NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL: July 1983

☐ NEW

☒ REVISION NO.

PROJECT TITLE: NRU Coolant Boilaway and Damage Progression Tests

FIN NUMBER: B2277

NRC OFFICE: U. S. Nuclear Regulatory Research

NRC B&R NUMBER: 60190201

DOE CONTRACTOR: Pacific Northwest Laboratory - Battelle Memorial Institute

CONTRACTOR ACCOUNT NUMBER: TD1053

SITE: Richland, Washington

DOE B&R NUMBER: 40-10-01-06

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER	PERIOD OF PERFORMANCE
NRC PROJECT MANAGER Dr. R. Van Houten	RES/DAE/FBBR	427-4266	STARTING DATE On-Going
OTHER NRC TECHNICAL STAFF Dr. G. Marino	RES/DAE/FBBR	427-4266	COMPLETION DATE Sept. 30, 1985
DOE PROJECT MANAGER Maynard Plahuta	RL-DOE	444-7034	
CONTRACTOR PROJECT MANAGER M. D. Freshley	PNL	444-7411 375-2530	
PRINCIPAL INVESTIGATOR(S) JP Pilger GE Russcher LL King FE Panisko LJ Parchen GM Hesson MC Wismer	PNL PNL	444-5063 375-2952	

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 83	FY 84	FY 85	FY	FY
Direct Scientific/Technical	7.5	11.9	2.2		
Other Direct (Graded)	3.2	5.1	1.0		
TOTAL DIRECT STAFF YEARS	10.7	17.0	3.2		
COST PROPOSAL					
Direct Salaries Summary for FLHT Test Series	520	885	181		
Materials and Services (Excluding ADP)	300	857	0		
ADP Support	30	20	5		
Subcontracts	200	45	0		
Travel Expenses Foreign Canada	20	25	8		
Travel Expenses Domestic	10	10	5		
Indirect Labor Costs	150	265	54		
Other (Specify) Other Direct Costs - Indirect Services	193	368	71		
General and Administrative (%)	370	629	129		
TOTAL OPERATING COST	1793*	3104	453		
CAPITAL EQUIPMENT FIN CHARGED: _____	150	100	0		
TOTAL PROJECT COST	1943**	3204	453		

FY _____

MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER

NRC FORM 189 (3-81)

*Includes expected $30K for reimbursement of British PIE.

**Includes $800K for FY83 Authorization of FIN-B2859 (TD1759)-UK Contribution to NRU CRDP Tests

NRC FORM 189 (3-81) — U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

FIN NUMBER: B 2277

DATE: July 1983

PROJECT TITLE: NRU Coolant Boilaway and Damage Progression Tests (FLHT Series)

DOE PROPOSING ORGANIZATION: Richland Operations Office - Energy Programs Division

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 MTH 1st	2nd	3rd	4th	FY 83 FLHT 1st	2nd	3rd	4th	FY 84 1st	2nd	3rd	4th	FY 85 1st	2nd	3rd	4th	FY 1st	2nd	3rd	4th
Design and Fabrication FLHT-1 and -2	SCHEDULE	△			▲	△						▲-1		▲-2							
	COST					$487K				$1464K											
Safety Analysis and Test Operations	SCHEDULE	△			▲	△						▲-1		▲-2							
	COST					$233K				$835K				$128K							
Instrument Procurement	SCHEDULE	△			▲	△					▲-1		▲-2								
	COST					$234K				$378K											
Project Management QA/QC Licensing/Shipping	SCHEDULE	△			▲	△															
	COST					$351K				$392K				$225K							
Post Test Examination	SCHEDULE												△		▲-1		▲-2				
	COST									$100K (2)				$100K							
TOTAL ESTIMATED PROJECT COST		$ 1172K (1)				$1305K				$3169K				$453.K							

$2477K**

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

Note: -1 and -2 refer to milestones for FLHT-1 and FLHT-2, respectively.

*Funds available for FY-83 Costs:

B2277 FY-82 Carryover	$ 145K
B2277 FY-83 Authorization	$1143K
B2859 FY-83 Authorization	$ 800K
Cost transfer B2277 to B2084	$ 260K
	$2348K

APPROVAL AUTHORITY-SIGNATURE: [signature]

DATE: 9/5/83

(1) Includes $150K Capital (2) Capital Costs

**FY83 $129K Funding expected or delay of activity

TD1053
B2277
300A01171

TITLE: NRC - NRU Coolant Boilaway and Damage Progression Tests

For the purpose of clarity, M.D. Freshely has separated this project into two major tasks, FLHT TESTS, and FLST TESTS. The costs have been split and reported on separate 189 forms. However, this still remains one project under TD1053 and FIN B2277.

