pressing models can be used with the FRACAS-II subcode of FRAP-T. A new model for cladding creep under tensile stress will be developed to support PCMI model improvements in FRAP-T.

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[a] D. L. Hagrman, Materials Properties Data for Fusion Reactor Analysis, IS-NSMD-83-009, April 1983.

Project Title

FUEL BEHAVIOR MODEL DEVELOPMENT

DOE Proposing Organization IDAHO OPERATIONS OFFICE (ID)

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(3) Work to be Performed and Expected Results (Continued)

FY-1984: (Continued)

MATPRO Maintenance and Improvements (Continued)

Several subcodes will be produced in preparation for coupling subroutines based on the TRAP-MELT code to SCDAP. Documented models for the equilibrium vapor pressures of CsI, CsOH, zircaloy cladding components, and control rod components will be prepared in support of SCDAP. Models for the dynamic viscosity, density, and molecular mean free paths of H_2 - H_2O mixtures will also be developed for SCDAP. In addition, the particle diffusion coefficients in H_2 - H_2O mixtures will be produced.

NRC Technical Assistance

The technical assistance part of the program will consist of three activities. First, a library of SCDAP/MOD0 input decks will be assembled to provide quick response to NRC requests. The library will consist of SCDAP/MOD0 input decks used in previous analyses by various organizations within EG&G Idaho. The decks will be converted to the format required for the fast running version of SCDAP/MOD0. Five input decks have been targeted for inclusion to the library. These decks represent the Power Burst Facility (PBF) Severe Fuel Damage (SFD) test series 1 scoping test, the German tests at Karlsruhe, the TMI reactor, a pressurized water reactor, and a boiling water reactor of primary concern to probability risk assessment activities being conducted by the NRC. Later in FY-1984, an input deck for RELAP5/SCDAP/MOD1 will be assembled for TMI.

The second part of the technical assistance program is a SCDAP/MOD1 calculation that models the TMI incident of March 1979. The companion RELAP5 input deck is currently available and a SCDAP/MOD1 deck would be assembled and executed. The final part of the technical assistance program is designated as special projects. One activity has thus far been identified, namely, a set of SCDAP/MOD0 calculations to evaluate threshold of damage to a reactor core as a function time at temperature.

FY-1985:

Summary

The project consists of maintaining the FRAP-T6 code and the MATPRO package. Model enhancements based on FEMAXI code calculations and experimental data from Halden and PBF will be evaluated and some incorporated into FRAP-T6. MATPRO model enhancements based on a sensitivity study will be incorporated.

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(3) Work to be Performed and Expected Results (Continued)

FY-1985: (Continued)

FRAP-T6 Maintenance and Improvements

During FY-1983 and FY-1984, models for accurate calculations of uniform axial stress and the maximum hoop stress in cladding were developed. An additional model to calculate localized axial stress caused by formation of circumferential ridges is needed to perform the SCC analysis. An empirical model will be developed to calculate the localized axial stresses based on results generated by the FEMAXI code developed by the Japan Atomic Energy Research Institute.

The fuel compliance model, relocation relaxation model, and the effective thermal expansion model are based on data from a few experiments. FRAP-T6 analyses and a literature survey have shown that this data base is inadequate and a broader data base should be used to refine these models. This work will define required data from selected Halden and PBF experiments. The broad data base will represent the effect of fabricated gap size, pellet design parameters, burnup levels, steady state and transient power cycles on cladding stresses and strains.

MATPRO Maintenance and Improvements

Results from the sensitivity performed with SCDAP late in FY-1983 will be used along with a critical analysis of available data sources to improve those preliminary models developed in FY-1982[a] which affect important SCDAP predictions significantly. Minor maintenance of the package will continue and draft copy will be prepared in preparation for publication of a complete new MATPRO handbook to be completed in FY-1986.

