NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL: 8/1/83

☐ NEW

☐ REVISION NO.

PROJECT TITLE: LWR Debris Formation and Relocation	FIN NUMBER: A-1335
	NRC B&R NUMBER: 60190201
NRC OFFICE: Office of Research	
DOE CONTRACTOR: Sandia National Laboratories	CONTRACTOR ACCOUNT NUMBER: DE-AC04-76DP00789
SITE: Albuquerque, NM 87185	DOE B&R NUMBER: 401001060

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER	PERIOD OF PERFORMANCE
NRC PROJECT MANAGER: R. W. Wright	NRC/RES	427-4717	STARTING DATE: 10/1/83
OTHER NRC TECHNICAL STAFF			COMPLETION DATE: 9/30/84
DOE PROJECT MANAGER: R. N. Holton	DOE/ERT	846-5208	[redacted]
CONTRACTOR—PROJECT MANAGER: A. W. Snyder	SNL/6400	844-8203	
J. V. Walker	SNL/6420	844-2876	
PRINCIPAL INVESTIGATOR(S): P. S. Pickard (Task Leader)	SNL/6423	844-6136	
A. C. Marshall		844-0338	
K. O. Reil		844-3294	

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 83	FY 84	FY 85	FY 86	FY 87
Direct Scientific/Technical	6.9	7.9	8		
Other Direct (Graded)					
TOTAL DIRECT STAFF YEARS	6.9	7.9	8		

COST PROPOSAL	FY 83	FY 84	FY 85	FY 86	FY 87
Direct Salaries	801	880	1038		
Material and Services (Excluding ADP)	1125	768	611		
ADP Support	20	18	16		
Subcontracts	50	204	182		
Travel Expenses — Foreign	0	10	1		
Travel Expenses — Domestic	7	20	6		
Indirect Labor Costs					
Other (Specify)					
General and Administrative (%)					
TOTAL OPERATING COST	2003	1900	1854		
CAPITAL EQUIPMENT FIN CHARGED: ______					
TOTAL PROJECT COST	2003	1900	1854		

FY 84 MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
158	158	158	158	158	158

APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
158	162	158	158	158	158

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PROJECT TITLE

Debris Formation and Relocation

DOE PROPOSING ORGANIZATION

Sandia National Laboratories

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

TASK		FY 83	FY 84	FY 85	FY 86	FY 87
Out-of-Pile Devel. Tests	SCHEDULE	——▲ (4th)				
	COST	693				
DFR -- Phase I DF-1,2,3,4,5	SCHEDULE	△ (2nd) ——	——▲ (4th)			
	COST	1310	1050			
DFR -- Phase II DQ-1,2,2,4,5	SCHEDULE		△ (4th) ——	——▲ (4th)		
	COST		850	1854		
DFR -- Phase III (Melt Progression)	SCHEDULE			△ (4th) ——	—— - -	
	COST					
	SCHEDULE					
	COST					
TOTAL ESTIMATED PROJECT COST		2003	1900	1854		

PROJECT DESCRIPTION: (Provide narrative descriptions of the following topics in the order listed. Attach on plain paper to this NRC Form 189. If an item is not applicable, so state.)

1. OBJECTIVE OF PROPOSED WORK
2. SUMMARY OF PRIOR EFFORTS
3. WORK TO BE PERFORMED AND EXPECTED RESULTS
4. DESCRIPTION OF ANY FOLLOW-ON EFFORTS
5. RELATIONSHIP TO OTHER PROJECTS
6. REPORTING SCHEDULE
7. SUBCONTRACTOR INFORMATION
8. LIST NEW CAPITAL EQUIPMENT REQUIRED
9. DESCRIBE SPECIAL FACILITIES REQUIRED
10. CONFLICT OF INTEREST INFORMATION

SEE NRC MANUAL CHAPTER 1102 FOR ADDITIONAL INFORMATION

APPROVAL AUTHORITY—SIGNATURE | DATE 8/2/83

6423 6420 0155 6400 6000

LWR DEBRIS FORMATION AND RELOCATION - A-1335

Objective

Provide a phenomenological data base for understanding and analysis of the in-vessel phase of severe core damage accidents in LWR's. This data base is essential to realistically define uncertainties in current probabilistic risk assessments (PRA) used extensively in the regulatory process, and to develop an improved NRC PRA analysis capability (MELCOR, MELPROG) for evaluating consequences of severe accidents.