TOTAL PROJECT COSTS

FLHT TESTS

FY83 - $1943K	FY84 - $3204K	FY85 - $453K	

FLST TESTS

FY83 - $-0-	FY84 - $1333K	FY85 - $3368K	FY86 - $1200K

1. Objective of Proposed Work

The program will develop a well-characterized data set for evaluating the consequences of coolant boilaway and core damage progression in a light-water reactor. Coolant boilaway will be simulated using low-level fission heat as a surrogate for the system enthalpy and decay heat expected to drive a postulated coolant boilaway accident. These data will provide a basis for accident mitigation strategy development and damage assessment for a postulated coolant boilaway incident.

A two-test sequence is proposed where two full-length test assemblies using 12-rod fuel bundles will be irradiated. The tests will be performed in the U-2 loop of the NRU reactor, Deep River, Ontario. The data that will be obtained include:

- temperature distribution in a full-length bundle as a function liquid level,
- data on fuel bundle damage progression, i.e., core degradation,
- cladding melt progression, dissolution of UO_2 and solidification data,
- melt and grid spacer interaction,
- coolant boilaway behavior,
- hydrogen evolution,
- debris bed formation and coolability data,
- ID/OD cladding oxidation and embrittlement data, and
- test train design verification needed for subsequent tests.

The CBDP integrated effect tests will provide data to assess and confirm the validity of results obtained from numerous separate effects tests being conducted by the NRC.

Experiments will be designed and conducted in such a way to optimally use the advantages inherent in the NRU reactor for testing of this kind. These advantages include: (1) capabilities for testing multi-rod bundles with lengths to 12 ft under thermal-hydraulic conditions representative of contemporary LWRs, (2) the ability to achieve requisite power densities typical of TMI-2 accident conditions using fuels with normal commercial enrichments, and (3) the ability to provide prototypic coolant mass fluxes at the fluid/vapor interface typical of a TMI boildown condition. These advantages will reduce uncertainties in scaling factors and interpretation of the experimental results which must be applied to results from small-scale separate effects tests.

2. Summary of Prior Efforts 1983

- Prepared and issued the following papers and reports:

  Mohr, C. L. and G. M. Hesson. August 1983. "LOCA Rupture Strains and Coolability of Full-Length PWR Fuel Bundles." In Proceedings of the Seventh International Conference on Structural Mechanics in Reactor Technology (SMIRT-VII), Chicago, Illinois.

  NUREG/CR-2526, Data Report for Thermal-Hydraulic Experiment 2 (TH-2).

  NUREG/CR-2527, Data Report for Thermal-Hydraulic Experiment 3 (TH-3).

  NUREG/CR-2528, Data Report for the Third Materials Experiment (MT-3).

  NUREG/CR-3272, Data Report for the Fourth Materials Experiment (MT-4).

  Marshall, R. K., et al. June 1983. LOCA Simulation in NRU Program The Continuous Measurement of Coolant Liquid Level During the MT-4 Experiment in the NRU Reactor. NUREG/CR-3183, PNL-4650, Pacific Northwest Laboratory, Richland, Washington.

  Russcher, G. E., et al. June 1983. Experiment Operations Plan for the MT-4 Experiment in the NRU Reactor. NUREG/CR-2881, PNL-4293, Pacific Northwest Laboratory, Richland, WA.

  Russcher, G. E., et al. June 1983. Experiment Operations Plan for the TH-3 Experiment in the NRU Reactor. NUREG/CR-2660, PNL-4332, Pacific Northwest Laboratory, Richland, WA.

- Completed the design of the test train for Materials Test 6 (MT-6), a 21-rod configuration designed for operation in NRU to 2200°F.

- Demonstrated the feasibility of fabricating dual density thoria insulation for high temperature shroud application.

- Designed the test train for the first Full-Length High Temperature coolant boilaway and damage progression test (FLHT-1).

- Initiated fabrication and development work for the first full-length coolant boilaway and damage progression test (FLHT-1).

- Prepared a draft experiment plan for the full-length coolant boilaway and damage progression tests (FLHT-1 and 2).

- Prepared the PSAR and issued it to obtain AECL approval to conduct FLHT-1.

- Prepared a design of a hydrogen measurement and experiment/control system including the piping arrangement for disposal of the experiment effluents.