NRC Technical Assistance

The technical assistance program will address two areas. First, the SCDAP input deck library will be expanded to have more decks available for meeting short term calculation needs of the NRC. Three more decks will be added. They will be companion RELAP5/SCDAP decks for plants of current concern to NRC severe accident, accident management, source term, and licensing

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a/ D. L. Hagrman, Materials Properties Models for Severe Core Damage Analysis, EGG-CDD-5801, (May 1982).

Project Title

FUEL BEHAVIOR MODEL DEVELOPMENT

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(3) Work to be Performed and Expected Results (Continued)

FY-1985: (Continued)

NRC Technical Assistance (Continued)

activities. The plants currently under consideration are H. B. Robinson, Seabrook (i.e. RESAR-3S), North Anna, and Arkansas Nuclear One-Units 1 and 2.

The second part of the technical assistance program will be the special projects tasks, which will be used to address current NRC needs as determined by the NRC Technical Monitor.

(4) Description of Any Follow-On Effort

FY-1986, FY-1987, and Beyond:

A minimal effort will be provided to maintain the FRAP-T6 computer code and the MATPRO library of computerized materials properties models used by the FRAPCON, FRAP-T, and SCDAP fuel behavior computer codes. The FRAP-T6/MOD2 assessment effort begun during FY-1985 will be completed in FY-1986, and a final updated version of the code will be released to the NESC. The MATPRO models used for analysis of severe reactor accidents will be updated as dictated by comparisons with new relevant data from separate effects and integral severe fuel damage experiments.

During FY-1986, SCDAP/MOD1 will be independently assessed and findings reported to the SCDAP development project (A6360). A minimal effort for SCDAP assessment is expected during FY-1987. Technical assistance will continue to be provided to NRC during FY-1986 and FY-1987.

(5) Relationships to Other Projects

This project is closely associated with the Modeling Severe Fuel Damage Project (A6360) being performed at the INEL and the FRAPCON code development (B2043) and pellet-cladding interaction modeling (B2452) efforts being performed at Battelle Pacific Northwest Laboratories (PNL). During FY-1984 and beyond, this project encompasses the efforts of a previous project, Fuel Behavior Analysis and Code Assessment (A6046). The fuel behavior models and computer codes developed and/or assessed as part of this project are used extensively by the Thermal Fuels Behavior Program, the Loss-of-Fluid Test (LOFT) Program, and by other federally funded projects in development of experimental procedures and in interpreting experimental data. The computer

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(5) Relationships to Other Projects (Continued)

codes are also used by NRC's Severe Accident Sequence Analysis Project (A6354) and to support NRC's Fission Product Source Term Project. The project derives inputs for model development and code assessment from research projects conducted at Argonne National Laboratory, Oak Ridge National Laboratory, PNL, Battelle Columbus Laboratories, Sandia National Laboratories, INEL, and the NRC sponsored program at the Halden Test Reactor, Halden, Norway.

(6) Reporting Schedule

FY-1983:

T. M. Howe et al., Fission Gas Release Modeling for SCDAP/MOD0, EGG-NSMD-6108 (November 1982).

V. N. Shah and G. A. Berna, Constitutive Models for the FRACAS-II Subcode of FRAP-T6, EGG-NSMD-6103 (November 1982).

V. N. Shah, FRAP-T6 Analysis of Pellet Cladding Mechanical Interaction, EGG-NSMD-6155 (February 1983).

L. J. Siefken et al., FRAP-T6: A Computer Code for the Transient Analysis of Oxide Fuel Rods, NUREG/CR-2148, EGG-2104 Addendum (May 1983).

V. N. Shah et al., Developmental Assessment of FRAP-T6/MOD1, EGG-NSMD-6289 (June 1983).

F. M. Haggag, Sensitivity Study with SCDAP/MOD0, (To be Published August 1983).

FY-1984:

S. R. Wagner, SCDAP Input Deck Library, (To be Published September 1984).

R. Chambers, SCDAP/MOD1 Analysis of TMI-2 Event, (To be Published September 1984).

V. N. Shah et al., Cladding Stresses During PCMI, (To be Published September 1984).

V. N. Shah et al., Developmental Assessment of PCMI Models in FRAP-T6, (To be Published September 1985).