Program Objectives

The accident at TMI-2 focused attention on the problems associated with severe LWR accidents. The Damaged Fuel Relocation (DFR) program, and other programs, have been initiated by NRC to investigate the key in-vessel phenomena that determine the progression and consequences of the severe core damage accident. The objective of the DFR program is to provide a unique separate effects data base that allows realistic model development and sequence analysis. The models developed are essential to understanding uncertainties in risk estimates, analyzing the requirements for and effectiveness of mitigation features, or understanding the important aspects of responding to a severe core damage accident.

This program uses the information and perspective gained in NRC safety analysis programs (MELCOR, MELPROG, SASA, SAUNA) and the severe fuel damage phenomenology programs, to identify the needs and major safety issues. The major areas of phenomenology which will be addressed by the DFR program include:

1. Behavior of fuel and cladding during core degradation from an intact geometry to a damaged core or debris configuration.

2. Response of the severely damaged core to the reintroduction of (ECCS) coolant, especially the redistribution of quenched material, short term cooldown, increased steam generation, and oxidation reaction kinetics.

Information concerning the principal physical processes which occur during the severe core damage and the termination phase is needed to assure:

-- Correct assessment of the accident conditions and environment, including core configuration and potential hydrogen and radiological source terms.

-- Improved estimates of the time available for corrective action and/or evaluation.

-- An understanding of the effect of the reintroduction of coolant to the damaged core, including transient steam/H_2 effects and coolability implications.

-- Design of effective accident mitigation systems.

-- Informed prediction of the accident progression and dissemination of factual information.

-- Suf'icient information to establish procedures and training programs to assure proper response implementation.

This information is an essential feature of reliable risk estimates and an important ingredient in establishing licensing requirements.

The focus of the DFR experiments is on phenomenological investigations which can readily be used to develop accident models. Models developed from a fundamental understanding of the accident process allows reliable predictions to be made over a broad range of possible accident conditions. Accurate predictions of accident behavior cannot be uniquely made based on "end state" data for a few "simulations", consequently, the following features have been incorporated into the DFR program:

1. The experiments will be relatively small scale (9 rod bundles) to permit a parametric experimental approach. The important parameters include steam flow rate, relative pressure, axial temperature gradient, and the damage conditions at quench. Other parameters include fuel geometry (PWR vs. BWR), the effect of fuel cracking, and the influence of the fuel spacer location.

2. The experiments will utilize the ACRR, to provide a fission heat source to simulate decay heat conditions, and an external steam supply to provide preconditioned steam (e.g., superheat, flowrate, pressure). This approach allows the correct phenomenological conditions to be obtained.

3. High resolution diagnostics will be utilized to obtain accurate phenomenological data throughout the accident sequence. The most important form of diagnostics involves direct v..ual observation of the fuel bundle during the damage progression. Hydrogen detection (Raman Spectroscopy) and radiometric temperature

measurements are also utilized in DFR tests. Post-Irradiation Examination will also be employed to determine detailed end state conditions.

4. Unit experiment costs will be kept as low as possible to allow maximum coverage of the key in-vessel parameters. Furthermore, experiment hardware will be designed to be flexible in order to provide quick response to our changing understanding of data needs, particularly in support of the development of accident progression codes used both by IDCOR and NRC in severe accident rulemaking activities.

The DFR experimental program will be implemented in two experiment series:

1. Damaged Fuel Relocation (DF) -- visually observed fuel damage in flowing steam environment using neutronic heating of small test bundles and slow cooling termination of the experiment.

2. Damaged Fuel Quench (DQ) -- as in the DF experiments, except that the experiment is terminated by quenching the damaged fuel bundle.

2. <u>Summary of Prior Efforts</u>

During FY83, work was performed in all of the major elements of the DFR program including:

-- Completion of Diagnostic Development Tests
-- Completion of OOP Steam System and Test Assemblies
-- Completed OOP Tests on:
  -- Raman H_2 Measurements
  -- CuO Recombination Tests
  -- System Hardware Tests
  -- OPST-1
-- Fabricated In-Pile Steam System
-- Fabrication of DF-1 Hardware
-- ACRR Safety Review Committee Hearings
-- DF-1 Scheduled for Sept/FY83

Diagnostic development tests have been completed in both air and steam environments to develop visual diagnostics for DFR configurations. These tests have demonstrated that high resolution visual observation is achievable under these conditions and that radiometric temperature measurements can be made, both directly and with film.