- Ordered and received the data acquisition and control system for FLHT-1 and 2 tests.

- Prepared and delivered two presentations before the ACRS Reactor Fuels Subcommittee meetings (January and May 1983).

- The following program reviews were given: NRC, December 13, 1982 in Silver Spring, Maryland; NRC, January 7, 1983 in Silver Spring, Maryland; the NRC on February 9, 1983 in Richland, Washington; NRC, March 8, 1983, Silver Spring, Maryland; and NRC, April 18 and 19, 1983, Program Status Meeting in Idaho Falls, Idaho.

3. Work to be Performed and Expected Results - FY-1984

- Design new DERM tools to section the high temperature FLHT shrouds.

- Develop low density or dual density thoria for shroud insulation in FLHT-2 as required.

- Fabricate the test train for FLHT-1.

- Complete the design and fabricate the hydrogen measurement and experiment control system for the FLHT Series.

- Perform the NRU damage progression test FLHT-1 and complete preliminary test results evaluations.

- Begin necessary post-test examinations and collection and qualification of test data needed for later topical reports and final reports.

- Fabricate the test train for FLHT-2.

- Provide the project management for the NRU fuel damage progression test program including test scheduling, test safety analysis, test assembly shipping/licensing, testing, evaluating results, reporting and waste disposal. (No funding is included for AECL subcontract financing or waste disposal.)

- Prepare the documents required for all FY-1984 program tests in the NRU reactor including nondestructive and destructive (hot-cell) post-test examinations and procedures.

- Continue the systematic review with AECL of program support changes which might reduce the cost and improve the quality and timeliness of program test data.

- Work to QA levels and procedures consistent with those employed in previous NRU program activities.

- Provide technical assistance as requested by NRC/DAE staff. (No funding included for FY-1984).

4. Description of Any Follow-On Efforts

In October 1984, the FLHT-2 test will be conducted in NRU to provide fuel bundle damage progression data to temperatures as high as 4000°F (2477K). Post-test examination and data reporting of both FLHT-1 and 2 tests will then be completed. Following the FLHT-2 test, the PNL design and fabrication efforts will concentrate on conducting the first Full-Length "Source Term" (FLST-1) test in July 1985. See the attached 189 amendment for additional details.

5. Relationship to Other Projects

This program relates to those other Nuclear Regulatory Commission programs which are concerned with the performance characteristics of nuclear reactor fuels under adverse operating conditions. The NRU Coolant Boilaway and Damage Progression experiments will provide experimental data for other severe accident analysis involved with:

- the behavior of damage fuel

- hydrogen generation

- fuel-structure interaction

- fission product release and transport

These data from the NRU tests will provide data that will be utilized in other programs for severe accident sequence analysis, accident management, containment analyses, risk code development, and assessment of accident consequences and risk evaluations. The proposed tests complement the PBF and ACRR experimental programs.

The NRU Coolant Boilaway and Damage Progression Tests will be the first full-length, nuclear-heated PWR multi-rod boilaway tests ever performed. The deformation, rupture and debris bed data can be used to evaluate code models and quantify the conservatism in safety limits used in the nuclear industry. The results of this program provide the critical length-dependent information for the SFD data base and expand the data to be obtained from both ACRR, PBF, and testing in other domestic and foreign laboratories.

The proposed tests will define severe fuel damage conditions and damage progression mechanisms for the 3400-4000°F (2144-2477K) temperature range. The use of full-length fuel rods in the NRU facility will produce data for evaluating the effects on cooling and debris bed formation of mass transport at the liquid-vapor interface, cladding rupture, damage propagation, and coolant flow blockage during coolant boilaway. This

data set will provide a basis for accident mitigation strategy development and evaluation for a postulated coolant boilaway incident. It provides a basis for developing concepts for accident prevention and quantifies potential safety margins.

6. Report Schedule - FY-1983

- Technical Status Letter Report - Monthly
- RSR Quarterly Technical Reports
- Safety Analysis Report, Addendum required by AECL - September 1983

7. Subcontractor Information

In the past few years, approximately one-third of the total costs incurred on this program was disbursed through subcontracts to AECL, Chalk River, Ontario. These expenditures reimbursed AECL on a commercial use rate basis for conducting tests, and on a cost-plus-fee basis for NRU modifications required for testing. Beginning in FY-1984, it is expected that an NRC-AECL agreement will be put in place to cover these costs; therefore, beginning in FY-1984, costs needed for AECL expenditures are not included in this plan.

The General Electric Company in San Jose, California, will be used to verify key thermal-hydraulic safety calculations using the computer code THTD at a cost of approximately $50K.

8. New Capital Equipment Required

The FY-1984 capital equipment needs are as follows:

- $100K - DERM fixturing and shroud cutting tools for use at CRNL

9. Special Facilities Required

No special facilities will be required. Spent fuel handling and storage are still being provided by CRNL. Hot cells are available at CRNL on a use-rate basis.

10. Conflict of Interest

The proposed program has been reviewed by Battelle's Corporate Scope Coordinator, who indicates that it does not duplicate work being performed for others.

NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL

☐ NEW
☐ REVISION NO.

PROJECT TITLE

NRU Coolant Boilaway and Damage Progression Tests (Amendment #1 - FLST Series)

FIN NUMBER

NRC OFFICE

NRC B&R NUMBER

DOE CONTRACTOR

CONTRACTOR ACCOUNT NUMBER TD1053

SITE

DOE B&R NUMBER

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER
NRC PROJECT MANAGER		
OTHER NRC TECHNICAL STAFF ____		
DOE PROJECT MANAGER		
CONTRACTOR-PROJECT MANAGER		
PRINCIPAL INVESTIGATOR(S)		

PERIOD OF PERFORMANCE

STARTING DATE

COMPLETION DATE

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 83	FY 84	FY 85	FY 86	FY
Direct Scientific/Technical		4.5	12.5		
Other Direct (Grades)		2.0	5.3		
TOTAL DIRECT STAFF YEARS		6.5	17.8		
COST PROPOSAL					
Direct Salaries Summary for FLST Test Series		338	1008		
Material and Services (Excluding ADP)		487	758		
ADP Support		5	15		
Subcontracts		0	0		
Travel Expenses Foreign Canada		3	25		
Travel Expenses Domestic		0	10		
Indirect Labor Costs		101	302		
Other (Specify) Other direct costs/indirect service		157	385		
General and Administrative (%)		240	715		
TOTAL OPERATING COST	0	1333	3218	1200	
CAPITAL EQUIPMENT PIN CHARGED: _____	0	0	150	0	
TOTAL PROJECT COST	0	1333	3368	1200	

FY _____	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
MONTHLY FORECAST EXPENSE	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER

NRC FORM 189 (3-81)

NRC FORM 189 (2-81) U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

FIN NUMBER: B 2277

DATE: July 1983

PROJECT TITLE

NRU Coolant Boilaway and Damage Progression Tests (Amendment #1 - FLST Series)

DOE PROPOSING ORGANIZATION

Richland Operations Office - Energy Programs Division

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

TASK		FY 84				FY 85				FY 86				FY				FY			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Design, Development Fabrication of FLST-1, -2, -3	SCHEDULE	△						-1		-2	-3										
	COST	$907K				$2168K				$500K											
Safety Analysis and Test Operations	SCHEDULE	△						-1		-2	-3										
	COST	$216K				$ 450K				$300K											
Instrument Procurement	SCHEDULE	△	▲			▲															
		-1				-2	-3														
	COST	$200K				$ 660K				0											
Project Management QA/QC Licensing/Shipping	SCHEDULE	△										▲									
	COST	$ 10K				$ 90K				$100K											
Post-Test Examination	SCHEDULE									▲		▲									
										-1		-2									
	COST					0 *				$300K											
TOTAL ESTIMATED PROJECT COST		$1333K				$3368K*				$1200K											

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

Note: -1, -2, and -3 refer to Milestones for FLST-1, -2, and -3, respectively.

SEE NRC MANUAL CHAPTER 1102 FOR ADDITIONAL INFORMATION

APPROVAL AUTHORITY-SIGNATURE

DATE 8/5/83

*Includes $150K capital.

This supplement to the CBDP Program provides the necessary "189" information for the proposed full-length source-term (FLST) tests in NRU. This supplement defines the program activities and the funding required to support those activities in FY-1984 in order to perform the first FLST test in July 1985 as scheduled.

1. Objective of Proposed Work

The proposed work is complimentary to that described in the CBDP 189 for the FLHT tests in that the FLST tests will provide data on the distribution of the fission products and aerosols released during the high-temperature boilaway transients. The quantity of the released fission products will be measured in the test assembly effluent system starting near the top of the fuel bundle and continuing to the effluent catch tank. Thus, the main objective is to measure source terms from severely damaged fuel using irradiated full-length fuel bundles at temperatures to 3100K (5120°F).