Several series of tests have been performed with the OOP steam system. The use of Raman spectroscopy (pulsed UV) to measure the H_2 concentration in the bundle effluent. Test series have been completed to demonstrate sensitivity (~1% H_2 in steam), linearity as a function of pressure, and to demonstrate compatibility between the UV laser light and induced fluorescence and visual optical equipment.

Tests were also performed to demonstrate the efficiency of the CuO recombination bed. Tests were run at a range of CuO temperatures (320-500°C) and steam/H_2 ratios which confirmed that with CuO temperatures above 420°C, essentially no H_2 buildup is observed during the duration of the test.

System demonstration tests (OPST) were performed to test the integration of steam supply, optical system, and data acquisition and control systems.

The hardware for the in-pile tests was fabricated and assembled for the DF-1 experiment which is scheduled for September.

The DFR reactor safety review was completed. The complexity of these computer-controlled, actively contained tests required extensive review. Several sets of safety-related verification tests were defined and performed.

3. <u>Work to be Performed and Expected Results</u>

During FY83 out-of-pile development tests were completed and the DF-1 test will be performed to initiate the in-pile test series. During FY84, the first phase (DF) of the DFR tests will be completed and the DQ series of tests will be initiated. The DFR program is being considered in three phases:

<u>Phase 1</u> DF Series
-- 5 experiments with visual diagnostics.
-- Steam flow rate and relative pressure effects.
-- BWR vs. PWR geometry.
-- Grid spacer location effect.
-- Initial to substantial melt relocation.

<u>Phase 2</u> DQ Series
-- 5 separate-effects experiments, with reflood.
-- Matrix on damage and quench factors (steam flow, initial condition, relative pressure, fuel cracking spacer location, quench mode and rate, extent of damage).

Phase 3 "Response"
-- Follow-on experiments if required.
-- Respond to unresolved issues.

The Phase I experiments are scheduled for completion in FY84. Quenched experiments, Phase II, will begin in 4Q FY84 and are scheduled for completion in FY85.

4. Follow-On Efforts

Beyond FY85 a third phase of the DFR program is possible. This work may include additional experiments suggested by the results of the DF and DQ experiments, gross melt relocation experiments and continued experiment analysis and model development.

5. Relationship to Other Projects

This program is providing critical data relevant to a number of severe accident rulemaking related programs. Specifically the data relates directly to uncertainty analyses being conducted in the Severe Accident Sequence Analysis Program (DAE), and the Melt Progression Phenomenology Program (DAE). Furthermore, phenomenological models based in part on this data will go directly into the NRC PRA code MELCOR and the Phenomenological codes SCDAP and MELPROG. Data from this program will confirm models used to predict H_2 generation rates and timing and contribute to a number of NRC programs to deal with H_2 control. Since knowledge of the thermophysical conditions in-vessel is critical to correctly quantify fission product chemistry and hence release fractions, data generated in this program is required before realistic source terms can be generated. Finally, since a severe accident is not over until the debris can be cooled, this program provides important information on debris characteristics essential to defining coolability limits. Damage states defined as a result of this work will be used with the basic LWR coolability models to determine at what stage in the accident the debris can be cooled and how best to do so. This program also relates to the large scale test program being conducted at the Power Burst Facility. Small scale separate effects experiments complement PBF results by providing a broad coverage of parameter space not possible in large integral tests.

6. Reporting Schedule

Results from the DFR program will be reported in topical reports. In addition, regular and frequent communication between NRC and SNL project leaders will be maintained through telephone and staff visits to the site. A mid-year program review will be conducted to evaluate program results and implications for future

directions. Furthermore, regular monthly and quarterly reports will be provided.

7. Subcontractor Information

No subcontractor support required.

8. List of New Capital Equipment Required -- FY83

Multi-Channel Optical Analyzer -- 34K

9. Utilization of Facilities and Test Installation

This program utilizes the Annular Core Research Reactor located at Sandia Laboratories. This reactor is unique in the world in that it provides large exposure volumes both in steady state and in a prompt burst mode. The facility represents a capital investment of approximately $10M and has an annual operating cost of $850,000. It is estimated that a period of 5 years would be required to replace this facility at a cost of $25M.

10. Conflict of Interest

No significant contractual or organizational relationships of Sandia National Laboratories, its employees, or anticipated subcontractors and/or consultants exists with industries regulated by the NRC and suppliers thereof that might give rise to an apparent or actual conflict of interest.