A three-test series (FLST-1, 2, 3) is proposed using 12-rod fuel bundles with preirradiated fuel rods in each bundle. Fresh rods in the bundles would contain the main bundle temperature sensors. The specific advantages of performing these tests in NRU are presented in the CBDP 189.

2. Summary of Prior Efforts

See CBDP 189.

3. Work to be Performed and Expected Results - FY-1984

Much of the work to be performed in support of the FLHT tests series in FY-1984 and 1985 is required to maintain the proposed FLST test schedule. The following work/activities are required in FY-1984 for FLST testing:

- Complete the conceptual and detailed preliminary design of the experimental test train.
- Complete the conceptual and initiate detailed preliminary design of the test assembly remote disconnect/discharge arrangement.
- Complete the conceptual and initiate detailed preliminary design of the fission product and aerosol sample measuring stations.
- Initiate development of test assembly remote disconnect systems.
- Complete development for in-pool test bundle assembly using irradiated fuel rods.
- Procure necessary development materials as well as long-lead time hardware in time to meet the July 1985 test date (must ship test train hardware from PNL to AECL by May 1985).

- Procure long lead time test instrumentation--mainly high-temperature thermocouples.

- Initiate safety analyses for the FLST series including performing the necessary thermal-hydraulic calculations.

- Initiate the FLST-1 test operations plan especially 1) for handling the irradiated rods during test bundle assembly in the NRU storage pool, and 2) for the post-test handling of fission products coupons and other test assembly irradiated samples.

- Initiate procurement of irradiated rods.

4. Description of Follow-on Efforts

- Conduct FLST-1 with peak temperatures to 2500K (4040°F), July 1985.

- Conduct FLST-2 with peak temperatures to 2700K (4400°F), November 1985.

- Conduct FLST-3 with peak temperatures to 3100K (5120°F), March 1986.

5. Relationship to Other Projects

The CBDP 189 gives the general relationship of this program to other projects. In particular, this proposed effort will provide data to those programs studying fission product release and transport and the resulting effects on public health and safety. The proposed tests will complement the PBF and ACRR experimental programs.

6. Report Schedule

- Technical Status Monthly Letter Reports

- RSR Quarterly Test Reports

7. Subcontractor Information

No subcontracts are expected for this project, (See CBDP 189): However, considerable additional effort will be required of AECL to prepare for the source-term test series. A preliminary estimate of the costs for casks, piping modifications, structural support, etc., total approximately $3M.

8. New Capital Equipment Required

No equipment is required in FY-1984. It is expected that $150K for procurement of capital equipment for the fission product sampling system will be needed in FY-1985.

9. Special Facilities Required

No special facilities will be required.

10. Conflict of Interest

The proposed program has been reviewed by Battelle's Corporate Scope Coordinator, who indicates that it does not duplicate work being performed for others.

NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL: June, 1983

☐ NEW

☒ REVISION NO.

PROJECT TITLE: EFFECTIVENESS OF LWR ESF SYSTEMS UNDER SEVERE ACCIDENT CONDITIONS

FIN NUMBER: B2444

NRC OFFICE: NUCLEAR REGULATORY RESEARCH

NRC S&R NUMBER: 60190101

DOE CONTRACTOR: PACIFIC NORTHWEST LABORATORY, BATTELLE MEMORIAL INSTITUTE

CONTRACTOR ACCOUNT NUMBER: TD 1579

SITE: RICHLAND, WASHINGTON

DOE S&R NUMBER: ~~40-10-01-06~~

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER
NRC PROJECT MANAGER C. W. Nilsen	RES/DET/CEBR	443-5910
OTHER NRC TECHNICAL STAFF		
DOE PROJECT MANAGER Maynard J. Plahuta	RL-EPD	444-7034
CONTRACTOR PROJECT MANAGER W. K. Winegardner	PNL-EPD	444-7511
PRINCIPAL INVESTIGATOR(S) E. P. Coomes P. C. Owczarski F. R. Zaloudek	PNL-EPD PNL-GRED PNL-EPD	444-7511 444-7511 444-7511

PERIOD OF PERFORMANCE

STARTING DATE: Ongoing

COMPLETION DATE: 09/30/86

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 82	FY 83	FY 84	FY 85	FY 86
Direct Scientific/Technical	1.5	1.9	4.4	4.4	
Other Direct (Graded)					
TOTAL DIRECT STAFF YEARS	1.5	1.9	4.4	4.4	
COST PROPOSAL ($K)					
Direct Salaries	76	103	232	255	
Materials and Services (Excluding ADP)	11	15	30	35	
ADP Support	5	35	50	50	
Subcontracts	14	50	70	75	
Travel Expenses — Foreign	0	10	10	10	
Travel Expenses — Domestic	~~2~~	~~15~~	~~20~~	~~20~~	
Indirect Labor Costs	22	30	70	77	
Other (Specify) Other Direct Costs/Indirect Services	13	20	43	47	
General and Administrative (%)	53	72	165	181	
TOTAL OPERATING COST	200	350	690	750	750
CAPITAL EQUIPMENT FIN CHARGED:					
TOTAL PROJECT COST	200	350	690	750	750

FY _____

MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER

NRC FORM 189 (3-81)

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NRC FORM 189 (2-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

FIN NUMBER: B2444

DATE: June, 1983

PROJECT TITLE: EFFECTIVENESS OF LWR ESF SYSTEMS UNDER SEVERE ACCIDENT CONDITIONS

DOE PROPOSING ORGANIZATION: RICHLAND OPERATIONS OFFICE/ENERGY PROGRAMS DIVISION

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

TASK		FY 82				FY 83				FY 84				FY 85				FY 86			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
ESF System Effectiveness Assessment	SCHEDULE									△											
	COST									200				300				300			
Model Development/ Validation	SCHEDULE	△																			
	COST	120				240				300				300				300			
Experimental Programs	SCHEDULE	△																			
	COST	. 23				167				190				150				150			
	SCHEDULE																				
	COST																				
	SCHEDULE																				
	COST																				
TOTAL ESTIMATED PROJECT COST		143				407*				690				750				750			

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
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3. WORK TO BE PERFORMED AND EXPECTED RESULTS
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5. RELATIONSHIP TO OTHER PROJECTS
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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: John D. Hyslop

DATE: JUN 29 1983

*Includes $56K/FY82 carry over

1. Objective of Proposed Work

The objective of the proposed work is to predict fission product removal effectiveness of various Engineered Safety Feature (ESF) systems under postulated, severe accident conditions. Work scope has been expanded to incorporate activities previously conducted under FIN NOS. B2413 (Fission Product Behavior in Past Fuel Cycle Accidents) and B2445 (Aerosol Effects on LWR ESF Systems Design and Criteria). Filtration, spray, and pressure suppression systems that will be considered include: (1) containment spray and spray additive systems (PWR), (2) containment recirculating filter systems, (PWR), (3) auxiliary building filter systems, (4) main steam isolation valve (MSIV) leakage control system (BWR), (5) suppression pools (BWR), (6) standby gas treatment system (BWR), and (7) pressure suppression by ice (PWR). Work will include the definition of physical and chemical conditions expected to be imposed on ESF systems under postulated severe accident conditions, development of codes and models (and mechanistic descriptions of the underlying retention processes) for predicting system performance, and experimental investigations to validate proposed models. Efforts to provide guidelines for system design and operating requirements, to identify possible add on features, to develop information that will not only identify the more important systems but permit their emphasis in future regulatory processes, and to identify information gaps are also included.

2. Summary of Prior Efforts (FY-83)

An initial review of the adequacy of state-of-art assessment models and experiments for the validation of models was completed. Several information gaps were identified. A preliminary, first principle model for predicting the extent of removal or scrubbing of fission product aerosols and gases by ice beds was developed as a result of this review. Further, an expanded experimental program that proposes investigation of fission product retention by ice beds, containment air coolers, and sprays was defined. Publication of information compiled concerning ESF system design and the models and experimental investigations currently being used to evaluate system performance was begun.

Work was begun on the installation/development of a computer code system for use in the assessment of system performance under severe accident conditions. In addition to installation of several state-of-art codes for definition of accident conditions, development of initial versions of computer codes to predict fission product retention by suppression pools (SPARC) and ice beds (ICEDF) was completed. These two codes were also used as part of the high priority NRC effort to better define radionuclide releases (source terms) under severe LWR accident conditions. In addition to the

above two codes, a mechanistic model to predict particle washout by sprays was developed and incorporated into an existing aerosol transport code. Postulated accident sequences for use in the assessment of ESF system effectiveness were also selected.

Literature was reviewed to identify foreign reactor and domestic and foreign fuel cycle incidents that could aid in the effort to quantify uncertainties associated with fission product release and thus better define severe accident conditions. The review revealed one incident not previously discussed in conjunction with TMI that could conceivably provide insights. In this particular incident, the Lucens accident, most of the fission products that were released were apparently retained by heavy water that had been expelled from the moderator vessel prior to their release. Review of the PRTR incident continued. However, little new information was uncovered. Interviews with the person who was the shift supervisor at the time of the incident confirmed that precise release pathways will be difficult to define.

3. Work to be Performed and Expected Results for FY-84, 85

Incorporation of the preliminary ESF system fission product depletion models into a series of thermal hydraulic and aerosol transport codes for predicting the consequences of postulated, severe accidents will be emphasized. It is expected that the resulting assessment system will be available early in FY-84 and that evaluatin of ESF system effectiveness will continue throughout the remainder of FY-84 and FY-85. The focus of this evaluation will be the identification of the more important ESF systems while considering a spectrum of accident conditions. Identification and improvement of numerical models that will assist in providing best estimates of the spectrum of chemical and physical properties of the severe environments expected to be imposed on ESF systems and in the evaluation and predictin of system performance under such conditions will continue in FY-84. Efforts to use published information to validate PNL developed codes will also be emphasized in FY-84. Assessment of the adequacy of research programs for addressing accident phenomena that could impair ESF system performance e.g., hydrogen burns, as well as the identification of information gaps related to ESF system assessment models and experimental efforts will continue. Details of the proposed FY 84, 85 effort follow.

- ESF System Effectiveness Assessment - This task is to provide the assessments of ESF system performance in terms of fission product removal. FY 84, 85 efforts will focus on the use of an assessment system comprised of computer codes to describe the various thermal hydraulic and material release, transport, and retention processes. Installation of state-of-art computer codes developed by others for predicting accident thermal hydraulic conditions and fission product transport will continue. Codes

still unavailable at the time of writing of the proposed effort include those to describe fission product release from fuel and from molten core-concrete interactions (CORSOR, CORCON, VANESSA) and thermal hydraulic conditions and fission product transport and retention in primary systems (MERGE, TRAP-MELT). The above codes, plus the previously installed MARCH code, will then be linked to a code for estimating the extent of fission product retention in the containment vessel. At the minimum the latter, containment code will require combining previously installed state-of-art codes for estimating aerosol depletion by natural processes (e.g., NAUA, CORRAL, MAEROS) with the codes that have been developed to predict ESF system effectiveness (e.g., SPARC & ICEDF).

Development of a new code that combines containment vessel thermal hydraulic models, descriptions of natural aerosol transport processes and engineeed removal processes is a possible alternative effort. In any case, installation of an initial assessment system is expected to be complete by the end of the first quarter of FY-84. The code system will then be used for the remainder of FY-84 and during FY-85 to provide guidelines for light water reactor ESF system design and operating requirements and to develop information that will not only identify the more important systems but permit their emphasis in future regulatory processes. Assessment with this code system will be based primarily on a spectrum of postulated accident sequences, obviously emphasizing those sequences that could conceivably involve one or more ESF systems. Use of ESF system assessment codes alone or in conjunction with containment vessel aerosol transport models, while considering preselected ranges of accident conditions, will also be investigated as a technique for gaining insights into system performance.

- Model Development/Validation - This task is to identify the need for and provide the numerical models needed to predict accident conditions and ESF performance. Development of the mechanistic descriptions of underlying transport processes associated with fission product retention by ESF systems is a complex task. Further, the short time frames associated with the high priority source term reassessment prevented comprehensive consideration of all processes and factors during the development of the initial models for ice bed and suppression pool scrubbing.

  Hydrodynamic processes affecting bubble size, shape, and rise velocity will be emphasized in FY-84 efforts to develop an improved suppression pool scrubbing model. The role of surfactants and pool debris on circulation will also be considered along with fission product removal as the result of entrance/high velocity impingement effects. Efforts will also be made to model particle reentrainment at the pool surface as the result of bubble action and local jets.

Factors to be considered in FY-84 efforts to develop an improved ice-bed scrubbing model include additional investigation of the extent of gas mixing in the ice compartment and of the flow patterns around basket wires, particle growth due to water vapor uptake, and availability of ice surfaces for aerosol deposition. It is expected that improved models for both ice bed and suppression pool scrubbing will be completed by the end of FY-84.

Work will begin on the development of preliminary models to decribe the fission product removal effectiveness of other ESF systems including air cleaning/filtration and containment cooling systems. The former will require consideration of gas and aerosol retention mechanisms in moisture separators, prefilters, HEPA filters, and charcoal adsorbers. Consideration of the need for models for potential add on systems, e.g., vent/filter systems that could conceivably incorporate gravel bed filtration systems, will also be initiated. As indicated in the previous section, FY-84 work may also include the development of a containment computer code that couples the PNL developed models for ESF systems with thermal hydraulic models and descriptions of natural aerosol transport and retention processes.

Verification of models will be initiated in FY-84. Literature will continue to be reviewed for related modeling and experimental efforts and any results from these efforts will then be compared to those obtained from the codes/models developed as part of the proposed program. EPRI sponsored computer code development and experimental efforts related to suppression pool retention are examples of activities that may prove to be of use in FY-84 validation efforts. However, the schedule for the publication/release of results from these EPRI sponsored projects is unavailable at the time of writing of the proposed effort.

- Experimental Programs - This task is to identify the need for experimental programs. Once proposed programs have been accepted and potential funding sources identified, it is expected that major experimental efforts will be covered by separate project/budget proposals. In general, the identification process has focused on the need for experiments to validate the numerical models used for predicting the extent of fission product removal (decontamination factors). Assuming acceptance of FY-83 proposals, it is expected that FY-84 work will include definition of experimental programs in sufficient detail to develop firm cost information. Investigation of the need for experiments related to phenomenological issues that could affect the performance of ESF systems will be expanded. Examples of such issues include the potential effects of hydrogen burns and possibility of impairment/failure of system components by debris and/or high aerosol concentrations. Investigation of the need for experiments related to proposed add on systems, e.g., vent/filter systems, will be initiated.

4. Expected Results Beyond FY-84, 85

Although investigation of the impact of a range of accident conditions will begin in FY-84, it is anticipated that the wide spectrum of postulated sequences and the large number of systems will extend the performance assessment beyond the end of FY-85. It is expected that experimental investigations as well as modeling will be used in this continuing assessment and proposals and recommendations for new test programs are anticipated. Ultimately it is expected that the most effective systems for a broad spectrum of accident conditions will be identified. It is anticipated that code development/verification efforts will continue beyond FY-85 with emphasis on the generic designs associated with standardized plants. Further, it is expected that efforts will be expanded to include reliability and aging aspects of ESF systems. Any such efforts, i.e., those related to risk perspectives and time-related degration will, of course, be coordinated with other NRC activities in these areas. Work beyond FY-85 is also expected to emphasize expanded consideration of add-on or alternative systems, e.g., vent/filter systems, including cost-benefit analyses.

5. Relationship to Other Projects

The proposed project is part of a major NRC program to provide verified analytical methods that will permit best-estimate analyses of postulated severe accidents and is related to numerous safety/risk studies sponsored by NRC, DOE, and private industry. More specifically, the project is related to NRC sponsored activities in areas such as severe accident sequence analysis, behavior of damaged fuel, fuel-structure interaction, fission product transport, containment analysis, accident consequence reevaluation, and risk reduction. The project is part of the Nuclear Power Plant Severe Accident Research Plan described in NUREG-0900. Project personnel participate in the activities of the Severe Accident Source Term Program Office, Office of Nuclear Regulatory Research. Ultimately the project should provide technical bases for regulatory decisions and the assessment of the utility of proposed safety improvements.

6. Reporting Schedule

A. K. Postma, W. K. Winegardner, and M. W. Jankowski, Studies of Fission Product Scrubbing Within Ice Compartments, NUREG/CR-3248, FY-83.

P. C. Owczarski, A. K. Postma, R. I. Schreck, Technical Bases and User's Manual for SPARC - A Suppression Pool Aerosol Removal Code, NUREG/CR-3317, FY-83.

PNL Staff, Fission Product Retention by ESF Systems, Background Information (working title), draft by end of FY-83.

PNL Staff, Improvement/Validation of Codes/Models for Evaluation of ESF System Performance (working title), draft by end of FY-84.

PNL Staff, Assessment of ESF System Fission Product Removal Effectiveness Under Severe Accident Conditions (working title), draft by end of FY-85.

7. Subcontractor Information

NRC management approval will be obtained before entering into any new consultant agreement or subcontract. It is expected that Dr. Arlin K. Postma, Benton City Technology will continue to be retained as a consultant and principal investigator.

8. Capital Equipment Required

Not applicable

9. Special Facilities Required

Not applicable

10. Conflict of Interest

This proposed project has been reviewed by Battelle's Corporate Scope Coordinator, who indicates that it does not duplicate work being performed for others.